
3.10 SOILS, GEOLOGY, AND SEISMICITY

Introduction

This section addresses local and regional geologic and seismic characteristics within the Santa Clara-Alum Rock Corridor. It describes the local faulting, soils and soil resource conditions; the potential effects of seismicity; and the potential effects of planning and development on soil resource issues relevant to the project area. The proposed construction of new transit facilities, including station areas and associated roadway modifications, has the potential to cause direct and indirect impacts on local soils resources. Related plans and policies are referenced, including the San Jose General Plan¹ and the Santa Clara County General Plan.² The discussion describes existing conditions and potential impacts of the proposed project in the context of the regulatory environment that governs the construction of this type of project, based on an analysis prepared by PBS&J. This study included a site reconnaissance³, analysis of project plans, review of appropriate regulations, and communication with the Santa Clara County Planning Department and City of San Jose Public Works Department. Erosion and sedimentation issues are addressed Section 3.12, Hydrology and Water Quality, because they are primarily related to turbidity and other depositional effects in local and regional water bodies.

Soils, geology and seismicity conditions are important aspects of all development projects in the San Francisco Bay Area. Although most projects have little or no effect on geology, any project involving construction will have some effect on soils and topography (grading), and all may be affected by anticipated geologic events (earthquakes). The purposes of reviewing the soils, geology, and seismicity conditions with respect to the Santa Clara-Alum Rock Corridor are (1) to identify potentially hazardous conditions; (2) to identify the potential impacts of alignment design and development; and (3) to provide information about the regulations and techniques used to reduce, eliminate or avoid these conditions and impacts.

Background information was collected from topographical maps of the area and reports prepared by the Department of Water Resources, the United States Geological Survey, the Natural Resources Conservation Service (formerly the Soil Conservation Service), the California Geological Survey (formerly the Division of Mines and Geology), the Association of Bay Area Governments, the City of San Jose, and Santa Clara County dealing with geotechnical conditions in the Bay Area; the Soil Survey of Santa Clara County; and Environmental Site Assessment reports provided by various public and private agencies, all of which are cited in the endnotes. These data, in conjunction with the results of field surveys by PBS&J geologists in 2001 and reevaluation in 2004, were used to determine the existing site conditions, on-site resources, and physical relationships to known active faults. Potential

¹ City of San Jose Community Development Department, *San Jose 2020 General Plan*, adopted August 1994, most recent update May 6, 2004.

² Santa Clara County Community Development Department, *Santa Clara County General Plan 1995-2010*, July 1996.

³ Site inspection by PBS&J, January 2004.

soils, geologic, and seismic impacts were identified by assessing what changes implementation of proposed project could cause in ground conditions during and following the construction period.

Existing Conditions

Environmental Setting

Regional Geology. The regional geologic framework of the Bay Area (Figure 3.10-1), and the City of San Jose in particular, can be understood through the theory of plate tectonics. Earth's mantle is composed of several large plates that move relative to each other. The San Andreas Fault Zone is at the junction of two such plates. The Pacific plate, on the west side of the fault zone, is moving north relative to the North American plate on the east side. All of the geologic formations in San Jose are on the North American plate. One of the results of plate movement is the regional rock deformation that is expressed in the general northwest trend of the Santa Clara Valley and the ridges on either side of the City. This is visible, for example, in the orientation of such Hills as Poverty Ridge and Oak Ridge about six and eight miles to the east. Another result of plate movement, discussed below, is the regional seismicity that San Jose has in common with the rest of the Bay Area.⁴

Seismicity. The City of San Jose, including the Santa Clara-Alum Rock Corridor, lies within the San Andreas Fault System, which is approximately 44 miles wide in the Bay Area.⁵ The principal active faults, on which there is evidence of displacement during Holocene time (the last 11,000 years), include the San Gregorio, San Andreas, Hayward, Calaveras, and Marsh Creek faults.⁶ Figure 3.10-1 shows the approximate position of the major fault zones, the general distribution of the major groups of rock units, and the location of the project site in relation to these features. Table 3.10-1 contains the estimated maximum parameters for earthquakes on known major faults potentially affecting the project site. Terms that may be unfamiliar to the general public are defined in the glossary prior to the endnotes of this section.

