3.9 Geology, Soils, and Seismicity

3.9.1 Introduction

This section identifies geologic, soils, and seismic conditions that could affect or be affected by the project. The section describes the regulatory setting, affected environment, impacts, and possible mitigation measures associated with geology, soils, and seismicity of the project environment. The discussion of impacts includes consequences of the project on geology, soils, and seismicity, as well as how geology, soils, and seismicity would affect the project. The *Merced to Fresno Section Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012a) provides detailed geologic, soils, and seismic information.

The Program EIR/EIS documents concluded that in the Merced to Fresno area the project would have a low potential for impacts due to prevailing geology, soils, and seismicity. Design practices will lessen potential effects from major geologic hazards, such as major fault crossings, oil fields, and landslide areas. Mitigation strategies included reducing potential impacts on a site-specific basis using detailed geotechnical studies to address ground shaking, fault crossings, slope stability/landslides, areas of difficult excavation, hazards related to oil and gas fields, and mineral resources. The project development incorporates design standards from the American Association of State Highway and Transportation Officials (AASHTO), the American Railway Engineering and Maintenance-of-Way Association (AREMA), the California Department of Transportation (Caltrans), and the International Building Code (IBC) to address the identified geologic and soil conditions. Key references that would be used for design are listed in Section 3.9.6, Project Design Features.

This section does not evaluate the geology, soils, and seismicity events listed below because they do not present a risk in the Merced to Fresno Section:

- Landslides. The topography is flat and there is no evidence of landslides.
- Land subsidence from water, oil, gas, or geothermal wells. Water withdrawal is controlled to minimize the potential for ground subsidence. There are no known active oil, gas, or geothermal wells near the project.
- Volcanic ash fall from a volcanic eruption within the Mono Lake-Long Valley Volcanic Area. The occurrence of volcanic activity is very low according to the United States Geological Survey (USGS) (e.g., 1% per year), and the prevailing wind is away from the project site, making the chance of ash fall very low.
- Ground movement from fault rupture. The closest active or potentially active fault is located at least 25 miles from the project alternatives, including the north-south alignments, wyes, stations, and HMF sites.
- Seiches and tsunami flooding. There are no oceans, bays, or other bodies of water sufficient to result in a damaging seiche or tsunami near the project alignments
- Excavation in rock because the depth of bedrock is estimated to be 6 miles below ground surface (bgs).
- Disruption of mineral, fossil fuel, and geothermal resources because these resources do not exist in the project vicinity.
- Subsurface gas hazards because no part of the Merced to Fresno Section includes tunneling or substantial subsurface earthwork that would be in a confined condition.

Geologic and soil conditions depend on the proximity to streams and rivers; these are discussed in Section 3.8, Hydrology and Water Resources. Section 3.11, Safety and Security, addresses HST earthquake safety. Section 3.14, Agricultural Lands, addresses the quality of soils for agricultural use.

Construction of this project requires substantial quantities of borrow material for use as track ballast and subgrade materials in approach fills for elevated structures and for aggregate in concrete construction. The Office of Mine Reclamation (California Department of Conservation [DOC]) provided a list of quarries within the state of California (DOC 2010). The Merced to Fresno Section of the HST Project would require, depending on the alternative, approximately 1,675,000 to 2,700,000 tons of aggregate and 680,000 to 1,000,000 cubic yards of fill (assuming no fill is provided by project excavation). For elevated structures with slab track, an additional 11,240 to 63,280 cubic yards of aggregate would be needed. Borrow requirements for the project were evaluated and five permitted and operating aggregate quarries were identified in California with capacity for ballast. Figure 3.9-1 shows the location of these quarries. USGS surveys concluded that there were 196 million tons of aggregate permitted for mining within the San Joaquin Valley air basin in 2001. USGS estimated that this represents only about 6% of the resource (California Geological Survey [CGS] 2006). Based on this estimate, there would be sufficient aggregate and fill available in the air basin to provide material for the project without harmfully depleting available sources; therefore, borrow sites are not evaluated in the analysis of geology, soils, and seismicity.

3.9.2 Laws, Regulations, and Orders

Key federal, state, and local laws and regulations that pertain to geology, soils, and seismicity and that are most relevant to the proposed project are summarized below. The summary of key federal, state, and local laws and regulations is followed by a listing of key design standards and guidelines that could be used during design and construction of the project. Use of these guidelines and standards could help in mitigating the risks of hazards associated with geology, soils, and seismicity.

3.9.2.1 Federal

Federal guidelines (NEPA) are discussed in Section 3.1, Introduction to Chapter 3.

3.9.2.2 State

Alquist-Priolo Earthquake Fault Zoning Act (Public Resources Code Section 2621 et seq.)

This Act provides policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prevent the location of developments and structures for human occupancy across the trace of active faults.

Seismic Hazards Mapping Act (Public Resources Code Sections 2690 to 2699.6)

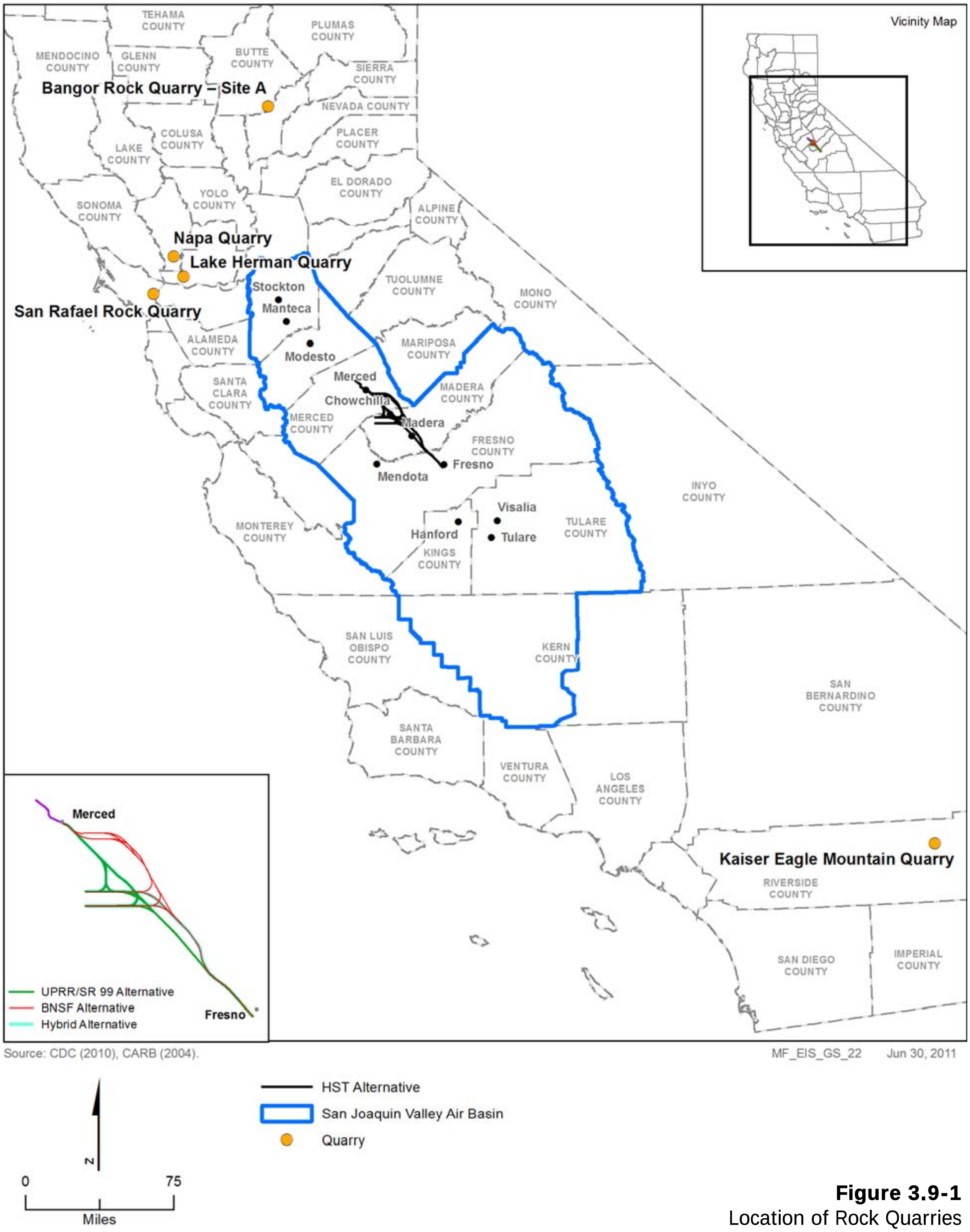
This Act requires that site-specific geotechnical investigations be conducted within the zones of required investigation to identify and evaluate seismic hazards and formulate mitigation measures prior to permitting most developments designed for human occupancy.

Surface Mining and Reclamation Act (Public Resources Code Section 2710 et seq.)

This Act addresses the need for a continuing supply of mineral resources, and is intended to prevent or minimize the adverse impacts of surface mining on public health, property, and the environment.

California Building Standards Code (California Code of Regulations Title 24)

The California Building Standards Code governs the design and construction of buildings, associated facilities, and equipment and applies to buildings in California.



Source: CDC (2010), CARB (2004).

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Figure 3.9-1
Location of Rock Quarries

3.9.2.3 Regional and Local

The State of California requires all cities and counties to adopt plans that provide objectives and policies addressing public health and safety, including protection against the impacts of seismic ground motions, fault ruptures, and geological and soils hazards. These plans also provide for protection from excessive soil erosion, slope failures, and hazards related to oil and gas fields. Table 3.9-1 provides a list of the plans and policies adopted by the cities and counties in the Merced to Fresno Section that were identified and considered in the preparation of this analysis. Regional plans have not been prepared for the management of geologic resources or seismic risks.

Table 3.9-1
Local Plans and Policies

Policy Title	Summary
Merced County	
Merced County General Plan (Merced County 1990)	Provides goals, objectives, policies, and implementation to protect people and structures from known seismic and geologic hazards and to manage soil erosion, protect water quality, mineral, energy, historical, and air resources. • Chapter 5 Safety: – Goal 1, Objective 1.A addresses seismic and geologic hazards. – Goal 3, Objective 3.A, Policy 2, Policy 3, and Implementation of Uniform Building Code (UBC) related to construction on unstable soils address unstable soils, slope instability, subsidence, and liquefaction. • Chapter 6 Open Space/Conservation: Goal 2, Objective 2.A, Policies 1 and 3 address soil erosion.
City of Atwater	
City of Atwater General Plan (City of Atwater 2000), Chapter 5, Seismic and Public Safety	Provides goals, policies, and implementation programs for seismic activity, liquefaction, ground subsidence, and wind erosion. • Goal SF-1 and Policy SF-1.1 address seismic activity. • Goal SF-2 and Policy SF-2.1 address liquefaction. • Goal SF-3 and Policy SF-3.1 address ground subsidence. • Goal SF-7, Policy SF-7.1, and Implementation Program SF-7.a address soil erosion by wind.
City of Merced	
City of Merced General Plan (City of Merced 2012)	Provides goals and policies for conservation of soil, air quality, and safety from hazards of earthquake activity and other geologic activity. • Chapter 7 Open Space, Conservation, and Recreation: Goal OS-5, Policy OS-5.2, and Implementation Actions 5.2.a and 5.2.c address conservation of soil resources and soil erosion. • Chapter 8 Sustainable Development: Goal SD-1, Policy SD-1.6, and Implementation Action 1.6a address air quality and dust and particulate emissions during construction, grading, excavation, and demolition. • Chapter 11 Safety: – Goal S-2, Policy S-2.1, Implementation Action 2.1a, and Policy S-2.2 address seismic safety. – Policy S-2.3 addresses ground failure and subsidence. – Policy S-3.2 addresses dam failure.

Policy Title	Summary
Madera County	
Madera County General Plan, Part II (Madera County 1995)	Provides goals, policies, and implementation programs to protect and enhance natural qualities of streams, creeks, and groundwater; to conserve mineral resources; and to minimize loss of life, injury, and property damage due to seismic and geologic hazards including landslide hazards, unstable slopes, steep slopes, and expansive soils. • Section 5 Agricultural and Natural Resources: – Goal 5.C, Policy 5.C.2, and Implementation Program 5.1 address water quality, sedimentation and erosion, diversion or obstruction of stream channels, and pollution of waterways with detrimental material. – Goal 5.I and Policy 5.I.2 address mineral resources. • Section 6 Health and Safety: – Goal 6.A and Policy 6.A.1 address geologic and seismic hazards including ground shaking, landslides, liquefaction, and critically expansive soils. – Policies 6.A.2 and 6.A.3 address landslide hazards, unstable slopes, and steep slopes. – Implementation Program 6.1-UBC addresses seismic concerns.
City of Chowchilla	
City of Chowchilla General Plan (City of Chowchilla 2011)	Provides objectives and policies to improve air quality and minimize risks posed by geologic or seismic activity. • Open Space and Conservation Element: Objective OS-22, Policy OS 22.3, and Implementation Measure OS 22.3.A address air quality and dust during construction/demolition, and particulate emissions from construction, grading, excavation, and demolition. • Public Safety Element: Objective PS 1 and Policies PS 1.1 to PS 1.4 address geologic or seismic instability including liquefaction and slumping.
City of Madera	
City of Madera General Plan (City of Madera 2009)	Provides goals, policies, and action items for water quality, air quality, and seismic or geologic hazards. • Chapter 5 Conservation Element: – Goal CON-4, Policy CON-10, and Action Item CON-10.1 address water quality and site runoff control. – Goal CON-11, Policy CON-28, and Action Item CON-28 address air quality, dust, and particulate emissions from construction, grading, excavation, and demolition. • Chapter 6 Health and Safety Element: Goal HS-1 and Policy HS-8 address safe housing, and protection from damage caused by earthquakes, geologic conditions, and soil conditions.

