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Environmental Report for 1990

**Lawrence Livermore
National Laboratory**

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This report is prepared for the U.S. Department of Energy (DOE) by the Environmental Protection Department at the Lawrence Livermore National Laboratory (LLNL). This publication presents the results of LLNL's environmental monitoring and compliance effort and provides an assessment of the impact of LLNL operations on the environment.

This document is the responsibility of the Regulatory Affairs Division of the Environmental Protection Department (EPD). Within this division, the Environmental Monitoring Group (EMG) sampled the environment, interpreted the results, performed the impact analysis of radiological emissions from LLNL, and compiled the information presented here.

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CONTENTS

List of Figures	xv
List of Tables	xix
Abstract	1
Executive Summary	3
LLNL Background Information	3
Introduction	6
LLNL Livermore Site	6
Air Monitoring	6
Sewage Monitoring	7
Routine Water Monitoring	7
Soil Monitoring	8
Vegetation and Foodstuff Monitoring	10
Environmental Radiation Monitoring	11
Environmental Radiological Program Summary	11
Groundwater Protection	12
Summary of Environmental Compliance Activities	13
Quality Assurance Activities	15
LLNL Site 300	15
Air Monitoring	15
Routine Water Monitoring	15
Groundwater Protection	16
Soil Monitoring	16
Vegetation Monitoring	17
Environmental Radiation Monitoring	17
Environmental Radiological Program Summary	18
Noise Monitoring	18
Summary of Environmental Compliance Activities	18
Introduction	21
LLNL Livermore Site	
Setting	25
Introduction	25
Location	25
Climate	25
Geology	26
Topography	26
Hydrogeology	27
Compliance Summary	31
Introduction	31
Summary of Permits as of March 1, 1991	31
Department of Energy Tiger Team	31
Resource Conservation and Recovery Act (RCRA) Hazardous	
Waste Management Activities	32
Waste Minimization	32
Hazardous Waste Permits	32
Inspections	32

Contents

Waste Accumulation Areas	33
RCRA Personnel Training	33
Resource Conservation and Recovery Act (RCRA) and Other	
Federal and State Regulation of Storage Tanks	33
Tank Integrity Testing	33
Underground Tank Permits	34
Inspections	34
Comprehensive Environmental Response, Compensation,	
and Liability Act (CERCLA)/Superfund Amendments	
and Reauthorization Act (SARA)—Title I	35
Ground Water Project	35
Superfund Amendments and Reauthorization	
Act (SARA)—Title III	36
SARA/OSHA Personnel Training	36
Toxic Substances Control Act (TSCA)	37
National Environmental Policy Act (NEPA)	37
Environmental Assessments	37
Environmental Impact Statement/Environmental	
Impact Report	38
Endangered Species Act	38
National Historic Preservation Act	39
Clean Water Act—National Pollutant Discharge Elimination	
System (NPDES)/Waste Discharge Requirements	39
Groundwater Discharge Permits	39
Wastewater Permits	39
Inspections	40
Clean Air Act/Air Quality Management Activities	40
Reports	40
National Emission Standards for Hazardous Air Pollutants	41
Air Permits	41
Inspections	41
Compliance Summary, First Quarter 1991	41
Tiger Team Assessment	41
Comprehensive Environmental Response, Compensation,	
and Liability Act (CERCLA)	42
Clean Air Act	42
AB2588 Air Toxics "Hot Spots" Information and	
Assessment Act of 1987	42
Resource Conservation and Recovery Act (RCRA)	42
Regulatory Agency Inspections	43
Current Issues and Actions	44
Environmental Permits	44
Air Permits	44
Water Permits	44
Underground Tank Permits	44
Hazardous Waste	44
Environmental Program Information	47
Introduction	47
Environmental Protection Department	47
Environmental Guidance Division	47
Environmental Restoration Division	48

Hazardous Waste Management Division	48
Regulatory Affairs Division	48
Livermore Site Permits	48
Environmental Assessments Performed During 1990	49
Environmental Assessments	49
Environmental Impact Statement/Environmental Impact Report	50
Pollution Abatement Projects	51
Sanitary Sewer Discharge Control Project	51
Compliance Activities	52
Building Inspections	52
Waste Accumulation Area Inspections	52
Spill Response	52
Site Evaluations Prior to Construction	53
Environmental Training	53
Air Monitoring	57
Introduction	57
Methods	57
Results	59
Airborne Radioactivity	59
Beryllium in Air	60
Effluent Releases	61
Radioactive Effluents	61
Nonradioactive Effluents	61
Sewage Monitoring	73
Introduction	73
Methods	74
Results	76
Radioactivity in Sewage	76
Nonradioactive Pollutants in Sewage	78
Environmental Impact	79
Radioactivity in Sewage	79
Nonradioactive Liquid Effluents	80
Radiological Discharge Limits to the Sanitary Sewer System (NRC, DOE, and DHS)	80
Discharge Limits to the Sanitary Sewer System of the City of Livermore	81
Routine Water Monitoring	89
Introduction	89
Methods	89
Results	92
Radioactivity in Water	92
Special Assessment of Tritium in Rain and Stormwater	94
Nonradioactive Pollutants in Water	95
Environmental Impact	95
Soil Monitoring	105
Introduction	105
Methods	105
Results	107
Environmental Impact	108
Special Projects	108

Contents

Plutonium in Soil, LLNL Site Southeast Quadrant	108
Tritium in the Unsaturated Zone	109
Vegetation and Foodstuff Monitoring	117
Introduction	117
Methods	117
Vegetation	117
Wine	118
Honey	119
Milk	119
Results	119
Vegetation	119
Wine	119
Honey	120
Milk	121
Environmental Impact	122
Environmental Radiation Monitoring	127
Introduction	127
Methods	127
Results	128
Environmental Impact	129
Environmental Radiological Program Summary	133
Introduction	133
Natural and Man-Made Radiation	133
Measurement of Radioactivity and Dose	134
Natural Sources of Radioactivity	134
Man-Made Sources of Radioactivity	136
Radiation Protection Standards	136
Potential Radiological Dose from the Livermore Site	136
EPA Clean Air Act Code	137
Continuous-Point-Source Code	137
Summary	139
Overview	140
Air Monitoring	140
Sewage Monitoring	141
Water Monitoring	142
Surface Water	142
Groundwater	143
Soil Monitoring	143
Plutonium in Soil, LLNL Site Southeast Quadrant	144
Tritium in the Unsaturated Zone	144
Vegetation and Foodstuff	145
Vegetation	145
Wine	145
Honey	146
Milk	146
Environmental Impact	146
Radiation Monitoring	147
Environmental Nonradiological Program Summary	153
Introduction	153
Air Monitoring	153
Sewage Monitoring	153

Water Monitoring	154
Surface Water	154
Groundwater	154
Soil Monitoring	155
Groundwater Protection	157
Introduction	157
Historical Background	157
Scope of Activity	157
VOCs in Unsaturated Sediment and Groundwater	159
Fuels and Aromatic Hydrocarbons	160
Radiological Parameters	161
Environmental Restoration Accomplishments at the Livermore Site	161
Quality Assurance and Statistical Methods	163
Introduction	163
DOE Tiger Team Audit	164
Deviations and Changes to the Sampling Program	164
Sampling Location Designators	164
Air Sampling Program	164
Sewage Monitoring Program	165
Routine Water Sampling Program	165
Vegetation and Foodstuff Sampling Program	165
Environmental Radiation Monitoring Program	166
Meteorology Monitoring Program	166
Soils/Sediments Monitoring Program	166
Participation in Laboratory Intercomparison Studies	166
Duplicate Analyses	166
Statistical Methods	166
Radiological Data	167
Nonradiological Data	167
Summary Statistics	167
Statistical Comparisons	167
LLNL Site 300	177
Setting	177
Introduction	177
Location	177
Climate	177
Geology	178
Hydrogeology	180
Compliance Summary	181
Introduction	181
Summary of Permits	181
Department of Energy Tiger Team	181
Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Activities	181
Waste Minimization	182
Hazardous Waste Permits	182
Inspections	182
Waste Accumulation Areas	183
RCRA Personnel Training	183

Contents

Resource Conservation and Recovery Act (RCRA) and Other	
Federal and State Regulation of Storage Tanks	183
Tank Integrity Testing	184
Underground Tank Fees	184
Inspection	184
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I	184
Remedial Investigations/Feasibility Studies (RI/FS)	185
General Services Area	185
Building 834 Complex	185
High-Explosives (HE) Process Area	185
East and West Firing Areas	185
Pit 6 Area	186
Dry Wells RI	186
Carnegie Fault Zone Investigation	186
Building 823 Disposal Site	186
Paper Canyon Area	186
Additional Soil Vapor Surveys at Building 833 and in the GSA	186
Sealing and Abandoning Old Production Wells	186
Geophysical Logging	186
Superfund Amendments and Reauthorization Act (SARA)—Title III	186
SARA/OSHA Personnel Training	187
Toxic Substances Control Act (TSCA)	187
National Environmental Policy Act (NEPA)	187
Environmental Assessments	188
Environmental Impact Statement/Environmental Impact Report	188
Endangered Species Act	188
National Historic Preservation Act	189
Clean Water Act—National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements	189
Groundwater and Surface Water Discharge Permits	189
Inspection	189
Clean Air Act/Air Quality Management Activities	189
Air Permits	189
Inspections	190
National Emission Standards for Hazardous Air Pollutants	190
Compliance Summary, First Quarter 1991	190
Tiger Team Assessment	190
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	190
Clean Air Act	190
Clean Water Act	191
Resource Conservation and Recovery Act (RCRA)	191
Regulatory Agency Inspections	191
Current Issues and Actions	191
Environmental Permits	191
Air Permits	191
Water Permits	192

Underground Tank Permits	192
Hazardous Waste	192
Environmental Program Information	193
Introduction	193
Environmental Protection Department	193
Environmental Guidance Division	193
Environmental Restoration Division	194
Hazardous Waste Management Division	194
Regulatory Affairs Division	194
Site 300 Permits	194
Environmental Assessments Performed During 1990	195
Environmental Assessments	195
Environmental Impact Statement/Environmental	
Impact Report	195
Pollution Abatement Projects	195
Compliance Activities	196
Building Inspections	196
Waste Accumulation Area Inspections	197
Spill Response	197
Environmental Training	197
Air Monitoring	199
Introduction	199
Methods	199
Results	200
Airborne Radioactivity	200
Beryllium in Air	201
Environmental Impact	202
Routine Water Monitoring	207
Introduction	207
Methods	207
Surface Water	207
Water Supply Wells	207
Site 300 Groundwater	207
Site 300 Area Groundwater	208
Sampling and Analysis	208
Results	211
Surface Water	211
Water Supply Wells	211
Site 300 Groundwater	212
Site 300 Area Groundwater	212
Environmental Impact	213
Soil Monitoring	221
Introduction	221
Methods	221
Results	222
Environmental Impact	223
Vegetation Monitoring	225
Introduction	225
Methods	225
Results	225
Environmental Impact	227

Contents

Environmental Radiation Monitoring	229
Introduction	229
Methods	229
Results	229
Environmental Impact	229
Noise Monitoring	233
Introduction	233
Methods	233
Results	233
Environmental Impact	233
Environmental Radiological Program Summary	235
Introduction	235
Radiation Protection Standards	235
Potential Radiological Dose from Site 300	235
EPA Clean Air Act Code	236
Continuous-Point-Source Code	236
Radiation Dose Summary	237
Air Monitoring	237
Airborne Radioactivity	237
Water Monitoring	237
Surface Water	237
Water Supply Wells	238
Site 300 Groundwater	238
Site 300 Area Groundwater	238
Compliance Groundwater Monitoring	238
Pit 1 Landfill Area	238
Pit 7 Landfill Complex	238
Pits 2 and 8 Landfill Areas	238
Pit 6 Landfill Area	239
Building 817 High-Explosives (HE) Process Area	239
Groundwater Investigation and Feasibility Study Activities	239
Tritium Investigation	239
Soil Monitoring	239
Environmental Impact	240
Vegetation Monitoring	240
Environmental Impact	241
Radiation Monitoring	241
Penetrating Radiation	241
Environmental Nonradiological Program Summary	245
Introduction	245
Air Monitoring	245
Water Monitoring	245
Surface Water	245
Water Supply Wells	245
Site 300 Groundwater	245
Site 300 Area Groundwater	246
Compliance Groundwater Monitoring	246
Pit 1 Landfill Area	246
Pit 7 Landfill Complex	246
Pits 2 and 8 Landfill Areas	247
Pit 6 Landfill Area	247

Building 817 High-Explosives (HE) Process Area	247
Groundwater Investigation and Feasibility Study Activities	248
TCE Investigation	248
HE Compounds Investigation	248
Noise Monitoring	249
Groundwater Protection	251
Introduction	251
Methods	251
Results	252
Environmental Impact	255
Groundwater Investigation and Feasibility Study Activities	255
TCE Investigation	255
HE Compounds Investigation	255
Tritium Investigation	256
Landfill and Lagoon Closures	256
Scope of Activity	256
Environmental Restoration Accomplishments at Site 300	259
Quality Assurance and Statistical Methods	269
Introduction	269
Deviations and Changes to the Sampling Program (Site 300)	269
Sample Location Designators	269
Air Sampling Program	269
Routine Water Sampling Program	269
Compliance Groundwater Sampling Program	269
Soil Monitoring Program	270
Vegetation Sampling Program	270
Environmental Radiation Monitoring Program	270
Statistical Methods	270
Radiological Data	270
Nonradiological Data	270
Summary Statistics	271
Statistical Comparisons	271
Appendices	273
Appendix A. Radiological Methods	273
Appendix B. Methods of Dose Calculations	279
Appendix C. Nonradiological Methods	287
Appendix D. 1990 EPD Publications	291
References	297
Glossary	307
External Distribution	327

LIST OF FIGURES

EX-1.	Estimated population distribution (in thousands) within 80 km of Livermore, by sectors	4
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LLNL Livermore Site

L-SET-1.	Wind rose showing the average annual wind speed, frequency of occurrence, and direction at the Livermore site, 1990	26
L-SET-2.	Approximate groundwater surface elevation contours (feet above mean sea level, msl), Livermore site and vicinity	28
L-A-1.	Air sampling locations, Livermore-site perimeter, 1990.....	57
L-A-2.	Air sampling locations, Livermore Valley, 1990	58
L-A-3.	Monthly mean concentration of beryllium on air filters, Livermore-site perimeter, 1990.....	60
L-SW-1.	LLNL 1990 tritium concentration in sewage effluent	77
L-SW-2.	LLNL monthly average plutonium concentration in sewage since 1973	78
L-W-1.	Water sampling locations, Livermore Valley, 1990.....	90
L-W-2.	Rain sampling locations, Livermore site and Valley, 1990	91
L-W-3.	Groundwater sampling locations, Livermore Valley, 1990	92
L-W-4.	Stormwater runoff sampling locations, Livermore site, 1990.....	93
L-SO-1.	Soil sampling locations, Livermore Valley, 1990.....	105
L-SO-2.	LLNL arroyo sediment sampling locations, 1990.....	107
L-SO-3.	Approximate locations of surface soil samples in the Plutonium Study Area.....	111
L-V-1.	Vegetation sampling locations, Livermore Valley, 1990.....	117
L-V-2.	Tritium in retail wines, plotted by sampling year	120
L-V-3.	Mean tritium in retail wines, 1980–1990, decay-corrected and plotted by vintage year.....	121
L-V-4.	Tritium concentration in honey	121

List of Figures

L-R-1.	Locations of Livermore-site gamma and neutron dosimeters, 1990.....	127
L-R-2.	Locations of Livermore Valley gamma dosimeters, 1990.....	128
L-R-3.	Off-site gamma radiation background dose frequency distribution, Livermore, 1990	129
L-RS-1.	Radiation dose terminology and corresponding units of measure	135
L-RS-2.	Calculated radiological dose by radionuclide from the air pathway to the hypothetical maximally exposed individual, Livermore site, 1978–1990	138
L-RS-3.	Maximum air pathway dose at the Livermore-site perimeter, 1973–1990.....	138
L-RS-4.	Typical annual radiation doses from various sources (NCRP 1987).....	139
L-G-1.	Isoconcentration contour map of total VOCs at LLNL.....	158
L-G-2.	Tritium concentrations at LLNL, January 1990.....	160

LLNL Site 300

3-SET-1.	Wind rose showing the average annual wind speed frequency of occurrence and direction at Site 300 for 1990	177
3-SET-2.	Topography and groundwater surface elevations at Site 300.....	179
3-A-1.	Air sampling locations, Site 300, 1990	200
3-A-2.	Monthly mean concentration of beryllium on air filters, Site 300, 1990	202
3-W-1.	Surface water sampling locations, Site 300, 1990.....	208
3-W-2.	Active and inactive water supply wells, Site 300, 1990	209
3-W-3.	Active on-site wells replacing sealed and abandoned production wells, Site 300, 1990	210
3-W-4.	Annual samples collected from surrounding area groundwater, Site 300, 1990	211
3-SO-1.	Soil sampling locations, Site 300, 1990	222
3-V-1.	Vegetation sampling locations, Site 300, 1990	226
3-R-1.	Location of Site 300 gamma dosimeters, 1990.....	230

List of Figures

3-N-1.	Noise monitoring locations in Tracy and surrounding area, 1990	233
3-G-1.	Landfills (active and inactive) and monitoring wells, Site 300, 1990	253
3-G-2.	Several environmental restoration activities are in progress at Site 300	256
3-G-3.	Distribution of TCE in perched groundwater in the vicinity of the Building 834 Complex, June-December 1990	257
3-G-4.	Isoconcentration contour map of TCE in the Neroly upper blue sandstone (Tnbs ₂) aquifer, HE Process Area, October-December 1990	258
3-G-5.	Total VOC concentration in groundwater from the alluvial/shallow bedrock aquifer in the central GSA, October-December 1990	259
3-G-6.	Groundwater tritium activity isopleth map, WFA and EFA, October 1990	260

LIST OF TABLES

LLNL Livermore Site

L-SET-1.	Average annual percent frequency of wind direction at 10-m level, versus wind speed (m/s) for the Livermore site, 1990.....	27
L-C-1.	Appraisals/inspections 1990	45
L-EP-1.	TFA NPDES self-monitoring sampling schedule	54
L-EP-2.	TFB NPDES self-monitoring "start-up" requirements	55
L-EP-3.	TFB NPDES self-monitoring sampling schedule.....	56
L-A-1.	Gamma activity on air filters—Livermore-site perimeter, 1990	62
L-A-2.	Plutonium-239 activity on air filters—Livermore Valley, 1990.....	63
L-A-3.	Plutonium and uranium activity on air filters—Livermore-site perimeter, 1990.....	64
L-A-4.	Tritium in air—Livermore-site perimeter, 1990	67
L-A-5.	Tritium in air—Livermore Valley, 1990	69
L-A-6.	Beryllium concentration on air filters—Livermore-site perimeter, 1990.....	70
L-A-7.	Radioactive airborne effluent releases from the Livermore site, 1981–1990	71
L-A-8.	Nonradioactive airborne emissions—Livermore site, 1990	71
L-SW-1.	Estimated total radioactivity in sanitary sewer effluent, LLNL, 1990	76
L-SW-2.	Sewer discharge release limits for tritium (^3H), ^{137}Cs , and ^{239}Pu	76
L-SW-3.	Various radionuclides in sanitary sewer effluents—LLNL and Livermore Water Reclamation Plant (LWRP), 1990.....	84
L-SW-4.	Metal discharged to sanitary sewer system—LLNL, 1990 monthly summary.....	85
L-SW-5.	Positively detected parameters in LLNL sanitary sewer effluent, 1990.....	86
L-SW-6.	Radioactive liquid effluent releases from the Livermore site, 1981–1990.....	88

List of Tables

L-W-1.	EPA groundwater standard methods.....	96
L-W-2.	Gross alpha activity in water—Livermore Valley, 1990.....	97
L-W-3.	Gross beta activity in water—Livermore Valley, 1990.....	98
L-W-4.	Various radionuclides in stormwater runoff, 1990.....	99
L-W-5.	Tritium in water—Livermore Valley, 1990.....	100
L-W-6.	Tritium in groundwater—Livermore Valley, 1990.....	101
L-W-7.	Tritium in rain water—Livermore site, 1990.....	102
L-W-8.	Tritium in rain water—Livermore Valley, 1990.....	103
L-W-9.	LLNL stormwater runoff—nonradioactive parameters, 1990.....	104
L-SO-1.	Positively detected radionuclides in soil—Livermore Valley, 1990.....	112
L-SO-2.	Positively detected radionuclides in arroyo sediments near the Livermore site, 1990.....	113
L-SO-3.	Positively detected metals (in mg/L) in arroyo sediments near the Livermore site, 1990.....	114
L-SO-4.	Positively detected organic compounds (mg/kg) in arroyo sediments near the Livermore site, 1990.....	115
L-V-1.	Tritium in vegetation—Livermore Valley, 1990.....	123
L-V-2.	Tritium in retail wine, 1990.....	123
L-V-3.	Tritium in honey, 1990.....	124
L-V-4.	Tritium in milk, 1990.....	124
L-V-5.	Potassium-40 in milk, 1990.....	125
L-V-6.	Cesium-137 in milk, 1990.....	126
L-R-1.	Environmental radiation measurements (TLD)—Livermore-site perimeter, 1990.....	130
L-R-2.	Environmental radiation measurements (TLD)—Livermore Valley, 1990.....	131
L-R-3.	Environmental neutron monitoring—Livermore-site perimeter, 1990.....	132

L-RS-1.	Radiation dose from the air pathway, all Livermore-site facilities, during 1990 (Clean Air Act Code)	149
L-RS-2.	Estimated radiation dose to the public from Livermore-site airborne effluents during 1990 (Continuous-Point-Source Code)	150
L-RS-3.	Summary of radiological dose assessment—Livermore site, 1990	151
L-RS-4.	Comparison of radiation doses—Livermore site, 1990.....	152
L-QA-1.	LLNL/Livermore Valley sampling location designators, 1990.....	168
L-QA-2.	Quality assurance analyses for the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program, 1990.....	171
L-QA-3.	Quality assurance for the DOE Environmental Measurements Laboratory (EML) Quality Assessment Program, 1990.....	172
L-QA-4.	Quality assurance—duplicate sampling, selected parameters, 1990.....	173

LLNL Site 300

3-SET-1.	Average annual percent frequency of wind direction at 10-m level versus wind speed (m/s) for Site 300, 1990.....	178
3-C-1.	Appraisals/inspections of Site 300 during 1990.....	192
3-A-1.	Gamma activity on air filters—Site 300, 1990	203
3-A-2.	Plutonium and uranium activity on air filters—Site 300, 1990	204
3-A-3.	Beryllium concentration on air filters—Site 300, 1990.....	205
3-A-4.	Nonradioactive airborne emissions, Site 300, 1990	206
3-W-1.	EPA groundwater standard methods.....	214
3-W-2.	Gross alpha activity in surface water, Site 300, 1990.....	215
3-W-3.	Gross beta activity in surface water, Site 300, 1990	215
3-W-4.	Tritium in water, Site 300, 1990.....	216
3-W-5.	Positively detected parameters in active and inactive water supply wells (on-site and off-site), Site 300, 1990	217
3-W-6.	Tritium in active and inactive water supply wells (on-site and off-site), Site 300, 1990.....	218

List of Tables

3-W-7.	Positively detected parameters in active on-site wells replacing sealed and abandoned production wells, Site 300, 1990	219
3-W-8.	Positively detected parameters of annual samples collected from surrounding area groundwater, Site 300, 1990	220
3-SO-1.	Positively detected radionuclides in soil—Site 300, 1990.....	223
3-V-1.	Tritium in vegetation—Site 300, 1990.....	227
3-R-1.	Environmental radiation measurements (TLD)—Site 300, 1990	231
3-RS-1.	Radiation dose from the air pathway (Clean Air Act Code calculations) for Site 300, 1990.....	242
3-RS-2.	Estimated radiation dose to the public from Site 300 airborne effluents during 1990 (Continuous-Point-Source Code)	242
3-RS-3.	Summary of radiological dose assessment for Site 300, 1990	243
3-RS-4.	Comparison of radiation doses—Site 300, 1990.....	244
3-G-1.	Water quality parameters and detection limits for monitoring wells, Site 300, 1990.....	262
3-G-2.	Positively detected parameters in Pit 1 Area monitoring wells, Site 300, 1990.....	263
3-G-3.	Positively detected parameters in Pit 7 Complex area monitoring wells, Site 300, 1990.....	264
3-G-4.	Positively detected parameters in Pits 2 and 8 Area monitoring wells and Well NC2-07, Site 300, 1990.....	265
3-G-5.	Positively detected parameters in Pits 1 and 2 Area barcad samplers, Site 300, 1990	266
3-G-6.	Positively detected parameters in Pit 6 Area monitoring wells, Site 300, 1990	267
3-G-7.	Positively detected parameters in HE Process Area monitoring wells at the high-explosives rinse-water surface impoundments, Site 300, 1990	268
3-QA-1.	Site 300 sampling location designators, 1990	271
APP-C-1.	EPA groundwater standard methods.....	290

ABSTRACT

This report documents the results of the Environmental Monitoring Program at the Lawrence Livermore National Laboratory (LLNL) and presents summary information about environmental compliance for 1990. To evaluate the effect of LLNL operations on the local environment, measurements of direct radiation and a variety of radionuclides and chemical compounds in ambient air, soil, sewage effluent, surface water, groundwater, vegetation, and foodstuff were made at both the Livermore site and at Site 300 nearby.

LLNL's compliance with all applicable guides, standards, and limits for radiological and nonradiological emissions to the environment was evaluated. Aside from an August 13 observation of silver concentrations slightly above guidelines for discharges to the sanitary sewer, all the monitoring data demonstrated LLNL compliance with environmental laws and regulations governing emission and discharge of materials to the environment. In addition, the monitoring data demonstrated that the environmental impacts of LLNL are minimal and pose no threat to the public or to the environment.

This report meets the requirements of *Department of Energy Orders 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements*, and *5400.1, General Environmental Protection Program*.

LLNL BACKGROUND INFORMATION

Who operates the Lawrence Livermore National Laboratory (LLNL)?

The University of California operates LLNL for the United States Department of Energy (DOE). In addition, the Laboratory conducts projects for other Federal agencies, as well as for State and regional agencies and for private utilities.

When did the Lawrence Livermore National Laboratory open?

The Lawrence Livermore National Laboratory was established in 1952 to conduct research on nuclear weapons and magnetic fusion energy, an experimental energy source. Three years later, the Laboratory's Site 300 opened to conduct materials testing and high-explosives (HE) diagnostic work.

How have the Laboratory's research activities expanded?

Other major programs have been added to the Laboratory's original scope. These programs include:

- Laser fusion and laser isotope separation,
- Biomedical and environmental sciences, and
- Applied energy technology.

What kinds of technical support do these research activities require?

These programs require research in basic scientific disciplines, such as chemistry and materials science, computer science and technology, biological sciences, engineering, and physics.

Where is the Lawrence Livermore National Laboratory?

The Laboratory has two sites, both of which are located in northern California. The Livermore site is adjacent to the City of Livermore within eastern Alameda County's Livermore Valley—about 40 mi (65 km) east of San Francisco. Site 300 is located in the sparsely populated hills of the Diablo Range, 15 mi (24 km) southeast of Livermore.

What is the population of Livermore?

Approximately 54,000 people live in Livermore today, in a community that melds high-tech research and education with the vineyards and agribusiness in the surrounding hills.

How many people live nearby?

Nearly six million people live within 50 mi (80 km) of the Livermore site. This population base provided the Laboratory with its approximately 7,800 employees

Executive Summary

during 1990. (See the Bay Area Map, **Figure EX-1**, which shows the location of the Laboratory and the surrounding areas.)

Are high explosives tested at the Lawrence Livermore National Laboratory?

Yes, most of LLNL's materials testing and high-explosives (HE) diagnostic work is conducted at the Laboratory's Site 300.

What environmental regulations apply to LLNL operations?

Laboratory operations are subject to Federal, State, regional, and local environmental requirements.

How does LLNL comply with emission standards?

Emission requirements are met through stringent emission-control and monitoring programs that manage effluents at their sources. These programs control potentially hazardous emissions, such as common laboratory chemicals, metals, and solvents—as well as radioactive materials, such as tritium, uranium, and plutonium.

How is environmental compliance assured at LLNL?

While all LLNL Associate Directors are responsible for assuring that activities in their directorates comply with environmental regulations, the Environmental Protection Department helps them achieve this goal.

Who monitors emissions from LLNL to assess environmental compliance?

The Environmental Monitoring Group (EMG) within the Regulatory Affairs Division of the Environmental Protection Department conducts an environmental monitoring program. That program has three purposes: (1) to evaluate the effectiveness of control measures, (2) to assess compliance with applicable emission standards, and (3) to estimate the impact of ongoing Laboratory operations on the environment.

Figure EX-1. Estimated population distribution (in thousands) within 80 km of Livermore, by sectors.

What is the scope of LLNL's environmental monitoring program?

Monitoring program techniques can detect radioactive and nonradioactive pollutants at environmental background levels. The sampling program includes collection and analysis of air, soil, water, sewage effluent, vegetation, and foodstuffs. In addition, sensitive devices called gamma and neutron dosimeters measure environmental radiation levels at numerous nearby locations.

What standards and methods guide environmental monitoring sample collection and analyses?

Whenever possible, Federal and State standard methods are used to collect and analyze samples. If Federal or State standard methods are not specified, LLNL develops its own procedures. LLNL uses procedures that are derived from published techniques and modified to meet specific analytical requirements.

Who analyzes environmental monitoring samples?

Environmental monitoring samples are analyzed by LLNL's analytical laboratories or by State-certified commercial laboratories.

Where are the environmental monitoring findings documented?

The principal compilation of these findings is this report. This document provides information about emissions and the impact of ongoing LLNL operations, and summarizes LLNL's compliance with specific environmental regulations and orders.

What does all this environmental monitoring technical data mean?

This report presents both environmental monitoring data *and* information about *what* those data mean. The chapters include comparisons with data from past years, comparisons with regulatory standards—and for radiation, comparisons with natural sources.

What are the bases of risk assessment and radiation dose calculations?

Assessment of public impacts and risks from emissions is based on effluent discharges, measurements of environmental media, and comparison to regulatory standards. Radiation doses are calculated both for the points of hypothetical maximum public exposure and for the total population within a 80-km (50-mi) radius of the LLNL sites.

Is this report the only source of LLNL's environmental documentation?

This report presents summary information about compliance activities at LLNL during 1990. However, several other reports contain additional detailed or historical information about compliance or cleanup activities. Many of those reports are listed in **Appendix D** of this publication.

INTRODUCTION

LLNL sustains an important commitment to environmental compliance and accountability. Both monitoring and compliance activities are summarized in this document to provide a complete picture of the environmental program at LLNL.

Analytical data are produced from sampling air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and through measurement of environmental radiation. The Environmental Protection Department performed more than 150,000 analyses of environmental samples during 1990.

This Executive Summary contains the essential elements of the report, without the technical details, which are contained in the later chapters. This summary provides a comprehensive synopsis for the casual reader. For scientists, technicians, regulators, or readers with technical interests, this summary provides an overview, indicating (by the headings and subheadings) the location of supporting methodologies, data, and findings among the chapters that follow.

LLNL LIVERMORE SITE

Air Monitoring

LLNL conducts environmental surveillance and effluent air monitoring to determine the quantity of airborne radionuclides or metals being released into the air by Laboratory operations. The Laboratory maintains six continuously operating high-volume air-particulate samplers on the Livermore-site perimeter, and 13 samplers spread throughout the Livermore Valley. The filters are removed periodically from these monitoring devices and analyzed for gross radioactivity, as well as for a variety of specific radioactive materials and metals, including plutonium, uranium, cesium, radium, thorium, beryllium, and lead.

Alpha and Beta Radiation. Most of the gross alpha air filter determinations were several orders of magnitude below any applicable concentration standards, and near the background counting limits of the very sensitive laboratory analytical counting equipment. Most of the gross alpha and beta radiation activity results from the naturally occurring radioisotopes of uranium and thorium and their decay products.

Plutonium (Pu) and Uranium (U). A location at the southeast perimeter registered the highest concentrations of plutonium in the air. This sample was collected in August. The concentration measured was only about one-tenth of one percent (0.1%) of the DOE Derived Concentration Guide (DCG). The DCG specifies the amount of radiation that could be consumed or inhaled continuously for 365 days per year, without exceeding public radiation standards. The maximum measured concentrations of ^{238}U were less than five-hundredths of one percent (0.05%) of the DOE guidelines.

Tritium (^3H). Concentrations of airborne tritium (a radioactive form of hydrogen) also are determined at each of the six on-site perimeter locations, and at six off-site locations. The highest annual average concentrations were observed at the Laboratory's southeast perimeter. These concentrations were only approximately two-tenths of one percent (0.2%) of the DCG. In addition, all of these values generally are lower than those reported during the previous year.

Beryllium (Be). The presence of beryllium (a light metal that is a suspected

carcinogen) is attributed to suspension of surface soils containing naturally occurring beryllium. Airborne beryllium measurements for the Livermore-site perimeter are less than 5.3% of the monthly ambient concentration guide established by the Bay Area Air Quality Management District.

Permitted Releases. During 1990, gaseous tritium (a radioactive form of hydrogen gas) was released to the atmosphere during routine operations at LLNL. These emissions complied with National Emission Standards for Hazardous Air Pollutants (NESHAPS) requirements. Slightly more than half the tritium was released as tritiated water (HTO) vapor. The remaining tritium released was tritium gas (HT). Nearly all (99.98%) of the discharge to the atmosphere during 1990 came from Building 331, the Tritium Facility. The highest single weekly emission from the facility was about 5.4% of the annual total and occurred during the first week of October.

Sewage Monitoring

During 1990, LLNL discharged approximately 341,000 gallons of wastewater daily containing sanitary sewage and industrial wastes. This wastewater is treated at the Livermore Water Reclamation Plant (LWRP).

Administrative and engineering controls prevent potentially contaminated wastewater from being directly discharged into the sewer. A unique, state-of-the-art system continuously monitors for conditions that might produce adverse impacts on operations at the LWRP. In addition, the outflow water is analyzed both for compliance with discharge permits and to assess the effectiveness of the control systems. The compliance analysis evaluates water quality and checks for metals, toxic organic compounds, and radioactive contaminants within the LLNL effluent. The monitoring program confirms compliance status with local, State, and Federal regulations and guidelines governing discharges to the sanitary sewer.

Radioactive Substances. There were no releases of radioactive materials to the

sanitary sewer that exceeded any discharge limits during 1990. Furthermore, all monitored forms of radioactivity remained at levels consistent with those observed during the last ten years. The continuous monitoring system detected a single spill of ^{241}Am (radioactive americium) in November, which did not violate discharge guidelines. The annual average ^{137}Cs (radioactive cesium) concentration in sewer effluent was only 0.00065% of the DOE discharge limit. The annual average ^{239}Pu concentration was only 0.00014% of the DOE discharge limit.

The annual average concentration of tritium in LLNL effluent was about 0.015% of the DOE annualized discharge limit for a public sewer system. Tritium was the most prevalent radioactive substance discharged to the sanitary sewer. The total amount is well within the environmental protection standard established by the State of California and adopted by DOE. The total also is within the range reported during the previous ten years.

Nonradioactive Substances. Except for rare, brief incidents, sewer discharges were well within compliance limits for nonradioactive substances. Most exceptions were brief instances when the sewage effluent pH exceeded the bounds prescribed by the LWRP. The pH exceptions were reported to LWRP in routine monthly data transmittals. On one occasion in August, a discharge of silver resulted in a daily concentration that narrowly exceeded the limits for that metal. The silver release was detected by the continuous monitoring system, and LWRP was notified of the release. No special action was needed to treat the affected sewage.

Environmental Impact. None of these releases resulted in any significant impact on the operations of the LWRP.

Routine Water Monitoring

Surface water, drinking water, and stormwaters from the Livermore site and the surrounding areas are monitored for the presence of radioactive constituents

Executive Summary

and nonradioactive pollutants, including solvents, metals, and pesticides.

Alpha and Beta Radiation. In 1990, runoff from four rainstorms was sampled. All measurements of gross alpha and gross beta radioactivity were low, a small fraction of the respective EPA and DHS maximum contaminant levels (MCLs). Gross alpha and beta activities in the surface and domestic water samples collected in 1990 also were well below MCLs.

Tritium. Water from 12 Livermore Valley sites is monitored quarterly. These samples include tap water from various sources, as well as surface water from recreational parks and ornamental displays. Tritium concentrations in these waters ranged from 0.1% to 5.4% of the State of California drinking water standard. The highest value of 5.4% was observed at the LLNL swimming pool. The highest off-site concentrations, 0.6% (six-tenths of one percent) of the standard, was at Shadow Cliffs Regional Park.

Groundwater that may be used as drinking water also is monitored in the Livermore Valley. The tritium concentrations observed in traditional off-site wells ranged from 0.04% to 3.3% of the standard.

A special assessment of rain and stormwater tritium levels was begun in 1990. Although the assessment is not complete and conclusions are premature, certain generalities are observed in the data.

- No unusual tritium releases occurred immediately prior to or simultaneously with the rainstorms;
- The level of tritium in rain and stormwater is elevated, on and immediately adjacent to LLNL and Sandia National Laboratories, Livermore (SNLL);
- The magnitude of the tritium in the rain can not be correlated simply with facility emissions;
- The elevated levels seem localized to the LLNL and SNLL area.

Radiation Dose. An estimate can be made of the radiation dose that may be delivered to an adult who consumes water containing measured tritium concentrations. All these doses are less than

0.056 mrem (the value estimated for the on-site swimming pool). They are based both on a water consumption of 2 L/day and on DOE dose-conversion factors, which produce doses identical to the those calculated using the State of California methods. The actual dose (if any) from the swimming pool and surface water sources would be considerably less, because these sources are not drinking water sources. Methods used to calculate doses are presented in **Appendix B**.

The maximum hypothetical dose that could be received from consuming rain or stormwater is calculated by the EPA-approved AIRDOS-EPA computer model. This dose, from all pathways—including rain and stormwater—is 0.24 mrem, which is 2.4% of the standard set by the EPA.

Stormwater Analysis. Data for chemical parameters in stormwater also were collected. The stormwater runoff sporadically showed acetone and other organic compounds at various locations. Only a few other pollutants were seen at detectable levels. Nonradiological pollutants were not seen above regulatory limits in any of the stormwater samples.

Environmental Impact. The data showed that the impacts of LLNL operations are small: the concentrations of all monitored substances were just a small percentage of the applicable regulatory standards.

Soil Monitoring

Soil sediments can accumulate certain contaminants released to the atmosphere or through liquid effluents. Soil and arroyo sediment samples are analyzed annually to document any changes in environmental levels of both radioactive and nonradioactive contaminants that may have resulted from LLNL operations.

Plutonium. Elevated levels of ^{239}Pu , resulting from an estimated 32 mCi Pu released to the sewer in 1967 and first observed in soils near the Livermore Water Reclamation Plant (LWRP) during the early 1970s, were detected again. The highest value at LWRP represents 1.1% of the proposed EPA soil standard for

unrestricted use of surface soil. One other Livermore Valley soil sample showed a slightly elevated plutonium concentration. Measurements of this magnitude occasionally have been seen during past years at several soil sampling locations. While significantly different from concentrations measured at other locations, the elevated Livermore Valley concentration represents only three-tenths of one percent (0.3%) of the proposed EPA standard. During 1990, sediment samples from arroyos near the Livermore site also were collected. Plutonium-239 was detected in the arroyos at natural background concentrations, reflective of worldwide fallout.

Special Study: Plutonium in Soil, LLNL Site Southeast Quadrant. The DOE Tiger Team stated that LLNL had not investigated and evaluated "the cause of measurable off-site plutonium contamination" as determined from high-volume air particulate samples collected during 1988, adjacent to the southeast quadrant of the site. While the Tiger Team did mention that the "detected concentrations were much less than any regulatory limits and presented no imminent threat to the public or the environment," the Team did indicate that the concentrations may be "due to soil contamination at the southwest [sic] portion of LLNL caused by historical activities."

LLNL has initiated a grid-based soil and sediment sampling and analysis plan to characterize and quantify plutonium in the southeast quadrant of the site. To date, approximately 200 soil and sediment sampling locations have been selected, initial samples have been collected, and analyses are under way. No final data are available. Results will be fully documented when the analyses are complete and interpreted.

Other Radionuclides. During routine surveillance monitoring, other detected radionuclides in soil were found at levels similar to those reported in 1988 and 1989. The concentrations detected reflect worldwide fallout and naturally occurring concentrations of nuclides.

Special Study: Tritium in the Unsaturated Zone. The Environmental Restoration Division (ERD) conducted assessments of tritium concentrations in unsaturated zone sediments at the Livermore site. Data collected indicate that tritium is present in some unsaturated sediments in concentrations significantly above LLNL background levels. Concentrations as high as 2.2×10^8 pCi/L in extracted soil moisture have been reported at a site where a leak was detected in an underground waste-retention tank.

The only potentially significant transport pathway to human populations for the contamination is inhalation of tritiated water vapor from direct soil evaporation or from water taken up by plants and released to the air by transpiration from plant leaves. Transpired water from a single tree located near the Building 292 tritium contamination area was measured with tritium concentrations as high as 5×10^6 pCi/L, although most observations indicated much lower concentrations. Other measurements showed that the transpired water from other vegetation in the area does not contain tritium at significantly elevated levels (Macdonald et al. 1990). Most areas where elevated tritium concentrations were detected are paved with asphalt, thereby limiting potential soil evaporation. Investigations and remediation studies continue.

No specific concentration standards exist for tritium in soil; however, concentration limits can be derived from exposure standards. Screening level calculations, using the standard EPA code AIRDOS-EPA and conservative (worst-case) assumptions, including maximum-observed transpired water concentrations, indicate that no potential doses from any of the measured tritium concentrations in soil could exceed 0.01% of dose standards.

Lead and Other Metals. The level of lead (Pb) in one sediment sample of concern reported in 1989 was investigated during 1990. Additional samples taken

Executive Summary

from the same area during 1990 did not exhibit lead concentrations above natural background levels. For other metals, no concentrations were detected above regulatory limits or above levels normally encountered in sediments.

Organic Compounds. Aroclor 1260, the polychlorinated biphenyl (PCB) detected in low concentrations at two arroyo sediment sampling locations in 1989, was not detected in any 1990 sample. None of the levels detected for other organic compounds were above regulatory standards. Many of these detected compounds are typical of fuel constituents and are expected in locations where stormwater runoff concentrates.

Environmental Impact. In general, the impact of LLNL operations on soil and arroyo sediments has not changed from previous years and remains insignificant. Most substances of interest or concern were detected at natural background concentrations, in trace amounts, or were unmeasurable by the analytic method. Where contamination from past activities has been identified, investigations to quantify and remediate the contamination have been initiated.

Vegetation and Foodstuff Monitoring

Sampling of vegetation can provide information about the presence of radionuclides in the environment. In addition, the foodstuff pathway can be an important contributor to human exposure. Therefore, vegetation and foodstuff analyses are performed throughout the year for areas near the Livermore site and, to allow comparisons, for areas beyond the influence of LLNL. In general, LLNL impacts on vegetation and foodstuffs in the Livermore Valley were minimal.

Vegetation. The 1990 tritium concentrations in vegetation were reduced from those reported in 1989, and were within the range of values normally reported for vegetation in the area. However, one sample exhibited an elevated tritium concentration well above any other values detected during

1990. A resampling of vegetation from the area produced more representative values. Based on the conservative assumption that an adult's diet includes vegetables with the highest observed average tritium concentration (with the high value discussed above included in the calculation of the average), and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose would be 0.07 mrem/y (0.0007 mSv/y), or about 1% of the dose received during a routine chest x-ray.

Wine. Samples of retail wines produced from grapes grown in the Livermore Valley, from grapes grown in other areas of California, and from grapes grown in Europe were analyzed for tritium content. All concentrations were low; however, among the three groups of wine sampled in 1990, the average tritium content of the Livermore Valley wines statistically was the greatest, the average tritium content of the wine from other California regions statistically was the lowest, and the average European wine tritium content statistically ranked in between.

The California and European averages were statistically unchanged from those reported in 1989. However, the 1990 values reported from Livermore wines were statistically lower than those reported in 1989. Livermore Valley and California wines each have maintained essentially constant levels of tritium concentrations since monitoring began. European wines once contained higher tritium concentrations than local wines. But during the past ten years, the tritium content of European wines has decreased to approximately the same levels as Livermore wines.

The 1990 monitoring of tritium in wine, as in past years, indicates that all the tritium concentrations detected were low, at, or near the tritium concentrations measured in tap water. There are no health standards for radionuclides in wine. However, all the wine tritium data were far below acceptable levels for drinking water. In fact, the highest tritium value for wine produced from grapes grown in the

Livermore Valley represented only 1.5% of the allowable levels for California drinking water. Based on the very conservative assumption that wine is consumed in the same quantities as water (2 L/day), the corresponding annual dose associated with the highest detected tritium value is 0.014 mrem (0.00014 mSv), only about 0.1% (one-tenth of one percent) of the dose received from a conventional chest x-ray. More realistic wine-consumption models result in far lower doses. Therefore, the potential radiation dose from consuming wine from any area is minute.

Milk. Tritium levels in milk were comparable to those reported in previous years. Other radionuclides in milk could not be detected, or were present at natural background concentrations. The highest concentration of tritium in milk produced in the Livermore Valley was lower than the highest concentrations measured in samples collected outside the Livermore Valley. The calculated annual radiation dose from tritium that could be received from consuming this milk was 0.005 mrem/y (0.00005 mSv/y), based on a milk intake of 310 L/y. This calculated dose is only about 0.05% (one-twentieth of one percent) of the dose received from a conventional chest x-ray, and is much smaller than the potential dose from naturally occurring potassium-40 (^{40}K) in milk. The annual ^{40}K dose from milk consumption can be as high as 10 mrem/y (0.1 mSv/y).

Honey. The concentrations of tritium in honey produced in the Livermore Valley were not statistically different than those found in honey from other areas of California. Historically, the tritium content in honey fluctuates significantly from year to year. The average Livermore Valley concentration sometimes is higher and sometimes is lower than other California honeys. There are no safety standards for radionuclides in honey. However, none of the measured tritium levels observed would be a health concern even if the honey were consumed in the same quantities as drinking water, where safety standards exist.

Environmental Radiation Monitoring

Penetrating radiation (radiation that can penetrate more than 1 cm into living tissue, such as gamma rays, high-energy beta rays, neutrons and x-rays) cannot be chemically trapped or collected on filters. Highly sensitive devices called thermoluminescence dosimeters (TLDs) are used to measure doses from external (outside the body) sources. External doses from gamma radiation are measured at 22 LLNL site-perimeter locations, and 55 off-site locations. The average annual TLD gamma radiation dose for all perimeter locations was statistically the same as the natural background external dose measured in the Livermore Valley, 65.0 mrem/y versus 65.1 mrem/y. The annual dose is almost identical to those for 1987, 1988, and 1989. This similarity demonstrates that there is no measurable dose caused by direct radiation from LLNL operations beyond the Livermore-site boundary.

Environmental neutron dose measurements are made using ^{235}U track-etch detectors at eight locations along the Livermore-site perimeter. The annual average neutron environmental background radiation dose at the Livermore-site perimeter for 1990 was similar to 1987, 1988, and 1989 values.

Environmental Radiological Program Summary

Small amounts of radioactive materials from operations at the Livermore site were discharged to the environment in 1990. In accordance with DOE environmental protection orders and other Federal and State requirements, the Environmental Monitoring Group assessed the radiological impact from operations at LLNL during 1990. Potential radiation doses to the public were calculated both from LLNL radioactive emissions to the atmosphere and from measured radionuclide concentrations in environmental media.

Based on emissions, radiation doses were calculated by two methods: the EPA Clean Air Act Code (CAAC, which

Executive Summary

includes AIRDOS-EPA) and the Continuous-Point-Source (CPS) Code. These codes calculate the air pathway doses from inhalation, air submersion, ingestion, and ground surface irradiation. The codes are run using LLNL-specific meteorology. Doses are expressed in millirem, effective dose equivalent.

Dose Assessment. The total dose at the fence-line from air emissions caused by Livermore-site operations during 1990 represented 3% or less of the EPA limit.

Groundwater Protection

Historical Background. In the 1940s, prior to its use as a research laboratory, the Livermore site was the Livermore Naval Air Station, used by the U.S. Navy as a flight-training base and as an aircraft rework facility.

During the Navy tenancy, volatile organic compounds (VOCs) were used routinely on site in aircraft and engine assembly, repair, overhaul operations, and paint stripping of aircraft. Much of this activity was performed in the southeast part of the site and in the unpaved areas adjacent to the landing mat. Beginning in 1954, in addition to storing organic solvents at the north end of the taxi strip, LLNL (known then as the University of California Radiation Laboratory) stored and treated hazardous waste on a section of the Navy's east taxi strip. From 1956 to the present, LLNL has engaged in research and other activities that involved the storage, use, and disposal of VOCs, fuel hydrocarbons, and other hazardous materials. However, all practices known to contribute VOCs to the soil or groundwater have been discontinued. In addition, since the late 1970s, the Laboratory has taken many steps to eliminate discharges of hazardous material to the environment.

Investigation has determined that a groundwater plume containing VOCs appears to be migrating to the west-northwest, from the southwest corner of the site, at a rate of about 70 ft per year. Three California Water Service municipal

supply wells are situated within three miles of this plume. These wells feed a blended water system that serves a population of more than 10,000 people.

Scope of Activity. Since being placed on the National Priority List, and the consequent involvement of EPA, LLNL's groundwater cleanup project has been structured to conform with both specific EPA guidance and the negotiated Federal Facility Agreement. The scope of the environmental restoration effort encompasses numerous activities designed to be performed over several years to investigate, evaluate, and eventually remedy potentially hazardous compounds that may have affected soil and groundwater.

VOCs in Unsaturated Sediment and Groundwater. Restoration activities continued at the Livermore site on two areas containing VOCs and fuel hydrocarbons in the unsaturated sediments above the water table. The data indicated that total VOC concentrations exceeding one part-per-million (ppm) in unsaturated sediment occur in only one area in the southeast corner of the Livermore site.

Eight chlorinated solvents were detected in groundwater in the LLNL area in concentrations exceeding Federal or State action levels or MCLs. Trichloroethylene (TCE) was the most abundant VOC and occurred in the eastern portion of the Livermore site in concentrations exceeding one ppm. VOCs have migrated off site into two areas: one area is about 800 ft south of the southeastern Livermore site (onto DOE property administered by Sandia National Laboratories, Livermore); the other area is about 2,500 ft west of Vasco Road (onto private property).

Fuels and Aromatic Hydrocarbons. Significant concentrations of fuel hydrocarbons (FHCs) occur only in the Gasoline Spill Area, where about 17,000 gallons of leaded gasoline leaked prior to 1979.

Radiological Parameters. Tritium is the only radiological substance present in groundwater in concentrations that exceed an MCL. In the southeast part of the Livermore site, one well contains tritium

slightly above the MCL of 20,000 pCi/L. Additional investigations have detected tritium in four other monitor wells in concentrations from 910 to 16,000 Ci/L. The natural 12.3-y half-life for tritium and the slow movement of groundwater ensure that the observed tritium will have decayed to well below the MCL long before migrating off site.

Summary of Environmental Compliance Activities

Permits and Inspections by Outside Agencies. LLNL held 262 permits or licenses for activities that might release pollutants to the environment. Agencies that monitor compliance—with terms of their permits and with Federal, State, and local regulations—conducted 35 days of inspections during 1990. In addition, DOE also participated in extensive reviews of both environmental, safety, and health (ES&H) compliance (throughout the six-week Tiger Team visit) and of the overall tank program appraisal (during November 1990).

DOE Tiger Team. The most extensive investigation of the Laboratory was the DOE Tiger Team Assessment of ES&H Programs. The team report concluded that LLNL operations were satisfactory, but recommended some changes to obtain consistent and verifiable compliance with ES&H requirements and itemized a number of findings. In response, the Laboratory developed an Action Plan that defined and scheduled activities to address the Team's recommendations.

Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Activities. LLNL continued development of permit applications for the Hazardous Waste Management Facility, in conjunction with the U.S. Environmental Protection Agency (EPA) and the California Department of Health Services. Construction and upgrading of Waste Accumulation Areas to meet new standards were part of improvements in waste handling practices. A Waste Minimization Program also has been

defined. The Laboratory withdrew plans to operate its incinerator, submitting a closure plan instead. In addition, 1,926 Livermore site and Site 300 employees received RCRA training.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks. The Tank Integrity Testing Program tested 29 underground diesel fuel and gasoline systems. All systems were leak-tight. Twenty-three underground waste-water retention systems also were tested, of which five systems could not meet the minimum leak-rate criterion. Four of those systems have been repaired. Screening for soil contamination produced primarily negative results at nine tank locations.

A program is under way to repair leaks in systems that do not receive hazardous wastewaters. Tanks that do not meet current design criteria are being closed, or scheduled for upgrades. LLNL has paid fees for 65 hazardous waste and hazardous-product tank permits for the Livermore site.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I. A primary concern is groundwater contamination with volatile organic compounds (VOCs) and fuel hydrocarbons. The Ground Water Project addresses CERCLA compliance issues at the Livermore site through source investigations, continued sampling, monitoring, and remediation, as specified in the three-party Federal Facility Agreement.

Superfund Amendments and Reauthorization Act (SARA)—Title III. The data base containing a physical inventory of all chemicals subject to reporting requirements under SARA Title III was updated to reflect changes in Laboratory chemical use.

Toxic Substances Control Act (TSCA). The PCB (polychlorinated biphenyl) annual report required under Federal Toxic Substances Control Act was prepared and made available for EPA inspection.

National Environmental Policy Act (NEPA). During 1990 more than 122 projects were evaluated under NEPA and under amended policies and procedures for DOE compliance with NEPA. Assessments were prepared covering land purchases, expansion of research facilities, and groundwater remediation activities. In addition, work began on the sitewide EIS/EIR for continued operations at LLNL and Sandia's Livermore site.

Endangered Species Act. Four surveys of biological resources at both the Livermore site and Site 300 assessed the impact of proposed projects on sensitive plant or wildlife species or habitats. Neither sensitive plant or wildlife species (nor habitat suitable to support rare plants) were found within the project areas. The surveys determined that marginal potential habitat for the California tiger salamander and red-legged frog (two Federal candidate species and species of special concern) occurs along the lower portion of Arroyo Las Positas.

National Historic Preservation Act. During 1990, four cultural resource surveys assured that proposed Laboratory actions did not affect significant archeological or historical resources.

Clean Water Act—National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements. LLNL held two permits from the Regional Water Quality Control Board for discharge of treated groundwater to the ground and to stormwater channels. The Livermore site renewed the Wastewater Discharge Permit from the City of Livermore Water Reclamation Plant (LWRP) for discharges to the city sewer system. Under this permit, LLNL must conduct a monitoring program in accordance with Federal regulations. Since December 1989, sampling of categorical processes has shown only four instances of noncompliance. A small silver spill in discharged sewage was detected during August 1990 and was reported to the LWRP.

Clean Air Act/Air Quality Management Activities. The Bay Area Air Quality Management District (BAAQMD) issued

192 permits to LLNL. Boilers and solvent cleaners accounted for nearly 80% of these permits.

Using the SCREEN plume-dispersion computer simulation model, the Laboratory prepared a screening risk assessment of the impact of toxic air emissions on the surrounding area (required by the BAAQMD). This analysis showed that maximum values for carcinogenic and noncarcinogenic risks from exposure to LLNL toxic air emission were below the threshold values; therefore, a full risk assessment was not required.

BAAQMD conducted 20 days of inspections at the Livermore site during 1990. These inspections yielded three Notice of Violations (NOVs) for (1) operating two paint spray-booths without permits; (2) using an improper mixture of thinner in paint that resulted in excessive volatile organic content; and (3) operating a silk-screening unit without proper controls.

There was controversy about which rule applied to item (3). The District interpreted that this silk-screening unit was regulated by rules governing cold cleaners; LLNL identified surface preparation rules as the applicable standard. In response to these NOVs, the paint spray-booths received permits to operate; the paint shop corrected its thinner-to-paint proportions; and the cold cleaner was shut down until the rule applicability issues could be sorted out and compliance measures taken.

Pollution Abatement Projects. In May 1990, a draft Pollution Prevention Awareness Plan was submitted to DOE. The plan integrates key pollution-prevention elements into LLNL's day-to-day activities.

LLNL again improved its ability to monitor and control pollutants inadvertently released to the sanitary sewer system. This program improved handling practices and retention tank systems. It installed additional monitoring facilities to track inadvertent releases and improved monitoring capabilities at the discharge point to the city sewer. The program's final major element was construction of a sewage diversion system and structure to

divert LLNL's and SNLL's entire combined sewer flow if an inadvertent release were to be detected.

Environmental Protection Department Internal Compliance Activities. Analysts in the Environmental Operations Group provide guidance on routine regulatory requirements and materials management practices. They also assist characterization and containment during incidents that release potentially hazardous substances to the environment. During 1990, nine incidents required reporting to regulatory agencies. All incidents were contained at the time of occurrence or notice, and cleanup has been completed and verified.

Quality Assurance Activities

The Environmental Monitoring Group (EMG) conducted quality assurance (QA) activities to ensure the accuracy and reliability of all reported data, in accordance with DOE Order 5700.6B and LLNL QA policy. Monitoring took place according to written, quality-assurance procedures, as required by the EMG Quality Assurance Plan. Contract and on-site laboratories complied with EMG quality assurance procedures and passed EMG audits. The laboratories also participated satisfactorily in national cross-check programs. Changes and deviations to sampling programs were documented. Nearly all scheduled samples were collected, and the amount of data ultimately received was greater than 95% of that originally planned.

LLNL SITE 300

Air Monitoring

LLNL conducts surveillance and effluent air monitoring to determine if airborne radionuclides or metals are released by Laboratory operations. At Site 300, LLNL maintains eight continuously operating high-volume air-particulate samplers. Filters from these samplers are analyzed for radioactivity and metals, including plutonium, uranium, cesium, radium, thorium, beryllium, and lead.

Alpha and Beta Radiation. Gross alpha and beta radioactivity air measurements were at or near the lowest limit of detection, 1×10^{-14} $\mu\text{Ci/mL}$ (3.7×10^{-10} Bq/mL), for the analytical method. Most of the observed gross alpha and beta radioactivity resulted from naturally occurring radioisotopes.

Plutonium. The highest concentrations of plutonium were observed in the May and December samples. The level represented only two one-thousandths of one percent (0.002%) of the DOE Derived Concentration Guide (DCG).

Uranium. The highest concentration of ^{238}U was observed in the February sample. The recorded level represented only 0.03% of the DOE DCG. The highest concentration of ^{235}U was observed in the July sample at a level that represented only 0.002% of the DOE DCG. These overall levels were essentially the same as those reported in previous years.

Beryllium. The highest monthly concentration of beryllium was measured during January, at a concentration less than 4.3% of the the established San Joaquin Air Quality District air concentration limit. Local and areawide undisturbed soils contain approximately one part-per-million of beryllium. Windblown suspension of soil particles can account for the majority of these measured concentrations.

Routine Water Monitoring

Surface water, domestic water, and rain water at Site 300 and locations nearby are monitored for radionuclides and for non-radioactive pollutants, such as metals, solvents, and pesticides.

Solvents. A small amount of trichloroethylene (TCE) was detected in one on-site drinking-water supply well during the third quarter. The concentration was below the California Department of Health Services maximum contaminant level. TCE was not detectable in subsequent samples from that same well.

There were four active off-site water supply wells. Trihalomethane (THM) compounds were detected in one well during

Executive Summary

two sequential samplings. These findings resulted from collecting the sample from a mislabeled chlorinated water supply rather than from the untreated well water. However, the two combined THM concentrations were far below the MCL.

TCE also was detected at a concentration of 8 mg/L in an on-site monitoring well. However, this well was sampled with a portable submersible pump that has been implicated in contamination of groundwater samples. Samples taken subsequently from this monitoring well indicated TCE concentrations below the detection limit, which confirmed that earlier the TCE detection was not representative. Use of the pump was stopped immediately.

Another well sampling detected volatile aromatic compounds: chlorobenzene, toluene, and total xylene. All these values were below MCLs and did not recur in subsequent samplings. Remaining results indicated concentrations were comparable to natural background and were well below MCLs.

Tritium. The highest tritium concentrations in active on-site and off-site water supply wells were 0.03% to 0.13% of the State of California Drinking Water Standard, respectively. Results from a newly sampled well paralleled those of a long-existing well for gross alpha, gross beta, and tritium. All results were below the appropriate MCLs.

Tritium concentrations in one well increased slightly from 1989 values. The well is maintained to supply fire-suppression water to the Site 300 fire department. The well does not supply drinking water and currently is under investigation for remediation.

Dose Assessment. An estimate of the annual effective dose to an adult who consumes water from the well containing the highest tritium concentration is less than 0.0006 mrem. This value is based on a water consumption of 2 L/day and DOE dose-conversion factors, which produce doses identical to the those calculated using the State of California methods.

Groundwater Protection

Groundwater monitoring is conducted under two programs at LLNL. One program is designed to meet regulatory commitments established for specific site investigations, such as the investigation of trichloroethylene (TCE), tritium, and high-explosive (HE) compounds in groundwater at Site 300. The other program consists of routine compliance monitoring around landfill and wastewater surface impoundment units.

Environmental Impact. Routine monitoring of radiological and nonradiological substances has not identified new impacts on the groundwater at Site 300. Existing impacts are under investigation and are discussed in the sections that follow. Remedial action is mitigating existing impacts.

TCE Investigations. In 1982, LLNL began initial assessment of the environmental effects of TCE released in several areas of the site. To date, TCE has been identified in soil, rock, or groundwater in seven Site 300 areas.

High-Explosive Compounds

Investigation. Rinse water from buildings within the HE Process Area historically has been disposed of in unlined lagoons adjacent to the processing buildings. Sporadic, but generally low, concentrations of HE compounds, metals, and VOCs were identified beneath some of the lagoons.

Tritium Investigation. Debris from HE tests historically has been disposed of in landfills at the northern end of Site 300. In 1984, tritium levels in water from four nearby monitoring wells rose above the California drinking water standard. A tritium investigation was initiated. To date, two other areas with tritium present in the groundwater have been identified.

Soil Monitoring

Soil can accumulate certain contaminants released to the atmosphere or through liquid effluents. Soil samples are taken annually at Site 300 to document any changes in environmental radioactivity levels and to evaluate any increases that may have resulted from LLNL operations.

Concentrations and distributions of all observed nuclides in Site 300 soil for 1990 remain similar to levels measured in 1988 and 1989, and lie within ranges reported in previous years. The data indicate that greater-than-background concentrations of ^{238}U are limited to isolated regions near the firing tables and disposal areas. The highest value (about 20 times greater than natural background) was observed near an on-site landfill. In 1989, the maximum value was detected near a now-inactive firing table. In 1990, the sample from this location registered only slightly above natural background levels.

In 1988, the gravel from this same firing table was removed to an on-site landfill as part of a sitewide restoration effort. The 1989 and 1990 ^{238}U values probably indicate residual material in this area. With the exception of the elevated ^{238}U concentrations observed near the bunkers and the landfills, the activities of all other samples were representative of background or naturally occurring radionuclides.

Vegetation Monitoring

Vegetation monitoring can provide information about the presence or release of radionuclides in the environment. DOE orders require both sampling and pathway analyses for vegetation at and near DOE facilities. Quarterly vegetation samples were collected at and around Site 300 during 1990.

Tritium. With the exception of two locations, tritium levels in vegetation were at or near the lowest detection limits, and were similar to levels reported in 1988 and 1989.

As in 1989, vegetation samples from two locations contained the highest tritium values. However, in both cases the maximum tritium concentrations in vegetation in 1990 were less than the maximum levels in 1989. Tritium has been observed in the vegetation of these two areas since 1971. These two sampling locations are adjacent to landfills that include tritium-bearing debris from firing tables. Because seasonal rains spread tritium from this debris, tritium is present in the soil and groundwater where

these samples routinely are collected. These landfill areas are under continued investigation for soil and groundwater tritium contamination.

Dose Calculation. Using conservative pathway modeling assumptions, the calculated annual average dose from vegetation at the location with the highest detected tritium values is 0.23 mrem/y (0.0023 mSv), or about 2% of the dose received from a conventional chest x-ray. This calculation assumes an adult's diet includes vegetables with the highest average tritium concentration, and includes meat and milk derived from livestock fed on grasses with the same concentration. In actuality, this dose would never be received, because vegetation at Site 300 is neither consumed by people nor used for grazing livestock.

Environmental Radiation Monitoring

Penetrating radiation cannot be chemically trapped or measured by collection on filters. It is measured using radiation dosimeters. Doses from external (outside the body) sources of gamma radiation are measured at 13 Site-300-perimeter locations and three off-site locations. Highly sensitive devices called thermoluminescence dosimeters (TLDs) measure these external doses.

Doses. The average annual TLD gamma radiation dose for all perimeter locations was 77.7 mrem. The off-site measured doses are 78 mrem, just west of Site 300, and 70 and 57 mrem within the City of Tracy. These regions contain different terrain and geological composition. The region around Site 300 has elevated levels of naturally occurring uranium and may be different from the sediment soil base of the San Joaquin Valley. Observed geological differences between the two locations may account for the different measured external radiation doses. The Laboratory is investigating these differences, and has increased the off-site TLD monitoring network around Site 300 to confirm this difference.

Environmental Radiological Program Summary

Because the Advanced Test Accelerator (ATA) at Site 300 was shut down during 1990, there were no radioactive activation products released to the atmosphere from Site 300 operations. Thus, potential radiological doses from Site 300 operations are so low that statistically they equal zero. They are much lower than doses normally received from natural background radiation sources.

Noise Monitoring

Site 300 conducts high-explosives (HE) testing. LLNL conducted 105 HE tests at Site 300 during 1990. Because the site is relatively remote, these experiments can be performed with minimal off-site impact from annoying noises or damaging overpressures. A limit has been set on the amount of HE that can be detonated based on meteorological measurements made at least twice per day. To monitor this process, six microbarograph sensors are maintained in or near the City of Tracy.

There were no complaints about noise or overpressure from residents in the vicinity of the Site 300 tests. Measurements in the vicinity of Site 300 and in the City of Tracy demonstrated that the noise limit was not exceeded. None of the 105 tests produced objectionable sound levels at any of the six measurement stations.

Summary of Environmental Compliance Activities

The environmental compliance summary section briefly describes environmental activities performed by LLNL to comply with Federal, State, and local laws and regulations.

Resource Conservation and Recovery Act (RCRA) Hazardous Waste Activities. The Resource Conservation and Recovery Act (RCRA) and the California Hazardous Waste Control Law (HWCL) set requirements in California for management of hazardous wastes that are administered by the U.S. Environmental Protection

Agency (EPA) and by the California Department of Health Services (DHS).

Hazardous Waste Permits. Under EPA, Regional Water Quality Control Board (RWQCB), and DHS oversight, Site 300 is preparing to close landfill Pit 1 and Pit 7 during the summer of 1991.

The Site 300 Building 883 Hazardous Waste Container Storage Facility was operated in 1990 under permits issued by EPA and DHS. Open burning of high-explosives waste continued under interim status standards at Site 300.

During inspection of RCRA-regulated units in March, EPA identified conditions of RCRA noncompliance and potential violations. LLNL corrected those conditions, and EPA has confirmed the compliance.

As required by the DHS, LLNL corrected its 1989 Waste Analysis Plan that incorrectly identified the waste code for a category of solvents.

Construction of and Improvements to Waste Accumulation Areas. Four of the 15 waste accumulation areas (WAA) at Site 300 were established in 1990. These areas accommodate temporary storage (less than 90 days) of hazardous waste before pickup by the Hazardous Waste Management Division for off-site disposal.

RCRA Personnel Training. During 1990, a total of 1,926 LLNL Livermore site and Site 300 employees received annual training sessions and as-needed briefings in waste handling practices for hazardous waste generators.

Regulation of Storage Tanks. Federal and State laws regulate the design, operation, monitoring, and closure of tanks that contain or can receive hazardous products or hazardous waste. Underground tanks at Site 300 contain diesel fuel, gasoline, and potentially contaminated wastewater. Aboveground tanks contain diesel fuel, insulating oil, trichloroethylene, and potentially contaminated wastewater. At Site 300, LLNL paid annual fees to San Joaquin Valley Public Health Service (SJCHD) for 15 petroleum tanks.

Site 300 had 11 aboveground and 16 underground tanks in service during 1990.

Eleven underground diesel fuel and gasoline systems were tested for leak-tightness in 1990 and found to be leak-tight. Three underground wastewater retention tanks, including the replacement for a tank removed in 1989, also were tested and determined to be leak-tight.

LLNL established a program to reconcile the daily inputs and withdrawals from underground vehicle-fuel tank systems. The underground diesel fuel tanks for emergency generators are monitored according to a routine tank gaging and reconciliation program.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I. Also known as the Superfund Act, CERCLA authorizes the EPA to identify and clean up hazardous chemicals and substances released to the environment.

In August 1990, EPA placed Site 300 on the CERCLA National Priorities List. EPA and LLNL agreed to combine negotiation of RCRA and CERCLA restoration requirements under a single Federal Facility Agreement. Negotiations began in the fall of 1990 and are ongoing. Until negotiations are complete, investigations and remedial actions continue under the joint oversight of EPA, RWQCB, and DHS. Areas of investigation include TCE in soil, rock, and groundwater; high-explosives (HE) compounds in the HE Process Area; and tritium in the Pit 7 Complex and in the Building 850 area.

As part of the general oversight of CERCLA investigations at Site 300, a number of Draft Remedial Investigations (RI) and Feasibility Studies (FS) were completed during 1990. Remedial actions continue.

Geologic mapping and subsequent investigations identified a potentially active fault near the Pit 6 landfill. The fault passes a minimum of 100 ft south of Pit 6, and poses no direct hazard to the landfill itself.

In 1989 and 1990, soil vapor surveys near Building 833 and parts of the General Services Area assessed distribution of VOCs in the soil. This first survey used a

vacuum probe and gas chromatography. A second soil vapor survey used the PETREX technique in the same general areas during the spring of 1990. The second study confirmed the results of the first study, and expanded the survey area.

Finally, eight unused Site 300 water supply wells were sealed with grout and abandoned in 1990.

Superfund Amendments and Reauthorization Act (SARA)—Title III.

SARA Title III, also known as the Emergency Planning and Community Right-to-Know Act, requires that the manufacture, use, and storage of certain hazardous chemicals be reported to organizations responsible for emergency response planning. In California this information must be provided to the State Office of Emergency Services, to the county, and to local fire departments. Site 300 database inventories were updated routinely to reflect changes in use and storage of the required chemicals.

Clean Water Act—National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements. Site 300 held three permits from the Regional Water Quality Control Board, required by Federal and State of California regulations. The first, Waste Discharge Requirement, pertains to inactive landfills located at Site 300. The second (also an NPDES permit), Waste Discharge Requirement, applies to the cooling tower discharges at Site 300. Finally, the third Waste Discharge Requirement covers sewer lagoons, septic tanks, leachfields, and the high-explosives rinse water surface impoundment at Site 300.

Clean Air Act. The San Joaquin County Air Pollution Control District (SJCAPCD) enforces air pollution prevention and control programs for air emissions from stationary sources in San Joaquin County. Site 300 held nine air permits from the SJCAPCD in 1990.

Endangered Species Act. Staff from the California Department of Fish and Game and the U.S. Fish and Wildlife Service performed their annual inspection of the endangered wildflower, *Amsinckia grandiflora*, in April 1990.

Executive Summary

A survey at Site 300 was undertaken along Corral Hollow Creek at the nine proposed groundwater treatment facilities and discharge locations that are part of groundwater remediation efforts. No sensitive plant or wildlife species were found within the areas. In particular, no conclusive evidence of the San Joaquin Kit Fox was found. No habitat suitable to support rare plants exists within the project vicinity. A second survey was conducted for six of these locations that concentrated on locating wetlands and *Amsinckia grandiflora*. No new locations

of *Amsinckia grandiflora* were found at Site 300 during any 1990 survey.

Environmental Protection Department Internal Compliance Activities. Environmental analysts from the Environmental Operations Group help employees to implement environmental requirements, so current and planned operations and experiments comply with Federal, State, and local environmental regulations. Compliance is maintained and verified by staff who keep abreast of all existing and planned activities, review construction documents, inspect facilities, and audit waste management procedures.

Now in its twenty-third year of publication, this *Environmental Report for 1990* reaches many audiences and serves many purposes. A partial list of readers includes members of Federal, State, county, city, and regional government agencies and regulatory bodies; Lawrence Livermore National Laboratory (LLNL) employees; the research and scientific communities; educators and students; legislators; the news media; local business leaders; neighbors; and interested members of the public. This work is published not only to comply with *Department of Energy Orders 5484.1 and 5400.1*, but to document and validate the Laboratory's environmental stewardship in a way that is understandable and credible to readers in all of the groups previously listed.

While the range of readership is broad, the depth of readership usually is varied. Because most readers will not read this entire publication, it is organized as a reference rather than as a narrative text. Each major chapter contains its own introduction and is designed to stand alone. This design produces duplicate material within the sections and requires re-explanation of abbreviations and acronyms. While intended to help browsers find the essential information about a specific topic in one place, this redundancy may become tedious for cover-to-cover readers. But the arrangement permits thorough coverage of a subject within a single chapter, without requiring readers to turn to or cross reference other portions of the text.

Monitoring data within this publication is divided into two parts: the Livermore site and Site 300. This division reflects the difference in location and operation of the two sites. The site-specific divisions are organized by the environmental medium monitored (air, sewage, groundwater and surface water, soil, vegetation and food-stuff, and environmental radiation), because each medium represents a pathway by which Laboratory operations could impact the environment.

Another design convention involves the treatment of units of measure. *Système International* (SI) units of measure appear first in this text, followed (in parentheses) by traditional units. Where data are

represented in more than one notation, the intent is not to resist contemporary technical style, but to aid nontechnical readers.

The highest level summary with the broadest readership appeal is contained in the Executive Summary, which begins with background information to familiarize first-time readers. The Executive Summary contains all of the essential findings of the entire report, without most of the technical or scientific terminology and detailed methodology. The subject sequence in the Executive Summary parallels the sequence in the data chapters that follow. Like the publication as a whole, the Executive Summary is presented in two parts—Livermore site and Site 300. For the nontechnical reader, this chapter provides a comprehensive, one-stop synopsis; for the regulator, scientist, or technician, the chapter provides a concise overview with supporting methodologies, data, and findings available within the chapters that follow.

Two new appendices have been added for 1990. **Appendix A** explains the radiological monitoring methodology, and **Appendix C** presents a corresponding explanation of nonradiological monitoring methodology.

Readers wishing clarification on the meaning of terms in this publication are referred to the Glossary near the end of this publication.

Livermore Site
Aerial view
looking west

Introduction

The environmental effects of Lawrence Livermore National Laboratory (LLNL) Livermore-site operations are governed by location, climate, and geology. For example, the dispersal of airborne emissions from the site is controlled by wind patterns and rainfall. Data on wind and rainfall are used to calculate the effects of emissions on nearby populations. Similarly, the dispersal of any groundwater contaminants is constrained by the particular geology of the site. This chapter is a brief overview of facts about Livermore-site surroundings that are used in determining environmental effects of various emissions.

Location

In 1952, when weapons research and development first took place at the Livermore site, the site was approximately one mile away from the city limits of the City of Livermore. However, during the last 30 years, the City has grown and is placing residential, industrial, and commercial developments on parcels adjacent to the Livermore site. Recently, a vacant parcel located about 244 m (800 ft) west of the Livermore-site western boundary was annexed by the City of Livermore and rezoned to allow low-density (3 units per acre), single-family residential development. Construction of residences on this property began in 1989.

Sandia National Laboratories, Livermore (SNLL) is located immediately to the south of the Livermore site. Operated by AT&T Technologies, Inc., SNLL also is under DOE contract to provide research and development associated with nuclear weapons systems engineering and related national security tasks. Although their primary missions are similar, LLNL and SNLL are separate facilities, each having its own local management, and each reporting to a different DOE operations office.

Other property south of the site includes agricultural areas and low-density residential areas. Grazing is the primary activity, although orchards and vineyards may be found to the south; there is also a business park to the southwest of the Livermore site.

Farther south, property is primarily open space or rural ranchettes, with some agricultural use.

The property east of the site is agricultural land with low-density residential development. Farther east, foothills of the intercoastal range define the eastern margin of the Livermore Valley.

A business park is located directly north of the Livermore site, and a 287-acre parcel of open space and agricultural land northeast of the site recently has been rezoned to allow development of a center for heavy industry.

The Livermore site occupies an area of 3.28 km² (1.3 mi²). Recently, DOE obtained additional land around the Livermore site to serve as a buffer zone. Additional land also has been acquired for security buffer zones on the east and west sides of the SNLL site.

Climate

The climate of the Livermore Valley is characterized by mild, rainy winters and warm, dry summers. The mean annual temperature is 12.5°C (59°F); the normal seasonal temperature range is defined by nighttime winter lows in the vicinity of 0°C (32°F) and summer daytime highs around 38°C (100°F). Annual wind data are given in **Figure L-SET-1** and **Table L-SET-1**. Prevailing winds for approximately 45% of the year are from the west and southwest. During the

Livermore Site Setting

remainder of the year, it is calm (approximately one-third of the year) or wind directions are variable.

Both rainfall and wind exhibit a strong seasonal pattern. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months. The highest and lowest annual rainfalls on record are 782 mm (30.8 in) and 138 mm (5.4 in). Rainfall at the Livermore site for 1990 was 175 mm (6.90 in).

Figure L-SET-1. Wind rose showing the average annual wind speed, frequency of occurrence, and direction at the Livermore site, 1990.

Geology

Topography. The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley forms an irregularly shaped lowland area approximately 26 km (16 mi) long, east to west; the valley averages 11 km (7 mi) in width, north to south. The floor of the valley slopes to the west from an elevation of approximately 200 m (660 ft) at the eastern end to approximately 90 m (295 ft) at its drainage outlet, which is located near the southwestern corner.

Surface drainage is by westward-flowing intermittent streams (arroyos) that merge in the west end of the valley to form the southward-flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system. Winter flows that are not captured as groundwater recharge flow out the southwestern corner of the valley and eventually enter San Francisco Bay by way of Alameda Creek. Surface-water bodies near the Livermore site include the South Bay Aqueduct, which runs from northeast to southwest, 0.2 km (0.1 mi) to the southeast of the Livermore site; the treatment tanks and reservoir of the Patterson Pass water treatment facility, about 1.2 km (0.7 mi) east of the Livermore site; Frick Lake, an area of enclosed drainage 4 km (2.4 mi) north of the Livermore site, where winter storm flows accumulate in an intermittent pond; and the Springtown Pond, an artificial decorative pond maintained in a community recreation area 2.6 km (1.6 mi) northwest of the Livermore site. Lake Del Valle, a water storage reservoir 8 km (4.9 mi) south of the Livermore site, provides aquatic recreation (swimming, boating, and fishing), as does the Shadow Cliffs Regional Park, 11 km (6.7 mi) to the west. Lake Isabel, 9 km (4.9 mi) to the southwest, is a fee-for-fishing area. San Antonio Reservoir, 13 km (8 mi) to the southwest, is used for water storage. Both Lake Isabel and the Shadow Cliffs facility are excavations produced by gravel

Table L-SET-1. Average annual percent frequency of wind direction at 10-m level, versus wind speed (m/s) for the Livermore site, 1990. Winds are based on one-hour averages. (Row and column totals do not add up due to rounding of numbers.)

Direction	0.0–0.9 Calm	1.0–2.9	3.0–4.9	5.0–6.9	≥7.0	Total
N	1.6	0.4	0.5	0.4	0.2	3.0
NNE	1.6	1.4	1.2	0.3	0.1	4.5
NE	1.6	2.3	2.4	0.2	0.0	6.5
ENE	1.6	1.2	0.3	0.2	0.3	3.5
E	1.6	0.7	0.4	0.2	0.2	3.1
ESE	1.6	0.7	0.3	0.1	0.0	2.7
SE	1.6	0.3	0.0	0.0	0.0	1.9
SSE	1.6	0.4	0.1	0.0	0.0	2.1
S	1.6	2.6	0.5	0.2	0.1	5.1
SSW	1.6	3.8	1.5	0.6	0.3	7.8
SW	1.6	5.7	6.0	2.9	0.6	16.7
WSW	1.6	5.7	5.1	2.0	0.3	14.8
W	1.6	4.6	5.8	2.5	0.0	14.5
WNW	1.6	2.0	1.3	0.6	0.0	5.4
NW	1.6	1.4	0.8	0.2	0.0	4.0
NNW	1.6	1.4	1.1	0.2	0.1	4.3
Total	25.7	34.8	27.1	10.3	2.1	100.0

quarry operations, which continue to mine additional pits in the same general area. The Livermore site normally receives its treated water supply from the Hetch-Hetchy Aqueduct (which supplies San Francisco), located 11 km (6.7 mi) southwest of Livermore.

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

The Livermore Valley is bordered in the east by the Altamont Hills, where Miocene Neroly and Cierbo Formations and rocks of the Late Cretaceous Great Valley sequence are exposed. Within the valley, lacustrine and fluvial valley fill deposits occur to depths in excess of 1 km (0.6 mi). The oldest of these is the Lower Livermore Formation of late Tertiary age—a hard, locally lithified, predominantly fine-grained sedimentary sequence that is exposed in the hills south of the Livermore Valley. This formation is encountered beneath the Livermore site at depths ranging from 7 m (23 ft) in the east to 119 m (389 ft) in the west. Above the Lower Livermore Formation are the heterogeneous, unconsolidated alluvial sediments of the Pleistocene Upper Livermore Formation, which consist of complexly interbedded layers of poorly sorted clay, silt, sand, and gravel. The late Pleistocene

Livermore Site Setting

and Holocene alluvial deposits that form the uppermost sequence of valley sediments are virtually identical to the Upper Livermore Formation.

The Livermore Formation (and overlying alluvial deposits) contain the aquifers of the Livermore Valley groundwater basin. This is an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Zone 7 conducts artificial recharge as needed to maintain groundwater levels. This recharge is done by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the eastern portion of the valley. Groundwater flow in the valley

generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater flow in the basin is generally assumed to be primarily horizontal, although a significant vertical component probably exists in fringe areas and under localized sources of recharge.

Beneath the Livermore site, the depth to the water table varies from about 43 m (140 ft) to 8 m (25 ft). **Figure L-SET-2** shows a contour map of water-table elevations (feet above mean sea level) for the Livermore site area. Although water-table elevations vary with seasonal and year-to-year variations in both natural and artificial recharge, the qualitative patterns shown in **Figure L-SET-2** are generally

Figure L-SET-2. Approximate groundwater and surface elevation contours (feet above mean sea level, msl), Livermore site and vicinity.

maintained. At the eastern edge of the Livermore site, groundwater gradients (change in elevation per unit of horizontal distance) are quite steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Groundwater flow under the northern and western portions of the site is generally westward. Under the southeast corner of the site, there is an apparent groundwater depression, a phenomenon that has been further investigated; a detailed description of findings

to date is provided in Dresen and Nichols (1986). Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 m/day (3.3 to 52 ft/day) (Weiss Associates 1985). This, in combination with the observed water-table gradients, yields groundwater velocity estimates of 5 to 90 m/y (16 to 293 ft/y). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

Introduction

This section briefly describes environmental activities performed by Lawrence Livermore National Laboratory (LLNL) in response to legal requirements. Included is a description of environmental permits issued to or held by the Livermore site during the year. Also, environmental documents associated with the NEPA process are summarized. A table of public hearings, regulatory inspections, and regulatory permits is presented in **Table L-C-1** below. In addition, this section summarizes pollution abatement projects and special environmental projects or studies conducted or in progress during 1990. For further information about these activities, refer to the documents in the Information Repositories at the LLNL Visitors Center and the City of Livermore Public Library. In addition, a list of 1990 Environmental Protection Department publications is presented in **Appendix D**.

Summary of Permits as of March 1, 1991

Air	192 Permits to Operate for various equipment
Water	Waste Discharge Requirements (WDR) Order No. 88-075 for discharge of treated groundwater to ponds National Pollutant Discharge Elimination System (NPDES) Permit No. 90-106 for discharge of treated groundwater to storm drains
Hazardous Waste	Interim Status Document CA2890012584
Sewer	Discharge permit No. 1205A
Tanks	Fees paid for 65 tanks
Other	Federal Facility Agreement for Livermore groundwater investigation/remediation

Department of Energy Tiger Team

DOE conducted the Tiger Team Assessment of LLNL Environmental, Safety, and Health (ES&H) Programs from February 26 through April 5, 1990. The Team concluded that curtailment or cessation of any LLNL operations are not warranted and that compliance issues identified by the Team are known to Federal, State, and local regulatory agencies. The Team concluded generally that "environmental and safety activities are informal, fragmented, and inconsistently implemented" and that LLNL needed to "change the culture" to attain consistent and verifiable compliance with statutes, regulations, and DOE orders. Specific

findings are written up in more detail in the Tiger Team Assessment (DOE 1990). In response to this report, LLNL developed an Action Plan in which the Laboratory committed to correct deficiencies identified by the DOE Tiger Team Assessment and by self-assessments. This Plan describes: changes in organizational structure to strengthen line management responsibility and accountability for ES&H/QA issues; self-assessment activities to identify, resolve, and prevent future noncompliance with regulations; and commitment of significant funding for corrective actions. Details of the Action Plan are found in the report (LLNL 1990).

Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Activities

The Resource Conservation and Recovery Act (RCRA) provides the framework at the Federal level for regulating the generation and management of solid wastes, including wastes designated as hazardous. Similarly, the California Hazardous Waste Control Law (HWCL) sets requirements for the management of hazardous wastes in California. RCRA and HWCL regulate treatment, storage, and disposal facilities through permit programs administered by the U.S. Environmental Protection Agency (EPA) and the California Department of Health Services (DHS) respectively. Both permit processes require regulatory agency review and approval of a facility's Part A and Part B permit applications. These applications provide information on the facility and the wastes managed at the facility.

Waste Minimization. The Laboratory has instituted a Waste Minimization Program and submitted a Waste Minimization Program Plan to DOE in May 1990. The Plan was written to meet the requirements of *DOE Orders* 5820.2A and 5400.1, RCRA sections 3002(b) and 3005(h), and 22 *California Code of Regulations*. The Plan is made up of a general waste minimization plan for the Laboratory as a whole and incorporates a series of waste minimization "miniplans" tailored to the specific needs of individual programs and directorates that generate hazardous waste.

Hazardous Waste Permits. The Livermore site hazardous waste storage and treatment management units continue to operate under interim status provisions (Interim Status Document, EPA identification number CA2890012584). Specific units include container storage, tank storage, and various treatments.

In the fall of 1989, EPA solicited public comment on its proposed denial of the LLNL hazardous waste management facility permit. As described in the Environmental Report for 1989, LLNL significantly revised the Part A and Part B

permit applications in response to the proposed denial. The revised permit application was submitted to the regulatory agencies in December 1989. On January 23, 1990, LLNL and DOE formally withdrew the incinerator from the Part B permit application and subsequently submitted a detailed closure plan for the incinerator. On September 11, 1990, EPA issued its decision to deny a final RCRA hazardous waste permit for the incinerator and to defer its decision on the other portions of the proposed permit denial, pending review of the extensive materials submitted during the public comment period.

A closure plan initially was submitted to DHS in December 1989 for Area 612-3, a drum/container storage unit. DHS reviewed and commented on the plan, which subsequently was revised by LLNL. The DHS subsequently issued a Notice of Public Comment Period for the plan on June 27, 1990, but had not made a final decision regarding this matter as of the end of 1990.

Inspections. The Department of Health Services inspected LLNL hazardous waste management units and generator operations on February 26 and 28, 1990. An inspection report was received in May. It cited the following: improper labeling of containers (three containers were observed that either lacked labels or had labels that were only partially completed); one container located at a satellite work station was open; a fire extinguisher at one waste accumulation area (WAA) lacked a tag documenting maintenance activities; and one WAA lacked a readily accessible eyewash/safety shower. The Laboratory corrected the observed violations and responded to DHS with documentation of corrections in a letter dated June 26, 1990. DHS issued a Return to Compliance letter on September 5, 1990.

On September 21, 1990, EPA visited the Livermore site as part of a nationwide information gathering effort to review training programs for incinerator operators. Although the LLNL incinerator has not operated since 1988, the inspector

reviewed the histottraining records on file. Staff who had ated the incinera-
tor in the past alsoe interviewed. As
of the end of 1990, report had been
received by the Latory regarding the
findings of this sur

Waste Accumula Areas. A waste
accumulation areaan officially desig-
nated area that meurrent environ-
mental standards guidelines for
temporary (less th) days) storage of
hazardous waste le pickup by the
Hazardous Wasteiagement (HWM)
Division for trans) either an on- or
off-site permitted rdous waste man-
agement facility. There are 55 WAAs at
the Livermore siteen of which were
established durin70, when five were
removed from ser.

RCRA Personnaining. Annual
training sessions as-needed briefings
are conducted on e handling practices
for generators of rdous waste and for
workers assigned pport the permitted
hazardous waste agement facilities.
This training is baupon requirements
set forth in 40 CoFederal Regulations
Parts 262.34 and 26, and 22 California
Code of Regulationtions 66508 and
67105. Employeeen to identify the
basis (i.e., legal, ratory, policy, and
DOE orders) for L waste practices
and the respectivste-management
responsibilities faste generators,
Environmental Asts, and HWM field
technicians. The se also includes
training in the idication of the factors
to determine if a ie is hazardous, in
the determinatiothe need for permits
and controls, and e reduction of the
volume of wasteharged. Other topics
include preparatbf waste for transport
and for storage in As, the protocol for
sampling waste, aration of documen-
tation for waste osal, and response
to emergencies a WAA (or in a labo-
ratory or a shop)ing 1990, a total of
1,926 LLNL Livore site and Site 300
employees receithis training.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks

Federal and State laws provide com-
prehensive regulation of the design, oper-
ation, monitoring, and closing of tank
systems that contain hazardous products
or hazardous waste. The California
Underground Tank Regulations, found in
23 California Code of Regulations Chapter 3,
Subchapter 16, regulate underground
storage tank systems (USTs) used for
containment of hazardous products or
hazardous waste. County health depart-
ments, such as the Alameda County
Health Department (ACHD), have been
delegated authority by the Regional
Water Quality Control Board to enforce
these regulations. Federal standards for
design, construction, operation and main-
tenance, and closure for hazardous prod-
ucts and petroleum products contained in
USTs are found in 40 Code of Federal
Regulations Part 280. Additional Federal
standards for petroleum tanks are given
in 40 Code of Federal Regulations Part 112.
Standards for design, construction, oper-
ation and maintenance, and closure of
hazardous wastes in tanks (both above-
ground and underground) are the subject
of RCRA regulations in 40 Code of Federal
Regulations Part 265. The Livermore site
has 42 aboveground and 46 underground
tanks in service, which may contain either
hazardous products or hazardous waste.
Of these, 33 tanks contain wastewater and
the other 55 tanks contain product.

To ensure that LLNL's UST program is
in full compliance with Federal and State
regulations, a preliminary classification
of USTs as hazardous or nonhazardous
wastewater was made in 1989, based on
existing data and known uses for each
tank. In a second phase, these classifica-
tions will be verified by an extensive
sampling program.

Tank Integrity Testing. The tank leak-
tightness testing program is in place.
Underground tank systems are tested to

Livermore Site
Compliance
Summary

determine their structural integrity in accordance with testing requirements set forth in Federal and State regulations. Single-walled, underground wastewater systems are tested, including those not presently regulated. The underground portions of tank systems are tested (as a whole or by component parts) using methods that may include precision tests, dye tests, helium-injection detection, and hydrostatic tests. All leak-tightness test results for regulated systems are provided to ACHD. Twenty-nine underground diesel fuel and gasoline systems were tested in 1990. All of these systems were leak-tight.

In addition, 23 underground wastewater retention systems were tested. These systems receive and retain wastewater from processes identified as being of potential concern (i.e., metal plating, printed-circuit boards, and semiconductors). Water is retained by these systems until the appropriate mode of disposal has been determined, based on the results of tank content analyses. Testing in 1990 identified five wastewater systems that could not meet the minimum leak-rate criterion. Leak sites for four of these were repaired. A program is under way for necessary repair of the remaining systems containing non-hazardous waste.

Closure Plans, Closure Reports, or cleanup reports were completed in 1990 for tank systems (or portions of systems) that were out of service, previously removed (but not officially closed), or planned for removal from service. Closure requirements for hazardous USTs include a Closure Plan prior to closure of the system, quarterly reports if a leak has been identified, and a Closure Report following closure activities. The Closure Plans require a detailed review of the uses of the tank, a sampling plan, a site plan, and other information to ensure that no environmental contamination has occurred—or if it has occurred, that it is adequately corrected. Ten Closure Plans/Reports were submitted for regulatory review in 1990.

Funding for fiscal year 1991 includes approval for 24 tanks requiring upgrades to meet Federal and State design specifications. Engineering assessments to certify the integrity of all single-wall hazardous waste systems and all newly installed systems are in progress, and are being conducted by staff dedicated to their completion. Additional funding has been requested for fiscal year 1992.

LLNL completed implementation of a comprehensive inventory reconciliation program for petroleum USTs. The results of the reconciliations are reported quarterly to the ACHD. Tanks with volumes greater than 20,000 gallons are tested monthly, with the results reported monthly to the ACHD.

The Environmental Restoration Division (ERD) at LLNL in 1990 investigated tank systems that may have released potential contaminants to the environment. During the calendar year 1990, investigation of nine tank systems were under ERD supervision. Soil sample analysis from these sites showed that none of these systems released any compounds above the hazardous waste regulatory limits for soils. Because tritium is not regulated as a hazardous waste, a risk assessment is under way on tritiated water that leaked into the soil beneath one tank system.

Underground Tank Permits. LLNL paid annual fees to the ACHD for 65 hazardous waste and hazardous product underground tank permits for the Livermore site, although the number of underground tanks requiring permits has decreased as tanks have been closed or reclassified as nonhazardous due to use changes.

Inspections. In January, an inspector from ACHD inspected the floor of the Building 322 plating shop for approval of coating material and sampling procedures. Approvals were granted verbally. The inspector returned on November 20 to inspect tank 298-R1U1 and analytical records for several other tanks. No report had been received as of the end of 1990.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I

Also known as the "Superfund" Act, CERCLA is a Federal statute that gives the Federal government the power to identify and clean up hazardous chemicals and substances released to the environment.

The Environmental Restoration Program (ERP) is a DOE program aimed at the cleanup of environmental contamination caused by former materials handling and waste handling practices at DOE facilities. A general budget category was created for this program at the request of the House Armed Services Committee. Funding began in 1988, however, LLNL's environmental investigations have been ongoing since 1979. ERP efforts at the Livermore site are directed mainly toward the Ground Water Project. (At Site 300, the funds are used for the ongoing Environmental Restoration Project activities, as described in the Site 300 Compliance Summary chapter.)

Ground Water Project. The Ground Water Project continues to address CERCLA compliance issues at the Livermore site in accordance with provisions specified in the Federal Facility Agreement (FFA) under CERCLA Section 120, between the United States Environmental Protection Agency, United States Department of Energy, California Department of Health Services, and the Regional Water Quality Control Board. As required by the FFA, the Project addresses these issues through investigations of potential source areas (such as leaking underground tank systems), continued sampling of groundwater and monitoring, and remediation. Source investigations continue to probe all possible contaminated areas. A computerized source investigation tracing system has been implemented to follow the investigation of all potential sources at LLNL. If contamination is detected above standards, then the area is evaluated further to determine the extent of the contamination. Compliance monitoring

and sampling of groundwater, surface water, soil, sediments, and air for toxic materials led to the conclusion early on (fully confirmed by the *Baseline Public Health Assessment of CERCLA Investigation at the LLNL Livermore Site*, September 1991, UCRL-53953) that the primary medium of concern is groundwater and that the principal compounds of potential concern are VOCs and fuel hydrocarbons. Pilot remediation has been initiated in two areas: the Southwest Corner with Treatment Facilities A and B (TFA and TFB) and the Gasoline Spill Area. In addition, work continues on various computer models and algorithms to support remediation design and planning activities. Effective remediation will require a predictive ability as part of the EPA Remedial Investigation/Feasibility Study process, with an eye toward full-scale operations commencing in 1992.

The scope of these assessment and restoration efforts encompasses a set of diverse activities designed to investigate, evaluate, and eventually remediate potentially hazardous compounds that may have affected soil and groundwater. These activities include the following: investigation of the hydrology, geology, soil properties, and hydrogeology of the site; investigation of known and suspected sources of contamination; installation of monitor and extraction wells; sampling and analysis of soil and groundwater; aquifer testing; development of computer models and a conceptual site model to aid groundwater study; continuation of a historical records search to identify potential sources of contamination; assessment of potential risks to public health from potential contamination of soil and groundwater; providing project information to the public and coordinating community involvement; evaluation of numerous studies designed to aid site remediation; preparation of reports documenting the investigation, evaluation, and remediation; testing and implementation of appropriate technologies to accomplish environmentally responsive cleanup of the site.

Livermore Site Compliance Summary

TFA has treated approximately 17,400,000 gallons of groundwater during 1990, for a total of 24,100,000 gallons treated since operation of TFA began. Approximately 30 lbs (~2.5 gal) of VOCs were removed from the groundwater and destroyed by TFA.

TFB treated 1,000,000 gallons of water in 1990. Approximately 0.8 lbs (~0.1 gal) of VOCs were removed from groundwater and destroyed. The LLNL Ground Water Project has implemented its community relations plan, establishing a community relations work group with regularly scheduled meetings and a published a quarterly to keep members informed. The LLNL Ground Water Project also has submitted to regulatory agencies all of the Remedial Investigation and Feasibility Study reports. Copies of these documents are available to the public at the LLNL Visitor Center and the Livermore Public Library. Monthly project reports and an Annual Project report provide extended detail about the LLNL Ground Water Project's activities.

Superfund Amendments and Reauthorization Act (SARA)—Title III

SARA Title III also is known as the Emergency Planning and Community Right-to-Know Act. It requires owners/operators of facilities that have certain hazardous chemicals on site to provide information on the manufacture, use, and storage of those chemicals to organizations responsible for emergency-response planning. In California, this information must be provided to the California Office of Emergency Services, the county, and the local fire department.

A physical inventory of all chemicals subject to reporting under SARA Title III was conducted during the months of November and December 1988. The inventory included the chemical name, the location, the weight, the type of container, and the physical state of the substance. The inventory included the Livermore site, Site 300, and leased space off site. In early

1989, the data were entered into a computerized database system, and reports were generated for local emergency planning agencies. Periodic updates to the inventory reflect changes in chemicals handled on site.

SARA/OSHA Personnel Training. LLNL also provides training for hazardous waste operations and emergency response. This training is based on requirements in 40 *Code of Federal Regulations* Part 1910.120. There are two initial training courses. The first is a 40-hour course geared to general workers performing cleanup operations or investigations, and who are engaged in activities that expose (or potentially expose) the worker to hazardous substances and health hazards. The second is a 24-hour course for HWM operators and workers who are on site only occasionally, for a specific limited task, and who are unlikely to be exposed over permissible exposure limits. This course also is for workers regularly on site who work in fully monitored and characterized areas where there is minimal potential for exposure to hazardous substances and health hazards. The course covers the hazards of waste sites, the general physical and hazardous properties of chemical compounds, the fundamental toxicological concepts important in determining the toxicity of materials and predicting their effect on exposed individuals, and the physical hazards (heat stress, noise, and ionizing radiation) involved in working at a waste site. The course also covers exposure guidelines, protective clothing and devices, air monitoring, site characteristics, control and safety planning, drum and container handling, confined-space entry, emergencies, and hazard communication.

SARA/OSHA supervisory training also is offered. This training is an eight-hour course required for personnel who will lead others in the field at cleanup operations and at HWM. The course emphasizes the safety and health program, planning and coordination, site management, personal protective equipment, spill containment programs, and health hazard monitoring procedures.

Toxic Substances Control Act (TSCA)

The Toxic Substances Control Act (TSCA) is a broad statute that empowers EPA to regulate hazardous chemicals (not regulated already by other laws) produced, used, or imported into the United States. The TSCA regulations that affect the Livermore site are those regulating the storage and disposal of polychlorinated biphenyls (PCBs). The PCB annual report required under 40 *Code of Federal Regulations* 761.180 was prepared and is kept on record, available for EPA inspection.

National Environmental Policy Act (NEPA)

NEPA establishes Federal policy for protection of environmental quality and provides the means for implementing that policy. Within NEPA, the major means to achieve established goals is the requirement for Federal agencies to assess the environmental impacts of their decisions through preparation of an Environmental Impact Statement (EIS) for any major Federal or Federally funded project that may have significant impacts on environmental quality. If the need for an EIS is not clear, an environmental assessment (EA) must be prepared with a definitive conclusion either calling for an EIS or making a finding of no significant impact (FONSI). In the latter case, no EIS is required.

Groups of actions that individually or cumulatively do not have a significant effect on the human environment can be exempt from the NEPA process by establishing "categorical exclusions." A memorandum was written when a proposed action clearly would have no significant environmental impacts, but because of limited DOE experience, the action had not yet been added to the list of categorical exclusions. DOE discontinued the use of memorandums as of September 1990.

An Action Description Memorandum (ADM) is written when the proposed action is not clearly insignificant. The ADM is used by DOE to determine if an EA or an EIS is needed.

In 1990, over 122 projects were evaluated under NEPA and under the applicable policies and procedures for DOE compliance with NEPA (*Federal Register* Vol. 52, No. 240, December 15, 1987), as amended. These projects included 20 ADMs, 29 Memorandums, and 60 Categorical Exclusions. Ten projects were determined by DOE to require EAs, nine of which were for projects at the Livermore site and are described below. These are listed below. Nine of the ten currently are under DOE review. A Finding of No Significant Impact (FONSI) was issued by DOE in June 1990 for the Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL. Three projects were evaluated under CEQA and University of California procedures for CEQA implementation.

Environmental Assessments. Environmental Assessments were prepared for the following nine LLNL Livermore-site proposed actions.

Environmental Assessment of the Uranium Demonstrations System (UDS) at LLNL. The UDS operations are proposed to support LLNL's continuing effort to demonstrate uranium enrichment by the Atomic Vapor Laser Isotope Separation (AVLIS) process.

Environmental Assessment for the Multi-User Tandem Laboratory (MTL) (Building 190) at LLNL. This document considers the potential environmental impacts from current and planned operations in the MTL in the northwest section of LLNL. Building 190 is a laboratory where research activities are performed. It houses an electrostatic accelerator, with which accelerated beams of heavy or light ions are used in a broad variety of basic and applied research in nuclear physics, materials science, and accelerator mass spectrometry.

Environmental Assessment for Acquisition of East Avenue, Alameda County, California. This document addresses the potential impacts from acquiring the section of East Avenue between South Vasco and Greenville Roads, and from

Livermore Site Compliance Summary

construction of project-related facilities to control or restrict public access to sensitive facilities at LLNL and Sandia National Laboratories, Livermore (SNLL), and to enhance future security at the laboratories to allow an integrated site security system.

Environmental Assessment for Ion Accelerator in Building 235 at LLNL. This document considers the potential environmental effects from conduct of experiments using a commercially manufactured 4.0 MeV ion accelerator in Building 235.

Environmental Assessment for an addition to Building 166. This document addresses the potential environmental impacts from establishment of facilities for the growth and processing of semiconductor crystals. The crystal growth facility would use a process known as metalorganic chemical vapor deposition (MOCVD) that involves the pyrolysis of metal alkyls and metal hydrides.

Environmental Assessment for Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL (DOE/EA-0421). This document assesses the potential for environmental impact from resumption of testing with surrogate materials in the EDS at LLNL. In these tests, rare-earth metals would be used as surrogates for, and in lieu of, plutonium. The test provides operating experience and information to evaluate the design and operability of the Atomic Vapor Laser Isotope Separation (AVLIS) separator hardware in an integrated system configuration. The FONSI stipulated that an Action Plan for implementation of commitments for mitigation of environmental impacts associated with the project (as well as annual progress reports) are required in accordance with Secretary of Energy Notice, Number 15, 1990 (SEN-15-90).

In addition, DOE Order 5400.4, issued October 6, 1989, specifies that the NEPA and CERCLA processes should be integrated by conducting the NEPA and CERCLA environmental planning and review procedures concurrently. During 1990, LLNL prepared three EAs (one at

Livermore site and two at Site 300) for environmental restoration activities. The EAs (which also are written to meet the requirements of CEQA) are written as chapters within the Feasibility Study (FS) documents.

Environmental Impact Statement/Environmental Impact Report. In addition to the NEPA/CEQA documents discussed previously, work began on the sitewide EIS/EIR. In October 1990, the DOE published a Notice of Intent (NOI) in 55 *Federal Register* 41048 to prepare a joint EIS/EIR for continued operation of both LLNL (operated by the University of California for the DOE) and SNLL (operated by the Sandia Corporation for the DOE). That same month, UC filed a Notice of Preparation (NOP) with the California Office of Planning and Research to prepare a joint EIS/EIR. Both the NOI and the NOP were sent to the California State Clearinghouse for distribution within the state.

Both the NOI and the NOP invited the public to attend a scoping meeting on November 15, 1990, in Livermore, California, and to provide written comments until the close of the comment period then set for November 30, 1990. At the request of the public, UC and the DOE subsequently extended the deadline to December 15, 1990.

During the EIS/EIR scoping process, the DOE and UC received a total of 282 comments from 61 members of the public; interested groups; and Federal, State, and local officials.

Endangered Species Act. Four surveys for biological resources were conducted during 1990 both at the main site and Site 300. These surveys were conducted to determine whether proposed projects at these locations could impact sensitive plant or wildlife species or habitats. Special attention was given to the presence of sensitive species: Federal- and State-Listed Endangered or Threatened Species, Federal Candidate Species, Fully Protected Species of Special Concern, and California Native Plant Society-listed species.

Surveys at the main site were conducted for the proposed drainage retention basin redevelopment project and for the Livermore Site Ground Water Project entitled *Biological Impacts Associated with the Proposed Retention Basin and Ground Water Projects at LLNL and the Ground Water Projects at Site 300* (Biosystems Analysis, Inc. 1990). No sensitive plant or wildlife species were found within the project areas during the survey. No habitat suitable to support rare plants was found within the project vicinity. The surveys determined that marginal potential habitat for the California tiger salamander and red-legged frog (two Federal candidate species and species of special concern) occurs along the lower portion of Arroyo Las Positas.

National Historic Preservation Act. During 1990, four cultural resource surveys were undertaken to ensure that proposed laboratory actions did not affect significant archeological or historical resources. Two of the surveys occurred in LLNL's newly acquired land adjacent to Vasco Road. A third archeological survey was undertaken for the DOE-proposed acquisition of approximately 14 acres of land adjacent to Site 300. In addition, prior to their demolition two buildings at the LLNL main site were assessed for potential historical significance. Results of all investigations were not historically significant.

Clean Water Act—National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements

Clean water is the subject of Federal, State, and local regulations. The National Pollutant Discharge Elimination System (NPDES), under the Federal Clean Water Act, establishes permit requirements for discharges into surface waterways. In addition, the State of California requires permits for any discharges that have the potential to influence adversely the beneficial uses of waters of the State. The

Regional Water Quality Control Boards (RWQCBs) are responsible for issuance and enforcement of both permit types. Finally, the City of Livermore Water Reclamation Plant (LWRP) requires permits for discharges to the city sanitary sewer system.

Groundwater Discharge Permits. The Waste Discharge Requirements, Order 88-075, pertains to activities undertaken to investigate and remediate groundwater contamination at the Livermore site. The order allows discharge of treated groundwater to specified areas on DOE property. The NPDES permit (CA 0029289, also designated as Waste Discharge Requirement Order 90-106), applies to discharges to the ground from monitoring wells used in the groundwater investigation. The Self-Monitoring Programs required by these permits are described in the Environmental Program Information chapter.

Wastewater Permits. The Livermore site renewed the Wastewater Discharge Permit from the City of Livermore Water Reclamation Plant (LWRP) for discharges to the city sanitary sewer system. Permit No. 1250a is in effect from September 1, 1990, through August 31, 1991. Under the provisions of that permit, LLNL is required to conduct a monitoring program for the major categories in accordance with Federal regulations with quarterly sampling and semiannual reporting of the results to the Livermore Water Reclamation Plant. Processes from metal-finishing to electrical and electronic categories have been identified. The pretreatment program consists of 28 individual processes and 3 retention tank systems. Fourteen of the processes are sampled quarterly, 14 do not require sampling, because they do not discharge to the sanitary sewer. And the 3 tank systems are sampled and analyzed before each discharge. One addition to this list is the Site 300 Paint Shop at Building 872. The shop has been reported to the LWRP in the last two reports, because waste from this process was brought to the Livermore site for discharge to the LWRP one time in 1989.

Livermore Site Compliance Summary

Since December 1989, sampling has shown four instances of noncompliance. Three of those instances were one-time pH excursions from different processes. Each process was corrected by the addition of still-rinses. The other incident was a metals excursion at a bright-dip operation, which, upon investigation, was found to be caused by a dirty sample collection site. All of these events have been reported to the LWRP. No violation notices have been issued.

Inspections. The LWRP spent ten days on site during Calendar Year (CY) 1990, inspecting and sampling discharges. Each of these inspections is summarized briefly below.

The LWRP inspector spent two separate days in February and March reviewing the Building 322 plating shop. This area was inspected first in February. During the March inspection, samples of the Building 322 plating shop wastewater discharge were collected. No formal reports were received from the LWRP.

On April 30, specific areas of Buildings 196 Sewer Monitoring Station, 197 semiconductor and metal finishing process, 514 Liquid Waste Treatment, 612 Waste Storage, 131 Microfab Processing Laboratory and 253 Hazards Control bright-dip operation were inspected by the LWRP. No violations were noted; however, the inspector arranged to return to participate in the quarterly pretreatment program. Split samples were collected on May 8, 9, and 18. The inspector observed a pH excursion. Corrective action was taken while sampling at Building 131.

On May 31, the inspector toured a construction site checking for potential sewer discharge concerns. None were noted.

Pretreatment processes were inspected and sampled at Buildings 131 and 253 on August 15. The inspector requested modifications at the Building 131 sampling location. These modifications subsequently were completed and reported to the LWRP.

On November 5, the LWRP inspected and sampled the Building 321 water jet,

inspected various processes at Buildings 406 and 691, and toured the sewer diversion facility. No issues were noted by the inspector.

On December 10, samples were collected at Building 141, and the Building 251 facility was inspected. Modifications to aid sample collection at Building 141 were requested as well as building a berm around the Building 251 tank system. These changes were being pursued at the end of 1990.

Clean Air Act/Air Quality Management Activities

The Clean Air Act is the Federal law that authorizes the EPA to set air quality standards and to assist State and local governments to develop and execute air pollution prevention and control programs. The Bay Area Air Quality Management District (BAAQMD) is the local agency responsible for enforcing these standards (as well as the State and local standards) for air emissions from stationary sources in the San Francisco Bay Area—including the Livermore site.

Reports. After reviewing LLNL's air-toxics emission inventory submitted to the BAAQMD in November 1989 (as required by AB2588, the Air Toxics "Hot Spots" Information and Assessment Act of 1987) the BAAQMD requested that the Laboratory assess the impact of toxic air emissions on the surrounding area. Following guidance issued by the California Air Resources Control Board and the BAAQMD, the SCREEN computer simulation model was used to perform a screening risk assessment. The results of this work were submitted to the District in October 1990. The District reviewed the document and asked for additional refinement of the work performed. A revised report was submitted in December 1990. This report showed that the maximum value for carcinogenic risk caused by exposure to the toxic air emission from LLNL operations is 7.7×10^{-6} , which is below the threshold of 1×10^{-5} . The maximum value for noncarcinogenic risk

is 0.036, which is below the threshold of 1.0. If the threshold values had been exceeded, BAAQMD would require a full risk assessment.

National Emission Standards for Hazardous Air Pollutants. In October 1989, the EPA issued new NESHAP requirements for radionuclide emissions from DOE facilities. DOE initiated discussions with the EPA to develop a Memorandum of Understanding on how the DOE facilities would achieve compliance with these standards. Pending resolution of the DOE/EPA discussions, LLNL drafted a work plan to satisfy the new requirements and began to assemble information needed to meet the new standards. This information included reviewing operations that employ radionuclides and gathering data for modeling each source. The work plan projected completion of a report by July 1993.

Air Permits. The BAAQMD issued 192 permits to LLNL. These 192 permits were Permits to Operate for the following operations or equipment:

96 boilers, 51 solvent cleaners, 12 particulate capture devices (cyclones and/or baghouses), 6 cleaning/refurbishment devices, 4 printing presses, 4 oil shale experimental equipment, 3 paint spray booths, 2 vapor recovery systems, 2 groundwater stripping systems, 2 ovens, 1 gasoline station recovery system, 1 fire test cell, 1 wet scrubber, and 7 miscellaneous sources.

Inspections. The Bay Area Air Quality Management District conducted 20 days of inspections at the Livermore site during 1990. Inspections were conducted to review start-up of new equipment and operation of existing equipment with permits. As a result of these inspections, the Laboratory received three Notice of Violations. They were issued for: operating a silk-screening unit without proper controls (the District interpreted this unit as regulated by rules pertaining to cold cleaners, rather than by the surface preparation rules—as LLNL thought applicable); operating two paint spray booths without permits; and using an

improper mix of thinner in paint, resulting in too much volatile organic content. In response to these NOV's the Laboratory took the following actions: the cold cleaner was shut down until the rule applicability could be sorted out and compliance measures taken; the paint spray-booths received permits to operate; and the paint shop corrected their mixing proportions of thinner to paint.

Compliance Summary, First Quarter 1991

This summary updates the environmental compliance status and environmental issues and actions at the Lawrence Livermore National Laboratory during the period January 1 through March 31, 1991. This summary is in the format specified for self-assessments: Compliance Summary, Current Issues and Actions, and Environmental Permits.

Tiger Team Assessment. The Laboratory continues to undertake those actions identified in its Action Plan, which was prepared in response to DOE's Tiger Team Assessment of LLNL operations. The Action Plan includes descriptions of the actions to be taken at the site to respond satisfactorily to the findings, to show schedules and due dates for activities, and to identify parties responsible for implementing the Action Plan. The document also identifies actions and costs that are included (or planned for inclusion) in DOE's Five-Year Plan.

A significant amount of progress has been made towards the 573 subtasks identified in the Action Plan prepared in response to the April 1990 Tiger Team Assessment of LLNL and approved by DOE in early October 1990. Of the 573 subtasks identified in the Action Plan, 291 had completion dates prior to the end of the first quarter of FY91. Of this number, 196 were completed, 39 were more than 75% complete, and 56 were less than 75% complete. The majority of those not completed are a result of not being able to acquire qualified staff as fast as originally anticipated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). During the first quarter of 1991, the Environmental Protection Department responded to two incidents that required agency notification. Agencies notified included the Department of Energy, the Environmental Protection Agency, the California Department of Health Services, and the California Regional Water Quality Control Board. Neither incident caused any adverse impact to human health or the environment, and neither incident required notification of the National Response Center under Section 103(a), the Emergency Release Notification provision of CERCLA.

A groundwater cleanup program is ongoing at the Livermore site pursuant to provisions of the Federal Facility Agreement under CERCLA/SARA Section 120, because this site is listed on EPA's National Priority List. Groundwater at LLNL contains solvents that had been used by the U.S. Navy to clean airplanes in the 1940s.

On February 1, 1991, LLNL completed the draft Proposed Remedial Action Plan (PRAP) for cleaning up groundwater and soil contamination at the Livermore site. Recommendations to clean up groundwater include a proposal to extract groundwater at 18 locations and to treat the water by applying appropriate techniques. Contaminated soil will be treated by extracting fuel hydrocarbons or volatile organic compounds by vacuum-induced venting and treatment of vapors at the surface by oxidation. The EPA, DHS, and RWQCB are reviewing the draft PRAP.

Clean Air Act. Data has been provided to EPA for compliance with the National Emission Standard Hazardous Air Pollutant (NESHAP) requirements for releases of radioactive emissions from DOE facilities. EPA reviewed the data and found that LLNL had not fully complied with these standards. EPA issued a Findings of Violation and an order to come into compliance to the University of California and the Department of Energy on April 19, 1991.

The EPA order requires that every release point from an operation using radionuclides must be evaluated using an EPA computer model. The decision to install stack monitoring depends on the outcome of this evaluation. EPA acknowledged in the Finding of Violation document that it appeared that LLNL had monitored and modeled the major contributors to these emissions. Negotiations to further demonstrate compliance with these requirements are being conducted with EPA.

AB2588 Air Toxics "Hot Spots" Information and Assessment Act of 1987.

As a result of the air toxics emission inventory submitted to the BAAQMD in November 1989 in accordance with AB2588, the BAAQMD requested that LLNL assess the impact of toxic air emissions on the surrounding area. A screening risk assessment was prepared using the SCREEN model and submitted to BAAQMD in October. A revised report was submitted in December 1990. This report showed that the maximum value for carcinogenic risk due to exposure to the toxic air emission from LLNL operations is 7.7×10^{-6} and the maximum value for noncarcinogenic risk is 0.036. BAAQMD continued to have concern about some of the assumptions used (urban versus rural designations) that could impact the outcome of the modeling effort. In response to this concern, LLNL performed an additional screening level risk assessment using the Industrial Source Code—Short Term model. This evaluation predicted a carcinogenic risk of 3×10^{-6} , which is below the threshold of 1×10^{-5} , and noncarcinogenic hazard indices of 0.089 for chronic exposures and 0.42 for acute exposures, both of which are below the threshold of 1.0. If the threshold values had been exceeded, the BAAQMD would require a full risk assessment.

Resource Conservation and Recovery Act (RCRA). Proposed and recent changes to the California Hazardous Waste Control Law are being evaluated for impacts on

LLNL activities. Of particular concern are the proposed Permit-by-Rule (PBR) regulations and the revisions to the definition of storage.

The PBR regulations will allow certain treatment technologies to be used for certain waste streams without having to complete the formal hazardous waste permitting process. However, these rules do require significant effort to ensure that proper documentation and procedures are followed and are available for inspection. As part of its ongoing efforts to better manage wastes, LLNL is reviewing various proposed operations for application of the PBR requirements.

The 1990 revision of the definition of storage in the California Hazardous Wastes Control Law has the potential to bring a number of areas under permit conditions that currently are operated in accordance with generator standards. Discussions are ongoing with the Department of Health Services to understand better the applicability of this regulation to a facility such as LLNL, which has both permitted and generator operations.

Regulatory Agency Inspections. No formal inspection reports were received during the period from January through March 1991 for any of the inspections listed below.

Appraisals/Inspections, January—March 1991

<u>Purpose and Date</u>	<u>Performing Agency</u>
Annual Inspection of permitted sources (Jan. 2, 4, 28, 29, 30)	Bay Area Air Quality Management District
All units at HWM and various WAAs and associated generation points (Jan. 9, 10, 11, 14, 15 and Feb. 5)	California Department of Health Services
Inspect and sample three processes in B197 and B511 (Feb. 6)	Livermore Water Reclamation Plant
Inspection of various permitted sources (Feb. 6, 12, 14, 19)	Bay Area Air Quality Management District
Tour Groundwater Treatment Facility and sample B131 tank and cleanroom (March 1)	Livermore Water Reclamation Plant
Inspection of newly permitted sources (March 4, 7)	Bay Area Air Quality Management District

Current Issues and Actions

As discussed in LLNL's Environmental Reports for 1989 and 1990, EPA proposed to deny the hazardous waste facility permit for the LLNL Livermore site. LLNL responded to this proposal with a revised Part B permit application, which deleted the incinerator and added mixed-waste storage and treatment units. LLNL and DOE subsequently submitted a letter to EPA and DHS dated January 23, 1990, formally withdrawing the incinerator permit application. The incinerator closure plan was subsequently submitted to the agencies for review in April 1990. On September 11, 1990, EPA issued a notice that they had decided to deny the incinerator permit and to defer any action on the other portions of the proposed permit denial.

The final decision to deny the incinerator portion of the permit application became effective on October 15, 1990. The closure plans for the incinerator and a separate storage area—Area 612-3—were approved in letters signed by DHSA on March 18 and by EPA on March 25, 1991. In a concurrently signed letter, EPA and DHS approved the December 18, 1989, Revised Part A application. This approval allows the continued operation of existing waste management units, acknowledges the planned closure of the incinerator and Area 612-3, allows the use of Building 693 to replace storage capacity lost by closure of Area 612-3, allows hazardous waste storage at Building 233, and allows one storage tank of up to 5,000 gallon capacity in the 612 recessed loading bay.

Environmental Permits

Air Permits. Permits are obtained from the BAAQMD for the Livermore site and from the San Joaquin County Air Pollution Control District for Site 300, as identified in the Annual Report. As of March 1, 1991, LLNL had received 15 new permits and 23 exemptions, submitted 28 permit applications and 46 exemption requests to the Districts for consideration, and was preparing an additional 7 permit applications and 12 exemption requests.

Water Permits. There are two water discharge permits for the Livermore site for discharge of treated groundwater produced by environmental restoration activities. The environmental restoration activities are being conducted under a Federal Facility Agreement under CERCLA/SARA Section 120 between the EPA, DOE, California Department of Health Services, and the California Regional Water Quality Control Board. The treated groundwater is discharged either to a recharge basin, located south of the site, or to arroyos.

The Livermore Reclamation Plant (City of Livermore) has permitted LLNL for discharge of sanitary and industrial wastewaters that meet discharge limits to the sanitary sewer system.

Underground Tank Permits. Fees have been paid to Alameda County for 65 underground tank permits.

Hazardous Waste. The LLNL site hazardous waste management units continue to operate under interim-status standards.

Table L-C-1. Appraisals/inspections 1990.

Date	Purpose	Performing agency
Jan. 9, 11, 24	Annual inspection of permitted units	BAAQMD
Jan.	Inspection of B322 ^a floor for approval of coating	ACHD
Feb.-March	DOE Tiger Team accompanied by regulatory agency representatives	DOE, EPA, DHS
Feb. 26 & 28	WAA and HWM inspection	DHS
Feb.	Inspect B322 plating shop	LWRP
March	Sampling of B322 plating shop discharge and total effluent at B196	LWRP
April 30	Inspect specific discharges at B196, 197, 514, 612, 131, & 253	LWRP
May 8, 9, & 18	Quarterly Pretreatment Sampling Wastewater discharges	LWRP
May 21	Inspect newly permitted units	BAAQMD
May 25	B321 asbestos removal	BAAQMD
May 31	B391 LANSAs construction site	LWRP
June 14	B272 refurbishment project Discussion of B196 and Facility A	BAAQMD
June 15	B141 vapor degreasers, B166, T1786, ^a B383, & B391 cold cleaners	BAAQMD
June 28	Permitted sources inspection of 7 boilers, 3 vapor degreasers & 1 spray cleaner	BAAQMD
June 29	Permitted sources inspection of 2 boilers, 3 cold cleaners, & 1 solvent cleaner	BAAQMD
July	No inspections	
Aug. 3	B332 fuming box scrubber & B332 solvent cleaner	BAAQMD
Aug. 9	Permitted source inspection B224 milling machine, B175 solvent cleaner	BAAQMD

...continued

Livermore Site
Compliance
Summary

Table L-C-1. Appraisals/inspections 1990 (concluded).

Date	Purpose	Performing agency
Aug. 15	Inspect and sample B131 & 253 for pretreatment program	LWRP
Aug. 17	Permitted sources, 3 solvent cleaners in B321 and various lathes	BAAQMD
Sept. 12	Review out-of-service sources (paperwork) and B511 degreasers	BAAQMD
Sept. 26	B418 paint spray booths View Facility B for Permit to Operate	BAAQMD
Oct. 3	Inspect permitted air sources	BAAQMD
Oct. 4	Incinerator training records	EPA
Oct. 10	Inspect permitted air sources	BAAQMD
Oct. 23	Inspect sources at B611, 691, 381, & 169B	BAAQMD
Nov. 5	Inspect B418 paint shop sources	BAAQMD
Nov. 8	Inspect and sample B321 water jet, inspect various processes at B406 and B691, tour sewer diversion facility	LWRP
Nov. 15	Sitewide EIS/EIR public scoping session	DOE
Nov. 16	Inspect sources at B418, 432, 438, & 490 Notice of Violation issued for silk-screening unit at B438	BAAQMD
Nov. 20	Review underground tank records	ACHD
Nov. 30	Inspect B438 to verify compliance Notice of Violation issued for paint spray booths without permits	BAAQMD
Dec. 10	Inspect B141 and 251 discharges	LWRP

^a B### indicates building number, and T#### indicates trailer number.

Introduction

Lawrence Livermore National Laboratory (LLNL) has a substantial continuing commitment to environmental compliance and accountability. Each year, the Environmental Protection Department (EPD) makes a significant effort to monitor the environment near the Livermore site and Site 300. In 1990, over 150,000 analyses of environmental samples were performed. This effort, which is conducted in accordance with *DOE Orders* 5400.1 and 5484.1, has three purposes: (1) to assess the effectiveness of pollution control programs, (2) to assess compliance with applicable environmental laws and regulations, and (3) to estimate the impact of operations on the environment. Data are produced from sampling of air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and environmental radiation; the type of samples collected at a specific location depends on the site and the potential pollutants to be monitored. Complete details regarding individual monitoring activities can be found in specific chapters grouped by environmental media. These chapters also document a special study of tritium in rain and stormwater runoff, discussed in the Water Monitoring chapter. Special studies of plutonium at the southeast quadrant of the site and tritium in unsaturated soils throughout the site are discussed in the Soil Monitoring chapter. Summary information on monitoring activities can be found in the Environmental Radiological Program Summary, Environmental Nonradiological Program Summary, and in the Radiological and Nonradiological Methods Appendices.

Although its monitoring activities are quite comprehensive, the main mission of the Environmental Protection Department is to interact with Laboratory programs, thereby ensuring that operations are conducted in a manner that limits environmental impacts to levels consistent with regulatory guidelines. The activities that are required by environmental statutes are described in the preceding chapter (Compliance Summary). The remainder of this chapter describes the activities, carried out by EPD at the Livermore site, which were mandated by DOE or implemented independently by LLNL.

Environmental Protection Department

The Environmental Protection Department comprises four divisions: Environmental Guidance Division, Environmental Restoration Division,

Hazardous Waste Management Division, and Regulatory Affairs Division. Working with LLNL programs, the EPD assures that LLNL can meet its environmental responsibilities as stipulated in environmental legislation, regulations, and DOE orders.

Environmental Guidance Division. The Environmental Guidance Division helps LLNL programs and organizations to operate in an environmentally sound manner and to meet compliance requirements. Specifically, the Division staff:

- Advises and trains program personnel on regulatory compliance, waste minimization, and pollution abatement;
- Identifies and alerts program line management of potential environmental contamination and compliance problems in the early project planning stages;
- Assists programs in conducting compliance audits;

Livermore Site Environmental Program Information

- Responds during emergencies to advise on environmental cleanup standards, sampling, and possible need for reporting to regulatory agencies.
- Coordinates regulatory requirements for tanks and wastewater systems, including record keeping and regulatory interface;
- Prepares risk assessments, reports, and documents, such as Environmental Impact Reports and Statements (EIRs and EISs), for compliance with the National Environmental Policy Act and the California Environmental Quality Act.

Environmental Restoration Division.

The Environmental Restoration Division was established in response to past hazardous materials handling and disposal practices, and past leaks and spills that resulted in environmental contamination at levels unacceptable by current standards. The staff of this Division:

- Plans, directs, and conducts assessments to determine the impact of such releases on the environment;
- Conducts restorations to reduce contamination to acceptable levels that will not harm human health or the environment;
- Investigates field sites to determine the existence and extent of contamination;
- Manages corrections such as soil removal and groundwater and surface water treatment; and
- Closes inactive facilities in a manner designed to prevent environmental contamination.

Hazardous Waste Management Division.

The Hazardous Waste Management Division manages and processes all LLNL-generated hazardous wastes, radioactive wastes, and mixed wastes for storage, treatment, and transportation for recycling or off-site disposal. The Division staff also manages the Waste Minimization Program. Specifically, the Hazardous Waste Management staff:

- Processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal or recycling;

- Tracks and documents the movement of hazardous, mixed, and radioactive waste from waste accumulation areas to final disposal, both on and off site;

- Responds to emergencies; and
- Participates in spill cleanup.

Regulatory Affairs Division. The Regulatory Affairs Division assures LLNL compliance with environmental regulations through the regulatory permitting process for such environmental matters as hazardous waste handling, air emissions sources, and water discharges. The Division also has responsibility for monitoring the environment and preparing the numerous reports required by various environmental regulations and DOE orders, including this report. The Regulatory Affairs Division staff:

- Monitors environmental media to verify compliance with established limits and to ensure there is no environmental degradation due to LLNL activities;
- Works with regulatory agencies in the preparation of reports, permit applications, and other documents required to demonstrate compliance with environmental regulations;
- Maintains knowledge of legislation that may impact LLNL activities; and
- Interacts with the community on environmental issues and the impact of LLNL operations.

Livermore Site Permits

The Permits Group of the Regulatory Affairs Division maintained the following permits for Laboratory operations:

Air—192 Permits to Operate for various equipment. Issued by Bay Area Air Quality Management District. Renewed annually.

Water—Waste Discharge Requirements (WDR) Order No. 88-075 for discharge of treated groundwater to ponds. National Pollutant Discharge Elimination System (NPDES). Permit No. 90-106 for discharge of treated groundwater to storm drains. Issued by the San Francisco Bay Regional

Water Quality Control Board. The Self-Monitoring Programs required by these permits are as follows:

Treatment Facility A—In 1990, LLNL continued a self-monitoring program, as required by the RWQCB Waste Discharge Requirement Order No. 88-075, to verify the performance and effectiveness of Treatment Facility A (TFA) and the LLNL recharge basin, located south of East Avenue. The self-monitoring sample collection schedule for TFA is presented in **Table L-EP-1**. Only one effluent discharge limit has been exceeded to date. On February 20, 1990, effluent from TFA contained 10.3 ppb total VOCs (including 8.8 ppb PCE, 0.6 ppb 1,1-DCA, and 0.9 ppb chloroform), exceeding our discharge limit of 5 ppb total VOCs. On February 27, LLNL received these analytic results and ceased operation of TFA to investigate. It was determined that mineral particles or precipitates were adhering to the quartz ultraviolet tubes, thus limiting the effectiveness of the ultraviolet light and clogging the air flow in the second-stage polishing system. In response, the tubes and filters have been replaced periodically to keep the system operating effectively. The cause of this scaling is being investigated.

Treatment Facility B—In February 1991, the self-monitoring program for TFB will be implemented as required by RWQCB Waste Discharge Requirement Order No. 90-106. The start-up sampling requirements are presented in **Table L-EP-2**. The self-monitoring sample collection schedule for TFB is presented in **Table L-EP-3**. Prior to the implementation of the self-monitoring program, LLNL collected weekly TFB influent and effluent samples for analysis by EPA Method 601. To date, no VOCs have been detected in any TFB effluent samples.

Hazardous Waste—Interim Status Document CA2890012584. Issued by the U.S. Environmental Protection Agency and the California Department of Health Services.

Sewer—Discharge permit No. 1205A. Issued by the City of Livermore Water Reclamation Plant. Renewed annually.

Tanks—Fees paid for 65 storage and wastewater retention tanks. Program implemented by Alameda County.

Other—Federal Facility Agreement for Livermore groundwater investigation/remediation.

Environmental Assessments Performed During 1990

In 1990, more than 122 projects were evaluated under NEPA and under the applicable policies and procedures for DOE compliance with NEPA (*Federal Register* Vol. 52, No. 240, December 15, 1987), as amended. These projects included 20 ADMs, 29 Memorandums, and 60 Categorical Exclusions. Ten projects were determined by DOE to require EAs, nine of which were for projects at the Livermore site and are described below. Nine of the ten currently are under DOE review. A Finding of No Significant Impact (FONSI) was issued by DOE in June 1990 for the Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL. Three projects were evaluated under CEQA and University of California procedures for CEQA implementation.

Environmental Assessments. Environmental Assessments were prepared for the following proposed actions at the Livermore site:

Environmental Assessment of the Uranium Demonstrations System at LLNL. The UDS operations are proposed to support LLNL's continuing effort to demonstrate uranium enrichment by the Atomic Vapor Laser Isotope Separation (AVLIS) process.

Environmental Assessment for the Multi-User Tandem Laboratory (MTL) (Building 190) at LLNL. This document considers the potential environmental impact from current and planned

Livermore Site
Environmental
Program
Information

operations in the MTL, which is located in the northwest section of LLNL. Building 190, a laboratory where research activities are performed, houses an electrostatic accelerator with which accelerated beams of heavy or light ions are used in a broad variety of basic and applied research in nuclear physics, materials science, and accelerator mass spectrometry.

Environmental Assessment for Acquisition of East Avenue, Alameda County, California. This document addresses the potential impact from acquiring the section of East Avenue between South Vasco and Greenville Roads, and from construction of project-related facilities to control or restrict public access to sensitive facilities at LLNL and Sandia National Laboratories, Livermore (SNLL), and to enhance future security at the laboratories to allow an integrated site security system.

Environmental Assessment for Ion Accelerator in Building 235 at LLNL. This document considers the potential environmental impact from conduct of experiments using a commercially manufactured 4.0 MeV ion accelerator in Building 235.

Environmental Assessment for an addition to Building 166. This document addresses the potential environmental impact from establishment of facilities for the growth and processing of semiconductor crystals. This facility would use a process known as metalorganic chemical vapor deposition (MOCVD) that involves the pyrolysis of metal alkyls and metal hydrides.

Environmental Assessment for Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL (DOE/EA-0421). This document assesses the potential for environmental impact from resumption of testing with surrogate materials in the EDS at LLNL. In these tests, rare-earth metals would be used as surrogates for, and in lieu of, plutonium. The test provides operating experience and information to evaluate the design and operability of the AVLIS separator hardware in an integrated

system configuration. The FONSI stipulated that an Action Plan for implementation of commitments for mitigation of environmental impacts associated with the project (as well as annual progress reports) are required in accordance with of Energy Notice, Number 15, 1990 (SEN-15-90).

In addition, DOE Order 5400.4, issued October 6, 1989, specifies that the NEPA and CERCLA processes should be integrated by conducting the NEPA and CERCLA environmental planning and review procedures concurrently. During 1990, LLNL prepared three EAs (one at the Livermore site and two at Site 300) for environmental restoration activities. The EAs (which also are written to meet the requirements of CEQA) are written as chapters within the Feasibility Study (FS) document. The Livermore site document is entitled *CERCLA Feasibility Study for the LLNL Site* (Isherwood et al. 1990).

Environmental Impact Statement/Environmental Impact Report. In addition to the NEPA/CEQA documents discussed previously, work began on the sitewide EIS/EIR. In October 1990, the DOE published a Notice of Intent (NOI) in 55 *Federal Register* 41048 to prepare a joint EIS/EIR for continued operation of both LLNL [operated by the University of California (UC) for the DOE] and SNLL, (operated by the Sandia Corporation for the DOE). That same month, UC filed a Notice of Preparation (NOP) with the California Office of Planning and Research to prepare a joint EIS/EIR. Both the NOI and the NOP were sent to the California State Clearinghouse for distribution within the state.

Both the NOI and the NOP invited the public to attend a scoping meeting on November 15, 1990, in Livermore, California, and to provide written comments until the close of the comment period then set for November 30, 1990. At the request of the public, UC and the DOE subsequently extended the deadline to December 15, 1990.

During the EIS/EIR scoping process, the DOE and UC received a total of 282 comments from 61 members of the public; interested groups; and Federal, State, and local officials.

Pollution Abatement Projects

A draft Pollution Prevention Awareness Plan (PPAP) was developed and submitted to DOE in May 1990 in accordance with DOE Order 5400.1. The Plan proposes that the following key elements be integrated into LLNL's day-to-day activities: communicating management's commitment to curtail pollution; publicizing the goals of pollution prevention; educating individuals on pollution prevention through formal training courses; organizing events implementing pollution prevention; recognizing individuals who prevent pollution; reviewing historical events and their solutions, and using this information to recommend new solutions; and providing updates on regulatory requirements, new technology, and management changes.

In 1990, the following activities were begun or were in progress:

- Continued communicating management's commitment to curtail pollution.
- Distributed an administrative memo from John Nuckolls, LLNL Director, on the appointment of an Environmental, Safety and Health (ES&H) Council on January 9, 1990.
- Distributed a memo on ES&H/affirmative action/equal employment opportunity and other institutional responsibilities of associate directors/deputy associate directors/departments heads/division leaders to LLNL managers on April 11, 1990.
- Publicized the goals of Pollution Prevention.
- Published an article in *Newsline* (an LLNL periodical) entitled "Environmental Protection Offers Some Disposal Tips" on February 7, 1990.
- Conducted formal training classes and educated individuals on pollution prevention.

—Continued conducting waste generator training classes taught by Environmental Protection Department staff.

- Organized pollution-prevention events.

—A paper-recycling working group spearheaded the expansion of a pilot paper recycling program that was first implemented in 1989. A sitewide paper recycling program was implemented in April 1991.

—Presented a Pollution Prevention display with handouts at an on-site Energy Fair.

- Reviewed historical events and their solutions, then recommended new solutions.

—The Environmental Protection Department published and distributed Environmental Alerts to all LLNL employees. These one-page notices convey pertinent information on planned environmental events.

- Provided updates on regulatory requirements, new technology, and management changes.

—Environmental Analysts assigned to specific site areas continued as the liaison between EPD and the various programs. Changed and new regulatory requirements, new technology, and management changes related to environmental issues were conveyed through these Environmental Analysts.

Sanitary Sewer Discharge Control Project. LLNL has been improving its ability to monitor and control pollutants inadvertently released to the sanitary sewer system. The Sanitary Sewer Discharge Control Project addresses four key elements to achieve this goal: (1) an upgraded sewer monitoring system at Building 196 provides increased detection capability, parameter-specific sensitivity, and improved reliability to reduce both system maintenance requirements and downtime; (2) a sewage diversion system and structure allows diversion of LLNL's and SNLL's entire sewer flow to prevent a detected release from leaving the site;

(3) satellite monitoring stations at nine key points in the sewer system provide an early alarm warning and result in improved response time. The stations also provide information regarding pH variations and samples of the discharge, making it easier to locate the cause of all types of sewer alarms; and (4) a facility-specific control program for LLNL (including some upgraded and some new retention tank systems) enhances building surveys of process discharges and building sewer layouts, resulting in better administrative controls. The major aspects of these upgrades were completed in 1990.

Compliance Activities

The Environmental Operations Group is responsible for working closely with LLNL programs and departments to implement environmental requirements, so that planned and current operations and experiments comply with Federal, State, and local environmental regulations. The group consists of environmental analysts assigned to specific LLNL programs and departments to assist in day-to-day environmental activities. In addition to advising LLNL staff, analysts review and verify that proper procedures are followed for the management of hazardous wastes and for the implementation of appropriate pollution abatement controls. Compliance status is maintained and verified by the analysts who keep abreast of existing and planned activities, review construction documents, inspect facilities, and audit waste management procedures.

Building Inspections. Formal, detailed building inspections for each LLNL facility are conducted based on a schedule established by the Hazards Control Health and Safety Team. These inspections scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of waste accumulation areas waste accumulation areas (WAAs),

potential release pathways to the environment (e.g., storm and sanitary sewer drains), hazardous product storage areas, wastewater retention systems, operating equipment (e.g., vacuum pumps, transformers, capacitors, baghouses), and laboratory and machine shop areas. An inspection report is prepared for the program/department, and follow-up procedures are used to ensure implementation of recommendations or corrections. Walk-through inspections are conducted on an as-needed basis. Nine formal building inspections were conducted during 1990. The number of formal building inspections was significantly fewer in 1990 because of work performed in support of the Tiger Team Assessment and subsequent corrective actions.

Waste Accumulation Area Inspections. Inspections are conducted at least weekly at all WAAs by the program representatives. These inspections help ensure that WAAs are operated in compliance with regulatory requirements. An inspection checklist is completed and corrections are implemented. In addition, biweekly oversight inspections are conducted at all WAAs by EPD staff to help ensure that programs meet their responsibilities to manage their WAAs and wastes in compliance with Federal and State requirements.

Spill Response. Investigation, sampling, and evaluation of all potentially hazardous spills and leaks to the environment are conducted. This process includes assisting in cleanup of spills, determining if a spill must be reported to regulatory agencies, and verifying that cleanup is complete. Environmental Operations provides guidance to the programs on preventing spill recurrence.

During 1990, the Environmental Protection Department responded to nine incidents that were reported to regulatory agencies. Six of these incidents occurred at the Livermore site and three at Site 300. All spills were contained at the time of occurrence or notice, and cleanup has been verified as complete.

Site Evaluations Prior to Construction.

Sampling and analysis for potential contaminants is conducted at all proposed construction sites to ensure that any soil and debris generated is disposed of appropriately. During 1990, Environmental Operations conducted site evaluations for 33 construction projects.

Environmental Training. The Environmental Protection Department sponsored training for 3,253 people, including RCRA and SARA/OSHA programs. Additionally, EPD routinely participates in biweekly briefings to orient all new employees concerning approved environmental practices and procedures.

Table L-EP-1. TFA NPDES self-monitoring sampling schedule.

Sample location Frequency	TFA-I001 Analysis	TFA-PP3 ^a	TFA-C1E/C1W and TFA-C2E/C2W	Land observation
Daily	Flow rate	Flow rate	—	—
Weekly	—	EPA 601	—	Perform observation
Monthly	EPA 601 pH	Temperature pH		Complete report
Quarterly (March, June, Sept., Dec.)	Chlorides	Chlorides Fish toxicity ^b Turbidity ^c	Chlorides EPA 601	—
Semiannually (April, Oct.)	Metals ^d	Metals ^d	Metals ^d gross alpha and beta particles, tritium Fish toxicity ^b	—
Annually (April)	EPA 624 ^e EPA 625	EPA 624 ^e EPA 625 Gross alpha and beta particles, tritium	EPA 602 EPA 625	—

Specific requirements:

- Sampling of TFA-C1E/C1W and TFA-C2E/C2W should be coincident with TFA-I001 and TFA-PP3 sampling.
- If any instantaneous maximum limit is exceeded, then sampling frequency shall be increased to daily, until two samples collected on consecutive days show compliance with instantaneous maximum.

^a TFA-PP3 replaces TFA-E1W/TFA-E1E as the TFA effluent sample.

^b Fish toxicity, 96 hours survival in undiluted waste.

^c Jackson turbidity units.

^d Priority pollutant metals: antimony, chromium (total), mercury, silver, arsenic, copper, nickel, thallium, beryllium, lead, selenium, zinc, cadmium. PLUS: boron, chromium (+6), iron, manganese, and cyanide.

^e When schedule calls for coincident EPA 601 and 624 analyses, perform only EPA 624.

Table L-EP-2. TFB NPDES self-monitoring "start-up" requirements.

Sample location Frequency	TFB-I002 Analysis	TFB-E002	TFB-R002
Daily (for the first week)	—	EPA 601	—
Weekly (for the first 4 weeks)	EPA 601	—	EPA 601
Initially	EPA 624 ^a EPA 625 Chlorides Metals ^b	EPA 624 ^a EPA 625 Chlorides Metals ^b Gross alpha and beta particles, tritium	EPA 602 EPA 625 Chlorides Metals ^b Gross alpha and beta particles, tritium

^a When schedule calls for coincident EPA 601 and 624 analyses, do only EPA 624.

^b Priority Pollutant Metals: antimony, chromium (total), mercury, silver, arsenic, copper, nickel, thallium, beryllium, lead, selenium, zinc, cadmium. PLUS: boron, chromium (+6), iron, manganese, and cyanide.

Table L-EP-3. TFB NPDES self-monitoring sampling schedule.

Sample location Frequency	TFB-I002 Analysis	TFB-E002	TFB-R002	Land observation
Daily	Flow rate	Flow rate	Flow rate	—
Weekly	—	EPA 601	—	Perform observation ^a
Monthly	EPA 601 pH	Temperature pH	EPA 601 Temperature pH	Complete report
Quarterly (Jan., April, July, Sept.)	Chlorides	Chlorides Fish toxicity ^b Turbidity ^c	Chlorides	—
Semiannually (Feb., Aug.)	Metals ^d	Metals ^d	Metals ^d Fish toxicity ^b Turbidity ^c	— —
Annually (Feb.)	EPA 624 ^e EPA 625	EPA 624 ^e EPA 625 Gross alpha and beta particles, tritium	EPA 602 EPA 625 Gross alpha and beta particles, tritium	

Specific requirements:

- Sampling of TFB-R002 should be coincident with TFB-I002 and TFB-E002 sampling.
- If any instantaneous maximum limit is exceeded, then sampling frequency shall be increased to daily, until two samples collected on consecutive days show compliance with instantaneous maximum.

^a Each discharge.

^b Fish toxicity, 96 hours survival in undiluted waste.

^c Jackson turbidity units.

^d Priority pollutant metals: antimony, chromium (total), mercury, silver, arsenic, copper, nickel, thallium, beryllium, lead, selenium, zinc, cadmium. PLUS: boron, chromium (+6), iron, manganese, and cyanide.

^e When schedule calls for coincident EPA 601 and 624 analyses, perform only EPA 624.

Introduction

Lawrence Livermore National Laboratory (LLNL) conducts surveillance and effluent air monitoring to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations, and what the concentrations are. Air monitoring involves measurement of particles collected on filters, or of vapor chemically trapped in air samplers. Concentrations of various airborne radionuclides (including particulates and tritium water vapor) and beryllium are measured at the Livermore-site perimeter and at off-site locations throughout the Livermore Valley. Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters, and is discussed in a following chapter. These radionuclides also are measured to comply with the Clean Air Act, National Emissions Standards for Hazardous Pollutants (NESHAPS).

Methods

LLNL maintains six continuously operating high-volume air-particulate (Hi-Vol) samplers on the Livermore-site perimeter, shown in **Figure L-A-1**, and 13 Livermore Valley Hi-Vol samplers, shown in **Figure L-A-2**. The physical location of these sampling stations have not changed, but new location codes have been assigned (see Quality Assurance chapter for cross-reference information). The samplers are positioned to ensure reasonable probability that any significant concentration of particulate effluents from LLNL operations will be detected, regardless of local meteorology.

The six Hi-Vol samplers on the Livermore-site perimeter and seven of the off-site Livermore Valley samplers are equipped with $5.2 \times 10^{-2} \text{ m}^2$ Whatman 41 cellulose filters. These samplers operate at average flow rates of 400 L/min. These flow rates are verified at regular intervals with a portable field-calibration unit. If a sampler fails, it is repaired and then calibrated with a spirometer that itself was calibrated using a unit traceable to the National Institute for Standards and Technology (NIST), formerly known as the National Bureau of Standards (NBS). An easily dissolvable filter and a low trace-metal background are required for airborne-beryllium

Figure L-A-1. Air sampling locations, Livermore-site perimeter, 1990.

Livermore Site Air Monitoring

analyses. Whatman 41 filters provide a balance between such requirements and particulate-collection efficiency (Lindeken et al. 1963).

All air filters are changed weekly. Each filter is identified by its location, date on, date off, elapsed sampling time, and flow rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets. Each filter sample is given a serial number that accompanies it throughout the analysis. After a four-day delay for decay of the radon-thoron daughters, gross alpha and beta activities on the filters are determined with a gas-flow proportional counter. This counter is used only for environmental samples to avoid possible contamination. Separate ^{239}Pu and ^{90}Sr calibration sources determine alpha and beta counting efficiencies, respectively. These standards are traceable to NIST or equivalent certification. Counting-efficiency

measurements are made with each set of filters counted. A background count is taken at the beginning of each run and between each set of ten samples. Records are kept of background and counting-efficiency variations that occur in the counting equipment. As an indicator of any increased activity, filters from Locations PATT, RRCH, ALTA, LCCY, and ERCH are analyzed for gross alpha and gross beta activities. Filters from all other locations are analyzed for additional constituents, as described below.

Monthly composites of Livermore-site-perimeter samples (Locations SALV, MESQ, CAFE, MET, VIS, and COW) are sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the site-perimeter filters from individual locations are analyzed for the presence of ^{239}Pu , ^{235}U , and ^{238}U . Selected off-site samples from the Livermore Valley (Locations TANK, ZON7, FCC, HOSP, LWRP, and FIRE) are analyzed for ^{239}Pu . These filters are ashed and then dissolved in a mixture of nitric acid (HNO_3) and hydrochloric acid (HCl) and/or hydrofluoric acid (HF). Plutonium and uranium then are separated by an ion-exchange process. Plutonium is purified further by ion exchange, electroplated onto a stainless-steel disk, and submitted for alpha spectrometry. Uranium is purified further by ion exchange and submitted for analysis by mass spectrometry.

Replicate samples are taken to confirm the results obtained from the samplers. An additional air sampler is operated in parallel with the permanent sampler at one of the six Livermore-site-perimeter locations. This parallel operation is continued for one month; the filters are exchanged weekly, and both filters are submitted for analysis in the usual manner. Monthly rotation of the extra sampler among the six locations ensures that all perimeter samplers are checked annually. The replicate samples then are compared with respect to gross alpha and beta activities and to ^{239}Pu content.

Figure L-A-2. Air sampling locations, Livermore Valley, 1990.

Concentrations of airborne tritiated water are determined for each of the Livermore-site-perimeter air-sampling locations, off-site Locations XRDS and VET, and four additional Livermore Valley locations (Locations ZON7, ALTA, LCCY, and FIRE). Water vapor is trapped on silica-gel samplers operated at a flow rate of 0.7 L/min for a two-week period. The average flow rate is calculated from the initial and final flow rates, which are measured biweekly with a rotometer that is calibrated annually. The silica gel columns are exchanged biweekly. Each sample is identified by its location, date on, date off, elapsed sampling time, and flow rate. This information is transferred to log sheets at the Livermore site, and each sample is given a serial number that accompanies it throughout the analysis. A parallel air-tritium sampler is rotated among the perimeter locations at one-month intervals, as is done for the particulate parallel sampler. The collected water is recovered by freeze-drying. The water is electrolytically enriched for tritium and measured by liquid-scintillation counting.

For beryllium measurements, every month, half of the weekly air filters from the Livermore-site-perimeter samplers are composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% HNO₃ and 20% perchloric acid (HClO₄). The solutions then are evaporated to a few milliliters. Care is taken to prevent the samples from baking dry. After the samples are diluted with water, they are filtered. Any residues are discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is accomplished by atomic absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200 ng of beryllium, and several samples spiked with essentially carrier-free ⁷Be. Standards of 1, 2, and 5 g/L are prepared by diluting an intermediate 1-ppm stock solution obtained

from an NIST-traceable 1,000-ppm stock dilution. The diluent in all cases is 1% HNO₃ in water.

Results

Airborne Radioactivity. LLNL analyzes air filters for gross alpha and gross beta activity to ensure that releases of radionuclides other than those specifically targeted for will be detected, and to identify trends in the LLNL environs. The values reported are similar to those observed in previous years. Gross alpha and gross beta values show no significant differences between samples taken at the Livermore-site perimeter and Livermore Valley. Most of the gross alpha determinations were at or near the detection limit of the method. Typical gross alpha activity is $<1 \times 10^{-15}$ $\mu\text{Ci/mL}$ (3.7×10^{-11} Bq/mL), and typical beta activity is 1×10^{-14} $\mu\text{Ci/mL}$ (3.7×10^{-10} Bq/mL). Most of the observed alpha and beta activity results from the naturally occurring radioisotopes of uranium and thorium and their decay products.

Table L-A-1 lists the activities of selected gamma-emitting radionuclides that contribute to the activity in the Livermore-site-perimeter samples. Of the nuclides tabulated, ⁷Be, ⁴⁰K, ²²⁶Ra, ²²⁸Ra, and ²²⁸Th occur naturally. The primary source of the ¹³⁷Cs is long-term global fallout and fallout resuspension. Other fission products normally are detectable only after events such as atmospheric nuclear tests by other nations or releases such as the Chernobyl accident. In addition to providing baseline data on global fallout, analysis of these fission products enables LLNL to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at the LLNL. The Derived Concentration Guides (DCGs) for these radionuclides also are in **Table L-A-1**. DCGs specify the concentrations of radionuclides in air (or water) that could be inhaled (or consumed) continuously 365 days a year without exceeding the DOE primary radiation protection standard to the public of 100 mrem/y effective

Livermore Site Air Monitoring

dose equivalent (U.S. Department of Energy 1990). (The Environmental Radiological Program Summary chapter provides an explanation of this and other units of dose.) Finally, the percentage of the DCGs is presented. These values demonstrate the low levels of gamma activity present at the Livermore-site perimeter.

Table L-A-2 shows the concentration of plutonium on air filter samples collected in the Livermore Valley. **Table L-A-3** shows the concentrations of airborne ^{239}Pu , ^{235}U , and ^{238}U (depleted uranium) in the Livermore-site perimeter. The DCG is based on the typical environmental oxide chemical form. Location SALV at the southeast perimeter of the Livermore site registered the highest concentrations of plutonium in air of all sampling locations. This sample was collected in August. The concentration measured for this sample, $2.15 \times 10^{-17} \mu\text{Ci/mL}$ ($7.955 \times 10^{-13} \text{ Bq/mL}$), represents 0.11% of the DCG. No other statistically significant differences between

Figure L-A-3. Monthly mean concentration of beryllium on air filters, Livermore-site perimeter, 1990.

locations or samples were noted. The overall levels determined essentially were the same as those reported in 1989. The maximum measured concentrations of ^{238}U are less than 0.05% of the DCG (U.S. Department of Energy 1990).

Table L-A-4 shows the average biweekly tritiated water-vapor concentrations observed at the Livermore-site-perimeter sampling locations. The highest annual mean concentrations were observed at Locations SALV, CAFE, and VIS. These concentrations were approximately $1.75 \times 10^{-11} \mu\text{Ci/mL}$ ($6.475 \times 10^{-7} \text{ Bq/mL}$) or 0.02% of the DCG.

Table L-A-5 shows the average biweekly tritiated water-vapor concentrations for the Livermore Valley sampling locations. The highest annual average concentrations were observed at Locations ZON7 and VET approximately $0.8 \times 10^{-11} \mu\text{Ci/mL}$ ($2.96 \times 10^{-7} \text{ Bq/mL}$); this concentration is 0.008% of the DCG. The highest biweekly concentration was observed in June at Location ALTA. This concentration, $2.78 \times 10^{-11} \mu\text{Ci/mL}$ ($1.0286 \times 10^{-6} \text{ Bq/mL}$), is 0.03% of the DCG. These 1990 tritium values generally are lower than those reported last year.

Beryllium in Air. **Table L-A-6** shows average monthly concentrations of airborne beryllium for the Livermore-site-perimeter sampling locations. The concentrations, which are less than 5.3% of the monthly ambient concentration guide established by the Bay Area Air Quality Management District, can be attributed to suspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and Livermore's air typically contains 10 to 100 µg of particulates per cubic meter. By using a value of $50 \mu\text{g/m}^3$ for an average dust load, and 1 ppm for beryllium content of this dust, an airborne beryllium concentration of $5.0 \times 10^{-5} \mu\text{g/m}^3$ can be calculated.

In view of the range of natural variation expected in these background values, this value is in excellent agreement with the data in **Table L-A-6**.

The monthly airborne beryllium concentrations for the Livermore site are plotted in **Figure L-A-3**. Values plotted for September through December represent the limit of detection for the contract laboratory, which modified its analytical procedures during those months. This procedure modification, which was instituted by the contract laboratory, raised the detection limit. Consequently, very low values could not be determined. Although the detection limit of the new method still allows adequate analysis of data relative to regulatory guidelines, we have requested that previous analysis technique be reinstated. (The previous analysis technique was a graphite furnace beryllium analysis technique with a lower detection limit.) That graphite furnace method was reinstated in May.

Effluent Releases

Radioactive Effluents. In 1990, a total of 1,281.64 Ci of tritium were released to the atmosphere from operations at LLNL. Of this, approximately 699.84 Ci were released as tritiated water (HTO). The remaining tritium was elemental tritium gas (HT). Once released to the environment, the potential dose from elemental tritium gas is approximately 25,000 times lower than a dose from a comparable release of tritiated water. Therefore, the tritiated hydrogen gas did not contribute significantly in calculations of the overall dose. Releases of the short-lived radionuclides ^{13}N and ^{15}O from Building 194 (the electron-positron linear accelerator)

totaled 48 Ci. Comparative releases of radioactive effluents at LLNL during the ten-year period from 1981 through 1990 are shown in **Table L-A-7**. The radioactive emissions from LLNL operations during 1990 were within the range of previous years.

Of the 1,281.64 Ci of tritium discharged to the atmosphere by LLNL in 1990, 1,281.3 Ci came from the Tritium Facility (Building 331). The highest single weekly emission from the facility was 68.7 Ci of tritium gas during the week of October 1, 1990.

Nonradioactive Effluents. The release of air pollutants at the Livermore Site can be contrasted to the most recent estimated annual daily release of air pollutants for the entire Bay Area. For example, the total organic emissions from solvent degreasing is estimated at 11.5 tons per day, versus LLNL's 0.017 tons per day (0.15% of total Bay Area emissions) in 1990. The evaporation of total organic nonprecursor solvents in the Bay Area is 9.2 tons per day, versus LLNL's 0.049 tons per day (0.5% of total Bay Area emissions) in 1990. Bay Area Air Quality Management District (BAAQMD) estimates coatings and printing emissions at 56.2 tons per day, versus LLNL's 0.011 tons per day (0.02% of total Bay Area emissions) in 1990.

Table L-A-8 lists the estimated LLNL 1990 releases for organic precursor and nonprecursor compounds, chlorofluorocarbons (an organic nonprecursor), and other LLNL airborne emissions.

Livermore Site
Air Monitoring

Table L-A-1. Gamma activity on air filters—Livermore-site perimeter, 1990.^a

	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Month	[10 ⁻¹³ μCi/mL ± 2σ (%)]						
	[10 ⁻¹⁶ μCi/mL ± 2σ (%)]						
Jan.	0.48 ± 2	≤1.36	≤0.06	≤0.06	≤0.12	≤0.26	≤0.13
Feb.	0.68 ± 2	≤1.32	≤0.06	≤0.06	≤0.12	≤0.25	≤0.14
Mar.	0.98 ± 2	≤1.07	≤0.05	0.13 ± 83	≤0.09	≤0.19	≤0.12
Apr.	1.17 ± 2	4.83 ± 38	0.09 ± 77	0.18 ± 50	0.26 ± 40	0.27 ± 75	0.32 ± 39
May	1.22 ± 2	8.21 ± 31	0.13 ± 84	0.19 ± 58	0.30 ± 49	0.46 ± 67	0.42 ± 40
June	0.77 ± 2	5.67 ± 40	0.08 ± 74	0.10 ± 78	0.26 ± 49	≤0.22	0.21 ± 73
July	0.98 ± 2	5.39 ± 37	0.10 ± 78	0.12 ± 74	0.28 ± 40	0.47 ± 50	0.39 ± 43
Aug.	0.79 ± 2	5.94 ± 42	0.12 ± 43	≤0.04	0.35 ± 40	0.43 ± 67	0.27 ± 55
Sept.	1.36 ± 2	7.28 ± 27	0.11 ± 65	≤0.08	0.37 ± 29	0.68 ± 34	0.48 ± 30
Oct.	1.61 ± 2	9.40 ± 20	0.16 ± 39	0.11 ± 57	0.49 ± 28	0.56 ± 37	0.53 ± 26
Nov.	1.24 ± 2	6.00 ± 52	0.16 ± 46	≤0.04	0.45 ± 44	0.59 ± 60	0.44 ± 53
Dec.	1.36 ± 2	≤1.41	≤0.05	≤0.05	0.28 ± 58	≤0.22	≤0.12
Median ^b	1.05 ^c	≤5.53	≤0.10	≤0.09	≤0.28 ^c	≤0.35	≤0.30
MAD (%) ^c	31 ^d	40.1	36.8	38.9	44.9 ^d	35.7	50.8
DCG ^d	5 × 10 ⁻⁸	9 × 10 ⁻¹⁰	4 × 10 ⁻¹⁰	1 × 10 ⁻⁹	1 × 10 ⁻¹²	3 × 10 ⁻¹²	4 × 10 ⁻¹⁴
% of DCG	2 × 10 ⁻⁴	6 × 10 ⁻⁵	3 × 10 ⁻⁶	9 × 10 ⁻⁷	3 × 10 ⁻³	1 × 10 ⁻³	8 × 10 ⁻²

^a All Livermore-site perimeter samples composited.

^b Mean value reported because of QA requirements, see Quality Assurance chapter.

^c Standard Deviation Mean percent calculated because of QA requirements, see Quality Assurance chapter.

^d DCG in μCi/mL.

Table L-A-2. Plutonium-239 activity on air filters—Livermore Valley, 1990.

Month	Sampling location ^a						
	TANK	ZON7	FCC	HOSP [10 ⁻¹⁷ μCi/mL ± 2σ (%)]	LWRP	FIRE	TFIR ^a
Jan.	0.03 ± 72	0.05 ± 73	0.01 ± 141	0.02 ± 127	0.11 ± 92	0.02 ± 76	0.02 ± 90
Feb.	0.03 ± 74	0.02 ± 87	0.04 ± 74	0.02 ± 92	0.01 ± 163	0.02 ± 100	0.01 ± 133
Mar.	0.02 ± 77	0.03 ± 59	0.02 ± 71	0.02 ± 66	0.02 ± 78	0.02 ± 67	0.11 ± 28
April	0.03 ± 92	0.02 ± 94	0.02 ± 82	0.03 ± 70	0.04 ± 70	0.06 ± 49	0.05 ± 67
May	0.11 ± 41	0.58 ± 18	0.03 ± 72	0.06 ± 49	0.16 ± 32	0.06 ± 69	0.03 ± 65
June	0.03 ± 66	0.02 ± 77	0.02 ± 72	0.02 ± 74	0.18 ± 25	0.02 ± 63	0.02 ± 97
July	— ^b	0.03 ± 58	0.01 ± 103	0.05 ± 68	0.14 ± 33	0.05 ± 44	0.04 ± 47
Aug.	0.07 ± 51	0.06 ± 42	0.04 ± 49	0.02 ± 69	0.014 ± 28	0.03 ± 56	0.05 ± 45
Sept.	0.03 ± 62	0.06 ± 50	0.05 ± 47	0.06 ± 42	0.30 ± 19	0.06 ± 41	0.04 ± 53
Oct.	0.02 ± 96	0.04 ± 51	0.07 ± 46	0.05 ± 47	0.11 ± 34	0.07 ± 50	0.09 ± 47
Nov.	0.06 ± 54	0.12 ± 37	0.27 ± 22	0.18 ± 67	0.09 ± 40	0.06 ± 54	0.04 ± 55
Dec.	0.03 ± 70	0.28 ± 27	0.11 ± 41	— ^b	0.08 ± 50	0.07 ± 57	0.61 ± 17
Mean	0.04	0.11	0.06	0.05	0.12	0.04	0.09
SDM (%)	66	152	125	96	69	47	356
DCG (%) ^c	1 × 10 ⁻³	3 × 10 ⁻³	2 × 10 ⁻³	1 × 10 ⁻³	3 × 10 ⁻³	1 × 10 ⁻³	2 × 10 ⁻³

^a See Fig. L-A-2 for sampling locations. Location TFIR is in the City of Tracy.

^b No data available for these samples, see Quality Assurance chapter.

^c DCG for Pu in air = 2 × 10⁻¹⁴ μCi/mL or 2 × 10⁻² pCi/m³.

Table L-A-3. Plutonium and uranium activity on air filters—Livermore-site perimeter, 1990.

Month	Location ^a	²³⁹ Pu ^b [10 ⁻¹⁷ μCi/mL±2σ]	²³⁸ U [10 ⁻⁵ μg/m ³]	²³⁵ U [10 ⁻⁷ μg/m ³]	²³⁵ U/ ²³⁸ U [10 ⁻³]
Jan.	SALV	0.74 ± 15	8.73	4.21	4.88
	MESQ	0.03 ± 71	5.27	2.87	5.52
	CAFE	0.08 ± 51	7.07	2.58	3.69
	MET	0.02 ± 97	5.35	2.84	5.38
	VIS	0.09 ± 39	3.59	1.97	5.57
	COW	0.03 ± 76	4.87	2.86	5.95
Feb.	SALV	0.17 ± 33	3.09	2.12	6.95
	MESQ	0.04 ± 69	6.11	4.38	7.27
	CAFE	0.16 ± 36	6.68	4.58	6.94
	MET	0.03 ± 111	4.13	2.97	7.29
	VIS	0.02 ± 82	2.48	1.75	7.16
	COW	0.04 ± 103	4.86	3.45	7.19
March	SALV	0.10 ± 40	3.94	2.75	6.97
	MESQ	0.02 ± 97	5.19	3.74	7.21
	CAFE	0.10 ± 46	7.59	5.39	7.09
	MET	0.06 ± 71	4.62	3.31	7.17
	VIS	0.08 ± 49	3.29	2.35	7.13
	COW	0.03 ± 85	7.21	4.69	6.51
April	SALV	0.16 ± 37	6.79	4.59	6.85
	MESQ	0.03 ± 82	8.14	5.77	7.18
	CAFE	0.03 ± 92	8.70	6.20	7.22
	MET	0.02 ± 107	6.43	4.57	7.21
	VIS	0.04 ± 80	5.25	3.74	7.23
	COW	0.02 ± 41	7.20	5.11	7.19
May	SALV	0.35 ± 22	6.54	4.97	7.16
	MESQ	0.20 ± 30	8.38	5.98	7.13
	CAFE	0.25 ± 27	8.49	6.00	7.07
	MET	0.20 ± 32	7.50	5.33	7.10
	VIS	0.27 ± 29	3.32	2.38	7.15
	COW	0.14 ± 43	6.85	4.87	7.11
June	SALV	0.12 ± 39	5.35	3.76	7.04
	MESQ	0.09 ± 46	6.33	4.54	7.18
	CAFE	0.06 ± 50	6.97	4.96	7.12
	MET	0.08 ± 44	4.70	3.36	7.15
	VIS	0.04 ± 64	4.18	2.98	7.12
	COW	0.04 ± 58	5.67	4.08	7.19

...continued

Table L-A-3. Plutonium and uranium activity on air filters—Livermore-site perimeter, 1990.

Month	Location ^a	²³⁹ Pu ^b [10 ⁻¹⁷ μCi/mL±2σ]	²³⁸ U [10 ⁻⁵ μg/m ³]	²³⁵ U [10 ⁻⁷ μg/m ³]	²³⁵ U/ ²³⁸ U [10 ⁻³]
July	SALV	0.37 ± 22	9.57	6.75	7.05
	MESQ	— ^c	6.77	4.84	7.15
	CAFE	0.11 ± 49	9.83	6.90	7.02
	MET	0.03 ± 84	7.93	5.61	7.08
	VIS	0.10 ± 43	5.56	3.95	7.11
	COW	0.07 ± 51	8.94	6.34	7.09
Aug.	SALV	2.15 ± 9	8.42	5.92	7.03
	MESQ	1.11 ± 11	6.51	4.63	7.10
	CAFE	0.09 ± 46	10.02	7.11	7.13
	MET	2.06 ± 11	7.72	5.51	7.13
	VIS	0.36 ± 26	5.73	4.08	7.13
	COW	0.77 ± 15	8.36	5.89	7.05
Sept.	SALV	0.48 ± 16	11.09	8.08	7.28
	MESQ	0.08 ± 44	9.06	6.59	7.29
	CAFE	0.09 ± 46	14.37	10.25	7.13
	MET	0.03 ± 69	8.49	7.26	7.40
	VIS	0.14 ± 29	7.91	5.70	7.21
	COW	0.16 ± 32	9.09	6.57	7.22
Oct.	SALV	0.10 ± 36	10.31	7.37	7.15
	MESQ	0.84 ± 11	11.96	8.59	7.18
	CAFE	0.46 ± 18	12.89	9.25	7.18
	MET	0.11 ± 36	11.45	8.25	7.21
	VIS	0.82 ± 16	11.46	8.24	7.19
	COW	0.58 ± 16	11.89	8.59	7.22
Nov.	SALV	0.09 ± 46	9.05	6.43	7.10
	MESQ	0.36 ± 18	10.94	7.88	7.20
	CAFE	0.06 ± 53	13.09	9.30	7.10
	MET	0.03 ± 76	11.98	8.64	7.21
	VIS	0.54 ± 21	10.31	7.39	7.17
	COW	0.05 ± 46	12.33	8.85	7.18
Dec.	SALV	0.07 ± 47	2.03	1.30	6.41
	MESQ	0.05 ± 56	6.46	4.65	7.21
	CAFE	0.19 ± 32	7.50	5.46	7.28
	MET	0.07 ± 51	6.16	4.46	7.23
	VIS	0.13 ± 33	5.00	3.56	7.11
	COW	0.09 ± 42	5.45	3.94	7.22

...continued

Table L-A-3. Plutonium and uranium activity on air filters—Livermore-site perimeter, 1990 (concluded).

Annual averages									
Location	²³⁹ Pu			²³⁸ U			²³⁵ U		
	10 ⁻¹⁷ μCi/mL	SDM (%)	Percent of DCG ^d	10 ⁻⁵ μg/m ³	SDM (%)	Percent of DCG ^e	10 ⁻⁷ μg/m ³	SDM (%)	Percent of DCG ^f
SALV	0.41	143	0.021	7.11	41	0.024	4.85	44	0.001
MESQ	0.26	144	0.013	7.59	28	0.025	5.37	31	0.001
CAFE	0.14	85	0.007	9.43	28	0.031	6.50	34	0.001
MET	0.23	254	0.011	7.21	35	0.024	5.09	38	0.001
VIS	0.22	111	0.011	5.67	50	0.019	4.01	52	0.001
COW	0.17	145	0.008	7.73	33	0.026	5.44	35	0.001

^a See Fig. L-A-1 for sampling locations.

