3.2.3 Geology/Soils/Seismic/Topography

Regulatory Setting

For geologic and topographic features, the key federal law is the Historic Sites Act of 1935, which establishes a national registry of natural landmarks and protects "outstanding examples of major geological features." Topographic and geologic features are also protected under CEQA.

This section also discusses geology, soils, and seismic concerns as they relate to public safety and project design. Earthquakes are prime considerations in the design and retrofit of structures. The Department's Office of Earthquake Engineering is responsible for assessing the seismic hazard for Department projects. The current policy is to use the anticipated Maximum Credible Earthquake (MCE) from young faults in and near California. The MCE is defined as the largest earthquake that can be expected to occur on a fault over a particular period of time.

State Standards

Alquist-Priolo Earthquake Fault Zoning Act

California's Alquist-Priolo Act (PRC 2621 et seq.), originally enacted in 1972 as the Alquist-Priolo Special Studies Zones Act and renamed in 1994, is intended to reduce the risk to life and property from surface fault rupture during earthquakes. The Alquist-Priolo Act prohibits the location of most types of structures intended for human occupancy across the traces of active faults and strictly regulates construction in the corridors along active faults (Earthquake Fault Zones). It also defines criteria for identifying active faults, giving legal weight to terms such as *active*, and establishes a process for reviewing building proposals in and adjacent to Earthquake Fault Zones.

Under the Alquist-Priolo Act, faults are zoned, and construction along or across them is strictly regulated if they are *sufficiently active* and *well-defined*. A fault is considered sufficiently active if one or more of its segments or strands shows evidence of surface displacement during Holocene time (defined for the purposes of the act as within the last 11,000 years). A fault is considered well-defined if its trace can be clearly identified by a trained geologist at the ground surface or in the shallow subsurface, using standard professional techniques, criteria, and judgment (Hart and Bryant 1997).

Seismic Hazards Mapping Act

Like the Alquist-Priolo Act, the Seismic Hazards Mapping Act of 1990 (PRC 2690–2699.6) is intended to reduce damage resulting from earthquakes. While the Alquist-Priolo Act addresses surface fault rupture, the Seismic Hazards Mapping Act addresses other earthquake-related hazards, including strong ground shaking, liquefaction, and seismically induced landslides. Its provisions are similar in concept to those of the Alquist-Priolo Act: the State is charged with identifying and mapping areas at risk of strong ground shaking, liquefaction, landslides, and other corollary hazards, and cities and counties are required to regulate development within mapped Seismic Hazard Zones.

Under the Seismic Hazards Mapping Act, permit review is the primary mechanism for local regulation of development. Specifically, cities and counties are prohibited from issuing development permits for sites in Seismic Hazard Zones until appropriate site-specific geologic or geotechnical investigations have been carried out, and measures to reduce potential damage have been incorporated into the development plans.

California Building Standards Code

The State of California's minimum standards for structural design and construction are given in the California Building Standards Code (CBSC) (24 CCR). The CBSC is based on the Uniform Building Code (UBC) (International Code Council 1997), which is used widely throughout the United States (generally adopted on a state-by-state or district-by-district basis) and has been modified for California conditions with numerous, more detailed or more stringent regulations. The CBSC requires that "classification of the soil at each building site will be determined when required by the building official" and that "the classification will be based on observation and any necessary test of the materials disclosed by borings or excavations." In addition, the CBSC states that "the soil classification and design-bearing capacity will be shown on the (building) plans, unless the foundation conforms to specified requirements." The CBSC provides standards for various aspects of construction, including (i.e., not limited to) excavation, grading, and earthwork construction; fills and embankments; expansive soils; foundation investigations; and liquefaction potential and soil strength loss. New structures constructed as part of the project would be required to comply with all applicable provisions of the CBSC.

California Department of Transportation Standards

In addition to the CBSC, the Department's highway and bridge facilities are subject to numerous standards, including *Caltrans Guidelines for Structures Foundations Report, Version 2* (California Department of Transportation 2006a); *Caltrans Seismic Design Criteria* (California Department of Transportation 2006b); *Caltrans Highway Design Manual (Topic 829)* (California Department of Transportation 2008); *Caltrans Bridge Design Specifications (Section 8)*(California Department of Transportation 2004); and *Caltrans Standard Specifications* (California Department of Transportation 2006c). These standards were developed to ensure that all Department facilities are constructed and maintained to the highest safety standards.

Landslide Hazard Identification Program

The Landslide Hazard Identification Program requires the State Geologist to prepare maps of landslide hazards within urbanizing areas. According to Public Resources Code Section 2687(a), public agencies are encouraged to use these maps for land use planning and for decisions regarding building, grading, and development permits.

Local Standards

Geotechnical Investigations

Local jurisdictions typically regulate construction activities through a multistage permitting process that may require the preparation of a site-specific geotechnical investigation. The purpose of a site-specific geotechnical investigation is to provide a geologic basis for the development of appropriate construction design. Geotechnical investigations typically assess bedrock and Quaternary geology, geologic structure, soils, and the previous history of excavation and fill placement.

Regulation HS.I-22 of the Public Health and Safety Element of the Solano County General Plan (Solano County 2008) requires geotechnical evaluations and recommendations before new development occurs in areas with geologic, soils, or seismic hazards (see the section titled "Solano County General Plan").

