3.7 GEOLOGY, SOILS, AND SEISMICITY

Introduction

This section summarizes the geologic, soil, and seismic hazards along the project corridor, and the potential for transit service in this corridor to expose people or structures to these hazards. The project corridor is located in the San Francisco Bay Area, a seismically active region with more than 10 severe earthquakes occurring throughout historical time. For this reason, the design of the project to avoid collapse during an earthquake and to achieve acceptable levels of public safety is an important consideration. Site-specific geologic conditions, such as soil types and underlying geologic materials, provide the basis for determining which areas along the corridor are susceptible to seismic and geologic hazards.

Potential geologic hazards along the corridor are identified below:

- **Strong Seismic Ground Shaking.** Strong seismic ground shaking has the potential to severely impact transportation systems in the Bay Area, as seen from the 1989 Loma Prieta earthquake that destroyed a nearly 1.5-mile section of Interstate 880 in Oakland and a portion of the upper deck of the San Francisco-Oakland Bay Bridge. Geologic maps showing nearby faults and underlying soils and geology are used to identify areas along the project corridor with strong ground shaking potential. The distribution and type of soils found along the project corridor were obtained from United States Department of Agriculture (USDA) Soil Conservation Service (SCS) county soils reports.

- **Seismic-Related Ground Failure, including Liquefaction.** Liquefaction occurs when ground shaking loosens soil particles and causes soil to liquefy and resemble quicksand. Liquefaction may cause structures to collapse, since structures are no longer supported in the soil. The liquefaction potential of deposits along the project corridor is approximated using newly developed, nine-county Bay Area liquefaction hazard mapping completed for the United States Geological Survey (USGS).

- **Landslides, Lateral Spreading, and Subsidence.** Landslides, lateral spreading, and subsidence are geologic hazards that result from unstable soils and underlying geologic materials. Landslides are the sudden fall of rock or earth on a steep slope and may be triggered by earthquakes or heavy rain. Lateral spreading occurs when liquefaction on gentle slopes causes subsurface soil layers to move downslope. Subsidence is the compacting and sinking of soils that result in a shallow hole in the earth's surface. These geologic hazards have the potential to cause severe damage to transportation systems, as they may result in the misalignment of transit guideways and the collapse of buildings and structures.

- **Expansive or Erosive Soils**. Expansive soils are soils that expand or contract when they absorb or lose water. The expansion and contraction of soils may cause cracking, tilting, and eventual collapse of structures. Excessive soil erosion can eventually lead to damage of building foundations and roadways.

No comments regarding geology, soils, and seismicity were received in response to the Notices of Preparation released in 2005 and 2008. Please refer to Appendix A for a copy of the NOPs.

Existing Conditions

The project corridor is located in east Contra Costa County within the San Francisco Bay Area. The corridor extends to the northwestern margin of the San Joaquin Valley, with Mount Diablo to the west and Suisun Bay and the Sacramento/San Joaquin River Delta to the north.

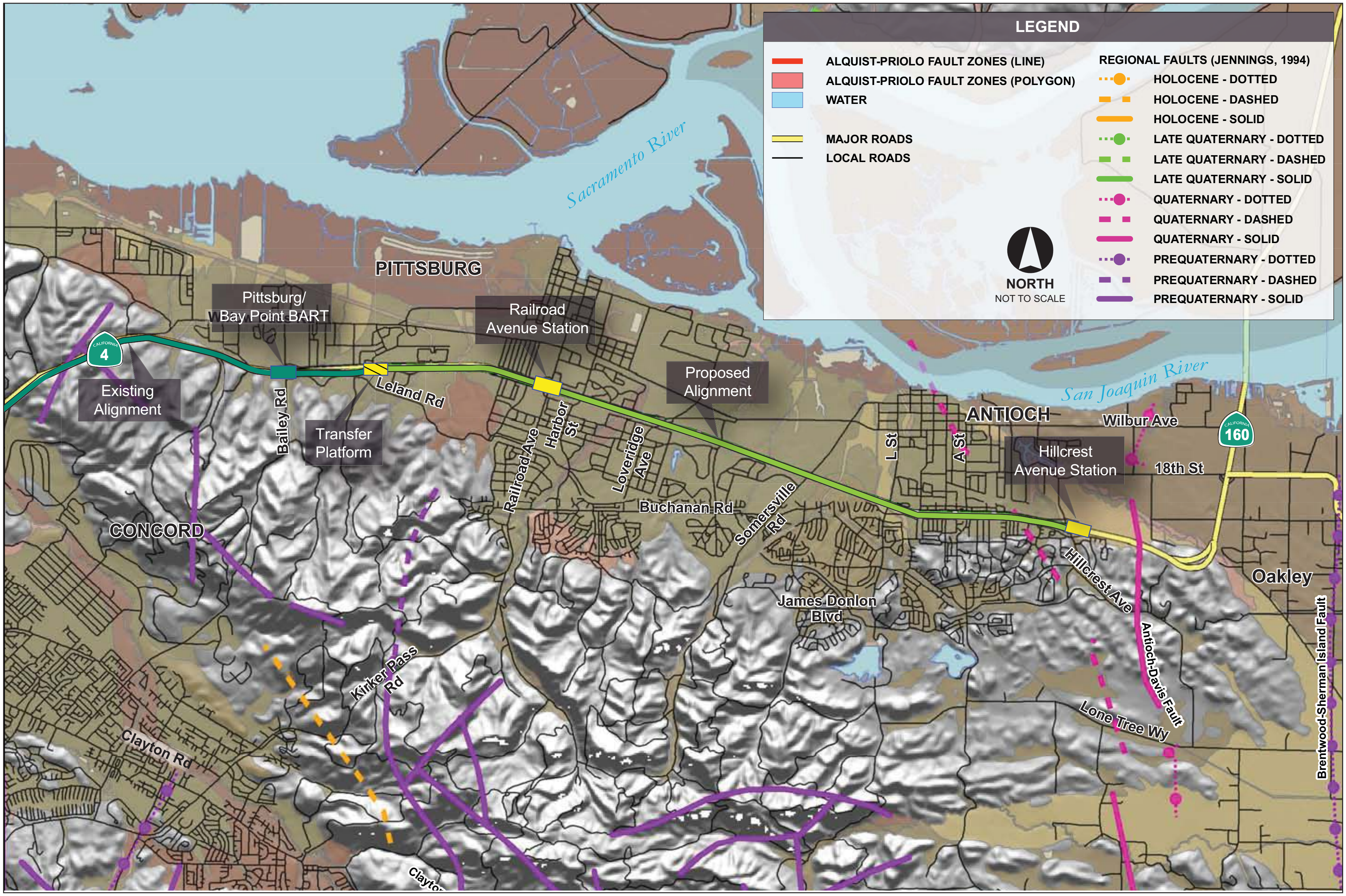
The San Francisco Bay Area is characterized by a high level of seismic activity, with more than 10 severe earthquakes occurring throughout historical time. Underlying geologic conditions, topography, soil composition, and faulting characteristics affect the potential for seismic and geologic hazards. These geologic features and potential hazards are summarized below.

Regional Geology

The diverse, geologic conditions of Contra Costa County and the greater San Francisco Bay Area are largely defined by the network of major active faults, or cracks in the earth's crust, that occur within the region. The San Andreas Fault System is the most prominent feature in the region and includes several major fault zones, or areas with numerous fractures, including the San Andreas, Hayward, and Calaveras fault zones. Figure 3.7-1 shows the locations of faults in the region.

The San Andreas Fault zone is on one of the major faults in the San Andreas Fault System. It is more than 800 miles long, extending to a depth of 10 miles beneath the earth's surface. The earth's outer layers are organized into about a dozen large pieces, called crustal plates. The San Andreas Fault serves as the division between the Pacific and North American crustal plates. The Pacific Plate is located to the west of the fault, and the North American plate is east of the fault. The Pacific Plate moves northwestward in relation to the North American Plate, and in the process creates vibrations, or earthquakes, along the fault.

Bedrock is the solid rock that forms the earth's crust and underlies all soil or other loose materials. The San Andreas Fault separates two bedrock complexes or distinct groups of rocks: the Salinian Block and the Franciscan Formation. The Salinian Block lies west of the fault, and the Franciscan Formation lies to the east. Contra Costa County lies east of the fault and is underlain by the Franciscan Formation. As bedrock eventually breaks down to form



Source: William Lettis & Associates, Inc., Jennings, 1994; California Geological Survey Zone Map, and Environmental Science Associates, 1991.

REGIONAL FAULTS NEAR THE PROJECT CORRIDOR

FIGURE 3.7-1

soil, the rocks of the Franciscan Formation have influence the types and characteristics of soils within the project corridor.