The City of San Jose and the rest of the Bay Area are in one of the most active seismic regions in the United States. Each year, low and moderate magnitude earthquakes occurring within or near the Bay Area are felt by residents of the City. Most recently, the Moment Magnitude (M_w) 6.9 Loma Prieta earthquake ($M_{7.1}$ on the Richter scale—see Glossary) of October 1989 on the San Andreas Fault, caused severe damage throughout the Bay Area, including extensive damage to buildings and bridge approaches. The incorporation of earthquake safety designs for construction in the City, through the use of the *California Building Code* (see below) and amendments to the Code, as adopted by the City

⁴ Oakeshott, G.B., *California's Changing Landscapes, A Guide to the Geology of the State*, 2nd edition, McGraw-Hill Book Company, San Francisco, 1978, 378 pages.

⁵ Wallace, R.E., "General Features", in Wallace, R.E., ed. *The San Andreas Fault System, California*, United States Geological Survey Professional Paper 1515, January 1990, pages 3-12.

⁶ Bortugno, E.J., R.D. McJunkin, and D.L. Wagner, *Map Showing Recency of Faulting, San Francisco - San Jose Quadrangle, California*, California Geological Survey (formerly the California Division of Mines and Geology), Regional Geologic Map Series, No. 5A, 1991, Sheet 5 of 5, map scale 1:250,000.

Table 3.10-1
Estimated Maximum Parameters
for Nearby Known Faults Affecting the Santa Clara-Alum Rock Corridor

Fault	Sargent	San Andreas	North & South Hayward	Northern & Central Calaveras
Moment Magnitude ^a	6.6	7.9	6.9	6.2
Duration of Strong Shaking (seconds) ^b	18–30	30–60	30–60	18–30
Maximum Intensity (MMI) ^c	VII	VII–VIII	VII–VIII	VII–VIII
Approximate Peak Horizontal Accelerations in Rock and Stiff Soil (Gravity) ^d	0.10–0.30	0.30–0.50	> 0.60	0.40–0.50
Approximate Distance and Direction from Site to Fault (Miles)	27 S	12 SW	1.9 NE	5 NE

Source: PBS&J, 2001, reevaluated 2004.

Notes:

- a. For the purposes of describing the size of the design (or scenario) earthquake of a particular fault segment, **moment magnitude** (Mw) of the characteristic earthquake for that segment has replaced the concept of a maximum credible earthquake of a particular Richter magnitude. This has become necessary because the Richter Scale “saturates” at the higher magnitudes; that is, the Richter scale has difficulty differentiating the size of earthquakes above magnitude 7.5. The Mw scale is proportional to the area of the fault surface that has slipped, and thus, is directly related to the length of the fault segment. Although the numbers appear lower than the traditional Richter magnitudes, they convey more precise (and more useable) information to geologic and structural engineers.
- b. Duration of ground motion at 0.5g within 10 miles of the fault. Estimates based on relationships developed by Bolt, 1973.
- c. Estimated Modified Mercalli Intensity damage level based on relationships developed by Perkins and Boatwright, 1995, or Richter, 1958 (San Andreas fault only).
- d. Estimates based on relationships developed by Seed and Idriss, 1972, Joyner and Boone, 1981, Campbell and Sadigh, 1983.

of San Jose (Title 24 of the City’s *Municipal Code*), has ensured that no new structures in the City would be specifically hazardous during an earthquake.⁷

The major fault zones of the San Andreas Fault System were the sources of the previously mentioned earthquakes, and are expected to be the sources of most future earthquakes in the area.⁸ It is necessary to design structures and facilities in San Jose to withstand the anticipated effects of seismic vibration from distant, as well as nearby, sources.⁹ Recognizing this necessity, the Santa Clara County Geologic

⁷ *San Jose 2020 General Plan*, updated May 6, 2004.

⁸ a) Jennings, C.W., *Fault Activity Map of California and Adjacent areas, with locations and ages of Recent Volcanic Eruptions*, Geologic Data Map No. 6, California Geological Survey, 1994, scale 1:750,000, accompanied by 92 pages of explanatory text.

b) Association of Bay Area Governments, *The San Francisco Bay Area On Shaky Ground*, Publication Number P95001EQK, April 1995, 56 pages, 13 maps, scale 1:1,000,000.

⁹ Seismology Committee, Structural Engineers Association of California, *Recommended Lateral Force Requirements and Tentative Commentary*, San Francisco, California, 5th edition, revised 30 June 1998, 163 pages, see page 1.

Hazard Maps¹⁰ specifically identify segments of known active regional faults crossing the County (San Andreas, Hayward, Calaveras) and suspected local faults (Stanford, Monte Vista, Sargent, Silver Creek) as sources of seismic activity that must be taken into consideration during the planning of development in the County or City.

