# 9.0 GEOLOGY

## 9.1 INTRODUCTION AND METHODOLOGY

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

The project is located in a seismically active region underlain by unconsolidated and poorly consolidated deposits and consolidated bedrock. Geologic hazards with the greatest potential to impact the project include landslides, strong ground shaking, localized liquefaction and lateral spreading, and soil erosion. Potential geotechnical hazards include the presence of expansive soils, as well as soft and loose soils.

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

### 9.1.1 Methodology

Existing conditions were determined from review of published literature, examination of aerial photographs, and site-specific field inspection of the locations of project components. Descriptions of geologic units in the project area were derived from published mapping by Chin et al. (1993) and Wagner and Bortugno (1982).

Soil descriptions were obtained from mapping by the United States Department of Agriculture, Soil Conservation Service , Soil Survey of Sonoma County (Miller 1972). Evaluation of landslide hazards was based upon published geologic mapping, aerial reconnaissance video review, and site-specific field inspections of proposed pole locations, existing access roads, and substation sites. Information on mineral resources was obtained from U. S. Geological Survey (USGS) and California Geologic Survey (CGS) sources. Information on paleontology was obtained from the University of California Paleontology Department.

Seismic information was developed by Geomatrix Consultants for PG&E's Geosciences Department based upon a thorough review of several data sources. Their assessment included potential for seismically related hazards, including fault rupture, seismic ground shaking, and liquefaction. Excerpts of their report are included in this document.

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

## 9.2 REGULATORY FRAMEWORK

The only pertinent regulation for geology is related to earthquake fault zones. California enacted the Alquist-Priolo Special Studies Zones Act in 1972, which requires the establishment of "earthquake fault zones" (formerly known as "special studies zones") along known active faults in California (Hart and Bryant 1997). Strict regulations on development within these zones are enforced to reduce the potential for damage due to fault displacement. Please see section 9.3.6, Seismicity for further discussion.

## 9.3 EXISTING CONDITIONS

The project is located in the central portion of the northern Coast Ranges geomorphic province of California. The Coast Ranges extend approximately 600 miles from southern California to the Oregon border and are comprised of a northwest trending series of mountain ranges and intervening valleys that reflect past and current regional tectonic forces. The east-dipping sedimentary rocks of the Coast Ranges are flanked on the east by sedimentary rocks of the Great Valley geomorphic province (Page 1966).

### 9.3.1 Topography

The proposed transmission route originates at the Lakeville substation at the eastern edge of the valley drained by the Petaluma River and ascends obliquely across the Sonoma Mountains and descends into the Sonoma Valley, terminating at the Sonoma substation. Relief is fairly gentle at each end of the project and on the flanks of the Sonoma Mountains, but becomes relatively steep to moderately steep in the central portion of the Sonoma Mountains. The Lakeville substation is at approximately 106 feet (all elevations are given relative to mean sea level [MSL]) and the route rises to approximately 180 feet as it enters the western edge of the Sonoma Mountains. The route ascends the mountains attaining a maximum elevation of 712 feet as it crosses the Rodgers Creek drainage. It then descends the eastern flank of the mountains to 165 feet in the vicinity of Felder Creek, terminating at the Sonoma substation at an elevation of approximately 54 feet.

### 9.3.2 Geology

The Sonoma Mountains are comprised predominately of the Miocene-Pliocene Sonoma Volcanics, which overlie a pre-Miocene basement composed chiefly of Franciscan Formation rocks on the west and the Great Valley Sequence on the east. The Sonoma Volcanics are locally underlain by non-marine Miocene sediments of the Petaluma Formation. The mapped geologic units in the project area are shown on the Generalized Geologic Map, Figure 3-4.

#### 9.3.2.1 Geologic Structure

The project is located within the tectonically active and geologically complex northern Coast Ranges, which has been shaped by continuous deformation resulting from tectonic plate convergence (subduction) beginning in the Jurassic period (about 145 million years ago). Eastward thrusting of the oceanic plate beneath the continental plate resulted in the accretion (building up) of materials onto the continental plate. These accreted materials now largely comprise the Coast Ranges.

Beginning in the Cenozoic time period (about 25 to 30 million years ago), the tectonics along the California coast changed to a right-lateral strike-slip displacement which became superimposed on the earlier structures resulting in the formation of northwest-trending, near-vertical faults comprising the San Andreas fault system. The northern Coast Ranges were segmented into a series of tectonic blocks separated by major faults including the San Andreas, Healdsburg-Rodgers Creek, Maacama, and Green Valley faults. The project is located astride two structural blocks: the Sebastopol Structural Block in the west and the Santa Rosa Structural Block in the east. These blocks are separated by the Healdsburg-Rodgers Creek fault. This block-bounding fault has been tectonically active during the Holocene (see section 9.3.6, Seismicity). Several faults cut portions of the structural blocks, including the Tolay fault west of the Lakeville substation within the Sebastopol Structural Block as well as others east and north of the project within the Santa Rosa Structural Block, which include Carneros, West Napa, Green Valley, Maacama, and Bennett Valley faults (Fox et al. 1983).

#### 9.3.2.2 Surficial Deposits

Surficial deposits are generally made up of unconsolidated sediments. Surficial deposits within the project area include Pleistocene Older Alluvium (Qoa on Figure 3-4) and Holocene Younger Alluvium (Qya on Figure 3-4). The Older Alluvium consists of non-marine, dissected fan and alluvial deposits ranging in size from gravel to clay. The Younger Alluvium consists of unconsolidated stream, channel, levee, flood plain, basin, terrace, and fan deposits ranging in size from boulder to clay.

Older Alluvium underlies the Sonoma substation site as well as portions of segments 1, 2, and 17 of the proposed project. Younger Alluvium underlies the Lakeville substation site, as well as segments 17 and 2 of the proposed project route. Please refer to Figure 3-4, Generalized Geologic Map of locations of segments relative to geologic features.

#### 9.3.2.3 Bedrock

Basement rocks of the Franciscan Formation (mg on Figure 3-4) are located over a half mile southwest of the project. They are comprised of metagraywacke of Mesozoic age. Bedrock underlying project locations ranges in age from Pliocene to Miocene. Non-marine sediments of the late Miocene Petaluma Formation (Tpne) underlie and interfinger with the Sonoma Volcanics along the flanks of the Sonoma Mountains (Wagner and Bortugno 1982, Fox 1983). Volcanic and volcaniclastic rocks of the Sonoma Volcanics (Tvs) form the ridges and upper flanks of the Sonoma Mountains.

The following sections briefly describe the two formations within the project area.

Petaluma Formation (Tnpe) – The Petaluma Formation is considered to be of late Miocene age and consists of interfingering beds and lenses of poorly consolidated clay, shale, silt, sand, and gravel, and local interbeds of tuff and diatomite (Fox et al. 1983). The Petaluma Formation overlies the Tolay Volcanics west of the project area and interfingers with or is in an angular unconformity with overlying Sonoma Volcanics. The Petaluma Formation is located on the flanks of the Sonoma Mountains. It underlies portions of segments 1 and 2 of the proposed project.