Solano County General Plan

Goals, policies, and implementation programs contained in the Public Health and Safety Element of the Solano County General Plan (Solano County 2008) that are applicable to the proposed project are as follows:

> **HS.G-1:** Minimize the potential for loss of life and property resulting from natural or human-caused hazards.
>
> **SEISMIC SAFETY AND LAND STABILITY**
>
> **Policies**
>
> **HS.P-12:** Require new development proposals in moderate or high seismic hazard areas to consider risks caused by seismic activity and to include project features that minimize these risks.
>
> **HS.P-13:** Review and limit the location and intensity of development and placement of infrastructure in identified earthquake fault zones.
>
> **HS.P-14:** Identify and minimize potential hazards to life and property caused by fault displacement and its impact on facilities that attract large numbers of people, are open to the general public, or provide essential community services and that are located within identified earthquake fault zones.
>
> **HS.P-15:** Reduce risk of failure and reduce potential effects of failure during seismic events through standards for the construction and placement of utilities, pipelines, or other public facilities located on or crossing active fault zones.
>
> **HS.P-16:** Require minimum setbacks for construction along creeks between the creek bank and structure, except for farm structures that are not dwellings or places of work, based on the susceptibility of the bank to lurching caused by seismic shaking.
>
> **HS.P-17:** Restrict the crossing of ground failure areas by new public and private transmission facilities, including power and water distribution lines, sewer lines, and gas and oil transmission lines.
>
> **HS.P-18:** Make information about soils with a high shrink-swell potential readily available. Require proper foundation designs in these areas.
>
> **HS.P-19:** Minimize development in areas with high landslide susceptibility.

Implementation Programs

Regulations

HS.I-19: Adopt and enforce the most current versions of the International Building Codes, as modified by the California Building Standards Commission.

HS.I-21: Require geotechnical investigation and recommendations for buildings meant for public occupancy within geologic hazard areas. A state certified Engineering Geologist shall produce a report examining development issues that considers:

- soil, slope, or other geologic hazard conditions found on site;
- potential off-site development impacts, such as increased runoff and/or slope instability; and
- requirements of any regulations concerning the hazard area.

HS.I-22: Require geotechnical evaluation and recommendations before new development in moderate or higher-hazard areas. Such geotechnical evaluation shall analyze the potential hazards from:

- landslides
- liquefaction
- expansive soils
- steep slopes
- erosion
- subsidence
- Alquist-Priolo Earthquake Fault Zones or other identified fault zones
- tsunamis
- seiches

Require new development to incorporate project features that avoid or minimize the identified hazards. Costs related to providing or confirming required geotechnical reports will be borne by the applicant.

Affected Environment

The *Assessment of Fault Rupture and Analysis of Displacement Hazard, Solano Transportation Authority Interchange Project, Cordelia, California (I-80/I-680/SR 12 Interchange)* (Fault Rupture Assessment) and the *Environmental Geotechnical Memorandum, I-80/I-680/SR 12 Interchange Project, Solano County, California, 04-Sol-12, 680, 80 PM Var.* (Environmental Geotechnical Memorandum) were prepared for the project alternatives in 2009. All suggested and applicable measures have been incorporated into the section below. However, as mentioned in both of these studies, additional site-specific study will be required during latter phases of project development. These future studies are also mentioned in the section below.

The project area is located in the Coast Ranges geomorphic province (California Geological Survey 2002). The analysis presented herein focuses on the Quaternary sediments and geologic

hazards pertaining to the project area, except for the ground shaking analysis. This analysis requires a broader view of the region due to the potential for other primary impacts should fault rupture or displacement occur in outlying areas.

Geology and Topography of the Project Area

Surface Geology

Because of the geographical extent of the project alternatives, the project area is divided into three segments: western, central, and eastern. The western segment begins just west of the I-80/Red Top Road interchange and ends at the I-80/Suisun Valley Road interchange. The central segment begins at the I-80/Suisun Valley Road interchange and ends at the SR 12E/Chadbourne Road interchange. The eastern segment begins at the SR 12E/Chadbourne Road interchange and ends at the Fairfield Overhead where SR 12E crosses over the UPRR tracks west of Suisun City.

The Environmental Geotechnical Memorandum indicates that the project area is underlain by alluvial and bedrock units. Bedrock consists of sedimentary rock formations, metamorphic rocks, and volcanic rock units that extend across Solano County from the marshlands on the east to the foothills on the west. Geologic units and structures in the vicinity of the project area have been mapped by several geologists, including Wagner and Bortugno (1982), Manson (1998), Bezore et al. (1988), and Graymer et al. (2002).[1] Based on the published geologic maps, the central and eastern portions of the project area are underlain by late Pleistocene to Holocene age alluvial fan deposits (Qf) and Holocene fan deposits (Qhf), which are the most extensive Quaternary age units in the project area. The alluvial fan deposits consist of sediments deposited by streams that originate from mountain canyons and flow onto alluvial valley floors or alluvial plains in the form of debris flows, hyperconcentrated mudflows, or stream flows. The particle size of these deposits typically decreases downslope from the fan apex. In some places, Holocene fan deposits (Qhf) may be only a thin veneer over late Pleistocene to Holocene fan deposits (Qf). Holocene-age natural levee deposits (Qhl) were formed by streams that overtopped their banks and deposited sediment adjacent to their channels.

The southwestern (western segment) portion of the project area is located on hillside terrain underlain by bedrock units that consist primarily of sedimentary and volcanic formations that have been folded and faulted as well as having been influenced by local landslides. The Eocene-age Markley Formation (Tmk) consists of micaceous marine sandstones. The overlying Pleistocene-age Sonoma volcanics contain extrusive basalt and ryholite flows, agglomerates and tuffs, ash-flow tuffs, and andesitic-flow breccias and agglomerates. Potassium/argon radiometric dating of the Sonoma volcanics exposed locally near St. Helena indicates an age of 2.9 million years.

Figure 3.2.3-1 depicts lithologic descriptions, as shown in the Environmental Geotechnical Memorandum for the project alternatives. The main geologic units, as described by Bezore et.al. (1998), mapped within the project area include:

[1] Relevant portions of these published maps are shown on Plates 4, 5, and 6 of the Environmental Geotechnical Memorandum.