Policy Title	Summary
Fresno County	
Fresno County General Plan (Fresno County 2000)	Provides goals and policies to protect and enhance water quality, to conserve mineral deposits and oil and gas resources, to improve air quality, and to address seismic and geologic hazards including shrink-swell or expansive soils, soil erosion, unstable slopes, steep slopes, and landslide hazards. • Chapter 5, Open Space and Conservation Element: – Goal OS-A and Policies OS-A.25 and OS-A.26 address water quality and sedimentation and soil erosion. – Goal OS-C and Policies OS-C.2, OS-C.9, and OS-C.10 address mineral deposits and oil and gas resources. – Goal OS-G, Policy OS-G.13, and Implementation Program OS-G.C address air quality and dust control. • Chapter 6, Health and Safety Element: – Goal HS-D addresses minimizing the loss of life, injury, and property damage due to seismic and geologic hazards. – Policies HS-D.2, HS-D.3, HS-D.4, and HS-D.7 address seismic and geologic hazards including earthquake fault zones and seismic zones. – Policy HS-D.8 addresses shrink-swell or expansive soils. – Policy HS-D.9 addresses soil erosion. – Policy HS-D.10, HS-D.11, and HS-D.12 address unstable slopes, steep slopes, and landslide hazards.
City of Fresno	
City of Fresno General Plan (City of Fresno 2002)	Provides objectives and policies regarding mineral resources and public health and safety, including seismic protection, geological and soils hazards, and bluff preservation protection. • Chapter 4.G Resource Conservation Element: Objective G-7 and Policy G-7-d address the conservation of aggregate mineral resources. • Chapter 4.I Safety Element: – Objective I-3, and Policies I-3-a, I-3-c, and I-3-d address geological unstable conditions that include seismic hazards, and geological and soils hazards. – Objective I-4 and Policy I-4-a address geologic hazards along the San Joaquin River bluffs.

3.9.3 Methods for Evaluating Impacts

The methodology used to describe the affected environment and evaluate the potential environmental impacts of the project on geology, soils, and seismicity involved a review and assessment of published maps, professional publications, and reports pertaining to the geology, soils, and seismicity of the project vicinity. The information included USGS topographic maps; USGS and CGS geologic and landslide maps; Natural Resources Conservation Service (NRCS) soils maps; CGS Seismic Hazard Zone maps; USGS and CGS active fault maps; USGS and CGS ground shaking maps; USGS and State of California mineral commodity producer databases; and online databases for mineral resources, fossil fuels, and geothermal resources published by the State of California Department of Conservation, Division of Oil, Gas, and Geothermal Resources.

The analysis included a review of geotechnical data collected for the current 15% level of design. These data are summarized in two reports: (1) *Final Merced to Fresno Section 15% Geotechnical Report UPRR/SR 99 Alternative* (Authority and FRA 2011a), and (2) *Final Merced to Fresno Section 15% Geotechnical Report BNSF Alternative Including Ave 21 and Ave 24* (Authority and FRA 2011b). The two reports summarize the geologic setting for the alignments, describe site conditions, and provide preliminary evaluations and recommendations for geologic hazards, natural chemical hazards and corrosion potential, and foundation support methods. The preliminary geotechnical information included representative boring logs along the alternatives, as well as preliminary engineering interpretations. Much of the information on borings had been obtained at stream and river crossings. These reports also summarize the results of geotechnical explorations conducted by Caltrans and others along or within the vicinity of the HST alternatives.

The impact analysis evaluates two risks:

- The proposed project's potential to increase the risk of personal injury, loss of life, and damage to property, including planned new facilities, *as a result of* existing geologic, soils, and seismic conditions.
- The potential adverse effects of the project on the existing geology, soils, and seismicity; e.g., erosion of topsoil.

3.9.3.1 Methods for Evaluating Effects under NEPA

Pursuant to NEPA regulations (40 CFR 1500-1508), project effects are evaluated based on the criteria of context and intensity. Context means the affected environment in which a proposed project occurs. Intensity refers to the severity of the effect, which is examined in terms of the type, quality, and sensitivity of the resource involved, location and extent of the effect, duration of the effect (short- or long-term), and other considerations. Beneficial effects are identified and described. When there is no measurable effect, an impact is found not to occur. The intensity of adverse effects is the degree or magnitude of a potential adverse effect, described as negligible, moderate, or substantial. Context and intensity are considered together when determining whether an impact is significant under NEPA. Thus, it is possible that a significant adverse effect may still exist when the intensity of the impact is determined to be negligible or even if the impact is beneficial.

For geology, soils, and seismicity, an impact with *negligible* intensity is defined as an increased risk or adverse effects related to geology, soils, and seismicity that are slightly greater, but very close to the existing conditions. An impact with *moderate* intensity is defined as an increased risk of personal injury, loss of life, and damage to property as a result of existing geologic, soils, and seismic conditions and adverse effects of the project on the existing geology, soils, and seismicity in specific sites or localized areas but that would not have wide-ranging effects. Effects with *substantial* intensity are defined as increased risk of personal injury, loss of life, and damage to property as a result of the project on a regional scale. Additionally, adverse effects of the project on the existing geology, soils, and seismicity (e.g., erosion of topsoil) on a regional scale are effects with substantial intensity.

3.9.3.2 CEQA Significance Criteria

Based on the CEQA Guidelines, including Appendix G, a project would result in a significant impact if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving the following:
    - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault.
    - Strong seismic ground shaking.
    - Seismically related ground failure, including but not limited to, liquefaction.
    - Seiche or tsunami hazard.

  - Dam failure inundation hazard.
  - Landslides, including seismically induced landslides.

- Result in substantial soil erosion or the 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, with the potential to result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse.
- Be located on expansive soil, as defined in Table 18-1-B of the current UBC, creating substantial risks to life or property.
- Be constructed on corrosive soils, creating substantial risks to life or property.
- Result in the loss of availability of a known mineral, petroleum, or natural gas resource of regional or statewide value.
- Result in the loss of availability of a locally important mineral resource recovery site.
- Be located in an area of subsurface gas hazard, creating substantial risks to life or property.

Definitions

Liquefaction: a type of ground failure in which soils lose their strength as a result of build-up in pore-water pressure during and immediately following ground shaking.

Land subsidence: Loss of surface elevation due to removal of subsurface support. A common cause of subsidence in the area has been oil or groundwater withdrawal.

Soil shrink-swell potential: Also called expansion potential. The potential of a soil to expand and contract with wetting and drying cycles.

Seismic loading: The force of an earthquake on a structure.

3.9.3.3 Study Area for Analysis

The potential area of disturbance associated with the construction of the project includes the proposed HST alignments and associated facilities, as well as the roadway changes necessary to accommodate the HST alignments and associated facilities. These are described in Section 3.1, Introduction to Chapter 3, and in more detail in Chapter 2, Alternatives.

Geologic hazards and seismic hazards, such as soil failures, settlement, corrosivity, shrink/swell, erosion, and earthquake-induced liquefaction risks, are potential direct effects that affect the area immediately adjacent to the HST alignment alternatives. For assessment of these risks, the study area is 150 feet on either side of the project alternative construction footprints. The study area encompasses a half-mile radius for subsurface gas hazards, mineral resources, and oil and gas resources, which expands to 2 miles around the proposed HMFs and the proposed stations. The regional study area encompasses the San Joaquin Valley for review of seismicity, faulting, and dam failure inundation. Earthquake faults were identified within a 100-mile distance from the proposed alignment.

3.9.4 Affected Environment

The affected environment for geology, soils, and seismicity includes the following elements: physiography and regional geologic setting, geology of the proposed HST alternatives, site soils, geologic hazards, primary seismic hazards, secondary seismic hazards, areas of difficult excavation, and mineral and energy resources. The defined affected environment is used to describe the context by which the evaluation will be made to determine whether an impact is significant under NEPA.

3.9.4.1 Physiography and Regional Geologic Setting

The project is in the Central Valley of California, which is in the Great Valley Geomorphic and Physiographic Province (CGS 2002). The Central Valley is a large, nearly flat valley bound by the Klamath and Trinity mountains to the north, the southern Cascade Range and Sierra Nevada to the east, the San Emigdio and Tehachapi mountains to the south, and the Coast Ranges and San Francisco Bay to the west. The Central Valley consists of the Sacramento Valley in the north and the San Joaquin Valley in the south.

The Central Valley occupies a structural trough created about 65 million years ago by collision of the Pacific and North American tectonic plates. Sediment from ocean water, river deposition, and glacial deposition filled the trough with an approximately 6-mile-thick layer of continental and marine sediments above rock (Authority and FRA 2004).

The study area is located in the central part of the San Joaquin Valley. The topography in this part of the Central Valley is flat-lying, with elevations across the project alternatives, including the north-south alignments, wyes, stations, and HMFs ranging between +170 feet (North American Vertical Datum of 1988 [NAVD 88]) to +305 feet (NAVD 88). There is a general downward gradient in the study area to the west-southwest, determined principally by the gentle slope of the vast alluvial fans extending from the Sierra Nevada in the east to the center of the San Joaquin Valley.

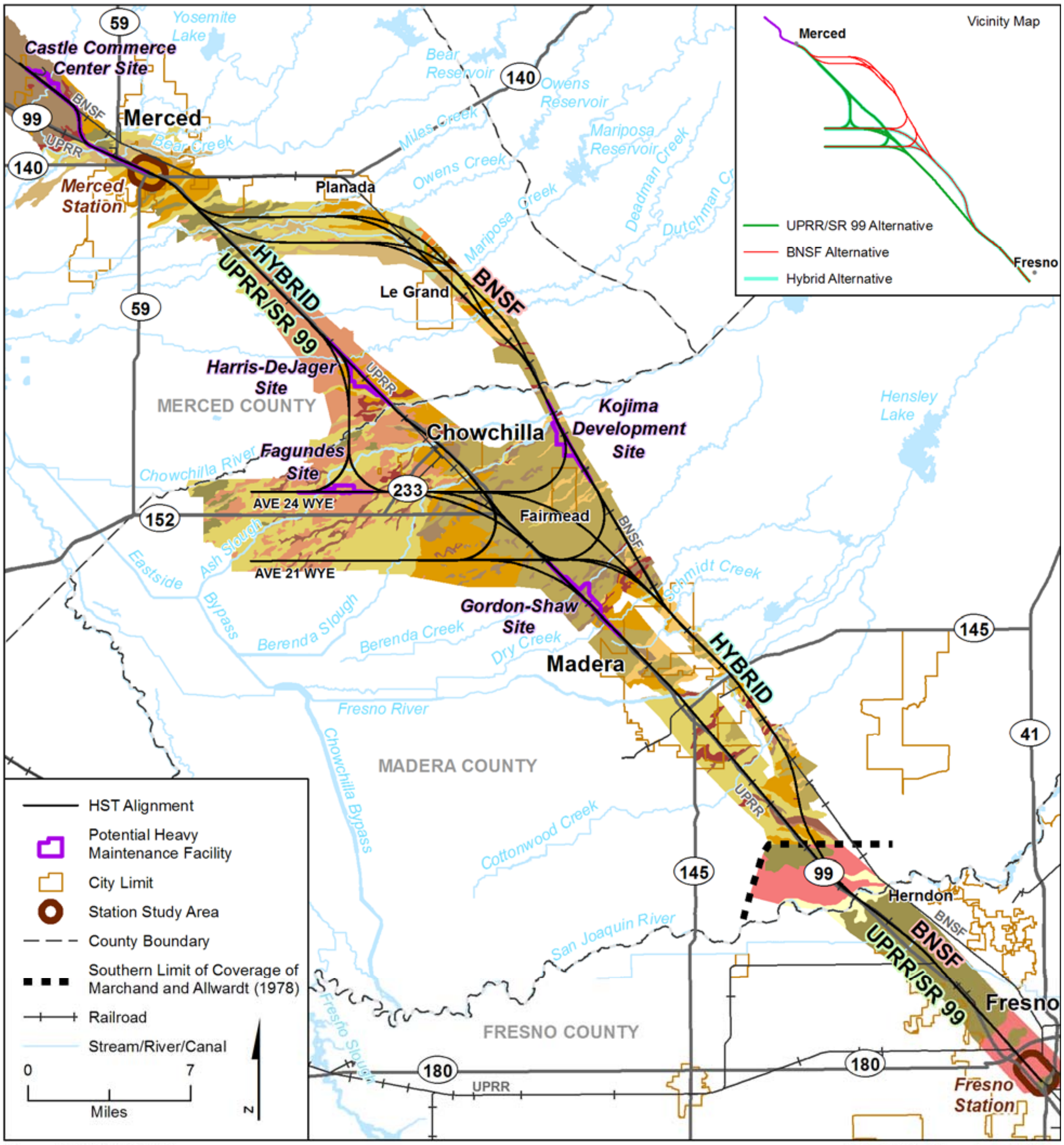
The only steep slopes, defined for this project as slopes taller than 15 feet and steeper than 2H:1V (horizontal to vertical), or approximately 27 degrees, along the HST alignments are located along river and creek banks. There are over 15 primary rivers, streams, or intermittent creeks that intersect the UPRR/SR 99, BNSF, and Hybrid Alternative rail corridors within Merced, Madera, and Fresno counties. These waterways or drainages are listed and illustrated in Section 3.8, Hydrology and Water Resources. There are three locations where the slope height is 15 feet or taller: Fresno River has 15-foot-tall slopes; Berenda Creek has 15- to 20-foot-tall slopes; and the tallest of the slopes is about 50 feet along the banks of the San Joaquin River. More typically the slopes are less than 10 feet in height, with slope angles that range from relatively flat to occasional slopes steeper than 45 degrees.

