BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT GEOTECHNICAL MEMORANDUM

PREPARED FOR:

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Federal Transit Administration

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This Geotechnical Memorandum was prepared in 2014 to identify mitigation strategies for the early alternatives and station plans being considered at that time. However, the mitigation measures identified in this memorandum are relevant to the current proposed project and have been incorporated into the SEIS/SEIR as appropriate.

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Project Description

The Phase II Project consists of an approximately six-mile extension of the BART system from the terminus of VTA's BART Silicon Valley—Berryessa Extension Project (Phase I) from San Jose to Santa Clara (see Figure 1). Phase I is currently under construction and scheduled to be operational in late 2017. The Phase II Project would include approximately five miles of subway tunnel from Berryessa Station, continuing through downtown San Jose, and terminating at grade near the Santa Clara Caltrain Station (see Figure 2). In addition, four passenger stations are proposed. Passenger service on the Phase II Project is scheduled to begin in 2025/2026.

There are two construction methods proposed for the five-mile-long tunnel portion of the BART extension—the Twin-Bore and Single-Bore Options—between the East and West Tunnel Portals. Under the Twin-Bore Option, two twin-bore tunnels would be excavated with one track in each. Each tunnel bore would have an outer diameter of approximately 20 feet. The depth of the tunnel would be between 10 and 75 feet below ground surface. The crown, or top, of the tunnel of the Twin-Bore Option would be, on average, 40 feet below the surface. Under the Single-Bore Option, one large-diameter tunnel bore would be excavated which would contain both northbound and southbound tracks. The tunnel bore would have an outer diameter of approximately 45 feet. The crown, or top, of the tunnel of the Single-Bore Option would be, on average, 70 feet below the surface.

1.1 Alignment and Station Features by City

1.1.1 City of San Jose

1.1.1.1 Connection to Phase I Berryessa Extension

The BART extension would begin where the Phase I tail tracks end. The at-grade Phase I tail tracks would be partially removed to allow for construction of the bored tunnels, East Tunnel Portal, and supporting facilities.

The alignment would transition from a retained-fill configuration east of U.S. 101 and south of Mabury Road near the end of the Phase I alignment into a retained-cut configuration and enter the East Tunnel Portal just north of Las Plumas Avenue.

South of the portal, the alignment would pass beneath North Marburg Way, then approximately 25 feet below the creek bed of Lower Silver Creek for the Twin-Bore Option, or approximately 30 feet for the Single-Bore Option, just to the east of U.S. 101, then curve under U.S. 101 south of the McKee Road overpass, and enter Alum Rock/28th Street Station.

1.1.1.2 Alum Rock/28th Street Station

Alum Rock/28th Street Station would be located between U.S. 101 and North 28th Street and between McKee Road and Santa Clara Street. The station would be underground with street-level entrance portals with elevators, escalators, and stairs covered by canopy structures. In general, each station would have a minimum of two entrances. A parking structure of up to seven levels would accommodate BART park-and-ride demand with 1,200 parking spaces. The station would include systems facilities both above and below ground.

From Alum Rock/28th Street Station, the alignment would curve under North 28th Street, North 27th Street, and North 26th Street before aligning under Santa Clara Street. The alignment would continue under the Santa Clara Street right-of-way (ROW) until the alignment approaches Coyote Creek.

1.1.1.3 Tunnel Alignment near Coyote Creek

For the Twin-Bore Option, the alignment would transition north of Santa Clara Street beginning just west of 22nd Street and pass approximately 20 feet beneath the creekbed of Coyote Creek to the north of Santa Clara Street and avoid the Coyote Creek/Santa Clara Street bridge foundations. The alignment would transition back into the Santa Clara Street ROW near 13th Street, west of Coyote Creek. However, for the Single-Bore Option, the alignment would continue directly under Santa Clara Street and pass approximately 55 feet beneath the creekbed of Coyote Creek and approximately 20 feet below the existing bridge foundations.

1.1.1.4 13th Street Ventilation Structure

A systems facility site would be located at the northwest corner of Santa Clara and 13th Streets. This site would include a tunnel ventilation structure, which would be an aboveground structure with an associated ventilation shaft.

1.1.1.5 Downtown San Jose Station

There are two station location options for the Downtown San Jose Station: the Downtown San Jose Station East Option and the Downtown San Jose Station West Option, as described in detail below. The alignment for this area would be the same irrespective of the station option.

The station would consist of boarding platform levels and systems facilities aboveground and within the tunnel beneath Santa Clara Street, as well as entrances at street level. In general, each station would have a minimum of two entrances. Elevators, escalators, and stairs that provide pedestrian access to the mezzanine would be at station portal entrances. Escalators and stairs would be covered by canopy structures. The station would not have dedicated park-and-ride facilities. Under either Downtown San Jose Station Option, streetscape improvements, guided by San Jose's Master Streetscape Plan, would be provided along Santa Clara Street to create a pedestrian corridor. For the East Option, streetscape improvements would be between 7th and 1st Streets; for the West Option, streetscape improvements would be between 4th and Market Streets.

Downtown San Jose Station East Option

The alignment would continue beneath Santa Clara Street to the Downtown San Jose Station East Option. Under the Twin-Bore Option, crossover tracks would be located east of the Downtown San Jose Station between 7th and 5th Streets (within the cut-and-cover box). Under the Single-Bore Option, the crossover tracks would be located east of the station between 9th and 5th Streets.

Downtown San Jose Station West Option

The alignment would continue beneath Santa Clara Street to the Downtown San Jose Station West Option. Crossover tracks for the Twin-Bore Option would be located east of the Downtown San Jose Station between 2nd and 4th Streets (within the cut-and-cover box). Under the Single-Bore Option, the crossover tracks would be located east of the station between 7th and 2nd Streets.

1.1.1.6 Tunnel Alignment into Diridon Station

There are two station location options at Diridon Station: the Diridon Station South Option and the Diridon Station North Option, as described in detail below. The alignment into Diridon Station varies between the North and South Options and between the Twin-Bore and Single-Bore Tunnel Options as described below.

Tunnel Alignment into Diridon Station South Option

The alignment would continue beneath Santa Clara Street from the Downtown San Jose Station and shift south beginning just west of South Alamaden Boulevard to pass between the SR 87 bridge foundations. For the Twin-Bore Option, the alignment would pass 40 feet below the riverbed of the Guadalupe River and a retaining wall west of the river, and over 20 feet below the creekbed of Los Gatos Creek. For the Single-Bore Option, the alignment would pass 50 feet below the riverbed of the Guadalupe River, the retaining wall, and the creekbed of Los Gatos Creek. After passing under Los Gatos Creek, the alignment for both options would enter the Diridon Station between Los Gatos Creek and Autumn Street.

Tunnel Alignment east of Diridon Station North Option

Under the Twin-Bore Option, the alignment would continue beneath Santa Clara Street from the Downtown San Jose Station and shift south beginning just west of South Almaden Boulevard to pass between the SR 87 bridge foundations. The alignment would then pass 45 feet below the riverbed of the Guadalupe River and a retaining wall, then veer back north to a location just south of and adjacent to Santa Clara Street. The alignment passes 25 feet below the creekbed of Los Gatos Creek. After passing under Los Gatos Creek, the alignment would enter Diridon Station under Autumn Street and directly south of Santa Clara Street. The

Diridon Station North Option is closer to Santa Clara Street in comparison to the South Option.

Under the Single-Bore Option, the alignment would continue beneath Santa Clara Street, continue 50 feet below the riverbed of the Guadalupe River and 50 feet below the creekbed of Los Gatos Creek. After passing under Los Gatos Creek, the alignment would shift north and enter Diridon Station between Autumn and Montgomery Streets, directly south of Santa Clara Street. The Diridon Station North Option is closer to Santa Clara Street in comparison to the South Option.

1.1.1.7 Diridon Station

There are two station location options for the Diridon Station: the Diridon Station South Option and the Diridon Station North Option. The alignment varies by station location. Diridon Station would be generally located between Los Gatos Creek to the east, the San Jose Diridon Caltrain Station to the west, Santa Clara Street to the north, and West San Fernando Street to the south. The South Option would be located midway between Santa Clara Street and Stover Street. The North Option would be located adjacent to, and just south of, Santa Clara Street.

The station would consist of a boarding platform level, a mezzanine level, and entrances at street-level portals. The station would have a minimum of two entrances. Entrances would have elevators, escalators, and stairs covered by canopy structures. Systems facilities would be located aboveground and underground at each end of the station.

An existing VTA bus transit center would be reconfigured for better access and circulation to accommodate projected bus and shuttle transfers to and from the BART station. Kiss-and-ride facilities would be located along Cahill Street. No park-and-ride parking would be provided at this station.

Tunnel Alignment West of Diridon Station North Option

For the South Option, west of the station, the alignment for both the Twin-Bore and Single-Bore Options would continue beneath the Diridon Caltrain Station train tracks and White Street. The alignment would then turn towards the north, crossing under The Alameda at Cleaves Avenue and under West Julian Street at Morrison Avenue before aligning under Stockton Avenue.

Under the Diridon Station North Option and Twin-Bore Option, west of the station, the alignment would continue beneath the Diridon Caltrain Station train tracks and White Street. The alignment would then turn towards the north, crossing under The Alameda at Wilson Avenue and under West Julian Street at Cleaves Street before aligning under Stockton Avenue.

Under the Diridon Station North Option and Single-Bore Option, west of the station, the alignment would continue under White and Bush Streets south of The Alameda. The alignment would then turn towards the north, crossing under The Alameda at Sunol Street and under West Julian Street at Morrison Avenue before aligning under Stockton Avenue.

1.1.1.8 Tunnel Alignment along Stockton Avenue

Around Pershing Avenue, all of the options—the Twin-Bore and Single-Bore Options and the Diridon Station South and North Options—converge back onto the same alignment under Stockton Avenue.

1.1.1.9 Stockton Avenue Ventilation Structure

On the east side of Stockton Avenue between Schiele Avenue and West Taylor Street, there are three alternate locations for a systems facility site that would house a tunnel ventilation structure, which would be an aboveground structure with an associated ventilation shaft.

1.1.1.10 Tunnel Alignment near I-880

The alignment would continue north and cross under the Caltrain tracks and Hedding Street. The alignment would continue on the east side of the Caltrain tracks and cross under Interstate (I-) 880 before ascending and exiting the West Tunnel Portal near Newhall Street.