Sonoma Volcanics (Tvs) – In the project area, the Sonoma Volcanics' lower members form erosionally resistant shields of northwest-trending ridges including the Sonoma Mountains (Fox et al. 1983). The Sonoma Volcanics in the project area consist of silicic basalt, andesite, and dacite flows above interlayered ash deposits and rhyolite flows. Rocks of the Sonoma Volcanics underlie the portions of segment 1.

#### 9.3.2.4 Subsurface Exploration

No subsurface exploration has been performed at this time for the project. Subsurface exploration may be performed, if necessary, at some of the proposed tubular steel pole sites.

### 9.3.3 Soils

Soils within the project area have been mapped as "soil associations," a broad grouping of soils with common characteristics, and as "soil series" that are specific types of soil mapping units, which generally have similar management uses or requirements such as slope steepness. Five soil associations occupy the terrain crossed by the project. The distribution of soil associations in the project area is shown on Figure 3-5, Generalized Soil Association Map. The main characteristics of the mapped soil associations and their component soil series are given in Table 9-1, Mapped Soil Associations in Project Area.

**Table 9-1**
**Mapped Soil Associations in Project Area**

| Map Unit, Number and Name[1] | Soil Series and Percentage[2] | Topographic Location | Location by Segment - %/portion (N, S, E, W, C [central])[1] | Erosion Potential[3] | Permeability[4] | Drainage | Shrink-Swell Potential | Corrosion Potential |
|---|---|---|---|---|---|---|---|---|
| 1. Clear Lake-Reyes | Clear Lake - 50%<br>Reyes – 40% | Basins, tidal flats | Lakeville ss - 100<br>1 – 12/W | Clear Lake - Slight<br>Reyes – None to slight | Clear Lake - Slow<br>Reyes – Slow | Clear Lake – Poorly drained<br>Reyes – Poorly drained | Clear Lake – High<br>Reyes – High | Clear Lake – High<br>Reyes – High |
| 2. Haire-Diablo | Haire – 45%<br>Diablo - 45% | Terraces, uplands | 1 – 21/W | Haire – Slight to moderate<br>Diablo - Moderate | Haire – Slow<br>Diablo - Slow | Haire – Moderately well-drained<br>Diablo – Well-drained | Haire – Moderate<br>Diablo - High | Haire – Moderate<br>Diablo - High |
| 3. Huichica-Wright-Zamora | Huichica – 35%<br>Wright – 30%<br>Zamora – 25% | Low bench terraces, alluvial fans | Sonoma ss – 100<br>1 – 5/E<br>2 – 100<br>17 – 64/W, E | Huichica – Slight<br>Wright – None to slight<br>Zamora – Slight | Huichica – Very slow<br>Wright – Very slow<br>Zamora - Slow | Huichica – Moderately well to somewhat poorly drained<br>Wright – Somewhat poorly drained<br>Zamora – Well-drained | Huichica – Moderate<br>Wright – Low<br>Zamora – Moderate | Huichica – Moderate to high<br>Wright – High<br>Zamora - Moderate |

[1] *Refer to Figure 3-5, Generalized Soil Associations Map for soil association distribution in project area.*

[2] *Other related soil series occupy remaining area percentage.*

[3] *Erosion hazard rating for typical soil profile.*

[4] *Permeability of surface horizon; may vary with depth.*

**Table 9-1**
**Mapped Soil Associations in Project Area (continued)**

| Map Unit, Number and Name[1] | Soil Series and Percentage[2] | Topographic Location | Location by Segment - %/portion (N, S, E, W, C [central])[1] | Erosion Potential[3] | Permeability[4] | Drainage | Shrink-Swell Potential | Corrosion Potential |
|---|---|---|---|---|---|---|---|---|
| 4. Yolo-Cortina-Pleasanton | Yolo – 60%<br>Cortina – 15%<br>Pleasanton – 15% | Flood plains, alluvial fans, low terraces | 17 – 36/C | Yolo – Slight<br>Cortina – Slight<br>Pleasanton - Slight | Yolo – Moderate<br>Cortina – Very rapid<br>Pleasanton – Moderately slow | Yolo – Well-drained<br>Cortina – Excessively drained<br>Pleasanton – Well-drained | Yolo – Low to moderate<br>Cortina – Low<br>Pleasanton - Low | Yolo – Low<br>Cortina – Low<br>Pleasanton - Low |
| 5. Goulding-Toomes-Guenoc | Goulding – 70%<br>Toomes – 10%<br>Guenoc – 10% | Uplands | 1 – 62/C | Goulding – Moderate<br>Toomes – Slight to moderate<br>Guenoc – Moderate to high | Goulding – Moderate<br>Toomes – Moderate<br>Guenoc – Moderate to slow | Goulding – Well-drained<br>Toomes – Well-drained<br>Guenoc – Well-drained | Goulding – Moderate<br>Toomes – Moderate<br>Guenoc - Moderate | Goulding – Moderate<br>Toomes – Moderate<br>Guenoc - Moderate |

#### 9.3.3.1 Soil Associations

The five soil associations and their relationship to the project are described below.

*Clear Lake-Reyes association (Map Unit 1 on Figure 3-5)*

This association is comprised of nearly level to gently sloping soils that are poorly drained clays to clay loams. They are located on basins and on tidal flats. The Lakeville substation is underlain by these soils as well as the western end of segment 1 of the project.

*Haire-Diablo association (Map Unit 2 on Figure 3-5)*

This association is comprised of gently sloping to steep soils that are well-drained to moderately well-drained sandy loams to clays. They are located on terraces and uplands. Portions of segment 1 of the proposed project cross this association. Half of the Lakeville substation site is located on this soil association.

*Huichica-Wright-Zamora association (Map Unit 3 on Figure 3-5)*

This association is comprised of nearly level to moderately sloping soils that are well-drained to excessively drained loams to silty clay loams. They are located on low bench terraces and alluvial fans. The Sonoma substation site is underlain by these soils. Portions of segments 1, 2, and 17 of the proposed project cross these soils.

*Yolo-Cortina-Pleasanton association (Map Unit 4 on Figure 3-5)*

This association is comprised of nearly level to moderately sloping soils that are well-drained to excessively drained very gravelly sandy loams to clay loams. They are located on flood plains, alluvial fans, and low terraces. These soils are located in the central portion of segment 17 of the proposed project route.

*Goulding-Toomes-Guenoc association (Map Unit 5 on Figure 3-5)*

This association is comprised of well-drained, gently sloping to very steep clay loams to loams located on uplands of the Sonoma Mountains. The east-central portion of segment 1 is underlain by these soils.

### 9.3.4 Mineral Resources

The most significant mineral resource in the project area is non-metallic minerals such as broken and crushed rock products.

The California Division of Mines and Geology (CDMG) 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. In general, areas subject to pressures of urbanization are zoned by the CDMG, while those areas outside these areas are not. MRZ categories defined by the CDMG are presented below:

- **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.

Most of the project is outside a classified MRZ. Local areas along Sonoma Creek are zoned MRZ-2 and MRZ-3 based upon sand and gravel reserves. The western and eastern edges of Sonoma Valley are zoned MRZ-1. The western boundary of this zone intersects segment 2 of the proposed project route (Stinson 1987).

