Chapter 13—Geology and Mineral Resources

13.1 Introduction

This chapter describes existing geological and soil conditions, potential associated geologic and geotechnical hazards, and potential impacts and proposed mitigation measures for the project.

The project is located in a seismically active area and is underlain by young geologic deposits. Geologic hazards with the greatest potential impact to the project are landslides, earth flows, debris flows, surface fault rupture, strong ground shaking, liquefaction, liquefaction-induced lateral spreading, and differential compaction. Geotechnical hazards include the presence of expansive soils, soft and loose soils, differential settlement, erosion, and the potential for ground subsidence caused by groundwater withdrawal. In addition to general geologic and geotechnical hazards, underground portions of the proposed project may potentially be impacted by high groundwater levels, erosion, unstable soil conditions, and settlement during excavation, grading, and backfilling operations.

Proper siting of the proposed project components, design-level geotechnical investigations, and appropriate engineering and construction measures will avoid, eliminate, or reduce potential impacts of geologic hazards to a less than significant level.

13.1.1 Methodology

Existing conditions were determined from review of available published and unpublished literature, examination of boring logs of subsurface deposits contained in area geotechnical reports, and examination of recent (1998, 1999) aerial photographs. Descriptions of geologic units in the project area derive from published sources, including:

- 1:24,000-scale geologic mapping of the Diablo, Tassajara, Byron Hot Springs, Dublin, Livermore, Altamont, Midway, and La Costa Valley 7.5-minute quadrangles (Dibblee, 1980)
- 1:75,000-scale geologic mapping of bedrock formations in Alameda County (Graymer, et al., 1996)
- 1:100,000-scale geologic mapping of Quaternary deposits in Alameda County (Helley and Graymer, 1997)

Soils descriptions were obtained from mapping by the United States Department of Agriculture, Soil Conservation Service, published as soil surveys of Alameda and Contra Costa Counties (Welch, 1966 and 1977, respectively). Evaluation of landslide, earth flow, and debris flow hazards in the project area were based on geologic mapping (Dibblee, 1980) and on published reports by the California Division of Mines and Geology (CDMG, 1991) and the United States Geological Survey (USGS) (Ellen, 1997 and Wentworth, 1997).

Information on mineral resources in the project area was obtained from USGS and CDMG sources (Baily and Harden, 1975 and Stinson, et al., 1986), as well as the Alameda County Planning Department.

Assessment of the potential for fault rupture, seismic ground shaking from local and regional sources, and liquefaction-related ground deformation included a review of mapped fault locations from both CDMG and USGS sources (Herd, 1977; Dibblee, 1980; Hart, 1981c; and Jennings, 1994). The locations of Alquist-Priolo Earthquake Fault Zones were obtained from maps and a fault zone index published by the CDMG (CDMG, 1982 and 1992). Fault descriptions and parameters were reviewed from a variety of published sources, including CDMG Fault Evaluation Reports (Hart, 1981a and 1981b; Smith, 1981), available geologic reports (Carpenter, 1980; Sweeney, 1981), and numerous published papers (Wesnousky, 1986; Oppenheimer and Lindh, 1992; Wakabayashi and Smith, 1994; Kelson, et al., 1996). Liquefaction hazards were identified according to the historical occurrence of liquefaction (Youd and Hoose, 1978; Holtzer, 1990), available liquefaction hazard maps produced by the Association of Bay Area Governments (ABAG, 1980), and the locations of potentially liquefiable soil types from geologic and soil maps.

Geotechnical hazards included ground subsidence and differential ground deformation related to the presence of expansive, soft, and loose soils and groundwater withdrawal. Assessment of potential hazards from expansive and potentially corrosive soils is based on interpretation of the published soil surveys.

Limited information is available about local groundwater and subsurface soil profiles along the proposed transmission line routes and at the substation sites. Site-specific, design-level geotechnical investigations will be performed as necessary to evaluate subsurface conditions that may affect construction, operation, and maintenance of proposed project facilities.

13.2 Existing Conditions

13.2.1 Tri-Valley Area

13.2.1.1 Topography

The project area is located within the east-central part of the California Coast Range Province. The coast ranges, extending approximately 600 miles from the Oregon border to the Santa Ynez River, near Santa Barbara, are characterized by elongate ranges and narrow valleys that are approximately parallel to the coast. Structural features, including faults and synclinal folds, largely control topography within the province and reflect both previous and existing regional tectonic regimes (Sweeney, 1981; Norris, 1990).

The project is located in an area referred to locally as the “Tri-Valley area” and in the surrounding hills. The Tri-Valley area is a topographic depression within the Diablo Range, a northwest-trending line of hills and mountains defining the western edge of the San Joaquin Valley in central California. The Tri-Valley basin is comprised of three valleys: Amador Valley, Livermore Valley, and San Ramon Valley. The Livermore and Amador Valleys, which are adjacent in an east-west orientation, comprise the major part of the basin. San Ramon is a smaller northwest-trending valley that extends from the northwest edge of Amador Valley. Elevations within the Tri-Valley basin range from approximately 300 feet above sea level at the drainage exit of Amador Valley southwest of Pleasanton, to approximately 700 feet above sea level along Livermore Valley's eastern margin.

The Diablo range consists of fairly rugged mountains that range between approximately 100 feet near San Francisco Bay and 4,000 feet along Valpe Ridge. North and east of Livermore, the Diablo Range rises to elevations between approximately 1,000 and 2,000 feet above sea level. In these areas, the hills are moderately steep and have well rounded ridges. To the west, the Tri-Valley basin is separated from San Francisco Bay by the East Bay Hills, a line of hills with elevations generally between 1,000 and 2,000 feet. To the south, the valley is bounded by a series of northwest-trending ridges that reach from approximately 1,000 feet near the valley to over 3,000 feet 10 miles south of Livermore. These uplands have steep to very steep slopes with narrow ridges containing numerous bedrock outcrops. To the northwest lie the Diablo foothills, rising to Mount Diablo with an elevation of 3,849 feet above sea level.

Several northwest/southeast-trending drainages are intercepted by the Livermore and Amador Valleys. Arroyo Las Positas and Arroyo Mocho carry surface drainage from the northeastern and southeastern extensions of the valley while Arroyo Valle drains the southern portion. These streams carry runoff to the west where the Amador Valley meets the San Ramon Valley along the eastern edge of the East Bay Hills. Drainage from the Livermore, Amador, and San Ramon Valleys is carried southward by Arroyo de la Laguna to Alameda Creek, which drains westward to San Francisco Bay through Niles Canyon, a narrow gorge through the East Bay Hills.

13.2.1.2 Geology

Geologic Structure

Located along the complex boundary margin between the North American and Pacific Plates, geologic conditions within the project area have been and continue to be primarily controlled by interaction of these two massive crustal plates. Under the current tectonic regime, the Pacific Plate moves northwestward relative to the North American Plate at a rate of about 5 centimeters per year. Much of this relative movement at the latitude of the San Francisco Bay Area is accommodated primarily by strike-slip motion along a number of major faults, including the San Gregorio, San Andreas, Hayward, Calaveras, and Greenville (Page, 1992). In addition to these, countless other faults within the region accommodate relative motion between major faults and relieve compressional stresses that also act along the plate boundary.

The majority of the project area lies within the Livermore Basin, a deep sedimentary trough known as a "pull-apart" basin, which formed due to localized extensional stresses resulting from discontinuous translational displacement along the plate boundary. The basin is filled primarily with late Miocene and Pliocene sediments that have since been folded and faulted as a result of more recent compressional stresses (Darrow, 1979). The Calaveras and Greenville faults bound the Livermore Basin to the west and east, respectively. To the north-northeast, Mount Diablo, an intruded and uplifted block of Cretaceous sediments, rises above the basin.

Southern portions of the South Area of the proposed project and eastern portions of the North Area lie within the Diablo Range. The Diablo Range is described as a series of large anticlinal folds with Franciscan cores arranged in echelon and separated by synclinal folds containing younger rocks (Norris, 1990). The range is bounded on the east by the Coast Range Thrust Zone, also known as the Great Valley Fault System.