1.1.2 City of Santa Clara

The BART Extension Alternative in Santa Clara would consist of the Newhall Maintenance Facility, system facilities, storage tracks for approximately 200 BART revenue vehicles (passenger cars), the Santa Clara Station, and tail track. The San Jose/Santa Clara boundary is located approximately midway through the Newhall Maintenance Facility.

1.1.2.1 Newhall Maintenance Facility

The Newhall Maintenance Facility would begin north of the West Tunnel Portal at Newhall Street in San Jose and extend to Brokaw Road near the Santa Clara Station in Santa Clara. A single tail track would extend north from the Santa Clara Station and cross under the De La Cruz Boulevard overpass and terminate on the north side of the overpass. The maintenance facility would serve two purposes: (1) general maintenance, running repairs, and storage of up to 200 BART revenue vehicles and (2) general maintenance of non-revenue vehicles. The facility would also include maintenance and engineering offices and a yard control tower. Several buildings and numerous transfer and storage tracks would be constructed.

1.1.2.2 Santa Clara Station

The closest streets to the Santa Clara Station would be El Camino Real to the southwest, De La Cruz Boulevard to the northwest, and Coleman Avenue to the northeast near the intersection of Brokaw Road. The station would be at grade, centered at the west end of Brokaw Road, and would contain an at-grade boarding platform with a mezzanine one level below. Access to the mezzanine would be provided via elevators, escalators, and stairs covered by canopy structures. An approximately 240-foot-long pedestrian tunnel would connect from the mezzanine level of the BART station to the Santa Clara Caltrain plaza, and an approximately 175-foot-long pedestrian tunnel would connect from the mezzanine level to a new BART plaza near Brokaw Road. Kiss-and-ride, bus, and shuttle loading areas would be provided on Brokaw Road.

A parking structure of up to five levels would be located north of Brokaw Road and east of the Caltrain tracks within the station area and would accommodate 500 BART park-and-ride parking spaces in addition to public facilities on the site.

An approximately 150-foot-high radio tower and an associated equipment shelter would be located within the systems site.

1.2 VTA's Transit-Oriented Joint Development (CEQA Only)

VTA is proposing to construct Transit-Oriented Joint Development (TOJD) with office, retail, and residential land uses at the four BART stations (Alum Rock/28th Street, Downtown San Jose, Diridon, and Santa Clara), which offers the benefit of encouraging transit ridership. VTA is also proposing to construct TOJD at two mid-tunnel ventilation structure locations (the northwest corner of Santa Clara and 13th Streets and east of Stockton Avenue south of Taylor Street). VTA's primary objective for the proposed TOJD is to encourage transit ridership and support land use development patterns that make the most efficient and feasible use of existing infrastructure and public services while promoting a sense of community as envisioned by the San Jose and Santa Clara General Plans and relevant adopted specific plans. Estimates for VTA's TOJD at the station sites and at the mid-tunnel ventilation structure locations are provided below and are based on current San Jose and Santa Clara general plans, approved area plans, the existing groundwater table constraints, and market conditions.

Table 1 summarizes the land uses at each proposed TOJD location. The number of parking spaces is based on meeting the Cities of San Jose and Santa Clara parking requirements.

Table 1: Summary of Proposed TOJD

Location	Residential (dwelling units)	Retail (square feet)	Office (square feet)	Parking (spaces)
Alum Rock/28th Street Station	275	20,000	500,000	2,150
Santa Clara and 13th Streets Ventilation Structure	N/A	13,000	N/A	N/A
Downtown San Jose Station – East Option (at 3 sites)	N/A	160,000	303,000	1,398
Downtown San Jose Station – West Option	N/A	10,000	35,000	128
Diridon Station South Option	N/A	72,000	640,000	400
Diridon Station North Option	N/A	72,000	640,000	400
Stockton Ventilation Structure	N/A	15,000	N/A	N/A
Santa Clara Station	220	30,000	500,000	2,200

Chapter 2
Previous Studies Conducted

2.1 Previous Studies Conducted

The following documents from the previous studies that had been conducted were referred in the preparation of this geotechnical memorandum.

a) Silicon Valley Rapid Transit Project Stations Segment Geotechnical and Seismic Design Criteria Report for Parking Garages and Ancillary Facilities Final Volume 1 – Geotechnical
b) Silicon Valley Rapid Transit Project Stations Segment Geotechnical and Seismic Design Criteria Report for Parking Garages and Ancillary Facilities Final Volume 2 – Seismic
c) Silicon Valley Rapid Transit Project Tunnel Segment Geotechnical Data Report Volume I of VI
d) Silicon Valley Rapid Transit Project Tunnel Segment Geotechnical Data Report Volume III of VI
e) Silicon Valley Rapid Transit Project Geotechnical Report Yards & Shops Segment Draft
f) Geotechnical Data Report – Phase Two 65% Engineering Design Investigation (December 16, 2008)
g) Silicon Valley Rapid Transit Corridor Volume 1 Final Environmental Impact Statement and 4(f) Evaluation (March 2010).
h) BART Silicon Valley Santa Clara Extension Supplemental EIS/EIR (9-10-2013).
i) Earth Tech, Inc., Geotechnical Exploration Findings and Recommendations Report.
j) Geomatrix Consultants; 2004; Summary Discussion of Silver Creek Fault (Version 1.0A). Southwest San Francisco Bay Area, California; consultant report prepared for Valley Transit Authority; Project No. 8679.

Chapter 3
Environmental and Regulatory Setting

3.1 Geology and Seismicity

This section describes the regional and local geology along the SVSX corridor and the susceptibility of subsurface soils to seismically induced hazards. The SVSX corridor includes the entire 6-mile alignment from the Berryessa BART Station to the planned Santa Clara BART Station and runs through portions of the cities of San Jose, and Santa Clara. Regional and local geologic faults and past and probable future seismic activity are addressed.

3.1.1 Methodology for Identifying Existing Conditions

Information about the geologic/seismic conditions and liquefaction potential along the SVSX corridor is based on the *Geotechnical Exploration Findings and Recommendations Report* (Earth Tech, Inc., 2003) as well as additional geotechnical and seismic reports prepared during the Conceptual and Preliminary Engineering design phases of the Silicon Valley Rapid Transit Project. These studies evaluated general subsurface conditions and seismicity, engineering properties related to subsurface soil conditions, and provided preliminary geotechnical recommendations for the Silicon Valley Rapid Transit Project.

To evaluate the geologic conditions, geologic publications and other published reports were reviewed and subsurface exploration was conducted. For the tunnel alignment of the Silicon Valley Rapid Transit Project, 76 geotechnical borings were drilled. Out of these borings, 20 borings were drilled at three proposed underground stations (Alum Rock, Downtown San Jose, and Diridon/Arena), 53 borings along the tunnel alignment, and 3 borings at the portals. In addition, 146 Cone Penetrometer Tests (CPTs) were performed along the tunnel alignment, including 38 CPTs at the three proposed underground stations. The sampling depths for the borings and CPTs ranged from near surface to up to approximately 220 feet below ground surface. For the Newhall Yard and Shops Facility, 32 geotechnical borings and 35 CPTs were drilled or pushed. The sampling depths for the borings and CPTs ranged from 20 to 81 feet below ground surface. (No borings were drilled or CPTs performed at the two alternate station locations at 23rd Street and Diridon West.)

3.1.2 Geology and Soils

The proposed SVSX corridor is located in the Santa Clara Valley, which extends southeastward from San Francisco Bay and is one of many northwest/southeast-trending valleys situated between mountain ranges within the Coast Ranges Geomorphic Province of Northern California. The Santa Clara Valley is an alluvium-filled basin located between the Santa Cruz Mountains to the southwest and the Diablo Range to the northeast. The valley is covered by alluvial fan, levee, and active stream channel deposits with marine estuary deposits located along the Bay margins. These unconsolidated deposits cover Tertiary through Cretaceous age bedrock. The SVSX corridor is located in an area of the valley where the ground surface is very level and there are no large steep slopes.

According to the Map of Quaternary Deposits in the San Francisco Bay Region by Witter et al. (2006), the proposed SVSX corridor is underlain by a variety of alluvial deposits. The alluvium has been identified as Holocene age alluvial fan deposits (Qf & Qhf), fine-grained Holocene alluvial fan deposits (Qhff), Holocene alluvial fan levee deposits (Qhl), Holocene Stream Channel Deposits (Qhc), and Historic Artificial Channel Deposits (ac). Fine-grained Holocene alluvial fan deposits (Qhff) occur on the flatter distal portions of fans and consist primarily of silt and clay-rich sediments with interbedded layers of coarser sand and occasional gravel. The Holocene alluvial fan levee deposits (Qhl) consist of silt, sand, and clay. Artificial fill may be present over any of the Holocene age deposits along the SVSX corridor. Areas within the SVSX corridor with other soil conditions such as expansive or compressible soils will be identified by detailed geotechnical investigation during the design phase.

The bedrock buried at great depth beneath the SVSX corridor is presumed to be the Franciscan Complex of the upper Jurassic to Cretaceous age. The Franciscan Complex bedrock is overlain by thick (over 1000 feet) deposit of Tertiary marine/non-marine sediments and by Pleistocene to Recent deposits. Therefore, the Franciscan Complex bedrock is at much greater depth than will be encountered during the construction of the SVSX corridor.

The following sections describe the extent of the various Quaternary Deposits mapped by Witter et al. (2006) beneath the different options for alignments and station locations. Figure 3A shows the project alignments and proposed stations locations on the Quaternary Deposits Map.

Eastern Station Option 1: Alum Rock Alignment and Station

The northern part of the Alum Rock Alignment (for the first 900 feet south of its connection with the southern terminus of the SVBX) is mapped as underlain by Holocene Alluvial Fan Levee Deposits (map symbol “Qhl”) described as:

“Natural levee deposits of alluvial fans are formed by streams that overtop their banks and deposit sediment adjacent to the channel. Mapping of these deposits is based on interpretation of topography; levees are identified as long, low ridges oriented down fan. They contain coarser material than adjoining inter-levee areas, especially adjacent to creek banks where the coarsest material is deposited during floods. Levee deposits are loose, moderately to well-sorted sand, silt and clay.”