^b In all tables, activity listed as ²³⁹Pu includes activity caused by ²⁴⁰Pu.

^c No data. See Quality Assurance chapter.

^d DCG = 2×10^{-14} μCi/mL for ²³⁹Pu activity in air or 2×10^{-2} pCi/m³.

^e DCG = 1×10^{-13} μCi/mL (≈ 0.3 μg/m³) for ²³⁸U activity in air.

^f DCG = 1×10^{-13} μCi/mL (≈ 0.047 μg/m³) for ²³⁵U activity in air.

Table L-A-4. Tritium in air—Livermore-site perimeter, 1990.

Month	Sampling location ^a					
	SALV	MESQ	CAFE [10 ⁻¹¹ μCi/mL ± 2σ (%)]	MET	VIS	COW
Jan.	2.27 ± 9 2.33 ± 4	0.80 ± 10 1.22 ± 8 1.07 ± 12 0.92 ± 12	1.88 ± 4 2.01 ± 7	0.82 ± 10 1.13 ± 13	0.91 ± 7 1.26 ± 9	1.24 ± 10
Feb.	1.09 ± 7 1.05 ± 7	1.22 ± 7 0.94 ± 8 0.64 ± 14	1.52 ± 6 1.80 ± 5	0.62 ± 12 0.23 ± 25 0.20 ± 28	1.33 ± 6 0.72 ± 10	0.83 ± 9 0.58 ± 13
Mar.	1.60 ± 7 2.00 ± 6	0.60 ± 18 0.87 ± 13	1.82 ± 6 1.73 ± 7	0.31 ± 29 0.25 ± 34 0.26 ± 33 0.49 ± 17 0.51 ± 13	1.41 ± 7 1.45 ± 8	1.07 ± 9 1.27 ± 9
April	1.25 ± 8 2.89 ± 5	0.98 ± 12 1.05 ± 13	1.52 ± 7 0.93 ± 13	0.51 ± 21 0.57 ± 17 0.83 ± 15	1.68 ± 6 2.04 ± 7	0.86 ± 11 1.55 ± 8 1.51 ± 9
May	1.25 ± 7 1.25 ± 9	0.84 ± 12 0.47 ± 26	2.15 ± 5 0.63 ± 17	0.50 ± 19 0.26 ± 41	1.38 ± 6 1.92 ± 7	0.73 ± 11 0.69 ± 12 0.66 ± 15 0.49 ± 21
June	1.71 ± 9 1.20 ± 10	2.48 ± 7 0.65 ± 18	1.19 ± 12 1.71 ± 7	0.84 ± 18 0.31 ± 37	3.81 ± 5 2.14 ± 6 1.92 ± 6 2.15 ± 6	2.06 ± 7 1.82 ± 8 0.67 ± 15
July	1.53 ± 8 1.32 ± 8	0.54 ± 25 0.29 ± 35	0.63 ± 18 0.58 ± 19	0.16 ± 83 ≤0.12	1.65 ± 8 1.74 ± 8 2.08 ± 6 2.37 ± 6	0.69 ± 18 0.65 ± 16
Aug.	1.29 ± 11 2.70 ± 5 3.03 ± 5 1.31 ± 11 1.18 ± 12	≤0.13 0.54 ± 17 0.42 ± 37	0.27 ± 45 1.16 ± 11 0.73 ± 16	0.19 ± 65 0.30 ± 28 0.38 ± 39	2.21 ± 7 1.81 ± 6 1.36 ± 10	0.74 ± 17 1.84 ± 7 0.91 ± 10 0.70 ± 19

...continued

Table L-A-4. Tritium in air—Livermore-site perimeter, 1990 (concluded).

Month	Sampling location ^a					
	SALV	MESQ	CAFE [10 ⁻¹¹ μCi/mL ± 2σ (%)]	MET	VIS	COW
Sept.	1.10 ± 9 1.04 ± 11 1.18 ± 10	0.33 ± 38	0.77 ± 13 0.82 ± 4	0.42 ± 24 0.33 ± 33	1.66 ± 6 1.15 ± 10	0.66 ± 13 0.95 ± 12
Oct.	1.96 ± 6 2.00 ± 6	2.27 ± 5	3.87 ± 4 3.93 ± 3	1.40 ± 9 1.26 ± 10	1.99 ± 4 2.12 ± 5	1.37 ± 7 0.89 ± 10
Nov.	2.13 ± 5 1.58 ± 7	1.31 ± 7 2.38 ± 5	6.34 ± 2 2.29 ± 5	0.94 ± 9 1.60 ± 7	1.97 ± 5 1.62 ± 6	1.16 ± 7 1.33 ± 7
Dec.	0.96 ± 8 1.55 ± 7	2.42 ± 4 1.61 ± 7	2.93 ± 3 2.80 ± 4	1.29 ± 6 1.31 ± 9 2.21 ± 6	1.13 ± 7 2.33 ± 4	0.93 ± 8 1.03 ± 8
Mean ^b	1.63	1.04	1.84	0.66	1.77	1.03
SDM (%)	35.9	65.4	73.2	76.8	32.8	40.8
Percent of DCG ^c	0.02	0.01	0.02	0.007	0.02	0.01
Dose (mrem) ^d	1.3 × 10 ⁻²	0.8 × 10 ⁻²	1.5 × 10 ⁻²	0.5 × 10 ⁻²	1.4 × 10 ⁻²	0.8 × 10 ⁻²

^a See Fig. L-A-1 for sampling locations.

^b Livermore-site perimeter overall average = 1.33 × 10⁻¹¹ μCi/mL.

^c DCG = 1 × 10⁻⁷ μCi/mL (1 × 10⁻¹ pCi/mL).

^d This dose is the effective dose equivalent.

Table L-A-5. Tritium in air—Livermore Valley, 1990.

Month	Sampling location ^a					
	ZON7	ALTA	LCCY [10 ⁻¹¹ μCi/mL ± 2σ (%)]	FIRE	XRDS	VET
Jan.	1.15 ± 7	0.24 ± 30	0.23 ± 28	0.47 ± 15	0.55 ± 10	0.89 ± 9
	0.63 ± 20	0.51 ± 21	0.30 ± 34	0.65 ± 17	0.24 ± 45	0.60 ± 18
Feb.	0.66 ± 12	0.27 ± 27	0.18 ± 34	0.32 ± 17	0.48 ± 14	0.74 ± 10
	0.33 ± 24	0.21 ± 33	0.13 ± 53	0.22 ± 31	0.17 ± 42	0.38 ± 20
Mar.	0.94 ± 11	0.44 ± 26	0.21 ± 57	0.30 ± 32	0.39 ± 25	0.91 ± 11
	1.31 ± 8	0.84 ± 12	0.63 ± 17	0.50 ± 19	0.53 ± 16	0.70 ± 15
Apr.	0.65 ± 14	0.87 ± 13	0.13 ± 63	0.51 ± 19	0.52 ± 17	0.71 ± 14
	1.44 ± 9	— ^b	0.63 ± 20	0.59 ± 20	0.80 ± 15	0.69 ± 18
May	0.53 ± 16	0.89 ± 10	0.15 ± 53	0.09 ± 38	0.38 ± 20	0.58 ± 16
	0.55 ± 20	0.22 ± 45	≤0.10	0.10 ± 78	0.20 ± 44	0.17 ± 68
June	1.39 ± 12	2.78 ± 7	0.68 ± 20	0.49 ± 27	0.65 ± 18	0.65 ± 21
	1.08 ± 10	0.68 ± 15	≤0.10	0.27 ± 37	0.86 ± 12	0.76 ± 13
July	0.63 ± 19	0.26 ± 41	≤0.11	≤0.11	0.21 ± 49	0.13 ± 95
	1.06 ± 10	0.28 ± 33	0.09 ± 93	0.31 ± 30	0.42 ± 20	0.26 ± 33
Aug.	1.06 ± 12	0.26 ± 47	0.13	≤0.11	0.42 ± 27	0.19 ± 64
	1.09 ± 9	0.27 ± 36	0.24 ± 37	0.16 ± 48	0.69 ± 14	0.32 ± 27
	0.71 ± 20	0.28 ± 48	0.29 ± 47	0.19 ± 67	0.47 ± 29	0.19 ± 99
Sept.	0.87 ± 14	0.28 ± 40	≤0.08	0.21 ± 46	0.41 ± 21	0.37 ± 28
	0.66 ± 17	0.24 ± 47	0.15 ± 58	0.24 ± 50	0.15 ± 63	0.25 ± 41
Oct.	0.94 ± 10	0.35 ± 22	0.58 ± 17	0.75 ± 11	0.48 ± 16	1.43 ± 7
	0.88 ± 11	0.48 ± 18	0.37 ± 24	— ^b	0.65 ± 14	1.28 ± 8
						1.33 ± 8
Nov.	0.61 ± 14	0.42 ± 19	0.17 ± 29	0.28 ± 16	0.39 ± 20	0.88 ± 10
	1.07 ± 9	0.59 ± 14	0.61 ± 15	0.67 ± 13	0.59 ± 13	1.57 ± 6
Dec.	0.56 ± 12	0.43 ± 16	0.55 ± 13	1.10 ± 7	0.40 ± 17	1.75 ± 6
	0.86 ± 12	0.99 ± 10	0.60 ± 15	— ^b	0.79 ± 12	0.63 ± 16
Average^c	0.87	0.55	0.29	0.38	0.47	0.71
SDM (%)	33	96	72	66	41	64
Percent of DCG^d	9 × 10⁻³	6 × 10⁻³	3 × 10⁻³	4 × 10⁻³	5 × 10⁻³	7 × 10⁻³
Dose (mrem)^e	0.7 × 10⁻²	0.5 × 10⁻²	0.2 × 10⁻²	0.3 × 10⁻²	0.5 × 10⁻²	0.6 × 10⁻²

^a See Fig. L-A-2 for sampling locations.

^b No data. See Quality Assurance chapter.

^c Livermore Valley overall average = 0.54 × 10⁻¹¹ μCi/mL.

^d DCG = 1 × 10⁻⁷ μCi/mL.

^e This dose is the effective dose equivalent.

Livermore Site
Air Monitoring

Table L-A-6. Beryllium concentration on air filters—Livermore-site perimeter, 1990.

Month	Sampling location ^a											
	SALV		MESQ		CAFE		MET		VIS		COW	
	10 ⁻⁵ μg/m ³	%ACG ^b	10 ⁻⁵ μg/m ³	%ACG ^b	10 ⁻⁵ μg/m ³	%ACG ^b	10 ⁻⁵ μg/m ³	%ACG ^b	10 ⁻⁵ μg/m ³	%ACG ^b	10 ⁻⁵ μg/m ³	%ACG ^b
Jan.	<34.1	<3.4	<19.4	<1.9	<29.3	<2.9	<26.0	<3.0	<25.2	<2.5	<19.4	<1.9
Feb.	<19.5	<1.9	<19.5	<1.9	<19.5	<2.0	<25.9	<2.6	<19.4	<1.9	<19.4	<1.9
Mar.	<25.9	<2.6	<19.4	<1.9	<19.4	<1.9	<52.6	<5.3	<22.4	<2.2	<19.4	<1.9
Apr.	<19.4	<1.9	<19.4	<1.9	<19.4	<1.9	<19.4	<1.9	<19.4	<1.9	<19.4	<1.9
May	3.1	0.3	4.3	0.4	4.3	0.4	3.4	0.3	2.8	0.3	2.7	0.3
June	4.3	0.4	5.5	0.6	5.3	0.5	4.4	0.4	3.6	0.4	5.3	0.5
July	3.1	0.3	7.0	0.7	7.3	0.7	5.6	0.6	4.9	0.5	<0.2	<0.02
Aug.	0.8	0.8	<0.8	<0.8	1.1	0.1	<1.2	<0.1	<1.3	<0.1	0.9	0.1
Sept.	5.8	0.6	4.3	0.4	6.7	0.7	5.3	0.5	4.7	0.5	4.9	0.5
Oct.	7.0	0.7	6.2	0.6	10.1	1.0	10.1	1.0	9.5	0.9	10.5	1.1
Nov.	6.3	0.6	8.1	0.8	9.2	0.9	6.9	0.7	5.6	0.6	6.1	0.6
Dec.	<8.7	<0.8	9.1	0.9	6.7	0.7	<5.6	0.6	<4.4	<0.4	<4.4	<0.4
Median ^{c,d}	6.7	0.7	7.6	0.8	8.2	0.8	6.3	0.6	5.2	0.5	5.7	<0.6
MAD (%) ^e	53		43		42		54		60		84	

^a See Fig. L-A-1 for sampling locations.

^b Percent of ambient concentration guide (%ACG), ACG set by the Bay Area Air Quality Management District is 0.01 μg/m³ or (1,000 × 10⁻⁵ μg/m³).

^c Livermore-site perimeter overall annual median is 6.7 × 10⁻⁵ μg/m³.

^d Median. See Quality Assurance chapter.

^e Median absolute deviation. See Quality Assurance chapter.

Table L-A-7. Radioactive airborne effluent releases from the Livermore site, 1981–1990.

Year	Airborne effluents (Ci)	
	³ H	¹³ N and ¹⁵ O
1981	2,619	344
1982	2,014	584
1983	3,245	855
1984	7,354	81
1985	2,204	520
1986	1,254	113
1987	2,751	62
1988	3,983	30
1989	2,952	42
1990	1,282	48

Table L-A-8. Nonradioactive airborne emissions—Livermore site, 1990.

Pollutant	Estimated release (tons/day)	Percent of total Bay Area emissions
Particulates	0.0035	0.0004
Organic compounds	0.0313	0.0026
Oxides of sulfur	0.0024	0.0022
Oxides of nitrogen	0.0834	0.0179
Carbon monoxide	0.0172	0.0007
Chlorofluorocarbons	0.0449	0.0087

^a Based on the most recent 1988 BAAQMD emissions data.

Introduction

The Livermore site discharges approximately 341,000 gallons per day of wastewater to the City of Livermore sewer system; this amount constitutes about 10% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories, Livermore (SNLL). SNLL discharges to the Lawrence Livermore National Laboratory (LLNL) collection system; the sewage combines with LLNL sewage before it is released at a single point to the municipal collection system. The wastewater contains sanitary sewage and industrial effluent (from both LLNL and SNLL) and is discharged in accordance with permit requirements and the City of Livermore Municipal Code. The effluent is processed at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management Program, the treated sanitary wastewater is transported out of the valley through a pipeline and discharged into the San Francisco Bay. A small portion of the treated effluent from the LWRP is used for summer irrigation of the municipal golf course, which is adjacent to the LWRP. Sludge from the treatment process is disposed of in landfills.

Administrative and engineering controls at the Livermore site prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Wastewater is collected and monitored at several different points: from its generation to its release to the municipal collection system. Moreover, personnel who generate waste receive training about the materials that are permitted to be released.

Before the wastewater is released to the LLNL collection system, potentially contaminated wastewater is collected in retention tanks at the facility where it is generated. Then, the contents of the tanks are analyzed. The liquids are discharged to the sanitary sewer only if laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). If liquid effluents exceed permissible pollutant levels, the effluents are treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or the effluents are shipped to an off-site treatment or disposal facility. Radioactive

materials in the waste are reduced to levels well below DOE (U.S. Department of Energy 1990) and LWRP discharge limits. (The discharge limits of LWRP, DOE, and Title 17 of the *California Code of Regulations* are reproduced at the end of this chapter.) These sewer guidelines were developed by LLNL for specific sources and operations to ensure that sewer effluent for the entire site complies with LLNL's waste discharge permit.

In addition, the outflow to the municipal collection system is sampled continuously and analyzed both for compliance with the discharge permit and for conditions that may upset the LWRP treatment process or impact public health. An on-line monitoring system that provides real-time information and a flow-proportional sampler are located at the outfall from the Livermore site. The effluent is continuously monitored for pH, selected metals, and radioactivity. If warning levels occur, an alarm is registered at the LLNL Fire Dispatchers Station, which is attended 24 hours a day. A sanitary sewer spill plan

Livermore Site Sewage Monitoring

and a trained response team have been established to minimize effects of a spill, should one occur. The monitoring system provides a continuous check on sewage control and, since July of 1990, includes direct notification of LWRP in the event that an exceedance of regulatory standards is detected.

In addition, LLNL is implementing a system of satellite monitoring stations that operates in conjunction with the sewer monitoring system. The satellite monitoring stations are positioned at strategic locations within the main sewer system to help pinpoint the area at the Livermore site from which a spill originated. Each station consists of an automatic sampler that collects samples on a time-proportional basis. In the event of a spill, these samples are analyzed. Currently, there are five satellite monitoring stations. Four more will be installed in 1991 to provide the capability to pinpoint further any area from which a spill may occur. LLNL also intends to implement continuous pH monitoring at these stations in 1991.

Finally, LLNL is completing construction of a diversion system to hold wastewater that is unacceptable for release to LWRP. At present, once an unacceptable discharge has been detected by the monitoring system, the only action LLNL can take is to notify the LWRP of the event and the possible need to divert sewage into the LWRP holding pond. To protect the LWRP and to minimize any cleanup that might become necessary, the LLNL diversion and retention system will retain approximately 200,000 gallons of potentially contaminated sewage until it can be analyzed and appropriate handling methods determined. The diversion system will ensure that all but the first few minutes of wastewater flow that trigger an alarm are retained at LLNL for evaluation and disposal, if necessary.

LLNL receives water from two suppliers. During the summer months, June through August, deliveries are taken primarily from the Alameda County Flood Control and Water Quality Conservation

District Zone 7. This water is a mixture of groundwater and water from the South Bay Aqueduct of the State Water Project. For the remainder of the year, LLNL's water usually is supplied from the Hetch-Hetchy Aqueduct. Water quality parameters for these sources are obtained from the suppliers. That information is used to evaluate compliance with terms of the discharge permit covering changes in water quality between receipt and discharge.

Since 1980, the LWRP has been connected to a pipeline constructed as part of the Livermore-Amador Valley Wastewater Management Program to transport wastewater out of the valley for discharge into the San Francisco Bay. Although some treated LWRP effluent still is used to irrigate municipal property during summer months, treated sewage no longer is discharged into Arroyo Las Positas. This practice has eliminated the primary means of pollutant migration to local and downstream groundwater from LWRP.

Methods

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for four seconds for every 1,000 gallons of effluent. Aliquots of this composite are transferred to plastic bottles and submitted for analysis. Daily composites of treated effluent from LWRP are collected by LWRP employees. Aliquots of these composites are placed in 500-mL polyethylene bottles, which are retained for weekly collection by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge three times a week.

Standard quality control procedures are maintained. When each sewage field sample is collected, it is labeled with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies that sample during analysis.

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the

Livermore-site and LWRP effluents also is analyzed for gamma-emitting radionuclides and ^{239}Pu . For the first 11 months of the year, heavy metals analysis also was performed on a monthly basis. This analysis now is performed weekly, as required by permit conditions promulgated in December. In addition, composite samples from the LWRP digesters are analyzed monthly for gross radioactivity and heavy metals; composites of the monthly samples are analyzed quarterly for plutonium and cesium content.

Water quality and organic compounds also are monitored. Once each quarter, a portion of the 24-hour composite sample and an instantaneous grab sample of the LLNL sewage effluent are subjected to an extensive set of analyses. These analyses include parameters specified on LWRP's National Pollutant Discharge Elimination System permit, including metals, nutrients, pesticides, and priority pollutants. The Federal priority pollutants are measured using EPA methods 624 and 625 to establish baseline information for these parameters.

Quarterly samples also are collected at the point of discharge of specified metal finishing and electrical (and electronic) component categorical processes to ensure compliance with EPA discharge limits for those processes. LLNL reports the results of the analyses of the point source discharges semiannually to the LWRP, the agency delegated by EPA to implement those regulations. These results are not reported here.

For those samples analyzed for gross alpha and beta activity, about 25 mL of an 80% / 20% mixture of HNO_3 and HClO_4 is added to an aliquot (350 mL if the sample is from on site; 100 mL if from LWRP), and the mixture is heated to dryness on a hotplate. The residue is taken up in 10 mL of HNO_3 and 5 mL of 5% H_2O_2 . The volume is reduced to 3–5 mL on a hotplate, transferred to 5-cm-diameter planchets, and counted.

For tritium analyses, a 5-mL aliquot of distilled sewage sample is added to 15 mL of Packard Instagel in a 25-mL screw-cap

polyethylene bottle. Fifteen mL of Instagel is used as a control blank. Both the sample and the blank are placed in the refrigerated detection chamber of the scintillation counter for a 1-hr temperature equilibration prior to counting. Each sample is counted for 100 min.

Plutonium is separated by coprecipitation with manganese dioxide (MnO_2). The manganese dioxide then is ashed and dissolved in HNO_3 and H_2O_2 . Plutonium is purified by ion exchange, electroplated onto a stainless-steel disk, and submitted for alpha spectrometry.

Cesium is separated by ion exchange with ammonium molybdophosphate (AMP). The AMP crystals are transferred to a counting vial with concentrated HCl , which then is submitted for gamma spectrometry.

Monthly composites of Livermore-site sewage effluent are analyzed for arsenic, cadmium, chromium, copper, iron, lead, nickel, silver, aluminum, beryllium, and zinc. The monthly composite sample is prepared by combining 500-mL daily samples. A solution of HNO_3 (80%) and HClO_4 (20%) is 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 is reduced to about 100 mL. After the 500-mL aliquot from the last day has been added, the combined volume is reduced to about 50 mL. When the solution is cool, about 50 mL of deionized water is added, and the liquid is filtered through No. 40 Whatman paper. The paper is placed in a platinum crucible and digested with about 5 mL of HF , 16 mL of HNO_3 , and 4 mL of HClO_4 to a residue of about 4 to 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 metal content is determined by means of atomic-absorption spectrophotometry, with the exception of arsenic, which is analyzed by means of inductively coupled plasma mass spectrometry. The

Livermore Site
Sewage
Monitoring

required calibration standards are prepared by dilution of a 1,000-ppm, NIST-traceable stock solution.

For mercury analysis, 25 ml is taken from the daily sample and transferred to a glass bottle with a ground-glass stopper. At the end of the month, 100 ml of the solution is reduced with 5 ml of H₂SO₄ and 5 ml of HNO₃ (80%). Potassium permanganate then is added to eliminate sulfides and chlorides. The sample is heated in a water bath for two hours at 95°C. After cooling, 6 mL of sodium chloride-hydroxylamine sulfate reduces the excess permanganate, after which 5 ml of stannous sulfate is added. The resulting solution is analyzed

by cold-vapor atomic absorption. Each time the analysis is performed, standards are run to calibrate the method, as described above.

Results

Radioactivity in Sewage. Determination of the total radioactivity released as tritium, alpha emitters (calibrated with ²³⁹Pu), and beta emitters (calibrated with ⁹⁰Sr) was based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever was higher (see **Table L-SW-1**). The combined releases of tritium, alpha and beta radiation were 48% of the 1 Ci/y California Title 17 limit

Table L-SW-1. Estimated total radioactivity in sanitary sewer effluent, LLNL, 1990.

Radioactive emitter	Estimate based on effluent concentration [Ci]	Limit of sensitivity [Ci]
Tritium	0.68 ^{a,b}	0.10
Alpha radiation	0.0022	0.0063 ^a
Beta radiation	0.0076 ^a	0.0058

^a Used for determination of the total radiation release because it is the more conservative value.

^b 0.68 Ci includes 0.48 Ci from LLNL plus 0.2 Ci from SNLL.

Table L-SW-2. Sewer discharge release limits for tritium (³H), ¹³⁷Cs, and ²³⁹Pu.

	³ H	¹³⁷ Cs	²³⁹ Pu
CA Title 17 concentrations used to establish release limits	1 × 10 ⁻¹ μCi/mL	4 × 10 ⁻⁴ μCi/mL	8 × 10 ⁻⁴ μCi/mL
CA Title 17 daily	1 Ci ^a	0.5 Ci ^a	1 Ci ^a
monthly	1 Ci ^b	0.8 Ci ^b	1 Ci ^b
yearly	1 Ci ^a	1 Ci ^a	1 Ci ^a
DOE annualized discharge limit for application of BAT	1 × 10 ⁻² μCi/mL	1.5 × 10 ⁻⁵ μCi/mL	1 × 10 ⁻⁵ μCi/mL

^a CA Title 17 regulations impose a 1 Ci combined limit on the total of all radiation released, i.e., the total release of all isotopes must not exceed 1 Ci. If a total of 1 Ci of a particular isotope were released during the year, this would require that no other isotopes be released.

^b Limits similar to those applied to daily releases except total releases for the month must not exceed these quantities.

^c The DOE annualized discharge limit for application of BAT is five times the DCG (ingested water) for each radionuclide released.

(Table L-SW-2 summarizes regulatory limits applied to the discharge of radionuclides in LLNL sewage). The total of 0.48 Ci (1.7×10^{10} Bq) is based on the results shown in Table L-SW-1, reduced by reported SNL tritium releases of 0.2 Ci (7.4×10^9 Bq). Figure L-SW-1 shows the daily concentration of tritium for 1990. The concentrations of ^{239}Pu , ^{137}Cs and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in Table L-SW-3. For tritium, month-to-month variations in the data presented in Table L-SW-3 correlate well with documented discharges by LLNL and SNL facilities. For plutonium and cesium, the variations are not well understood, and may be a byproduct of the extremely sensitive analysis required to measure these concentrations.

During 1990 there were no inadvertent releases of radioactive materials to the sanitary sewer system that exceeded any discharge limits. Although not of regulatory significance, the release of approximately 93 μCi (3.4×10^6 Bq) of ^{241}Am was detected by the sewer monitoring system on November 12, 1990. The incident was reported to the LWRP and DOE, and a report on LLNL's investigation is being prepared.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 1.46×10^{-6} $\mu\text{Ci/mL}$ (0.054 Bq/ml), about 0.015% of the DOE annualized limit for application of best available technology (BAT) for discharges to a public sewer system (the significance of this limit is described in *Radiological Discharge Limits to the Sanitary Sewer System*,

Figure L-SW-1. LLNL 1990 tritium concentration in sewage effluent.

Livermore Site
Sewage
Monitoring

below). The daily concentration presented in **Figure L-SW-1** was multiplied by the volume of sewage released on that day and then summed to determine the total radiation released in the form of tritium, as given in **Table L-SW-1**. The annual average concentration of ^{137}Cs was $9.86 \times 10^{-11} \mu\text{Ci/mL}$ ($3.65 \times 10^{-6} \text{ Bq/mL}$), only 0.00065% of the DOE annualized discharge limit for application of BAT. The annual average ^{239}Pu concentration was $13.0 \times 10^{-12} \mu\text{Ci/mL}$ ($0.48 \times 10^{-6} \text{ Bq/mL}$), which was 0.00014% of the DOE annualized discharge limit for application of BAT. **Figure L-SW-2** shows the average monthly plutonium concentrations in sewage since 1973.

Nonradioactive Pollutants in Sewage. The monthly average metal concentrations in the LLNL sanitary sewer effluent are listed in **Table L-SW-4**. Except for

chromium in the month of July, all the reported numbers were well below the discharge limits set by the City of Livermore. Several instances occurred during the month of July, when excessive chlorination, coupled with failures of a sampling pump, caused corrosion of the stainless-steel components of the system macerator. The chrome from the stainless steel released directly into the composite sample stream caused artificially high concentrations of chromium to appear in the July samples. Therefore, as previously reported to the LWRP, the chromium concentration reported for the month of July is not considered representative of the actual concentration in LLNL sewage. On a yearly average basis, the metals that approached closest to the discharge limits were chrome and copper respectively at 25% and 22% of the permitted concentrations.

Figure L-SW-2. LLNL monthly average plutonium concentration in sewage since 1973.

Results of quarterly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table L-SW-5**. The tables present the average concentration of various substances and reflect LLNL's compliance with the City of Livermore sewer discharge ordinance.

A brief silver spill and pH excursions were the only instances in 1990 for which parameters exceeded permit guidelines. These excursions were identified by the continuous on-line monitoring system. Events generating an alarm—including the silver spill—were reported to the LWRP when they occurred. By agreement with the LWRP, momentary pH events were reported as part of a monthly status report of LLNL sewer monitoring data.

Environmental Impact

Radioactivity in Sewage. To prevent discharges of radioactive materials to the sanitary sewer, LLNL limits the use of those materials, and implements engineering controls to prevent the release of radioactivity to the environment. When a process does not lend itself to such controls, or when an extra measure of security is warranted, liquid effluents with potential for containing radioactive materials are not discharged directly into the sanitary sewer, but are routed to retention tanks. The retention tanks collect potentially contaminated liquids until a thorough characterization can be performed. When a retention tank becomes full, a sample of the liquid is analyzed to determine pollutant concentrations. If necessary, the wastewater can be treated at LLNL's Hazardous Waste Management Facility to filter out radioactivity to the lowest levels reasonably achievable, and well below discharge limits. Once treated and below acceptable limits (verified by resampling and analysis), the liquid waste is discharged to the City of Livermore sanitary sewer system.

DOE requires that radiological releases to the sanitary sewer comply with local

and State regulations. The most stringent of these limits for total radioactivity released to the sanitary sewer is applied by 17 *California Code of Regulations*. Furthermore, DOE has established criteria for the application of BAT to sewer effluent releases to protect public health adequately and minimize degradation of the environment.

Table L-SW-6 summarizes the liquid releases over the past nine years. During 1990, a total of 0.68 Ci (2.52×10^{10} Bq) of tritium was discharged to the sanitary sewer. This is the combined release from the Livermore site and from SNLL; SNLL records account for 0.20 Ci (1.78×10^{10} Bq) of this amount, and LLNL therefore released 0.48 Ci (0.74×10^{10} Bq). This amount is well within environmental protection standards established by DOE. This amount also is within the range reported in the past.

In 1990 the total activity released by LLNL in the form of alpha and beta emitters (including tritium) was 48% of the 1 Ci Title 17 limit. For specific isotopes, the average tritium concentration was 0.015% of the DOE limit for application of BAT, while the combined ^{239}Pu and ^{137}Cs discharges were 0.00014 and 0.00065% of the limit for the application of BAT.

A summary of the ^{239}Pu monitoring data since 1973 (**Figure L-SW-2**) demonstrates that the 1990 levels of ^{239}Pu continued at the historical levels generally seen since 1981 (approximately 1×10^{-11} $\mu\text{Ci/mL}$, or 0.37 Bq/ml), with the exception of a peak in 1987. This peak was well below the applicable DOE annualized discharge limits for application of BAT. Historically, levels generally are one-millionth (0.000001) of that limit. The greatest part of the discharged plutonium is concentrated in sludge at the LWRP, which is dried and disposed of at the sanitary landfill. The plutonium concentration observed in that sludge, of 2.3×10^{-8} $\mu\text{Ci/dry gm}$ (0.74×10^{-3} Bq/dry gm), is 600 times lower than the proposed EPA guideline for unrestricted use (13×10^{-6} $\mu\text{Ci/dry gm}$).

Livermore Site
Sewage
Monitoring

Nonradioactive Liquid Effluents. High- and low-pH discharges in the combined LLNL/SNLL sewer effluent generated one alarm during 1990. The alarm was caused by the release of pH 3.0 effluent in January 1990. Additional momentary pH spikes occurred intermittently during the year, but their durations were too short or they were too close to the discharge limits to generate an alarm. The frequency of the brief excursions from the permit guidelines was reduced in May 1990, when LWRP relaxed its pH limits.

An observation of high chloride content occurred during the fourth quarter of the year. At that time, LLNL was receiving water from Zone 7. The chloride concentration of the supplied water averaged 152 mg/L. Because the City ordinance allows a chloride increment of 75 mg/L, a chloride concentration as high as 227 mg/L was permissible for the period during which the sample was taken. The measured value of 200 mg/L, although high compared to levels observed during the rest of the year, did not violate the terms of the sewer discharge permit.

One notice of violation was received from the LWRP for a discharge of silver that occurred on August 13, 1990. On that day 233 grams of silver were released during a ten-minute period. The silver concentration in the daily composite sample was 0.23 ppm, compared to the discharge permit level of 0.2 ppm. Analysis of the following day's composite sample demonstrated that LLNL once again was in compliance with the permit.

All alarms were reported promptly to the LWRP, both verbally and in writing. By agreement with the LWRP, excursions that did not generate alarms were reported in a routine monthly report. No specific source was identified for any of the events. None of these releases resulted in any adverse impact on the operation of the LWRP.

Radiological Discharge Limits to the Sanitary Sewer System (NRC, DOE, and DHS)

As directed by DOE Order 5400.5, LLNL discharges to the sanitary sewer are consistent with the requirements imposed by the State of California Department of Health Services (17 *California Code of Regulations*). Section 30287 of these regulations states the following:

(a) No licensee shall discharge licensed material into a sanitary sewerage system unless;

(1) It is readily soluble or dispersible in water; and

(2) Radioactive material released into the system by the user in any one day does not exceed the larger of

(A) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration not exceeding the limits specified in Section 30355 Appendix A, Table I, Column 2 of this part; or

(B) Ten times the quantity of such material specified in Section 30356, Appendix B, and

(3) The quantity of any radioactive material released into the system by the user in any one month, if diluted by the average monthly quantity of sewage released by the user, will not result in an average concentration exceeding the limits specified in Section 30355, Appendix A, Table I, Column 2 of the part; and

(4) The total quantity of radioactive material, released into the sewerage system by the user does not exceed one curie per year.

(5) Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section, provided that the user provides for appropriate radiological monitoring whenever any noise line in the user's installation which may carry such excreta is spared.

DOE orders also require BAT as the level of treatment for liquid wastes released to the sanitary sewer, when concentrations of radionuclides exceed, on an annual average basis, five times the Derived Concentration Guidelines (DCG) reference value for ingested water (*DOE Order 5400.5, Chapter III*). This is an internal DOE standard, specified for each specific radionuclide, which, if exceeded, would require LLNL to implement treatment and/or improved control measures to reduce the annual concentration of the radionuclide in question.

Applying ALARA principals, LLNL restricts releases to the sanitary sewer as described in the Introduction of this section.

For the radionuclides of concern (^3H , ^{137}Cs , and ^{239}Pu), the release limits established by the DHS (17 *California Code of Regulations*) and the DOE guidance for applying BAT are presented in **Table L-SW-2**, based on an average discharge of 341,000 gallons per day.

To provide a workable standard that can be applied on a daily basis, LLNL has chosen to apply the DOE annualized concentration guidance for application of BAT on a daily basis. These values are smaller than the daily sewer effluent concentration limits established by the DHS.

Discharge Limits to the Sanitary Sewer System of the City of Livermore

Sections 13.32.06, 13.32.08, 13.32.09, 13.32.100, and 13.32.110 of the *City of Livermore Municipal Code* state the discharge limits for Livermore's sanitary sewer system. These sections are reprinted below.

Section 13.32.06 General Discharge Prohibitions

No person shall contribute or cause to be contributed, directly or indirectly, any pollutant or wastewater that will interfere with the operation or performance of the publicly 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 that the city, the state, or the EPA has notified the user is a fire hazard or a hazard to the system.

(b) Solid or viscous substances that 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 or 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

Livermore Site
Sewage
Monitoring

than retail produce establishments, or other foods not intended primarily for immediate consumption.

(c) Any wastewater having a pH less than 5.0 or greater than 10.0. 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 that may cause the POTW 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 non-compliance 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 that contain more than 100 mg/L of freon extractable fat, oil, or grease.

(h) Any substance that 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 that 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 that 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 that causes a hazard to human life or creates a public nuisance.

(n) Any waters or wastes containing total dissolved solids increment greater than 325 mg/L¹, nor chloride increment greater than 75 mg/L² 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 300 (the average BOD for residential users) unless a city permit is obtained.

(p) Any waters or wastes containing more than 300 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 limitations for such user(s) to correct the interference with the POTW.

Section 13.32.08. 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 13.32.09. Modification of Federal Categorical Pretreatment Standards

"Where the city's wastewater treatment system achieves consistent 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 that is achieved by the system in 95% 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, Section 403.7, are fulfilled and prior approval from state/EPA is obtained."

Section 13.32.100. Specific Pollutant Limitations

"No person shall discharge wastewater containing in excess of:

0.06	mg/L arsenic
0.14	mg/L cadmium
1.0	mg/L copper
0.04	mg/L cyanide
1.0	mg/L lead
0.01	mg/L mercury
0.61	mg/L nickel
0.2	mg/L silver
0.61	mg/L total chromium
3.0	mg/L zinc
1.0	mg/L total toxic organics."

Section 13.32.110 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."

¹ According to the the San Francisco Water Department, the Hetch-Hetchy water supply contains total dissolved solids at 200 mg/L. Alameda County Zone 7 water averages 260 mg/L. The requirement not to exceed the increment of 325 mg/L therefore translates to an absolute concentration of 525 to 585 mg/L.

² Hetch-Hetchy water contains chloride at 10 mg/L. Zone 7 water averages 150 mg/L. LLNL therefore is allowed to discharge water with chloride content in the range from 85 to 225 mg/L.

Livermore Site
Sewage
Monitoring

Table L-SW-3. Various radionuclides in sanitary sewer effluents—LLNL and Livermore Water Reclamation Plant (LWRP), 1990.

Month	³ H [10 ⁻⁶ μCi/mL ± 2σ (%)]		¹³⁷ Cs [10 ⁻¹¹ μCi/mL ± 2σ (%)]		²³⁹ Pu [10 ⁻¹² μCi/mL ± 2σ (%)]		²³⁹ Pu [10 ⁻⁸ μCi/g ± 2σ (%)]
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP	LWRP sludge ^a
Jan.	3.69 ± 3.6	0.26 ± 4.3	4.02 ± 30	<1.50	6.55 ± 20	0.45 ± 67	
Feb.	1.23 ± 3.9	0.23 ± 4.1	6.57 ± 19	1.45 ± 70	5.58 ± 20	0.30 ± 80	
Mar.	0.59 ± 4.0	0.37 ± 3.8	2.66 ± 62	1.61 ± 41	6.34 ± 16	0.28 ± 80	2.69 ± 4
Apr.	0.40 ± 3.9	0.22 ± 4.2	3.32 ± 25	<0.82	5.27 ± 19	0.26 ± 67	
May	0.71 ± 3.7	0.22 ± 3.8	8.25 ± 15	1.52 ± 49	3.92 ± 22	0.44 ± 63	
June	1.34 ± 3.9	0.20 ± 4.0	31.50 ± 10	2.94 ± 30	4.14 ± 25	0.30 ± 77	1.42 ± 7
July	1.13 ± 3.6	0.22 ± 4.1	19.70 ± 12	<1.11	4.04 ± 17	<0.02	
Aug.	1.69 ± 4.7	0.30 ± 5.9	5.72 ± 18	0.95 ± 60	28.1 ± 9	1.10 ± 32	
Sep.	0.70 ± 5.5	0.32 ± 5.0	3.74 ± 31	1.97 ± 71	15.5 ± 12	0.88 ± 40	1.73 ± 6
Oct.	1.98 ± 5.0	0.29 ± 6.3	25.60 ± 7	<1.80	25.4 ± 9	0.76 ± 35	
Nov.	0.93 ± 5.6	0.30 ± 6.2	5.74 ± 23	<1.10	42.2 ± 8	1.98 ± 24	
Dec.	3.09 ± 5.9	0.41 ± 6.6	<1.48	<1.44	9.02 ± 13	0.90 ± 34	3.48 ± 5
Mean	1.46	0.28	9.86	1.48	13.0	0.64	2.33
SDM (%)	70	24	101	24	96	83	40
Total Release (Ci/y)	0.48		48.1 × 10⁻⁶		6.3 × 10⁻⁶		
Percent of Limit							
DOE	0.015%		0.00065%		0.00014%		
Ca Title 17			48%	(³H + Cs + Pu)			

^a Sludge from LWRP digesters is dried prior to analysis. The resulting data indicates the plutonium concentration in the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

Table L-SW-4. Metal discharged to sanitary sewer system—LLNL, 1990 monthly summary.

	Cd	Total Cr	Cu	Fe	Pb	Ni	Ag	Zn	Al	Be	Hg ^a	As ^a
Month	(mg/L)											
Jan.	0.003	0.16	0.14	0.63	0.033	0.026	0.002	0.31	0.50	0.0003		
Feb.	0.003	0.05	0.13	0.68	0.018	0.016	0.007	0.34	0.44	0.0003		
Mar.	0.002	0.04	0.16	0.88	0.012	0.019	0.004	0.33	0.53	0.0002		
Apr.	0.003	0.15	0.24	1.01	0.021	0.034	0.002	0.40	0.33	0.0004		
May	0.005	0.28	0.17	1.24	0.019	0.021	0.001	0.23	1.16	0.0002		
June	0.002	0.03	0.14	1.45	0.018	0.017	0.001	0.23	0.87	0.0002		
July	0.003	0.73	0.23	0.70	0.035	0.041	0.003	0.33	0.51	0.0003		
Aug.	0.002	0.21	0.35	0.55	0.032	0.029	0.007	0.59	0.42	0.0002		
Sept.	0.004	0.19	0.34	1.06	0.038	0.092	0.022	0.59	0.36	0.0002	0.001	0.004
Oct.	0.010	0.01	0.28	0.11	0.033	0.041	0.005	0.69	0.16	0.0004	0.001	0.006
Nov.	0.003	0.02	0.23	1.42	0.024	0.018	0.002	0.45	0.55	0.0002	0.001	0.004
Dec. (Mean) ^b	0.003	0.02	0.18	0.66	0.026	0.018	0.010	0.40	0.38	0.0013	0.007	0.003
Mean	0.004	0.16	0.22	0.87	0.026	0.031	0.006	0.41	0.52	0.0003	0.0025	0.004
SDM (%)	61	128	35	45	32	69	107	36	50	88	120	30
DL ^c	0.14	0.62	1	— ^d	0.2	0.61	0.2	3	— ^d	— ^d	0.01	0.06
Percent of DL	2.9	25	22	— ^d	13	5.1	3.0	14	— ^d	— ^d	25	7

^a The permit was amended in August 1990 to require mercury and arsenic analysis.

^b The permit was amended in December 1990 to require weekly metals analysis.

^c Discharge limits established in the City of Livermore Municipal Code (May 23, 1990).

^d No established limit for analyte.

Table L-SW-5. Positively detected parameters in LLNL sanitary sewer effluent, 1990.

Positively detected parameter ^a	Jan-Mar	Apr-June	July-Sept	Oct-Dec	Mean	SDM (%)
<u>Physical and chemical (mg/L)</u>						
Biochemical oxygen demand	160	120	160	12	113	62
Chemical oxygen demand	260	390	230	50	233	60
Settleable solids (mL/L)	17	18	15	0.1	12.5	67
Total dissolved solids	250	170	360	490	318	44
Total solids	240	10,000 ^b	360	620	407	48
Total suspended solids	300	190	220	10	180	68
Volatile solids (% total solids)	83	<0.1	47	35	41	83
Ammonia nitrogen (as N)	34	27	24	0.67	21	67
Chloride	38	4	55	200	74	116
Nitrate nitrogen (as N)	<0.1	0.1	<0.1	1.2	0.1 ^c	0 ^d
Nitrate nitrogen (as NO ₃)	— ^e	— ^e	<0.4	5.2	2.8 ^c	86 ^d
Nitrite nitrogen (as N)	— ^e	— ^e	0.02	0.40	0.21	128
Nitrite nitrogen (as NO ₂)	<0.03	<0.03	0.06	1.3	0.05 ^c	40 ^d
Sulfate	22	12	19	77	33	92
Total alkalinity (as CaCO ₃)	160	140	150	130	145	9
Total Kjeldahl nitrogen (as N)	35	41	36	1	28	65
Total phosphorus (as P)	4.7	4.7	4.1	1.0	3.6	49
Total phosphorus (as PO ₄)	— ^e	— ^e	12	3	8	83
Arsenic	0.003	0.003	0.004	0.005	0.004	25
Boron	0.3	0.2	0.3	0.4	0.3	27
Calcium	8	10	15	35	17	73
Total chromium	0.03	<0.05	<0.05	<0.05	0.05 ^c	0 ^d
Copper	0.29	0.24	0.23	<0.05	0.20	52
Lead	0.006	<0.3	<0.2	<0.2	0.2 ^c	50 ^d
Magnesium	1.7	1.9	4.3	20.0	7.0	126
Mercury	0.0020	0.0030	0.0027	<0.0005	0.0021	54
Nickel	0.04	0.03	<0.10	<0.10	0.07 ^c	43 ^d
Potassium	18	16	17	7	15	35
Silver	0.02	0.08	<0.05	<0.05	0.05 ^c	30 ^d
Sodium	33	32	58	130	63	73
Zinc	0.72	<0.05	0.36	<0.05	0.21 ^c	80 ^d
<u>Organic compounds (mg/L)</u>						
Oil and grease	80	42	24	52	50	47
Phenolics	0.11	0.03	0.12	0.13	0.10	47
Total organic carbon	74	43	48	6	43	66

...continued

**Table L-SW-5. Positively detected parameters in LLNL sanitary sewer effluent, 1990
(concluded).**

Positively detected parameter ^a	Jan-Mar	Apr-June	July-Sept ^f	Oct-Dec	Mean	SDM (%)
Purgeable-extractable pollutants (EPA Methods 624/625, µg/L)						
Acetone	<2	23	<1,000	71	47 ^c	74 ^d
Benzyl alcohol	<10	<10	20	<10	10 ^c	0 ^d
Bis(2-ethylhexyl)phthalate	<20	53	<20	<20	20 ^c	0 ^d
Bromodichloromethane	<0.2	<1	<100	2.0	1.5 ^c	60 ^d
Bromoform	<0.2	<1	<100	4.8	2.9 ^c	79 ^d
Butoxy ethanol phosphate	300 ^g	100 ^g	— ^e	60 ^g	153	84
Chloroform	21	6	<100 ^f	4	10	90
Dibromodichloromethane	<0.2	<1	<100	3.8	2.4 ^c	75 ^d
1,3-dichlorobenzene	<2	<2	<100	1.5	2 ^c	13 ^d
1,4-dichlorobenzene	10	4 ^g	<100 ^f	1	5	92
Dimethyl disulfide	— ^e	8 ^g	— ^e	— ^e	8	0
Ethylbenzene	<0.2	1	<100	<0.5	0.75 ^c	53 ^d
Freon 113	1.5	<1	<100	<0.5	1.25 ^c	40 ^d
Tetrachloroethylene	0.6	<1	<100	<0.5	0.8 ^c	31 ^d
Toluene	1.4	<1	<100	<0.5	1.2 ^c	38 ^d
Total xylene isomers	0.2	2	<100	<0.5	1.25 ^c	72 ^d
1,1,1-trichloroethane	1.4	<1	<100	<0.5	1.2 ^c	38 ^d

^a The sewer effluent samples were also analyzed for the following compounds. The concentrations of these compounds were below the detection limits shown:

Organochlorine pesticides	Detection limits µg/L	Organochloride pesticides	Detection limits µg/L
Aldrin	0.05	DDE (mixed isomers)	0.05
Chlordane	0.3	DDD (mixed isomers)	0.05
Endrin	0.1	Heptachlor	0.05
Dieldrin	0.05	Heptachlor Epoxide	0.05
BHC (mixed isomers)	0.05	Methoxychlor	0.2
DDT (mixed isomers)	0.1	Polychlorinated biphenyls	0.3

^b Outlier. This value is not consistent with the total suspended solids and total dissolved solids values reported for the sample. The value is not included in the calculation of the mean and SDM.

^c Median. See Quality Assurance chapter.

^d Median absolute deviation. See Quality Assurance chapter.

^e No data reported by testing laboratory.

^f Due to matrix contamination, the third quarter sample was diluted 100-fold prior to analysis for purgeable-extractable pollutants. Upper limits are not included in calculations of the mean and SDM. See Quality Assurance chapter.

^g Semi-quantified result.

Livermore Site
Sewage
Monitoring

Table L-SW-6. Radioactive liquid effluent releases from the Livermore site, 1981–1990.

Year	Liquid effluents (Ci)	
	³ H (LLNL and SNLL)	²³⁹ Pu
1981	6.0	9.2×10^{-5}
1982	1.6	4.3×10^{-6}
1983	1.7	6.7×10^{-6}
1984	1.7	3.2×10^{-6}
1985	3.6	4.8×10^{-6}
1986	2.0	1.5×10^{-5}
1987	1.4	6.9×10^{-4}
1988	1.5	2.2×10^{-5}
1989	1.6	4.8×10^{-6}
1990	0.68	6.3×10^{-6}

Introduction

Lawrence Livermore National Laboratory (LLNL) performs surveillance monitoring of waters at the Livermore site and in surrounding regions of the Livermore Valley. The waters monitored in the Livermore Valley include lakes and aqueducts, tap water, stormwater runoff, and drinking water supply wells. The samples are analyzed for gross alpha and beta radiation, tritium, and nonradioactive pollutants, including solvents, metals, and pesticides.

As noted in the Sewage Monitoring chapter, a small fraction of treated effluent from LWRP is used to irrigate nearby municipal property. This effluent contains low levels of tritium that come from natural sources, from radioactive fallout, and from normal LLNL and SNLL operational releases to the sanitary sewer system. As part of a study begun in 1977, tritium measurements are made annually on well-water samples collected from neighboring wells to determine the extent of tritium migration into the groundwater. Many of the wells are in the immediate vicinity of LWRP. However, additional samples also are collected from areas some distance away.

Beginning in 1975, LLNL's Environmental Monitoring Program was expanded to include surface runoff monitoring. The program originally was designed to detect the pesticides used at LLNL (herbicides, fungicides, and insecticides) in samples collected following the first major storm from the drainage ditch at the northwest corner of the Livermore site. Additional sampling points subsequently were added, and the samples were analyzed for metals, radioactivity, general water-quality parameters, and other priority pollutants, in addition to pesticides.

On the Livermore site, stormwater is channeled through storm sewers designed to accommodate a ten-year flow. Open ditches are used in undeveloped areas of the site. In 1990, the west perimeter drainage channel was completed to drain the buffer zone land on the western edge of the Livermore site. The Arroyo Las Positas flow is channeled north to the northeast corner of the site, then west along the north perimeter to an outlet at the northwest corner. This outlet, which also constitutes the main pathway for the site's surface drainage (storm and irrigation runoff), runs north to the Western Pacific railroad tracks, then west, where it joins the Arroyo Seco. The main channel of the Arroyo Seco crosses the center of

the SNLL site from the southeast to the southwest corner of the Livermore site.

Methods

Livermore Valley water-sampling locations for surface and domestic water in the vicinity of the Livermore site are shown in **Figure L-W-1**. Locations DEL, ZON7, DUCK, ALAG, SHAD, CAL are surface water sources (ponds, creeks, aqueducts, or reservoirs). Location POOL is the on-site swimming pool. The other locations (GAS, TAP, PALM, and ORCH) are domestic water supplies. Historical location 20 (Annual Environmental Report for 1989) was the rainfall collection location for the Livermore site. New locations have been established for a

Livermore Site

Routine Water Monitoring

special assessment of tritium in rain and stormwater (**Figure L-W-2**). Rain samples are collected after each rainstorm and stormwater samples are collected during the storm. Rain is analyzed for tritium. Stormwater analysis is discussed below. Other water samples are taken quarterly and analyzed for gross alpha, gross beta, and tritium activities. Because of the low tritium levels typically found in most samples, it is necessary to distill and enrich the samples before liquid-scintillation counting.

The locations of wells near LWRP that are sampled for tritium measurements

(to determine the extent of tritium migration into the groundwater) are shown in **Figure L-W-3**. This figure also illustrates the locations of additional sampling sites some distance from LWRP.

As presently designed, the stormwater runoff monitoring program calls for the sampling of nine locations (**Figure L-W-4**) during the period of active surface water flow that follows the first major storm of the rain season. Additional sampling has been performed as part of a special assessment to quantify tritium in rain and stormwater, and to develop a database in support of an NPDES permit application that will be filed in late 1991.

Location ALPE is the influent to the east side of the Livermore site that feeds the Arroyo Las Positas flow, location CDB is at the on-site drainage basin, and location ALPW is the effluent into the redirected Arroyo Las Positas channel at the northwest site boundary. Location ASE is in the Arroyo Seco channel influent to the SNLL site. Location ASS is the effluent to the Arroyo Seco channel of a culvert that collects surface drainage from the southeast area of the Livermore site. Location ASN is the Arroyo Seco channel effluent at the western boundary of the Livermore site (Vasco Road). Location ALPN is at the northern section of Arroyo Las Positas channel flowing westward. Location 4THA is at a northward-flowing channel on the western side of the Livermore site. Location 438E is at a northward-flowing channel draining the southeast quadrant of the Livermore site.

Grab samples are obtained with a tethered plastic pail from surface sources, such as ponds, creeks, and reservoirs. A 500-mL sample for tritium analysis is collected in an argon-flushed glass container fitted with a ground-glass stopper. Samples for other radiological analyses are collected in 500-mL polyethylene bottles.

Groundwater monitoring wells are purged of stagnant water prior to sampling. For wells with high water-production rates, this process entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For

Figure L-W-1. Water sampling locations, Livermore Valley, 1990.

wells with low water-production rates, the well is manually bailed to dryness. Sampling occurs when the well has produced sufficient water for the required samples. All sampling equipment is chosen so that it will not add compounds to the analysis sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

As samples are collected in the field, they are labeled with sampling location and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 10% of the samples are duplicates.

For those samples that are analyzed for gross alpha and gross beta activity, a 100-mL sample or less (depending on the solid content) is digested with a mixture of 80% HNO_3 and 20% HClO_4 , and then dried. The residue is taken up with

HNO_3 and a few milliliters of 5% hydrogen peroxide (H_2O_2). The solution is evaporated to about 5 mL and transferred to a 5-cm-diameter serrated, stainless-steel planchet. After the planchet is dried and flamed, the sample is counted for 30 minutes in a proportional counter. A blank is processed with each set of samples, and ^{239}Pu and ^{90}Sr standards are counted with every sample set. Background measurements are made between every ten sample-counting measurements.

Samples analyzed for tritium are electrolytically enriched and then counted by liquid-scintillation spectrometry. Each counting set includes a total of eight standards to establish quench corrections, and eight blanks to determine background.

For beryllium analysis, a 100-mL sample is digested with HNO_3 . The residue is diluted to 100 mL with deionized

Figure L-W-2. Rain sampling locations, Livermore site and Valley, 1990.

Livermore Site

Routine Water Monitoring

water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Table L-W-1 lists the standardized methods used in the analyses of groundwater and stormwater samples for nonradioactive contaminants.

Results

Radioactivity in Water. **Table L-W-2** shows the gross alpha activities in Livermore Valley water samples. Gross beta activities for Livermore Valley samples are shown in **Table L-W-3**. Gross alpha and beta activities in these surface and domestic water samples collected

in 1990 were below EPA and DHS maximum contaminant levels (MCLs, U.S. Environmental Protection Agency 1977, 22 *California Code of Regulations* Section 64443).

Table L-W-4 contains the data for radioactivity in stormwater runoff. The runoff from four rainstorms (May 27, November 25, December 10, and December 15) were sampled. Not every location developed sufficient runoff to allow sampling. All measurements of gross alpha and gross beta radioactivity were low, a small fraction of the respective MCLs. The MCLs apply to drinking water, as exemplified by the surface waters and

Figure L-W-3. Groundwater sampling locations, Livermore Valley, 1990.

tap waters reported in **Tables L-W-2** and **L-W-3**. Stormwater is not drinking water and the MCLs are used for comparison and trending purposes only. The tritium concentration measured on site at Location ALPN during the December 10 storm was 1.75 times the MCL of $20 \times 10^{-6} \mu\text{Ci/mL}$. This concentration is lower than the highest observed during the 1989 monitoring period.

In general the year's monitoring data reflect the wide range of tritium concentrations seen in the past (i.e., from $<130 \text{ pCi/mL}$ to $57,400 \text{ pCi/mL}$ seen in 1989). These observations and those made in 1989 are being investigated as part of a special assessment of tritium in rain and stormwater that is discussed below.

Table L-W-5 shows tritium data for Livermore Valley water samples. The samples have concentrations that are well below the MCL. The highest average concentration of tritium in water, $1,090 \text{ pCi/L}$, occurred in the on-site swimming pool (Location POOL). This represents 0.05% of the DCG for drinking water and 5.45% of the DHS Drinking Water Standard (DWS). The averages and the percent of DWS for the year also are presented in **Table L-W-5** for each location.

Table L-W-5 also includes an estimate of the annual (effective) dose that may be delivered to an adult who consumes water containing the listed tritium concentrations. These doses, which are all less than 0.056 mrem (the value estimated for Location POOL), are based both on a water consumption of 2 L/day and on the dose-conversion factors contained in ICRP 30, provided by DOE (U.S. Department of Energy 1988b). The actual dose (if any) from the swimming pool and surface water sources would be considerably less, because they are not used as drinking water sources. Methods used to calculate doses are presented in **Appendix B**.

The tritium data for production wells used by local water-supply agencies and for wells in the vicinity of LWRP are shown in **Table L-W-6**. These wells are

used to monitor groundwater quality in the vicinity of LWRP. They are not drinking-water sources. The highest tritium values appear in monitoring wells down-gradient of LWRP. Tritium activities in the monitoring wells were at or near background levels (averaging 108 pCi/L , range 7 to 652 pCi/L). All samples were well below the limit of $20,000 \text{ pCi/L}$ for water adopted by the State of California

Figure L-W-4. Stormwater runoff sampling locations, Livermore site, 1990.

(22 *California Code of Regulations* Section 64443). These tritium levels are similar to those observed in the 1989 samples.

Special Assessment of Tritium in Rain and Stormwater. In the 1989 Site Environmental Report, elevated stormwater tritium concentrations associated with a rain in March 1989 were reported. The tritium concentrations ranged from 57,400 pCi/L to 9,620 pCi/L. Although tritium emissions from LLNL and SNLL are monitored, as are the appropriate end-point substances (allowing an accurate assessment of the potential human impact) stormwater and rain monitoring were expanded to understand better the migration of tritium through the environment.

This expanded monitoring is a special assessment that will be performed for at least one complete rain season (bridging two calendar years and two Site Environmental Reports). This special assessment includes analysis of the monitoring data, evaluation of meteorological conditions surrounding the rainstorm, and modeling of the transport and rain-out of tritium. Reported here are the data collected during 1990 from 17 rain-monitoring locations and eight stormwater-monitoring locations that will be used in the special assessment.

Rain is collected at seven on-site locations and ten off-site locations (**Figure L-W-2**). The rain is collected in stainless-steel buckets fixed at least three feet above the ground in open unsheltered areas and rain gauges are located with the buckets. Stormwater is collected from eight locations (**Figure L-W-4**), either on site or immediately adjacent to LLNL. Samples are collected early during the storm based on the availability of stormwater at each location. Rainstorms are defined as being separated by approximately 12 hours of no rain. The rain and stormwater samples are distilled to remove possible interfering contaminants prior to low-background scintillation counting.

Radiation dose is calculated using the EPA-mandated AIRDOS-PC code, as

described in the Environmental Radiological Program Summary chapter. The AIRDOS-PC code calculates airborne tritium moisture concentrations, and sets water concentrations in vegetation and drinking water at this calculated value. This tends to maximize the calculated dose. Rain water and runoff are not specifically addressed in this EPA code.

The tritium concentration of rain collected on site varied widely (**Table L-W-7**). For example, samples from the November 15, 1990, rain resulted in a 55.8-fold difference between the highest concentration (19,500 pCi/L collected at Location CDB), and the lowest (collected at Location SALV (349 pCi/L). The smallest variation was a seven-fold difference observed in samples from the November 21, 1990 rainstorm. The tritium concentration at off-site locations, especially those 0.5 km (0.23 mi) or more from the site, are lower than concentrations observed on site (**Table L-W-8**). The tritium concentration observed in stormwater runoff during these rainstorms did not correlate with the rain data collected during the same storm.

The concentration of tritium in stormwater is dependent upon the total surface area of the runoff, among many other factors. The concentrations (**Table L-W-4**) varied widely, ranging from the highest concentration (35,000 pCi/L), obtained at the on-site Location ALPN, to the lowest (137 pCi/L), also observed at the same location. The median tritium concentration was 817 pCi/L, with the mean concentration being 3,355 pCi/L.

Conclusions are premature, but certain generalities are observed from the data. The level of tritium in rain water and stormwater on and immediately adjacent to LLNL and SNLL is elevated. The elevated concentrations seem very localized to the LLNL and SNLL area. The magnitude of tritium in the rain cannot be correlated simply with facility emissions, and no unusual tritium releases occurred immediately prior to or simultaneously with the rainstorm.

Nonradioactive Pollutants in Water.

Table L-W-9 shows data for physical and chemical parameters in stormwater. Most potential pollutants in the storm runoff were not present at detectable levels. Acetone was detected at four locations, with the highest concentration being 16 µg/L. These levels are very low, even less than those observed in 1989. Other organics, such as 2,4-dinitrophenol and solvents, sporadically are observed at various locations. Metals were not detected above the normal background levels expected for water that has been in contact with soil. The data showed no significant impact of LLNL operations on other waters sampled.

Environmental Impact

The stormwater runoff showed acetone and other organics sporadically at various locations. Only a few other pollutants

were seen at detectable levels. Non-radiological pollutants above applicable regulatory limits were not seen in any stormwater samples. Although the special assessment of tritium is not complete, the impact of tritium that is released to the air and subsequently is incorporated into rain water and stormwater has been determined. The estimate of the dose to the maximally exposed individual was determined by using the AIRDOS-EPA model and includes all pathways to man, specifically the rain water/stormwater pathway. As discussed in the Environmental Radiological Program Summary chapter of the Livermore site section, this dose to the maximally exposed individual, 0.22 mrem/y (0.0022 mSv/y), is a small fraction of the EPA standard allowable dose of 10 mrem/y (0.1 mSv/y). The data and the estimated potential maximal dose from other waters shows that LLNL impacts are minimal.

Livermore Site
Routine
Water
Monitoring

Table L-W-1. EPA groundwater standard methods.

Analyte	EPA method	Analyte	EPA method
Metals		Organic compounds	
Antimony	204.1	Volatile organic compounds	
Arsenic	206.2, 7060	Purgeable halocarbons	601
Barium	208.1, 6010	Purgeable priority pollutants	624
Beryllium	210.2, 7091	Title 22 organic compounds	608
Cadmium	213.1, 7130, 7131	Extractable priority pollutants	625
Chromium	218.2, 7191	Low-level phenolic compounds	
Cobalt	219.1	Total organic halide (TOX)	9020
Copper	220.1, 6010, 7210	Total organic carbon (TOC)	9060
Iron	236.1, 6010	Oil and grease	413.1
Lead	239.2, 7421	Chemical oxygen demand (COD)	410.4
Manganese	243.1, 6010, 7460		
Mercury	245.1, 7470		
Molybdenum	246.1		
Nickel	249.1, 6010		
Selenium	270.2, 7740		
Silver	272.1, 6010		
Sodium	273.1, 6010		
Thallium	279.1		
Vanadium	286.1, 6010		
Zinc	289.1, 6010		
Nonmetallic inorganic compounds			
Total dissolved solids	160.1		
Total suspended solids	160.2		
Total Kjeldahl nitrogen	351.3		
Ammonia nitrogen (as N)	350.2		
All alkalinities	310.2		
Nitrate	353.2		
Nitrite	353.2		
Fluoride	340.2		
Chloride	325.3		
Sulfate	375.3		

Table L-W-2. Gross alpha activity in water—Livermore Valley, 1990.

Table E-W-2. Gross alpha activity in water					
Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[pCi/L $\pm$ 2 σ (%)]			
DEL	6	2 $\pm$ 2	0 $\pm$ 2	0.6	149
ZON7	4	2 $\pm$ 2	0 $\pm$ 2	1.0	82
DUCK	4	7 $\pm$ 11	4 $\pm$ 10	4.0	54
GAS	4	1 $\pm$ 2	0 $\pm$ 3	0.8	67
B253	0	N/A	N/A	N/A	N/A
ALAG	4	3 $\pm$ 3	0 $\pm$ 2	1.3	101
SHAD	4	1 $\pm$ 3	0 $\pm$ 2	0.5	115
CAL	5	0 $\pm$ 2	0 $\pm$ 1	0	N/A
TAP	3	1 $\pm$ 1	0 $\pm$ 1	0.3	173
PALM	4	2 $\pm$ 2	0 $\pm$ 2	1.0	82
ORCH	4	6 $\pm$ 6	4 $\pm$ 5	2.5	120
BELL	4	0 $\pm$ 2	0 $\pm$ 2	0	N/A
POOL	14	4 $\pm$ 5	0 $\pm$ 2	1.4	108

^a See Fig. L-W-1 for sampling locations.

Livermore Site
Routine
Water
Monitoring

Table L-W-3. Gross beta activity in water—Livermore Valley, 1990.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[pCi/L ± 2σ (%)]			
DEL	6	3 ± 2	2 ± 2	2.5	20
ZON7	4	4 ± 2	2 ± 2	3.0	27
DUCK	4	13 ± 7	1 ± 2	6.8	84
GAS	4	3 ± 2	1 ± 2	2.3	43
B253	0	N/A	N/A	N/A	N/A
ALAG	4	3 ± 2	2 ± 2	2.5	23
SHAD	4	3 ± 2	1 ± 2	2.5	40
CAL	5	4 ± 2	0 ± 2	1.8	82
TAP	3	1 ± 2	0 ± 1	0.67	87
PALM	4	2 ± 2	0 ± 1	1.3	77
ORCH	4	12 ± 4	2 ± 3	5.8	76
BELL	4	20 ± 3	2 ± 2	7.3	118
POOL	14	13 ± 2	1 ± 3	7.3	50

^a See Fig. L-W-1 for sampling locations.

Table L-W-4. Various radionuclides in stormwater runoff, 1990.

Location ^a	Date	³ H [pCi/L ± 2σ (%)]	Gross alpha (pCi/L ± 2σ)	Gross beta (pCi/L ± 2σ)
ALPE	05/27/90	513 ± 26.4	11 ± 5	11 ± 2
	12/15/90	545 ± 26.9	1 ± 2	6 ± 3
	02/16/90	— ^c	10 ± 8	28 ± 5
CDB	05/27/90	712 ± 19.5	0 ± 2	1 ± 2
	11/25/90	1,510 ± 9.9	0 ± 1	5 ± 2
	12/10/90	6,660 ± 3.1	1 ± 1	4 ± 2
	12/10/90	— ^b	1 ± 2	3 ± 2
	12/10/90	6,670 ± 3.1	0 ± 1	6 ± 2 QA
	12/10/90	— ^b	2 ± 2	3 ± 2 QA
	12/15/90	1,680 ± 9.6	1 ± 2	4 ± 3
ALPW	05/27/90	542 ± 25.0	1 ± 3	3 ± 2
	11/25/90	626 ± 22.0	3 ± 3	6 ± 2
	12/10/90	1,910 ± 8.0	3 ± 2	6 ± 3
	12/10/90	— ^b	1 ± 2	6 ± 2
	12/15/90	3,550 ± 5.1	3 ± 2	3 ± 3
ASS (ASW)	05/27/90	2,300 ± 6.8	0 ± 2	3 ± 2
	11/25/90	251 ± 53.1	0 ± 1	7 ± 2
	12/10/90	10,400 ± 2.3	3 ± 3	8 ± 3
	12/10/90	— ^b	2 ± 3	11 ± 3
	12/15/90	355 ± 40.7	0 ± 1	3 ± 3
4THA	05/27/90	391 ± 33.2	0 ± 2	2 ± 2
	11/25/90	232 ± 56.8	0 ± 1	4 ± 2
	12/10/90	1,110 ± 12.8	1 ± 2	6 ± 3
	12/10/90	— ^b	8 ± 5	7 ± 3
	12/15/90	922 ± 16.4	2 ± 2	0 ± 3
	12/15/90	788 ± 19.0	0 ± 1	1 ± 3
438E	05/27/90	836 ± 16.2	1 ± 2	2 ± 2
	11/25/90	720 ± 19.4	0 ± 1	5 ± 2
	12/10/90	12,600 ± 2.1	1 ± 2	5 ± 2
	12/10/90	— ^b	2 ± 2	2 ± 2
	12/15/90	585 ± 25.1	0 ± 2	2 ± 3
ALPN	05/27/90	709 ± 18.9	1 ± 1	4 ± 2
	11/25/90	137 ± 95.3	1 ± 1	4 ± 2
	12/10/90	35,000 ± 1.2	0 ± 2	6 ± 4
	12/10/90	— ^b	1 ± 3	2 ± 3
	12/15/90	3,860 ± 4.8	1 ± 2	6 ± 4
	11/15/90	4,730 ± 3.9		

^a See Fig. L-W-4 for sampling locations.

^b No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^c Sample contaminated during laboratory analysis.

Livermore Site
Routine
Water
Monitoring

Table L-W-5. Tritium in water—Livermore Valley, 1990.

	Sampling location ^a					
	DEL ^b	ZON ^{7b}	DUCK ^b	GAS ^c	ALAG ^b	SHAD ^b
	[pCi/L $\pm$ 2 σ (%)]					
First quarter	51 $\pm$ 15	27 $\pm$ 26	180 $\pm$ 6	60 $\pm$ 12	35 $\pm$ 17	127 $\pm$ 6
Second quarter	54 $\pm$ 13 43 $\pm$ 13	23 $\pm$ 28	119 $\pm$ 7	24 $\pm$ 27	25 $\pm$ 21	106 $\pm$ 7
Third quarter	7 $\pm$ 13	25 $\pm$ 22	68 $\pm$ 10	35 $\pm$ 18	31 $\pm$ 18	125 $\pm$ 6
Fourth quarter	45 $\pm$ 12	43 $\pm$ 14	63 $\pm$ 10	33 $\pm$ 17	27 $\pm$ 22	112 $\pm$ 7
Mean	49	30	108	38	30	118
SDM (%)	8.2	31.0	50.8	40.6	15.0	8.6
Percent of DWS ^e	0.25	0.15	0.54	0.19	0.15	0.59
Effective dose (mrem)	0.002	0.002	0.005	0.002	0.002	0.006

	Sampling location ^a					
	CAL ^b	TAP ^c	PALM ^c	ORCH ^f	BELL ^c	POOL ^g
	[pCi/L $\pm$ 2 σ (%)]					
First quarter	34 $\pm$ 17	28 $\pm$ 19	24 $\pm$ 21 23 $\pm$ 22 ^d	18 $\pm$ 27	25 $\pm$ 20	1,080 $\pm$ 13 1,190 $\pm$ 12 — ^h
Second quarter	32 $\pm$ 16	24 $\pm$ 21 18 $\pm$ 27 ^d	22 $\pm$ 23	34 $\pm$ 16	26 $\pm$ 22	1,240 $\pm$ 12 1,150 $\pm$ 12 1,190 $\pm$ 12
Third quarter	31 $\pm$ 19 41 $\pm$ 15 ^d	25 $\pm$ 24	35 $\pm$ 17	26 $\pm$ 23	28 $\pm$ 22	1,060 $\pm$ 14 1,180 $\pm$ 13 ^d 1,110 $\pm$ 13 ^d 838 $\pm$ 17 720 $\pm$ 20
Fourth quarter	36 $\pm$ 16	24 $\pm$ 23 38 $\pm$ 17 ^d	27 $\pm$ 22	14 $\pm$ 42	30 $\pm$ 19	836 $\pm$ 16 1,300 $\pm$ 11 1,330 $\pm$ 11
Mean	33	25	27	23	27	1,085
SDM (%)	6.7	7.5	21.2	38.6	8.1	18.7
Percent of DWS ^e	0.17	0.13	0.13	0.12	0.14	5.42
Effective dose (mrem)	0.002	0.001	0.001	0.001	0.001	0.054

^a See Fig. L-W-1 for sampling locations.

^b Surface water.

^c Tap water—Livermore locations.

^d Duplicate sample not included in Mean or SDM% calculation.

^e DWS (California State Drinking Water Standard) = 200×10^{-7} μ Ci/mL.

^f Well water.

^g LLNL swimming pool.

^h No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

Table L-W-6. Tritium in groundwater—Livermore Valley, 1990.

Well identification ^a	Activity [pCi/L $\pm$ 2 σ (%)]	Percent of DWS ^b
3S1E-01H3	9 $\pm$ 45	0.05
3S1E-01P2	189 $\pm$ 5	0.95
3S1E-01R2	69 $\pm$ 9	0.35
3S1E-02R1	227 $\pm$ 4	1.14
3S1E-01P3	29 $\pm$ 22	0.15
3S1E-11B1	652 $\pm$ 3	3.26
3S1E-12A2	83 $\pm$ 8	0.42
3S1E-18A5	19 $\pm$ 31	0.10
3S1E-16L5	42 $\pm$ 13	0.21
3S1E-16L7	35 $\pm$ 17	0.18
3S1E-16L7 QA	27 $\pm$ 19	0.14
3S2E-07C2	113 $\pm$ 7	0.57
3S2E-08F1	12 $\pm$ 38	0.06
3S2E-08F1 QA	7 $\pm$ 64	0.04

^a See Fig. L-W-3 for sampling locations.

^b DWS (State of California Drinking Water Standard) = 200×10^{-7} μ Ci/mL, or 20,000 pCi/L.

Livermore Site
Routine
Water
Monitoring

Table L-W-7. Tritium in rain water—Livermore site, 1990.

		Sampling location ^a						
		Date	COW	MET	VIS [pCi/L ± 2σ (%)]	B343	SALV	B291
Q1		__b	__b	__b	__b	__b	__b	__b
Q2		__b	__b	__b	__b	__b	__b	__b
Q3		__b	__b	__b	__b	__b	__b	__b
Q4	11/15/90	585 ± 23	992 ± 14	__c	13,900 ± 2	349 ± 38	__c	19,500 ± 2
	11/21/90	1,110 ± 13	1,230 ± 11	2,530 ± 6	7,810 ± 3	2,180 ± 7	3,000 ± 5	2,390 ± 7
	11/26/90	471 ± 29	≤128	1,740 ± 9	2,570 ± 6	421 ± 32	1,540 ± 10	1,380 ± 11
	12/11/90	946 ± 15	293 ± 44	4,560 ± 4	6,140 ± 3	1,820 ± 8	1,050 ± 13	6,140 ± 3
	12/17/90	2,120 ± 8	342 ± 42	895 ± 17	10,500 ± 2	525 ± 28	1,680 ± 10	10,300 ± 2
	12/20/90	571 ± 24	144 ± 90	6,100 ± 3	1,610 ± 9	2,730 ± 7	4,450 ± 4	__c
Mean		976.2	521.5	3,165.0	7,088.3	1,337.5	2,344.0	7,942.0
SDM (%)		64	90	67	66	77	59	93

^a See Figure L-W-2 for sampling locations.

^b No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^c No sample generated during rainstorm.

Table L-W-8. Tritium in rain water—Livermore Valley, 1990.

		Sampling location ^a									
	Date	ZON7	SLST	AQUE	GTES	ESAN	BVA	VINE	FCC	PARK	DEL7
		[pCi/L ± 2σ (%)]									
Q1	}	No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."									
Q2											
Q3											
Q4	11/15/90	2,840 ± 6	≤134	877 ± 16	— ^c	≤204	— ^b	321 ± 40	— ^b	— ^b	291 ± 44
	11/21/90	976 ± 14	247 ± 51	2,330 ± 7	≤119	776 ± 31	— ^b	277 ± 45	≤194	≤121	≤122
	11/26/90	221 ± 60	≤131	272 ± 49	863 ± 16	357 ± 38	— ^b	≤129	≤129	≤129	≤130
	12/11/90	692 ± 20	320 ± 41	1,300 ± 12	498 ± 29	1,110 ± 13	— ^c	388 ± 34	206 ± 63	≤126	223 ± 58
	12/17/90	541 ± 27	169 ± 84	497 ± 30	230 ± 62	303 ± 47	300 ± 48	≤140	≤142	151 ± 94	≤141
	12/20/90	1,760 ± 9	≤128	3,340 ± 5	≤140	1,740 ± 17	240 ± 54	≤125	≤137	≤138	≤126
Mean		1,172	152 ^d	1,436	230 ^d	748	270	209 ^d	142 ^b	129 ^d	136 ^d
SDM (%)		83	15 ^e	82	48 ^e	79	16	39 ^e	9 ^e	6 ^e	9 ^e

^a See Figure L-W-2 for sampling locations.

^b No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^c No sample generated during rainstorm.

^d Median value.

^e Median absolute deviation (%).

Livermore Site

Routine Water Monitoring

Table L-W-9. LLNL stormwater runoff—nonradioactive parameters, 1990.^a

Positively detected parameters	Sampling location ^b						
	ALPE	CDB	ALPW	438E	4THA	ALPN	ASS
<u>Physical (mg/L)</u>							
Arsenic	<0.002	0.005	0.004	0.008	0.006	0.015	<0.002
Barium	<0.05	<0.05	<0.05	<0.05	<0.05	0.06	0.06
Bicarbonate Alk	40	24	28	18	32	35	41
Cadmium	<0.0005	0.0013	0.0006	0.0020	0.0014	<0.0005	0.0007
COD	125	150	180	225	250	160	240
Chloride	9.4	6.1	10	5.0	15	8.9	21
Chromium	0.006	0.006	0.009	0.006	0.006	0.006	<0.005
Fluoride	0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1
Lead	0.005	0.003	0.004	0.009	0.005	<0.002	0.007
Mercury	<0.0005	<0.0005	<0.0005	0.0006	<0.0005	<0.0005	<0.0005
Nitrate plus Nitrite	16.0	12	9.1	5.9	10.0	5.6	10
Oil and Grease	<5	5	<5	7	<5	<5	6
Sulfate	<1	9	9	6	9	9.0	13
<u>Organics (µg/L)</u>							
Acetone	<5	9.5	14.0	16.0	13	<5.0	10
Chloroform	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<1
2,4-Dinitrophenol	<20	<20	<20	<20	23	<20	<20
Tetrachloroethylene	<0.5	2.0	<0.5	9.5	<0.5	<0.5	<1
TOC (mg/L)	29	29	35.0	38	56	29	40
1,1,1-Trichloroethane	<0.5	<0.5	<0.5	2.0	<0.5	<0.5	<1
Trichlorofluoromethane	<0.5	1.0	<0.5	4.0	<0.5	<0.5	<1
<u>Hydrocarbons (µg/L)</u>							
C8–C35 Hydrocarbons	400	6,000	5,000	6,000	10,000	7,000	8,000

^a Values shown are the greatest of all samples taken during 1990.

^b See Fig. L-W-4 for sampling locations.

The following organic compounds would have been reported had they appeared above the detection limits indicated below.

Title 22 organics (µg/L)	Detection limits	Purgeable priority pollutants (EPA 624) (µg/L)	Detection limits
2,4,5-TP (Silvex)	1	Acrolein	5
2,4-D	10	Acrylonitrile	5
Endrin	0.01	All other analytes	0.5–20
Lindane	<0.4		
Methoxychlor	10		
Toxaphene	0.5		

Introduction

Soil is an integrating medium that can account for contaminants released to the atmosphere or through liquid effluents. Since 1972, annual soil sampling in the vicinity of the Livermore site has been part of the continuing Lawrence Livermore National Laboratory (LLNL) monitoring program designed to document any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from Livermore site operations. Prior to 1988, soil samples were collected at sites selected at random from Livermore Valley locations previously sampled in a 1971–1972 study, which was conducted to determine the background concentrations of radionuclides in area soils. In 1988, surveillance soil sampling locations were chosen to coincide with air sampling locations or to give coverage to areas of known past contamination or concern. The 1988 sampling locations, resampled in 1989, were resampled again during 1990. The use of constant sampling locations allows for better trending of the data and closer monitoring of areas of concern.

During 1990, sediment samples from the arroyos near LLNL also were collected, continuing a monitoring effort begun in 1988. The sampling of sedimentary material from streams or ponds can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment. As a result of the accumulation of contaminants, sediment sampling is a more sensitive indicator of waterborne radionuclides than water sampling (U.S. Department of Energy 1988d). The sediments also have the potential to concentrate nonradioactive constituents present in stormwater runoff. Chemical and radiological analyses determined if significant buildup of pollutants has occurred. The arroyo sediment sampling locations were chosen to coincide with major stormwater sampling locations.

Methods

Figure L-SO-1 shows the soil-sampling locations in the Livermore Valley. The sampling locations were the same as those sampled in 1988 and 1989, but the locations were renamed with new sample location designators during 1990 (see Quality Assurance chapter).

Figure L-SO-1. Soil sampling locations, Livermore Valley, 1990.

Livermore Site Soil Monitoring

Sampling activities followed standardized written procedures (Brekke et al. 1988). Samples are taken from reasonably level areas that have undisturbed soil. A 2-m square is marked off in each area, and an 8.25-cm-diameter coring tool, designed at LLNL, collects 5-cm-deep subsamples at the corners and center of the square. All subsamples are collected to a depth of 5 cm because surface deposition from the air is the primary pathway for potential contamination. The five subsamples of soil collected from each 2-m square are combined into a single composite sample in a plastic bag. A label is affixed to the bag, and the sample is identified by a sample identification code, called the sample identifier. This identifier, which includes the sampling location designator, is entered in a logbook, with all pertinent sampling information and a description of the sample location. The code identifies the sample throughout all sampling and laboratory activities, including data reporting. For clarity, only sampling location designators are used in the data tables of this report.

Plutonium-239 content is determined from an aliquot of each sample. Following drying, grinding, sieving, and blending, the soil is leached by heating for four hours with a mixture of concentrated HNO_3 and HCl . The plutonium then is separated and purified by ion exchange and electroplating, and is submitted for alpha spectroscopy. Other sample aliquots, which are analyzed by gamma spectroscopy (for over 150 radionuclides), first are dried at 110°C for a minimum of two days, pulverized, passed through a 32-mesh sieve, and blended. The gamma spectroscopy involves approximately 300-g aliquots of the soils, which are sealed in 200-cm³ thin-walled aluminum cans. The samples are gamma-counted with a $\text{Ge}(\text{Li})$ detector.

Approximately 10% of the soil sampling locations are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections,

two adjacent cores, 5-cm deep, are taken from the corners and center of each 2-m square. Separate composites of the five cores then are made, and the composites are identified with unique sample identifier codes.

Figure L-SO-2 shows the six arroyo sampling locations near the Livermore site. Standard written sampling procedures are followed (Brekke et al. 1988). At each location, a 30-ft (9.2-m) transect is laid out (starting from a permanent marker), and four numbers between 1 and 30 are randomly generated. These numbers represent the distance (in feet) along the transect where samples are taken. Samples are taken with a split-spoon sampler driven into the soil to a depth of 2 ft (0.61 m) to allow for better characterization of volatile organic compounds. The bottom 6 in (0.15 m) are sealed in a stainless-steel sampling tube and are submitted for organic compounds and metals analyses. The next higher 6 in (0.15 m) are submitted for radiological analyses (tritium, gamma emitters, and plutonium). Sample identifier codes are written on the sample tube, on a label attached to the sample tube, and in a logbook. The sample identifier code and the sampling date identify each sample throughout the sampling and analytical processes.

Gamma spectroscopy and plutonium analyses are conducted on aliquots of arroyo sediment samples using the techniques outlined above for soil samples. Tritium analysis is performed by liquid-scintillation counting of water recovered by freeze-drying additional aliquots of the arroyo sediment samples. The arroyo samples are analyzed for metals by inductively coupled plasma-emission spectroscopy (ICP) following extraction in water for comparison to Soluble Threshold Limit Concentrations (STLC). The arroyo samples are analyzed for organic compounds by standard EPA methods (method 8010 for halogenated volatile organic compounds, method 8020 for aromatic volatile organic compounds, and method 8080 for pesticides and PCBs).

Ten percent of the arroyo samples are collected in duplicate, in accordance with quality assurance protocols (Holland 1987). Duplicate samples are collected adjacent to sampling locations using identical procedures. The duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Results

Table L-SO-1 presents data on the concentrations of ^{239}Pu , ^{40}K , ^{137}Cs , ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U , ^{238}U , and ^{241}Am in soils from the Livermore Valley sampling locations. Only positively detected radionuclides are shown. The twofold rationale for including the naturally occurring nuclides (^{40}K , ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U , and ^{238}U) and the long-lived fission product (^{137}Cs) is to provide baseline data on global fallout and to permit monitoring

the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL.

The concentrations and distributions of all observed nuclides in soil for 1990 are within the ranges reported in previous years. Elevated levels of ^{239}Pu , resulting from an estimated 32 mCi Pu release to the sewer in 1967 and first observed in soils near the Livermore Water Reclamation Plant (LWRP) during the early 1970s, again were detected at locations WRP1, WRP2 and WRP3. The highest value of $145 \times 10^{-9} \mu\text{Ci/g}$ (0.0054 Bq/g) represents 1.1% of the proposed EPA soil standard of $0.2 \mu\text{Ci/m}^2$ (7407 Bq/m^2) for unrestricted use of surface soil [or $13 \times 10^{-6} \mu\text{Ci/g}$ (0.5 Bq/g), assuming average Livermore Valley soil densities].

Similarly, $33 \times 10^{-9} \mu\text{Ci/g}$ (0.0012 Bq/g) of ^{239}Pu was detected at location ZON7. This concentration is greater than those

Figure L-SO-2. LLNL arroyo sediment sampling locations, 1990.

reported for this location during previous years and is significantly different from concentrations measured at other locations; it represents 0.3% of the proposed EPA standard. Measurements of this magnitude have been seen occasionally in past years at a variety of soil sampling locations. The elevated concentration will be investigated in greater detail during 1991.