Surficial Deposits

Northern portions of the South Area and the central portions of the North Area generally lie over Quaternary alluvial, colluvial, and basin deposits of the Livermore Valley. North, south, and east of the Livermore Valley proposed project facilities generally overlie the bedrock of the Diablo Range. Quaternary deposits include those of the following ages: Historic (the past approximately 200 years), Holocene (200 to 11,000 years ago), Pleistocene (11,000 to 3 million years ago), and Pliocene (3 to 7 million years ago). Surficial geologic units within the project vicinity, from youngest to oldest, are described in the following sections.

Gravel Pits (Historic). The southern Livermore Valley is a rich source of sand and gravel aggregate for construction. Gravel pits located along the southern margins of the valley have been created for the excavation of stream channel and Holocene alluvial deposits. Gravel pits are not traversed by proposed project components. The closest approach is near the Vineyard Substation.

Floodplain Deposits (Holocene). Much of the Livermore Valley is comprised of Holocene floodplain deposits. These deposits generally consist of medium to dark gray, dense, sandy to silty clay with local lenses of coarser material (silt, sand, and pebbles). Holocene floodplain deposits underlie portions of the South Area transmission line.

Basin Deposits (Holocene). Holocene basin deposits are found within the western Livermore and San Ramon Valleys. Basin deposits contain finer grained material than floodplain deposits, generally consisting of very fine silty clay to clay. Mapped Holocene basin deposits are not crossed by the proposed project facilities.

Alluvial Fan and Fluvial Deposits (Holocene). The largest Holocene alluvial fan and fluvial deposits near the project area are located within the eastern and southeastern reaches of the Livermore Valley. Smaller deposits are located near the eastern edge of the San Ramon Valley, along Dougherty Creek, and within the narrow valleys of the Diablo Range west of Midway. Alluvial fan and fluvial deposits generally contain brown or tan, medium dense to dense, gravelly sand or sandy gravel which grades to sandy or silty clay with distance from the sediment source.

Alluvial Fan and Fluvial Deposits (Pleistocene). Pleistocene alluvial fan and fluvial deposits in the project vicinity are primarily found along the southern and northeastern margins of the Livermore Valley and within the narrow valleys of the surrounding hills. These deposits generally consist of brown dense gravely and clayey sand or clayey gravel, grading upward to sandy clay. Pleistocene alluvial and fluvial deposits are overlain by Holocene deposits on lower parts of the alluvial plain and are incised by channels that are partly filled with Holocene alluvium on higher parts of the alluvial plain. Pleistocene deposits can be distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than Holocene deposits and have maximum thickness of at least 50 meters (Helley and Graymer, 1997).

Alluvial Terrace Deposits (Pleistocene). Occupying the outer margins of the Livermore and Vallecitos Valleys, alluvial terrace deposits consist of crudely bedded, clast-supported gravels, cobbles, and boulders with a sandy matrix. Coarse sand lenses may also be present within terrace deposits, which have been formed as Pleistocene alluvial fan deposits were incised by more recent stream channels. Proposed transmission line in the South Area is underlain by mapped Pleistocene alluvial terrace deposits.

Livermore Gravels (Pliocene and Pleistocene). The Livermore Gravels are described as poorly to moderately consolidated, indistinctly bedded, cobble conglomerate, gray conglomeratic sandstone, and gray coarse-grained sandstone (Helley and Graymer, 1997). Some siltstone and claystone deposits are also found within the formation. Clasts are predominantly sandstone with some siliceous chert and volcanics. Estimated to be approximately 4,000 feet thick (Ollenburger, 1988), the Livermore Gravels were deposited as a result of rapid uplift of the central Diablo Range between 300,000 and 5 million years ago. In the project area, Livermore Gravels are found primarily in the hills north and south of the Livermore Valley.

Bedrock

Shallow or outcropping bedrock units are found in the hills north and east of the Livermore Valley. Mapped bedrock formations (Graymer, et al., 1996) underlying proposed project components include the following:

- **Green Valley and Tassajara Formations (Pliocene and Miocene, 2.5 to 26 million years ago)—**The Green Valley and Tassajara formations consist of non-marine sandstone, siltstone, and conglomerate. In the project area, these formations are primarily found north of the Livermore Valley, underlying the proposed North Area Phase 1 transmission line route.
- **Neroly and Cierbo Sandstones (late Miocene)—**Neroly Sandstone is a brown, massive, marine sandstone with abundant clasts of volcanic rocks. Cierbo Sandstone is a light-gray, massive sandstone. The Cierbo Sandstone unit locally can be highly fossiliferous, containing marine fossils primarily of the genus *Ostrea*. In the project area, these formations are primarily found along the eastern and western slopes of the Altamont Hills, underlying the proposed North Area Phase 2 transmission line route.
- **Formations of the Great Valley Sequence—**The Great Valley sequence consists mainly of Jurassic to late Cretacteous (65 to 190 million years ago) shale, sandstone, and conglomerate that are thought to have initially been deposited in a marine forearc basin associated with an offshore subduction trench. In the project area, geological units of the Great Valley sequence are primarily of late Cretaceous age and they comprise the majority of mapped bedrock in the Altamont Hills east of the Livermore Valley.

Subsurface Deposits

No soil boring information for specific substation and transmission tower locations was available during preparation of this report. Subsurface deposits are highly variable across the project area, where valley sediments may extend hundreds of feet deep and hilly regions may have little or no soil cover. Composition of subsurface soils may also be highly variable, depending on location, deposition, and formational history. A design-level geotechnical investigation will be performed if necessary to evaluate site-specific subsurface conditions at substation sites and along proposed transmission line routes for analysis and design of project facilities.

13.2.1.3 Soils

Soils are the byproduct of physical and chemical weathering of underlying rock and alluvial deposits. They consist of mineral and organic matter and are created through physical, chemical, and biological processes. The United States Department of Agriculture (USDA) Soil Conservation Service (SCS) prepares soil surveys that classify soil characteristics and their suitability for agriculture and development based on soil associations, i.e., distinct combinations of soils. Five soils associations, composed of 15 different soil series, have been mapped by the SCS in the project area. A description of the soil groups within each association is presented in Table 13-1. Soil properties of particular interest include shrink-swell and erosion potential, as these properties may impact proposed project facilities.

The Altamont-Diablo association is found in the upland areas north and east of the Livermore Valley. The area is characterized by smooth, round hills and rolling to steep topography, with particularly steep slopes along streams. The hills range in height from 700 to 1,700 feet. Altamont, Diablo, and Linne soils predominate in the project area. These soils formed in material that weathered from interbedded sedimentary rock and are typically moderately fine and fine textured. They are typically well drained, moderately deep to deep, and have moderate to high fertility and available water-holding capacity. Minor deposits of Pescadero, Cropley, and Conejo soils, poorly drained and saline-alkali, are found within small valleys of the association.

The Yolo-Pleasanton association is found in the valley area near Pleasanton and Livermore. The topography of the area is level, with a few sloping escarpments on the low terraces. Elevations range from 220 to 880 feet. Soils of this association found in the project area include the Yolo, Livermore, and Pleasanton series. These soil groups are typically very deep, well drained, and neutral to moderately alkaline. Yolo-Pleasanton soils are the most intensively cultivated in the Livermore Valley area.

The Positas-Perkins association is found on the terraces south of Livermore Valley. Elevations within the area range from 100 to 900 feet and the topography is sloping to very steep. Positas soils form a majority of the association in the project area, which also contains small amounts of Azule soils and Diablo clay, very deep soil. The Positas soils are generally shallow to a claypan and have low fertility and available water-holding capacity.

The Clear Lake-Sunnyvale association occurs in the northern Livermore Valley. Elevations range from approximately 400 to 900 feet, with nearly level topography except for some moderate sloping on terraces. Clear Lake soils, found in basin areas, are deep, clayey, and imperfectly and moderately well drained. They have a high water-holding capacity and are very fertile. Soils in the project area that are also part of the Clear Lake-Sunnyvale association include limited proportions of Danville and Pescadero soils.