Holocene Alluvial Fan Deposits, Fine Facies (map symbol “Qhff”) are mapped at the eastern edge of the Holocene Alluvial Fan Levee Deposits beneath the Alum Rock Alignment and Alum Rock Station site. Holocene Alluvial Fan Levee Deposits are described as:

“Fine-grained alluvial fan and flood plain over bank deposits laid down in very gently sloping portions of the alluvial fan or valley floor. Slopes in these distal alluvial fan areas are generally less than or equal to 0.5 degrees, soils are clay rich, and ground water is within 3 meters of the surface. Deposits are dominated by clay and silt, with interbedded lobes of coarser alluvium (sand and occasional gravel). Deposits of coarse material within these fine-grained materials are elongated in the down fan or down valley direction. These lobes are potential conduits for ground water flow. The surface contact with relatively coarser facies, fan (Qhf) and levee (Qhl), is both gradational and inter-fingering.”

Approximately 1000 feet south of the beginning point (the SVBX/SVSX connection), the Alum Rock Alignment crosses a relatively narrow (less than 100 feet wide) channel which Witter et al. (2006) mapped as Artificial Stream Channel (historic) (map symbol “ac”) and are described as:

“Modified stream channels including straightened or realigned channels, flood control channels, and concrete canals. In most cases, artificial channels were differentiated from natural channels by interpretation of 7.5-minute topographic quadrangles. Additionally, field inspection and interpretation of aerial photographs were used to identify artificial channels. Deposits within artificial channels can range from almost none in some concrete canals, to significant thicknesses of loose, unconsolidated sand, gravel and cobbles, similar to deposits of modern stream channel deposits (Qhc).”

The Alum Rock Station site is mapped as underlain by Holocene Alluvial Fan Deposits, Fine Facies (map symbol "Qhff") which are described above. The remainder of the Alum Rock Alignment is on Qhff until it crosses back onto Holocene Alluvial Fan Levee Deposits ("Qhl" described above) on the west side of North 26th Street.

The Alum Rock Alignment is mapped as underlain by Qhl (described above) for approximately 3800 feet with the exception of a relatively narrow stream channel (140 feet wide, located just east of 17th Street) mapped as Historic Stream Channel Deposits (map symbol "Qhc") and described as:

"Fluvial deposits within active, natural stream channels. Materials consist of loose, unconsolidated, poorly to well sorted sand, gravel and cobbles, with minor silt and clay. These deposits are reworked by frequent flooding and exhibit no soil development. These deposits, like most other alluvial deposits, fine downstream (i.e. sediment is coarser upstream). Mapping of modern stream channels is based on topographic map inspection augmented, in places, by interpretation of aerial photography or orthophoto quadrangles. Where available, early twentieth century (1914-1916) topographic maps were reviewed to evaluate whether stream channels shown on recent 7.5-minute maps have been altered since the early twentieth century. If the channels appear on recent maps as unchanged since the earlier maps, the channel and its banks were mapped as modern stream channel deposits. Contacts generally are shown near the top of the bank on either side of the channel, although the deposits actually lie near the bottom of the channel."

However, this segment of track will be inside a tunnel located approximately 50 feet below the ground surface, thereby passing under the stream channel deposits.

From southwest of 14th Street to northeast of 3rd Street, the Alum Rock Alignment along the Santa Clara Street is mapped as underlain by Holocene Alluvial Fan Deposits (map symbol "Qhf") described as:

"Sediment deposited by streams emanating from mountain canyons onto alluvial valley floors or alluvial plains, including debris flow, hyper-concentrated mudflow, and braided stream deposits. Alluvial fan sediment includes sand, gravel, silt, and clay, and is moderately to poorly sorted, and moderately to poorly-bedded. Sediment clast size and general particle size typically decreases down slope from the fan apex. Many Holocene alluvial fans exhibit levee/inter-levee topography, particularly the fans associated with creeks flowing west from the East Bay hills [see Holocene alluvial fan levee deposits (Qhl) below]. Alluvial fan surfaces are steepest near their apex at the valley mouth, and slope gently basin ward, typically with gradually decreasing gradient. Alluvial fan deposits are identified primarily on the basis of fan morphology and topographic expression. Holocene alluvial fans are relatively undissected when compared to older alluvial fans. In places, Holocene deposits may be only a thin veneer over Pleistocene deposits."

Eastern Station Option 2: 23rd Street Alignment and Station

The 23rd Street Alignment begins at the SVBX/SVSX connection point and proceeds southeast on Holocene Alluvial Fan Levee Deposits ("Qhl" described above) until just south of McKee Road where is crosses onto Holocene Alluvial Fan Deposits, Fine Facies ("Qhff" described above). Half way between North 27th and North 26th Streets, the alignment crosses back onto Holocene Alluvial Fan Levee Deposits ("Qhl" described above).

The 23rd Street Station site is mapped as underlain by Holocene Alluvial Fan Levee Deposits ("Qhl" described above).

From southwest of 14th Street to northeast of 3rd Street, the 23rd Street Alignment along the Santa Clara Street is mapped as underlain by Holocene Alluvial Fan Deposits ("Qhf" described above).

Downtown San Jose Station

The Downtown Alignment and Station are mapped as underlain by Holocene Alluvial Fan Deposits ("Qhf" described above).

Diridon Station Option 1: Diridon East Alignment and Station

With the exception of the Guadalupe River, Los Gatos Creek and southwest of Almaden Boulevard to Schiele Avenue, the Diridon East Alignment and Station are mapped as underlain by Holocene Alluvial Fan Deposits ("Qhf" described above). The river and creek channels are mapped as Historic Stream Channel Deposits ("Qhc" described above).

Northwest of Schiele Avenue, the Diridon East Alignment and Station are mapped as underlain by Holocene Alluvial Fan Levee Deposits ("Qhl" described above).

Diridon Station Option 2: Diridon West Alignment and Station (Stockton)

Southeast of Almaden Boulevard to Schiele Avenue, the Diridon West Alignment and Station are mapped as underlain by Holocene Alluvial Fan Deposits ("Qhf" described above).

Northwest of Schiele Avenue to between Asbury and Emory Streets, the Diridon West Alignment is mapped as underlain by Holocene Alluvial Fan Levee Deposits ("Qhl" described above).

From between Asbury and Emory Streets to Newhall Street, the Diridon West Alignment is mapped as underlain by Holocene Alluvial Fan Deposits ("Qhf" described above).

Newhall Yard and Shops Facility and Santa Clara Station

Northwest of Newhall Street to the intersection of Campbell Avenue and El Camino Real, the remaining SVSX corridor and most of the Newhall Yard and Shops Facility are mapped as underlain by Holocene Alluvial Fan Deposits, Fine Facies ("Qhff" described above).

3.1.3 Seismicity

The SVSX corridor lies between the active San Andreas Fault to the west and the Hayward and Calaveras faults to the east. It is located within one of the most seismically active regions in the world. The San Andreas Fault system marks the tectonic boundary between the Pacific and North American plates. Motion across the plate boundary is accommodated on a number of faults. Based on Section 4.7.3 Seismicity of "Silicon Valley Rapid Transit Corridor Final EIS", Table 2 provides a listing of the some of the major faults in the region along with information on their location and past and probable future seismic activity, including 2002 data from the Working Group on California Earthquake Probabilities.

The Hayward and San Andreas faults have the highest slip rates and are the most active of all the faults in the Bay Area. Based on the information depicted in Figures 3A and 3B, the Hayward Fault is the closest known active fault to the SVSX corridor and was the source of an 1868 Magnitude 7 Earthquake. The San Andreas Fault, the longest active fault in California, was the source of the San Francisco 1906 Magnitude 7.9 Earthquake and the 1989 magnitude 7.1 (Loma Prieta) Earthquake and passes within 16.9 kilometers southwest the SVRT Corridor. The Calaveras Fault, a main component of the San Andreas Fault

System, produced earthquakes of magnitude 5.9 in 1979 and 6.2 in 1984 and passes within approximately 5.2 kilometers northeast of the alternatives' alignments.

Other active faults in the San Francisco Bay Region that are capable of producing large magnitude earthquakes are the San Gregorio, Rodgers Creek, Hayward Southeast Extension, Sargent, Concord-Green Valley, Ortigalita, Silver Creek, and Greenville Fault zones along with the faults of the Foothills thrust belt. All of these faults are located within 40 miles of the SVSX corridor.

The Silver Creek Fault has been mapped through the San Jose area based upon seismic refraction profiling, gravity data, and interferometric synthetic aperture radar (InSAR) data. Currently, there is no direct evidence to that proves the fault is a potential source of future earthquakes. However, a sag in the upper 300 meters of alluvial sediments directly above a Silver Creek Fault in the Franciscan bedrock at a depth of over 1000 meters below the ground surface suggests ground surface deformation may have occurred during the Holocene. (Wentworth et al; 2010).

TABLE 2 – FAULTS IN THE VICINITY OF THE SVSX CORRIDOR

Fault/Thrusts	Location and Description	Seismic Activity
Hayward Fault	Closest active fault to the corridor. Extends 100 km from the area of Mount Misery in San Jose to Point Pinole on San Pablo Bay.	Last major earthquake occurred in October 1868 and had a Richter magnitude of 7. Capable of generating a maximum credible earthquake (MCE) of moment magnitude (Mw) 7.1 (Working Group on California Earthquake Probabilities [WGCEP], 2002).
Hayward Southeast Extension	Sequence of southwest–verging, reverse faults, located in the restraining left-step between the Calaveras and Hayward Fault	Capable of creating a MCE of Mw 6.7, with a recurrence interval of 292 years (WGCEP, 2002).
Roger Creek Fault	44 km. long, northern continuation of Hayward Fault.	Most likely source of the next Mw 6.7 or larger earthquake in the Bay Area, with 27 percent probability of occurring in the time period 2002 to 2031 (WGCEP, 2002).
Calaveras Fault	Main component of the San Andreas system, branching off the main San Andreas Fault south of Hollister, extending northwards for approximately 120 km and ending in the area of Danville.	Generated a number of moderate-size earthquakes in historic time, including the 1979 local magnitude (ML) 5.9 Coyote Lake and 1984 ML 6.2 Morgan Hill events. WGCEP (2002) suggests that the probability of one earthquake with mean magnitude from M 5.8 o M 6.9 occurring in 2002-2031 is 59 percent.
Foothills Thrust Belt	Sequence of southwest dipping thrusts, bounded by the San Andreas Fault to the west. From north to south, the main mapped thrust faults include the Stanford, Pulgas, Monte Vista, Shannon, Berrocal, Sierra Azul, and Sargent faults.	Active faults, capable of generating a MCE of Mw 6.8 (Fenton and Hitchcock, 2001).
San Andreas Fault	Extends from the Gulf of California, Mexico, to Point Delgado on the Mendocino Coast in Northern California, a total distance of 1,200 km.	Largest active fault in California, responsible for the largest earthquake in California, the 1906 Mw 7.9 San Francisco earthquake. Assigned a recurrence interval of 378 years to a Mw 7.9 1906-type event (WGCEP, 2002).
San Gregorio Fault	Principal active fault west of the San Andreas Fault in the coastal region of Central California.	WGCEP (2002) assigns an MCE of Mw 7.4 for an earthquake rupturing the entire length of the fault
Silver Creek Fault	Generally a north-northwest trending oblique-reverse-slip fault that externs over a distance of about 50 to 70 km, sub-parallel to and west of the Hayward and Calaveras fault zone (Fenton and Hitchcock, 2001). Southern reach is exposed while northern reach is buried beneath undisturbed Quaternary Sediments. (Geomatrix, 2004; HMM/Bechtel, 2005).	Maximum magnitude distribution for the faults is in the range of 6.3 to 6.9 (HMM/Bechtel, 2005). The potential for fault rupture to occur along northern reach is undetermined. Only the northern reach is located in the SVRTC. (Wentworth et al., 2010)

Source: Section 4.7.1 Seismicity of “Silicon Valley Rapid Transit Corridor Final EIS”.

