Site Overview

Introduction

Lawrence Livermore National Laboratory is a premier applied-science national security laboaratory. LLNL's primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable, and to prevent the spread and use of nuclear weapons worldwide. This mission enables LLNL programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply LLNL's unique capabilities and to enhance the competencies needed for our national security mission. LLNL serves as a resource to the U.S. government and a partner with industry and academia.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, health and safety, and medical departments—necessary to support its operations and about 9000 personnel.

Meteorology and geography play primary roles in how the environment is affected by human actions. Dispersal of particles in air, for example, is influenced by the wind and rain, which in turn are influenced by geographical characteristics. Similarly, the movement of groundwater is constrained by the particular geology of a site.

Thus, knowledge of wind, rainfall, geology, and geographical characteristics is used to understand the effects that operations at LLNL might have on the surrounding environment. Some history and a description of these characteristics help us understand the importance of LLNL's meteorological and geographic setting.

Location

LLNL consists of two sites—the Livermore site located in Livermore, California in Alameda County, and the Experimental Test Site (Site 300) located near Tracy, California, in San Joaquin and Alameda counties (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

LLNL was founded at the Livermore site in 1952 at a former U.S. Navy training base. At that time the location was relatively isolated, being approximately 1.6 km (1 mi) from the Livermore city limits. Over time, Livermore evolved from a small town of fewer than 7000 people when LLNL began to its present population, which is about 76,700 (State of California 2002). The economy, which had been primarily agricultural, diversified to include light industry and business parks. Within the last few years, single-family residential developments have begun to fill the formerly vacant fields immediately to the west of the Lab. Livermore residences are now near LLNL's western boundary.

The Livermore site occupies an area of 3.28 km^2 (1.3 mi^2), including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories/California (Sandia/California), operated by Lockheed-Martin under U.S. Department of Energy (DOE) contract. Sandia/California engages in research and development associated with nuclear weapons systems engineering as well as related national security tasks. Although components of their missions are similar, LLNL and Sandia/California are separate entities, each with its own management.

To the south of LLNL, there are also some low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards. A business park lies to the southwest. Farther south, property is primarily open space and ranchettes with some agricultural use. Single-family dwellings and apartments lie immediately to the west. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills that define the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare (500-acre) parcel of open space to the northeast has been rezoned to allow development of light industry.

Major population centers near Livermore include the nearby communities of Pleasanton and Tracy, and the more distant metropolitan areas of Oakland, San Jose, and San Francisco, as well as Stockton in the San Joaquin Valley. There are 6.9 million residents within an 80-km (50-mi) radius of the Livermore site.

Site 300, LLNL's Experimental Test Site, is located 20 km (12 mi) east of the Livermore site in San Joaquin and Alameda counties in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 km^2 (11.8 mi^2). SRI International operates a testing site located approximately 1 km (0.62 mi) south of Site 300. Property immediately to the east of Site 300 is owned by Fireworks America, which uses it for packaging and storing fireworks displays. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills to the northwest. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is

Figure 1-1. Locations of LLNL Livermore site and Site 300

the town of Tracy, population 65,600 (State of California 2002), located 10 km (6 mi) to the northeast. Within 80 km (50 mi) of Site 300, there are 6 million residents, many of whom are located in the metropolitan areas of Oakland, San Jose, and Stockton.

Meteorology

Meteorological data (including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate. A detailed review of the climatology for LLNL can be found in *Climatology of Lawrence Livermore National Laboratory* (Gouveia and Chapman 1989). The mean daily maximum, minimum, and average temperatures for the Livermore site in 2002 were 20.4˚C (68.7˚F), 9.0˚C (48.7˚F), and 14.7˚C (58.4˚F), respectively. The mean daily maximum, minimum, and average temperatures for Site 300 in 2002 were 20.2˚C (68.3˚F), 13.1˚C (55.5˚F), and 16.2˚C (61.9˚F), respectively. The nighttime temperatures are typically higher (and diurnal temperature ranger smaller) at Site 300 compared to the Livermore site; stronger winds at a higher elevation prevent formation of strong radiational inversions near the ground. Temperatures range from –4˚C (25˚F) during the coldest winter mornings to 40˚C (104˚F) during the warmest summer afternoons. The coldest weather during 2002 occurred during the last week of January when the temperature dipped to –2˚C (27 to 28˚F) on three mornings at LLNL and –1˚C (30˚F) at Site 300 on one morning. The warmest day was July 10 when the temperature reached 40.1˚C (104.2˚F) at the Livermore site and 39.0˚C (102.2˚F) at Site 300.