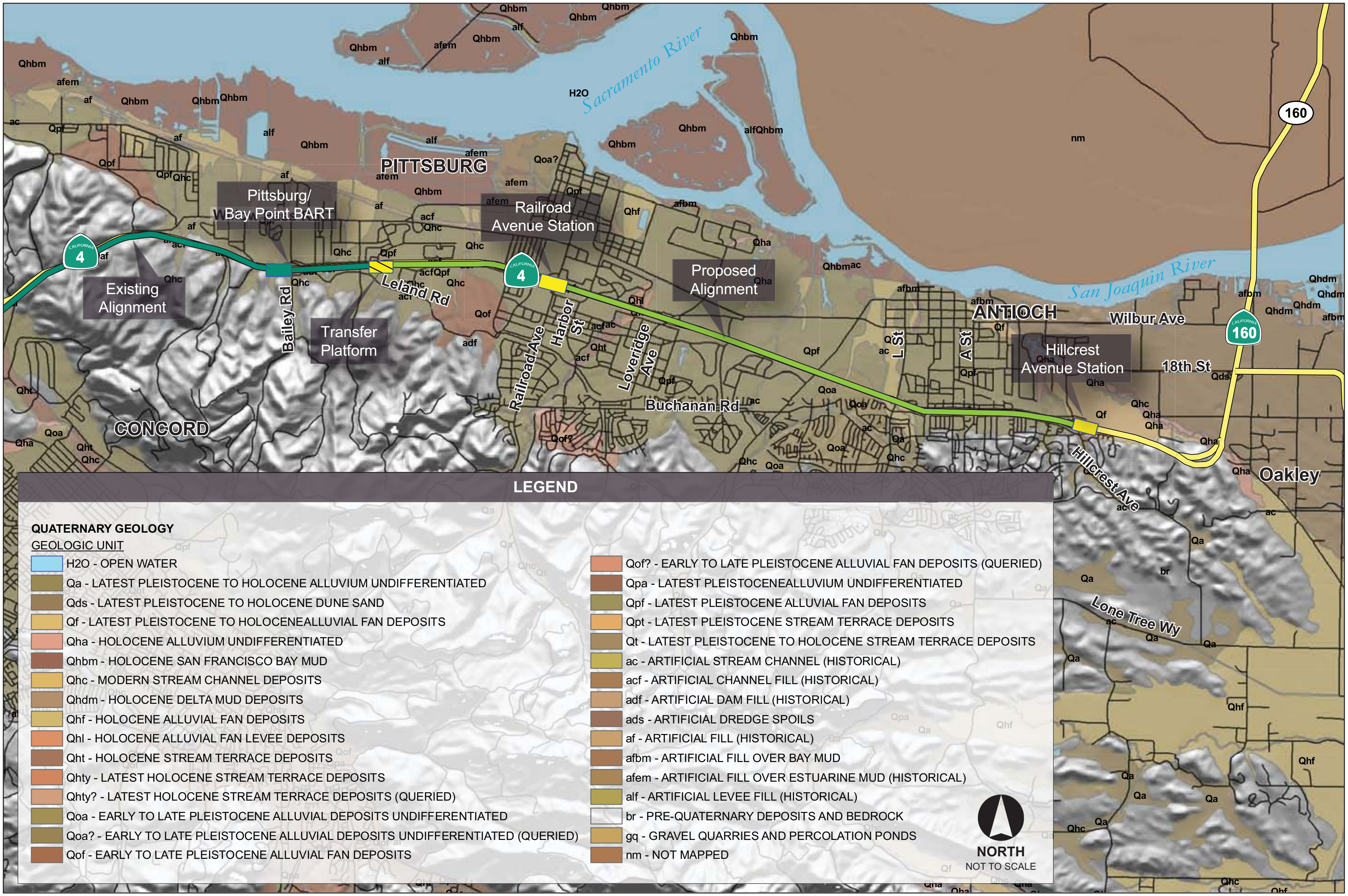
California is divided into geomorphic provinces, which are geologic regions with distinctive landscapes or landforms. The San Andreas Fault serves as the boundary between the Coast Ranges Geomorphic Province and the Pacific Ocean. The project corridor, which includes the cities of Pittsburg and Antioch, lies in the Coast Ranges Geomorphic Province. The Coast Ranges Geomorphic Province contains nearly parallel mountain ranges and valleys that trend northwest, parallel to the San Andreas Fault. Mount Diablo sits among the eastern ridges of the Coast Ranges and is the highest peak in the East Bay at 3,849 feet above mean sea level.

Project Corridor Geology and Seismicity

Since the majority of the project corridor lies within the cities of Pittsburg and Antioch, including the two stations, the transfer facilities, and the track work, this description of the geologic, soils, and seismic conditions concentrates on these geographic areas. However, because the Remote Maintenance Facility for two of the Hillcrest Avenue Station options extends further to the southeast towards Oakley, information on Oakley is also summarized here.

Geologic Conditions. Quaternary geology is the geology of the Quaternary period, the youngest geologic period when most of the earth's landscape was formed. Figure 3.7-2 shows the Quaternary geology of the project corridor, which provides an understanding of the underlying geologic materials, such as age and composition (e.g., sand versus clay). Information about the underlying geology is important for the design of the Proposed Project, as certain geologic materials can pose construction and design constraints. For example, younger soils are typically weaker in their ability to support different types of structures. Also, some materials present construction challenges, such as building a foundation in alluvial sand or building one in bedrock.

Within the cities of Pittsburg and Antioch, common geologic units include Pleistocene alluvial fan deposits (Qpf), Holocene colluvium (Qhc), and Alluvial fan deposits (Qf). The Pleistocene period spans from about 11,500 to 1 million years ago. The term "alluvial" refers to mud or sand deposited by flowing water. Pleistocene alluvial fan deposits were deposited by streams coming from mountain canyons onto alluvial valley floors or alluvial floodplains, and typically include sand, gravel, silt, and clay. The Holocene epoch is a geologic period that spans from present day to about 10,000 years ago. The term "colluvium" refers to rock and soil that accumulate at the base of a hill. Holocene colluvium consists of deposits within active, natural stream channels, and includes sand, gravel, and cobbles with minor silt and clay. Alluvial fan deposits are located on gently sloping, fan-shaped surfaces, and include gravel, silt, and clay. In portions of the City of Pittsburg near the existing Pittsburg/Bay Point BART Station, the project corridor is underlain by Artificial fill (Af) and Artificial dam fill (Adf). Artificial fill is



Source: William Lettis & Associates, Inc. and Witter et al., 2006.

QUATERNARY GEOLOGY ALONG THE PROJECT CORRIDOR

FIGURE 3.7-2

material deposited by humans within the last 150 years, and artificial dam fill is material used to construct earth dams, rock-fill dams, embankments, and levees, also within the last 150 years.

In Oakley, the dominant geologic units underlying the project corridor are Holocene alluvial deposits (Qhf). These sediments were deposited by streams coming from mountain canyons onto alluvial valley floors or alluvial plains, including debris flow, hyperconcentrated mud flow, and braided stream deposits. About 9 percent of the central San Francisco Bay Area is covered by Holocene alluvial deposits, and it is the most common Quaternary map unit in the region.[1]

Mineral Resources. The project corridor passes near the Domengine sandstone mineral resources area. Domengine sandstone is a highly valued resource on the county, state, and national levels. However, a mineral resource map of Contra Costa County does not indicate the presence of Domengine Sandstone beneath the project corridor.[2]

Soils. A soil association is a landscape that has a distinctive pattern of soils in defined proportions. It typically consists of one or more major soils and at least one minor soil, and it is named after the major soils.[3] Soil maps created by the USDA SCS show that two soil associations occur within the project corridor: the Capay-Rincon association and the Brentwood-Rincon Zamora association.[4]

Table 3.7-1 lists the properties and limitations of the soil types in the project corridor, including the shrink-swell potential, or the potential for the soils to be expansive, and the corrosivity of soils to uncoated steel. Expansive soils are soils that expand or contract when they absorb or lose water, which may cause cracking, tilting, and eventual collapse of structures. Corrosivity is the ability of soil to break down certain substances, particularly metals. Soil surveys typically generalize soil properties, and thus soil corrosivity estimates likely are conservative along the project corridor. The specific soil types along the project corridor are shown in Figure 3.7-3, derived from the soil classification map produced by the USDA SCS county soils report.[5]

Table 3.7-1 indicates that soils along the corridor are highly corrosive to uncoated steel. Corrosivity is based on several soil characteristics including resistivity, conductivity, and pH (a measure of acidity). Soil resistivity is the ability of soil to resist or oppose the movement of electrical current, while conductivity is the ability of soil to carry an electrical current. These

1 United States Geological Survey, Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California, Part 3: *Description of Mapping and Liquefaction Interpretation*, Open-File Report 2006-1037.

2 Contra Costa County; *Contra Costa County General Plan 2005-2020*, January 2005.

3 U.S. Department of Agriculture, Soil Survey of Contra Costa County, California, 1977.

4 U.S. Department of Agriculture, Soil Conservation Service, University of California Agricultural Experiment Station, *General Soil Map, Contra Costa County, California,* 1976.

5 U.S. Department of Agriculture, Soil Survey of Contra Costa County, California, 1977.

Table 3.7-1
Soil Types Underlying Project Corridor

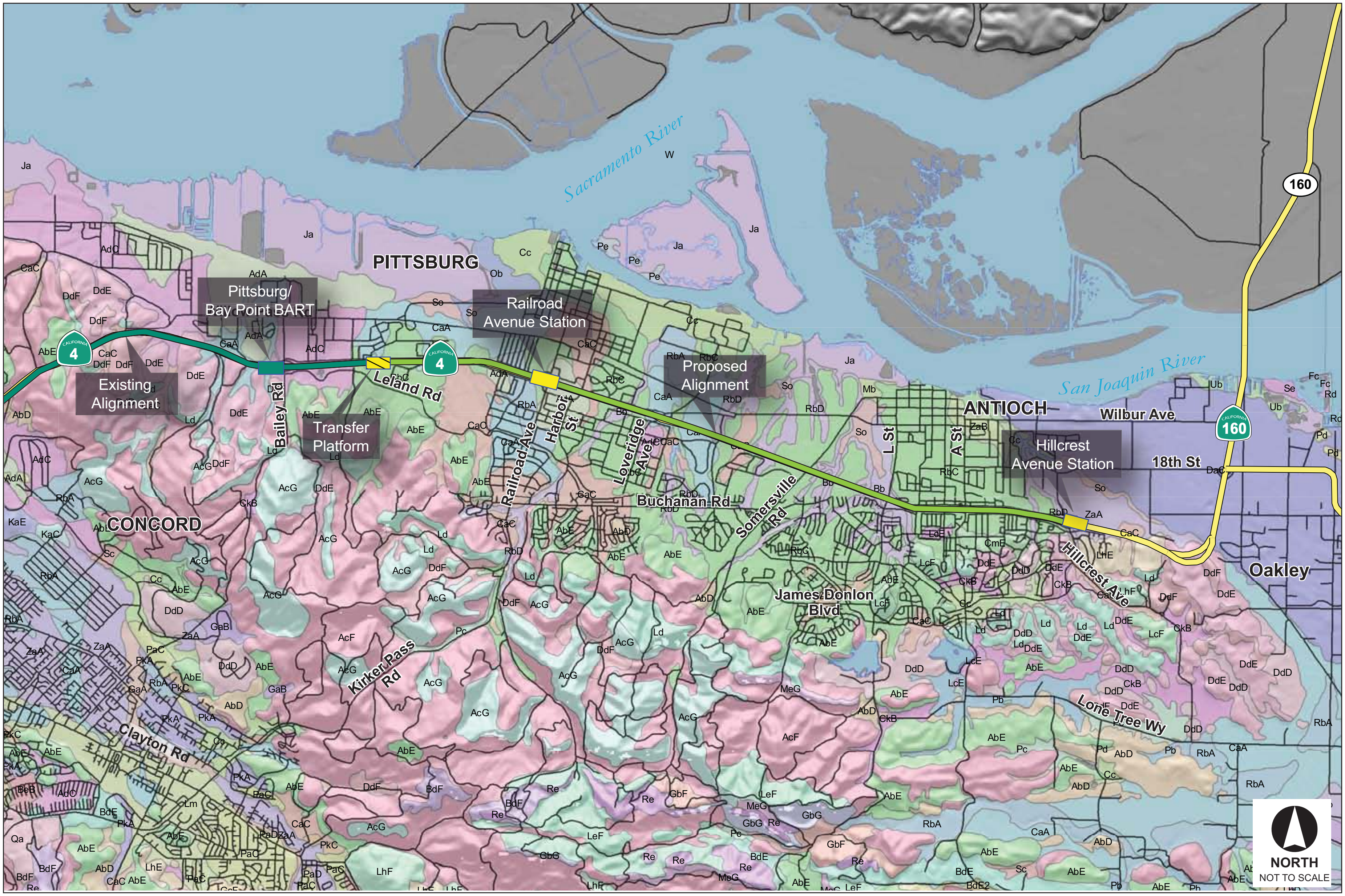
General Location Along Corridor	Soil Series and Map Symbol	Depth to Bedrock (feet)	Depth to Water Table (feet)	Depth to Surface (Typical Profile) (feet)	USDA Texture	Shrink-Swell Potential	Corrosivity to Uncoated Steel
Pittsburg	Antioch: AdA, AdC	> 5	(a)	0-17 17-36 36-60	Loam Clay Clay loam	Low High Moderate	High High High
	Brentwood: Bb	> 5	(a)	0-60	Clay loam	High	High
	Capay: CaA, CaC	> 5	(a)	0-60	Clay	High	High
	Rincon: RbA, RbC, RbD	> 5	(b)	0-12 12-29 29-65	Clay loam Clay Silty Clay loam	Moderate High Moderate	Moderate High High
	Sycamore: So	> 5	3.5-5	0-66	Silty Clay loam and Silt loam	Moderate	High
Antioch	Capay: CaA, CaC	> 5	(a)	0-60	Clay	High	High
	Diablo: DdE	3.5-5	(a)	0-42 42	Clay Shale	High	High
	Los Osos: LhE	2-3.5	(a)	0-32 32	Clay loam and clay Sandstone	High	High
	Rincon: RbC, RbD	> 5	(b)	0-12 12-29 29-65	Clay loam Clay Silty clay loam	Moderate High Moderate	Moderate High High
	Zamora: ZaA	> 5	(a)	0-46 46-72	Silty clay loam Silty clay loam and clay loam; gravelly in places	Moderate Moderate	High High
Oakley	Brentwood: Bb	> 5	(a)	0-60	Clay loam	High	High
	Capay: CaA	> 5	(a)	0-60	Clay	High	High
	Delhi: DaC	> 5	(a)	0-60	Sand	Low	Low
	Marcuse: Mb	> 5	3.5-4	0-60	Clay	High	Very High
	Sorrento: Sm	> 5	(a)	0-60	Silty clay loam and clay loam	Moderate	High
	Sycamore: So	> 5	3.5-5	0-66	Silty clay loam and silt loam	Moderate	High

