CALIFORNIA HIGH-SPEED TRAIN

Program Environmental Impact Report/Environmental Impact Statement

Bay Area to Merced

GEOLOGY & SOILS TECHNICAL EVALUATION

January 2004

Prepared for:

California High-Speed Rail Authority

U.S. Department of Transportation
Federal Railroad Administration

CALIFORNIA HIGH SPEED RAIL AUTHORITY

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CALIFORNIA HIGH-SPEED TRAIN PROGRAM EIR/EIS

Bay Area to Merced Geology and Soils Technical Evaluation

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ACRONYMS

AUTHORITY	CALIFORNIA HIGH-SPEED RAIL
CEQA	CALIFORNIA ENVIRONMENTAL QUALITY ACT
CGS	CALIFORNIA GEOLOGICAL SURVEY
COG	COUNCIL OF GOVERNMENTS
EIR	ENVIRONMENTAL IMPACT REPORT
EIS	ENVIRONMENTAL IMPACT STATEMENT
EPA	ENVIRONMENTAL PROTECTION AGENCY
FAA	FEDERAL AVIATION ADMINISTRATION
FHWA	FEDERAL HIGHWAY ADMINISTRATION
FRA	FEDERAL RAILROAD ADMINISTRATION
FTA	FEDERAL TRANSIT ADMINISTRATION
HST	HIGH SPEED TRAIN
MTA	METROPOLITAN TRANSPORTATION AUTHORITY
RTP	REGIONAL TRANSPORTATION PLAN
USGS	U.S. Geological Survey

1.0 INTRODUCTION

The California High-Speed Rail Authority (Authority) was created by the Legislature in 1996 to develop a plan for the construction, operation, and financing of a statewide, intercity high-speed passenger train system.[1] After completing a number of initial studies over the past six years to assess the feasibility of a high-speed train system in California and to evaluate the potential ridership for a variety of alternative corridors and station areas, the Authority recommended the evaluation of a proposed high-speed train system as the logical next step in the development of California's transportation infrastructure. The Authority does not have responsibility for other intercity transportation systems or facilities, such as expanded highways, or improvements to airports or passenger rail or transit used for intercity trips.

The Authority adopted a *Final Business Plan* in June 2000, which reviewed the economic feasibility of a 1,127-kilometer-long (700-mile-long) high-speed train system. This system would be capable of speeds in excess of 321.8 kilometers per hour (200 miles per hour [mph]) on a dedicated, fully grade-separated track with state-of-the-art safety, signaling, and automated train control systems. The system described would connect and serve the major metropolitan areas of California, extending from Sacramento and the San Francisco Bay Area, through the Central Valley, to Los Angeles and San Diego. The high-speed train system is projected to carry a minimum of 42 million passengers annually (32 million intercity trips and 10 million commuter trips) by the year 2020.

Following the adoption of the Business Plan, the appropriate next step for the Authority to take in the pursuit of a high-speed train system is to satisfy the environmental review process required by federal and state laws which will in turn enable public agencies to select and approve a high speed rail system, define mitigation strategies, obtain necessary approvals, and obtain financial assistance necessary to implement a high speed rail system. For example, the Federal Railroad Administration (FRA) may be requested by the Authority to issue a *Rule of Particular Applicability*, which establishes safety standards for the high-speed train system for speeds over 200 mph, and for the potential shared use of rail corridors.

The Authority is both the project sponsor and the lead agency for purposes of the California Environmental Quality Act (CEQA) requirements. The Authority has determined that a Program Environmental Impact Report (EIR) is the appropriate CEQA document for the project at this conceptual stage of planning and decision-making, which would include selecting a preferred corridor and station locations for future right-of-way preservation and identifying potential phasing options. No permits are being sought for this phase of environmental review. Later stages of project development would include project-specific detailed environmental documents to assess the impacts of the alternative alignments and stations in those segments of the system that are ready for implementation.

The decisions of federal agencies, particularly the Federal Railroad Administration (FRA) related to high-speed train systems, would constitute major federal actions regarding environmental review under the National Environmental Policy Act (NEPA). NEPA requires federal agencies to prepare an Environmental Impact Statement (EIS) if the proposed action has the potential to cause significant environmental impacts. The proposed action in California warrants the preparation of a Tier 1 Program-level EIS under NEPA, due to the nature and scope of the comprehensive high-speed train system proposed by the Authority, the need to narrow the range of alternatives, and the need to protect/preserve right-of-way in the future. FRA is the federal lead agency for the preparation of the Program EIS, and the Federal Highway Administration (FHWA), the U.S. Environmental Protection Agency (EPA), the U.S. Corps of Engineers (USACE), the Federal Aviation Administration (FAA), the U.S. Fish and Wildlife Service (USFWS), and the Federal Transit Administration (FTA) are cooperating federal agencies for the EIS.

A combined Program EIR/EIS is to be prepared under the supervision and direction of the FRA and the Authority in conjunction with the federal cooperating agencies. It is intended that other federal, state,

[1] Chapter 796 of the Statutes of 1996; SB 1420, Kopp and Costa.

regional, and local agencies will use the Program EIR/EIS in reviewing the proposed program and developing feasible and practicable programmatic mitigation strategies and analysis expectations for the Tier 2 detailed environmental review process which would be expected to follow any approval of a high speed train system.

The statewide high-speed train system has been divided into five regions for study: Bay Area-Merced, Sacramento-Bakersfield, Bakersfield-Los Angeles, Los Angeles-San Diego via the Inland Empire, and Los Angeles-Orange County-San Diego. This Cultural Resources Technical Evaluation for the Bay Area – Merced Region is one of five such reports being prepared for each of the regions on the topic, and it is one of fifteen technical reports for this region. This report will be summarized in the Program EIR/EIS and it will be part of the administrative record supporting the environmental review of alternatives.

1.1 Alternatives (No-Project, Modal, HST)

1.1.1 No-Project Alternative

The No-Project Alternative serves as the baseline for the comparison of Modal and High-Speed Train alternatives (Figure 1). The No-Project Alternative represents the state's transportation system (highway, air, and conventional rail) as it existed in 1999-2000 and as it would be after implementation of programs or projects currently programmed for implementation and projects that are expected to be funded by 2020. The No-Project Alternative addresses the geographic area serving the same intercity travel market as the proposed high-speed train (generally from Sacramento and the San Francisco Bay Area, through the Central Valley, to Los Angeles and San Diego). The No-Project Alternative satisfies the statutory requirements under CEQA and NEPA for an alternative that does not include any new action or project beyond what is already committed.

The No-Project Alternative defines the existing and future statewide intercity transportation system based on programmed and funded (already in funded programs/financially constrained plans) improvements to the intercity transportation system through 2020, according to the following sources of information:

- State Transportation Improvement Program (STIP)
- Regional Transportation Plans (RTPs) for all modes of travel
- Airport plans
- Intercity passenger rail plans (California Rail Plan 2001-2010, Amtrak Five- and Twenty-year Plans)

As with all of the alternatives, the No-Project Alternative will be assessed against the purpose and need topics/objectives for congestion, safety, air pollution, reliability, and travel times.

Figure 1:
No-Project Alternative – California Transportation System

1.1.2 Modal Alternative

There are currently only three main options for intercity travel between the major urban areas of San Diego, Los Angeles, the Central Valley, San Jose, Oakland/San Francisco, and Sacramento: vehicles on the interstate highway system and state highways, commercial airlines serving airports between San Diego and Sacramento and the Bay Area, and conventional passenger trains (Amtrak) on freight and/or commuter rail tracks. The Modal/System Alternative consists of expansion of highways, airports, and intercity and commuter rail systems serving the markets identified for the High-Speed Train Alternative. Figure 2 shows the modal alternative for the Bay Area-to-Merced Corridor. The Modal Alternative uses the same inter-city travel demand (not capacity) assumed under the high-end sensitivity analysis completed for the high-speed train ridership in 2020. This same travel demand is assigned to the highways and airports and passenger rail described under the No-Project Alternative, and the additional improvements or expansion of facilities is assumed to meet the demand, regardless of funding potential and without high-speed train service as part of the system.

The additional improvements or expansion of facilities is assumed to meet the demand, regardless of funding potential and without high-speed train service as part of the system.

The Modal Alternative for the Bay Area-to-Merced region consists of two major sets of proposed improvements (see Figure 2):

- Improvements to Highways: Consisting of additional highway lanes to provide sufficient highway capacity and associated interchange reconfiguration, crossing bridge widening, ramp widening, cross street and intersection widening (Figure 1.1-2). Within the region, these improvements, therefore, would occur along proposed portions of Interstate (I) 5, I-880. I-580, I-80, and State Route (SR) 152. Table 1 lists the proposed highway improvements in the Bay Area-to-Merced region.
- Improvements to Airports: Primarily consisting of improvements to terminal gates and runways to provide sufficient landside and airside capacity and associated taxiways, ground access, parking, terminal and support facilities and airports that can serve the same geographic area and demand as the proposed High-Speed Train (HST) Alternative. Within the study area corridor, these proposed improvements would occur at San José International Airport and Oakland International Airport (Figure 1.1-3). Table 2 lists the airport improvements associated with the airports.

Table 1: Proposed Modal Alternative Highway Improvements
Bay Area to Merced

Highway Corridor	Segment (From – To)	No. of Additional Lanes[1] (Total – Both Directions)	No. of Existing Lanes (Total - Both Directions)	Type of Improvement
Segment 1: Merced to San José				
SR 152	SR 99 to I-5	2	1-2	widening
SR 152	I-5 to US 101	2	1-2	widening
US 101	SR 152 to Gilroy	2	2-3	widening
US 101	Gilroy to I-880	2	2-5	widening
Segment 2: San José to San Francisco				
US 101	I-880 to Redwood City	2	4-5	widening
US 101	Redwood City to SFO	2	4-5	widening
US 101	San Francisco International Airport (SFO) to San Francisco	2	4-6	widening
Segment 3: San José to Oakland				
I-880	US 101 to Fremont/Newark	2	3-4	widening
I-880	Fremont/Newark to I-238	2	3-4	widening
I-880	I-238 to I-80	2	2-4	widening
Segment 4: I-580 to I-5 (via I-238)				
I-580	I-880 to I-5 (via I-238)	2	4-6	widening
Segment 5: San Francisco to Sacramento				
I-80	San Francisco to I-880	2	5-6	widening
I-80	I-880 to I-5 (Sacramento)	2	4-6	widening

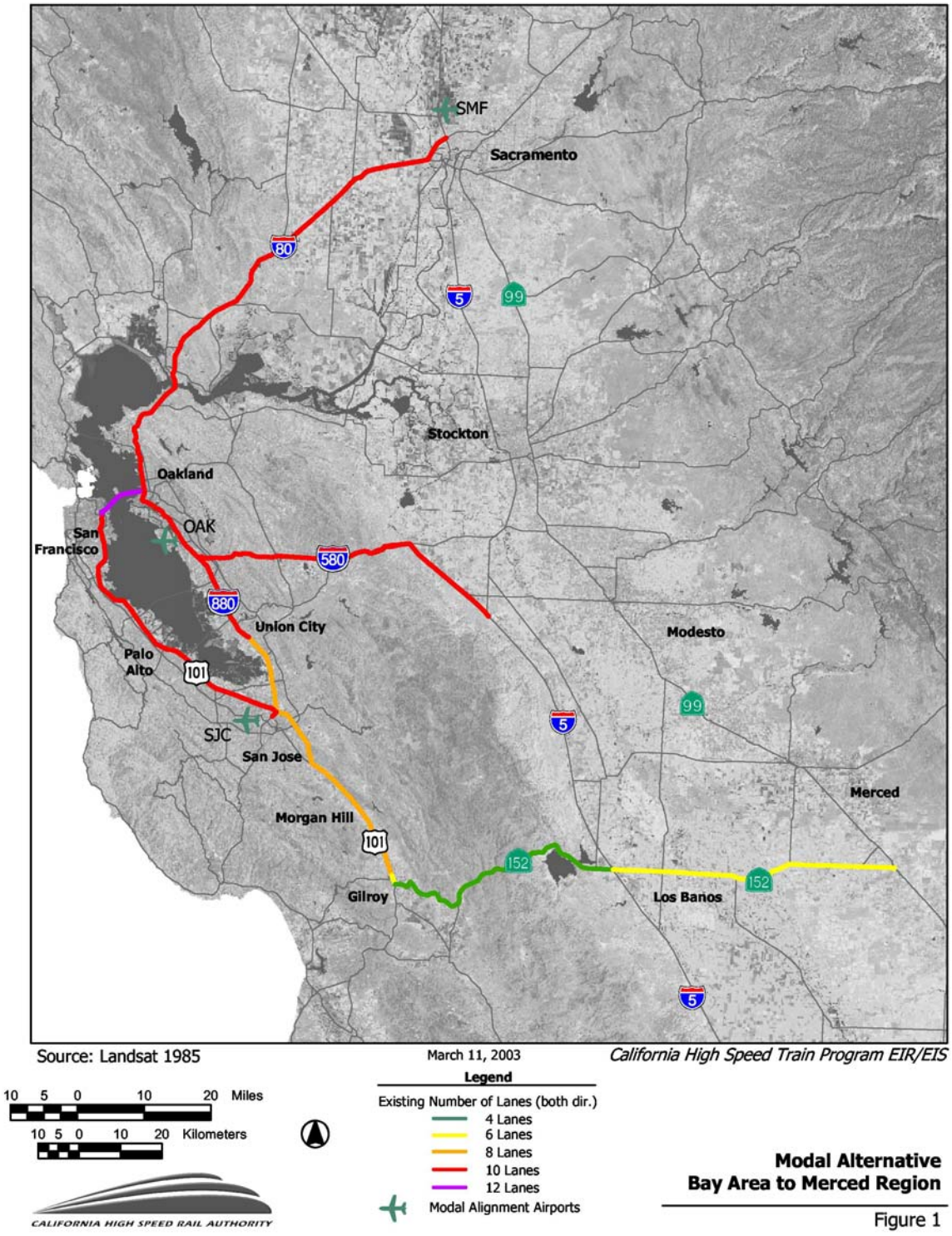
[1] Represents the number of through lanes in addition to the total number of existing lanes that approximate an equivalent level of capacity to serve the representative demand.

