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# Environmental Radiation Monitoring

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## Introduction

In accordance with federal regulations and Department of Energy (DOE) Orders 5400.1 and 5400.5, Lawrence Livermore National Laboratory monitors gamma radiation to establish radiation levels in its vicinity and to determine the direct 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 to both terrestrial and cosmic radiation sources as well as LLNL sources, if any.

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## *Cosmic Radiation Component*

Gamma radiation in air is produced by the interaction of cosmic rays, which contain high-energy particles and emanate primarily from beyond the solar system, with atmospheric nuclei. The cosmic radiation component accounts for about half the observed site annual average gamma radiation.

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## *Terrestrial Radiation Component*

Terrestrial gamma radiation is primarily caused by naturally occurring isotopes of the uranium, thorium, and actinium 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



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characterizing the natural background radiation, LLNL can determine whether or not there is a contribution to gamma exposure from Laboratory operations.

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## 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 various 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.

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.

Details of the TLD calculations and reporting of external gamma radiation dose are described in an Operations and Regulatory Affairs Division procedure.

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## Monitoring Locations

In 1999, external doses from gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 12-1**) and at 23 Livermore Valley locations (**Figure 12-2**), which are used for background comparison to perimeter location data. Similarly, gamma doses are monitored at eight perimeter monitoring locations at Site 300 (**Figure 12-3**). Additionally, five off-site locations near Site 300 and two locations in nearby Tracy are also monitored for comparison with the Site 300 data. Summary dose calculations for all gamma-monitoring locations are presented in **Table 12-1**.