Both rainfall and wind exhibit strong seasonal patterns. These wind patterns 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. Most precipitation occurs between October and April, with very little rainfall during the warmer months.

Annual wind data for the Livermore site are given in **Figure 1-2**. These data show that about 50% of the wind comes from the southwest to westerly direction. This prevailing pattern occurs primarily during the summer. During the winter, the wind blows more often from the northeast. However, the peak wind gust of 23.2 m/s (52 mph) from the SSW occurred early on December 16, as a strong cold front swept the area.

Based on a 45-year record, the highest and lowest annual rainfalls were 541 and 211 mm (21.31 and 8.31 in.), and the normal annual rainfall is 350 mm (13.78 in.). In 2002, the Livermore site received 271 mm (10.66 in.) of rain, or 77% of normal. Most of the rain fell during the last two months of the year, including 102 mm (4.00 in.) in the 8 days ending on December 20. The December total rainfall of 132 mm (5.21 in.) was the greatest ever recorded for the month of December at the Livermore site since records have been kept (1958). The maximum daily rainfall of 36.8 mm (1.45 in.) fell on December 16.

The meteorological conditions at Site 300, while generally similar to those at the Livermore site, are modified by higher elevation and more pronounced topological relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-2**. The data show that winds are stronger and show less directional distribution than at the Livermore site. Winds from the west-southwest through west and northwest through north occurred 40% and 30% of the time during 2002. The cold front passage early on December 16 caused even stronger winds at Site 300, briefly reaching hurricane force. The peak gust reached 33 m/s (83 mph) from the south, the highest ever recorded at Site 300 since measurements have been taken (1990). As is the case for the Livermore site, precipitation at Site 300 is seasonal, with most rainfall occurring between October and April. Since Site 300 is situated downwind (north) of more significant terrain (winds are typically southerly during storms) than at LLNL, rainfall amounts are typically 15% or so lower than

