Chapter 10—Geology and Mineral Resources

10.1 Introduction

This chapter describes existing geological and soil conditions; associated potential geologic, seismic, and geotechnical hazards; and potential paleontological and mineral resources. It then describes potential impacts and proposed mitigation measures for the Project.

The Project is located in a seismically active area and portions of the Project Area have underlying young geologic deposits. Geologic and seismic hazards with the greatest potential impact to the Project include slope instability, fault surface rupture, strong ground shaking, and seismic-induced ground failure. Geotechnical hazards with the greatest potential impact to the Project include expansive, soft, loose, and/or compressible soils; corrosive soils; ground settlement and/or subsidence; and erosion. Additionally, high groundwater levels, unstable soil conditions, settlement, and erosion may affect underground portions of the proposed Project and adjacent facilities during excavation, grading, and backfill operations associated with Project construction. Impacts associated with erosion and high groundwater levels are addressed in Chapter 9, Hydrology and Water Quality.

Design-level geotechnical investigations and appropriate engineering and construction measures will eliminate or reduce potential impacts of geologic and geotechnical hazards to a less-than-significant level.

10.1.1 Methodology

Existing conditions were evaluated following a review of available published and unpublished literature, as referenced at the end of this chapter. Descriptions of geologic units in the Project Area are derived from published sources including:

- 1:24,000-scale geologic mapping of the Montara Mountain and San Mateo 7.5-minute quadrangles (Pampeyan 1994)
- 1:24,000-scale geologic mapping of the San Francisco South and part of the Hunters Point 7.5-minute quadrangles (Bonilla 1998)
- 1:62,500-scale geologic mapping of onshore portions of San Mateo County (Brabb, et al. 1998)

Soil locations and descriptions were obtained from maps and reports prepared by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NCRS, formerly known as the Soil Conservation Service) and published as a soil survey of San Francisco County and the eastern part of San Mateo County (Kashiwagi and Hokholt 1991). Information on mineral resources in the Project Area was obtained from reports and maps published by the United States Geological Survey (USGS) and State of California Division of Mines and Geology (CDMG), now known as the California Geological Survey (Bailey and Harden 1975, and Stinson, et al. 1986).

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 (Brabb and Olson 1986; Hart 1981; and Jennings 1994). The locations of Alquist-Priolo Earthquake Fault Zones were obtained from maps and an index published by CDMG (CDMG 1974, 1982, and 2000) and fault descriptions and parameters were developed based on a variety of published sources (Blake 2001; Mualchin 1996; CDMG 1996; and others as referenced). In addition to these sources, information and conclusions presented in a geologic hazard evaluation prepared by PG&E for gas transmission lines in the City of San Bruno (PG&E 1992) were used to evaluate seismic hazards in the vicinity of the proposed transition station.

Evaluation of landslide, earth-flow, and debris-flow hazards in the Project Area was based on geologic mapping and published reports by USGS (Brabb and Pampeyan 1972; Ellen 1997; and Wentworth 1997). Liquefaction and liquefaction-induced ground failure hazards were identified according to documented occurrences of historical liquefaction (Youd and Hoose 1978, and Holtzer 1998), available liquefaction hazard maps (Youd and Perkins 1987, and Knudsen, et al. 1997 and 2000), and the locations of potentially liquefiable soil types from geologic and soil maps.

Potential geotechnical hazards were evaluated based on interpretation of available geologic maps, reports, and soil surveys. Potential geotechnical hazards during construction were evaluated based on the standard construction methods and procedures outlined in Chapter 2, Project Description. Limited information is available concerning local groundwater and subsurface soil profiles along the proposed transmission line alignment and at specific transition station and substation sites. Site-specific, design-level geotechnical investigations will be necessary to evaluate subsurface conditions that may affect construction, operation, and maintenance of Proposed Project facilities.

10.2 Existing Conditions

10.2.1 General Conditions

10.2.1.1 Topography

The Project Area is on the San Francisco Peninsula, in the west-central part of the Coast Range Province of California. 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 in the province and reflect both previous and existing regional tectonic regimes (Norris 1990).

The San Francisco Peninsula, bounded on the east by San Francisco Bay and on the west by the Pacific Ocean, belongs to the same topographic unit as the Santa Cruz Mountains, which extend approximately 80 miles in a southeasterly direction from San Francisco, at the northern end of the peninsula, to the Pajaro River, near Watsonville, California. Elevations on the peninsula range from sea level to approximately 2,400 feet at Sierra Morena, located approximately 4 miles southwest of the Jefferson Substation (all elevations presented relative to mean sea level [MSL]). From south to north along the Proposed Project route, major topographic features include the Crystal Springs and San Andreas valleys, coastal hills, San Francisco Bay flatlands, Colma Valley, San Bruno Mountain, and Visitacion Valley.

Segment 1 of the Proposed Project route begins at the Jefferson Substation, located at an elevation of approximately 520 feet near the southeast end of Crystal Springs Valley. From the Jefferson Substation, the alignment traverses hillsides and ridgelines along the eastern margins of the Crystal Springs and San Andreas valleys. The two valleys are elongated, northwest-trending depressions created by preferential erosion of broken and sheared rock in the San Andreas fault zone. The ridges and hills surrounding the Crystal Springs and San Andreas valleys are part of the coastal hills, which represent the northernmost extent of the Santa Cruz Mountains.

Three reservoirs, Upper Crystal Springs Reservoir, Lower Crystal Springs Reservoir, and San Andreas Lake, are located in the valleys. Upper and Lower Crystal Springs reservoirs primarily occupy the Crystal Springs Valley, which drains from southeast to northwest. San Andreas Lake occupies the San Andreas Valley, which drains in the opposite direction, from northwest to southeast. The two valleys meet near Crystal Springs Dam, where the natural drainage route turns sharply to the northeast. Downstream of the dam, San Mateo Creek flows through a narrow, steep-sided gap in the coastal hills to the San Francisco Bay.

Floor elevations in the Crystal Springs and San Andreas valleys range from approximately 400 feet at the southeast end of the Crystal Springs Valley and 450 feet at the northwest end of the San Andreas Valley to approximately 150 feet at the base of Crystal Springs dam. The spillway elevation for the Upper and Lower Crystal Springs reservoirs is 284 feet and the spillway elevation for San Andreas Lake is 450 feet. Ridgetop elevations along the west side of the Crystal Springs and San Andreas valleys generally range from approximately 1,000 to 1,200 feet, while ridgetop elevations along the east side of the valleys are significantly lower, ranging from approximately 500 to 800 feet.

Near the northwest end of the San Andreas Valley (approximately milepost [MP] 14.7), the Segment 1 alignment turns northeastward and down the east-facing slopes of the coastal hills to the San Francisco Bay flatlands. The flatlands, occupying a broad alluvial plain between the coastal hills and tidal marshland along the margins of San Francisco Bay, are highly urbanized and range in elevation from sea level to approximately 100 feet. Segment 1 ends in the flatlands near the mouth of Colma Valley.

Segments 2, 3, and 4 of the Project route follow the Colma Valley in a northwesterly direction from the San Francisco Bay flatlands to the southern slopes of San Bruno Mountain near the head of the valley. The Colma Valley, which is approximately 2 to 3 miles wide, is a gently sloping basin bounded by the coastal hills to the southwest and by San Bruno Mountain to the north. Runoff collected in the valley flows to San Francisco Bay through Colma Creek, which is confined to an open concrete channel for most of its length. Elevations along the central trough of the valley range from near sea level to approximately 200 feet at the drainage divide, near the headwaters of Colma Creek.

Segment 5 of the Project route begins near the head of Colma Valley and follows a small canyon up and around the west and north sides of San Bruno Mountain, which rises to an elevation of approximately 1,300 feet. Descending from a maximum elevation of approximately 725 feet on the north side of San Bruno Mountain, the alignment follows a northern ridge of the mountain eastward, towards San Francisco Bay. Near the eastern end of the ridge, at an elevation of approximately 100 feet, the alignment turns to the north and descends to the Martin Substation, located at the mouth of Visitacion Valley near the margins of the bay. The elevation at the Martin Substation, approximately 10 feet, is the lowest encountered along the Proposed Project route.

10.2.1.2 Geology

Geologic Structure

The San Francisco Bay region is located along the complex boundary margin between two tectonic plates: the North American Plate and the Pacific Plate. As a result, geologic conditions in the Project Area have been and continue to be primarily controlled by the interaction of these two massive blocks of the earth’s crust. 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 (De Mets et al. 1990). Within the past several million years, a shift to slightly oblique movement between the two plates has led to formation of the northwest-oriented mountains of the Coast Ranges. Relative movement between the North American and Pacific Plates at the latitude of the San Francisco Bay region is accommodated by predominantly strike-slip motion along a number of major faults, including the San Andreas, San Gregorio, Hayward, and Calaveras faults. In addition to these, countless other faults in the region accommodate relative motion between major faults and relieve compressional stresses along the plate boundary.

For much of its length, the San Andreas Fault is the boundary between basement rocks of the Franciscan Complex and the Salinian Block. However, on the San Francisco Peninsula, the boundary between Franciscan and Salinian basement rocks is marked by the Pilarcitos Fault, which, in the Project vicinity, runs roughly parallel to and several miles southwest of the San Andreas Fault. The Franciscan Complex, found northeast of the Pilarcitos Fault, is of Jurassic and Cretaceous age and consists of mafic and ultramafic basement rocks and sedimentary rocks that were deposited in a deep ocean environment and subsequently accreted to the western margin of the North American Plate. The Salinian Block, found southwest of the Pilarcitos Fault, is a continental block of Late Cretaceous granitic basement rock overlain by Cretaceous and Tertiary sedimentary and volcanic rocks. As the Project is located entirely northeast of the Pilarcitos Fault, basement rocks underlying the Project Area generally belong to the Franciscan Complex.