- Qhf—Fan deposits (Holocene): Moderately sorted to poorly sorted and moderately bedded to poorly bedded sand, gravel, silt, and clay deposited where streams emanate from upland regions onto more gently sloping valley floors or plains.
- Qhl—Natural levee deposits (Holocene): Moderately sorted to well-sorted sand with some silt and clay deposited by streams that overtop their banks during flooding.
- Qf—Fan deposits (late Pleistocene to Holocene): Poorly sorted, moderately bedded to poorly bedded sand, gravel, silt, and clay deposited in gently sloping alluvial fans. These deposits are about 10% denser and have 50% greater penetration resistance than unit Qhf.
- Qls—Landslide deposits (Holocene and Pleistocene): Chaotic deposits of sand, silt, clay, angular boulders, and blocks of bedrock up to hundreds of feet long deposited by gravity-driven skidding and flow.
- Tsv—Sonoma volcanics, undivided (Pleistocene): Basalt to rhyolite flows, agglomerates, and tuffs.
- Tst—Ash-flow tuff (Pliocene): Pumicitic, locally welded, with agglomeritic tuff.
- Tsa—Andesites (Pliocene): Andesitic flows, breccias, and agglomerates.
- Tss—Sandstone and volcanic gravel (Pliocene): Poorly consolidated, tuffaceous sandstone with lenses of volcanic conglomerate.
- Tmk—Markley formation (Eocene): Gray to yellow-brown, micaceous marine arkosic sandstone. Massive to well-bedded; contains abundant muscovite.
- Ku—Undivided sandstone, siltstone, and shale of the Great Valley Complex (late Cretaceous): Interbedded carbonaceous−biotite wacke, white−mica−carbonaceous sandstone, greenish−gray mudstone and shale, laminated fine−grained sandstone and gray shale, carbonaceous siltstone, black shale, and fine−grained mica wacke.

Subsurface Geology

According to published geologic maps and as reported in the project's Environmental Geotechnical Memorandum, the geologic units beneath specific portions of the project area are those shown in Table 3.2.3-1.

Table 3.2.3-1. Subsurface Geologic Units for the Project Area[a]

Approximate Location and Segment	Geology
I-80/SR 12W interchange and its vicinity (eastern and central segments)	Fan deposits (Qf) (late Pleistocene to Holocene); alluvium, undivided (Qa) (late Pleistocene to Holocene); artificial fill (af); Markley formation (Tmk) (Eocene); andesites (Tsa) (Pliocene); Sonoma volcanics, undivided (Tsv) (Plioecene)
Future I-680/Red Top Road interchange and its vicinity (western segment)	Fan deposits (Qf) (late Pleistocene to Holocene); fan deposits (Qhf) (Holocene); some modern stream channel deposits (Qhc) (Holocene)
Green Valley Road and its vicinity (western segment)	Fan deposits (Qf) (late Pleistocene to Holocene); fan deposits (Qhf) (Holocene); ash-flow tuff (Tst) (Pliocene); some modern stream channel deposits (Qhc) (Holocene)
Suisun Valley Road and its vicinity (western and central segments)	Fan deposits (Qhf) (Holocene); ash-flow tuff (Tst) (Pliocene)
I-80/SR 12E interchange and SR 12E (eastern segment)	Mainly alluvial fan deposits (Qhf) (Holocene); natural levee deposits (Qhl) (Holocene)

[a] Adapted from the first table shown on page 4 of the project's Environmental Geotechnical Memorandum.

For more information on subsurface geology and structure, including a detailed explanation of bedding planes, folds, and faults, refer to the Environmental Geotechnical Memorandum prepared for the proposed project.

Topography

Review of the 1980 United States Geologic Survey (USGS) map for the Fairfield South and Cordelia, California quadrangles indicates that the project area is located at approximate elevations between more than ten and more than 250 feet above mean sea level. The project area generally slopes to the east, toward wetlands and sloughs associated with Suisun Bay. The general terrain of the project area consists of hills on the north and northwest sides near Red Top Road and relatively level areas (Suisun Valley and Green Valley) in the central and eastern segment of the project area.

Seismicity

The project area is located in a region of California characterized by locally high historical seismic activity and is within UBC Seismic Hazard Zone 4. A number of active faults and fault zones are present in and adjacent to the project area. Consequently, the project area is subject to surface fault rupture and ground shaking (primary hazards), and seismically induced ground failure (a secondary hazard).

Fault Rupture Hazard

The purpose of the Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act) is to regulate development near active faults to mitigate the hazard of surface rupture. Faults in an Alquist-Priolo Earthquake Fault Zone are active faults. As defined under the Alquist-Priolo Act, an active fault is one that has had surface displacement within Holocene time.

The dominant tectonic features in the project area are the Green Valley fault[2, 3] and the Cordelia fault zone, both of which are zoned by the State of California pursuant to the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant 1997), and are considered a Type A (highest risk) seismic source by the UBC and California Building Codes (International Conference of Building Officials 1998[4]).

The Green Valley fault extends from Suisun Bay northwest to Wooden Valley, traversing the rapidly developing I-680 corridor in central and eastern Solano County, near Fairfield. Along its length, the Green Valley fault intersects several major transportation routes, rail lines, power transmission lines, pipelines, and levees.

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[2] The Green Valley fault is often grouped together with the Concord fault and referred to as the Concord-Green Valley fault system. Part of the eastern San Andreas fault system, it is composed of at least two major fault segments, from south to north: the Concord fault (10–15 miles long) and the Green Valley fault (18–27 miles long).