#### 9.3.4.1 Sand and Gravel Quarries

The project does not cross areas presently being used for mineral extraction. However, extraction operations exist outside the project area. Sonoma Volcanics have been quarried for block and paving stone in the past and are currently being extracted (Goldman 1966). Basalt is being extracted in Petaluma west of Highway 101 and at a quarry in Napa. A small quarry is located along the north side of Highway 116, about a mile and one-half south of the central portion of segment 1.

#### 9.3.4.2 Oil and Minerals

Oil and mineral resources apparently do not have potential within the project area.

#### 9.3.4.3 Hydrothermal Resources

Geothermal resources in the Sonoma Valley exist as a widely distributed, moderately shallow, low-temperature source. The resource is characterized as a liquid-dominated hydrothermal convection system that ascends into fractures and faults within permeable units of the Sonoma Volcanics (Campion et al. 1984). The hydrothermal area northeast of the project and north of Sonoma is located in an area designated "most likely geothermal production zone" by the USGS (Youngs et al. 1983). A number of wells with elevated temperatures are located outside this main hydrothermal area and are located south of the project area (Youngs et al. 1983).

### 9.3.5 Paleontology

In general, vertebrate fossils are considered to be scientifically significant fossils as compared to more abundant plant and invertebrate fossils (Department of Interior 2000). There are exceptions to this generality, as some plant and invertebrate fossils are rare. Potential paleontological resources were analyzed by examining University of California Museum of Paleontology (UCMP) databases of known paleontological sites in the general project vicinity. Known vertebrate sites were reviewed by UCMP staff using their vertebrate database. No vertebrate localities are recorded within 10 miles of the project area (Pat Holroyd, personal communication on July 21, 2003). In addition, plant fossil locations were reviewed by UCMC staff. The nearest plant fossil locality in the UCMC database is near Mount George northeast of Napa, well east of the project area (Diane Erwin, personal communication on July 23, 2003).

### 9.3.6 Seismicity

The project crosses the Sonoma Mountains of the northern Coast Range, which is seismically active. Structure within the northern Coast Ranges is characterized by predominantly northwest-trending folds and faults, associated with the San Andreas fault system. The San Andreas fault system is a major transform boundary that accommodates differential right-lateral motion between the North American and Pacific tectonic plates at a rate of about 4 centimeters per year (DeMets et al. 1990).

The spatial distribution of regional seismicity for the time period from 1769 to December 2000 is shown along with the major regional faults on Figure 9-1. Seismicity shown represents a composite catalog, including the Northern California Seismic Network catalog (NCSN) (1967 to present) from the U.S. Geological Survey, the UC Berkeley catalog (1910 to present) from the Seismological Laboratory at the University of California Berkeley, the California catalog (1769 to present) from the U.S. Geological Survey National Earthquake Information Center, and the catalog prepared for the National Ground Motion Hazard Mapping Project (NGMHMP) by the U.S. Geological Survey (Mueller et al. 1997). Earthquakes were selected for the composite catalog in the following order of preference: NCSN, UC Berkeley, and California. Moment magnitudes from the NGMHMP catalog were given preference over magnitudes from the other catalogs. All earthquakes in the composite catalog are shown on Figure 9-1.

#### 9.3.6.1 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 levels of ground shaking. Therefore, the seismic parameters referenced in this chapter are defined as follows.

*Magnitude (M)*

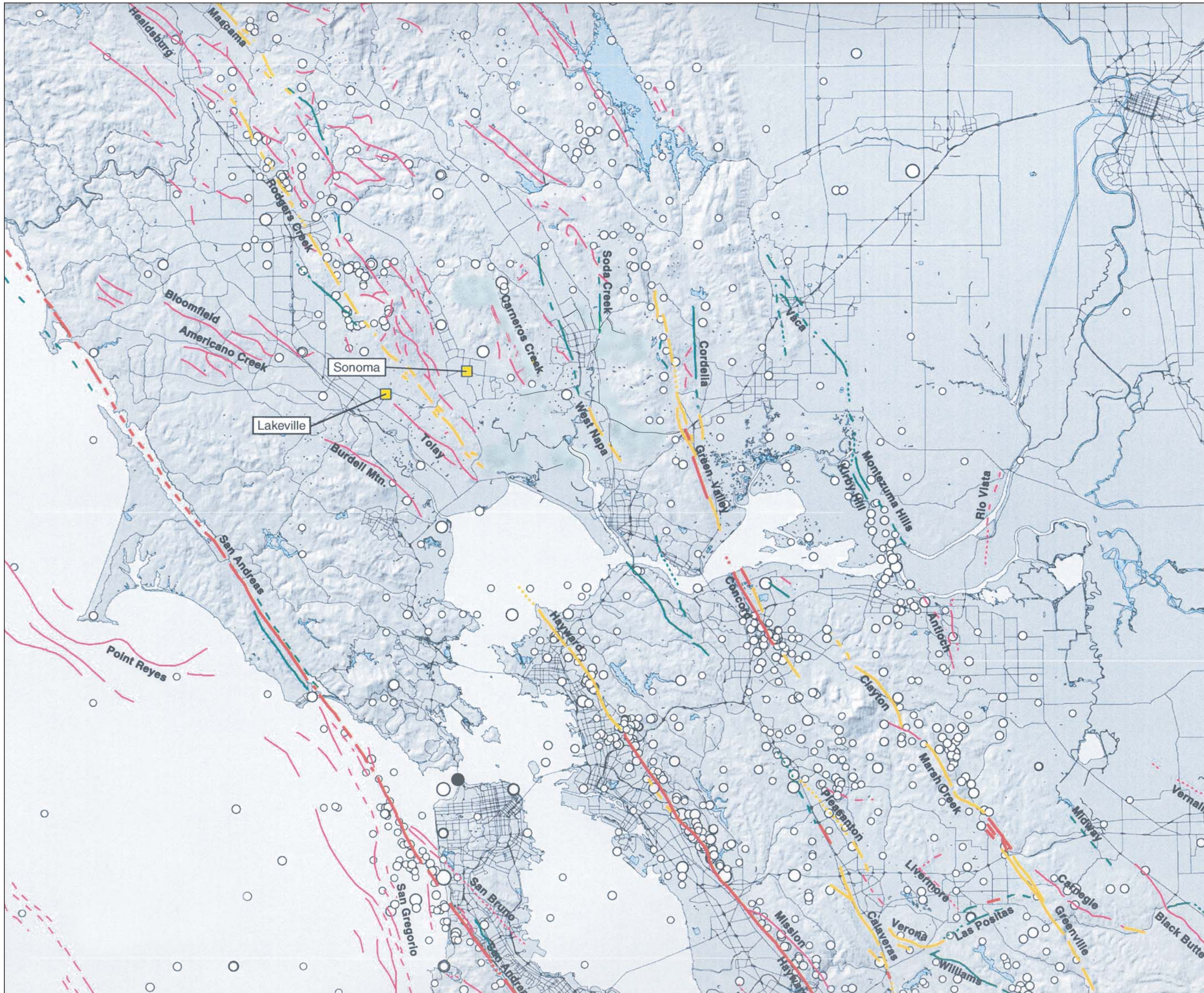
The magnitude (M), or size, of an earthquake is measured by a number of methods. Several of these, including the Richter ($M_L$), surface wave ($M_s$), and body wave ($M_b$) methods, evaluate the magnitude of an earthquake by measuring the amplitude of seismic waves as recorded by a seismograph. Because of the instrumental properties of seismographs, these methods provide inconsistent results above or below a certain range of magnitudes. A more robust and currently preferred measure of magnitude is moment magnitude ($M_w$). 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. Both $M_w$ and $M_L$ are used in this chapter to describe earthquake size.