TABLE 13-1
Soil Associations in the Tri-Valley Project Area

Soil Series	Relative Quantity	Location	Shrink-Swell Potential	Erosion Potential
Altamont-Diablo Association, gentle to steep slopes				
Altamont	Large	Altamont Hills	High	Moderate–Severe
Diablo	Large	Hills North and South of Livermore Valley	Moderate–High	Slight–Very Severe
Linne	Moderate	North Livermore and East Altamont Hills	Low	Slight–Very Severe
Pescadero	Small	Narrow Valley Bottoms	Moderate–High	Slight
Cropley	Small	Dougherty Hills	High	Slight–Moderate
Conejo	Small	Tassajara Creek Valley	Moderate	Slight
Yolo-Pleasanton Association, gentle slopes				
Yolo	Small	South Livermore Valley	Low	Slight–Moderate
Livermore	Small	South Livermore Valley	Low	Slight
Pleasanton	Small	South Livermore Valley	Low–Moderate	Slight–Moderate
Positas-Perkins Association, gentle to very steep slopes				
Positas	Moderate	South Livermore Hills	Low–High	Slight–Very Severe
Azule	Small	South Livermore Valley	Moderate–High	Slight–Moderate
Diablo, Very Deep	Small	Hills South of Livermore Valley	Not Available	Moderate–Very Severe
Clear Lake-Sunnyvale Association, gentle slopes				
Clear Lake	Moderate	North Livermore Valley	High	Slight
Danville	Small	South Livermore Valley	Moderate	Slight
Rincon-San Ysidro Association, gentle slopes				
Rincon	Small	Valleys West of Midway	Moderate–High	Slight
San Ysidro	Small	South Livermore Valley	Low–High	Slight

Note: Shrink-swell potential measures the tendency of a soil to expand or contract with changes in water content. Erosion potential is primarily dependent on degree of slope and vegetation, although soil composition also plays a role.

Rincon-San Ysidro association soils in the project area are found in the northeastern Livermore Valley and in the valleys west of Midway. Topography in these areas is characterized by nearly level or sloping fans and flood plains, with elevations from approximately 300 to 600 feet. The association consists primarily of Rincon and San Ysidro soils, which formed from alluvium derived from sedimentary rock. Rincon soils are generally deep, well drained, and have high available water capacity with moderate fertility. San Ysidro soils are generally shallow and moderately well drained with low available water capacity and fertility.

Published soil descriptions are limited to a depth of 5 to 6 feet and may not be representative of deeper conditions. Landfilling, highway and street construction, and construction of commercial and residential developments have caused substantial changes to natural soils. Therefore, developed area soil conditions may be highly variable.

13.2.1.4 Mineral Resources

Sand and Gravel Quarries

The most significant mineral resources identified in the project area are Portland cement, concrete-grade sand, and gravel deposits in the south Livermore Valley. These deposits are a major source of aggregate for the San Francisco Bay Area. Major quarry operators in the area include Kaiser Sand & Gravel, the Jamieson Company, and RMC Lonestar, Inc. Because sand and gravel are bulky, low cost commodities, transportation is a major cost factor in marketing these materials. The size and close proximity of these deposits to other Bay Area cities makes them a significant local and regional resource.

The CDMG has mapped portions of the project area as Mineral Resource Zones (MRZs) with the following characteristics:

- MRZ-1: Areas where adequate information indicates that no significant aggregate deposits are present, or where it is judged that little likelihood exists for their presence.
- MRZ-2: Areas where adequate information indicates that significant aggregate deposits are present, or where it is judged that a high likelihood for their presence exists.
- MRZ-3: Areas containing aggregate deposits, the significance of which cannot be evaluated from available data.
- MRZ-4: Areas where available information is inadequate for assignment to any other MRZ.

Areas classified as MRZ-2 that also have existing land uses compatible with mining have been further delineated as Mineral Resource Sectors.

Oil and Minerals

The Livermore Oil Field, located east of Livermore, produced approximately 1.6 million barrels of oil between 1967 and 1987 (Darrow, 1988). As of 1987, estimated reserves of only 132,000 barrels remained. A few individual oil wells are scattered elsewhere in the project area, although remaining resources are considered to be limited. Other potentially valuable mineral resources identified within the region include manganese, chromium, gemstones, pyrite, dimension stone, and natural gas (Bailey and Harden, 1975).

13.2.1.5 Paleontology

Fossils have been found in many of the gravels and unconsolidated rocks of the Livermore Valley, Diablo Range, and Altamont Hills. They included invertebrate and oyster shells, plant fossils, and bone fragments from a variety of mammals, including mammoths, camelids, giant sloths, horses, shrews, beavers, and squirrels. The deposits are widely scattered and are not considered to be particularly unique (Alameda County Planning Department, 1994).

13.2.1.6 Seismicity

The project area is located in the seismically active San Francisco Bay region, which has experienced repeated moderate to large earthquakes. Notable historic seismic events affecting the project area are presented in Table 13-2. It is likely that the Tri-Valley area will experience periodic minor to moderate earthquakes and potentially a major earthquake (moment magnitude M7, or greater; see Magnitude below) during its service life. A 1990 estimate, made by the Working Group on California Earthquake Probabilities (WGCEP, 1990), gave a 67-percent probability for one or more M7 earthquakes to occur within the Bay Area in the 30-year period between 1990 and 2020. More recent data suggests that the probability of a large earthquake may be substantially higher (Schwartz, 1994).

Seismic Parameters

Earthquakes, their sources, and the effects of seismic ground motion are measured by a number of parameters, including magnitude, intensity, fault length and rupture area, maximum credible earthquake, and peak ground acceleration. These seismic parameters are used to evaluate and compare earthquake events, seismic potential, and ground shaking.

Magnitude. The magnitude, or size, of an earthquake is measured by a number of methods. Several of these, including the Richter (M_L), surface wave (M_s), and body wave (M_b) methods evaluate the magnitude of an earthquake by measuring the amplitude of seismic waves as recorded by a seismograph. Due to the instrumental properties of seismographs, these methods provide inconsistent results above or below a certain range of magnitudes. A more robust measure of magnitude is moment magnitude, or M_W. Evaluation of M_W is based on the seismic moment of an earthquake, which can be described as the leverage of forces across the area of fault slip. Because it is directly related to the area of the fault ruptured during an earthquake, moment magnitude is a consistent measurement of size from the smallest to the largest events. For moment magnitudes 5 to 7, the magnitude measurement approximates that of 5 to 7 magnitude on the Richter scale. In this chapter, M_W is used to describe earthquake size.

Intensity. Rather than a mechanical measure of source size, earthquake intensity is a subjective measurement of earthquake shaking on a local level. Because it is based on observed effects of ground shaking on people, structures, and the environment, intensity is a useful method for estimating the magnitude of earthquakes for which no instrumental data is available. Intensity can also be used to compare levels of seismic response between different sites for the same earthquake event.

TABLE 13-2
Significant Historic Earthquakes Affecting the Tri-Valley Project Vicinity

			Approximate Distance from Project Area[2]	
Date	**Locality (Fault name if known)**	**Magnitude[1]**	**Miles**	**Km**
1989/10/17	Loma Prieta (San Andreas)	6.9	35	55
1988/06/13	Alum Rock (Calaveras)	5.1	20	30
1986/03/31	Mount Lewis	5.7	7	11
1984/04/24	Morgan Hill (Calaveras)	6.2	25	40
1980/01/24	Livermore (Greenville-Marsh Creek)	5.8	0	0
1979/08/06	Coyote Lake (Calaveras)	5.9	40	65
1911/07/01	Calaveras Fault	6.5	20	30
1910/03/11	Watsonville	5.8	50	80
1906/04/18	San Francisco (San Andreas)	7.8	30	50
1903/08/03	San Jose	5 ½	20	30
1903/06/11	San Jose	5 ½	15	25
1899/07/06	Morgan Hill	5 ¾	30	50
1898/03/31	Mare Island	6 ½	40	65
1897/06/20	Gilroy	6 ¼	45	70
1892/04/21	Winters	6 ¼	50	80
1892/04/19	Vacaville	6 ½	40	65
1890/04/24	Pajaro Gap	6 ¼	50	80
1889/05/19	Antioch	6 ¼	15	25
1884/03/26	Santa Cruz Mountains	6	40	65
1881/04/10	Western San Joaquin Valley	6	40	65
1870/02/17	Los Gatos	6	30	50
1868/10/21	Hayward Fault	7	8	13
1866/07/15	Western San Joaquin Valley	6	40	65
1865/10/08	Southern Santa Cruz Mountains	6 1/2	35	55
1864/03/05	East of San Francisco Bay	5 3/4	5-10	10-15
1861/07/04	San Ramon Valley (Calaveras)	5 3/4	1	1
1858/11/26	San Jose Region (Mission[4])	6 1/4	5-10	10-15
1856/02/15	San Francisco Peninsula	5 3/4	30	50
1838/06/---	San Francisco Peninsula	7	30	50
1808/06/21	San Francisco Region	6[4]	---[4]	---[4]

[1] Magnitude is moment magnitude (M_W) for earthquakes after 1911. For earthquakes before 1911, magnitudes are estimated from observed shaking intensity

[2] Distances are estimated from reported extent of fault rupture for earthquakes after 1911. For earthquakes before 1911, distances are estimated from location of causative fault. If causative fault is unknown, distance is estimated from area of highest reported shaking intensity.