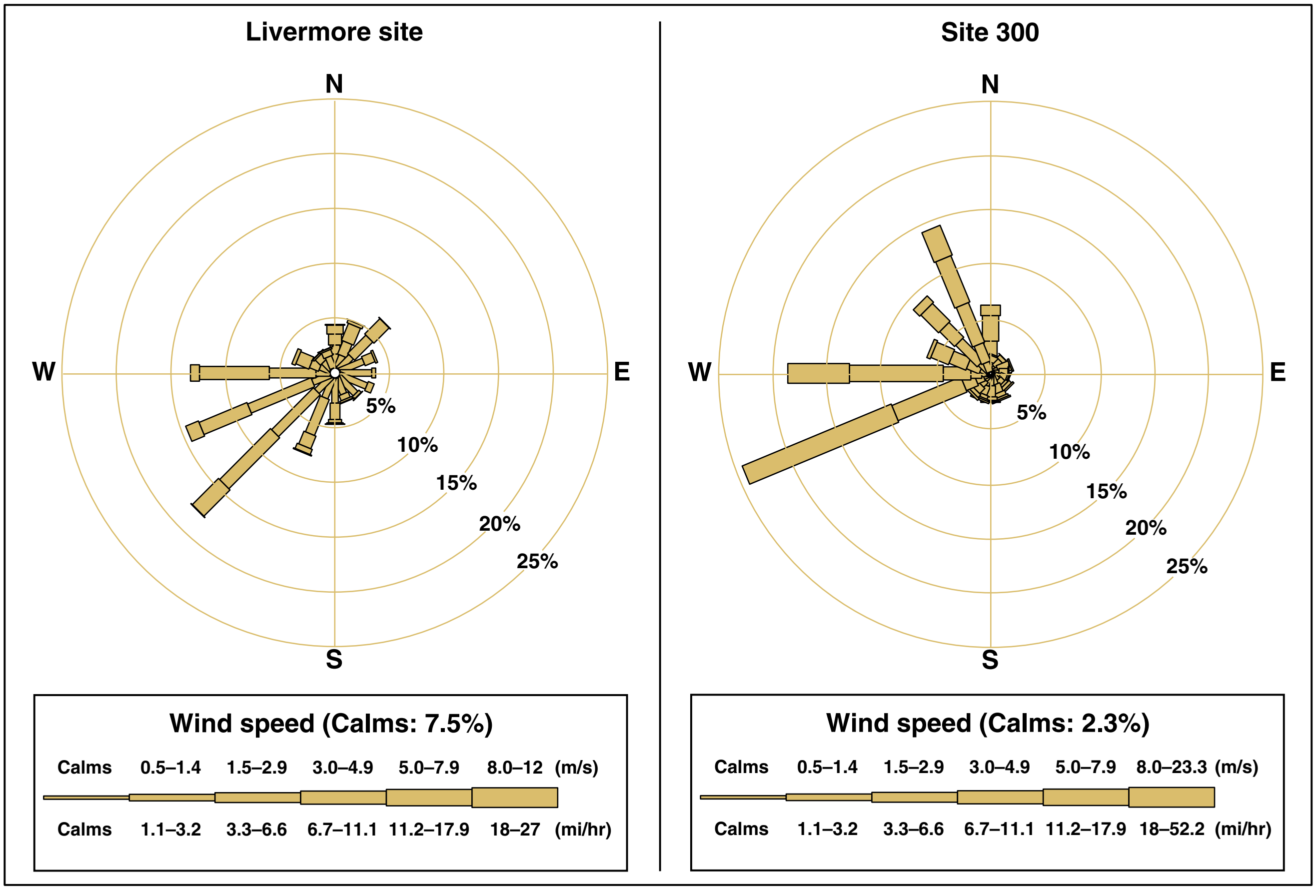

Figure 1-2. Wind rose showing wind direction and speed frequency at the Livermore site, 2002. The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes. The average wind speed in 2002 at the Livermore site was 2.4 m/s (5.3 mph); at Site 300 it was 5.5 m/s (12.4 mph).

at the Livermore site. Similar to the Livermore site, Site 300 received most of its rainfall during November and December, including 88.1 mm (3.47 in.) during the 8 days ending on December 20. The maximum daily rainfall of 27.4 mm (1.08 in.) occurred on November 8. Rainfall for 2002 was about 25% below normal, or 220 mm (8.65 in.) at Site 300.

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, the most prominent valley in the Diablo Range, is an east-west trending structural and topographic trough that is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits, consisting of gravels, sands, silts, and clays, at an average thickness of about 100 m (325 ft). The valley is approximately 25-km (16-mi) long and averages 11-km (6.8-mi) in width. The valley floor is at its highest elevation of 220 m (720 ft) above sea level along the eastern margin and gradually dips to 92 m (300 ft) at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow intermittently. Surface waterways in the vicinity of the Livermore site are the Arroyo Seco (along the southwest corner of the site), the Arroyo Las Positas (along the northern perimeter of the site), and the Arroyo Mocho (southwest of the site). These arroyos are shown in **Figure 7-1**.

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 ranges from approximately 538 m (1765 ft) above sea level at the northwestern corner of the site to approximately 150 m (490 ft) in the southeast portion.

Hydrogeology

Livermore Site

The hydrogeology and movement of groundwater in the vicinity of the Livermore site have been the subjects of several investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; Blake et al. 1995; Thorpe et al. 1990). This section is a summary of the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for groundwater management in the Livermore Valley basin (SFBRWQCB 1982a,b).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley groundwater basin, an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain groundwater levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. 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 primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the water table varies in depth from the surface from about 10 to 40 m (30 to 130 ft). **Figure 1-3** shows a contour map of water table elevations for the Livermore site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-3** are generally maintained. At the eastern edge of the Livermore site, groundwater gradients (change in vertical elevation per unit of horizontal distance) are relatively 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 most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of groundwater recovery and remediation in the