3.2 Regulatory Setting

Majority of the area in California is seismically active. There are several state regulations that work together to identify seismic hazard zones and establish guidelines for site development and building in different seismic zones. Additionally, the general plans of the cities of San Jose, and Santa Clara contain seismic safety policies.

3.2.1 Alquist-Priolo Earthquake Fault Zoning Act

Pursuant to provisions of the "Alquist-Priolo Earthquake Fault Zoning Act" (Public Resources Code, Division 2, Chapter 7.5), the California State Geologist delineates "Earthquake Fault Zones" on maps around faults that are known to be "sufficiently active and well-defined." The State defines an "active fault" as one for which there is evidence that it has ruptured the ground surface within the last 11,000 years. The purpose of the Act is to regulate development on or near active fault traces in order to reduce the hazard of fault rupture by requiring geologic investigations be conducted prior to approval of such development and prohibiting the construction of new structures intended for human occupancy across the surface traces of an active fault Section 2621.5). The Act addresses only the hazard of surface fault rupture; it does not address other earthquake hazards such as earthquake-induced landslides, ground shaking, and liquefaction.

The Silicon Valley Rapid Transit Project does not propose construction within any "Alquist-Priolo Earthquake Fault Zones". Although the northernmost portion of the "Silicon Valley Rapid Transit Corridor" is approximately 1.3 kilometers from the "Earthquake Fault Zone" around the Hayward Fault Southeast Extension, that is not close enough to pose a significant surface rupture hazard to the project.

Wentworth et al (2010) mapped the Silver Creek Fault as the fault passing beneath the project alignment in general and the 23rd Street Station alternate in specific. However, the State Geologist has not delineated an "Earthquake Fault Zone" around the Silver Creek Fault. The last evaluation of the Silver Creek Fault conducted by the State Geologist's office was done in 1981 (Bryant; FER-106); the report recommended that the northern portion of the Silver Creek Fault not to be zoned. The "Revised Earthquake Fault Zone Maps" for the San Jose East Quadrangle (released in 1982) does not show a zone along the northern portion of the Silver Creek Fault and there is no "Earthquake Fault Zone Map" for the San Jose West Quadrangle. Therefore, the project will not be subject to the requirements of the "Alquist-Priolo Earthquake Fault Zoning Act".

3.2.2 Seismic Hazards Mapping Act

Pursuant to provisions of the Seismic Hazards Mapping Act (Public Resources Code, Division 2, Chapter 7.8), the State Geologist delineates “Seismic Hazard Zones” on maps that identify areas potentially susceptible to earthquake-induced landslides or liquefaction. A project proposed to be located within a “State Seismic Hazard Zone” must have the seismic hazard potential evaluated by site-specific studies and standard analysis procedures to identify ways to reduce the hazards, as necessary.

All of the SVSX corridor alignment and proposed stations are located within a State “Seismic Hazard Zone of Required Investigation of Potential Liquefaction”, which is defined as an:

“Area where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693c would be required.”

Therefore, the potential for liquefaction to occur and cause ground surface deformation beneath the proposed SVSX corridor must be evaluated prior to project approval.

None of the project is located within a State “Seismic Zone of Required Investigation of Potential Earthquake-induced Landsliding.”

3.2.3 California Building Code

The California Building Code is contained in the California Code of Regulations, Title 24, Part 2, which is a portion of the California Building Standards Code, and includes design and construction requirements related to fire, life safety, and structural safety. The California Building Code incorporates the Uniform Building Code (a widely adopted model building code in the United States) by reference, and includes necessary California amendments. These amendments include criteria for seismic design. The proposed SVSX corridor would be built according to California Building Code specifications for seismic safety.

3.2.4 City of San Jose General Plan Hazards Chapter

The hazards chapter of the San Jose General Plan provides policies to minimize risk through design and mitigation. As noted below, geotechnical studies are required for the development of proposals. Geotechnical studies for the project area that assess seismic and geologic hazards associated with the Silicon Valley Rapid Transit Project are discussed at the beginning of this section. They will continue to be prepared during final engineering to ensure adequate design and hazard mitigation.

Soils and Geologic Conditions Goal:

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

Soils and Geologic Conditions Policy 6:

Development in areas subject to soils and geologic hazards should incorporate adequate mitigation measures.

3.2.5 City of Santa Clara General Plan

The City of Santa Clara's General Plan recognizes seismic hazards and provides policies to address safety for earthquake activity and geologic conditions. In addition, the City of Santa Clara has adopted the California Building Code with local amendments, which is implemented and enforced by the City of Santa Clara's Building Inspection Division. The Building Code includes provisions to address appropriate design and construction in seismically active areas. It also includes provisions to ensure that the foundation and building design is appropriate to site soil conditions.

The City of Santa Clara's General Plan includes the following policies with respect to seismic hazards:

5.10.5-P5 Regulates development, including remodeling or structural rehabilitation, to ensure adequate mitigation of safety hazards, including flooding, seismic, erosion, liquefaction and subsidence dangers.

5.10.5-P6 Requires that new development is designed to meet current safety standards and implement appropriate building codes to reduce risks associated with geologic conditions.

5.10.5-P7 Implements all recommendations and design solutions identified in project soils reports to reduce potential adverse effects associated with unstable soils or seismic hazards.

Chapter 4
Operational and Construction Impacts

4.1 Operational Impacts

Potential seismic hazards may arise from three sources: surface fault rupture, ground shaking and liquefaction.

4.1.1 Surface Fault Rupture

SVSX Corridor

Where the plane of an active fault intersects the ground surface there is a potential for future fault rupture to displace man-made structures that straddle the fault trace. The magnitude and sense of displacement will be a function of the length of the fault involved in the release of seismically accumulated strain and other local factors.

There are no known active faults crossing the SVSX corridor and it is not located within an “Earthquake Fault Zone” as defined and mapped under the “Alquist-Priolo Earthquake Fault Zoning Act”. Therefore, geologic investigation of potential surface fault rupture is not required under the provisions of the act. However, the potential for surface rupture to occur along the Silver Creek Fault, which has been mapped as passing beneath the project, has not been determined. Based upon the recent findings of Wentworth et al (2010), there may be potential for surface deformation related to fault displacement to occur above the buried Silver Creek Fault. A detailed discussion of the evidence used by Wentworth and other to map the Silver Creek Fault as crossing beneath the SVSX corridor is included in Appendix A.

Eastern Station Option 2: 23rd Street Alignment and Station

No known-to-be active or potentially active faults have been mapped through or in close proximity to the 23rd Street Station alternate. However, the Silver Creek Fault has been mapped directly beneath the 23rd Street Station and its level of activity has not been determined. Therefore, the potential for surface fault rupture to occur at the 23rd Street Station is unknown. There is no direct evidence that proves there has been Holocene surface fault rupture along the mapped trace of the Silver Creek Fault. However, there is a possibility that, if the Silver Creek Fault is capable of displacement along the buried bedrock surface, the sag identified in the younger alluvium (directly above the Silver Creek Fault in the buried bedrock) could increase and manifest as a sag in the ground surface in response to an earthquake originating on the Silver Creek Fault. Propagation of such displacement upward through over 1000 feet of alluvium would likely result in a broad (several hundred feet wide) zone of down-warping of the ground surface. Such surface deformation would probably be measured in fractions of an inch spread out over the width of the sagging zone. Quantification of such potential deformation would require more detailed investigation.

Geomatrix's (2004) detailed discussion of the potential for the Silver Creek Fault to produce surface fault rupture where its mapped trace crosses the SVSX corridor is included in Appendix B.

Other Stations

No active or potentially active faults have been mapped through or in close proximity to the project alignments of any of the other stations. Therefore, the potential for fault rupture to occur at the alignments or stations other than the 23rd Street Station is considered negligible.

4.1.2 Ground Shaking

Of the many active faults within the region, the San Andreas, Hayward, and Calaveras faults have the greatest potential to release earthquakes that will produce strong ground shaking at the SVSX corridor alignments and stations. Other active faults in the region may produce significant ground shaking at the SVSX corridor. Therefore, the potential for strong ground shaking to occur at the SVSX corridor is considered moderate to high. The proximity of these faults and other nearby active faults such as the Silver Creek Fault, which are capable of generating large magnitude earthquakes, means that strong ground shaking will eventually subject the proposed alignments and structures to strong seismic accelerations. Structures could be damaged or destroyed and people could be harmed during a major seismic event originating on any of the nearby faults.

If the Bank of America building is selected as the station entrance option for the Downtown San Jose Station, the building would be required to be seismically retrofitted to current applicable building codes consistent with Secretary of Interior standards. Refer to the Section 5.4 of the Silicon Valley Rapid Transit Corridor Final EIS, "Cultural and Historical Resources", for adverse effects to this historic resource related to seismic retrofitting.

