Environmental Radiation Monitoring

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Introduction

In accordance with federal regulations and applicable portions of U.S. Department of Energy (DOE) Orders 5400.1 and 5400.5, Lawrence Livermore National Laboratory monitors the natural background gamma radiation to establish radiation levels in its vicinity and to determine the environmental radiological impact of its operations. Gamma radiation in the environment primarily occurs naturally from terrestrial and cosmic sources. Because environmental radiological monitoring is used as one measure of the potential radiation dose that the public may receive as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for the Livermore site perimeter, Site 300 perimeter, and off-site locations. Gamma radiation has been measured at the Livermore site since 1973 and at Site 300 since 1988. The absorbed gamma radiation dose imparted to thermoluminescent dosimeters (TLDs) is the result of TLD exposure from both terrestrial and cosmic radiation sources as well as LLNL sources, if any.

Cosmic Radiation Component

Gamma radiation in air is produced by the interaction of cosmic rays. Cosmic rays consist of high-energy particles and emanate primarily from beyond the solar system. Radiation observed in the lower atmosphere and at the earth's surface are secondary radiations formed in the reaction of these high-energy particles with nuclei in the upper atmosphere. The cosmic radiation component accounts for about half the observed site annual average gamma radiation.

Terrestrial Radiation Component

Terrestrial gamma radiation is caused by naturally occurring isotopes of the uranium (uranium-238 parent), thorium (thorium-232 parent), and actinium (uranium-235 parent) decay series that are present in soil worldwide and that produce

gamma radiation during radioactive decay. The concentration of naturally occurring radionuclides in soil is variable and is determined by the ratio of thorium-232 to uranium-238 (present in these regions at the time of the earth's formation over four billion years ago), which ranges from 3 to 4 around the world. By characterizing the natural background radiation, LLNL can determine whether or not there is a contribution to gamma exposure from Laboratory operations.

General Methods

LLNL deploys TLDs in the field to assess the environmental impact of laboratory operations at both the Livermore site and Site 300. This assessment is done by comparing the gamma radiation data acquired from the Livermore perimeter site locations to the locations monitored in the Livermore Valley, and gamma radiation data from Site 300 perimeter locations to locations in the City of Tracy and near Site 300. Should a significant deviation from the expected values occur, an action level investigation of possible sources for the deviation is implemented.

As previously mentioned, the variability of the naturally occurring radioisotopes present in the soil due to geological formations is the largest contributor to variations in measurements. Meteorological conditions contribute to seasonal variability, as does cosmic variation.

LLNL deploys TLDs at the beginning of each quarter of the year and retrieves them from the monitoring locations as near to the end of the quarter as possible in order to have a 90-day exposure period. All data are normalized to a 90-day standard quarter basis in order to make valid comparisons for the measurement period.

Details of the TLD calculations are described in an Operations and Regulatory Affairs Division (ORAD) procedure. Reporting of external gamma radiation dose can be found in Chapter 12 of the Data Supplement.

Monitoring Locations

In 2002, external doses from gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 12-1**) and at 22 Livermore Valley locations (**Figure 12-2**), which are used for background comparison to perimeter location data. Similarly, gamma doses were monitored at 13 monitoring locations in the first two quarters at Site 300 (**Figure 12-3**); the number of monitoring locations was reduced to 9 in the 3rd and 4th quarters of 2002. The locations that were removed (3-123-TD, 3-124-TD, 3-125-TD, 3-126-TD) were added in the 3rd and 4th quarters of 2000 for monitoring accessibility following a vehicle fire that occurred in the 2nd quarter and resulted in the loss of several samples in that year. Additionally, the Site 300 data had previously been compared to 4 near–Site 300 locations and 2 locations in nearby Tracy. Two of the near–Site 300 locations have been removed this year due to private property access issues. Summary dose calculations for all gamma-monitoring locations are presented in **Table 12-1**. These site locations are depicted in **Figure 12-3**.