Table 2: Proposed Modal Alternative Airport Improvements – Year 2020
Bay Area to Merced

Airport Name	Additional Gates	Additional Runways
San José International Airport	14	one
Oakland International Airport	19	one

Source: Parsons Brinckerhoff, November 2002

Figure 2:
Modal Alternative – Bay Area-to-Merced Region



1.1.3 High Speed Train Alternative

The Authority has defined a statewide high speed train (HST) system capable of speeds in excess of 200 miles per hour (mph) (320 kilometers per hour [km/h]) on dedicated, fully grade-separated tracks, with state-of-the-art safety, signaling, and automated train control systems. State of the art high speed steel-wheel-on-steel-rail technology is being considered for the system that would serve the major metropolitan centers of California, extending from Sacramento and the San Francisco Bay Area, through the Central Valley, to Los Angeles and San Diego. Figure 3 shows the High Speed Train Alternative for the Bay Area-to-Merced Corridor.

The High-Speed Train Alternative includes several corridor and station options. A steel-wheel on steel-rail, electrified train, primarily on exclusive right-of-way with small portions of the route on shared track with other rail is planned. Conventional "non-electric" improvements are also being considered along the existing LOSSAN rail corridor from Los Angeles to San Diego. The train track would be either at-grade, in an open trench or tunnel, or on an elevated guideway, depending on terrain and physical constraints.

For purposes of comparative analysis, the HST corridors will be described from station-to-station within each region, except where a by-pass option is considered when the point of departure from the corridor will define the end of the corridor segment.

The Bay Area-to-Merced corridor can be broadly divided into three regional segments. Each segment has several alternative alignments for all or a portion of the length of the segment. Each segment may be further subdivided for analyzing and reporting potential impacts. The various segment options, along with station locations, are described below.

1.1.3.1 Segment 1 – Merced to San José

In this segment, all alignments would be on an exclusive guideway with separate tracks for high-speed trains and would connect to the Sacramento-to-Bakersfield high-speed train corridor. Two separate corridors are being studied:

Corridor 1A. This corridor would run between Merced and San José, via Pacheco Pass and Gilroy. Two options for the alignment are being considered:

- Gilroy Option: This alignment would extend from Merced through the San Joaquin Valley and Pacheco Pass, through Gilroy, and then north along the Caltrain/Union Pacific Railroad (UPRR) rail corridor. Within this option, two suboptions are under consideration – the alignment of each is a reflection of the design speed.

  Stations would include Los Baños (near I-5) in the San Joaquin Valley, Gilroy (near the existing Caltrain Station), and the existing San José (Diridon) Station.

- Gilroy Bypass Option: This alignment would extend from Merced through the San Joaquin Valley and Pacheco Pass and then north along the Caltrain/UPRR rail corridor.

  Stations would include Los Baños (near I-5) in the San Joaquin Valley, Morgan Hill (near the existing Caltrain Station), and the existing San José (Diridon) Station.

Figure 3a:
High Speed Rail Alternative – Bay Area-to-Merced Region

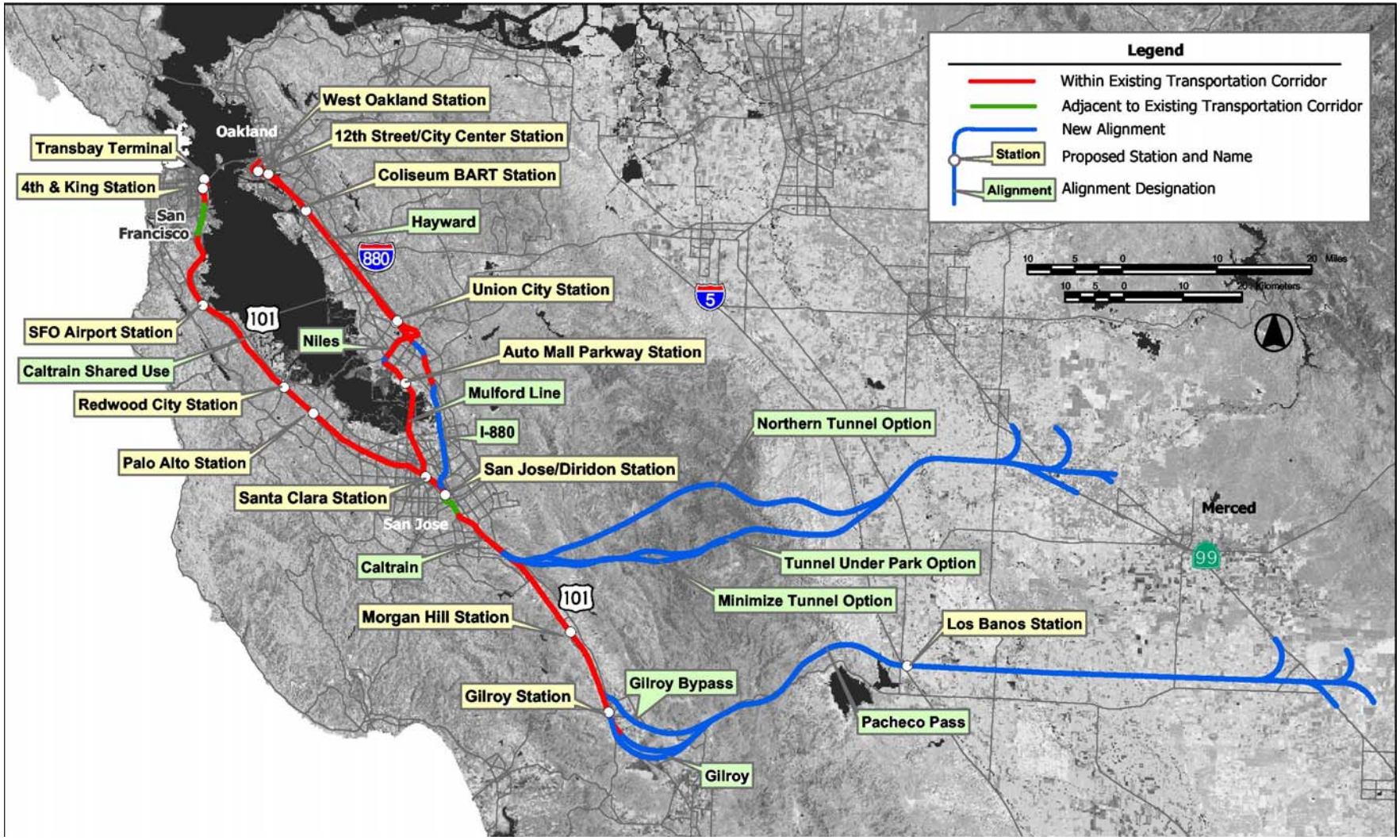
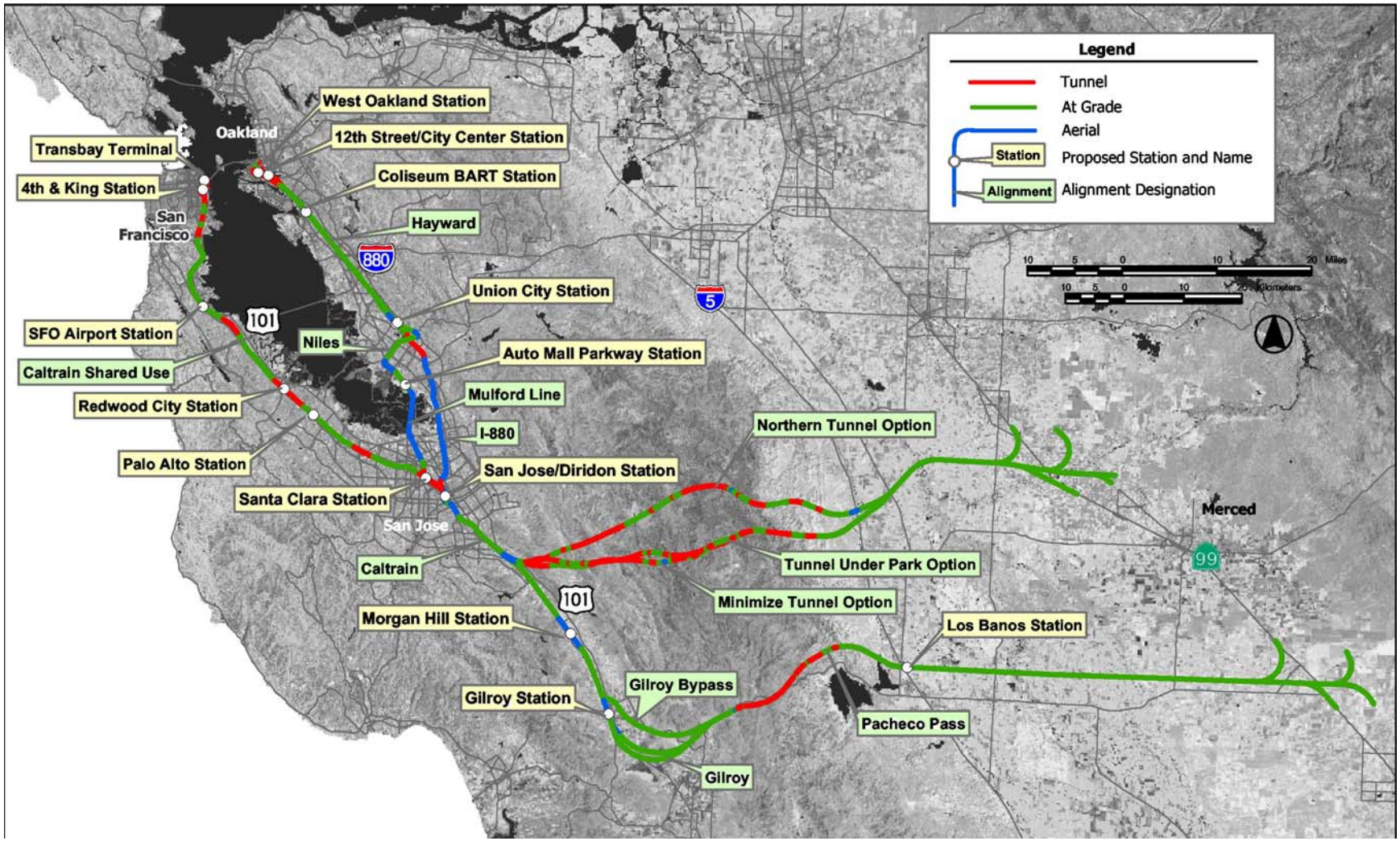


Figure 3b:
High Speed Rail Alternative – Bay Area-to-Merced



Corridor 1B. This corridor would run between Merced and San José, via Atwater and across the Diablo Mountain Range and would include one station – at the existing San José (Diridon) Caltrain Station. Three options for the alignment are being considered:

- Northern Tunnel Option: This alignment would emanate from the BNSF rail corridor or the UPRR corridor near the town of Atwater, north of Merced. The alignment would extend west across the San Joaquin Valley passing north of the town of Newman. The tracks would cross the Diablo Mountain Range in a series of tunnels, passing north of Henry Coe State Park. The alignment then would connect with the Caltrain/UPRR rail corridor north of SR 85.
- Tunnel Under Park Option: This alignment is similar to the Northern Tunnel Option except that the segment through the Diablo Mountain Range would cross Henry W. Coe State Park primarily in tunnel. The alignment then would connect with the Caltrain/UPRR rail corridor north of SR 85.
- Minimize Tunnel Option: This alignment is similar to the Tunnel Under Park Option except that the segment through the Diablo Mountain Range would cross Henry W. Coe State Park primarily at-grade. The alignment then would connect with the Caltrain/UPRR rail corridor north of SR 85.

1.1.3.2 Segment 2 –San José to San Francisco

There is one alignment being considered in this segment; it would provide for high-speed trains sharing tracks with Caltrain commuter trains. The entire alignment would be grade-separated, and all Caltrain stations would have four tracks or by-pass tracks.

Stations would include an optional station at Santa Clara; a station in either Palo Alto or Redwood City; a station in Millbrae near the San Francisco International Airport; and in San Francisco, a station at Fourth and King streets and at the lower level of the proposed new Transbay Terminal.

1.1.3.3 Segment 3 –San José to Oakland

There are two options under consideration for the alignment in this segment.

- I-880 Option: From San José, this alignment would follow north along I-880 and then transition to UPRR's Hayward rail line.

  Stations would include the planned Warm Springs Bay Area Rapid Transit (BART) Station in Fremont or the Union City BART Station; the Oakland Airport/Coliseum BART Station; and either the West Oakland Station or the 12th Street/City Center Station in Oakland.

- Mulford Line Option: From San José, this alignment would travel north along UPRR's Mulford rail line to the UPRR's Niles Line and then onto UPRR's Hayward line.

  Stations would include the Auto Mall Parkway Station or the Union City BART Station; the Oakland Airport/Coliseum BART Station; and in Oakland, either the West Oakland Station or the 12th Street/City Center Station.

1.2 GEOLOGY AND SOILS METHODOLOGY

The geology and soils impact and resource analysis for this program-level EIR/EIS is focused on a broad comparison of the potential impacts of seismic hazards, active fault crossings, slope stability, and location of oil and gas fields. The influence of these conditions and the influence of difficult excavation on construction and the impact of the alternative projects on mineral resources are also evaluated. The potential impact of these conditions along the proposed High Speed Train and Modal Alternatives are compared to the No-Project Alternative. Detailed soils evaluation has been deferred to subsequent analysis.

Both the soils and the geology of the Bay Area-Merced region are highly variable, with alignments crossing broad alluvial valleys as well as rugged mountains. The geologic units and soils are discussed in Section 2.2. The methodology used to determine table values is discussed in Section 3. A comparison table of all the alignment alternatives is provided in this section, with a more detailed table in Section 4. Some of the proposed HST alignments follow or parallel existing roads or railways (with less impact) while other alignment segments traverse roadless areas through the Diablo Range (with presumably more impact); impacts and mitigations are discussed in Section 4.

The summary tables for the Bay Area-Merced region identify resources and hazards within the specified zone of interest for each of the corridor segments and around station sites for the high-speed train alternative, and along highway corridors and around airports for the Modal Alternative. Reference to the particular issues that will need additional study is made in the tables and discussed in Section 5.

Most of the table column headings of the Summary and Comparison Tables correspond or overlap with criteria from the California Environmental Quality Act (listed below):

CEQA criteria for significant geologic, soils, and seismic impacts include the following questions: “Would the project expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

- 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? Refer to Division of Mines and Geology Special Publication 42.
- Strong seismic ground shaking?
- Seismic-related ground failure, including liquefaction?
- 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, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code, creating substantial risks to life or property?
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of waste water?
- Result in the loss of availability of a known mineral resource that would be of value to the region?
- Result in the loss of availability of oil and gas resources or have impacts on underground construction due to the presence of oil and gas fields?

Each of these CEQA criteria is included in the baseline conditions and subsequent analysis of potential impacts.