Source: U.S. Department of Agriculture, Soil Conservation Service, 1977.

Notes:

a. No water table within the depth of observation, which is normally a depth of 5 feet unless limited by bedrock.

b. In RbA, RbC, and RbD, no water table is within the depth of observation. In RcA, a seasonal high water table is at a depth of 3.5-4.5 feet.



Source: William Lettis & Associates, Inc. and USDA Soil Classification Map.

SOILS TYPES ALONG THE PROJECT CORRIDOR

FIGURE 3.7-3

LEGEND

MAJOR ROADS

SOILS

MAP UNIT

AaE - ALO CLAY, 15 TO 30 PERCENT SLOPES
AaF - ALO CLAY, 30 TO 50 PERCENT SLOPES
AaG - ALO CLAY, 50 TO 75 PERCENT SLOPES
AbD - ALTAMONT CLAY, 9 TO 15 PERCENT SLOPES
AbE - ALTAMONT CLAY, 15 TO 30 PERCENT SLOPES
AcF - ALTAMONT-FONTANA COMPLEX, 30 TO 50 PERCENT SLOPES
AcG - ALTAMONT-FONTANA COMPLEX, 50 TO 75 PERCENT SLOPES
AdA - ANTIOCH LOAM, 0 TO 2 PERCENT SLOPES
AdC - ANTIOCH LOAM, 2 TO 9 PERCENT SLOPES
BaA - BOTELLA CLAY LOAM, 0 TO 2 PERCENT SLOPES
Bb - BRENTWOOD CLAY LOAM
Bc - BRENTWOOD CLAY LOAM, WET
BdE - BRIONES LOAMY SAND, 5 TO 30 PERCENT SLOPES
BdE2 - BRIONES LOAMY SAND, 15 TO 30 PERCENT SLOPES, ERODED
BdF - BRIONES LOAMY SAND, 30 TO 50 PERCENT SLOPES
BeB - BRIONES FINE SANDY LOAM, 2 TO 5 PERCENT SLOPES
CaA - CAPAY CLAY, 0 TO 2 PERCENT SLOPES
CaC - CAPAY CLAY, 2 TO 9 PERCENT SLOPES
CbA - CAPAY CLAY, WET, 0 TO 2 PERCENT SLOPES
Cc - CLEAR LAKE CLAY
CeA - CONEJO CLAY LOAM, 0 TO 2 PERCENT SLOPES
ChA - CONEJO CLAY LOAM, CLAY SUBSTRATUM, 0 TO 2 PERCENT SLOPES
CkB - CROPLEY CLAY, 2 TO 5 PERCENT SLOPES
CmE - CUT AND FILL LAND-DIABLO COMPLEX, 9 TO 30 PERCENT SLOPES
DAM - DAM
DaC - DELHI SAND, 2 TO 9 PERCENT SLOPES
DdD - DIABLO CLAY, 9 TO 15 PERCENT SLOPES
DdE - DIABLO CLAY, 15 TO 30 PERCENT SLOPES
DdF - DIABLO CLAY, 30 TO 50 PERCENT SLOPES
DeE - DIBBLE SILTY CLAY LOAM, 15 TO 30 PERCENT SLOPES
DeF - DIBBLE SILTY CLAY LOAM, 30 TO 50 PERCENT SLOPES
Ea - EGBERT MUCKY CLAY LOAM
Fc - FLUVAQUENTS
Fd - FONTANA-ALTAMONT COMPLEX
GaA - GARRETSON LOAM, 0 TO 2 PERCENT SLOPES
GaB - GARRETSON LOAM, 2 TO 5 PERCENT SLOPES
GbF - GAVIOTA SANDY LOAM, 30 TO 50 PERCENT SLOPES
GbG - GAVIOTA SANDY LOAM, 50 TO 75 PERCENT SLOPES
GbG - GAVIOTA SANDY LOAM, 50 TO 75 PERCENT SLOPES
GcF - GILROY CLAY LOAM, 30 TO 50 PERCENT SLOPES
GcG - GILROY CLAY LOAM, 50 TO 75 PERCENT SLOPES
Ja - JOICE MUCK
KaC - KIMBALL GRAVELLY CLAY LOAM, 2 TO 9 PERCENT SLOPES
KaE - KIMBALL GRAVELLY CLAY LOAM, 9 TO 30 PERCENT SLOPES
Kb - KINGILE MUCK
LbD - LINNE CLAY LOAM, 5 TO 15 PERCENT SLOPES
LbE - LINNE CLAY LOAM, 15 TO 30 PERCENT SLOPES
LcE - LODO CLAY LOAM, 9 TO 30 PERCENT SLOPES
LcF - LODO CLAY LOAM, 30 TO 50 PERCENT SLOPES
LcG - LODO CLAY LOAM, 50 TO 75 PERCENT SLOPES
Ld - LODO-ROCK OUTCROP COMPLEX
LeE - LOS GATOS LOAM, 15 TO 30 PERCENT SLOPES
LeF - LOS GATOS LOAM, 30 TO 50 PERCENT SLOPES
LeG - LOS GATOS LOAM, 50 TO 75 PERCENT SLOPES
LhE - LOS OSOS CLAY LOAM, 15 TO 30 PERCENT SLOPES
LhF - LOS OSOS CLAY LOAM, 30 TO 50 PERCENT SLOPES
LhG - LOS OSOS CLAY LOAM, 50 TO 75 PERCENT SLOPES
Lm - LOS ROBLES CLAY LOAM
Ma - MARCUSE SAND
Mb - MARCUSE CLAY
Mc - MARCUSE CLAY, STRONGLY ALKALI
Md - MERRITT LOAM
MeF - MILLSHOLM LOAM, 30 TO 50 PERCENT SLOPES
MeG - MILLSHOLM LOAM, 50 TO 75 PERCENT SLOPES
Ob - OMNI SILTY CLAY
PaC - PERKINS GRAVELLY LOAM, 2 TO 9 PERCENT SLOPES
PaD - PERKINS GRAVELLY LOAM, 9 TO 15 PERCENT SLOPES
Pb - PESCADERO CLAY LOAM
Pc - PESCADERO CLAY, LOAM STRONGLY ALKALI
Pd - PIPER SAND
Pe - PIPER LOAMY SAND
Ph - PIPER FINE SANDY LOAM
PkA - POSITAS LOAM, 0 TO 2 PERCENT SLOPES
PkC - POSITAS LOAM, 2 TO 9 PERCENT SLOPES
Qa - QUARRY
RbA - RINCON CLAY LOAM, 0 TO 2 PERCENT SLOPES
RbC - RINCON CLAY LOAM, 2 TO 9 PERCENT SLOPES
RbD - RINCON CLAY LOAM, 9 TO 15 PERCENT SLOPES
RcA - RINCON CLAY LOAM, WET, 0 TO 2 PERCENT SLOPES
Rd - RINDGE MUCK
Re - ROCK OUTCROP-XERORTHENTS ASSOCIATION
Rh - RYDE SILT LOAM
Sa - SACRAMENTO CLAY
Sb - SACRAMENTO CLAY, ALKALI
Sc - SAN YSIDRO LOAM
Se - SHIMA MUCK
Sh - SOLANO LOAM
Sk - SOLANO LOAM, STRONGLY ALKALI
Sm - SORRENTO SILTY CLAY LOAM
Sn - SORRENTO SILTY CLAY LOAM, SAND SUBSTRATUM
So - SYCAMORE SILTY CLAY LOAM
Sp - SYCAMORE SILTY CLAY LOAM, CLAY SUBSTRATUM
TaC - TIERRA LOAM, 2 TO 9 PERCENT SLOPES
TaD - TIERRA LOAM, 9 TO 15 PERCENT SLOPES
Ub - URBAN LAND
VaF - VALLECITOS LOAM, 30 TO 50 PERCENT SLOPES
Vb - VENICE MUCK
W - WATER
Wa - WEBILE MUCK
ZaA - ZAMORA SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPE
ZaB - ZAMORA SILTY CLAY LOAM, 2 TO 5 PERCENT SLOPE
NOT MAPPED

Source: William Lettis & Associates, Inc. and USDA Soil Classification Map.