3.9.4.2 Geology along the Proposed HST Alternatives

Geologic formations along the proposed alignments include the Post-Modesto, Modesto, Riverbank, Turlock Lake, North Merced Gravel, Laguna, Mehrten, Great Valley Sequence, and Pleistocene nonmarine formations. The Modesto, Riverbank, and Turlock Lake formations are similar in four respects: (1) the parent material of the sand and silt fraction, (2) a tendency toward coarser material at the top of each geologic layer, (3) deposition as sequential overlapping alluvial terrace and fan systems, and (4) the origin of much of the sediment. Bedrock is about 6 miles bgs.

Surficial geology underlying the project alternatives, including the north-south alignments, wyes, stations, and HMFs consists primarily of alluvial deposits of clay, silt, sand, and gravel with varying grain sizes and content. The soil type and consistency of these deposits vary by location. Figure 3.9-2 shows surficial geology, and Table 3.9-2 provides a summary of information on mapped surficial geology. Table 3.9-3 identifies the predominant geology from north to south within each of the three HST alignments.

The available exploration information for soils (Authority and FRA 2011a, b) is mainly from three sources: (1) geotechnical explorations conducted by Caltrans at river and stream crossings or at roadway over- or undercrossings, where bridges have already been constructed; (2) investigations for environmental cleanups or monitoring recorded in the State of California Water Resources Control Board GeoTracker database; and (3) explorations from assorted building projects along the alignments. Geotechnical explorations for these locations indicate that soils generally consist of layers of clay, silt, and sand of varying grain-size distributions, consistencies, and thicknesses. Most soils along the alternatives, including the north-south alignments, wyes, stations, and the HMFs are competent stiff silts and clays or dense sands. Competent soils are soils that resist settlement and would not continue to compress when bearing the weight of typical project components. However, there are some occurrences of fine-grained soil that range from soft to stiff in consistency to cohesionless soils that can range from loose to very dense. Generally, these less competent silts and sands are located in the upper 10 to 20 feet. Between 20 and 30 feet, soils are typically more competent, stiff or medium dense, silts and sands. Dense sands and hard silts are usually encountered at depths of 30 to 60 feet bgs. Gravels occur in some soil layers. Similar soil conditions are expected throughout the area based on the geological processes that resulted in the soil profile.



Source: USGS (1965, 1978).

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Coverage of Marchand and Allwardt (1978)

Youngest to Oldest

- 🟫 hal, Post-Modesto
- 🟫 mh, Undifferentiated post-Modesto and Modesto Formation
- 🟨 m2, Modesto Formation - Upper member
- 🟫 m2b, Modesto Formation - Upper member
- 🟧 m2e, Modesto Formation - Upper member
- 🟥 m1, Modesto Formation - Lower member
- 🟧 m1b, Modesto Formation - Lower member
- 🟫 m1e, Modesto Formation - Lower member
- 🟧 r3, Riverbank Formation, upper unit
- 🟫 rg, North Merced Riverbank
- 🟫 rg, Riverbank Formation, upper unit
- 🟫 r2, Riverbank Formation, middle unit
- 🟨 t2, Turlock Lake Formation
- 🟩 Qtnm, North Merced Gravel
- 🟧 Tl, Laguna Formation
- 🟩 Tm, Mehrten Formation

Coverage of Matthews and Burnet (1965)

- 🟨 Qsc, Great Valley Sequence - Stream Deposits
- 🟥 Qf, Great Valley Sequence - Fans
- 🟫 Qc, Pleistocene nonmarine

Figure 3.9-2
Surficial Geology
within the Study Area

Table 3.9-2
Summary of Mapped Surficial Geologic Units

Map Symbol	Geologic Formation and Formation Subunit	Geologic Unit Type	Description
hal	Post-Modesto	Alluvium	Alluvial sand, silt, and gravel associated with floodplains and low terraces
mh	Undifferentiated post-Modesto and Modesto Formation	Alluvium	Alluvial sand, silt, and gravel; includes some young colluvium in foothill valley bottoms
m2	Modesto Formation - Upper member	Coarse alluvium	Alluvial sand, silt, and gravel of channels, terraces, and upper fans
m2b	Modesto Formation - Upper member	Fine alluvium	Alluvial sand, silt, and clay of interdistributary areas, lower fans, and flood basins, commonly stratified
m2e	Modesto Formation - Upper member	Eolian sand	Associated with subdued, stabilized dunes
m1	Modesto Formation - Lower member	Coarse alluvium	Alluvial sand, silt, and gravel of channels, terraces, and upper fans
m1b	Modesto Formation - Lower member	Fine alluvium	Alluvial sand, silt, and clay of interdistributary areas, lower fans, and flood basins, commonly stratified
m1e	Modesto Formation - Lower member	Eolian sand	Moderately well sorted
r3	Riverbank Formation[a], upper unit	Alluvium	Alluvial sand, silt, and gravel
Rg	Riverbank Formation, upper unit	Lag gravel	Gravel derived from regrading of North Merced and older gravels
r2	Riverbank Formation, middle unit	Alluvium	Alluvial sand, silt, and gravel
t2	Turlock Lake Formation	Arkosic alluvium	Alluvial granitic sand and minor gravel overlying stratified fine sand, silt, and minor clay
QTnm	North Merced Gravel	Lag gravel	Thin, locally derived pediment veneer of cobble gravel capping Tertiary and pre-Tertiary rocks
Tl	Laguna Formation	Arkosic alluvium	Granitic sand, silt, and minor gravel underlying the China Hat Gravel Member
Tm	Mehrten Formation	Fluvial deposits	Andesitic fluvial sand, silt, and minor gravel, presumably reworked from volcanic mudflow deposits to the northeast
Qsc	Great Valley Sequence – Stream Deposits	Alluvial deposits	No description available
Qf	Great Valley Sequence – Fan Deposits	Fan deposits	No description available
Qc	Pleistocene Nonmarine	Alluvial deposits	No description available

[a] Identification as Riverbank Formation is based upon available data but is a somewhat uncertain conclusion and subject to confirmation.

Sources: USGS (1978) and USGS (1965).

Table 3.9-3
Predominant Geologic Formation Subunits between City of Merced and the City of Fresno

Location	UPRR/SR 99 Alternative	BNSF Alternative	Hybrid Alternative
Merced Area	Riverbank Formation – upper unit (r3): sand, silt, and gravel	Riverbank Formation – upper unit (r3): sand, silt, and gravel	Riverbank Formation – upper unit (r3): sand, silt, and gravel
Merced to Chowchilla Area	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay Riverbank Formation – upper unit (r3) and middle unit (r2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay
Chowchilla Area	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel
Ave 24 and 21 Wye Area	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Modesto Formation – lower member (m1b): sand, silt, and clay; and upper member (m2): sand, silt, and gravel Riverbank Formation – upper unit (r3): sand, silt, and gravel
Chowchilla to Madera Area	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel Turlock Lake Formation – (t2): sand and minor gravel overlying fine sand, silt, and minor clay	Riverbank Formation – middle unit (r2): sand, silt, and gravel Turlock Lake Formation (t2): sand and minor gravel overlying fine sand, silt, and minor clay
Madera to Fresno County Line Area	Modesto Formation – upper member (m2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2) sand, silt, and gravel
County Line to Fresno Area	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available
Fresno Area	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available

Depth to groundwater ranges from 0 to 190 feet bgs in the study area and varies considerably (about 20 feet or more) each season, depending on rainfall conditions. In general, groundwater is typically shallower toward the northern and southern ends of the UPRR/SR 99 and BNSF alternatives and deepest between the cities of Chowchilla and Madera. Groundwater is also generally deeper toward the northeast part of the study area and becomes shallower toward the southwest part. Table 3.9-4 provides a summary of groundwater depths at different locations along the alignments.

Table 3.9-4

Summary of General Groundwater Locations

Location	Groundwater Depth (feet)
Atwater to Merced Area	0 to 50
Downtown Merced Station Area	50
Merced to Chowchilla Area	50 to 100
Chowchilla Area	38 to 75[a]
Chowchilla to Madera Area	150 to 190
Madera Area	100 to 150
Madera to Fresno, Downtown Fresno Station Area	50 to 100

[a] Source: Advanced Environmental Concepts (2004).

Source: California Department of Water Resources (2000), except as noted for the Chowchilla area.

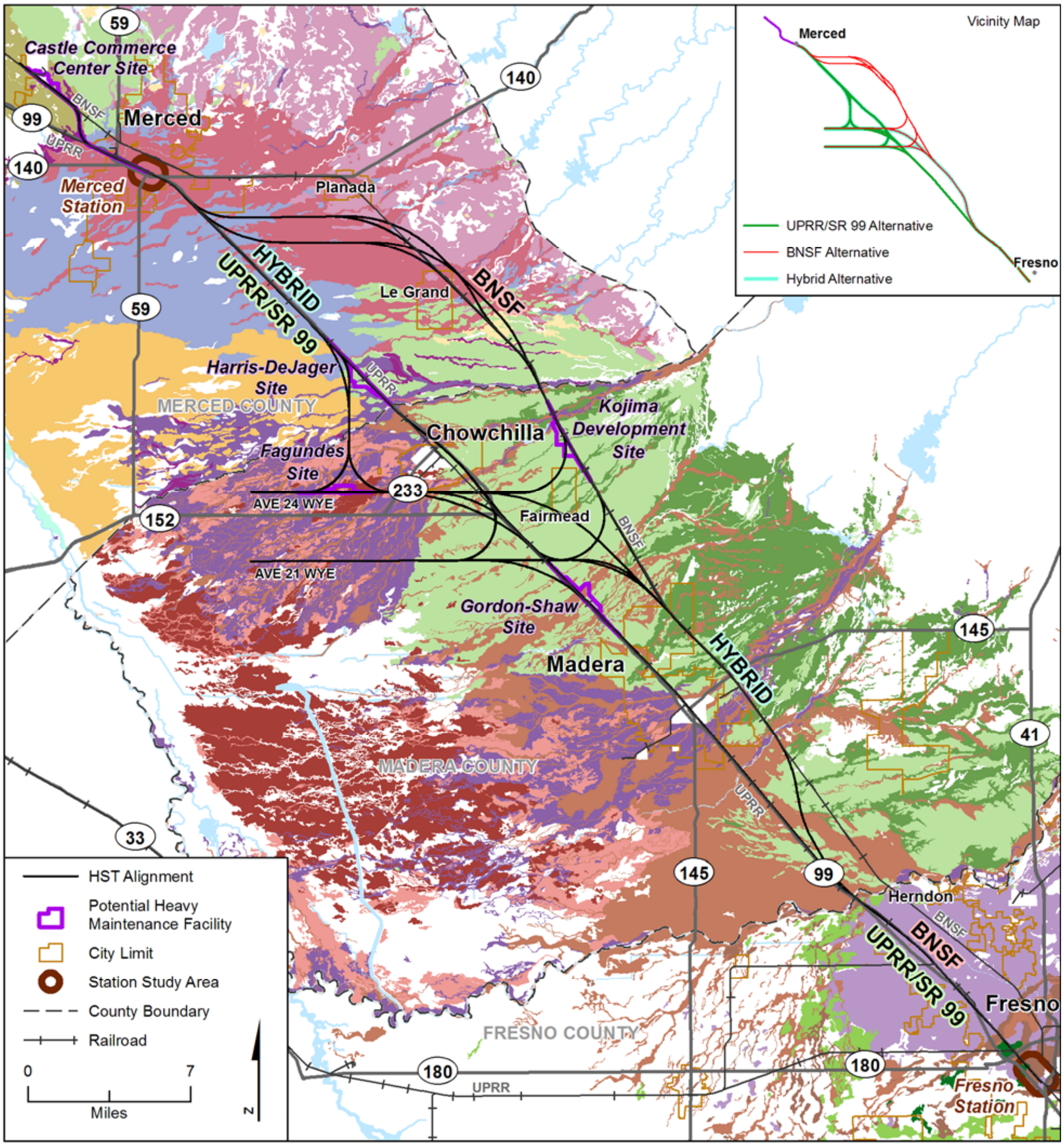
3.9.4.3 Site Soil

NRCS soil surveys describe soils associated with the proposed alternatives, including the north-south alignments, wyes, stations, and HMFs (NRCS 1962a, 1962b, 1971). This soil information is based on conditions within the upper 4 to 5 feet of the ground surface. Figure 3.9-3 shows the soil associations in the study area. Table 3.9-5 provides a summary of the physiographic features, soil associations, and counties of occurrence.