The San Francisco Bay, located east of the Project Area, occupies a Late Pliocene structural depression that has been flooded several times in response to Pleistocene glacial cycles. Sediment deposition within the basin now occupied by the bay has been strongly influenced by ocean-level fluctuations. During periods of glacial advance, sea levels were lower, leaving the basin dry and subject to alluvial deposition, stream channel erosion, and aeolian (wind-related) processes. During periods of glacial retreat, sea levels rose, flooding the basin and resulting in fluvial deposition of fine-grained sediments at the bottom of the bay. Flatlands, created by alluvial deposition of locally-derived sediments, are found between the bay margins and the surrounding hills. Historical development around the bay margins has included placement of artificial fill materials bayward of the natural shoreline, significantly altering the shoreline and reducing the size of the bay.

Within the Project Area, the Crystal Springs and San Andreas valleys are structurally controlled by the San Andreas fault zone, which runs along the bottom of both valleys. The valleys were created as highly sheared, fractured, and otherwise altered bedrock within the fault zone weathered and eroded more rapidly than surrounding, comparatively more intact materials. The Colma Valley occupies a structural trough, formed in bedrock of the Franciscan Complex, that extends in a northwesterly direction from San Francisco Bay to the Pacific Ocean. The bedrock trough is bounded by the northeastern side of the San Andreas fault zone and beneath the Project Area has an estimated maximum depth of approximately 1,500 feet (USGS 1997).

Surficial Deposits

Portions of Segment 1, all of Segments 2, 3, and 4, and portions of Segment 5 have underlying Quaternary and Late-Tertiary fill and alluvial and colluvial deposits. Quaternary and Upper Tertiary deposits include those of the following ages: Historic (formed in the past 200 years); Holocene (formed between 200 and 11,000 years ago); Pleistocene (formed between 11,000 and 1.6 million years ago); and Pliocene (formed between 1.6 and 5.3 million years ago). A majority of Segment 1, along eastern ridges of the Crystal Springs and San Andreas valleys, and portions of Segment 5, on the slopes of San Bruno Mountain, are on shallow residual soils and bedrock materials. Surficial geologic units in the Project vicinity, from youngest to oldest, are described in the following subsections.

Artificial Fill (Historic)

Artificial fill materials encountered within the Project Area include loose to very well-consolidated gravel, sand, silt, clay, rock fragments, organic matter, and man-made debris in various combinations. The thickness of artificial fill materials is variable and may exceed 100 feet in some areas. Some fill materials are well compacted and firm, but fill placed before 1965 is typically not compacted and consists of dumped materials (Brabb, et al. 1998). Artificial-fill materials in the Project Area take the form of roadway embankments, graded building pads for hillside development, and materials placed to raise the elevation of lowlands along the margins of the San Francisco Bay.

Geologic and soil mapping within the Project Area indicates that much of the Project route has underlying artificial-fill materials or native soils that have been otherwise mechanically altered by historic earthwork operations. Artificial-fill materials are primarily found along Segment 1 of the Project route in the form of roadway embankments associated with Highway 280, Skyline Boulevard, and San Bruno Avenue. Where the alignment crosses or follows these roadways, it is likely that artificial-fill materials will be encountered in upper levels of the subsurface profile.

Because Segments 2, 3, and 4 are primarily located along existing transportation corridors within a highly urbanized environment, it is likely that they are predominantly underlain by artificial fill or mechanically-altered earth materials. Although portions of Segment 5 traverse areas that are less urbanized than those found elsewhere, the entire segment follows existing roadways and therefore is likely to have underlying fill materials for much of its length.

Along Segment 5, between MP 4.0 and the Martin Substation, artificial-fill materials are mapped beneath the Project route. In this area, it appears that earthfill has been placed to raise the elevation of lowlands along the margins of the San Francisco Bay. As a result, artificial-fill materials in this area may have underlying marshland, mudflat, or other soft-bay deposits.

Stream-Channel Deposits (Historic or Holocene)

Natural stream-channel deposits generally consist of poorly- to well-graded sand, silt, silty sand, or sandy gravel with minor cobbles. Many of the stream channels identified within the Project Area have been straightened, channelized, and/or otherwise modified with various engineering works, as described in Chapter 9, Hydrology and Water Quality. Where stream channels have been relocated, channel deposits may be encountered along the route of the original channel. Stream-channel deposits mapped within the Project Area are typically localized and confined to a relatively narrow band along natural-drainage paths.

Significant streams and associated stream-channel deposits crossed by the Project route include San Mateo Creek near MP 7 of Segment 1; an unnamed creek or drainage channel near MP 1.4 of Segment 2; and Colma Creek, near MP 2.4 of Segment 2. Between MP 2.4 and the end of Segment 2, the alignment runs roughly parallel and adjacent to the existing Colma Creek channel and may overlie natural-channel deposits. Various minor-stream channels are crossed by the Segment 1 alignment in the hills above the Crystal Springs and San Andreas valleys, and by the Segment 5 alignment around the west and north slopes of San Bruno Mountain.

Bay Mud (Holocene)

Bay mud consists of water-saturated, estuarine mud underlying the marshlands and tidal mudflats of the San Francisco Bay. Generally composed of soft and silty clays, bay mud also typically contains lenses of fine sand and peaty material. Bay mud is not mapped as a surficial material along the Project route; however, along Segment 5 between MP 4 and the Martin Substation, bay-mud deposits may underlie mapped artificial-fill materials.

Alluvial-Fan and Fluvial Deposits (Holocene)

Alluvial-fan and fluvial deposits generally contain brown or tan, medium-dense to dense, gravelly sand or sandy gravel grading to sandy or silty clay. Within the Project Area, alluvial and fluvial deposits are typically found adjacent to natural-stream channels and range in thickness from several feet to several hundred feet beneath the lowlands bordering the San Francisco Bay.

Along Segment 1, minor alluvial deposits are mapped crossing the alignment between MP 2.0 and MP 3.0. The largest mapped area of Holocene alluvial fan and fluvial deposits along the Project route is found in the Colma Valley, adjacent to Colma Creek. Segment 2, between MP 1 and the end of the segment, is predominantly underlain by these deposits. The Martin Substation, at the end of Segment 5, is also underlain by mapped Holocene alluvial and fluvial deposits.

Colluvium (Holocene)

Slope-wash and ravine fill are classified as colluvial-type deposits, which consist of loose sediments at the foot of a slope brought there principally by gravity and slope wash. Holocene colluvium within the Project Area generally consists of loose-to-firm, friable, and unsorted sand, silt, clay, gravel, rock debris, and organic material in varying proportions. Within the Project Area, colluvial deposits are mapped along Segment 5 of the alignment on the northern slopes of San Bruno Mountain.

Colma Formation – Shallow Marine and Subaerial Dune Deposits (Pleistocene)

The Colma formation, formed under shallow marine and subaerial dune conditions during the late Pleistocene (between 70,000 and 130,000 years ago), is found in the Colma Valley and surrounding flatlands. Within the valley, Colma formation deposits typically consist of weakly-consolidated and friable sand with some sandy silt, clay, and gravel. In flatland areas south of the Colma Valley, deposits of the Colma formation generally consist of sandy clay and silty sand. The total thickness of the formation is unknown, but probably exceeds 100 feet (Pampeyan 1994).

Aside from alluvial and fluvial deposits mapped along Segment 2 between MP 1.0 and the end of the segment, deposits of the Colma formation are mapped under the entire Project route between MP 15.5 of Segment 1 and MP 0.3 of Segment 5.

Santa Clara Formation (Lower Pleistocene and Upper Pliocene)

Mapped in the Crystal Springs Valley south of Upper Crystal Springs Reservoir, the Santa Clara formation typically consists of well-graded, moderately consolidated conglomerate and pebbly-to-cobbly sand, silt, and clay (Pampeyan 1994). Deposits of the Santa Clara formation are not mapped along the Project route, but are found immediately west of the Jefferson Substation.

Merced Formation (Lower Pleistocene and Upper Pliocene)

The Merced formation, formed under shallow-marine and intertidal conditions, typically consists of yellowish-gray, medium- to very-fine-grained, poorly-indurated to friable sandstone, siltstone, and claystone, with some conglomerate lenses and a few friable beds of white-volcanic ash. Beds of the Merced formation have been deformed by folding and faulting and now dip primarily to the northeast at moderate to steep angles.

Based on available geologic maps, the Merced formation is exposed and underlies artificial-fill materials in the coastal hills between Highway 280 and Skyline Boulevard. In this area, outcrops of the Merced formation are mapped underlying Segment 1 of the alignment, between MP 14.9 and MP 15.5. Relatively minor outcrops of the Merced formation are also mapped underlying the Segment 1 alignment near MP 9.0 and MP 14.0.

Bedrock

Shallow- or outcropping-bedrock units are found along the ridges and hillsides east of the Crystal Springs and San Andreas valleys and on the slopes of San Bruno Mountain. In most of these areas, bedrock is typically encountered within several feet of the ground surface and is overlain by a mantle of weathered rock and residual soil materials. Mapped bedrock formations (Brabb, et al. 1998) underlying proposed Project components are as follows.