*Intensity (I)*

Earthquake intensity (I) is a subjective measurement of earthquake shaking on a local level, rather than a mechanical measure of earthquake source size. Because intensity is based on observed effects of ground shaking on people, structures, and the environment, it 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. The Modified Mercalli Intensity Scale, ranging in observed effects from imperceptible (I) to complete catastrophe, (XII), is used to characterize the intensity of an 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 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 displacement and the recorded seismic history of the region.




## LEGEND

### Fault Recency Classification

- Faults with historic surface rupture/creep (<200 years)
- Faults that displace Holocene (<11,000 years)
- Faults that displace Late Quaternary deposits or geomorphic surfaces (<7,000 years)
- Quaternary faults (<1,600,000 years)

Faults traces on land shown as solid where well located, dashed where uncertain or inferred, and dotted where buried. Data from Jennings (1994).

### Historic Seismicity

- 1-2
- 2-3
- 3-4
- 4-5
- 5-6
- 6-7
- 7-10

Notes:
Composite Independent Seismicity Catalog (1769 to December 2000).
Catalog sources include:
University of California, Berkeley catalog and Berkeley Digital Seismic Network Catalog.
U.S. Geological Survey
- Northern California Seismic Network Catalog
- National Earthquake Information Center California Catalog
- National Ground Motion Hazard Mapping Program, Frankel and others (1996) Western U.S. Moment Magnitude Catalog

Significant San Francisco Bay Region Earthquakes, Bakun (1999)

Base Map from U.S. Geological Survey.

N

0 5 10 20 Miles

0 10 20 40 Kilometers

**Lakeville-Sonoma 115 kV Transmission Line Project**

FIGURE 9-1

# Fault Activity and Historic Seismicity

EDAW April 2004 PG&E Pacific Gas and Electric Company.

*Attenuation*

In an earthquake, sudden rupture or displacement along a fault releases energy in the form of seismic waves, which travel 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. The amount of acceleration, velocity, and displacement caused by the passage of seismic waves decreases with the distance from a 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 upon 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 (g, 32 ft/sec$^2$ or 9.8 meters/sec$^2$) experienced at a site due to the passage of seismic waves. The 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, Idriss 1997). Estimated PGAs presented in this chapter are for soil sites.

#### 9.3.6.2 Fault Classification and Zoning

*Classification*

Project area faults shown on Figure 9-1 are classified as Historic, Holocene, Late Quaternary, Quaternary, or Pre-Quaternary (Jennings 1994). The Historic and Holocene faults are classified as active faults by CDMG and the Quaternary faults are classified as potentially active. The following criteria are used for classification:

- Historic: fault displacement has occurred within the past 200 years.
- Holocene: shows evidence of fault displacement within past 11,000 years, but without historic record.
- Late Quaternary: shows evidence of fault displacement within 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.

Tables 9-2 and 9-3 list active and potentially active faults in the project vicinity and provide data with reference to the Lakeville and Sonoma substation sites.

The strength of the shaking at a site is a function of the earthquake magnitude, the distance between the fault rupture and the site, and the soil conditions at the site. Unless otherwise noted, the estimated rupture lengths and maximum magnitude values ($M_m$) shown on Tables 9-2 and 9-3 are from published sources (e.g., Peterson et al. 1996; Working Group on California Earthquake Potential, 1996; and, Working Group on California Earthquake Probabilities, 1999). Where reported values were not available, fault lengths were measured off published maps and magnitudes were calculated using published relations that relate fault-rupture dimensions to earthquake magnitude (e.g., Wells and Coppersmith 1994). Distances between the surface traces of the faults and the substation sites were measured from available geologic maps. The substation sites are assumed to be soil sites, not underlain by bedrock. The calculated values for PGA shown on Tables 9-2 and 9-3 are based on an average of values derived from five attenuation relations for strike-slip faults for rock site conditions (Abrahamson and Silva 1997, Boore et al. 1997, Campbell 1997, Idriss 1997, and Sadigh et al. 1997).

#### 9.3.6.3 Alquist-Priolo Earthquake Fault Zones

The Alquist-Priolo Special Studies Zones Act of 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” or “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 been generally 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 the CGS (formerly CDMG) for a particular fault may be wider than the actual fault zone occupied by traces of the fault.

**Table 9-2**
**Known Active and Potentially Active Faults – Lakeville Substation**

| Fault | Approx. Distance from Substation (km) | Age Classification | Activity Classification | Potential Rupture Length (km) | Mmax [1] (Mw) | PGA [2] (g) |
|---|---|---|---|---|---|---|
| Bartlett Springs | 70 | Holocene & Early Quaternary | Active | 85 | 7.1 | 0.0754 |
| Burdell Mtn. | 9 | Early Quaternary | Potentially Active | 18 | 6.5 | 0.3304 |
| Carneros | — | Pre Quaternary ? | Not Active | Not active | — | — |
| Unnamed faults W of Carneros | 17 | Early Quaternary | Potentially Active | 3 | 5.5 to 6 | 0.1522 |
| Collayomi | 60 | Holocene & Late Quaternary | Active | 29 | 6.5 | 0.0614 |
| Concord-Green Valley | 35 | Holocene / Historic creep | Active | 66 | 6.9 | 0.1328 |
| Cordelia | 36 | Holocene & Late Quaternary | Active | 19 | 6.6 | 0.13 |
| Greenville | 62 | Holocene & Historic | Active | 73 | 6.9 | 0.0754 |
| Hayward | $\leq$33 | Historic | Active | 86 | 7.1 | 0.1567 |
| Hunting Creek-Berryessa | 43 | Holocene-Early Quaternary | Active | 60 | 6.9 | 0.1088 |
| Maacama (south) | 41 | Holocene | Active | 41 | 6.9 | 0.114 |
| Maacama (central) | 82 | Holocene / Historic creep | Active | 60 | 7.1 | 0.0642 |
| Maacama (north) | 140 | Holocene / Historic creep | Active | 81 | 7.1 | 0.0371 |
| Rogers Creek | 3 | Holocene | Active | 63 | 7.0 | 0.542 |
| San Andreas | 28 | Historic | Active | 470 | 7.9 | 0.2714 |
| Soda Creek | 25 | Late Quaternary | Potentially Active | 19 | 6.6 | 0.1555 |
| Tolay | <1 ** | Early Quaternary | Potentially Active | 16 to 35 | 6.5 to 6.9 | 0.5809 |
| Vaca-Kirby Hills | 50 | Late Quaternary | Potentially Active | 18 to 35 | 6.5 to 6.9 | 0.0937 |
| West Napa | 23 | Holocene & Late Quaternary | Active | 30 | 6.5 | 0.1596 |
| Bartlett Springs | 70 | Holocene & Early Quaternary | Active | 85 | 7.1 | 0.0754 |