SOILS MAP LEGEND

FIGURE 3.7-3L

attributes are based on the amount of soluble salts in the soil. Generally, low resistivity and high conductivity indicate a more corrosive condition. In addition, soils with values below pH 7 indicate acidic conditions, which have a corrosive effect on metals and concrete. High concentrations of chloride and sulfate can also lead to high corrosivity of buried utilities and foundation elements.

Expansive soil types are listed in a soil survey of Contra Costa County, which was compiled by the USDA SCS.[6] The soil expansion potential along the project corridor is summarized in Figure 3.7-4. The Linear Extensibility Percentage (LEP) is the index for shrink-swell developed by the soil survey. The shrink-swell classes are defined as follows: low (LEP $<$3%); moderate (LEP 3-6%); high (LEP 6-9%); and very high (LEP $>$9%).[7] Figure 3.7-4 shows that several areas in and surrounding the corridor within the cities of Pittsburg and Antioch have high expansion potential, but the majority of the corridor through these cities has moderate expansion potential.

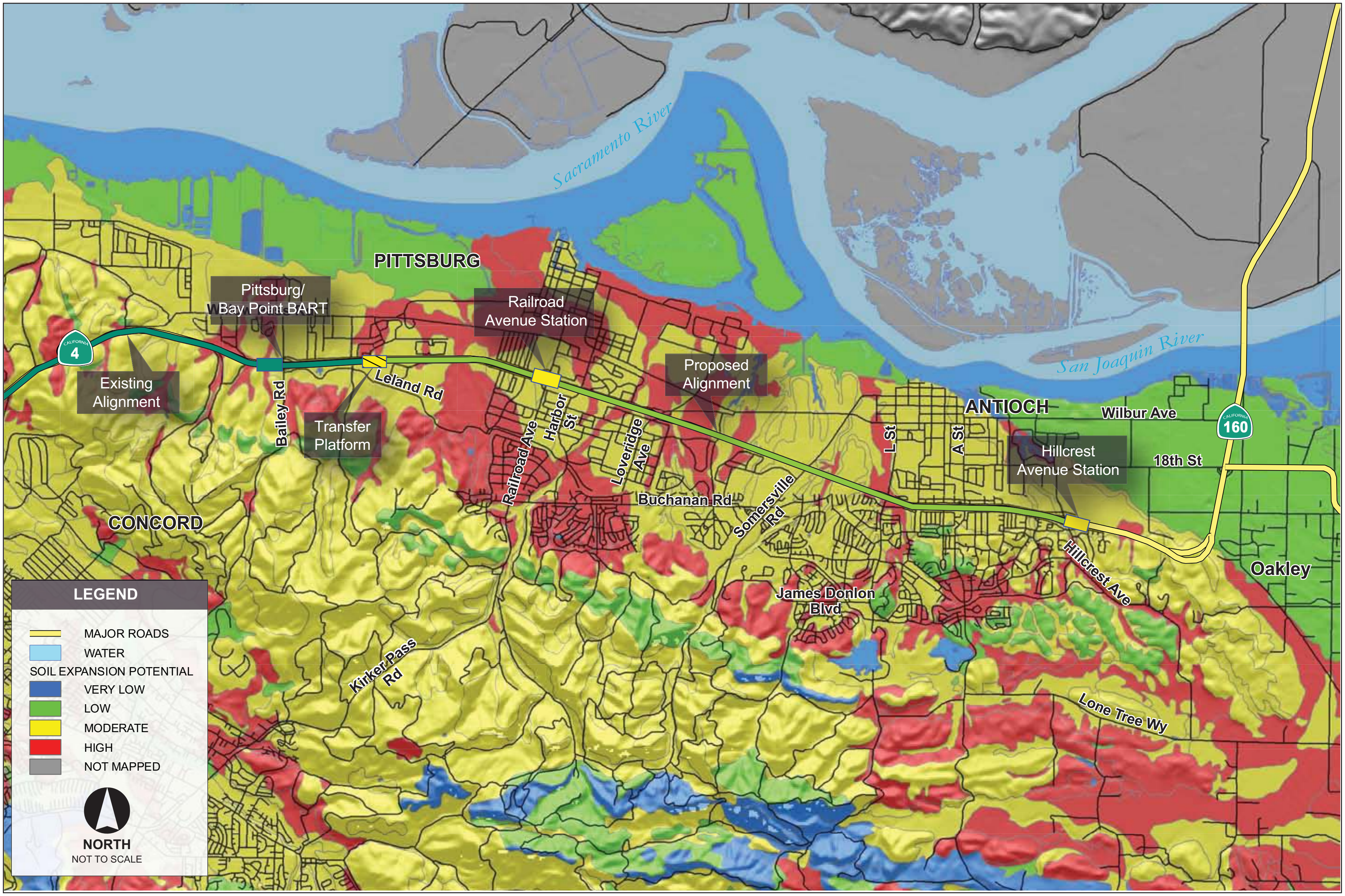
The presence of expansive soils may also indicate a potential for settlement. Settlement takes place when vertical loads compress expansive soils by squeezing out air and water from the soils, causing structures to sink into the ground. If different soil conditions cause the ground under a structure to settle to different depths (differential settlement), structural damage such as cracked foundations, cracked columns, and even collapse could result. Erosive soils are soils that are easily worn away and transported to another area either by wind or water. Soils that contain high amounts of silt (fine soil particles smaller than sand) are more easily erodible than sandy soils. Excessive soil erosion can eventually lead to damage of building foundations and roadways. In addition, eroded soil may be carried to waterways resulting in siltation, or the deposition of finely divided soil and rock particles to the bottom of streams, river beds, or reservoirs. Siltation may cause turbidity, or a muddy or cloudy appearance in the water. This may be dangerous to aquatic plants since less light reaches the water column, preventing photosynthesis (the process by which plants use energy in sunlight to make carbohydrates).

Soil erosion occurs mostly in areas with unnatural slopes that are created by cut-and-fill activities. Construction activities that create these conditions would therefore increase the likelihood of soil erosion. Once the soil is graded and covered with concrete, structures, asphalt, or vegetation, the soil erosion potential decreases. The soil types along the project corridor are shown in Figure 3.7-3 and described in Table 3.7-1. Table 3.7-1 indicates that there are few silty soils that underlie the project corridor, indicating a low potential for soil erosion.

---

6 U.S. Department of Agriculture, Soil Conservation Service, University of California Agricultural Experiment Station. 1976. *General Soil Map*, Contra Costa County, California.

7 Soil Survey Staff, Soil survey laboratory methods manual, *Soil Survey Investigations* Rep. 42. Ver. 3, National Soil Survey Center, Lincoln, NE, 1996.



Source: William Lettis & Associates, Inc. and USDA Soil Classification Map.

SOIL EXPANSION POTENTIAL ALONG THE PROJECT CORRIDOR

FIGURE 3.7-4

Faulting and Seismicity. The State of California defines an active fault as one that has had surface displacement within the Holocene epoch, approximately the last 10,000 years. The Alquist-Priolo Earthquake Fault Zones, established by the California Geological Survey, are regulatory zones around the surface traces of active faults that are used to regulate construction projects, as required by the Alquist-Priolo Earthquake Fault Zoning Map. Alquist-Priolo Fault Zones in the region include the San Andreas, Rodgers Creek, Hayward, Calaveras, Concord/Green Valley, and Greenville fault zones, as shown in Figure 3.7-1. The project corridor, however, is not within a currently designated Earthquake Fault Zone. The Mount Diablo Thrust Fault occurs in Contra Costa County, but is not zoned under the Alquist-Priolo Act since it does not exhibit surficial displacement. Two quaternary faults, the Antioch-Davis Fault, and the Brentwood-Sherman Island fault, intersect the project corridor but are not a surface rupture hazard and are not zoned under the Alquist-Priolo Act.

Ground Shaking. Since active regional faults occur in the vicinity of the project corridor, with the Concord/Green Valley Fault 6 miles to the west, the project corridor is susceptible to potentially high-intensity ground shaking in the event of an earthquake on these faults. Table 3.7-2 lists the active faults in the vicinity of the project corridor and presents their seismic characteristics. Ground-shaking intensity describes how much the ground shakes in a given location.

The intensity of ground shaking depends on the magnitude of the vibrations that travel through the bedrock when a fault slips. Rock motions move up through the soil layers to the ground surface where they become ground motions. Therefore, ground motions caused by the same rock motions will vary due to the soil conditions. The potential ground motion (measured as a percentage of g, or the acceleration of gravity) with a 10-percent probability of occurring in 50 years along the project corridor from any fault within the vicinity of the corridor is 0.81 g.

The Modified Mercalli (MM) intensity scale is commonly used to qualitatively describe ground-shaking intensity. The scale consists of 12 increasing levels of intensity, designated by Roman numerals, from imperceptible shaking to catastrophic destruction. There is no mathematical basis for the scale, as it is an arbitrary ranking based on the observed effects of an earthquake. Table 3.7-3 provides an abbreviated description of the 12 levels of the MM intensity scale and the corresponding average peak acceleration values. The project corridor would experience ground motion of 0.81 g, which corresponds to a ground shaking intensity of MM IX (violent).

Specific faults in proximity to the corridor would result in different ground-shaking intensities, depending on the distance from the fault and level of activity. Areas within the project corridor would experience potential maximum ground-shaking intensities of MM VI (moderate)

Table 3.7-2
Active Faults in the Vicinity of the Project Corridor

Faults	Distance and Direction from Project Corridor	Recency of Movement	Historical Seismicity[a]	Maximum Moment Magnitude Earthquake (MW)[b]
San Andreas	40 miles west	Historical (1906; 1989 ruptures) Holocene	M7.1, 1989 M8.25, 1906 M7.0, 1838 Many <M6	7.9
Hayward	20 miles west	Historical (1836; 1868 ruptures) Holocene	M6.8, 1868 Many <M4.5	7.1
Concord-Green Valley	6 miles west	Historical (1955 rupture) Holocene	Historical Active Creep	6.9
Calaveras (Northern)	15 miles south	Historical (1861 rupture) Holocene	M5.6, M6.4, 1861 M4-M4.5 swarms, 1970, 1990	6.8
Marsh Creek-Greenville	10 miles southeast	Historical (1980 rupture) Holocene	M5.6, 1980	6.9
Mount Diablo Blind-Thrust	10 miles southwest	Historical	Slip rate 3 mm/year	6.6
Rodgers Creek	23 miles north	Historical Holocene	M6.7, 1898 M5.6, 5.7, 1969	7.0

Source: Contra Costa Transportation Authority, *2004 Update to the Contra Costa Countywide Comprehensive Transportation Plan and Proposed Measure C Extension, Draft Environmental Impact Report*, Public Review Draft, SCH. No. 2003062128, January 2004.