The remaining soil values reflect worldwide fallout and naturally occurring concentrations of nuclides. The ^{241}Am detected at WRP2 in the same sampling area exhibiting elevated plutonium levels probably is caused by a combination of natural decay of the trace concentrations of ^{241}Pu that also are present and small amounts of ^{241}Am associated with previous releases.

Table L-SO-2 presents data on radionuclides detected in the arroyo sediment samples. Again, only positively detected levels are shown. Plutonium-239 levels are at background concentrations, reflective of worldwide fallout. Most other radionuclides were detected at levels similar to those reported in 1988 and 1989. Cesium-137 is a fission product found at worldwide background concentrations. Potassium-40, ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U and ^{238}U are naturally occurring radionuclides that were detected at background concentrations. Tritium concentrations are below those reported in 1988 and 1989.

Table L-SO-3 presents data on metals that were detected in the sediment samples. The level of lead (Pb) in one sample of concern taken in 1989 (ASE, 79 mg/L) was investigated during 1990. Additional samples taken from this area did not exhibit lead concentrations above background levels. For other metals, no concentrations above STLC limits or above levels normally encountered in sediments were detected.

Table L-SO-4 presents data on positively detected organic compounds in the sediment samples. Current analytical techniques for detection of organic compounds are much improved; therefore, traces of a variety of compounds (many

of which were undetectable before 1989) were observed in all samples.

The PCB Aroclor 1260, detected at two locations in low concentrations in 1989, was not detected in any 1990 sample. Many other detected compounds are typical of fuel constituents and are expected in locations that concentrate stormwater runoff. Others are typical laboratory solvents. None of the levels detected for organic compounds are above regulatory standards.

Environmental Impact

Routine soil and arroyo sediment sample analyses indicate that the impact of LLNL operations on these media in 1990 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations, in trace amounts, or in amounts that could not be measured above detection limits. Even where contamination exists, concentrations either are below regulatory standards, or remain on site and are being evaluated for remedial actions. Sampling of soils and arroyo sediments will continue on an annual basis.

Special Projects

Plutonium in Soil, LLNL Site Southeast Quadrant. The DOE Tiger Team stated that LLNL had not investigated and evaluated "the cause of measurable off-site plutonium contamination" as part of Finding RAD/CF-3, following its audit during early 1990 [U.S. Department of Energy, Environment, Safety, and Health, *Tiger Team Assessment of Lawrence Livermore National Laboratory*, DOE/EH-0142 (Draft) (U.S. DOE 1990)]. The data mentioned was from high-volume air particulate samples collected during 1988 adjacent to the southeast quadrant of the site. The Tiger Team did mention that the "detected concentrations were much less than any regulatory limits and presented no imminent threat to the public or the environment." However, the Tiger Team stated that because the site did not detect plutonium in any stack monitors, the

source of the measured airborne contamination was "unmonitored and unquantified," and may be "due to soil contamination at the southwest (sic) portion of LLNL caused by historical activities."

LLNL responded to the Tiger Team with a plan to address all audit findings [LLNL, *Action Plan in Response to the April 1990 Tiger Team Assessment of the Lawrence Livermore National Laboratory* (LLNL 1990)]. Part of the planned LLNL action regarding Finding RAD/CF-3 involved the initiation of a grid-based soil and sediment sampling and analysis plan to characterize and quantify plutonium in the southeast quadrant of the site. Localized high-volume air particulate sampling also is planned. The additional soil and air sampling should allow quantification of the source term associated with the resuspension pathway for use in dose assessments and will help verify that no unknown, unmonitored sources exist.

To date, approximately 200 soil and sediment sampling locations have been selected at random using a coarse grid (Figure L-SO-3). Initial samples have been collected, and analyses are under way. Samples are being collected to a depth of 1.25 cm. If any analytical results indicate elevated plutonium levels, additional samples will be collected in the affected area, and a finer grid will be used to define the area.

No final data are yet available. Results will be documented fully when the data analysis is complete and interpreted.

Tritium in the Unsaturated Zone. As part of the Remedial Investigation/Feasibility Study (RI/FS) (Thorpe et al. 1990; Isherwood et al. 1990), the Environmental Restoration Division conducted assessments of tritium concentrations in unsaturated soil sediments (vadose zone) at the Livermore site. The following discussion is largely excerpted from Isherwood et al. 1990.

Tritium, if present in the vadose zone, is found in the water held in the spaces between soil particles. The amount of tritium present is dependent on the water

content of the unsaturated sediments. At LLNL, water typically represents 5 to 20% of the vadose zone by weight. The reported tritium concentrations in sediments are not directly comparable to measurements derived from groundwater. To make this distinction, tritium measurements from the vadose zone are reported in picocuries per liter of soil moisture (pCi/L_{sm}) in RI/FS reports.

Data collected indicate that tritium is present in the vadose zone (at some locations) in concentrations significantly above the LLNL background level of about $3,5000 \text{ pCi/L}_{\text{sm}}$. Vadose zone tritium levels in the Building 514 Area have been measured as high as $2.7 \times 10^6 \text{ pCi/L}_{\text{sm}}$. In the Building 292 Area, a maximum concentration of $2.2 \times 10^8 \text{ pCi/L}_{\text{sm}}$ was reported adjacent to an underground tank that failed its annual leak test. This area is now under detailed investigation, the results of which will be reported as part of LLNL's underground tank program. In three other areas (Eastern Landing Mat Storage Area, West Traffic Circle, Old Salvage Yard), the highest vadose zone tritium concentrations reported were 9.4×10^4 , 9.7×10^4 , and $1.4 \times 10^5 \text{ pCi/L}_{\text{sm}}$. These areas also remain under investigation.

None of the above-mentioned vadose zone contamination threatens drinking-water supplies and no edible vegetation is directly affected. Therefore, the only potentially significant transport pathway to human populations for the vadose zone tritium contamination is inhalation of tritiated water vapor. Such water vapor may result from direct soil evaporation or from water taken up by plants and released to the air by transpiration from plant leaves. Transpired water from a single tree located near the Building 292 tritium contamination area has been measured with tritium concentrations as high as $5 \times 10^6 \text{ pCi/L}$, although most observations have indicated much lower concentrations. Other measurements have shown that the transpired water from other vegetation in the area does not contain

Livermore Site
Soil Monitoring

tritium at significantly elevated levels (Macdonald et al. 1990). Significantly elevated air concentrations in the area, which might implicate direct soil evaporation, have not been detected at the nearest perimeter monitoring stations. Furthermore, most of the areas where elevated tritium concentrations have been detected are paved with asphalt, thereby limiting potential soil evaporation.

No specific concentrations standards currently exist for tritium in soil; however, concentrations limits can be derived from exposure standards. Federal regulations

(40 *Code of Federal Regulations* 61.92) prohibit emissions that would cause any member of the public to receive in one year a maximum effective dose equivalent of more than 10 mrem/y from the air pathway. Screening level calculations, using the standard EPA code AIRDOS-EPA and conservative (worst-case) assumptions, indicate that no potential doses from any of the measured tritium concentrations in soil could exceed 0.01% of this standard (Macdonald et al. 1990). These calculations included an assessment of the potential dose attributable to transpired water from the tree in the Building 292 area.

Figure L-SO-3. Approximate locations of surface soil samples in the Plutonium Study Area.

Livermore Site
Soil Monitoring

Table L-SO-1. Positively detected radionuclides in soil—Livermore Valley, 1990
(sampling depth = 0 to 5 cm).

	²³⁹ Pu	⁴⁰ K	¹³⁷ Cs	²²⁶ Ra	²²⁸ Ra	²⁴¹ Am	²³⁵ U	²³² Th	²³⁸ U
Location ^a	[10 ⁻⁹ μCi/dry g ± 2σ (%)]	[10 ⁻⁶ μCi/dry g ± 2σ (%)]					[10 ⁻² μg/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]	
VIS	7.7 ± 3	10.8 ± 3	0.03 ± 16	0.74 ± 2	0.69 ± 4	<0.05	2.24 ± 59	7.16 ± 3	3.09 ± 62
PATT	3.5 ± 4	14.0 ± 4	0.15 ± 5	1.33 ± 2	0.92 ± 4	<0.05	2.66 ± 56	9.46 ± 3	<1.95
NEP	2.5 ± 4	15.4 ± 4	0.11 ± 5	0.69 ± 3	0.64 ± 4	<0.05	1.82 ± 73	6.55 ± 3	<0.72
ZON7	33.0 ± 3	14.6 ± 3	0.12 ± 6	0.76 ± 2	0.72 ± 4	<0.05	2.89 ± 50	7.31 ± 3	2.73 ± 88
COW	1.8 ± 5	13.3 ± 3	0.07 ± 10	0.68 ± 3	0.64 ± 4	<0.01	1.96 ± 46	6.94 ± 3	3.00 ± 58
FCC	2.9 ± 5	11.8 ± 4	0.11 ± 6	0.65 ± 2	0.59 ± 4	<0.01	3.31 ± 46	6.43 ± 3	4.41 ± 51
HOSP	7.5 ± 3	12.5 ± 3	0.35 ± 3	0.64 ± 2	0.57 ± 5	<0.03	1.54 ± 93	6.01 ± 3	<1.17
TANK	0.5 ± 8	10.4 ± 3	0.03 ± 26	0.56 ± 2	0.63 ± 3	<0.05	2.29 ± 53	6.50 ± 2	2.40 ± 79
MET	1.1 ± 7	16.1 ± 2	0.05 ± 13	0.78 ± 2	0.73 ± 3	<0.05	1.59 ± 94	7.65 ± 2	3.18 ± 88
MESQ	1.7 ± 6	15.7 ± 2	0.06 ± 13	0.81 ± 2	0.74 ± 3	<0.02	2.01 ± 70	7.48 ± 2	3.15 ± 82
WRP1	145.0 ± 2 ^b	11.7 ± 3	0.03 ± 11	0.64 ± 2	0.68 ± 3	<0.06	<1.03	6.43 ± 5	2.37 ± 53
WRP2	71.6 ± 2 ^b	13.6 ± 4	0.08 ± 8	0.76 ± 2	0.80 ± 3	0.06 ± 83	2.33 ± 57	7.59 ± 2	3.09 ± 70
WRP3	42.2 ± 2 ^b	13.7 ± 3	0.04 ± 15	0.76 ± 2	0.79 ± 3	<0.05	2.47 ± 61	8.34 ± 2	3.63 ± 76
WRP4	1.4 ± 5 ^b	7.0 ± 3	<0.02	0.41 ± 2	0.43 ± 4	<0.04	1.31 ± 87	4.35 ± 4	<1.50
WRP5	15.1 ± 2 ^b	9.7 ± 4	0.02 ± 30	0.57 ± 3	0.56 ± 5	<0.01	1.68 ± 43	6.09 ± 3	<1.35
WRP6	14.9 ± 2 ^b	11.9 ± 3	0.05 ± 14	0.62 ± 2	0.63 ± 4	<0.04	1.77 ± 60	6.56 ± 3	<1.59
Mean	6.2 (22.0)^b	12.6	0.08	0.71	0.67	0.05^c	2.06	6.93	2.57^c

Table L-SO-2. Positively detected radionuclides in arroyo sediments near the Livermore site, 1990.

	²³⁹ Pu	³ H	⁴⁰ K	¹³⁷ Cs	²²⁶ Ra	²²⁸ Ra	²³⁵ U	²³² Th	²³⁸ U
Location ^a	[10 ⁻⁹ µCi/dry g ± 2σ (%)]	10 ⁻⁷ µCi/mL ^b ± 2σ (%)]	[10 ⁻⁶ µCi/dry g ± 2σ (%)]			[10 ⁻² µg/dry g ± 2σ (%)]		[µg/dry g ± 2σ (%)]	
ALPE-1	0.11 ± 20	9.1 ± 16	15.1 ± 3	≤0.003	0.75 ± 2	0.81 ± 4	1.9 ± 28	8.4 ± 3	2.9 ± 27
ALPE-2	0.28 ± 14	11.9 ± 12	13.9 ± 3	0.013 ± 66	0.70 ± 2	0.80 ± 3	2.8 ± 18	8.4 ± 2	2.9 ± 25
ALPE-3	0.73 ± 8	8.5 ± 16	12.8 ± 3	0.012 ± 55	0.68 ± 2	0.71 ± 4	2.3 ± 25	7.3 ± 3	≤0.8
ALPE-4	0.38 ± 14	11.5 ± 13	14.2 ± 3	≤0.003	0.74 ± 2	0.77 ± 4	1.9 ± 30	7.6 ± 3	1.3 ± 52
CDB-1	4.68 ± 4	11.9 ± 12	14.8 ± 4	≤0.003	0.64 ± 3	0.82 ± 4	2.8 ± 22	8.3 ± 3	2.9 ± 33
C7/B-2	1.92 ± 14	11.6 ± 12	14.9 ± 3	≤0.002	0.66 ± 2	0.81 ± 3	2.8 ± 20	7.6 ± 4	2.6 ± 47
CDB-3	0.78 ± 7	12.7 ± 11	15.3 ± 5	≤0.003	0.74 ± 3	0.87 ± 5	2.8 ± 26	9.1 ± 4	1.2 ± 72
CDB-4	2.35 ± 5	12.0 ± 12	14.8 ± 3	≤0.003	0.71 ± 3	0.86 ± 4	2.8 ± 32	9.1 ± 3	≤0.8
ALPW-1	0.12 ± 30	≤1.3	12.4 ± 4	0.032 ± 26	0.62 ± 3	0.82 ± 4	2.8 ± 24	8.6 ± 3	3.0 ± 25
ALPW-2	5.52 ± 3	3.4 ± 39	16.0 ± 4	0.014 ± 60	0.64 ± 3	0.76 ± 5	2.8 ± 25	8.4 ± 3	2.6 ± 16
ALPW-3	3.93 ± 4	4.1 ± 32	17.2 ± 3	≤0.003	0.73 ± 2	0.86 ± 3	2.3 ± 21	9.2 ± 2	2.2 ± 28
ALPW-4	0.24 ± 15	3.0 ± 44	12.0 ± 3	0.029 ± 28	0.56 ± 3	0.68 ± 4	2.3 ± 19	7.2 ± 3	2.2 ± 54
ASE-1	0.47 ± 11	17.5 ± 9	12.3 ± 3	0.020 ± 25	0.49 ± 2	0.51 ± 4	1.9 ± 22	5.3 ± 3	1.9 ± 31
ASE-2	0.38 ± 11	22.7 ± 7	12.0 ± 2	0.022 ± 25	0.56 ± 2	0.54 ± 4	1.9 ± 20	5.7 ± 3	1.6 ± 52
ASE-3	2.23 ± 5	5.7 ± 24	11.9 ± 8	0.033 ± 15	0.46 ± 3	0.49 ± 5	1.9 ± 26	5.1 ± 3	≤1.4
ASE-4	0.29 ± 13	19.3 ± 8	12.9 ± 3	≤0.003	0.64 ± 2	0.65 ± 4	2.3 ± 19	7.1 ± 3	2.2 ± 27
ASS-1	0.21 ± 13	5.0 ± 27	14.1 ± 3	≤0.003	0.71 ± 2	≤0.02	2.8 ± 19	8.7 ± 3	3.1 ± 43
ASS-2	0.09 ± 25	5.3 ± 25	14.3 ± 3	≤0.002	0.64 ± 2	0.74 ± 3	2.8 ± 27	7.2 ± 4	2.6 ± 57
ASS-3	0.06 ± 27	6.4 ± 21	13.5 ± 4	≤0.003	0.64 ± 3	0.81 ± 4	2.3 ± 23	8.4 ± 3	2.8 ± 35
ASS-4	0.21 ± 13	6.0 ± 22	12.9 ± 3	≤0.003	0.62 ± 2	0.74 ± 4	2.3 ± 22	7.5 ± 2	2.6 ± 37
ASN-1	0.97 ± 6	6.6 ± 20	10.7 ± 3	0.028 ± 19	0.46 ± 3	0.46 ± 5	1.9 ± 23	5.0 ± 31	1.5 ± 28
ASN-2	0.52 ± 8	5.2 ± 25	10.4 ± 3	0.015 ± 21	0.45 ± 2	0.48 ± 4	1.9 ± 13	4.6 ± 5	1.6 ± 46
ASN-3	0.67 ± 7	20.4 ± 8	14.2 ± 3	0.024 ± 31	0.58 ± 2	0.62 ± 4	2.3 ± 21	5.9 ± 4	2.6 ± 19
ASN-4	0.55 ± 10	4.8 ± 27	12.5 ± 2	0.021 ± 30	0.53 ± 2	0.60 ± 3	1.9 ± 20	6.2 ± 2	1.5 ± 56
Mean	1.15	9.4	13.5	0.0008 ^c	0.62	0.68	2.4	7.3	2.1
SDM (%)	133	62	12	69 ^d	15	28	16	20	34

^a See Fig. L-SO-2 for sampling locations.

^b Activity in recovered water.

^c Median value. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

Livermore Site
Soil Monitoring

Table L-SO-3. Positively detected metals^a (in mg/L) in arroyo sediments near the Livermore site, 1990.

Location ^b	Ba	Cd	Co	Total Cr	Cu	Ni	Pb	V	Zn	As	Sb	Hg	Ag	Mo
ALPE-1	5.1	≤0.04	0.45	0.12	≤0.08	1.00	≤0.3	0.47	0.76	0.03	≤0.06	≤0.001	≤0.02	≤0.08
ALPE-2	9.2	≤0.04	0.68	0.11	≤0.08	1.20	≤0.3	0.70	0.10	0.04	0.08	≤0.001	≤0.02	≤0.08
ALPE-3	8.2	≤0.04	0.60	0.06	≤0.08	1.20	≤0.3	0.59	0.07	0.03	≤0.06	≤0.001	≤0.02	≤0.08
ALPE-4	9.2	≤0.04	0.54	0.08	≤0.08	0.87	≤0.3	0.49	0.06	0.03	≤0.06	≤0.001	≤0.02	≤0.08
CDB-1	6.5	≤0.04	0.33	≤0.05	0.11	0.54	≤0.3	0.20	0.20	0.04	≤0.06	≤0.001	0.02	≤0.08
CDB-2	8.4	≤0.04	0.42	≤0.05	0.14	0.63	≤0.3	0.25	0.21	0.03	≤0.06	0.002	0.02	≤0.08
CDB-3	8.0	≤0.04	0.42	≤0.05	0.11	0.66	≤0.3	0.24	0.12	0.04	≤0.06	≤0.001	0.04	≤0.08
CDB-4	6.6	≤0.04	0.33	≤0.05	0.12	0.55	≤0.3	0.22	0.18	0.03	≤0.06	≤0.001	0.04	≤0.08
ALPW-1	9.0	≤0.05	0.40	0.15	0.85	0.63	≤0.2	0.55	1.50	0.06	≤0.20	≤0.001	≤0.05	≤0.20
ALPW-2	7.8	≤0.04	0.44	0.06	0.18	0.84	≤0.3	0.25	0.30	0.08	≤0.06	≤0.001	≤0.02	0.09
ALPW-3	7.3	≤0.04	0.46	≤0.05	0.13	0.81	≤0.3	0.28	0.16	0.03	≤0.06	≤0.001	0.02	0.09
ALPW-4	6.6	0.04	0.28	0.32	3.80	0.51	≤0.3	0.50	1.80	0.08	≤0.06	≤0.001	0.05	≤0.08
ASE-1	4.5	≤0.04	0.24	0.06	0.11	0.32	≤0.3	0.18	0.11	0.04	0.08	≤0.001	≤0.02	≤0.08
ASE-2	5.2	≤0.04	0.11	0.07	0.08	0.21	≤0.3	0.21	0.23	0.05	0.11	≤0.001	≤0.02	≤0.08
ASE-3	3.5	≤0.04	0.19	≤0.05	≤0.08	0.21	≤0.3	0.10	0.18	0.03	≤0.06	0.002	≤0.02	≤0.08
ASE-4	5.1	≤0.04	0.23	0.06	0.08	0.33	≤0.3	0.24	0.13	0.05	≤0.06	≤0.001	≤0.02	≤0.08
ASE-5	9.2	≤0.04	0.29	0.07	0.11	0.39	≤0.3	0.20	0.20	0.03	≤0.06	≤0.001	≤0.02	≤0.08
ASE-6	8.9	≤0.04	0.21	0.06	≤0.08	0.26	0.3	0.15	0.22	0.04	≤0.06	≤0.001	≤0.02	≤0.08
ASE-7	5.5	≤0.04	0.24	≤0.05	≤0.08	0.32	≤0.3	0.15	0.33	0.03	≤0.06	≤0.001	≤0.02	≤0.08
ASS-1	11.0	≤0.04	0.32	0.23	0.32	0.34	≤0.3	0.25	0.14	0.08	0.15	≤0.001	≤0.02	0.08
ASS-2	12.0	0.10	0.45	0.37	≤0.08	0.58	≤0.3	0.82	0.26	0.08	0.14	≤0.001	≤0.02	≤0.08
ASS-3	8.0	≤0.04	0.32	0.13	0.36	0.23	≤0.3	0.37	0.12	0.04	0.10	≤0.001	≤0.02	≤0.08
ASS-4	5.2	0.04	0.23	0.16	0.23	0.22	0.3	0.18	0.37	0.10	0.06	≤0.001	≤0.02	≤0.08
ASN-1	4.2	≤0.04	0.21	0.19	0.56	0.23	3.9	0.16	1.30	0.04	≤0.06	≤0.001	≤0.02	≤0.08
ASN-2	9.1	≤0.04	0.31	0.18	0.25	0.38	0.4	0.26	1.30	0.04	≤0.06	0.002	≤0.02	≤0.08
ASN-3	6.0	≤0.04	0.30	0.18	0.30	0.30	≤0.3	0.16	1.50	0.03	≤0.06	≤0.001	≤0.02	≤0.08
ASN-4	7.8	≤0.04	0.44	≤0.05	0.16	0.29	0.4	0.27	0.28	0.04	≤0.06	0.002	≤0.02	≤0.08
Mean	7.3	0.04^c	0.35	0.07^c	0.11^c	0.52	0.3^c	0.31	0.45	0.05	0.06^c	0.001^c	0.02^c	0.08^c
SDM (%)	29	0^d	38	0^d	0^d	57	0^d	59	117	44	0^d	0^d	0^d	0^d

^a Other metals for which analysis was performed include beryllium, thallium, and selenium. However, all values for these metal analyses were below detection limits.

^b See Fig. L-SO-2 for sampling locations.

^c Median value. See Quality Assurance chapter.

^d Median absolute deviation, MAD (%). See Quality Assurance chapter.

Table L-SO-4. Positively detected organic compounds (mg/kg) in arroyo sediments near the Livermore site, 1990.

Location ^a	Benzene	Chloro- form	1,1- DCA ^b	cis-1,2- DCE ^c	1,2- DCE ^d	Freon 113	Methylene Chloride	Tetrachloro- ethylene	1,1,1- TCA ^e	TCE ^f	Toluene	Trichloro- fluoro- methane	Total Xylenes
ALPE-1	0.015	≤0.0002	≤0.0002	0.0003	0.0003	≤0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	0.068	≤0.0002	≤0.002
ALPE-2	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.025	≤0.0002	≤0.002
ALPE-3	0.001	≤0.0002	≤0.0002	0.0002	0.0002	≤0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	0.056	≤0.0002	≤0.002
ALPE-4	≤0.001	≤0.0002	≤0.0002	0.0007	0.0007	≤0.0002	0.0003	≤0.0002	≤0.0002	≤0.0002	0.140	≤0.0002	≤0.002
ALPW-1	0.007	0.0003	≤0.0002	0.0004	0.0004	0.0006	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.058	≤0.0002	0.002
ALPW-2	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0003	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.003	≤0.0002	≤0.002
ALPW-3	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.011	≤0.0002	≤0.002
ALPW-4	0.002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.049	≤0.0002	≤0.001
ASE-1	0.002	≤0.0002	≤0.0002	0.0003	0.0003	≤0.0002	0.0003	≤0.0002	≤0.0002	≤0.0002	0.110	≤0.0002	≤0.002
ASE-2	0.002	≤0.0002	≤0.0002	0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.041	≤0.0002	≤0.002
ASE-3	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0004	≤0.0002	≤0.0002	≤0.0002	0.066	0.0004	≤0.002
ASE-4	0.003	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0004	≤0.0002	≤0.0002	≤0.0002	0.099	≤0.0002	≤0.002
ASN-1	0.006	0.0010	0.0002	≤0.0002	≤0.0002	0.0016	0.0002	0.0025	0.0009	0.0004	0.052	≤0.0002	≤0.002
ASN-2	0.018	0.0012	≤0.0002	≤0.0002	≤0.0002	0.0002	0.0003	0.0040	0.0013	0.0005	0.120	≤0.0002	≤0.002
ASN-3	0.002	0.0005	≤0.0002	0.0008	0.0008	≤0.0002	0.0002	0.0009	0.0002	≤0.0002	0.066	≤0.0002	≤0.002
ASN-4	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	0.017	≤0.0002	≤0.002
ASS-1	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	0.015	≤0.0002	≤0.002
ASS-2	≤0.001	≤0.0002	0.0004	≤0.0002	0.0004	≤0.0002	0.0004	≤0.0002	≤0.0002	≤0.0002	0.034	≤0.0002	≤0.002
ASS-3	≤0.001	0.0003	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0002	≤0.0002	0.0002	≤0.0002	0.032	≤0.0002	≤0.002
ASS-4	≤0.001	0.0014	0.0013	0.0009	0.0009	0.0003	0.0003	0.0003	0.0010	0.0007	0.073	≤0.0002	0.007
CDB-1	≤0.001	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.008	≤0.0002	≤0.002
CDB-2	≤0.001	0.0004	≤0.0002	≤0.0002	≤0.0002	0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.007	≤0.0002	≤0.002
CDB-3	0.001	0.0005	≤0.0002	≤0.0002	≤0.0002	0.0005	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.007	≤0.0002	≤0.002
CDB-4	≤0.001	0.0003	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	≤0.0002	0.007	≤0.0002	2
Median	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.049g	0.0002	2
MAD(%)	0	0	0	0	0	0	0	0	0	0	80h	0	

^a See Fig. L-SO-2 for sampling locations.

^b 1,1-Dichloroethane.

^c cis-1,2-Dichloroethylene.

^d 1,2-Dichloroethylene.

^e 1,1,1-Trichloroethane.

^f Trichloroethylene.

^g Mean value. See Quality Assurance chapter.

^h Standard Deviation (%). See Quality Assurance chapter.

Introduction

Sampling and analysis of native vegetation can provide information about the presence of radionuclides in the environment. Native vegetation is specifically mentioned by DOE in its monitoring regulations as a medium that is appropriate for sampling and analysis (U.S. Department of Energy 1988d). The requirements also call for pathway analyses, and specifically mention analyses of milk and other representative samples of the pathway-significant agricultural products grown within 16 km of the site. Lawrence Livermore National Laboratory (LLNL) collects and analyzes samples of vegetation, honey, goat's milk, and wine, and then calculates any potential human dose from these substances.

Methods

Vegetation. At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley. **Figure L-V-1** shows the 1990 vegetation-sampling locations in the

Livermore Valley. The sampling locations are the same as those sampled in 1988 and 1989, but the locations were renamed with new sample location designators during 1990 (see Quality Assurance chapter).

Figure L-V-1. Vegetation sampling locations, Livermore Valley, 1990.

Livermore Site
Vegetation and
Foodstuff
Monitoring

The use of constant sampling locations allows better trending of the data and closer monitoring of areas of concern. Sampling activities follow standardized written procedures (Brekke et al. 1988). Grass samples are cut at ground level, and any soil or dead tissue is discarded. The bulk volume of the samples is between 0.5 and 1 L (approximately 1 kg). Each sample is collected, double-bagged in plastic, labeled according to sample type and location, and frozen in a dry-ice chest to minimize water loss to the bag's surface. The samples later are transferred to a freezer in the laboratory. A label is affixed to the bag, and the sample is identified by a sample identification code. This identifier, which includes the sampling location designator, is entered in a logbook, along with all pertinent sampling information. The code identifies the sample throughout all sampling and laboratory activities and data reporting. For clarity, only sampling location designators appear in the data tables of this report. Two subsamples of vegetation are collected each quarter at each sampling location. One subsample is for analysis and the other is preserved in the laboratory freezer, in case the first sample is lost during analysis, or in case the analysis result is in question and reanalysis of the sample is necessary for data verification.

Water from the vegetation samples is collected using freeze-drying techniques. The tritium content of the recovered water is determined by liquid-scintillation counting.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, a total of four subsamples of vegetation are collected, using identical methodology from a sampling location. Two of the bags serve as the official sample. The other two bags are considered the duplicate sample. Duplicate samples are preserved, stored, processed, and analyzed with methods identical to those employed for all other samples.

Wine. As in past years, three types of retail wine samples were collected and

analyzed: wines produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California (outside the Livermore Valley), and wines produced from grapes grown in Europe. California and Europe were divided into 10 and 12 wine-producing regions, respectively. Eight estate-grown and -bottled wines that were produced in seven of the California regions and ten estate-grown and -bottled wines that were produced in nine of the European regions were purchased as representative samples of these regions. Ten estate-grown and -bottled Livermore wines completed the sampling for 1990. Approximately 10% of the total complement of wines were sampled in duplicate to comply with quality assurance protocols (Holland 1987).

This year's sampling plan continued the practice of determining the tritium content of wines purchased from retail outlets. To provide data on the potential tritium exposure from wine consumption, the wines were selected based on general availability. Thus, the wines were selected from different vintages (i.e., from wines produced in different years). Consequently, the tritium values are not indicative of how the year's operations at the Livermore site affected grapes and wines produced in 1990. However, wine sample data can be decay-corrected to its initial tritium concentrations, given the number of months that have elapsed between production and analysis. The decay-corrected data can be used to determine trends and may help determine the impact of vintage-year operations.

The wine samples are purchased at local retailers and are submitted unopened to the Nuclear Chemistry Division for tritium analyses. The wine samples are oxidized in a Peterson furnace, gas-converted, and analyzed for tritium content by gas-proportional counting. The analysis methods are highly sensitive, and only such techniques could determine differences in the tritium content. If less-sensitive methods, such as those employed by commercial analytical laboratories, were used, the tritium content

of all samples would be near or below detection limits and no differences would be apparent.

Honey. Samples of honey available for purchase in 1990 from a variety of flower sources both inside and outside the Livermore Valley also were analyzed for tritium content. Because honey purchased in 1990 may not have been produced during 1990, the tritium values are not indicative of the year's tritium emissions. However, these values do serve as an index of potential exposure. Following oxidation of the samples in a Parr oxygen bomb, the tritium content of the water produced is determined by gas-proportional counting. Honey-sample submittals complied with quality assurance protocols (Holland 1987).

Milk. During 1990, goat-milk samples were obtained monthly from four farms within about 5 km (3 mi) of the Livermore site. Production from the farms was variable, so samples were obtained as available. (See the Quality Assurance chapter for a discussion of deviations from the sampling program.) Samples also were obtained from two non-Livermore Valley locations in California for determination of background concentrations. As in past years, cartoned milk, purchased in a store, also was analyzed for comparative purposes.

A portion of each milk sample was freeze-dried. Then the collected water was analyzed for tritium activity by liquid-scintillation counting. Another portion of each milk sample was preserved with formalin, and was analyzed for gamma-emitting isotopes by counting a 1-L aliquot in a Marinelli beaker using Ge(Li) spectrometers. At least one milk source was sampled in duplicate each month to comply with quality assurance protocols (Holland 1987).

Results

Vegetation. Table L-V-1 shows tritium data for vegetation collected in the Livermore Valley. California experienced its fifth consecutive year of drought during 1990, and native vegetation was affected by reduced precipitation. Therefore, samples were unavailable from three locations

during the third quarter and one location during the fourth quarter.

In general, the 1990 tritium concentrations in vegetation are less than those reported in 1989, and are within the range of values normally reported for vegetation in the area. One sample, however, exhibited a notably elevated tritium concentration. The value from the fourth quarter sampling at Location RAIL [16,100 pCi/L (596 Bq/L)] was among the highest values ever reported for that location. It also was well above any other values detected from all locations in the Livermore Valley during 1990.

Duplicate analyses of the sample using the second subsample of collected vegetation stored in the laboratory freezer corroborated the value. However, a resampling of vegetation from the area produced values that were more representative of the values found there during previous quarters and year-round during 1990 throughout the Livermore Valley.

Contamination of the original sample is suspected, but cannot be proven. For this reason, both values detected at Location RAIL in the fourth quarter are presented in Table L-V-1. Mean levels and effective dose data are calculated both with and without the use of the suspect data.

An analysis of variance (ANOVA) indicated that there are no statistically significant differences in the tritium content of the vegetation among any of the sampling locations, with the exception of Location AQUE. This location produced values that were slightly greater than those from other locations.

Wine. The results from the 1990 wine tritium analyses are shown in Table L-V-2. The sample numbers shown in the table were assigned randomly to wine samples from each region, and are not related to sample numbers used in previous years. In general, the tritium concentrations were similar to those reported in previous years; tritium concentrations in wines from all areas remained low. The data for the 1990 sampling year were analyzed using ANOVA. The statistical analysis showed that although concentrations were low, the mean of the Livermore wines

Livermore Site Vegetation and Foodstuff Monitoring

sampled was statistically greater than both the European and California wines sampled. The mean tritium content of the European wines was also statistically greater than that of the California wines. Multiple comparison tests indicated that the mean levels of the 1990 sampling year data from California and Europe were not statistically different than those reported for the 1989 sampling year. However, the 1990 values reported from Livermore wines were statistically lower than those reported in 1989. **Figure L-V-2** shows the results of the wine analyses by sampling year since monitoring began.

Regression analyses and ANOVA of the wine data (when decay-corrected and grouped by vintage year) showed no statistically significant trends in the tritium content of Livermore or California wines. The tritium content of vintage European wines has decreased significantly since monitoring began, and also has statistically decreased since 1980. However, during the past ten vintage years, European and Livermore wines have exhibited comparable

tritium concentrations (no statistical differences), with Livermore wines having higher concentrations some years, and European wines having higher concentrations in other years (**Figure L-V-3**). Vintage wines from both Livermore and Europe consistently have contained statistically higher tritium concentrations than vintage wines from California during the same period.

Honey. Table L-V-3 shows tritium data for honey collected from producers in the Livermore Valley and from other producers in California. Although the mean tritium concentration of Livermore Valley honey is greater than that of honey from other areas of California, the difference is not statistically significant, as determined by ANOVA. The single high value of note from the Livermore Valley (793 pCi/L; 29 Bq/L) was corroborated by a replicated analysis. Similar values from both Livermore and other areas of California have been reported in past years, and the large variance of honey tritium values is not unusual. (For example, see the LLNL *Annual Environmental Reports* for 1983 and 1988.)

Analysis of variance also indicated that the tritium concentrations in Livermore honey have not changed significantly during the past three years. Statistical analyses also indicated that 1990 California honey tritium values were not significantly different from those reported for 1989. **Figure L-V-4** shows the mean values for Livermore Valley honey collected from 1979 through 1990, and other California honeys collected from 1980 through 1990. The graph shows that the tritium content of honey fluctuates significantly from year to year, and that the mean Livermore Valley concentration is sometimes higher and sometimes lower than that of other California honey. Large variance in both Livermore Valley and California honey tritium concentrations are often seen in the sample data, as evidenced by the large standard-error bars for many of the points.

There are no health or environmental standards for radionuclides in honey. However, none of the tritium values observed

Figure L-V-2. Tritium in retail wines, plotted by sampling year (error bars are ± 1 standard error).

would be of health concern even if the honey were consumed in the same quantities as drinking water, for which safety standards do exist (the California drinking-water standard is 20,000 pCi/L; 741 Bq/L). The highest tritium concentration detected in honey (793 pCi/L; 29 Bq/L) represents 4% of this standard.

Milk. The activities of ^{137}Cs (cesium-137, a fallout product), ^{40}K (potassium-40, a naturally occurring nuclide), and tritium in goat-milk samples collected during 1990 are shown in **Tables L-V-4** through **L-V-6**. No other nuclides were present at detectable levels; ^{137}Cs and ^{40}K were detected at background levels. Tritium levels in milk are comparable to those reported in previous years. The highest concentration of tritium in milk produced in the Livermore Valley was 378 pCi/L (14 Bq/L). Higher concentrations [462 and 463 pCi/L (both 17 Bq/L)] were measured in samples collected outside the Livermore Valley. Concentrations generally were higher at the end of the year for samples from all locations, but are within the range of values reported in previous years. An analysis of variance showed that tritium values for Livermore milk, as a whole, are not significantly different (95% confidence) than background concentrations.

Dose calculations are based on a milk intake of 310 L/y, dose factors provided by DOE (U.S. Department of Energy 1988b), and on models described in **Appendix B**. Because ^{40}K is not an effluent at LLNL and because values from all milk samples were similar, individual doses were not calculated for each sampling location. However, regardless of sampling location, the annual dose received from milk consumption due to naturally occurring ^{40}K may be as high as 10 mrem (0.1 mSv). Potassium-40 is the major ingestion-pathway contributor to natural background dose (see Environmental Radiological Program Summary chapter, **Table L-RS-4**). On the other hand, the maximum dose resulting from tritium (**Table L-V-4**) that could have been received from ingestion of milk during 1990 was 4.6×10^{-3} mrem/y (4.6×10^{-5} mSv/y).

Figure L-V-3. Mean tritium in retail wines, 1980–1990, decay-corrected and plotted by vintage year (error bars are ± 1 standard error). No 1989 Livermore wines have as yet been analyzed.

Figure L-V-4. Tritium concentration in honey (error bars are ± 1 standard error).

Environmental Impact

In general, LLNL impacts on vegetation in the Livermore Valley in 1990 were minimal. Tritium levels detected in the Livermore Valley vegetation were generally comparable to those observed in previous years. The effective dose equivalents shown in **Table L-V-1** were derived using the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b) and the dose-pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). Based on the conservative assumption that an adult's diet includes vegetables with the highest observed average tritium concentration (with the sample suspected of contamination included in the calculation of the average), and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is approximately 6.6×10^{-2} mrem/y (6.6×10^{-4} mSv/y).

The results of this year's monitoring of tritium in wine, as in past years, indicate that all the tritium concentrations detected were low and at or near the concentrations measured in tap water (**Table L-W-5**). There are no health standards for radio-nuclides in wine. However, all the wine tritium levels were far below drinking water standards. In fact, even the highest detected value [300 pCi/L (11 Bq/L)] was only 1.5% of the California drinking water standard [20,000 pCi/L (741 Bq/L)]. Doses from wine consumption can be calculated according to methods for water ingestion, which are detailed in **Appendix B**.

The corresponding annual dose of the highest detected tritium value [300 pCi/L (11 Bq/L)], based on the very conservative assumption that wine is consumed in the same quantities as water (730 L/year, or

2 L/day), is 0.014 mrem (1.4×10^{-4} mSv). Using a more realistic wine consumption factor (52 L/year, or 1 L/week of wine from a single area), and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.00058 mrem (5.8×10^{-6} mSv), from European wine would be 0.00036 mrem (3.6×10^{-6} mSv), and from California wine would be 0.00013 mrem (1.3×10^{-6} mSv). Compared with an annual background dose of 300 mrem (3 mSv) (including radon) and a 10-mrem (0.1-mSv) dose from a typical chest x-ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Therefore, although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

Milk produced in the Livermore Valley did not contain tritium in any quantities greater than are contained in milk produced in other areas of California. Associated doses, like those for wine, were negligible, and were minute in comparison with the doses associated with naturally occurring ^{40}K in milk. Other radionuclides in milk could not be detected, or were present at background concentrations.

Honey produced in the Livermore Valley did not contain tritium in statistically different quantities than that contained in honey from other areas of California, and concentrations have not changed significantly over the past three years. As in past years, the concentration of tritium measured in both Livermore Valley and California honeys was highly variable. Consequently, the environmental impact could not be measured and is considered minimal.

Table L-V-1. Tritium in vegetation—Livermore Valley, 1990.

	Sampling location ^a							
	PATT	ZON7	I580	AQUE	RAIL	VASW	TESW	FCC
	[pCi/L of moisture content $\pm 2\sigma$ (%)]							
First quarter	236 $\pm$ 52	729 $\pm$ 18	352 $\pm$ 36	1,830 $\pm$ 8	645 $\pm$ 20	465 $\pm$ 28	1,640 $\pm$ 9	156 $\pm$ 79
Second quarter	151 $\pm$ 79	1,120 $\pm$ 12	327 $\pm$ 37	1,820 $\pm$ 8	771 $\pm$ 17	$\leq$ 790	532 $\pm$ 23	157 $\pm$ 75
Third quarter	— ^b	349 $\pm$ 37	— ^b	— ^b	419 $\pm$ 30	243 $\pm$ 51	205 $\pm$ 60	298 $\pm$ 42
Fourth quarter	280 $\pm$ 46	975 $\pm$ 14	— ^b	426 $\pm$ 30	16,100 ^c $\pm$ 2	408 $\pm$ 33	214 $\pm$ 61	978 $\pm$ 14
					571 $\pm$ 23			
Mean	222	793	340	1,359	602 (3,701) ^c	477	648	397
SDM (%)	29	43	5	59	24 (187) ^c	48	105	99
Effective dose (mrem) ^d	4.0×10^{-3}	1.4×10^{-2}	6.0×10^{-3}	2.4×10^{-2}	1.1×10^{-2} (6.6×10^{-2})	8.5×10^{-3}	1.2×10^{-2}	7.1×10^{-3}

^a See Fig. L-V-1 for sampling locations.

^b No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^c Sample contamination suspected. Summary data with this data point included in the calculations are presented in parentheses.

^d This dose represents the total effective dose from the forage-cow-milk pathway. See Appendix B.

Table L-V-2. Tritium in retail wine, 1990.

Sample	Area of production		
	Livermore Valley	California (Non-Livermore Valley) [pCi/L $\pm 2\sigma$ (%)]	Europe
1	102 $\pm$ 25	$\leq$ 52	149 $\pm$ 38
2	106 $\pm$ 20	23 $\pm$ 78	148 $\pm$ 35
3	93 $\pm$ 17	$\leq$ 17	137 $\pm$ 45
4	300 $\pm$ 9	32 $\pm$ 60	85 $\pm$ 53
5	208 $\pm$ 12	21 $\pm$ 87	111 $\pm$ 43
6	257 $\pm$ 13	$\leq$ 45	87 $\pm$ 28
7	179 $\pm$ 13	128 $\pm$ 52	136 $\pm$ 27
8	238 $\pm$ 10	$\leq$ 51	77 $\pm$ 58
9	116 $\pm$ 20		106 $\pm$ 35
10	173 $\pm$ 12		72 $\pm$ 28
Mean	177	39 ^a	111
SDM (%)	41	38 ^b	27

^a Median value. See Quality Assurance chapter.

^b Median absolute deviation, MAD (%). See Quality Assurance chapter.

Table L-V-3. Tritium in honey, 1990.

Sample ^a	Sampling location [pCi/L (in water recovered $\pm 2\sigma$ (%))]	
	Livermore	California
1	126 $\pm$ 19	78 $\pm$ 26
2	128 $\pm$ 18	126 $\pm$ 18
3	238 $\pm$ 11	107 $\pm$ 20
4	793 $\pm$ 6	187 $\pm$ 14
5		74 $\pm$ 27
Mean	321	114
SDM (%)	99	40

^a Four samples were obtained from the Livermore Valley and five samples were obtained from other areas of California.

Table L-V-4. Tritium in milk, 1990.

	Sampling location						
	WRD ^a	MZF ^a	LUP ^a	COOL ^a	MOD ^b	TUR ^b	CART ^c
	[pCi/L $\pm 2\sigma$ (%)]						
Jan.	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d
Feb.	— ^d	238 $\pm$ 54	$\leq$ 123	— ^d	— ^d	— ^d	$\leq$ 127
Mar.	— ^d	189 $\pm$ 63	$\leq$ 117	— ^d	— ^d	— ^d	242 $\pm$ 50
Apr.	— ^d	$\leq$ 130	$\leq$ 128	— ^d	— ^d	— ^d	317 $\pm$ 43
May	$\leq$ 125	$\leq$ 126	272 $\pm$ 47	— ^d	— ^d	— ^d	$\leq$ 123
June	— ^d	$\leq$ 127	$\leq$ 125	— ^d	$\leq$ 132	— ^d	$\leq$ 124
July	333 $\pm$ 43	165 $\pm$ 75	$\leq$ 122	— ^d	$\leq$ 122	— ^d	$\leq$ 136
Aug.	$\leq$ 136	$\leq$ 134	$\leq$ 134	— ^d	$\leq$ 135	— ^d	$\leq$ 135
Sept.	336 $\pm$ 39	$\leq$ 128	355 $\pm$ 37	— ^d	193 $\pm$ 67	$\leq$ 127	328 $\pm$ 40
Oct.	$\leq$ 125	128 $\pm$ 98	154 $\pm$ 82	128 $\pm$ 97	160 $\pm$ 78	166 $\pm$ 76	$\leq$ 123
Nov.	346 $\pm$ 39	— ^d	378 $\pm$ 36	323 $\pm$ 42	462 $\pm$ 29	463 $\pm$ 29	269 $\pm$ 50
Dec.	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d
Median	235	130	131	226^e	148	166	136
MAD^f(%)	45	3	9	61^g	14	23	10
Effective dose (mrem)	4.6 $\times 10^{-3}$	2.5 $\times 10^{-3}$	2.6 $\times 10^{-3}$	4.4 $\times 10^{-3}$	2.9 $\times 10^{-3}$	3.2 $\times 10^{-3}$	2.6 $\times 10^{-3}$

^a Livermore Valley sampling location.

^b California (non-Livermore Valley) sampling location.

^c Sample purchased in carton from store.

^d No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^e Mean value. See Quality Assurance chapter.

^f Median absolute deviation. See Quality Assurance chapter.

^g SDM (%). See Quality Assurance chapter.

Table L-V-5. Potassium-40^a in milk, 1990.

	Sampling location						
	WRD ^b	MZF ^b	LUP ^b	COOL ^b	MOD ^c	TUR ^c	CART ^d
	[pCi/L $\pm$ 2 σ (%)]						
Jan.	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e
Feb.	— ^e	1,608 $\pm$ 3	1,686 $\pm$ 4	— ^e	— ^e	— ^e	1,449 $\pm$ 2
Mar.	— ^e	1,606 $\pm$ 3	1,527 $\pm$ 3	— ^e	— ^e	— ^e	1,472 $\pm$ 4
Apr.	— ^e	1,635 $\pm$ 3	1,435 $\pm$ 2	— ^e	— ^e	— ^e	1,696 $\pm$ 3
May	1,582 $\pm$ 3	1,427 $\pm$ 2	1,727 $\pm$ 3	— ^e	— ^e	— ^e	1,519 $\pm$ 3
June	— ^e	1,804 $\pm$ 3	1,591 $\pm$ 3	— ^e	1,835 $\pm$ 4	— ^e	1,565 $\pm$ 2
July	1,797 $\pm$ 3	1,823 $\pm$ 3	1,664 $\pm$ 2	— ^e	1,802 $\pm$ 3	— ^e	1,739 $\pm$ 2
Aug.	1,855 $\pm$ 3	1,920 $\pm$ 3	1,952 $\pm$ 3	— ^e	1,922 $\pm$ 3	— ^e	1,872 $\pm$ 3
Sept.	1,732 $\pm$ 3	1,758 $\pm$ 3	1,568 $\pm$ 3	— ^e	1,954 $\pm$ 3	1,730 $\pm$ 2	1,899 $\pm$ 3
Oct.	1,726 $\pm$ 3	1,794 $\pm$ 2	1,279 $\pm$ 3	1,705 $\pm$ 3	1,818 $\pm$ 3	1,861 $\pm$ 3	1,831 $\pm$ 3
Nov.	1,175 $\pm$ 3	— ^e	1,711 $\pm$ 3	1,841 $\pm$ 3	1,601 $\pm$ 3	1,698 $\pm$ 3	1,850 $\pm$ 3
Dec.	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e	— ^e
Mean	1,645	1,708	1,614	1,773	1,822	1,763	1,689
SDM (%)	15	9	11	5	7	5	10

^a Potassium-40 is a naturally occurring radionuclide and is not an emission from LLNL.

^b Livermore Valley sampling location.

^c California (non-Livermore Valley) sampling location.

^d Sample purchased in carton from store.

^e No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

Table L-V-6. Cesium-137 in milk, 1990.

	Sampling location						
	WRD ^a	MZF ^a	LUP ^a	COOL ^a [pCi/L $\pm$ 2 σ (%)]	MOD ^b	TUR ^b	CART ^c
Jan.	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d
Feb.	— ^d	≤ 0.397	≤ 0.390	— ^d	— ^d	— ^d	≤ 0.140
Mar.	— ^d	≤ 0.145	0.938 ± 71	— ^d	— ^d	— ^d	≤ 0.130
Apr.	— ^d	≤ 0.151	≤ 0.607	— ^d	— ^d	— ^d	0.622 ± 99
May	≤ 0.151	≤ 0.138	≤ 0.036	— ^d	— ^d	— ^d	0.985 ± 89
June	— ^d	≤ 1.620	3.358 ± 70	— ^d	≤ 0.171	— ^d	≤ 0.950
July	≤ 0.180	≤ 0.700	1.429 ± 73	— ^d	≤ 0.172	— ^d	≤ 0.143
Aug.	≤ 0.812	≤ 0.506	≤ 0.725	— ^d	≤ 0.384	— ^d	≤ 0.160
Sept.	≤ 0.316	≤ 0.150	≤ 0.151	— ^d	≤ 0.458	≤ 0.143	≤ 0.161
Oct.	≤ 0.150	≤ 0.140	≤ 0.139	≤ 0.887	1.361 ± 88	≤ 0.771	≤ 0.458
Nov.	≤ 0.130	— ^d	≤ 0.880	≤ 0.833	≤ 0.377	≤ 1.180	≤ 0.700
Dec.	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d	— ^d
Median	0.17	0.15	0.67	0.86	0.38	0.77	0.31
MAD (%)^e	18	9	60	3	37	53	55

^a Livermore Valley sampling location.

^b California (non-Livermore Valley) sampling location.

^c Sample purchased in carton from store.

^d No data. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

Introduction

Penetrating radiation, which cannot be measured by collection of material on filters (nor chemically trapped), is measured using radiation dosimeters. The dosimeters provide a measure of the total amount of penetrating radiation—both background radiation and any radiation that has man-made origins—at a particular location. Penetrating radiation primarily includes gamma rays, but also includes neutron radiation.

Methods

External doses from gamma radiation are measured at 22 Livermore-site-perimeter locations (**Figure L-R-1**) and 55 off-site locations (**Figure L-R-2**). Thermoluminescence dosimeters (TLDs) are used to measure external gamma radiation doses. The dosimeters are mounted in the field on existing structures (such as fence lines) at approximately 1 m above ground level. The dosimeters are exchanged, data are analyzed, and the dose rates are calculated quarterly.

The dosimeters contain three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Each dosimeter is heat-sealed in a 8.9 cm $\times$ 5.7 cm (3-1/2 in $\times$ 2-1/4 in), 4.5-mil-thick foil pouch for protection against light and moisture. The TLDs measure gamma radiation exposure from all sources. These include natural sources, fallout from past nuclear weapons testing, and any contribution from Lawrence Livermore National Laboratory (LLNL). Off-site dosimeters are located in areas surrounding the Livermore site and in nearby residential areas. These areas are considered background, and they are used for comparison with the perimeter dosimeters. When a TLD is missing, the annual dose is calculated as four times the average quarterly dose as determined from available data.

Figure L-R-1. Locations of Livermore-site gamma and neutron dosimeters, 1990.

Livermore Site
Environmental
Radiation
Monitoring

The TLDs measure environmental gamma radiation exposure in milliroentgens (mrem). The measured exposure is converted to dose by calibrating the dosimeters to read out in absorbed dose and then applying a quality factor for a beta/gamma radiation field. The resulting dose equivalents (mrem) are compared to radiation protection standards. The dose at the Livermore-site boundary also is compared to background measurements to determine the contribution, if any, from LLNL operations.

Environmental neutron dose measurements using ^{235}U track-etch detectors also are made at eight locations on the Livermore-site perimeter. A detailed description of the detector and the spark-counting procedure may be found in Fisher (1976). Neutron-monitoring locations are shown in **Figure L-R-1**.

Results

Table L-R-1 shows the quarterly and annual TLD gamma radiation dose equivalents for perimeter locations, and **Table L-R-2** presents data for off-site locations. The average annual dose equivalent from external exposure at the LLNL site perimeter, 65.0 mrem (0.65 mSv), is statistically the same as the background external dose measured in the Livermore Valley, 65.1 mrem (0.651 mSv), as determined by analysis of variance.

Figure L-R-3 presents the 1990 distribution of environmental gamma doses measured at the 55 off-site locations. The annual total dose is almost identical to that in 1987, 64 mrem (0.64 mSv); 1988, 63 mrem (0.63 mSv); and 1989, 63 mrem (0.63 mSv).

Table L-R-3 presents the data for neutron monitoring at the Livermore-site perimeter.

Figure L-R-2. Locations of Livermore Valley gamma dosimeters, 1990.

The annual average neutron radiation dose at the Livermore-site perimeter for 1990 is 4.6 mrem (0.046 mSv), similar to the values in 1987, 5.0 mrem (0.05 mSv); 1988, 4.2 mrem (0.042 mSv); and 1989, 5.3 mrem (0.053 mSv). The neutron doses measured at the site boundary are consistent with those expected from natural background radiation.

Environmental Impact

Based on past measurements (Lindeken et al. 1973), environmental terrestrial exposure rates in the Livermore Valley vary from 30 to 60 mrem/y (0.3 to 0.6 mSv/y). Cosmic radiation is about 35 mrem/y (0.35 mSv/y) [calculated from local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966)]. This combination results in a total typical exposure rate of 65 to 95 mrem/y (0.65 to 0.95 mSv/y). Exposures measured at the LLNL perimeter fall within these predicted values and are identical to the off-site doses, which are considered natural background. This indicates that there is no contribution to the external dose at or beyond the Livermore-site fence line from LLNL operations.

Figure L-R-3. Off-site gamma radiation background dose frequency distribution, Livermore, 1990.

Table L-R-1. Environmental radiation measurements (TLD)—Livermore-site perimeter, 1990.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	
Location ^a	(mrem)				Annual Total
1	17	17	19	19	71
2	15	16	16	16	63
3	17	17	17	18	69
4	17	18	17	18	71
5	16	18	17	19	72
6	17	17	17	18	69
7	17	17	16	18	68
8	17	17	17	18	69
9	16	18	17	18	67
10	15	16	15	17	63
11	13	13	12	13	52
12	14	15	13	15	57
13	14	14	14	14	56
42	15	16	16	17	64
47	16	17	16	17	65
48	15	16	16	17	64
49	15	16	16	17	64
50	14	15	15	16	60
52	15	17	16	18	66
53	16	17	16	17	65
54	15	17	16	17	64
56	15	16	15	17	62
Mean	15.5	16.5	16.0	17.1	65.0
SDM (%)	7.6	7.4	10.0	8.2	7.8

^a See Fig. L-R-1 for locations.

Table L-R-2. Environmental radiation measurements (TLD)—Livermore Valley, 1990.

Jan.-Mar. Apr.-June July-Sept. Oct.-Dec.						Annual
Location ^a	(mrem)					Total
14	14	— ^b	15	16	60	
15	17	— ^b	14	16	63	
16	16	— ^b	17	19	71	
17	15	16	17	16	66	
18	15	17	15	16	63	
19	15	15	15	16	61	
20	15	15	15	17	62	
21	14	14	14	15	58	
22	17	17	17	18	69	
23	16	17	16	18	67	
24	16	17	17	18	68	
25	17	17	16	18	68	
26	16	16	16	17	65	
27	17	20	18	19	74	
28	17	18	18	19	73	
29	16	18	17	19	70	
30	16	17	16	17	67	
31	15	16	15	17	63	
32	15	16	16	17	64	
33	16	17	16	17	66	
34	17	17	17	18	70	
35	15	16	17	16	66	
36	16	60 ^c	17	18	111 ^c	
37	— ^b	16	15	— ^b	64	
38	17	17	17	19	70	
39	15	18	17	19	69	
40	16	17	16	— ^b	65	
41	16	17	15	17	65	
43	15	17	16	18	66	

Jan.-Mar. Apr.-June July-Sept. Oct.-Dec.						Annual
Location ^a	(mrem)					Total
44	— ^b	17	17	18	67	
45	14	15	14	16	59	
46	15	15	15	16	62	
51	16	16	16	17	65	
55	15	16	15	17	63	
57	16	17	17	19	70	
58	15	16	16	18	66	
59	15	16	16	18	66	
60	15	18	17	17	67	
61	13	— ^b	14	15	56	
62	14	15	14	15	58	
63	16	17	16	18	68	
64	16	17	16	17	66	
65	16	17	16	17	66	
66	16	17	18	17	68	
67	16	17	16	17	66	
68	15	17	16	16	64	
69	14	15	14	16	59	
70	15	17	16	17	65	
71	17	— ^b	— ^b	21	76	
72	18	19	18	19	74	
73	16	17	16	17	67	
74	14	15	15	16	61	
75	13	14	13	14	54	
76	11	12	11	12	46	
77	19	15	14	15	63	
Mean	15.6	16.5 (17.3) ^c	15.9	17.2	65.1 (65.9) ^c	
SDM (%)	8.4	8.4 (36.4) ^c	9.0	8.7	7.9 (12.2) ^c	

^a See Fig. L-R-2 for locations.

^b No data available; dosimeter was missing. See Quality Assurance chapter.

^c Outlier (see Quality Assurance chapter) used in average as designated by parenthesis.

Table L-R-3. Environmental neutron monitoring—Livermore-site perimeter, 1990.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual Total
Location ^a	(mrem)				
1	0.9	1.2	1.5	0.9	4.5
2	1.3	0.8	1.2	0.6	3.9
3	1.2	0.6	0.8	1.2	3.8
4	1.4	— ^b	1.0	1.6	5.3 ^c
5	1.0	1.2	1.0	1.1	4.3
6	1.0	0.7	1.3	1.5	4.5
7	1.0	1.3	1.3	2.0	5.6
8	1.1	1.2	1.2	1.6	5.1
Mean	1.1	1.0	1.2	1.3	4.6
SDM (%)	16	29	19	34	14

^a See Fig. L-R-1 for locations.

^b Sample lost or damaged during analysis.

^c Annual total determined by adding the average value, in place of the missing value. Annual total interpolated.

ENVIRONMENTAL RADIOLOGICAL PROGRAM SUMMARY

Introduction

Because of the broad distribution of this report outside the scientific community, a short general discussion of radiation precedes presentation of the Livermore site radiological program summary. Many of the terms used in this report, such as "rad" and "rem," have no counterparts in everyday English. This discussion enables the nontechnical reader to understand the radiological dose assessment information contained in this report more easily. [The interested reader is referred to *Radiation: Doses, Effects, Risks* (U.N. Environment Programme, 1985), from which some of this discussion is excerpted.]

Natural and Man-Made Radiation

Atoms are made up of three types of particles: protons, electrons, and neutrons. Atoms of the same element have the same number of protons. However, atoms of the same element can have different numbers of neutrons within their "centers or nuclei." Those atoms of elements that have differing numbers of neutrons, but the same number of protons, belong to different varieties or "isotopes" of the element.

Isotopes are distinguished by the total number of protons and neutrons within their nuclei. For example, uranium-238 has 92 protons and 146 neutrons, whereas uranium-235 has 92 protons and 143 neutrons. Generically, species of atoms that are so characterized are called "nuclides."

Many nuclides are unstable because the particles in the nuclei cannot remain tightly clustered together. Eventually some of the particles will break away. For example, two protons and two neutrons will eventually break away from the nucleus of uranium-238, creating thorium-234, with 90 protons and 144 neutrons. However, thorium-234 also is unstable and becomes protactinium-234, with 91 protons and 143 neutrons. Protactinium-234 is extremely unstable. It continues to lose particles until it finally ends up as lead.

This transformation process is called "radioactive decay" or "radioactivity," and

the unstable nuclides are called "radio-nuclides." The time required for a radioactive substance to decay to half of its original activity is termed "half-life." Half-life can range from fractions of a second to thousands of years, depending on the radionuclide. For example, tritium (the radioactive form of hydrogen) has a 12-year half-life; uranium and plutonium have half-lives of many thousands of years. As each change occurs, energy is released and is transmitted as radiation. Alpha radiation is a highly energetic helium nucleus that is emitted from the nucleus of a radioactive isotope. This particle is massive and positively charged. It consists of two protons and two neutrons. A beta particle is an ordinary electron that is ejected from the nucleus of an unstable radioactive atom during the transformation of a neutron into a proton. Frequently, the unstable nuclide will be so "excited" that the emission of particles is insufficient to reach a more stable state. The unstable nuclide then emits a burst of electromagnetic energy called "gamma" radiation. Gamma radiation does not involve the emission of particles.

The different forms of radiation are emitted with different energies and penetrating power—and have different effects on living things.

Alpha radiation can be halted by a sheet of paper, and can scarcely penetrate the

dead outer layers of skin. Alpha radiation is not dangerous, unless substances emitting it get inside the body through an open wound, or are eaten or breathed in. Then alpha radiation becomes especially damaging. Beta radiation is more penetrating. It can pass through a centimeter or two of living tissue. Gamma radiation is extremely penetrating and can pass through most materials, but is significantly attenuated by thick slabs of dense materials such as lead or concrete.

Measurement of Radioactivity and Dose. The radioactivity of a nuclide is measured by the number of transformations that take place each second. Radiation is measured in units called curies (abbreviated Ci). Each curie equals 3.7×10^{10} (37 billion) transformations per second or 3.7×10^{10} Becquerel (Bq).

However, radioactivity (the number of transformations), is not a measurement of the effect of the nuclide on living tissue. It is the *energy* that radiation deposits as it traverses matter that does the damage. The amount of energy deposited in living tissue is called the "dose." The radiation dose can originate outside the body from radionuclides that produce penetrating radiation, or from any radionuclide that irradiates the body from within, after being inhaled in air, or swallowed in food or water. Doses are expressed in different ways, depending on how much of the body (and what parts of it) are irradiated or exposed to radiation, whether one individual or many people are exposed, and the length of time of the exposure.

The amount of radiation energy absorbed per gram of tissue is called the absorbed dose. It is measured in units called "rads" or "grays" (G) (100 rads equal 1 G). However, an identical absorbed dose of alpha radiation is much more damaging than one of beta or gamma radiation. Consequently, a dose must be weighted for its potential to damage, giving alpha radiation 20 times the weight of the others. This weighted dose is known as the "dose equivalent," and it is measured in units called "rem" or "sievert" (Sv) (100 rem equals 1 Sv).

Just as one type of radiation can be more damaging than the others, some parts of the body can be more vulnerable than others. The different parts of the body also are given weightings. For example, a given radiation dose is more likely to cause fatal cancer in the lung than in the thyroid. The reproductive organs are of particular concern, because of the potential risk of genetic damage. Once particular organs are weighted appropriately, the dose equivalent becomes the "effective dose equivalent," also expressed in rems or sieverts.

The effective dose equivalent describes only doses to individuals. When all the individual effective dose equivalents received by a group of people are added up, the result is called "the collective effective dose equivalent," and is expressed in "person-rem" or "person-sievert."

One further definition is required. Many radionuclides decay so slowly that they are radioactive far into the future. Therefore, the collective effective dose equivalent that will be delivered to generations of people over time is called the "collective effective dose equivalent commitment."

This hierarchy of concepts is illustrated in **Figure L-RS-1**. Most of the discussion in this section addresses absorbed dose and effective dose equivalent. However, the other terms are used to ensure accuracy and eliminate ambiguity.

Natural Sources of Radioactivity. By far the greatest part of radiation received by the world's population comes from natural sources, such as cosmic radiation, radiation from radioactive materials in rocks, and radon gas released from within the earth. Human exposure to natural radiation can be external (from substances that may remain outside the body) or internal (from substances inhaled in air or swallowed in food or water). Individual exposures vary with location. The approximate average radiation exposure from natural sources including radon in the general Livermore area is 300 mrem/y (millirem) (3.0 mSv/y).

Approximately 30 mrem (0.3 mSv) of the exposure to external natural radiation

comes from cosmic rays. Most of these rays originate deep in interstellar space, although some are released from the sun during solar flares. Cosmic rays irradiate the earth directly, and interact with the atmosphere to produce other types of radiation and different radioactive materials. The earth's poles receive more cosmic radiation than the equatorial regions, because the earth's magnetic field diverts the radiation. More significantly, the radiation level increases with altitude, because there is less air overhead to act as a shield.

Another major source of external radiation is radioactive materials in rocks. This source accounts for approximately 30 mrem/y (0.3 mSv/y) of exposure in the general Livermore area. The main radioactive materials in rocks are potassium-40, rubidium-87, and two series of radioactive elements arising from the decay of uranium-238 and thorium-232. The levels

of terrestrial radiation differ from place to place around the United States and around the world.

Much of the internal dose to humans from natural sources of radioactivity is derived from terrestrial sources. Inhalation exposure is dominated by the short-lived decay products of radon, resulting in a dose of approximately 200 mrem/y (2 mSv/y) or 67% of natural exposure, depending on the geographical location. Radon seeps out of the earth worldwide, but levels in outside air vary markedly from place to place. Radon in water and natural gas provide additional, but less important, sources of radon in homes. Consumption of water high in radon is not the main exposure source. A greater exposure arises from radon in water vapor from showers.

Ingestion of radionuclides is another source of internal exposure. The foods we

Radioactivity	Term	Units of measure
Absorbed dose: Energy imparted by radiation per gram of tissue.	rad
Dose equivalent: Absorbed dose weighted for the potential of different radiations to do damage.	rem
Effective dose equivalent: Dose equivalent weighted for susceptibility to harm different tissues.	rem
Collective effective dose equivalent: Effective dose equivalent to a group of people from a source of radiation.	person-rem
Collective effective dose equivalent commitment: Collective effective dose equivalent delivered over time to generations of people.	person-rem

Figure L-RS-1. Radiation dose terminology and corresponding units of measure (adapted from U.N. Environment Programme 1985).

eat also contain natural radioactivity, which results in approximately a 40 mrem/y (0.4 mSv/y) dose, depending on the soil type and other factors at the location where the food is grown.

Man-Made Sources of Radioactivity. Man-made radionuclides have been used in medicine, consumer products, the production of energy, and the production of nuclear weapons. Generally, exposure to man-made sources can be controlled more readily than exposure to most natural sources. However, exposure to external irradiation caused by fallout from past nuclear explosions is virtually inescapable.

At present, medical treatment is the greatest source of human exposure from man-made radiation. Individual doses vary enormously—from zero for someone who has never had an x-ray examination, to many thousand times the annual average dose from natural radiation for some patients undergoing treatment for cancer. Another source of human exposure to man-made radiation is consumer products, including luminous-dial watches, smoke detectors, airport x-ray baggage-inspection systems, optical lenses, false teeth, and tobacco products. On the average, medical and consumer-product sources of radiation result in a dose of approximately 65 mrem/y (0.65 mSv/y).

Radiation Protection Standards

The DOE environmental radiation protection standards are provided in *DOE Order 5400.5, Radiation Protection of the Public and the Environment* (U.S. Department of Energy 1990). That order incorporates a new system for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The primary DOE radiation standards for protection of the public are 100 mrem/y (1 mSv/y) effective dose equivalent for prolonged exposure, and 500 mrem/y (5 mSv/y) effective dose equivalent for occasional

exposure. These limits are based on the dose to the maximally exposed individual in an uncontrolled area.

This definition of "effective dose equivalent" differs from the definition provided earlier. This term is defined as the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and Lawrence Livermore National Laboratory (LLNL) also comply with the EPA's standard for radiation protection. This EPA radiation dose standard, which applies to air emissions, is contained in 40 *Code of Federal Regulations* Part 61, Subpart H, of the Clean Air Act, and is 10 mrem/y (0.1 mSv/y) whole-body effective dose equivalent. Before December 15, 1989, the standard was 25 mrem/y (0.25 mSv/y) dose equivalent for whole-body exposures from the air pathway, and 75 mrem/y (0.75 mSv/y) dose equivalent for exposure of any organ from the air pathway.

The EPA air dose model, AIRDOS-EPA, is set forth in the Clean Air Act Code (CAAC), and has been used by LLNL to calculate off-site doses. But to fulfill the DOE requirement, LLNL historically has used the Continuous-Point-Source Code (CPS Code). This procedure results in different calculated individual doses, because the model assumptions and calculations are different. In recent years, LLNL has run both model codes and presented the results of each. Both model codes were run in 1990. The results are summarized in **Tables L-RS-1 through L-RS-4**.

Potential Radiological Dose from the Livermore Site

Small amounts of radioactive materials from operations at the Livermore site were discharged to the environment in air and sewer effluents during 1990. The total amount of tritium released to the atmosphere by LLNL in 1990 was 1,281.64 Ci; of that, 699.84 Ci was in the form of tritiated water. An additional 295 Ci of tritium was released by Sandia National Laboratories, Livermore (SNLL), with approximately

51 Ci in the form of tritiated water. The total quantity of ^{13}N (half-life of ten minutes) and ^{15}O (half-life of two minutes) released in 1990 was 48 Ci at the Livermore site. The amount of radioactivity released from LLNL during 1990 was less than during 1989 and was well within the range of previous years (see **Table L-A-7** in the Air Monitoring chapter).

In accordance with DOE environmental protection orders and other Federal and State requirements, the Environmental Monitoring Group assessed the radiological impact from operations at LLNL during 1990. Potential radiation doses to the public that were calculated from radionuclide concentrations in environmental media (determined by surveillance sampling) are presented with the data in the various chapters. Doses calculated from emissions of radioactive materials to the atmosphere are presented here. Sewer effluents are not consumed, thus they do not represent an ingestion or inhalation pathway.

Radiation doses based on emissions were calculated by two methods: the EPA Clean Air Act Code (CAAC) (40 *Code of Federal Regulations* Part 61, Subpart H), which contains the AIRDOS-EPA and RADRISK models, and the Continuous-Point-Source (CPS) Code (Peterson et al. 1976). EPA mandates use of the CAAC AIRDOS-RADRISK model. Both model codes are run because LLNL had used the CPS Code prior to the EPA requirement to use the CAAC AIRDOS-RADRISK model, and because the results from the CPS Code can be compared to results from previous years.

The CAAC is used to calculate the estimated dose at the site perimeter, the dose to the nearest resident, and the dose at the maximum off-site exposure location for each emission source. The CPS Code is used to calculate the estimated dose at the site perimeter, the dose to the nearest resident, and the maximum off-site dose, as well as collective person-rem dose to the population residing within 80 km (50 mi) of the Livermore site. Both methods are based on conservative assumptions.

Any actual dose received by an individual would be much less. **Appendix B** contains definitions of the doses discussed in this subsection and the mathematical equations used to perform this assessment.

These codes were used to determine the doses caused by releases of tritium, ^{13}N , and ^{15}O . As discussed in the Environmental Radiation Monitoring chapter, there was no evidence of gamma or neutron exposure in excess of background values. The 1990 average external gamma-radiation (fence-line) doses measured at the Livermore-site boundary and Livermore Valley locations were 65.0 mrem (0.650 mSv) and 65.9 mrem (0.659 mSv), respectively (see Environmental Radiation Monitoring chapter). Consequently, there were no doses in excess of background levels.

EPA Clean Air Act Code. This year, as for 1989, the air pathway doses calculated using the Clean Air Act Code include exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The Clean Air Act Code was run using specific meteorology for the Livermore site. The air pathway dose calculated is expressed as effective dose equivalents.

The EPA limit for airborne emissions is 10 mrem/y (0.1 mSv/y) effective dose equivalent. The total fence-line dose from air emissions from Livermore-site operations in 1990 was 0.29 mrem (0.0029 mSv). The dose to the nearest resident was 0.11 mrem (0.0011 mSv). And the dose at the point of maximum off-site exposure was 0.24 mrem (0.0024 mSv). These doses represent less than 3% of the 1990 EPA limit. Doses for emissions from specific facilities also were calculated. See **Table L-RS-1**.

Continuous-Point-Source Code. Air pathway doses also are calculated using CPS Code (**Table L-RS-2**) for each facility considered to have a measurable airborne discharge to the atmosphere. The maximum combined inhalation dose (i.e., the total from facility discharges) from airborne emissions at the Livermore-site perimeter

Livermore Site Environmental Radiological Program Summary

was 0.20 mrem (0.0020 mSv). The maximum combined inhalation dose from airborne emissions to the nearest resident was 0.13 mrem (0.0013 mSv).

Figure L-RS-2 compares the calculated radiological dose from airborne emissions at the site perimeter in 1990 with similar air pathway doses for the previous 12 years. This figure also shows the contribution of each radionuclide to the total dose. (There have been no ^{41}Ar emissions since the LLNL research reactor was shut down in 1980.) The dose from tritium was attributable entirely to tritiated water (HTO). Elemental tritium (HT) dose was evaluated, but it did not present a measurable contribution to the dose; therefore, it was not included in the graph.

Figure L-RS-3 presents graphically the dose at the site perimeter since 1973. The current DOE radiation protection limit for the public is 100 mrem (1 mSv) during a one-year period. Prior to 1986, this limit was 500 mrem/y (5 mSv/y). As illustrated in **Figure L-RS-3**, the total off-site dose

Figure L-RS-2. Calculated radiological dose by radionuclide from the air pathway to the hypothetical maximally exposed individual, Livermore site, 1978-1990.

has decreased significantly compared with past years. Fluctuation in dose from year to year is caused by changes in operations and operating schedules, and by enhanced environmental protection efforts. Since 1984, the off-site doses have remained very low, all less than 0.4% of the DOE limit. The calculated doses by year from 1984 to 1990 were 0.09 mrem (0.0009 mSv), 0.22 mrem (0.0022 mSv), 0.16 mrem (0.0016 mSv), 0.18 mrem (0.0018 mSv), 0.11 mrem (0.0011 mSv), 0.31 mrem (0.0031 mSv), and 0.20 mrem (0.0020 mSv), respectively.

Table L-RS-3 is a summary of the radiological dose to the maximally exposed individual in the public. This individual is a hypothetical person who lives at a location and has a lifestyle that results in receipt of the maximum possible calculated radiation dose from Livermore-site operations. This dose includes all significant exposure pathways (not just the air pathway) and is derived using the most conservative, but realistic, exposure data and assumptions. The inhalation submersion pathways are calculated using the CPS Code. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1990 was 0.28 mrem (0.0028 mSv).

The DOE radiation protection limit to the public is 100 mrem/y (1 mSv/y). For comparison, during the same period

Figure L-RS-3. Maximum air pathway dose at the Livermore-site perimeter, 1973-1990.

the average resident of the Livermore Valley received a dose of approximately 300 mrem/y (3.0 mSv/y) from natural background radiation, including the dose from radon. The dose from radon is included because, at 200 mrem (2 mSv), it represents the largest single source of radiation exposure for Livermore-area residents.

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km (50-mi) radius of LLNL. The estimated collective effective dose equivalent to the total population within 80 km (50 mi) of LLNL was 0.28 person-rem (0.0028 person-mSv) during 1990. This dose is based on a population of six million within 80 km (50 mi) of LLNL. The collective population dose from natural sources of radiation (using 300 mrem/y (3.0 mSv/y) as a typical average from natural sources) during the same period was estimated to be 1.9×10^6 person-rem (1.9×10^4 person-Sv).

Table L-RS-4 compares the dose to the public resulting from Livermore-site operations with the dose to the public from natural and other background sources of radiation. The dose resulting from Livermore-site operations is negligible.

Summary

Overall, all measured and calculated radiation doses were well below the applicable standards for radiation protection of the public. Moreover, the potential radiological doses from Livermore-site operations were substantially less than the doses normally received from natural background radiation sources.

A committee of the National Academy of Sciences has suggested that the average risk factor for total body exposure to ionizing radiation is on the order of 120 fatal cancers for each 1,000,000 person-rem of exposure (NAS 1980). From **Table L-RS-3**, the total body dose to the maximally exposed person is 0.28 mrem (0.0028 mSv) from all 1990 LLNL operations, including all exposure pathways. Thus, the 1990

annual risk to the hypothetical maximally exposed individual of developing a fatal cancer is less than one in 20 million. Moreover, the annual average total body dose to individuals in the United States from natural sources, including radon, is approximately 300 mrem/y (3.0 mSv/y) [plus approximately 65 mrem/y (0.65 mSv/y) from man-made sources such as medical procedures, consumer products, weapons fallout, and airline travel]. **Figure L-RS-4** shows the distribution of annual radiation doses from various sources.

The risk of developing cancer from radon can be used as a basis for risk comparison. Radon is a radioactive gas in our environment that results from the decay of naturally occurring uranium within the earth's crust. Radon gas is ubiquitous. It is a source of radiation dose to everyone. Radon gas in water and air results primarily in a radiation dose to the lung. The lung dose from environmental radon air concentrations, particularly in our homes, is a public health concern. The EPA estimates that up to 20,000 lung cancer deaths per year may

Figure L-RS-4. Typical annual radiation doses from various sources (NCRP 1987).

be attributable to radon exposure (U.S. EPA 1986). For the U.S. population of 240 million, the estimated annual risk of death from lung cancer is approximately one in 12,000.

The doses presented above for Livermore-site operations were calculated using conservative assumptions. They are not doses actually received by anyone. Any dose actually received by an individual would be considerably less. Thus, these maximum credible doses show that Livermore-site operations had no significant impact on public health during 1990.

Overview

This section of the Radiation Program Summary reviews monitoring data acquired to validate the effectiveness of LLNL administrative and engineering controls that prevent the introduction of radiation to the environment. Because the assumptions used in the radiation dose assessment purposely overestimate and therefore maximize the hypothetical exposure of the public to LLNL emissions, these results are not used directly in performing the dose assessment. However, they verify that the dose assessment process is conservative, and that the models represent all important contributions to public exposure.

Air Monitoring

LLNL conducts air monitoring to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations. Air monitoring includes both measurement of particles collected on filters and vapor chemically trapped in air samplers. Concentrations of various airborne radionuclides (including particulates and tritium water vapor) are measured at the Livermore-site perimeter and at off-site locations near the Livermore site. Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters and is discussed in a following section.

LLNL analyzes air filters for gross alpha and gross beta activity to ensure that releases of radiation are detected, and to identify trends in the LLNL environs. The values reported for 1990 are similar to those observed previously. Gross alpha and gross beta values show no significant differences between samples taken at the Livermore-site perimeter and in the Livermore Valley. Most of the gross alpha determinations were at or near the detection limit of the method. Typical gross alpha activity was $<1 \times 10^{-15} \mu\text{Ci/mL}$ ($3.7 \times 10^{-11} \text{Bq/mL}$), and typical beta activity was $1 \times 10^{-14} \mu\text{Ci/mL}$ ($3.7 \times 10^{-10} \text{Bq/mL}$). Most of the observed alpha and beta activity results from the naturally occurring radioisotopes of uranium and thorium and their decay products.

In addition to generic radiation surveillance, LLNL performs sensitive isotope-specific analysis for specific radionuclides. Individual measurements are presented in the Livermore Site Air Monitoring chapter, which is summarized here. This program showed no evidence of monitored radionuclides above DOE screening levels (*DOE Order 5400.5 Derived Concentration Guidelines*, or DCGs). This condition held true for a suite of gamma-emitting radioisotopes, as well as for plutonium, uranium, and tritium.

The gamma-radiation surveillance program includes the naturally occurring isotopes ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th , along with ^{137}Cs , which are caused primarily by long-term global fallout and fallout resuspension. Other fission products normally are detectable only after events such as atmospheric nuclear tests by other nations or releases, such as the Chernobyl accident. In addition to providing baseline data on global fallout, analysis of these fission products enables LLNL to monitor the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL.

The highest concentration of plutonium, observed during August near the southeast corner of the site, was

2.15×10^{-17} $\mu\text{Ci/mL}$ (7.96×10^{-13} Bq/mL), or 0.11% of the DCG. No other statistically significant differences between locations or samples were noted. The overall levels determined were essentially the same as those reported in 1989. The measured concentrations of ^{238}U were less than 0.039% of the DCG. For tritium, the highest mean annual concentrations occurred along the perimeter of the southeast quadrant of the site. These concentrations were approximately 1.75×10^{-11} $\mu\text{Ci/mL}$ (6.48×10^{-7} Bq/mL) or 0.02% of the DOE Derived Concentration Guide.

In the Livermore Valley, the highest annual average tritium concentrations observed were just east of LLNL, and just west of SNLL. The concentrations were approximately 0.8×10^{-11} $\mu\text{Ci/mL}$ (3×10^{-7} Bq/mL), or 0.008% of the DCG. The highest biweekly concentration was observed in June at Location ALTA, five miles northeast of LLNL. That concentration, 2.78×10^{-11} $\mu\text{Ci/mL}$ (1.03×10^{-6} Bq/mL), was 0.03% of the DCG. All of these preceding values are generally lower than their counterparts reported last year.

LLNL also monitors facilities that are known to produce radioactive effluents. In 1990, a total of 1,281.64 Ci (4.742×10^{13} Bq) of tritium was released to the atmosphere from operations at LLNL. Of this amount, approximately 699.84 Ci (2.589×10^{13} Bq) were released as tritiated water (HTO). The remaining tritium was elemental tritium gas (HT). Once released to the environment, the potential dose from elemental tritium gas is approximately 25,000 times lower than a dose from a comparable release of tritiated water. Therefore, the tritiated hydrogen gas did not contribute significantly in calculations of the overall dose. Of the 1,281.64 Ci (4.742×10^{13} Bq) of tritium discharged to the atmosphere by LLNL in 1990, 1281.3 Ci (4.7419×10^{13} Bq) came from the Tritium Facility (Building 331). The highest single weekly emission from the facility was 68.7 Ci (2.5419×10^{12} Bq) of tritium gas during the week of October 1, 1990.

Releases of the short-lived radionuclides ^{13}N and ^{15}O from Building 194 (the electron-positron linear accelerator) totalled 48 Ci (1.776×10^{12} Bq). The 1990 emissions were within the range of previous years' emissions.

Sewage Monitoring

LLNL is required by 17 *California Code of Regulations* to limit the total annual discharges of radiation to the sanitary sewer to less than one curie. DOE Order 5400.5 also limits the concentrations of specific radionuclides. LLNL demonstrates compliance with these requirements through analysis of flow-proportional composite samples of its daily effluent. Aliquots are analyzed daily for the presence of alpha- and beta-emitting isotopes, and for tritium. Portions of the daily samples are combined and analyzed monthly for plutonium and cesium. To determine the impact of its operations on the Livermore Water Reclamation Plant (LWRP), LLNL also monitors treatment plant effluent and LWRP process tanks that concentrate solids.

The sewer monitoring program is discussed in more detail in the Sewage Monitoring chapter. Analytical methods are outlined there, as well as in **Appendix A**. In summary, the results show that LLNL is in compliance with all regulations and guidelines governing releases of radioactivity to the sanitary sewer. Total discharges, dominated by tritium, were 48% of the 17 *California Code of Regulations* limit. The annual average concentration of tritium in LLNL effluent was 1.46×10^{-6} $\mu\text{Ci/mL}$ (0.054 Bq/mL), about 0.015% of the DOE annualized discharge limit for application of best available technology (BAT) to a public sewer system. Cesium discharges, averaging 9.86×10^{-11} $\mu\text{Ci/mL}$ (3.65×10^{-6} Bq/mL), were only 0.00065% of the DOE discharge limit. The annual average ^{239}Pu concentration was 13.0×10^{-12} $\mu\text{Ci/mL}$ (0.48×10^{-6} Bq/mL), or 0.00014% of the DOE discharge limit.

These parameters were lower at the treatment plant, where the concentration of tritium averaged 0.28×10^{-6} $\mu\text{Ci/mL}$

Livermore Site
Environmental
Radiological
Program
Summary

(0.010 Bq/ml), cesium averaged 1.48×10^{-11} $\mu\text{Ci/ml}$ (0.55×10^{-6} Bq/ml), and plutonium averaged 0.64×10^{-12} $\mu\text{Ci/ml}$ (0.24×10^{-6} Bq/ml). The concentration of plutonium in LWRP sludge was 2.3×10^{-8} $\mu\text{Ci/dry gm}$ (0.74×10^{-3} Bq/dry gm), 600 times lower than the proposed EPA guideline for unrestricted use, which is 13×10^{-6} $\mu\text{Ci/dry gm}$.

To aid the LWRP further in protecting its operations, LLNL continuously monitors its effluent for radiation. This system detected the release of 93 μCi of ^{241}Am on November 12. The LWRP was notified of the release prior to its arrival at the treatment plant, and chose not to take special action prior to its introduction to the treatment system. The release did not violate any discharge requirements.

Water Monitoring

LLNL performs surveillance monitoring of water at the Livermore site and in surrounding regions of the Livermore Valley. The waters monitored in the Livermore Valley include lakes and aqueducts, tap water, stormwater runoff, and drinking water supply wells.

Surface Water. Six surface water sources, four domestic water supplies, and the on-site swimming pool are monitored for gross alpha activity, gross beta activity, and tritium activity. Several additional locations have been established for a special assessment of tritium in rain water and stormwater.