*** Buried fault trace projects through/near the Lakeville substation*

[1] *Mmax is designated as the maximum moment magnitude calculated from rupture area relationships.*

[2] *PGA is the peak ground acceleration resulting from an earthquake event.*

**Table 9-3**
**Known Active and Potentially Active Faults – Sonoma Substation**

| Fault | Approx. Distance from Substation (km) | Age Classification | Activity Classification | Potential Rupture Length (km) | Mmax [1] (Mw) | PGA [2] (g) |
|---|---|---|---|---|---|---|
| Bartlett Springs | 65 | Holocene & Early Quaternary | Active | 85 | 7.1 | 0.0813 |
| Burdell Mtn. | 16 | Early Quaternary | Potentially Active | 18 | 6.5 | 0.2192 |
| Carneros | — | Pre Quaternary? | Not Active | Not active | — | — |
| Unnamed faults W of Carneros | 7 | Early Quaternary | Potentially Active | 3 | 5.5 to 6 | 0.2976 |
| Collayomi | 58 | Holocene & Late Quaternary | Active | 29 | 6.5 | 0.0636 |
| Concord-Green Valley | 24 | Holocene / Historic creep | Active | 66 | 6.9 | 0.1875 |
| Cordelia | 27 | Holocene & Late Quaternary | Active | 19 | 6.6 | 0.15 |
| Greenville | 55 | Holocene & Historic | Active | 73 | 6.9 | 0.09 |
| Hayward | $\leq$31 | Historic | Active | 86 | 7.1 | 0.17 |
| Hunting Creek-Berryessa | 34 | Holocene-Early Quaternary | Active | 60 | 6.9 | 0.14 |
| Maacama (south) | 44 | Holocene | Active | 41 | 6.9 | 0.11 |
| Maacama (central) | 85 | Holocene / Historic creep | Active | 60 | 7.1 | 0.06 |
| Maacama (north) | 145 | Holocene / Historic creep | Active | 81 | 7.1 | 0.04 |
| Rogers Creek | 4 | Holocene | Active | 63 | 7.0 | 0.51 |
| San Andreas | 36 | Historic | Active | 470 | 7.9 | 0.22 |
| Soda Creek | 15 | Late Quaternary | Potentially Active | 19 | 6.6 | 0.24 |
| Tolay | 9 | Early Quaternary | Potentially Active | 16 to 35 | 6.5 to 6.9 | 0.37 |
| Vaca-Kirby Hills | 40 | Late Quaternary | Potentially Active | 18 to 35 | 6.5 to 6.9 | 0.12 |
| West Napa | 13 | Holocene & Late Quaternary | Active | 30 | 6.5 | 0.26 |

[1] *Mmax is designated as the maximum moment magnitude calculated from rupture area relationships.*

[2] *PGA is the peak ground acceleration resulting from an earthquake event.*

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 CGS-designated "earthquake fault zone."

Within vicinity of the project, the Rodgers Creek segment of the Hayward-Rodgers Creek fault is associated with an Alquist-Priolo Earthquake Fault Zone designation. The designated zone is crossed by the project. Mapped traces of the Rodgers Creek fault in the project area are shown on Figure 3-4 and regionally on Figure 9-1.

#### 9.3.6.4 Faults in the Project Area

Active faults pose a potential hazard either directly, due to sudden permanent ground deformations (fault rupture and related deformation), or indirectly, due to strong ground shaking. The existing Lakeville and Sonoma substation sites are not within identified Alquist-Priolo Earthquake Hazards Zones that would indicate investigations to assess the potential for surface-fault rupture are required.

*San Andreas Fault*

Within the northern Coast Ranges, the San Andreas fault system comprises a 100+ kilometer (km) wide zone of major northwest-trending, right-lateral strike-slip faults that include from west to east, the San Andreas, Healdsburg-Rodgers Creek, Maacama, and Green Valley-Bartlett Springs faults (Figure 9-1). Each of these faults is associated with variable levels of microseismicity and/or historical seismicity, indicating ongoing and active tectonic deformation. The Maacama and Bartlett Springs faults are believed to be the relatively young continuations of the Hayward-Rodgers Creek and Calaveras-Green Valley fault zones, respectively (Helley et al. 1977, Castillo and Ellsworth 1993). Both of these major fault zones are associated with a north to northwest trending linear alignment of microseismicity. The onset of strike-slip motion on these faults and their evolution is closely related to the northward migration of the Mendocino Triple Junction, which is the intersection of the North American Plate, the Pacific Plate, and the Juan de Fuca Plate (Dickenson and Snyder 1979).

*Maacama-Healdsburg-Rodgers Creek and Bartlett Springs-Green Valley fault zones*

These fault zones are both spatially associated with relatively continuous, northwest-trending zones of seismicity that lie predominantly to the east of the mapped fault traces. The alignment of seismicity associated with the Maacama-Healdsburg-Rodgers Creek fault system is relatively linear, compared to the more diffuse alignment of seismicity along the Bartlett Springs-Green Valley fault zones. Focal mechanisms of earthquakes along the Maacama and Bartlett Springs fault systems are compatible with right-lateral strike-slip motion on northwest-trending planes, which is consistent with the pattern of regional deformation in the Pacific-North American plate boundary (Eberhart-Philips 1988, Castillo and Ellsworth1993).

Surprisingly, there is very little seismicity associated with the northern San Andreas fault.
The most significant historical earthquake in the region was the great 1906 M 7.9 San Francisco earthquake, which ruptured a 470 km long segment of the San Andreas fault extending from San Juan Bautista northward to Shelter Cove. The earthquake also caused coseismic ground deformation just south of Clear Lake, in the form of en echelon ground cracks extending for a distance of about 2 km (Lawson 1908). The northern San Andreas fault has remained relatively aseismic since this event.

Other notable events in the region include the October 1969 $M_L$ 5.6 and $M_L$ 5.7 earthquakes, which occurred on the Healdsburg-Rodgers Creek fault zone. On September 3, 2000 a $M_L$ 5.2 earthquake occurred 15 km northwest of Napa near Yountville. This earthquake caused a surprising amount of damage in the City of Napa. The unusually high levels of shaking recorded in the City of Napa were most likely due to amplification of the shaking by the young sediments along the Napa River and focusing of strong motion to the southeast in the direction of the fault rupture (USGS 2000).

*Other Faults in the Project Area*

Few pre-Quaternary faults cut bedrock units in the project area. Unnamed faults east of the Rodgers Creek fault are located in the eastern portion of the project area along the eastern flank of the Sonoma Mountains. These faults are not classified as potentially active (Jennings 1994).

## 9.4 POTENTIAL IMPACTS AND MITIGATION MEASURES

### 9.4.1 Significance Criteria

Significance criteria were developed from the CEQA Guidelines**.** Impacts from the proposed project would be considered significant if they resulted in increased exposure of people or structures to major geologic hazards 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.