Notes:

a. Richter magnitude (M) and year for recent and/or large events. The Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave.

b. Moment magnitude is related to the physical size of a fault rupture and movement across a fault. The Maximum Moment Magnitude (M_W) is derived from the joint CGS/USGS Probabilistic Seismic Hazard Assessment for the State of California, 1996 (CGS CFR 96-08 and USGS CFR 96-706). Maximum Moment Magnitude for Mount Diablo Fault is derived from USGS WG 02.

Table 3.7-3
Modified Mercalli Intensity Scale

Intensity Value	Intensity Description	Average Peak Acceleration (g)[a]
I	Not felt, except by a very few under especially favorable conditions.	< 0.0017
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.	< 0.014
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.	< 0.014
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	0.014-0.039
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.	0.039-0.092
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.	0.092-0.18
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.	0.18-0.34
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.	0.34-0.65
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.	0.65-1.24
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rail bent.	> 1.24
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.	> 1.24
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.	> 1.24

Sources: Bolt, 1998; and CGS, 2003.

Note:

a. g (gravity) = 980 centimeters per second squared. 1.0 g of acceleration is a rate of increase in speed equivalent to a car traveling 328 feet from rest in 4.5 seconds.

from most of the active earthquake faults in the vicinity of Contra Costa County.[8] The Concord/Green Valley Fault may produce greater ground-shaking intensities along the corridor due to its proximity to the project area. The potential maximum ground-shaking intensity estimated from this fault ranges from MM VIII (very strong) to MM X (very violent). In addition, potential maximum ground-shaking intensities from the Marsh Creek/Greenville and Mount Diablo Thrust faults are estimated to range from MM VIII (very strong) to MM X (very violent) due to their proximity to the project corridor.

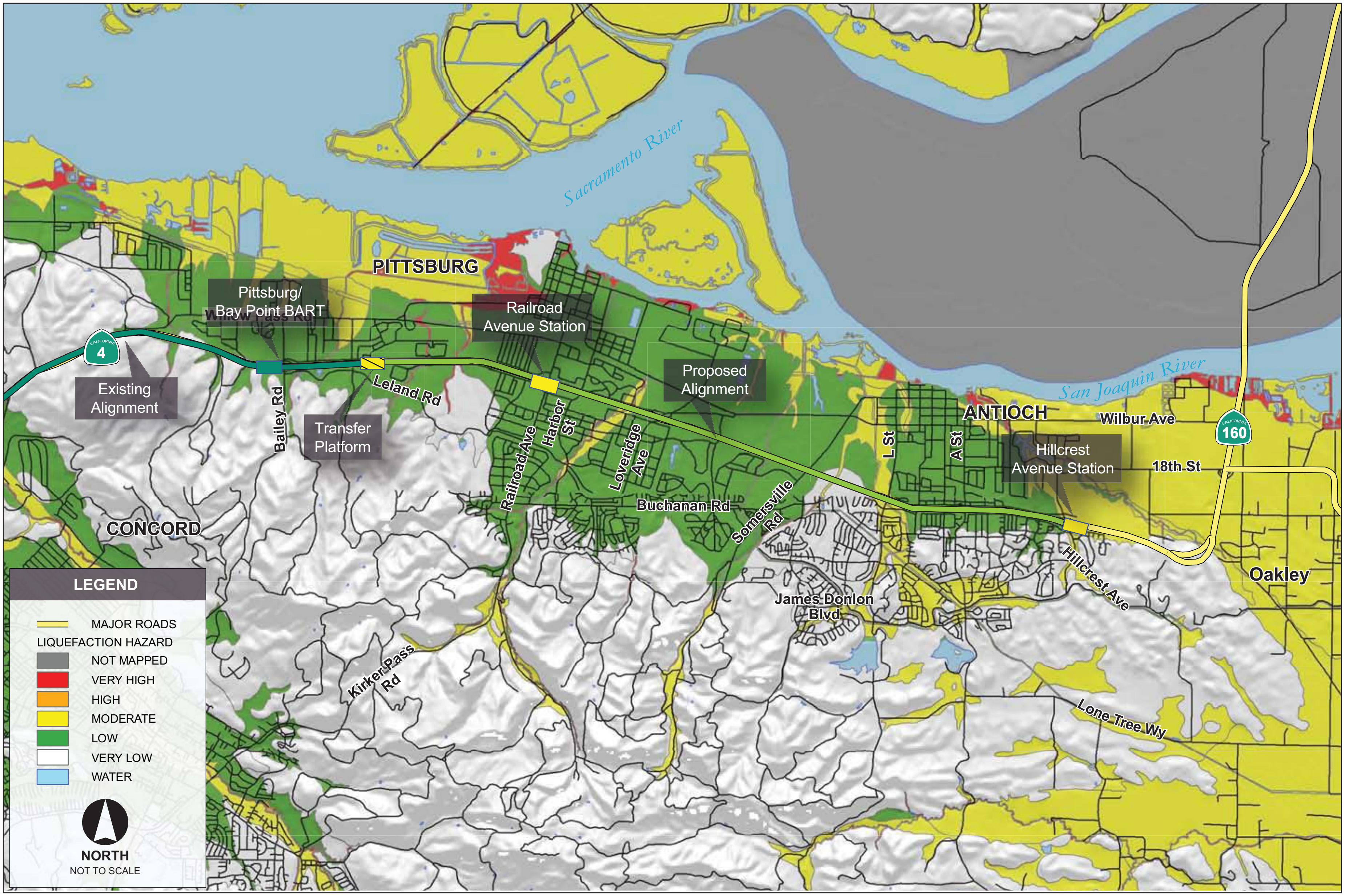
Flooding from Dam Failure. Ground shaking during an earthquake may damage dams and create potentially serious flooding hazards from reservoirs near the project corridor. Four reservoirs occur in the vicinity of the project. The Antioch Municipal Reservoir and the 80-acre Contra Loma Reservoir are approximately 2 miles from the proposed Hillcrest Avenue Station in Antioch. The Marsh Creek Reservoir and the Los Vaqueros Reservoir are large water bodies to the southeast, approximately 3 and 5 miles, respectively, from the unincorporated community of Byron. Given the distance of these reservoirs from the project corridor, they are not likely to impact the project with flooding in the event of dam failure. The State Department of Water Resources Division of Safety of Dams is in charge of regulating dam safety. The Department has inspected large reservoirs in the County, resulting in the strengthening of many dams.

Liquefaction. Liquefaction occurs when ground shaking loosens soil particles and causes soil to liquefy and resemble quicksand. William Lettis & Associates, Inc. (WLA) provided a map of the liquefaction potential along the project corridor. As shown in Figure 3.7-5, small areas in and surrounding the corridor in the City of Pittsburg have high liquefaction potential, but the majority of the corridor through Pittsburg and Antioch have low liquefaction potential. The easternmost portion of the project corridor passing through Antioch and Oakley has moderate liquefaction potential.

Landslides, Lateral Spreading, and Subsidence. Other potential geologic hazards that may occur in the project corridor are landslides, lateral spreading, and subsidence.

Landslides. Areas of potential slope instability and landslide hazards are shown in Figure 3.7-6, as compiled by WLA. The project corridor is located in lowland areas with elevations ranging from approximately 25 to 120 feet above sea level. Areas with high landslide potential have steep slopes, which are greater than 26 percent. A small area near the existing Pittsburg/Bay Point BART Station is moderately unstable. In Antioch, one area adjacent to the project corridor has a high susceptibility to landsliding. However, the vast majority of the area's topography is flat and is not susceptible to landsliding.

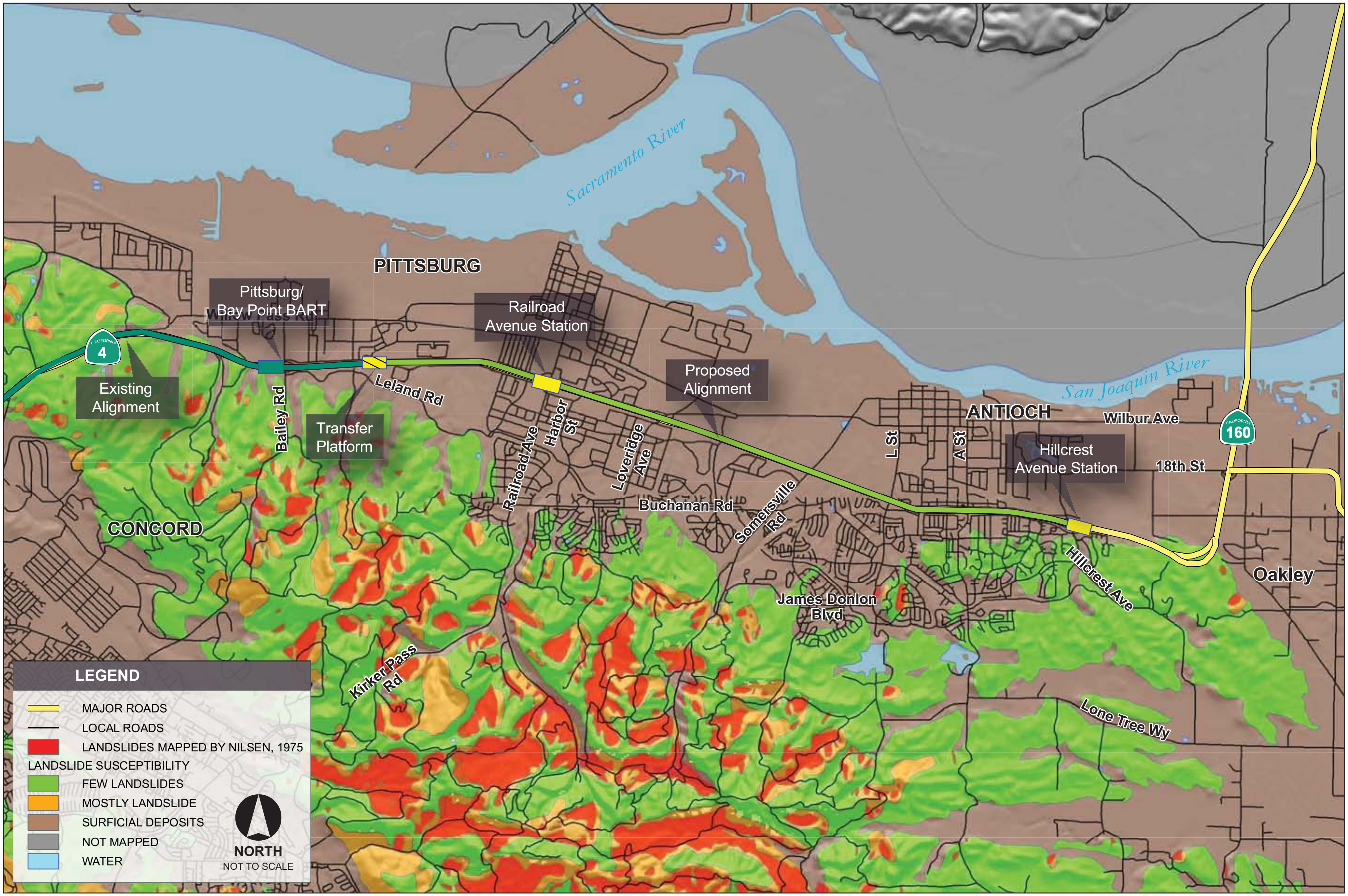
[8] Contra Costa Transportation Authority, *2004 Update to the Contra Costa Countywide Comprehensive Transportation Plan and Proposed Measure C Extension, Draft Environmental Impact Report*, Public Review Draft, SCH. No. 2003062128, January 2004.