The soils within the study area generally occur within one of the four landform groups. The locations and characteristics of soils within each group are summarized below:

- Recent alluvial fans and floodplains. These soils are found in Merced, Madera, and Fresno counties. They are developed in nearly level and gently sloped ground conditions, along drainage ways, on alluvial fans, and on floodplains. Characteristics often vary greatly within short distances because they formed as stream deposits. Some areas may have compacted silt or sand or an iron-silica hardpan. Typically these soils have little clay content, exhibit low shrink-swell potential, are moderately to highly corrosive to uncoated steel, and are slightly corrosive to concrete. These soils also have high potential for water and wind erosion, and some areas are slightly to moderately saline and alkaline at depths of 4 to 5 feet.

- Older, low alluvial terraces. These soils are found in Merced, Madera, and Fresno counties. They are often found in rolling topography, and can include a strongly cemented or indurated hardpan in the subsoil. The hardpan can be composed of cemented silica or clay. These soils contain expansive clays, resulting in high shrink-swell potential. These soils are highly corrosive to uncoated steel and moderately corrosive to concrete. They can have a moderate potential for water erosion and a high potential for wind erosion.



Source: NRCS (1962a,b, 1971).

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Merced County Associations

- Delhi-Atwater association
- Fresno-Traver association
- Hanford-Grangeville association
- Lewis-Landlow-Burchell association
- Pachappa-Grangeville association
- Redding-Pentz-Peters association
- Rossi-Waukena association
- San Joaquin-Madera association
- Whitney-Rocklin-Montpellier association
- Wyman-Yokohl-Marguerite association

Madera County Associations

- Cometa-Whitney association
- Fresno-El Peco association
- Hanford-Tujunga association
- Pachappa-Grangeville association
- San Joaquin-Madera association
- Traver-Chino association

Fresno County Associations

- Greenfield-Atwater association
- Hanford-Delhi-Hesperia association
- Hanford-Hesperia association
- Hanford-Tujunga association
- San Joaquin-Exeter-Ramona association

Figure 3.9-3
Soil Associations within the Study Area

Table 3.9-5
Summary of Soil Associations

Soil Association	Counties of Occurrence	Landform Groups[a]	Soil Hazards
Pachappa-Grangeville association	Merced, Madera	Recent alluvial fans and flood plains	• low to moderate shrink-swell potential • moderately to highly corrosive to uncoated steel • slightly corrosive to concrete • moderate potential for water erosion • high potential for wind erosion
Hanford-Tujunga association	Madera, Fresno		
Hanford-Grangeville association	Merced		
Wyman-Yokohl-Marguerite association	Merced		
Hanford-Hesperia association	Fresno		
Hanford-Delhi-Hesperia association	Fresno		
Greenfield-Atwater association	Fresno		
Delhi-Atwater association	Merced		
San Joaquin-Madera association	Merced	Older, low alluvial terraces	• high shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • moderate potential for water erosion • high potential for wind erosion
San Joaquin-Exeter-Ramona association	Fresno		
San Joaquin-Madera association	Madera		
Cometa-Whitney association	Madera		
Fresno-Traver association	Merced	Basin areas (including saline-alkali basins)	• moderate shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • high potential for water erosion • moderate to high wind erosion potential
Lewis-Landlow-Burchell association	Merced		
Fresno-El Peco association	Madera		
Traver-Chino association	Madera		
Rossi-Waukena association	Merced		
Whitney-Rocklin-Montpellier association	Merced	High terraces	• moderate to high shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • moderate potential for water erosion • low to high potential for wind erosion
Redding-Pentz-Peters association	Merced		

[a] As mapped by NRCS, not necessarily observed in the study area.

Sources: NRCS (1962a, 1962b, 1971).

- Basin areas (including saline-alkali basins). These soils are found primarily in Merced and Madera counties. The topography of these areas is nearly level or gently undulating. They have more clay content, and nearly all have accumulations of salt and alkali due to poor drainage. Most of these soils have cemented lime-silica hardpans in the subsoil. These soils exhibit moderate shrink-swell potential, are highly corrosive to uncoated steel, and are moderately corrosive to concrete. They are also moderately to highly susceptible to water and wind erosion.
- High terraces. These soils are found primarily in Merced County. They tend to occur in undulating landscape and have textures ranging from fine sand to gravel. Some of the high terrace soils are underlain by an iron-silica hardpan or claypan. Despite the coarser texture, these soils have a moderate to high potential for shrink-swell, are highly corrosive to uncoated steel, and are moderately corrosive to concrete. The potential for water erosion is moderate, and the potential for wind erosion is from low to high, depending on surface textures.

There are several soil types found in the project area. Table 3.9-6 summarizes the general types of surface soils along each of the HST alignments.

Table 3.9-6

Predominant Soil Associations between City of Merced and the City of Fresno

Location	UPRR/SR 99 Alternative	BNSF Alternative	Hybrid Alternative
Merced	Wyman-Yokohl-Marguerite association	Wyman-Yokohl-Marguerite association	Wyman-Yokohl-Marguerite association
Merced to Chowchilla	Lewis-Landlow-Burchell association	Wyman-Yokohl-Marguerite association and Redding-Penz-Peters association	Lewis-Landlow-Burchell association
Chowchilla	San Joaquin-Madera association	San Joaquin-Madera association	San Joaquin-Madera association
Ave 24 and 21 Wyes	San Joaquin-Madera association with some Hanford-Tujunga association	San Joaquin-Madera association	Traver-Chino association and Pachappa-Grangeville association
Chowchilla to Madera	San Joaquin-Madera association	San Joaquin-Madera association with some Cometa-Whitney association	San Joaquin-Madera association with some Cometa-Whitney association
Madera to Fresno County Line	San Joaquin-Madera association, Pachappa-Grangeville association, and Hanford-Tujunga association	San Joaquin-Madera association and Cometa-Whitney association with some Pachappa-Grangeville association and Hanford-Tujunga association	San Joaquin-Madera association and Cometa-Whitney association with some Pachappa-Grangeville association and Hanford-Tujunga association
County Line to Fresno	San Joaquin-Exeter-Ramona association	San Joaquin-Exeter-Ramona association	San Joaquin-Exeter-Ramona association

3.9.4.4 Geologic Hazards

The review of the affected environment considered two types of non-seismic geologic hazards for the project alternatives, including the north-south alignments, wyes, stations, and HMFs: slides or slumps along steep slopes located adjacent to rivers and creeks, and general land subsidence. These geologic hazards pose potential threats to the health and safety of residents if the hazard were to occur:

- *Slides and Slumps.* Topography along the alternatives, including the north-south alignments, wyes, stations, and the HMFs is generally very flat with principal relief occurring where stream channels have been incised into the landscape. Large, deep-seated landslide areas have not been identified during review of available USGS and CGS landslide inventories. A number of streams, creeks, and rivers occur along the alternatives, including the north-south alignments, wyes, stations, and HMFs with slopes that vary in height and steepness. Localized, surficial failures of these slopes can occur from changes in groundwater, erosion, changes in slope steepness from construction activities, or new earth loads being placed at the top of the slope. The potential for the slumps and slides increases with slope steepness and height.

- *Land Subsidence.* There is a long history of land subsidence in the San Joaquin Valley in response to water and mineral (oil and gas and geothermal resources) extraction, which in some areas has been close to 30 feet. Within the project vicinity, land subsidence has been estimated at less than 1 foot. Although the mechanism is different, another cause of land subsidence is the ongoing decomposition of organic-rich soils.

Land Subsidence

Land subsidence usually involves the settlement of the ground surface due to compaction or settlement of the underlying soil. The compaction or consolidation can occur hundreds of feet below the ground surface, or it can be a surface feature. In the San Joaquin Valley up to 30 feet of subsidence has occurred from a combination of groundwater and oil withdrawal. The consequence of subsidence can be large depressions—miles in width—at the ground surface Subsidence can be controlled by either not withdrawing groundwater or oil, or by re-injecting water to compensate for the fluid being removed.

3.9.4.5 Primary Seismic Hazards

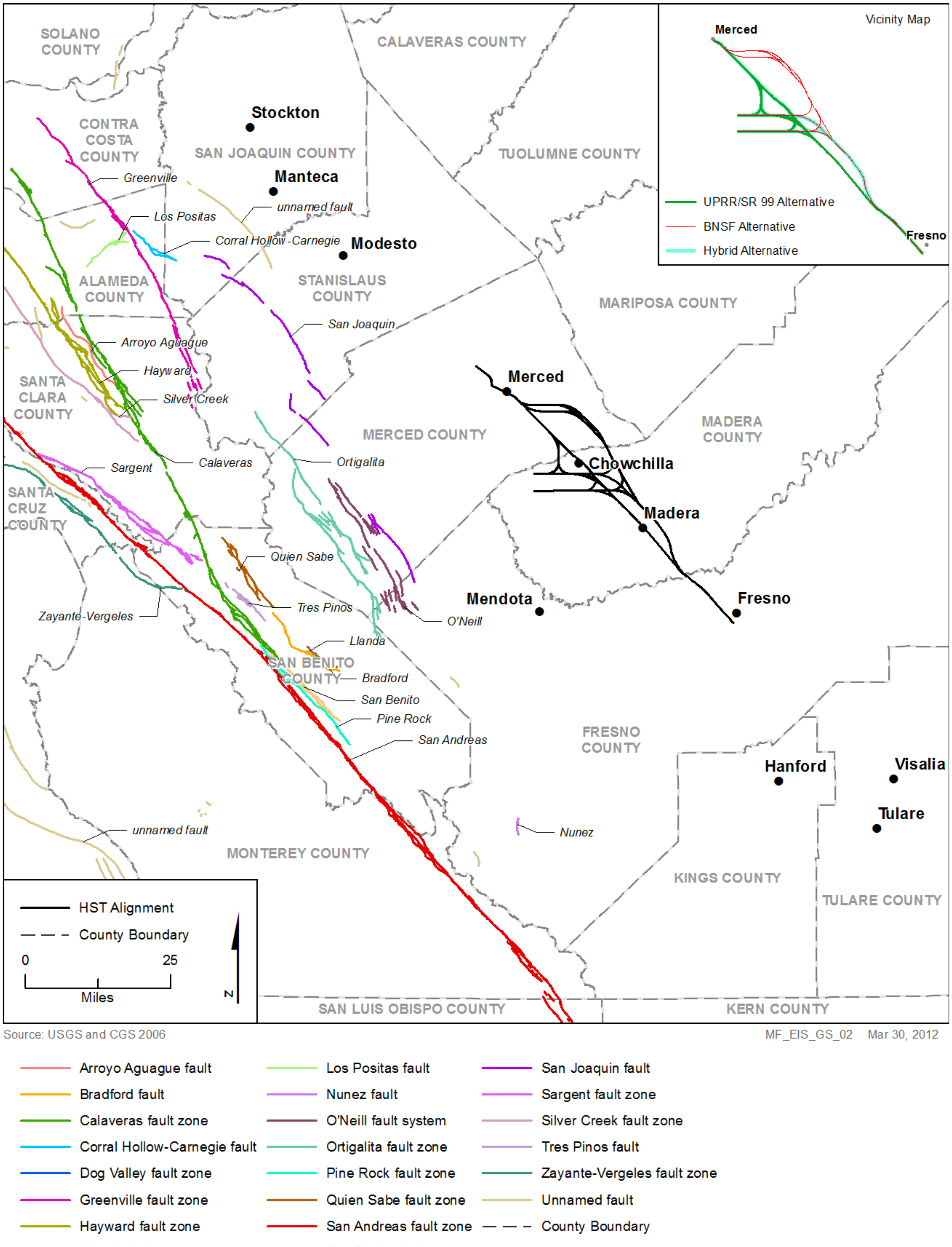
The primary seismic hazards assessed for the project alignments are surface fault ruptures transecting the alignment(s) and ground shaking. Active faulting is prevalent throughout California. Figure 3.9-4 shows active and potentially active faults within about 65 miles of the HST alternatives. A seismic event along any of these faults, depending on type and exposure, can result in permanent offsets at the ground surface along the fault line, and, depending on proximity to the event epicenter, varying degrees of ground shaking.