Whiskey Hill Formation (Middle and Lower Eocene)

The Whiskey Hill formation, mapped near the southern end of Crystal Springs Valley, is composed of light-gray to buff, coarse-grained, arkosic sandstone, silty claystone, glauconitic sandstone, and tuffaceous siltstone. The formation is traversed by Segment 1 of the Project route, between MP 2.2 and MP 3.4.

Unnamed Sandstone (Cretaceous or Jurassic)

The slopes of San Bruno Mountain are underlain by dark-gray to yellowish-brown graywacke sandstone, interbedded with shale in roughly equal amounts. The unnamed sandstone materials resemble graywacke units of the Franciscan Complex, but have better developed bedding features. A majority of Segment 5, between MP 0.3 and MP 4.2, is underlain by this unnamed sandstone formation.

Rocks of the Franciscan Complex (Cretaceous or Jurassic)

The Franciscan Complex contains a heterogeneous assemblage of deep-sea sediments and related oceanic crustal rocks of Mesozoic age (65 to 200 million years old). Accreted to the western margin of the North American Plate through tectonic subduction, the complex is highly disrupted, much of it having been mixed into a melange of different materials. The Franciscan Complex consists predominantly of graywacke sandstone interbedded with lesser amounts of dark shale. Outcrops of submarine basalt (greenstone), limestone, chert, and metamorphic blueschist are also contained within the complex.

Within the Project Area, the most common Franciscan unit is sheared rock, or melange, predominantly consisting of graywacke, siltstone, and shale. Substantial portions of the unit have been sheared, although hard blocks of all Franciscan rock types have been identified. Franciscan sheared rock is mapped on the hillsides and ridges east of the Crystal Springs and San Andreas valleys. Numerous outcrops of Franciscan greenstone (dark-green to red, altered basaltic rocks) and Franciscan sandstone (greenish-gray graywacke sandstone with interbedded siltstone and shale) are found within the sheared rock unit.

Rocks of the Franciscan Complex, particularly those belonging to the sheared rock or melange unit, are mapped underlying much of the Segment 1 alignment between the Jefferson Substation and the proposed overhead-to-underground transition station near MP 14.7. Portions of the alignment underlain predominantly by the sheared rock unit are found between MP 0.8 and MP 2.2; MP 3.4 and MP 5.0; MP 6.7 and MP 7.2; and MP 11.0 and MP 13.5. The Franciscan sandstone unit is mapped underlying Segment 1 of the alignment from MP 14.0 to MP 14.9, including the area underlying the proposed transition station.

Serpentinite (Cretaceous and/or Jurassic)

The Franciscan Complex mapped within the Project Area includes serpentinite and associated ultramafic rocks. Serpentinite refers to rocks consisting predominately of serpentine minerals that formed from the shearing and alteration of ultramafic igneous rocks (peridotite and dunite). Two varieties of serpentinite occur and are mapped in the Project Area. “Blocky serpentinite” consists of dark-green to black, hard, moderately-fractured and serpentinized ultramafic rocks. “Sheared serpentinite” consists of light greenish-gray to bluish-green, highly sheared, and completely serpentinized ultramafic rock. Outcrops of sheared serpentinite commonly include blocks and inclusions of ultramafic rocks, silica-carbonate rock, and other metamorphic rocks (Brabb, et al. 1998).

Almost all serpentinite masses contain the fibrous serpentine mineral chrysotile. The chrysotile asbestos minerals occur as visible and microscopic fracture-filling, cross-fiber veins in blocky and sheared serpentinite. The occurrence and distribution of chrysotile asbestos can vary widely within serpentinite outcrops. Serpentinite also contains the other serpentine mineral, antigorite, a light-green, fine-grained platy mineral.

Next to Franciscan sheared rock, serpentinite is the second-most-common rock unit mapped along hillsides and ridges east of the Crystal Springs and San Andreas valleys. Based on available geologic maps, portions of the Segment 1 alignment underlain predominantly by serpentinite materials are found between MP 0.2 and MP 0.8; MP 5.0 and MP 6.7; MP 7.2 and MP 8.8; and MP 9.4 and MP 11.0.

Subsurface Deposits

The composition of subsurface soils may vary, depending on location, deposition, formational history, and mechanical alteration. Subsurface deposits are highly variable across the Project Area, because valley and flatland sediments may extend hundreds of feet deep and hilly regions may have little or no soil cover. The presence of artificial-fill materials, which are particularly inconsistent in both composition and material characteristics, also contributes to a high level of variability in subsurface conditions across the Project Area.

A field investigation to assess soil properties at specific substation and transmission-line locations has not been performed for this Project. However, a design-level geotechnical investigation will be performed to evaluate site-specific subsurface conditions along the proposed Project route as part of the design and construction of Project facilities. Geotechnical field investigations generally include one or more of the following activities: soil borings, test pits, cone penetrometer testing, geophysical surveys, and/or laboratory testing of soil samples.

Soils

Soils are the byproduct of physical and chemical weathering of rock and alluvial deposits. They consist of mineral and organic matter and are created through physical, chemical, and biological processes. The USDA NRCS prepares and maintains soil surveys that classify soil characteristics and their suitability for agriculture and development. Nineteen individual soil units, including combinations of one or more distinct soil types and slope conditions, are mapped by NRCS in the Project Area.

Published soil descriptions are limited to a depth of five to six 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 soil profiles. As a result, soil conditions in developed areas may be highly variable.

Although the nineteen soil units mapped within the Project Area are composed of thirteen distinct soil types, approximately 90 percent of the Project route is underlain by only four soil types: Orthents, Urban soils, Fagan loam, and Los Gatos loam. Mapped soil units in the Project Area, including constituent soil types, are shown on Table 10-1. A description of soil types and relevant properties are shown on Table 10-2. Soil properties of particular interest include shrink-swell, erosion, slippage, and corrosion potential, as these properties may impact proposed Project facilities. In addition, the relative density or consistency of the soil, which can also be highly variable across a site, can also impact proposed Project facilities. In particular, the presence of soft or loose soils may impact design parameters and construction methods.

TABLE 10-1
Mapped Soil Units in the Project Vicinity

Map Units	Constituent Soil Types and Approximate Percentages
Barnabe-Candlestick Complex, 30 to 75 Percent Slopes	Barnabe Series (45%) Candlestick Series (35%) Others (20%)
Barnabe-Rock Outcrop Complex, 15 to 75 Percent Slopes	Barnabe Series (40%) Rock Outcrop (40%) Others (20%)
Candlestick-Kron-Buriburi Complex, 30 to 75 Percent Slopes	Candlestick Series (40%) Kron Series (25%) Buriburi Series (20%) Others (15%)
Candlestick Variant Loam, 2 to 15 Percent Slopes	Candlestick Variant (90%) Others (10%)
Fagan Loam, 15 to 50 Percent Slopes	Fagan Series (85%) Others (15%)
Los Gatos Loam, 30 to 75 Percent Slopes	Los Gatos Series (85%) Others (15%)
Maymen Gravelly Loam, 30 to 50 Percent Slopes	Maymen Series (85%) Others (15%)
Obispo Clay, 5 to 15 Percent Slopes	Obispo Series (75%) Others (25%)
Obispo Clay, 15 to 30 Percent Slopes	Obispo Series (75%) Others (25%)
Orthents Cut and Fill, 0 to 15 Percent Slopes	Orthents Cut and Fill (95%) Others (5%)
Orthents Cut and Fill, 15 to 75 Percent Slopes	Orthents Cut and Fill (95%) Others (5%)
Orthents Cut and Fill—Urban Land Complex, 0 to 5 Percent Slopes	Orthents Cut and Fill (55%) Urban Soils (35%) Others (10%)
Orthents Cut and Fill—Urban Land Complex, 5 to 75 Percent Slopes	Orthents Cut and Fill (50%) Urban Soils (35%) Others (15%)
Sirdrak Sand, 5 to 50 Percent Slopes	Sirdrak Series (90%) Others (10%)
Typic Argiustolls—Loamy Urban Land Association, 5 to 15 Percent Slopes	Typic Argiustolls (50%) Urban Soils (30%) Others (20%)
Urban Land	Urban Soils (85%) Others (15%)
Urban Land—Orthents Cut and Fill Complex, 0 to 5 Percent Slopes	Urban Soils (50%) Orthents Cut and Fill (45%) Others (5%)
Urban Land—Orthents Cut and Fill Complex, 5 to 75 Percent Slopes	Urban Soils (50%) Orthents Cut and Fill (40%) Others (10%)
Urban Land—Orthents Smoothed Complex, 5 to 50 Percent Slopes	Urban Soils (65%) Orthents Smoothed (25%) Others (10%)

TABLE 10-2
Soil Types Mapped in the Project Vicinity

Soil Type	Approximate Percentage	Location	Erosion Potential	Shrink-Swell Potential	Slippage Potential	Corrosion Potential
Barnabe Series	< 5	SBM	high to very high	low	not rated	moderate
Buriburi Series	< 1	SBM, Hilltops East of SAR	high to very high	low	not rated	moderate
Candlestick Series	< 5	SBM, Hilltops East of SAR	high to very high	low to moderate	high	moderate
Candlestick Variant	< 1	Valley South of UCSR	slight to moderate	moderate	not rated	moderate
Fagan Series	30	Hillsides East of SAFZ	high to very high	high	moderate	moderate
Kron Series	< 1	SBM, Hilltops East of SAR	high to very high	low	not rated	moderate
Los Gatos Series	5	Ridges and Uplands East of SAFZ	high to very high	low to moderate	not rated	moderate
Maymen Series	< 1	Ridges and Uplands East of SAFZ	high	low	not rated	high
Obispo Series	< 5	Hillsides East of SAFZ	slight to moderate	moderate	not rated	low to moderate
Orthents (Cut and Fill, Smoothed)	40	Hwy 280, West-Facing Hills East of SAFZ, Flatlands, Colma Valley	slight to very high	not rated	not rated	not rated
Sirdrak Series	< 1	SBM	moderate to high	low	not rated	moderate
Typic Argiustolls	< 5	SBM	moderate	moderate to high	not rated	not rated
Urban Soils	15	West-Facing Hills East of SAFZ, Flatlands, Colma Valley	not rated	not rated	not rated	not rated