In general, our methodology involved the acquisition and analysis of available statewide GIS (Geographic Information Systems) layers pertinent to these impacts. Criteria for definition of hazards were identified based upon generally accepted statewide practices and these hazards were then compared as impacts to each project alternative. A numerical ranking system was developed compare impacts between the alternatives. The summary tables for the region are then completed that identify geology, soils, and seismic hazards within the study area for each of the corridor segments and around station sites for the high-speed train alternative, and along highway corridors and around airports for the Modal Alternative.

Subsequent to the numerical ranking, a summary table was developed to present impacts in terms of "High, Medium, and Low" impacts, such that impacts could be evaluated in the project summary table. The numerical ranking system is described in Chapter 4.0

2.0 BASELINE/AFFECTED ENVIRONMENT

2.1 STUDY AREA

The Study Area for geology and soils is defined as 200 ft from corridors and around stations. Two hundred feet incorporates all cross-sections with the exception of deep cuts and fills. Comparisons of alternative alignments were generally made for this screening level document based on length of alignment or number of impact sites within the various geologic conditions. Due to the scale of this statewide project, the HST environmental impact analysis was performed by a project-wide Program Management Team (Parsons Brinkerhoff) who retained five segments, or Regional Analysis Teams.

This portion of the report addresses the Bay Area-Merced segment, as shown in Figure 4. The Bay Area to Merced portion of the proposed HST project spans the central part of the Central Valley from about 20 miles southeast of Merced, north to about 5 miles north of Merced and west to the San Francisco Peninsula. Four different HST alignment options cross the Diablo Range; all lie between California State Highway 152 in the south and California State Highway 130 in the north. The Bay Area portion of the HST alignment follows existing Right of Ways for Southern Pacific Railroad or Caltrain through alluvial plains and urban areas between Gilroy, San Jose, San Francisco, and Oakland. New transportation corridors will be developed through the Diablo Range and Central Valley portions.

2.2 GEOLOGY

For purposes of description, the proposed alignments can be considered in three parts: the flat-lying portion from Merced west across the Central Valley to about Interstate 5, the mountainous Diablo Range portion, and the mostly flat-lying Bay Area portion. The most challenging part of the proposed HST route is the Diablo Range portion where the rail alignments must traverse rugged terrain in difficult rock. Both sides of the mountain range are marked by active faults. Three modal segments and the No-Project alternative also cross the Diablo Range.

In the following sections we characterize the topography, geology, and soils along the identified alignment alternatives for the HST, and for the Modal and No-Project alternatives. Geology and soils are described for a swath about 500 feet to either side of the linear features and around proposed stations for the HST. For the No-Project and Modal alternatives, where structures exist, the descriptions cover a narrower swath, closer to 150 feet to either side of the highways and around airport runways.

2.2.1 Topography

Topography along the HST alignments is shown on Figure 5. The eastern ends of the alignments cross the broad, alluvial basin occupied by the Central Valley. The termini at San Francisco and Oakland are located in the alluviated valley occupied by the San Francisco Bay; the rugged hills of the Diablo Range lie between the two valleys. Elevations in the Central Valley along the east-west portions of the HST alignments and along SR 152 range from 10 m below mean sea level (msl) at the San Joaquin River to 58 m above msl near the foot of the Diablo Range. The topographic high points along to the Diablo crossings reach elevations of about 850 m to 1000 m across the crest of the range. The alignments traverse these high points in tunnels, with tunnel inverts reaching elevations of 650 m beneath Henry Coe Park. The SR152 HST alignment closely parallels the modal SR152 through Pacheco Pass; maximum elevation for the HST is 385 m in a tunnel beneath ridges reaching as high as 550 m.

Figure 4: Geology – Bay Area-to-Merced Region

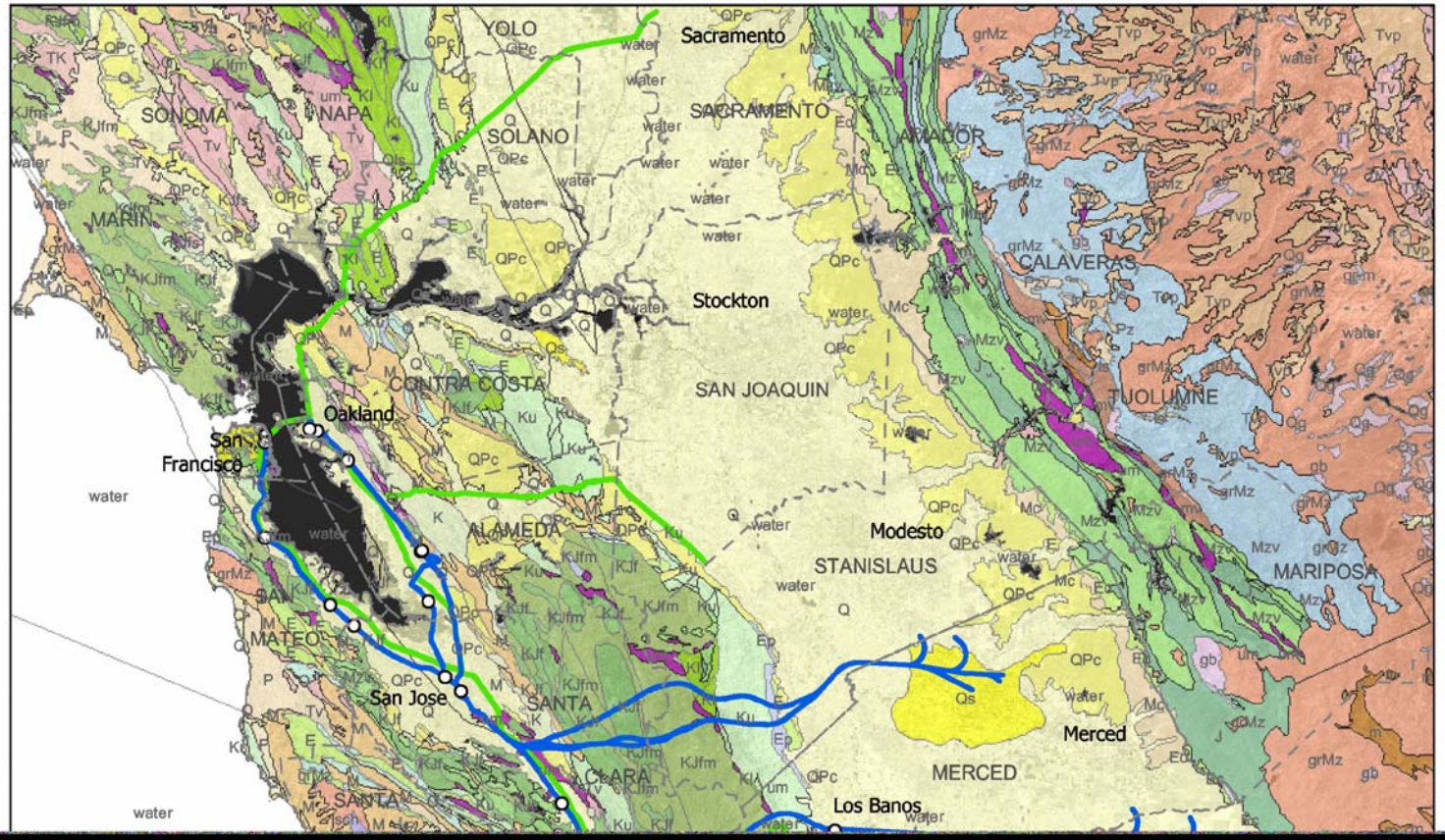


Figure 5: Topography – Bay Area-to-Merced Region

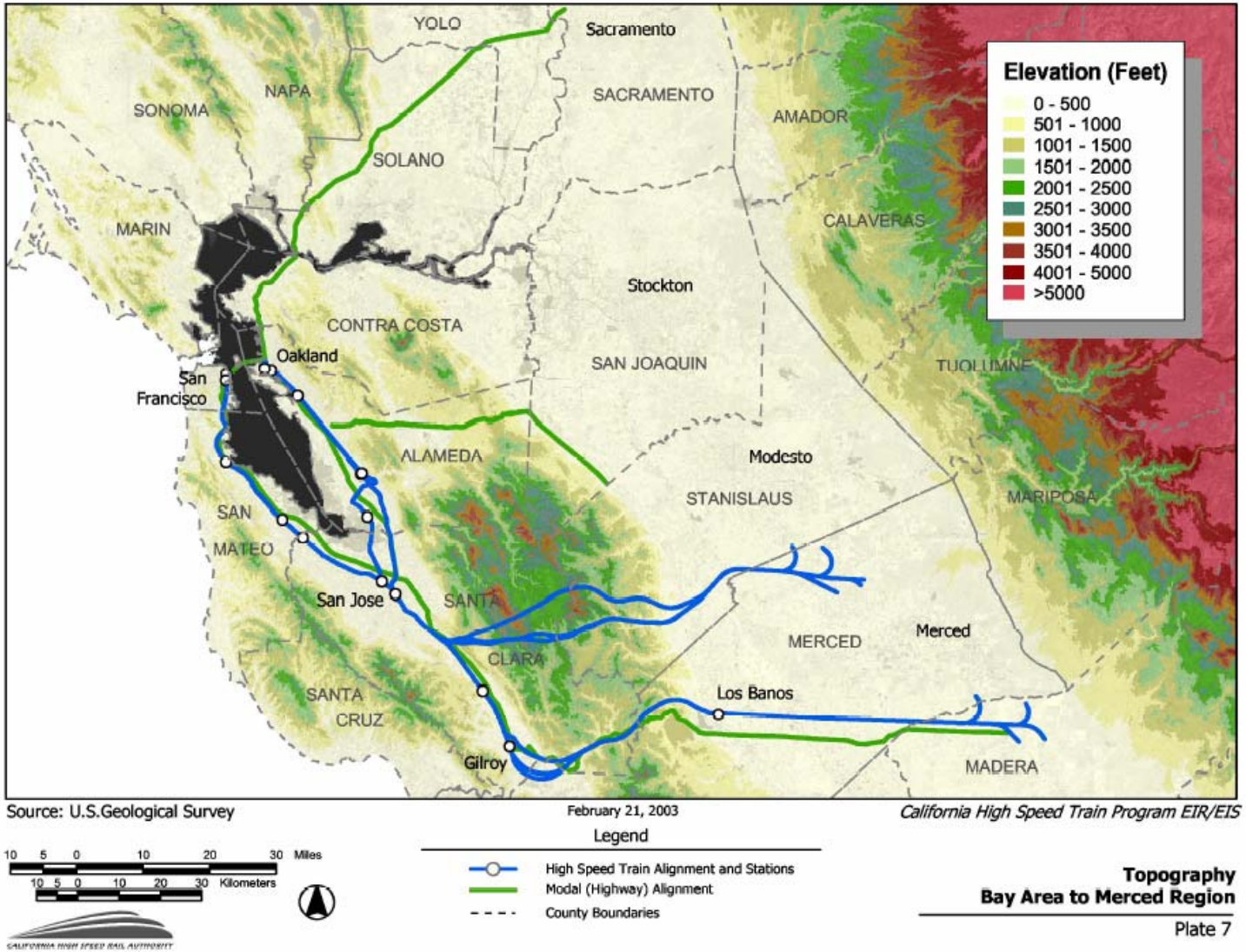


TABLE A.1 in Appendix A lists 3 to 5 elevations along sections of each of the proposed HST alignments. The elevations include the lowest, the highest, and intermediate elevations at stations. Elevations are derived from the alignment profiles provided and checked against local U.S. Geological Survey topographic maps.

2.2.2 Geologic Materials

Geologic units along the study area are shown on Figure 4 (Jennings, 1977, 1991). This section provides a general discussion of the geology and geologic structures traversed by alternatives and facilities. The section is broken into the four major segments and their alternatives (Central Valley and Diablo Range to San Jose, West Bay, and East Bay). This map and the regional geologic maps from the CDMG were used in hardcopy format for much of the project analysis involving geology (Wagner et al., 1981, 1982, 1991). Because of the distinctly different topography and surface within the study area, the description of units is broken into subsections corresponding to physiographic sub-regions.

2.2.2.1 Central Valley

While several subdivisions are shown on the regional geologic maps (Wagner et al., 1991; Wagner et al., 1981) all units occurring within the Central Valley are combined as Quaternary Alluvium (Q and Qs on Figure 4) (see Table 3 for a chart of Geological Ages). These units are fluvial, alluvial and terrace deposits consisting of water-laid sand, gravel, and cobbles derived from upslope parent rocks. All deposits become finer-grained with proximity to the northwest-flowing San Joaquin River, and coarser-grained closer to the hills on either side of the valley. Individual geologic units, called formations, in the Central Valley include the Modesto Formation, the Riverbank Formation, the Dos Palos Alluvium, the Los Banos Alluvium, the San Luis Ranch Alluvium, and the Patterson Alluvium.

Table 3: Geologic Ages

Era	Period	Epoch	Years Before Present
Cenozoic	Quaternary	Holocene	11,000
		Pleistocene	1.8 million
	Tertiary	Pliocene	5.3 million
		Miocene	23.8 million
		Oligocene	33.7 million
		Eocene	54.8 million
		Paleocene	65 million
Mesozoic	Cretaceous		144 million
	Jurassic		206 million
	Triassic		248 million
Paleozoic			540 million
Precambrian			At least 4.3 billion

The east third of the I-80 to I-880 modal alignment, and the east half of the SR 152 modal alignment both cross the Central Valley. The two HST alignments that extend west from the trunk line up the Central Valley also cross the Central Valley.

2.2.2.2 Diablo Range

The geology of the Diablo Range is generally that of a large anticline (an upwarped fold) with an exposed core of dense, partially to completely metamorphosed rock. The flanks of the anticline are composed of the sedimentary Great Valley Sequence (K, Kl, or Ku on Figure 4), younger Tertiary sedimentary units (M, E, or Ep on Figure 4), and Pleistocene layers (QPc on Figure 4). The younger units (Late to Early Tertiary) (see Table 3 for a chart of Geological Ages) are marine deposits interbedded with continental deposits of shale to sandstone to conglomerate; these units are exposed on the eastern flank of the hills of the Diablo Range. Slopes in Tertiary units can be unstable even at low angles as the degree of compaction and cementation is generally low. The Great Valley Sequence is a series of non-metamorphosed sedimentary units ranging in age from Cretaceous to Early Tertiary. They are marine deposits of shale to sandstone with occasional beds of conglomerate. The sand units are generally finer-grained and more cemented than those of the younger Tertiary units. Great Valley units are prone to land sliding where the dip angle of the rock is similar to the local slope; they are not generally difficult to excavate.