The review of information published by the USGS and CGS determined the following primary seismic hazards for the project:

Definition

A *fault zone* is a group of fractures in soil or rock where there has been displacement of the two sides relative to one another. A fault zone ranges from a few feet to several miles wide.

- *Active and Potentially Active Faults.* An active fault is defined as a ground rupture that has occurred within approximately the last 11,000 years. A potentially active fault includes ruptures that occurred between 11,000 and 1.6 million years ago. No active or potentially active faults intersect or are located within 25 miles of the project alignments. However, 25 active or potentially active faults or fault systems are located within 65 miles of the project and range in length from less than 10 miles to over 500 miles. The largest of the faults is the San Andreas Fault zone, which is located approximately 65 miles from the project. The closest active or potentially active faults identified by the USGS and CGS are the Ortigalita Fault zone, about 34 miles west of the UPRR/SR 99 Alternative, and the San Joaquin Fault zone located about 25 miles west of



Source: USGS and CGS 2006

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Figure 3.9-4
Active and Potentially Active Faults within about 65 miles of the HST Alternatives

the nearest alternative. Caltrans has estimated the maximum credible earthquake to be a magnitude of 7.0 for the Ortigalita Fault zone, and 6.5 to 7.5 for the San Joaquin Fault zone. Refer to the *Merced to Fresno Section Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012a) for more detailed information about active and potentially active faults.

- *Ground Shaking.* The relative intensity of ground shaking is anticipated to be moderate, with peak ground accelerations at the ground surface potentially greater than 0.35g, where g is the acceleration of gravity. This level of ground shaking is based on a seismic event with a 2% probability of being exceeded in a 50-year interval, with an associated return period of approximately 2,500 years. The 0.35g level of ground surface shaking results from a 50% amplification of ground motion arriving in firm-ground or soft rock motions below the site, as ground motions propagate through the soil column. Information about ground motions available on the USGS website suggests that the primary cause of shaking likely would be a nearby shallow earthquake (magnitude 5.2 at 4.5 miles), but that large, distant (greater than 30 miles) events with a magnitude greater than 6.6 also generally contribute to the ground motion hazard. Historical earthquakes and their magnitudes within about 100 miles of the project area are shown on Figure 3.9-5.

Ground Shaking Level

Many methods are used to describe ground motions that develop during earthquakes. The most common method of measuring the size of ground shaking is in terms of ground acceleration. The acceleration of gravity is approximately 32.2 feet per second. This is referred to as 1 g or 1.0 gravitation acceleration unit. Large nearby earthquakes can cause ground shaking from less than 0.1g to 1.0g in the severest of events.

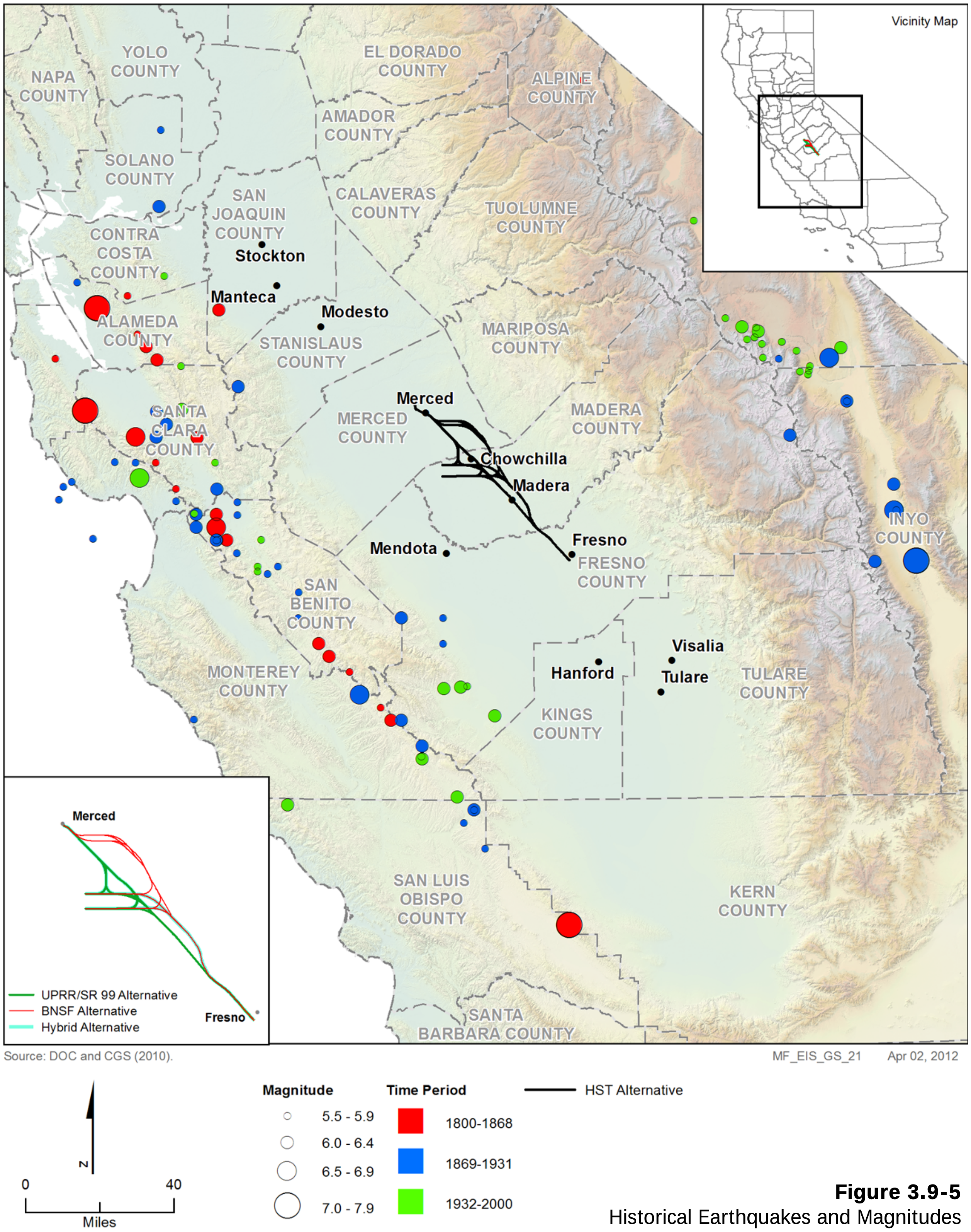
The frequency of earthquake occurrence is a common method of defining the risk of shaking. The International Building Code in the United States is based on an earthquake that has a 2% chance of occurring in 50 years. This chance of occurrence equates to approximately one such event in 2,500 years.

3.9.4.6 Secondary Seismic hazards

A number of secondary seismic hazards could occur within the study area if there were strong ground shaking at the site. The strong ground shaking could result from either a nearby or distant earthquake, depending on the combination of earthquake magnitude and distance from the project. These secondary hazards include liquefaction, seismically induced slides or slumps, and floods resulting from seismically induced dam failure. The first two of these hazards occur primarily either where liquefiable soils exist or where there are steep slopes within the alternatives, including the north-south alignments, wyes, stations, and HMFs. In contrast, the seismically induced floods could occur when any one of several dams located 10 miles or more from the project alignments fail, releasing impounded water that could eventually inundate the area.

A potential for liquefaction exists where groundwater is close to the ground surface and there are loose cohesionless soils. In general, groundwater is located below 50 feet, as summarized in Table 3.9-4. The exceptions occur between Atwater and Merced, in Chowchilla, and localized areas near river and stream crossings, where groundwater is within 50 feet of the ground surface. At these locations the potential for liquefaction exists if saturated near-surface soils are loose, cohesionless soils. Available geotechnical information is insufficient to identify locations with liquefaction potential; therefore, further detailed subsurface geotechnical investigations and geotechnical design evaluations are warranted.

The two primary consequences of liquefaction are loss in soil strength during and following ground shaking, and ensuing ground settlement following seismic loading as liquefaction-induced water pressures dissipate. The severity of this occurrence depends on the relative density, grain-size characteristics, thickness of the liquefied stratum, and magnitude of the causative seismic event. Where liquefaction occurs at stream and river crossings, there is also the potential for liquefaction-induced lateral spreading or flow of the soil. These liquefaction-related ground displacements could occur on ground that has slope angles of 5 degrees or more. Waterway crossings discussed in Section 3.8, Hydrology and Water Resources, are the most susceptible locations for liquefaction-induced lateral spreading or flow failures.



Source: DOC and CGS (2010).

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Figure 3.9-5
Historical Earthquakes and Magnitudes within 100 Miles of Project Area

The inertial effects of ground shaking can also be sufficient to cause slopes to fail, even where liquefaction does not occur. In this case inertial forces in combination with gravity loads exceed the strength of the soil. When this exceedance occurs, slope movements can result and, depending on magnitude of movement, failure can ensue. This hazard is most critical where slopes are steep (i.e., greater than 2H:1V (horizontal to vertical) and where soil strength is low. The degree of risk of a slope failure is usually determined by comparing the force resisting failure (i.e., soil strength) to forces causing failure (i.e., gravity and earthquake loads). This ratio of resistance to load defines a dimensionless factor of safety. Slopes with static factors of safety less than 1.5 have a higher risk to seismic slope failures. When the factor of safety is less than 1.0, slope movement is predicted. All of the natural waterway crossings in the project study area are candidate locations for these slope failures.

The last type of secondary hazard involves water inundation resulting from the failure of dams located to the east of the project. A review of dam inundation maps prepared by each county (Merced, Madera, and Fresno counties) shows that dams located on Bear Creek; on Owens Creek; near Deadman Creek; and on the Chowchilla River, the Fresno River, and the San Joaquin River are potential sources of inundation.

The areas of potential inundation are shown in Figure 3-12 of the *Merced to Fresno Section Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012a). The inundation areas shown in the technical report represent conservative scenarios based on two key assumptions:

- Seismic shaking associated with the seismic event causes catastrophic failure of the dam/retaining structures, and
- Retained waters are at their maximum operating elevation (not the maximum flood stage) at the time of the seismic event.

Based on these conditions, the water depth along the HST alignments could be over the top of the rail tracks in some areas in the event of a failure.

3.9.4.7 Areas of Difficult Excavation

For these discussions difficult excavation is defined as excavation methods requiring more than standard earth moving equipment or special controls to enable the work to proceed. Areas of difficult excavation are most common in rock formations and possibly cemented or hardpan strata not amenable to excavation with a ripper-equipped dozer.

Rock is located far below the ground surface in the Merced to Fresno Section; therefore, the potential for encountering rock is not likely. However, cemented zones and hardpan can occur within the project area, particularly along the BNSF alignment, and the cemented zones and hardpan can be rock-like in consistency. Cemented zones and hardpan form as a result of the soil weathering process and can develop in most of the surficial site soils previously described. These cemented zones and hardpan may pose local excavation issues for conventional machinery, depending on the thickness and degree of cementation of the hardpan or cemented layer. In areas that have been used for agricultural purposes, the hardpan has often been removed or tilled to improve the drainage characteristics of the soil. Past land use, as well as infrastructure development in the study area, should limit the locations where hardpan and cemented zones pose a potential problem for excavations.

It is possible the combinations of soil conditions and shallow groundwater locations would also result in difficult excavation conditions if sufficient consideration is not given to specific conditions when excavating below-grade sections of the track. Any time excavations extend below ground water levels, there is a need to prevent excess hydrostatic pressures. These conditions are most critical where loose, cohesionless deposits have to be excavated in areas of high groundwater. Conditions between Atwater and Merced could have high groundwater and localized, near-surface deposits of loose, cohesionless soils that could create difficult excavation. Though unlikely, other localized areas where groundwater is near the surface and loose soil conditions exist cannot be ruled out.

3.9.4.8 Mineral and Energy Resources

Active mining operations in the San Joaquin Valley region are for building materials or aggregate (near-surface sand and gravel) and industrial minerals such as lime, pumice, and gypsum. Aggregate resources are the only mineral resources within the immediate study area.