Results of Gamma Monitoring

Figure 12-4 shows gamma doses for the Livermore site perimeter, Livermore Valley, and Site 300 from 1988 through 2002. Beginning in 1995, all quarterly gamma radiation data points were normalized to 90-day standard quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). Correcting the

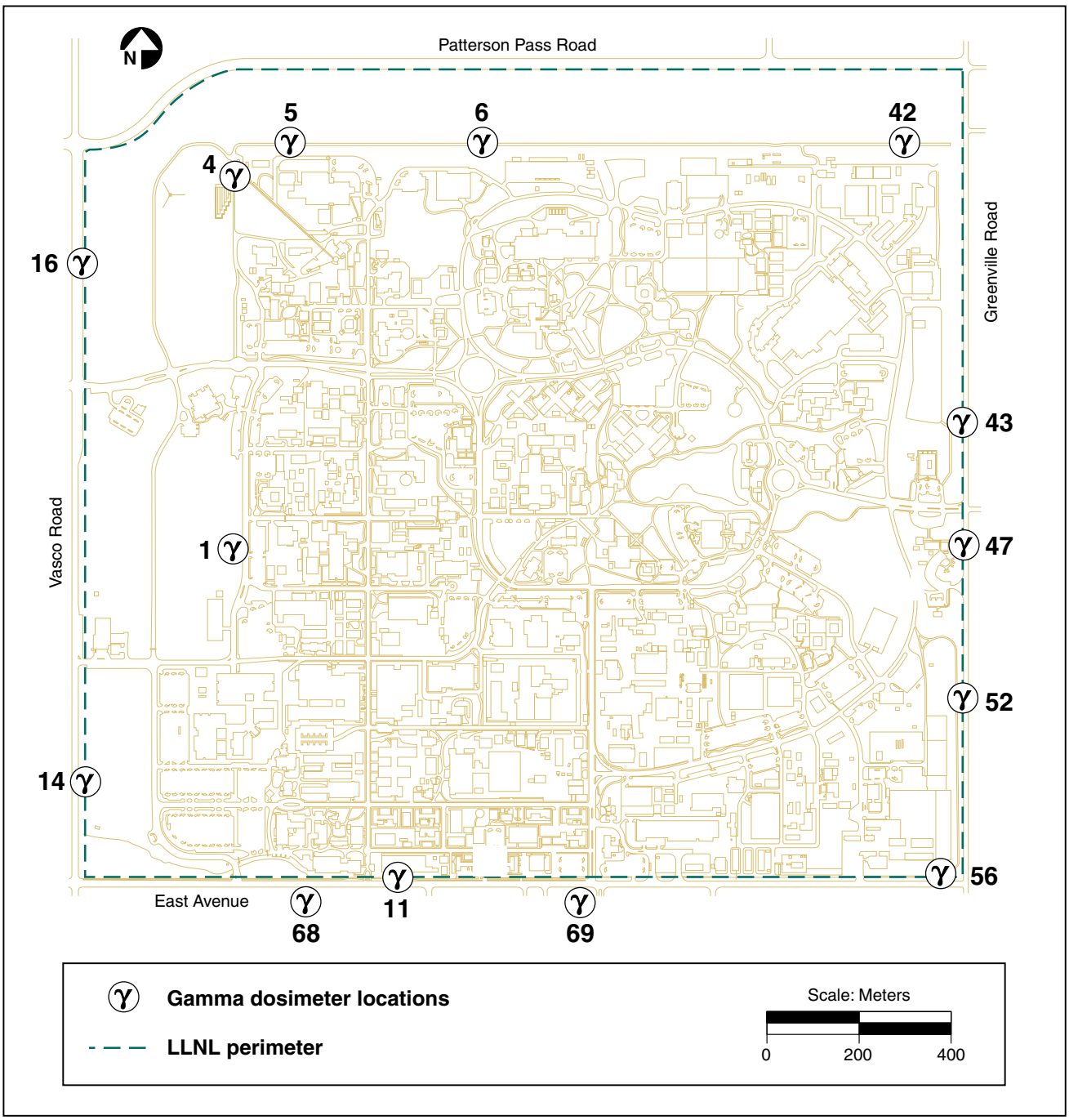

Figure 12-1. Gamma dosimeter locations, Livermore site, 2002

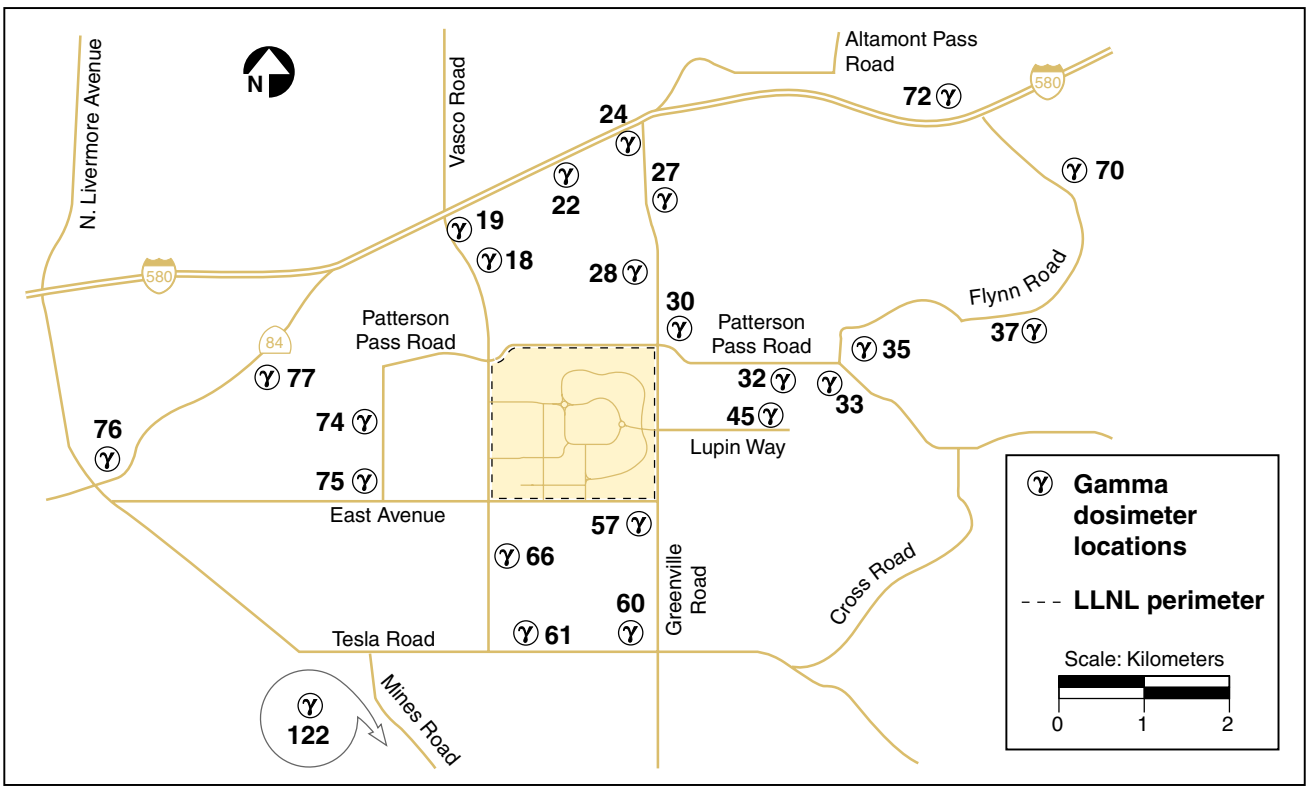

Figure 12-2. Gamma dosimeter locations, Livermore Valley, 2002

data by this method normalizes the data for comparison and reduces the data variability due to field duration.