[3] The Green Valley fault in the vicinity of the project area consists of four distinct fault strands (Fault Rupture Assessment; Environmental Geotechnical Memorandum).

[4] The 1998 International Conference of Building Officials maps have recently been superseded by an interactive U.S. Geological Survey website (http://gldims.cr.usgs.gov/webapps/cfusion/Sites/qfault/index.cfm) that plays the same role relative to the International Building Code (IBC) and the later (post-1997) versions of the CBSC, which are based on IBC instead of UBC. The older information and classification of these faults is provided herein to stress their high seismic potential.

The Cordelia fault zone, located approximately 5,800 feet east of the Green Valley fault, has a well-defined north-striking surface expression, and may represent a secondary trace of the Green Valley fault, according to the Fault Rupture Assessment. See Plate 7 of the Environmental Geotechnical Memorandum for images of these earthquake fault zones as they relate to the project area. Also see Plate 3 of the Environmental Geotechnical Memorandum for a map of the regional faults surrounding the project area.

Both of the faults are generally located in the western segment of the project area. The Green Valley fault and the Cordelia fault zone cross the project alignment of Alternative B. These faults are within State (Alquist-Priolo) Earthquake Fault Zones. No fault is directly beneath any proposed elevated structures that are proposed for Alternative B or Alternative B, Phase 1.[5,6] However, under Alternative C and Alternative C, Phase 1, several proposed structures are located in the vicinity of the Green Valley fault.

In summary, the potential for surface fault rupture in the vicinity of the project area is generally high.

Ground-Shaking Hazard

The project area is located within UBC Seismic Hazard Zone 4 and is located in a region of California characterized by locally high historical seismic activity. The State of California (Hart and Bryant 1997) and the U.S. Geological Survey (U.S. Geological Survey 2008) recognize various active seismic sources in the project area vicinity. As described above, the risk of surface rupture in the study area is generally high because of its proximity to active faults. Earthquake-induced ground shaking also poses a significant hazard.

The intensity of ground shaking that would occur in the project area as a result of an earthquake is partly related to the size of the earthquake, its distance from the project area, and the response of the geologic materials within the project area. As a rule, the greater the earthquake magnitude and the closer the fault rupture to the site, the greater the intensity of ground shaking. When various earthquake scenarios are considered, ground-shaking intensities will reflect both the effects of strong ground accelerations and the consequences of ground failure.

Estimates of Earthquake Shaking

Based on the seismic hazard map prepared by Mualchin (1996), the peak bedrock acceleration in the project area ranges from 0.5 *g* to 0.6 *g* (where one *g* equals the force of gravity). According to the *Caltrans Guidelines for Structures Foundation Report* (California Department of Transportation 2006a), the value of peak bedrock acceleration (for a specific project site or area) from the seismic hazard map should be verified using the attenuation relation by Sadigh et al.

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[5] The primary rupture zone for the Cordelia fault does not intersect the proposed elevated structure, and thus the risk for surface-fault rupture is considered low. However, to account for uncertainty in the borehole and geophysical data and the spacing between boreholes that led to these conclusions, the proposed structure should be designed to accommodate minor secondary displacement (e.g., tilting, shearing, and settlement) associated with an earthquake on the Cordelia fault, as recommended in the Fault Rupture Assessment. See the section titled "Avoidance, Minimization, and/or Mitigation Measures" for more information.

[6] Several primary active faults directly impact the proposed structures within the Green Valley fault, but Alternative C has more proposed structures in the vicinity of the Green Valley fault compared to Alternative B (Fault Rupture Assessment; Environmental Geotechnical Memorandum).

(1997). Based on the attenuation relation, the controlling fault is the Cordelia fault, and peak bedrock acceleration of 0.6 *g* is anticipated in the project area. Furthermore, based on a probabilistic seismic hazard map that depicts the peak horizontal ground acceleration values exceeded at a 10% probability in 50 years (Cao et al. 2003; California Geological Survey 2003), the probabilistic peak horizontal ground acceleration values in the project area range from 0.5 *g* to 0.6 *g*, thus confirming that the possibility of the project area experiencing strong ground shaking may be considered moderate to high.

Based on existing published data on officially recognized faults, the following faults are considered to have the greatest potential to affect the project area due to both fault rupture and ground shaking: the Cordelia fault, the Green Valley fault, and the Vaca-Kirby Hill–Montezuma Hills faults (these latter faults are considered early Quaternary and therefore "potentially active").[7] Maximum credible earthquake magnitudes for some of the major faults in the vicinity of the project area determined by Mualchin (1996) are summarized in Table 3.2.3-2. Based on the project's Environmental Geotechnical Memorandum, these maximum credible earthquake magnitudes represent the largest earthquakes that could occur on the given fault based on the current understanding of the regional tectonic structure.

Table 3.2.3-2. Characteristics of Local Faults[a]

Fault/Faults	Maximum Credible Earthquake Magnitude[b]	Distance between Fault/ Faults and Project Area (miles)	Peak Bedrock Acceleration (*g*)[b]	Zoned by State of California
Cordelia	6.5	0	0.6	Yes
Green Valley	6.75	0	0.6	Yes
Vaca-Kirby Hill–Montezuma Hills	6.75	~7	0.6	Yes

[a] Adapted from Table 1 on page 11 of the Environmental Geotechnical Memorandum prepared for the proposed project.
[b] Mualchin 1996.

Accordingly, based on available geological and seismic data, the possibility of the project area experiencing strong ground shaking may be considered moderate to high.