The online mapping system of the California Department of Conservation (DOC) Division of Oil, Gas, and Geothermal Resources (DOGGR) identifies 16 oil, gas, or geothermal wells located along the alternatives, including the north-south alignments, wyes, stations, and HMFs; however, these wells are inactive and have been plugged and abandoned (DOC 2009). There are no other known active gas or oil fields, or geothermal resources identified within the study area.

3.9.4.9 Affected Environment by HST Alternative

The affected environment for the three HST alternatives, including the north-south alignments, wyes, stations, and HMFs is generally very similar in the Merced to Fresno Section. This similarity results from the geological processes that formed the surface and subsurface soils within the Central Valley of California. These geologic processes have led to a very flat topography, competent soils in most areas, and deep groundwater along most of the alternatives, including the north-south alignments, wyes, stations, and HMFs. These similar conditions also have led to similar sets of geologic hazards for the HST alternatives, stations, and the HMFs.

3.9.5 Environmental Consequences

3.9.5.1 Overview

Geologic, soil, and seismic conditions are similar for all three HST alternatives, including the north-south alignments, wyes, stations, and HMFs, and risks can be addressed with conventional foundation design methods used to reduce geologic risks where they are present. These foundation design methods are available for elevated structure, retained fill, at-grade, and retained cut components of each alignment. The engineering design methods are included in AASHTO, AREMA, Caltrans, and IBC standards and guidelines, as described in Section 3.9.6, Project Design Features.

Geologic risks that should be considered during design and construction include unstable soils and settlement that presents a low risk to existing infrastructure with incorporation of standard engineering design features. The existing infrastructure includes roadways, bridges, buildings, and residential structures. The risk is also low to new HST facilities, such as elevated, retained fill, at-grade, and retained-cut segments of the alignments, with incorporation of standard engineering design features. The severity of these risks is limited because the geology along the alternatives, including the north-south alignments, wyes, stations, and HMF sites, is generally very competent, with only localized areas of potentially loose or compressible soils. Where geologic hazards exist, well-proven methods outlined in standard guidance and engineering standards are available to address these hazards. For example, wind and water erosion of stockpiled soil would be addressed by implementing provisions in the *Caltrans Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a). Risks to the alternatives, including the north-south alignments, wyes, stations, and HMFs, from unstable soils, settlement, and erosion are considered to have impacts with negligible intensity under NEPA and would be less than significant under CEQA because of the incorporation of appropriate construction BMPs and standard engineering design measures.

Potential operational impacts for each alternative, including the north-south alignments, wyes, stations, and HMFs, include low soil bearing strength, soil settlement, shrink-swell and corrosive soils, slope failures, ground shaking, and secondary seismic hazards such as liquefaction, liquefaction-related slope movement, and liquefaction-related settlement. The engineering design would incorporate guidelines issued by AASHTO, AREMA, Caltrans, and IBC. With proper incorporation of these guidelines, the severity of these impacts to elevated, retained fill, at-grade, and retained cut segments of the alignments would be limited. Collectively, these design measures would reduce the intensity of effects on public health from geologic hazards to negligible under NEPA and to a less than significant impact under CEQA.

3.9.5.2 No Project Alternative

As discussed in Chapter 1, Purpose, Need, and Objectives of the Project, and Section 3.18, Regional Growth, the population in the San Joaquin Valley has been and is projected to continue growing. To accommodate this growth, farmland has been and likely would continue to be converted to other uses, such as residential developments, small business, light industrial development, and transportation infrastructure. Sections 3.2, Transportation, and 3.19, Cumulative Impacts, list foreseeable future transportation and development projects, which include expansion of SR 99, shopping centers, large residential developments, and quarries. Plans for expanding SR 99 include full access interchanges and additional auxiliary lanes slated for completion by 2020 between Merced and Fresno. These projects are planned or approved to accommodate the growth projections in the area.

Infrastructure and development projects carry risks on public safety and on the potential for property damage caused by geology, soils, and seismicity. Risks to infrastructure and developments include localized deposits of soils that have low bearing support or exhibit excessive settlement under load, or involve geologic hazards from steep slopes near rivers and streams, primary seismic hazards from earthquake ground shaking, and secondary hazards from earthquake-induced liquefaction and slope failures. The infrastructure and development projects would apply standard engineering design features to address and minimize these risks.

Conversely, infrastructure and development projects could affect geology and soils. Changes in local conditions from project implementation include water or wind erosion, loss of valuable topsoil, or constraints on the potential for oil and gas resource development. Infrastructure and development projects would not affect seismicity. The increasing population would result in development in areas where the risk of geologic and seismic hazards, such as slope instability near rivers or liquefaction in areas of liquefiable soils, is higher, ultimately resulting in more risk to the public and a greater chance of property damage. In addition, the use of older buildings to accommodate the increasing population could present a risk during a seismic event, as these buildings were typically built to less stringent standards.

As discussed in Section 3.13, Station Planning, Land Use, and Development, it is anticipated that development projects under the No Project Alternative would occur at the edge of currently developed areas, rather than in already developed areas, and would thus expand the area in which impacts such as erosion would occur from increased amounts of pervious surface water runoff. Because local regulations are established to manage water runoff and other geologic issues, the new development is anticipated to be an impact with negligible intensity under NEPA and managed to less than significant impacts under CEQA.

3.9.5.3 High-Speed Train Alternatives

Construction Period Impacts

Common Geology, Soils, and Seismicity Impacts

Because of the flat topography, competent soils, and groundwater typically located at depths of 50 feet or more, there are only a limited number of environmental consequences possible during construction relative to geology, soils, and seismicity. The risk areas are generally located near streams and river crossings where soils tend to be softer and groundwater is often closer to the ground surface. The potential impacts of construction relative to geology, soils, and seismicity include localized deposits of low-strength soils, areas with potential for ground settlement, and soil erosion. Table 3.8-7 in Section 3.8, Hydrology and Water Resources, quantifies the areas where construction impacts could occur.

Unstable Soils Resulting in Onsite or Offsite Slumps and Small Slope Failures

Unstable soils consist of loose or soft deposits of sands, silts, and clays. These soils exhibit low shear strength and, when loaded, can fail through bearing failures or slope instabilities. Although the HST alternatives, including the north-south alignments, wyes, stations, and HMFs, appear to be dominated by competent soils near the ground surface, unstable soils can occur on a localized basis, particularly near river and stream crossings. Stream crossings and proximity to streams are listed and discussed in the *Merced to Fresno Section Hydraulics and Floodplain Technical Report* (Authority and FRA 2012b) for each HST alternative and the HMF alternatives.

Construction of the project on soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, instability of cut-and-fill slopes required for the HST tracks, or collapse of retaining structures used for retained fills or retained cuts. Over 50% of exploration locations in the corridor have loose to medium dense soils close to the ground surface. Such soils would have relative densities of 20% to 60%, which would make them potentially susceptible to low static strength. Potentially resulting slumps and slope failures could endanger people or onsite and offsite properties. Although this risk would be greater if a large seismic event were to occur, the likelihood of a large earthquake during construction is considered low because of the relatively short duration of construction relative to the frequency of large earthquakes.

This type of impact is mostly associated with retained fill because the additional weight imposed on the ground can cause bearing capacity failures if the load exceeds the bearing strength of the soil. Conventional design methods are available to evaluate the potential for bearing failure, and where potential bearing capacity issues exist, various conventional construction methods are available to reduce the risk of these issues, including the use of ground improvement or the use of lightweight fills.

With implementation of normal design standards and guidelines in addition to standard safety practices during construction, these risks would have negligible intensity under NEPA and a less than significant impact under CEQA.

Soil Settlement at Structures or Along Trackway

Soil settlement could occur during project construction if imposed loads cause compression of the underlying materials. It is a time-dependent process and most problematic at locations where soft deposits such as silty or clay soils exist that have not previously been compacted by loads of levels to be imposed. Such loads would be placed for approach fills for elevated guideways, for retained fill segments of the alignments, or for track subgrade and ballast materials that are placed to meet track grade requirements.

Although soils along the alignments are generally competent (medium dense, stiff, or better), localized deposits of soft or loose soils could occur at various locations, particularly at water crossings where soft or loose soils appear to be more prevalent. Geotechnical explorations prior to construction would identify the locations with potential for settlement. Incorporating engineering design features that address soft deposits of silty or clay soils would render the potential for soil settlement to an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

In some locations, settlement could also affect nearby existing structures or buried utilities located close to the area of construction. This impact would result from either new earth fills, including retained fills, placed in areas underlain by settlement-prone (loose or soft) soils or from dewatering excavations for below-grade sections of track where shallow groundwater occurs and soils are loose or soft. Several borings at river and stream crossings along the alternatives had sample descriptions indicating soft or loose silts. Manuals, such as the *Field Guide to Construction Dewatering* (Caltrans 2001) describe BMPs that can be used to avoid this type of hazard. With implementation of standard construction and engineering design standards and practices, the potential for affecting structures or utilities adjacent to construction areas would have negligible intensity under NEPA and would be less than significant under CEQA.

Another potential source of settlement is from displacement of retaining walls in retained cut segments of the track alignment. This consequence can occur where retaining walls support earth pressures and nearby building loads. If the pressures on the retaining wall are underestimated and the wall deforms outward, soil behind the wall could settle, resulting in damage to structures supported on the soil or utilities located in the soil. The final design would incorporate AASHTO and AREMA methods for estimating wall loads to minimize the risk of damage to nearby structures. Incorporating engineering design features that address soft deposits of silty or clay soils would render the potential for soil settlement an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

Soil Erosion

Accelerated soil erosion, including loss of topsoil, could occur as a result of construction of the project on erosion-prone soils. Soils that have a high potential for wind or water erosion were identified for all alternatives, including the north-south alignments, wyes, stations, and HMFs (see Section 3.9.4). Areas of potential soil erosion are identified in the *Merced to Fresno Section Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012a). With the development of any alternative, the potential for more surface water runoff exists during construction when existing vegetation is removed, and soils are exposed to either wind or water erosion. Surface water runoff could also result from the construction of temporary impermeable work surfaces.

If exposed soils are not protected from wind or water erosion, such as areas cleared of vegetation and stockpiles of excavation materials, the topsoil could erode and cause indirect impacts on water quality and loss of high value soil. The potential for erosion from water increases slightly from west to east. Methods that involve more exposure of the ground during construction would have greater risks from water and wind erosion. Some methods of construction, such as elevated structures located on deep foundations, would have limited potential for erosion because of the limited exposed earth, while other methods, such as at-grade segments, could have greater risk. Both the retained cut and retained fill have limited severity of risk because of the limited area of exposed earth during construction.

With the implementation of standard construction practices, such as those listed in the *Caltrans Construction Site Best Management Practices (BMPs) Manual* (Caltrans 2003b) and the Caltrans *Construction Site Best Management Practices (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a) that reduce the potential for erosion, these potential impacts would have negligible intensity under NEPA and would be less than significant under CEQA.

Difficult Excavations Due to Hardpan and Shallow Groundwater

Upper layers of soil can contain cemented zones and hardpan that can be very difficult to excavate with conventional machinery. Excavations in these soils may require blasting if conventional machinery is not adequate. These soils are typical in this area and contractors are familiar with methods to handle excavations in hardpan.

Excavations in loose, cohesionless deposits that extend below groundwater levels could also result in difficult excavations. At these locations, hydrostatic pressures can result in instabilities of the excavation side-slopes or heave of the excavation base, leading to loss of ground support. These conditions can be encountered in localized areas such as at river crossings. These types of design issues are routinely handled during construction through the use of construction dewatering with deep groundwater wells and well points that lower the water level; by use of sheetpile walls systems to stabilize the soil; or by using techniques such as jet grouting and cement deep soil mixing techniques that add cement to the soil, thereby providing a cement-soil mix that resists hydrostatic forces. Alternatively, excavations can be avoided by using deep foundations that can be driven or drilled into the loose, water-saturated soil.

Locations where retained cut alignment segments are planned would be most affected by hardpan and shallow groundwater conditions. Both the retained fill and at-grade design types would usually involve limited need to excavate the hardpan or work below the groundwater level, and deep foundations for elevated structures are conventionally constructed into hard geologic materials, such as rock, and below the groundwater.

With the implementation of methods in the Caltrans *Construction Site Best Management Practices (BMPs) Manual* (Caltrans 2003b) and the Caltrans *Construction Site Best Management Practices (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a), these potential impacts would have negligible intensity under NEPA and would be less than significant under CEQA.

Alignment Alternatives

Impacts during the construction period would be similar for the UPRR/SR 99, the BNSF, and the Hybrid alternatives because of similar topography (all are relatively flat-lying), geologic units, soils, groundwater location, and levels of earthquake-induced ground shaking. The subtle difference between the three alternatives is the potential for higher water erosion for the HST alignments that are west of SR 99 than those that are east of SR 99. In general, the western alignments have more areas of soils with high water erosion potential, primarily in Merced County. As the distance from the mountains increases, soils tend to be finer. This trend in finer grained soils to the west of SR 99 could also mean that the amount of unstable or settlement-prone soils increase slightly for the alignments west of SR 99 relative to the eastern alignments. Overall, soils are competent along all HST alignments except in isolated locations near rivers and streams.