On the basis of research conducted since the 1989 Loma Prieta earthquake, the United States Geological Survey (USGS) and other scientists conclude that there is a 62 percent probability of at least one M_w 6.7 or greater earthquake, capable of causing widespread damage, striking the San Francisco Bay region before 2032. The Hayward-Rodgers Creek fault system has the highest probability (27 percent) of generating a M_w 6.7+ earthquake in this timeframe: the San Andreas, 21 percent; and the Calaveras, 11 percent.¹¹ Earthquakes of this magnitude are sufficient to create ground accelerations in bedrock and in stiff unconsolidated sediments severe enough to cause major damage to structures and foundations not designed specifically to resist the lateral forces generated by earthquakes, and to underground utility lines not designed with sufficient flexibility to accommodate expected seismic ground motion.¹²

There are other active and potentially active fault zones that could affect the project site. These include faults that are historically active (during the last 200 years), those that have been active in the geologically recent past (about the last 11,000 years, referred to as the Holocene epoch), and those that have been active at some time during the Quaternary geologic period (the last 1.6 million years). The San Andreas, Hayward, Rodgers Creek, and Calaveras fault zones are all, at least partially, historically active. Parts of each of these major fault zones have been classified as Holocene or Quaternary depending on the age of the evidence of the most recent movement.¹³

A characteristic earthquake on the entire San Andreas Fault (M_w 7.9) probably is the largest that would affect the project area. However, because a characteristic earthquake on the entire Hayward Fault (M_w 6.9) would be closer to any point on the project alignment, its effects would be about as severe. Other faults that exist in the vicinity are pre-Quaternary in origin, generally being related to the Coastal thrust belt or the Coast Range thrust. They were active tens of millions of years ago, but have shown no evidence of activity during the last 1.6 million years.¹⁴

The State-zoned active fault traces closest to the project area are those of the Hayward Fault, about 1.9 miles northeast of the Corridor (Figure 3.10-1). Because it does not cross the Corridor, the fault

¹⁰ Santa Clara County Planning Office, *Geologic Hazard Zones*, Fault Rupture Hazard Zones, Map 20, February 26, 2002, scale 1:36,000.

¹¹ Working Group on California Earthquake Probabilities, *Earthquake Probabilities in the San Francisco Bay Region: 2002 to 2031 - A Summary of Findings*, United States Geological Survey Open File Report 03-214, Online Version, last modified 25 June 2003.

¹² a) Borderdt, R.D., *et al.*, *Maximum Earthquake Intensity Predicted on a Regional Scale*, United States Geological Survey, Miscellaneous Field Investigations Map MF-709, 1975, scale 1:125,000.

b) Steinbrugge, K.V., J.H. Bennett, H.J. Lagorio, J.F. Davis, G.A. Bordardt, and T.R. Topozada, *Earthquake Planning Scenario for a Magnitude 7.5 Earthquake on the Hayward Fault in the San Francisco Bay Area*, California Geological Survey, Special Publication 78, 1987, 243 pages, 12 scenario maps, scale 1:200,000, see maps and accompanying text on adjacent page.

¹³ Ibid, Jennings, 1994.

¹⁴ Ibid.

does not constitute a fault-line rupture hazard for the project, although, because of its proximity, it does pose a groundshaking hazard (see below). Other faults in the vicinity of San Jose that are zoned by the State under the Alquist-Priolo Earthquake Fault Zoning Act of 1972 include the San Andreas (11 miles southwest) and the Calaveras (five miles northeast). These faults also pose groundshaking hazards, but not as severe as those from the Hayward Fault. The nearby traces of the Hayward Fault in the Earthquake Fault Zone are historically active and show continuing evidence of ground surface rupture during the historical age (the last 400 years, a very short time in terms of geologic activity). The entire Hayward Fault is capable of generating a characteristic earthquake of M_w 7.1 and peak horizontal ground accelerations in excess of 0.6g (60 percent of the force of gravity) near the epicenter of the earthquake.¹⁵

No other Alquist-Priolo Earthquake Fault Zone, Santa Clara County Fault Rupture Hazard Zone, or known active fault trace crosses or trends toward the Corridor.¹⁶ Other faults of unknown potential, mentioned in the discussion of Seismicity (above), do not pose known fault-line rupture or groundshaking hazards because they have shown no evidence of activity during the last 1.6 million years.