[3] Information from Andrews (1992), Oppenheimer and MacGregor-Scott (1992), and Ellsworth (1990).

[4] Precise data is unavailable.

Maximum Credible Earthquake (MCE). Geometric fault parameters are used to estimate the maximum credible earthquake (MCE) that can be produced by a given fault or fault segment. Based on empirical relationships between the potential area of rupture and earthquake magnitude, the MCE is a rational and believable event that can be supported by the geologic evidence of past movement and the recorded seismic history of the region.

Attenuation. In an earthquake, sudden rupture or displacement along a fault releases energy in the form of seismic waves, which travel outward from the source. The amount of energy released by an earthquake is related to its magnitude. Seismic waves travel through the earth causing displacements or movements of the ground, similar to ripples on a pond. As waves travel away from the source, their energy is both absorbed and spread over an increasingly larger area through a process called attenuation. Through attenuation, amount of acceleration, velocity, and displacement caused by the passage of seismic waves decreases with distance from the source. Thus, both the distance from the seismic source and earthquake magnitude affect the amount of wave energy reaching a given location. A number of empirical attenuation relationships, which describe the relationship between the amplitude of ground motion, earthquake magnitude, and distance, have been developed based on analysis of past earthquake motions. These relationships are used to estimate ground motions resulting from potential future earthquakes.

Acceleration. Acceleration is the rate of change of the velocity of particles within the ground or structures caused by the passage of seismic waves. The peak ground acceleration (PGA) is the highest acceleration (expressed as a fraction of the acceleration due to gravity, 32 ft/sec^2 or 9.8 meters/sec^2) experienced at a site due to the passage of seismic waves. PGA is dependent on a number of parameters, including earthquake magnitude, distance from the seismic source, and local soil conditions. For this analysis, estimated peak ground accelerations were developed using published attenuation relationships (Abrahamson and Silva, 1997, Idriss, 1991/94). Estimated PGAs presented in this chapter are for rock and shallow soil sites and are based on MCE magnitudes and estimated distances from the project facilities. Sites containing subsurface profiles other than rock and shallow soil would require further investigation and analysis to estimate PGA.

Faults

Classification. Regional faults shown in Figure 13-1 are classified by age as Historic, Holocene, Late Quaternary, Quaternary, and Pre-Quaternary (Jennings, 1994) according to the following criteria:

- Historic: fault displacement has occurred within the past 200 years
- Holocene: shows evidence of fault displacement within the past approximately 11,000 years but without historic record
- Late Quaternary: shows evidence of fault displacement within the past 700,000 years but may be younger due to a lack of overlying deposits that enable more accurate age estimates
- Quaternary: shows evidence of displacement sometime during the past 1.6 million years
- Pre-Quaternary: without recognized displacement during the past 1.6 million years

Faults of Quaternary age in the project vicinity are also described by one of two activity classes, active and potentially active, as defined by the CDMG (CDMG, 1992). “Active” describes Historic and Holocene faults that have had surface displacement within about the last 11,000 years. “Potentially active” describes faults showing evidence of surface displacement during Quaternary time (the past 1.6 million years).

Active and potentially active faults in the project vicinity have been mapped and documented by a number of government agencies. The USGS, CDMG, and the State of California Division of Water Resources (CDWR) have all published numerous maps and reports on faults of various types, ages, and levels of activity. General agreement between sources was found for the location and activity of faults listed in Table 13-3, which presents information on active and potentially active faults within approximately 60 miles of the project area.

Alquist-Priolo Earthquake Fault Zones. The Alquist-Priolo Special Studies Zones Act, passed in 1972, requires the establishment of “earthquake fault zones” (formerly known as “special studies zones”) along known active faults in California (CDMG, 1992). Strict regulations on development within these zones are enforced to reduce the potential for damage due to fault displacement. However, these restrictions apply only to occupied structures and none of the proposed project facilities will be manned. In order to qualify for “earthquake fault zone” status, faults must be “sufficiently active” and “well-defined.”

As a result, only faults or portions of faults with a relatively high potential for ground rupture are zoned, while other faults, which may meet only one of the “sufficiently active” and “well-defined” criteria, are not zoned. The potential for fault rupture, therefore, is not limited solely to faults or portions of faults delineated as “earthquake fault zones.”

Five faults in the general project vicinity—Calaveras, Pleasanton, Verona, Las Positas, and Greenville—have Alquist-Priolo Earthquake Fault Zones associated with them (CDMG, 1982). However, due to zoning criteria, not all mapped traces of these faults are zoned.

Other Faults in the Project Area. In addition to the five faults identified with earthquake fault zones, a number of other faults have been identified in the project area. The Livermore fault, as shown in Figure 13-1, was identified primarily based on a well-defined groundwater barrier, air photo lineaments, and an outcrop recognized at Oak Knoll in western Livermore (Carpenter, 1980).

Because of limited surficial evidence, the location, age, and extent of the Livermore fault is somewhat uncertain. The Elk Ravine fault, located in the Altamont Hills, is identified as Pre-Quaternary by Jennings (1994) and is likely to be inactive. Other faults within the Livermore Valley that have been identified at various times, but with a much lower degree of certainty, include the Mocho and Parks faults. These have also been identified based primarily on inferred groundwater barriers.

Insert Figure 13-1 Approximate Location of Mapped Faults
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Insert Figure 13-1 Approximate Location of Mapped Faults

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TABLE 13-3
Active and Potentially Active Faults in the Project Vicinity

Fault	Distance in Miles[1]	Age[2]	Activity	MCE[3] (M_W)
Greenville	0	Historic	Active	7.0
Las Positas	0	Historic	Active	6.3
Verona	0	Holocene	Active	6.3
Livermore	1	Quaternary	Potentially Active	6.2
Elk Ravine	0	Pre-Quaternary	Likely Inactive	--
Pleasanton	1.5	Holocene	Active	6.2
Midway	1	Quaternary	Potentially Active	6.8
Coast Range - Central Valley	1	Holocene	Active	7.3
Calaveras	3	Historic	Active	7.2
Williams	1	Quaternary	Potentially Active	6.0
Sherburne Hills	2	Quaternary	Potentially Active	6.0
Marsh Creek	2	Holocene	Active	6.7
Corral Hollow	4	Quaternary	Potentially Active	6.9
Carnegie	4	Holocene	Active	6.9
Miller Creek	5	Quaternary	Potentially Active	6.3
Mission	7	Quaternary	Potentially Active	6.3
Hayward	8	Historic	Active	7.5
Clayton	9	Holocene	Active	6.6
Concord	10	Historic	Active	6.9
Antioch	13	Quaternary	Potentially Active	6.8
San Andreas	27	Historic	Active	8.3

[1] Distance is measured from the fault to the nearest facilities associated with project.

[2] From Jennings (1994), Wakabayashi, et al. (1992), and Wakabayashi and Smith (1994).

[3] MCE = Maximum Credible Earthquake (moment magnitude, M_W), preferred value as estimated from Caltrans (1996), Wesnousky (1986), and CDMG (1996).

Recently active and well-defined faults both are located near proposed project facilities and could generate strong ground shaking. Therefore, potential earthquakes on these larger faults are expected to largely control design parameters for project facilities.