Source: William Lettis & Associates, Inc. and Witter et al., 2006.

LIQUEFACTION HAZARDS ALONG THE PROJECT CORRIDOR

FIGURE 3.7-5



Source: William Lettis & Associates, Inc.; Nilsen, 1975; and Wentworth et al., 1997.

LANDSLIDE HAZARDS ALONG THE PROJECT CORRIDOR
FIGURE 3.7-6

Four units mapped by the USGS are described below and correlated to landslide hazard classes used in the WLA regional mapping as shown in Table 3.7-4.

Table 3.7-4
Classification of USGS Hazard Mapping

USGS Classification	WLA Hazard Class
Mostly Landslide	Moderate to High
Many Landslides	Moderate
Few Landslides	Low to Moderate
Flat Land	Not Used

Source: William Lettis & Associates, Inc., January, 2007.

- **Mostly Landslide** – consists of mapped landslides, intervening areas typically narrower than 1,500 feet, and narrow borders around landslides; defined by drawing envelopes around groups of mapped landslides.
- **Many Landslides** – consists of mapped landslides and more extensive intervening areas than in “Mostly Landslide”; defined by excluding areas free of mapped landslides; outer boundaries are quadrangle and county limits to the areas in which this unit was defined.
- **Few Landslides** – contains few, if any, large mapped landslides, but locally contains scattered small landslides and questionably identified larger landslides; defined in most of the region by excluding groups of mapped landslides, but defined directly in areas containing the “Many Landslides” unit by drawing envelopes around areas free of mapped landslides.
- **Flat Land** – areas of gentle slope at low elevation that have little or no potential for the formation of slumps, translational slides, or earth flow except along stream banks and terrace margins; defined by the distribution of surficial deposits.[9]

Areas within the moderate to high susceptibility zones are expected to experience widespread slope failure from large earthquakes, and moderate distributed slope failure from smaller events. Slope displacements could range between inches to several feet, depending on peak ground acceleration levels. WLA notes that the susceptibility zones are quite broad and do not factor site-specific conditions that could affect the slope susceptibility rating at a microscale. Areas with moderate susceptibility zones could experience localized slope failure during large earthquakes, and minor slope movements during smaller events. The magnitude of slope movements is estimated to be on the order of fractions of an inch to several inches. Areas in

[9] Wentworth, C.M., 1997, General distribution of geologic materials in the San Francisco Bay region, California: a digital map database: U.S. Geological Survey Open-File Report 97-774, database resolution 1:125,000.

the low to moderate zones should not experience significant occurrences of slope failure or movements even under very strong ground shaking from the largest scenario events.

Lateral Spreading. Lateral spreading occurs when liquefaction on gentle slopes causes subsurface soil layers to move downslope. Lateral spreads are most common on slopes ranging between 0.3 and 3 degrees and in areas of loose, saturated soils with a potential for liquefaction. As shown in Figure 3.7-5, areas with moderate liquefaction potential exist in and surrounding the project corridor in the cities of Antioch and Oakley. These areas are also gently sloped, with a potential for lateral spreading to occur. The majority of the corridor through the City of Pittsburg has a low liquefaction potential, and therefore has a low probability of lateral spread.

Subsidence. Subsidence is the compacting and sinking of soils that result in a shallow hole in the earth's surface. Weak soils are prone to subsidence and occur along the project corridor. The strength of the soil types listed in Table 3.7-1 is provided by the soil survey of Contra Costa County.[10] The majority of soils along the project corridor have low strength and are thus prone to subsidence.

Paleontological Resources

Paleontological resources are the fossilized remains or impressions of prehistoric plants and animals. They are valuable, nonrenewable, scientific resources used to document the existence of extinct life forms and to reconstruct the environments in which they lived. Fossils can be used to determine the relative ages of the depositional layers in which they occur and of the geologic events that created those deposits. In the context of CEQA, fossils of land-dwelling vertebrates and their environment are considered important (i.e., significant) paleontological resources. Such fossils typically are found in river, lake, and bog deposits, although they may occur in nearly any type of sedimentary sequence.

The Conformable Impact Mitigation Guidelines Committee of the Society of Vertebrate Paleontology (SVP, 1995) published *Standard Guidelines* in response to a recognized need to establish procedures for the investigation, collection, preservation, and cataloguing of fossil-bearing sites.[11] The *Standard Guidelines* are widely accepted among paleontologists, followed by most investigators, and identify the key phases of paleontological resource protection as (1) assessment and (2) implementation. Assessment involves identifying the potential for a project site to contain significant nonrenewable paleontological resources that could be damaged or destroyed by project excavation or construction. Implementation involves formulating and applying measures to reduce such adverse effects. The SVP defines the level of potential as one of three sensitivity categories for sedimentary rocks: High, on the basis of

[10] U.S. Department of Agriculture, Soil Conservation Service, University of California Agricultural Experiment Station (USDA), 1976.

[11] Society of Vertebrate Paleontology, Conformable Impact Mitigation Guidelines Committee, Policy Statements, *Assessment and Mitigation of Adverse Impacts to Nonrenewable Paleontologic Resources: Standard Guidelines*, 2007.

known fossil content; Moderate, because of some association with known fossil-bearing localities elsewhere; and Low, because of relative youthful age and/or high-energy depositional history.

The project alignment, station sites, and study area are entirely on relatively young alluvial sediments (Quaternary: less than 1.6 million years old) composed of material eroded from the Tertiary bedrock (1.6 to 66 million years old) in the hills south of the study area. The Tertiary rock units are known to contain vertebrate fossils (salamander, shrew, rabbit, mouse, weasel, etc.) and there have been vertebrate fossils recovered from indurated Quaternary rocks in Contra Costa County.[12] No rock units are exposed in the study area. Fossils eroded from pre-existing rock units and re-deposited in relatively modern alluvial fans generally are not considered significant paleontological resources because of their degraded condition and displacement from original point of deposition. All of the project alignments and most of the station sites have been graded at some time, thereby virtually eliminating the possibility that paleontological resources would be found intact during construction of the project. Consequently, the project corridor is considered to have little or no scientific value for the recovery of paleontological resources.

Applicable Policies and Regulations

The BART Facility Standards, which include seismic design criteria for BART facilities, are not applicable to this project, because the proposed technology is not BART technology and because specific project design criteria have been developed, as described below. In addition, federal, state, or local laws, regulations, ordinances, or rules related to geologic hazards and the construction and operation of transit service in the project corridor are also summarized below.

Project Design Criteria. The goal of the design criteria for the Proposed Project is to ensure that all structures, equipment, and equipment supports are designed to survive ground motions without collapse. The objectives are to ensure safety, prevent prolonged interruption of project operations due to structural failure or damage, and to protect the permanent stationary facilities. The station structures and buildings would be designed in accordance with the latest California Building Standards Code (CBSC) and National Fire Protection Association (NFPA) code. The bridge structures would be designed to the Caltrans non-collapse standards in accordance with the Caltrans Bridge Design Manual, which establishes minimum life-safety requirements, and supplemented by appropriate standards from the American Railway Engineering and Maintenance-of-Way Association (AREMA) code. Additional codes to be followed include American Concrete Institute (ACI), American Institute of Steel Construction (AISC), the Structural Welding Code (AWS), and other California building codes for mechanical and electrical systems.

[12] University of California Museum of Paleontology, available at http://bscit.berkeley.edu/ucmp/loc.shtml: online search through UCMP Locality Search, January 16, 2008.

California Building Standards Code (CBSC). The project is located in a seismically active area and must, therefore, comply with California Code of Regulations (CCR) Title 24, also known as the CBSC. The CBSC is applicable only to building structures included in the project. The CBSC is a design code for structures to withstand seismic hazards and provides standards for project construction, including excavation, grading, earthwork construction, fill embankments, expansive soils, foundation investigations, liquefaction potential, and soil strength loss. The CBSC is based on the 2006 International Building Code, which is published by the International Conference of Building Officials. The Code is widely used throughout the United States, generally adopted on a state-by-state or district-by-district basis, and has been modified for California conditions with more detailed and stringent regulations.

California Department of Transportation (Caltrans). Much of the project corridor lies within State Route 4 (SR 4), and any work within the right-of-way is subject to Caltrans requirements governing allowable actions and modifications to the right-of-way.

Soil Erosion Control. Construction, including excavation and grading of areas in the project corridor, could lead to soil erosion. Soil erosion causes the loss of topsoil and can have a local impact on water quality due to increased sediments in stormwater. Additional information on water quality is available in the Section 3.8, Hydrology and Water Quality, of this EIR. The regulations applicable to soil erosion and stormwater issues are highlighted below.

National Pollutant Discharge Elimination System. The National Pollutant Discharge Elimination System (NPDES) is a permit program that controls water pollution by regulating sources that discharge pollution into waters of the U.S. Nonpoint source pollutants in stormwater may include suspended sediment released from soil erosion at construction sites. In California, the State Water Resources Control Board (SWRCB) is authorized by the United States Environmental Protection Agency (US EPA) to administer the NPDES program through the Regional Water Quality Control Boards (RWQCBs). All construction activity that occurs within the cities of Pittsburg and Antioch requires a NPDES permit. The San Francisco Bay and Central Valley RWQCBs require that any construction activity affecting 10,000 square feet or more and that has the potential to discharge stormwater to a water body of the U.S. must obtain coverage under the State Water Resources Control Board's NPDES General Permit for Stormwater Discharges Associated with Construction Activity (General Permit Order No. 99-08-DWQ). The permit specifically requires that a Stormwater Pollution Prevention Plan (SWPPP) be prepared to identify pollutant sources that may affect the quality of discharges of stormwater associated with construction activities. As part of the SWPPP, the County and the cities require that Best Management Practices (BMPs) be implemented in the design of a Proposed Project’s storm drainage system to reduce or eliminate stormwater pollution during the construction phase.