The 17 rain water sampling locations consist of seven on-site and ten off-site locations. The rain water samples are collected in open unsheltered areas with stainless-steel buckets positioned at least three feet above the ground. A rain gauge is also located at each sampling location.

In addition to collecting rain samples for tritium analysis, nine stormwater runoff locations are sampled following the first major storm of the rain season. These nine locations include the Arroyo Los Positas, Arroyo Seco, and drainage channel influent and effluent points to the

LLNL site, SNLL site, and the LLNL on-site drainage retention basin.

Reported in the Livermore Site Routine Water Monitoring chapter are the data collected during 1990 from 17 rain-monitoring locations and eight stormwater-monitoring locations that will be used in the special assessment.

Conclusions are premature, but certain generalities are observed from the data. The level of tritium in rain and stormwater on and immediately adjacent to LLNL and SNLL is elevated. The elevated concentrations seem very localized to the LLNL and SNLL area. The magnitude of tritium in the rain cannot be correlated simply with facility emissions, and no unusual tritium releases occurred immediately prior to or simultaneously with the rainstorm.

The radiological results for surface water, storm runoff, and rain samples collected on site and off site around the Livermore Valley were below EPA and DHS maximum contaminant levels (MCL). Livermore Valley samples resulted in tritium concentrations that are well below recommended limits. The highest average concentration of tritium in water, 1,090 pCi/L, occurred in the on-site swimming pool.

The MCL apply to drinking water, as exemplified by the surface waters and tap waters. Storm and pool water is not drinking water, and the MCL are used for comparison and trending purposes only. Methods used to calculate doses are presented in **Appendix B**. Although the special assessment of tritium is not complete, the impact of tritium that is released to the air and subsequently may be incorporated into rain water and stormwater has been determined. The estimate of the dose to the maximally exposed individual was determined by using the AIRDOS-EPA model and includes all pathways to man, specifically the rain water/stormwater pathway. As discussed in the Environmental Radiological Program Summary chapter of the Livermore Site section, this dose to the maximally exposed individual, 0.22 mrem/y (0.0022 mSv/y), is a small

fraction of the EPA standard allowable dose of 10 mrem/y (0.1 mSv/y).

Groundwater. Tritium and alpha, beta, and gamma activities have been detected on site in a very few wells as part of the LLNL Livermore-site Ground Water Project. LWRP effluent containing low levels of tritium from natural sources, radioactive fallout, and normal LLNL and SNLL operational releases is used to irrigate municipal property near LWRP. Nearby wells are used to monitor groundwater quality and determine the extent of tritium migration into the groundwater. There is no immediate environmental impact because the above-mentioned wells are not used as drinking water sources.

With one exception, levels detected have been well within the range of normal, natural background levels and well below the State of California MCL. However, tritium concentrations just above the MCL have been detected on site in two wells in the Taxi Strip/Old Salvage Yard area. The two wells in the Taxi Strip/Old Salvage Yard area do not supply drinking water. Again, MCL apply only to drinking water and are used here for comparison and trending purposes. Presently there is no impact of this contamination because the water is not consumed.

Soil Monitoring

Soil is an integrating medium that can absorb contaminants from the atmosphere or from liquid effluents. Since 1972, annual soil sampling in the vicinity of the Livermore site has been part of the continuing LLNL surveillance monitoring program designed to document any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from Livermore-site operations.

During 1990, sediment samples from the arroyos near LLNL also were collected. The sampling of sedimentary material from streams or ponds can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment.

As a result of the accumulation of contaminants, sediment sampling is a more sensitive indicator of waterborne radionuclides than water sampling (U.S. Department of Energy 1988d). Radiological analyses determine if significant buildup of pollutants has occurred.

The monitoring provides baseline data on global fallout and permits monitoring the containment of the small inventories of mixed fission products and radiochemical tracers used at LLNL.

Elevated levels of ^{239}Pu , resulting from the release of an estimated 32 mCi Pu to the sewer in 1967 and first observed in soils near the Livermore Water Reclamation Plant (LWRP) during the early 1970s, again were detected at locations WRP1, WRP2 and WRP3. The highest value detected was $145 \times 10^{-9} \mu\text{Ci/g}$ (0.0054 Bq/g); this represents 1.1% of the proposed EPA soil standard of $0.2 \mu\text{Ci/m}^2$ (7,407 Bq/m²) for unrestricted use of surface soil [or $13 \times 10^{-6} \mu\text{Ci/g}$ (0.5 Bq/g), assuming average Livermore Valley soil densities].

Similarly, $33 \times 10^{-9} \mu\text{Ci/g}$ (0.0012 Bq/g) of ^{239}Pu was detected at another Livermore Valley sampling location. This concentration is greater than those reported for this location during previous years and is significantly different from concentrations measured during 1990 at other locations; it represents 0.3% of the proposed EPA standard. Measurements of this magnitude have been seen occasionally in past years at a variety of soil sampling locations.

The remaining soil values reflect worldwide fallout and naturally occurring concentrations of nuclides.

Radiological constituents in arroyo sediment samples also were examined. Plutonium-239 levels were at background concentrations, reflective of worldwide fallout. Most other radionuclides were detected at levels similar to those reported in 1988 and 1989. Cesium-137 is a fission product found at worldwide background concentrations. Potassium-40, ^{226}Ra , ^{228}Ra , ^{232}Th , ^{235}U and ^{238}U are naturally occurring radionuclides that were detected

at background concentrations. Tritium concentrations are below those reported in 1988 and 1989.

Soil and arroyo sediment sample radiological analyses indicate that in general the impact of LLNL operations on these media in 1990 has not changed from previous years, and remains insignificant. Most analytes were detected at background concentrations, in trace amounts, or in amounts that could not be measured above detection limits. Even in areas where contamination exists, concentrations are either below regulatory standards or remain on site and are being evaluated for remedial actions.

Plutonium in Soil, LLNL Site

Southeast Quadrant. The DOE Tiger Team stated that LLNL had not investigated and evaluated "the cause of measurable off-site plutonium contamination" as determined from high-volume air particulate samples collected during 1988 adjacent to the southeast quadrant of the site. The Tiger Team did mention that the "detected concentrations were much less than any regulatory limits and presented no imminent threat to the public or the environment." However, the Tiger Team stated that because the site did not detect plutonium in any stack monitors, the source of the measured airborne contamination was "unmonitored and unquantified," and may be "due to soil contamination at the southwest (sic) portion of LLNL caused by historical activities."

Part of the planned LLNL action regarding this Tiger Team finding involves the initiation of a grid-based soil and sediment sampling and analysis plan to characterize and quantify plutonium in the southeast quadrant of the site. Localized high-volume air particulate sampling also is planned. The additional soil and air sampling should allow quantification of the source term associated with the resuspension pathway for use in dose assessments and will help verify that no unknown, unmonitored sources exist.

To date, approximately 200 soil and sediment sampling locations have been

selected at random using a coarse grid. Initial samples have been collected, and analyses are under way. If any analytical results indicate elevated plutonium levels, additional samples will be collected in the affected area, and a finer grid will be used to define the area.

No final data are yet available. Results will be documented fully when the data analysis is complete and interpreted.

Tritium in the Unsaturated Zone. As part of the Remedial Investigation/Feasibility Study (RI/FS) (Thorpe et al. 1990; Isherwood et al. 1990), the Environmental Restoration Division conducted assessments of tritium concentrations in unsaturated soil sediments (vadose zone) at the Livermore site. Concentrations are reported as pCi/L of soil moisture (pCi/L_{sm}).

Data collected indicate that tritium is present in the vadose zone at some locations in concentrations significantly above the LLNL background level of about 3,500 pCi/L_{sm}. Vadose zone tritium levels in the Building 514 Area have been measured as high as 2.68×10^6 pCi/L_{sm}. In the Building 292 Area, a maximum concentration of 2.2×10^8 pCi/L_{sm} was reported adjacent to an underground tank that failed its annual leak test. This area now is under detailed investigation, the results of which will be reported as part of LLNL's underground tank program. In three other areas (Eastern Landing Mat Storage Area, West Traffic Circle, Old Salvage Yard), the highest vadose zone tritium concentrations reported were 9.4×10^4 , 9.7×10^4 , and 1.4×10^5 pCi/L_{sm}. These areas also remain under investigation.

None of the above-mentioned vadose zone contamination threatens drinking water supplies and no edible vegetation is directly affected. Therefore, the only potentially significant transport pathway to human populations for this contamination is inhalation of tritiated water vapor resulting from evaporation or from water taken up by plants and released to the air by transpiration from plant leaves. Transpired water from a single tree located near the Building 292 tritium contamination area

has been measured, and tritium concentrations as high as 5×10^6 pCi/L were found, although most observations have indicated much lower concentrations. Other measurements have shown that the transpired water from other vegetation in the area does not contain tritium at significantly elevated levels (Macdonald et al. 1990). Significantly elevated air concentrations in the area, which might implicate direct soil evaporation, have not been detected. Furthermore, most of the areas where elevated tritium concentrations have been detected are paved with asphalt, thereby limiting potential soil evaporation.

No specific concentrations standards currently exist for tritium in soil; however, concentration limits can be derived from exposure standards. Federal regulations (40 *Code of Federal Regulations* 61.92) forbid emissions that would cause any member of the public to receive in one year a maximum effective dose equivalent of more than 10 mrem/y from the air pathway. Screening level calculations, using the standard EPA code AIRDOS-EPA and conservative (worst-case) assumptions, including maximum-observed transpired water concentrations, indicate that no potential doses from any of the measured tritium concentrations in soil could exceed 0.01% of this standard (Macdonald et al. 1990).

Vegetation and Foodstuff

Sampling and measurement of native vegetation can provide information about the presence of radionuclides in the environment. LLNL collects and analyzes samples of vegetation, honey, goat's milk, and wine, and calculates any potential human dose from these substances.

Vegetation. In general, the 1990 tritium concentrations in vegetation are reduced from those reported in 1989, and are within the range of values normally reported for vegetation in the area. One sample, however, exhibited a notably elevated tritium concentration [16,100 pCi/L (596 Bq/L)]. The value was among the highest values ever reported for that location. The value was also well above any other values detected from all locations in the Livermore

Valley during 1990. Duplicate analyses of the sample using the second subsample of collected vegetation stored in the laboratory freezer corroborated the value. However, a resampling of vegetation from the same area produced values that were more representative of the values found during previous quarters and year-round throughout the Livermore Valley.

Wine. In general, wine tritium concentrations were similar to those reported in previous years; concentrations in wines from all areas remained low. The data for the 1990 sampling year were analyzed using analysis of variance (ANOVA). The statistical analysis showed that although all concentrations were low, the mean of the Livermore wines sampled was statistically greater than both the European and California wines sampled. The mean tritium content of the European wines was also statistically greater than that of the California wines. Multiple comparison tests indicated that the means of the 1990 sampling year data from California and Europe were not statistically different than those reported for the 1989 sampling year. However, the 1990 values reported from Livermore wines were statistically smaller than those reported in 1989.

Regression analyses and ANOVA of the wine data when decay-corrected and grouped by vintage year showed no statistically significant trends in the tritium content of Livermore or California wines since monitoring began. The tritium content of vintage European wines has significantly decreased since monitoring began, and also has statistically decreased since 1980. However, over the past ten vintage years, European and Livermore wines have exhibited comparable tritium concentrations (no statistical differences), with Livermore wines having higher concentrations some years, and European wines having higher concentrations in other years. Vintage wines from both Livermore and Europe consistently have contained statistically higher tritium concentrations than vintage wines from California during the same period.

Honey. Tritium concentrations in honey collected from producers in the Livermore Valley and from other producers in California were determined. Although the mean tritium concentration of Livermore Valley honey was greater than that of honey from other areas of California, the difference was not statistically significant, as determined by an analysis of variance. A single high value of note from the Livermore Valley [793 pCi/L (29 Bq/L)] was corroborated by a replicated analysis. Similar values from both Livermore and other areas of California have been reported in past years. A large variance among honey tritium values is not unusual (for example, see Livermore Site Annual Environmental Reports for 1983 and 1988).

Analysis of variance also indicated that the tritium concentrations in Livermore honey have not changed significantly during the past three years. Statistical analyses also indicated that California honey tritium values were not significantly different from those reported for 1989. The tritium content of honey fluctuates significantly from year to year, and the mean Livermore Valley concentration is sometimes higher and sometimes lower than that of other California honeys. Large variance in both Livermore Valley and California honey tritium concentrations often are seen in the sample data.

There are no health or environmental standards for radionuclides in honey. However, none of the tritium values observed would be of health concern even if the honey were consumed in the same quantities as drinking water, for which safety standards do exist [the California drinking-water standard is 20,000 pCi/L (741 Bq/L)]. The highest tritium concentration detected in honey [793 pCi/L (29 Bq/L)] represents four percent of this standard.

Milk. The activities of ^{137}Cs (a fallout product), ^{40}K (a naturally occurring nuclide), and tritium in goat-milk samples collected during 1990 were determined. No other nuclides were present at detectable levels; ^{137}Cs and ^{40}K were

detected at background levels. Tritium levels in milk are comparable to those reported in previous years. The highest concentration of tritium in milk produced in the Livermore Valley is 378 pCi/L (14 Bq/L). Higher concentrations [462 and 463 pCi/L (both 17 Bq/L)] were measured in samples collected outside the Livermore Valley. Concentrations generally were higher at the end of the year for samples from all locations, but are within the range of values reported in previous years. An analysis of variance showed that tritium values for Livermore milk, as a whole, are not significantly different (95% confidence) than background concentrations.

Dose calculations for milk are based on an intake of 310 L/y, dose factors provided by DOE (U.S. Department of Energy 1988b), and on models described in **Appendix B**. Regardless of sampling location, the annual dose received from milk consumption due to naturally occurring ^{40}K may be as high as 10 mrem (0.1 mSv). Potassium-40 is the major ingestion-pathway contributor to natural background dose. On the other hand, the maximum dose resulting from tritium that could be received from ingestion of milk during 1990 was 4.6×10^{-3} mrem/y (4.6×10^{-5} mSv/y).

Environmental Impact. In general, LLNL radiological impacts on vegetation in the Livermore Valley in 1989 were minimal. Tritium levels found in the Livermore Valley vegetation were generally comparable to those observed in previous years. Based on the conservative assumption that an adult's diet includes vegetables with the highest observed average tritium concentration (with the sample suspected of contamination included in the calculation of the average), and meat and milk derived from livestock fed on grasses with the same concentration, the maximum potential dose is 6.6×10^{-2} mrem/y (6.6×10^{-4} mSv/y).

As in past years, the results of this year's monitoring of tritium in wine indicate that all the tritium concentrations detected were low and were at or near the concentrations measured in tap water.

There are no health standards for radionuclides in wine. However, all the wine tritium data were far below drinking water standards. In fact, even the highest detected value [300 pCi/L (11 Bq/L)] was only 1.5% of the California drinking water standard [20,000 pCi/L (741 Bq/L)]. Doses from wine consumption can be calculated according to methods for water-ingestion detailed in **Appendix B**. The corresponding annual dose of the highest detected tritium value [300 pCi/L (11 Bq/L)], based on the extremely conservative assumption that wine is consumed in the same quantities as water (730 L/year, or 2 L/day), is 0.014 mrem (1.4×10^{-4} mSv).

Using a more realistic wine consumption factor (52 L/year, or 1 L/week of wine from a single area), and the mean tritium values detected in wines from the three sampling areas, the annual dose from Livermore wine would be 0.00058 mrem (5.8×10^{-6} mSv), from European wine would be 0.00036 mrem (3.6×10^{-6} mSv), and from California wine would be 0.00013 mrem (1.3×10^{-6} mSv). Compared to an annual background dose of 300 mrem (3 mSv) (including radon) and a 10 mrem (0.1 mSv) dose from a typical chest x-ray (Shleien and Terpilak 1984), the potential dose from consuming wine from any area is minute. Although Livermore wines contained statistically more tritium than wines produced in other areas of California, the effects of the tritium are negligible.

Honey produced in the Livermore Valley did not contain tritium in statistically different quantities than that contained in honey from other areas of California. Concentrations have not changed significantly over the past three years. As in past years, the concentration of tritium measured in both Livermore Valley and California honeys was highly variable. Consequently, no environmental impact could be measured.

Milk produced in the Livermore Valley did not contain tritium in any quantities greater than are contained in milk

produced in other areas of California. Associated doses, like those for wine, were negligible, and were minute in comparison with the doses associated with naturally occurring ^{40}K in milk. Other radionuclides in milk could not be detected, or were present at background concentrations.

Radiation Monitoring

Penetrating radiation, which cannot be measured by collection of material on filters (nor chemically trapped), is measured using radiation dosimeters. The dosimeters provide a measure of the total amount of penetrating radiation, at a particular location: both background radiation and any radiation that has man-made origins. Penetrating radiation primarily includes gamma rays, but may also consist of neutron radiation.

Annual doses from gamma radiation are measured at 22 Livermore-site-perimeter locations and 55 off-site locations. The average annual dose equivalent from external exposure at the Livermore-site boundary [65.0 mrem/y (0.650 mSv/y)], is statistically the same as the background external dose measured in the Livermore Valley [65.9 mrem/y (0.659 mSv/y)], as determined by analysis of variance. The annual off-site total dose was almost identical to that in 1987 (64 mrem/y, or 0.64 mSv/y), 1988 (63 mrem/y, or 0.63 mSv/y), and 1989 (63 mrem/y, or 0.63 mSv/y). This similarity demonstrates that there is no measurable dose caused by direct radiation from LLNL operations at any point beyond the Livermore-site boundary.

The annual average neutron radiation dose at the Livermore-site perimeter for 1990 is 4.6 mrem/y (0.046 mSv/y), similar to the 1987 (5.0 mrem/y, or 0.05 mSv/y), 1988 (4.2 mrem/y, or 0.042 mSv/y), and 1989 (5.3 mrem/y or 0.053 mSv/y) values. The neutron doses measured at the site boundary are consistent with those expected from natural background radiation.

Livermore Site
Environmental
Radiological
Program
Summary

Based on past measurements (Lindeken et al. 1973), environmental terrestrial exposure rates in the Livermore Valley vary from 30 to 60 mrem/y (0.3 to 0.6 mSv/y). Calculated from local elevation and geomagnetic altitude according to the data of Lowder and Beck (1966) cosmic radiation is about 35 mrem/y (0.35 mSv/y). This combination results in a total typical exposure rate of 65 to 95 mrem/y

(0.65 to 0.95 mSv/y). Exposures measured at the LLNL perimeter fall within these predicted values.

In addition, the external dose measured at the LLNL perimeter is identical to the off-site dose, which is considered natural background. This data indicates that there is no contribution to the external dose from LLNL operations at or beyond the Livermore-site fence line.

Table L-RS-1. Radiation dose from the air pathway, all Livermore-site facilities, during 1990 (Clean Air Act Code).^a

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Tritium facility, B331	³ H/1281.3 ^c	0.27	0.10	0.22
Insulating core accelerator, B212	0 ^d	0	0	0
Rotating target neutron source, B292	0 ^d	0	0	0
Incinerator, B624	0 ^d	0	0	0
Hazardous Waste, DECON, B419	0(LOS) ^e	0	0	0
Laser complex, B175	0(LOS) ^e	0	0	0
Laser complex, B391, B381, B298	³ H/0.34 ^f	1×10^{-3}	8.8×10^{-4}	8.8×10^{-4}
Linear accelerator, B194	¹³ N/24 ¹⁵ O/24	0.014	0.004	0.016
Nuclear Chemistry, B151	MFPg/1.7 $\times 10^{-4}$	1.3×10^{-3}	1×10^{-4}	1.3×10^{-4}
Reactor, B261	0 ^h	0	0	0
Plutonium Facility, B332	0(LOS) ^e	0	0	0
Nuclear Chemistry, heavy elements, B251	0(LOS) ^e	0	0	0
Total	1329.6	0.29	0.11	0.24
Percent of Federal Emission Standardⁱ		2.9	1.1	2.4

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations* Part 61, Subpart H.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose. The doses are calculated using the most conservative exposure assumption and are not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^c Doses based on 699.5 Ci of HTO and 581.8 Ci HT released by LLNL. Does not include releases of 295 Ci of tritium in 1990 by Sandia National Laboratories.

^d Facility not operated in 1990.

^e Limit of sensitivity.

^f Doses are based on 0.34 Ci of HTO.

^g Mixed fission products.

^h Facility shut down March 31, 1980.

ⁱ Federal Emission Standards (contained in 40 *Code of Federal Regulations* Part 61, Subpart H), 10 mrem/y effective dose equivalent.

Table L-RS-2. Estimated radiation dose to the public from Livermore-site airborne effluents during 1990 (Continuous-Point-Source Code).

Facility	Nuclide/ emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Tritium facility, B331	³ H/1281.3 ^b	0.099	0.070	0.099	0.280
Insulating core accelerator, B212	0	0	0	0	0
Rotating target neutron source, B298	0	0	0	0	0
Incinerator, B624	0	0	0	0	0
Hazardous waste DECON, B419	0(LOS) ^c	0	0	0	0
Laser complex, B175	0(LOS) ^c	0	0	0	0
Laser complex, B391, B381, B298	³ H/0.34 ^d	1×10^{-4}	1×10^{-4}	1.2×10^{-4}	1.4×10^{-4}
Linear accelerator, B194	¹³ N/24 ¹⁵ O/24	0.096 ^e	0.058 ^e	0.096 ^e	1×10^{-7e}
Nuclear Chemistry, B251	MFP ^f 1.7×10^{-4}	6.8×10^{-6}	1.5×10^{-5}	6.8×10^{-6}	2.3×10^{-5}
Reactor, B261	0 ^g	0	0	0	0
Plutonium facility, B332	(LOS) ^c	0	0	0	0
Nuclear Chemistry heavy elements, B251	0(LOS) ^c	0	0	0	0
Total	1329.6	0.20	0.13	0.20	0.28

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption. It is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b Doses are based on 699.5 Ci of HTO and 581.8 HT released by LLNL. Does not include releases of 295 Ci of tritium in 1990 by Sandia National Laboratories.

^c Limit of sensitivity.

^d Doses are based on 0.34 Ci of HTO.

^e Submersion dose for short-lived, gaseous air activation products.

^f Mixed fission products.

^g Facility shut down March 31, 1980.

Table L-RS-3. Summary of radiological dose assessment—Livermore site, 1990.

Effective dose equivalent to the maximally exposed public individual						
Nuclide	Pathways			Total		Percent of DOE primary radiation protection standard for the public ^b
	Inhalation/ submersion ^a (mrem)	Ingestion— foodstuffs (mrem)	Ingestion— water (mrem)	(mrem)	(mSv)	
³ H	0.099	0.024	0.06 ^c	0.183	0.00183	0.18
¹³ N, ¹⁵ O	0.096	N/A ^d	N/A ^d	0.096	0.00096	0.09
Livermore-site Total^e				0.28	0.0028	0.28

^a The inhalation/submersion dose was derived using the Continuous-Point-Source code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption. It is not a dose actually received by any member of the public. The actual dose received by any member of the public would be considerably less.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y.

^c Dose maximum from any water, potable or nonpotable.

^d There is no ingestion dose from short half-life air activation products.

^e This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table L-RS-4. Comparison of radiation doses—Livermore site, 1990.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
<u>LLNL Sources</u>		
Atmospheric emissions	0.195 ^b	0.28 ^c
Liquid emissions	0	0
<u>Other Sources^d</u>		
Natural radioactivity ^e		
Cosmic radiation	30	180,000
Terrestrial radiation	30	180,000
Internal (food consumption)	40	240,000
Radon	200	1,200,000
Medical radiation ^f		
(Diagnostic procedures)	53	320,000
Weapons test fallout ^f	1	6,000
Nuclear fuel cycle ^f	0.04	2,400

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km (50-mi) radius of the Livermore site (approximately 6,000,000).

^b These doses represent the maximum committed effective dose equivalent from all LLNL emissions. It is calculated using the most conservative exposure assumptions. It is not a dose actually received by any member of the public. Therefore, it is not used to calculate LLNL population dose.

^c Populations dose from Livermore-site emissions.

^d From National Council on Radiation Protection (NCRP) 1987.

^e These values vary with location.

^f This dose is an average over the U.S. population.

ENVIRONMENTAL NONRADIOLOGICAL PROGRAM SUMMARY

Introduction

Lawrence Livermore National Laboratory (LLNL) conducts extensive monitoring at the Livermore site to ensure that nonradiological pollutants are not being released to the environment. These monitoring programs and their results are summarized in this chapter. Results of these programs demonstrate LLNL's continued compliance with regulatory requirements, as well as the effectiveness of LLNL's operational controls. Investigations of areas contaminated by past practices and the remedial programs to correct them also are summarized.

Air Monitoring

LLNL conducts surveillance monitoring to determine if airborne hazardous materials are being released by Laboratory operations. Air monitoring involves measurement of particles collected on filters. Concentrations of beryllium are measured at the Livermore-site perimeter and at off-site locations near the Livermore site to comply with the Clean Air Act National Emissions Standards for Hazardous Pollutants. The monthly average concentrations of airborne beryllium average less than $7 \times 10^{-5} \mu\text{g}/\text{m}^3$ and are less than 5.3% of the monthly ambient concentration guide established by the Bay Area Air Quality Management District (BAAQMD). The beryllium levels are attributed to suspension of surface soil containing naturally occurring beryllium.

Abatement devices, which minimize air pollutants, now are installed on all units that emit nonprecursor solvents and that first operated in 1988 or thereafter. Non-precursor solvents do not change chemical composition, but they contribute to atmospheric smog formation after they are released to the air. All LLNL-installed abatement devices meet BAAQMD criteria for best available technology.

The release of air pollutants at the Livermore site can be contrasted with the estimated daily release of air pollutants for the entire Bay Area. For example, the

evaporation of total organic nonprecursor solvents in the Bay Area is 9.2 tons/day, versus the Livermore site's 0.049 tons/day (0.5%). BAAQMD estimates for coatings and printing emissions are 56.2 tons/day, versus Livermore site's 0.011 tons/day (0.025).

Sewage Monitoring

LLNL is required by the Livermore Water Reclamation Plant to maintain the quality of its sanitary sewer effluent. The parameters for regulation include metals and organic toxins concentrations and water quality indicators—factors that have the potential to adversely affect the operations of the LWRP or its ability to dispose of waste in a normal fashion. To demonstrate compliance with these requirements, LLNL acquires samples in flow-proportional composites of its sewage and analyzes them for metals, and samples quarterly for a complete range of water quality parameters.

The sewage monitoring program is discussed in more detail in the Sewage Monitoring chapter. Analytical methods are outlined there, as well as in **Appendix A**. In summary, the results show that LLNL is in compliance with all regulations and guidelines governing the quality of its sewage. Throughout the year, metals concentrations remained well below the

discharge guidelines. Chromium and copper were the metals that most closely approached the discharge guidelines, with yearly averages at 25% and 22% of their limits, respectively. The results for the quarterly toxin monitoring were unexceptionable and well within permitted concentrations.

To aid the LWRP further in protecting its operations, LLNL continuously monitors its effluent for pH excursions and episodes of high metals concentrations. This monitoring system detected several brief pH excursions during 1990, and one spill of silver. The LWRP was notified of all releases prior to their arrival at the treatment plant, but in no instance did an excursion require LWRP to take special action prior to the entry of LLNL effluent into the treatment system.

Water Monitoring

Surface water and groundwater sources, the on-site swimming pool, and domestic water supplies are water-sampling locations in the vicinity of the Livermore site. Their samples are analyzed for solvents, metals, and pesticides, in addition to the radioactive constituents discussed in the radiological program summary.

Surface Water. LLNL's surveillance monitoring program was expanded in 1975 to include surface runoff monitoring. The program was originally designed to detect pesticides used at LLNL (including herbicides, fungicides, and insecticides) in samples collected in one location after the first major storm. Additional sampling points subsequently were added, and the samples now are analyzed for metals, solvents, general water-quality parameters, and other priority pollutants, in addition to pesticides. Standard EPA methods are used in the analyses of groundwater and stormwater samples for nonradioactive contaminants.

Most potential pollutants in the storm runoff were not present at detectable levels during 1990. The stormwater runoff showed acetone and other organics spo-

radically at various locations. Only a few other pollutants were found at detectable levels. No nonradiological pollutants were seen in any stormwater samples above applicable regulatory limits. Sampling data showed no significant impact of LLNL operations on other waters sampled.

Groundwater. Groundwater protection activities for the Livermore site are substantially to investigate contamination caused by past practices and to determine the feasibility of and initiate pilot remediation programs. As required by the RWQCB, more than 300 monitor wells have been completed, logged, sampled, and hydraulically tested. Since being placed on the National Priority List and the consequent involvement of EPA, LLNL's groundwater cleanup project has been restructured to conform to specific EPA guidance and the negotiated Federal Facilities Agreement.

The Livermore site is divided into five areas for the groundwater cleanup project. VOC concentrations above State action levels are the primary concern in three of the five areas near the southern portion of the site. Groundwater and soil samples taken from the southwest corner, south central, and southeast corner areas of the site have indicated varying levels of PCE, TCE, 1,1-DCE, 1,2-DCE, 1,2-DCA, and CCL₄ contamination. Not all compounds have been seen at every location. The highest concentration of VOCs occurs in the south-central area, where 3 ppm of TCE was detected.

A gasoline spill area near the former Building 403 is believed to have been caused by approximately 35 years of automotive-repair and fuel-dispensing activities. Investigations suggest that at least 10,000 gallons of fuel leaked into the soil and groundwater from an underground storage tank over a period of years. Sampling of the 28 monitoring wells installed in the vicinity of the spill indicates the presence of a cylindrical soil column, roughly 3,900 cu. yds. in size, that is contaminated with fuel hydrocarbons.

The fifth area consists of the remainder of the site not already described. No specific releases have been identified or recorded. However, VOCs (primarily TCE) have been detected, and investigations to identify possible sources of contamination are in progress.

Numerous restoration efforts have been completed or initiated at the Livermore site. Known sources of contamination—such as leaking tanks, landfills, and surface impoundments—have been removed. Monitoring wells have been installed and possible cross-contamination wells have been closed. Treatment facilities have been installed at two locations to treat VOC-contaminated groundwater.

Contamination caused by past practices is the focus of continuing investigation and restoration activities at LLNL. There is no immediate impact due to the contamination because the contaminated water is not consumed.

Soil Monitoring

During 1990, sediment samples from the arroyos near LLNL were collected, continuing a monitoring effort begun in 1988. Analyses were conducted for a full suite of nonradiological constituents, including metals, volatile organic compounds, non-volatile organic compounds, pesticides, and PCBs, to determine if significant buildup of pollutants had occurred.

The level of lead (Pb) in one sample taken in 1989 (ASE, 79 mg/L) prompted an investigation during 1990. Additional samples were taken from this area, but did not exhibit lead concentrations above background levels. For other metals, no concentrations above STLC limits or above levels normally encountered in sediments were detected.

Current analytical techniques for detection of organic compounds are much improved compared to past years. Therefore, traces of a variety of compounds (many of which were undetectable before 1989) were observed in all samples.

The PCB Aroclor 1260, detected at two locations in low concentrations in 1989, was not detected in any 1990 sample. None of the levels detected for other organic compounds are above regulatory standards. Many of these detected compounds are typical of fuel constituents and are expected in locations that concentrate stormwater runoff. Others are typical laboratory solvents.

Nonradiological analyses of arroyo sediment samples indicate that the impact of LLNL operations on this medium in 1990 has not changed from previous years and remains insignificant. Most analytes were detected at background concentrations, in trace amounts, or could not be detected.

Introduction

Groundwater protection activities for the Livermore site substantially are performed as investigation, feasibility, and pilot remediation of contamination caused by past practices. This chapter, which presents a summary of these activities, was prepared by the Environmental Restoration Division.

Historical Background

In the 1940s, prior to its use as a research laboratory, the Livermore site was the Livermore Naval Air Station, used by the U.S. Navy as a flight-training base and as an aircraft rework facility. An asphalt-paved landing mat was located near the center of the site, with peripheral taxiways and a concrete parking apron. Some unpaved areas within the landing mat were used for maintenance of aircraft and for storage and disposal of fuels, solvents, and other related materials. The Livermore Naval Air Station closed in the late 1940s. Short-term users of the site after the naval station closure included the California Research and Development Corporation, Pratt and Whitney, and miscellaneous interim users.

During the U.S. Navy tenancy, VOCs were used routinely on site in aircraft and engine assembly, repair, overhaul operations, and paint stripping of aircraft. Much of this activity was performed in the southeast part of the site and in the unpaved areas adjacent to the landing mat. In addition to storing organic solvents at the north end of the taxi strip, beginning in 1954, Lawrence Livermore National Laboratory (LLNL), known then as the University of California Radiation Laboratory, stored and treated hazardous waste on a section of the Navy's east taxi strip. From 1956 to the present, LLNL has engaged in research and other activities that involved the storage, use, and disposal of VOCs, fuel hydrocarbons, and other hazardous materials. However, all practices known to contribute VOCs to the soil or groundwater

have been discontinued. In addition, since the late 1970s, LLNL has taken many steps to eliminate discharges of hazardous materials to the environment.

The groundwater investigation was initiated in December 1983, after the detection of perchloroethylene (PCE) and trichloroethylene (TCE) in off-site and on-site monitor wells. (Previously, LLNL had performed preliminary investigations of groundwater occurrence and quality in 1980–1983.) Under requirements of the RWQCB, more than 300 monitor wells have been completed, logged, sampled, and hydraulically tested. These data have been interpreted in conjunction with results of record searches to determine the extent and possible sources of contamination. The sources of VOCs in the groundwater are believed to be related directly to the solvent disposal practices employed by the U.S. Navy during its occupation of the site in the 1940s.

Investigation has determined that a groundwater plume containing VOCs appears to be migrating to the west-northwest, from the southwest corner of the site, at a rate of about 21.3 m (70 ft) per year (**Figure L-G-1**). Three California Water Service municipal supply wells are situated within three miles of this plume. These wells feed a blended water system that serves a population of more than 10,000 people.

Scope of Activity

Since being placed on the National Priority List and the consequent involvement of EPA, LLNL's groundwater cleanup

Livermore Site Groundwater Protection

project has been restructured to conform with specific EPA guidance and the negotiated Federal Facility Agreement. The scope of the environmental restoration effort encompasses numerous activities designed to be performed over several years to investigate, evaluate, and eventually remediate potentially hazardous compounds that may have affected soil and groundwater. The activities include the following:

- Investigation of the hydrogeology of the site.
- Investigation of known and suspected sources of contamination.
- Installation of monitor and extraction wells.
- Sampling of soil and groundwater.
- Evaluation and closure of potential conduit wells.

- Aquifer testing.
- Development of computer models and a conceptual site model to aid groundwater study.
- Continuation of a historical records search to identify potential sources of contamination.
- Assessment of potential risks to public health resulting from potential contamination of soil and groundwater.
- Providing project information to the public and coordinating community involvement in the remedial process.
- Evaluation of numerous studies designed to aid site remediation.
- Preparation of reports documenting the investigation, evaluation, and remediation.
- Implementation of appropriate technologies to accomplish environmentally responsive cleanup of the site.

Figure L-G-1. Isoconcentration contour map of total VOCs at LLNL.

Several documents related to the environmental restoration effort have been submitted to the regulatory authorities. The Work Plan outlines the activities above and other related tasks associated with formal Remedial Investigation (RI) and Feasibility Study (FS) reports, and resultant remedial action. The RI report provides significant detail regarding environmental evaluation and restoration to date. A Community Relations Plan (CRP) has been submitted and, as provided in the CRP, personnel in the Ground Water Project hold public meetings, publish a newsletter, and have formed a Community Work Group to keep the public informed and to provide a pathway for public input to the remedial action process. A Quality Assurance Project Plan (QAPP) outlines methods and processes to ensure that the precision, accuracy, completeness, representativeness, and comparability of project data are known and maintained at an acceptable level.

The name of the project, the LLNL Livermore-site Ground Water Project, reflects the emphasis of the investigation at the Livermore site. The investigation also encompasses soil, air, and surface water as these environmental media relate to the investigation and remediation efforts. Because the involvement of air and surface water is minor, it does not receive as much emphasis as soil and groundwater.

The compounds that have been found in the investigation include primarily VOCs and fuel hydrocarbons as listed below.

- Trichloroethylene (TCE)
- Tetrachloroethylene (PCE)
- 1,1,1-Trichloroethane (1,1,1-TCA)
- 1,1-Dichloroethylene (1,1-DCE)
- 1,2-Dichloroethylene (1,2-DCE)
- 1,1-Dichloroethane (1,1-DCA)
- 1,2-Dichloroethane (1,2-DCA)
- Carbon tetrachloride (CCl₄)
- Chloroform (CHCl₃)
- Freon 113 (C₂Cl₃F₃)
- Freon 11 (Cl₃CF)
- Petroleum hydrocarbons

In addition, tritium has been detected in a very few wells (**Figure L-G-2**). With one

exception, levels detected have been below the State of California Maximum Contaminant Levels (MCLs). However, tritium concentrations just above the MCL exist in one well in the Taxi Strip/Old Salvage Yard area. The migration of tritium has been determined and the tritium is expected to decay without affecting any drinking water supplies.

As part of the Remedial Investigation, LLNL continues to develop additional wells, sample groundwater and soil, and perform hydraulic tests. These activities enable LLNL to refine its understanding of the hydrogeologic system and to determine the extent of VOCs present. To facilitate the development of the Feasibility Study, LLNL has executed pilot studies for the extraction and treatment of groundwater in the off-site area, as well as groundwater and soil vapor in the Gasoline Spill Area. Using the acquired data, LLNL is developing both analytic and numeric models to assist in the design of optimal remediation strategies and to satisfy other CERCLA requirements.

VOCs in Unsaturated Sediment and Groundwater

Restoration activities continued at the Livermore site on two areas containing volatile organic compounds and fuel hydrocarbons. Present data indicate that total VOC concentrations exceeding one part per million (ppm) in unsaturated sediment occur in only one area, near Building 518 in the southeast corner of LLNL, where a maximum total VOC concentration of about six ppm was measured in sediments from a depth of about 6.10 m (20 ft). Soil samples from the potential source areas contained total VOC concentrations ranging from less than five parts per billion (ppb) to <500 ppb, with most containing less than 100 ppb. Notable exceptions are the East Taxi Strip and the East Traffic Circle in eastern LLNL, where total VOCs in the vadose zone have been reported in concentrations up to 300 ppb and 800 ppb, respectively.

Livermore Site Groundwater Protection

Eight chlorinated solvents, perchloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), 1,2-dichloroethylene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethane (1,1-DCA), carbon tetrachloride, and chloroform, have been detected in groundwater in the LLNL area in concentrations exceeding Federal or State action levels or MCLs. TCE is the most abundant VOC and occurs in eastern LLNL in concentrations exceeding one ppm. PCE occurs mainly in the southwest part of LLNL and in the adjacent off-site area to the west. PCE also is present in eastern LLNL, where it is subordinate to TCE. Freon 113 has been reported sporadically above its MCL in one well [Monitor Well (MW) 501]. The presence of Freon 113 will be considered in the design of the treatment system for that area.

The VOCs in groundwater in the LLNL vicinity occur in relatively large but diffuse plumes that underlie about 85% of the

LLNL site, representing a total area of about 3.58 km² (1.4 mi²) (**Figure L-G-1**). The calculated volume of VOCs in groundwater is less than 200 gal. The plumes are about 9.14 m to 30.5 m (30 to 100 ft) thick, and VOCs seldom are found below a depth of 61.0 m (200 ft). VOCs have migrated off-site into two areas: (1) about 762 m (2,500 ft) west of Vasco Road onto private property, and (2) about 244 m (800 ft) south of southeastern LLNL onto DOE property administered by Sandia National Laboratories, Livermore (SNLL). Chemical and hydraulic data strongly indicate that a TCE plume northwest of LLNL originates on private property. That plume currently is under investigation by the RWQCB and property owners in that area. For more detailed information, see Isherwood et al. (1990).

Fuels and Aromatic Hydrocarbons

Significant concentrations of FHCs occur only in the Gasoline Spill Area, where about 64,300 L (17,000 gal) of leaded

Figure L-G-2. Tritium concentrations at LLNL, January 1990.

gasoline leaked prior to 1979. Total aromatic hydrocarbon concentrations above one ppm in the vadose zone are 9.14 m to 10.7 m (30 to 35 ft) from the leak point, and diminish to 0.1 ppm within 12.2 m to 13.7 m (40 to 45 ft) of the leak point.

Total fuel hydrocarbon (TFH) concentrations exceeding 10 ppm in groundwater are restricted to the immediate vicinity of the gasoline leak point and decrease significantly in all directions. TFH concentrations ranging from 0.001 to 100 ppm are confined to a roughly oval-shaped area extending from the leak point approximately 107 m (350 ft) to the north and south, 122 m (400 ft) to the east, and 152 m (500 ft) to the west. Benzene concentrations above the 0.001 ppm (State MCL) are restricted to an area within 91.4 m (300 ft) of the leak point. FHCs in groundwater are not present below about 150 ft. The only other FHC reported in concentrations exceeding an MCL is ethylene dibromide, which recent analyses suggest is present in five monitor wells in the immediate vicinity of the gasoline leak point.

Radiological Parameters

Tritium is the only radiological substance present in groundwater in concentrations that exceed an MCL. In the southeast part of LLNL, MW-206 contains tritium slightly above the MCL of 20,000 pCi/L (**Figure L-G-2**). At the time of the Remedial Investigation (RI) (Thorpe et al. 1990), only three other LLNL monitor wells contained detectable concentrations of tritium. Investigations subsequent to the remedial investigation have detected tritium in four other monitor wells in concentrations from 910 to 16,000 pCi/L. The natural 12.3-y half-life for tritium and the slow movement of groundwater ensure that the observed tritium will have decayed to well below the MCL long before migrating off site (Isherwood et al. 1990).

Environmental Restoration

Accomplishments at the Livermore Site

As of December 31, 1990, the following environmental restoration tasks have been accomplished at the Livermore site.

- Taxi Strip Impoundments—Removed soil and cleaned up area.
- East Traffic Circle Landfill—Removed waste and cleaned up area.
- PCB-Containing Units—Remediated affected areas, removing 11 transformers, 12 capacitors, and miscellaneous switch gear.
- Leaking Tanks—Removed 17 tanks and cleaned up affected areas.
- Community Relations Plan—Submitted final plan to regulatory authorities.
- Community Relations Group—Established work group with regularly scheduled meetings and a quarterly publication to keep members informed.
- Quality Assurance Project Plan—Submitted final plan to regulatory authorities.
- Work Plan for RI/FS—Submitted final plan to regulatory authorities.
- Baseline Public Health Assessment—Submitted report to regulatory authorities.
- Began Pilot Studies—Southwest/Offsite Areas and Gasoline Spill Area.
- Potential Conduit Wells—Destroyed and sealed 19 wells to prevent vertical migration of contaminants.
- RI Report—Submitted final report to regulatory authorities.
- Installed Monitor Wells—More than 300 wells drilled, sampled, and flow-tested.
- FS Report—Submitted draft of final report to regulatory authorities.
- Pilot Studies—Treatment Facilities TFA and TFB installed to remove VOCs from the groundwater using an ultraviolet-light/hydrogen-peroxide (UV/H₂O₂) system to oxidize halogenated hydrocarbons. Gas venting system installed to remove hydrocarbons from the unsaturated zone at the Gasoline Spill Area.

Introduction

The Environmental Monitoring Group (EMG) conducts quality assurance (QA) activities at both Lawrence Livermore National Laboratory (LLNL) and Site 300 to comply with *DOE Order 5700.6B* (U.S. Department of Energy 1986). This order sets forth DOE policy, requirements, and responsibilities for the establishment and maintenance of plans and actions that assure quality achievement in DOE programs. The order identifies the American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1, *Quality Assurance Program Requirements for Nuclear Facilities* (ASME 1989) as the preferred quality assurance standard. *DOE Order 5400.1* specifically refers to quality assurance with respect to environmental monitoring and states that a quality assurance program consistent with *DOE Order 5700.6B* shall be established covering each element of environmental monitoring and surveillance. Furthermore, *DOE Order 5400.xy* specifies that the environmental monitoring plan shall contain appropriate QA sections, consistent with the 18-element format of ANSI/ASME NQA-1 regarding all monitoring and surveillance activities at the site. This order specifically identifies QA requirements for radiological effluent and surveillance monitoring.

In addition, the LLNL QA policy states that "all programs and line organizations use QA to assist in providing confidence that objectives will be achieved with due consideration for health, safety, and environmental concerns" (LLNL 1985). Furthermore, the Environmental Protection Department (EPD) QA policy states that "all EPD QA plans must include elements of national consensus standards that are judiciously and selectively applied. ANSI/ASME NQA-1 is the DOE preferred standard for quality assurance." The QA goal for EPD is to "assure that research, development, demonstration, scientific investigations and production activities are performed in a controlled manner; that components, systems and processes are designed, developed, constructed, tested, operated and maintained according to engineering standards, quality practices and technical specifications/operational safety requirements, and that resulting technology data are valid and retrievable."

Environmental monitoring at LLNL takes place in accordance with the above-mentioned DOE orders and LLNL QA policies. A separate QA document has been prepared by EMG that addresses all 18 points of NQA-1 (Holland 1987). Sampling is conducted according to written procedures described in the EMG Procedures Manual (Brekke et al. 1988).

Environmental monitoring samples are analyzed by LLNL or commercial laboratories. When available, EPA standard methods are used to analyze the samples. If EPA standard methods are not available, custom analytical procedures, usually developed at LLNL, are used. The radiochemical methods used by the Nuclear Chemistry Division are described in detail in another report (Garrison et al. 1985). When required analyses are performed by independent contractors, LLNL contracts with laboratories certified by the State of California. LLNL requires its contractors

to maintain adequate quality assurance programs and documentation of methods.

Audits of both contract laboratories and on-site laboratories are required as part of the EMG QA plan. Furthermore, both internal and independent audits of EMG are performed annually.

DOE Tiger Team Audit

An independent audit regarding the status of Environment, Safety, and Health (ES&H) Programs at LLNL was conducted by the U.S. Department of Energy Tiger Team from February 26 to April 5, 1990. The audit was conducted by a team comprised of professionals from DOE, contractors, and consultants. The audit was comprehensive and assessed the full range of environmental monitoring and compliance activities.

The Tiger Team concluded that all operations could continue at LLNL; no curtailment or cessation of any activities was warranted. However, the Team did note several findings in the U.S. Department of Energy, Environment, Safety, and Health, *Tiger Team Assessment of the Lawrence Livermore National Laboratory*, April 1990, DOE/EH-0142 (Draft) (U.S. DOE 1990), some of which directly involved environmental monitoring and analytical laboratory activities. In general, Tiger Team findings corroborated self-assessment findings. The Environmental Monitoring Group participated fully in the audit and in the preparation of the LLNL action plan response to the draft Tiger Team report, *Action Plan in Response to the April 1990 Tiger Team Assessment of the Lawrence Livermore National Laboratory*, September 1990 (LLNL 1990). The Environmental Monitoring Group has also taken steps to comply with the action plan so all deficiencies can be resolved in a timely manner.

Deviations and Changes to the Sampling Program

The following paragraphs describe changes to the environmental sampling effort and also describe those regularly scheduled samples for which data are

not reported because of an inability to collect the sample or loss of the sample during analysis.

Sampling Location Designators. During 1990, sampling location designators for all locations from most media routinely sampled by EMG were renamed using an alphabetic naming system. Previous sample location designator systems were either cumbersome or strictly numerical in nature, making their use prone to typographical errors and other problems. When describing a sampling location, most personnel commonly use the name of the location, such as Altamont Pass, Patterson Pass, FCC, LWRP, Zone 7, etc. The new system uses alphabetic abbreviations of location names (for example: ALTA, PATT, FCC, LWRP, ZON7), and has been applied to the soil, arroyo sediments, surface water, air (particulate and tritium), vegetation, foodstuff, sewage, stormwater runoff, and rain monitoring networks. The new sample location designators are used on maps and tables in this report and will be used in all future publications. **Table L-QA-1** provides a cross-reference between the new location designators and those used in previous years. The great number of sampling locations precludes the use of the new system for the radiation (TLD) monitoring network. Similarly, the system has not been applied to groundwater monitoring wells because the wells already have established names that are used by other groups.

Air Sampling Program. An additional air tritium sampler was installed in the proximity of the on-site swimming pool. During 1990, 864 of 936 possible air particulate samples and 338 of 349 possible air tritium samples were taken as part of the routine monitoring program. These represent sample recovery rates of 92% and 97%, respectively. The EMG Quality Assurance Plan sets a minimum sample recovery rate of 85%. The reasons for lost air particulate samples were usually air sampler malfunction or loss of electric power to the samplers. Two locations were without power for extended periods because of

construction activities; the high-volume particulate sampler at Location PATT was off-line for approximately three months, as was the sampler at Location HOSP. One sample was lost during analysis.

In December 1990, all high-volume air particulate sampler flow controllers were upgraded for more reliable flow control over the sampling period. The flow rate was adjusted to 400 L/min, and the samplers now maintain consistent flow for 24 hr/day over the week-long sampling period. Lost air tritium samples were usually the result of air sampler malfunctions or the breakage of sample flasks. Two samples were lost during analysis.

Sewage Monitoring Program. The Hazards Control Radioanalysis Laboratory reduced its tritium counting time from 200 to 100 min/sample from August 23 through December 31, 1990. This change was necessary to handle an increase in the number of tritium samples. The change resulted in a 40% increase in the tritium limit of sensitivity. On August 27, a change in our LWRP permit required monthly sewage samples to be analyzed for mercury and arsenic. Another change in the permit during December required weekly metals analyses. This requirement necessitated a change in sampling procedures and resulted in reduced gross alpha and gross beta sensitivities, because less sample material was available for each analysis.

A high level of chrome was detected during July because of degradation of a stainless-steel part in the sample collection apparatus. Repairs were made and the equipment was reconfigured to prevent recurrence of the incident. Erroneous tritium data for January through May were corrected when discovered during a routine quality-assurance data check. Lastly, the third quarter water quality sample could not be analyzed routinely due to matrix contamination. The sample was diluted by a factor of 100 prior to analysis for purgeable/extractable pollutants.

Sewage samples from LWRP were not obtained for two days during July, and for

one day during September. Of the 899 scheduled samples from both LLNL and LWRP, 875 were collected and analyzed, a collection efficiency of 97%.

Routine Water Sampling Program. Our rain-monitoring network was expanded to 17 locations and rain and stormwater collections were sought for every rainstorm (see Routine Water Monitoring chapter). Nine of the rain sampling locations have rain gauges as well as collection containers. Unfortunately, rainfall in California was infrequent and of limited quantity. Stormwater runoff and rain samples could not be collected at the normal frequency. This scarcity of rainfall also is the primary reason for reduced data collection efficiency in the surface waters program this year. No other changes were made to the routine water sampling program. Three local water supply wells, monitored annually, could not be sampled because they were dry. Another well had a disabled pump that precluded sample acquisition. Stormwater samples taken on December 10, 1990, were filtered prior to analysis for gross alpha and gross beta activity. Both the filtrate and residue were analyzed. Therefore, there are two gross alpha and gross beta values for that date. Samples taken for tritium analysis were not filtered. Two-hundred-twelve of 227 routine samples were collected, a collection efficiency of 93%.

Vegetation and Foodstuff Sampling Program. No changes were made to the vegetation sampling program. No vegetation was collected at three locations during the third quarter and at one location during the fourth quarter because of a drought-induced lack of available green vegetation.

Milk samples, scheduled to be collected every month, were not always available from the producers. Samples from new locations became available during May and October (Locations COOL, MOD, TUR). Milk was not produced at Location WRD until May. The goats at Location MZF stopped milk production in November. No milk was collected from any suppliers

during January or December. The goats normally do not produce milk during these winter months.

Wine and honey sampling programs were unchanged from 1989.

Environmental Radiation Monitoring Program. No major changes were made to the environmental radiation monitoring program. During 1990, ten of 308 environmental dosimeters (97% collection efficiency) were missing at the time of collection. All the missing dosimeters were from off-site locations. Dosimeter loss usually is a result of construction activities or vandalism. The second quarter neutron sample from Location 4 was lost in analysis. TLDs irradiated by the State of California Department of Health Services to known radiation levels were submitted as standards in the analysis of dosimeters. They were submitted with other quality control samples (blanks and background dosimeters).

Fenceline and off-site radiation now must comply with (be lower than) the new NESHAPS effective dose equivalents of 10 mrem/y. This value is a reduction from the previous DOE-allowed maximum level of 25 mrem/y for whole body, and 75 mrem/y for any critical organ.

Meteorology Monitoring Program. Data recovery from the meteorological monitoring program during 1990 was 100%. Equipment at the meteorological tower was operational for the entire year. New, NIST-traceable, calibrated sensors were installed at both the 10-m and 40-m levels of the tower. Air temperature, wind speed, and wind direction sensors were replaced with newly calibrated instruments twice during the year.

Soils/Sediments Monitoring Program. No changes were made to the soil and sediment monitoring program. All samples were acquired and analyzed according to the Environmental Monitoring Plan (100% collection efficiency). Soil samples were again collected from fixed locations, as described in the 1988 and 1989 Annual Monitoring Report (Brekke et al. 1989; Sims et al. 1990).

Participation in Laboratory Intercomparison Studies

During 1990, LLNL participated in the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program. **Table L-QA-2** shows the comparison of analyses by LLNL with known values. The errors are calculated at the 1- σ level. None of the reported analyses are outside LLNL accuracy goals or the EPA control limits. Contract laboratories also are required to participate in the program; however, permission to publish their results has not been granted.

LLNL also participated in the 1990 intercomparison studies by the DOE Environmental Measurements Laboratory. The data from this study are presented in **Table L-QA-3**. Only one of the analyses falls outside the established 20% accuracy goal. That sample is not of an analyte of concern at LLNL. In addition, LLNL analyses of the intercomparison samples agreed with analyses performed by other laboratories in the study.

Duplicate Analyses. **Table L-QA-4** presents data generated by the duplicate sampling regime. Samples from both the Livermore site and Site 300 are included to provide a larger data set for statistical analysis. The regression analyses for these sample media (where enough data pairs were generated to allow the analyses) show good agreement between routine samples and quality assurance duplicates, with the exception of ^{239}Pu in air samples. These deviations, also seen during 1989, are thought to be caused by the proximity of the levels to detection limits, but remain under investigation by the Nuclear Chemistry Division. Individual ratios of quality assurance duplicates to routine samples did not exceed the data goal of 30%.

Statistical Methods

Data review and analyses are conducted in accordance with the EMG Quality Assurance Plan (Holland 1987) and the EMG Procedures Manual (Brekke et al. 1988). Both documents contain detailed information regarding the acceptability of

data and the procedures that are followed for the identification, notification, and correction of suspect data.

Statistical methods used in this report have been implemented pursuant to *DOE Order 5400.xy*, Chapter VII (Data Analysis and Statistical Treatment) (U.S. Department of Energy 1988d). The methods employed reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Radiological Data. The precision of radiological analytical results is displayed in the data tables as 2- σ counting errors, expressed as a percentage of the associated value. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a 2- σ counting error greater than 100% is said to be at the lower limit of detection (LLD) and is presented in the tables with a less-than sign (<) to indicate its LLD status. However, the actual LLD values are used in the calculations of all summary statistics.

Nonradiological Data. Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than sign (<). As with the radiological data, the actual detection limit values are used in the calculation of summary statistics.

Summary Statistics. Determinations of measures of central tendency and associated measures of dispersion are calculated according to *DOE Order 5400.xy* protocols. For data sets containing few LLDs, measures of central tendency are reported as the arithmetic mean $\pm$ one standard deviation (SDM), with the standard deviation

expressed as a percentage of the mean. For data sets containing many (one-third or more of the total) LLD values, measures of central tendency are reported as the median value $\pm$ the median absolute deviation (MAD, median of the differences of all data values from the median), with the MAD expressed as a percentage of the median. By convention, summary statistics are not expressed with less-than signs (<). The use of LLDs in computations leads to overestimates of the central tendency because the actual values of data expressed as below the detection limit are quite likely less than the LLD value used in the calculations.

Where unusually high values were detected from areas of known contamination, means and standard deviations are calculated both with and without inclusion of the high values. The calculations without high values are reported in parentheses. This procedure was done so that measures of central tendency are not skewed by the presence of the high values. Otherwise, the common use of such data could bias estimates of the overall impact of LLNL operations.

Statistical Comparisons. Standard comparison techniques (t-test and ANOVA) have been used where appropriate for the determination of the statistical significance of the difference between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made, it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word significant in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance, and are based on professional judgment.

Table L-QA-1. LLNL /Livermore Valley sampling location designators, 1990.

Media	Location	Current designator	Previous designator(s)
<u>Air Particulate</u>			
	NW Perimeter (Met Tower)	L-MET	90-13
	Cowbarn	L-COW	90-15
	E Perimeter (Visitors Center)	L-VIS	90-14
	East & Greenville Aves. (Salvage)	L-SALV	90-01
	East Ave. "South" Cafeteria	L-CAFE	90-12
	Mesquite Way	L-MESQ	90-02
	East Ave. Firehouse	L-FIRE	90-17
	Sandia Tanks	L-TANK	90-03
	Zone 7	L-ZON7	90-04
	Patterson Pass	L-PATT	90-05
	Altamont Pass	L-ALTA	90-07
	Residence (N. Vasco Rd.)	L-RRCH	90-06
	FCC Station	L-FCC	90-08
	Livermore City Corp Yard	L-LCCY	90-09
	LWRP Sewer Plant	L-LWRP	90-16
	Livermore VA Hospital	L-HOSP	90-10
	Residence (Mines Rd.)	L-ERCH	90-11
<u>Air Tritium</u>			
	NW Perimeter (Met Tower)	L-MET	93-13
	Cowbarn	L-COW	93-15
	E Perimeter (Visitors Center)	L-VIS	93-14
	East & Greenville Aves. (Salvage)	L-SALV	93-01
	East Ave. "South" Cafeteria	L-CAFE	93-12
	West Parking Lot (Mesquite Way)	L-MESQ	93-02
	East Ave. Firehouse	L-FIRE	93-17
	West of Sandia (Veterinarian)	L-VET	93-S2
	East of Sandia (Cross Road)	L-XRDS	93-S1
	Zone 7	L-ZON7	93-04
	Altamont Pass	L-ALTA	93-07
	Livermore City Corp Yard	L-LCCY	93-09
<u>Goat's Milk</u>			
	Residence (Tesla Road)	L-MZF	91-07
	Residence (Greenville Road)	L-WRD	91-05
	Residence (Lupin Way)	L-LUP	91-13
	Residence (Marina)	L-COOL	—
	Cartoned Milk	C-CART	91-97
	Pre-Pasteurized (Turlock)	C-TUR	—
	Residence (Modesto)	C-MOD	—

...continued

Table L-QA-1. LLNL /Livermore Valley sampling location designators, 1990.

Media	Location	Current designator	Previous designator(s)
<u>Vegetation</u>			
	Patterson Pass	L-PATT	95-04
	Zone 7	L-ZON7	95-15
	I-580 & Greenville Road	L-I580	95-20
	Aqueduct	L-AQUE	95-23
	North of LLNL: Railroad Tracks	L-RAIL	95-29
	Vasco Road (West of LLNL)	L-VASW	95-31
	Tesla Road (West)	L-TESW	95-32
	FCC Station	L-FCC	95-33
<u>Soil</u>			
	Mesquite Way	L-MESQ	L-02
	Sandia Tanks	L-TANK	L-03
	Zone 7	L-ZON7	L-04
	Patterson Pass	L-PATT	L-05
	FCC Station	L-FCC	L-08
	Livermore VA Hospital	L-HOSP	L-10
	NW Perimeter (Met Tower)	L-MET	L-13
	E Perimeter (Visitors Center)	L-VIS	L-14
	Cowbarn	L-COW	L-15
	NE Corner Perimeter Fence	L-NEP	L-18
	LWRP Sewer Plant (1/3 N)	L-WRP1	L-19
	LWRP Sewer Plant (2/3 N)	L-WRP2	L-20
	LWRP Sewer Plant (NW)	L-WRP3	L-21
	LWRP Sewer Plant (1/3 W)	L-WRP4	L-22
	LWRP Sewer Plant (2/3 W)	L-WRP5	L-23
	LWRP Sewer Plant (SW)	L-WRP6	L-24
<u>Arroyo Sediment</u>			
	Central Drainage Basin	L-CDB	CDB
	Arroyo Las Positas East	L-ALPE	ALPE
	Arroyo Las Positas West	L-ALPW	ALPW
	Arroyo Seco North	L-ASN	ASN
	Arroyo Seco South	L-ASS	ASS
	Arroyo Seco East	L-ASE	ASE
<u>Sewage</u>			
	Building 196	L-B196	LLNL
	LWRP	L-LWRP	LWRP

...continued

Table L-QA-1. LLNL /Livermore Valley sampling location designators, 1990 (concluded).

Media	Location	Current designator	Previous designator(s)
<u>Runoff</u>			
	Arroyo Las Positas (E of LLNL)	L-ALPE	01
	Central Drainage Basin	L-CDB	02
	Arroyo Las Positas (NW boundary)	L-ALPW	03
	Arroyo Seco E. (influent to Sandia)	L-ASE	04
	Arroyo Seco South (W. Parking Lot)	L-ASS	05
	Arroyo Seco North (Vasco/East Ave.)	L-ASN	06
	East of B-438	L-438E	—
	Arroyo Las Positas (N at cowbarn)	L-ALPN	—
	4th and A Streets	L-4THA	—
<u>Rain</u>			
	Zone 7	L-ZON7	—
	Cowbarn	L-COW	—
	FCC Station	L-FCC	—
	Del Valle/Zone 7	L-DEL7	—
	Camp Parks	L-PARK	—
	Vineyard	L-VINE	—
	NW Perimeter (Met Tower)	L-MET	—
	Residence (South L St.)	L-SLST	—
	Residence (Buena Vista Ave.)	L-BVA	—
	Visitors Center	L-VIS	—
	Building 291	L-B291	—
	Central Drainage Basin	L-CDB	—
	Greenville and Tesla Rds.	L-GTES	—
	East of Sandia	L-ESAN	—
	Building 343	L-B343	—
	Aqueduct	L-AQUE	—
	East & Greenville Aves. (Salvage)	L-SALV	—
<u>Water</u>			
	Del Valle Lake	L-DEL	92-11
	Zone 7	L-ZON7	92-15
	Springtown Duck Pond	L-DUCK	92-16
	Gas Station Tap Water	L-GAS	92-19
	Arroyo de Laguna (Sunol)	L-ALAG	92-24
	Shadow Cliffs	L-SHAD	92-26
	Calaveras Reservoir	L-CAL	92-29
	Building 151 Tap Water	L-TAP	92-30
	Residence (Palm Ave.)	L-PALM	92-31
	Private Well	L-ORCH	92-34
	Residence (Bell Ave.)	L-BELL	92-37
	LLNL Pool	L-POOL	92-43

Table L-QA-2. Quality assurance analyses for the EPA's Environmental Radioactivity Laboratory Intercomparison Studies Program, 1990.^a

Analysis	Media	Value reported (pCi/L $\pm$ 1 σ)		Normalized deviation from the known value ^b
		LLNL	Known	
Tritium	Water	4963 $\pm$ 74	4976 $\pm$ 498	-0.04
		2937 $\pm$ 59	2933 $\pm$ 358	0.02
		7607 $\pm$ 112	7203 $\pm$ 720	0.97
Gamma ¹³⁷ Cs	Air (pCi/filter)	12.3 $\pm$ 2.9	10.0 $\pm$ 5.0	0.81
		22.0 $\pm$ 0.0	20.0 $\pm$ 5.0	0.69

^a All data were provided by LLNL's Nuclear Chemistry Division.

^b Acceptable deviations are between -2 and 2 (-2 < x < 2).

Table L-QA-3. Quality assurance for the DOE Environmental Measurements Laboratory (EML) Quality Assessment Program, 1990.^{a,b}

Analysis	Media	LLNL value	EML value	LLNL/EML ratio
⁷ Be	Air	54.3	51.4	1.06
⁵⁴ Mn		10.3	9.6	1.07
		33.6	33.3	1.01
⁵⁷ Co		9.0	6.5	1.38
		12.5	11.4	1.10
⁶⁰ Co		8.9	9.4	0.94
		23.1	25.4	0.91
¹³⁴ Cs		16.1	18.2	0.88
		17.9	16.3	1.10
¹³⁷ Cs		22.3	20.4	1.09
		16.2	15.7	1.03
²³⁸ U		2.1	2.0	1.04
		1.1	1.0	1.10
²³⁹ Pu		0.036	0.039	0.92
		0.046	0.051	0.90
⁴⁰ K	Soil	433	513	0.84
¹³⁷ Cs		201	196	1.03
²³⁹ Pu		196	212	0.92
	Water	1.29	1.15	1.12
³ H		1,800	1,960	0.92
		4,330	3,900	1.11
⁵⁴ Mn		95.4	103.0	0.93
⁵⁷ Co		190	198	0.96
⁶⁰ Co		167	206	0.81
¹³⁴ Cs		385	462	0.83
¹³⁷ Cs		188	198	0.95
¹⁴⁴ Ce		427	403	1.06
²³⁹ Pu		1.25	1.04	1.21
		0.94	1.09	0.86

^a All values are relative. The exponents are not included; therefore, values do not indicate actual concentrations.

^b All data were provided by LLNL's Nuclear Chemistry Division.

Table L-QA-4. Quality assurance—duplicate sampling, selected parameters, 1990.

Media	Parameter	Data capture (%) ^b	Precision ^c	Ratio ^d	Regression analysis ^a		
					Correlation coefficient	Slope	Y-intercept
Sewage		97					
LLNL	³ H		13.12/−36.10		0.98	1.004	−160 pCi/L
LWRP	³ H			0.94			
Water		93					
Livermore Valley	³ H		20.64/−23.52		0.99	1.001	−43 pCi/L
Vegetation		93					
Livermore Valley	³ H			1.08			
Site 300	³ H			1.20			
Air		95					
	²³⁹ Pu		91.55/−90.98		0.27	0.126	0.09×10^{-17} μCi/mL
	³ H		76.82/−53.70		0.95	0.939	240 pCi/L
	²³⁸ U		8.55/−23.15		0.95	0.993	-4.0×10^{-6} μg/m ³
Soil	²³⁹ Pu	100		0.89			
Groundwater		98					
	TOC		13.90/−21.29		0.84	0.71	0.23 mg/L
	Conductivity		6.22/−10.04		0.99	0.95	21.94 μmhos/cm
	As		8.45/−6.07		0.99	1.01	−7.12 mg/L
Milk	³ H	90		1.00			

^a Only calculated for data sets with more than 8 valid data pairs.

^b Ratio of samples collected for that medium to the number of samples scheduled to be collected.

^c Calculated according to the methodology in *Quality Assurance Handbook for Air Pollution Measurement Systems* (EPA 1976) for data sets with more than 8 valid data pairs.

^d Only used for data sets with less than 8 valid data pairs. Value is ratio of QA sample/routine sample.

Site 300
Aerial view
looking east

Introduction

The environmental effects of Site 300 operations are influenced by location, climate, and geology. For example, the dispersal of airborne emissions from the site is controlled by wind patterns and rainfall. Data on wind and rainfall are used to calculate the effects of emissions on nearby populations. Similarly, any contamination of groundwater and leaching of contaminants to groundwater, and their subsequent dispersal, are constrained by the particular geology of the site. This chapter is a brief overview of facts about Site 300 surroundings that are used in determining environmental effects of various emissions.

Location

Site 300 is Lawrence Livermore National Laboratory's (LLNL's) high-explosives (HE) testing site. It is located 24 km (15 mi) east of the Livermore site in the Altamont Hills of the Diablo Range and occupies an area of 30.3 km² (10.2 mi²). Two additional HE testing facilities are located in close proximity to Site 300. To the east, and adjacent to Site 300, is a testing facility operated by Physics International. A similar facility operated by SRI International is located approximately 1 km (0.6 mi) south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300. Wind turbine generators are present northwest of the site. The remainder of the land around Site 300 is in agricultural use, primarily grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 25,000), located 10 km (6 mi) to the northeast.

Climate

The climate at Site 300, while generally similar to the Livermore site, is modified by higher elevation and greater relief. The temperature range is somewhat more extreme than the Livermore site, and surface wind patterns are influenced by local topography. Annual wind data are presented in **Figure 3-SET-1** and **Table 3-SET-1**. Rainfall for 1990 was 170 mm (6.71 in). For the 18-y period from 1973 through 1990, the average rainfall was 263 mm (10.34 in).

Figure 3-SET-1. Wind rose showing the average annual wind speed frequency of occurrence and direction at Site 300 for 1990.

Table 3-SET-1. Average annual percent frequency of wind direction at 10-m level versus wind speed (m/s) for Site 300, 1990. Winds are based on one-hour averages. (Row and column totals do not add up due to rounding of numbers.)

Direction	0.0-0.9 Calm	1.0-2.9	3.0-4.9	5.0-6.9	≥7.0	Total
N	0.4	1.6	1.0	0.9	0.4	4.3
NNE	0.4	1.0	0.1	0.0	0.0	1.6
NE	0.4	1.3	0.0	0.0	0.0	1.8
ENE	0.4	1.7	0.0	0.0	0.0	2.1
E	0.4	1.2	0.0	0.0	0.0	1.6
ESE	0.4	0.9	0.0	0.0	0.0	1.3
SE	0.4	0.6	0.1	0.0	0.0	1.1
SSE	0.4	1.0	0.1	0.1	0.0	1.6
S	0.4	2.8	0.7	0.6	0.2	4.6
SSW	0.4	1.4	0.1	0.2	0.1	2.1
SW	0.4	1.3	0.5	2.5	1.0	5.7
WSW	0.4	2.5	5.3	17.4	5.2	30.8
W	0.4	3.5	4.6	4.3	0.3	13.0
WNW	0.4	2.8	1.4	0.9	0.1	5.6
NW	0.4	5.3	2.3	2.1	0.4	10.5
NNW	0.4	4.5	3.0	2.6	1.7	12.2
Total	6.6	33.4	19.1	31.4	9.4	100.0

Geology

The topography of the site is irregular, with a series of steep hills and ridges oriented along a generally northwest/southeast trend; these hills and ridges are separated by intervening ravines. The elevation ranges from approximately 150 m (506 ft) at the southeast corner of the site to approximately 538 m (1,750 ft) in the northwestern portion.

Knowledge of the geology and hydrogeology of Site 300 is based on regional geologic mapping by Huey (1948), Raymond (1969), and Dibblee (1980). These and subsequent detailed geologic and hydrologic studies were reported in the *Draft California Environmental Impact Report* prepared to support the 1987 renewal of LLNL's contract with the Department of Energy (UC 1986). More recent studies are reported in a series of topical and Remedial Investigation (RI) reports, e.g., Raber (1983), Raber

and Carpenter (1983), Carpenter et al. (1983, 1986, 1988), Taffet and Lamarre (1988), Taffet et al. (1989a), Crow and Lamarre (1990), and McIlvride et al. (1990). Detailed geologic and hydrogeologic investigations continue and will be discussed in subsequent reports.

Site 300 is underlain primarily by Tertiary sedimentary rocks of the Pliocene and Miocene. Two stratigraphic units contain bedrock aquifers of hydrogeologic significance: the late Tertiary nonmarine sequence (Dibblee 1980), which consists of poorly sorted sandstones, siltstones, and claystones with irregularly distributed channel fills of silty and gravelly sandstones; and the Miocene Neroly Formation, which consists of interbedded sandstones, siltstones, and claystones containing considerable amounts of volcanic ash and some tuff. Two zones in the Neroly Formation are characterized by relatively thick and persistent sandstones that are potential aquifers; these are

informally named the Neroly upper blue sandstone and the Neroly lower blue sandstone. The bedrock is overlain locally by older alluvial and terrace deposits beneath Quaternary colluvium, alluvium, valley fill, and stream deposits. Along the northern and southern borders of the site, older beds crop out. These include the marine Cierbo Formation, locally the Eocene Tesla Formation, and the Cretaceous Panoche Formation, part of the Great Valley Sequence.

The structural geology at Site 300 is complex (see **Figure 3-SET-2**). The axis of the Patterson Anticline extends across the northern part of the site from northwest to

southeast. Two major faults are found at Site 300. The Carnegie Fault, which strikes along the southern boundary, is a regionally significant structural boundary between strongly folded rocks to the south and more gently folded rocks to the north. In the northern part of the site, the Elk Ravine Fault, which strikes southeasterly across the site, offsets beds containing aquifers. Recently, LLNL has mapped previously undiscovered faults in the southwestern part of Site 300; their hydrogeologic significance is not yet clear. However, if the faults extend southeastward, they may cause hydrologic discontinuities in areas under investigation.

Figure 3-SET-2. Topography and groundwater surface elevations at Site 300 (adapted from Crow and Lamarre 1990).

Hydrogeology

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

Small perched aquifers were identified beneath Building 834 in the southeastern part of Site 300 (Carpenter et al. 1983, 1986; Bryn et al. 1990); in the vicinity of Building 815 in the south-central part of the site (Crow and Lamarre 1990); and between Pit 7 and Elk Ravine in the northern part of Site 300 (Buddemeier et al. 1987; Taffet et al. 1989a). The perched spring in the south part of the HE Process Area is an outcrop of the perched aquifer of Building 815. Other small perched springs and isolated perched aquifers occur, but are not known to be significant to investigations at Site 300. The perched aquifers are not shown on **Figure 3-SET-2**.

Regional aquifers are found in the sandstones of the Neroly formation. A water-table aquifer occurs in the Neroly upper blue sandstone beneath parts of the site; the aquifer is confined in the southern part of Site 300. Lower in the stratigraphic sequence, in the Neroly lower blue sandstone, the aquifers usually are confined, with some artesian head, except in the northwest, where the water is unconfined. Wells completed in the water-table aquifer tend to produce less water than wells completed in the confined aquifers. These shallower aquifers are not used to produce drinking and process water.

A thick Neroly sandstone, stratigraphically near the base of the formation,

contains confined water. Wells 18 and 20, completed in this aquifer, are used to supply drinking and process water; these wells are located in the western part of the General Services Area.

Interstitial permeability is generally low in the Neroly sandstones. However, these beds usually are strongly fractured, and much of the water flowing to wells probably moves through these fractures. Hydraulic tests indicate that hydraulic conductivity varies widely, from the range of 1×10^{-3} cm/sec in the better wells, approximately 1×10^{-4} cm/sec in average wells, to a low in the range of 1×10^{-6} cm/sec in the smallest producers (Buddemeier et al. 1987; Weiss Associates 1988; Taffet et al. 1989a; Crow and Lamarre 1990).

Figure 3-SET-2 shows the elevation of water in the regional aquifer at Site 300. The contours are based on water levels in aquifers present beneath those parts of Site 300 where water level measurements are available. The map of the piezometric surface (defined as the level to which water rises in a well penetrating an aquifer, whether the aquifer is unconfined or confined) is based primarily on water levels in the Neroly lower blue sandstone aquifer, except in the northwest part of the site near Pit 7 and Building 851. In that region, the water contoured is in a perched aquifer. The aquifer in the Neroly lower blue sandstone is under water-table conditions similar to those in the northwestern part of the site; the aquifer becomes confined to the southeast. The hydraulic head increases progressively in that direction. In the General Services Area, some wells completed in this aquifer flow spontaneously.

Generally, the piezometric surface is controlled by the structural configuration of the aquifers. The direction of flow, perpendicular to the contours of the piezometric surface (**Figure 3-SET-2**), is to the northeast in the northern part of the site, becoming generally southerly to southeasterly in the southern part of the site.

Introduction

This section briefly describes additional environmental activities performed by Lawrence Livermore National Laboratory (LLNL) to comply with Federal, State, and local laws and regulations at Site 300. These related environmental activities were performed by the Environmental Protection Department. Included is a description of environmental permits issued to or held by LLNL for Site 300 during the year. A table of public hearings, regulatory inspections, and regulatory permits is presented in **Table 3-C-1**. For further information about these activities, the interested reader is referred to the documents contained in the Information Repositories located at the LLNL Visitors Center and the City of Livermore Public Library. In addition, a list of 1990 Environmental Protection Department publications is presented in **Appendix D**.

Summary of Permits

Air	Nine Permits to Operate various equipment.
Water	Waste Discharge Requirements Order 80-184 for Class II-1 solid waste landfills. Waste Discharge Requirements Order 82-105 for cooling tower discharges (Also an NPDES permit). Waste Discharge Requirements Order 85-188 for sanitary and industrial wastewater discharges to ponds and septic systems.
Hazardous Waste	Part B permit CA2890090002 for hazardous waste storage and Interim Status for open burning of high explosives.
Tanks	Paid fees for 15 tanks.

Department of Energy Tiger Team

DOE conducted the Tiger Team Assessment of LLNL Environmental, Safety, and Health Programs from February 26 through April 5, 1990. The Team concluded that curtailment or cessation of any LLNL operations were not warranted and that compliance issues identified by the Team were known to Federal, State and local regulatory agencies. The Team concluded generally that "environmental and safety

activities are informal, fragmented, and inconsistently implemented" and that LLNL needed to "change the culture" to attain consistent and verifiable compliance with statutes, regulations, and DOE orders. Specific findings are detailed in the Tiger Team's Assessment (U.S. DOE 1990).

In response to this report, LLNL developed an Action Plan whereby the Laboratory committed to correct deficiencies identified by the DOE Tiger Team Assessment and by self-assessments. This Plan describes changes in organizational structure to strengthen line management responsibility and accountability for ES&H/QA issues; self-assessment activities to identify, resolve, and prevent future noncompliance with regulations; and commitment of significant funding for corrective actions. Details of the Action Plan are found in the report (LLNL 1990).

Resource Conservation and Recovery Act (RCRA) Hazardous Waste Management Activities

The Resource Conservation and Recovery Act (RCRA) provides the framework at the Federal level for regulating the generation and management of solid wastes, including those that are designated as hazardous. Similarly, the California Hazardous Waste Control Law (HWCL) sets requirements for the management of

Site 300 Compliance Summary

hazardous wastes in California. RCRA and HWCL regulate treatment, storage, and disposal facilities through permit programs administered by the U.S. Environmental Protection Agency (EPA) and the California Department of Health Services (DHS), respectively. Both permit processes require regulatory agency review and approval of a facility's Part A and Part B permit application. Applications provide information on the facility and on wastes managed at the facility.

Waste Minimization. The Laboratory instituted a Waste Minimization Program and submitted a Waste Minimization Program Plan to DOE in May 1990. The Plan meets the requirements of *DOE Orders* 5820.2A and 5400.1, RCRA sections 3002(b) and 3005(h), and 22 *California Code of Regulations*. The Plan contains a general waste minimization plan for the whole Laboratory and incorporates a series of waste minimization "miniplans" tailored to the specific needs of individual programs and directorates that generate hazardous waste.

Hazardous Waste Permits. Landfill Pits 1 and 7 were operated at Site 300 under provisions of the Interim Status Document CA2890090002 until November 1988, when their use ceased. The landfills had been used for disposing firing table gravel and debris. The proposed landfill Closure and Post-Closure Plans were under review by the EPA, RWQCB, and DHS during 1990. The plans were submitted for public review and comment in December 1990. Upon completion of the review and approval process, the landfills will be closed. The closure activities are expected to occur during the summer of 1991. The Site 300 Building 883 Hazardous Waste Container Storage Facility was operated in 1990 under provisions of Part B permits issued by EPA and DHS in November 1989. These permits allow the facility to store specific wastes in containers, provided that certain administrative and operational conditions are met.

A high-explosives burn facility continued operation at Site 300 during 1990 under interim status standards.

Inspections. EPA inspected the RCRA-regulated units at Site 300 on March 21, which resulted in a Warning Letter being issued to LLNL on June 28, 1990. This letter included the inspection report, which identified conditions at the facility at the time of the inspection, areas of noncompliance with RCRA regulations, and potential RCRA violations. Specific observations identified in the inspection report include:

- Hazardous wastewater storage for more than 90 days in a portable tank, and records of weekly inspections for leaks or deterioration were not available;
- Accumulation start dates not identified on labels for two waste containers held at a waste accumulation area (WAA);
- The emergency coordinator was not clearly defined in contingency plans;
- Training records lacked a description of the hazardous waste training requirements;
- Employees working alone did not have immediate access to external emergency assistance at one WAA;
- Three plans used at Site 300 to respond to various contingencies were incomplete and inconsistent;
- A written report of a leak from a retention tank containing oily wastewater was not filed with EPA;
- An exception report was not filed for one manifest; the waste minimization plan was not submitted to regulatory agencies by December 27, 1989;
- Signs were needed to designate storage areas within the permitted storage area;
- A container of lead shot (D008) was observed in the permitted storage unit, although that waste stream is not identified in the permit;
- Land disposal restriction (LDR) notifications were not provided with three manifests;
- The appropriate treatment standard was not marked on one manifest;
- The proper EPA waste code was not shown on one waste container filled with Freon.

In response to these observations, LLNL made the necessary corrections and provided EPA with documentation to support

the corrections. EPA sent LLNL a letter dated August 22, 1990, which stated that LLNL had addressed the violations and documented the facility's return to compliance with the regulations cited in the inspection report.

DHS notified LLNL in a letter dated June 26, 1990, that based on review of the revised Part B permit application received January 26, 1989, and observations made in a September 29, 1988, DHS inspection report, that Table III-1 of the Waste Analysis Plan incorrectly identified the waste code for one category of solvents. This inaccuracy subsequently was corrected and submitted to the agencies. DHS responded with a Return To Compliance letter dated January 30, 1991.

On August 8, DHS toured the two landfills being considered for closure pursuant to the Closure/Post-closure Plans originally submitted in 1988. This tour was an opportunity for DHS staff and management to become more familiar with the project and the proposed closure activities.

Staff from EPA viewed the Environmental Restoration Division groundwater investigation activities in the eastern General Services Area on November 14 as part of their general oversight of the CERCLA investigations.

Waste Accumulation Areas. A waste accumulation area is an officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before pickup by the Hazardous Waste Management Division for transport to Building 883 or to a permitted off-site hazardous waste management facility.

There are 15 WAAs at Site 300, four of which were established in 1990.

RCRA Personnel Training. Annual training sessions and as-needed briefings in the area of waste handling practices are conducted for generators of hazardous waste. This training is based on requirements set forth in 40 *Code of Federal Regulations* Part 265.16 and 22 *California Code of Regulations* Section 67105. Employees learn to identify the basis (i.e., legal, regulatory,

policy, and DOE orders) for LLNL waste practices and the respective waste-management responsibilities of waste generators, Environmental Analysts, or Hazardous Waste Management field technicians. The course also includes training in identification of factors used to determine if a waste is hazardous, in the determination of the need for permits and controls, and in the reduction of the volume of waste to be discharged. Other topics include preparation of waste for transport and for storage in WAAs, the protocol for sampling waste, preparation of documentation for waste disposal, and response to emergencies at the WAA or in a laboratory or a shop. During 1990, a total of 1,926 LLNL Livermore site and Site 300 employees received this training.

Resource Conservation and Recovery Act (RCRA) and Other Federal and State Regulation of Storage Tanks

Federal and State laws provide comprehensive regulation of the design, operation, monitoring, and closing of tank systems that contain hazardous products or hazardous waste. The California Underground Tank Regulations, found in 23 *California Code of Regulations* Chapter 3, Subchapter 16, regulate underground tank systems (USTs) used for containment of hazardous products or hazardous waste. The County Health Department, San Joaquin County Public Health Services (SJCPHS) has been delegated authority by the Regional Water Quality Control Board to enforce these regulations. Federal standards for hazardous products and petroleum products contained in underground storage tanks (USTs) are found in 40 *Code of Federal Regulations* Part 280, and standards for hazardous wastes in tanks (both aboveground and underground) are the subject of RCRA regulations in 40 *Code of Federal Regulations* Part 265.

Underground tanks at Site 300 contain diesel fuel, gasoline, and potentially contaminated wastewater; aboveground tanks contain diesel fuel, insulating oil,

trichloroethylene, and potentially contaminated wastewater. Some of the wastewater systems are a combination of underground and aboveground tanks. Site 300 currently has 11 aboveground and 16 underground tanks in service, 22 of which contain hazardous products and five contain waste.

To ensure that LLNL's UST program is in full compliance with Federal and State regulations, a preliminary classification of USTs according to hazardous or nonhazardous storage was made in 1989, based on existing data and known uses for each tank. In a second phase, these classifications will be verified by an extensive sampling program.

Tank Integrity Testing. As part of the tank leak-tightness testing program, underground tank systems are tested to determine their structural integrity in accordance with testing requirements set forth in Federal and State regulations. Single-walled underground wastewater systems are tested, including those not presently regulated. The underground portions of tank systems are tested, as a whole or by component parts, using methods that may include precision tests, dye tests, helium-injection detection, and hydrostatic tests. All leak-tightness test results for regulated systems are provided to SJCPHS. Eleven underground diesel fuel and gasoline systems were tested in 1990 and found to be leak-tight.

Three underground wastewater retention tanks were tested for leak tightness in 1990. These systems receive and retain oily wastewater from floor cleanup and steam-cleaning operations. Water is retained by these systems until the appropriate mode of disposal has been determined, based on the analyses of representative samples. Testing in 1990 determined the wastewater systems to be leak-tight. Testing included a newly installed tank that replaced one removed in 1989.