The Franciscan Complex is found in the central part of the Diablo Range as well as along the margins of San Francisco Bay (labeled KJf or KJfm on Figure 4). The Franciscan Complex comprises an ensemble of rock types associated with oceanic crust and deep-ocean sediments. These rocks were metamorphosed to varying degrees when they were partially subducted during Late Cretaceous time. Subduction and subsequent uplift have caused the Franciscan to become tectonically mixed, resulting in the juxtaposition of many rock types separated by sheared shale or serpentine rock. Rock types typical of the Franciscan include sandstone, shale, conglomerate, metamorphosed greywacke sandstone, chert, greenstone (marine basalt), diabase, gabbro, ultramafic rocks, and serpentinite (serpentine rock). Chert, greenstone, diabase, gabbro, and ultramafic rocks all can be very dense and hard making surface excavation difficult.

Serpentine often occurs as the main component of sheared rock (also known as mélange) in the Franciscan. Serpentinite can, in some occurrences, contain asbestos-type fibrous minerals. Excavation or grading in such rock may require special dust control procedures to prevent asbestos fibers from becoming airborne. Blueschist, blocks of extremely dense metamorphic rock, referred to as “knockers” because they occur as discrete blocks that protrude from eroded hillsides, are mapped in places along the alignment, especially along the SR-152 route west of Pacheco Pass. Blueschist knockers may be difficult to excavate both in cuts and tunnels. Numerous fracture and shear zones are known to occur within the Franciscan because of the tectonic history. The fracture zones and knockers have the potential for creating conditions of difficult excavation in tunnels.

Modal alternative SR 152 crosses the Diablo Range through Pacheco Pass. Modal alternative I-580 crosses the Diablo Range north of the HST crossings, and goes through the large Livermore Valley, a large structural valley set within the Diablo Range. Most of the Livermore Valley is underlain by alluvium. Modal alternative I-80 crosses the Coast Ranges north of the Diablo Range. The geologic units along this alternative are similar to those of the Diablo Range (Franciscan and Great Valley Sequence).

HST alternative SR-152 loosely parallels the SR-152 highway, thus the rock types are very similar. The two Diablo Direct HST alternatives and the SR 130 alternative cross a remote and mostly roadless portion of the Diablo Range. Large portions of these routes are planned as tunnels. All three of the HST alternatives pass through the metamorphic core of the range where a wide variety of Franciscan rock can be expected.

2.2.2.3 Santa Clara Valley

The bedrock of the Santa Clara Valley is Franciscan Complex; however, Quaternary alluvium covers the bedrock in most places, and a thin veneer of colluvium and/or alluvial terraces is mapped along the margins of the valley (Q and QPc on Figure 4). Franciscan bedrock is exposed at the surface in several

places along the proposed Morgan Hill-San Jose portion of the alignment (KJf and KJfm on Figure 4). Most of these exposures are mapped as serpentinite with some metagreywacke (metamorphosed greywacke sandstone).

Modal alternative Highway 101 and the western extent of SR 152 cross the Santa Clara Valley and are mostly constructed at grade or in cut and fill through low bedrock hills of Franciscan Complex. North of Morgan Hill highway cuts are through massive serpentinite.

HST alternative San Jose to Gilroy follows the existing right of way and closely parallels Highway 101. The same geologic units are present along the HST corridor as along the modal corridor.

2.2.2.4 San Francisco Bay margins

The margins of San Francisco Bay are mapped as Quaternary intertidal deposits, alluvium, and artificial fill (all labeled Q on Figure 4). Older alluvium, Quaternary continental and marine deposits, and Franciscan Complex are mapped further from the Bay margin and closer to the surrounding hills. Intertidal deposits are described as organic-rich mud that is inundated at high tide. In many places along the margins of San Francisco Bay, intertidal deposits are covered by artificial fill. Some of these fills are very old and were not engineered. Younger fills were engineered, but perhaps not to the level required by modern standards. Organic-rich deposits and fill compress over time, thus subsidence should be expected where alignments cross areas of artificial fill over intertidal deposits such as along the Niles-Mulford HST alternative, and along parts of Highway 101. Earthquake ground shaking can cause settlement in these deposits as well. Issues with subsidence and differential settlement in particular areas are discussed in Section 2.4.4.

Older alluvium is present beneath the modern alluvium and at higher elevations away from the bay margins (QPc on Figure 4). Older alluvium is unconsolidated water-laid clay, sand, gravel, and cobbles derived from upslope parent rocks; it is generally better drained than the younger alluvium. Hills along the margins of San Francisco Bay are Franciscan Complex (described above; labeled KJf on Figure 4) as are the hills in the City of San Francisco. In South San Francisco, a large, coherent block of greywacke dominates the Franciscan Complex (San Bruno Mountain). Typical Franciscan mélange containing serpentinite and chert are mapped in the City of San Francisco.

Modal alternative Highway 101 along the Peninsula is mostly at-grade over alluvium and fill. A few cuts and fills occur in and south of San Francisco within typical Franciscan rock: a mixture of large and small blocks of serpentinite, greywacke and greenstone. I-880 in the East Bay is mostly built on alluvium and fill over intertidal deposits.

HST alternatives for the Peninsula segment from San Jose to San Francisco follow the existing Caltrain corridor that is built over alluvium and fill. Several tunnels through alluvium and possibly into Franciscan bedrock are planned along the route south of San Francisco. Most of the alignment in the city of San Francisco will be in a tunnel through Franciscan rock, some of which will likely contain a mixture of large and small blocks of chert, greenstone, graywacke and massive serpentinite. The East Bay HST alternative will follow the existing train right of way mostly over alluvium and fill. The City Center station of the East Bay line will be underground beneath downtown Oakland, constructed within semi-consolidated sediments. Both in San Francisco and Oakland, underground construction must avoid existing transportation tunnels (e.g. BART and MUNI).

2.2.3 Groundwater

Groundwater is addressed here in a very preliminary and regional manner. No attempt was made to contour or discern groundwater levels throughout the project area. However, groundwater generally occurs in two distinct regions throughout the study area. Relatively uniform, unconfined aquifers and associated water tables are expected in the two valleys at either end of the alignments, including the Central Valley to the east and the San Francisco Bay/Santa Clara Valley to the west. Groundwater in

these basins is routinely pumped for domestic and agricultural purposes and subject to long-term changes in water levels due to overdraft and recharge conditions. A general statement that depth to groundwater is shallow can be made about recharge/discharge areas such as near the San Joaquin River and its tributaries in the Central Valley, near the margins of San Francisco Bay, and in the area of the Sacramento-San Joaquin River Delta. Occurrence of groundwater in the Diablo Range would likely be influenced by fracture patterns and rock type. Further information on groundwater and hydrology is contained in the Technical Evaluation report for Hydrology and Water Quality.

2.2.4 Oil and Gas Fields

Oil and gas maps produced by the CGS for the DOG (Division of Oil and Gas) and digitized into GIS layers for the entire state (DOG, 2001) are shown on Figure 6. Oil and gas fields exploit subsurface deposits of hydrocarbons trapped within upwarped or domed geologic structures, or at changes in rock type in the subsurface. Within the Bay Area to Merced region oil and gas fields are located in the Santa Clara, northern San Joaquin, and southern Sacramento valleys.

The major issue associated with oil, gas, and geothermal resources is the exclusion of future resource availability caused by the placement of facilities (railroad track, roadways, parking areas). In addition, subsurface oil and gas deposits could impact tunnel construction and lining design, as well as operational considerations. Potential impacts on oil, gas, or geothermal resource availability were evaluated based on a comparison of known resource location versus facility location. Potential resources were identified from published resource maps produced by the *California Department of Conservation - Division of Oil, Gas, and Geothermal Resources (CDC 2001a, CDC2001b)*.

2.2.5 Mineral Resources

Mineral resources have been mapped by the USGS for most of the Bay Area-Merced region. Mineral resources in the region include aggregate (sand and gravel, and crushed rock) along active or ancient water courses; specialty sand and diatomite along the eastern margin of the Diablo Range and the Coast Ranges; clay near ancient or recent lake deposits in South San Francisco and in places along the eastern margin of the Coast Ranges; metallic ores (magnesite, chromite, magnesium) have been mined in the Diablo Range.

2.2.6 Potentially Unstable Slopes/Land sliding

Slope instability (landslides and debris flows) can require stabilization planning, design, and construction costs and, if not adequately characterized and mitigated during construction, can cause severe damage to surface and near-surface improvements. Typically, site-specific studies are undertaken to address subsurface conditions and perform quantitative analysis of slope stability and design of mitigation measures where necessary. Since this evaluation precedes the availability of a design, a more general approach was taken. Each of the geologic formations mapped by Jennings (1977, 1991) and depicted on Figure 4 were assigned a formational rating for slope stability (low meaning relatively stable formational characteristics relative to potential for slope failure). The potentially unstable formations were then compared to the Digital Elevation Model (DEM) that has been queried for slope areas flatter than and steeper than 33% slope gradient. For purposes of this project, the criteria for mapping potentially unstable slopes was all areas in which slope gradients exceed 33% and are not underlain by rock units having high strength characteristics (i.e. low instability ratings). A 200-foot wide buffer zone around these potentially unstable areas was created to take into consideration other site improvements that may be influenced as well. The extent of potentially unstable slopes meeting these criteria within the project area is shown on Figure 7. Since a statewide map showing existing landslides was not available, it was not used in our analysis.

Figure 6: Oil and Gas Fields – Bay Area-to-Merced Region

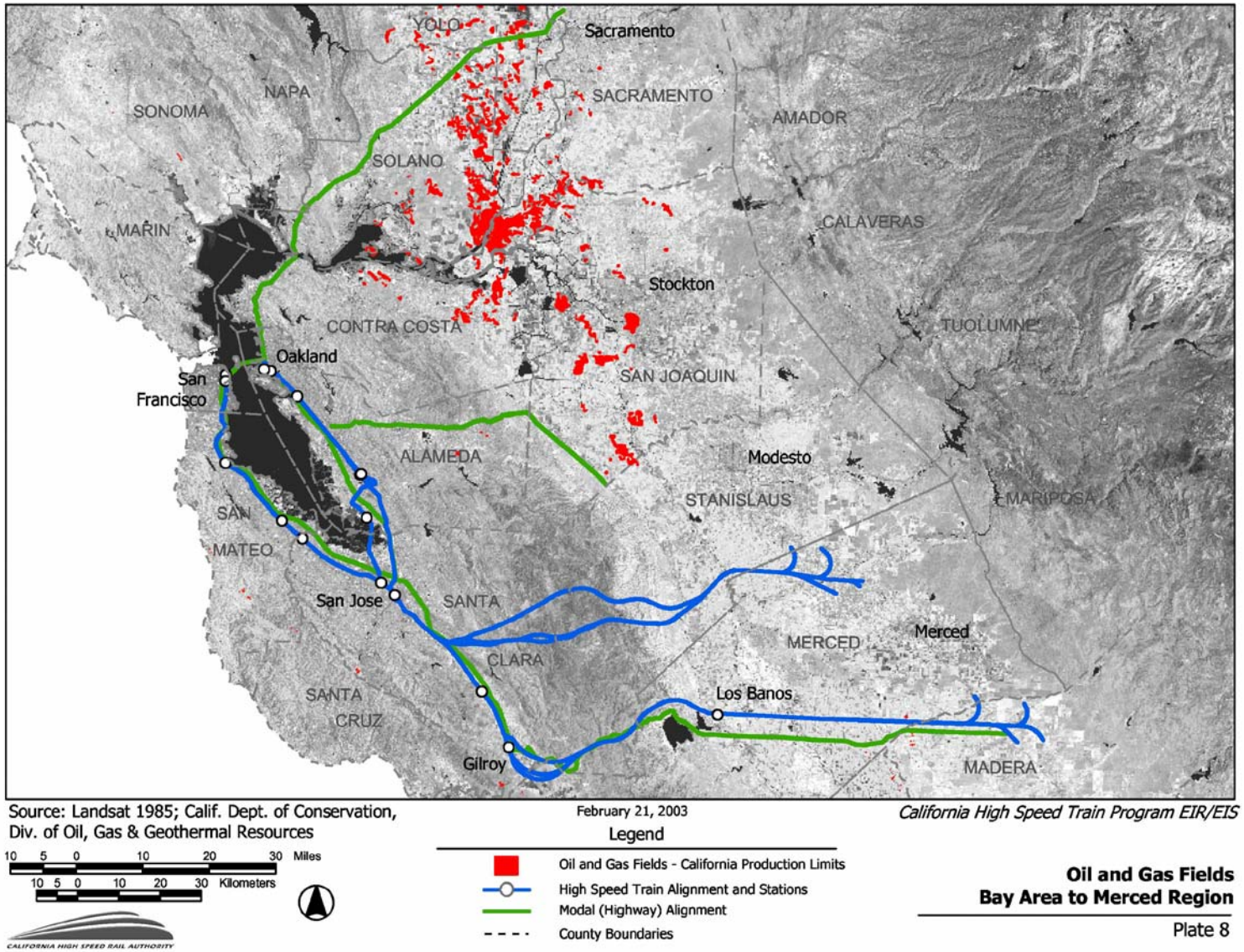
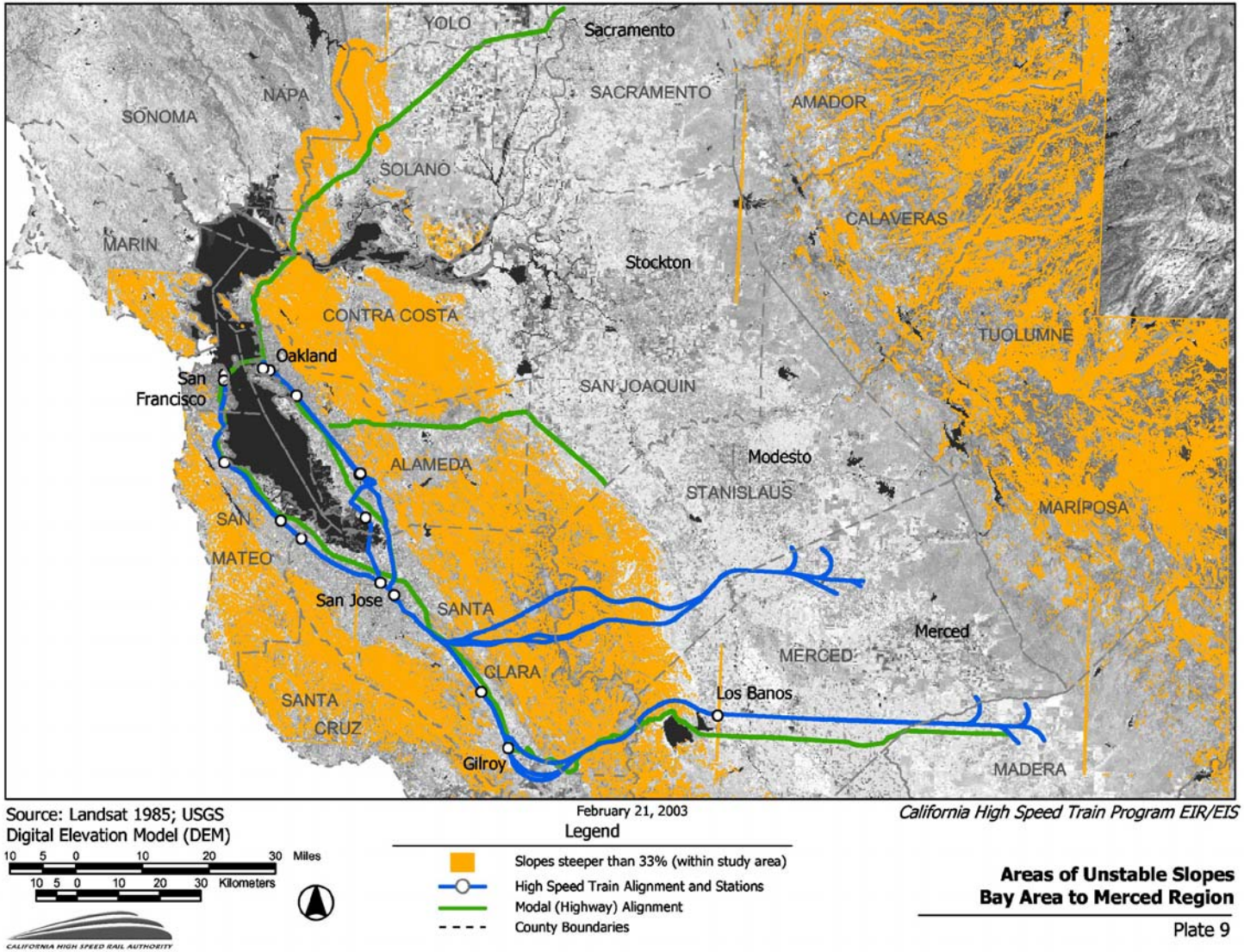