Liquefaction Susceptibility

Liquefaction is a phenomenon in which the strength and stiffness of unconsolidated sediments are reduced by earthquake shaking or other rapid loading. Poorly consolidated, water-saturated fine sands and silts having low plasticity and within 50 feet of the ground surface are typically considered to be the most susceptible to liquefaction. Soils and sediments that are not water saturated and that consist of coarser or finer materials are generally less susceptible. Geologic age also influences the potential for liquefaction. Sediments deposited within the past few thousand years are generally much more susceptible than older Holocene sediments; Pleistocene sediments are even more resistant; and pre-Pleistocene sediments are generally immune (California Division of Mines and Geology 1997).

[7] Based on research conducted on the earthquake probabilities in the San Francisco Bay region, the Working Group on California Earthquake Probabilities (2003) suggests the Green Valley fault has a 4% probability of one or more major (i.e., magnitude greater than 6.7) earthquakes during the coming 30 years. According to the same study, there is a 62% probability of at least one earthquake of magnitude 6.7 or greater striking the San Francisco Bay region before 2031.

The potential for liquefaction in the project area was preliminarily evaluated by the project's Environmental Geotechnical Memorandum. Based on available boring information, the project area is generally underlain by stiff to very stiff clay with occasional pockets/lenses/layers of loose to medium dense sands. Also, based on the Liquefaction Susceptibility Map included as Plates No. 8-1 and 8-2 in the project's Environmental Geotechnical Memorandum, the liquefaction potential within the project area corridor is considered moderate, with the exception of areas along the eastern portion of Jameson Canyon Creek; at Suisun Creek, Green Valley Creek, and Ledgewood Creek; and in the eastern segment of the project area, where it is considered high. See Plate 8 of the project's Environmental Geotechnical Memorandum for the liquefaction susceptibility map for the project area.

Two potential ground failure types associated with liquefaction are lateral spreading and differential settlement (Association of Bay Area Governments 2001). Lateral spreading involves a layer of ground at the surface being carried on an underlying layer of liquefied material over a nearly level surface toward a river channel or other open face. Differential settlement occurs when the layers that liquefy are not of uniform thickness, a common problem when the liquefaction occurs in artificial fills. Settlement can range from 1% to 5%, depending on the cohesiveness of the sediments (Tokimatsu and Seed 1984). The moderate liquefaction susceptibility in the project area and the soil characteristics equate to a high risk of lateral spreading along the creek areas and a moderate risk of differential settlement elsewhere.

Seismically Induced Ground Failure and General Slope Stability

The project alternatives would extend across hillsides and slopes that may pose some risk from landslides or debris flows. According to the State's Landslide Hazard Report for the Cordelia Quadrangle (Manson 1998), there are landslide deposits, elevated landslide potential, and some debris-flow potential in the southwestern portion of the project area (see Parikh 2009, Plates 10-1 and 10-2 for Manson's [1998] Landslide Inventory Map; Plates 11-1 and 11-2 for the Landslide Susceptibility Map; and Plates 12-1 and 12-2 for the Debris-Flow Susceptibility Map).

Approximately 400 to 1,400 feet northwest of its intersection with I-80, the proposed extension of Red Top Road under both alternatives would cross a large mapped landslide which appears to have moved toward the east. Where the proposed extension of Red Top Road intersects SR 12W, it would cross onto a series of mapped landslides that, except for 450 feet of apparently intact bedrock ridgeline, extend approximately 1,400 feet to the northeast where the proposed road will curve around and reach the valley margin. Where the Red Top Road extension is planned, Manson (1998) categorized the hillsides as "Area 4—most susceptible to landsliding" and the eastern half of that area as "Area C—most susceptible to debris flows."

Soils

Surface Soil Conditions

According to the Soil Survey of Solano County, California (Bates 1977), the predominant surface soil materials within the project area are the Clear Lake clay (CeA), Conejo gravelly loam (Co), Sycamore silty clay loam (Sr), and Yolo silty clay loam (Ys)[8]. These soils are

[8] See Plate 9 of the Environmental Geotechnical Memorandum for a figure showing all surface soil map units in the project area.

generally fine-textured, poorly drained to well drained, have slopes between 0%–2%, very slow runoff to slow runoff; low to high shrink-swell potential; and generally a slight hazard of water erosion.

Based on Table 3.2.3-3 and on Plate 9 of the project's Environmental Geotechnical Memorandum, the soils in the project area are mainly silty clay loams and clay loams. Permeability or hydraulic connectivity is moderately low to high and runoff rate is very slow to rapid. Soils are poorly drained to well drained and erosion hazard is low to moderately high. Shrink-swell potential varies depending on texture, but is considered high for any soils with a high clay content.

Subsurface Soil Conditions

The underlying native soil map units and their characteristics are shown in Table 3.2.3-3. Additional subsurface soil conditions and groundwater conditions[9] within the project area limits are shown in the first table on page 7 of the project's Environmental Geotechnical Memorandum.

Table 3.2.3-3. Underlying Native Soil Map Unit Characteristics of the Project Area[a]

Soil Map Unit	Soil Map Unit Name	Surface Texture	Permeability	Slope (%)	Drainage	Available Water Holding Capacity	Erosion Hazard	Shrink-Swell Potential
Sr	Sycamore silty clay loam	Silty clay loam	Moderately high	0–2	Poorly drained	High	Low	Moderate
Ss	Sycamore silty clay loam, drained	Silty clay loam	Moderately high	0–2	Poorly drained	High	Low	Moderate
CeA	Clear Lake clay	Clay	Moderately low to high	0–2	Poorly drained	Moderate	Moderate	High
HaF	Hambright loam	Loam to cobbly loam	Moderately high to high	15–40	Well drained	Very low	Moderately high	Low to moderate
CiA	Clear Lake clay, saline	Clay	Moderately low to high	0–2	Poorly drained	Low	Moderate	High
BrA	Brentwood clay loam	Clay loam	Moderately high	0–2	Well drained	High	Low	High
AoA	Antioch–San Ysidro complex	Sandy loam to clay loam	Very low to moderately low	0–2	Moderately well drained	Very low	Moderately high	Low to high

[a] Adapted from the first table shown on page 13 of the project's Environmental Geotechnical Memorandum and Soil Survey of Solano County, California (Bates 1977).

