1. Introduction

Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). The DOE selected Lawrence Livermore National Security (LLNS) to manage and operate LLNL. The contract began October 1, 2007. The new management team includes Bechtel National, University of California, BWX Technologies (BWXT), Washington Group International, Battelle, and Texas A&M University.

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security, and conducts major research in atmospheric, earth, and energy sciences; bioscience and biotechnology; and engineering, basic science, and advanced technology. The Laboratory, with a staff of more than 8000, serves as a scientific resource to the U.S. government and a partner to industry and academia.

1.1 Location

LLNL consists of two sites—an urban site in Livermore, California, referred to as the "Livermore site"; and a rural experimental test site, referred to as "Site 300," near Tracy, California. See **Figure 1-1**.

Figure 1-1. Location of the two LLNL sites—the Livermore site and Site 300.

The Livermore site is just east of Livermore, a city of about 80,000 in Alameda County. The site occupies 1.3 mi^2, including the land that serves as a buffer zone around most of the site.

Within an 50-mi radius of the Livermore site are communities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 7.1 million people within 50 mi of the Laboratory, only about 10% are within 20 mi.

Site 300, LLNL's Experimental Test Site, is located in the Altamont Hills of the Diablo Range and straddles the San Joaquin and Alameda county line. The site is 12 mi east of the Livermore site and occupies 10.9 mi^2.

The city of Tracy, with a population of over 80,000, is approximately 6 mi to the northeast (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 6.2 million people who live within 50 mi of Site 300, 95% are more than 20 mi away in distant metropolitan areas such as Oakland, San Jose, and Stockton.

1.2 Meteorology

Meteorological towers at both the Livermore site and Site 300 continuously gather data including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature. Mild, rainy winters and warm-to-hot, dry summers characterize the climate at both sites. For a detailed review of the climatology for LLNL, see Gouveia and Chapman (1989). A new 52-m meteorological tower was installed at Site 300 in 2007; this new tower and the old 8-m tower in use since 1979 provided simultaneous measurements during 2007 for continuity and to observe any differences between the two tower locations. The old tower was retired in early 2008.

Both wind and rainfall exhibit strong seasonal patterns. Wind patterns at both sites tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. Approximately 55% of the seasonal rain at both sites falls in January, February, and March and approximately 80% falls in the five months from November through March, with very little rain falling during the warmer months. For a detailed review of rainfall at LLNL, see Bowen (2007). The meteorological conditions at Site 300 are modified by higher elevation and more pronounced topological relief. The complex topography of the site strongly influences local wind and temperature patterns.

The wind patterns, or wind roses, for the two towers at Site 300 are similar but they do show subtle differences. The data from the old tower indicates a distinct maximum from the west–southwest while the data from the new tower has the peak spread over the southwest and west–southwest sectors. Similarly the old tower data indicates a secondary peak of winds blowing from the northwest and north–northwest while the secondary peak at the new tower includes a slightly greater frequency of winds from adjacent sectors (west–northwest and north). Possible explanations for these subtle differences are that the new tower is located on grassy terrain and just downwind of higher terrain while the old tower is located on a small hill and therefore experiences less frictional effect from the ground. The new tower is also located at a slightly higher elevation and possibly receives more mixing from higher winds.

Temperature, rainfall, and wind speed data for the Livermore site and Site 300 towers during 2007 are summarized in **Table 1-1**. Annual wind data for the Livermore site and Site 300 are shown in **Figure 1-2**.

Table 1-1. Summary of temperature, rainfall, and wind speed data at the Livermore site and Site 300 during 2007.

	Livermore Site		Site 300 (old tower)		Site 300 (new tower)	
Temperature	**°C**	**°F**	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	22.6	72.6	21.4	70.5	22.0	71.6
Mean daily minimum	7.0	44.6	12.2	54.0	11.6	52.9
Average	14.8	58.6	16.8	62.2	16.8	62.2
High	42.0	108	39.4	103	39.9	104
Low	–6.7[a]	20[a]	–2.8	27	–3.1	26
Rainfall	**cm**	**in.**	**cm**	**in.**	**cm**	**in.**
Total for 2007	21.7	8.53	18.8	7.40	17.9	7.04
Normal[b]	34.6	13.62	27.0	10.64	—[c]	—[c]
Wind	**m/s**	**mph**	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.5	5.6	6.4	14.4	6.3	14.1
Peak gust speed	18.3	41	28.3	63	31.5	71

(a) Record low.

(b) Based on the mean, 1971–2000, at both sites.

(c) Normal values not available because of brief measurement history at new tower.

1.3 Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 14 mi long and varies in width generally between 2.5 and 7 mi. The valley floor is at its highest elevation of 720 ft above sea level along the eastern margin near the Altamont Hills and dips gradually to 300 ft at the southwestern corner. The valley floor is covered primarily by alluvial and floodplain deposits consisting of gravels, sands, silts, and clays with an average thickness of about 325 ft. Ephemeral waterways flowing through the Livermore site include Arroyo Seco along the southwestern corner and Arroyo Las Positas along the eastern and northern perimeters. See Karachewski et al. (2008) for a detailed discussion of the Livermore site hydrogeology.