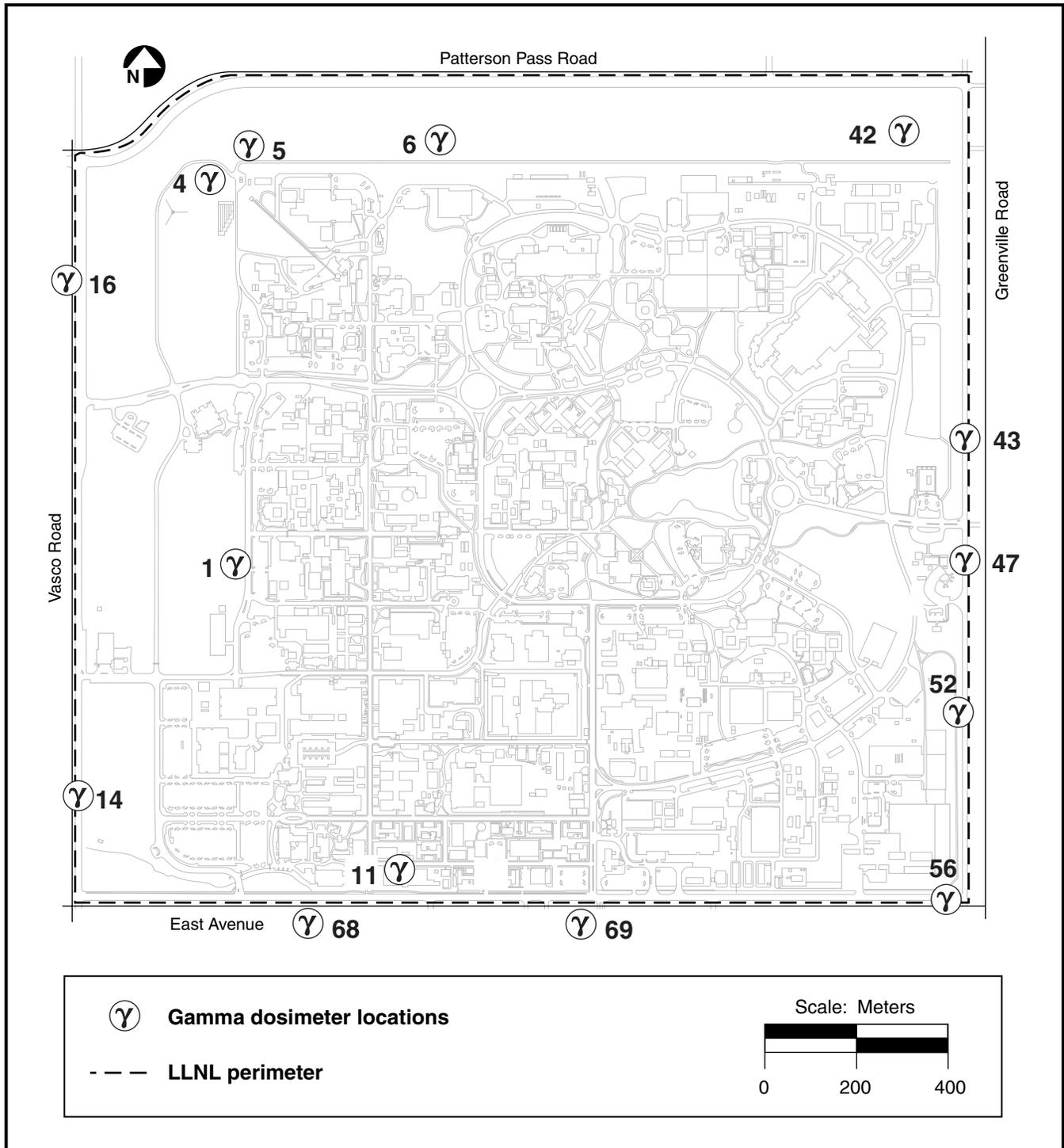
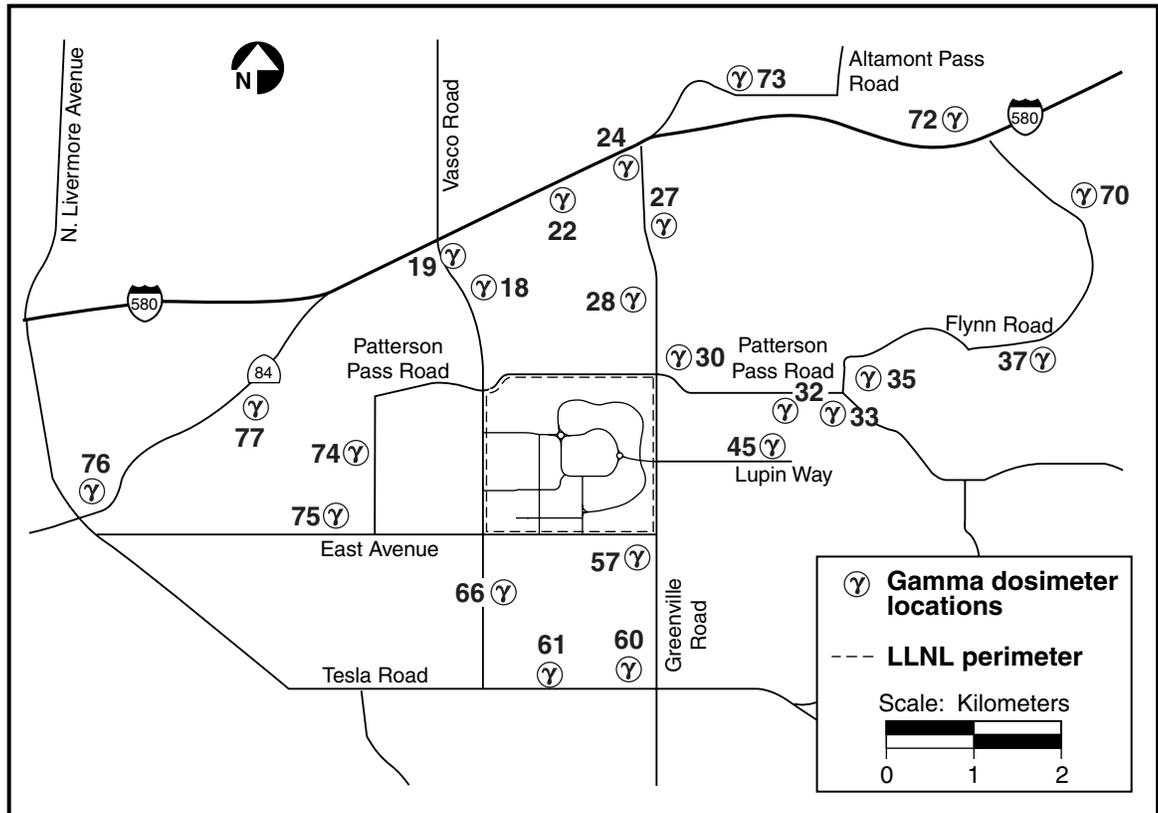


Figure 12-1. Gamma dosimeter locations, Livermore site, 1999.