Uncertain or potentially unidentified faults are unlikely to significantly increase seismic risk but could increase the risk of surface rupture in the project area. Because some project facilities are proposed near queried, inferred, and/or questionable fault traces, further geological and site-specific geotechnical studies may be necessary for evaluation of fault rupture hazard at these locations.

Earthquakes generated by faults near the project vicinity, while not directly influencing fault rupture hazard, contribute significantly to the potential for strong seismic ground shaking within the project area. Nearby faults posing the greatest potential seismic risk to project facilities include the Coast Range-Central Valley, Hayward, Concord, and San Andreas faults.

Landslides

Landslides, earthflows, and debris flows are relatively common features in the steep hills surrounding the Livermore Valley. A landslide is a mass of rock, soil and/or debris that has been displaced downslope by sliding, flowing, or falling. Landslides include cohesive block glides and disrupted slumps that have formed by the translation or rotation of slope materials along one or more planar or curviplanar surfaces. Earthflows are relatively shallow deposits of soil or other colluvial material that have oozed downslope, commonly at a rate too slow to observe except over long duration. Debris flows are generally short-lived phenomena resulting from rapid failure of surficial slope materials. Typically, debris flows leave a train of mud and debris in a scoured channel following runout of the flow. Numerous landslide deposits are mapped in the hills surrounding the Livermore Valley. Debris flow source areas, often characterized by concave topographical forms above steep slopes, are also mapped in the project area.

Landslides occur when shear stresses within a soil or rock mass exceed the available shear strength of the mass. Failure conditions can be achieved by increasing the stresses within a slope, decreasing the internal strength of the slope, or by a combination of both. Stresses can be magnified by increasing the weight of overlying slope materials through saturation, by adding material (surcharge) to the slope, by applying foundation loads, or through seismic loading. Slope shear strength can be reduced through erosion or removal of supporting material at the slope toe, increased pore water pressure within the slope, and weathering/decomposition of supporting soils. Zones of low shear strength within slopes are generally associated with the presence of certain clays, bedding, or fracture surfaces.

Landslide potential is influenced by a number of factors; some of the most significant being slope, water, and zones of weakness. In general, slope is the most important factor contributing to landslide hazard, with steep slopes being more susceptible to failure than shallow ones. The presence of water within a slope, often the most variable factor contributing to landslide potential, has a doubly detrimental effect on stability by both increasing slope stresses and reducing slope strength. Although landslide activity is generally greatest during wet winter seasons, landslides can occur at any time, with no apparent triggering mechanism. Bedding planes, joints, discontinuities, weathered seams, and pre-existing failure surfaces may also create zones of weakness within a slope that increase the potential for failure.

Both the CDMG and the USGS have evaluated landslide hazards within the project area (CDMG, 1991 and Wentworth, et al., 1997). The USGS categorizes areas according to the relative concentration of existing landslides, with areas classified as "mostly landslide," "many landslides," "few landslides," and "flat land." Areas designated as "mostly landslide" by the USGS are generally the same areas classified as "most susceptible" to landsliding by the CDMG. Such areas consist of mapped landslides, narrow intervening areas, and narrow borders around landslides. Areas classified as "mostly landslide" by the USGS generally present the greatest potential landsliding hazard to proposed project facilities, although mapped and unmapped landslides are likely to exist in areas with other classifications.

Potential debris flow source areas have been mapped in the project area by the USGS (Ellen, et al., 1997). Source areas are generally found on steep slopes within concave topographical profiles. Locations particularly susceptible to hazard from debris flows include not only source areas but also areas beneath steep hillsides, near the mouths of steep sidehill drainages, and near the mouths of canyons that drain steep terrain.

In general, the greatest potential for landslides, earthflows, and debris flows within the project area exists in the hills around the Livermore Valley. Slope instability may also be a significant hazard around stream banks and other local topographic features, both natural and man-made.

13.2.2 North Area—Phase 1

13.2.2.1 Topography

Transmission Line

The North Area Phase 1 transmission line route, from Mileposts B10.4 to B17.2 and V0.0 to V1.0, traverses valley and hill terrain north of the Livermore Valley. From approximately Mileposts B10.4 to B13.2 and V0.0 to V1.0, the transmission line route lies at the northern end of the Las Positas Valley, characterized by generally flat to moderately sloping topography. Elevations along the route within the valley range from approximately 550 to 800 feet.

Between Mileposts B13.2 and B17.2, the proposed route traverses moderate to steeply sloping terrain, ranging in elevation from approximately 600 to 1,000 feet. The alignment crosses Collier Canyon and Doolin Canyon, two narrow valleys trending in a southerly direction towards the Livermore Valley.

Substations

The proposed North Livermore Substation site is located over gently sloping terrain of the Las Positas Valley at an elevation of approximately 555 feet.

The proposed Dublin Substation site is located along the western side of an unnamed drainage tributary to Tassajara Creek. Elevations at the property range from approximately 560 to 700 feet in terrain that ranges from moderately to steeply sloping.

13.2.2.2 Geology

Transmission Line

Portions of the proposed transmission line route in Las Positas Valley, Collier Canyon, Doolin Canyon, and their tributaries generally overlie Pleistocene alluvial fan and fluvial deposits. In the western portion of the corridor, from approximately Mileposts B11.4 to B12.0 and B13.2 to B17.2, underlying bedrock generally consists of the Green Valley and Tassajara formations. Along the eastern portion of the corridor, between approximately Mileposts B10.4 and B10.8, bedrock beneath the route primarily consists of Neroly and Cierbo sandstones.

Substations

Pleistocene alluvial fan and fluvial deposits generally underlie the proposed North Livermore Substation site, while both Pleistocene alluvial/fluvial deposits and Livermore Gravels underlie the proposed Dublin Substation site.

13.2.2.3 Soils

Transmission Line

Soil associations along the proposed North Area Phase 1 transmission line route include the Altamont-Diablo and Clear Lake-Sunnyvale associations. The Diablo soil series is most common between Mileposts B14.2 and B17.2 in the hills north of Livermore, while small amounts of both Pescadero and Clear Lake soils are found in the valley bottoms of Collier, Doolin, and Tassajara Canyons and their tributaries. Soils of the Linne, Diablo, and Altamont series are found in the hills at the north end of the Las Positas Valley, between Mileposts B10.4 and B14.2. Clear Lake soils have been identified in large quantity over the bottom of the Las Positas valley, from approximately Mileposts B12.0 to B13.2 and V0.0 to V1.0.

Substations

The proposed North Livermore Substation site overlies clays of the Clear Lake series, a high plasticity soil found on very gently sloping or flat-lying plains (0 to 3 percent slopes). The soil formed in fine-textured alluvium from sedimentary rock and has a high shrink-swell potential. Its pH varies from slightly acid to moderately alkali. Because of shallow slopes, erosion potential at the site is considered to be low.

Clays of both the Diablo and Pescadero Series underlie the proposed Dublin Substation site. Diablo clay, on 30 to 50 percent slopes, is considered to be moderately to highly erodable, while the Pescadero soils, in the bottom of the valley, present only a minor erosion hazard. Both soils have a high shrink-swell potential.

Mineral Resources

No significant mineral resources have been mapped along the proposed transmission line route or at proposed substation locations.

13.2.2.4 Faults and Seismicity

Transmission Line

No mapped fault traces have been identified along the North Area Phase 1 transmission line route. However, the easternmost portion of the Phase 1 route near Milepost B10.4 and the existing Contra Costa-Newark transmission line is located just within an Alquist-Priolo Earthquake Fault Zone that has been established for the Greenville fault.

Substations

The Greenville fault, at its closest approach (approximately 2.3 miles) to the northeast, is the nearest known active fault to the proposed North Livermore Substation. Herd (1977) and Dibblee (1981) have also mapped an unnamed, queried fault approximately 1,200 feet southwest of the site. The proposed Dublin Substation is approximately 3 miles from the Pleasanton fault and approximately 5 miles from both the Greenville and Calaveras faults.