LLNL has established a daily program to reconcile daily the inputs into and withdrawals from underground vehicle-fuel tank systems. The underground diesel fuel

tanks that serve as fuel supplies for emergency generators are monitored according to a program of routine tank gaging and reconciliation. The results of the program are reported to SJCPHS quarterly.

Underground Tank Fees. LLNL has paid annual fees to SJCHD for 15 petroleum tanks at Site 300. All of these tanks are in service.

Inspection. On three occasions in 1990, SJCPHS visited Site 300 to witness soil sampling that was part of closure activities for three underground tank systems. On May 30, 1990, soil sampling was performed to complete closure of the already-removed underground diesel fuel tank system at Building 873. On June 27 soil sampling was performed coincident with the removal of the diesel fuel tank at Building 874, and on November 11 soil sampling was performed in conjunction with the removal of a small underground tank that received drainage from a drum storage area (since removed) at Building 875.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Superfund Amendments and Reauthorization Act (SARA)—Title I

Also known as the Superfund Act, CERCLA is a Federal statute that gives the Environmental Protection Agency the authority to identify and clean up hazardous chemicals and substances released to the environment.

At Site 300, ongoing remedial investigations, feasibility studies, and remedial actions are being performed. As discussed in the *Environmental Report for 1989*, in March 1989 EPA sent LLNL a proposed RCRA cleanup order under provisions of RCRA 3008(h); in July 1989 EPA nominated Site 300 for inclusion on the National Priorities List (NPL). In August 1990 EPA placed Site 300 on NPL to be regulated under authority of CERCLA. In October 1990, EPA agreed to suspend negotiations on the March 1989 RCRA 3008(h) Administrative Order in favor of a Federal Facility Agreement (FFA). EPA chose to negotiate

an FFA that would encompass the environmental restoration requirements of RCRA as well as CERCLA. The negotiations began in the fall of 1990 and are ongoing. An Interim Letter of Agreement was signed by EPA, DOE, and UC in October 1990. Until these negotiations are completed, investigations and remedial actions continue under the joint oversight of EPA, RWQCB, and DHS. The areas of investigation include the following: TCE in soil, rock, and/or groundwater at the Building 834 complex; HE Process Area; the General Services Area; Pit 6; the Pit 7 Complex; Pit 8; high-explosives (HE) compounds in the HE Process Area; and tritium in the Pit 7 Complex and the Building 850 area. Highlights of these activities are presented below.

Remedial Investigations/Feasibility Studies (RI/FS). At Site 300, a number of Draft Remedial Investigations (RI) and Feasibility Studies (FS) were completed during 1990. Remedial actions continue. Details can be found in the LLNL Site 300 Environmental Investigations Quarterly reports (UCAR-10194-90-1 through 4).

These reports, usually written separately, present the results of investigations in a given study and are submitted to cognizant regulatory agencies for consideration of appropriate choices for remediation. The RI reports include detailed discussions of the environment, geology and geohydrology, environmental risk of any toxic chemicals encountered, and assessment of the risk to the public health and safety. The FS reports include proposals for alternatives for remedial action alternatives with cost estimates under several conditions, from no action to full remediation. Short summaries are included here; the RI and FS reports should be consulted for details. At the end of 1990, comments on these reports had not been received from regulatory agencies.

General Services Area. Draft RI report (McIlvride et al. 1990) and Draft FS (Ferry et al. 1990)—Volatile Organic Compounds (VOCs) have been identified in the shallow groundwater beneath the GSA in three localities. One plume is in the western part

of the area; three small plumes are in the central GSA; and one plume is in the eastern GSA. The eastern GSA plume extends about 4,000 ft off site in the gravels of Corral Hollow Creek. A groundwater treatment unit to remove VOCs was designed and fabrication begun. The required permits are anticipated.

Building 834 Complex. Draft RI/FS report (Bryn et al. 1990)—An isolated, perched aquifer that contains TCE has been defined. Techniques for removal of TCE vapor from the vadose zone above the water table and from the shallow perched water have been designed and pilot-tested. However, it was concluded that the water containing VOCs presents no threat to the underlying drinking water aquifer because they are separated by approximately 250 ft of low-permeability rock. The Draft FS report includes various remediation alternatives.

High-Explosives (HE) Process Area. RI report (Crow and Lamarre 1990)—The groundwater beneath a small part of the HE Process Area near Buildings 815 and 817 contains low concentrations of the HE compound RDX. Trace concentrations of HMX in water from one well were detected at concentrations very near the detection limit. The area where HE compounds are present in the groundwater has been successfully bounded. TCE has been detected at levels above MCLs in the first two aquifers beneath an area near and to the southeast of Building 815. Subsurface investigations to identify the bounds of the TCE plume are being conducted using exploratory monitoring wells.

Several new monitoring wells were drilled in the central and northwestern parts of the HE Process Area to determine whether significant quantities of contaminants were present. No significant contamination was found in water from any of the wells.

East and West Firing Areas. Draft RI of the Building 850/East Firing Area (Taffet et al. 1991)—This report discusses the distribution of low concentrations of tritium in the groundwater near the firing table at

Building 850, in the alluvium in Doall Ravine to the southeast, and in the adjacent part of the East Firing Area to the southeast along Elk Ravine.

Pit 6 Area. Draft RI of Pit 6 Landfill Area (Taffet 1990)—Pit 6 is underlaid by a small plume of TCE in groundwater that discharges to the surface at small springs at the southeastern edge of the Pit 6 Area.

Dry Wells RI. Some dry wells could not be evaluated in time for inclusion in the dry wells RI report (Lamarre et al. 1989). These dry wells were investigated and reported in a letter (Hoffman 1990). Investigations of these dry wells indicated that the concentrations of metals, VOCs, and HE compounds detected in soil and rock samples collected near them present no threat to the drinking water aquifers.

Carnegie Fault Zone Investigation. In April 1990, during geologic mapping in the vicinity of Pit 6, a fault showing evidence of Holocene displacement was observed in a cut slope on State of California property (the State Vehicle Recreation Area manager's residence), about 1,000 ft southeast of the landfill. As a result of subsequent detailed geologic investigations, which included logging of 1,184 ft of exploratory trenches and other excavations, it has been determined that the fault represents a potentially active strand of the Corral Hollow-Carnegie Fault Zone located generally south and west of the Site 300 property. The potentially active fault passes a minimum of 100 ft south of Pit 6, and poses no direct hazard to the landfill itself.

Building 823 Disposal Site. In the HE Process Area, a Site Investigation of a disposal site west of Building 823 (Crow et al. 1990) was completed. Several shallow aquifers were found; the shallowest one contained TCE at concentrations below the MCL for that substance. It was concluded that the VOCs did not threaten drinking water supplies and pose no threat to public health and safety.

Paper Canyon Area. In the Paper Canyon area east of Pit 6, two wells were drilled in 1989, near the downgradient

end of a landfill. Water from these wells has been sampled for four quarters, and no VOCs were detected. It was concluded that the disposal site has no impact on area groundwater quality.

Additional Soil Vapor Surveys at Building 833 and in the GSA. In 1989 and 1990, soil vapor surveys near Building 833 and parts the GSA were used as a semi-quantitative diagnostic technique to assess distribution of VOCs in the soil. One technique uses a vacuum probe in shallow boreholes to transfer soil gases to an on-site gas chromatograph.

As part of a study funded by HAZWRAP, a second soil vapor survey using the PETREX technique was performed in the spring of 1990 in the same general areas. The PETREX study had two results: first, its results compared well with results of the survey that used the vacuum probe technique; second, because the PETREX survey covered areas not included in the vacuum probe, the study provided additional information about the organic soil vapors near Building 833 and in the GSA.

Sealing and Abandoning Old Production Wells. During 1990, eight unused Site 300 water supply wells were sealed with grout and abandoned. Well construction data for these wells was evaluated. Under certain circumstances, cross-contamination of deeper aquifers with VOCs from shallower aquifers could have occurred.

Geophysical Logging. A QA/QC procedure for downhole geophysical logging was developed.

Superfund Amendments and Reauthorization Act (SARA)—Title III

SARA Title III also is known as the Emergency Planning and Community Right-to-Know Act. It requires owners/operators of facilities that have certain hazardous chemicals on site to provide information on the manufacture, use, and storage of those chemicals to organizations responsible for emergency response planning. In California this information must

be provided to the State Office of Emergency Services, the county, and local fire departments.

A physical inventory of all chemicals subject to reporting under SARA Title III was conducted during November and December 1988. The inventory included the chemical name, the location, the weight, the type of container, and the physical state of the substance. The inventory included the Livermore site, Site 300, and leased space off the site. In early 1989, the data were entered into a computerized database system, and generated reports for local emergency planning agencies. The inventory continues to be updated to reflect changes in chemicals handled on site.

SARA/OSHA Personnel Training. LLNL also provides training for hazardous waste operations and emergency response. This training is based on requirements in 40 *Code of Federal Regulations* Part 1910.120. There are two initial training courses. The first is a 40-hour course geared to general workers performing cleanup operations or investigations, who are engaged in activities that expose (or potentially expose) these workers to hazardous substances and health hazards. The second is a 24-hour course for HWM operators and workers who occasionally are on site only for a specific limited task, and who are unlikely to be exposed over permissible exposure limits. This course also is for employees regularly on site who work in fully monitored and characterized areas where there is minimal potential for exposure to hazardous substances and health hazards. The course covers the hazards of waste sites, the general physical and hazardous properties of chemical compounds, the fundamental toxicological concepts important in determining the toxicity of materials and predicting their effect on exposed individuals, and the physical hazards (heat stress, noise, and ionizing radiation) involved in working at a waste site. The course also covers exposure guidelines, protective clothing and devices, air monitoring, site characteristics, control and safety planning, drum and container

handling, confined-space entry, emergencies, and hazard communication.

SARA/OSHA supervisory training also is offered. This training is an eight-hour course required for personnel who will lead others in the field at cleanup operations and at HWM. The course emphasizes the safety and health program, planning and coordination, site management, personal protective equipment, spill containment programs, and health hazard monitoring procedures.

Toxic Substances Control Act (TSCA)

The Toxic Substances Control Act (TSCA) is a broad statute that empowers EPA to regulate hazardous chemicals (not already regulated by other laws) imported to, produced, or used in the United States. The TSCA regulations that affect the Livermore site are those regulating the storage and disposal of polychlorinated biphenals (PCBs). The PCB annual report, required under 40 *Code of Federal Regulations* 761.180, was prepared and is kept on record, available for EPA inspection.

National Environmental Policy Act (NEPA)

NEPA establishes Federal policy for protection of environmental quality and provides the means to implement that policy. Within NEPA, the major means to achieve established goals is the requirement for Federal agencies to assess the environmental impacts of their decisions through preparation of an Environmental Impact Statement (EIS) for any major Federal or Federally funded project that may have significant impacts on environmental quality. If the need for an EIS is not clear, an environmental assessment (EA) must be prepared with a definitive conclusion: either calling for an EIS, or making a finding of no significant impact (FONSI). In the latter case, no EIS is required.

Groups of actions that individually or cumulatively do not have a significant effect on the human environment can be exempt from the NEPA process by

establishing categorical exclusions. A memorandum was written when a proposed action clearly would have no significant environmental impacts. But because of limited DOE experience, the action had not yet been added to the list of categorical exclusions. DOE discontinued the use of memorandums as of September 1990.

An Action Description Memorandum (ADM) is written when the proposed action is not clearly insignificant. The ADM is used by DOE to determine if an EA or an EIS is needed.

In 1990, more than 122 projects were evaluated under NEPA and under the applicable policies and procedures for DOE compliance with NEPA (*Federal Register* Vol. 52, No. 240, December 15, 1987, as amended). These projects included 20 ADMs, 29 memorandums, and 60 categorical exclusions. Ten projects were determined by DOE to require EAs, one of which was for Site 300 and is described below. Nine of the ten currently are under DOE review. A Finding of No Significant Impact (FONSI) was issued by DOE in June 1990 for the Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL. Three projects were evaluated under CEQA and University of California (UC) procedures for CEQA implementation.

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In addition, *DOE Order 5400.4*, issued October 6, 1989, specifies that the NEPA and CERCLA processes should be integrated by conducting the NEPA and CERCLA environmental planning and review procedures concurrently. During 1990, LLNL prepared three EAs (one at the Livermore site and two at Site 300) for environmental restoration activities.

The EAs (which also meet CEQA requirements) are written as chapters within the Feasibility Study (FS) documents. The two Site 300 documents are entitled *Feasibility Study of the General Services Area (GSA), Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1990) and *Remedial Investigation and Feasibility Study for the Lawrence Livermore National Laboratory Site 300 Building 834 Complex* (Bryn et al. 1990).

Environmental Impact Statement/Environmental Impact Report. In addition to the NEPA/CEQA documents discussed previously, work began on the sitewide EIS/EIR. In October 1990, the DOE published a Notice of Intent (NOI) in 55 *Federal Register* 41048 to prepare a joint EIS/EIR for continued operation of both Lawrence Livermore National Laboratory (operated by UC for the DOE) and Sandia, Livermore (operated by the Sandia Corporation for the DOE). That same month, UC filed a Notice of Preparation (NOP) with the California Office of Planning and Research to prepare a joint EIS/EIR. Both the NOI and the NOP were sent to the California State Clearinghouse for distribution within the state.

Both the NOI and the NOP invited the public to attend a scoping meeting on November 15, 1990, in Livermore, California, and to provide written comments until the close of the comment period, then set for November 30, 1990. At the request of the public, UC, and the DOE subsequently extended the deadline to December 15, 1990.

During the EIS/EIR scoping process, the DOE and UC received a total of 282 comments from 61 members of the public; interested groups; and Federal, State, and local officials.

Endangered Species Act. Staff from the California Department of Fish and Game and the U.S. Fish and Wildlife Service performed their annual inspection of the endangered wildflower, *Amsinckia grandiflora*, on April 4, 1990.

A survey at Site 300 was undertaken at the locations of nine proposed groundwater treatment facilities and discharge

locations that are part of the Site 300 groundwater remediation efforts along Corral Hollow Creek. No sensitive plant or wildlife species were found within the project areas. No habitat suitable to support rare plants exists within the project vicinity. A second survey was conducted for six of these locations that concentrates on locating wetlands and *Amsinckia grandiflora*. The report of the results of this survey currently is being reviewed by LLNL staff.

A thorough survey for the presence of San Joaquin Kit Fox and Waters of the United States and/or wetlands was undertaken for nine areas that could be impacted by Site 300 groundwater remediation activities and for ten dry well locations. The survey for kit fox included night spotlighting, ground surveys for dens, and placement of scent stations in selected locations. The studies did not find conclusive evidence of San Joaquin Kit Fox at Site 300.

No new locations of *Amsinckia grandiflora* were found at Site 300 during any of the 1990 surveys.

National Historic Preservation Act. During 1990, four cultural resource surveys were conducted to ensure that proposed laboratory actions did not affect significant archeological or historical resources. Two of the surveys concerned LLNL's newly acquired land adjacent to Vasco Road. A third archeological survey was conducted for the DOE-proposed acquisition of approximately 14 acres of land adjacent to Site 300. In addition, two buildings at the LLNL main site were assessed prior to their demolition for potential historical significance. Results of all investigations showed that the proposed actions would not affect archeological or historical resources.

Clean Water Act—National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Requirements

Clean water is the subject of Federal, State, and local laws and regulations. The National Pollutant Discharge Elimination

System (NPDES), under the Federal Clean Water Act, establishes the permit requirements for discharges into surface waterways. In addition, the State of California requires permits for any discharges that could adversely affect State waters. The Regional Water Quality Control Boards (RWQCBs) are responsible for issuance and enforcement of both types of permits.

Groundwater and Surface Water Discharge Permits. Site 300 has three permits issued by the Regional Water Quality Control Board. Waste Discharge Requirement, Order 80-184, for a Class II-1 solid waste disposal site pertains to inactive landfills located at Site 300. Waste Discharge Requirement, Order 82-105, is a permit that applies to the cooling tower discharges at Site 300. This permit also is an NPDES permit, because discharges may enter stormwater drainages. Finally, Waste Discharge Requirement, Order 85-188, is a permit for the sewer lagoons, septic tanks, leachfields, and the high-explosives rinse water Class II surface impoundment at Site 300. In May 1990, LLNL submitted an application for another NPDES permit to discharge treated groundwater to Corral Hollow Creek. This application was still under consideration by the RWQCB at the end of 1990.

Inspection. On April 5, 1990, RWQCB performed an inspection of discharges permitted under WDR Order 85-188. No inspection report was received.

Clean Air Act/Air Quality Management Activities

The Clean Air Act is the Federal law that authorizes the EPA to set air quality standards and to assist State and local governments to develop and execute air pollution prevention and control programs. The San Joaquin County Air Pollution Control District (SJCAPCD) is the local agency responsible for enforcing these standards (as well as State and local standards) for air emissions from stationary sources in San Joaquin County.

Air Permits. Site 300 holds nine air permits from the SJCAPCD for the following

equipment: two gasoline station vapor recovery systems, one paint spray-booth, one sawdust collector, and five boilers.

Inspections. On June 12, 1990, the SJCAPCD conducted an inspection of the vapor recovery system; no discrepancies were found.

National Emission Standards for Hazardous Air Pollutants. In October 1989, the EPA issued new NESHAP requirements for radionuclide emissions from DOE facilities. DOE initiated discussions with the EPA to develop a Memorandum of Understanding on how the DOE facilities would achieve compliance with these standards. Pending resolution of the DOE/EPA discussions, LLNL drafted a work plan to satisfy the new requirements and began to assemble information needed to meet the new standards. This information included reviewing operations that employ radionuclides and gathering data for modeling each source. In the work plan, it was projected that a report would be completed by July 1993.

Compliance Summary, First Quarter 1991

This summary updates the environmental compliance status and environmental issues and actions at the Lawrence Livermore National Laboratory during the period January 1 through March 31, 1991. This summary is in the format specified for self-assessments: Compliance Summary, Current Issues and Actions, and Environmental Permits.

Tiger Team Assessment. The Laboratory continues to undertake those actions identified in its Action Plan. The Action Plan was prepared in response to DOE's Tiger Team Assessment of LLNL operations. The Action Plan includes descriptions of the actions to be taken at the site to respond satisfactorily to the findings; to show schedules and due dates for activities; and to identify parties responsible for implementing the Action Plan. The document also identifies actions and costs that are included (or planned for inclusion) in DOE's Five-Year Plan.

A significant amount of progress has been made towards the 573 subtasks identified in the Action Plan prepared in response to the April 1990 Tiger Team Assessment of LLNL and approved by DOE in early October 1990. Of the 573 subtasks identified in the Action Plan, 291 had completion dates prior to the end of the first quarter of FY91. Of this number, 196 were completed, 39 were more than 75% complete, and 56 were less than 75% complete. The majority of those not completed are a result of not being able to acquire qualified staff as fast as originally anticipated.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Groundwater contamination resulting from LLNL historical operations has been detected at Site 300. Environmental restoration activities have been ongoing under the oversight of the California Regional Water Quality Control Board and the U.S. EPA under the Interim Letter of Agreement signed by EPA, DOE, and UC in October 1990. Site 300 was added to the National Priority List in 1990. DOE received a draft Federal Facility Agreement in 1991, and negotiations with EPA, DHS, and the RWQCB are under way.

The document entitled *Draft Feasibility Study of Landfill Pit 6, Lawrence Livermore National Laboratory Site 300* (UCRL-AR-106307) (Taffet 1991) was completed and submitted to the agencies as required by the Interim Letter of Agreement. This report provides a recommendation for remediation consisting of landfill modifications, monitoring, and additional investigations at Pit 6.

The remedial activities completed at Site 300 during the fourth quarter of 1990 are described in the document, *Lawrence Livermore National Laboratory Site 300 Environmental Investigations Quarterly, October-December 1990* (UCAR-10194-90-4) (Carlsen et al. 1990). This document was submitted to the RWQCB by February 15, 1991, as required.

Clean Air Act. Data has been provided to EPA for compliance with the National Emission Standard Hazardous Air

Pollutant (NESHAP) requirements for releases of radioactive emissions from DOE facilities. EPA reviewed the data and found that LLNL had not fully complied with these standards. EPA issued a Finding of Violation and an order to come into compliance to the University of California and the Department of Energy on April 19, 1991. The EPA order requires that every release point from an operation using radio-nuclides must be evaluated using an EPA computer model. The decision to install stack monitoring depends on the outcome of this evaluation. EPA acknowledged in the Finding of Violation document that it appeared that LLNL had monitored and modeled the major contributors to these emissions. Negotiations to further demonstrate compliance with these requirements are being conducted with EPA.

Clean Water Act. A National Pollutant Discharge and Elimination System permit (CA0082651), which allows discharge of treated groundwater from environmental restoration activities being conducted in the General Services Area of Site 300, was issued in February 1991.

Resource Conservation and Recovery Act (RCRA). Proposed and recent changes to the California Hazardous Waste Control Law are being evaluated for impacts on LLNL activities. Of particular concern are the proposed Permit-by-Rule (PBR) regulations and the revisions to the definition of storage.

The PBR regulations will allow certain treatment technologies to be used for certain waste streams without having to complete the formal hazardous waste per-

mitting process. However, these rules do require significant effort to ensure that proper documentation and procedures are followed and are available for inspection. As part of its ongoing efforts to manage wastes better, LLNL is reviewing various proposed operations for application of the PBR requirements.

The 1990 revision to the definition of storage in the California Hazardous Waste Control Law has the potential to bring a number of areas under permit conditions that currently are operated in accordance with generator standards. Discussions are ongoing with the Department of Health Services to understand better the applicability of this regulation to a facility such as LLNL, which has both permitted and generator operations.

Regulatory Agency Inspections. No formal inspection reports were received during the period from January through March 1991 for any of the inspections listed below.

Current Issues and Actions

As discussed in the Environmental Reports for 1989 and 1990, LLNL has been in the process of obtaining approval from the EPA and DHS to close two landfills at Site 300. In a March 25, 1991, letter, EPA and DHS approved the Closure Plan for the two landfills. These landfills were last operated in 1988.

Environmental Permits

Air Permits. Permits are obtained from the Bay Area Air Quality Management District for the Livermore site and from the San Joaquin County Air Pollution

Appraisals/Inspections January–March 1991

Purpose and date

Tour various environmental restoration projects (March 13)

Annual count of *Amsinckia grandiflora*, an endangered flower (March 13)

Performing agency

Environmental Protection Agency

U.S. Fish & Wildlife and California Fish & Game

Site 300
Compliance
Summary

Control District for Site 300, as identified in the Annual Report. As of March 1, 1991, LLNL had received 15 new permits and 23 exemptions, submitted 28 permit applications and 46 exemption requests to the Districts for consideration, and was preparing an additional 7 permit applications and 12 exemption requests.

Water Permits. Site 300 has four water discharge permits. One NPDES permit allows the discharge of water from cooling towers to the ground, and a second recently issued permit allows discharge of treated groundwater to Corral Hollow Creek. One Waste Discharge Order allows

the discharge of high-explosives process water and photo rinse water into a surface impoundment system, as well as the discharge of sewage from buildings into the sanitary sewage systems (leachfields and sewer lagoon). Another Waste Discharge Order applies to inactive landfills.

Underground Tank Permits. Fees have been paid to San Joaquin County for 15 tanks at Site 300.

Hazardous Waste. The Site 300 container storage area is operated under permits issued by the EPA and California Department of Health Services. A high-explosives open burning unit continues to be operated under interim-status standards.

Table 3-C-1. Appraisals/inspections of Site 300 during 1990.

Date	Purpose	Performing agency
Feb.-March	DOE Tiger Team accompanied by regulatory agency representative	DOE, EPA, DHS
March 21	S-300 RCRA inspection	EPA
April 4	Annual <i>Amsinckia grandiflora</i> count	U.S. F&W and California F&G
April 5	S-300 WDR 85-188	RWQCB
May 30	Witness soil sampling at B874 former diesel tank location	SJCPHS
June 12	Vapor recovery system	SJCAPCD
June 27	Inspect tank closure at B874	SJCPHS
Aug. 8	Familiarization tour for landfill closure at Site 300	DHS
End Sept.	View Pit 6 fault	California Mines & Geology
Oct. 11	Water quality	RWQCB-CV
Nov. 5	B875 tank closure	SJCPHS
Nov. 14	View eastern GSA cleanup	EPA
Nov. 13-30	Appraisal of overall tank program	DOE

Introduction

Lawrence Livermore National Laboratory (LLNL) has a substantial continuing commitment to environmental compliance and accountability. Each year, the Environmental Protection Department (EPD) makes a significant effort toward monitoring the environment near the Livermore site and Site 300. In 1990, over 150,000 analyses of environmental samples were performed. This effort, which is conducted in accordance with *DOE Orders* 5400.1 and 5484.1, has three purposes: (1) to assess the effectiveness of pollution control programs, (2) to assess compliance with applicable environmental laws and regulations, and (3) to estimate the impact of operations on the environment. Data are produced from sampling of air, sewage effluent, groundwater and surface water, soil, vegetation and foodstuff, and environmental radiation; the type of samples collected at a specific location depends on the site and the potential pollutants to be monitored. Complete details regarding individual monitoring activities can be found in specific chapters grouped by environmental media. Summary information on monitoring activities can be found in the Environmental Radiological Program Summary, the Environmental Nonradiological Program Summary, and in the Radiological and the Nonradiological Methods Appendices.

Although its monitoring activities are quite comprehensive, the main mission of the Environmental Protection Department is to interact with laboratory programs to ensure that operations are conducted in a manner that limits environmental impacts to levels consistent with regulatory guidelines. The activities that are required by environmental statutes are described in the Compliance Summary chapter. The remainder of this chapter describes those activities, carried out by EPD at Site 300, that were mandated by DOE or implemented independently by LLNL.

Environmental Protection Department

The Environmental Protection Department comprises four divisions: Environmental Guidance, Environmental Restoration, Hazardous Waste Management, and Regulatory Affairs. Working with LLNL programs, the EPD assures that LLNL can meet its environmental responsibilities as stipulated in environmental legislation, regulations, and DOE orders.

Environmental Guidance Division. The Environmental Guidance Division helps LLNL programs and organizations to operate in an environmentally sound manner

and to meet compliance requirements. Specifically the Division staff:

- Advises and trains program personnel on regulatory compliance, waste minimization, and pollution abatement;
- Identifies and alerts program line management of potential environmental contamination and compliance problems in the early project planning stages;
- Assists program in conducting compliance audits;
- Responds during emergencies to advise on environmental cleanup standards, sampling, and possible need for reporting to regulatory agencies;

Site 300

Environmental Program Information

- Coordinates regulatory requirements for tanks and wastewater systems, including record keeping and regulatory interface;

- Prepares risk assessments, reports, and documents, such as Environmental Impact Reports and Statements (EIRs and EISs), for compliance with the National Environmental Policy Act and the California Environmental Quality Act.

Environmental Restoration Division.

The Environmental Restoration Division was established in response to past hazardous materials handling and disposal practices, and past leaks and spills that resulted in environmental contamination at levels unacceptable by current standards. The staff of this Division:

- Plans, directs, and conducts assessments to determine the impact of such releases on the environment;
- Conducts restorations to reduce contamination to acceptable levels that will not harm human health and the environment;
- Investigates field sites to determine the existence and extent of contamination;
- Manages corrections such as soil removal and groundwater and surface water treatment; and
- Closes inactive facilities in a manner designed to prevent environmental contamination.

Hazardous Waste Management

Division. The Hazardous Waste Management Division manages and processes all LLNL-generated hazardous wastes, radioactive wastes, and mixed wastes for storage, treatment, and transportation for recycling or off-site disposal. The Division staff also manages the Waste Minimization Program. Specifically, the Hazardous Waste Management staff:

- Processes, stores, packages, solidifies, treats, and prepares waste for shipment and disposal or recycling;
- Tracks and documents the movement of hazardous, mixed, and radioactive waste from waste accumulation areas to final disposal, both on and off site;
- Responds to emergencies; and
- Participates in spill cleanup.

Regulatory Affairs Division. The Regulatory Affairs Division assures LLNL compliance with environmental regulations through the regulatory permitting process for such environmental matters as hazardous waste handling, air emissions sources, and water discharges. The Division also has responsibility for monitoring the environment and preparing the numerous reports required by various environmental regulations and DOE orders, including this report. The Regulatory Affairs Division staff:

- Monitors environmental media to verify compliance with established limits and to ensure there is no environmental degradation due to LLNL activities;
- Works with regulatory agencies in the preparation of reports, permit applications, and other documents required to demonstrate compliance with environmental regulations;
- Maintains knowledge of legislation that may impact LLNL activities; and
- Interacts with the community on environmental issues and the impact of LLNL operations.

Site 300 Permits

Air	Nine Permits to Operate various equipment. San Joaquin County Air Pollution Control District. Renewed annually.
Water	Waste Discharge Requirements Order 80-184 for Class II-1 solid waste landfills. Central Valley Regional Water Quality Control Board. Waste Discharge Requirements Order 82-105 for cooling tower discharges. (Also an NPDES permit.) Waste Discharge Requirements Order 85-188 for sanitary and industrial wastewater discharges to ponds and septic systems.
Hazardous Waste	Part B permit CA2890090002 for hazardous waste storage and Interim Status for open burning of high explosives.

Tanks U.S. Environmental Protection Agency and State of California Department of Health Services.
Paid fees for 15 tanks. San Joaquin Co.

Environmental Assessments Performed During 1990

In 1990, more than 122 projects were evaluated under NEPA and under the applicable policies and procedures for DOE compliance with NEPA (*Federal Register* Vol. 52, No. 240, December 15, 1987), as amended. These projects included 20 ADMs, 29 Memorandums, and 60 Categorical Exclusions. Ten projects were determined by DOE to require EAs, one of which was for Site 300 and is described below. Nine of the ten currently are under DOE review. A Finding of No Significant Impact (FONSI) was issued by DOE in June 1990 for the Resumption of Surrogate Testing in the Engineering Demonstration System (EDS) at LLNL. Three projects were evaluated under CEQA and University of California procedures for CEQA implementation.

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Study of the General Services Area (GSA), Lawrence Livermore National Laboratory Site 300 (Ferry et al. 1990) and *Remedial Investigation and Feasibility Study for the Lawrence Livermore National Laboratory Site 300 Building 834 Complex* (Bryn et al. 1990).

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During the EIS/EIR scoping process, the DOE and UC received a total of 282 comments from 61 members of the public; interested groups; and Federal, State, and local officials.

Pollution Abatement Projects

A draft Pollution Prevention Awareness Plan (PPAP) was developed and submitted to DOE in May 1990, in accordance with *DOE Order 5400.1*. The plan proposes that the following key elements be integrated into LLNL's day-to-day activities: communicating management's commitment to curtail pollution; publicizing the goals of

Site 300

Environmental Program Information

pollution prevention; educating individuals on pollution prevention through formal training; organizing events implementing pollution prevention; recognizing individuals who prevent pollution; reviewing historical events and their solutions and using this information to recommend new solutions; and providing updates on regulatory requirements, new technology, and management changes.

In 1990, the following activities were begun or were in progress:

- Continued communicating management's commitment to curtail pollution.

- Distributed an administrative memo from John Nuckolls, LLNL Director, on the appointment of an Environmental, Safety, and Health (ES&H) Council on January 9, 1990.

- Distributed a memo on ES&H/affirmative action/equal employment opportunity and other institutional responsibilities of associate directors/deputy associate directors/departments heads/division leaders to LLNL managers on April 11, 1990.

- Publicized the goals of Pollution Prevention.

- Published an article in *Newsline* (an LLNL periodical) entitled "Environmental Protection Offers Some Disposal Tips" on February 7, 1990.

- Conducted formal training classes and educated individuals on pollution prevention.

- Continued conducting waste generator training classes taught by Environmental Protection Department staff.

- Organized pollution-prevention events.

- A paper-recycling working group spearheaded the expansion of a pilot paper recycling program that was first implemented in 1989. A sitewide paper recycling program was implemented in April 1991.

- Presented a Pollution Prevention display with handouts at an on-site Energy Fair.

- Reviewed historical events and their solutions, then recommended new solutions.

- The Environmental Protection Department published and distributed Environmental Alerts to all LLNL employees. These one-page notices convey pertinent information on planned environmental events.

- Provided updates on regulatory requirements, new technology, and management changes.

- Environmental Analysts assigned to specific site areas continued as the liaison between EPD and the various programs. Changed and new regulatory requirements, new technology, and management changes related to environmental issues were conveyed through these Environmental Analysts.

Compliance Activities

The Environmental Operations Group is responsible for working closely with LLNL programs and departments to implement environmental requirements so that planned and current operations and experiments function in compliance with Federal, State, and local environmental regulations. The group consists of environmental analysts assigned to specific LLNL programs and departments to assist in day-to-day environmental activities. In addition to advising LLNL staff, the analysts also review and verify that proper procedures are followed for the management of hazardous wastes and for the implementation of appropriate pollution abatement controls. Compliance status is maintained and verified by the analysts, who keep abreast of all existing and planned activities, review construction documents, inspect facilities, and audit waste management procedures.

Building Inspections. Formal, detailed building inspections are conducted for each Site 300 facility every year. In these inspections, program management and environmental analysts scrutinize proper handling and management of hazardous and radioactive wastes and waste streams, management and maintenance of waste accumulation areas (WAA), potential

release pathways to the environment (e.g., storm and sanitary sewer drains), hazardous product storage areas, wastewater retention systems, operating equipment (e.g., vacuum pumps, transformers, capacitors, baghouses), and laboratory and machine shop areas. An inspection report is prepared for the program/department, and follow-up procedures are used to ensure implementation of recommendations and/or corrections. Walk-through inspections are conducted on an as-needed basis.

Waste Accumulation Area Inspections.

Inspections are conducted at least weekly at all WAAs. These inspections help ensure that WAAs and wastes in containers are in compliance with Federal and State requirements. An inspection checklist is completed and corrections are implemented.

Spill Response. Investigation, sampling, and evaluation of all potentially hazardous spills and leaks to the environment are conducted. This process includes assisting in cleanup of spills, determining if a spill must be reported to regulatory agencies, and verifying that cleanup is complete. Environmental Operations provides guidance to the programs on preventing spill recurrence.

During 1990, the Environmental Protection Department responded to nine

incidents that were reported to regulatory agencies. Three of these incidents occurred at Site 300 and are described briefly below.

The first incident involved a leak of nonhazardous high-explosives process wastewater through the primary liner of the surface impoundment system. The leaked substance was intercepted by the leachate collection system and returned to the overflow pond. No wastewater was released to the environment.

The second incident involved a release of approximately 25 gal of oily wastewater to the ground during a test of the Building 865 retention tank piping. The spill immediately was cleaned up and the system repaired.

The third incident occurred when a pipe froze and ruptured at the Building 817 retention tank, which contains nonhazardous high-explosives rinse water. The area was cleaned up immediately and the system was repaired.

Environmental Training. The Environmental Protection Department sponsored training that included RCRA and SARA/OSHA programs for 3,253 people from the Livermore site and from Site 300. Additionally, EPD routinely participated in biweekly briefings to orient new employees concerning approved environmental practices and procedures.

Introduction

Lawrence Livermore National Laboratory (LLNL) carries out surveillance air monitoring to determine if airborne radionuclides or hazardous materials from operations at Site 300 affect the environment or public health. Air monitoring involves measurement of materials collected on filters in air samplers. Concentrations of various airborne radionuclides, including particulates, and beryllium are measured at the Site 300 perimeter and at an off-site location near Site 300. These measurements also are made to comply with the Clean Air Act National Emissions Standards for Hazardous Pollutants (NESHAPS). Penetrating radiation, which cannot be measured by collection of material on filters, is discussed in the Environmental Radiation chapter.

Methods

Concentrations of various airborne radionuclides and beryllium are measured at Site 300 and in the City of Tracy. Analyses for plutonium, uranium, and gamma emitters are performed on a composite sample consisting of air filters from all sampling locations. **Figure 3-A-1** shows sampling locations. The samplers are positioned to ensure that any significant concentration of effluents from Site 300 operations would be detected, regardless of local meteorology. These samplers are operated at an average flow rate of 400 L/min. The flow rates are verified at regular intervals using a portable field-calibration unit. If a sampler fails, it is repaired and then calibrated with a spirometer that itself was calibrated using a unit traceable to the National Institute for Standards and Technology (NIST), formerly the National Bureau of Standards (NBS).

The eight samplers at Site 300 use 5.2×10^{-2} m² Whatman 41 cellulose filters. An easily dissolvable filter that has a low trace-metal content is required for airborne-beryllium analyses. Whatman 41 filters represent a balance between such requirements and particulate-collection efficiency (Lindeken et al. 1963).

All air filters are changed weekly. Each filter is identified by its location, date on, date off, elapsed sampling time, and flow

rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets. Then each sample filter is given a serial number that accompanies it throughout the analysis. After a four-day delay for decay of radon-thoron daughters, gross alpha and beta activities on the filters are determined with a gas-flow proportional counter. This counter normally is used only for environmental samples to avoid possible contamination. Separate ²³⁹Pu and ⁹⁰Sr standards determine alpha and beta counting efficiencies, respectively. These standards are traceable to NIST or equivalent certification. Counting-efficiency measurements are made with each set of filters counted. A background count is taken at the beginning of each run and between each set of ten samples. Records are kept of background and counting-efficiency variations that occur in the counter.

Monthly composites of Site 300 filters are sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the Site 300 composites are analyzed for the presence of ²³⁹Pu, ²³⁵U, and ²³⁸U. These filters are ashed and then dissolved in a mixture of nitric acid (HNO₃) and hydrochloric (HCl) and/or hydrofluoric

Site 300 Air Monitoring

(HF) acid. Plutonium and uranium then are separated by an ion-exchange process. Plutonium is purified further by ion exchange, electroplated onto a stainless-steel disk, and submitted for alpha spectrometry. Uranium is further purified by ion exchange and submitted for analysis by mass spectrometry.

For beryllium measurements, every month half of the weekly air filters from each of the Site 300 samplers are composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% HNO_3 and 20% HClO_4 (perchloric acid). The solutions then are evaporated to a few milliliters (mL). Care is taken to prevent the samples from baking dry. After the samples are diluted with water, they

are filtered. Any residue is discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is done by atomic absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200 ng of beryllium, and several samples spiked with essentially carrier-free ^7Be . Standards of 1, 2, and 5 g/L are prepared by diluting an intermediate 1-ppm stock solution obtained from an NIST-traceable 1,000-ppm stock dilution. The diluent in all cases is 1% HNO_3 in water.

Results

Airborne Radioactivity. LLNL analyzes air samples for gross alpha and gross

Figure 3-A-1. Air sampling locations, Site 300, 1990.

beta activity to ensure that releases of radionuclides—other than those specifically targeted—will be detected, and to identify trends in the Site 300 environs. Most determinations were at, or near, the analytical limit of detection for the method. Typical gross alpha activity is 1.2×10^{-15} $\mu\text{Ci/mL}$ (56 pBq/mL). Typical beta activity is 1×10^{-14} $\mu\text{Ci/mL}$ (370 pBq/mL). Most of the observed gross alpha and beta activity results from naturally occurring radioisotopes of uranium and thorium and their decay products.

Table 3-A-1 lists the activities of selected gamma-emitting radionuclides that normally contribute to gross beta activity in Site 300 and Tracy samples. Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th are naturally occurring. The primary source of ^{137}Cs and ^{22}Na normally is long-term global fallout and fallout resuspension. Other fission products normally are detectable only after events such as atmospheric nuclear tests by other nations or releases, such as the Chernobyl accident.

The Derived Concentration Guides (DCGs) for these radionuclides also are presented in **Table 3-A-1**. DCGs are concentrations of radionuclides in air (or water) that could be inhaled continuously (or consumed) 365 days a year without exceeding the DOE primary radiation protection standard to the public of 100 mrem/y (1 mSv/y) effective dose equivalent (U.S. Department of Energy 1990). (The Environmental Radiological Program Summary chapter provides an explanation of this and other units of dose.) All these radionuclides were measured at concentrations significantly below the DCGs.

Table 3-A-2 shows the concentration of ^{239}Pu , ^{238}U , and ^{235}U on air filter samples collected from Site 300. The highest concentrations of ^{239}Pu were observed in the May and December composites at a level of approximately 0.04×10^{-17} $\mu\text{Ci/mL}$ (0.015 pBq/mL, or 0.002% of the DCG). This is less than half the highest monthly concentration experienced in 1989, and represents a return to pre-1988 levels.

The highest concentration of ^{238}U was observed in the February composite at a level of 9.86×10^{-5} $\mu\text{g/m}^3$ (0.03% of the DCG). The highest concentration of ^{235}U was observed in the July composite at a level of 9.33×10^{-7} $\mu\text{g/m}^3$ (0.002% of the DCG). No other significant differences between locations or samples were noted. The overall levels were essentially the same as those reported in previous years.

The ratio of ^{235}U to ^{238}U is used as an indicator of the source of the ^{238}U . Both ^{235}U and ^{238}U occur naturally in the area. The ratio of the two isotopes as they exist naturally is approximately 7×10^{-3} . LLNL uses small amounts of ^{238}U at Site 300, but does not use ^{235}U . Therefore, if the ratio remains constant (within the limit of sampling and analytical error), then the ^{238}U measured is caused by natural sources. The $^{235}\text{U}/^{238}\text{U}$ ratio for January, February, May, July, August, and December show statistically significant deviations from the natural ratio, indicating the presence of depleted uranium from Site 300 operations. The measured concentrations of ^{238}U , however, are well below (0.02%) the DCG (U.S. Department of Energy 1990).

Beryllium in Air. **Table 3-A-3** shows the average monthly concentrations of airborne beryllium for the Site 300 sampling locations. The concentrations average 0.8% or less, with the highest concentration 4.2% or less of the ambient concentration limit established by the San Joaquin County Air Pollution Control District ($0.01 \mu\text{g/m}^3$). These concentrations can be attributed to suspension of surface soil containing naturally occurring beryllium. Local soils contain approximately 1 ppm of beryllium, and Central Valley air typically contains 10 to 100 μg of particulates per cubic meter. Using a value of $50 \mu\text{g/m}^3$ for an average dust load and 1 ppm for beryllium content of this dust, an airborne beryllium concentration of 5.0×10^{-5} $\mu\text{g/m}^3$ can be calculated. In view of the range of natural variation expected in these background values, this value is in excellent agreement with the data in **Table 3-A-3**.

Site 300 Air Monitoring

The monthly airborne beryllium concentrations for Site 300 and Tracy are plotted in **Figure 3-A-2**. Values plotted for January through April represent the limit of detection for the contract laboratory. This contract laboratory modified its analytical procedures during those months, resulting in a raised detection limit.

Figure 3-A-2. Monthly mean concentration of beryllium on air filters, Site 300, 1990.

Consequently, very low values could not be determined. Although the detection limit of the new method still allowed adequate analysis of data relative to regulatory guidelines, we requested that the previous analysis technique—a graphite furnace method—be reinstated. The graphite furnace method was reinstated in May.

Environmental Impact

The concentrations of beryllium and radionuclides measured around Site 300 and in the City of Tracy were well below all standards and, except for uranium isotopes, reflect background or naturally occurring levels of these chemicals. The $^{235}\text{U}/^{238}\text{U}$ ratios shown in **Table 3-A-2** are less than 7×10^{-3} , the ratio of naturally occurring concentrations of these isotopes. These ratios confirm the presence of depleted uranium at Site 300.

Certain equipment operations at Site 300 require permits from San Joaquin County. Total estimated emissions are reported to the San Joaquin County Air Pollution Control District. The total estimated air emissions during 1990 from equipment operations at Site 300 are given in **Table 3-A-4**.

Table 3-A-1. Gamma activity on air filters—Site 300, 1990.^a

	⁷ Be	⁴⁰ K	¹³⁷ Cs	²² Na	²²⁶ Ra	²²⁸ Ra	²²⁸ Th
Month	[10 ⁻¹³ μCi/mL ± 2σ (%)]	[10 ⁻¹⁶ μCi/mL ± 2σ (%)]					
Jan.	0.65 ± 2	≤0.99	≤0.04	≤0.04	≤0.07	≤0.15	≤0.08
Feb.	1.00 ± 2	≤1.09	≤0.04	0.15 ± 54	≤0.07	≤0.16	≤0.10
Mar.	1.19 ± 2	≤0.51	≤0.02	0.15 ± 28	≤0.04	≤0.08	≤0.06
April	1.18 ± 2	3.35 ± 56	≤0.03	0.22 ± 50	≤0.13	≤0.13	0.20 ± 58
May	1.17 ± 2	2.80 ± 56	0.07 ± 66	0.20 ± 38	≤0.11	≤0.22	≤0.19
June	1.04 ± 2	≤0.59	0.06 ± 66	0.16 ± 34	≤0.05	≤0.23	≤0.06
July	1.43 ± 2	3.36 ± 50	0.10 ± 70	0.16 ± 36	0.14 ± 80	≤0.12	≤0.09
Aug.	1.17 ± 2	3.36 ± 43	0.11 ± 61	0.11 ± 54	0.22 ± 48	≤0.11	0.19 ± 53
Sept.	1.56 ± 2	3.05 ± 48	0.10 ± 54	0.13 ± 50	0.21 ± 62	0.29 ± 60	0.24 ± 56
Oct.	1.69 ± 2	6.37 ± 37	0.11 ± 57	0.12 ± 61	0.22 ± 59	0.40 ± 68	0.33 ± 49
Nov.	1.11 ± 2	3.88 ± 43	≤0.03	0.11 ± 60	0.25 ± 59	≤0.13	0.25 ± 48
Dec.	0.44 ± 2	≤0.39	≤0.01	≤0.01	≤0.03	≤0.06	≤0.04
Mean ^b	1.14	≤2.93^b	≤0.05^b	≤0.13	≤0.12^b	≤0.14^b	≤0.15^b
SDM (%) ^c	31	48^c	50.0^c	46^c	63^c	32^c	52^c
DCG (μCi/mL)	4 × 10⁻⁸	9 × 10⁻¹⁰	4 × 10⁻¹⁰	1 × 10⁻⁹	1 × 10⁻¹²	3 × 10⁻¹²	4 × 10⁻¹⁴
Percent of DCG	3 × 10⁻⁴	3 × 10⁻⁵	1 × 10⁻⁶	1 × 10⁻⁶	1 × 10⁻³	5 × 10⁻⁴	4 × 10⁻²

^a All Site 300 samples composited.

^b Median value reported caused by quality assurance requirements, see Quality Assurance chapter.

^c Median absolute deviation percent (MAD%) calculated caused by quality assurance requirements, see Quality Assurance chapter.

Site 300
Air Monitoring

Table 3-A-2. Plutonium and uranium activity on air filters—Site 300, 1990.^a

Month	²³⁹ Pu [10 ⁻¹⁷ μ Ci/mL $\pm$ 2 σ (%)]	²³⁸ U [10 ⁻⁵ μ g/m ³]	²³⁵ U [10 ⁻⁷ μ g/m ³]	²³⁵ U/ ²³⁸ U [10 ⁻³]
Jan.	0.01 $\pm$ 56	2.84	1.20	4.23
Feb.	0.005 $\pm$ 82	9.86	2.89	2.93
Mar.	0.008 $\pm$ 50	2.31	1.54	6.67
April	0.008 $\pm$ 54	5.36	3.68	6.85
May	0.03 $\pm$ 22	8.96	4.15	4.63
June	0.008 $\pm$ 38	2.99	1.99	6.66
July	0.01 $\pm$ 38	3.58	9.33	2.61
Aug.	0.02 $\pm$ 30	1.22	5.12	4.20
Sept.	0.02 $\pm$ 32	5.40	3.96	7.33
Oct.	0.01 $\pm$ 36	8.67	6.19	7.14
Nov.	0.02 $\pm$ 30	7.92	5.80	7.32
Dec.	0.04 $\pm$ 44	18.9	10.8	0.57
Mean	0.02	6.50	4.72	
SDM (%)	63	57	57	
% DCG	0.0001^b	0.02^c	0.001^d	

^a Composite of all Site 300 samples.

^b DCG = 2×10^{-14} μ Ci/mL for ²³⁹Pu activity in air.

^c DCG = 0.3 μ g/m³ for ²³⁸U activity in air (1×10^{-13} μ Ci/mL).

^d DCG = 0.047 μ g/m³ for ²³⁵U activity in air (1×10^{-13} μ Ci/mL).

Table 3-A-3. Beryllium concentration on air filters—Site 300, 1990.

Month (1990)	Sampling location ^a							
	EOBS	ECP	WCP	LIN	GOLF (10 ⁻⁵ µg/m ³)	TFIR ^b	NPS	WOBS E801
Jan.	<19.46	<19.41	<19.45	<19.46	<19.48	<18.91	<19.56	<22.35
Feb.	<39.17	<19.43	<19.42	<19.42	<19.41	<18.79	<38.96	<39.17
Mar.	<20.88	<19.38	<22.19	<19.44	<22.44	<19.40	<19.44	<19.44
Apr.	<19.36	<19.42	<19.38	<19.37	<19.38	<23.80	<19.36	<19.37
May	1.20	1.50	2.80	1.80	1.70	3.10	1.40	2.70
June	2.43	3.08	2.56	2.43	2.88	5.12	1.92	3.72
July	3.88	0.78	3.11	5.42	<.17	4.66	<0.16	11.08
Aug.	5.15	4.74	1.16	<0.78	<0.81	<0.78	<0.8	<0.90
Sept.	6.21	4.12	2.95	2.95	9.32	6.98	4.11	2.95
Oct.	3.89	3.11	6.22	5.45	5.45	10.87	4.67	5.06
Nov.	4.26	4.02	3.24	4.13	4.57	8.84	3.88	5.51
Dec.	<4.21	<5.76	<4.19	<6.12	6.54	4.80	<4.20	<4.18
Median^c	4.71	4.43	3.72	5.44	6.00	7.91	4.16	5.29
MAD (%)	40	48	49	61	79	51	74	66

Percent of ambient concentration guide ^d for above concentrations									
Month (1990)	EOBS	ECP	WCP	LIN	GOLF	TFIR ^b	NPS	WOBS	E801
Jan.	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<2.0	<4.2	<2.2
Feb.	<3.9	<1.9	<1.9	<1.9	<1.9	<1.9	<3.9	<2.4	<3.9
Mar.	<2.1	<1.9	<2.2	<1.9	<2.2	<1.9	<1.9	<1.9	<1.9
Apr.	<1.9	<1.9	<1.9	<1.9	<1.9	<2.4	<1.9	<1.9	<1.9
May	0.1	0.2	0.3	0.2	0.2	0.3	0.1	0.2	0.3
June	0.2	0.3	0.3	0.2	0.3	0.5	0.2	0.3	0.4
July	0.4	0.1	0.3	0.5	<0.02	0.5	<0.02	0.4	1.1
Aug.	0.5	0.5	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sept.	0.6	0.4	0.3	0.3	0.9	0.7	0.4	0.3	0.3
Oct.	0.4	0.3	0.6	0.5	0.5	1.1	0.5	0.6	0.5
Nov.	0.4	0.4	0.3	0.4	0.5	0.9	0.4	0.3	0.6
Dec.	<0.4	<0.6	<0.4	<0.6	0.7	0.5	<0.4	<0.4	<0.4
Median	0.5	0.4	0.4	0.5	0.6	0.8	0.4	0.4	0.5

^a See Fig. 3-A-1 for sampling locations.

^b Tracy firehouse.

^c Site 300 overall annual median is 4.77×10^{-5} µg/m³.

^d Percent of ambient concentration guide (%ACG). ACG set by the San Joaquin County Air Pollution Control District (SJCAPCD) is 0.01 µg/m³ ($1,000 \times 10^{-5}$ µg/m³).

Table 3-A-4. Nonradioactive airborne emissions, Site 300, 1990.

Pollutant	Estimated release (tons/day)
Particulates	0.0020
Organic compounds	0.0011
Oxides of sulfur	0.0018
Oxides of nitrogen	0.0259
Carbon monoxide	0.0056
Chlorofluorocarbons	0.0032

Introduction

The Environmental Monitoring Group conducts an ongoing routine monitoring program for surface and domestic water in the vicinity of Site 300. Groundwater monitoring around the landfills and surface impoundments and monitoring to investigate contamination caused by historical operations are described in the Groundwater Protection subsection.

Sewage from the administrative area in the southeast corner of Site 300 is discharged to a lined pond for digestion and evaporation. Other facilities at Site 300 are served by septic tanks.

Methods

Surface Water. Surface water samples (**Figure 3-W-1**) are collected quarterly from an off-site creek (GEO), rainfall (RAIN), and a spring-fed pond near Bunker 812 (CRK). The water samples are analyzed for gross alpha, gross beta, and tritium activity. Because the tritium levels typically found are very low, it is necessary to distill and enrich the samples before liquid-scintillation counting.

Water Supply Wells. The single, inactive Site 300 water supply well that is monitored is Well 01. This well is maintained to supply fire-suppression water to the Site 300 Fire Department, but not to supply drinking water.

Wells 18 and 20 produced drinking water in 1990, and these wells are routinely monitored. The active and inactive water supply wells sampled in 1990 are shown in **Figure 3-W-2**. Wells 19 and 04 were sealed and abandoned in the first and second quarters of 1990, respectively. Well CARNRW2 is an off-site water supply well, as are Wells CDF1, CON1, and GALLO1.

These inactive and active water supply wells are sampled quarterly for metals (beryllium, chromium, copper, and lead); volatile organic compounds (VOCs); and for gross alpha, gross beta, and tritium activity. If gross alpha or gross beta activity is detected at or above California

Department of Health Services (DHS) maximum contaminant levels (MCLs), the samples then are analyzed for isotopes of radium and uranium to determine if the activity is caused by naturally occurring radionuclides. As with the surface water samples, all tritium samples collected from water supply wells are enriched before counting. In addition, active water supply wells (18 and 20) are sampled monthly for VOCs.

Site 300 Groundwater. Monitoring Wells NC2-11D, NC7-61, NC7-69, and W-7A are located in areas of site activity that previously were monitored by sampling inactive water supply wells (**Figure 3-W-3**). These inactive wells have been sealed and abandoned to prevent potential inter-aquifer contaminant migration caused by their location within multiple water-bearing zones. Well NC2-11D replaces Well 03; Wells NC7-61 and NC7-69 replace Well 08; and Well W-7A replaces Well 07 as monitoring locations. These on-site monitoring wells are sampled quarterly for metals (beryllium, chromium, copper, and lead), VOCs, and for gross alpha, gross beta, and tritium activity.

In the fourth quarter of 1990, Wells NC7-61 and NC7-69 were analyzed additionally for uranium and radium isotopes. Well W-7A is located on the outer edge of a TCE plume being investigated by the Environmental Restoration Division (ERD)

Site 300 Routine Water Monitoring

(Lamarre et al. 1990a). A remedial investigation report for the Site 300 general services area was prepared and submitted to regulatory agencies in May 1990 (McIlvride et al. 1990), followed by a draft feasibility study for the Site 300 general services area in December 1990 (Ferry et al. 1990). Well W-7A results are not discussed in this report.

Site 300 Area Groundwater. Samples are collected annually from nine groundwater sources (four from off-site active water supply wells, and five from off-site surveillance wells) from the area surrounding Site 300 to characterize local groundwater quality and assess better potential Site 300 environmental impacts. These samples are analyzed for metals, minerals, phenolic

compounds, VOCs, pesticides, herbicides, gross alpha, gross beta, and tritium activity, as well as for high-explosives compounds. These wells include water supply wells CARNRW2, CDF1, CON1, GALLO1, and GALLO2 (all of which are sampled quarterly for parameters already discussed), along with surveillance Wells Wellman2, VIE1, VIE2, MUL1, and MUL2 (**Figure 3-W-4**). Wellman2 could not be sampled in 1990 because of a broken pump. Plans to replace the pump are unknown because the Wellman property is for sale.

Sampling and Analysis. Grab samples of surface sources, such as ponds, creeks, and reservoirs, are obtained with a tethered plastic pail. A 500-mL sample

Figure 3-W-1. Surface water sampling locations, Site 300, 1990.

is collected for tritium analysis in an argon-flushed glass container fitted with a ground-glass stopper. Samples for other radiological analyses are collected in 500-mL polyethylene bottles.

Groundwater monitoring wells are purged of stagnant water prior to sampling. In the case of wells with high water-production rates, this process entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For wells with low water-production rates, the well is bailed manually until dry. Sampling occurs after the well has produced sufficient water for the required samples. All sampling equip-

ment is chosen so that it will not add compounds to the sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

As samples are collected in the field, they are labeled with the sampling locations and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 19% of the water samples are duplicates.

For samples that are analyzed for gross alpha and beta activities, a 100-mL sample (or less, depending on the solid content) is digested with a mixture of 80% nitric acid (HNO_3) and 20% perchloric acid

Figure 3-W-2. Active and inactive water supply wells, Site 300, 1990.

Site 300
Routine Water
Monitoring

up with HNO_3 and a few milliliters of 5% hydrogen peroxide (H_2O_2). The solution is evaporated to about 5 mL and transferred to a 5-cm-diameter serrated, stainless-steel planchet. After the planchet is dried and flamed, the sample is counted for 30 min in a proportional counter. A blank is processed with each set of samples. The plutonium-239 (^{239}Pu) and strontium-90 (^{90}Sr) standards are counted with every sample set. Background measurements are made between every ten sample-counting measurements.

Samples analyzed for very low levels of tritium are electrolytically enriched and then counted by liquid-scintillation

spectrometry. Each counting set includes a total of eight standards—to establish quench corrections—and eight blanks—to determine background. Otherwise, samples are counted by liquid-scintillation spectrometry.

For beryllium analysis, a 100-mL sample is digested with HNO_3 . The residue is diluted to 100 mL with deionized water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Table 3-W-1 lists the standardized methods used in the analyses of both groundwater and stormwater samples for nonradioactive contaminants.

Figure 3-W-3. Active on-site wells replacing sealed and abandoned production wells, Site 300, 1990.

Results

Surface Water. Table 3-W-2 shows the gross alpha activities in Site 300 surface water samples. Gross beta activities for Site 300 surface water samples are shown in Table 3-W-3. Gross alpha and beta activities in these surface water samples collected in 1990 were below EPA and DHS MCLs (U.S. Environmental Protection Agency 1977; 22 *California Code of Regulations* Chapter 15, as amended).

Table 3-W-4 shows tritium data for Site 300 surface water samples. The samples have concentrations that are well below recommended concentration guide values. The highest concentration of tritium in water, 54.7 pCi/L, occurred in rain that was collected on December 15, 1990.

Water Supply Wells. Results of the active and inactive water supply well monitoring (both on-site and off-site) are shown in Table 3-W-5. These tabulated results represent the highest value detected for the parameter over the year, as well as constituents sporadically detected during the year. Therefore, the values are conservative estimates of groundwater constituents. Table 3-W-6 shows tritium data for the active and inactive water supply well monitoring (both on-site and off-site). The tritium concentrations observed in the on-site inactive water supply Well 01 have increased slightly from 1989 values, ranging from 1,740–2,420 pCi/L to 1990 values of 3,000–4,300 pCi/L. These concentrations all are a fraction of the drinking water MCL

Figure 3-W-4. Annual samples collected from surrounding area groundwater, Site 300, 1990.

Site 300

Routine Water Monitoring

for tritium of 20,000 pCi/L; however, Well 01 is not used as a drinking water supply.

Another constituent of concern, observed in the on-site active water supply wells, is a small amount of TCE that was detected (at a concentration of 0.9 µg/L below the MCL of 5 µg/L) once during third quarter monitoring in Well 18. Subsequent samples collected from Well 18 indicated TCE concentrations below the detection limit of 0.5 µg/L.

Trihalomethane (THM) compounds were detected in the off-site active water supply well CARNRW2 on two sequential sampling events (third and fourth quarters, 1990). These findings resulted from collecting the sample from a mislabelled chlorinated water supply, rather than from untreated well water. The combined quarterly THM concentrations of 4.9 µg/L and 31.7 µg/L, respectively, were far below the MCL of 100 µg/L. Subsequent samples have been collected from the untreated well water source.

Site 300 Groundwater. Table 3-W-7 shows the results from wells located in areas of site activity previously monitored by sampling inactive water supply wells, which have been sealed and abandoned. These wells were sealed to prevent communication between aquifers. The replacement wells still monitor the individual aquifers.

Copper was detected in the fourth quarter 1990, at a concentration of 0.037 mg/L (below the secondary MCL of 1.0 mg/L). Because of a procedural problem, EMG had to request a separate copper analysis with a lower level of sensitivity this particular quarter. The procedural problem has been resolved. Future analyses will use the standard analysis for copper.

NC7-61, a monitoring well established in 1989 in the Pit 7 Area, shows tritium concentrations (310,000 pCi/L) in excess of the MCL. Tritium contamination in the Pit 7 Complex area is well documented in the *LLNL Site 300 Environmental Investigation Quarterly Reports* (Lamarre et al. 1990a-c; Carlsen et al. 1990) and is under investigation for remediation. Well NC7-61 is located adjacent to Well NC7-69; how-

ever, it monitors a shallower water-bearing aquifer. Tritium continues to be detected well below the MCL of 20,000 pCi/L in Well NC7-69. Well NC7-69 first was sampled in the first quarter 1990, and resulted in the detection of TCE at a concentration of 8 µg/L. This well was sampled using a portable submersible pump implicated in other instances as a contributing factor in contaminating groundwater samples (Lamarre et al. 1990a). Use of the pump was discontinued, and TCE has not been seen in any subsequent samples collected from this location.

Gross alpha concentration in Well NC7-61 was slightly higher in the fourth quarter of 1990. It was reanalyzed for radium-226 to define further the alpha-emitting radionuclides present, pursuant to Title 22 drinking water regulations (even though NC7-61 is not used for drinking water purposes). The results of the radium-226 analysis were below the detection limit of 1 pCi/L. We are investigating further this elevated from alpha level. All other gross alpha concentrations in these active on-site wells are consistent with historical values.

Site 300 Area Groundwater. Table 3-W-8 shows the data from the nine groundwater sampling locations in the vicinity of Site 300. The results of these analyses indicated no concentrations above background, with the exception of THM compounds in Well CARNRW2 (already discussed). Manganese was detected in two off-site surveillance wells during annual sampling at an average concentration of 0.18 mg/L, three and one-half times the secondary drinking water standard for manganese (0.05 mg/L). Secondary drinking water standards are based on the aesthetic qualities of water, such as taste, color, odor, and clarity. There is no primary drinking water standard for manganese.

Manganese is believed to occur naturally at elevated concentrations in the groundwater of the Site 300 area. These concentrations reflect the generally poor quality of groundwater as a drinking water source in the area.

Environmental Impact

The resulting tritium concentration of 54.7 pCi/L from rain collected on December 15, 1990, represents 0.003% of the MCL specified by DHS for drinking water (22 *California Code of Regulations* Chapter 15, as amended).

Table 3-W-4 also includes an estimate of the effective dose that may be delivered to an adult who consumes water (as stated above) containing the listed tritium concentrations. These doses, all of which are less than 0.002 mrem, are based on a water consumption of 2 L/day, every day for a year, and the dose-conversion factors provided by DOE (U.S. Department of Energy 1988b). The actual dose (if any) from these water sources would be considerably less, because these sources are not used as drinking water sources. Methods used to calculate doses are presented in **Appendix B**.

Table 3-W-6 includes an estimate of the annual effective dose that may be delivered to an adult who consumes water containing the listed tritium concentrations. The doses from the active on-site water

supply wells (Wells 18 and 20) are all equal to or less than 0.0004 mrem. Similarly, the doses from the active off-site water supply wells (Wells CARNRW2, CDF1, CON1, and GALLO1) are all equal to or less than 0.0006 mrem. All of these tritium concentrations are a small fraction of the MCL for tritium in drinking water of 20,000 pCi/L. Well 01 displays the highest tritium concentrations of the data for wells presented in **Table 3-W-5** and **Table 3-W-6**; however, this well is not a drinking water supply. These data and estimates of potential maximal doses from tritium in various waters in the Site 300 area demonstrate that the radiological impact of LLNL operations in this area is minimal. LLNL is investigating several areas of groundwater contamination at Site 300, reported here and in the Groundwater Protection chapter. LLNL, in cooperation with regulatory agencies, is developing and implementing plans to minimize potential health effects to the public and remediate the contamination as appropriate.

Site 300
Routine Water
Monitoring

Table 3-W-1. EPA groundwater standard methods.

Analyte	EPA method	Analyte	EPA method
<u>Metals</u>		<u>Organic compounds</u>	
Arsenic	7060	<u>Volatile organic compounds</u>	
Barium	200.7, 6010	Purgeable halocarbons	601
Beryllium	210.2, 7091	Purgeable aromatics	602
Cadmium	200.7, 6010, 7130, 7131	Purgeable priority pollutants	624
Chromium	218.2, 7191	Title 22 pesticides	608
Copper	220.1, 6010, 7210	Title 22 herbicides	509B
Iron	6010	Low-level phenolics	420.1
Lead	7421	<u>Indicator parameters</u>	
Manganese	6010, 7460	pH	150.1
Mercury	7470	Specific conductivity	120.1
Nickel	6010	Total organic carbon (TOC)	415.1, 415.2
Potassium	6010	Total organic halide (TOX)	9020
Selenium	7740		
Silver	272.2, 6010		
Sodium	6010		
Vanadium	6010		
Zinc	6010		
<u>Nonmetallic inorganic compounds</u>			
Total dissolved solids	160.1		
Total suspended solids	160.2		
Total Kjeldahl nitrogen	351.3		
Ammonia nitrogen (as N)	350.3		
All alkalinities	310.2		
Nitrate	353.2		
Nitrite	353.2		
Fluoride	340.2		
Chloride	325.3		
Sulfate	375.4		

Table 3-W-2. Gross alpha activity in surface water, Site 300, 1990.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[pCi/L ± 2σ]			
GEO	3	2 ± 5	0 ± 7	≤1.7	74.9
CRK	5	4 ± 9	4 ± 9	≤5.2	41.2
RAIN	0	— ^b	— ^b	— ^b	— ^b

^a See Fig. 3-W-1 for sampling locations.

^b Not applicable.

Table 3-W-3. Gross beta activity in surface water, Site 300, 1990.

Location ^a	Number of samples	Maximum	Minimum	Mean	SDM (%)
		[pCi/L ± 2σ]			
GEO	3	10 ± 6	5 ± 6	7.0	38.0
CRK	5	9 ± 2	1 ± 7	5.8	52.0
RAIN	0	— ^b	— ^b	— ^b	— ^b

^a See Fig. 3-W-1 for sampling locations.

^b Not applicable.

Site 300
Routine Water
Monitoring

Table 3-W-4. Tritium in water, Site 300, 1990.

	Location ^a		
	GEO ^b	CRK ^b [pCi/L $\pm$ 2 σ (%)]	RAIN ^c
First quarter	43.2 $\pm$ 13	14.6 $\pm$ 33	23.1 $\pm$ 27
Second quarter	35.0 $\pm$ 16	15.2 $\pm$ 32	48.0 $\pm$ 90
			38.3 $\pm$ 16
Third quarter	— ^d	31.0 $\pm$ 17	— ^d
Fourth quarter	— ^d	14.2 $\pm$ 38	27.4 $\pm$ 27
			54.7 $\pm$ 13
			46.5 $\pm$ 15
Average	39.1	18.8	39.7
SDM (%)	15	43	31
Percent of DWS^e	0.2	0.09	0.2
Effective dose (mrem)	0.002	0.0009	0.002

^a See Fig. 3-W-1 for sampling locations.

^b Surface water.

^c Rain water.

^d No data available. See Quality Assurance chapter, "Deviations and Changes to the Sampling Program."

^e DWS (California drinking water standard) = 200×10^{-7} μ Ci/mL or 20,000 pCi/L.

Table 3-W-5. Positively detected parameters in active and inactive water supply wells (on-site and off-site), Site 300, 1990.

Parameter	Well ^a						
	WELL01 ^b	WELL18 ^c	WELL20 ^c	CARNRW2 ^d	CDF1 ^d	CON1 ^e	GALLO1 ^e
Metals (mg/L)							
Chromium	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	<0.005
Lead<0.002	<0.002	<0.002	0.004	0.003	<0.002	<0.002	<0.002
Purgeable pollutants (EPA Methods 601/624, µg/L)							
Bromodichloromethane	<0.5	<0.5	<0.5	4.6	<0.5	<0.5	<0.5
Bromoform	<0.5	<0.5	<0.5	13.0	<0.5	<0.5	<0.5
Chloroform	<0.5	<0.5	<0.5	4.9	<0.5	<0.5	<0.5
Dibromochloromethane	<0.5	<0.5	<0.5	9.2	<0.5	<0.5	<0.5
Trichloroethylene	<0.5	0.9	<0.5	<0.5	<0.5	<0.5	<0.5
Radiological (pCi/L)							
Gross alpha	2 ± 14	2 ± 10	0 ± 6	2 ± 10	3 ± 5	6 ± 5	3 ± 3
Gross beta	6 ± 7	7 ± 3	9 ± 6	9 ± 2	14 ± 4	11 ± 3	8 ± 2
Tritium	4,300 ± 1,720	7.0 ± 4.4	19.4 ± 5.0	18.7 ± 5.4	19.3 ± 6.0	25.6 ± 6.4	19.8 ± 5.5

^a See Fig. 3-W-2 for sampling locations.

^b Well 01 is an inactive on-site water supply well maintained to supply fire-suppression water to the Site 300 fire department.

^c Well 18 and Well 20 are active on-site water supply wells. Well 18 is a backup water supply for Well 20, which is currently used for the production of drinking water at Site 300.

^d Wells CARNRW2 and CDF1 are off-site active water supply wells for the Carnegie State Vehicle Recreation Area and the Castle Rock Department of Forestry, respectively.

^e Wells CON1 and GALLO1 are off-site active private water supply wells.

The following compounds would have been reported, had they appeared at or above the detection limits indicated below:

Metals (mg/L)		Purgeable halocarbons (EPA Method 601, µg/L)		Purgeable priority pollutants (EPA Method 624, µg/L)	
Beryllium	0.0005	All analytes	0.5	Acetone	5
Copper	0.08			Acrolein	5
				Acrylonitrile	5
				Methoxychlor	10
				Methyl ethyl ketone	10
				Methylene chloride	2
				All other analytes	0.5

Site 300
Routine Water
Monitoring

Table 3-W-6. Tritium in active and inactive water supply wells (on-site and off-site), Site 300, 1990.

	Well ^a						
	WELL01 ^b	WELL18 ^c	WELL20 ^c	CARNRW2 ^d [pCi/L $\pm$ 2 σ]	CDF1 ^d	CON1 ^e	GALLO1 ^e
First quarter	3200 $\pm$ 400 3000 $\pm$ 400 ^f	7.03 $\pm$ 4.43	8.03 $\pm$ 5.16	11.1 $\pm$ 4.98 18.7 $\pm$ 4.96 ^f	6.64 $\pm$ 5.32	15.1 $\pm$ 5.29	19.8 $\pm$ 5.52
Second quarter	3000 $\pm$ 500 ^g	3.60 $\pm$ 3.60	5.06 $\pm$ 4.05	4.52 $\pm$ 4.52	4.68 $\pm$ 4.68	3.76 $\pm$ 3.76	5.20 $\pm$ 5.20
Third quarter	3800 $\pm$ 400	2.04 $\pm$ 2.04	19.4 $\pm$ 5.02 8.32 $\pm$ 4.53 ^h	11.4 $\pm$ 5.44	19.3 $\pm$ 6.04	5.26 $\pm$ 4.62	3.62 $\pm$ 3.62
Fourth quarter	3700 $\pm$ 400 4300 $\pm$ 400 ^h	5.96 $\pm$ 5.96	8.71 $\pm$ 5.44	10.4 $\pm$ 5.90	19.0 $\pm$ 6.65	25.6 $\pm$ 6.37	15.9 $\pm$ 5.95
Mean	3500	4.66	9.90	11.22	12.41	12.43	11.13
SDM (%)	15	48	56	45	63	81	71
Percent of DWS^h	17.5	0.02	0.05	0.06	0.06	0.06	0.06
Effective dose (mrem)	0.174	0.0002	0.0004	0.0005	0.0006	0.0006	0.0006

^a See Fig. 3-W-2 for sampling locations.

^b Well 01 is an inactive on-site water supply well maintained to supply fire-suppression water to the Site 300 fire department.

^c Wells 18 and 20 are active on-site water supply wells. Well 18 is a backup water supply for Well 20, which is currently used for the production of drinking water at Site 300.

^d Wells CARNRW2 and CDF1 are off-site active water supply wells for the Carnegie State Vehicle Recreation Area and the Castle Rock Department of Forestry, respectively.

^e Wells CON1 and GALLO1 are off-site active private water supply wells.

^f Quality Assurance sample.

^g Sample collected for analysis by the Environmental Restoration Division.

^h DWS (California Drinking Water Standard) = 200×10^{-7} μ Ci/mL or 20,000 pCi/L.

Table 3-W-7. Positively detected parameters in active on-site wells replacing sealed and abandoned production wells, Site 300, 1990.

Parameter	Well ^a		
	NC2-11D	NC7-61	NC7-69
<u>Metals (mg/L)</u>			
Chromium	<0.005	0.005	<0.005
Copper	<0.08	<0.08	<0.05
Iron	— ^b	— ^b	0.06
Magnesium	— ^b	— ^b	18.0 ^c
Manganese	— ^b	— ^b	0.07
<u>Purgeable pollutants (EPA Method 601/624, µg/L)</u>			
Chloroform	<0.5	0.9	<1.0
Ethylbenzene	— ^b	1.3	<0.5
Fluorobenzene	— ^b	3.0	— ^b
Toluene	— ^b	1.6	<0.5
Trichloroethylene	<0.5	<1.0	8.0 ^c
Trichlorofluoromethane	<0.5	0.5	<0.5
Total xylene isomers	— ^b	4.8	<0.5
<u>Radioactivity (pCi/L)</u>			
Gross alpha	4 ± 3	5 ± 4	1 ± 2
Gross beta	6 ± 2	7 ± 2	4 ± 2
Tritium	1,500 ± 200	327,000 ± 1,300	3,300 ± 600
Uranium-234	— ^b	3.0 ± 0.4	0.5 ± 0.1
Uranium-238	— ^b	2.2 ± 0.3	0.5 ± 0.2

^a See Fig. 3-W-3 for sampling locations.

^b Analysis not performed.

^c Samples collected for analysis by the Environmental Restoration Division.

Site 300
Routine Water
Monitoring

Table 3-W-8. Positively detected parameters of annual samples collected from surrounding area groundwater, Site 300, 1990.

Parameter	Well ^a								
	CARNRW2 ^b	CDF1 ^b	CON1 ^c	GALLO1 ^c	GALLO2 ^c	VIE1 ^c	VIE2 ^c	MUL1 ^c	MUL2 ^c
Metals (mg/L)									
Arsenic	<0.002	0.005	— ^d	0.002	0.002	0.015	<0.002	0.005	<0.002
Barium	<0.05	<0.05	— ^d	<0.05	0.05	<0.05	<0.05	<0.05	<0.05
Chromium	<0.005	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Copper	<0.08	<0.08	<0.08	<0.08	0.06	<0.05	<0.05	<0.05	<0.05
Lead	0.003	<0.002	<0.002	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
Magnesium	4.6	16.0	7.2	0.8	6.6	20.0	18.0	29.0	50.0
Manganese	<0.04	<0.04	0.17	<0.05	0.06	<0.04	<0.04	<0.04	0.29
Mercury	0.0002	<0.0001	<0.0001	<0.0005	<0.0005	<0.0002	<0.0001	<0.0002	<0.0002
Potassium	9.0	8.0	9.0	4.0	5.0	6.0	2.0	5.0	7.0
Selenium	<0.002	<0.002	<0.002	<0.002	0.008	<0.002	<0.002	<0.002	<0.002
Zinc	<0.05	<0.05	<0.05	<0.05	0.22	<0.05	<0.05	0.06	0.05
Inorganic compounds (mg/L)									
Total alk (as CaCO ₃)	220	210	180	240	270	210	280	200	180
Ammonia nitrogen	— ^d	— ^d	— ^d	— ^d	0.39	— ^d	— ^d	— ^d	— ^d
Calcium	22	52	45	4.6	19	35	140	73	160
Carbonate alk	<1.0	<1.0	<1.0	88	36	<1.0	<1.0	<1.0	<1.0
Chloride	110	110	190	130	130	78	86	55	70
Conductivity (μmhos/cm)	1,240	1,120	2,220	1,220	1,350	1,070	1,200	1,100	1,890
Fluoride	0.3	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.7
Low-level phenolics	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrate (as NO ₃)	<0.4	2.2	<0.4	0.44	4.4	18.0	13.0	3.9	8.6
Nitrate (as N)	<0.1	0.5	<0.1	0.1	1.0	4.1	2.9	0.9	2.0
pH	7.9	5.7	6.1	8.6	8.3	7.7	7.2	7.2	6.9
Sodium	200	170	420	280	240	97	70	71	110
Sulfate	230	240	750	190	250	120	200	200	620
Filterable residue (TDS)	790	720	1600	780	820	500	740	490	1000
Purgeable pollutants (EPA Methods 601/624, μg/L)									
Bromodichloromethane	4.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Bromoform	13.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chloroform	4.9	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<1.0	<1.0
Dibromochloromethane	9.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Radiological (pCi/L)									
Gross alpha	2 ± 10	3 ± 5	6 ± 5	2 ± 3	3 ± 3	1 ± 3	5 ± 4	2 ± 9	2 ± 4
Gross beta	9 ± 2	14 ± 4	11 ± 3	4 ± 2	8 ± 2	8 ± 2	6 ± 2	15 ± 13	5 ± 4
Tritium	18.7 ± 5	19.3 ± 6	25.6 ± 6	19.8 ± 6	<300	<500	<500	<500	<500
Uranium-234	— ^d	— ^d	— ^d	— ^d	0.8 ± 0.1	— ^d	— ^d	— ^d	— ^d
Uranium-238	— ^d	— ^d	— ^d	— ^d	0.6 ± 0.1	— ^d	— ^d	— ^d	— ^d

^a See Fig. 3-W-4 for sampling locations. WELLMAN2 could not be sampled in 1990 because of a broken pump. Plans to replace the pump are unknown, because the Wellman property is for sale.

^b Wells CARNRW2 and CDF1 are off-site active water supply wells for the Carnegie State Vehicle Recreation Area and the Castle Rock Department of Forestry, respectively.

^c Wells are off-site active private water supply wells.

^d No analysis performed. See Quality Assurance chapter.

Introduction

Soil is an integrating medium that can account for contaminants released to the atmosphere or through liquid effluents (U.S. Department of Energy 1988d). An intensive soil sampling program conducted in 1971 and 1972 (Lindeken 1973) provided a data base for the concentration ranges of various radionuclides in soil near the Livermore site and at Site 300. Since 1972, soil sampling at Site 300 has been part of the continuing Lawrence Livermore National Laboratory (LLNL) environmental surveillance monitoring program designed to document any changes in environmental radioactivity levels and to evaluate any increase in radioactivity that might result from LLNL operations. Because high-explosive tests at Site 300 occasionally involve the use of depleted uranium (^{238}U), one purpose of the annual soil sampling is to determine how these tests perturb the natural uranium content of the soil. Including the other naturally occurring nuclides (^{40}K , ^{226}Ra , ^{228}Ra , ^{232}Th , and ^{235}U) and the long-lived fission product (^{137}Cs) provides background information and baseline data on global fallout.

Methods

In 1990, soil samples were collected from 14 locations at Site 300. Eleven of the samples were collected from locations that were sampled annually since 1973. Two samples were collected from locations in drainage channels added to the soil surveillance network in 1986. One sampling location near Bunker 801 was added to the network in 1989. However, the sampling locations were renamed with new sample location designators during 1990 (see Quality Assurance chapter).

Figure 3-SO-1 shows the soil sampling locations at Site 300.

Sampling activities followed standardized written procedures (Brekke et al. 1988). Samples are taken from reasonably level areas that represent undisturbed soil. A 2-m square is marked off in each area. An 8.25-cm-diameter coring tool, designed at LLNL, is used to collect 5-cm-deep subsamples at the corners and center of the square. All subsamples are collected to a depth of 5 cm, because surface deposition from the air is the primary pathway for potential contamination. The five subsamples of soil collected from each 2-m square

are combined into a single composite sample in a plastic bag. A label is affixed to the bag, showing a sample identification code, called the sample identifier. This identifier, which includes the sampling location designator, is entered in a logbook, with all pertinent sampling information and the sample location description. The code identifies the sample throughout all sampling and laboratory activities and during data reporting. For clarity, only sampling location designators are used in the data tables of this report.

After collection, the samples are dried, ground, and blended. Plutonium-239 content is determined from an aliquot of each sample after drying, grinding, sieving, and an acid-leaching procedure (the soil is leached by heating for four hours with a mixture of concentrated HNO_3 and HCl). The plutonium then is separated and purified by ion exchange and electroplating, and finally it is submitted for alpha spectroscopy.

Other sample aliquots, which are analyzed by gamma spectroscopy (for over 150 radionuclides), first are dried at 110°C for a minimum of 2 days, then they are

Site 300
Soil
Monitoring

pulverized, passed through a 32-mesh sieve, and blended. The gamma spectroscopy involves approximately 300-g aliquots of the soils, which are sealed in 200-cm³ thin-walled aluminum cans. The samples are counted for gamma-emitters with a Ge(Li) detector.

Approximately 10% of the soil-sampling locations are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, 2 adjacent cores, 5-cm deep, are taken from the corners and center of each 2-m square. Separate composites of the 5 cores then are made, and the composites are identified with unique sample identifier codes.

Results

Table 3-SO-1 presents data on the concentrations of ²³⁹Pu, ⁴⁰K, ¹³⁷Cs, ²²⁶Ra, ²²⁸Ra, ²³²Th, ²³⁵U and ²³⁸U in soils from the Site 300 sampling locations; only positively detected nuclides are shown. The concentrations and distributions of all observed nuclides in Site 300 soil for 1990 remain similar to the levels measured in 1988 and 1989, and lie within the ranges reported in previous years. The soil samples once again show that greater-than-background concentrations of ²³⁸U are limited to isolated regions near the firing tables and disposal areas. The highest ²³⁸U value of 62.2 µg/g (about 20 times greater

Figure 3-SO-1. Soil sampling locations, Site 300, 1990.

than background) was observed in the vicinity of an on-site landfill.

In 1989, a maximum value of 98.2 µg/g was detected in the vicinity of an inactive firing table (soil sampling location 812N). In 1990, the sample from this location registered only slightly above background levels. In 1988, the gravel from this firing table was removed to an on-site landfill as part of a sitewide restoration effort. The 1989 and 1990 values probably indicate residual material in this area.

Environmental Impact

In the past, ²³⁸U-contaminated gravel from the firing tables was removed to

on-site landfills. These landfills at Site 300 have been inactive since 1988. As in the past, the 1990 analyses indicated that increased ²³⁸U in soil is essentially limited to areas adjacent to firing bunkers (Gudiksen et al. 1973; Holland et al. 1987; Holland and Brekke 1988) and near the landfills. However, the level of contamination has been reduced, probably because of the bunker cleanup operations that removed contaminated gravel to the landfills.

With the exception of elevated ²³⁸U concentrations observed near the bunkers and the landfills, the activities observed in samples collected are representative of background or naturally occurring radionuclides.

Table 3-SO-1. Positively detected radionuclides in soil—Site 300, 1990 (sampling depth = 0 to 5 cm).

Location ^a	²³⁹ Pu	⁴⁰ K	¹³⁷ Cs	²²⁶ Ra	²²⁸ Ra	²³² Th	²³⁸ U	²³⁵ U
	[10 ⁻⁹ µCi/dry g ± 2σ (%)]		[10 ⁻⁶ µCi/dry g ± 2σ (%)]			[µg/dry g ± 2σ (%)]		[10 ⁻² µg/dry g ± 2σ (%)]
834W	4.3 ± 5	13.5 ± 3	0.18 ± 3	0.93 ± 2	1.05 ± 3	9.9 ± 4	2.3 ± 48	2.1 ± 96
801W	1.2 ± 10	14.8 ± 4	0.04 ± 22	1.04 ± 2	0.98 ± 4	10.7 ± 3	5.4 ± 56	4.1 ± 49
NPS	2.7 ± 4	15.4 ± 2	0.12 ± 10	0.77 ± 2	0.68 ± 4	6.6 ± 3	≤1.4	3.2 ± 61
EOBS	0.4 ± 14	13.8 ± 3	0.02 ± 40	0.92 ± 2	0.84 ± 4	8.9 ± 3	≤2.8	≤1.4
DSW	5.4 ± 3	12.5 ± 4	0.23 ± 6	0.98 ± 3	0.76 ± 6	8.2 ± 5	62.2 ± 9	12.8 ± 22
812N	0.4 ± 12	8.5 ± 3	0.02 ± 45	0.40 ± 3	0.40 ± 6	4.5 ± 4	17.7 ± 19	3.3 ± 58
801E	5.5 ± 3	11.9 ± 3	0.22 ± 5	0.95 ± 2	0.88 ± 3	9.2 ± 2	≤2.5	1.7 ± 85
GOLF	2.5 ± 4	14.9 ± 3	0.05 ± 15	0.79 ± 2	0.84 ± 4	8.5 ± 3	≤2.0	≤1.5
851N	2.7 ± 4	13.4 ± 3	0.10 ± 9	1.30 ± 2	1.39 ± 3	14.7 ± 2	3.3 ± 84	2.8 ± 59
EVAP	0.8 ± 7	12.1 ± 4	0.03 ± 13	0.87 ± 2	0.86 ± 3	8.1 ± 5	5.6 ± 26	≤1.1
WOBS	4.9 ± 3	12.2 ± 3	0.23 ± 5	0.67 ± 2	0.77 ± 4	8.2 ± 2	≤2.9	≤1.6
858S	4.4 ± 4	14.6 ± 3	0.21 ± 5	1.14 ± 2	0.92 ± 4	9.5 ± 3	2.7 ± 79	3.3 ± 59
856N	3.2 ± 3	11.2 ± 3	0.14 ± 4	0.84 ± 2	0.94 ± 3	9.1 ± 4	3.1 ± 49	≤1.1
801N	2.7 ± 6	14.5 ± 3	0.12 ± 8	1.24 ± 2	1.18 ± 3	12.7 ± 2	3.8 ± 81	2.6 ± 70
Mean	2.9	13.1	0.12	0.92	0.89	9.2	3.0 ^b	2.4 ^b
SDM (%)	61	14	67	25	26	27	25 ^c	38 ^c

^a See Fig. 3-SO-1 for sampling locations.