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**Figure 12-2.** Gamma dosimeter locations, Livermore Valley, 1999.

### **Collocated Monitoring Locations**

The State of California Department of Health Services, Radiological Health Branch (CDHS-RHB) performs routine, independent gamma monitoring at several sites collocated with LLNL's TLD network. CDHS-RHB site locations correspond to several Livermore site perimeter, valley, Site 300, and off-site locations near Site 300. Although CDHS-RHB has been co-monitoring these locations for several years, CDHS-RHB personnel have added other sites to their network and continue to monitor at one Livermore site perimeter location that LLNL discontinued in its TLD monitoring network in 1995. This location, which lies approximately halfway between site 14 and site 16 on the Vasco Road perimeter, was formerly designated as a valley site location in 1994 although it is actually located just outside the LLNL perimeter at Vasco Road and the Mesquite Way perimeter entrance. The nine locations monitored by CDHS-RHB are LLNL-15, -19, -28, -47, -75, -78, -91, -96, and -99. CDHS-RHB added location LLNL-47 to its network in the third quarter 1999. (See Figures 12-1, 12-2, and 12-3 for these corresponding locations.)

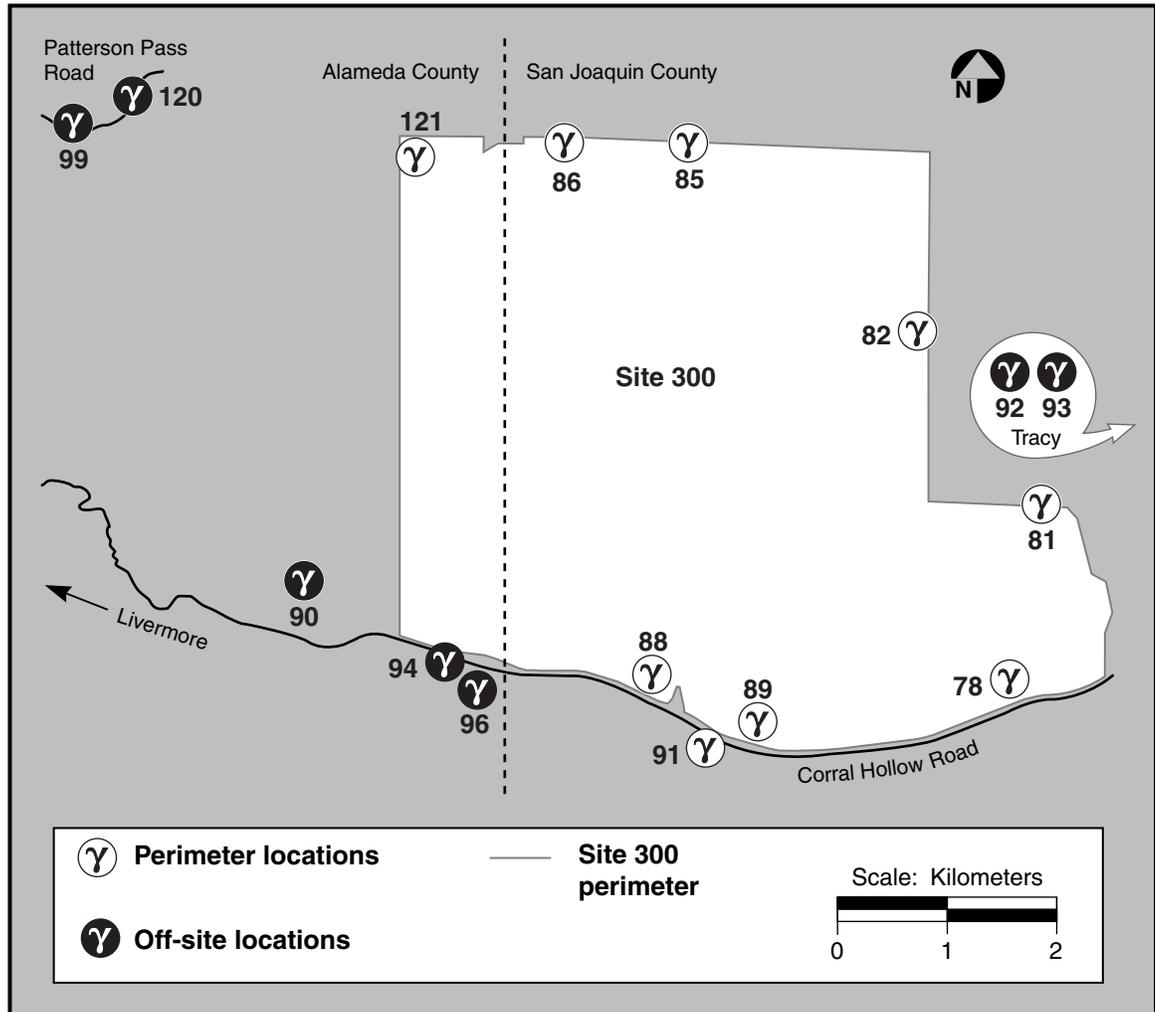


Figure 12-3. Gamma dosimeter locations, Site 300 and vicinity, 1999.

Table 12-1. Summary of dose calculations for gamma-monitoring locations (mSv)<sup>(a)</sup> at all LLNL sites, 1999.

Quarter	Location				
	Livermore site Mean 2 SE <sup>(b)</sup>	Livermore Valley Mean 2 SE	Site 300 Mean 2 SE	Tracy Mean 2 SE	Near Site 300 Mean 2 SE
First	0.142 ± 0.006	0.140 ± 0.005	0.172 ± 0.009	0.148 ± 0.01	0.187 ± 0.025
Second	0.144 ± 0.006	0.143 ± 0.006	0.175 ± 0.008	0.144 ± 0.024	0.189 ± 0.023
Third	0.144 ± 0.007	0.143 ± 0.007	0.181 ± 0.015	0.147 ± 0.013	0.201 ± 0.027
Fourth	0.146 ± 0.006	0.143 ± 0.006	0.178 ± 0.010	0.152 ± 0.017	0.189 ± 0.036
Annual dose	0.577 ± 0.025	0.571 ± 0.022	0.706 ± 0.040	0.591 ± 0.066	0.770 ± 0.109

<sup>a</sup> 1 mSv = 100 mrem.

<sup>b</sup> SE = Standard Error (standard deviation of the mean).



## Results of Gamma Monitoring

Figure 12-4 shows gamma doses for the Livermore site perimeter, Livermore Valley, and Site 300 from 1988 through 1999. Beginning in 1995, all quarterly gamma radiation data points were normalized to standard, 90-day quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). Correcting the data to standard quarters to normalize the data to the same number of days deployed reduces the variability caused by exposure duration.