SBM	San Bruno Mountain
SAR	San Andreas Reservoir
LCSR	Lower Crystal Springs Reservoir
UCSR	Upper Crystal Springs Reservoir
SAFZ	San Andreas Fault Zone
nr	not rated

Orthents Soils

Orthents soils, mapped underlying approximately 40 percent of the Project route, consist of soils that have been mechanically altered as a result of earthwork activities. Earthwork operations, including cut, fill, and other grading work, have been performed in the Project Area for roadway construction, landscaping, and urban development. Because they consist of soil materials derived from both local and outside sources and have been constructed by mechanical means, Orthents soils are highly variable in depth, texture, and material properties. They are typically well drained, with moderate to high erosion potential dependent on the degree of slope.

Often found in conjunction with Urban soils, Orthents are predominantly found along the Highway 280 corridor, ridgelines east of the Crystal Springs and San Andreas valleys, the flatlands west of the San Francisco Bay, and the Colma Valley. Orthents soils are mapped underlying the proposed transition-station location, near MP 14.7 of Segment 1.

Urban Soils

Urban soils, underlying areas designated as Urban land by the NRCS, are mapped along approximately 15 percent of the Project route and are mostly covered by asphalt, concrete, buildings, and other structures. Within the Project Area, Urban soils are primarily encountered in the highly-urbanized flatlands east of the San Francisco Bay and within the Colma Valley. Locally, Urban soils may be expected to underlie portions of the alignment that run beneath existing roadways, which includes Segment 1 from MP 14.7 to the end, Segment 2 between MP 0.0 and MP 0.3, and all of Segments 3, 4, and 5. Soils underlying areas designated as Urban land are typically similar to Orthents soils, although in some cases, soils underlying roadways and other paved areas may be similar to natural soils found nearby.

Fagan Loam

Fagan loam is the most common naturally-occurring soil within the Project Area, underlying approximately 30 percent of the Project route. Typically 40 to 60 inches thick, soils described as Fagan loam were formed in material weathered from soft sandstone and shale. They are generally well drained, with low permeability and high water capacity. Fagan-loam soils also generally have high to very-high erosion potential, high shrink-swell potential, low strength, and are susceptible to slippage when wet. Primarily mapped on west-facing hillsides within the Crystal Springs and San Andreas valleys, Fagan loam underlies approximately 60 percent of the Segment 1 alignment. It is not mapped in the vicinity of other Project segments.

Los Gatos Loam

Los Gatos loam is mapped in upland areas east of the Crystal Springs and San Andreas valleys and underlies approximately 10 percent of the Segment 1 alignment. Formed in material weathered from hard, fractured sandstone, soils described as Los Gatos loam are moderately deep and well drained. Permeability is moderately low and available water capacity is low to moderate. Los Gatos loam soils generally have high to very high erosion potential.

Other Soil Types

According to NRCS mapping, approximately 10 percent of the Project route is underlain by a variety of natural soil types other than those discussed above. These minor soil types are found in relatively small and/or discontinuous patches along the ridges and hillsides east of Crystal Springs and San Andreas valleys and on the slopes of San Bruno Mountain. On hillsides, these soils typically have high to very high erosion potential and some of the deeper soil profiles are susceptible to slippage when wet. Moderate-to-high shrink-swell potential has also been identified in a number of the minor soil types. On some slopes, shallow or outcropping bedrock is common.

Mineral Resources

Non-metallic mineral commodities, consisting primarily of broken- and crushed-rock products, represent the most significant mineral resource on the San Francisco Peninsula. Commercial rock quarries, both active and abandoned, are identified on the slopes of San Bruno Mountain and in the coastal hills surrounding the San Andreas and Crystal Springs valleys. Although low-grade chromite has been identified in serpentinitic rocks in the vicinity of Crystal Springs Reservoir, no economic deposits of metallic minerals are known to exist within the Project Area (Pampeyan 1994).

The California Division of Mines (CDMG) and Geology has classified the regional significance of mineral resources in accordance with the California Surface Mining and Reclamation Act of 1975 (SMARA). Mineral Resource Zones (MRZs) delineated by CDMG identify the presence and significance of mineral deposits within the Project Area. MRZ categories, as defined by the CDMG, are as follows:

- **MRZ-1.** Areas where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence
- **MRZ-2.** Areas where adequate information indicates that significant mineral deposits are present, or where it is judged that a high likelihood exists for their presence
- **MRZ-3.** Areas containing mineral 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
- **SZ.** Areas containing unique or rare occurrence of rocks, minerals, or fossils that are of outstanding scientific significance

Peninsula Watershed lands of the San Francisco Public Utilities Commission (SFPUC) were not classified for mineral resources by CDMG because at the time of the classification study they were not considered to be under pressure to urbanize and were neither actively urbanizing nor located in a specific area approved by the State Mining and Geology Board. As a result, much of the Segment 1 alignment between MP 2.0 and MP 14.9 has not been zoned for mineral resources.

Within the Project Area, areas classified as MRZ-1 are identified between MP 15.4 and the northern end of Segment 1; along all of segments 2, 3, and 4; and between MP 0.00 and MP 0.5 of Segment 5. Areas classified as MRZ-3 are identified along Segment 1 between MP 0.0 and MP 2.0, MP 5.2 and 6.0, and MP 14.9 and 15.4. Areas classified as MRZ-4 or located within unclassified watershed areas comprise a significant majority of the Segment 1 alignment between MP 2.0 and MP 14.9. No areas classified as SZ are mapped within the Project Area.

Areas classified as MRZ-2, which comprise the most economically viable mineral sources in the Project Area, are identified along or adjacent to Segment 5 of the alignment, between MP 0.0 and MP 3.9. Sandstone materials have been quarried from this area, which encompasses virtually all of San Bruno Mountain, since the late 1800’s (Stinson, et al. 1986). Quarry operations currently operate on the northern side of the mountain, approximately one half mile south of the Project route.

Paleontology

Based on a review of vertebrate and invertebrate locality data from the University of California Museum of Paleontology (UCMP), fossils have been found within a number of rock formations located on the San Francisco Peninsula. Within the Project Area, fossils are particularly common in the Merced formation, which is mapped underlying Segment 1 of the alignment, between MP 14.9 and MP 15.5. Weakly-consolidated deposits of the Colma formation, mapped underlying much of the alignment between the north end of Segment 1 and the south end of Segment 5, are also known to be fossil-bearing (Pampeyan 1994). Fossils are generally uncommon or not present in other rock formations within the Project Area.

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 10-3. A 1999 estimate, made by the Working Group on California Earthquake Probabilities (WGCEP 1999), gave a 70 percent probability for one or more magnitude 6.7 or greater earthquakes to occur within the Bay Area in the 30-year period between 2000 and 2030. Therefore, it is likely that the Project will experience periodic minor to moderate earthquakes and potentially a major earthquake (magnitude 7.0 or greater) during its service life.

TABLE 10-3
Significant Historic Earthquakes Affecting the Project Vicinity

Date	Locality, Fault Name in parenthesis (if known)	Magnitude[a]	Approximate Distance from Project Area[b]	
			miles	km
1989/10/17	Loma Prieta (San Andreas)	6.9	30	50
1984/04/24	Morgan Hill (Calaveras)	6.2	50	80
1957/03/22	Daly City (San Andreas)	5.3	< 5	< 8
1911/07/01	Calaveras Fault	6.5	40	65
1906/04/18	San Francisco (San Andreas)	7.8	0	0
1898/03/31	Mare Island	6 1/2	30	50
1890/04/24	Pajaro Gap	6 1/4	50	80
1884/03/26	Santa Cruz Mountains	6	< 40	< 65
1870/02/17	Los Gatos	6	30	50
1868/10/21	Hayward Fault	7	15	25
1865/10/08	Southern Santa Cruz Mountains	6 1/2	< 40	< 65
1864/02/26	Southern Santa Cruz Mountains	6	< 40	< 65
1858/11/26	San Jose Region (Mission?)	6 1/4	< 40	< 65
1856/02/15	San Francisco Peninsula	5 3/4	< 10	< 15
1838/06/--[c]	San Francisco Peninsula	7	0	0
1808/06/21	San Francisco Region	6[c]	--[c]	--[c]

Notes:

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

[b] 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.

[c] Precise data is unavailable

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

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. Therefore, the seismic parameters presented and referenced in the text and tables of this chapter are defined as follows.

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. In this chapter, where possible, 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.

Maximum Credible Earthquake (MCE)

Geometric fault parameters are used to estimate the 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. Amount of acceleration, velocity, and displacement caused by the passage of seismic waves decrease with distance from the source, through attenuation. 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 models, 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 models 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 chapter, estimated peak ground accelerations were developed using published attenuation relationships (Abrahamson and Silva 1997, and 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 Area. Sites containing subsurface profiles other than rock and shallow soil require further investigation and analysis to estimate PGA at the ground surface.