13.2.2.5 Landslides

Transmission Line

The North Area Phase 1 transmission line route generally traverses area classified as “mostly landslide” by the USGS between approximately Mileposts B13.8 and B17.2. A number of large landslide complexes have been mapped along the route between Mileposts B15.0 and B16.1. Outside of this section, mapped landslides crossed by the route are generally smaller and less continuous. A few debris source areas have also been mapped within the hilly terrain along the route.

Substations

The proposed North Livermore Substation site is located in a relatively flat area where landslide susceptibility is very slight. The proposed Dublin Substation, however, is located in an area classified as “mostly landslide” by the USGS. A portion of a landslide mapped by the CDMG is found over the western side of the site and several other landslides are mapped nearby. Small debris flow source areas have been mapped in the hills above the proposed Dublin Substation site.

13.2.3 North Area—Phase 2

13.2.3.1 Topography

Phase 2 of the North Area transmission line route, from Mileposts A0.0 to A0.2, C0.0 to C7.8, W2.5 to W3.8, and B10.1 to B10.4, traverses the Altamont Hills between Midway and North Livermore. Slopes across the proposed route are generally moderate to very steep, with elevations ranging from approximately 400 feet at the Midway Substation to nearly 1,300 feet near Milepost C6.3. The proposed route intersects a number of ridges and narrow valleys in its path across the hills.

13.2.3.2 Geology

Across the Altamont Hills, the transmission line route primarily overlies bedrock formations of the Great Valley Sequence. Portions of the corridor at both the eastern and western ends overlie sandstones of the Neroly and Cierbo formations. Alluvial fan and fluvial deposits are found within the narrow valleys crossed by the route. On the western side of the hills, these alluvial and fluvial deposits are generally Pleistocene in age, while on the eastern side some are of Holocene age, particularly those within the valleys west of Midway.

13.2.3.3 Soils

The Altamont-Diablo soil association is by far the most common along the proposed Phase 2 transmission line route. A minor amount of Rincon-San Ysidro association soil is found within the valleys west of Midway, near the Tesla Substation. These soils, of the Rincon series, have been identified over a small portion of the route between Mileposts A0.0 and A0.2. From Mileposts C0.0 to C1.2, the route generally overlies soils of the Linne, Altamont, and Diablo series. The remainder of the route, from Milepost C1.2 to Milepost B10.2, primarily overlies soils of the Altamont series, with limited areas of Pescadero series soils within some of the narrow valley bottoms crossed by the alignment.

13.2.3.4 Mineral Resources

Although manganese, gemstone, and limestone deposits have been identified in the Altamont Hills east of Livermore, no mapped deposits are crossed by the proposed transmission line route.

13.2.3.5 Faults and Seismicity

The Phase 2 route crosses the active Greenville fault and its associated Alquist-Priolo Earthquake Fault Zone from approximately Mileposts W3.0 to W3.8 and B10.1 to B10.4. Multiple fault traces have been mapped within the fault zone, on some of which offset was documented after the January 1980 Livermore earthquakes. Some traces of the Greenville fault mapped by Dibblee (1981) are outside of the Alquist-Priolo Earthquake Fault Zone and cross the proposed route between approximately Mileposts C7.5 and C8.0. A trace of the Elk Ravine fault, mapped by Jennings (1994) as a Pre-Quaternary fault, crosses the transmission line route near Milepost C2.0. Nearby faults include the potentially active Midway and Coast Range-Central Valley faults, which are located along the western margins of the San Joaquin Valley, near the Tesla Substation.

13.2.3.6 Landslides

The proposed Phase 2 transmission line route either overlies or approaches areas classified as “mostly landslide” by the USGS from approximately Mileposts C0.6 to C0.9, C1.2 to C1.4, C1.8 to C4.0, C4.5 to C5.6, and C7.3 to W3.1. The largest mapped concentration of existing slides is found between approximately Mileposts C3.0 and C4.0. Some debris flow source areas have also been mapped along the route.

13.2.4 South Area

13.2.4.1 Topography

Transmission Line

The portion of the proposed transmission line route between approximately Mileposts M4.2 and M5.3 lies in the generally level to moderately sloping terrain of the southern Amador Valley. The remainder of the South Area route is found in the moderately to steeply sloping hills southwest of Livermore and southeast of Pleasanton. Elevations within the South Area range from approximately 350 to 1,150 feet.

Transition Structure

The proposed transition structure site is located at an elevation of approximately 800 feet in the moderately to steeply sloping terrain of the hills southeast of Pleasanton.

13.2.4.2 Geology

Transmission Line

Livermore Gravel deposits, the most common beneath the South Area, underlie the transmission line route between approximately Mileposts MX0.3 and M4.2. Within the Vallecitos Valley, from approximately Mileposts MX0.0 to MX0.3, the alignment generally overlies Pleistocene alluvial terrace, Pleistocene alluvial/fluvial, and Holocene flood plain deposits. The northern portion of the South Area, between Mileposts M4.2 and M5.3, generally overlies Pleistocene deposits, mostly alluvial terraces with some alluvial/fluvial material.

Transition Structure

The proposed transition structure site overlies mapped deposits of Pliocene/Pleistocene age Livermore Gravels.

13.2.4.3 Soils

Transmission Line

Soil associations along the proposed South Area transmission line route include the Positas-Perkins, Yolo-Pleasanton, Altamont-Diablo, Clear Lake-Sunnyvale, and Rincon-San Ysidro associations. Soils of the Positas series are generally located from Mileposts MX0.0 to MX0.3 and approximately MX1.5 to M4.2. The Yolo, Livermore, and Pleasanton soil series, members of the Yolo-Pleasanton association, are generally found over gravelly deposits in Vallecitos Valley (Mileposts MX0.0 to MX0.6), and the southern Amador Valley near the Vineyard Substation (Mileposts M4.2 to M5.3). The Diablo soil series is common from Mileposts MX0.6 to approximately MX1.5 in the hills southwest of Livermore.

Transition Structure

The proposed transition structure site overlies soil described as Positas gravelly loam, a sandy, gravelly clay soil found on moderate to steep slopes. The soil formed in weakly consolidated clay, sand, and gravel, and it has a moderate to high shrink-swell potential. Its pH varies from medium acid to mildly alkali. Because of moderate to steep slopes, erosion potential at the site is considered to be severe.

13.2.4.4 Mineral Resources

Transmission Line

Mineral Resource Zones 2 and 3 have been mapped by the CDMG along the South Area transmission line route. MRZ-2 classification is found from approximately M5.2 to the Vineyard Substation. Areas classified as MRZ-3 are found from approximately Mileposts M4.1 to M4.8. While the proposed transmission line route overlies some MRZ-2 areas, none are designated as mineral resource sectors.

Transition Structure

No significant mineral resources have been mapped at the proposed transition structure location.

13.2.4.5 Faults and Seismicity

Transmission Line

Portions of the proposed transmission line route, between the Vallecitos Valley and the Vineyard Substation, overlie an Alquist-Priolo Earthquake Fault Zone and mapped traces of the Verona fault between approximately Mileposts MX0.2 and MX0.7. Additional fault traces, mapped by Smith (1981), underlie the route between Mileposts MX0.9 and MX1.2.

Transition Structure

The proposed transition structure site is located approximately 1 mile (2 km) northeast of the Verona fault and approximately 3 miles (5 km) northeast of the Calaveras fault.

13.2.4.6 Landslides

Transmission Line

Areas classified as “mostly landslide” by the USGS are found near or underlying the proposed transmission line route between approximately Mileposts MX1.2 and M4.0. Some debris flow source areas have been mapped along the route, mostly scattered in the hills between approximately Mileposts MX1.2 and MX1.4.

The largest mapped landslide (CDMG, 1991) along the proposed route is found between approximately Mileposts M2.2 and M2.6. Mapped landslides near the underground portion of the route are found between approximately Mileposts M2.8 and M3.1. Other mapped landslides along the route are generally small and discontinuous.

Transition Structure

Although it is nearly surrounded by areas designated as “mostly landslide,” the proposed transition structure site lies in an area categorized as “few landslides” by the USGS. No landslides are mapped at the site by the CDMG (CDMG, 1991). Some debris flow source areas are also mapped in the area around the site.