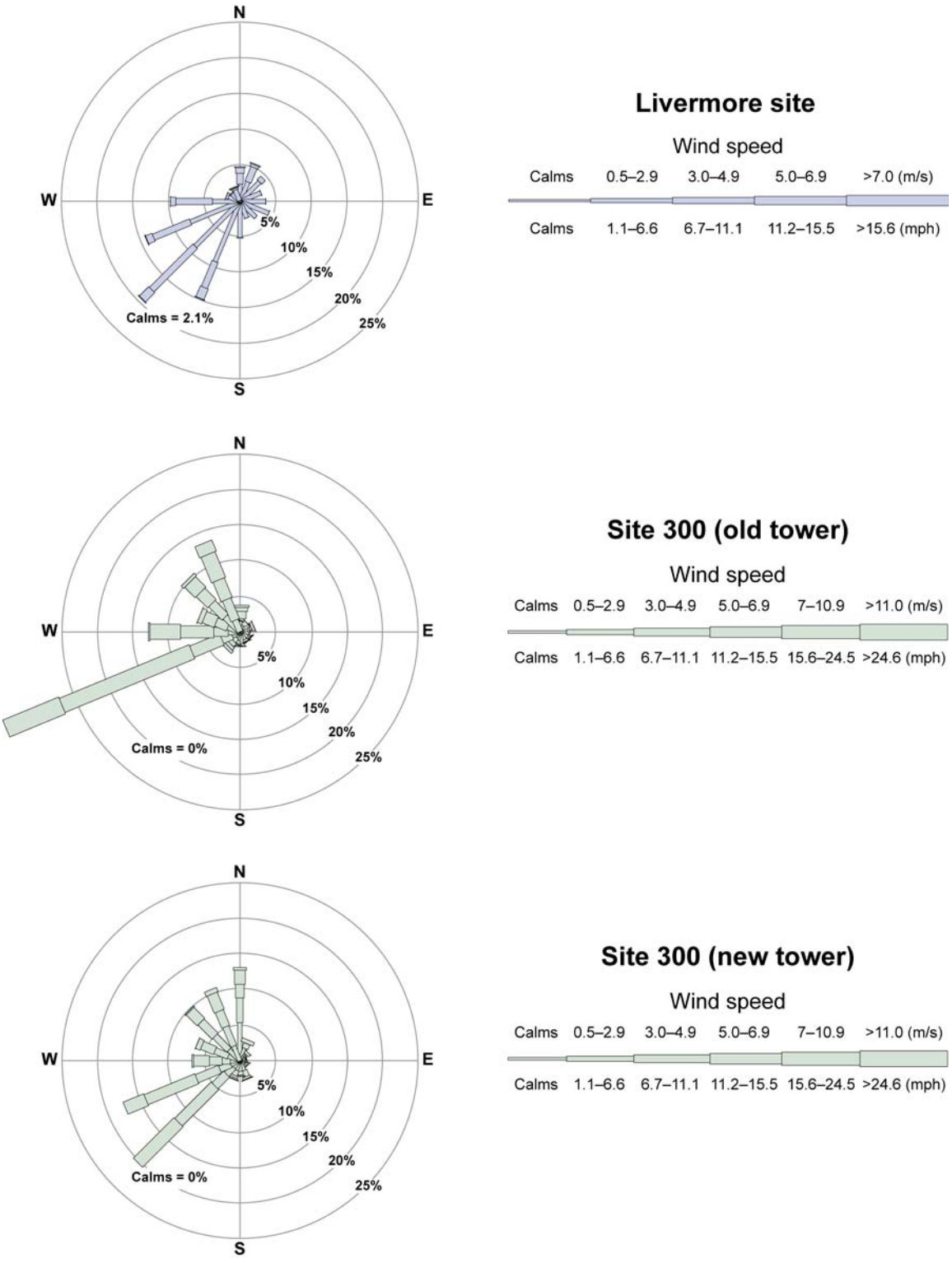

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2007. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest–southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation of Site 300 ranges from about 1740 ft above sea level at the northwestern corner of the site to approximately 490 ft in the southeastern portion. Corral Hollow Creek, an ephemeral stream that drains toward the San Joaquin Basin, runs along the southern and eastern boundaries of Site 300.

1.4 Hydrogeology

The Livermore Formation and overlying alluvial deposits contain the primary aquifers of the Livermore Valley groundwater basin. Natural recharge occurs primarily along the basin margins and arroyos during wet winters. In general, groundwater flows toward the central east–west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists along the basin margins under localized sources of recharge and near heavily used extraction or water production wells. Beneath the Livermore site, the depth to the water table varies from about 30 to 130 ft below the ground surface.

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Groundwater occurs primarily in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill and underlying decomposed bedrock, especially during wet winters. Much less groundwater is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined groundwater separated from an underlying main body of groundwater by impermeable layers; normally these perched zones are laterally discontinuous. Because water quality is generally 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. Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out along the canyon bottom because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the deeper bedrock aquifers.

The thick Neroly Formation lower blue sandstone, stratigraphically near the base of the formation, generally contains confined groundwater. Wells located in the western part of the Site 300 General Services Area pump water from this aquifer, which is used for drinking and process supply.

Contributing Authors

Lindee Berg, Brent Bowen, Donald MacQueen, Sandra Mathews, Michael Taffet