Fault Classification and Zoning

Classification

Project Area faults shown on Figures 10-1 and 10-2 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 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 within 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). Pre-Quaternary age faults are classified as “inactive.” This classification is not meant to imply that inactive fault traces will not rupture, only that they have not been shown to have ruptured within the past 1.6 million years and that the probability of fault rupture is low.

Active and potentially-active faults within the Project limits and immediate vicinity have been mapped and documented by a number of government agencies. The USGS and CDMG have 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 10-4, which presents information on active and potentially-active faults within approximately 30 miles of the Project Area.

TABLE 10-4
Active and Potentially Active Faults in the Project Vicinity

Fault	Distance From Project Facilities[a] (miles)	Age[b]	Activity	MCE[c]
San Andreas	0	Historic	Active	7.9
Serra	0	Late Quaternary	Potentially Active	n/a[d]
Foothill Thrust	0	Quaternary	Potentially Active	n/a
Pilarcitos	2	Quaternary	Potentially Active	n/a
San Gregorio	6	Holocene	Active	7.3
Monta Vista - Shannon	15	Late Quaternary	Potentially Active	6.8
Hayward	15	Historic	Active	7.1
Calaveras	25	Historic	Active	6.8

Notes:
[a] Distance is measured from mapped traces of the fault to the nearest facilities associated with the Project
[b] From Jennings (1994)
[c] MCE: Maximum Credible Earthquake (moment magnitude, M_W), preferred value as estimated from Mualchin (1996) and CDMG (1996).
[d] n/a: not available

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. 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.”

To meet requirements of the Alquist-Priolo Special Studies Zones Act, “earthquake fault zone” boundaries have generally been established approximately 500 feet on either side of major, active fault traces and approximately 200 to 300 feet on either side of well-defined, minor fault traces. Exceptions to this general pattern of “earthquake fault zone” delineation periodically occur where faults are obscured, poorly located, locally complex, and / or not vertical. Because of these criteria for determining zone boundaries, an “earthquake fault zone” designated by CDMG for a particular fault may be wider than the actual fault zone occupied by traces of the fault. Conversely, due to specific zoning criteria, mapped fault traces not shown to be “sufficiently active” or “well-defined” may not be included within the designated Alquist-Priolo “earthquake fault zone.” Therefore, in some cases the actual zone of potential surface rupture may not be entirely included within the CDMG-designated “earthquake fault zone.”

Within the general Project vicinity, the San Andreas fault has an Alquist-Priolo Earthquake Fault Zone associated with it (CDMG 1974, 1982, 2000). The San Andreas Earthquake Fault Zone is shaded on Figures 10-1 and 10-2, which also show the approximate location of mapped fault traces. Due to zoning criteria, not all mapped traces of the San Andreas fault are included within the earthquake fault zone. Alquist-Priolo Earthquake Fault Zones are not associated with any of the other faults found within the Project Area.

Faults Within the Project Area

San Andreas Fault

The San Andreas fault zone, extending approximately 600 miles, from Mexico to the north coast of California, accommodates predominantly right-lateral movement between the Pacific and North American crustal plates. Rather than slipping along a single break in the Earth's surface, movement along the San Andreas fault typically occurs within a zone of multiple fractures. Where individual fractures within the fault zone are observed or inferred at the ground surface, they are mapped as fault traces. For much of its length through the two valleys, the fault zone underlies reservoir waters; however, where it is exposed, the zone of mapped faulting ranges from several hundred to several thousand feet wide.

Near the south end of the alignment, a mapped fault trace diverges eastward from the main trace of the San Andreas fault. This divergent trace has been referred to as the Cañada trace of the San Andreas fault; however, the trace is also roughly coincident with the northern half of the Hermit fault, a thrust fault mapped for approximately 15 miles in a southeastern direction from the southern end of Upper Crystal Springs Reservoir (Brabb and Olson 1986). Based on a review of available literature, the nature of the Cañada trace, as a branch of the San Andreas Fault or as a zone of thrust faulting associated with the Hermit fault, is unclear. Evidence of fault rupture along the Cañada trace was not reported following the 1906 earthquake; however, an Alquist-Priolo Earthquake Fault Zone has been established for the Cañada trace, indicating that it is considered to be active by CDMG (CDMG 1974). It should be noted that, based on recent and ongoing studies, Robert H. Wright, the Geologist for the Town of Woodside, has indicated that the geologic unconformity that has been mapped as the Cañada and Hermit Faults may be irregular erosion surface and not a fault. (Personal communication between James C. Gamble / PG&E and Robert H. Wright / Town of Woodside).

Historical earthquakes along the Peninsula segment of the San Andreas fault zone in 1838 and 1906 resulted in surface rupture near the Project Area. Following the 1906 earthquake, measured ground deformations on the San Francisco Peninsula ranged from approximately 9 feet of right-lateral slip across a single fault trace to a total of approximately 17 feet of combined slip and ground distortion across the entire fault zone (Brabb and Olson 1986). Analysis of ground-deformation data from locations near San Andreas Lake by Pacific Gas and Electric Company (PG&E 1992) indicates that all significant ground deformation during the 1906 event occurred within approximately 450 feet of the main fault trace.

As shown on Figure 10-1, portions of the Segment 1 alignment are located within the Alquist-Priolo Earthquake Fault Zone associated with the San Andreas Fault. Portions of the Segment 1 alignment that are located within the Alquist-Priolo Earthquake Fault Zone include the Jefferson Substation at MP 0.0, the transmission line alignment between MP 12.5 and MP 14.9, and the proposed overhead-underground transition station near MP 14.7.

INSERT FIGURE 10-1

(2 pages)

10-1 CONTINUED

FIGURE 10-2
(2pgs)

FIGURE 10-2

Mapped fault traces, both within and outside the CDMG-designated “earthquake fault zone,” also intersect or closely approach the proposed alignment. The Cañada trace of the San Andreas fault is mapped within 100 feet of the Jefferson Substation. Between approximately MP 14.1 and MP 14.9, Segment 1 of the proposed alignment crosses the main trace of the 1906 rupture and several other mapped traces within the fault zone. Near MP 14.7, the parcel on which the proposed transition station is located is transected by several mapped traces of the San Andreas fault, including the main (1906) and lesser associated traces.

Serra Fault

Traces of the Serra fault, as shown on Figures 10-1 and 10-2, are mapped roughly parallel to and approximately ½ to 1 mile east of the San Andreas Fault Zone between the cities of Burlingame and South San Francisco. A mapped trace of the Serra fault is crossed by the Segment 1 alignment near MP 15.5.

The Serra fault is thought to consist of a series of southwest-dipping thrust faults connected with the San Andreas fault at depth and accommodating localized compression along the fault boundary. While identified as a Late Quaternary fault by Jennings (1994), more recent investigations (Hengesh, et al. 1996) have encountered evidence of Holocene movement along traces of the Serra fault. Because the Serra fault likely intersects the San Andreas fault at relatively shallow depth, it is unlikely that the Serra fault is capable of acting as an independent seismic source. However, coseismic rupture on the Serra fault may occur during a major seismic event on the San Andreas fault.

Other Faults Within the Project Area

Most of the faults mapped in the hills east and southeast of the Jefferson Substation are identified as Pre-Quaternary (inactive) faults by Jennings (1994), with the exception of two Quaternary (potentially active) fault traces that appear to diverge from the San Andreas fault zone south of Upper Crystal Springs reservoir. The first potentially active fault trace, mapped as part of the Hermit fault (Brabb and Olson 1986), appears roughly coincident with the Alquist-Priolo zoned Cañada trace of the San Andreas Fault and is identified within several hundred feet of the Jefferson Substation. The second, unnamed fault trace diverges in a more easterly direction and is crossed by the Segment 1 alignment near MP 0.3. This unnamed Quaternary fault may be part of a potentially-active zone of thrust faulting, known as the Stanford fault zone, that is considered similar in origin and nature to the Serra fault zone. Unnamed faults identified as Pre-Quaternary are mapped underlying the Jefferson Substation and near MP 0.5, MP 0.9, MP 2.3, and MP 3.4 of the Segment 1 alignment.

Towards the north end of the Project Area, the Hillside fault, City College fault, and unnamed faults on the north side of San Bruno Mountain are identified as Pre-Quaternary (Jennings 1994) and are likely to be inactive. A queried trace of the Hillside fault crosses Segment 5 of the Project route near MP 0.1; mapped traces of unnamed faults on the north side of San Bruno Mountain intersect or approach the Segment 5 alignment near MP 2.1, MP 3.4, and MP 3.8; and a queried trace of the City College fault is mapped several hundred feet north of the Martin Substation.

On some maps (Bonilla 1971, and Jennings 1994), the inferred trace of the hypothetical San Bruno fault is shown underlying the proposed alignment within the Colma Valley. The San Bruno fault, first postulated by A. C. Lawson in 1895, was thought to extend in a northwest/southeast direction down the center of the Colma Valley. During design of the San Francisco Bay Area Rapid Transit (BART) extension from Colma to the San Francisco International Airport, a comprehensive investigation of the hypothetical San Bruno fault was performed by the USGS. Results of the investigation provided no positive evidence supporting the existence of the San Bruno fault (USGS 1997).