13.2.5 Summary of Geotechnical and Seismic Hazards

Geotechnical hazards and conditions that exist in the project area include:

- Soft or loose soils
- High groundwater levels
- Erosion
- Topography changes or unstable soil conditions from excavation, grading, or fill
- Slope instability
- Unique geological or physical features

Geotechnical hazards related to excavation, trenching, filling, and grading activities during construction include the following:

- Ground subsidence
- Settlement
- Expansive, soft, or loose soils
- Erosion
- Topography changes, or unstable soil conditions from excavation, grading, or fill
- Slope instability, landslides, mudflows, or debris flows
- Paleontologic resources
- Mineral resources

Seismic hazards include:

- Surface fault rupture
- Strong ground motions from local and regional seismic sources
- Liquefaction and seismic ground failure

Most of the geologic, geotechnical, and seismic hazards are found to some extent in all of the proposed project areas. Therefore, most hazards are addressed as generally applicable in Section 13.3, Potential Impacts. In some cases, where a potential hazard is primarily applicable to a particular location, that location is described.

13.3 Potential Impacts

13.3.1 Significance Criteria

Standards of significance were derived from Appendix G of the CEQA Guidelines. Impacts from the proposed project would be considered significant if they resulted in increased exposure of people or structures to major geologic hazards such as seismic activity, liquefaction, settlement, flooding, landslides, or slope instability, or if the project resulted in substantial soil erosion or loss of a unique geologic feature. However, geologic impacts are typically considered less than significant if, through engineering, geotechnical investigation, and construction techniques, the risk of damage to structures can be greatly reduced, although not eliminated completely.

13.3.2 Construction Impacts

Impact 13.1. Soft or Loose Soils. Saturated loose sands and soft clays may pose difficulties in access for construction and in excavating for pole and tower foundations. Soft or loose soils could also cause instability of trenches and other excavations during construction of underground facilities. However, design-level geotechnical studies will be performed to evaluate the potential for, and effects of, soft or loose soils where necessary. Where potential problems exist, the near-surface soft and loose soils may be overexcavated during construction and replaced with engineered backfill, or other ground treatment will be performed. Appropriate shoring and construction methods for trenches and other excavations will be designed. Where necessary, construction activities will be scheduled for the dry season to allow safe and reliable truck and equipment access. These impacts will be less than significant, and therefore, mitigation is not required.

Impact 13.2. Erosion. The potential for erosion significantly increases as slopes become steeper and less vegetated. Therefore, construction activities such as excavation, grading, trenching, and backfilling have the potential to cause increased soil erosion because of surface disturbance and vegetation removal. An Erosion Control Plan will be developed and will be implemented throughout the project construction period. Erosion control measures will include avoiding excessive disturbance of steep slopes, using drainage control structures to direct surface runoff away from disturbed areas, strictly controlling vehicular traffic, implementing a dust control program during construction, and revegetating disturbed areas following construction (see Chapters 7, 8, 10, and 11). Impacts will be less than significant. Mitigation is not required.

Impact 13.3. Slope Instability and Unstable Soil Conditions. Destabilization of natural or constructed slopes could occur as a result of construction activities. Excavation, grading, and fill operations could alter existing slope profiles and could result in the excavation of slope-supporting material, steepening of the slope, or increased loading, particularly at the transition structure site. However, appropriate design features and construction procedures will be implemented to maintain stable slope configurations during construction. Construction activities may be suspended during and immediately following periods of heavy precipitation when slopes are more susceptible to failure. In developing grading plans and construction procedures for access roads, substations, and transmission tower, the stability of both temporary and permanent cut, fill, and otherwise impacted slopes will be addressed. Grading plans will be designed to maintain adequate drainage of improved areas and minimize the potential for erosion and flooding during construction.

During construction of the underground transmission line, appropriate support and protection measures will be implemented to protect surrounding structures and utilities. Such measures may include trench shoring and bracing to limit ground deformation and underpinning of nearby foundations. Appropriate construction practices will be followed to protect the safety of workers and the public during trenching and excavation operations. A design-level geotechnical investigation will be performed to evaluate subsurface conditions, identify potential hazards, and provide information for development of excavation plans and procedures. Potential impacts would be less than significant, and mitigation is not required.

Impact 13.4. Paleontologic Resources. Some fossil-bearing geologic formations are located in the project area. If paleontological resources are found, Mitigation Measure 13.1 will be implemented, thereby reducing any potential impact to a less than significant level.

Impact 13.5. Mineral Resources. Although mapped mineral resource zones are found in the South Area, most of them are in locations where project facilities already exist, such as the Vineyard Substation and the Tesla-Newark transmission line corridor. No project facilities are located within specially designated mineral resource sectors. Aggregate and other mineral resources are known to exist in the project area. However, there are no specially designated mineral resource sectors in the area of the proposed route. Therefore, potential impacts to these resources will be less than significant, and mitigation is not required.

13.3.3 Operation Impacts

Impact 13.6. Ground Subsidence. Subsidence is the settling of the ground surface caused by compaction of underlying unconsolidated sediments, often because of groundwater withdrawal. Ground subsidence may cause relative elevation changes within an area, increasing the potential for inadequate drainage or flooding. The potential for subsidence due to compaction from groundwater withdrawal, strong ground motions, and the presence of soft, loose, compressible soils will be evaluated during design-level geotechnical investigations. The need to place additional fill or construct berms to reduce potential flooding because of past subsidence will also be evaluated. PG&E will remove or rework near-surface deposits likely to experience settlement prior to placing new fill. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geologic hazards. Potential impacts would be less than significant, and mitigation is not required.

Impact 13.7. Settlement. Settlement is the deformation of soil in response to load, which can be applied by foundations or placement of fill. Both long and short-term processes contribute to settlement, which may continue for as long as the load is applied. Differential settlement (where one area settles a different amount relative to another) occurs as a result of both environmental factors and spatial variations in load. Soft or loose foundation soils are generally susceptible to settlement, as are saturated clays.

A design-level geotechnical investigation will be performed to evaluate the potential for settlement of proposed project facilities. Results of the investigation will be used to develop appropriate foundation and structural designs to accommodate expected settlements. Potentially problematic near-surface soils identified during the geotechnical investigation may be excavated, removed, and replaced with engineered fill. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geologic hazards. Potential impacts would be less than significant, and mitigation is not required.

Impact 13.8. Expansive, Soft, or Loose Soils. Shrink-swell, or expansive soil behavior, is a condition in which soil reacts to changes in moisture content by expanding or contracting. Expansive soils may cause differential and cyclical foundation movements that can cause damage and/or distress to overlying structures and equipment.

Many of the identified soil groups within the project area have high clay contents and most have a moderate to high shrink-swell potential, as shown in Table 13-1. Potential operation impacts from saturated loose sands and soft clays include excessive settlement, low foundation bearing capacity, and limitation of year-round access to project facilities. Design-level geotechnical studies will be conducted, if necessary, to develop appropriate design features for locations where potential problems are known to exist. Appropriate design features may include excavation of potentially problematic soils during construction and replacement with engineered backfill, ground treatment processes, direction of surface water and drainage away from foundation soils, and the use of deep foundations such as piers or piles. Implementation of these standard engineering methods would reduce potential impacts to a less than significant level and mitigation is not required.

Impact 13.9. Slope Instability, Landslides, Mudflows, or Debris Flows. Slope instability, landslides, mudflows, and debris flows have the potential to undermine foundations and cause distortion and distress to overlying structures, and displace or destroy project components. A design-level geotechnical survey will be performed, if necessary, to evaluate the potential for unstable slopes, landslides, mudflows, and debris flows along proposed transmission line routes.

Relatively long span capabilities allow for the placement of transmission lines over slide areas. In cases of shallow sliding, slope creep, or raveling, specially designed deep foundations may be used to anchor the overlying structure to underlying competent material. Excavation or stabilization of unstable slope material may also be performed.

Facilities will be located away from steep hillsides, debris flow source areas, the mouths of steep sidehill drainages, and the mouths of canyons that drain steep terrain. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geologic hazards. Potential impacts would be less than significant, and mitigation is not required.