Livermore Site

The quarterly and annual 2002 TLD gamma radiation dose for the Livermore site perimeter is summarized in **Table 12-1**. The annual dose from external radiation exposure at the Livermore site perimeter is 0.646 ± 0.028 mSv (64.6 ± 2.8 mrem). The quarterly means that produce the annual total are reported in Table 12-1 of the Data Supplement.

Site 300

The summary dose reported in **Table 12-1** for the Site 300 perimeter in 2002 is 0.755 ± 0.025 mSv (75.5 ± 2.3 mrem). The measured dose at the off-site locations near Site 300 was 0.751 ± 0.068 mSv (75.1 ± 6.8 mrem). The annual dose measured for Tracy is 0.679 ± 0.060 mSv (67.9 ± 6.0 mrem).

The region around Site 300 has higher levels of naturally occurring uranium present in the local geological area called the Neroly Formation. The off-site locations have historically represented the high end of background radiation due to this geological substrate. This area is underlain by a geological substrate composed of alluvial deposits

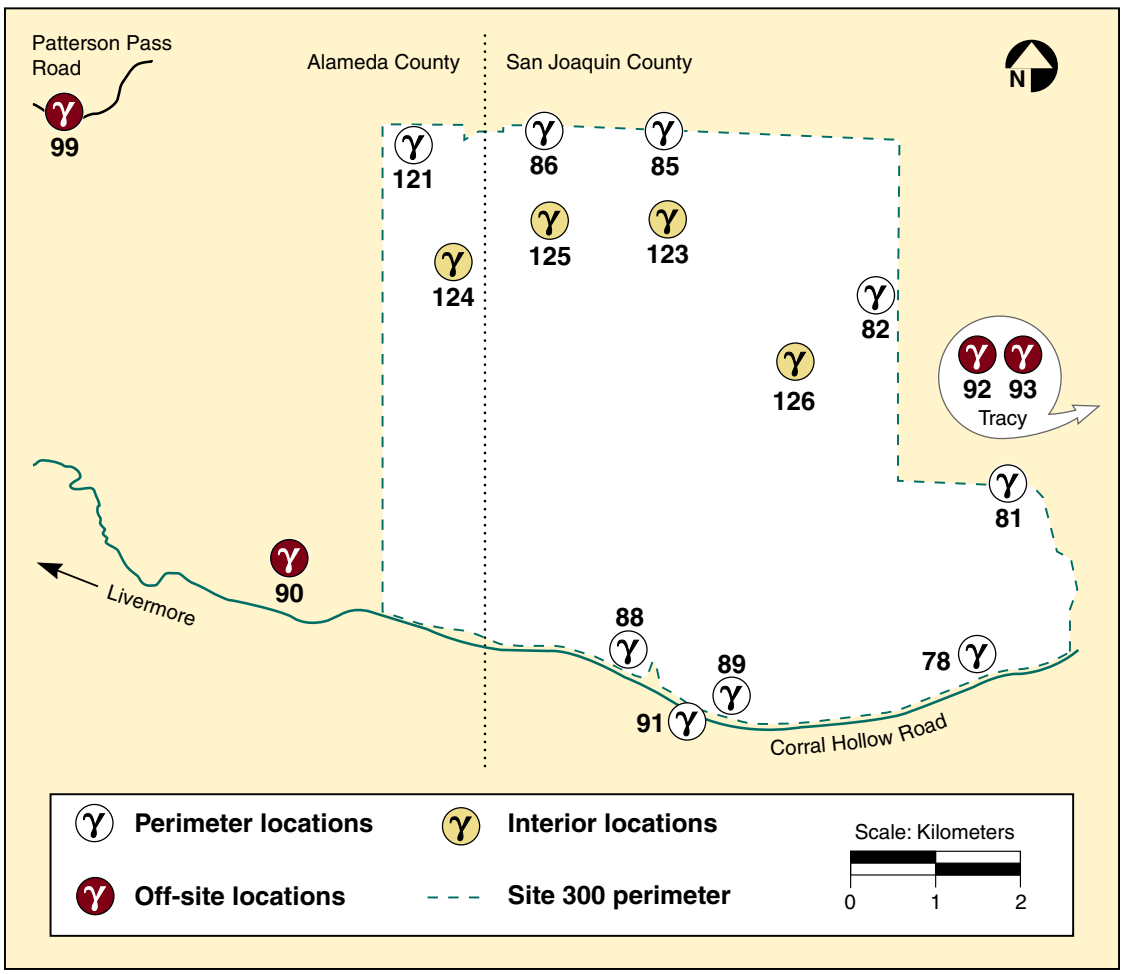

Figure 12-3. Gamma dosimeter locations, Site 300 and vicinity, 2002

of clays, sands, and silts overlying bedrock. The difference in the doses can be directly attributed to the difference in geologic substrates.