Because of its size and history of producing large, destructive earthquakes, the San Andreas fault is expected to largely control seismic design parameters for proposed Project facilities. Uncertain, queried, or unidentified faults and/or fault traces are unlikely to significantly increase overall seismic risk but could increase the local risk of surface rupture within the Project Area. Because some Project facilities are located over or near mapped 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. Large, active, and nearby faults posing significant seismic risk to Project facilities include the San Gregorio, Hayward, and Calaveras faults. The San Gregorio fault is located approximately 6 miles southwest, the Hayward fault is located about 15 miles northeast, and the Calaveras fault is located about 25 miles east of the Project Area.

Liquefaction and Lateral Spreading

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.

Soils in the area most susceptible to liquefaction include Holocene stream channel and alluvial deposits and areas where artificial-fill materials have been placed along the margins of the San Francisco Bay. Based on available maps published by USGS (Knudsen, et al. 2000), the potential for liquefaction in the Project Area is generally low to very low except for some portions of the alignment within the Colma and Visitacion valleys. Soils underlying Segment 2 between approximately MP 1.7 and the end of the segment and Segment 4 near MP 0.4 are shown to have high liquefaction potential. Soils underlying Segment 5 between approximately MP 4.0 and the end of the segment are shown to have very high liquefaction potential. Soils underlying the Martin Substation, at the end of the alignment, are characterized as having moderate liquefaction potential.

Four instances of ground settlement and lateral spreading as a result of liquefaction were observed in the Colma Valley following the 1906 San Francisco earthquake (Youd and Hoose 1978). No cases of ground failure were reported within the Project Area as a result of the 1989 Loma Prieta earthquake (Holtzer 1998).

Seismic Slope Instability

Strong earthquakes often cause landslides, particularly in areas already susceptible to landslides due to other factors, including the presence of existing landslide deposits. Landslides are typically a major effect of ground shaking during earthquakes with magnitudes of 5 and greater, especially where earth materials are water-saturated. Failure of steep slopes, collapse of natural-stream banks, and reactivation of existing landslides may occur widely during a major earthquake.

Many earthquake-induced landslides result from liquefaction phenomena, but others simply represent failure of slopes that were marginally stable under static conditions. Therefore, portions of the Project Area susceptible to landslide, earth flow, and debris-flow hazards under non-seismic conditions may also be susceptible to slope failure as a result of strong seismic ground shaking.

Ground Cracking

Ground cracking, such as that observed during the 1989 Loma Prieta earthquake in the Santa Cruz Mountains, is a secondary effect of seismic ground shaking. It appears as open fissures or cracks in the ground, particularly along the crests of ridges, that open in response to strong shaking. The exact mechanism that causes earthquake-induced ground cracks is not clear; however, these fissures could severely damage overlying structures during an earthquake. Ground cracking is typically a problem only on narrow-crested, steep sided ridges, similar to some of those traversed by Segment 1 of the Proposed Project route along the eastern margins of the Crystal Springs and San Andreas Valleys.

Landslides

Landslides, earthflows, and debris flows are relatively common features along the ridges and hillsides of the San Francisco Peninsula. 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.

Landslides occur when shear stresses within a soil or rock mass exceed the available shear strength of the mass. Failure conditions may occur when stresses acting on a slope increase, the internal strength of the slope decreases, or a combination of both occurs. Stresses can increase through an increase in the weight of overlying slope materials (by saturation), the addition of material (surcharge) to the slope, application of foundation loads, or 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 degree of slope, the presence and movement of water, and zones of weakness. In general, degree of 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.

The USGS has mapped landslide deposits and evaluated general landslide hazards within the Project Area (Brabb and Pampeyan 1972; and Wentworth, et al. 1997). Areas along the Project route have been subsequently categorized by USGS according to the relative concentration of existing landslides using the designations “mostly landslide,” “many landslides,” “few landslides,” and “flat land.” Areas designated as “mostly landslide” generally consist of mapped landslides, narrow intervening areas, narrow borders around landslide areas. These areas generally present the greatest potential landslide hazard to proposed Project facilities; however, mapped and unmapped landslides may exist in areas with other classifications.

Although a number of landslide deposits are mapped in the hills through which the Project route passes, areas designated by the USGS as “mostly landslide” (Wentworth, et al. 1997) are encountered only along Segment 1 of the alignment, near MP 1.0 and between MP 1.3 and MP 1.8. Two minor (less than 500 feet across) landslides are mapped near MP 1.0 and one relatively large landslide is mapped between MP 1.3 and MP 1.8 (Brabb and Pampeyan 1972). Recent and/or unmapped landslide deposits may be encountered along any portion of the Project route that traverses hilly terrain, particularly Segment 1 from MP 0.0 to MP 15.6 and Segment 5 from MP 0.0 to MP 4.5.

Potential debris-flow source areas have also been mapped within 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 at the mouths of canyons that drain steep terrain.

Potential debris-flow source areas have been mapped along and in the hills above the Segment 1 and Segment 5 alignments. Along Segment 1, mapped potential debris flow source areas are concentrated near the Jefferson Substation (MP 0.0) and from MP 0.9 to MP 1.5, MP 3.8 to MP 4.8, MP 6.8 to MP 7.2, and MP 14.8 to MP 15.0. Along Segment 5, mapped potential debris-flow source areas are concentrated from MP 0.0 to MP 1.2 and MP 2.2 to MP 4.5. These areas generally present the greatest potential debris-flow hazard to proposed Project facilities. However, as with potential landslide deposits, conditions for development of debris-flows may exist along any portion of the Project route that traverses or runs downslope of hilly terrain.

In general, the greatest potential for landslides, earthflows, and debris flows within the Project Area exists along the hillsides and ridgelines east of the Crystal Springs and San Andreas valleys and in the vicinity of San Bruno Mountain. Slope instability may also be a locally significant hazard around stream banks and other local topographic features, both natural and man-made.

10.3 Potential Impacts

10.3.1 Significance Criteria

Standards of significance were derived from Appendix G of the current (2002) 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 that results in substantial adverse effects. 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.

Impacts would be considered significant if:

- Known mineral resources would be rendered inaccessible by construction.
- Landslides, earth flows, debris flows, or substantial erosion could be triggered or accelerated by construction.
- Alteration of topography, which results in substantial soil erosion or the loss of topsoil beyond that which would occur through natural processes, is necessary.
- A high potential for ground rupture exists due to landslides or the presence of an active earthquake fault crossing transmission-line routes or the transition station resulting in exposure of people or structures to potential substantial adverse effects.
- A high potential for earthquake-induced ground shaking exists that could cause liquefaction, lateral spreading, and/or ground cracking along the transmission-line routes or at the transition station, resulting in exposure of people or structures to potential substantial adverse effects.
- Corrosive soils are present that could result in substantial damage to underground facilities associated with the transmission lines, transition station, and substations.
- Facilities are constructed on expansive soils, which could result in substantial damage to facilities.
- Facilities are constructed in soft or loose soils resulting in settlement which causes substantial damage to facilities.
- Excavation of asbestos-containing materials is necessary which could result in impacts to human health.
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state, or a locally-important mineral resource-recovery site delineated on a local general plan, specific plan, or other land-use plan.
- Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.

10.3.2 Summary of Geological, Seismic, and Geotechnical Hazards

Proposed Project facilities may be impacted by geological, seismic, and geotechnical conditions and hazards identified within the Project Area. These hazards may impact the Project during construction, operation, and maintenance of the proposed facilities.

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

- Soft or loose soils
- Slope or excavation instability
- Paleontologic resources
- Mineral resources
- Asbestos-containing materials

Geologic, seismic, and geotechnical hazards related to operation and maintenance of the proposed facilities include the following:

- Slope instability, including landslides, earth flows, and debris flows
- Fault surface rupture
- Strong ground shaking from local and regional seismic sources
- Seismic-induced ground failure, including liquefaction, lateral spreading, seismic slope instability, and ground cracking
- Expansive, soft, loose, and/or compressible soils
- Corrosive soils

Many of these geologic, seismic, and geotechnical, hazards are generally applicable to large portions of the Project Area. Other hazards are applicable only to specific locations that will be identified during design and construction phases of the Project. Therefore, most hazards are addressed in the following chapter as they are generally applicable to the Proposed Project. In some cases, where a potential hazard is primarily applicable to a specific, known location, that location is described.

10.3.3 Construction Impacts

Impact 10.1: 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, appropriate measures will be implemented to avoid, accommodate, replace, or improve soft or loose soils encountered during construction. Such measures, typical of common construction practice, may include: locating construction facilities and operations away from areas of soft and loose soil; overexcavating soft or loose soils and replacing them with engineered backfill materials; increasing the density and strength of soft or loose soils through mechanical vibration and/or compaction; and treating soft or loose soils in-place with binding or cementing agents. 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. As a result, potential construction impacts from soft or loose soils will be less than significant, and therefore, further mitigation is not required.

Impact 10.2: Slope or Excavation Instability. Destabilization of natural or constructed slopes could occur as a result of construction activities. Excavation, grading, and fill operations associated with providing access to proposed tower locations and other Project facilities could alter existing slope profiles and could result in the excavation of slope-supporting material, steepening of the slope, or increased loading. Excavation operations during construction of underground portions of the Project could result in unstable excavation slopes, caving, and displacement of the adjacent ground surface. However, as discussed below, appropriate design features and construction procedures will be implemented to maintain stable slopes and excavations during construction.