Contra Costa County Clean Water Program. Contra Costa County, the 19 incorporated cities, and the Contra Costa County Flood Control & Water Conservation District joined to form the Contra Costa County Clean Water Program (CCCWP). The program monitors the NPDES program and the Stormwater Utility areas for most of Contra Costa County. CCCWP develops and implements specific programs to meet NPDES requirements. The CCCWP obtained a Joint Municipal NPDES permit from the San Francisco Bay and Central Valley RWQCBs. The permit contains a comprehensive plan to reduce the discharge of pollutants to the "maximum extent practicable." The permit requirements are implemented by the cities of Pittsburg and Antioch in their respective jurisdictions.

Impact Assessment and Mitigation Measures

Standards of Significance

The Proposed Project would result in significant geo-seismic impacts if it would:

- Expose people or structures to potential substantial adverse effects, including risk of loss, injury, or death involving (i) rupture of a known earthquake fault, (ii) strong seismic ground shaking, (iii) seismic-related ground failure, including liquefaction, or (iv) landslides;
- Result in substantial soil erosion or loss of topsoil;
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsiding, liquefaction, or collapse; or
- Be located on expansive soil as defined in Table 18-1-B of the UBC (1994), creating substantial risks to life or property.

To classify impacts for potential geo-seismic hazards, a level of significance is determined and reported in the italicized summary impact statement that precedes each impact discussion. Conclusions of significance are defined as follows: significant (S), potentially significant (PS), less than significant (LTS), no impact (NI), and beneficial (B). If the mitigation measures would not diminish potentially significant or significant impacts to a less-than-significant level, the impacts are classified as "significant and unavoidable effects (SU)." For this section, GEO refers to Geology, Soils, and Seismicity.

Project-Specific Environmental Analysis

Operational Impacts

Impact GEO-1 Potential impacts from ground rupture due to movement of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map, would not affect the Proposed Project. (NI)

The project corridor is not within a currently designated Alquist-Priolo Earthquake Fault Zone. The closest known active or potentially active earthquake fault (Concord-Green Valley) is approximately 6 miles west of the corridor. The Proposed Project includes a fixed guideway for DMU tracks, an at-grade transfer platform, a station in the SR 4 median at Railroad Avenue, a station and train service/storage in the SR 4 median slightly east of Hillcrest Avenue, and a tunnel accessing a maintenance annex to the north of SR 4. A pedestrian concourse over westbound SR 4 would provide passenger access to the station. The proposed location of these Proposed Project facilities would not fall within a currently designated Alquist-Priolo Earthquake Fault Zone. Therefore, no impacts related to ground rupture are anticipated from the construction or operation of the Proposed Project.

Impact GEO-2 The Proposed Project would be subject to substantial seismic ground shaking; however, the Proposed Project design criteria would reduce potential risks to structures, facilities, and passengers to a less-than-significant level. (LTS)

The project corridor is susceptible to seismic ground shaking as a result of faults in the vicinity of the corridor. There is a 10 percent probability that in 50 years, a strong seismic event would occur along the project corridor with peak horizontal ground accelerations of up to 0.81g. In addition, the Concord/Green Valley Fault may produce greater ground-shaking intensities along the corridor due to its proximity to the project area. The potential maximum ground-shaking intensity estimated from this fault ranges from MM VIII (very strong) to MM X (very violent). In addition, potential maximum ground-shaking intensities from the Marsh Creek/Greenville and Mount Diablo Thrust faults are estimated to range from MM VIII (very strong) to MM X (very violent) due to their proximity to the project corridor. Therefore, horizontal and vertical ground accelerations from earthquakes along these faults have the potential to increase above-grade structures to lateral stresses and below-grade structures to lateral earth pressures.

The Proposed Project would include several above-grade, at-grade, and below-grade structures as part of the project design. These structures would be susceptible to increased lateral stresses and lateral earth pressures from ground accelerations during seismic events. At-grade structures would include much of the guideway for the DMU tracks, the transfer platform, stations, the staff building room, train control huts, and maintenance facilities. Aerial structures would include overcrossings of local roads and a utility corridor, pedestrian connections from the Railroad Avenue Station platform to Railroad Avenue, and a pedestrian concourse over westbound SR 4 to provide passenger access between the Hillcrest Avenue Median Station and the parking area. Below-grade structures would include a tunnel accessing a maintenance annex to the north of SR 4. The Proposed Project would incorporate design criteria to ensure that all structures, equipment, and equipment supports are designed to survive ground motions without collapse, with the objectives of ensuring safety, preventing prolonged interruption of project operations due to structural failure or damage, and protecting the permanent stationary facilities. The station structures and buildings would be designed in accordance with the latest CBSC and NFPA code. The Proposed Project bridge structures would be designed to the Caltrans non-collapse standards in accordance with the Caltrans Bridge Design Manual, which establishes minimum life-safety requirements, and supplemented by appropriate standards from the AREMA code. Additional codes to be followed include ACI, AISC, AWS, and other California building codes for mechanical and electrical systems. The design criteria for the Proposed Project would ensure that above-grade and below-grade structures would be able to withstand certain levels of lateral stresses and lateral earth pressures from seismic events, so that structures would be able to meet the performance goals outlined above. Given that the project design criteria would be incorporated in the design and construction of the project components, potential impacts from ground shaking would be reduced to a less-than-significant level.

Impact GEO-3 *Potential impacts from seismic-related ground failure, including liquefaction, would not adversely affect the Proposed Project, because compliance with the project design criteria would reduce the risks to property and passengers to acceptable engineering standards and practices. (LTS)*

The majority of the project corridor has low liquefaction and landsliding potential (see Figures 3.7-5 and 3.7-6). A few areas along the project corridor in the City of Antioch have moderate liquefaction potential, and an area along the corridor near the existing Pittsburg/Bay Point BART Station has a moderate potential for landsliding. Potential impacts of seismic-related ground failure may include ground fissures, differential settlement, and displacement of foundations that would damage project structures. However, potential failure of slopes supporting project structures would not be considered life-threatening due to the low slope heights and deep foundations associated with the structural components of the Proposed Project. In addition, the Proposed Project would incorporate design criteria to ensure that all structures, equipment, and equipment supports are designed to survive ground motions without collapse. BART's objectives are to ensure safety, prevent prolonged interruption of project operations due to structural failure or damage, and protect the station facilities, in accordance with the various codes and regulations described in "Applicable Policies and Regulations" and summarized in Impact GEO-2. Given that the project design criteria would be incorporated in the design and construction of the project components, potential impacts from seismic-related ground failure would be reduced to a less-than-significant level.

Impact GEO-4 *Potential impacts from lateral spreading, subsidence, and collapse as a result of underlying unstable geologic units would not adversely affect the Proposed Project, because compliance with the project design criteria would reduce risks to property and passengers to acceptable engineering standards and practices. (LTS)*

Soils beneath the project corridor are prone to lateral spreading and subsidence. Lateral spreading occurs when liquefaction on gentle slopes causes subsurface soil layers to move downslope. As shown on Figure 3.7-5, a few areas along the corridor in the City of Antioch have moderate liquefaction potential and are gently sloped, and would therefore be susceptible to lateral spreading. In addition, subsidence is the compacting and shrinking of soils that result in a shallow hole due to weakness of the soils. The majority of soils along the project corridor have low strength maximum ground-shaking intensities from the Marsh Creek/Greenville and Mount Diablo Thrust faults and are thus prone to subsidence.

Potential impacts of lateral spreading and subsidence may include damage to the overlying structures for the Proposed Project, which could potentially cause personal injury to the occupants of the facilities. The Proposed Project would incorporate design criteria to ensure that all structures, equipment, and equipment supports are designed with the objectives of ensuring safety, preventing prolonged interruption of the Proposed Project's operations due to structural failure or damage, and protecting the station facilities. The station structures and buildings would be designed in accordance with the codes and regulations described under "Applicable Policies and Regulations" and summarized in Impact GEO-2. Given that the project design criteria would be incorporated in the design and construction of the project components, potential impacts from lateral spreading and subsidence would be reduced to a less-than-significant level.

Impact GEO-5 *Potential impacts from expansive soils would not adversely affect the Proposed Project, because compliance with the project design criteria would reduce risks to property and passengers to acceptable engineering standards and practices. (LTS)*

As shown on Figure 3.7-4, several areas in and surrounding the corridor in the cities of Pittsburg and Antioch have high expansion potential, but the majority of the corridor has moderate expansion potential. Expansive soils have the potential to damage foundations, pavements, retaining walls, and other rigid structures that are components of the Proposed Project. The project design criteria would require a site-specific geotechnical investigation to determine the presence of expansive soils beneath project structures, and would incorporate the principal design codes of the CBSC, which provides standards for project construction, including such aspects as earthwork construction, fill embankments, expansive soils, foundation investigations, and soil strength loss. Incorporation of the project design criteria in the construction of the Proposed Project would reduce the potential impacts from expansive soils to a level that is less than significant.

Impact GEO-6 *Potential impacts from corrosive soils would not adversely affect the Proposed Project, because compliance with the project design criteria would reduce risks to property and passengers to acceptable engineering standards and practices. (LTS)*

Soils along the project corridor are highly corrosive to uncoated steel. Corrosive soils have the potential to damage structural improvements and reduce their strength. Potential impacts may include damage to subsurface piping, and weakening of building foundations and slabs on grade. The Proposed Project involves excavation and grading activities that could expose project structures to corrosive soil. However, the project design criteria would require a site-specific geotechnical investigation to determine the presence of corrosive soils beneath project structures, and would incorporate the principal design codes of the CBSC which provide standards for corrosive soils. Incorporation of the project design criteria in the construction of the Proposed Project would reduce the potential impacts from corrosive soils to a level that is less than significant.

Construction Impacts

Impact GEO-7 *Construction of the Proposed Project could result in soil erosion impacts as a result of excavation and grading activities. (PS)*

Soil erosion occurs mostly in areas with unnatural slopes that are created by cut-and-fill activities. Construction activities that create these conditions may therefore increase the likelihood of soil erosion, which has the potential to impact water quality. (See Section 3.8, Hydrology and Water Quality, for a discussion of water quality impacts.)

For construction of the project alignment and each of the stations, construction yards and staging areas would be needed for temporary construction offices and storage of materials and equipment. These yards would typically be graded and surfaced with gravel for vehicle and equipment use and construction parking.

Construction of the Proposed Project would involve soil excavation and grading, resulting in potential soil erosion. Excavation and grading activities would occur during the modifications at the existing Pittsburg/Bay Point Station and tailtracks, the construction of the new transfer platform to the east of the Pittsburg/Bay Point BART Station, the construction of the new Railroad Avenue and Hillcrest Avenue Stations (including parking areas and access roads), and the construction of the new maintenance facility and storage/parking area. Excavation and grading within the SR 4 median would be minor for the construction of the guideway and for preparation and installation of a subterranean drainage system. Most excavation and grading activities would occur outside of the SR 4 right-of-way in the Hillcrest Avenue Station area. Construction of the train control huts and staff building would not involve excavation that would result in substantial erosion or other geological related impacts because the structures require only minor grading and excavation.