Project impacts would be significant if the project were to cause the following:

- The project would expose people or structures to geological hazards or related geotechnical hazards, such as surface rupture of a known earthquake fault, strong seismic shaking, seismic related ground failure (e.g., liquefaction), landslides, earth flows, debris flows and unstable geologic units, substantial soil erosion or loss of topsoil, or soft or loose or expansive soils.

- The project would result in physical changes to the topography, directly affecting or changing the context within which a paleontological resource or unique geologic feature exists, thereby diminishing their values.
- The project would substantially affect significant mineral resources identified by the California Department of Conservation or the Sonoma County General Plan by precluding them from extraction.

### 9.4.2 Summary of Potential Geologic, Seismic, and Geotechnical Hazards

The proposed project may be impacted by geologic, seismic, and geotechnical conditions and hazards that exist in the project area. These hazards may impact the project during construction, operation, and maintenance over the life of the project. The following are the potential hazards that may impact the project.

Potential geologic and geotechnical hazards related to excavation and grading activities during construction and maintenance include:

- Soft or loose soils
- Slope instability including landslides
- Soil erosion
- Expansive soils
- Flooding
- Loss of mineral resources
- Loss of paleontologic resources
- Loss of unique geologic features

Potential geologic, seismic, and geotechnical hazards related to operation and maintenance of the proposed project include the following:

- Surface fault rupture
- Ground shaking
- Liquefaction
- Lateral spreading

### 9.4.3 Construction Related Impacts

**Impact 9.1: Soft or Loose Soils.**

Saturated, loose sands and soft clays may pose difficulties in access for construction and in excavating for pole foundations. Soft or loose soils could also cause instability of excavations during construction of foundations. 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 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; therefore, further mitigation is not required.

**Impact 9.2: Erosion.**

Surface disturbance will result from the construction of new access roads and, to a limited extent, the use of existing access roads that are not paved. The amount of surface disturbance is related to slope steepness which tends to dictate the amount of earth required to be moved to provide safe access road grades. In addition, the slope steepness greatly influences how rainfall runoff may cause soil erosion and contribute to sediment loading. To reduce erosion an erosion control plan will be developed before construction. The plan will evaluate the slope steepness and soil types for the pole locations and access routes. The plan will also recommend construction and maintenance procedures that include best management practices, limitation of sidehill fills, drainage control, surface treatments, and revegetation standards. Implementation of the Erosion Control and Restoration Plan in Appendix A will reduce soil erosion potential to acceptable levels and therefore, further mitigation is not required.

**Impact 9.3: Slope Instability and Unstable Soil Conditions.**

Destabilization of natural or constructed slopes could occur as a result of construction activities. Excavation, grading, and fill operations associated with providing access to proposed pole locations and other project facilities could alter existing slope profiles making them unstable as a result of over excavation of slope material, steepening of the slope, or increased loading. 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 and transmission poles, 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.

For construction requiring excavations, such as foundations, appropriate support and protection measures will be implemented to maintain the stability of excavations and to protect surrounding structures and utilities. 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, where necessary, 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 9.4: Paleontology Resources.**
No known fossil locations are catalogued within the project area. If paleontological resources are found during construction activities, Mitigation Measure 9.4 will be implemented, thereby reducing any potential impact to a less than significant level.

**Mitigation Measure 9.4.** 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 formulate 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 under the direction of the paleontologist).

**Impact 9.5: Mineral and Unique Geological Resources.**
Economically viable sources of rock materials are not known in the immediate project area. Nor are there unique geologic features identified within project area. Therefore, the potential for the loss of mineral or unique geologic features is low. Potential impacts to these resources are not anticipated and mitigation is not required.

### 9.4.4 Operation Impacts

**Impact 9.6: Slope Instability, Landslides, Mudflows, or Debris Flows.**

Slope instability, including landslides, earth flows, and debris flows, have 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 slope instability including: landslides, earth flows, and debris flows along proposed transmission line route and in the vicinity of other project facilities. Proper design allows for the transmission line to span large unstable 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 9.7: Flooding.**

Examination of Federal Emergency Management Agency (FEMA) Rate Insurance Maps indicates that potential 100-year and 500-year floods in the project vicinity are concentrated along reaches of Adobe Creek near the Lakeville substation and along reaches of Nathanson Creek in downtown Sonoma northeast of the Sonoma substation site and locally, along major tributary streams. The project is outside of mapped potential flood zones. Impacts associated with flooding are not anticipated and mitigation is not necessary.

**Impact 9.8: Surface Fault Rupture.**

A number of active and potentially active faults have been identified within the project area, one of which, the Rodgers Creek fault, is crossed by the proposed project between poles 41 - 43 (see Figure 9-1). Review of Association of Bay Area Governments (ABAG 2003) sources indicate that the project area would experience moderate to very strong shaking intensity in the event of a Magnitude 7 earthquake along the Rodgers Creek segment of the Hayward-Rodgers Creek Fault System. Very strong levels of shaking intensity (Modified Mercalli Intensity VIII would occur east of Lakeville substation to Sonoma substation. This would include segments 1, 2, and 17 of the project route. The Lakeville substation site is characterized as susceptible to moderate levels of shaking intensity (Modified Mercalli Intensity VI).

Based on data used in the working group of US Geological Survey, California Geological Survey, and consultants, estimated maximum displacement of the Rodgers Creek Fault in a large event is two to three meters (6.56 to 9.84 ft) (pers. comm. Norman Abrahamson, PG&E Geosciences Department, July 2004). The Alquist-Priolo Special Studies Zones Glen Ellen Quadrangle Revised Official Map, July 1, 1983, has two fault traces mapped at the line crossing at Rodgers Creek. The two traces are at an angle to the proposed line of about 49 and 61 degrees, respectively, with an average for the fault zone of about 58 degrees. For right-lateral fault displacement, calculated maximum increase in the approximate 1,275 ft distance between poles would be 3.6 to 4.8 ft for an angle of 61 degrees, and 4.3 to 6.5 ft for an angle of 49 degrees.

Mac Tafarodi, PG&E Senior Transmission Line Engineer, (pers. comm. August 25, 2004) indicates that the increase in distance between poles would result in the following: reduction of slack and increased tension in the conductors; for suspension tubular steel poles (TSP) and insulator strings, the insulator strings would be pulled at an angle at the TSP adjacent the fault crossing and decreasingly so for suspension TSPs along the line away from the fault crossing; for dead-end TSPs, the steel poles would deflect (bend) elastically. Additional conductor wire would have to be spliced into the conductors after a large earthquake event with significant fault displacement in order to restore normal operating conditions.

Potential impacts from surface fault rupture may be significant. Potential impacts to project facilities from surface fault rupture could occur to transmission line poles and substations. For overhead transmission lines, the flexible capacity of the transmission lines themselves can generally accommodate surface fault displacements. Transmission poles are susceptible to damage or failure if they directly overlie a fault trace that experiences surface rupture.