Environmental Consequences

Risk of Fault Rupture during Operations

Based on available knowledge of fault locations and fault rupture hazard, the risk of surface fault rupture in the project area is generally high because of its proximity to active faults. Fault rupture has the potential to compromise the structural integrity of proposed new facilities and cause injury to construction workers. Effects of the project alternatives related to potential structural

[9] Groundwater depths in the project area typically range from 10–15 feet below ground surface.

damage and injury caused by fault rupture would be minimized with implementation of state and local requirements and recommendations from the draft geotechnical reports.

The No-Build Alternative would not result in new structures in the project area. There would be no potential structural damage or resulting injury caused by fault rupture associated with the No-Build Alternative.

Risk from Ground Shaking during Operation

Based on available knowledge of fault locations and ground shaking potential, the possibility of the project area experiencing strong ground shaking may be considered moderate to high because of its proximity to active faults. Without proper seismic engineering, a large earthquake on a nearby fault could cause moderate ground shaking in the project area, potentially resulting in liquefaction and associated ground failure, such as lateral spreading or differential settlement, which in turn could increase the risk of structural loss, injury, or death. Effects of the project alternatives related to potential structural damage and injury caused by ground shaking would be minimized with implementation of state and local requirements and recommendations from the draft geotechnical reports.

The No-Build Alternative would not result in new structures in the project area. There would be no potential structural damage or resulting injury caused by ground shaking associated with the No-Build Alternative.

Risks from Development on Unstable Materials

Liquefaction in the project area could increase the risk of structural loss, injury, or death. Effects of the project alternatives related to potential structural damage and injury caused by liquefaction would be minimized with implementation of state and local requirements and recommendations from the draft geotechnical reports.

The impact of the post-liquefaction settlement on the roadway portions of the project alternatives is relatively small because the potentially liquefiable soil layers are generally covered by cohesive soils, which tend to serve as a “soil mat” and should reduce the potential impact of liquefaction. Any potential post-liquefaction settlement at abutments, bents, or piers of proposed bridge structures may cause downdrag (due to the clay above the liquefiable sand layer) and reduce the load carrying capacity of the piles. Typical mitigation (described below) is to design the foundation for such conditions. Based on the Environmental Geotechnical Memorandum prepared for the project alternatives, liquefaction should not be a significant impact on pavement surfaces because the resulting settlements are generally aerial in type and localized.

The No-Build Alternative would not result in new construction in the project area. There would be no potential structural damage or resulting injury resulting from development on materials prone to ground failure, including materials subject to liquefaction associated with the No-Build Alternative.

Risk from Landslides or Other Slope Failure during Operation

The project alternatives would extend across hillsides and slopes that may pose some risk from landslides or debris flows. As such, new construction in the project area would be at risk for structural damage or personal injury resulting from landslides or other slope failure.

Effects of the project alternatives related to potential structural damage and injury caused by landslides or other slope failures would be minimized with implementation of state and local requirements and recommendations from the draft geotechnical reports.

The No-Build Alternative would not result in new construction in the project area. There would be no potential structural damage or resulting injury resulting from landslides or other slope failure associated with the No-Build Alternative.

Risk during Operation as a Result of Development on Expansive Soils

Various soil map units (both surface and subsurface) in the project area have been identified as having moderate to high shrink-swell potential and therefore have the potential to compromise the structural integrity of proposed new facilities (including roadways, bridges, and other associated features). Effects of the project alternatives related to potential structural damage caused by shrink-swell would be minimized with implementation of state and local requirements and recommendations from the draft geotechnical reports. Furthermore, project activities would cause no change in current conditions with respect to the current shrink-swell hazards.

The No-Build Alternative would not result in new construction in the project area. There would be no potential structural damage or resulting injury resulting from development on expansive soils associated with the No-Build Alternative.

Risk during Operation as a Result of Weak Foundation Materials and Postconstruction Settlement

In general, short-term and long-term consolidation settlements do not appear to be a reason for concern in the project area, except near Suisun Valley Road and Dan Wilson Creek where soft clays are indicated in test borings. In these areas, consolidation settlements may pose a significant hazard to the immediate structures. Conducting future geotechnical investigations and implementing recommendations from the draft geotechnical reports would lessen the severity of this potential hazard.

The No-Build Alternative would not result in new construction in the project area and therefore, there would be no potential structural damage or resulting injury resulting from weak foundation materials and postconstruction settlement associated with the No-Build Alternative.

Runoff, Erosion, and Sedimentation from Grading Activities Associated with Construction

Grading, excavation, removal of vegetation cover, and loading activities associated with construction activities could temporarily increase erosion and sedimentation. Construction

activities also could result in soil compaction and wind erosion effects that could adversely affect soils and reduce the revegetation potential at the construction sites and staging areas.

A SWPPP will be developed by a qualified engineer or erosion control specialist and implemented before construction as described in Section 3.2.2, "Water Quality and Stormwater Runoff." Furthermore, compliance with the County's Grading Ordinance also would minimize any negative effects associated with erosion and sedimentation. A grading permit as required by Chapter 31 of the Solano County Code (Solano County 2009) will be required for this project. As part of this permit, the project applicant will be required to submit a grading and erosion control plan, vicinity and site maps, and other supplemental information. Additionally, standard conditions in the grading permit include an extensive list of BMPs similar to those described in a SWPPP above.