All structures associated with the SVSX corridor would be designed in accordance with current seismic design standards as found in the California Uniform Building Code, as well as the BART Facilities Standards, Release 1.2 (May 2004). The ground motion criteria to be used for seismic design of the BART trackway structures—including tunnels, underground and aboveground passenger stations, bridges, retaining walls, cut-and-cover, and U-wall subway structures—would be in accordance with Silicon Valley Rapid Transit Tunnel Segment Report on Seismic Ground Motions (HMM/Bechtel, 2005). These measures would minimize the potential exposure of people to harm from geologic or seismic hazards to a negligible level.

4.1.3 Liquefaction

Liquefaction is a phenomenon in which saturated cohesionless soils are subject to temporarily and essentially total loss of shear strength under the reversing, cyclic shear stresses due to strong ground shaking, causing them to liquefy. Submerged, cohesionless sands and silts of low to medium relative density are the type of soils which usually are susceptible to liquefaction. Factors known to influence liquefaction include soil type, relative density, and grain size, depth to groundwater, age of soil, and the intensity and duration of ground shaking. Soils most susceptible to liquefaction are Holocene age, loose, coarse-grained poorly graded sands and low plasticity silts below the water table. Clays are generally not susceptible to liquefaction although some low-plasticity (LL<35) with high moisture content (w% > 0.9 LL) are vulnerable to significant strength loss under minor strains.

Liquefaction can causes structures built on or above liquefiable soils to experience bearing capacity failure and collapse. Flow failure, lateral spreading, differential settlement, loss of bearing capacity, ground fissures and sand boils are evidence of generation of excess pore pressure and liquefaction. Lateral spreading is a phenomenon in which surficial soil displaces along a shear zone that has formed within an underlying liquefied layer. Upon reaching mobilization, the surficial blocks resting upon the liquefied layer can be transported down slope or in the direction of a free face by seismic and gravitational forces.

The SVSX corridor is located entirely within a zone of “Required Investigation of Potential Liquefaction” delineated by the State Geologist on two “Seismic Hazard Zone” maps (San Jose East Quadrangle, released in January 2001; and San Jose West Quadrangle, released in February 2002). Therefore, site-specific evaluations of the potential for ground deformation to occur as a result of liquefaction must be conducted. If analysis determines that liquefaction is likely to occur and result in ground deformation, appropriate mitigation measures must be recommended and incorporated into design of the project improvements.

The U. S. Geological Survey (USGS) published “Maps of Quaternary Deposits and Liquefaction Susceptibility of the Central San Francisco Bay Region” (Knudsen et al.; 2000 and Witter et al.; 2006) that show the distribution of various susceptibilities to liquefaction. (Refer to Figure 5 for the 2006 Liquefaction Susceptibility Map with the proposed project alignments and stations overlaid.) The following sections describe the liquefaction susceptibilities associated with the Quaternary deposits mapped by the USGS along the SVSX corridor.

Eastern Station Option 1: Alum Rock Alignment and Station

Witter et al (2006) rated the Holocene alluvial fan deposits - fine facies (“Qhff”) beneath the Alum Rock Alignment and Station as having “moderate” liquefaction susceptibility. The Alum Rock Alignment crosses an narrow Historic Artificial Channel (“ac”) that is also rated as having “moderate” liquefaction susceptibility.

Eastern Station Option 2: 23rd Street Alignment and Station

Witter et al (2006) rated the Holocene alluvial fan levee deposits (“Qhl”) beneath the 23rd Street Alignment and Station as having “moderate” liquefaction susceptibility. The 23rd Street Alignment that crosses a narrow Historic Artificial Channel (“ac”) approximately 3000 feet north of the 23rd Street Station that is also rated as having “moderate” liquefaction susceptibility.

The 23rd Street Alignment crosses a narrow Holocene Stream Channel (“Qhc”) approximately 850 feet southwest of the 23rd Street Station that is rated as having “very high” liquefaction susceptibility.

Downtown San Jose Station

Witter et al (2006) rated the Holocene alluvial fan levee deposits (“Qhl”) mapped beneath the Downtown San Jose Station as having “moderate” liquefaction susceptibility.

Diridon Station Option 1: Diridon East Alignment and Station

Witter et al (2006) rated the Holocene alluvial fan (“Qhf”) deposits rated beneath the Diridon East Station as having “moderate” liquefaction susceptibility.

The two approximately 100 foot-wide stream channels (“Qhc”) crossed by the proposed Diridon East Alignment (approximately 100 and 700 feet northeast of the Diridon East Station) are mapped as having “very high” liquefaction susceptibility. The approximately 500 foot-long segment of the Diridon East Alignment between the two stream channels is rated as having “moderate” liquefaction susceptibility.

Diridon Station Option 2: Diridon West Alignment and Station (Stockton)

Witter et al (2006) rated the Holocene alluvial fan deposits (“Qhf”) mapped beneath the Diridon West Station (Stockton) as having “moderate” liquefaction susceptibility.

The two approximately 100 foot-wide stream channels (“Qhc”) crossed by the proposed Diridon West (Stockton) Alignment (approximately 100 and 700 feet northeast of the Diridon East Station) are rated as having “very high” liquefaction susceptibility. The approximately 500 foot-long segment of the Diridon West (Stockton) Alignment between the two stream channels is rated as having “moderate” liquefaction susceptibility.

The intervals of Holocene Alluvial Fan Levee Deposits (“Qhl”) and Holocene Alluvial Fan Deposits – fine-facies (“Qhff”) mapped beneath the alignment between the Diridon West Station and the Santa Clara Station are also rated as having “moderate” liquefaction susceptibility.

Newhall Yard and Shops Facility and Santa Clara Station

Witter et al (2006) rated the Holocene alluvial fan deposits (“Qhf”) beneath the Newhall Yard and Shops Facility and Santa Clara Station as having “moderate” liquefaction susceptibility.

4.1.3.1 Site-Specific Evaluations of Potential Liquefaction Settlements

The published potential liquefaction and liquefaction susceptibility maps are based on a generalized characterization of soil conditions. Therefore, according to site-specific liquefaction analyses that were performed by PARIKH Consultants, Inc. in “Silicon Valley Rapid Transit Project Stations Segment Geotechnical and Seismic Design Criteria Report for Parking Garages and Ancillary Facilities Final Volume 2 – Seismic” at the Alum Rock Station, Diridon/Arena Station and Santa Clara Station along the SVSX corridor, the results indicated that post-liquefaction settlements on the order of less than 1 inch to 2 inches are anticipated in the vicinity of:

Eastern Station Option 1: Alum Rock Alignment and Station,
Diridon Station Option 1: Diridon East Alignment and Station, and
Santa Clara Station.

Based upon the similarity of the subsurface soils beneath the alternate station sites for which the analyses have not been performed, this same order of post-liquefaction settlement should be expected for the:

Eastern Station Option 2: 23rd Street Alignment and Station, and
Diridon Station Option 2: Diridon West Alignment and Station (Stockton).

Greater amounts of post-liquefaction settlements may be expected where the alignment of the SVSX corridor crosses beneath the stream channels (which have very high liquefaction susceptibility).

4.1.3.2 Surface Damage/Manifestation of Liquefaction

The potential for liquefaction-induced ground surface deformation to occur depends on the thickness of the liquefiable layer relative to the thickness of the overlying non-liquefiable material. Ishihara (1985) suggests, based on empirical observations from a number of Japanese earthquakes, that surface manifestation of liquefaction will not be significant if: (1) the site is relatively level, (2) the edges of the sand bodies are constrained so that lateral spreading towards a free-face is prevented, and (3) the ratio of the thickness of the non-liquefiable surface crust to the thickness of the liquefied underlying layer is greater than the boundary criteria provided (Ishihara, 1985).

As the ground surface is relatively flat along the SVSX, and is typically not adjacent to large open cuts or free-faces, the potential for flow slide failures or lateral spreads is considered to be very low.

In locations susceptible to liquefaction, the primary liquefaction hazard would be seismically induced settlement and temporary increase in lateral earth pressures on below-grade structures. Although a soil layer may or may not fully liquefy during an earthquake, it can still experience settlement.
The BART Facilities Standards Design Criteria (Release 1.2 – Facility Design – Criteria – Structural – Foundations – section 2.1.1) limits the total settlements for trackway structure foundations to 1 inch or less; thus, there would be a need to reduce the liquefaction-related settlement hazard along some portions of the BART alignment. Methods used on recent BART

projects should be referred to the “Mitigation for Liquefaction Hazard” in the following section.

4.1.3.3 Potential Liquefaction-related Uplift of Buried Structures

During an earthquake, an underground structure that is buoyant (total weight less than the weight of the displaced soil and water) and located in saturated liquefiable soil deposits may be susceptible to buoyant uplift. If the soil liquefies fully, a buoyant structure could float upward toward the ground surface. A partly liquefied soil deposit would retain some of its initial shear strength and resist the uplift to some degree. The tendency for upward displacement of buried structures (such as the project’s buried tunnels and stations) would also depend upon the density and thickness of the overlying soil. The increased pore pressure that is responsible for liquefaction could cause water and soil to migrate into the void beneath an uplifting structure thereby increasing the upward force. Deformation of the ground surface, buildings, and utilities located above an uplifted structure could be significant.

4.1.4 Earthquake-Induced Landslides

The SVSX corridor is located on nearly flat terrain, and is not identified on any California Geological Survey Seismic Hazard Zone maps as being potentially susceptible to earthquake-induced landslides. Therefore, this potential hazard is considered very low and no measure will be necessary to mitigate it.

4.1.5 Expansive Soil

Expansive soils will shrink and swell as a result of change in moisture contents. This can cause heaving and cracking of slab-on-grade, pavements, and structures founded on shallow foundations. This is a particular concern for the proposed building structures for the system facilities, parking lot, vehicular access and pedestrian access at the stations. Some of the soil samples tested at shallow depth at the stations and Newhall Yards and Shops yielded high Plasticity Indices between 21 and 40. This indicates a moderate to high expansion potential. Based on the boring data, subsurface soil underneath the track on grade of the 23rd Street Alignment between the south of the man-made channel and the “Alternate East Tunnel Portal” has a moderate expansive potential.

4.2 Construction Impacts

4.2.1 SVSX Corridor Tunnel and Cut and Cover Stations

To construct the station boxes, tieback anchors (long metal rods or tendons drilled and grouted into the ground that support construction area walls during initial excavation of underground facilities) may be used to provide an open and unrestricted trench area that does not interfere with the construction of the stations. Tiebacks may remain in the ground after completion of construction. Alternatively, internal bracing comprised of large metal shuts may be used to support the construction area walls, which would be subsequently removed during construction of the stations.