^b Median value. See Quality Assurance chapter.

^c Median absolute deviation (%). See Quality Assurance chapter.

Introduction

Sampling and measurement of native vegetation can provide information about the presence of radionuclides in the environment. Native vegetation is mentioned specifically in DOE monitoring regulations as an appropriate medium for sampling and analysis (U.S. Department of Energy 1988d). The requirements also call for vegetation radionuclide pathway analyses. Lawrence Livermore National Laboratory (LLNL) collects and analyzes vegetation samples from Site 300, then a potential human dose from this pathway is calculated.

Methods

At quarterly intervals, samples of vegetation (usually native grasses) are collected at Site 300 and at off-site locations near Site 300. **Figure 3-V-1** shows the 1990 vegetation-sampling locations at Site 300. The sampling locations are the same as those sampled in 1988 and 1989, but the locations were renamed with new sample location designators during 1990 (see Quality Assurance chapter). The use of constant sampling locations allows better data trending and closer monitoring at areas of concern.

Sampling activities follow standardized written procedures (Brekke et al. 1988). Grass samples are cut at ground level. Any soil or dead tissues are discarded. The bulk volumes of the samples are between 0.5 and 1 L (approximately 1 kg). As each sample is collected, it is double-bagged in plastic, labeled according to sample type and location, then frozen in a dry-ice chest to minimize water loss on the bag's surface. A label is affixed to the bag, and the sample is identified by a sample identification code, called the sample identifier. This identifier, which includes the sampling location designator, is entered in a logbook, with all pertinent sampling information and a description of the sample location. The code identifies the sample throughout all sampling and laboratory activities and for data reporting. For clarity, only sampling location designators are used in the data tables of this report. The vegetation samples later are transferred to a freezer in the laboratory.

Two subsamples of vegetation are collected each quarter at each sampling location. One subsample is analyzed and the other one is preserved in the laboratory freezer—in case the first sample is lost during analysis, or the measurement result is questionable, requiring reanalysis of the sample for data verification.

Water from the vegetation samples is collected using freeze-drying techniques. The tritium content of the recovered water is determined by liquid-scintillation counting.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, a total of four vegetation subsamples from a sampling location are collected using identical methodology. Two of the bags serve as the official sample. The other two bags are considered the duplicate sample. Duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Results

Table 3-V-1 shows tritium data for vegetation collected at Site 300. With the exception of two locations, most values are at or near detection limits, and are similar to those reported in 1988 and 1989. As was the case in 1989, vegetation samples from locations DSW and EVAP contained the highest tritium values detected. However, in both cases, the maximum tritium concentrations in vegetation detected in

Site 300
Vegetation
Monitoring

1990 were less than the maximum levels detected in 1989. Both of these locations are in areas presently under investigation by the Environmental Restoration Division for tritium contamination of groundwater. Tritium has been observed in the vegetation of these two areas since 1971.

These sampling locations are adjacent to landfills that include tritium-containing debris from firing tables. As a result of seasonal rains spreading tritium from this debris, tritium is present in the soil and groundwater in the area where these samples routinely are collected. The landfill areas are under continued investigation for soil and groundwater tritium contamination, as described in reports published by

the Environmental Restoration Division of LLNL's Environmental Protection Department (see, e.g., Lamarre et al. 1989a-c; Taffet et al. 1989a).

The effective dose equivalents shown in **Table 3-V-1** were derived using dose-conversion factors provided by DOE (U.S. Department of Energy 1988b) and a dose-pathway model from NRC Regulatory Guide 1.109 (U.S. Nuclear Regulatory Commission 1977). See **Appendix B** for a detailed discussion of dose-calculation methods. The calculated annual average dose from vegetation at Location EVAP, based on the highest measured mean value of 13,074 pCi/L (484 Bq/L), is 0.23 mrem (0.0023 mSv), using conservative

Figure 3-V-1. Vegetation sampling locations, Site 300, 1990.

pathway modeling assumptions. (An adult's diet is assumed to include vegetables with the highest-observed average tritium concentration, and both meat and milk derived from livestock fed on grasses with the same concentration.) In actuality, this dose never would be received, because vegetation at Site 300 is consumed neither by people nor by grazing livestock.

Environmental Impact

In general, LLNL impacts on vegetation at Site 300 for 1990 were minimal.

With the exception of vegetation from the two known sites of contamination, tritium levels found in the Site 300 vegetation were comparable to those observed in previous years: they were low, near the limits of detection. The known contamination areas are well-delineated and are very localized. The affected vegetation is neither ingested directly by people nor consumed by livestock. Tritium levels in vegetation at Site 300 will continue to be monitored.

Table 3-V-1. Tritium in vegetation—Site 300, 1990.

	Sampling location ^a					
	CARN	GOLF	GEO	DSW	801E	EVAP
	[pCi/L of moisture content $\pm 2\sigma$ (%)]					
First quarter	≤ 122	≤ 120	≤ 119	182 ± 68	285 ± 44	359 ± 35
Second quarter	259 ± 47	≤ 116	164 ± 73	$7,930^b \pm 3$	417 ± 30	$42,400^b \pm 1$
Third quarter	176 ± 70	123 ± 99	151 ± 81	$3,310^b \pm 5$	≤ 121	$9,280^b \pm 3$
Fourth quarter	≤ 128	≤ 127	164 ± 78	431 ± 31	≤ 127	257 ± 50
Mean	152^c	122^c	150	307 (2,963)^b	206^c	308 (13,074)^b
SDM (%)	18^d	3^d	14	57 (122)^b	40^d	23 (153)^b
Effective dose (mrem) ^e	2.7×10^{-3}	2.2×10^{-3}	2.7×10^{-3}	5.5×10^{-3} (5.3×10^{-2}) ^b	3.7×10^{-3}	5.5×10^{-3} (2.3×10^{-1}) ^b

^a See Fig. 3-V-1 for sampling locations.

^b Data from area of known contamination. Summary statistics and doses with this value included in the calculation are in parentheses.

^c Median value. See Quality Assurance chapter.

^d Median absolute deviation (%). See Quality Assurance chapter.

^e This dose represents the total effective dose equivalent from the forage-cow-milk pathway. See Appendix B.

Introduction

Beginning July 1, 1988, the Environmental Monitoring Group at Lawrence Livermore National Laboratory (LLNL) implemented an environmental radiation monitoring program at Site 300 to evaluate the level of environmental radiation. Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters. The dosimeters provide a measure of the total amount of radiation, both background and any penetrating radiation that has man-made origins, at a particular location. This section contains the 1990 environmental penetrating radiation monitoring results for Site 300.

Methods

The program was designed to measure external doses from penetrating radiation (primarily gamma rays) at 13 Site-300-perimeter locations and three off-site locations (**Figure 3-R-1**). These measurements are made with Panasonic UD814 thermoluminescent dosimeters (TLDs). This type of dosimeter contains three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Each dosimeter is heat-sealed in a 8.9-cm $\times$ 5.7-cm (3-1/2-in $\times$ 2-1/4-in), 4.5-mm-thick foil pouch to protect against light and moisture. The dosimeters are mounted in the field on existing structures (such as fence lines), approximately 1 m (3.3 ft) above ground level. The dosimeters are exchanged and analyzed quarterly.

The TLDs measure environmental radiation exposure in milliroentgens (mrem). The measured exposure is converted to dose by calibrating the dosimeters to read out in absorbed dose and applying a quality factor for a beta/gamma radiation field. The resulting dose equivalents (mrem) are compared to radiation protection standards.

The TLDs measure radiation exposure from all sources of penetrating radiation. These include natural sources, fallout from nuclear weapons testing, and any contribution from Site 300 operations. Off-site dosimeters are located in areas accessible to the public. These areas are considered background and are used for comparison with the perimeter dosimeters.

Results

Table 3-R-1 presents the TLD data, expressed as dose equivalents (mrem) for 1990. The perimeter average measured dose in 1990 was 78.2 mrem/y (0.782 mSv/y), ranging from 70 to 94 mrem/y (0.70 to 0.94 mSv/y). The off-site measured doses are 78 mrem/y (0.78 mSv/y), just west of Site 300, and are 70 and 57 mrem/y (0.70 and 0.57 mSv/y) in the City of Tracy.

Environmental Impact

Initial network design limited monitoring to the site perimeter and three locations in the San Joaquin Valley near the City of Tracy. The off-site locations were chosen to provide exposure information about nearby population centers, as well as background radiation levels. The regions contain different terrain and geological composition. The region around Site 300 has elevated levels of naturally occurring uranium, and is geologically different than the San Joaquin Valley region. The differences observed between the two locations may account for the different measured external radiation doses. We are investigating these differences and have added five additional TLD monitors to increase our off-site network around Site 300 and to confirm these differences.

The TLDs measure radiation exposure from all sources of penetrating radiation. Based on past calculations (Lindeken et al. 1973), environmental terrestrial

Site 300
Environmental
Radiation
Monitoring

exposure rates in this region vary from 30 to 60 mrem/y (0.3 mSv to 0.6 mSv/y). Cosmic radiation is about 35 mrem/y (0.35 mSv/y), calculated from local elevation and geomagnetic latitude

according to the data of Lowder and Beck (1966). The 1990 average measured dose of 78.2 mrem (0.782 mSv) falls well within this 65 to 95 mrem/y (0.65 to 0.95 mSv/y) range.

Figure 3-R-1. Location of Site 300 gamma dosimeters, 1990.

Table 3-R-1. Environmental radiation measurements (TLD)—Site 300, 1990.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	
Location ^a	(mrem)				Annual Total
<u>Site 300 perimeter</u>					
78	16	19	18	19	72
79	17	18	18	17	70
80	17	18	18	19	72
81	21	22	22	23	88
82	19	20	19	20	78
83	19	21	20	21	81
84	18	19	18	20	75
85	18	19	19	20	76
86	18	19	18	19	74
87	22	23	24	25	94
88	17	19	18	19	73
89	18	23	20	21	84
90	20	21	19	20	80
Average	18.5	20.2	19.3	20.2	78.2
SDM (%)	9.2	9.5	9.5	9.9	9.0
<u>Off site</u>					
91	18	20	19	21	78
92	17	18	17	18	70
93	14	14	14	15	57
Average	16.3	17.3	16.7	18.0	68.3
SDM (%)	12.7	17.7	15.1	16.7	15.5

^a See Fig. 3-R-1.

Introduction

As noted earlier, Lawrence Livermore National Laboratory's (LLNL's) high-explosive (HE) testing is conducted at Site 300. Because the site is relatively remote, peak noise or overpressures from these experiments have minimal impact on populated areas. On the basis of meteorological measurements made prior to each test, a limit is set on the weight of HE that can be detonated without impact on populated areas. To monitor this limit, six microbarograph sensors are maintained in or near the City of Tracy.

Methods

Figure 3-N-1 shows the locations of the environmental overpressure stations in Tracy and surrounding areas. Each station consists of an outdoor weatherized B&K Company sound-level meter and a UHF radio telemetry link back to Site 300. Acoustic data are analyzed for overpressures in excess of regulatory limits during explosives testing, taking into account the acoustic propagation time.

Results

LLNL conducted 105 HE tests at Site 300 during 1990. Microbarograph measurements, taken in the vicinity of Site 300 and in the City of Tracy, demonstrated that the peak noise limit of 127 db (400 μ bar) was not exceeded. There were no complaints of noise or overpressure from residents in the vicinity of Site 300. Furthermore, none of the 105 tests produced peak sound levels above 115 db (112 μ bar) at any of the six stations.

Environmental Impact

Through compliance with the limit of 127 db (400 μ bar), LLNL has prevented any significant noise impact.

Figure 3-N-1. Noise monitoring locations in Tracy and surrounding area, 1990.

ENVIRONMENTAL RADIOLOGICAL PROGRAM SUMMARY

Introduction

A general discussion of radiation is presented in the Environmental Radiological Program Summary chapter for the Livermore site. The reader unfamiliar with the terms used throughout this chapter, such as "rad" and "rem," is referred to that chapter. More information is contained in *Radiation: Doses, Effects, Risks* (U.N. Environment Programme 1985).

Radiation Protection Standards

The DOE environmental radiation protection standards are provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (U.S. Department of Energy 1990). That order incorporates a new system for controlling exposures to the public from operations at DOE facilities. These standards are based on recommendations by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements.

The primary DOE radiation standards for protection of the public are 100 mrem/y (1 mSv/y) effective dose equivalent for prolonged exposure and 500 mrem/y (5 mSv/y) effective dose equivalent for occasional exposure. These limits are based on the dose to the maximally exposed individual in an uncontrolled area. "Effective dose equivalent" is the sum of the effective dose equivalent from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during the calendar year.

DOE and Lawrence Livermore National Laboratory (LLNL) also comply with EPA standards for radiation protection. The EPA radiation dose standards that apply to air emissions are contained in 40 *Code of Federal Regulations* Part 61, Subpart H, of the Clean Air Act. The EPA standard is 10 mrem/y (0.1 mSv/y) whole-body effective dose equivalent. Before December 15, 1989, the standard was 25 mrem/y (0.25 mSv/y)

dose equivalent for whole-body exposure from the air pathway, and 75 mrem/y (0.75 mSv/y) dose equivalent for exposure of any organ from the air pathway.

The EPA standard specifies that the AIRDOS-EPA Clean Air Act Code (CAAC) model code be used to estimate doses. To fulfill the DOE requirement, LLNL historically has used the Continuous-Point-Source Code (CPS Code). This approach results in somewhat different calculated individual doses because of the differences in model assumptions and calculations. The results of both codes are presented in Tables 3-RS-1 and 3-RS-2.

Potential Radiological Dose from Site 300

In accordance with DOE environmental protection orders and other Federal and State requirements, the Environmental Monitoring Group (EMG) assessed the radiological impact from operations at Site 300 during 1990. Potential radiation doses to the public are calculated from radionuclide concentrations in environmental media (determined by surveillance sampling), and these doses are presented with the data in the various chapters. Doses calculated from emissions of radioactive materials to the atmosphere are presented here.

There are two major sources by which radioactivity can enter the atmosphere at Site 300: operations at the Advanced Test

Accelerator (ATA) and high-explosives tests. Because airborne emissions from high-explosives tests cannot be monitored, potential impacts from these operations are assessed by a network of ambient air monitors.

The ATA was not operational during 1990. There were no air-activated radionuclide air emissions, so the source term for input to the dose predicting codes is zero.

As stated previously, radiation doses based on emissions are calculated by two methods: the EPA Clean Air Act Code (CAAC) (40 *Code of Federal Regulations* Part 61, Subpart H), which contains the AIRDOS-EPA and RADRISK models, and the Continuous-Point-Source (CPS) Code (Peterson et al. 1976).

The CAAC is used to calculate the estimated dose to the nearest resident and dose at the maximum off-site exposure location for each emission source. The CPS Code is used to calculate the estimated dose at the site perimeter, dose to the nearest resident, and maximum off-site dose, as well as collective person-rem dose to the population residing within 80 km (50 mi). Both methods are based on conservative assumptions. Any actual dose received by an individual would be much less.

These codes are used to determine the doses caused by any releases of ^{13}N and ^{15}O , air activation products. **Appendix B** contains definitions of the doses discussed in this chapter and the mathematical equations used to perform this assessment.

EPA Clean Air Act Code. The air pathway doses, calculated using the CAAC, include exposures from inhalation, air submersion, ingestion, and ground surface irradiation. The CAAC is run using the specific 1990 meteorology for Site 300. The air pathway dose is expressed as effective dose equivalent in millirem.

The EPA limit for airborne emissions is 10 mrem/y (0.1 mSv/y) effective dose equivalent. The total fence-line dose from air emissions from Site 300 operations in 1990 was zero mrem. The dose to the nearest resident was also zero mrem. The dose

at the point of maximum off-site exposure was zero mrem. These doses represent 0% of the EPA limit (see **Table 3-RS-1**).

Continuous-Point-Source Code. Air pathway doses also are calculated using the CPS Code (**Table 3-RS-2**). The maximum inhalation dose from airborne emissions at the Site 300 perimeter was zero mrem. The maximum inhalation dose from airborne emissions to the nearest resident was zero mrem.

Table 3-RS-3 is a summary of the radiological dose to the maximally exposed individual in the public. This individual is a hypothetical person who lives at a location and has a lifestyle that results in receipt of the maximum possible calculated radiation dose from Site 300 operations. This dose includes all significant exposure pathways, not just the air pathway, and is derived using the most conservative, but realistic, exposure data and assumptions. The inhalation submersion pathways are calculated using the CPS Code. The calculated committed (50-y) effective dose equivalent to the maximally exposed member of the public from all sources and pathways during 1990 was zero mrem. The DOE radiation protection limit to the public is 100 mrem/y (1 mSv/y). For comparison, the average resident in the Tracy area received a dose of approximately 300 mrem/y (3.0 mSv/y) from natural background radiation (including radon) during this same period (see **Table 3-RS-4**).

Finally, the CPS Code was used to calculate the collective population dose. The collective population dose is the sum of the doses to all individuals residing within an 80-km (50-mi) radius. The estimated collective effective dose equivalent to the total population within 80 km (50 mi) was zero person-rem during 1990. This dose is based on a population of 6 million within 80 km (50 mi) of LLNL. The collective population dose from natural sources of radiation, using 300 mrem/y (3.0 mSv/y) as a typical average from natural sources during the same period was estimated to be 1.9×10^6 person-rem (1.9×10^4 person-sievert).

Table 3-RS-4 compares the dose to the public resulting from Site 300 operations with the dose to the public from natural and other background sources of radiation. The dose resulting from Site 300 operations is zero.

Radiation Dose Summary

Overall, there were no emission sources, and the calculated potential radiation doses are zero. Site 300 operations had no significant radiological impact on public health during 1990.

This section of the Radiation Program summary summarizes monitoring data acquired to validate the effectiveness of Site 300 administrative and engineering controls that prevent the introduction of radiation to the environment.

Air Monitoring

Airborne Radioactivity. LLNL analyzes air filters for gross alpha and gross beta activity to ensure that releases of radionuclides other than those specifically targeted will be detected, and to identify trends in the Site 300 environs. Most of the gross alpha determinations were at or near the detection limit of the method. Typical gross alpha activity is less than 1.2×10^{-15} $\mu\text{Ci/mL}$ (4.44×10^{-11} Bq/mL), and typical beta activity is 1×10^{-14} $\mu\text{Ci/mL}$ (3.7×10^{-10} Bq/mL). Most of the observed alpha and beta activity results from the naturally occurring radioisotopes of uranium and thorium and their decay products.

Of the nuclides tabulated, ^7Be , ^{40}K , ^{226}Ra , ^{228}Ra , and ^{228}Th occur naturally. The primary source of the ^{137}Cs and ^{22}Na is long-term global fallout and fallout resuspension. All radionuclide air concentrations are below 0.04% of the DOE Derived Concentration Guide (DCG). DCGs specify the concentrations of radionuclides in air or water that could be inhaled or consumed continuously 365 days a year without exceeding the DOE primary radiation protection standard to the public of 100 mrem/y (1 mSv/y) effective dose equivalent (U.S. Department of Energy 1990). These very low DCG

percentages demonstrate the low levels of gamma activity present at Site 300 and in Tracy.

The highest concentrations of ^{239}Pu were observed in the May and December sample composites at a level of approximately 0.04×10^{-17} $\mu\text{Ci/mL}$ (0.002% DCG). This value is 2.4 times lower than the highest monthly concentration experienced in 1989, and represents a return to pre-1988 levels. The highest concentration of ^{238}U was observed in the February sample composite at a level of 9.86×10^{-5} $\mu\text{g/m}^3$ (0.03% DCG). The highest concentration of ^{235}U was observed in the July sample composite at a level of 9.33×10^{-7} $\mu\text{g/m}^3$ (0.02% DCG). No other statistically significant differences between locations or samples were noted. The overall levels determined were essentially the same as those reported in previous years.

Water Monitoring

The following paragraphs summarize radiological findings from the Routine Water (surface water, water supply wells, Site 300 groundwater, and Site 300 area groundwater) and Compliance Groundwater (Pits 1, 2, 6, 7, 8, and the Building 817 surface impoundments) monitoring programs. Compliance groundwater monitoring is performed in the vicinity of Site 300 landfill areas to fulfill the specific monitoring and reporting requirements of State and Federal agencies. Routine groundwater surveillance monitoring is performed to assess the potential impact of Site 300 operations on the area groundwater.

Surface Water. Surface water samples are collected quarterly from three locations, one of which is off site. The water samples are analyzed for gross alpha, gross beta, and tritium activity. Gross alpha and beta activities in these surface water samples were below EPA and DHS MCLs. All samples collected resulted in tritium concentrations that were well below recommended concentration guide values. The highest activity of tritium in water was measured in rain at a concentration of

54.7 pCi/L, which represents 0.003% of the MCL specified by DHS for tritium in drinking water.

Water Supply Wells. On-site water supply Wells 01 (inactive), 18, and 20, along with off-site water supply Wells CARNRW2, CDF1, CON1, and GALLO1, are sampled quarterly for gross alpha, gross beta, tritium activity, and for isotopes of radium and uranium, to determine if the activity is caused by naturally occurring radionuclides.

Well 01, the inactive water supply well, displayed the highest tritium concentration of the water supply wells, ranging from 3,000 to 4,300 pCi/L. However, these concentrations are a fraction of the drinking water MCL for tritium (20,000 pCi/L). This well is not a drinking water supply.

Site 300 Groundwater. Monitoring Wells NC2-11D, NC7-61, NC7-69, and W-7A are located in areas of site activity that previously were monitored by sampling inactive water supply wells. These on-site monitoring wells are sampled quarterly for gross alpha, gross beta, and tritium activity. In the fourth quarter of 1990, Wells NC7-61 and NC7-69 were analyzed additionally for uranium and radium isotopes.

Tritium was observed in Well NC7-61 at concentrations in excess of the MCL (20,000 pCi/L) during all four quarters of 1990.

Gross alpha activity in Well NC7-61 was slightly higher in the fourth quarter of 1990. The sample was reanalyzed for radium-226, to define further the alpha-emitting radionuclides present. Results were below the detection limit of 1 pCi/L.

Site 300 Area Groundwater. Samples are collected annually from nine groundwater sources (four from off-site active water supply wells, and five from off-site surveillance wells) from the area surrounding Site 300, to characterize local groundwater quality and to better assess potential Site 300 environmental impacts. These wells include water supply Wells CARNRW2, CDF1, CON1, GALLO1, and GALLO2, along with surveillance Wells Wellman2, VIE1, VIE2, MUL1, and MUL2.

These samples are analyzed for gross alpha, gross beta, and tritium activity. The results of these analyses indicated no radiological concentrations above background.

Compliance Groundwater Monitoring

Pit 1 Landfill Area. Pit 1 is in the detection monitoring mode, where by groundwater monitoring is regulated by the RWQCB, DHS, and EPA. Groundwater samples collected from eight monitoring wells (K1-01C, -02B, -03, -04, -05, -07, -08, and -09) are analyzed quarterly for gross alpha, gross beta, tritium activity (no distillation or enrichment of samples prior to counting by liquid-scintillation methods), and for isotopes of radium and uranium, to determine if the activity is caused by naturally occurring radionuclides.

All radiological results were well below the EPA or DHS MCLs.

Pit 7 Landfill Complex. The Pit 7 Complex also is in the detection monitoring mode where groundwater monitoring is regulated by the RWQCB, DHS, and EPA. Groundwater samples collected from eight monitoring wells (K7-01, -03, -06, -07, -10, and NC7-25, -26, -47) are analyzed quarterly for gross alpha, gross beta, tritium activity, and for isotopes of radium and uranium, to determine if the activity is caused by naturally occurring radionuclides. The Pit 7 Complex wells also provide monitoring data for inactive landfills 3, 4, and 5.

Similar to last year's findings, slightly elevated levels of gross alpha and gross beta activity were detected in Well K7-01. Further laboratory analysis of samples from Well K7-01 indicated these values were likely the result of naturally occurring uranium levels in the groundwater.

Pits 2 and 8 Landfill Areas. Wells K2-01C, -04S, -04D, which monitor inactive Pit 2, and Well K8-01, which monitors Pit 8, are not analyzed for radiological constituents. Well NC2-07, located at the site's eastern boundary, is the most down-gradient monitoring point for Pits 2, 3, 4, 7, and 8. This well is sampled quarterly for

tritium and semiannually for gross alpha and gross beta activity. Barcad samplers, which are used to monitor the deeper water-bearing zones beneath Pits 1 and 2, are sampled quarterly for gross alpha, gross beta, and tritium activity.

The tritium values for Wells K2-01C, K2-04D, and K2-04S continue to be observed at concentrations below the MCL of 20,000 pCi/L.

Pit 6 Landfill Area. Inactive Pit 6 is subject to RWQCB requirements. Groundwater (Wells K6-01, -03, -04; and EP6-07, -08, and -09) is analyzed quarterly for gross alpha, gross beta, tritium activity, and for isotopes of radium and uranium, to determine if the activity is caused by naturally occurring radionuclides.

During the third quarter, gross beta activity in Well K6-04 was measured at an elevated value of 48 pCi/L (just below the MCL of 50 pCi/L). In the fourth quarter, two independent laboratories performed gross beta analyses on samples from Well K6-04 that resulted in measurements of 7 pCi/L and 17 pCi/L, within the historical range of <6 to 17 pCi/L. (Both values were well below the MCL of 50 pCi/L.) Additional analyses of groundwater samples from Well K6-04 identified the beta emitter as part of the natural uranium decay chain.

Building 817 High-Explosives (HE) Process Area. The Building 817 HE Process Area is subject to RWQCB requirements. Groundwater from four wells (W-817-01, -02, -03, and -04) is analyzed quarterly for tritium. Tritium concentrations in the Building 817 HE Process Area were well below the EPA or DHS MCLs.

Groundwater Investigation and Feasibility Study Activities

A major portion of the groundwater protection program at Site 300 is the investigative work performed under requirements of the RWQCB, Central Valley Region, and the EPA.

Groundwater at Site 300 moves via pores and fractures. The regional groundwater table occurs within sandstone and

conglomerate beds. Site 300 drinking and process water is supplied by a deep confined aquifer, and groundwater generally follows the dip of the bedrock. Three known perched groundwater bodies exist locally beneath the site.

The environmental restoration efforts at Site 300 encompass a variety of activities supporting ongoing remedial investigations and feasibility studies to aid remediation of potential environmental conditions in compliance with Federal, State, and local laws and regulations. These activities are performed in geographic areas of known or suspected releases to determine the extent, if any, of hazardous substances that may have affected soil and/or groundwater.

The following section summarizes the investigation activities at Site 300 since the early 1980s. Summary results are presented in the accompanying figures found in the Site 300 Groundwater Protection chapter detailing the isoconcentrations of the contaminant for each investigation.

Tritium Investigation

Debris from HE tests has historically been disposed of in landfills at the northern end of Site 300. In 1981, the Hazardous Waste Assessment study of the hydrology, geology, and groundwater chemistry associated with Site 300 landfills was initiated. As part of this project, monitoring wells were installed at the landfills, and a program of periodic groundwater monitoring was initiated. In 1984, tritium levels in water from four of the wells rose above the California drinking water standard. A tritium investigation was initiated. To date, three areas with tritium present in the groundwater have been identified: the Pit 7 Complex, the Building 850 area in the West Firing Area, and near Pit 2 in the East Firing Area (Figures 3-G-2 and 3-G-6).

Soil Monitoring

Soil is an integrating medium that can absorb contaminants from the atmosphere or from liquid effluents (U.S. Department of Energy 1988d). Since 1972, soil sampling

Site 300

Environmental Radiological Program Summary

at Site 300 has been part of the continuing LLNL environmental surveillance monitoring program designed to document any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might result from LLNL operations. Because high-explosive tests at Site 300 occasionally involve the use of depleted uranium (^{238}U), one purpose of the annual soil sampling is to determine how these tests perturb the natural uranium content of the soil. Including the other naturally occurring nuclides (^{40}K , ^{226}Ra , ^{228}Ra , ^{232}Th , and ^{235}U) and the long-lived fission product (^{137}Cs) provides background information and baseline data on global fallout.

The concentrations and distributions of all observed nuclides in Site 300 soil for 1990 remain similar to the levels measured in 1988 and 1989, and lie within the ranges reported in previous years. The soil samples once again show that greater-than-background concentrations of ^{238}U are limited to isolated regions near the firing tables and disposal areas. The highest value detected 62.2 $\mu\text{g/g}$; about 20 times greater than background was observed in the vicinity of an on-site landfill.

In 1989, a maximum value of 98.2 $\mu\text{g/g}$ was detected in the vicinity of a now-inactive firing table. In 1990, the sample from this location registered only slightly above background levels. In 1988, the gravel from this firing table was removed to an on-site landfill as part of a sitewide restoration effort. The 1989 and 1990 values probably indicate residual material in this area.

Environmental Impact. In the past, ^{238}U -contaminated gravel from the firing tables was removed to on-site landfills. These landfills at Site 300 have been inactive since 1988. As in the past, the 1990 analyses indicated that increased ^{238}U in soil is essentially limited to areas adjacent to firing bunkers (Gudiksen et al. 1973; Holland et al. 1987; Holland and Brekke 1988) and near the landfills. However, the level of contamination has been reduced,

probably because of cleanup operations at the bunkers that removed contaminated gravel to the landfills.

With the exception of elevated ^{238}U concentrations observed near the bunkers and the landfills, the activity observed in samples collected are representative of background or naturally occurring radionuclides.

Vegetation Monitoring

Sampling and measurement of native vegetation can provide information about the presence of radionuclides in the environment. LLNL collects and analyzes vegetation samples from Site 300 for tritium, and then calculates the potential human dose from this pathway.

With the exception of two locations, most vegetation tritium values are at or near detection limits and are similar to those reported in 1988 and 1989. As in 1989, vegetation samples from two locations contained the highest tritium values detected. However, in both cases, the maximum tritium concentrations in vegetation detected in 1990 were less than the maximum levels detected in 1989. Both locations are in areas presently under investigation by the Environmental Restoration Division for tritium contamination of groundwater.

These sampling locations are adjacent to landfills that include tritium-containing debris from firing tables. As a result of seasonal rains spreading tritium from this debris, tritium is present in the soil and groundwater in the area where these samples routinely are collected.

Using conservative pathway modeling assumptions, the calculated annual average dose from vegetation, based on the highest measured mean value of 13,074 pCi/L (484 Bq/L), is 0.23 mrem/y (0.0023 mSv/y). (It is assumed that an adult's diet includes vegetables with the highest-observed average tritium concentration, and that both meat and milk derived from livestock fed on grasses with the same concentration.) In actuality, this dose would never be received, because vegetation at Site 300 is not consumed by people or by grazing livestock.

Environmental Impact. In general, LLNL impacts on vegetation at Site 300 during 1990 were minimal. With the exception of vegetation from the two known sites of contamination, tritium levels found in the Site 300 vegetation generally were comparable to those observed in previous years; they were low, near the limits of detection. The known contaminated areas are well-delineated and are very localized. The affected vegetation is neither ingested directly by people nor consumed by livestock.

Radiation Monitoring

Penetrating Radiation. Penetrating radiation, which cannot be measured by collection of material on filters (nor chemically trapped), is measured using thermoluminescent dosimeters (TLD).

The dosimeters provide a measure of the total amount of penetrating gamma radiation at a particular location (both background radiation and any radiation that has man-made origins). Penetrating radiation primarily includes gamma rays, which are measured by the TLDs, but it also includes neutron radiation, which is measured by fission track foils. Since there are no neutron sources at Site 300, neutron levels are not measured.

TLD gamma data, expressed as dose equivalents (mrem) for 1990, averaged 78.2 mrem (0.782 mSv), ranging from 70 to 94 mrem (0.70 to 0.94 mSv) at the perimeter. The off-site measured dose was 78 mrem (0.78 mSv) just west of Site 300 and 70 and 57 mrem (0.70 and 0.57 mSv) in the City of Tracy.

Table 3-RS-1. Radiation dose from the air pathway (Clean Air Act Code^a calculations) for Site 300, 1990.

Facility	Nuclide (Ci)	Dose at site perimeter (mrem) ^b	Dose to nearest resident (mrem) ^b	Dose at maximum offsite exposure (mrem) ^b
Advanced Test Accelerator	¹³ N/0 ¹⁵ O/0	0	0	0
Total		0	0	0
Percent of Federal Emission Standard^c		0	0	0

^a These doses were calculated pursuant to the National Emissions Standards for Hazardous Air Pollutants (Clean Air Act), 40 *Code of Federal Regulations* Part 61, Subpart H.

^b These doses are effective dose equivalents calculated using the EPA required method. These calculations were performed using the Clean Air Act Code, which contains the AIRDOS-EPA and RADRISK models for calculating atmospheric transport, exposure, and dose.

^c Federal Emission Standards (contained in 40 *Code of Federal Regulations* Part 61, Subpart H), 10 mrem/y (0.1 mSv/y) effective dose equivalent.

Table 3-RS-2. Estimated radiation dose to the public from Site 300 airborne effluents during 1990 (Continuous-Point-Source Code).

Facility	Nuclide/emission (Ci)	Dose at site perimeter (mrem) ^a	Dose to nearest resident (mrem) ^a	Dose at maximum offsite exposure (mrem) ^a	Collective dose (80-km radius of LLNL) (person-rem) ^b
Advanced Test Accelerator (ATA)	¹³ N/0 ¹³ O/0	0	0	0	0
Total		0	0	0	0

^a This dose represents the 50-y committed effective dose equivalent. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public.

^b The population dose is the collective (combined) dose of all individuals residing within an 80-km (50-mi) radius. These calculations are based on the same population distribution as that around the Livermore site (6,000,000). The population densities within 80 km (50 mi) of Site 300 are actually less. Therefore, the collective person-rem dose is conservative—the actual dose to the public within 80 km (50 mi) around Site 300 is actually lower. The population dose is calculated directly with the Continuous-Point-Source Code.

Table 3-RS-3. Summary of radiological dose assessment for Site 300, 1990.

Effective dose equivalent to the maximally exposed individual in the public						
Nuclide	Pathways			Total		Percent of DOE primary radiation protection standard for the public ^b
	Inhalation/ submersion ^a (mrem)	Ingestion— foodstuffs (mrem)	Ingestion— water (mrem)	(mrem)	(mSv)	
¹³ N, ¹⁵ O	0	N/A ^c	N/A ^c	0	0	0
Site 300 Total^d				0	0	0

^a The inhalation/submersion dose was derived using the Continuous-Point-Source Code, and it represents committed effective dose equivalents. It is calculated using the most conservative exposure assumption and is not a dose actually received by any member of the public.

^b The primary DOE radiation standard for protection of the public (all sources and all pathways) is 100 mrem/y (1 mSv/y).

^c There is no ingestion dose from short half-life air activation products.

^d This dose is the maximum potential dose to a member of the public from all sources and all exposure pathways.

Table 3-RS-4. Comparison of radiation doses—Site 300, 1990.

Location/source	Individual dose (mrem)	Population dose ^a (person-rem)
<u>Site 300 sources</u>		
Atmospheric emissions	0 ^b	0 ^c
<u>Other sources</u>		
Natural radioactivity ^d		
Cosmic radiation	30	240,000
Terrestrial radiation	30	300,000
Internal (food consumption)	40	168,000
Radon	200	1,200,000
Medical radiation ^{e,f} (Diagnostic procedures)	55	330,000
Weapons test fallout ^{e,g}	5	30,000
Nuclear power production ^{e,g}	5.5	33,000

^a The population dose is the collective (combined) dose for all individuals residing within an 80-km (50-mi) radius of LLNL (approximately 6,000,000).

^b This dose represents the maximum committed effective dose equivalent from all Site 300 emissions. It is calculated using the Continuous Point Source Code and the most conservative exposure assumptions and is not a dose actually received by any member of the public. Therefore, it is not used to calculate Site 300 population dose.

^c Population dose from Site 300 emissions is calculated directly with the Continuous-Point-Source Code.

^d These values vary with location and represent approximate averages in the vicinity of Site 300.

^e This dose is an average over the U.S. population.

^f From Mettler et al. (1990).

^g From Glasstone and Jordan (1980).

Introduction

EPD performs extensive monitoring at Site 300 to detect the movement of non-radiological contaminants from experimental areas into the environment, and to verify that other hazardous substances used on the site do not enter the environment. This chapter summarizes the results of this monitoring and the investigations being performed to remediate contamination due to past practices. The results of the monitoring effort demonstrate continued compliance with regulatory requirements, along with the effectiveness of operational controls.

Air Monitoring

The monthly airborne beryllium concentrations at Site 300 average less than $5 \times 10^{-5} \mu\text{g}/\text{m}^3$ and are less than 4.2% of the monthly ambient concentration guide established by the San Joaquin County Air Pollution Control District.

Water Monitoring

The following paragraphs summarize nonradiological findings from the Routine Water (surface water, water supply wells, Site 300 groundwater, and Site 300 area groundwater) and Compliance Groundwater (Pits 1, 2, 6, 7, 8, and the Building 817 surface impoundments) monitoring programs. Compliance groundwater monitoring is performed in the vicinity of Site 300 landfill areas to fulfill the specific monitoring and reporting requirements of State and Federal agencies. Routine groundwater surveillance monitoring is performed to assess the potential impact of Site 300 operations on the area groundwater.

Surface Water. Surface water samples are collected quarterly from three locations, one of which is off site. These samples are not analyzed for nonradiological constituents.

Water Supply Wells. On-site water supply Wells 01 (inactive), 18, and 20, along with off-site water supply Wells CARNRW2, CDF1, CON1, and GALLO1 are sampled quarterly for metals (beryllium,

chromium, copper, and lead) and for volatile organic compounds (VOCs). In addition, Wells 18 and 20 are sampled monthly for VOCs.

A small amount of TCE was detected at a concentration of $0.9 \mu\text{g}/\text{L}$ (below the MCL of $5 \mu\text{g}/\text{L}$) once during third-quarter monitoring in Well 18. Subsequent samples collected from Well 18 did not show the presence of TCE above the detection limit of $0.5 \mu\text{g}/\text{L}$.

Trihalomethane (THM) compounds were detected in samples collected during the third and fourth quarter 1990 from Well CARNRW2. These samples were collected from a mislabelled chlorinated water supply, rather than from untreated well water. The chlorinating process is responsible for presence of THM compounds in samples taken from the mislabelled water supply. The combined quarterly THM concentrations of $4.9 \mu\text{g}/\text{L}$ and $31.7 \mu\text{g}/\text{L}$, respectively, were far below the MCL of $100 \mu\text{g}/\text{L}$. Subsequent samples have been collected from the untreated well water source.

Site 300 Groundwater. Monitoring Wells NC2-11D, NC7-61, NC7-69, and W-7A are located in areas of site activity that previously were monitored by sampling inactive water supply wells. These on-site monitoring wells are sampled quarterly for metals (beryllium, chromium, copper, and lead), and for VOCs.

Site 300

Environmental Nonradiological Program Summary

Site 300 Area Groundwater. Samples are collected annually from nine groundwater sources (four from off-site active water supply wells and five from off-site surveillance wells) within the area surrounding Site 300 to characterize local groundwater quality and to better assess potential Site 300 environmental impacts. These wells include water supply Wells CARNRW2, CDF1, CON1, GALLO1, and GALLO2, along with surveillance Wells Wellman2, VIE1, VIE2, MUL1, and MUL2. These samples are analyzed for metals, minerals, phenolic compounds, VOCs, pesticides, herbicides, and for high-explosives compounds. In addition, Wells CARNRW1 and CON2 are sampled quarterly for VOCs. The results of these analyses indicated no concentrations above background levels, with the exception of THM compounds in Well CARNRW2 (already discussed).

Compliance Groundwater Monitoring

Pit 1 Landfill Area. Pit 1 is in the detection monitoring mode, in which groundwater monitoring is regulated by the RWQCB, DHS, and EPA. Groundwater samples are collected from eight monitoring Wells (K1-01C, -02B, -03, -04, -05, -07, -08, and -09). The samples are analyzed quarterly for metals, minerals, phenolic compounds, VOCs, pesticides, herbicides, nutrients, nitrate, nitrite, ammonia, total Kjeldahl nitrogen, indicator parameters, and for high-explosives compounds.

The sporadic occurrences of 1,3-dichlorobenzene (1,3-DCB) in the Pit 1 Area groundwater samples in the first quarter of 1990 are not considered representative of the area groundwater and are discussed in the Quality Assurance chapter.

Very low concentrations of Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) continues to be observed, but at levels far below the maximum contaminant level (MCL) for Freon-113 of 1200 µg/L.

TCE was detected for the first time in the first quarter of 1990 at a concentration of 3.8 µg/L (below the MCL of 5 µg/L). TCE was not detected in the subsequent three quarters.

Similarly, lead was detected for the first time in the first quarter of 1990 in Well K1-04, at a concentration of 0.011 mg/L (below the MCL of 0.05 mg/L). Lead was not detected in the subsequent three quarters.

Elevated levels of nitrate in the Pit 1 Area wells continue to be observed, but are considered to be natural constituents of the area groundwater.

There were no significant increases in either TOC or TOX concentration in 1990. Significant differences in specific conductance and pH were observed in 1990 between upgradient and downgradient wells. These differences are believed representative of natural groundwater chemical variability and do not represent a landfill-induced change in the groundwater chemistry, because specific conductance and pH values for samples collected from both upgradient and downgradient wells have shown significant increases. Also, the individual ionic constituents in the groundwater are comparable to historic values. It is unlikely that these increases are caused by contamination from the Pit 1 landfill.

Pit 7 Landfill Complex. The Pit 7 Complex also is in the detection monitoring mode, in which groundwater monitoring is regulated by the RWQCB, DHS, and EPA. Groundwater samples are collected from eight monitoring Wells (K7-01, -03, -06, -07, -10; and NC7-25, -26, and -47) and sampled quarterly for metals (lead and beryllium) and VOCs. Well K7-09 and piezometers NC7-22 and NC7-37 are sampled quarterly for volatile organic compounds (VOCs), specifically to monitor for TCE. The Pit 7 Complex wells also provide monitoring data for inactive landfills 3, 4, and 5.

The sporadic occurrences of 1,3-dichlorobenzene (1,3-DCB) in the Pit 7 Complex groundwater samples in the first quarter of 1990 are not considered representative of the area groundwater and are discussed in the Quality Assurance chapter.

TCE concentrations in the Pit 7 Complex area wells are similar to those reported last year. TCE continued to be observed in

Wells K7-01 and K7-03; however, the volatile compounds 1,2-dichloroethylene (1,2-DCE) and tetrachloroethylene (PCE) that were seen in 1989 were not observed in the Pit 7 Complex area in 1990. The occurrence of TCE in Well K7-06 during the third quarter 1990, resulted from samples from Wells K7-01 and K7-06 being switched sometime prior to laboratory analyses. This is discussed further in the Quality Assurance chapter of this report. The detection of 1,1-dichloroethylene (1,1-DCE) was observed in this same switched sample at a concentration of 0.6 µg/L (below the 1989 concentration in Well K7-01 of 1.4 µg/L, and above the MCL of 0.006 µg/L).

Pits 2 and 8 Landfill Areas. Groundwater from wells that monitor inactive Pit 2 (Wells K2-01C, -04S, -04D, and Well NC2-07) and Pit 8 (Well K8-01) is analyzed quarterly for metals (lead and beryllium), VOCs, nitrate, nitrite, ammonia, and total Kjeldahl nitrogen. Barcad samplers, which monitor the deeper water-bearing zones beneath Pits 1 and 2, are sampled quarterly for metals (lead and beryllium). Once a year, the barcads are sampled for a larger suite of metals. This inactive landfill is subject to RWQCB requirements.

The slightly elevated nitrate levels (above the MCL in Well K2-04S and near the MCL in Well K8-01) are considered natural constituents of this area's groundwater. In Well K8-01, TCE and 1,2-dichloroethane (1,2-DCA) continue to be detected at or above the MCLs. Additional characterization of the groundwater in this vicinity is being conducted as part of the Site 300 TCE investigation. Arsenic was observed slightly above the MCL of 0.05 mg/L in well K2-04S at a concentration of 0.053 mg/L, and in Barcad K2-02A at a concentration of 0.083 mg/L. The elevated arsenic levels are comparable to those observed in the Pit 1 Area monitoring wells and elsewhere at Site 300. These levels are considered natural constituents of the area groundwater.

Pit 6 Landfill Area. Inactive Pit 6 is subject to RWQCB requirements. Groundwater (Wells K6-01, -03, -04; and EP6-07,

-08, and -09) is analyzed quarterly for metals, minerals, phenolic compounds, VOCs, pesticides, herbicides, nutrients, nitrate, nitrite, ammonia, total Kjeldahl nitrogen, indicator parameters, and for high-explosives compounds.

The sporadic occurrences of 1,3-dichlorobenzene (1,3-DCB) in the Pit 6 Area groundwater samples in the first quarter of 1990 are not considered representative of the area groundwater, and are discussed in the Quality Assurance chapter.

TCE continued to be detected throughout the year at concentrations slightly above the MCL in Well EP6-09. The Pit 6 Area continues to be part of the ongoing Site 300 TCE investigation.

Building 817 High-Explosives (HE)

Process Area. The Building 817 HE Process Area is subject to RWQCB requirements. Groundwater from four wells (W-817-01, -02, -03, and -04) is analyzed quarterly for pH, total organic halides (TOX), total organic carbon (TOC), specific conductance, HE compounds (HMX, RDX, and TNT), nitrate and nitrite, VOCs, and metals. Samples for VOCs and HE compounds analyses also are collected from Well W-817-03A, a shallow well near the HE surface impoundments. Each quarter, an attempt is made to sample the five lysimeters underlying these HE surface impoundments. If water is present, it is analyzed for HE compounds.

The sporadic occurrences of 1,3-dichlorobenzene (1,3-DCB) in the Building 817 HE Process Area groundwater samples in the first quarter of 1990 are not considered representative of the area groundwater, and are discussed in the Quality Assurance chapter.

The lysimeters underlying the impoundments did not produce any water during 1990. Monitoring Well W-817-01 continues consistently to show small amounts of RDX (an HE compound). In addition, the HE compound HMX was detected during the third quarter of 1990 in Well W-817-01 for the first time since the fourth quarter of 1989. Elevated nitrate, selenium, and arsenic levels have been detected consistently in the wells of this area since their

Site 300

Environmental Nonradiological Program Summary

installation in 1985, and are considered natural constituents of the area groundwater. TCE continued to be seen during 1990 at concentrations above the MCL in Wells W-817-03, -03A, and -04. Investigations of the RDX (and other HE compounds) in Well W-817-01 and the TCE occurrences are part of the Site 300 groundwater investigations.

Statistical analyses showed no significant increase in TOX or TOC concentrations during 1990. As in the Pit 1 Area, significant differences in pH and specific conductance were observed between upgradient and downgradient wells. These differences are believed representative of natural groundwater chemical variability and do not represent a surface-impoundment-induced change in the Building 817 Process Area groundwater chemistry. Because specific conductance and pH values for samples collected from both upgradient and downgradient wells have shown significant increases, and because the individual ionic constituents in the groundwater are comparable to historic values, it is unlikely that the increases in specific conductance are caused by contamination from the HE Process Area surface impoundments.

Groundwater Investigation and Feasibility Study Activities

A major portion of the groundwater protection program at Site 300 is the investigative work performed under requirements of the Regional Water Quality Control Board (RWQCB), Central Valley Region, and the EPA.

Groundwater at Site 300 moves via pores and fractures. The regional groundwater table occurs within sandstone and conglomerate beds. Site 300 drinking and process water is supplied by a deep confined aquifer, and groundwater generally follows the dip of the bedrock. Three known perched groundwater bodies exist locally beneath the site.

The environmental restoration efforts at Site 300 encompass a variety of activities supporting ongoing remedial investiga-

tions and feasibility studies to aid remediation of potential environmental conditions in compliance with Federal, State, and local laws and regulations. These activities are performed in geographic areas of known or suspected releases to determine the extent, if any, of hazardous substances that may have affected soil and/or groundwater.

The following section summarizes the investigation activities at Site 300 since the early 1980s. Summary results are presented in the accompanying figures found in the Site 300 Groundwater Protection chapter detailing the isoconcentrations of the contaminant for each investigation.

TCE Investigation

In 1982, Lawrence Livermore National Laboratory (LLNL) began initial assessment of the environmental effects of TCE released in several areas of the site. By 1987, ten locations within the site were found to have TCE present in soil, rock, and/or groundwater. TCE investigations have continued, emphasizing the southeast part of the site (**Figure 3-G-2**), the Building 834 Complex (**Figure 3-G-3**), the HE Process Area (**Figure 3-G-4**), and the General Services Area (GSA) (**Figure 3-G-5**). Recent monitoring has also revealed trace amounts of TCE in groundwater near the Pit 7 Complex (in the West Firing Area) and at Pit 8 (in the East Firing Area). TCE also has been detected in groundwater at the Pit 6 Area. Environmental and monitoring investigations continue at these locations.

HE Compounds Investigation

Discharges of rinse water from buildings within the HE Process Area historically have been disposed of in unlined lagoons adjacent to the processing buildings. Use of these lagoons was terminated in 1985. The lagoons were closed and capped with impermeable clay in 1989. Concerns about the potential for groundwater degradation because of HE compounds in soil and rocks beneath the lagoons prompted field investigations within the HE Process Area in 1986 and 1987 (**Figure 3-G-2**). Sporadic, but generally low concentrations of HE

compounds, metals, and VOCs were identified beneath some of the lagoons and the HE Burn Pit facility.

Noise Monitoring

On the basis of meteorological measurements made prior to a test, a limit is set on the weight of HE that can be detonated without impact on populated areas. To monitor this limit, six microbarograph sensors are maintained in or near the City of Tracy.

LLNL conducted 105 high-explosives tests at Site 300 during 1990. Microbarograph measurements in the vicinity of Site 300 and the City of Tracy demonstrated that the peak noise limit of 127 db (400 μ bar) was not exceeded. There were no complaints of noise or overpressure from residents in the vicinity of Site 300. Furthermore, none of the 105 tests produced peak sound levels above 115 db (112 μ bar) at any of the six stations.

Introduction

Groundwater monitoring is conducted under two programs at Lawrence Livermore National Laboratory (LLNL). One program is designed to meet regulatory commitments established for specific site investigations, such as the investigation of trichloroethylene (TCE), tritium, and high-explosives (HE) compounds in groundwater at Site 300. Details of this program are described in the *LLNL Site 300 Environmental Investigations Quarterly Reports* (Lamarre et al. 1990a-c; Carlsen et al. 1990) and in the *Remedial Investigation of the High-Explosives (HE) Process Area LLNL Site 300* (Crow and Lamarre 1990); they are summarized in this report.

The other program consists of routine compliance monitoring around landfill and wastewater surface impoundment units, as required by the Regional Water Quality Control Board (RWQCB), Central Valley Region, California Department of Health Services (DHS), and the Environmental Protection Agency (EPA). The latter program is described below.

Methods

Groundwater monitoring in the vicinity of Site 300 landfills Pits 1 and 7 is regulated by RWQCB, DHS, and EPA. All other landfills are subject to RWQCB requirements only. At Pit 1, which is in the detection monitoring mode, groundwater samples from eight monitoring Wells (K1-01C, -02B, -03, -04, -05, -07, -08, and -09) are analyzed quarterly for drinking water parameters, groundwater quality parameters, and indicators of groundwater contamination, as specified in 40 *Code of Federal Regulations* Part 265.92.

At Pit 7, eight monitoring Wells (K7-01, -03, -06, -07, -10, and NC7-25, -26, and -47) are sampled quarterly for metals (lead and beryllium), and gross alpha, gross beta, and tritium activity. Well K7-09 and piezometers NC7-22 and NC7-37 are sampled quarterly for volatile organic compounds (VOCs), specifically, to monitor for TCE. Pit 7 wells also provide monitoring data for inactive landfills 3, 4, and 5. Because tritium and TCE were detected in some Pit 7 wells, the Pit 7 network is in the assessment monitoring mode, as described in 40 *Code of Federal Regulations* Part 265.92.

Groundwater from wells that monitor inactive Pit 2 (Wells K2-01C, -04S, -04D, and Well NC2-07) and Pit 8 (Well K8-01) is also analyzed quarterly using the same parameters as those used for groundwater from Pit 7 wells, with additional analyses for nitrate, nitrite, ammonia, and total Kjeldahl nitrogen. Well NC2-07, located at the site's eastern boundary, is the most downgradient monitoring point for Pits 2, 3, 4, 7, and 8. This well is sampled quarterly for tritium and semiannually for gross alpha and gross beta activity, and purgeable priority pollutants. Barcad samplers, which are used to monitor the deeper water-bearing zones beneath Pits 1 and 2, are sampled quarterly for metals (lead and beryllium), and for gross alpha, gross beta, and tritium activity. Once a year, the barcads are sampled for a larger suite of metals, including those listed in 22 *California Code of Regulations* Part 66699.

Inactive Pit 6 (Wells K6-01, -03, -04, and EP6-07, -08, and -09) is monitored for drinking water parameters, groundwater quality parameters, and indicators of groundwater contamination, as specified in 40 *Code of Federal Regulations* Part 265.92,

even though this landfill is not regulated under the Resource Conservation and Recovery Act (RCRA). This monitoring is done because records indicate that potentially hazardous waste was buried in this pit between 1964 and 1973. [This waste included capacitors suspected of containing polychlorinated biphenyls (PCBs), beryllium, mercury, miscellaneous chemicals, and other materials.]

In 1985, the Central Valley Region of the RWQCB issued new groundwater monitoring requirements (as part of Waste Discharge Order No. 85-188) for LLNL's two new Class II surface impoundments (Building 817 HE Process Area). These HE surface impoundments contain treated nonhazardous HE process wastewater and nonhazardous photo rinse water. Samples collected from four wells surrounding the HE surface impoundments are analyzed quarterly for pH, total organic halides (TOX), total organic carbon (TOC), specific conductance, HE compounds (HMX, RDX, and TNT), nitrate and nitrite, VOCs, and metals. Samples for VOCs, HE compounds, and tritium analyses are also collected from Well W-817-03A, a shallow well near the HE surface impoundments. Each quarter, an attempt is made to sample the five lysimeters underlying these HE surface impoundments. If water is present, it is analyzed for HE compounds.

LLNL has developed analytical procedures for the analysis of HE compounds. The HE compounds are analyzed using a high-performance liquid chromatograph (HPLC). First, 100 μ L of the sample are injected into an HPLC fitted with a Hewlett Packard RP-8 column. The flow rate is set at 1.0 mL/min, with a 35% methanol and 65% water solvent mixture. An ultraviolet detector at 230 nm is used for measurements, and measurements are taken at 254 nm for comparison.

Detection limits and analysis parameters are presented in **Table 3-G-1** for the groundwater protection monitoring wells shown in **Figure 3-G-1**.

Results

Results of the quarterly monitoring are shown in **Tables 3-G-2** through **3-G-7**. The tabulated results present the highest value detected for the parameter over the four quarters of 1990, as well as compounds sporadically detected. Therefore, the values found within the tables are conservative estimates of the groundwater constituents. Details of the quarterly sampling and monitoring results can be found in the *LLNL Site 300 Groundwater Monitoring Program Quarterly Reports* (Peeters et al. 1990; Fischer et al. 1990a-c). The occurrence of 1,3-dichlorobenzene (1,3-DCB) in water samples from the Pit 1, Pit 7 Complex, HE Process, and Pit 6 areas in the first quarter of 1990 are not considered to be representative of the groundwater. These sporadic occurrences are discussed in the Quality Assurance chapter.

At Pit 1 (**Table 3-G-2**), very low concentrations of Freon-113 (1,1,2-trichloro-1,2,2-trifluoroethane) continue to be observed in Wells K1-08 and K1-09 at maximum concentrations of 6.8 μ g/L and 20.0 μ g/L, respectively. Freon-113 was not detected in Well K1-05 during 1990. These levels are far below the maximum contaminant level (MCL) for Freon-113 of 1200 μ g/L (22 *California Code of Regulations* Chapter 15, as amended). TCE was detected for the first time in the first quarter of 1990 at a concentration of 3.8 μ g/L (below the MCL of 5 μ g/L). It was not detected during the subsequent three quarters. Similarly, lead was detected for the first time in the first quarter of 1990 in Well K1-04 at a concentration of 0.011 mg/L (below the MCL of 0.05 mg/L). Lead was not detected during the subsequent three quarters.

RCRA regulations in 40 *Code of Federal Regulations* Part 264.97 mandate that the Student's t-test be applied comparing pH, specific conductance, TOC, and TOX concentrations in 1990 to a 1986 background data set. These tests showed no significant increase in TOC or TOX concentrations throughout 1990 (Peeters et al. 1990; Fischer et al. 1990a-c). Although significant differences in specific conductance and pH

were observed in 1990 between upgradient and downgradient wells, it is believed that these differences were representative of natural groundwater chemical variability and did not represent a landfill-induced change in the groundwater chemistry. This is because specific conductance and pH values for samples collected from both upgradient and downgradient wells have shown significant increases, and the individual ionic constituents in the groundwater are comparable to historic values; thus it is unlikely that these increases are due to contamination from the Pit 1 landfill. An alternative, analyte-specific method for detection of changes in groundwater chemistry at both the Pit 1 and Building 817 HE Process Areas is being developed by

LLNL using EPA guidance (U.S. EPA 1989b) and will be applied when available. This method should decrease the incidence of sporadic findings unrelated to changes in groundwater chemistry that are caused by landfills. Elevated levels of nitrate in the Pit 1 and Building 817 HE Process Area wells continue to be observed; these are considered to be natural constituents of the area groundwater (Buddemeier et al. 1987; Carlsen et al. 1987).

Table 3-G-3 shows that TCE and tritium concentrations in the Pit 7 Complex area wells are similar to those reported last year. Tritium at concentrations exceeding the MCL continued to be detected during all four quarters of 1990 in Wells K7-01, K7-03, and NC7-25. TCE continued to be

Figure 3-G-1. Landfills (active and inactive) and monitoring wells, Site 300, 1990.

observed in wells K7-01 and K7-03; however, the volatile compounds 1,2-dichloroethylene (1,2-DCE) and tetrachloroethylene (PCE) that were seen in 1989 in the Pit 7 Complex area were not observed in 1990. The occurrence of TCE in Well K7-06 during the third quarter, 1990, was the result of samples from Wells K7-01 and K7-06 being switched sometime prior to laboratory analyses. This subject is discussed further in the Quality Assurance chapter of this report. The detection of 1,1-dichloroethylene (1,1-DCE) was observed in this same switched sample at a concentration of 0.6 µg/L (below the 1989 concentration in well K7-01 of 1.4 µg/L; and, above the MCL of 0.006 µg/L). Similar to last year's findings, slightly elevated levels of gross alpha and gross beta activity were detected in Well K7-01. Further laboratory analysis of samples from Well K7-01 indicated these values were likely the result of naturally occurring uranium levels in the groundwater, as previously reported (Raber and Carpenter 1983). The Pit 7 Complex area groundwater is included in the Site 300 investigations of TCE and tritium, discussed in the *LLNL Site 300 Environmental Investigations Quarterly Reports* (Lamarre et al. 1990a-c; Carlsen et al. 1990).

Table 3-G-4 shows monitoring data from Pit 2 (Wells K2-01C, K2-04S, and K2-04D); Pit 8 (Well K8-01); and Well NC2-07. As mentioned previously, the slightly elevated nitrate levels (above the MCL in Well K2-04S and near the MCL in Well K8-01) are considered to be natural constituents of this area's groundwater. In Well K8-01, TCE and 1,2-dichloroethane (1,2-DCA) continue to be detected at or above the MCLs. Additional characterization of the groundwater in this vicinity is being conducted as part of the Site 300 TCE investigation. The tritium values for Wells K2-01C, K2-04D, and K2-04S continue to be observed at concentrations below the MCL of 20,000 pCi/L. These wells are part of the Site 300 tritium investigation. Arsenic was observed slightly above the MCL of 0.05 mg/L in Well K2-04S at a concentration of 0.053 mg/L.

The elevated arsenic levels are comparable to those observed in the Pit 1 Area monitoring wells and elsewhere at Site 300, and these levels are considered to be a natural constituent of the area groundwater (Raber and Carpenter 1983).

Table 3-G-5 shows monitoring data from the Pits 1 and 2 barcads. The only data point exceeding any State action level or MCL is an arsenic value of 0.083 mg/L (the MCL is 0.05 mg/L) observed in Well K2-02A.

Table 3-G-6 shows the monitoring data for the Pit 6 wells. TCE continues to be detected at concentrations slightly above the MCL in Well EP6-09 throughout the year. The Pit 6 Area continues to be part of the ongoing Site 300 TCE investigation. During the third quarter, gross beta activity in well K6-04 was measured at an elevated value of 48 pCi/L (just below the MCL of 50 pCi/L). In the fourth quarter, two independent laboratories performed gross beta analyses on samples from Well K6-04 that resulted in measurements of 7 pCi/L and 17 pCi/L, within the historical range of <6 to 17 pCi/L (both values were well below the MCL of 50 pCi/L). Additional analyses performed on groundwater samples from Well K6-04 identified the beta emitter as part of the natural uranium decay chain.

Table 3-G-7 shows data for lysimeters and wells in the vicinity of the HE Process Area surface impoundments. The lysimeters underlying the impoundments did not produce any water during 1990. Monitoring Well W-817-01 continues to consistently show small amounts of RDX (an HE compound). In addition, the HE compound HMX was detected in the third quarter of 1990 in Well W-817-01 for the first time since the fourth quarter of 1989. Elevated nitrate, selenium, and arsenic levels have been consistently detected in the wells of this area since their installation in 1985, and are considered to be natural constituents of the area groundwater (Carlsen et al. 1987). TCE continued to be seen during 1990 at concentrations above the MCL in Wells W-817-03, -03A, and -04. Investigations of the RDX (and other HE

compounds) in Well W-817-01 and the TCE occurrences are part of the Site 300 groundwater investigations. As required by DHS, four wells (W-817-01, -02, -03, and -04) were subjected to the Student's t-test comparing 1990 TOX and TOC concentrations to the 1986 background data set. These tests showed no significant increase in TOX or TOC concentrations during 1990 (Peeters et al. 1990; Fischer et al. 1990a-c). As in the Pit 1 Area, significant differences in pH and specific conductance were observed between upgradient and downgradient wells. It is believed that these differences are representative of natural groundwater chemical variability and do not represent a surface-impoundment-induced change in the Building 817 Process Area groundwater chemistry. Because specific conductance and pH values for samples collected from both upgradient and downgradient wells have shown significant increases, and the individual ionic constituents in the groundwater are comparable to historic values, it is unlikely that the increases in specific conductance are due to contamination from the HE Process Area surface impoundments. When it is available, the alternative, analyte-specific statistical method mentioned in the preceding discussion of data for Pit 1 will also be applied to the data from the Building 817 Process Area monitoring wells.

Environmental Impact

Monitoring of radiological and nonradiological pollutants has not identified new impacts on the groundwater at Site 300. Existing impacts are under investigation and are discussed below. Remedial action is being taken to mitigate the existing impacts.

Groundwater Investigation and Feasibility Study Activities

A major portion of the groundwater protection program at Site 300 is the investigative work performed under requirements of the RWQCB, Central Valley Region, and the EPA.

Groundwater at Site 300 moves via pores and fractures. The regional groundwater table lies within sandstone and

conglomerate beds, and groundwater generally follows the dip of the bedrock. Three known perched groundwater bodies exist locally beneath the site. Site 300 drinking and process water is supplied by a separate deep confined aquifer.

The environmental restoration efforts at Site 300 encompass a variety of activities to support ongoing remedial investigations and feasibility studies, and to aid remediation of potential environmental conditions in compliance with Federal, State, and local laws and regulations. These activities, conducted in geographic areas of known or suspected releases, are performed to determine the extent, if any, of hazardous substances that may have affected soil and/or groundwater.

The following section summarizes the investigation activities at Site 300 since the early 1980s. Summary results are presented in the accompanying figures detailing the isoconcentrations of the contaminant for each investigation.

TCE Investigation

In 1982, LLNL began initial assessment of the environmental effects of TCE released in several areas of the site. By 1987, ten locations within the site were found to have TCE present in soil, rock, and/or groundwater. TCE investigations have continued, emphasizing the southeast part of the site (**Figure 3-G-2**), the Building 834 Complex (**Figure 3-G-3**), the HE Process Area (**Figure 3-G-4**), and the General Services Area (GSA) (**Figure 3-G-5**). Recent monitoring has also revealed trace amounts of TCE in groundwater near the Pit 7 Complex (in the West Firing Area) and at Pit 8 (in the East Firing Area). TCE also has been detected in groundwater at the Pit 6 Area. Environmental and monitoring investigations continue at these locations.

HE Compounds Investigation

Discharges of rinse water from buildings within the HE Process Area historically have been disposed of in unlined lagoons

Site 300

Groundwater Protection

adjacent to the processing buildings. Use of these lagoons was terminated in 1985, and they were closed and capped with impermeable clay in 1989. Concerns about the potential for groundwater degradation because of HE compounds in soil and rocks beneath the lagoons prompted field investigations within the HE Process Area in 1986 and 1987 (Figure 3-G-2). Sporadic, but generally low, concentrations of HE compounds, metals, and VOCs were identified beneath some of the lagoons and the HE Burn Pit facility.

Tritium Investigation

Debris from HE tests historically has been disposed of in landfills at the northern end of Site 300. In 1981, the Hazardous Waste Assessment study of the hydrology, geology, and groundwater chemistry associated with Site 300 landfills was initiated. As part of this project, monitoring wells were installed at the landfills, and a program of periodic groundwater monitoring was initiated. In 1984, tritium levels in water from four of the wells rose above the California drinking water standard. A tritium investigation was initiated. To date, three areas with tritium present in the groundwater have been identified: the

Pit 7 Complex, the Building 850 area in the West Firing Area, and near Pit 2 in the East Firing Area (Figures 3-G-2 and 3-G-6).

Landfill and Lagoon Closures

Until November 8, 1988, LLNL operated two Class II solid-waste landfills (Pits 1 and 7) at Site 300, which received firing-table debris from explosives testing. The landfills are subject to RCRA regulation and were operated under RCRA interim status. In March 1988, partly because the landfills were nearly full, LLNL decided not to pursue its RCRA Part B permit application for land disposal. Disposal of wastes at Pits 1 and 7 was discontinued in November 1988. LLNL has submitted a closure and post-closure plan for the landfills to the regulatory agencies, and anticipates that closure construction will begin during the summer of 1991.

As mentioned in the "HE Compounds Investigation" discussion, LLNL conducted field investigations within the HE Process Area during 1986 and 1988. HE compounds, metals, and VOCs were found beneath some of the lagoons. A closure plan was submitted to the RWQCB. LLNL closed the HE rinse-water lagoons during September and October of 1989.

Scope of Activity

The areas of investigation include the HE Process Area, the GSA, the Environmental Test Area (ETA), the East and West Firing Areas, and the Pit 6 Area (Figure 3-G-2). Activities associated with these areas include the following:

- Investigation of the site hydrogeology.
- Installation of monitor wells and piezometers.
- Aquifer testing.
- Survey of soil gas to aid location of potential source areas.
- Sampling saturated and unsaturated soil from boreholes and wells.
- Development of closure and post-closure plans for solid-waste landfills and the HE Burn Pit facility.
- Identification and investigation of former dry wells.

Figure 3-G-2. Several environmental restoration activities are in progress at Site 300.

Figure 3-G-3. Distribution of TCE in perched groundwater in the vicinity of the Building 834 Complex, June-December 1990.

Site 300

Groundwater Protection

- Evaluation, possible sealing, and abandonment of specific inactive water-supply wells.
- Investigation and closure of leaking underground tanks.
- Development of computer models and a conceptual site model to aid groundwater study.
- Continuation of a historical records search to identify potential sources of contamination.

- Preparation of reports documenting the investigation, evaluation, and remediation.

The compounds addressed in the investigation include primarily TCE, tritium, and HE compounds [cyclotetramethyltetramine (HMX) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)]. To date, no other major environmental contaminants have been identified for these areas.

Figure 3-G-4. Isoconcentration contour map of TCE in the Neroly upper blue sandstone (Tnbs₂) aquifer, HE Process Area, October-December 1990.

Environmental Restoration Accomplishments at Site 300

As of December 31, 1990, the following environmental restoration tasks have been accomplished at Site 300. Some of these tasks have been under way for several years.

- High-Explosives Lagoon Closure Plan—Submitted to RWQCB; HE lagoons closed.
- Closure and Post-Closure Plan for Landfill Pits 1 and 7—Submitted to EPA, RWQCB, and DHS.

- Solid Waste Assessment Test Completed for Landfill Pit 6—Report submitted to RWQCB.
- Work Plan for Environmental Restoration—Submitted to and accepted by RWQCB.
- Gravels at Firing Tables 801, 802, 812, 850, 851, and 854—Removed and disposed of in solid-waste landfills; report submitted to regulatory agencies.
- A Source Area for TCE—Identified in Pit 6 landfill, which produced a

Figure 3-G-5. Total VOC concentration in groundwater from the alluvial/shallow bedrock aquifer in the central GSA, October-December 1990.

Site 300

Groundwater Protection

- release to groundwater; the extent of that TCE plume has been outlined.
- Inactive Water-Supply Wells—Eight wells permanently sealed and abandoned.
- A TCE Source—Identified for central and eastern GSA groundwater plumes.

- Soil Vapor Survey—Completed for the southeastern part of the site; outlines the extent of TCE in groundwater on site and off site; submitted report to regulatory authorities.
- TCE in Soil and Perched Groundwater—Began remediation at the

Figure 3-G-6. Groundwater tritium activity isopleth map, WFA and EFA, October 1990.

Building 834 Complex; cleaned up TCE-containing soils to a depth of two feet.

- HE Process Area—Defined the extent of HE compounds in groundwater.
- RI Reports—Submitted to regulatory authorities: Pit 6, Pit 8, Pit 9, HE Burn Pits, Dry Wells, GSA, B850/EFA, and HE Process Area.
- RI/FS Reports—Submitted to regulatory authorities: Pit 7 Complex, Building 834 Complex, and GSA/Off-site Areas.
- Elk Ravine Fault—Determined that no Holocene (recent) movement has occurred; submitted report to regulatory authorities.

- Well Logs—Report containing all well logs for Site 300 submitted to regulatory authorities.
- Site Safety Plan for Environmental Restoration—Completed report.
- Monitor Wells Installed—More than 300 wells drilled, sampled, and flow-tested.
- Extent of Tritium—Determined for groundwater at East and West Firing Areas; there is no impact on human health.
- Underground Tanks—Removed and closed at Buildings 801 and 874.
- Corral Hollow Fault—Determined that Holocene (recent) movement has occurred.

Site 300
Groundwater
Protection

Table 3-G-1. Water quality parameters and detection limits for monitoring wells, Site 300, 1990.

Physical and chemical	Pits ^a	Detection limit (µg/L) ^b	Title 22 organics	Pits 1 and 6	Detection limit (µg/L) ^b
Ammonia nitrogen (as N)	1, 2, 6, 8	0.02	2,4,5-TP (Silvex)		1.0
Antimony	HE	0.2	2,4-D		10.0
Arsenic	1, 6, HE	0.001	Endrin		.01
Barium	1, 6, HE	0.05	Lindane		0.04
Beryllium	1, 2, 6, 7, 8, HE	0.0005	Methoxychlor		10.0
Bicarbonate alkalinity (as CaCO ₃)	1, 6	— ^c	Toxaphene		0.5
Cadmium	1, 6, HE	0.0005	Purgeable priority pollutants (EPA Method 624)	Pits 1, 2, 6, 7, 8 and HE ^a	Detection limit (µg/L) ^b
Carbonate alkalinity (as CaCO ₃)	1, 6	1	Acetone		5
Chloride	1, 6	— ^c	Acrolein		5
Chromium	1, 6, HE	0.005	Acrylonitrile		5
Cobalt	HE	0.05	Methoxychlor		10
Conductivity (µmhos/cm)	1, 6, HE	— ^c	Methyl ethyl ketone		10
Copper	HE	0.08	Methylene chloride		2
Filterable residue (TDS)	1, 6, HE	— ^c	All other analytes		0.5
Fluoride	1, 6	— ^c			
Hydroxide alkalinity (as CaCO ₃)	1, 6	1			
Iron	1, 6	0.1	Other organics	Pits ^a	Detection limit (mg/L) ^b
Lead	1, 2, 6, 7, 8, HE	0.002	Low-level phenolics	1, 6	0.005
Manganese	1, 6, HE	0.05	TOC	1, 6, HE	0.5
Mercury	1, 6, HE	0.0005	TOX	1, 6, HE	0.002
Molybdenum	HE	0.2			
Nickel	1, 6, HE	0.1			
Nitrate (as NO ₃)	1, HE	— ^c	Radiological	Pits	Detection limit (pCi/L) ^b
Nitrate (as N)	1, 2, 6, 8, HE	0.05	Gross alpha	1, 2, 6, 7, 8	4
Nitrite (as N)	1, 2, 6, 8, HE	0.01	Gross beta	1, 2, 6, 7, 8	4
Non-filterable residue (TSS)	1, 6	1	Tritium	1, 2, 7, 6, 8, HE ^a	500
pH (units)	1, 2, 6, 7, 8, HE	— ^c	²³⁸ U	1, 6	0.1
Selenium	1, 6, HE	0.002	²³⁵ U	1, 6	0.1
Silver	1, 6, HE	0.0005	²³⁴ U	1, 6	0.1
Sodium	1, 6	— ^c	²²⁶ Ra	1, 6	0.1
Sulfate	1, 6	— ^c			
Thallium	HE	0.2	High-explosives	Pits 1, 6, HE	Detection limit (µg/L) ^b
Total alkalinity (as CaCO ₃)	1, 6	— ^c	RDX		30
Total Kjeldahl nitrogen	1, 2, 6, 8	0.5	TNT		30
Vanadium	1, 6, HE	0.05	HMX		20
Zinc	HE	0.05			
Purgeable halocarbons (EPA Method 624)	Pits 1, 2, 6, 7, 8 and HE ^a	Detection limit (µg/L) ^b			
All analytes		0.5			

^a HE = High-Explosive Process-Water Surface Impoundment wells.

^b Detection limits can vary from sample to sample, depending on such items as matrix interference and instrument sensitivity.

^c Not applicable.

Table 3-G-2. Positively detected parameters in Pit 1 Area monitoring wells, Site 300, 1990.

Parameter	Well ^a							
	K1-01C	K1-02B	K1-03	K1-04	K1-05	K1-07	K1-08	K1-09
Physical and chemical (mg/L)								
Alkalinity (as CaCO ₃)	150	140	150	150	120	140	130	130
Ammonia nitrogen (as N)	0.06	0.04	0.04	0.03	0.04	0.04	0.03	0.03
Arsenic	0.012	0.013	0.015	0.013	0.016	0.015	0.016	0.015
Barium	0.05	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bicarbonate	150	140	150	150	120	140	130	130
Calcium (EDTA titration)	44	47	42	43	35	39	37	36
Chloride	41	50	36	40	41	40	40	40
Chromium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008
Conductivity (µmhos/cm)	590	650	570	670	690	600	590	580
Filterable residue (TDS)	400	390	370	370	370	380	390	370
Fluoride	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Iron	<0.1	<0.1	<0.1	<0.1	0.07	0.05	<0.1	<0.1
Lead	0.009	0.025	0.002	0.011	0.003	<0.002	0.007	0.010
Magnesium	19	20	18	17	18	19	18	17
Manganese	<0.05	<0.05	0.05	0.05	0.05	0.04	<0.05	<0.05
Mercury	0.0006	<0.0005	<0.0005	<0.0005	0.0002	0.0006	<0.0005	<0.0005
Nickel	<0.1	<0.1	<0.1	<0.1	0.05	0.03	0.04	<0.1
Nitrate plus nitrite (as NO ₃)	35	29	29	24	37	36	36	36
Non-filterable residue (TSS)	3.0	14.0	5.0	3.0	5.0	190.0	3.0	16.0
pH (units)	8.8	8.4	8.3	8.2	8.6	7.8	7.9	7.8
Potassium	5.4	2.8	3.8	4.6	4.3	3.8	4.0	3.3
Selenium	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Sodium	40.0	42.0	37.0	43.0	42.0	41.0	43.0	40.0
Sulfate	39.0	58.0	40.0	56.0	43.0	40.0	42.0	46.0
Vanadium	0.04	0.04	0.03	<0.05	0.07	0.09	0.08	0.07
Zinc	<0.05	<0.05	<0.05	<0.05	<0.08	<0.06	<0.08	<0.01
Organics compounds (mg/L)								
Total organic carbon (TOC)	1.1	1.1	1.2	0.9	1.3	1.8	4.3	1.2
Purgeable pollutants (EPA Methods 601/624, µg/L)								
1,3-Dichlorobenzene ^b	<0.5	<0.5	<0.5	<0.5	1.3	<0.5	<0.5	1.9
Freon-113	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	6.8	20.0
Trichloroethylene	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.8
Radiological (pCi/L)								
Gross alpha	4.0	2.0	2.0	3.0	2.0	2.0	3.0	1.0
Gross beta	4.0	10.0	5.0	5.0	32.0	3.0	4.0	4.0
Tritium	497 ± 492	800 ± 200	<500	<500	<500	<530	<500	<500
Uranium-234	5.4	1.3	1.0	1.6	1.4	1.6	1.0	1.2
Uranium-235	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Uranium-238	5.0	0.8	0.5	0.8	0.7	0.8	0.5	0.5
Radium-226	0.8	0 ± 0.6	<0.6	0 ± 0.8	0 ± 0.7	0.7 ± 0.5	0 ± 0.8	0 ± 0.7

^a See Fig. 3-G-1 for sampling locations.

^b See Quality Assurance chapter for discussion of 1,3-DCB occurring sporadically in first quarter 1990 samples.

Site 300
Groundwater
Protection

Table 3-G-3. Positively detected parameters in Pit 7 Complex area monitoring wells, Site 300, 1990.

Parameter	Well ^a							
	K7-01	K7-03	K7-06	K7-09 ^b	K7-10	NC7-25	NC7-26	NC7-47
Physical and chemical (mg/L)								
Barium	0.19	0.06	0.09	— ^c	<0.05	0.06	<0.05	<0.05
Lead	<0.002	0.002	0.006	— ^c	<0.002	0.003	0.003	<0.002
Vanadium	<0.2	<0.05	<0.2	— ^c	<0.2	<0.2	<0.2	<0.2
Purgeable pollutants (EPA Methods 601/624, µg/L)								
1,3-Dichlorobenzene ^d	<0.5	<0.5	<0.5	<0.5	2.3	<0.5	1.5	<0.5
1,1-Dichloroethylene	<0.5	<0.5	0.6	<1.0	<0.5	<0.5	<0.5	<0.5
Freon-113	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5
Toluene	— ^c	— ^c	— ^c	2.0	— ^c	— ^c	— ^c	— ^c
Trichloroethylene	5.6	3.2	6.2 ^e	<1.0	<0.5	<0.5	<0.5	<0.5
Total xylene isomers	— ^c	— ^c	— ^c	1.2	— ^c	— ^c	— ^c	— ^c
Radiological (pCi/L)								
Gross alpha	15.0	3.0	3.0	— ^c	3.0	12.0	1.0	3.0
Gross beta	22.0	5.0	4.0	— ^c	9.0	19.0	5.0	8.0
Tritium	54,300 ± 3,100	55,400 ± 1,400	<600	— ^c	<700	357,000 ± 10,000	880 ± 290	650 ± 350
Uranium-234	8.1	0.8	0.7	— ^c	1.2	12.6	0.6	2.3
Uranium-235	0.4	<0.1	<0.2	— ^c	<0.1	0.8	<0.1	0.2
Uranium-238	7.8	0.8	0.6	— ^c	0.8	10.4	0.9	1.8
Radium-226	1.7 ± 0.012	— ^c	— ^c	— ^c	— ^c	<1	— ^c	— ^c

^a See Fig. 3-G-1 for sampling locations.

^b Sample from Well K7-09 was analyzed for volatile organic compounds (EPA Method 624) only.

^c Analysis not performed.

^d See Quality Assurance chapter for discussion of 1,3-DCB occurring sporadically in first quarter 1990 samples.

^e See Quality Assurance chapter for discussion of samples from K7-01 and K7-06 being switched prior to lab analysis in the third quarter 1990.

Table 3-G-4. Positively detected parameters in Pits 2 and 8 Area monitoring wells and Well NC2-07, Site 300, 1990.

Parameter	Well ^a				
	K2-01C	K2-04D	K2-04S	K8-01	NC2-07
<u>Physical and chemical (mg/L)</u>					
Acetone	— ^b	— ^b	— ^b	<10	— ^b
Total alkalinity (as CaCO ₃)	— ^b	— ^b	— ^b	200	— ^b
Ammonia nitrogen	0.03	0.03	0.07	0.04	— ^b
Antimony	— ^b	— ^b	— ^b	— ^b	— ^b
Arsenic	— ^b	— ^b	— ^b	0.018	— ^b
Bicarbonate alkalinity (as CaCO ₃)	— ^b	— ^b	— ^b	200	— ^b
Calcium	— ^b	— ^b	— ^b	59	— ^b
Chloride	— ^b	— ^b	— ^b	69	— ^b
Chromium	— ^b	— ^b	— ^b	0.038	— ^b
Conductivity (µmhos/cm)	— ^b	— ^b	— ^b	830	— ^b
Fluoride	— ^b	— ^b	— ^b	0.4	— ^b
Lead	0.009	0.004	0.005	0.002	— ^b
Nitrate plus nitrite (as NO ₃)	3.1	7.2	7.8	42	— ^b
Nitrate plus nitrite (as N)	4.2	8.2	— ^b	9.5	— ^b
pH (units)	— ^b	— ^b	— ^b	7.6	— ^b
Potassium	— ^b	— ^b	— ^b	5.0	— ^b
Non-filterable residue (TSS)	— ^b	— ^b	— ^b	<1	— ^b
Selenium	— ^b	— ^b	— ^b	0.002	— ^b
Sodium	— ^b	— ^b	— ^b	51	— ^b
Sulfate	— ^b	— ^b	— ^b	86	— ^b
<u>Purgeable pollutants (EPA Methods 601/624, µg/L)</u>					
Chloroform	<0.5	<0.5	<0.5	0.5	<0.5
1,2-Dichloroethane	<0.5	<0.5	<0.5	4.0	<0.5
Ethylbenzene	— ^b	— ^b	— ^b	<1	— ^b
Toluene	— ^b	— ^b	— ^b	<1	— ^b
Trichloroethylene	<0.5	<0.5	<0.5	5.0	<0.5
<u>Radiological (pCi/L)</u>					
Gross alpha	9.0	2.0	4.0	5.0	5.0
Gross beta	11.0	5.0	6.0	10.0	7.0
Tritium	13,100	9,700	11,400	<500	500
Uranium-234	— ^b	— ^b	— ^b	5.3	— ^b
Uranium-235	— ^b	— ^b	— ^b	0.2	— ^b
Uranium-238	— ^b	— ^b	— ^b	3.3	— ^b

^a See Fig. 3-G-1 for sampling locations.

^b Analysis not performed.

Table 3-G-5. Positively detected parameters in Pits 1 and 2 Area barcad samplers, Site 300, 1990.