Groundshaking intensities associated with a characteristic earthquake of M_w 7.1 on the entire Hayward Fault are expected to be VII (strong) to VIII (very strong) on the Modified Mercalli Intensity (MMI) Scale.¹⁷ MMI VIII generally will not damage specially designed structures, but can cause some damage in structures of good workmanship, and moderate to heavy damage in ordinarily substantial buildings, foundations, roadbeds, and underground utilities. Seismic ground response of this intensity in the near vicinity of the fault trace would cause severe damage to older buildings, roadways, and infrastructure that were not constructed to resist the earthquake forces. For new buildings and infrastructure constructed to current California Building Code Zone 4 seismic-resistance standards, Caltrans seismic design criteria, or similar accepted standards using site-specific parameters to address the proximity of the fault, the damage potential would be somewhat lower but still could be considerable.¹⁸

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- ¹⁵ a) Bryant, W.A., *Fault Evaluation Report, SE segment of Hayward Fault, Crosley fault, Berryessa fault, Quimby fault, Clayton fault, SE segment of Mission fault, and inferred break of 1868*, California Geological Survey FER-105, December 19, 1980, 28 pages, 6 maps, scale 1:24,000.
b) Bryant, W.A., *Fault Evaluation Report, SE segment of Hayward Fault, Evergreen fault, Quimby fault, Silver Creek fault, and Piercy fault*, California Geological Survey FER-106, March 16, 1981, 22 pages, 6 maps, scale 1:24,000.
c) Hart and Bryant, 2003, *op. cit.*, Plate 3B, scale 1:62,500.
d) Jennings, 1992, *op. cit.*
- ¹⁶ County of Santa Clara Planning Department, *Santa Clara County Geologic Hazard Zones*, Panel 20, Online Version updated February 26, 2002.
- ¹⁷ Earthquake Hazard Map for NW San Jose/Milpitas/Santa Clara Scenario: North Hayward and South Hayward Segments of the Hayward-Rodgers Creek Fault System in *Earthquake Hazard Maps*, Association of Bay Area Governments website, <http://www.abag.ca.gov/bayarea/eqmaps/pickcity.html>, updated October 20, 2003.
- ¹⁸ a) "Probabilistic Seismic Hazards, Peak Ground Acceleration Atlas, Santa Rosa 1 x 2 Degree Sheet," in *Probabilistic Seismic Hazard Assessment Maps*, California Geological Survey website, <http://www.consrv.ca.gov/cgs/rghm/psha/>, last edited April 16, 2004.
b) Association of Bay Area Governments, 1995, *op. cit.*

From the review of regional and local geo-seismic conditions, structures and facilities in the Corridor would be subjected to at least one major earthquake during the span of time in which these structures and facilities would be utilized. The design earthquake for the project area is estimated by the United States and California Geological Surveys to be an M_w 7.1 earthquake on the Hayward Fault system, creating peak ground accelerations as great as 0.6g and probably higher. The resulting vibration would cause damage to the roadway infrastructure (primary effects) and could cause ground failures in the alluvium (secondary effects).

No landslide deposits have been mapped within the Corridor or in its immediate vicinity. The average gradient along the alignment is less than one percent. There are no slopes on the alignment.¹⁹

Topography. The ground surface on the project site is a nearly level plain that slopes very gently to the west-northwest at an average gradient of less than one percent. Elevations range from approximately 130 feet above mean sea level (+130 feet msl) in the higher elevations above Lower Silver Creek on the eastern end of the alignment to about +85 feet msl along the Lower Guadalupe River channel at the western extent of the project corridor.²⁰ The ground surface is urban land cover, consisting of asphalt and concrete roads and walks; adjacent residential, commercial and public building; and parks (especially near Lower Guadalupe River and Coyote Creek). Existing bridges span these two waterways.

Soils. The soils of Santa Clara County, including those within the Corridor, were mapped most recently in 1977 by the Natural Resources Conservation Service. The soil units beneath the Corridor are mapped as Yolo Association silty clay loams.²¹ Surface soils contain silty clays with medium to low infiltration rates (0.05 to 0.2 inches per hour) and high shrink-swell potential, and clay loams with medium infiltration rates (0.2 to 0.6 inches per hour) and moderate shrink-swell potential. The soils are slightly corrosive to untreated steel and concrete.

Specific treatments to eliminate the effects of soil expansion include, but are not limited to, grouting, recompaction, and replacement with non-expansive material. In San Jose, construction sites on expansive soil are required to be evaluated to determine the particular treatment that would be most appropriate. Because expansive soils are common throughout the Bay Area, contractors and soil testing firms are familiar with the procedures used to identify and eliminate the problems involved.

Groundwater in the region typically is shallow, at depths of about 10 to 30 feet below ground surface. Previous geotechnical investigations in the project vicinity have encountered groundwater at depths of about 20 feet below ground surface.

¹⁹ Site inspection by PBS&J, January 2004.

²⁰ United States Geological Survey, *San Jose East Quadrangle, California, 7.5 Minute Series (Topographic)*, photorevised 1973, scale 1:24,000.