According to Silicon Valley Rapid Transit Corridor Final EIS, additional analyses were conducted during preliminary engineering phase regarding potential surface settlements and lateral ground movements during construction of the bored tunnel and cut and cover stations for the Silicon Valley Rapid Transit Project Alternative. The purposes of these analyses were to assess the magnitude and likelihood of settlement and ground movement, physical damage to structures or utilities caused by potential settlement or ground movement, and functional adverse effects related to any physical damage on performance of structures or utilities that may be caused by tunnel boring and cut and cover construction, and to recommend appropriate mitigation measures.

Based on the analyses, the maximum surface settlement induced during tunnel boring along the tunnel alignment is predicted to be less than 1 inch, or in a range categorized as between “negligible and slight”. Minor cracking that can easily be patched, and sticking windows or doors would characterize slight damage. Any settlement would be distributed in a “trough” running parallel to and centered over the twin tunnel bores, with the maximum settlement occurring at the centerline of the trough between the two bores.

Based upon the proximity of the new alignments to the original alignment and comparison of their subsurface conditions, the maximum surface settlement anticipated along the 23rd Street Alignment and the Diridon West Alignment should be within the same order of magnitude as that estimated for the original tunnel alignment.

4.2.1.1 Temporary Excavation

The slope height, inclination, and temporary excavation depths should not exceed those specified in local, state, or federal safety regulations.

Strength softening, sloughing and erosion could be expected for the bare surficial soil materials if the temporary slopes are exposed to weather and rain for an extended period of time. Stiff clays exposed from the excavation also tend to develop soil creep due to seasonal change in moisture content resulting in sloughing. Therefore, adequate surface protection should be provided to protect the slope surface from erosion, excessive drying and/or saturation during construction.

All temporary excavations should be closely monitored during excavation to detect any evidence of instability, soil creep, settlements, etc. Appropriate mitigation measures and a comprehensive monitoring plan should be implemented to correct such situations that may cause or lead to future damage to facilities, utilities and other improvements.

Excavation bottom instability may occur as a result of bottom heave, piping, or blow-out. Bottom heave is typical for excavations in soft clays. In granular soils, bottom heave is normally not a problem. However, piping may be a concern if the force of the upward flow of water exceeds the buoyant weight of the soil at the excavation bottom. “Blow-out” is another mode of failure where a pervious sand layer is located below he clay layer at excavation bottom and is not drained in advance. “Blow-out” occurs when hydrostatic pressures at the base of the clay layer exceed the shear strength and weight of the clay plug. Based on the geology and available boring data, soft to medium stiff clay and loose to medium dense sand may be encountered at the bottom of excavation for the box of the stations along the SVSX corridor. Section 5.2.4 should be referred for the proposed mitigation measures.

4.2.1.2 Shoring

The shoring system should be designed to relatively rigid and with as many supports or struts as necessary to prevent excessive straining and deformation of the supported soils. This is also important with regard to existing asphalt concrete pavement of the nearby streets where tension cracking may develop, even under minor strains. It is also very important with regard to protection and movement of the existing utilities. Due to the presence of pocket/lenses/layers of loose to medium dense sand under measured groundwater, there is a potential that raveling/flowing ground could occur before the sidewall supports are installed. In which case, continuous steel sheeting should be used. Continuous interlocking sheet pile is also recommended for relatively deep excavations below the groundwater level with concern of trench bottom stability.

The sheeting should be driven to a sufficient depth below the excavation to prevent trench bottom instability (bottom heave, piping and blow out). The required depth should be determined by the contractor/shoring designer. The type of driving equipment (vibratory or impact hammers) employed for sheet pile installation should be chosen and verified for drivability by the shoring contractor. “Unconventional” method of driving such as banging with backhoe bucket is not recommended.

Horizontal struts should be placed against both sides of the sheeting at regular depths as the walls are exposed in order to maintain continuous stability of the excavation. Bracing should also be installed as soon as practical against the continuous sidewall support. Failure to provide such struts/bracings in a timely manner may result in lateral creep, which may cause damage to existing facilities. Removal of sheeting should be carried out in a manner that does not adversely affect any existing utilities and/or any other improvements.

When using braced and sheeted trenches, the inward lateral deflection, which occurs as the excavation progresses, must be considered. Local experience with similar subsurface soil conditions, as well as published data, indicates that settlement of the ground surface adjacent to the shoring is commonly on the order of 0.25% to 0.5% of the trench depth. Lateral movement of the same order of the magnitude should also be anticipated. This assumes good workmanship and the preloading of struts by onward jacking against the excavation sides to reduce lateral movement.

For cut and cover construction, surface settlement diminishes in magnitude with distance away from the shoring. Typically, the “zone of influence” of the maximum settlement has been found to extend a distance of about 0.7 times the excavation depth away from the shoring and then diminishes in magnitude gradually to zero at a horizontal distance of about 2 to 2.5 times the depth. The maximum surface settlement adjacent to the open cut excavations during construction is predicted to be approximately 1.4 inches. However, the potential for ground settlement during construction can be reduced through the use of soil-cement mix walls as recommended in Section 6.3.11 of “Silicon Valley Rapid Transit Corridor Final EIS”.

Based on the available boring data at the “Eastern Station Option 2: 23rd Street Alignment and Station” and “Diridon Station Option 2: Diridon West Alignment and Station (Stockton)”, the subsurface soil at these two locations generally consists of stiff to very stiff lean/fat clay, underlain by interbedded layers of hard lean clay and dense to very dense sand. It is our opinion that the maximum surface settlement adjacent to the open cut excavation during construction of these two alternate stations should be within the range of approximately 1.4 inches estimated for the other stations. Analyses should be performed during subsequent engineering phases to confirm the estimated maximum surface settlement at these two stations.

If existing utility lines are located within the potential zone of influence, they could experience distress as a result of the movement. If settlement estimated above cannot be tolerated, then clear distance can be increased by relocating the existing utilities or mitigation measures should be planned.

Utilities most sensitive to ground movement are water and gas mains constructed of cast iron. A review of the utility drawings shows water mains in San Jose dating to the late 1800s and early 1900s, which are assumed to be cast iron. Also identified is an abandoned brick-lined sewer crossing East Santa Clara Street, near City Hall.

Surface settlements and ground movements may cause damage to structures, facilities, and utilities. However, the occurrence of settlement does not necessarily result in damage. Depending on the predicted degree of adverse effect, probability of exceedance, structural sensitivity to movement, the SVSX corridor would include ground treatment measures, strengthening of structures, and underpinning of structures on a case-by-case basis prior to tunnel boring or cut and cover construction. The SVSX corridor also would employ Tunnel Boring Machines (TBMs) to minimize the risk of surface settlements and lateral ground movements. In addition to these design requirements, mitigation can be implemented to reduce the magnitude and likelihood of surface settlements and ground movements, physical damage, or adverse functional effects. Proposed mitigation measures for construction settlement should be referred to Section 5.1.3 below.

4.2.2 Construction Dewatering of Tunnels and Underground Stations

"Dewatering" shall mean any work or system required to lower the groundwater level for construction. The following groundwater levels throughout the SVSX corridor were measured or reported:

a) Based on the "Historically High" Water Table Depth (1967-1997) in Figure 6 "Water Level Contours" included in Silicon Valley Transport Project Tunnel Segment Geotechnical Data Report Volume I of VI, the historic high groundwater depths were typically less than 10 feet throughout the majority of the SVSX corridor, but somewhat greater depth at the locations of the Downtown San Jose Station, Diridon Station and Santa Clara Station.
b) Based on Chapter 6 of the "Silicon Valley Rapid Transit Corridor Final EIS", dewatering of the shallow groundwater zone (between approximately 20 and 30 feet below ground surface) will be required during excavation activities.
c) Based on Table A5-3 "Vibrating Wire Piezometer Table" of the Silicon Valley Transport Project Tunnel Segment Geotechnical Data Report Volume III of VI, groundwater depths measured from the vibrating wire piezometers in 2005 range from approximately 5 feet to 23.5 feet along the SVSX corridor.
d) Based on the "Silicon Valley Rapid Transit Project Geotechnical Report Yards & Shops Segment Draft", groundwater was initially encountered at a depth of 19 feet to 25 feet below grade and stabilized at roughly 4 feet to 15 feet below ground surface during drilling for the "Newhall Yards and Shops" in 2005.
e) According to the "Silicon Valley Rapid Transit Project Stations Segment Geotechnical and Seismic Design Criteria Report for Parking Garages and Ancillary Facilities Final Volume 1 – Geotechnical", groundwater was encountered between Elev. 75 feet and Elev. 80 feet (depths of 9 feet to 11 feet) near the eastern end at Alum Rock Station and between Elev. 52 feet and Elev. 59 feet (depths of 6 feet to 11 feet) near the western end at the Newhall Yards and Shops/Santa Clara Station based on the borings drilled for the "Silicon Valley Rapid Transit Tunnel Segment" and "Newhall Yard & Shops Segment".

Therefore groundwater should be anticipated during construction of the SVSX corridor. Groundwater may:

a) Cause instability of excavation for the walls (piping, erosion, etc,).
b) Cause instability of the excavation bottom (blow-outs, piping, etc.).

c) Excessive water in the excavations may also result in difficult working conditions at the bottom of excavations causing subsequent delay in work and/or additional efforts during construction.
d) Unstable excavation walls and bottom may cause slope failures, damage to the shoring system, etc., causing excessive settlement of surrounding ground, damage to adjacent underground and above ground utilities and structures and excessive long-term differential settlements.

Dewatering should be required at the construction for the station boxes to:

a) Provide a dry condition for construction.
b) Control the hydrostatic head within the cohesionless soil layers and to minimize the occurrence of raveling or flowing ground conditions and subsequent surface settlements.