The data represented in **Figure 12-5** show a slight increase for the 4th quarter for both the Livermore site and Livermore Valley data. Additionally, the data for Site 300, Tracy, and the near–Site 300 locations show a similar trend. Although the data does not suggest a serious impact on either health or the environment, it falls within the action level of investigation. There are no plausible explanations at this time.

Table 12-1. Summary of dose calculations for gamma-monitoring locations (mSv)[a] at all LLNL sites, 2002

Quarter	Location				
	Livermore site	Livermore Valley	Site 300	Tracy	Near Site 300
	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]	Mean 2 SE[b]
First	0.161 ± 0.007	0.161 ± 0.006	0.182 ± 0.010	0.167 ± 0.040	0.188 ± 0.038
Second	0.151 ± 0.006	0.150 ± 0.008	0.172 ± 0.011	0.147 ± 0.034	0.181 ± 0.019
Third	0.151 ± 0.007	0.153 ± 0.008	0.188 ± 0.010	0.153 ± 0.025	0.180 ± 0.029
Fourth	0.183 ± 0.008	0.182 ± 0.007	0.213 ± 0.018	0.212 ± 0.014	0.202 ± 0.045
Annual dose[c]	0.646 ± 0.028	0.646 ± 0.015	0.755 ± 0.025	0.679 ± 0.060	0.751 ± 0.068

a 1 mSv = 100 mrem

b SE = Standard Error (standard deviation of the mean)

c Annual dose is reported as the summation of the quarterly doses. The reported error is the root mean square of the quarterly errors.