²¹ United States Department of Agriculture, Natural Resources Conservation Service (formerly the Soil Conservation Service), *Soil Survey of Santa Clara County, California*, V.C. Miller, Party Chief, Washington, D.C., 1977.

Such characteristics as permeability, compressibility, and erosion hazard vary with grain size (clay, sand, gravel, etc.), grain-size distribution, and material density, etc., and may change rapidly over very short distances. The California Geological Survey identifies the project site as being in a Seismic Hazard Zone for liquefaction.²²

Even soils on nearly flat sites with low erosion potential in their natural condition can become erosion-prone when disrupted unless specific measures are taken to control erosion. Because the major adverse effects of potential erosion are turbidity and other deposition in the City's rivers and creeks, this issue is discussed in Section 3.12, Hydrology and Water Quality.

Geologic Units. The Santa Clara-Alum Rock Corridor is underlain by geologically young basin deposits. Previous geotechnical studies indicate the deposits in the vicinity of the alignment are young fine-grained alluvium (horizontally stratified clay and silt) and slightly older fine- to coarse-grained alluvium (moderately to poorly bedded, poorly sorted clay, silt, sand, and gravel). These natural unconsolidated sediments are easy to excavate; however, the materials do not provide sufficient strength for deep unsupported cuts to stand in relatively steep slopes during an entire construction season. The clayey portions of the material are prone to expansion and do not drain easily. The slightly coarser-grained sediments drain more readily. There is a probability of encountering pockets of liquefiable sand.²³

Regulatory Setting

State Policies and Regulations. The major State legislation regarding earthquake fault zones is the *Alquist-Priolo Earthquake Fault Zoning Act*. In 1972, the State of California began delineating Earthquake Fault Zones (called Special Studies Zones prior to 1994) around active and potentially active faults to reduce fault-rupture risks to structures for human occupancy.²⁴ The Act has resulted in the preparation of maps delineating Earthquake Fault Zones to include, among others, recently active segments of the Hayward Fault. The Act provides for special seismic design considerations if developments are planned in areas adjacent to active or potentially active faults.²⁵ The Santa Clara-Alum Rock Corridor is not crossed by any Alquist-Priolo Earthquake Fault Zone.

The major State regulations protecting the public from geo-seismic hazards, other than surface faulting, are contained in California Code of Regulations, Title 24, Part 2, the *California Building Code* and

²² California Geological Survey, *State of California Seismic Hazard Zones, Official Map, San Jose East Quadrangle and San Jose West Quadrangle*, revised: January 17, 2001 and February 2, 2002, respectively, scale 1:24,000.

²³ Santa Clara Valley Transportation Authority, *Capitol Expressway Corridor, San Jose, California, Draft Environmental Impact Statement/Draft Environmental Impact Report*, SCH # 2201092014, September 2003, Section 4.10, Geology, Soils, and Seismicity, 12 pages.

²⁴ *Alquist-Priolo Earthquake Fault Zoning Act*, California Public Resources Code, Division 2, "Geology, Mines, and Mining," Chapter 7.5 "Earthquake Fault Zones," Sections 2621 through 2630; signed into law December 22, 1972, most recently amended 1994.

²⁵ Hart, E.W., and W.A. Bryant, *Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Fault Zones Maps*, California Geological Survey (formerly the Division of Mines and Geology), Special Publication 42, 1997 Edition, Supplements 1 and 2 added 1999, 47 pages, Supplement 3 released May 1, 2003, updated on-line October 7, 2003, pages 9, 11, and 13.

California Public Resources Code, Division 2, Chapter 7.8, *The Seismic Hazards Mapping Act*. Both these regulations generally apply to public buildings (and a large percentage of private buildings) intended for human occupancy. Section 1634, *Nonbuilding Structures*, of the *California Building Code* extends code requirements to all other self-supporting structures (such as bridges and overcrossings) that carry gravity loads and resist the effects of earthquakes. Because nonbuilding structures along the alignment would be in the “near-source” area (closer than 3.1 miles to a known active fault) of the Hayward Fault, Section 1629, *Criteria Selection*, of the *California Building Code* requires special seismic design factors be applied to those structures.