However, 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. 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 Figure 9-1, are subject to potentially significant impacts from fault surface rupture. With implementation of Mitigation Measure 9.8, the impact from surface fault rupture would be reduced to a less than significant level.

**Mitigation Measure 9.8.** For overhead transmission lines, site-specific geotechnical investigations will be performed at specific pole locations to evaluate the potential for surface fault rupture. Where significant potential for surface fault rupture exists, pole locations will be adjusted where possible, to minimize any potential for damage. Incorporation of standard engineering practices as part of the project will ensure that people or structures are not exposed to fault rupture hazards and any impacts will be less than significant.

For substation improvements to existing sites, data will be reviewed to determine if a geotechnical investigation is necessary for improvements at the Lakeville substation. In addition, an evaluation of the significance of the Tolay fault will be undertaken. To the extent feasible, substation improvements will be designed to accommodate potential effects during a major earthquake along the Tolay and other nearby active faults.

**Impact 9.9: Strong Ground Shaking from Seismic Sources.**

Judging from the activity of major regional seismic sources (Tables 9-2 and 9-3), 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 general project area comes from the active Rodgers Creek fault, which has produced moderately large earthquakes. In the event of an MCE event on the Rodgers Creek fault, estimated horizontal PGAs for rock and shallow soil sites within the project area range from approximately 0.54 to 0.5g at the Lakeville substation and Sonoma substation sites, respectively (Abrahamson and Silva 1997, Idriss 1997). An MCE event on the Tolay fault, in close proximity to the Lakeville substation site is estimated to produce a PGA of approximately 0.58g (Table 9-2).

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. In addition to the Rodgers Creek and Tolay faults, other active or potentially active faults within the project area also present significant potential for strong ground shaking within the region. Fault data for potential seismic sources in the project area are presented in Tables 9-2 and 9-4. Use of site-specific seismic data for project design will reduce potential impacts of strong ground shaking to less than significant and further mitigation is not required

*Transmission Lines*

Generally, overhead 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 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 inspected substation damage in Los Angeles and Japan shortly after the Northridge and Kobe earthquakes. Damage has been found to vary dramatically with voltage. Damage was noted as extensive at 500 kV substations, significant at 230 kV substations, and minor at substations 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) Standard 693-1997 "Recommended Practices for Seismic Design of Substations," has specific requirements to mitigate possible substation equipment damage. These design guidelines will be implemented during construction of substation 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 is anticipated. Substation improvements 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 9.10: Liquefaction and Seismic Ground Failure.**

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. 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 and transmission pole sites.

*Liquefaction and Lateral Spreading*

A Review of ABAG (2003) sources indicate that the project area has liquefaction hazards characterized as very low, moderately low, and moderate in the event of a Magnitude 7 earthquake along the Rodgers Creek segment of the Hayward-Rodgers Creek Fault System. Moderate to very low hazard is postulated for the Lakeville substation site area. Moderately low liquefaction hazard is predicted for the Sonoma substation area and the eastern approximately one-half of segment 17 of the proposed project route. The other project segments lie in areas characterized as having very low liquefaction hazard potential.

Lateral spreading is related to liquefaction in areas of free slopes. Such free slope areas are confined to stream banks in the project area and are generally spanned by the existing and proposed transmission line. The potential for lateral spreading to affect project facilities is very low given the relatively low potential for liquefaction.

*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 along the crest of the Sonoma Mountains. Geotechnical data will be analyzed to evaluate the potential for seismic induced ground failure and develop appropriate engineering design and construction measures. 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 9.11: Expansive, Settlement Prone, Soft, or Loose Soils.**

Shrink-swell or expansive soil behavior is a condition in which soil reacts to changes in moisture content by expanding or contracting. 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 9-1. 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.

## 9.5 REFERENCES

Abrahamson, Norman. 2004. Personal communication between James Gamble, PG&E, and Norman Abrahamson, PG&E Geosciences Department. July.

Abrahamson, N.A., and Silva, W.J. 1997. Empirical response spectral attenuation relations for shallow crustal earthquakes: Seismological Research Letters, v. 68, no. 1, p. 94-127.

Association of Bay Area Governments (ABAG). 2003. "On Shaky Ground", website: http://www.abag.ca.gov/.

Boore, D.M., Joyner, W.B., and Fumal, T.E. 1997. Equations for estimating horizontal response spectra and peak acceleration from western North American earthquakes: A summary of recent work: Seismological Research Letters, v. 68, no. 1, p. 128-153.

Budding, K.E., Schwartz, D.P., and Oppenheimer, D.H. 1991. Slip rate, earthquake recurrence, and seismogenic potential of the Rodgers Creek fault zone, northern California – initial results: Geophysical Research Letters, v. 18, no. 3, p. 447-450.

California Building Code. 2001. California Code of Regulations, Title 24, Chapter 16.

California Geological Survey. 1983. Earthquake Fault Zones, Glenn Ellen quadrangle, Revised Official Map, effective July 1, 1983, scale 1:24,000.

California Geological Survey. 1983. Earthquake Fault Zones, Petaluma River quadrangle, Revised Official Map, effective July 1, 1983, scale 1:24,000.

California Geological Survey. 1997. Guidelines for evaluating and mitigating seismic hazards in California: California Geological Survey Special Publication 117, 74 p.

Campbell, K.W. 1997. Empirical near-source attenuation relationships for horizontal and vertical components of peak ground acceleration, peak ground velocity, and pseudo-absolute acceleration response spectra: Seismological Research Letters, v. 68, p. 154-179.

Campion, Linda F., C. Forrest Bacon, Rodger H. Chapman, Gordon W. Chase, and Leslie G. Youngs. 1984. Geothermal resources of the Sonoma Valley area, Napa and Sonoma counties, California USGS Open-File Report OFR 84-29.

Castillo, D.A., and Ellsworth, W.L. 1993. Seismotectonics of the San Andreas fault system between Point Arena and Cape Mendocino in northern California: Implications for the development and evolution of a young transform: Journal of Geophysical Research, v. 98, no. B4, p. 6543-6560.

Chin, J.L., Morrow, J.R., Ross, C.R., and Clifton, H.E. 1993. Geologic maps of upper Cenozoic deposits in central California, U.S. Geological Survey Miscellaneous Investigations Series Map I-1943, scale 1:250,000.

Cloud, W. K., Hill, D. M., Huffman, M. E., Jennings, C. W., McEvilly, T. V., Nason, R. D., Steinbrugge, K. V., Tocher, D., Unger, J. D., and T. L. Youd. 1970. The Santa Rosa Earthquakes of October, 1969: Mineral Information Service, vol. 23, California Division of Mines and Geology.

DeMets, C., Gordon, R.G., Argus, D.F., and Stein, S. 1990. Current plate motions: Geophysical Journal International, v. 101, no.2, p. 425-478.

Department of Interior. 2000. Fossils on Federal and Indian Lands, Report of the Secretary of the Interior, May 2000. Website: http://www.doi.gov/fossil/fossilreport.htm

Dickenson, W.R., and Snyder, W.S. 1979. Geometry of subducted slabs related to San Andreas transform: Journal of Geology, v. 87, p. 609-627.