Figure 7: Areas of Unstable Soils – Bay Area-to-Merced Region



2.2.7 Difficult Excavation Areas

Difficult excavation areas have been addressed relative to surface excavation characteristics and tunneling methods. Surface excavation (i.e. earthwork methods) methods differ significantly from deeper tunneling methods such as a Tunnel Boring Machine (TBM). Whereas hard rock at the surface may be difficult to excavate for bulldozers and other heavy earthmoving equipment, tunneling methods typically prefer these conditions. Conversely, fractures and faults create additional porosity along which groundwater tends to concentrate, making excavation through fractured rock difficult using tunneling methods. However, fracture rock conditions are preferred for surface excavation methods. For this reason, we have used rock hardness characteristics for portions of the alignment in which aerial and at-grade track is proposed and fault zone information for areas where tunneling is proposed. Each of the geologic formations mapped by Jennings (1977, 1991) and depicted in Figure 4 was assigned a formational rating for hardness and thus excavatability using surface methods. A 500-meter zone around faults was identified as difficult to excavate using tunneling methods. It should be noted, however, that some hard rock formations may contain rock too hard to tunnel using TBM methods and may require mining and blasting. The distribution of the Franciscan Complex (KJf and KJfm on Figure 4) generally coincides with regions of difficult excavation.

2.3 SOILS

Soil units mapped by the USDA National Resource Conservation Service (NRCS) provide information only for near-surface subsurface conditions. Figure 8 shows the distribution of the mapped soil units in relationship to the proposed alignments and station alternatives. These maps were prepared by the USDA on the basis of shallow (maximum 6.5 feet deep) hand auger borings that were logged and sampled. Samples were analyzed for various soil properties including geotechnical, agricultural, and land-use performance characteristics. Tables of soil parameters were not included in the available GIS data and therefore were not used to generate subsequent discussions regarding potentials for corrosivity, erodibility, and expansive soils conditions. The distribution of these soil units is highly variable along the alignments.

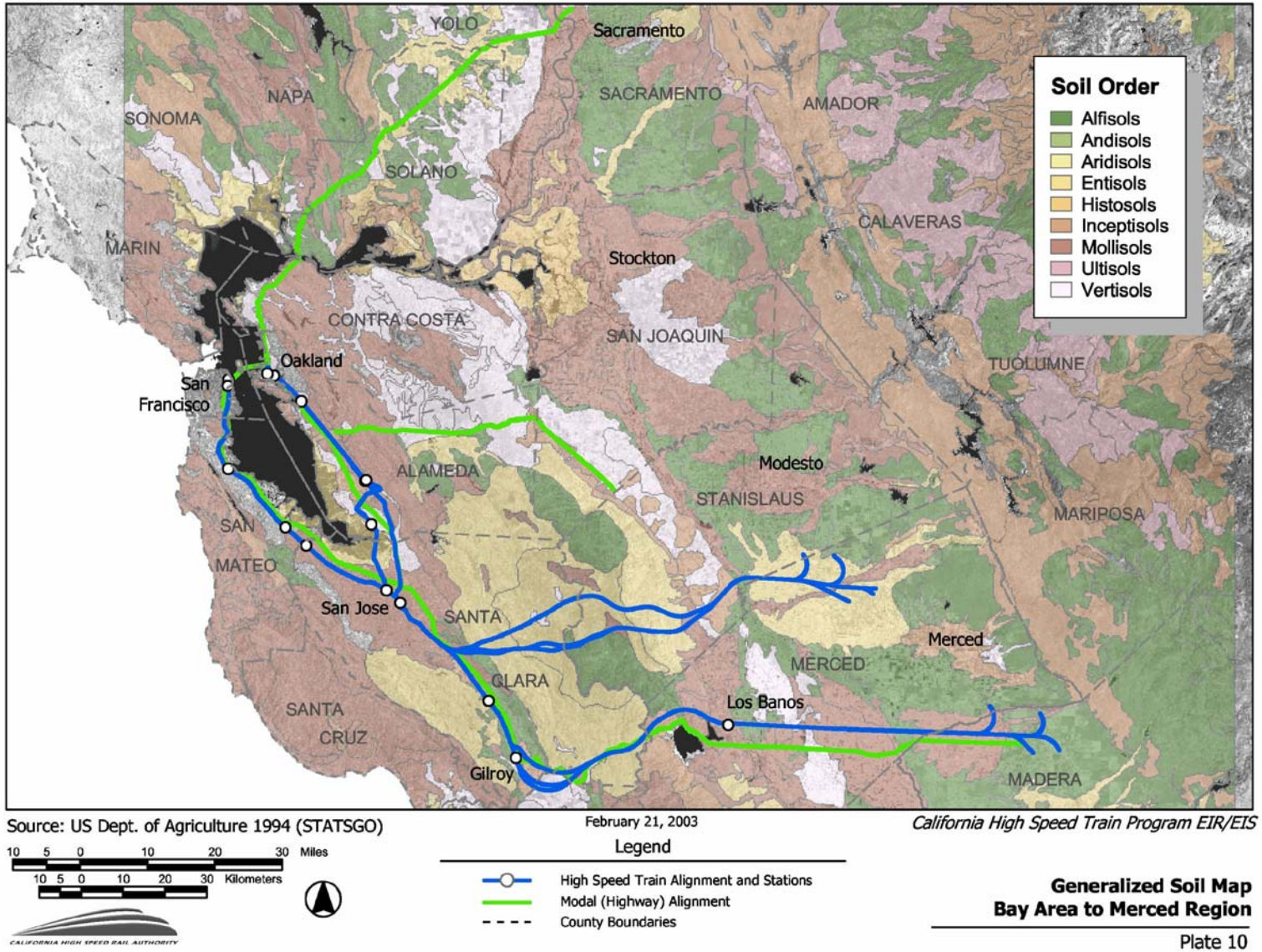
2.3.1 Corrosive Soils

Soils can contain low pH and/or high sulfate concentrations that can adversely influence proposed surface and subsurface improvements. Low pH soils can severely deteriorate buried metal pipelines and other metallic improvements. High sulfate content soils can deteriorate concrete and prevent complete curing of concrete reducing strength considerably. Corrosive soil units generally coincide with saline soils such as bay muds and evaporite deposits that may occur within the project area. Generalized extent of these areas can be mapped using pH and resistivity properties contained in soil parameter tables available at the county scale and used in conjunction with this soil unit GIS layer. This can be performed at a later stage in the project when a more refined project plan and design is available.

2.3.2 Erosion

Soils can contain very little fine-grained soil fraction and may be low in density rendering them more susceptible to erosion when exposed to high velocity flow of water or severe wind conditions. These soil units generally coincide with permeable and low-density soils such as young alluvium and other surficial deposits that occur within parts of the project area. Generalized extent of these areas can be mapped using USCS (Unified Soil Classification System) symbols describing the composition of soils and erodibility values contained in the soil parameter tables used in conjunction with this soil unit GIS layer. This can be performed at a later stage in the project when a more refined project plan and design is available.

Figure 8: Generalized Soil Map – Bay Area-to-Merced Region



2.3.3 Shrink-swell

Soils can contain high concentrations of clay that are susceptible to shrink and swell when wetted or allowed to dry. Severe shrinkage or swelling can damage adjacent and overlying foundations and other surface improvements. These soil units generally coincide either with broad floodplain sediments that tend to be more clayey due to their distance of transport and also occur as a result of weathering of the surface of other geologic units as soil profiles. These conditions may occur within the project area. Generalized extent of these areas can be mapped using USCS symbols and plasticity and liquid limit values contained in the soil parameter tables used in conjunction with this soil unit GIS layer. This can be performed at a later stage in the project when a more refined project plan and design is available.

2.4 SEISMIC HAZARDS

Three primary seismic hazards occur as a result of the presence of faults capable of generating earthquakes, including ground rupture potential, strong ground motion, and liquefaction and other related seismically-related ground deformation. Figure 9 shows the distribution of potentially damaging faults in the study region. Ground rupture occurs when a fault ruptures at depth and movement along the fault propagates to the ground surface. Ground motion occurs when faults rupture at depth where pressures are high and result in earthquakes. Liquefaction and other ground movements are the result of ground motions where localized subsurface conditions of geologic units are susceptible to collapse or flow. Each of these hazards is described more thoroughly below along with a description of their potential occurrence.

2.4.1 Regional Faulting and Historic Seismicity

Faulting is prevalent throughout California resulting in intense seismicity when compared to other parts of the country. Faulting within the study area has been evaluated on the basis of the most recent known age faulting. Three sources were compiled to evaluate faulting including the Fault Activity Map of California (Jennings, 1994), Alquist-Priolo (AP) Earthquake Fault Zones of California (CGS, 2002), and fault source information used by the California Department of Transportation (Mualchin, 1996). These sources were used to compile Figure 9, Quaternary Faults and Alquist-Priolo Earthquake Zoned Faults. It should be noted that faults mapped by Mualchin were useful in that GIS layers contain valuable fault names and parameters but are mapped irrespective of recency of movement. A-P mapping identifies those zones where the CGS considers faults to be present requiring further site-specific fault studies and recommendations for development. These zones generally include faults with known movement within the past 10,000 years (i.e. Holocene).

2.4.2 Ground Rupture Potential

The potential for ground rupture is typically estimated based upon the presence of faults with known displacement during recent geologic time. California generally categorizes fault as capable of future movement if there is evidence that the fault has moved within the past 10,000 years (i.e. Holocene) and defines this category of faults as “Active” (shown in red on Figure 9). Faults with movement within the past 1.6 million years (i.e. Quaternary) and no known Holocene displacement are considered moderately capable of rupture and are categorized as “Potentially Active” (shown in yellow on Figure 9). Faults older than 1.6 million years are treated with less concern and are called “Inactive”. Essential or critical facilities to human health and safety are required to recognize the potential for ground rupture on or immediately adjacent to both Active and Potentially Active Faults. For purposes of this project, Quaternary fault crossing zones are defined as areas where Quaternary faults transect any portion of the alignment including a 200-foot buffer allowing for other improvements associated with the project and still influenced by ground rupture potential. The potential for, magnitude of displacement, and direction of displacement are outlined (grouped in order of estimated activity) on Table 4.

Figure 9: Quaternary Faults and Alquist-Priolo Zoned Faults – Bay Area-to-Merced Region