Because the *California Building Code* normally is not applicable to structures within the rights-of-way of City roads, VTA has the option to use *California Building Code* design standards, or some other accepted standard, such as the Caltrans design standards.²⁶ The major State regulations protecting public roadways and bridges from geo-seismic hazards are contained in *Caltrans Seismic Design Criteria Version 1.2* (December 2001) and *Caltrans Highway Design Manual*, Section 110.6, Earthquake Consideration (November 2001). Bridge design, including seismic resistance, is required to be in accordance with Caltrans’ *Bridge Design Specifications*, *Bridge Memos to Designers*, *Bridge Design Practices Manual*, and *Bridge Design Aids Manual*. Bridge design is required to be based on the “Load Factor Design methodology with HS20-44 live loading.” Seismic resistant design is required to conform to the *Bridge Design Specifications*, and Section 20 of *Bridge Memos to Designers*, including the Caltrans Seismic Design Criteria. Because the Corridor is in the near-source area of the Hayward Fault, the seismic provisions contained in these design guidelines, or similarly accepted ones, would be applied to the construction of the proposed project in the Corridor.

City of San Jose General Plan. To ensure that the community’s vision is achieved, the City has adopted, in its *San Jose 2020 General Plan*²⁷, goals and policies aimed at land use and future development. City policies and land use decisions directly affect future development by requiring detailed site-specific evaluation of properties when the sources used to formulate the City’s General Plan Natural Hazards policies indicate there may be a potential hazard. Several of the Plan’s major goals are designed to protect the population of in San Jose from geo-seismic and other natural hazards, including the following.

The City’s Hazards Goal states:

Strive to protect the community from injury and damage resulting from natural catastrophes and other hazard conditions.

The Soils and Geologic Conditions Goal states:

Protect the community from the hazards of soil erosion, soil contamination, weak and expansive soils and geologic instability.

²⁶ Michael Enright, PE, Supervising Building Plan Check Engineer, City of Santa Rosa, letter to Blake Hillegas, City Planner, City of Santa Rosa, September 23, 2003.

²⁷ City of San Jose, Planning, Building and Code Enforcement Department, *San Jose 2020 General Plan*, adopted August 1994, most recent update May 6, 2004.

The Earthquakes Goal states:

Minimize the risk from exposure to seismic activity.

The City's Hazard Policies relate to administrative actions to be taken by the City when reviewing proposed development and considering it for project approvals. These policies are uniform for all development and are not directed, specifically, at any one project.

The City's Soils and Geologic Conditions Policies that relate to this project include:

The City should require soils and geologic review of development proposals to assess such hazards as potential seismic hazards, surface ruptures, liquefaction, landholdings, mudsliding, erosion, and sedimentation in order to determine if these hazards can be adequately mitigated.

The City should not locate public improvements and utilities in areas with identified soils and/or geologic hazards to avoid any extraordinary maintenance and operating expenses. When the location of public improvements and utilities in such areas cannot be avoided, effective mitigation measures should be implemented.

- Development in areas subject to soils and geologic hazards should incorporate adequate mitigation measures.
- Development proposed within areas of potential geological hazards should not be endangered by, nor contribute to, the hazardous conditions on the site or on adjoining properties.

The City's Earthquake Policies that relate to this project include:

- The City should only approve new development in areas of identified seismic hazard if such hazard can be appropriately mitigated.
- The location of public utilities and facilities, in areas where seismic activity could produce liquefaction, should only be allowed if adequate mitigation measures can be incorporated into the project.
- The City should continue to require geotechnical studies for development proposals; such studies should determine the actual extent of seismic hazards, optimum location for structures, the advisability of special structural requirements, and the feasibility and desirability of a proposed facility in a specified location.
- Vital public utilities as well as communication and transportation facilities should be located and constructed in a way that maximizes their potential to remain functional during and after an earthquake.
- According to *General Plan* Figure 15, "Acceptable Exposure to Seismic Risk Related to Various Land Uses", the project would be considered a Group 3 land use ("Major communication and transportation facilities, such as airports, telephone lines and terminals, bridges, tunnels, freeways and overpasses, and evacuation routes") in which only low level exposure to seismic risk should be allowed.

The current California Building Code is the basis for the City of San Jose Building Code. In addition to State amendments to the Uniform Building Code, jurisdictional authorities such as the City are permitted to develop local amendments, when deemed necessary. As required by law, the City has made findings based on local climatic, geologic and topographical conditions that allow for the adoption of a number of local code amendments considered necessary because, among other issues, of the existence of the Hayward Fault through the City. These amendments are incorporated in Title 24 of the City's *Municipal Code* to ensure seismic and soil safety design for construction.

Impact Assessment and Mitigation Measures

Approach and Methodology

For those areas in which transit development improvements are proposed, existing geologic and soil conditions described in the environmental setting were reviewed, to determine whether geologic or soils hazards could occur, based on VTA's thresholds of significance.