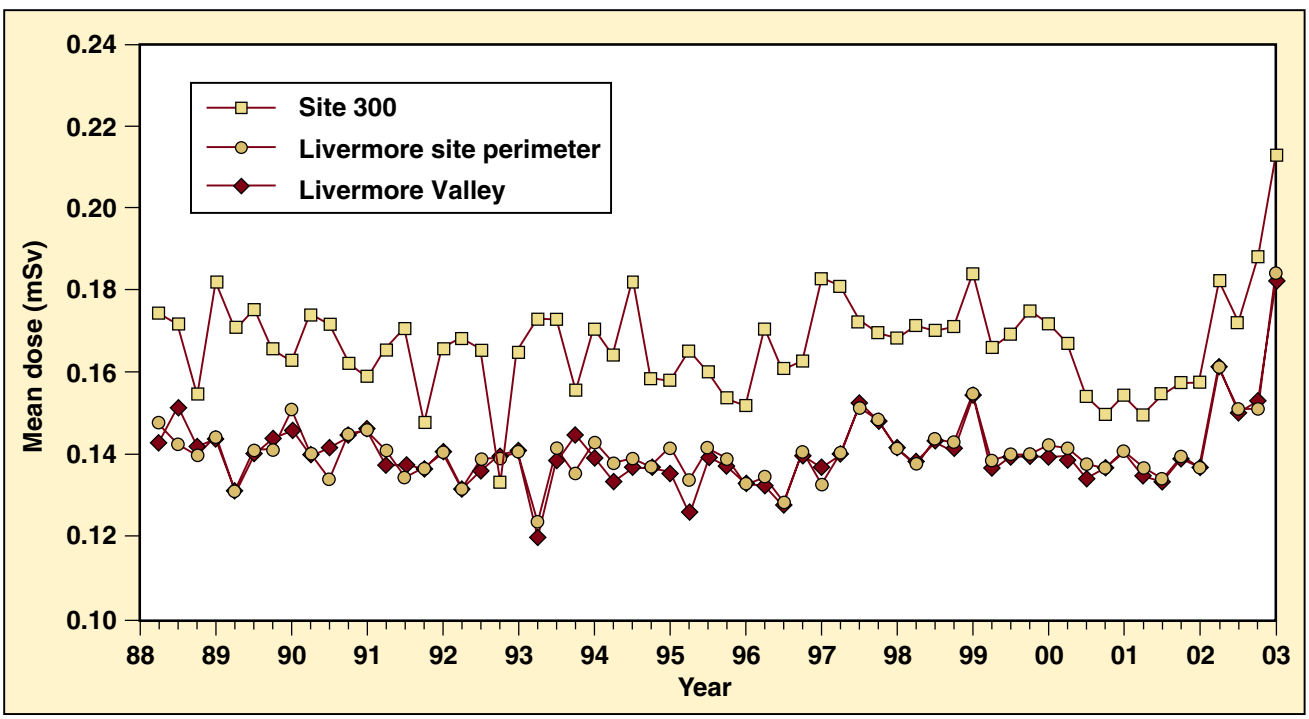

Figure 12-4. Quarterly gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988–2002

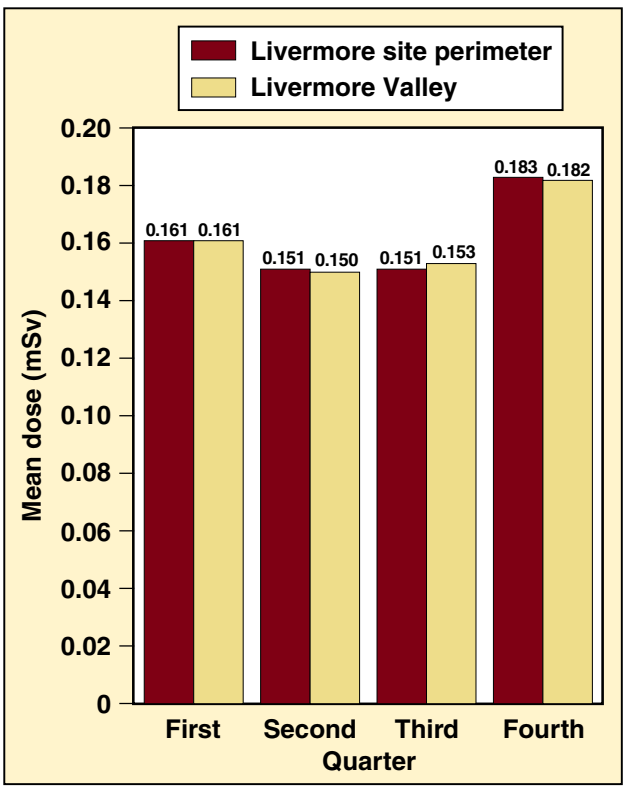

Figure 12-5. Comparison of the 2002 LLNL site perimeter and the Livermore Valley TLD quarterly mean dose (mSv)

Environmental Impact

Although the contribution of cosmic radiation may vary due to the sun cycle, the sum of the measured terrestrial and cosmic radiation dose has been observed to range from 0.55 to 0.65 mSv/y (55 to 65 mrem). In addition, variability due to the local geology and meteorology will also affect this range slightly. Direct radiation doses measured at the Livermore site perimeter in 2002 are at or near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered to be reference natural background levels for this area. Although measured gamma exposure at Site 300 and the local vicinity are slightly higher than that reported for the Livermore site and Livermore Valley, their range is attributed primarily to the variation of the geological substrate containing radionuclides of natural origin. The annual gamma radiation measured by the TLD network indicates that the exposure level is not elevated significantly above natural background for any of the monitoring sites due to LLNL operations and more importantly remains an adequate indicator of exposure risk.