Impact 13.10. Surface Fault Rupture. A number of active and potentially active faults have been identified within the project area, some of which are crossed by proposed transmission lines (see Figure 13-1). Potential impacts to project facilities from surface rupture occur primarily to transmission line towers. The flexure capability of the transmission lines themselves can generally accommodate expected surface fault displacements. Transmission towers, however, are susceptible to damage or failure if they overlie a fault trace that experiences surface rupture. However, previous earthquakes such as Northridge show that damage has been limited. Therefore, this impact would not be significant, and mitigation is not required.

Elk Ravine Fault. The Elk Ravine fault is a Pre-Quaternary fault located in the Altamont Hills. The proposed Phase 2 transmission line route crosses a trace of the fault mapped by Dibblee (1980) near Milepost C2.0. Because of the lack of evidence for Quaternary displacement, it is likely that the fault is inactive. As a result, the potential impact of surface rupture along the Elk Ravine Fault is considered to be less than significant, and mitigation is not required.

Greenville Fault. The Greenville fault, classified as an active fault by the CDMG, is located along the eastern margins of the Livermore Valley. Surface rupture was observed along the fault trace as a result of the 1980 (M_W 5.8) Livermore earthquake sequence (Carpenter, 1980), and mapped traces of the fault lie within an Alquist-Priolo Earthquake Fault Zone (CDMG, 1982).

The North Area Phase 2 transmission line route crosses the Greenville fault zone from approximately Mileposts C7.5 and C8.0, W3.0 to W3.8, and B10.1 to B10.4. In this area, transmission lines will be designed to accommodate potential fault displacement between towers. Geotechnical investigations will be performed at proposed tower locations to evaluate the potential for surface rupture. Where significant potential for surface rupture exists, tower locations will be adjusted as possible. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geological hazards. Potential impacts would be less than significant, and mitigation is not required.

Pleasanton Fault. The Pleasanton fault lies at the western end of the Livermore Valley north of Pleasanton. Only a portion of the fault lies north of Interstate 580, where sufficient evidence for Holocene faulting has been found within an Alquist-Priolo Earthquake Fault Zone. Traces of the fault have been mapped southward as far as the Verona fault, though no evidence of Holocene faulting has been reported south of the Alquist-Priolo Zone (Hart, 1981b). Similarly, traces of the fault have been mapped north of the Camp Parks area. The California Division of Mines and Geology suggests, however, that if Holocene faulting has occurred north of Camp Parks area, it is “minor, discontinuous, and distributive” (Hart, 1981b). Potential impacts will be less than significant because the project is not located adjacent to this fault.

Verona Fault. An Alquist-Priolo Earthquake Fault Zone has been established for the Verona fault, which lies southwest of the Livermore Valley. The proposed transmission line for the South Area would cross the Verona fault zone between approximately Mileposts MX0.2 and MX1.2. Because the fault is considered to be active, future surface rupture along the Verona fault is possible. In this area, transmission lines will be designed to accommodate potential fault displacement between towers. Site-specific geotechnical investigations will be performed at proposed tower locations to evaluate the potential for surface rupture. Where significant potential for surface rupture exists, tower locations will be adjusted as possible. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geological hazards. Potential impacts would be less than significant, and mitigation is not required.

Impact 13.11. Strong Ground Motions from Local and Regional Seismic Sources. Judging from the activity of major regional seismic sources (Table 13-3) and based on the WGCEP earthquake probability estimation, it is likely that the project would be exposed to at least one moderate or greater earthquake located close enough to produce strong ground shaking. The greatest potential for large ground motion over most of the project area is the Calaveras fault, which has produced numerous moderate to large earthquakes during historical time. In addition to active faults within the project area, the Hayward, Coast Range-Central Valley, Concord, and San Andreas faults also present significant potential for strong ground shaking within the region. Ground motion parameters for seismic sources are presented in Table 13-4.

Some types of substation equipment are susceptible to damage from earthquake shaking. PG&E has reviewed historical substation damage to determine the vulnerabilities of each specific type of equipment. The review included immediate visits to substations following past earthquakes. PG&E personnel were in Los Angeles and Japan reviewing substation damage shortly after the recent Northridge and Kobe earthquakes. Damage has been found to vary dramatically with voltage, with extensive damage to 500 kV substations, significant damage to 230 kV substations, and minor damage to equipment in voltage classifications of 115 kV and below. The most susceptible types of equipment to earthquake shaking damage are transformer radiators and bushings, circuit breakers, circuit switchers, and disconnect switches. The Institute of Electrical and Electronics Engineers (IEEE) 693 “Recommended Practices for Seismic Design of Substations” has specific requirements to mitigate damage that substation equipment has been subjected to in the past. These design guidelines will be implemented during substation construction. Substation equipment will be purchased using the seismic qualification requirements in IEEE 693. When these requirements are followed, very little structural damage from horizontal ground accelerations approaching 1.0 gravity (g) is anticipated. Substation control buildings will be designed in accordance with the Uniform Building Code. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geological hazards. Potential impacts would be less than significant, and mitigation is not required.

Generally, transmission lines, power lines, and pole lines can accommodate strong ground shaking and moderate ground deformations. In fact, wind loading design requirements are generally more stringent than are those designed to address strong seismic shaking. The potential impact from seismic ground shaking on transmission lines would be less than significant, and mitigation is not required.

Impact 13.12. Liquefaction and Seismic Ground Failure. Liquefaction is a process whereby strong ground shaking causes loose, saturated, unconsolidated sediments to lose strength and behave as a fluid. This subsurface process can cause ground deformation at the surface, including lateral spreading and differential compaction or settlement and sand boils. Loss of bearing strength and ground movements associated with liquefaction may result in damage to project facilities.

The potential for liquefaction is generally low within most of the project area. Soils in the area most susceptible to liquefaction include stream channel deposits found within and around the mouths of valleys in the hills and the margins of the Livermore Valley. Two instances of ground cracking were observed in the northern Livermore Valley following the 1906 San Francisco earthquake (Youd and Hoose, 1978) and no cases of ground failure were reported within the project area as a result of the 1989 Loma Prieta earthquake (Holtzer, 1990). A design-level geotechnical investigation will be performed to evaluate the liquefaction potential of soils underlying substation, transition station, transmission tower, and underground transmission line sites. Analysis of existing data will analyze the possibility of liquefaction, and develop appropriate engineering design and construction measures. These measures could include pile foundations, ground improvements of liquefiable zones, flexible bus connections, and slack in underground cables to allow ground deformations without damage to structures. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to geological hazards. Potential impacts would be less than significant, and mitigation is not required.

TABLE 13-4
Estimated Peak Horizontal Ground Accelerations on Rock at Proposed Substation and Transition Structure Sites

Site	Causative Fault	MCE[1] (M_W)	Approximate Distance From Fault (Miles)	Approximate Distance From Fault (Km)	PGA Rock[2] (g)
Dublin Substation	Pleasanton	6.2	3	5	0.43
Dublin Substation	Calaveras	7.2	5	8	0.46
Dublin Substation	Greenville	7.0	5	8	0.44
North Livermore Substation	Greenville	7.0	2	4	0.65
North Livermore Substation	Calaveras	7.2	9	15	0.28
Vineyard Substation	Verona	6.2	2	3	0.60
Vineyard Substation	Calaveras	7.2	3	5	0.60
Transition Structure	Verona	6.2	1	2	0.68
Transition Structure	Calaveras	7.2	3	5	0.60

[1] MCE = Maximum Credible Earthquake (moment magnitude, M_W), preferred value as estimated from Caltrans (1996), Wesnousky (1986), and CDMG (1996).

[2] PGA = Peak Horizontal Ground Acceleration for a rock/stiff soil site, estimated from Abrahamson and Silva (1997) and Idriss (1994) attenuation relationships. 1.0 g is equal to the acceleration of gravity, 32 ft/s^2 or 9.8 m/s^2

13.4 Mitigation Measures

13.4.1 Construction

Mitigation Measure 13.1. Paleontologic Resources. If fossils are encountered during construction, a qualified paleontologist will be contacted to examine the find and to determine its significance. If the find is deemed to have scientific value, the paleontologist and PG&E will devise a plan to either avoid impacts or to continue construction without disturbing the integrity of the find (for example, by carefully excavating the material containing the resources).

13.4.2 Operation

Because significant impacts during operation of the project have not been identified, mitigation measures are not required.

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