Parameter	Barcad sampler ^a					
	K1-01A	K1-01B	K1-02A	K2-01A	K2-01B	K2-02A K2-02B
Physical and chemical (mg/L)						
Arsenic	0.005	0.011	<0.002	0.013	0.021	0.083 <0.002
Barium	<0.1	<0.1	<0.1	0.06	<0.05	<0.05 <0.05
Iron	<0.04	0.23	<0.04	0.09	<0.04	0.27 0.13
Lead	<0.002	0.002	0.003	0.002	<0.002	<0.002 0.002
Manganese	0.04	0.07	0.04	0.05	<0.04	<0.04 0.04
Mercury	<0.0001	<0.0001	<0.0001	0.0006	<0.0001	<0.0001 0.0001
Radiological (pCi/L)						
Gross alpha	2.0	2.0	2.0	1.0	4.0	7.0 1.0
Gross beta	5.0	3.0	7.0	6.0	5.0	6.0 43.0
Tritium	<500	<500	<500	<500	<500	<500 <500
Uranium-234	0.8	<0.1	<0.5	0.4	2.7	4.4 <0.1
Uranium-235	<0.1	<0.1	<0.6	<0.1	<0.2	<0.3 <0.1
Uranium-238	0.4	<0.1	<0.5	<0.2	1.8	1.1 <0.1
Radium-226	0.8	<0.5	<0.7	0.6	<0.5	0.9 <0.7

^a See Fig. 3-G-1 for sampling locations.

**Table 3-G-6. Positively detected parameters in Pit 6 Area monitoring wells,
Site 300, 1990.**

Parameter	Well ^a					
	K6-01	K6-03	K6-04	EP6-07	EP6-08	EP6-09
<u>Physical and chemical (mg/L)</u>						
Total alkalinity (as CaCO ₃)	190	180	170	180	190	190
Ammonia nitrogen (as N)	0.14	0.38	0.09	0.33	0.07	0.09
Arsenic	0.013	0.022	0.019	0.024	0.020	0.018
Calcium (EDTA titration)	— ^b	52	48	— ^b	— ^b	— ^b
Chloride	90.0	92.0	88.0	100.0	110.0	120.0
Conductivity (µmhos/cm)	1260	1120	1200	1170	1140	1210
Fluoride	0.7	0.6	0.4	0.4	0.4	0.5
Iron	0.75	0.17	0.15	0.14	<0.1	0.14
Lead	<0.002	<0.002	0.002	<0.002	<0.002	<0.002
Magnesium	— ^b	27	23	— ^b	— ^b	— ^b
Manganese	0.11	0.10	<0.05	0.17	<0.05	<0.05
Mercury	<0.0005	<0.0005	<0.005	0.0011	<0.0005	<0.005
Nickel	<0.1	0.04	<0.1	0.04	<0.1	0.04
Nitrate (as NO ₃)	— ^b	<0.4	7.2	— ^b	— ^b	4.9
Nitrate (as N)	<0.1	0.1	1.7	<0.1	0.9	1.2
pH (units)	7.8	7.7	7.6	7.7	7.7	7.7
Potassium	— ^b	8.0	9.0	— ^b	— ^b	— ^b
Filterable residue (TDS)	810	860	650	750	760	740
Non-filterable residue (TSS)	4.0	5.0	3.0	2.0	1.0	1.0
Selenium	0.002	0.003	0.004	<0.002	0.004	0.004
Sodium	160	130	120	130	140	150
Sulfate	330	280	240	250	240	260
<u>Organic compounds (mg/L)</u>						
Low-level phenolics	0.007	<0.005	0.014	<0.005	<0.005	<0.005
Total organic carbon (TOC)	3.10	1.50	1.20	0.9	1.10	1.40
Total organic halides (TOX)	<0.02	<0.02	<0.02	<0.02	0.019	<0.02
<u>Purgeable pollutants (EPA Methods 601/624, µg/L)</u>						
1,3-Dichlorobenzene ^c	<0.5	<0.5	0.6	1.2	<0.5	<0.5
Trichloroethylene	<0.5	<0.5	<0.5	<0.5	<0.5	13.0
<u>Radiological (pCi/L)</u>						
Gross alpha	0 ± 3	3.0	3.0	2.0	3.0	2.0
Gross beta	7.0	10.0	48.0	8.0	9.0	11.0
Tritium	<500	<500	<500	<500	<500	<500
Thorium-228	— ^b	— ^b	0.4	— ^b	— ^b	— ^b
Uranium-234	0.4	0.3	0.6	1.6	0.7	1.3
Uranium-238	0.5	0.3	0.5	0.9	0.5	1.0
Radium-226	0 ± 0.6	<0.7	<0.6	<0.6	0.6	<0.8

^a See Fig. 3-G-1 for sampling locations.

^b Analysis not performed.

^c See Quality Assurance chapter for discussion of 1,3-DCB occurring sporadically in first quarter 1990 samples.

Table 3-G-7. Positively detected parameters in HE Process Area monitoring wells at the high-explosives rinse-water surface impoundments, Site 300, 1990.

Parameter	Well ^a				
	W-817-01	W-817-02	W-817-03	W-817-04	W-817-03A
Physical and chemical (mg/L)					
Total alkalinity (as CaCO ₃)	260	240	250	240	— ^b
Arsenic	0.067	0.065	0.053	0.070	— ^b
Bicarbonate alkalinity (as CaCO ₃)	250	240	250	240	— ^b
Calcium (EDTA titration)	18.0	39.0	29.0	20.0	— ^b
Carbonate alkalinity (as CaCO ₃)	40.0	<1.0	<1.0	<1.0	— ^b
Chloride	170	305	260	230	— ^b
Chromium	0.007	0.006	0.007	0.007	— ^b
Copper	<0.08	<0.08	<0.08	<0.08	— ^b
Conductivity (µmhos/cm)	2270	2670	2030	2050	2040
Lead	0.007	0.004	0.017	0.004	— ^b
Magnesium	6.4	18.0	12.0	10.0	— ^b
Mercury	0.0002	0.0002	<0.0005	0.0002	— ^b
Nickel	<0.1	0.10	<0.1	<0.1	— ^b
Nitrate plus nitrite (as NO ₃)	79	86	86	88	— ^b
Nitrate plus nitrite (as N)	18	20	20	20	— ^b
pH (units)	8.3	8.1	8.2	8.4	7.9
Potassium	13	14	15	11	— ^b
Selenium	0.035	0.10	0.030	0.028	— ^b
Silver	<0.05	<0.05	<0.05	<0.05	— ^b
Sodium	270	410	360	360	— ^b
Sulfate	140	460	260	290	— ^b
Filterable residue (TDS)	960	1500	1200	1200	— ^b
Vanadium	0.18	0.15	0.12	0.14	— ^b
Zinc	<0.05	<0.05	<0.05	<0.05	— ^b
Organics compounds (µg/L)					
Total organic carbon (TOC)	1.9	1.7	1.5	1.5	— ^b
Total organic halide (TOX)	0.020	<0.020	0.040	0.030	— ^b
Purgeable pollutants (EPA Methods 601/624, µg/L)					
1,3-Dichlorobenzene ^c	<0.5	1.4	2.0	1.9	<0.5
cis-1,2-Dichloroethene	<0.5	<0.5	<0.5	<0.5	2.5
1,2-Dichloroethylene (Total)	<0.5	<0.5	<0.5	<0.5	2.5
Trichloroethylene	<0.5	<0.5	24.0	10.0	64.0
High-explosive compounds (µg/L)					
HMX	23.0	<20.0	<20.0	<20.0	<20.0
RDX	122.0	<30.0	<30.0	<30.0	<30.0

^a See Fig. 3-G-1 for sampling locations.

^b Analysis not performed.

^c See Quality Assurance chapter for discussion of 1,3-DCB occurring sporadically in first quarter 1990 samples.

Introduction

The purpose of Lawrence Livermore National Laboratory's (LLNL's) Quality Assurance Program and a brief description of the DOE Tiger Team audit are presented in the Livermore Site Quality Assurance chapter. Similarly, LLNL's participation in the EPA Environmental Radioactivity Laboratory Intercomparison Studies, the cross-check studies conducted by the DOE Environmental Measurements Laboratory, and the results of the duplicate sampling regime are discussed in that chapter. Those discussions also apply to Site 300.

Deviations and Changes to the Sampling Program (Site 300)

Sample Location Designators. During 1990, sampling location designators for all locations from most media routinely sampled by EMG were renamed using an alphabetic naming system. Previous sample location designator systems were either cumbersome or strictly numerical in nature, making their use prone to typographical errors and other problems. When describing a sampling location, most personnel commonly use the name of the location, such as Carnegie, Geodetic Creek, North Power Station, East Observation Point, West Control Post, etc. The new system uses alphabetic abbreviations of location names (for example: CARN, GEO, NPS, EOBS, WCP), and has been applied to the soil, surface water, air particulate, and vegetation monitoring networks. The new sample location designators are used on maps and tables in this report and will be used in all future publications. **Table 3-QA-1** provides a cross-reference between the new location designators and those used in previous years. The large number of sampling locations precludes the use of the new system for the radiation (TLD) and noise monitoring networks. Similarly, the system has not been applied to groundwater monitoring wells because the wells already have established names that are used by other groups.

Air Sampling Program. As part of the Site 300 routine monitoring program, 509 of 520 possible air particulate samples were collected, a sample recovery rate of 98%. The loss of samples in 1990 was caused by air sampler malfunction or loss of electric power to samplers. Monitoring locations remained the same as those described in 1989.

Routine Water Sampling Program. On-site inactive water supply wells (Well 19 and Well 04) were sealed and abandoned in the first and second quarters of 1990, respectively. Insufficient samples were collected for tritium analyses from two surface water locations in the third quarter, and from one location during the fourth quarter. Because of drought conditions in California, these surface water sampling locations were dry.

Compliance Groundwater Sampling Program. Most compliance groundwater installations were sampled as scheduled in 1990. Of the 362 samples scheduled, 353 were obtained—a collection efficiency of 98%. One scheduled sampling location (Well K7-07) was dry throughout the year, so routine (quarterly) sampling was not possible. All remaining samples were collected and were analyzed for the full suite of pollutants, as scheduled, with the following exceptions: Wells NC7-16, NC7-22, NC7-30, and NC7-37 were dry during the first quarter and could not be sampled,

and nitrate and nitrite analyses for Pit 6 groundwater samples were not performed during the fourth quarter.

During the third quarter, the unusual occurrence of TCE in upgradient Well K7-06 and the lack of TCE in Well K7-01, where it typically occurs, was attributed to the samples being accidentally switched during the sampling and analytical activities. This explanation was substantiated during fourth quarter sampling and analyses when TCE was not detected in Well K7-06 (in either the routine or duplicate samples collected), but was detected in Well K7-01.

Other notable events included:

(a) Low levels of 1,3-dichlorobenzene were detected in four of 11 quality assurance samples analyzed during the first quarter. Additional samples taken during the second and third quarters were analyzed, and the contamination was not seen. Sample-bottle contamination is suspected as the reason for the initial detections. To preclude this possibility, trip blanks now are submitted with every sample batch.

(b) EPA Method 7741 was substituted for selenium analyses because of suspected method interferences.

(c) Results obtained from samples preserved with sulfuric acid from Pit 1 and the Building 817 HE Process Area in the fourth quarter were reported as a combined nitrate-nitrite value.

(d) The Environmental Restoration Division assumed sampling and monitoring of some Pit 7 piezometers (NC7-16, -20, -21, -30, -34, -40, -51, -52A, and -64) during the fourth quarter.

(e) Additional isotopic uranium analyses were conducted on Well NC7-25.

(f) Additional samples from Well K6-04 were analyzed to identify an elevated beta emitter.

(g) Well NC2-11D was analyzed for Cu during the fourth quarter by a different analytical method.

Soil Monitoring Program. No changes were made to the soil sampling program. All scheduled samples were collected and analyzed for the full suite of analytes.

Vegetation Sampling Program. No changes were made to the vegetation sampling program at Site 300. All samples were collected and analyzed as specified in the environmental monitoring plan.

Environmental Radiation Monitoring Program. During 1990, all dosimeters at the Site 300 perimeter were collected. To obtain more accurate determination of background radiation levels, five additional off-site TLD locations were added to the Site 300 network.

Statistical Methods

Data review and analyses are conducted in accordance with the EMG Quality Assurance Plan (Holland 1987) and the EMG Procedures Manual (Brekke et al. 1988). Both documents contain detailed information regarding the acceptability of data and the procedures that are followed for the identification, notification, and correction of suspect data.

The statistical methods used in this report have been implemented pursuant to *DOE Order 5400.xy*, Chapter VII (Data Analysis and Statistical Treatment) (U.S. Department of Energy 1988d). The methods employed reduce the large volumes of monitoring data to summary concentration estimates that are suitable for both temporal and spatial comparisons. Attention is given to estimating accuracy, bias, and precision of all data.

Radiological Data. The precision of radiological analytical results is displayed in the data tables as 2- σ counting errors, expressed as a percentage of the associated value. The counting errors are not used in any summary statistic calculations. By convention, any radiological result exhibiting a 2- σ counting error greater than 100% is said to be at the lower limit of detection (LLD) and is presented in the tables with a less-than sign (<) to indicate its LLD status; however, the actual LLD values are used in the calculations of all summary statistics.

Nonradiological Data. Nonradiological data that are reported as being below the analytical detection limit also are displayed in the tables with a less-than

sign (<). As with the radiological data, the actual detection-limit values are used in the calculation of summary statistics.

Summary Statistics. Determinations of measures of central tendency and associated measures of dispersion are calculated according to DOE Order 5400.xy protocols. For data sets containing few LLDs, measures of central tendency are reported as the arithmetic mean $\pm$ one standard deviation (SDM), with the standard deviation expressed as a percentage of the mean. For data sets containing many (one-third or more of the total) LLD values, measures of central tendency are reported as the median value $\pm$ the median absolute deviation (MAD, median of the differences of all data values from the median), with the MAD expressed as a percentage of the median. By convention, summary statistics are not expressed with less-than signs (<). The use of LLDs in computations leads to overestimates of the central tendency, because the actual values of data expressed as being below the detection limit are quite likely less than the LLD value used in the calculations.

Where unusually high values were detected for areas of known contamination, means and standard deviations are calculated both with and without the high values, and the calculations without the high values are reported in parentheses. This procedure was used so that measures of central tendency are not skewed by the presence of the high values. Otherwise, the common use of such data could bias estimates of the overall impact of LLNL operations.

Statistical Comparisons. Standard comparison techniques (t-test and ANOVA) are used where appropriate for the determination of the statistical significance of the difference between means. All such tests of significance have been performed at the 0.05 level. When such a comparison is made it is explicitly stated in the text as being "statistically significant" or "not statistically significant." Other uses of the word significant in the text do not imply that statistical tests have been performed. These uses instead relate to the concept of practical significance, and are based on professional judgment.

Table 3-QA-1. Site 300 sampling location designators, 1990.

Media	Location	Current designator	Previous designator(s)
<u>Air particulate</u>			
	East Observation Point	3-EOBS	40-01
	East Control Post	3-ECP	40-02
	West Control Post	3-WCP	40-03
	Linac Road	3-LIN	40-04
	Near Well #4 (Golf Course)	3-GOLF	40-05
	Tracy Firehouse	3-TFIR	40-06
	North Power Station	3-NPS	40-08
	West Observation Point	3-WOBS	40-09
	East of Building 801	3-801E	40-10

...continued

Table 3-QA-1. Site 300 sampling location designators, 1990 (concluded).

Media	Location	Current designator	Previous designator(s)
<u>Soil</u>			
	West of 834	3-834W	3ESEI01 or 1103
	Near 858	3-858S	3WSWI01 or 1104
	North of 856	3-856N	3WXXK01 or 1106
	North of Road to 851	3-851N	3WNWI01 or 1107
	North of East Observation Point	3-EOBS	3NNWL01 or 1110
	North of Well #8 (ERD Evaporator)	3-EVAP	3WNWK01 or 1109
	North Power Station	3-NPS	3NWXP01 or 1112
	West Landfill (Disp. Site West)	3-DSW	3NWXP02 or 1111
	Southwest of 802	3-801N	3NNWG01 or 1113
	East of 801	3-801E	3NXXH01 or 1114
	Behind 812	3-812N	3NXXC01 or 1115
	West of Cafeteria (Golf Course)	3-GOLF	3SEXL01 or 1116
	West Observation Point	3-WOBS	3WNWN01 or 1108
	West of 801	3-801W	1117
<u>Vegetation</u>			
	Carnegie	3-CARN	45-01
	Golf Course	3-GOLF	45-02
	Geodetic	3-GEO	45-03
	Disposal Site West	3-DSW	45-06
	Behind Building 801	3-801E	45-12
	Near Well #8 (ERD Evaporator)	3-EVAP	45-13
<u>Water</u>			
	Well 1	3-WELL01	42-01
	Private Well	3-CON1	42-07
	Private Well	3-CON2	—
	Well 18	3-WELL18	42-22
	Geodetic Creek	3-GEO	42-14
	Rain	3-RAIN	42-20
	812 Creek	3-CRK	42-21
	Carnegie Retention Well 1	3-CARNRW1	42-23
	Carnegie Retention Well 2	3-CARNRW2	42-24
	Well 20	3-WELL20	42-31
	Private Well	3-GALLO1	42-28
	Private Well	3-GALLO2	—
	CDF Well	3-CDF1	42-27
	Private Well	3-MUL1	—
	Private Well	3-MUL2	—
	Private Well	3-VIE1	—
	Private Well	3-VIE2	—

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RADIOLOGICAL METHODS

This appendix reviews the methods used in quantifying the presence of radiological constituents in the environment at the Lawrence Livermore National Laboratory (LLNL) site and at Site 300.

Air Monitoring

LLNL maintains six continuously operating high-volume air-particulate (Hi-Vol) samplers around the Livermore-site perimeter, 13 samplers in the Livermore Valley, eight samplers at Site 300, and one in the City of Tracy.

All of the Hi-Vol samplers are equipped with 21.6×27.9 cm Whatman 41 cellulose filters. These samplers operate at average flow rates of 400 L/min.

All air filters are changed weekly. Each filter is identified by its location, date on, date off, elapsed sampling time, and flow rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets. Each filter sample is given a serial number that accompanies it throughout the analysis.

After a four-day delay for decay of the radon-thoron daughters, gross alpha and beta activities on the filters are determined with a gas-flow proportional counter.

Filters from Locations PATT, RRCH, ALTA, LCCY, and ERCH are analyzed only for gross alpha and gross beta activities. Filters from all other locations are analyzed for additional constituents, as described below.

Monthly composites of Livermore-site-perimeter samples (Locations SALV, MESQ, CAFE, MET, VIS, and COW) and Site-300 filters are sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides using low-background Ge(Li) detectors. Following gamma counting, the site-perimeter filters and Site-300 filters from individual locations are analyzed for the presence of ²³⁹Pu, ²³⁵U, and ²³⁸U. Selected off-site samples from the Livermore Valley (Locations TANK, ZON7,

FCC, HOSP, LWRP, and FIRE) are analyzed for ²³⁹Pu. These filters are ashed and then dissolved in a mixture of nitric acid (HNO₃) and hydrochloric acid (HCl), and/or hydrofluoric acid (HF). Plutonium and uranium then are separated by an ion-exchange process. Plutonium is purified further by ion exchange, electroplated onto a stainless-steel disk, and submitted for alpha spectrometry. Uranium is purified further by ion exchange and submitted for analysis by mass spectrometry.

Concentrations of airborne tritium are determined for each of the Livermore-site-perimeter air-sampling locations, off-site Locations S1 and S2, and four additional Livermore Valley locations (Locations ZON7, ALTA, LCCY, and FIRE). Water vapor is trapped on silica-gel samplers operated at a flow rate of 0.7 L/min for a two-week period. The average flow rate is calculated from the initial and final flow rates, which are measured biweekly with a rotometer that is calibrated annually. The silica gel columns are exchanged biweekly. Each sample is identified by its location, date on, date off, elapsed sampling time, and flow rate. This information is transferred to log sheets at the Livermore site, and each sample is given a serial number that accompanies it throughout the analysis. The collected water is recovered by freeze-drying. The tritiated water is electrolytically enriched and measured by liquid-scintillation counting.

Sewage Analysis

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for four seconds for every 1,000 gallons of effluent.

Appendix A

Radiological Methods

Aliquots of this composite are transferred to plastic bottles and submitted for analysis. Daily composites of treated effluent from LWRP are collected by LWRP employees. Aliquots of these composites are placed in 500-mL polyethylene bottles, which are retained for weekly collection by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge three times a week.

Standard quality control procedures are maintained. When each sewage field-sample is collected, it is labeled with the sampling location and sampling date. In the laboratory, each sample is assigned a number that accompanies that sample during analysis. One replicate sample of Livermore-site effluent and one replicate sample of LWRP effluent are collected every Wednesday and submitted in duplicate for the gross alpha, gross beta, and tritium analyses.

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the Livermore site and LWRP effluents also are analyzed for gamma-emitting radionuclides and ^{239}Pu . In addition, the monthly composites from the LWRP digesters are analyzed for gross radioactivity. Every three months sludge samples are combined and analyzed to yield the quarterly plutonium and cesium content.

For those samples analyzed for gross alpha and beta activity, about 25 mL of an 80% / 20% mixture of HNO_3 and HClO_4 is added to an aliquot (350 mL for on-site samples; 100 mL for LWRP samples), and the mixture is heated to dryness on a hotplate. The residue is taken up in 10 mL of HNO_3 and 5 mL of 5% H_2O_2 . The volume is reduced to 3–5 mL on a hotplate, transferred to 5-cm-diameter planchets, and counted.

For tritium analyses, a 5-mL aliquot of distilled sewage sample is added to 15 mL of Packard Instagel in a 25-mL screw-cap polyethylene bottle. Fifteen mL of Instagel is used as a control blank. Both the sample

and the blank are placed in the refrigerated detection chamber of the scintillation counter for a 1-hr temperature equilibration prior to counting. Each sample is counted for 100 min.

Plutonium is separated by coprecipitation with manganese dioxide (MnO_2). The manganese dioxide then is ashed and dissolved in HNO_3 and H_2O_2 . Plutonium is purified by ion exchange, electroplated onto a stainless-steel disk, and submitted for alpha spectrometry.

Cesium is separated by ion exchange with ammonium molybdophosphate (AMP). The AMP crystals are transferred to a counting vial with concentrated HCl , which then is submitted for gamma spectrometry.

Water Analysis

At quarterly intervals, water samples from surface and groundwater sources in the Livermore Valley and at Site 300 are analyzed for gross alpha and beta radioactivity and for tritium content. These analyses are performed to determine if detectable changes in the radioactivity of water sources have occurred.

Once each year, groundwater samples taken in the vicinity of the Livermore Water Reclamation Plant (LWRP) are analyzed for tritium. These analyses are performed to determine the extent—if any—of tritium migration to the groundwater from LLNL's sewage effluent.

Tritium analysis also is performed on rain water samples taken at the Livermore site and at off-site locations in the vicinity of the Laboratory. These analyses are performed to determine the correlation between tritium concentrations measured in stormwater runoff and the concentrations measured in the collected rain water samples.

Grab samples are obtained with a tethered plastic pail from surface sources, such as ponds, creeks, and reservoirs. A 500-mL sample is collected for tritium analysis in an argon-flushed glass container fitted with a ground-glass stopper. Samples for other radiological analyses are collected in 500-mL polyethylene bottles.

Groundwater monitoring wells are purged of stagnant water prior to sampling. In the case of wells with high water-production rates, this process entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For wells with low water-production rates, the well is manually bailed until dry. Sampling occurs when the well has produced sufficient water for the required samples. All sampling equipment is chosen so that it will not add compounds to the analysis sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

Rain water is collected in stainless-steel buckets positioned with rain gauges at least three feet above the ground in open unsheltered areas. Samples (500-mL) are taken from the buckets for tritium analysis in triple-rinsed glass bottles. As samples are collected in the field, they are labeled with sampling location and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 10% of the water samples—except rain water samples—are duplicates. Water samples are analyzed for gross alpha and beta activity and tritium.

In the gross alpha and beta analysis, a 100-mL sample (or less, depending on the solid content) is digested with a mixture of 80% HNO_3 and 20% HClO_4 and dried. The residue is taken up with HNO_3 and a few milliliters of 5% hydrogen peroxide (H_2O_2). The solution is evaporated to about 5 mL and transferred to a 5-cm-diam serrated, stainless-steel planchet. After the planchet is dried and flamed, the sample is counted for 30 min in a Sharp 3-1/4-in proportional counter. A blank is processed with each set of samples.

Standards for ^{239}Pu and ^{90}Sr are used with every sample set. (See similar entry under "Soil Sampling and Analysis.") Background measurements are made between every ten sample-counting measurements.

For low-level tritium analysis, samples are electrolytically enriched and then coun-

ted by liquid-scintillation spectrometry. Each counting set includes eight standards to establish quench corrections and eight blanks to determine background.

All groundwater and stormwater radiological samples, except tritium, are sent to a contract analytical laboratory. Procedures used by the analytical laboratory are ASTM procedures or well-documented in-house procedures based on NRC guidelines.

Soil Sampling and Analysis

Soil samples are collected annually from reasonably level areas that represent undisturbed soil. A 2-m square is marked off in each area, and an 8.25-cm-diameter coring tool, designed at LLNL, is used to collect 5-cm-deep subsamples at the corners and center of the square. All subsamples are collected to a depth of 5 cm because surface deposition from the air is the primary pathway for potential contamination. The five subsamples of soil collected from each 2-m square are combined into a single composite sample in a plastic bag. A label is affixed to the bag, and the sample is identified by a sample identification code, called the sample identifier. This identifier is entered in a logbook, with all pertinent sampling information and a description of the sample location. The code identifies the sample throughout all sampling and laboratory activities and during data reporting.

After collection, the soil samples are dried, ground, and blended. Plutonium-239 content is determined from an aliquot of each sample following drying, grinding, sieving, and an acid-leaching procedure; the soil is leached by heating for four hours with a mixture of concentrated HNO_3 and HCl . The plutonium then is separated and purified by ion exchange and electroplating, and is submitted for alpha spectroscopy.

Other sample aliquots, which are analyzed by gamma spectroscopy (for over 150 radionuclides), first are dried at 110°C for a minimum of two days, pulverized, passed through a 32-mesh sieve, and blended. The gamma spectroscopy involves approximately 300-g aliquots of the soils, which are sealed in 200-cm³

Appendix A Radiological Methods

thin-walled aluminum cans. The samples are gamma-counted with a Ge(Li) detector.

Approximately 10% of the soil sampling locations are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, two adjacent cores, 5-cm deep, are taken from the corners and center of each 2-m square. Separate composites of the five cores then are made, and the composites are identified with unique sample identifier codes. The same soil sampling and analytical procedures apply at both the Livermore site and Site 300.

Arroyo Sediment Sampling. Arroyo sediment sampling follows standard written sampling procedures (Brekke et al. 1988). At each annual sampling location near the Livermore site, a 30-ft (9.2-m) transect is laid out (starting from a permanent marker), and four numbers between 1 and 30 are randomly generated. These numbers represent the distance in feet along the transect where samples are taken. Samples are taken with a split-spoon sampler driven into the soil to a depth of 2 ft (0.61 m) to allow for better characterization of volatile organic compounds. The bottom 6 in (0.15 m) are sealed in a stainless-steel sampling tube and are submitted for organic-compounds and metals analyses. The next higher 6 in (0.15 m) are submitted for radiological analyses (tritium, gamma emitters, and plutonium). Sample identifier codes are written on the sample tube, on a label attached to the sample tube, and in a logbook. The sample identifier code and the sampling date identify each sample throughout the sampling and analytical processes.

Gamma spectroscopy and plutonium analyses are conducted on aliquots of arroyo sediment samples using the techniques outlined above for soil samples. Tritium analysis is performed by liquid-scintillation counting of water recovered through freeze-drying from additional aliquots of the arroyo sediment samples.

Ten percent of the arroyo samples are collected in duplicate, in accordance with quality assurance protocols (Holland 1987).

Duplicate samples are collected adjacent to sampling locations using identical procedures. The duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Vegetation Sampling and Analysis

At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley and at Site 300. Sampling activities follow standardized written procedures (Brekke et al. 1988). Grass samples are cut at ground level, and any soil or dead tissues are discarded. The bulk volume of the samples is between 0.5 and 1 L (approximately 1 kg). Each sample is collected, double-bagged in plastic, labeled according to sample type and location, and frozen in a dry-ice chest to minimize water loss to the bag's surface. A label is affixed to the bag, and the sample is identified by a sample identification code, called the sample identifier. This identifier is entered in a logbook with all pertinent sampling information and a description of the sample location. The code identifies the sample throughout all sampling and laboratory activities and data reporting. The samples later are transferred to a freezer in the laboratory. Two subsamples of vegetation are collected each quarter at each sampling location. One subsample is used for analysis and the other is preserved in the laboratory freezer, in case the first sample is lost during analysis, or in case the measurement result is in question and reanalysis of the sample is necessary for data verification.

Water from the vegetation samples is collected using freeze-drying techniques. The tritium content of the recovered water is determined by liquid-scintillation counting.

Approximately 10% of the sites are sampled in duplicate to comply with quality assurance protocols (Holland 1987). For duplicate collections, a total of four subsamples of vegetation are collected from a sampling location, using identical methodology. Two of the bags serve as the official sample. The other two bags are

considered the duplicate sample. Duplicate samples are preserved, stored, processed, and analyzed with methods identical to those employed for all other samples.

Foodstuff Sampling and Analysis

Wine. Three types of retail wine samples are collected and analyzed annually: wines produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California (outside the Livermore Valley), and wines produced from grapes grown in Europe. California and Europe are divided into 10 and 12 wine-producing regions, respectively. Estate-grown and -bottled wines from as many of the regions as possible are purchased as representative samples. Several estate-grown and -bottled Livermore Valley wines also are collected. Approximately 10% of the total complement of wines are collected and analyzed in duplicate to comply with quality assurance protocols (Holland 1987).

The wines are purchased from retail outlets. To provide data on the potential exposure from wine consumption, the wines are selected based on general availability. Thus, the wines are selected from different vintages (i.e., from wines produced in different years). However, the wine sample data can be decay-corrected to original radiological concentrations, given the number of months that have elapsed between production and analysis.

The wine samples are submitted unopened to the Nuclear Chemistry Division for tritium analyses. The wine samples are oxidized in a Peterson furnace, gas-converted, and analyzed for tritium content by gas-proportional counting.

Honey. Samples of honey available for purchase from a variety of flower sources, both inside and outside the Livermore Valley, are analyzed annually for tritium content. Because honey purchased during a given year may not have been produced during that year, the tritium values are not indicative of the year's tritium emissions. But like that for wine, the data do serve as

an index of potential exposure. Following oxidation of the samples in a Parr oxygen bomb, the tritium content of the water produced is determined by gas-proportional counting. Honey-sample submittals comply with quality assurance protocols (Holland 1987).

Milk. Goat-milk samples are obtained monthly from four farms within about 5 km of the Livermore site. Production from the farms varies, so samples are obtained as available. Samples also are obtained from two non-Livermore-Valley California locations for determination of background concentrations. Cartoned milk, purchased in a store, also is analyzed for comparative purposes.

A portion of each milk sample is freeze-dried. The collected water then is analyzed for tritium activity by liquid-scintillation counting. Another portion of each milk sample is preserved with formalin, and is analyzed for gamma-emitting isotopes by counting a 1-L aliquot in a Marinelli beaker using Ge(Li) spectrometers. At least one milk source is sampled and analyzed in duplicate each month to comply with quality assurance protocols (Holland 1987).

Radiation Monitoring

Penetrating radiation, which cannot be measured by collection of material on filters, is measured using dosimeters.

The program was designed to measure external doses from penetrating radiation (primarily gamma rays). These measurements are made with Panasonic UD814 thermoluminescent dosimeters (TLDs). External doses from gamma radiation are measured at 22 Livermore-site- and 13 Site-300-perimeter locations, and at 55 Livermore and three Site 300 off-site locations. The dosimeters are mounted in the field on existing structures (such as fence lines) approximately one meter above ground level. The dosimeters are exchanged, analyzed, and dose rates are calculated quarterly.

Appendix A Radiological Methods

The dosimeters contain three elements of thallium-activated calcium sulfate (CaSO_4) and one element of lithium borate ($\text{Li}_2\text{B}_4\text{O}_7$). Each dosimeter is heat-sealed in a 3-1/2-in $\times$ 2-1/4-in, 4.5-mil.-thick foil pouch for protection against light and moisture. When a TLD is missing, the annual dose is calculated as four times the average quarterly dose as determined from available data.

The TLDs measure environmental gamma radiation exposure in milliroentgens (mrem). The measured exposure is converted to dose by calibrating the dosimeters to read out in absorbed dose

and then applying a quality factor for a beta/gamma radiation field. The resulting dose equivalents (mrem) are compared to radiation protection standards. The dose at the Livermore-site boundary also is compared to background measurements to determine the contribution, if any, from LLNL operations.

Environmental neutron dose measurements using ^{235}U track-etch detectors also are made at eight locations on the Livermore-site perimeter. A detailed description of the detector and the spark-counting procedure may be found in Fisher (1976).

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METHODS OF DOSE CALCULATIONS

Introduction

The radiological impact to the public from operations at Lawrence Livermore National Laboratory (LLNL) is assessed in accordance with applicable DOE orders. Based on releases of radioactivity to the environment and measurements of environmental media, four potential doses are calculated: the dose at the site perimeter, the dose to the nearest resident, the dose at the point of maximum exposure in an uncontrolled area, and the dose to the population residing within an 80-km (50-mi) radius of the site. The doses in this report may be compared to the radiation protection standards established by DOE and other regulatory bodies.

For the purposes of this report, doses are reported in terms of "effective dose equivalent," which is defined as the sum of the dose from external radiation and the committed (50-y) effective dose equivalent from ingestion and inhalation during a one-year period. This dose is a measure of the potential health effects from radiation exposure. It also accounts for the radiation dose delivered to the body from intakes of radionuclides with a long-effective half-life (i.e., radionuclides with long physical half-lives and long residency in the body). Thus, the "effective dose equivalent" includes the total dose received over a 50-y period following a one-year exposure. The effective dose equivalents in this report were calculated using the dosimetric parameters recommended by the International Commission on Radiological Protection (ICRP) in *Publications 26* (1977) and *30* (1980).

Pursuant to the National Emission Standards for Hazardous Air Pollutants, 40 *Code of Federal Regulations* Part 61, Subpart H (NESHAPS), doses from the air pathway are also reported in terms of "effective dose equivalent." These doses were derived using the Clean Air Act Code (CAAC), which contains models (AIRDOS-EPA and RADRISK), approved by EPA for calculating atmospheric transport and exposure. Population exposure was converted to radiation dose using dose conversion factors and weighting factors specified by the EPA.

Radiological Dose Assessment Performed for 1990

Each of the doses used to measure the radiological impact from LLNL during 1990 are described briefly in the following paragraphs.

1. External "fence-line" dose. The fence-line dose rate is a measure of the maximum external dose at locations of nearest uncontrolled public access. Dose rates from external penetrating radiations (primarily gamma rays and neutrons) are measured using environmental dosimeters

(thermoluminescence dosimeters and neutron detectors). The environmental dosimeters measure dose rates from all external radiation sources, including cosmic radiations, naturally occurring radioactivity in the environment, fallout from nuclear weapons testing, and any contribution from LLNL operations. Hence, these doses are not solely attributable to LLNL, and in most instances they are a measure of regional background. This is determined by comparing the perimeter measurements with those made at off-site (Livermore

Valley) locations. Moreover, these off-site measurements are made at points of maximum exposure and assume an occupancy of 24 hr/d, 365d/y. In actuality, no member of the public resides at these locations for extended periods of time; therefore, these estimates are conservative.

2. Ingestion dose. Potential doses from ingestion of locally produced foodstuff and surface water are based on actual measurements of radionuclide concentrations in the various media (determined by sampling). Conservative exposure data and current ICRP dosimetric factors are used to estimate doses to the individual. The following radionuclide exposure pathways are assessed by means of field measurements: tritium in water, tritium in milk, and tritium in vegetation (which includes the forage-cow-milk pathway).

3. Inhalation/submersion dose. Air pathway doses are calculated for each airborne radioactive discharge to the atmosphere. Inhalation and submersion doses are calculated to the nearest resident at the site perimeter, and at the point of maximum off-site exposure. The amount of radioactivity released by LLNL usually is too low to measure radionuclide concentrations accurately in ambient air and to determine dose. Therefore, environmental transport and exposure pathway models are used to calculate potential doses from effluent emissions (i.e., measurements made at a building stack). These doses are calculated by two methods to comply with both the DOE standards (equivalent to current ICRP recommendations) and the National Emission Standards for Hazardous Air Pollutants, 40 *Code of Federal Regulations* Part 61, Subpart H (NESHAPS).

Dose calculations were made using the Continuous-Point-Source computer code based on the Gaussian plume model (Peterson et al. 1976). This code provides ratios of concentration to release rate (χ/Q) through sixteen 22.5-degree compass sectors and distances from 0.1 to 100 km from potential release points. The average annual χ/Q values have been calculated using local meteorological data. These data were

obtained from sensors on the LLNL meteorological tower from heights of 10 and 40 m. From records of these data, wind speed, wind direction, and atmospheric stability estimates were tabulated at one-quarter-hour intervals during the calendar year. Digitized meteorological data became available at Site 300 in May 1986, and were used to perform dispersion calculations for the Advanced Test Accelerator emissions.

Variance in the horizontal wind direction was used to estimate Pasquill-Gifford stability categories based on the method described by Slade (1968). Lateral and vertical standard deviations σ_y and σ_z are entered in the computer code as functions of these stability categories and the respective distances. Based on the annual effluent data (release rate Q) and the appropriate χ/Q values, the radionuclide concentrations at the site perimeter and the nearest resident are calculated. "Nearest resident" refers to the resident nearest to the site perimeter.

4. Maximally exposed individual dose. This dose represents the maximum credible dose to any "hypothetical" member of the public. It includes contributions from all potential exposure pathways and is derived using the most conservative but realistic exposure data and assumptions. This hypothetical person is assumed to reside at the point of highest ground-level radionuclide air concentration continuously for 24 hr/d, 365 d/y. During this occupancy period, a portion of this person's diet consists of locally produced foodstuffs and drinking water containing the highest measured radionuclide concentration. Thus, this is not a dose actually received by any individual and should be viewed as a conservative estimate (i.e., overestimate) of the highest possible dose to any member of the public.

5. Collective population dose. The collective population dose is the dose for all individuals residing within an 80-km (50-mi) radius of the site. It is calculated by summing for each sector the average individual dose multiplied by the number of individuals residing in the sector.

The collective population dose is referred to as the "collective effective dose equivalent"; it is expressed in terms of person-mrem.

The effective dose equivalents shown in this report have been calculated using models and methods consistent with the NRC Regulatory Guide 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent* (U.S. Nuclear Regulatory Commission 1977). The dose and dose-rate conversion factor used in these calculations were obtained from the committed dose equivalent tables for

DOE dose calculations. These dose conversion factors are consistent with those specified in ICRP 30, *Limits of Intakes of Radionuclides by Workers* (ICRP 1980).

Examples of these calculations and assumptions are presented below.

Annual Dose from Potable Water

Based on the assumption that all water sampled is available as drinking water, the annual whole-body dose for tritium in mrem/y has been calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem/y}) = C_w \times U_w \times D_w \quad (\text{F-1})$$

where

C_w = concentration of tritium in water (pCi/L)

U_w = intake rate (L/y) = 730 L/y for maximally exposed individual

D_w = dose factor (mrem/pCi)

= 6.3×10^{-8} mrem/pCi for tritium for the whole-body ingestion pathway for an adult

$D_{\text{whole body}}$ = effective dose equivalent (mrem/y) from ingestion of 730 L of potable water with concentration C_w

Annual Dose from Forage-Cow-Milk Pathway for Tritium in Vegetation

Based on the assumption that all feed for the cattle was pasture grass, the effective dose equivalent per $\mu\text{Ci/mL}$ of tritiated water (HTO) for the maximally exposed individual has been calculated using the following equation:

$$D_{\text{whole body}}(\text{mrem/y}) = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \quad (\text{F-2})$$

where

D_{veg} = dose from ingestion of vegetables

D_{meat} = dose from ingestion of meat

D_{milk} = dose from ingestion of milk

Vegetation.

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

where

U_{veg} = intake rate (kg/y): 64 kg/y for maximally exposed individual

C_{veg} = concentration (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): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway

thus,

$$D_{\text{veg(mrem/y)}} = (0.40 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])$$

Meat.

$$D_{\text{meat(mrem/y)}} = U_{\text{meat}} \times C_{\text{meat}} \times D_{\text{HTO}} \quad (\text{F-2b})$$

where

U_{meat} = intake rate (kg/y): 110 kg/y for maximally exposed individual

$C_{\text{meat}} = (F_f) \times (Q_f) \times (C_{\text{veg}}) \times (e^{-\lambda_1 t_s})$

D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway

F_f = fraction of daily intake of nuclide per kg of animal/fish (pCi/kg in meat per pCi/d ingested by the animal) (d/kg)

Q_f = amount of feed consumed (kg/d)

C_{veg} = concentration (pCi/kg): $10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}} \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])$

λ_1 = radiological decay constant (d^{-1})

t_s = time between slaughter to consumption (d)

$$\begin{aligned} C_{\text{meat}} &= (1.2 \times 10^{-2} \text{ d/kg}) \times (50 \text{ kg/d}) \times (C_{\text{veg}} [\mu\text{Ci/mL}]) \times (10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \times (e^{[-1.5 \times 10^{-4}] \times \{20\}}) \\ &= (0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}]) \end{aligned}$$

thus,

$$\begin{aligned} D_{\text{meat(mrem/y)}} &= (110 \text{ kg/y}) \times (0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/mL}}) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}]) \times (6.3 \times 10^{-8} \text{ mrem/pCi}) \\ &= (0.41 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}]) \end{aligned}$$

Milk.

$$D_{\text{milk}}(\text{mrem/y}) = U_{\text{milk}} \times C_{\text{milk}} \times D_{\text{HTO}} \quad (\text{F-2c})$$

where

U_{milk} = intake rate (L/y): 310 L/y for maximally exposed individual

D_{HTO} = dose factor (mrem/pCi): 6.3×10^{-8} mrem/pCi for ^3H for the adult whole-body ingestion pathway

$C_{\text{milk}} = (F_m) \times (Q_f) \times (C_{\text{veg}}) \times (e^{-\lambda_i t_f})$

F_m = fraction of daily intake of nuclide per liter of milk (pCi/L in milk per pCi/d ingested by the animal) (d/L)

Q_f = amount of feed consumed (kg/d)

C_{veg} = concentration (pCi/kg): $(10^9 \frac{\text{pCi/L}}{\mu\text{Ci/mL}}) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}])$

λ_i = radiological decay constant (d^{-1})

t_f = transport time from milking to milk consumption (d)

$$\begin{aligned} C_{\text{milk}} &= (1.0 \times 10^{-2} \text{ d/L}) \times (50 \text{ kg/d}) \times (C_{\text{veg}} [\mu\text{Ci/mL}]) \times (10^9 \frac{\text{pCi/L}}{\mu\text{Ci/mL}}) \times (e^{-[1.5 \times 10^{-4}] \times [2]}) \\ &= (0.5 \times 10^9 \frac{\text{pCi/L}}{\mu\text{Ci/mL}}) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}]) \end{aligned}$$

thus,

$$\begin{aligned} D_{\text{milk}}(\text{mrem/y}) &= (310 \text{ L/y}) \times ([0.5 \times 10^9 \frac{\text{pCi/L}}{\mu\text{Ci/mL}}] \times [C_{\text{veg}} [\mu\text{Ci/mL measured}]]) \times (6.3 \times 10^{-8} \text{ mrem/pCi}) \\ &= (0.97 \times 10^4) \times (C_{\text{veg}} [\mu\text{Ci/mL measured}]) \end{aligned}$$

Whole Body.

$$\begin{aligned} D_{\text{whole body}}(\text{mrem/y}) &= ([0.40 \times 10^4] \times [C_{\text{veg}} [\mu\text{Ci/mL measured}]]) \\ &\quad + ([0.41 \times 10^4] \times [C_{\text{veg}} [\mu\text{Ci/mL measured}]]) \\ &\quad + ([0.97 \times 10^4] \times [C_{\text{veg}} [\mu\text{Ci/mL measured}]]) \end{aligned}$$

Thus,

$$D_{\text{whole body}}(\text{mrem/y}) = ([1.78 \times 10^4] \times [C_{\text{veg}} [\mu\text{Ci/mL measured}]])$$

Appendix B
Methods of
Dose
Calculations

Inhalation/Submersion Dose

The Continuous-Point-Source computer code was used to calculate the air pathway dose at the Livermore-site perimeter, to the nearest resident, and at the point of maximum exposure.

Inhalation Dose (^3H).

$$D_{\text{whole body}} (\text{mrem/y}) = C \times U \times D \quad (\text{F-3})$$

where

C = radionuclide concentration at the receptor ($[F] \times [\chi/Q] \times [Q]$)

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

χ/Q = diffusion parameter (s/m^3)

Q = release rate, Ci/y

U = intake rate (inhalation rate for adult is $8,400 \text{ m}^3/\text{y}$)

D = dose conversion factor (for ^3H : $9.45 \times 10^{-8} \text{ mrem/pCi}$; the tritium dose conversion factor was obtained by multiplying the inhalation dose factor, $6.3 \times 10^{-8} \text{ mrem/pCi}$, by 1.5 to include absorption through the skin)

thus,

$$D_{\text{whole body}} (\text{mrem/y}) = (3.17 \times 10^4 \left[\frac{\text{pCi/Ci}}{\text{s/y}} \right]) \times (\chi/Q [\text{s/m}^3]) \times (Q [\text{Ci/y}]) \times (8,400 [\text{m}^3/\text{y}]) \times (D [\text{mrem/pCi}])$$

External Immersion Dose (^{13}N and ^{15}O).

$$D_{\text{whole body}} (\text{mrem/y}) = C \times (\text{DRF}) \quad (\text{F-4})$$

where DRF, the dose-rate factor, is the external dose-equivalent rate per unit radionuclide concentration, $\frac{\text{mrem/y}}{\text{pCi/m}^3}$.

$$\text{For } ^{13}\text{N}, \text{DRF} = 5.11 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

$$\text{For } ^{15}\text{O}, \text{DRF} = 5.12 \times 10^{-3} \frac{\text{mrem/y}}{\text{pCi/m}^3}$$

and

C = radionuclide concentration at the receptor ($[F] \times [\chi/Q] \times [Q]$)

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

χ/Q = diffusion parameter (s/m^3)

Q = release rate, Ci/y

thus,

$$D_{\text{whole body}}(\text{mrem/y}) = (3.17 \times 10^4 [\frac{\text{pCi/Ci}}{\text{s/y}}]) \times (\chi/Q [\text{s/m}^3]) \times (Q [\text{Ci/y}]) \times (\text{DRF} [\frac{\text{mrem/y}}{\text{pCi/m}^3}])$$

Annual Population Dose

For population dose, the diffusion parameters and population figures for a sector (*i*) within 80 km (50 mi) of LLNL were summed over all directions (*n*). These values are determined in person-mrem.

$$\text{Dose (person-mrem/y)} = (F) \times (\sum_i^n [\chi/Q]_i P_i) \times Q \times U \times D \quad (\text{F-5})$$

where

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

$$(\sum_i^n [\chi/Q]_i P_i) = \text{Summation of the } (\chi/Q) \text{ for sector } i \text{ times the population in sector } i (P_i) \text{ for all regions } n, \text{ person-s/m}^3$$

Q = release rate, Ci/y

U = inhalation rate, average adult individual is (8,400 m³/y)

D = dose factor, mrem/pCi

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NONRADIOLOGICAL METHODS

This appendix reviews the methods used to quantify the presence of nonradio-logical constituents in the environment at the Lawrence Livermore National Laboratory (LLNL) site and at Site 300.

Beryllium in Air

Monitoring for beryllium concentration in air involves measurement of particles collected on filters from six continuously operating high-volume air-particulate (Hi-Vol) samplers on the Livermore-site perimeter, eight samplers at Site 300, and one in the City of Tracy.

All Hi-Vol samplers are equipped with 21.6×27.9 cm Whatman 41 cellulose filters. These samplers operate at average flow rates of 400 L/min.

All air filters are changed weekly. Each filter is identified by its location, date on, date off, elapsed sampling time, and flow rate. Filters are placed in glassine envelopes and transported to the Livermore site, where this information is transferred to log sheets. Each filter sample is given a serial number that accompanies it throughout the analysis.

Each month all filter papers are cut in half and composited by sampling location. Two paper filters at a time are wet-washed with a mixture of 80% HNO_3 and 20% perchloric acid (HClO_4). The solutions then are evaporated to a few milliliters. Care is taken to prevent the samples from baking dry. After the samples are diluted with water, they are filtered. Any residues are discarded, and the filtrates are diluted to 100 mL with deionized water. Quantification is accomplished by atomic-absorption spectrophotometry with electrothermal atomization. Quality control includes a reagent blank with blank filters, a blank spiked with 200 ng of beryllium, and several samples spiked with essentially carrier-free ^7Be . Standards of 1, 2, and 5 g/L are prepared by diluting an intermediate 1-ppm stock solution

obtained from an NIST-traceable, 1,000-ppm stock dilution. The diluent in all cases is 1% HNO_3 in water.

Sewage Analysis

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for four seconds for every 1,000 gallons of effluent. Aliquots of this composite are transferred to plastic bottles and submitted for analysis. Daily composites of treated effluent from LWRP are collected by LWRP employees. Aliquots of these composites are placed in 500-mL polyethylene bottles, which are retained for weekly collection by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge three times a week.

Standard quality control procedures are maintained. When each sewage field sample is collected, it is labeled with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies that sample during analysis.

Water quality and organic compounds also are monitored. Once each quarter a portion of the 24-hour composite sample and an instantaneous grab sample of the LLNL sewage effluent are subjected to an extensive set of analyses. These analyses include parameters specified on LWRP's National Pollutant Discharge Elimination System permit, including metals, nutrients, pesticides, and priority pollutants. The Federal priority pollutants are measured to establish baseline information for these parameters using EPA methods 624 and 625.

Appendix C

Nonradiological Methods

Quarterly samples also are collected at the point of discharge of specified metal-finishing and electrical (and electronic) component categorical processes to ensure compliance with EPA discharge limits for those processes. LLNL reports the results of the analyses of the point-source discharges semiannually to the LWRP, the agency delegated by EPA to implement those regulations. The results are not reported here.

Monthly composites of Livermore-site sewage effluent are analyzed for arsenic, cadmium, chromium, copper, iron, lead, nickel, silver, aluminum, beryllium, and zinc. The monthly composite sample is prepared by combining 500-mL daily samples. A solution of HNO_3 (80%) and HClO_4 (20%) is 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 is reduced to about 100 mL. After the 500-mL aliquot from the last day has been added, the combined volume is reduced to about 50 mL. When the solution is cool, about 50 mL of deionized water is added, and the liquid is filtered through No. 40 Whatman paper. The paper is placed in a platinum crucible and digested with about 5 mL of HF, 16 mL of HNO_3 , and 4 mL of HClO_4 to a residue of about 4 to 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 metal content is determined with an atomic-absorption spectrophotometer—with the exception of arsenic, which is analyzed using inductively coupled plasma mass spectrometry. The required calibration standards are prepared by dilution of a 1,000-ppm, NIST-traceable stock solution.

For mercury analysis, 25 mL is taken from the daily sample and transferred to a glass bottle with a ground-glass stopper. At the end of the month, 100 mL of the

solution is reduced with 5 mL of H_2SO_4 and 5 mL of HNO_3 (80%). Potassium permanganate then is added to eliminate sulfides and chlorides. The sample is heated in a water-bath for two hours at 95°C . After cooling, 6 mL of sodium chloride-hydroxylamine sulfate reduces the excess permanganate, after which 5 mL of stannous sulfate is added. The resulting solution is analyzed by cold-vapor atomic absorption. Each time the analysis is performed, standards are run to calibrate the method, as described above.

For the first 11 months of the year, metals analyses of LLNL samples were performed on a monthly basis, as described above. This analysis now is performed weekly, as required by permit conditions announced in December.

Water Analysis

Stormwater runoff samples and selected groundwater samples are analyzed for a variety of water quality parameters. These analyses are performed to determine if detectable changes in radioactivity or degradation of water quality have occurred.

Groundwater monitoring wells are purged of stagnant water prior to sampling. In the case of wells with high water-production rates, this process entails removing an amount of water equivalent to four times the amount of water standing in the well casing. For wells with low water-production rates, the well is bailed manually until dry. Sampling occurs when the well has produced sufficient water for the required samples. All sampling equipment is chosen so that it will not add compounds to the analysis sample. Containers and preservatives are used according to established EPA protocols for the analyte of interest.

As samples are collected in the field, they are labeled with sampling location and date. In the laboratory, each sample is assigned a number that accompanies it during analysis. During each sample collection period, at least 10% of the water samples are duplicates.

The following analyses are performed on the samples acquired:

Beryllium. A 100-mL sample is digested with HNO₃. The residue is diluted to 100-mL with deionized water, and the analysis is completed using atomic absorption spectrophotometry, as described for air analysis.

Groundwater and Stormwater.

Table App-C-1 lists the standardized methods used in the analysis of groundwater and stormwater samples.

High Explosives. All samples are analyzed in-house using High Performance Liquid Chromatography. Then 100 µL of the sample are injected into an HPL Chromatograph fitted with a Hewlett Packard RP-8 column. The flow rate is set at 1.0 mL/min, with a 35% methanol, 65% water solvent. An ultraviolet detector set at 230 nm is used, then used again set at 254 nm for comparison.

Arroyo Sediment Sampling and Analysis

Arroyo sediment sampling follows standard written sampling procedures (Brekke et al. 1988). At each annual sampling location near the Livermore site, a 30-ft (9.2-m) transect is laid out (starting from a permanent marker), and four numbers between 1 and 30 are generated randomly. These numbers represent the distance (in feet) along the transect where

samples are taken. Samples are taken with a split-spoon sampler driven into the soil to a depth of two feet (0.61 m) to allow for better characterization of volatile organic compounds. The bottom six inches (0.15 m) are sealed in a stainless-steel sampling tube and are submitted for organic compounds and metals analyses. The arroyo samples are analyzed for metals by inductively coupled plasma emission spectroscopy (ICP), following extraction in water. The samples are analyzed for organic compounds by standard EPA methods (method 8010 for halogenated volatile organic compounds, method 8020 for aromatic volatile organic compounds, and method 8080 for pesticides and PCBs).

Ten percent of the arroyo samples are collected in duplicate, in accordance with quality assurance protocols (Holland 1987). Duplicate samples are collected adjacent to sampling locations using identical procedures. The duplicate samples are preserved, stored, processed, and analyzed using methods identical to those employed for all other samples.

Noise Monitoring

To monitor peak noise during explosives testing at Site 300, six microbarograph sensors are maintained in or near the City of Tracy and data are analyzed for overpressures in excess of regulatory limits.

Appendix C
Nonradiological
Methods

Table APP-C-1. EPA groundwater standard methods.

Analyte	EPA method	Analyte	EPA method
<u>Metals</u>		<u>Organic compounds</u>	
Antimony	204.1	Volatile organic compounds	
Arsenic	206.2	Purgeable halocarbons	601
Barium	208.1	Purgeable priority pollutants	624
Beryllium	210.2	Title 22 organic compounds	608
Cadmium	213.1	Extractable priority pollutants	625
Chromium	218.1	Low-level phenolic compounds	
Cobalt	219.1	Total organic halide (TOX)	9020
Copper	220.1	Total organic carbon (TOC)	9060
Iron	236.1	Oil and grease	413.1
Lead	239.2	Chemical oxygen demand (COD)	410.1
Manganese	243.1		
Mercury	245.1		
Molybdenum	246.1		
Nickel	249.1		
Selenium	270.2		
Silver	272.1		
Sodium	273.1		
Thallium	279.1		
Vanadium	286.1		
Zinc	289.1		
<u>Nonmetallic inorganic compounds</u>			
Total dissolved solids	160.1		
Total suspended solids	160.2		
Total Kjeldahl nitrogen	351.3		
Ammonia nitrogen (as N)	350.2		
All alkalinities	310.2		
Nitrate	353.2		
Nitrate	354.1		
Fluoride	340.2		
Chloride	325.3		
Sulfate	375.3		

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A	Absorbed dose	The amount of energy deposited by radiation in a given amount of material. The unit of absorbed dose is the rad.
	Absorption	The process by which the number and energy of particles or photons entering a body of matter is reduced by interaction with the matter.
	Accuracy	The closeness of the result of a measurement to the true value of the quantity measured.
	ACHD	Alameda County Health Department.
	Action Level	Defined by regulatory agencies, it is the level of pollutants, which, if exceeded, requires regulatory action.
	ADM	Action Description Memorandum.
	AIRDOS	EPA computerized simulation model.
	ALARA	As Low As Reasonably Achievable. A U.S. Department of Energy (DOE) and Nuclear Regulatory Commission policy for radiation exposures. This approach to radiation exposure control or management maintains the exposures and resulting doses as far below the limit specified for the appropriate circumstances as social, economic, technical, and practical considerations permit.
	Alluvium	Sediment deposited by flowing water.
	Alpha particle	A positively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of a helium nucleus (two protons and two neutrons).
	Ambient air	The surrounding atmosphere (usually the outside air) that exists around people, plants, and structures. It is not considered to include the air immediately adjacent to emission sources.
	Analyte	A constituent that is being analyzed.
	Anion	A negatively charged ion.
	ANOVA	Analysis of variance. A test of whether two or more sample means (i.e., averages) could have been obtained from the same statistical population.

Glossary

	Aquifer	A saturated layer of rock or soil below the ground surface that can supply usable quantities of ground water to wells and springs. Aquifers can be a source of water for domestic, agricultural, and industrial uses.
	Aquitard	A geologic unit that functions as an upper or lower boundary of an aquifer.
	ARB	(California) Air Resources Board. The State agency responsible for developing control strategies to protect ambient air quality. This agency also regulates mobile sources.
	ATA	Advanced Test Accelerator.
	Atom	The smallest particle of an element capable of entering into a chemical reaction.
	Atomic absorption spectrometry	Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor. Abbreviated AA.
	AT&T	American Telephone & Telegraph.
	AVLIS	Atomic Vapor Laser Isotope Separation.
B	BAAQMD	Bay Area Air Quality Management District. The local agency responsible for regulating stationary air emission sources (including the Livermore site) in the San Francisco Bay Area.
	BAT	Best available technology (economically achievable).
	Beta particle	A negatively charged particle emitted from the nucleus of an atom. A beta particle has a mass and charge equal to those of an electron.
	Blank sample	A control sample that is identical, in principle, to the sample of interest, except that the substance being analyzed is absent. The measured value or signals in blanks for the analyte is believed to be caused by artifacts, and should be subtracted from the measured value. This process yields a net amount of the substance in the sample.
	Blind sample	A control sample of known concentration in which the expected values of the constituent are unknown to the analyst.
	Biota	The animal and plant life of a particular region considered as a total ecological entity.

BOD	Biochemical (biological) oxygen demand. A measure of the amount of oxygen in biological processes that breaks down organic matter in water; a measure of the organic pollutant load. BOD used as an indicator of water quality.
C	
CAA	Clean Air Act. The Federal law that authorizes the EPA to set air quality standards and to assist State and local governments to develop and execute air pollution prevention and control programs.
CAAC	Clean Air Act Code (EPA). Computer code required by the EPA for modeling air emissions.
CAM WET	California Assessment Manual, Waste Extraction Test. A Department of Health Services procedure for evaluating the leachability of certain metals, pesticides, and other organic compounds from a semi-solid or solid waste. It is used to determine the toxicity of a waste.
Cation	A positively charged ion.
CCR	California Code of Regulations.
CEQA	California Environmental Quality Act of 1970. This legislation regulates the issuance of permits for the construction and operation of any facility in California that has potential to cause harm to the environment. Federal facilities are exempt from CEQA. However, the University of California has voluntarily chosen to comply with this legislation.
CERCLA	<p>Comprehensive Environmental Response, Compensation and Liability Act of 1980. Also known as Superfund, this law authorizes the Federal government to respond directly to releases of hazardous substances that may endanger health or the environment. The EPA is responsible for managing Superfund. The major step in the Superfund process is the Remedial Investigation/Feasibility Study (RI/FS).</p> <p>In 1986, the President signed into law the Superfund Amendments and Reauthorization Act (SARA), which amended and reauthorized CERCLA for five years at a total funding level of \$8.5 billion. SARA also strengthened State involvement in the cleanup process and encouraged the use of treatment technologies and permanent solutions. However, the Superfund cleanup of groundwater at LLNL is funded by DOE.</p>
CFR	Code of Federal Regulations. A codification of all regulations developed and finalized by Federal government agencies in the <i>Federal Register</i> . RCRA regulations are contained in 40 <i>Code of Federal Regulations</i> .

Glossary

	Chain-of-custody	A method for documenting the history and possession of a sample from the time of its collection, through its analysis and data reporting, to its final disposition.
	Chlorocarbon	A compound of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethylene.
	COD	Chemical oxygen demand. A gross analytical test for the presence of organic compounds in water.
	Collective dose equivalent	The sums of the dose equivalents of all individuals in an exposed population within a certain radius, expressed in units of person-rem (or person-sievert).
	Collective effective dose equivalent	The sums of the effective dose equivalents of all individuals in an exposed population within a certain radius, expressed in units of person-rem (or person-sievert).
	Committed dose equivalent	The predicted total dose equivalent to a tissue or organ over a 50-y period after known intake of a radionuclide into the body. It does not include contributions from external dose. Committed dose equivalent is expressed in units of rem (or sievert).
	Committed effective dose equivalent	The sum of the committed dose equivalents to various tissues, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).
	Cosmic radiation	Very high energy radiation originating outside the earth's atmosphere. Cosmic radiation is one contributor to natural background radiation.
	CPS Code	Continuous-Point-Source computer code for plume dispersion and deposition calculations.
	Curie (Ci)	A unit of measurement of radioactivity, defined as the amount of radionuclide in which the decay rate is 2.22×10^{12} disintegrations per minute (3.7×10^{10} disintegrations per second), which is approximately equal to the decay rate of one gram of pure radium.
D	Daughter	A nuclide formed by the radioactive decay of another nuclide, called the parent.
	1,1-DCA	1,1-dichloroethane.

DCG	Derived Concentration Guide. Concentrations of radionuclides in water and air that could be consumed or inhaled continuously (365 days/y) and not exceed the DOE primary radiation protection standard to the public (100 mrem/y effective dose equivalent).
DEIS	Draft Environmental Impact Statement. (See EIS.)
DHS	Department of Health Services (California). The State agency that regulates hazardous waste management and remedial actions.
Disintegration (nuclear)	A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.
DOE	U.S. Department of Energy. The Federal agency that sponsors energy research and regulates nuclear materials used for weapons production.
Dose	The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram for irradiated material in any medium.
Dose commitment	The dose that an organ or tissue would receive during a specified period of time (e.g., 50 or 100 years) as a result of intake of one or more radionuclides from one year's release.
Dose equivalent	The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert). The dose equivalent to an organ, tissue, or whole body in a year will be that received from the direct exposure plus the committed dose equivalent received from radionuclides taken into the body during the year.
Dosimeter	A portable detection device for measuring the total accumulated exposure to ionizing radiation.
Dosimetry	The theory and application of the principles and techniques involved in measuring and recording radiation doses. The practical aspect concerns the use of various types of radiation measurement instruments.
DWS	Drinking water standard. A standard established by the State of California in 22 <i>California Code of Regulations</i> .
E EA	Environmental Assessment. A report that identifies potentially significant environmental impacts from any Federally approved or funded project that may change the physical environment. If an EA shows significant impact, an EIS is required.

Glossary

EDS	Engineering Demonstration System.		
Effective dose equivalent	An estimate of the total risk of potential effects from radiation exposure. EDE is the sum of the committed effective dose equivalent from internal deposition and the effective dose equivalent from external penetrating radiation received during a calendar year. The committed effective dose equivalent is the sum of the individual organ committed dose equivalents multiplied by weighting factors that represent the proportion of the total random risk that each organ would receive from uniform irradiation of the whole body.		
Effluent	A liquid or gaseous waste discharged to the environment.		
EIR	Environmental Impact Report. A detailed report, required by California law, on the significant environmental impacts from any project that may change the physical environment and that is carried out, approved, or funded by a local or State (California) public agency.		
EIS	Environmental Impact Statement. A detailed report, required by Federal law, on the significant environmental impacts that a pending structure or development will have on the environment. An EIS must be prepared by a government agency when a major Federal action is planned that will have significant environmental impacts.		
EMG	Environmental Monitoring Group of the LLNL Environmental Protection Department.		
EPA	Environmental Protection Agency. The Federal agency responsible for enforcing environmental laws. Although some of this responsibility may be delegated to State and local regulatory agencies, EPA retains oversight authority to ensure protection of human health and the environment. EPA administers the Superfund legislation and works with State and local agencies to provide technical oversight for cleanup activities at Federal facilities regulated by the Superfund program.		
EPD	Environmental Protection Department (LLNL).		
ERD	Environmental Restoration Division of the LLNL Environmental Protection Department.		
ERP	Environmental Restoration Program (at LLNL).		
F	<table><tr><td>Federal Facility</td><td>A facility that is owned or operated by the Federal government. With the passage of SARA, Federal facilities became</td></tr></table>	Federal Facility	A facility that is owned or operated by the Federal government. With the passage of SARA, Federal facilities became
Federal Facility	A facility that is owned or operated by the Federal government. With the passage of SARA, Federal facilities became		

subject to the same requirements that other responsible parties must follow once the Federal facilities are placed on the Superfund National Priorities List.

Federal Register

A document published daily by the Federal government containing notification of government agency actions. The Federal Register contains notification of EPA and DOE actions, including notification of EPA and DOE decisions concerning permit applications and rule making.

FEIS

Final Environmental Impact Statement. (See EIS.)

FFA

Federal Facilities Agreement. A document that specifies the required actions at a Federal facility, as agreed upon by various agencies (e.g., EPA, DHS, RWQCB, and DOE).

Fissile

Any material fissionable by neutrons of all energies (e.g., ^{235}U and ^{239}Pu).

Fluvial

Produced by the action of a stream or river.

FONSI

Finding of No Significant Impact.

FS

Feasibility Study. A study based on a Remedial Investigation to evaluate and develop remedial action alternatives that prevent or mitigate the migration or release of hazardous substances or contaminants.

G

g

Gram. A standard metric measure of weight approximately equal to 0.035 ounce.

Gamma ray

High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies the emission of alpha or beta particles. Gamma rays are identical to x-rays, except for the source of the emission.

Gray

The SI unit of measure for absorbed dose. The quantity of energy imparted by ionizing radiation to a unit mass of matter, such as tissue. One gray corresponds to one joule per kilogram.

Greek prefixes

Symbol	Name	Scientific notation	Decimal notation
m	milli	10^{-3}	0.001
μ	micro	10^{-6}	0.000001
n	nano	10^{-9}	0.000000001
p	pico	10^{-12}	0.000000000001

Glossary

H	Half-life (radiological)	The time required for one-half the radioactive atoms in a given amount of material to decay. After one half-life, 50 out of 100 atoms will have changed; during the next half-life, 25 more will decay, and so on, exponentially.
	Hazardous waste	Wastes exhibiting any of the following characteristics: ignitability, corrosivity, reactivity, or EP-toxicity (yielding toxic constituents in a leaching test). In addition, the EPA has listed as "hazardous" other wastes that do not necessarily exhibit these characteristics. Although the legal definition of hazardous waste is complex, the term generally refers to any waste that, if managed improperly, EPA believes could pose a threat to human health and the environment. RCRA regulations set strict controls on the management of hazardous wastes.
	HAZWRAP	Hazardous Waste Remedial Action Program. A packaging guide for transferring low-level radioactive mixed waste.
	HE	High explosives. Materials that release large amounts of energy when detonated.
	HMX	Cyclotetramethyltetramine. A high-explosive compound.
	HPLC	High-pressure liquid chromatograph. A technique to separate and quantify chemicals.
	HSWA	Hazardous and Solid Waste Amendments of 1984 to RCRA. These amendments to RCRA greatly expanded the scope of hazardous waste regulation. In HSWA, Congress directed EPA to take measures to reduce further the risks to human health and the environment caused by hazardous wastes.
	HT	Tritiated hydrogen gas. Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. Tritium emits a low-energy beta particle and has a half-life of 12.3 y.
	HTO	Tritiated water (and water vapor). (See HT.)
	HWCL	California Hazardous Waste Control Law. The law that sets requirements for the management of hazardous wastes in California.
	HWM	Hazardous Waste Management Division at LLNL.
	Hydraulic gradient	In an aquifer, the rate of change of total head (water-level elevation) per unit distance of flow at a given point, and in a given direction.
	Hydrology	The science dealing with the properties, distribution, and circulation of natural water systems.

I	ICP	Inductively coupled plasma emission spectroscopy. An analytical technique generally used to quantify metals, such as chromium, copper, and zinc.
	ICRP	International Commission on Radiological Protection. An international organization that studies radiation, including its measurement and effects.
	Inorganic compounds	Compounds that either do not contain carbon or do not contain hydrogen along with carbon. Inorganic compounds include metals, salts, and various carbon oxides (carbon monoxide, carbon dioxide).
	<i>In situ</i>	A term that refers to the treatment of contaminated areas without excavation or other removal, as in the <i>in situ</i> treatment of soils through biodegradation of contaminants on site.
	Interim status	A legal classification that applies to hazardous waste incinerators or other hazardous waste management facilities that were under construction or in operation by November 19, 1980, and can meet other interim status requirements. Interim status facilities may operate while EPA considers their permit application.
	Ion	An atom or compound that carries an electrical charge.
	Isopleth	A line on a map connecting points at which a given variable has a specified constant value, such as topographic contour lines.
	Isotopes	Forms of an element having the same number of protons in their nuclei, but different numbers of neutrons.
J	Joule	The SI unit of work or energy equal to 10 ⁷ ergs, or approximately 0.7375 foot-pound. (A foot-pound is the amount of energy to move one pound the distance of one foot.)
L	L	Liter. The SI measure of capacity approximately equal to 1.057 quart.
	Land Ban	A regulatory program that identifies hazardous wastes that are restricted from land disposal. The regulations incorporate a phasing-in of restrictions in three stages.
	LBL	Lawrence Berkeley Laboratory.
	LDR	Land disposal restriction. Environmental regulations limiting the type and amount of a chemical that can be disposed of by burial in soil.

Glossary

	Less than detection limits	A phrase indicating that a chemical constituent either was not identified or was not quantified at the lowest level of sensitivity of the analytical method used by the laboratory. Therefore, the chemical constituent either is not present in the sample, or is present in such a small concentration that it cannot be measured by the analytical procedure.
	LLNL	Lawrence Livermore National Laboratory.
	Lower limit of detection	The smallest concentration or amount of analyte that can be detected in a sample at a 95% confidence level.
	LWRP	Livermore Water Reclamation Plant. The City of Livermore's municipal wastewater treatment plant, which accepts discharges from the LLNL Livermore site.
M	MAD	Median absolute deviation. The median of the differences of all data values from the median.
	MATHEW / ADPIC codes	Transport and diffusion computer codes used to determine the concentration of pollutants at a distance from the source.
	MCL	Maximum contaminant level. Established by a regulatory agency.
	MOCVD	Metalorganic Chemical Vapor Deposition.
	mR	Milliroentgens. A unit of measurement that expresses radiation exposure.
	mrem	Millirem. A unit of measurement that expresses radiation dose to a person—equal to 0.00001 sievert.
	MTL	Multi-user Tandem Laboratory.
N	NAAQS	National Ambient Air Quality Standards. Air standards established by EPA to protect human health and the environment.
	NEPA	National Environmental Policy Act. Passed in 1969, this Federal legislation regulates the issuance of permits for the construction and operation of facilities that have the potential to make an impact on the environment or on public health. One provision of NEPA requires the preparation of an EIS by Federal agencies when major actions are taken. The agency responsible for assuring NEPA compliance at LLNL is DOE, with EPA oversight.

NESHAP	National Emission Standards for Hazardous Air Pollutants. These standards are found in the Clean Air Act. They set limits for such pollutants as beryllium and radionuclides.
NIST	National Institute for Standards and Technology. The Federal agency responsible for reference materials against which laboratory materials are calibrated. (Formerly known as the National Bureau of Standards.)
Nonpoint source	Any nonconfined area from which pollutants are discharged into a body of water (e.g., agricultural runoff, construction runoff, and parking-lot drainage).
NOV	Notice of Violation.
NPDES	National Pollutant Discharge Elimination System. This Federal regulation, under the Clean Water Act, requires permits for discharges into surface waterways. LLNL holds NPDES permits at the Livermore site for groundwater discharges to the arroyos and for cooling-tower discharges at Site 300.
NPL	National Priorities List. EPA's list of the top-priority hazardous waste sites in the country that are subject to the Superfund program.
NRC	Nuclear Regulatory Commission. The Federal agency charged with oversight of nuclear power, nuclear machinery, and applications not regulated by DOE or by the Department of Defense.
NTS	Nevada Test Site (DOE). The facility in the United States where nuclear weapons are tested.
Nuclide	A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons, number of neutrons, and energy content; or, alternatively, by the atomic number, mass number, and atomic mass. To be a distinct nuclide, the atom must be capable of existing for a measurable length of time.
0	
Off site	Outside the boundaries of the LLNL Livermore site and Site 300 properties.
On site	Within the boundaries of the LLNL Livermore site or Site 300 properties.
OSHA	Occupational Safety and Health Act.

Glossary

P	Part B permit	The second, narrative section submitted by generators of hazardous wastes in the RCRA permitting process. It covers in detail the procedures followed at a facility to protect human health and the environment.
	PCB	Polychlorinated Biphenyls. Any of a family of toxic compounds, now banned in the U.S., formerly used in industry and manufacturing.
	PCE	Tetrachloroethylene (also known as perchloroethylene). A volatile organic contaminant found in groundwater.
	Performance standards	Specific regulatory requirements established by EPA that limit the concentrations of designated organic compounds, particulate matter, and hydrogen chloride in emissions from incinerators. EPA also established performance standards for concentrations of metals and organic compounds in waste water.
	PETREX	A semiquantitative diagnostic technique to assess volatile organic compounds in soil.
	pH	A measure of hydrogen-ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, basic solutions have a pH greater than 7, and neutral solutions have a pH of 7.
	Piezometer	Generally, a small-diameter, nonpumping well used to measure the elevation of the water table or potentiometric surface.
	Point source	Any confined and discrete conveyance (e.g., pipe, ditch, well, or stack).
	Porter-Cologne Act	The California law that established a two-tier administrative organization to enforce its water-quality legislation: Regional Water Quality Control Boards and the State Water Resources Control Board.
	POTW	Publicly Owned Treatment Works. A general term for sewage treatment plants. The Livermore Water Reclamation Plant is the POTW that accepts sewage from the Livermore site.
	PPAP	Pollution Prevention Awareness Plan.
	ppb	Parts per billion. A unit of measure for the concentration of a substance in its surrounding medium. For example, one billion grams of water containing one gram of salt has a salt concentration of one part per billion.

ppm	Parts per million. A unit of measure for the concentration of a substance in its surrounding medium. For example, one million grams of water containing one gram of salt has a salt concentration of one part per million.
Precision	How closely a value of similar or replicate results approaches a common value in a series of measurements.
Pretreatment	Any process used to reduce a pollutant load before it enters the sewer system.
Pretreatment regulations	National wastewater pretreatment regulations adopted by EPA in compliance with the 1977 amendments to the Clean Water Act, which required that EPA establish pretreatment standards for existing and new industrial sources.
Priority pollutants	A set of organic and inorganic chemicals identified by EPA as indicators of environmental contamination.
Public comment period	A specified time allowed for the public to express views and concerns regarding an action by a public agency.
Public hearing	A formal gathering of officials and the public where the views and concerns of the public are expressed regarding a public agency's action; public comments may be written or oral. The agency is required to consider the comments when evaluating the action.
Public notice	Notification by an agency informing the public of agency actions (e.g., the issuance of a draft permit).
Q	
QAPP	Quality Assurance Project Plan. An LLNL plan that outlines methods and processes to ensure that the precision, accuracy, completeness, representativeness, and compatibility of project data are known and maintained at an acceptable level.
Quality assurance	A system of activities that provides the producer or user of a product or service the assurance that it meets defined standards of quality with a stated level of confidence.
Quality factor	The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses (on a common scale for all ionizing radiation) the biological damage to exposed persons. Quality factor is used because some types of radiation, such as alpha particles, are biologically more damaging than others.
R	
rad	The unit of absorbed dose. It is the quantity of energy imparted by ionizing radiation to a unit mass of matter such as tissue. One rad equals 0.01 joule per kilogram.

Glossary

Radioactive decay	The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.
Radioactivity	The spontaneous emission of radiation (generally alpha or beta particles, or gamma rays) from the nucleus of an unstable isotope.
Radionuclide	An unstable nuclide. See nuclide and radioactivity.
RADRISK	EPA computerized simulation model.
RCRA	Resource Conservation and Recovery Act of 1976. RCRA is an amendment to the first Federal solid waste legislation, the Solid Waste Disposal Act of 1965. In RCRA, Congress established initial directives and guidelines for EPA to regulate hazardous wastes.
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine. A high-explosive compound.
Reagent	Any substance used in a chemical reaction to detect or measure another substance, or to convert one substance into another by means of the reaction that it causes.
rem	Radiological unit of dose equivalent. Rem is the product of the absorbed dose (rad), quality factor (Q), distribution factor, and other necessary modifying factors. The unit rem describes the effectiveness of various radiations to produce biological effects (1 rem = 0.01 sievert).
Response to comments	A document that addresses all significant public comments received by EPA during the public comment period on a proposed permit or action. The document includes a summary of each comment, and EPA's response to each comment.
RI	Remedial Investigation. An investigation conducted to assess fully the nature and extent of the release (or threat of release) of hazardous substances, pollutants, or contaminants and to gather necessary data to support the corresponding feasibility study.
Riparian	Inhabiting the bank area along or about a body of water.
Risk assessment	The use of established methods to measure the risks posed by an activity, such as hazardous waste treatment. Risk assessments evaluate the relationship between exposure to toxic substances and the subsequent occurrence of health effects, as well as the potential for that exposure.

Roentgen A unit of exposure dose of x-ray or gamma radiation such that the electrons and positrons liberated by this radiation produce in air (when stopped completely) ions carrying positive and negative charges of 2.58×10^{-4} coulomb per kilogram of air. Abbreviated R.

RWQCB Regional Water Quality Control Board. The regional agency responsible for water quality standards and for the enforcement of State water quality laws within its jurisdiction. California is divided into a number of RWQCBs. The Livermore site is regulated by the San Francisco Bay Region, and Site 300 is regulated by the Central Valley Region.

S **SAL** State Action Level. See Action Level.

Sampling and Analysis Plan A detailed document describing the procedures to collect, handle, and analyze groundwater samples for detection or assessment-monitoring parameters. The plan details quality control measures that ensure that sample-collection, analysis, and data-presentation activities meet the prescribed requirements.

SARA Superfund Amendments and Reauthorization Act of 1986. This act modifies and reauthorizes CERCLA. Title III of this act is known as the Emergency Planning and Community Right-to-Know Act of 1986.

Saturated zone A subsurface zone below which all rock pore-space is filled with water (also called the phreatic zone).

Screen zone In well construction, the section of a formation that contains the screen or perforated pipe that allows water to enter the well.

SDM Standard Deviation of the Mean. (See Standard deviation.)

Sensitivity The capability of methodology or instrumentation to discriminate between samples having differing concentrations or between samples containing varying amounts of analyte.

Sewerage The system of sewers.

SI *Système International d'Unités*. An international system of physical units. Units of measure in this system include meters (length), kilogram (mass), kelvin (temperature), becquerel (radioactivity), gray (radioactive dose), and sievert (dose equivalent).

Glossary

Sievert	The SI unit of dose equivalent. This is the product of the absorbed dose (gray), quality factor (Q), distribution factor, and other necessary modifying factors. The unit Sv describes the effectiveness of various radiations to produce biological effects ($1 \text{ Sv} = \text{Gy} \times Q \times N = 100 \text{ rem}$).
Site 300	LLNL's high-explosives test facility, located approximately 15 miles east of the Livermore site.
SJCAPCD	San Joaquin County Air Pollution Control District. The local agency responsible for regulating stationary air emission sources (including Site 300) in the San Joaquin County.
SJCHD	San Joaquin County Health District. The local agency that enforces underground-tank regulations in San Joaquin County, including Site 300.
SJCPHS	San Joaquin County Public Health Services.
SNLL	Sandia National Laboratories, Livermore.
Spiked sample	A sample of material (gas, liquid, or solid) to which a known amount of some substance of interest (the spike) is added. Spiked samples are used to check on the accuracy of a routine analysis or the recovery efficiency of an analytical method.
Standard deviation	A statistical indication of the dispersion of a set of results around their average (mean).
STLC	Soluble Threshold Limit Concentration. A value used to determine if a waste is hazardous.
Superfund	The common name used for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). CERCLA is a Federal statute that gives the Federal government the responsibility to respond to hazardous waste releases that pose a potential threat to human health and the environment. California also has established a State Superfund under provisions of the California Hazardous Waste Control Act.
Surface impoundment	A natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials—although it may be lined with man-made materials. The impoundment is designed to hold an accumulation of liquid wastes, or wastes containing free liquids, and is not an injection well. Examples of surface impoundments are holding, storage, settling, and aeration pits, ponds, and lagoons.

	SWRCB	State Water Resources Control Board. The State agency that develops and adopts statewide water quality plans and policies, issues permits pertaining to water use property rights, and acts as an appellate agency for actions of the Regional Water Quality Control Boards.
T	TCA	Trichloroethane. A volatile organic contaminant.
	TCE	Trichloroethylene. A volatile organic contaminant.
	TCLP	Toxicity Characteristic Leaching Procedure. An analytical method to determine the mobility of both organic and inorganic compounds present in liquid, solid, and multiphase wastes. TCLP is used to determine applicability of Land Ban to a waste.
	TDS	Total Dissolved Solids. The portion of solid material in a waste stream that is dissolved and passed through a filter.
	TFA	Treatment Facility A.
	TFB	Treatment Facility B.
	THM	Trihalomethanes. A chemical often formed in drinking water by chlorination of the water.
	TLD	Thermoluminescent dosimeter. A device used to measure external gamma radiation levels.
	TNT	Trinitrotoluene. A high-explosive compound.
	TOC	Total organic carbon. The sum of the organic material present in a sample.
	TOX	Total organic halides. The sum of the organic halides present in a sample.
	Tritium	Tritium is the hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle and has a half-life of 12.3 y (chemical symbol: ^3H).
	TSCA	Toxic Substances Control Act. The law governing the control, use, and disposal of selected toxic pollutants, such as PCBs.
	T-test	A type of ANOVA that determines the significance of the difference between two sample means (averages).
	TTO	Total toxic organic compounds. A list of organic compounds for which EPA has established discharge limits that apply to specific processes or industries.

Glossary

	Tuff	A fragmental rock consisting of the smaller kinds of volcanic debris, usually stratified.
	Turbidity	A measure of the concentration of sediment or suspended particles in solution.
U	²³⁸ U	Uranium-238. It is also known as D-38 or DU (depleted uranium), a radionuclide.
	UDS	Uranium Demonstration System.
	Unsaturated zone	That portion of the subsurface in which the pores are only partially filled with water. The direction of water flow is vertical in this zone; also referred to as the vadose zone.
	USGS	U.S. Geological Survey. The Federal agency responsible for maintaining maps of the United States.
	UST	Underground Storage Tank. A device to contain an accumulation of hazardous materials or waste. The tank is constructed primarily of nonearthen material, and the entire surface area is totally below the surface of, and covered by, the ground.
V	Vadose zone	The partially saturated or unsaturated region above the water table that does not yield water to wells. (See Unsaturated zone.)
	VHS	Volatile Halogenated Solvent. A term used by LLNL for analysis of the solvents detectable by EPA Method 601.
	VOC	Volatile Organic Compound. Liquid or solid organic compounds that tend to pass spontaneously into the vapor state.
	VSI	Visual Site Inspection. An inspection (required by EPA as part of the RCRA permit process) to identify solid waste management units that could have released, or continue to release, hazardous constituents to the environment.
W	WAA	Waste Accumulation Area. An officially designated area that meets current environmental standards and guidelines for temporary (less than 90 days) storage of hazardous waste before its pickup by the Hazardous Waste Management Division for off-site disposal.
	Wastewater treatment system	A collection of treatment processes and facilities that reduce the amount of suspended solids, bacteria, oxygen-demanding materials, and chemical constituents in wastewater.

	Water table	The water level surface below the ground where the unsaturated zone ends and the saturated zone begins. It is the level where a well that is screened in the unconfined aquifer would fill with water.
	WDR	Waste Discharge Requirements. Issued by the California Regional Water Quality Control Board.
	Weighting factor	A value used to calculate dose equivalents. This value is tissue-specific and represents the fraction of the total health risk resulting from uniform, whole-body irradiation that could be contributed to that particular tissue. Weighting factors used in this report are recommended by the ICRP (Publication 26).
	Wind rose	A diagram that shows the frequency and intensity of wind from different directions at a particular place.
X	XRFA	X-Ray Fluorescence Analysis. The identification of elements through characteristic x-rays generated by excitation. The sewer-monitoring system uses this technology for metal detection.
Y	y	The SI abbreviation for year.
Z	Zone 7	The common name for the Alameda County Flood Control and Water Conservation District. Zone 7 is the water management agency for the Livermore-Amador Valley responsible for water treatment and distribution. Zone 7 also is responsible for management of agricultural and surface water and the groundwater basin.

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