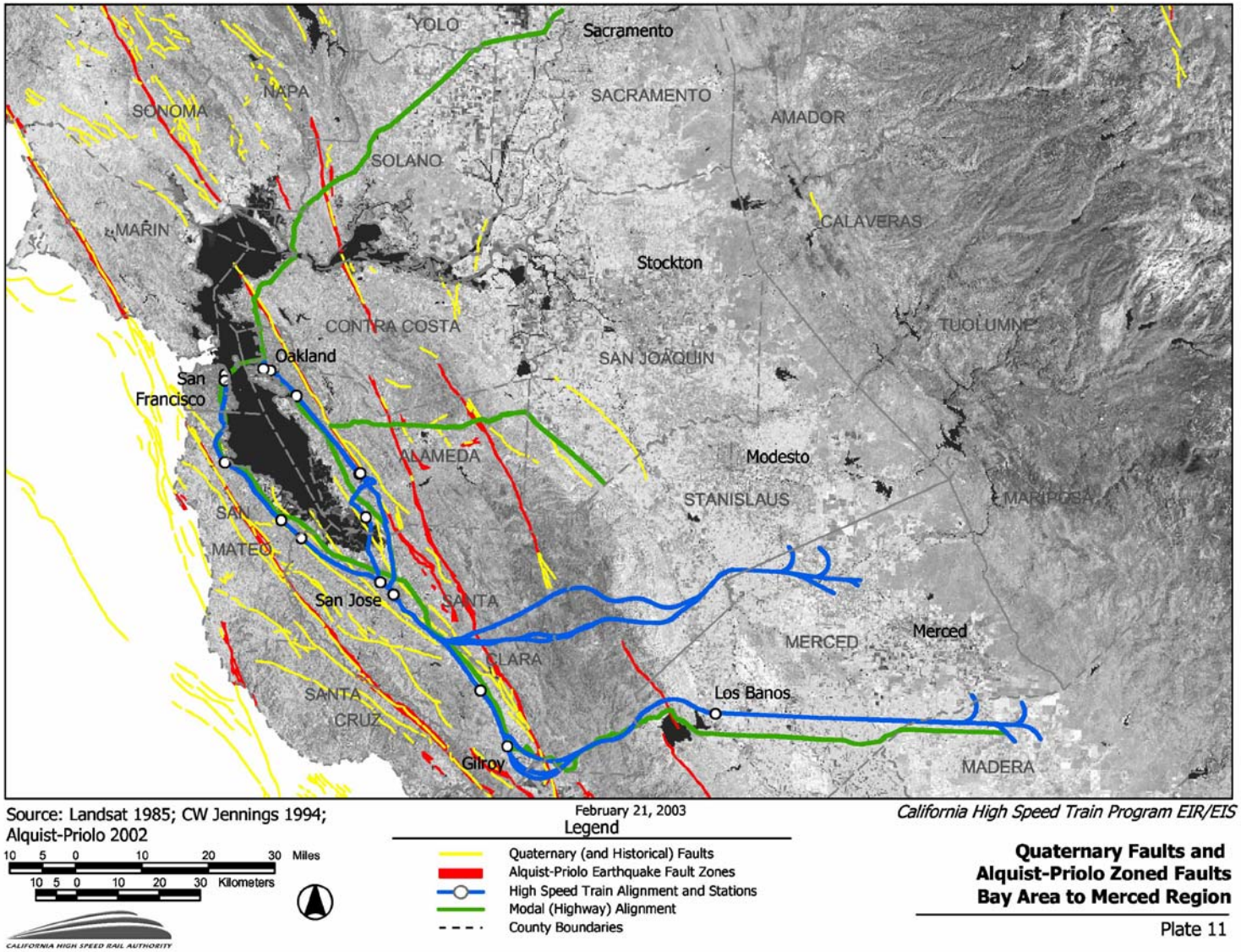


Table 4: Active Faults in the Bay Area-Merced Region

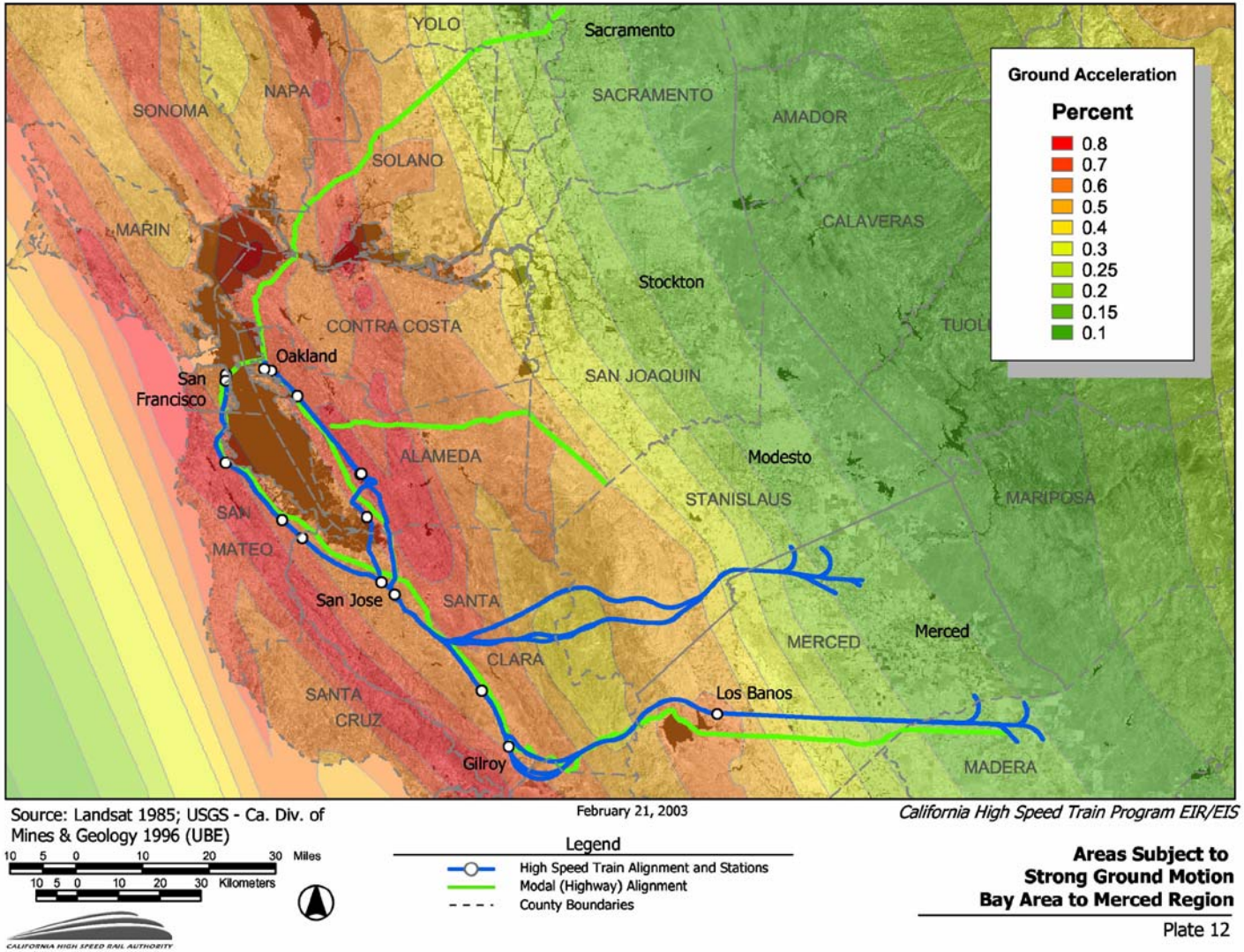
Fault Name	Recency of Movement	Potential Max EQ Magnitude	Slip Rate (mm/y)	Potential Displacement at surface[1] (at Mmax[2])	Direction of Movement
Quaternary Faults that intersect alignments					
Ortigalita Fault	Holocene	6.9	1	1.2 m	RL-SS & thrust N36W
Calaveras Fault (southern segmt)	Historical	6.2	15	0.5 m	RL-SS N28W
Calaveras Fault (northern segmt)	Historical	6.8	6	0.9 m	RL-SS N24W
Hayward Fault (total length)	Historical	7.1	9	1.5 m	RL-SS N35W
Green Valley Fault	Historical	6.9	6	1.0 m	RL-SS N20W
Greenville Fault	Holocene	6.9	2	1.0 m	N23-28W
Quaternary Faults within 5 miles of alignments					
San Andreas Fault	Historical	7.9	14 to 34	5.0 m	RL-SS N40W
Northern Hayward Fault	Historical	6.9	9	3.5 m	RL-SS N35W
Las Positas Fault	Holocene	--	--	No data	LL-SS & thrust N80E
Quien Sabe Fault	Holocene	6.4	1	0.6 m	RL-SS N35W
"Concealed Faults in South Bay"	Holocene	--	--	No data	RL-SS N 30 to 40 W
Sargent Fault	Historical	6.8	3	3.6 m	RL-SS & thrust N45W
Monte Vista-Shannon	Historical	6.8	0.4	1.0 m	RL-SS & thrust N45W

[1]Sources: USGS, 1996; Blake, 1995. [2]Mmax refers to the maximum capable earthquake as listed in USGS, 1996

2.4.3 Ground Motion Potential

Future potential strong ground shaking within the project area will be controlled by the behavior of faults, by the local conditions and thickness of the soil and alluvium, and the depth and type of bedrock. The CGS and USGS have generated maps that indicate potential seismic ground motions (USGS, CGS, 1996) (Figure 10).

Figure 10: Areas Subject to Strong Ground Motion – Bay Area-to-Merced Region



These maps are the result of computer modeling that factor in recency of fault movement and slip rate as well as documented (historic) seismicity defining future ground motions on the basis of probability of occurrence. In a general sense, the CGS-USGS model depicts the traces of the identified active faults as the locus of strong ground shaking with a decrease in shaking with distance from the faults. The probability of occurrence is provided in three probability scenarios including the Design Basis Event (10% probability of exceedance in 50 years), the Upper Bound Event (10% probability in 100 years), and the Maximum Capable Event (10% in 250 years). The State requires that essential and critical public facilities are designed to withstand catastrophic failure for the Upper Bound Event, or UBE. For purposes of this project, areas of potentially strong ground motion have been defined as areas where peak horizontal earthquake ground motion accelerations may exceed 50% (i.e. 0.50) g.

2.4.4 Liquefaction and Other Seismically Induced Ground Deformation

Liquefaction is a seismic-induced soil condition in which loose, saturated, granular (i.e. sandy) soils behave like a fluid when subjected to high-intensity ground shaking. Liquefaction occurs when three general conditions exist: 1) shallow groundwater, 2) low-density sandy soils, and 3) high-intensity ground motion. Studies indicate that saturated, loose and medium dense, near-surface cohesionless soils exhibit the highest liquefaction potential, while dry, dense, cohesionless soils and cohesive soils exhibit low to negligible liquefaction potential. Effects of liquefaction on level ground include sand boils, settlement, and bearing capacity failures below structural foundations. Groundwater contours for the entire project study areas was not available with reasonable accuracy that would be beneficial to this preliminary evaluation. Therefore, in the absence of this information and for purposes of this project, all areas were assumed potentially underlain by shallow groundwater. This allowed mapping of the aerial extent of potentially liquefiable zones by including areas where ground motions exceed 30% (i.e. 0.30) g but excluding areas mapped as underlain by rock. Areas of the project meeting these criteria are mapped on Figure 9.

Lateral spreading and differential settlement also occur in particular conditions as a result of earthquake ground shaking. Lateral spreading is the lateral movement of a mass of soil; often occurs at a boundary with a water body such as a bay margin or dredged canal. Differential settlement is the uneven lowering of different parts of an engineered structure due to subsidence of the underlying soil – especially prevalent at the boundary between a stiff and a soft soil. These issues are listed in Sections 4.1 and 4.2.

2.4.5 Tsunami and Seiche

A tsunami is a sea wave of local or distant origin that results from large-scale seafloor displacements associated with earthquakes, major submarine slides, or oceanic volcanic explosions. The waves are generally formed in groups that may have very long wavelengths (several to more than 100 miles), but are only a few feet high. As a tsunami enters shallow water near coastlines, the wave velocity diminishes and the wave height increases. If the trough of the wave reaches land first, the arrival of a tsunami is preceded by a recession of coastal waters; if the crest of the wave reaches land first, there would be a rise in water level. The large waves that follow can crest at heights of more than 50 feet and strike with devastating force. Because the Bay Area to Merced region of the project lies inland, there is no potential hazard from tsunami waves.

A seiche is the sloshing of a closed body of water caused by earthquake shaking or in response to a tsunami entering a bay. Wave heights of seiches are typically not as great as tsunamis, but have been observed to become large breakers upon reaching the shore. The HST alignments along the margins of the San Francisco Bay are most susceptible to these hazards where the alignments lie within a Coastal High Hazard Zone. The only other potential area subject to the formation of seiche waves is San Luis Reservoir near the SR 152 crossing of the Diablo Range. Further characterization of the hazard to the HST and alternatives from tsunami and seiche waves must be addressed in future studies.

3.0 METHODOLOGY FOR GEOLOGY AND SOILS

The proposed HST and Modal Alternatives were evaluated by comparing conditions and/or potential impacts including seismic hazards, active fault crossings potentially unstable slopes, difficult excavation areas, potential gas migration from oil and/or gas fields, and mineral resources. Criteria for geographic delineation of these potential hazards and/or conditions are described in previous sections. Soil conditions have been described previously in Baseline/Affected Environment (Section 2.0) but are not included in the methodology. These conditions include expansive soils (i.e. shrink-swell potential), erosion, and corrosivity. These conditions are proposed to be addressed in) Subsequent Analysis Requirements, as outline in Section 5.0 and are not considered of significant impact to the preliminary planning and environmental analysis of the project alternatives. Similarly, tsunamis and seiches are discussed in section 2.4.5 but were not considered significant to the project and were not included in our ranking methodology. The methodology used to compare alternative projects, alignments, and stations are outlined below. The results of these comparisons are summarized later in Section 4.0

3.1 SEISMIC HAZARDS

Seismic hazards have been evaluated by combining the influences of strong ground motion and liquefaction potential. These potential hazards are discussed previously in Sections 2.4.3 and 2.4.4. Strong ground motion zones have been defined previously as areas where peak horizontal earthquake ground motion accelerations may exceed 50% (i.e. 0.50) g. The aerial extent of the project within these strong ground motion zones is shown on Figure 10. Liquefaction potential has been previously defined as those areas where ground motions exceed 30% (i.e. 0.30) g but excluding areas mapped as underlain by rock. Those areas are shown on Figure 11. A ranking system was developed to compare alternative projects (i.e. Modal versus HST), alignments, and stations. This ranking system consists of the combination of the percentage of portions of the alignment within the strong ground motion zones and the percentage of alignment within the potentially liquefiable zones. Overlapping liquefaction/ground motion hazards are not considered duplicative in that they require unique mitigation effort. Stations were compared by determining whether any portion of the proposed station occurs within the ground rupture zone and a yes or no ranking, or:

Alignments - % in Strong Ground Motion Zone + % in Potentially Liquefiable Zones
Stations – Presence of any Part within either Zone?: Yes / No

Results of calculations using this methodology are contained in Section 4.0 (Potential Impacts and Mitigation).