Eberhart-Philips, D. 1988. Seismicity in the Clear Lake area, California, 1975-1983, in J.D. Sims (ed.), Late Quaternary climate, tectonism, and sedimentation in Clear Lake, northern California Coast Ranges: Geological Society of America Special Paper 214, p. 195-206.

Ellen, S.D., and Wentworth, C.M. 1995. Hillside materials and slopes of the San Francisco Bay region, California: U.S. Geological Survey Professional Paper 1357, 215 p., 7 pls. in binder.

Erwin, Diane M., Ph.D., Paleobotany Collection Manager, Museum of Paleontology, University of California, Berkeley, California, personal communication on July 23, 2003.

Federal Emergency Management Agency (FEMA). 2003. Flood hazard mapping data for Sonoma and Petaluma, California, website http://www.fema.gov/

Fox, K.F., Jr. 1983. Tectonic setting of Late Miocene, Pliocene, and Pleistocene rocks in part of the Coast Ranges north of San Francisco, California: U.S. Geological Survey Professional Paper 1239, 33 p., 1 pl. in pocket.

Fox, K.F., Jr., Sims, J.D., Bartow, J.A., and Helley, E.J. 1973. Preliminary geologic map of eastern Sonoma County and western Napa County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF – 483, scale 1:62,500.

Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., and Hopper, M. 1996. National seismic-hazard maps; documentation: U.S. Geological Survey Open-File Report 96-532, 110 p.

Goldman, H. B. 1966. Mineral Resources of California – Bulletin 191, California Division of Mines and Geology.

Hart, E.W., Bryant, W.A., and Smith, T.C. 1983. Summary report, fault evaluation program, 1981-1982 area (northern Coast Ranges region): California Division of Mines and Geology Open-File Report 83-10.

Hart, E.W. 1992. Recently active traces of the Rogers Creek fault Sonoma County, California: California Division of Mines and Geology, DMG Open-File Report 92-7, 18 p.

Hart, E.W., and Bryant, W.A. 1997. Fault-rupture hazard zones in California: California Geological Survey Special Publication 42, revised 1997 with Supplements 1 and 2 added 1999, 38 p.

Helley, E.J., Lajoie, K.R., Spangle, W.E., and Blair, M.L. 1979. Flatland deposits of the San Francisco Bay region, California – their geology and engineering properties, and their importance to comprehensive planning: U.S. Geological Survey Professional Paper 943, 88 p., 3 pls. in pocket.

Herd, D.G., and Helley, E.J. 1977. Faults with Quaternary displacement, northwestern San Francisco Bay region, California: U.S. Geological Survey Miscellaneous Field Studies map MF-818, scale 1:125,000.

Holroyd, Pat, Ph.D., Museum of Paleontology, University of California, Berkeley, California, personal communication on July 23, 2003.

Huffman, M.E., and Armstrong, C.F. 1980 (reprinted 2000). Geology for planning in Sonoma County: California Geological Survey Special Report 120, 31 p., 8 pls. in binder

Idriss, I.M. 1997. Selection of earthquake ground motions at rock sites: Report prepared for the Structures Division, Building and Fire Research Laboratory, National Institute of Standards and technology, Department of Civil Engineering, University of California, Davis.

IEEE Standard 693-1997. "Recommended Practice for Seismic Design of Substations," Institute of Electrical and Electronics Engineers, Inc. 1998.

International Building Code. 2000. Chapter 16 Structural Design. Published by International Code Council, Inc., USA.

Jennings, C.W. 1994. Fault activity map of California and adjacent areas, with locations and ages of recent volcanic eruptions: California Division of Mines and Geology Geologic Data Map No. 6, scale 1:750,000.

Lawson, A.C. 1908. State earthquake investigation commission, the California earthquake of April 18, 1906: Carnegie Institution of Washington, Publication 87.

Miller, V. C. 1972. Soil Survey of Sonoma County, California, U. S. Department of Agriculture, Soil Conservation Service in cooperation with the University of California Agricultural Experiment Station.

Mueller, C., Hopper, M., and Frankel, A. 1997. Preparation of Earthquake Catalogs for the National Seismic-Hazard Maps: Contiguous 48 States: U.S. Geological Survey Open-File Report 97-464.

National Earthquake Information Center. 2000. California earthquake catalog: U.S. Geological Survey, Golden, Colorado. URL: http://www.neic.cr.usgs.gov/neis/epic/epic.html

Northern California Seismic Network catalog (1967 to present). Northern California Earthquake Data Center, 215 McCone Hall, UC Berkeley, CA 94720-4760. Website: www@quake.geo.berkeley.edu

Page, B. M., 1966. Coast Ranges Province, Chapter VI in *Geology of Northern California, Bulletin 190, CDMG.*

Peterson, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P. 1996. Probabilistic seismic hazard assessment for the State of California: California Division of Mines and Geology Open-File Report 96-08; also published as U.S. Geological Survey Open-file Report 96-706.

Sadigh, K., Chang, C. Y., Egan, J.A., Makdisi, F.I., and Youngs, R.R.. 1997. Attenuation relationships for shallow crustal earthquakes based on California strong motion data: Seismological Research Letters, v. 68, no. 1, p. 180-189.

Seismological Laboratory, University of California, Berkeley. 2000. UC Berkeley and Northern California Seismic Network earthquake catalogs. URL: http://quake.geo.berkeley.edu/ncedc/catalog-search.html.

Soiland, Mark, personal communication January 21, 2004.

Stinson, Melvin C. 1987. Mineral Land Classification: Aggregate materials in the North San Francisco Bay Production-Consumption Region (Marin, Napa, and Sonoma counties, California). DMG Special Report 146 (Part III).

Tafarodi, Mac. 2004. Personal communication between James Gamble, PG&E and Mac Tafarodi, Senior Transmission Line Engineer. August 25, 2004.

UC Berkeley catalog (1910 to present): Berkeley Seimological Labratory, 215 McCone Hall, UC Berkeley, Berkeley, CA 94720-4760. Website: www@seismo.berkeley.edu

U.S. Geological Survey. 2000. Recent and Significant Past Earthquakes - Yountville, CA - Sept. 3, 2000; http://earthquake.usgs.gov/recent/reports, 3 p.

Wagner, D. L. and E. J. Bortugno, 1982. Geologic Map of the Santa Rosa Quadrangle. Division of Mines and Geology. Scale 1:250,000.

Wells, D.L., and Coppersmith, K.J. 1994. New empirical relationships among magnitude, rupture length, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, p. 974-1002.

Working Group on California Earthquake Probabilities. 1999. Earthquake probabilities in the San Francisco Bay region: 2000-2030 – a summary of findings: U.S. Geological Survey Open-File Report 99-517.

Working Group on Northern California Earthquake Potential. 1996. Database of potential sources for earthquakes larger than magnitude 6 in northern California: U.S. Geological Survey Open-File Report 96-705.

Youngs, Leslie G., Rodger H. Chapman, Gordon W. Chase, Stephen P. Bezore, and Hasu H. Majmundar. 1983. Investigation of low-temperature geothermal resources in the Sonoma Valley area, Sonoma and Napa counties, California. USGS Open-File Report OFR 83-13.