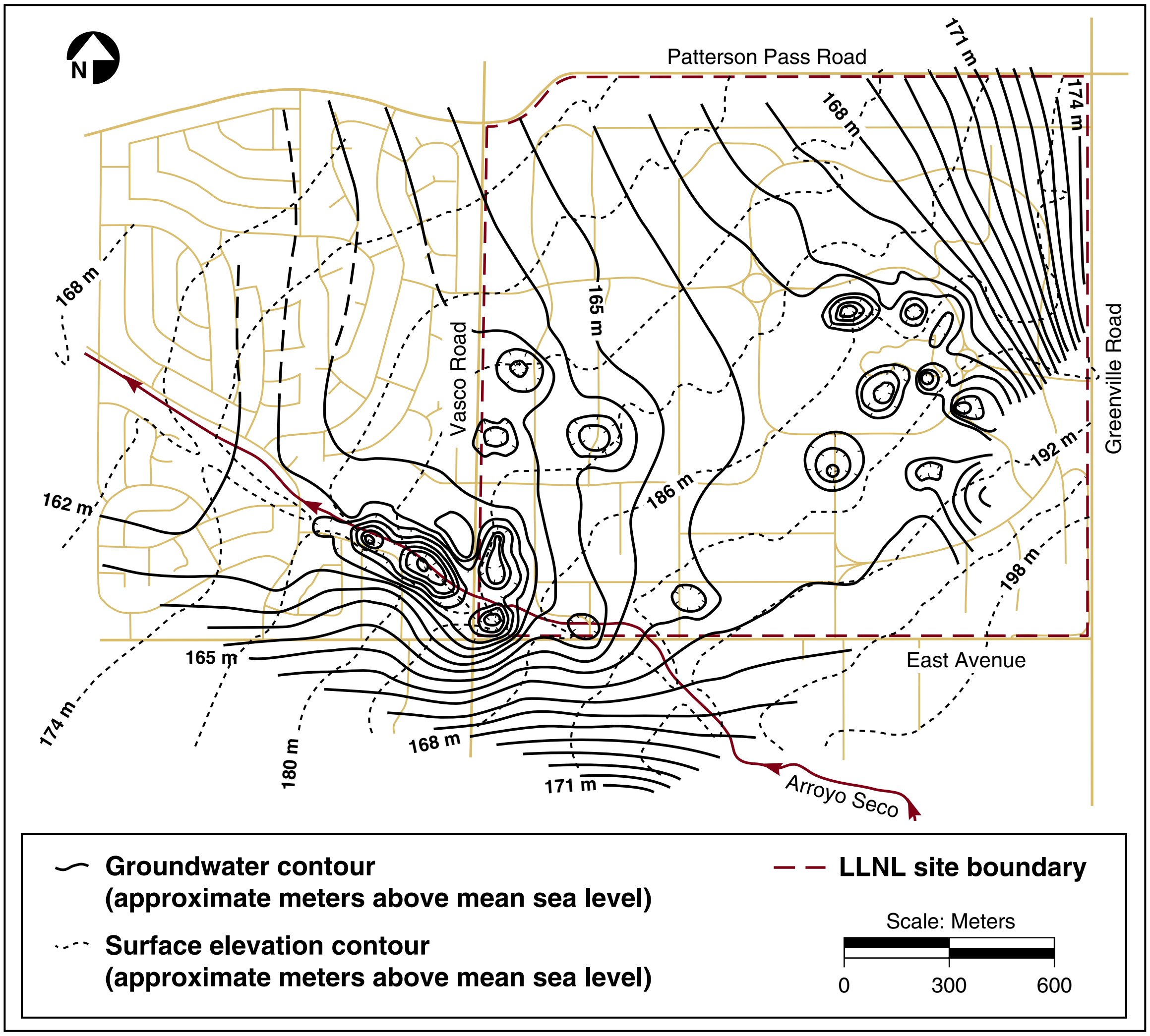

Figure 1-3. 2002 approximate groundwater and surface elevation contours, Livermore site and vicinity

southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity (a measure of the rate of flow) of the permeable sediments ranges from 1 to 16 m/day (3.3 to 52 ft/day) (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an estimated average groundwater velocity of 20 m/y (66 ft/y) (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable alluvial sediments that underlie the area.

Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most groundwater occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant groundwater is also locally present in permeable Quaternary alluvium valley fill. Much less groundwater is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable layers; normally they are discontinuous and highly localized. Because water quality generally 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.

Fine-grained siltstone and claystone interbeds may confine the groundwater and act as aquitards, confining layers, or perching horizons. Groundwater is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Groundwater flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, groundwater in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, groundwater in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly lower blue sandstone, stratigraphically near the base of the formation, generally contains confined water. Wells located in the western part of the General Services Area pump water from this aquifer and are used to supply drinking and process water.

Figure 1-4 shows the elevation contours for groundwater in the regional aquifer at Site 300. This map of the groundwater elevations is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out 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 bedrock aquifers.