Temporary construction slopes and existing natural or constructed slopes impacted by construction operations will be evaluated for stability. In developing grading plans and construction procedures for access roads, transmission towers, underground lines, and the overhead-underground transition station, the stability of both temporary and permanent cut, fill, and otherwise impacted slopes will be analyzed. Construction slopes and grading plans will be designed to limit the potential for slope instability, maintain adequate drainage of improved areas, and minimize the potential for erosion and flooding during construction. During construction, slopes affected by construction operations will be monitored and maintained in a stable condition. Construction activities likely to result in slope or excavation instability will be suspended during and immediately following periods of heavy precipitation when slopes are more susceptible to failure.

During construction of the underground portion of the Project route, appropriate support and protection measures will be implemented to maintain the stability of excavations and protect surrounding structures and utilities. Such measures, typical of common construction practice, include the proper use of excavation shoring and bracing systems to support excavation walls and limit ground deformation. Where excavations are located adjacent to structures, utilities, or other features that may be adversely impacted by potential ground movements, bracing, underpinning, or other methods of temporary support for the affected facilities will be designed and implemented. Appropriate construction methods and procedures, in accordance with state and federal health and safety codes, 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. Therefore, potential impacts from slope or excavation instability would be less than significant, and further mitigation is not required.

Impact 10.3: Paleontologic Resources. Some fossil-bearing geologic formations are located in the Project Area. Fossils are particularly common in the Merced formation, which is mapped underlying Segment 1 of the alignment, between MP 14.9 and MP 15.5. Weakly consolidated deposits of the Colma formation, mapped underlying much of the alignment between MP 15.5 of Segment 1 and MP 0.3 of Segment 5, are also known to be fossil-bearing (Pampeyan 1994). If paleontological resources are found, Mitigation Measure 10.1 will be implemented, thereby reducing any potential impact to a less-than-significant level.

Impact 10.4: Mineral Resources. Economically viable sources of rock materials, as identified by CDMG, are mapped along or adjacent to Segment 5 of the Project route between MP 0.0 and MP 3.9. However, the proposed alignment through this area underlies Guadalupe Canyon Parkway, a paved roadway through the mapped resource area. Because land beneath the roadway surface is characterized as "urbanized" by CDMG, the roadway is not included within any specially designated resource sectors. Construction of Project facilities along Bayshore Boulevard and Guadalupe Canyon Parkway will not block access to existing quarry operations on the north side of San Bruno Mountain. Therefore, potential impacts to these resources will be less than significant, and mitigation is not required.

Impact 10.5: Unique Geological or Physical Features. Project construction will require excavation and earthwork involving Franciscan serpentinite rock. Most serpentinite is known to contain naturally-occurring chrysotile asbestos; however, not all serpentinite outcrops contain sufficient quantities of chrysotile asbestos to be considered hazardous. Excavation and grading activities in serpentinite rock could cause potential airborne transport of chrysotile asbestos fibers. Such occurrences may pose a health concern to construction workers and the general community. PG&E will perform construction activities in accordance with Section 93105 *Asbestos Airborne Toxic Control Measure for Construction, Grading, Quarrying, and Surface Mining Operations* of Title 17 of the California Code of Regulations. Conformance with these regulations will reduce this impact to less than significant, and mitigation is not required.

10.3.4 Operation Impacts

Impact 10.6: Slope Instability, Including Landslides, Earth Flows, and Debris Flows. Slope instability, including landslides, earth flows, and debris-flows has the potential to undermine foundations, cause distortion and distress to overlying structures, and displace or destroy Project components. A design-level geotechnical survey will be performed to evaluate the potential for unstable slopes, landslides, earth flows, and debris flows along proposed transmission-line routes and in the vicinity of other Project facilities.

Relatively long-span capabilities allow for the placement of overhead transmission lines over slide areas. In cases of shallow sliding, slope creep, or ravelling, specially designed deep foundations may be used to anchor the overlying structure to underlying, competent material. As appropriate, stabilization of unstable slopes will be performed by excavating and removing unstable material, regrading unstable slopes to improve surface drainage and limit infiltration, installing subsurface drainage systems, and/or constructing improvements to mechanically restrain slope movement.

Facilities will be located away from very 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 slope-instability hazards. As a result, potential impacts would be less than significant, and further mitigation is not required.

Impact 10.7: Fault Surface Rupture. A number of active and potentially-active faults have been identified within the Project Area, some of which are crossed by the proposed transmission-line alignment (see Figures 10-1 and 10-2). As a result, potential impacts as a result of fault surface rupture are significant. Potential impacts to Project facilities from surface rupture occur primarily to overhead transmission-line towers, underground transmission lines, substations, and the proposed overhead-underground transition station.

For overhead transmission lines, 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 directly overlie a fault trace that experiences surface rupture. Previous earthquakes, such as the 1994 Northridge earthquake, show that damage to overhead transmission lines as a result of fault surface rupture has generally been limited. Because they are buried and unable to distribute fault displacements over a comparatively long span, underground transmission lines are more susceptible to impacts from fault surface rupture. Similarly, because they are fixed to the ground surface and relatively rigid, structures and equipment associated with substations and transition stations are also susceptible to impacts from fault surface rupture.

Within the Project Area, the potential for fault surface rupture is generally concentrated in the vicinity of mapped active and potentially-active fault traces and within established earthquake-fault zones. As demonstrated during major historical earthquakes on the San Andreas fault, surface fault rupture and significant ground distortion may occur within a zone extending several hundred feet on either side of the main fault trace. In addition, the difficulties involved in accurately identifying, locating, and assessing the potential activity of individual fault traces create significant uncertainty in predicting precisely where ground displacements are most likely to occur during an earthquake on a given fault. Therefore, proposed Project facilities that intersect, occupy, or are adjacent to active and potentially active fault traces and earthquake fault zones shown on Figures 10-1 and 10-2 are subject to potentially significant impacts from fault surface rupture. As discussed below, the potential impact of fault surface rupture for unidentified faults and for faults designated as pre-Quaternary (and therefore considered inactive) is generally considered less than significant.

Potential impacts to Project facilities as a result of fault surface rupture along mapped faults within the Project Area are discussed below. With implementation of Mitigation Measure 10.2, the impact from fault surface rupture would be reduced to a less-than-significant level.

San Andreas Fault

The San Andreas fault has produced several major historical earthquakes in the Project Area, at least two of which resulted in ground surface rupture near the location of proposed Project facilities. During the 1906 earthquake, the fault broke the ground in a complex, discontinuous, en echelon fashion with many subsidiary cracks. Following the earthquake, surveys of fencelines, roadways, and other linear features crossing the fault zone on the San Francisco Peninsula indicated distribution of ground deformation across an area up to 2,200 feet wide. Approximately 17 feet of displacement was measured across the entire zone of faulting, and up to approximately 9 feet of slip was measured along the main fault trace. Subsidiary cracks, with displacements up to several feet were observed at distances up to two hundred feet on either side of the main fault trace (Brabb and Olson 1986).

Available data indicates that most fault-related ground breakage during major earthquakes along the San Andreas fault zone may be expected to take place within approximately 200 feet of the main fault break (Brabb and Olson 1986). For a previous Project in the vicinity of the proposed overhead-underground transition station, PG&E evaluated ground-deformation data collected following the 1906 earthquake at locations near San Andreas Lake. Analysis of the data indicates that all significant ground deformation during the 1906 earthquake occurred within approximately 450 feet of the main fault trace (PG&E 1992).

For the PG&E study, significant ground deformation was defined as greater than one percent distortion, equivalent to 1 foot of shear displacement distributed over 100 feet. Ground distortions less than one percent were not considered significant to the performance of buried high-pressure gas lines constructed of welded-steel pipe. The levels of ground distortion considered significant may be different for overhead transmission-line towers, underground transmission lines, and structures or equipment associated with proposed Project facilities.

As shown on Figure 10-1, portions of the Segment 1 alignment cross mapped traces of the San Andreas fault, including the traces of the 1906 rupture, between MP 14.1 and MP 14.9. The parcel on which the proposed overhead-underground transmission station is located is transected by several mapped traces of the fault, including the trace of the 1906 rupture. The Cañada trace of the San Andreas fault, on which surface rupture was not reported following the 1906 earthquake, is mapped within 100 feet of the Jefferson Substation, at the beginning of the Segment 1 alignment.

Based on observed patterns of historical ground rupture and the proposed location of the Project route and facilities, construction of the Project would result in exposure of Project facilities to hazards associated with fault surface rupture within the San Andreas fault zone. As a result, fault rupture impacts would be significant, absent mitigation. Potential consequences of fault surface rupture within the San Andreas fault zone include: structural distress and/or failure of towers that support overhead lines; damage to structural components of the transition station facility; offset and/or rupture of underground portions of the transmission line; and failure of connections between Project components.

While it is likely that primary traces of the fault that have experienced significant surface rupture in the past will experience a majority of future displacement, the potential exists for significant displacement along comparatively less-active, new, or unmapped fault traces within the broader fault zone during future earthquake events. As a result, strategic siting of Project facilities, based on the location of existing fault traces identified through geotechnical investigation, will reduce the potential for damage as a result of fault rupture. In addition, implementation of Mitigation Measure 10.2, while not eliminating the possibility of damage to the line, will allow for rapid repair of rupture-induced damage. Therefore, damage will be temporary, reducing this impact to less than significant.

Serra Fault

During a major seismic event on the San Andreas fault, coseismic rupture may occur on strands of the Serra fault, which is located approximately ½ to 1 mile east of the San Andreas fault zone. Estimates of maximum displacement on the Serra fault as a result of coseismic slip are on the order of approximately 1 foot (PG&E 1992). The underground portion of Segment 1 of the Project route crosses a mapped trace of the Serra fault near MP 15.5. Based on available information, the potential impact of fault surface rupture along the Serra fault could be significant, absent mitigation. Implementation of Mitigation Measure 10.2, while not eliminating the possibility of damage to the line, will allow for rapid repair of rupture-induced damage. Therefore, damage will be temporary, reducing this impact to less than significant.