The potential soils and seismic effects on the environment in the Corridor may be considered from two points of view: the direct (construction) and indirect (operational) effects of the project. Potential construction effects related to soil excavation, erosion, and redeposition are discussed in Section 3.12, Hydrology and Water Quality, and Section 3.18, Construction Impacts. Potential indirect effects include the exposure of infrastructure and its users to soils and seismic processes that could produce damage or injury. The construction of the proposed project in the Corridor is not expected to have direct or indirect adverse effects on or from soils and seismic processes because all construction and operation activities are regulated by a set of existing laws that require such effects be avoided.

Standards of Significance

To address these issues, the following thresholds of significance apply to the Santa Clara-Alum Rock Corridor. Geology, soils, or seismicity effects associated with the proposed project in the Santa Clara-Alum Rock Corridor would be adverse if one or more of the following conditions were created in the vicinity of the project.

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death as a result of;
- Rupture of a known earthquake fault;
- Strong seismic groundshaking;
- Seismic-related ground failure, including liquefaction;
- Lateral spreading, subsidence, or collapse as a result of underlying unstable geologic units; or
- Expansive soil.

Environmental Analysis

In order to determine soils, geology, and seismicity impacts due to construction and operation of the proposed project, a level of significance is determined and reported. Conclusions of significance are defined as follows: significant (S), potentially significant (PS), less than significant (LTS), no impact (NI), and beneficial (B). If the mitigation measures would not diminish potentially significant or significant impacts to a less-than-significant level, the impacts are classified as “significant and unavoidable (SU).” For this section, GEO refers to Soils, Geology, and Seismicity.

For the purposes of this analysis, the proposed project includes the implementation of BRT and Single Car LRT in the Santa Clara-Alum Rock Corridor in two phases. Phase 1 includes the implementation of BRT service and Phase 2 includes the implementation of Single Car LRT service. Potential impacts related to soils, geology, and seismicity associated with Phase 1 and Phase 2 of the proposed project, including project options, would be largely similar. Therefore, the analyses for the two project phases are discussed together. Areas in which the effects of the two phases differ are detailed within the discussion of each significance threshold.

Potential impacts associated with the extension of transit services in the Capitol Expressway Corridor were analyzed in the Capitol Expressway Light Rail Final Supplemental Environmental Impact Report (FSEIR) dated January 2007, which is incorporated herein by reference. Potential impacts of the proposed project not analyzed in the Capitol Expressway Light Rail FSEIR are described below, as necessary.

GEO-1. The proposed project would not expose people or structures to the risk of loss, injury, or death caused by rupture of a known earthquake fault. (LTS)

Based on a comparison of the proposed project with the conditions outlined in the setting portion of this section showing that the project site is about 1.9 miles from the known traces of the nearest zoned active fault (the Hayward Fault), fault-line surface rupture would not be a substantial hazard within the Corridor. Therefore, impacts regarding safety as caused by rupture of a known earthquake fault would be less than significant.

GEO-2. The proposed project would not expose people or structures to the risk of loss, injury, or death caused by unmitigated strong seismic groundshaking. (LTS)

From a review of regional and local geo-seismic conditions, it is apparent that San Jose will be subjected to at least one major earthquake during the life of facilities constructed in the Corridor.²⁸ The design earthquake for the project area is estimated by the United States and California Geological Surveys to be a Mw 7.1 earthquake on the Hayward Fault, creating peak horizontal ground accelerations within the Corridor in excess of 0.6g. The resulting vibration (very strong seismically induced groundshaking) could cause damage to buildings, roads and

²⁸ Working Group on California Earthquake Probabilities, 2003, *op. cit.* The United States Geological Survey projected a 27 percent chance of at least one earthquake greater than Moment Magnitude 6.7 on the Hayward Fault between 2003 and 2032.

infrastructure (primary effects), and could cause ground failures such as liquefaction or settlement in the underlying alluvium (secondary effects).

Structures (such as stations and platforms) in the Corridor would be underlain by alluvial materials that, in their natural state, could respond poorly to loading during seismic ground motion. To reduce the primary and secondary risks associated with seismically induced groundshaking, it is necessary to take the location and type of subsurface materials into consideration when designing foundations and structures in the Corridor.