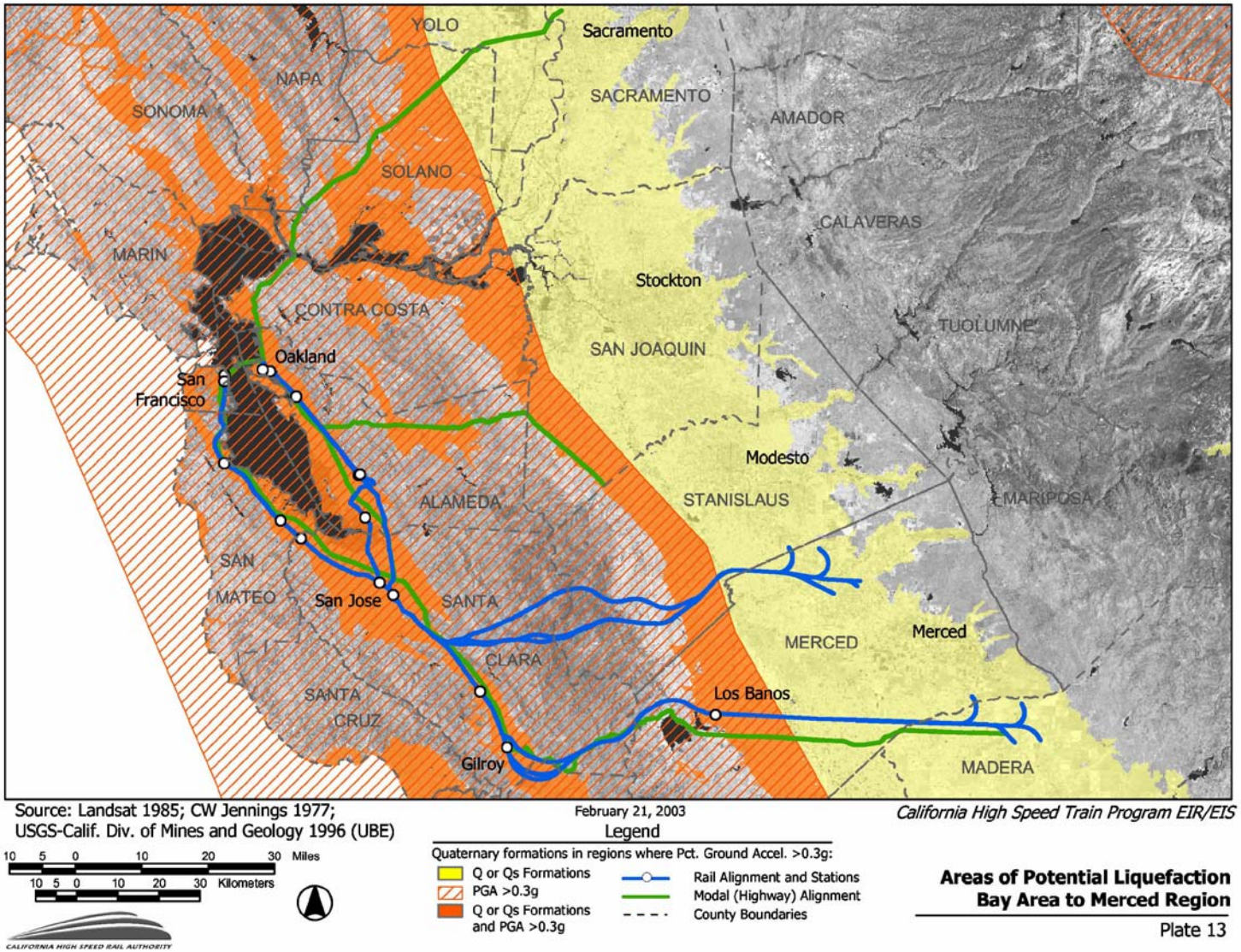
3.2 ACTIVE FAULT CROSSINGS

Ground rupture hazard has been evaluated by mapping any portion of the proposed project alignments and/or stations that occur within faults with known Quaternary movement. These potential hazards are discussed previously in Sections 2.4.2. The aerial extent of the project crossing mapped active fault zones is shown on Figure 9. A ranking system was developed to compare alternative projects (i.e. Modal versus HST), alignments, and stations. This ranking system consists of the number of fault crossings within any portion of the alignment and a yes or no rating for stations, or:

Alignments - Number of Active Fault Crossings
Stations – Presence of any Part within Zone?: Yes / No

Results of calculations using this methodology are contained in Section 4.0 (Potential Impacts and Mitigation).

Figure 11: Areas of Potential Liquefaction – Bay Area-to-Merced Region



3.3 SLOPE STABILITY

Potentially unstable slope areas have been defined previously in Section 2.2.7 as areas where slopes are steeper than 33% slope gradient and are not underlain by strong geologic rock formations. A 200-foot wide buffer zone was added to consider the influences of other improvements. These areas are shown on Figure 7. In order to compare alternative projects (i.e. Modal versus HST), alignments, and stations, a ranking system was developed in which the percentage of alignment within the potential potentially unstable zones are computed and compared. Stations were compared by determining whether any portion of the proposed station occurs within the potentially unstable slope areas with the 200-foot buffer and a yes or no ranking, or:

Alignments - % within 200-foot Buffer of Potentially Unstable Zones
Stations – Presence of any Part within Zone?: Yes / No

Results of calculations using this methodology are contained in Section 4.0 Potential Impacts and Mitigation).

3.4 DIFFICULT EXCAVATION

Areas of difficult excavation zones have been identified using both geologic formation characteristics as well as the existence of faults of any age, as described previously in Section 2.6. These zones consist of fault zones that may influence subsurface tunneling methods as well as hard rock zones that may influence surface excavation methods. In order to compare alternative projects (i.e. Modal versus HST), alignments, and stations, a ranking system was developed in which the percentage of alignment within the areas of difficult excavation applied to the corresponding track profile (i.e. at-grade/aerial versus tunnel) was computed and compared. Stations were evaluated by determining the presence of any part of the facility within the zone and a yes or no rating, or:

Alignment - % Surface Segments in Hard Rock and % Tunnel Segments within Fault Zones
Stations – Presence of any Part within either Zone?: Yes / No

Two of the proposed alignments crossing the Diablo Range have previously been preliminarily studied: the Northern Diablo crossing and the SR 152 crossing (Parsons/GTC, 2001). Other tunnels along the remaining two alternative Diablo Range crossings and at the two proposed terminal stations in San Francisco and Oakland will require additional study to consider tunneling conditions.

Results of calculations using this methodology are contained in Section 4.0 (Potential Impacts and Mitigation).

3.5 OIL AND GAS FIELDS

Areas of potential gas migration and the potential loss of valuable resources associated with the presence of known oil and gas fields are discussed previously in Section 2.4 and are distributed as shown on Figure 6. In order to compare alternative projects (i.e. Modal versus HST), alignments, and stations, a ranking system was developed in which the percentage of alignment within these oil and gas field areas was compared. Stations were compared by determining whether any portion of the proposed station occurs within the mapped oil and gas field areas with a yes or no ranking, or:

Alignments - % within Mapped Oil and Gas Fields

Stations – Presence of any Part within either Fields?: Yes / No

Results of calculations using this methodology are contained in Section 4.0 (Potential Impacts and Mitigation).

3.6 MINERAL RESOURCES

The major issue associated with mineral resources is the exclusion or restriction of current or future extraction due to facility (railroad track, roadways, and parking areas) location. Potential impacts on mineral extraction were evaluated based on a comparison of known resource location versus facility location. Criteria for identification of areas containing mineral resources are discussed previously in Section 2.2. In order to compare alternative projects (i.e. Modal versus HST), alignments, and stations, a ranking system was developed in which the number of occurrences of mined mineral resources is compared for alignments. Stations were compared by determining whether any portion of the proposed station occurs within the mapped resources as a yes or no rating, or:

Alignments – Number of Mapped Resources within 200-feet
Stations – Presence of Resources within 200-feet of any Part of Proposed Facilities

Results of calculations using this methodology are contained in Section 4.0 (Potential Impacts and Mitigation).

4.0 POTENTIAL GEOLOGICAL IMPACTS

For the Soils and Geology technical report, impacts are described for both construction and operations. Construction impacts are those having the potential to be encountered during construction or mitigated during construction – such as difficult excavation, or soil densification for liquefiable soils. Operational impacts are those that may need to be mitigated or inspected through the life of the project – such as creeping fault crossings or unstable slopes.

4.1 OPERATIONS

4.1.1 Impacts

Potential impacts are summarized for the High-Speed Train and Modal Alternatives in the attached Impact Analysis Tables. Ranking of each alignment project alternative is shown on Table 5. The numerical rankings using the methodology described in Section 3.0 were used to develop low, medium and high rankings for each alternative in Table 4. Six potential impacts were considered including seismic hazards, active fault crossings, slope stability, difficult excavation, oil and gas fields, and mineral resources. Each of these potential impacts is discussed in conjunction with the proposed project alternative in the following sections.

4.1.1.1 No-Project Alternative

The No-Project Alternative does not require any additional operations and is therefore not considered unique to the Modal Alternative. Potential impacts for the Modal Alternative (below) are thus considered applicable to this alternative as well.

4.1.1.2 High-Speed Train Alternative

Alternative alignments and stations were evaluated and are summarized in the attached Impact Analysis Tables. Potential impacts to the operation of the High Speed Train (HST) are summarized in the following sections.

4.1.1.2.1 Seismic Hazards

Seismic hazards include strong ground motion due to earthquakes and liquefaction and other seismically-induced ground movement. Strong ground motion and/or liquefaction or other seismically-induced ground movement during a major earthquake may influence the operation of the HST in the following respects:

- Potential risk to public safety and interruption of service due to derailment by strong ground motion during strong earthquakes
- Potential risk to public safety due to collapse or toppling of facilities during strong earthquakes
- Damage to facilities due to lateral spreading and/or differential settlement over soft or filled ground

The majority of the HST alternative alignments and stations around San Francisco Bay and the Santa Clara Valley are located in areas of potentially strong ground motion and in many places, liquefaction and differential settlement. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

Table 5: Detailed Analysis/Comparison Table Soils and Geology/Operations Impacts

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
NO-PROJECT ALTERNATIVE							
HIGHWAYS							
I-80 from I-5 to I-880	61	3	3	5	2	no	2
I-80 from I-880 to Hwy 101	100	0	0	0	0	no	8
Hwy 152 from Hwy 99 to I-5	5	0	0	0	1	no	0
I-580 from I-880 to I-5	79	4	2	8	0	no	0
Hwy 101 from I-880 to Hwy 152	100	0	0	2	0	no	4
Hwy 152 from Hwy 101 to I-5	67	2	11	4	0	no	38
I-880 from I-80 to Hwy 101 East bay	100	0	0	0	0	no	0
Hwy 101 from I-80 to I-880 West Bay	100	0	1	<1	0	no	0
AIRPORTS							
SFO	yes	no	no	no	no	no	no
OAK	yes	no	no	no	no	no	no
SJC	yes	no	no	no	no	no	no

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
MODAL ALTERNATIVE							
HIGHWAYS							
I-80 from I-5 to I-880	61	3	3	5	0	no	2
I-80 from I-880 to Hwy 101	100	0	0	0	0	no	8
Hwy 152 from Hwy 99 to I-5	5	0	0	0	0	no	0
I-580 from I-880 to I-5	79	4	2	8	0	Possibly yes	0
Hwy 101 from I-880 to Hwy 152	100	0	0	2	0	Yes, minor	4
Hwy 152 from Hwy 101 to I-5	67	2	11	4	0	no	38
I-880 from I-80 to Hwy 101 - East Bay	100	0	0	0	0	no	0
Hwy 101 from I-80 to I-880 -West Bay	100	0	1	<1	0	no	0
AIRPORTS							
SFO	yes	no	no	no	no	no	no
OAK	yes	no	no	no	no	no	no
SJC	yes	no	no	no	no	no	no

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability[3] (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
HST Corridor & Station Options							
San Jose to San Francisco							
Alignment	100%	0	<1	<1	0	yes	7
Stations							
-Transbay Terminal	yes	no	no	no	no	no	yes
-4th and King	yes	no	no	no	no	no	no
-Millbrae	yes	no	no	no	no	no	no
-Redwood City	yes	no	no	no	no	no	no
-Palo Alto	yes	no	no	no	no	no	no
-Santa Clara	yes	no	no	no	no	no	no
San Jose to Oakland							
Alignments							
- Hayward/ I-880	100%	1+	0	0	0	no	0
- Hayward/ Niles/ Mulford	100%	2	0	0	0	yes	0
Stations							
-West Oakland	yes	no	no	0	no	no	no
-12th St/City Center	Yes	no	no	0	no	no	yes
-Coliseum Bart Station	Yes	no	no	0	no	no	no
-Union City	yes	no	no	0	no	no	no
-Fremont	yes	no	no	0	no	no	no
San Jose to Merced							
Alignments							
-Northern Diablo Range	16	1	<1	14	0	Yes	17
-Diablo Range Direct, tunnel under park	15	2	4	18	0	Yes	20
-Diablo Range Direct fewer tunnels	15	2	8	18	0	Yes	22
Caltrain/Gilroy Pacheco Pass	34	2	1	4	<1	no	8
-Gilroy Bypass	34	2	1	4	<1	no	8
Stations							
-San Jose (Diridon)	yes	no	no	0	no	no	no
-Morgan Hill	yes	no	no	0	no	no	no
-Gilroy	yes	no	no	0	no	no	no
-Los Banos	no	no	no	0	no	no	no

4.1.1.2.2 Active Fault Crossings

Several active faults occur within the project areas and may influence the operation of the HST in the following respect:

- Potential risk to public safety and interruption of service due to derailment and damage to facilities by ground rupture along active faults

All four of the HST alternatives that cross the Diablo Range intersect two active faults: the Calaveras and Ortigalita faults. The Hayward/Niles/Mulford line of the East Bay HST alternative crosses the active Hayward Fault twice. No alignment alternatives cross the San Andreas Fault in the study area. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.2.3 Slope Stability

Several occurrences of potentially unstable slopes where proposed cut slopes or retention structures may require stabilization are observed within the project area and may influence the operation of the HST in the following respect:

- Potential risk to public safety and interruption of service due to failure of natural and/or construction cuts slopes or retention structures

All of the proposed HST alignment alternatives that cross the Diablo Range traverse steep and potentially unstable slopes when the alignment is at grade or cut into slopes. The northern end of San Jose to San Francisco segment crosses a small mapped landslide. There is little to no impact to the proposed alignments as they cross the low-topography Central Valley, Santa Clara Valley and margins of San Francisco Bay. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.2.4 Difficult Excavation

Several areas where hard rock may be difficult to excavate at the surface or fault and fracture zones exist along proposed tunnel alignments occur within the project areas. Difficult excavation is addressed in Construction Impacts.

4.1.1.2.5 Oil and Gas Fields

The potential for subsurface migration of oil and gas may influence the operation of the HST in the following respects:

- Migration of potentially explosive and or toxic gases into subsurface facilities such as tunnels
- Access to fields may be impacted

No tunnel segments or subsurface stations are located in an area of oil or gas fields; therefore there is no impact from this hazard. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Field access is not likely to be a major concern in the Bay Area to Merced region because in the areas where gas may be located in the future, exploration and production wells can be drilled directionally beneath the HST ROW. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.2.6 Mineral Resources

Several areas where mineral resources have been identified occur along the proposed HST alignment and/or stations. This condition is not expected to impact the operation of the HST. However, it is discussed later in Construction Impacts.

4.1.1.3 Modal Alternatives

The Modal Alternative includes improvement of existing highways and airports and was evaluated as summarized in the attached Impact Analysis Tables. Potential impacts to the operation of these improvements are summarized in the following sections.