Specific locations that have either soft fine-grained soils or loose-to-medium dense granular soils and could exhibit risks of bearing failures, slope instabilities, and excessive settlement are as follows:

- UPRR/SR 99 Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, Chowchilla River, Dry Creek, Fresno River, West Fourth Street overcrossing, Avenue 11 overcrossing, Avenue 8 overcrossing, and the San Joaquin River.

- BNSF Alternative: BNSF railroad underpass at G Street, Bear Creek Bridge, and Campus Park overhead.

- Hybrid Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, and Chowchilla River.

Areas of difficult excavation could occur where groundwater is shallow and localized, near surface deposits of loose, cohesionless soil occurs, such as between Atwater and Merced. The potential for encountering hardpan also is greater along the BNSF Alternative than in other locations.

Stations

Soils at the Merced and Fresno stations have a moderate potential for erosion by water. A moderate potential exists for wind erosion of soils at the Merced station, while soils at the Fresno station have a high potential for erosion due to wind. Although groundwater is shallower at the Merced station (at about 50 feet below ground compared to the Fresno station, which is between 80 and 90 feet below ground), little difference in construction or foundation behavior is expected at either location, unless deep basements are used for automobile parking. If deep parking garages were used, the Merced station could result in more dewatering for subsurface excavations, lower stability for excavation slopes, and a greater potential for settlement under construction loads than the Fresno station. There is one natural waterway crossing at the far northwestern portion of the study area for the Merced station where difficult excavation could be encountered. The Fresno station does not have any natural waterway crossings.

Heavy Maintenance Facility Alternatives

Potential for erosion by water is highest at the Fagundes HMF site; the other HMF sites have a moderate potential. Overall, the HMF with the lowest potential effect due to soils is the Castle Commerce Center site because it is a developed site with drainage facilities. The Fagundes, Gordon-Shaw, and Kojima Development HMF sites have the highest potential for high wind and water erosion susceptibility due to the soil types present. Groundwater is shallowest at Castle Commerce Center, including the track connecting to the Downtown Merced Station, compared to the other HMF sites, and this condition could result in more dewatering for subsurface excavations, lower stability for excavation slopes, and a greater potential for settlement under construction loads. There are two natural waterway crossings at the Castle Commerce Center and Gordon-Shaw HMF sites where difficult excavation could be encountered. The other three HMF sites have no natural waterway crossings or only one waterway crossing.

Project Impacts

Common Soils-Related Impacts

Geologic risks during the project are similar to those during the construction period; the difference is that there is a much longer exposure period during the project. This longer exposure period increases the potential risks from localized deposits of soft or loose soils, areas with potential for ground settlement, soils with high shrink-swell characteristics and high corrosivity potential, and slope failure.

Unstable Soils Resulting in Onsite or Offsite Slumps and Small Slope Failures

The potential for impacts from unstable soils during operation is the same as that described for construction, except that the exposure period increases. With the longer exposure period, the potential for creep- or groundwater-related soil failures increase. The unstable soils consist of loose or soft deposits of sands, silts, and clays that can occur on a localized basis and are likely to be more prevalent near river and stream crossings.

The adverse impacts from soft or loose soils would affect some design types more than others. For instance, unstable soils would represent a greater risk to locations where retained fills are planned than to at-grade segments of the alignment, because of the much greater load that retained fills would impose on the unstable soil. Typically, elevated structures supported on deep foundations are specifically designed to handle soft near-surface soils, and retained cuts can accommodate soft soil conditions. Where soft soil conditions are combined with the potential for small slumps and slope failures, the severity of the risk increases. In these locations, the potential impact of loss in bearing or additional soil loads associated with the slump or slope failure would also be considered.

The HST Project design would incorporate design methods that consider the short- and long-term impacts of unstable soils on the HST and nearby facilities. Where appropriate, engineered ground improvements, including regrading or groundwater controls, would be implemented to avoid long-term impacts from unstable soils. Implementation of these methods during final design would meet standards of design and building code requirements to provide either sufficient bearing capacity and slope stability or design measures that protect the facility from loads associated with unstable soils. With implementation of these design measures, the potential impacts from soft or loose soils would have negligible intensity under NEPA and would be less than significant under CEQA.

Soil Settlement

Soil settlement could occur during operation of the project at locations where soft deposits of silty or clay soils are subjected to new earth loads, as might occur with approach fills for elevated guideways, retained-fill segments, or for track subgrade and ballast materials that are placed to meet track grade requirements. Large loads associated with retained-fill segments of the alternatives potentially result in greater severity of risk for soil settlement at soft soil sites. Elevated structures on deep foundations, at-grade, and retained-cut segments of the alternatives represent minimum risk because they involve limited addition of new loads to the existing earth.

There are a number of locations along the construction footprint that would require new earth fills in areas that are potentially underlain by settlement-prone (loose or soft) soils. These specific locations would be identified during preconstruction and construction investigations. The potential consequence of excessive settlement represents a high risk to HST travel if unattended. However, settlement is typically a slow process that, with periodic maintenance, can quickly be remedied by dressing and or reballasting where required to maintain a safe track profile.

The HST Project design incorporates ground improvements and foundations that are resistant to settlement and would meet building code requirements. Also, additional fill material from other sources would be imported, as necessary. With implementation of these standard engineering design features, the potential risk of excessive ground settlement would be minimized and the impact would have negligible intensity under NEPA and would be less than significant under CEQA.

Moderate to High Shrink-Swell Potential

Soils located in the upper 5 feet of soil profile along all of the alternatives, including the north-south alignments, wyes, stations, and HMFs, generally have moderate-to-high shrink-swell potential. The potential for shrink-swell represents a risk to the operation of the track system and the track right-of-way for long-term operations for some of the design types. A consequence of shrink-swell potential includes differential track movement.

This type of impact is more critical to locations with at-grade segments than to elevated structures on deep foundations, retained fill, and retained cuts. The earth loads associated with at-grade segments of the alternatives may not be sufficient to overcome swell potential, and this swell would likely be variable along the alignment, leading to differential movement of the track system.

The project design reduces the risk from shrink-swell soils through soil improvement, or removing the upper 5 feet of soils that exhibit high shrink-swell potential and replacing the excavated soils with soils that do not exhibit these characteristics. Implementing project design features would render the risks from shrink-swell soils an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

Moderate to Highly Corrosive Soils

Soils along all of the alternatives, including the alignments, wyes, stations, and HMFs, generally have moderate-to-high corrosivity to uncoated steel and concrete in some locations. The potential for corrosion to uncoated steel and concrete represents a significant risk to the operation of the track system and the track right-of-way for long-term operations. Consequences of corrosion could include eventual loss in the structural capacity of the track connections or culvert drainage systems below the track or damage to switches or other moving parts of the track system.

The retained fill and at-grade segments would be most vulnerable to corrosive soils. The retained cut would generally have sufficient earth between the corrosive soil and the track to protect it from corrosion, and the elevated structures supported on deep foundations would use concrete that is resistant to concrete corrosion. As necessary, final designs would include epoxy-coated steel or double corrosion protection ground anchors to avoid long-term corrosion issues.

The project design reduces the risk from corrosive soils through soil improvement by removing the upper 5 feet of soils that exhibit high corrosivity characteristics and replacing the excavated soils with soils that do not exhibit these characteristics, or through the selection of appropriate material properties. Active and passive corrosion protection systems could also protect embedded and exposed steel structures from corrosion. Implementing project design features would render the intensity of the impacts from corrosive soils negligible under NEPA and less than significant under CEQA.

Slope Failure

Slopes along some rivers and streams could fail from either additional earth loads at the top of the slope, undercutting by stream erosion at the toe of the slope, or from additional seismic forces during a seismic event. These failures could endanger people and onsite and offsite structures if the HST track were damaged by the failure. Most slopes located along the HST alignments are less than 10 feet in height; therefore, the likelihood of slope failures is generally very low. However, slopes at Berenda Creek and the San Joaquin and Fresno rivers are 15 feet tall or greater, with the tallest at the San Joaquin River at 50 feet in height, resulting in a significant risk. Of the two rivers, the San Joaquin River has the higher risk, given the estimated 50-foot height of the slopes.

The consequence of slope failure would be either loss of bearing support to the track facilities or increased load on structures that are in the path of the slope failure. The former represents the higher risk because of the flat topography along the alternatives. Loss in bearing support would affect at-grade and retained-fill segments more than retained cuts and elevated structures supported on deep foundations. In the case of elevated structures, the location of the foundation would be sited during final design to avoid the area of slope failure.

The HST Project design addresses slope stability by incorporating standard IBC and other engineering standards and criteria. Detailed slope stability evaluations would be conducted and design measures such as structural solutions, e.g., tie backs/soil nails or retaining walls, or geotechnical solutions, e.g., ground improvement or regrading of slopes, would be implemented, as appropriate, to reduce the potential for future slumps and slope failures. These measures and solutions would render the intensity of impacts for slope failure at the Berenda Creek and the Fresno and San Joaquin rivers negligible under NEPA and less than significant under CEQA.

Common Seismic Impacts

Earthquakes could produce hazards to the HST system. These include high seismic ground motions and the risks from secondary seismic hazards associated with large seismic-induced ground motions.

Seismic-Induced Ground Shaking

A key consideration for the project alternatives, including the north-south alignments, wyes, stations, and HMFs, is seismic-induced ground shaking. The level of ground shaking is estimated to have a peak ground acceleration at the ground surface of up to 0.35g. This level of shaking would result in significant loads to structures supported on the soil, and could result in secondary seismic hazards such as liquefaction, liquefaction-induced slope failures, and post-seismic settlement as liquefaction-induced water pressures dissipate. The level of ground shaking could vary along the alignment depending on the amount of ground motion amplification or deamplification within specific soil layers; however, the likely level of seismic-induced ground motion is sufficient to represent a substantial impact regardless of the specific location.

The level of ground shaking represents a critical hazard to all design types. Elevated structures supported on deep foundations can be designed for moments and shear forces associated with the ground shaking, while the retaining walls for retained earth structures can be designed for the inertial response of the retained soil. Similar to the retained-fill design requirements, retained cuts can be designed for increased earth pressures from ground shaking.

Another key consideration is the response of the operating HST to a seismic event that shakes the track. Movement of the track would be transferred into the train. The train cars, spring system for the train cars, and the track design would be appropriately configured to resist the resulting inertial response of the train, while traveling at a high speed. Available information for other HST systems in seismically active areas such as Japan and Taiwan (see Section 3.11, Safety and Security) suggests that the design of California HST would be able to satisfy life-safety requirements for earthquake ground motions by implementing normal train and track systems.

Definitions

Moments and *shear forces* are engineering terms that refer to forces that develop in structures during seismic loading. During an earthquake, inertial forces often develop above the ground surface, when the mass of the structure accelerates from earthquake shaking. The combination of force and distance above the ground results in a moment about the ground, as would occur for an elevated track supported on a cast-in-drill-hole foundation. Shear develops from the horizontal application of this force to the column. Strict engineering standards must be met so that moments and shear forces are within design values.

The HST design would address seismic-induced ground shaking by specifying minimum seismic loading requirements for the train performance, by specifically evaluating the response of the track system, including elevated structures, and by confirming that soil provides sufficient support to the track. Detailed seismic response evaluations would be conducted, and design measures, such as enhanced structural detailing, more system redundancy, or special ground motion isolation systems would be implemented, as appropriate, to reduce the potential for failures from inertial forces resulting from the ground motions. Implementing project design features would render risks from seismically induced ground-shaking an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

Secondary Seismic Hazards

One of the primary consequences of strong ground shaking could be liquefaction of loose cohesionless soils located below the groundwater table. The potential for liquefaction and related hazards would be highest where groundwater is shallow. Such conditions exist between Atwater and the City of Merced, where groundwater tends to be less than 50 feet in depth, and next to rivers and streams. The consequences of liquefaction could be loss in soil bearing support, ground settlement, and instability or flow of slopes located in liquefiable soils.

The effect of these secondary seismic hazards could vary. Retained fills and at-grade structures could be more affected from loss of bearing support. Elevated structures located on deep foundations are capable of withstanding near-surface liquefaction, and retained-cut structures can be designed for increased loads from liquefied soil. Structures located on or in the path of moving ground associated with slope instability or flow can be designed for earth loads of the moving soil.