For this project, VTA has applied the Caltrans Seismic Design Criteria Version 1.2 and Caltrans Highway Design Manual, Section 110.6, Earthquake Consideration. Similarly, bridge design will be in accordance with Caltrans' Bridge Design Specifications, Bridge Memos to Designers, Bridge Design Practices Manual, and Bridge Design Aids Manual. Both phases of the proposed project would adhere to accepted standards ensuring maximum practicable protection for users of building and infrastructure and their associated trenches, slopes, and foundations. Adherence would include:

- the use of CBC or Caltrans Seismic Zone 4 Standards as the minimum seismic-resistant design for all proposed facilities;
- seismic-resistant earthwork and construction design criteria, based on the site-specific recommendations of a California Certified Engineering Geologist in cooperation with the project's California-registered geotechnical and structural engineers;
- an engineering analyses that demonstrates satisfactory performance of manufactured fill or natural unconsolidated sediments where either forms part or all of any foundation support, especially where the possible occurrence of liquefiable soils exists; and
- an analysis of soil expansion potential and appropriate remediation (compaction, removal/replacement, etc.) prior to using any expansive soils for foundation support.

Based on a comparison of the proposed transit improvements with the conditions outlined in the setting section showing that regulatory frameworks exist to address earthquake safety issues, seismically induced groundshaking and ground failure would not be a substantial hazard within the Corridor. Therefore, impacts related to safety during seismic shaking would be less than significant.

GEO-3. The proposed project would not expose people or structures to the risk of loss, injury, or death caused by unmitigated seismic-related ground failure, including liquefaction. (LTS)

The recognition by the State Seismic Hazards Mapping Program and the County Geologic Hazards Maps of the existence of liquefiable alluvium in the vicinity of the Corridor makes it necessary to ensure the soils used for foundation support are sound. Using unsuitable soils would have the potential to create future problems of rail or road settlement and utility line disruption through vertical or lateral movement. When loose soils are re-engineered specifically for stability prior to use, these potential effects can be eliminated. An acceptable degree of soil

stability can be achieved by the required incorporation of soil treatment programs (grouting, compaction, lime mixing, drainage control, etc.) in the excavation and construction plans to address site-specific soil conditions along the alignment. Site-specific analyses of foundation support conditions are required by the California Building Code in areas where unsuitable soil conditions are suspected. Such analyses contain recommendations for ground preparation and earthwork specific to the portion of the alignment being investigated that become an integral part the construction design.

As part of the construction permitting process, the State of California requires completed reports of soil conditions at construction sites to identify potentially unsuitable soil conditions. The evaluations must be conducted by registered soil professionals, and measures to eliminate inappropriate soil conditions must be applied, depending on the soil conditions. The design of foundation support must conform to the analysis and implementation criteria described in the California Building Code, Chapters 16, 18, and A33.

Based on a comparison of the proposed transit developments with the conditions outlined in the setting section showing that a regulatory framework exists to address unsuitable soils unit issues, liquefaction, or similar ground failure would not be substantial hazards within the Corridor. Therefore, impacts regarding safety as caused by unmitigated seismic-related ground failure, including liquefaction, would be less than significant.

GEO-4. The proposed project would not expose people or structures to the risk of loss, injury, or death caused by unmitigated lateral spreading, subsidence, or collapse as a result of underlying unstable geologic units. (LTS)

The presence of compressible soils in the Corridor makes it necessary to ensure the soils used for foundation support are sound. As discussed in GEO-3, the potential for unsuitable soils to create settlement problems for rails, roads, and utility lines through vertical or lateral movement, can be eliminated through soils re-engineering in the excavation and construction along the alignment. As part of the construction permitting process, the California Building Code requires completed reports of soil conditions at construction sites to identify and recommend treatment for potentially unsuitable soil conditions (see discussion in GEO-2 and GEO-3, above).

Based on a comparison of the proposed project with the conditions outlined in the setting section showing that a regulatory framework exists to address unsuitable soils unit issues, compression, settlement, or spreading would not be substantial hazards within the Corridor. In view of these circumstances, the proposed project would have a less-than-significant impact related to underlying unstable geologic units.

GEO-5. The proposed project would not expose people or structures to the risk of loss, injury, or death caused by unmitigated expansive soil. (LTS)

The previously documented existence of expansive soils in the vicinity of the Corridor makes it necessary to ensure the soils used for foundation support are sound. As discussed in GEO-3, the potential for unsuitable soils to create settlement problems for rails, roads, and utility lines through vertical or lateral movement, can be eliminated through soils re-engineering in the excavation and construction along the alignment. As part of the construction permitting process, the California Building Code requires completed reports of soil conditions at construction sites to identify and recommend treatment for potentially unsuitable soil conditions (see discussion in GEO-2 and GEO-3).

Based on a comparison of the proposed project with the conditions outlined in the setting section showing that a regulatory framework exists to address expansive soils conditions, there would not be a substantial hazard within the Corridor. In view of these circumstances, the proposed project would have a less-than-significant impact related to expansive soils.