Dewatering activities should be conducted within the excavation limits either by utilizing a well-based dewatering system and/or by pumping from the excavation using trash pumps in low spots. The following should be noted for the dewatering:

a) According to Section 6.3.9 Hazardous Materials of the "Silicon Valley Rapid Transit Center Final EIS", it is anticipated that groundwater encountered during excavation will contain contaminants that require remediation prior to discharge.
b) According to Section 6.3.9 Hazardous Materials of the "Silicon Valley Rapid Transit Center Final EIS", the variation of groundwater contamination will not allow the dewatering methods to adequately segregate clean groundwater from contaminated groundwater. Therefore, all extracted groundwater will be considered as potentially contaminated and will require characterization to determine the appropriate treatment requirements for discharge/disposal.
c) According to Section 6.3.9 Hazardous Materials of the "Silicon Valley Rapid Transit Center Final EIS", discharge of treated dewatering groundwater to the storm drain system is regulated by RWQCB.
d) Dewatering of excavation is normally the responsibility of the contractor.
e) Dewatering system should be properly designed to prevent pumping soil fines from the cohesionless soil with the discharge water. If soil fines are being pumped, the contractor should revise his dewatering operations; otherwise, failure of shoring, partial instability of excavation bottom resulting in intolerable settlement/movement of foundations of existing structures and utilities and unsafe working conditions might occur.

f) Dewatering should not be performed at an excessive rate that could disturb the groundwater regime.

4.2.3 Flooding

The potential for localized flooding at the construction site for the SVSX corridor should be reviewed. The review should also include a determination of which portions of the SVSX corridor fall below the 100-year plain elevation. The mitigation to minimize potential flooding should be referred to Section 5.1.5.

4.2.4 Noise and Vibration

According to Silicon Valley Rapid Transit Corridor Final EIS, construction of the SVSX corridor has the potential to generate high level of noise and vibration that may adversely affect nearby residential, commercial, and institutional land uses. In addition, some construction activities, such as the pile driving for the parking garage, pedestrian undercrossing and sheet piling for the shoring, may generate vibration levels that could damage nearby structures. In order to determine the potential noise and vibration effects during construction, an analysis of construction period effects from noise and vibration was performed for the SVSX corridor with the original project alignment. The noise and vibration impacts and proposed mitigation measures for these impacts should be referred to the “Silicon Valley Rapid Transit Corridor Final EIS”. A similar analysis is recommended for the “23rd Street Alignment and Station” and “Diridon West Alignment and Station (Stockton)” during subsequent engineering phases.

Chapter 5
Mitigation Measures

5.1 Mitigation Measures

5.1.1 Mitigation for Liquefaction Hazard

The following mitigation measures should be considered to minimize the potential impact due to the liquefaction:

a) Use of pile foundations is a cost-effective mitigation measure for the seismic liquefaction hazard. The parking garages at the stations will be supported on piles.

b) Use of pile foundations also provides ground densification.

c) For shallow foundation for other peripheral facilities around the stations and pavement and parking lot, the following may be required:

- Additional reinforcement, construction joints, and grade beams.
- Subgrade improvements (utilizing geotextile fabric and structural fill), etc. to accommodate potential ground settlements.
- Parking lots and pavements may require maintenance work should pavement damage occur due to differential settlements.

d) Mitigation of potential liquefaction-related uplift of the project's underground tunnels and stations situated below the water table in liquefiable soils could be mitigated by increasing the downward force with anchors or by designing the structures concrete foundations and walls thick enough to make the total weight of the structures large enough to completely counteract the liquefaction-related uplift force.

In addition to above, methods used in recent BART projects include:

e) In-situ treatment/densification with vibro-replacement stone columns; load transfer to underlying bearing layers, which are non-liquefiable with soil/cement columns.

f) Over-excavation method via removal and replacement with compacted engineered fill.

g) Methods considered to eliminate or minimize the effects of seismic liquefaction include, but are not limited to, dynamic compaction, vibro-compaction, surcharging, and/or compaction grouting.

The exact methodology(ies) to be used will be determined during subsequent engineering phases.

5.1.2 Mitigation for Expansive Soil

Building or track on grade damage due to volume changes associated with expansive soils can be reduced by:

a) Deepening the foundations to below the zone of moisture fluctuation with deep foundations.

b) Using mat foundations which are designed to resist the deflections associated with the expansive soil.

c) All perimeter footings should have a depth of a minimum 24 inches below the lowest adjacent grade to reduce the impact due to the uplift pressure in expansive soils.

d) Any expansive soil in the upper 18 inches of the building pads be lime treated or replaced with low to non-expansive soil with a Plasticity Index of 12 or less.

e) Use of moisture barrier to minimize the variation of change in the moisture content within the expansive soil.

5.1.3 Mitigation for Construction Settlement

The following mitigation measures should be implemented during construction to minimize the potential impact due to settlement.

a) Pre-construction condition surveys of the interiors and exteriors of select structures within the settlement trough (which is the profile of vertical settlement of a point above the tunnel and at a distance from the vertical plane containing the tunnel axis) along the tunnel alignment and within the limit of influence around the cut and cover excavations will be conducted by independent surveyors to assess the condition of each property. These surveys will include written and photographic (video and still) records. The results of these surveys will be compared with post-construction condition surveys so that any effects of tunneling and cut and cover construction on structures can be assessed. For the tunnel activity, surveys will occur as close to the planned dates of tunneling as possible so that the results are as current as possible. Therefore, surveys will be performed prior to passage of the tunnel boring machines with some surveys conducted once tunneling has commenced.

b) For the tunneling activity, ground surface monitoring will be performed prior to and during construction. Instrumentation will be installed to monitor ground movements and effects of tunnel boring on structures and utilities. Monitoring can be used to direct real-time modifications, as appropriate, to tunneling practices and procedures to assist in minimizing adverse effects along the tunnel alignment. The contractor should have a settlement-monitoring program for protection of the existing utilities and adjacent structures.

c) Monitoring points will be mounted on select structures within the settlement trough along the tunnel alignment and within the limit of influence around the cut and cover excavations to monitor any effects of settlement.

d) A pre-construction condition survey will be conducted of utilities deemed to be potentially at risk due to surface settlement or ground movement. Major utilities deemed to be at risk will be monitored during construction. Coordination with utility providers will be conducted prior to installation of utility monitoring points. The maximum allowable settlement (threshold) values, if any (such as for different types of utilities and different sensitivity) should be checked with the utility owners. These threshold values should be included in the project specifications. If these threshold values occur during construction, they may require the contractor to take precautionary measures and modify his operations to prevent further movements, settlement or damages.

e) The option of post construction repair is based on the probability of damage, predicted degree of damage, sensitivity of the structure or facility, and cost and ease of repair. If repair is not feasible, compensation may be necessary.

With implementation of design requirements and mitigation measures, the likelihood of damage due to surface settlements and ground movements is considered low. However, additional studies of potential settlements and ground movements should be conducted during subsequent engineering phases.

5.1.4 Mitigation for Excavation Bottom Stability or Disturbance

If excavation bottom fails due to bottom heave, piping or blow-out, the mitigation measures such as dewatering and/or installing deep sheeting should be considered to mitigate these conditions.

a) Dewatering.

b) Installing deep sheeting. The sheet pile may also function as a cut-off to prevent sand boiling at the bottom of excavation due to excessive hydrostatic pressure within the cohesionless soils.

c) Based on the boring data, encountering of the cohesionless soils at the foundation subgrade may be anticipated at isolated locations for the excavation of the stations. Deeper shoring may be required to penetrate through the aquifer to prevent the occurrence of the sand boiling condition. Deep Soil Mixing may have to be considered under this condition if drivability of the shoring sheet pile through the dense to very dense sand at depths is a geotechnical concern due to the vibration and/or noise impact on the surrounding environment.

The clays and saturated sands at the bottom of excavation are sensitive to disturbance. If these deposits are sufficiently disturbed due to construction activities at the bottom of the excavation, they could become soft and loose. Also, soft and loose, saturated native soil deposits may be encountered at the excavation bottom. In such cases, working conditions at the bottom of the excavation may become difficult; equipments used at the bottom of excavation may lose mobility etc. Adequate measures should be taken to minimize the disturbance of the sensitive deposits at the excavation subgrade. The disturbance of sensitive deposits or mitigating existing soft/loose ground conditions may be minimized by constructing a working platform at the bottom of the excavation by

a) Over-excavate 18 inches below the native subgrade.

b) Place a stabilizing geotextile fabric or a geogrid at the bottom of the over-excavation.

c) Backfill the over-excavation with Class 2 Aggregate Base or “Structural Backfill” or other bridging material; and

d) Overlap the ends of the geotextile fabric on top of the bridging material for a minimum distance of 2 feet.

5.1.5 Mitigation for Flooding

The following can be considered as the mitigation measures to minimize the risk of flooding at the construction site:

a) Foundation drainage should provide removal of any water that may otherwise tend to flow under the building.

b) It is recommended that at least 12 inches of soil be placed and compacted on the outside of the grade beam and slope sloped away from the foundation of the building at right angle to the grade beam to provide for rapid removal of surface water runoff.