4.1.1.3.1 Seismic Hazards

Seismic hazards include strong ground motion due to earthquakes and liquefaction and other seismically induced ground movement. Strong ground motion and/or liquefaction or other seismically induced ground movement during a major earthquake may influence the operation of Modal Alternative facilities in the following respects:

- Potential risk to public safety and interruption of service due to automobile and air traffic accidents caused by ground motion during strong earthquakes
- Potential risk to public safety due to collapse or toppling of facilities during strong earthquakes
- Damage to facilities due to lateral spreading and/or differential settlement over soft or filled ground

The majority of all the modal alternative alignments and airports are located in areas of potentially strong ground motion and to a lesser extent, liquefaction, lateral spreading and differential settlement. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.3.2 Active Fault Crossings

Several active faults occur within the project areas and may influence the operation of Modal Alternative facilities in the following respect:

- Potential risk to public safety and interruption of service due to damage to facilities by ground rupture along active faults

Three of the modal alignments, Interstates 580 and 80, and Highway 152 crossing the Diablo Range are susceptible to damage and disruption due to potential ground rupture. I-80 crosses the Hayward, Green Valley, and Cordelia faults; I-580 crosses the Hayward, Calaveras, and Greenville faults; and Highway 152 crosses the Calaveras and Ortigalita faults. These faults are all A-P zoned active faults. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.3.3 Slope Stability

Areas where potentially unstable slopes coincide with proposed cut slopes or retention structures will require stabilization occur within the project areas and may influence the operation of Modal Alternative facilities in the following respect:

- Potential risk to public safety and interruption of service due to failure of natural and/or construction cuts slopes or retention structures

Slope stability will be a major consideration when widening highways through the Diablo Range and the Coast Ranges as many of the slopes adjacent to the alignments were identified as unstable in the analyses. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.1.2, below.

4.1.1.3.4 Difficult Excavation

No tunnels are proposed for the modal alternative alignments; therefore the analysis is for surface excavation only. Areas where hard rock may be difficult to excavate at the surface occur along State Highway 152 alignment as well as Interstate 80 and 580, in the mountain crossings. This condition is not anticipated to influence operations. Difficult excavation is addressed in Construction Impacts.

4.1.1.3.5 Oil and Gas Fields

The potential for subsurface migration of oil and gas is not considered a potential impact to the proposed Modal Alternative since subsurface facilities are not typical to this style of infrastructure design.

4.1.1.4 Mineral Resources

Several areas where mineral resources have been identified occur along the modal alignments. This condition is not expected to impact the operation of the modal systems. However, it is discussed later in Construction Impacts.

4.2 CONSTRUCTION

4.2.1 Impacts

Potential construction impacts are summarized for the High-Speed Train and Modal Alternatives in the attached Construction Impacts Analysis Table (Table 6). Six potential impacts were considered, including seismic hazards, active fault crossings, slope stability, difficult excavation, oil and gas fields, and mineral resources. Each of these potential impacts is discussed in conjunction with the proposed project alternative in the following sections.

Table 6: Detailed Analysis/Comparison Table/Soils and Geology/Construction Impacts

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
NO-PROJECT ALTERNATIVE							
HIGHWAYS							
I-80 from I-5 to I-880	61	3	3	5	2	0	2
I-80 from I-880 to Hwy 101	100	0	0	0	0	0	8
Hwy 152 from Hwy 99 to I-5	5	0	0	0	1	0	0
I-580 from I-880 to I-5	79	4	2	8	0	0	0
Hwy 101 from I-880 to Hwy 152	100	0	0	2	0	0	4
Hwy 152 from Hwy 101 to I-5	67	2	11	4	0	0	38
I-880 from I-80 to Hwy 101 East bay	100	0	0	0	0	0	0
Hwy 101 from I-80 to I-880 West Bay	100	0	1	<1	0	0	0
AIRPORTS							
SFO	yes	no	no	no	no	no	no
OAK	yes	no	no	no	no	no	no
SJC	yes	no	no	no	no	no	no

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
MODAL ALTERNATIVE							
HIGHWAYS							
I-80 from I-5 to I-880	61	3	3	5	0	0	2
I-80 from I-880 to Hwy 101	100	0	0	0	0	0	8
Hwy 152 from Hwy 99 to I-5	5	0	0	0	0	0	0
I-580 from I-880 to I-5	79	4	2	8	0	Yes, Sand/grav operations	0
Hwy 101 from I-880 to Hwy 152	100	0	0	2	0	Yes, minor	4
Hwy 152 from Hwy 101 to I-5	67	2	11	4	0	0	38
I-880 from I-80 to Hwy 101 - East Bay	100	0	0	0	0	0	0
Hwy 101 from I-80 to I-880 - West Bay	100	0	1	<1	0	0	0
AIRPORTS							
SFO	yes	no	no	no	no	no	no
OAK	yes	no	no	no	no	no	no
SJC	yes	no	no	no	no	no	no

	Seismic Hazards (% of length)	Active Faults X-ings (No. of crossings)	Slope Stability (% of length)	Landslides (% of length)	Oil/Gas Fields (% of length)	Mineral Resources (present Y/N))	Difficult Excavation (% of length)
HST CORRIDORS AND STATION OPTIONS							
San Jose to San Francisco							
Alignment	100%	0	<1	<1	0	0	7
Stations							
-Transbay Terminal	yes	no	no	no	no	no	yes
-4th and King	yes	no	no	no	no	no	no
-Millbrae	yes	no	no	no	no	no	no
-Redwood City	yes	no	no	no	no	no	no
-Palo Alto	yes	no	no	no	no	no	no
-Santa Clara	yes	no	no	no	no	no	no
San Jose to Oakland							
Alignments							
- Hayward/ I-880	100%	1+	0	0	0	0	0
- Hayward/ Niles/ Mulford	100%	2	0	0	0	yes	0
Stations							
-West Oakland	yes	no	no	0	no	no	no
-12th St/City Center	yes	no	no	0	no	no	yes
-Coliseum Bart Station	yes	no	no	0	no	no	no
-Union City	yes	no	no	0	no	no	no
-Fremont	yes	no	no	0	no	no	no
San Jose to Merced							
Alignments							
-Northern Diablo Range	16	1	<1	14	0	yes	17
-Diablo Range Direct, tunnel under park	15	2	4	18	0	yes	20
-Diablo Range Direct, fewer tunnels	15	2	8	18	0	yes	22
Caltrain/Gilroy Pacheco Pass	34	2	1	4	<1	0	8
-Gilroy Bypass	34	2	1	4	<1	0	8
Stations							
-Diridon -SJ	yes	no	no	0	no	no	no
-Morgan Hill	yes	no	no	0	no	no	no
-Gilroy	yes	no	no	0	no	no	no
-Los Banos	no	no	no	0	no	no	no

4.2.1.1 No-Project Alternative

The No-Project Alternative does not require any additional construction and is therefore considered the same as Modal Alternative. Potential impacts for the Modal Alternative discussed in Section 4.2.1.3 below are thus considered applicable to this alternative.

4.2.1.2 High-Speed Train Alternative

Alternative alignments and stations were evaluated and are summarized in the attached Impact Analysis Tables (Table 6). Potential impacts to the operation of the High Speed Train (HST) are summarized in the following sections.

4.2.1.2.1 Seismic Hazards

Seismic hazards include strong ground motion due to earthquakes and liquefaction and other seismically induced ground movement. Strong ground motion and/or liquefaction or other seismically induced ground movement during a major earthquake may influence the construction of the HST in the following respects:

- Potential risk to worker safety and interruption of service due to derailment by strong ground motion during strong earthquakes
- Potential risk to worker safety due to collapse or toppling of partially constructed facilities during strong earthquakes

Although the majority of all of the HST alternative alignments and stations are located in areas of potentially strong ground motion and to a lesser extent, liquefaction, the likelihood of strong ground shaking impacting the project during construction is low. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.2.2 Active Fault Crossings

Several active faults occur within the project areas and may influence the construction of the HST in the following respect:

- Potential risk to worker safety due to ground rupture along active faults

With the avoidance of constructing tunnels across active faults, potential impact to construction of the HST alignment from rupture along an active fault is considered low. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.2.3 Slope Stability

Several occurrences of potentially unstable slopes where proposed cut slopes or retention structures may require stabilization are observed within the project area and may influence the construction of the HST in the following respect:

- Potential risk to worker safety due to failure of natural and/or temporary construction cuts slopes or from seismically-induced slope failure

The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.2.4 Difficult Excavation

Several areas where hard rock may be difficult to excavate at the surface or where fault and fracture zones exist along proposed tunnel alignments occur within the project area. This condition may influence the project construction in the following respects:

- Cost and duration of surface excavation (especially tunnel portals) during construction
- Cost and duration of tunneling along proposed tunnel segments
- Potential risk to air quality due to release of asbestos fibers during grading of serpentine rock

The most likely areas of difficult excavation will be the Diablo Range crossings where not only are rocks of the Franciscan Complex highly variable, but some rock units can be extremely dense and hard, and fracture zones are common. The Northern Diablo crossing has over 29 km of alignment in tunnels, the Diablo Direct (tunnel under park) has over 31 km in tunnels, the Diablo Direct (fewer tunnels) has near 30 km in tunnels, the Pacheco Pass crossing has nearly 14 km in tunnels, and the Pacheco Pass-Gilroy Bypass has nearly 19 km in tunnels – all these tunnels are through Franciscan rock. High rock variability is especially difficult for TBM methods, and may generate drilling delays as TBM bits are changed for different rock types. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. No one alternative segment is significantly better than the others with respect to difficult excavation.

Areas where serpentine bedrock (serpentinite) is exposed may be the source of asbestos fibers that may be released during grading operations. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.2.5 Oil and Gas Field Vapor Migration

The potential for subsurface migration of oil and gas may influence the construction of the HST in the following respects:

- Migration of potentially explosive and/or toxic gases into subsurface facilities such as tunnels

No tunnels occur in areas of oil and gas fields, thus no subsurface facilities are expected to be impacted by the presence of dangerous gases. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.2.6 Mineral Resources

Several areas where mineral resources have been identified occur along the proposed HST alignment and/or stations. This condition may influence construction of the HST in the following respects:

- Project easements for existing quarries
- Potential loss of existing mineral resources
- Potential loss for future extraction

The four HST alternatives that cross the Diablo Range north of Highway 152 cross through an area of known mineral resources. If the alignments cross active or potentially active quarries, mitigation measures will be required for access to quarries.

Mitigations could include revisions to the alignment to avoid or minimize loss of access to resource, obtaining easements for access, purchase of resources, or design to accommodate mining during HST operations and construction. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.3 Modal Alternatives

The Modal Alternative includes improvement of existing highways and airports and was evaluated as summarized in the attached Impact Analysis Tables. Potential impacts to the construction of these improvements are summarized in the following sections.

4.2.1.3.1 Seismic Hazards

Seismic hazards include ground motion due to strong earthquakes and liquefaction and other seismically induced ground movement. Strong ground motion and/or liquefaction or other seismically induced ground movement during a major earthquake may influence the construction of Modal Alternative facilities in the following respects:

- Potential risk to worker safety and interruption of service due to automobile and air traffic accidents caused by strong ground motion during strong earthquakes
- Potential risk to worker and public safety due to collapse or toppling of partially constructed facilities during strong earthquakes

Although the majority of all of the model alignments and airports are located in areas of potentially strong ground motion and to a lesser extent, liquefaction, the impacts to construction due to strong ground shaking or liquefaction are low. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.3.2 Active Fault Crossings

Several active faults occur within the project areas and may influence the construction of the model alternatives in the following respect:

- Potential risk to worker safety and interruption of service due to highway damage caused by ground rupture along active faults

The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.3.3 Slope Stability

Several occurrences of potentially unstable slopes where proposed cut slopes or retention structures may require stabilization are observed within the project area and may influence the construction of the modal alternatives in the following respect:

- Potential risk to worker and public safety and interruption of service due to failure of natural and/or temporary construction cuts slopes or retention structures

The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.3.4 Difficult Excavation

Several areas where hard rock may be difficult to excavate at the surface occur within the Modal Alternative project areas and may influence construction in the respect:

- Cost and duration of surface excavations during construction

The primary locations of difficult to excavate rock are the Diablo Range crossing of Highway 152 and of I-580 and the Coast Range crossing of I-80. The Impact Analysis Tables provide a relative comparison of

the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

4.2.1.3.5 Oil and Gas Fields Vapor Migration

The potential for subsurface migration of oil and gas may influence construction of the modal alternative in the following respect:

- Mitigation of potentially explosive gases into subsurface facilities

This impact does not affect the Bay Area-Merced region. The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative.

4.2.1.4 Mineral Resources

Several areas where mineral resources have been identified occur along or adjacent to the proposed Modal Alternative alignment. This condition may influence the construction of the Modal Alternative in following respect:

- Project easements for existing quarries
- Potential loss of existing mineral resources
- Potential loss for future extraction

The Impact Analysis Tables provide a relative comparison of the degree of impact on each alternative. Methods of mitigation of these potential impacts are provided in Section 4.2.2, below.

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6.0 PREPARERS

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APPENDIX – A

Topography Table

Bay Area to Merced Segment

Table A-1

Elevations Along HST Alignments

Values reported as (ground elevation / alignment elevation)

HST Corridor & Station Options		Max Elev. Ft above msl[1]	Min Elev. Ft above msl	Station Elev.
San Jose to San Francisco	*Highway 101/CalTrain corridor*	95 / 79	26 / -64	
Stations	-Transbay Terminal			13 / -46
	-4th and King			10 / 10
	-Millbrae			16 / 16
	-Redwood City			16 / 16
	-Palo Alto			72 / 72
	-Santa Clara			66 / 66
San Jose to Oakland	*Alt: Hayward/I-880*	92 / 98	16 / 23	
	Alt: Hayward/ Niles/ Mulford	89 / 115	0 / 13	
Stations	-West Oakland			10 / -43
	-12th St/City Center			43 / -72
	-Coliseum Bart Station			10 / 13
	-Union City			56 / 108
	-Diridon			98 / 148
San Jose to Merced Alternatives				
Northern Diablo Route	Route	3205 / 2411	13 / 36	
	Winton (Merced)			141 / 148
Diablo Range Direct, tunnel under park	Crossing of I-5			190 / 190
	Route	3008 / 1959	13 / 36	
	Crossing of Hwy 101			262 / 328
	Winton (Merced)			141 / 148
Diablo Range Direct, fewer tunnels	Route	2789 / 2116	13 / 36	
	Crossing of Hwy 101			262 / 328
	Winton (Merced)			141 / 148
San Jose to Chowchilla SR 152, Pacheco Pass	Route	1804 / 1263	-33 / 3	
	Chowchilla			289 / 289
Gilroy Bypass	Nothing greater or less than the Gilroy route			
Stations	-San Jose (Diridon)			98 / 148
	-Morgan Hill			348 / 394
	-Gilroy			197 / 236
	-Los Banos			131 / 131
	-Chowchilla			180 / 180

1: msl = mean sea level

Source: Preliminary engineering drawings of route and profiles.