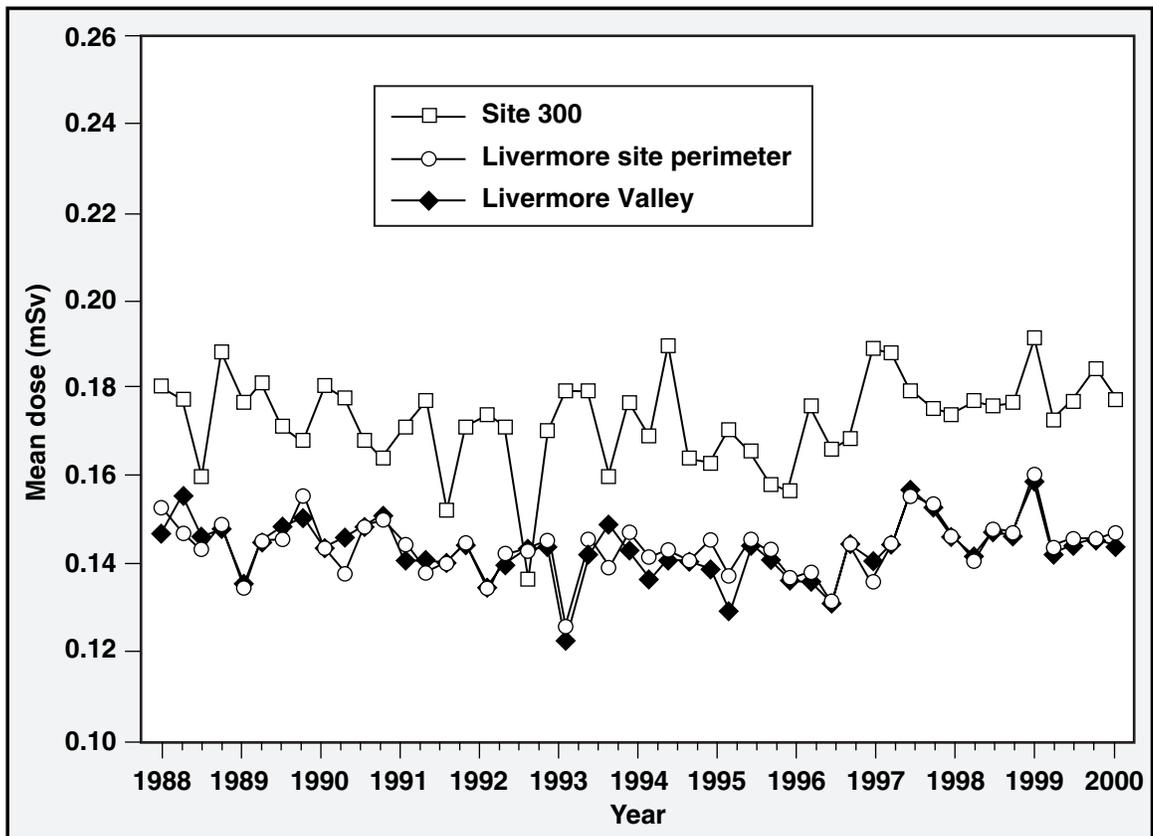


Figure 12-4. Quarterly gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988–1999.



### Livermore Site

**Table 12-1** presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore site perimeter locations and Livermore Valley off-site locations. The mean 1999 dose equivalent from external, direct-radiation exposure at the Livermore site perimeter, 0.577 mSv, is statistically the same as the background external dose measured in the Livermore Valley, 0.571 mSv. **Table 12-2** lists the yearly doses due to direct gamma radiation at the Livermore site perimeter. All doses fall within the predicted range for background radiation, and no LLNL operational impacts are discernible.

**Table 12-2.** Annual dose by year at the Livermore site perimeter caused by direct gamma radiation.<sup>(a)</sup>

Year	mSv	mrem
1988	0.59	59
1989	0.58	58
1990	0.58	58
1991	0.56	56
1992	0.56	56
1993	0.57	57
1994	0.56	56
1995	0.56	56
1996	0.55	55
1997	0.59	59
1998	0.60	60
1999	0.58	58

<sup>a</sup> Data normalized to standard 90 days per quarter (360 days per year).

### Site 300

As seen in **Table 12-1**, the measured Site 300-perimeter annual average dose in 1999 was 0.706 mSv, the measured dose at the off-site locations near Site 300 was 0.770 mSv, and the measured doses in and near Tracy were 0.591 mSv. All doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.



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At Site 300, the initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the City of Tracy, which were chosen to represent background radiation levels. However, the region around Site 300 has higher levels of naturally occurring uranium present in the local geological area called the Neroly Formation. The mean dose measured in the off-site locations of the area around Site 300, which is used to represent the high end of background radiation from this formation, was 0.772 mSv and is greater than the Site-300 perimeter dose of 0.710 mSv. The Tracy area, with a dose of 0.626 mSv, is underlain by a geological substrate composed of alluvial deposits of clays, sands, and silts overlying bedrock. The difference in doses can be directly attributed to the difference in geologic substrates.

The doses at the Livermore-site perimeter and in the Livermore Valley are comparable from 1988 to 1999. However, while Site 300 doses are similarly comparable, TLDs there continue to record slightly higher direct gamma doses than do the Livermore site and the Livermore Valley, which is expected, given the differences in geology among these sites.

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## **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 0.6 to 0.7 mSv/y. In addition, variability caused by the local geology and meteorology will also affect this range slightly. Direct radiation doses measured at the Livermore site perimeter in 1999 are near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. Although measured gamma exposure at Site 300 and the local vicinity are slightly higher than 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 above natural background for any of the monitoring sites because of LLNL operations.