Unnamed Pre-Quaternary Faults Southeast of Crystal Springs Reservoir

Overhead portions of the Segment 1 alignment cross a number of unnamed, Pre-Quaternary faults (Jennings 1994) mapped in the hills southeast of Crystal Springs reservoir. These unnamed fault traces cross the alignment near MP 0.5, MP 0.9, MP 2.3, and MP 3.4. An unnamed Pre-Quaternary fault is also mapped underlying the Jefferson Substation. Because of the lack of evidence for Quaternary displacement, it is likely that the unnamed faults are inactive. Therefore, the potential impact of fault surface rupture along these faults is considered less than significant and mitigation is not required.

Unnamed Quaternary Fault Southeast of Crystal Springs Reservoir

An unnamed Quaternary fault intersects the overhead portion of the Segment 1 alignment near MP 0.3. This fault may be associated with the potentially active Stanford fault zone, which is considered similar in origin and nature to the Serra fault zone. Because of its proximity to the San Andreas fault zone, the unnamed Quaternary fault may be subject to coseismic slip during a major event on the San Andreas fault. The potential impact of fault surface rupture along the unnamed Quaternary trace may be significant; although with implementation of Mitigation Measure 10.2, the potential impact would be reduced to a less-than-significant level.

Hillside Fault and Unnamed Faults on the North Side of San Bruno Mountain

The Hillside fault and unnamed faults on the north side of San Bruno Mountain are mapped Pre-Quaternary faults that cross Segment 5 of the Project route. A queried trace of the Hillside fault crosses the alignment near MP 0.1; mapped traces of unnamed faults on the north side of the mountain intersect or approach the alignment near MP 2.1, MP 3.4, and MP 3.8. Because of the lack of evidence for Quaternary displacement, it is likely that these faults are inactive. As a result, the potential impact of fault surface rupture along these faults is considered less than significant and mitigation is not required.

Unidentified Faults in the Project Area

Because of its location within a geologically active, intensely faulted area, it is likely that unidentified and unmapped faults exist within the Project Area. However, major active faults with significant potential for surface rupture typically exhibit the greatest degree of surface expression, and therefore are those most likely to be observed and documented. As a result, it is unlikely that major faults with significant potential for surface rupture are unmapped within the Project Area. The potential impact of fault surface rupture along unidentified and unmapped faults within the Project Area is therefore considered less than significant and mitigation is not required.

Impact 10.8: Strong Ground Shaking From Local and Regional Seismic Sources. Judging from the activity of major regional seismic sources (Table 10-3), and based on WGCEP estimates, it is likely that the Project will be exposed to at least one moderate or greater earthquake located close enough to produce strong ground shaking in the Project Area. The greatest potential for strong seismic ground shaking within the Project Area comes from the San Andreas fault, which has produced numerous moderate to large earthquakes during historical time.

In the event of an MCE event on the San Andreas fault, estimated horizontal PGAs for rock and shallow soil sites within the Project Area range from approximately 0.4 to 0.9g (Abrahamson and Silva 1997 and Idriss 1994). Because seismic waves attenuate with distance from their source, estimated bedrock accelerations are highest for portions of the Project near the fault zone and decrease with distance from the fault. Local soil conditions may amplify or dampen seismic waves as they travel from underlying bedrock to the ground surface. As part of a design-level geotechnical investigation, site-specific seismic analyses will be performed to evaluate PGAs for design of Project components.

In addition to the San Andreas and other active or potentially active faults within the Project Area, the San Gregorio, Hayward, and Calaveras faults also present significant potential for strong ground shaking within the region. Fault data for potential seismic sources in the Project Area are presented in Table 10-4.

Transmission Lines

Generally, overhead and underground transmission lines can accommodate strong ground shaking. In fact, wind-loading design requirements for overhead lines are generally more stringent than are those developed to address strong seismic ground shaking. The potential impact from seismic ground shaking on transmission lines would be less than significant, and mitigation is not required.

Substation and Transition Station Equipment

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 types of equipment most susceptible to damage from strong seismic ground shaking 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 past substation equipment damage. These design guidelines will be implemented during construction of substation and overhead-underground transition station improvements. 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 and transition-station 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 hazards associated with strong seismic ground shaking. Potential impacts would be less than significant, and further mitigation is not required.

Impact 10.9: Seismic-Induced Ground Failure, Including Liquefaction, Lateral Spreading, Seismic Slope Instability, and Ground Cracking. Modes of seismic-induced ground failure include liquefaction, lateral spreading, seismic slope instability, and ground cracking. Seismic-induced ground failure has the potential to distress, displace, and/or destroy Project components. Therefore, a design-level geotechnical investigation will be performed to collect data and assess the potential for seismic-induced ground failure in soil and rock materials underlying substation, transmission-tower, transition-station, and underground transmission-line sites.

Liquefaction and Lateral Spreading

Soils underlying Segment 2 between approximately MP 1.7 and the end of the segment and Segment 4 near MP 0.4 are shown to have high liquefaction potential. Soils underlying Segment 5 between MP 4.0 and the end of the segment are shown to have very high liquefaction potential. Soils underlying the Martin Substation, at the end of the alignment, are characterized as having moderate liquefaction potential.

Seismic Slope Instability

Portions of the Project Area susceptible to landslide, earth-flow, and debris-flow hazards may also be susceptible to slope failure as a result of strong seismic ground shaking.

Ground Cracking

Ground cracking is typically a problem only on narrow-crested, steep-sided ridges, similar to some of those traversed by Segment 1 of the Project route along the eastern margins of the Crystal Springs and San Andreas Valleys.

Geotechnical data will be analyzed to evaluate the potential for seismic-induced ground failure and develop appropriate engineering-design and construction measures. Appropriate measures could include construction of pile foundations, ground improvement of liquefiable zones, installation of flexible bus connections, and incorporation of 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 or seismic hazards. Potential impacts would be less than significant, and further mitigation is not required.

Impact 10.10: Expansive, Soft, Loose, and/or Compressible Soils. Shrink-swell, or expansive-soil behavior is a condition in which soil reacts to changes in moisture content by expanding or contracting. Many of the natural soil types identified within the Project Area have high clay contents and most have moderate to high shrink-swell potential, as shown in Table 10-2. Expansive soils may cause differential and cyclical foundation movements that can cause damage and/or distress to overlying structures and equipment. Potential operation impacts from loose sands, soft clays, and other potentially compressible soils include excessive settlement, low foundation-bearing capacity, and limitation of year-round access to Project facilities.

Design-level geotechnical studies will be conducted 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 further mitigation is not required.

Impact 10.11: Corrosive Soils. Corrosive subsurface soils, if they exist in the area of proposed underground structures, would have a detrimental effect on concrete and metals exposed to these soils. Depending on the degree of corrosivity of subsurface soils, concrete and reinforcing steel in concrete structures and bare-metal structures exposed to these soils could deteriorate, which could eventually lead to structural failures.

Design-level geotechnical studies will be conducted to identify the presence, if any, of potentially detrimental substances, such as chlorides and sulfates, in soils. Appropriate design measures for protection of reinforcement, concrete, and metal-structural components against corrosion will be utilized, such as use of corrosion-resistant materials and coatings, increased thickness of Project components exposed to potentially corrosive conditions, and use of passive and/or active cathodic protection systems. Implementation of these standard engineering methods would reduce potential impacts from corrosive soils to a less-than-significant level, and further mitigation is not required.

10.4 Mitigation Measures

10.4.1 Construction Mitigation Measures

Mitigation Measure 10.1: 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 (e.g., by carefully excavating the material containing the resources).

10.4.2 Operation and Maintenance Mitigation Measures

Mitigation Measure 10.2: Fault Surface Rupture.

Overhead Transmission Lines

For overhead transmission lines, site-specific geotechnical investigations will be performed at proposed tower locations to evaluate the potential for fault surface rupture. Where significant potential for fault 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 fault rupture hazards.

Underground Transmission Lines

Site-specific geotechnical investigations will be performed at locations where underground portions of the proposed transmission line cross mapped fault zones and intersect individual fault traces. Where significant potential for fault surface rupture is identified, appropriate engineering measures, such as installing breakaway connections and strategically locating splice boxes outside of the fault zone, will be implemented to protect sensitive equipment and limit the extent of potential repairs. Appropriate operation and maintenance measures will be implemented to prepare for potential fault-rupture scenarios and facilitate timely repair of facilities, if necessary. Preparation measures may include storage and maintenance of spare parts and equipment that may be needed to repair or temporarily bypass portions of the transmission line damaged as a result of fault surface rupture. Spare parts and equipment will be stored at the transition station or nearby PG&E facilities.

Overhead-Underground Transition Station

A geotechnical investigation will be performed at the proposed overhead-underground transition station location to identify primary and subsidiary traces of the San Andreas fault. Critical transition station facilities, including transmission-line support structures, the overhead-underground transition structure, and the control building, will not be sited over active or potentially active traces of the fault. To the extent feasible, station structures will be designed to accommodate anticipated displacement and distortion of the ground surface during a major earthquake along the San Andreas fault zone.

As with design of underground transmission lines, transition station facilities will be designed for ductility and strength using reinforced components and flexible connections. Overhead transmission-line spans will be designed to accommodate potential fault displacement between support structures.

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