Further information on the hydrology of both the Livermore site and Site 300 can be found in the groundwater monitoring and remediation information in Chapter 8.

Summary

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationships with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year we gain additional information that allows us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, soil, water, vegetation, and foodstuff—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each method used to monitor the environment.

Contributing Authors Acknowledgement

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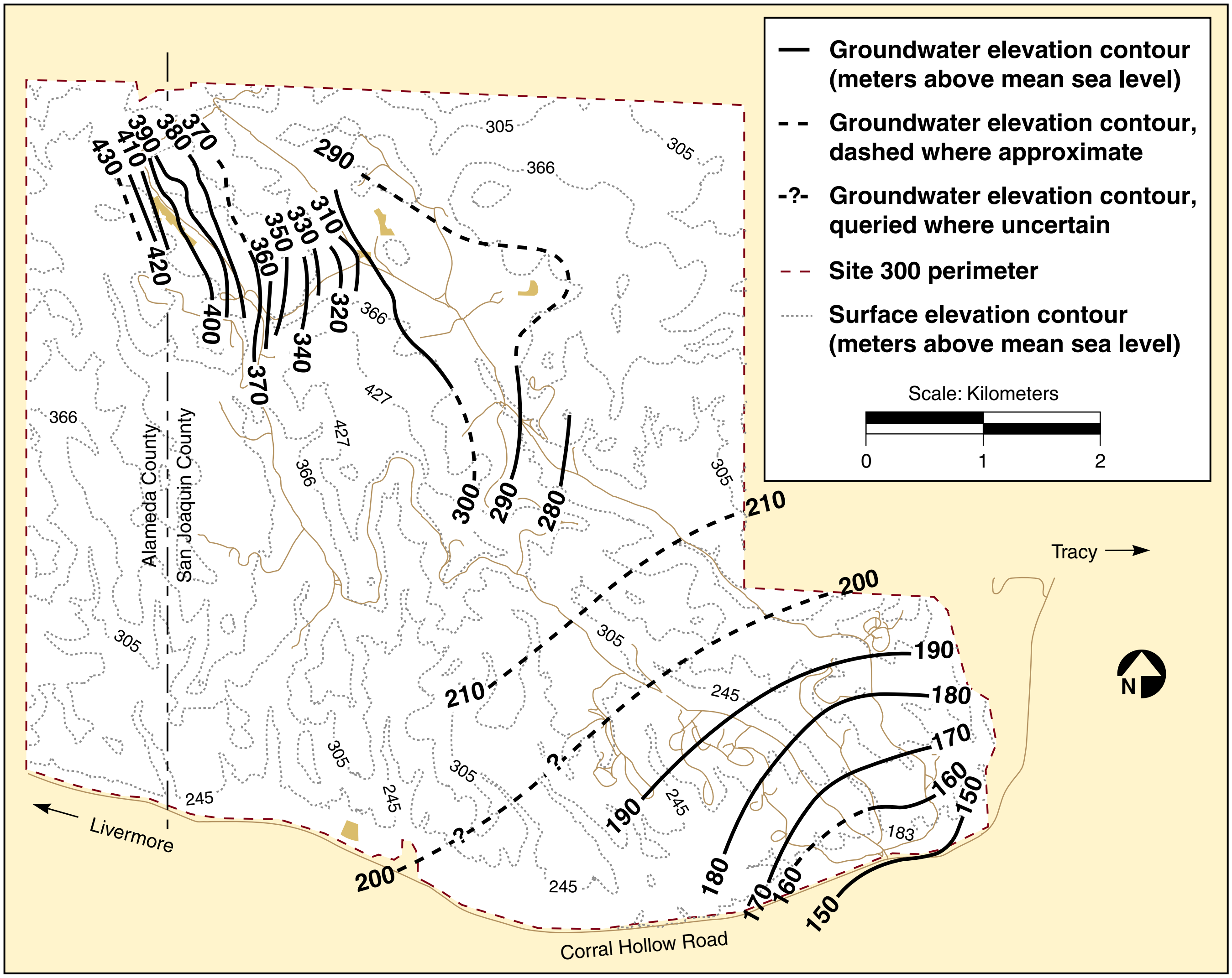

Figure 1-4. Approximate 2002 groundwater elevations for the principal continuous water-bearing zone at Site 300