The No-Build Alternative would not result in new construction in the project area. There would be no effects from runoff, erosion, and sedimentation from grading activities associated with construction.

Avoidance, Minimization, and/or Mitigation Measures

Future measures need to be conducted/developed prior to/or during the plans, specification, and estimate phase for any build alternative.

Implement Requirements from State and Local Standards into Final Project Design

UBC Seismic Hazard Zone 4/CBSC, Department, and County General Plan standards are required to be implemented and incorporated into the project design for applicable features to minimize the potential fault rupture, ground shaking, liquefaction, and shrink-swell hazards on associated project features. Structures must and will be designed to meet the regulations and standards associated with UBC Seismic Hazard Zone 4 hazards.

Implement Recommendations from Draft Geotechnical Reports to Accommodate Permanent Fault-Related Ground Deformation Effects from Surface Fault Rupture on Project Facilities and to Accommodate Effects of Ground Shaking on Project Facilities

Recommendations from both the Fault Rupture Assessment and the Environmental Geotechnical Memorandum for the proposed project will be incorporated in to the final project design.

The primary rupture zone for the Cordelia fault does not intersect proposed elevated structures, and thus the risk for surface-fault rupture is considered low. However, to account for uncertainty in the borehole and geophysical data that led to these conclusions, proposed structures should be designed to accommodate minor secondary displacement (e.g., tilting, shearing, and settlement) associated with an earthquake on the Cordelia fault.

The following recommendations from the Fault Rupture Assessment report and project's Environmental Geotechnical Memorandum will be incorporated in to the final project design to accommodate permanent fault-related ground deformation effects from surface fault rupture on project facilities.

- As described in the Fault Rupture Assessment, fault rupture hazard maps prepared for both the Cordelia and Green Valley Project sites should be considered during design of the proposed elevated structures for mitigation of surface-fault rupture. This could include avoidance where possible, or if not possible, special design to accommodate the estimated coseismic displacement yielded by the two approaches.[10]
- As described in the Environmental Geotechnical Memorandum, if avoidance is not possible, special design should be considered to accommodate the displacement estimated by the Department and based on scenario-based fault displacement hazard (FDHA) analysis approach.
- Department engineers responsible for the design of the elevated structures should evaluate the state's recommended criteria, Draft Memo to Designers 20-10 (California Department of Transportation 2007) for surface-fault rupture with regard to the results of the fault hazard displacement analysis. A geotechnical engineer and/or structural engineer should review the results of the two methods, consider an appropriate factor of safety and design the structures with respect to permanent ground deformation, as recommended in the Fault Rupture Assessment.
- On the basis of the Department's Draft Memo to Designers 20-10 (California Department of Transportation 2007), a fault displacement of 1.9 feet from the Green Valley fault should be considered in the design of elevated structures crossing the fault zone.

Based on the attenuation relation by Sadigh et al. (1997), the controlling fault is the Cordelia fault, and peak bedrock acceleration of 0.6 *g* is anticipated in the project area. The following recommendations from the Fault Rupture Assessment and the Environmental Geotechnical Memorandum will be incorporated in to the final project design to accommodate effects of ground shaking on project facilities:

- Structures should be designed based on the Acceleration Response Spectrum (ARS) Curve according to the *Caltrans Seismic Design Criteria Manual*.[11]
- Geologic conditions encountered at the Cordelia project site included lenses of saturated granular deposits. The Cordelia project site should be evaluated for liquefaction, lateral spreading and settlement associated with strong ground shaking.
- Geologic conditions encountered at the Green Valley project site included lenses of saturated fine- to coarse-grained deposits along the western and eastern margins of Quarry Hill. Portions of the Green Valley site should be evaluated for liquefaction, lateral spreading, and settlement associated with strong ground shaking.

[10] The fault displacement hazard analysis and the resulting displacement values for the multiple fault traces comprising the Green Valley fault depend on site information and results from previous studies. Future investigations (trenches and boreholes) may allow refinement of the calculations, an improved model of uncertainties, and revised fault rupture hazard maps.

[11] The criteria include, but are not limited to, designing infrastructure that can withstand an earthquake of magnitude 7.5 and a peak bedrock acceleration of 0.6 *g* with modifications. Other specific design criteria are further described in the *Caltrans Seismic Design Criteria Manual* (California Department of Transportation 2006b).

Conduct Future Geotechnical Investigations

In accordance with applicable state and local laws, a final geotechnical investigation (or investigations) will be conducted to evaluate the engineering properties of the subsurface soil materials for recommendation of geotechnical parameters, to address geotechnical hazards (e.g., slope stability, differential settlement) associated with different design elements , as well as hazards associated with potential fault rupture/creep or strong ground motion (e.g., shaking, liquefaction, earthquake-induced landslides).[12] The final geotechnical investigation will include recommendations for designing specific project elements to accommodate the effects of fault rupture and ground shaking.

Implement Recommendations from Draft Geotechnical Report to Accommodate Effects of Liquefaction on Project Facilities/Design Specific Project Elements to Accommodate Effects of Liquefaction

The following recommendations from the project's Environmental Geotechnical Memorandum will be incorporated into the final project design.

- Design foundations to withstand the effects of liquefaction. Any downdrag load on the piles due to potential post-liquefaction settlement should be considered in the vertical pile capacity analyses.
- Shallow zones of liquefiable materials can be removed and replaced or treated with materials that can improve their properties (such as by grouting).
- Site-specific liquefaction potential in areas with moderate and/or high liquefaction susceptibility should be evaluated in the plans, specifications, and estimates phase.