Site-specific geotechnical investigations during design are necessary at these locations to determine whether the type and density of the soil result in conditions that would be susceptible to liquefaction and are in need of stabilization. Detailed slope stability evaluations would also be conducted and design measures, such as ground improvement, use of retaining walls, or regrading of slopes, would be implemented, as appropriate, to reduce the potential for future slumps and slope failures. These design measures would render the risk of secondary seismic events an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

A seismically induced dam failure on one or more of the dams would be an unlikely event because the seismic event would need to be large enough to cause catastrophic damage to the dam structure, and the retained water would need to be at maximum operating elevation to cause inundation of the areas shown in Figure 3-6 of the *Merced to Fresno Section Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012a). Because dam failure is an unlikely event, the risk of dam failure is an impact with negligible intensity under NEPA and a less than significant impact under CEQA.

Alignment Alternatives

Impacts during project operation would be similar for the UPRR/SR 99, the BNSF, and the Hybrid alternatives because of similar geologic, soils, and seismic characteristics. As the distance from the mountains to the west increases, soils tend to be finer. This trend in finer grained soils to the west could also mean that the amount of unstable or settlement-prone soils increase slightly for the western alignments relative to the eastern alignments. Overall, soils are competent along all HST alignments except in isolated locations near rivers and streams. The location of softer soil and shallow groundwater would affect retained fill more than at-grade segments for soft soil conditions and retained cuts for high groundwater elevations.

Other potential impacts such as shrink-swell characteristics, soil corrosion, seismic ground motions, liquefaction potential, and other effects of earthquake loading are similar among all alternatives during the project duration. Operation of the project alternatives on soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, instability of cut-and-fill slopes required for the track, or collapse of retaining structures associated with retained cuts or retained fills, the intensity of effects of which are negligible under NEPA and less than significant under CEQA with standard engineering design measures.

HST Stations

The soils at the Merced station have a moderate shrink-swell potential, and the majority of the soils at the Fresno station have a low shrink-swell potential. Soil corrosivity is low to concrete and very high for steel at the Downtown Merced station site, and the majority of the soils at the Downtown Fresno station site have a low corrosivity to concrete and a moderate corrosivity to steel. There is one natural waterway crossing at the Downtown Merced station and no natural waterway crossings at the Fresno station. Therefore, the Merced station has a slightly higher potential for small slumps or slides and an increased presence of soft soils and shallow groundwater, which would, in turn, increase the potential for soil settlement. These effects would have negligible intensity under NEPA and would be less than significant under CEQA with standard engineering design measures.

Heavy Maintenance Facility Alternatives

There are two natural waterway crossings at the Castle Commerce Center and Gordon-Shaw HMF sites. The other three HMF sites have no natural waterway crossings or only one waterway crossing. Therefore, the Castle Commerce Center and Gordon-Shaw HMF sites have the potential for small slumps or slides and an increased presence of soft soils and shallow groundwater, which in turn would increase the potential for soil settlement. These effects would have negligible intensity under NEPA and would be less than significant under CEQA with standard engineering design measures.

3.9.6 Project Design Features

No project-level mitigation measures would be required. Project design would incorporate existing design measures and BMPs based upon federal and state regulations and based on the Program EIR/EIS documents. Table 5-1 in the *Merced to Fresno Section Geology and Soils Technical Report* (Authority and FRA 2012a) provides a matrix that lists relevant standards and regulations for the impacts identified above in Section 3.9.5, Environmental Consequences. Site-specific explorations would be carried out as design work progresses so that the Authority can incorporate site-specific engineering solutions that adhere to standard engineering design practices and codes into the design to reduce risks associated with geology, soils, and seismicity. Versions of the standard engineering design guidelines and standards applicable at the time this document was prepared (2011) are described below; the versions of these guidelines and standards applicable at the time of final design and construction will be used.

- **2010 AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications (5th Edition) and the 2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design**: These documents provide guidance for characterization of soils, as well as methods to be used in the design of bridge foundations and structures, retained cuts and retained fills, at-grade segments, and buried structures. These design specifications would provide minimum specifications for evaluating the seismic response of the soil and structures. (AASHTO 2009, 2010)
- **Federal Highway Administration (FHWA) Circulars and Reference Manuals:** These documents provide detailed guidance on the characterization of geotechnical conditions at sites, methods for performing foundation design, and recommendations on foundation construction. These guidance documents include methods for designing retaining walls used for retained cuts and retained fills, foundations for elevated structures, and at-grade segments. Some of the documents include guidance on methods of mitigating geologic hazards that are encountered during design.
- **AREMA Manual:** These guidelines deal with rail systems. Although they cover many of the same general topics as AASHTO, they are more focused on best practices for rail systems. The manual includes principles, data, specifications, plans, and economics pertaining to the engineering, design, and construction of railways. (AREMA 2009)
- **California Building Code (CBC):** CBC is based on 2009 IBC. This code contains general building design and construction requirements relating to fire and life safety, structural safety, and access compliance.
- **IBC and ASCE 7:** These codes and standards provide minimum design loads for buildings and other structures. They would be used for the design of the maintenance facilities and stations. Sections in IBC and ASCE-7 provide minimum requirements for geotechnical investigations, levels of earthquake

ground shaking, minimum standards for structural design, and inspection and testing requirements. (ICC 2006 and ASCE 2010)

- **Caltrans Design Standards:** Caltrans has specific minimum design and construction standards for all aspects of transportation system design, ranging from geotechnical explorations to construction practices. Caltrans design standards include state-specific amendments to the AASHTO LRFD Bridge Design Specifications and Guide Specifications for LRFD Seismic Bridge Design. These amendments provide specific guidance for the design of deep foundations used to support elevated structures, for design of mechanically stabilized earth (MSE) walls used for retained fills, and for design of various types of cantilever (e.g., soldier pile, secant pile, and tangent pile) and tie-back walls used for retained cuts.

- **ASTM International:** ASTM has developed standards and guidelines for all types of material testing, from soil compaction testing to concrete strength testing. The ASTM standards also include minimum performance requirements for materials. Most of the guidelines and standards cited above use ASTM or a corresponding series of standards from AASHTO to assure that quality is achieved in the constructed project. (ASTM 2012)

To manage geologic, soils, and seismic hazards, projects implement specific design measures to reduce and avoid impacts during construction and operation. These practices include the following:

- **Limit Groundwater Withdrawal:** Control the amount of groundwater withdrawal, re-inject groundwater at specific locations, or use alternate foundations to offset the potential for settlement. This control is important for locations with retained cuts in areas of high groundwater and where existing buildings are located near the depressed track section.

- **Monitor Slopes:** Incorporate slope monitoring into final design where a potential for long-term instability exists from gravity or seismic loading. This practice is important near at-grade sections where slope failure could result in loss of track support or where slope failure could result in additional earth loading to foundations supporting elevated structures.

- **Suspend Operations Before and After Earthquake:** Use motion-sensing instruments to provide ground-motion data; implement a control system to shut down HST operations temporarily during or after an earthquake to reduce risks. Monitoring is appropriate for any location where high ground motions could damage the HST track system. Candidate locations would include elevated guideways, retained earth, retained cut, and at-grade segments.

- **Conduct Geotechnical Inspections:** Prior to and throughout construction, conduct geotechnical inspections to verify that no new, unanticipated conditions are encountered and to determine the locations of unstable soils in need of improvement.

- **Improve Unstable Soils:** For unstable soils the risk of ground failure can be minimized or avoided by various methods. If the soft or loose soils are shallow, they can be excavated and replaced with competent soils. Where unsuitable soils are deeper, ground improvement methods such as stone columns, cement deep soil mixing (CDSM), or jet grouting could be used. Alternately, if sufficient construction time is available, preloading in combination with prefabricated vertical drains (wicks) and staged construction can be used to gradually improve the strength of the soil without causing bearing capacity failures. Both over-excavation and ground improvement methods have been successfully used to improve similar soft or loose soils. The application of these methods is most likely at stream and river crossings, where soft soils could occur; however, localized deposits could occur at other locations along the alignment. The ground improvement or over-excavation methods may also be necessary at the start of approach fills for elevated track sections or retained earth segments of the alignment if the earth loads exceed the bearing capacity of the soil. Alternately, at these locations earth fills might be replaced by light-weight fill such as extruded polystyrene (geofoam), or short columns and cast-in-drill hole (CIDH) piles might be used to support the transition from the elevated track to the at-grade alignment.

- **Improve Settlement-Prone Soils:** Settlement-prone soils are improved prior to facility construction. Ground improvement is used to transfer new earth loads to deeper, more competent soils. Another alternative is to use preloads and surcharges with wick drains to accelerate settlement within areas that are predicted to undergo excessive settlement. By using the preload and surcharge with wick drains, settlement would be forced to occur. The application of these methods is most likely at stream and river crossings, where soft soils are more likely to occur. Where groundwater is potentially within 50 feet of the ground surface, any below-ground excavations use well points in combination with sheetpile walls to limit the amount of settlement of adjacent properties from temporary water drawdown. Alternately, water can be re-injected to make up for localized water withdrawal.

- **Prevent Water and Wind Erosion:** Many engineering methods exist for controlling water and wind erosion of soils. These include use of straw bales and mulches, revegetation, and covering areas with geotextiles. Where the rate of water runoff could be high, rip rap and rip rap check dams could be used to slow down the rate of water runoffs. Other BMPs for water are discussed in Section 3.8 Hydrology and Water Resources. Implementation of these methods is important where large sections of earth would be exposed during construction, such as for retained-cut segments.

- **Modify or Remove and Replace Soils with Shrink-Swell Potential and Corrosion Characteristics:** One option is to excavate and replace soils that represent the highest risk. In locations where shrink-swell potential is marginally unacceptable, soil additives would be mixed with existing soil to reduce the shrink-swell potential. The decision whether to remove or treat the soil is made on the basis of specific shrink-swell potential or corrosivity characteristics of the soil, the additional costs for treatment versus excavation and replacement, as well as the long-term performance characteristics of the treated soil. This practice is important for at-grade segments of the alignment because these are most likely to be affected by shrink-swell potential or corrosive soils.

- **Evaluate and Design for Large Seismic Ground Shaking:** Conduct detailed seismic studies to establish the most up-to-date estimation of levels of ground motion. Use updated Caltrans seismic design criteria in the design of any structures supported in or on the ground. These design procedures and features reduce the potential that moments, shear forces, and displacements that result from inertial response of the structure lead to collapse of the structure. In critical locations, pendulum base isolators can reduce the levels of inertial forces. New composite materials can enhance seismic performance.

- **Secondary Seismic Hazards:** As discussed above, various ground improvement methods can be implemented to reduce the potential for liquefaction, liquefaction-induced lateral spreading or flow of slopes, or post-earthquake settlement. Ground improvement around CIDH piles improves the lateral capacity of the CIDH during seismic loading. CDSM or jet grouting develop resistance to lateral flow or spreading of liquefied soils.

3.9.7 NEPA Impacts Summary

This section summarizes impacts identified in Section 3.9.5, Environmental Consequences, and evaluates whether they are significant according to NEPA. Under NEPA, project effects are evaluated based on the criteria of context and intensity. Results of this environmental assessment identified NEPA impacts for both the No Project Alternative and the HST Project alternatives.

- The No Project Alternative represents changes in local conditions from infrastructure and development projects that result in greater water or wind erosion, loss of valuable topsoil, or constraints on the potential for oil and gas resource development that would result without the project. Because local regulations are established to manage water runoff and other geologic issues, new development projects would have an impact with negligible intensity under NEPA and, at a regional scale, the impacts would not be significant under NEPA.

NEPA impacts that could develop as a result of the HST alternatives include the following:

- Construction and long-term operation of the project alternatives, stations, and HMF on soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, instability of cut-and-fill slopes required for the track, or collapse of retaining structures associated with retained cuts or retained fills, the effects of which are negligible with standard engineering design measures.

- Settlement of soft or loose soil supporting structures and trackway could result in damage during construction and operation. The risk of this hazard along the alignments for elevated structures, retained cuts, retained fills, and at grade structures, as well as at the HMFs, would be negligible with design measures, for example, excavating underlying settlement-prone (loose or soft) soils and augmenting with new earth.

- Wind or water erosion of soil during both construction and operation are considered negligible with implementation of standard design measures and BMPs.

- The potential impacts of shrink-swell and corrosion on uncoated steel and concrete and the operation of the track system and the track right-of-way for long-term operations would be negligible by implementing standard design measures, for example, excavating underlying corrosive soils and augmenting with an imported soil base.

- The potential impacts of slope failure at stream crossings would be negligible with implementation of standard geotechnical engineering design.

- Effects from seismically induced ground motion are expected to be negligible with implementation of standard design measures.

Within the context of risk of injury to construction workers or HST passengers, the intensity of the geology, soils, and seismicity impacts would be negligible due to extensive avoidance standards, building codes, and regulations. Impacts would not be significant under NEPA.

3.9.8 CEQA Significance Conclusions

With implementation of standard engineering design measures and BMPs, impacts for elevated structures, retained cuts, retained fills, and at-grade segments of each alternative would be less than significant. Therefore, mitigation measures are not required.