In addition, excavation and grading would be required to construct the Proposed Project's guideway structures, which include one new above-grade, elevated structure on the west side of Century Boulevard in the City of Pittsburg to span a utility right-of-way and utility vehicle tunnel, and five overpass bridges at Century Boulevard, Somersville Road, Contra Loma Boulevard, A Street, and Cavallo Road.

There are few silty soils that underlie the project corridor, indicating a low potential for soil erosion. The majority of soils along the project corridor include clay, loam, and clay loam. The Rincon, Sycamore, and Zamora soil series exist along the project corridor and partially include silty soils. The Rincon soil series is characterized as having a silty clay loam approximately 29 to 65 feet below the ground surface. This soil series occurs along substantial portions of the project corridor, but is not expected to present a significant erosion potential given the depth of the silty clay loam below the ground surface. The Sycamore soil series includes a silty clay loam and silt loam approximately 0 to 66 feet below the ground surface. This soil series exists along a small portion of the corridor in Antioch, and is therefore not expected to present a significant erosion potential. The Zamora soil series also exists along small portions of the project corridor in the City of Antioch, and includes a silty clay loam from 0 to 46 feet, and a silty clay loam and clay loam from 46 to 72 feet below the ground surface. Given the small area where this soil series exists along the project corridor, it is not expected to present significant soil erosion potential.

The SWRCB adopted one statewide General Permit for Stormwater Discharges Associated with Construction Activity (General Permit Order No. 99-08-DWQ). The General Permit is implemented by the nine RWQCBs, including the San Francisco and Central Valley RWQCBs. The permit specifically requires that a Stormwater Pollution Prevention Plan (SWPPP) be prepared to identify pollutant sources that may affect the quality of discharges of stormwater associated with construction activities. As such, BART's contractors would develop and implement a SWPPP prior to construction, which would describe 1) standard temporary erosion control measures to reduce sedimentation and turbidity of surface runoff from disturbed areas, 2) personnel training, 3) scheduling and implementation of BMPs throughout the various construction phases and during various seasons, and 4) mitigation and monitoring throughout the construction period. Standard erosion control measures incorporated in the SWPPP would include:

- Temporary erosion control measures such as slope stabilizers, dust suppression, construction of berms and ditches, and sediment barriers.
- Dust erosion control measures to minimize wind erosion and loss of soil, such as spraying clean water on the soil in construction areas to minimize wind erosion and installing screening fabric to fencing along the median to control dust and wind-blown debris along the corridor.
- Sediment barriers, such as straw bales or silt fences, to slow runoff and trap sediment. These are generally placed below disturbed areas, at the base of exposed slopes. Sediment barriers are often placed around sensitive areas, such as wetlands or creeks, to prevent contamination by sediment-laden water. Barriers are placed around the project corridor, including ancillary facilities, to prevent sediment from leaving the site. Because the project corridor is relatively level, standard surface erosion control techniques should be effective. The need for runoff retention basins, drainage diversions, and other large-scale sediment traps shall be evaluated and incorporated into the construction SWPPP, as appropriate. Soil stockpiles generated during construction shall be covered and protected from rainfall if left on site for long periods of time.
- Temporary erosion control devices, installed in accordance with the required construction SWPPP before initial site clearing and visually inspected during the regular site environmental compliance inspections.

MITIGATION MEASURE. The following measure would help reduce impacts from construction to less-than-significant levels. (LTS)

GEO-7.1 Implement SWPPP and erosion control BMPs. The SWPPP and BMPs to control stormwater and erosion during the construction period, consistent with the requirements of coverage under the NPDES general permit for stormwater associated with construction activities. BMPs shall include, but are not limited to, erosion control measures, such as slope stabilizers, dust suppression, construction of berms and ditches, and sediment barriers. In addition, other BMPs may include:

- Construction scheduling, such as phasing and season avoidance, to minimize erosion and sediment;
- Perimeter protection such as straw wattles or silt fences;
- Check dams to prevent gully erosion and/or slow runoff flow rates to allow sediment to settle out;
- Gravel bag berm/barriers to prevent runoff or run-on of surface water flows;
- Street sweeping and vacuuming to remove vehicle-tracked soil and sediment;
- Storm Drain Inlet Protection such as filter bags and perimeter protection;
- Stabilized Construction Entrance to prevent vehicle tracking of sediment and debris on roadways; and
- Wind Erosion Control BMPs such wetting down of dry sediment or covering exposed surfaces.

Hillcrest Avenue Station Option Analysis

Operational impacts associated with the Northside West, Northside East, and Median Station East options are the same as described for the Median Station of the Proposed Project. No components associated with the three options fall within the Alquist-Priolo Earthquake Fault Zone. Additionally, similar to the Proposed Project, all station options would incorporate the project design criteria, which would ensure that all structures, equipment, and equipment support are designed to survive ground motions without collapse and would protect permanent stationary facilities. As with the Proposed Project, geo-seismic impacts related to the operation of the Hillcrest Avenue Station options would either be less than significant or negligible (no impact). However, given the location of the proposed Median Station East and the Northside East Station option, further earthwork is required to accommodate the proposed station components. These potential impacts are discussed below.

Impact GEO-8 Construction of the Northside East Station and the Median Station East options would require substantially greater earthwork, resulting in potentially greater soil erosion impacts than the other Hillcrest Avenue Station options. (PS)

Construction impacts related to the Northside East and Median Station East Station options would be substantially different than the Proposed Project.

The proposed Northside East Station option and associated project elements would be sited further east onto lands with much steeper slopes, expansive soils, and landslide potential. Specifically, the future parking lot would be sited on hilly terrain (two small hills). In order to accommodate the future surface parking lot, substantial earthwork would be necessary. Compared to the Proposed Project, additional earthwork and retaining walls would be required for the construction of the parking lot for the Northside East Station option.

The proposed Median Station East and associated project elements, such as the tunnel and maintenance facility, would also require cutting into the steeper slopes identified above, although not to the same extent. To accommodate the tunnel and maintenance facility, substantial earthwork would be necessary.

Due to the extensive grading, the Northside East and Median Station East Station option would result in significant soils erosion impacts. Soil erosion has the potential to degrade surface water by introducing sediments and silts. Further discussion on impacts to water quality from construction activities can be found in Section 3.8, Hydrology and Water Quality, of this report.

MITIGATION MEASURE. As with the proposed project, Mitigation Measure GEO-7.1, requiring erosion control BMPs such as slope stabilizers, dust suppression, construction of berms and ditches, and sediment barriers, would reduce this impact to less than significant. (LTS)

Cumulative Analysis

Geo-seismic impacts may result from activity along the network of major active faults in Contra Costa County and the greater Bay Area, as well as the San Andreas, the Hayward, and the Calaveras fault zones. However, potential impacts are site-specific and dependent on the underlying soils and geologic materials in a particular location. The cites of Pittsburg and Antioch share similar types of soils and geologic materials, providing the appropriate context for evaluating the geo-seismic impacts of the Proposed Project in combination with other foreseeable projects is the area. Other foreseeable development within this area includes the growth anticipated by the general plans for the cities of Pittsburg and Antioch (Ridership Development Plans), the Specific Plans that these cities have prepared around the proposed station areas, the SR 4 widening project between Loveridge Road and SR 160, and the increased use of the Union Pacific ROW for additional freight trains by Union Pacific (UP). In particular, planned development near the two stations include 1,845 new residential units and 1,004,000 square feet of commercial space in the area near the Railroad Avenue Station, and up to 2,500 new residential units and 2,150,000 square feet of office and retail uses near the Hillcrest Avenue Station area.

Impact GEO-CU-9 *Cumulative impacts from increased exposure to geologic and seismic hazards as a result of the Proposed Project in combination with other foreseeable projects and development would be less than significant because of required compliance with existing regulations and building codes protective of public safety and structural safety. (LTS)*

During construction, the Proposed Project would adhere to engineering design standards and principles that are intended to avoid structural failure from soil limitations and geologic hazards. These same standards are also intended to minimize disruption in the event of a seismic event. Similarly, Caltrans has its own design standards to ensure that its facilities, such as the proposed SR 4 widening and SR 4 Bypass improvements are constructed to an acceptable standard of safety. Similarly, additional use of the UP ROW by freight trains would adhere to federal regulations which would protect structural (and property) safety. Land development projects as envisioned by the cities of Pittsburg and Antioch in general and in the station areas in particular, and as described in Ridership Development Plans (RDPs) that the cities are preparing, would be governed by the CBSC. Additional local regulations and standards would ensure that potential impacts from geologic and seismic hazards, such as ground shaking, seismic-related ground failure, lateral spreading, subsidence, and expansive or erosive soils are minimized. Because design and construction of the cumulative projects must adhere to standards that were designed to be protective of the public and of structures, the cumulative impacts from exposure to geologic and seismic hazards would be less than significant.

Impact GEO-CU-10 *Construction impacts, such as soil erosion, associated with the Proposed Project in combination with other foreseeable development projects near the project corridor would be less than significant because of existing regulations and permits that govern construction activities. (LTS)*

The Proposed Project, in addition to other developments, such as the SR 4 widening and SR 4 Bypass improvements and the future transit oriented development at the proposed station areas, would be required to prepare and implement SWPPPs and erosion control measures during construction, pursuant to the NPDES program and the State Water Resources Control Board's General Permit for Stormwater Discharges Associated with Construction Activity. As described in Impact GEO-7, the Proposed Project would have less-than-significant construction impacts due to adherence to these measures. In addition, IS/EAs and a Revalidation for the SR 4 widening project state that implementation of effective BMPs would minimize potential impacts from soil erosion due to construction.[13,14 15] The documents state that the potential soil erosion impacts from construction are considered minor due to the short-term nature of construction activities. Because the cumulative projects would be subject to NPDES requirements and would implement BMPs, and because the Proposed Project's contribution to cumulative soil erosion impacts during the construction period would not be cumulatively considerable, cumulative construction impacts would be less than significant.

---

13 Caltrans, *Initial Study/Environmental Assessment, State Route 4 (East) Widening Project, Loveridge Road to State Route 160*, August 2005.

14 *Caltrans, Finding of No Significant Impact For State Route 4 (East) Widening Project: Loveridge Road to State Route 160,* July 2005.

15 Caltrans, State Route 4 (East) Widening Project: Loveridge Road to State Route 160 Revalidation. August 2008.