If shallow zones of liquefiable soils or soils susceptible to seismically induced settlement are determined to be present at any location where project activities would occur, corrective actions shall be taken, including removal and replacement of soils; on-site densification; grouting; and design of special foundations or other similar measures, depending on the extent and depth of susceptible soils. All of these measures reduce pore water pressure during ground shaking by densifying the soil or improving its drainage capacity.

Conduct Future Geotechnical Investigation/Implement Preliminary Recommendations from Draft Geotechnical Report to Accommodate Effects of Slope Failure on Project Facilities

The following recommendations from the project's Environmental Geotechnical Memorandum will be incorporated into the final project design.

- Because significant grading can be expected for construction of the roadway, site-specific investigation of those mapped landslides will be needed to assess the potential impacts and formulate appropriate mitigation measures.

[12] The last section of the Environmental Geotechnical Memorandum provides a recommended scope of geotechnical investigation.

- Specific recommendations pertaining to cut slopes and fill slopes/embankments should be incorporated into the final project design. For cut slopes, recommendations pertaining to suggested slope gradients, rock bedding and joint evaluation, drilling and geophysical testing, and slope stabilization measures should be implemented. For fill slopes/embankments, recommendations pertaining to suggested slope gradients and slope stabilization measures should be implemented.

Implement Preliminary Recommendations from Draft Geotechnical Report to Accommodate Effects of Consolidation Settlements on Project Facilities

The following recommendations from the project's Environmental Geotechnical Memorandum report will be incorporated into the final project design.

- Department embankment construction standards as outlined in Section 19 of the California Department of Transportation Standards Specifications (California Department of Transportation 2006c) should be followed.
- If further investigation shows that consolidation settlement may become critical to the other project improvements, mitigation measures such as phased construction, implementation of waiting periods, surcharge fill, wick drain installation, and monitoring may be required.

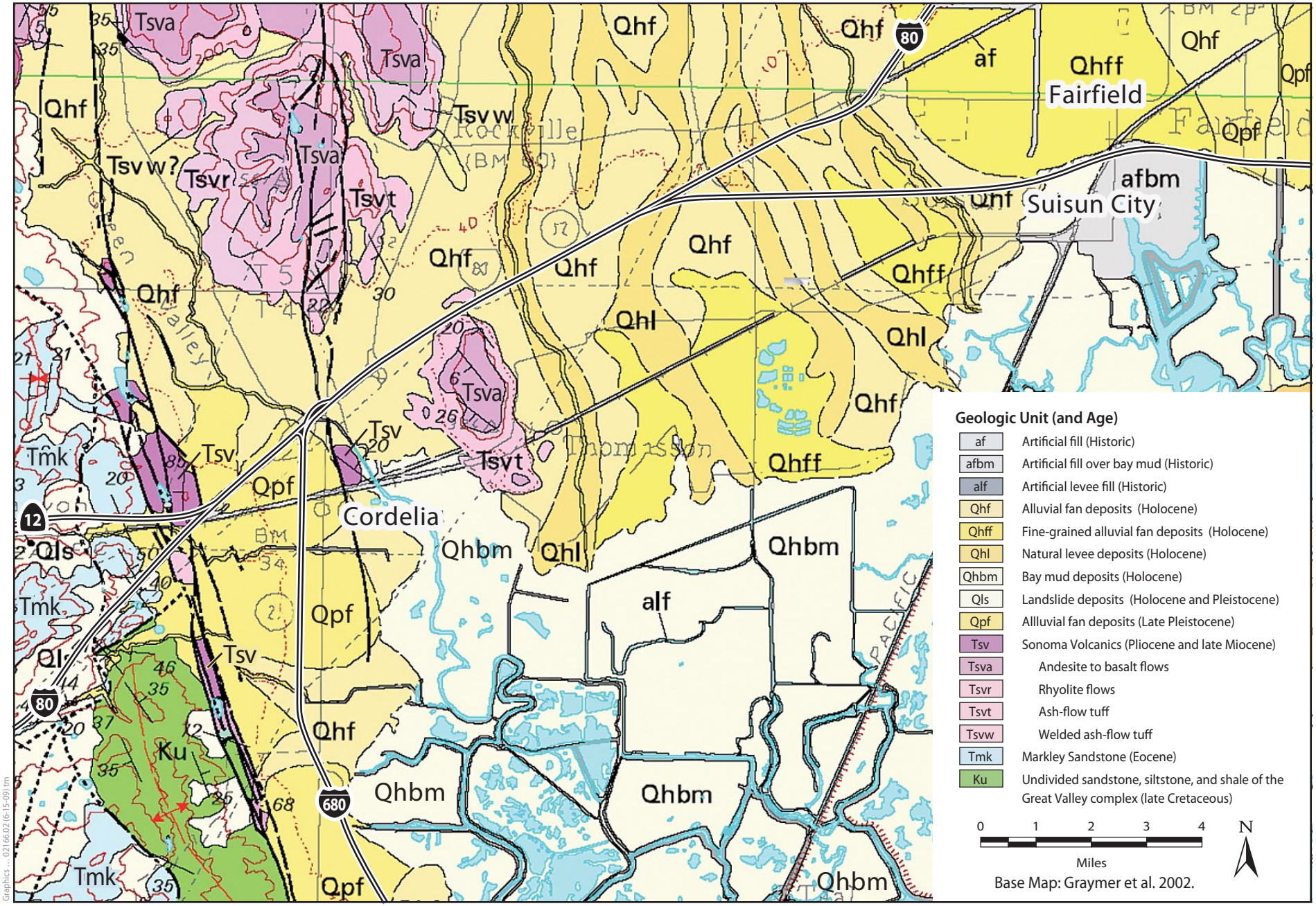

Figure 3.2.3-1
Geologic Map of the Project Vicinity