Chapter 6
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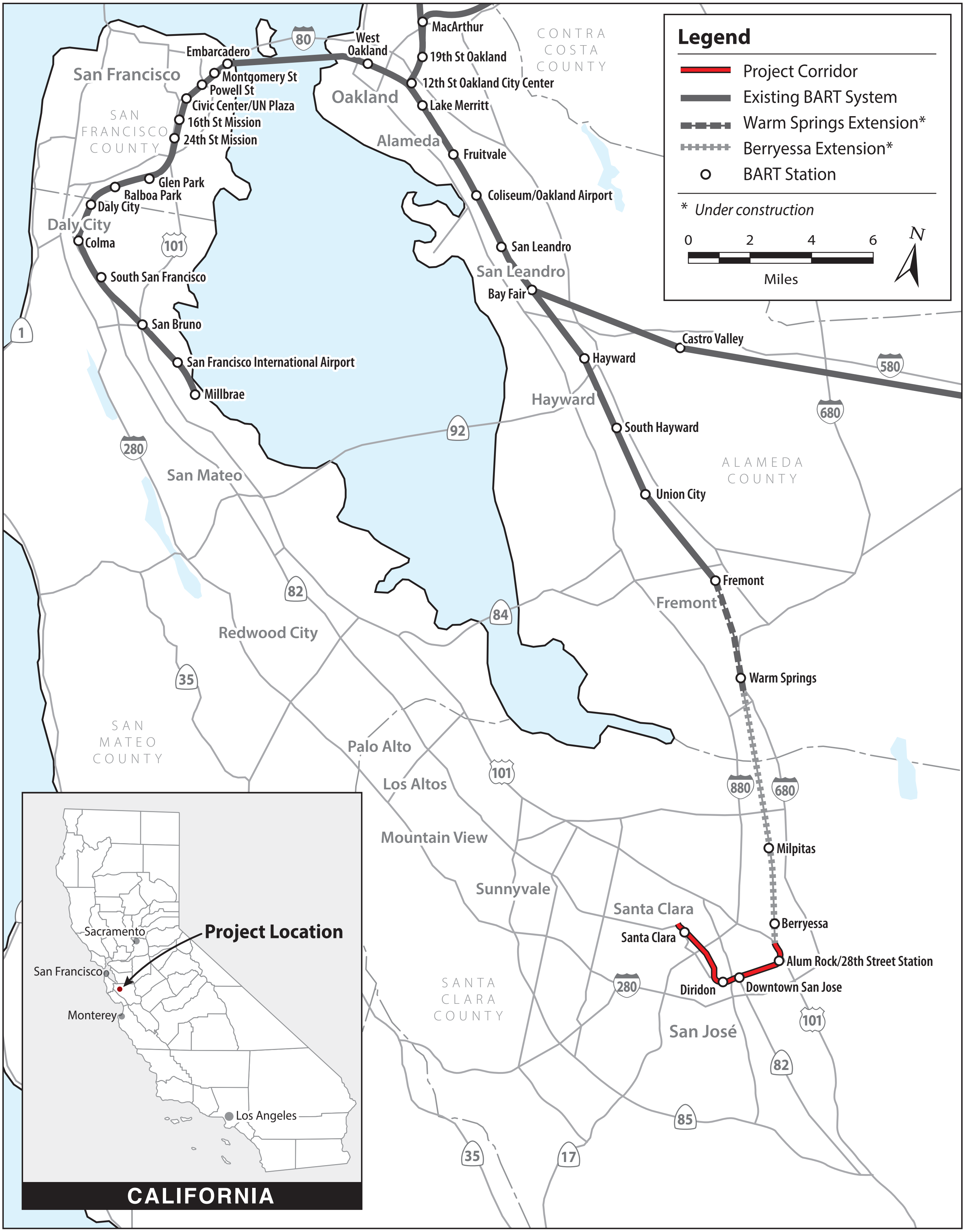
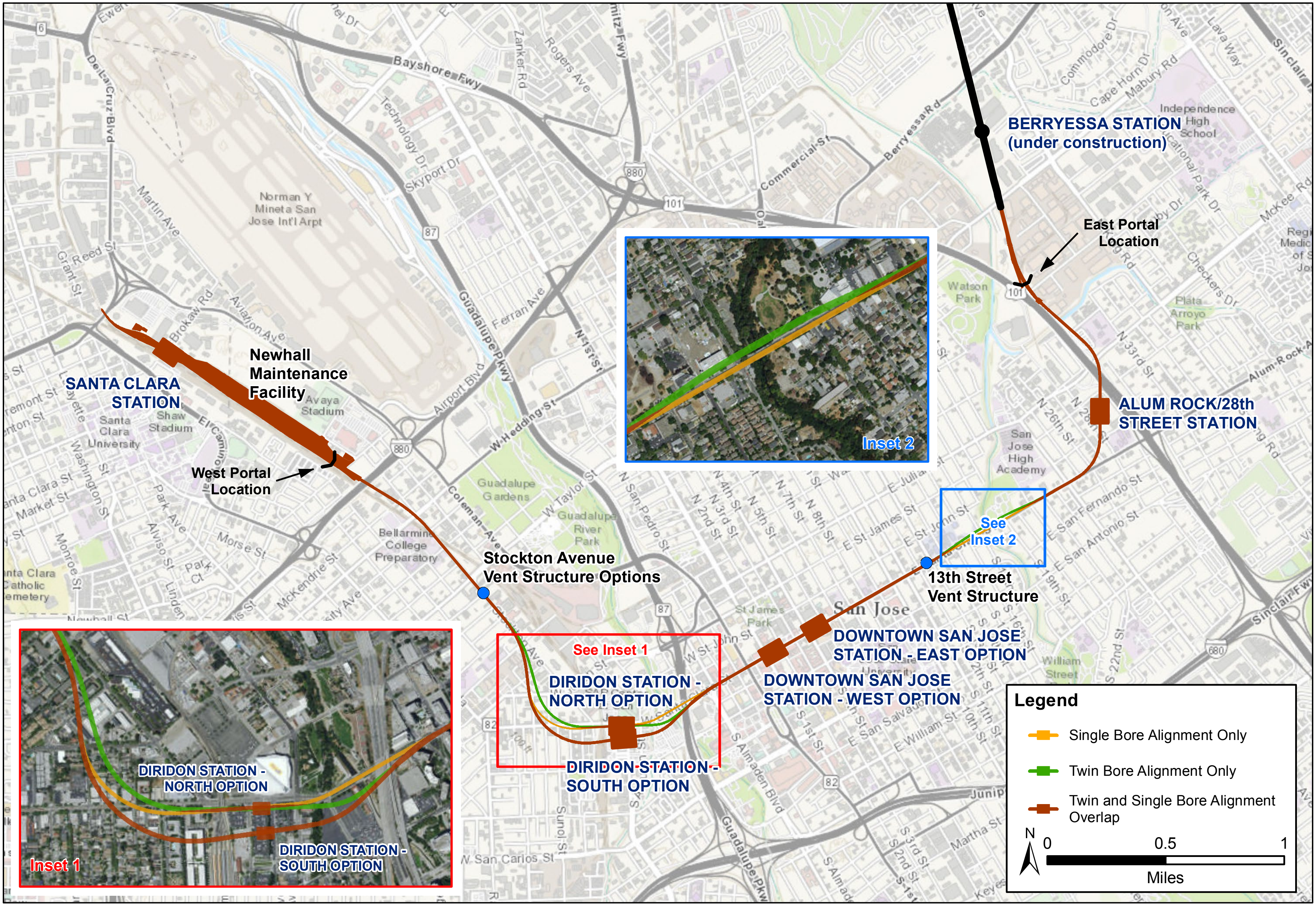


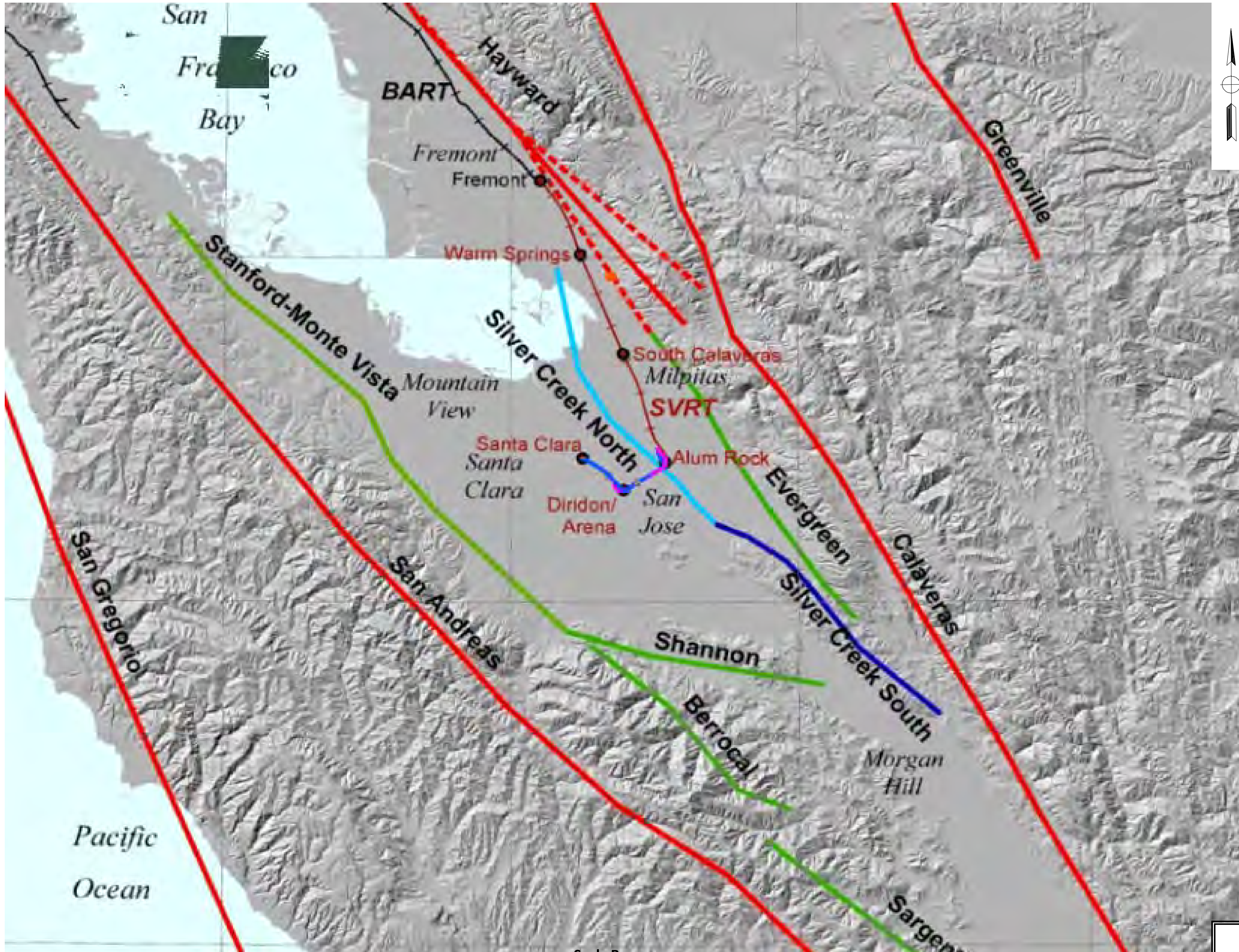
Graphics ... 00332.13 (10-27-2016)

Figure 1
Regional Location
VTA's BART Silicon Valley–Phase II Extension Project



Source: Station and Track, VTA 2014; Basemap, ESRI 2015

Figure 2
BART Extension Alternative
VTA's BART Silicon Valley – Phase II Extension Project



Reference: Geomatrix, 2004

Explanation

- WG02 faults
- Alternative south end of the Hayward fault
- Santa Clara Valley Margin faults
- Silver Creek North (SS)
- Silver Creek South (Rv)

FAULTS IN THE BAY REGION

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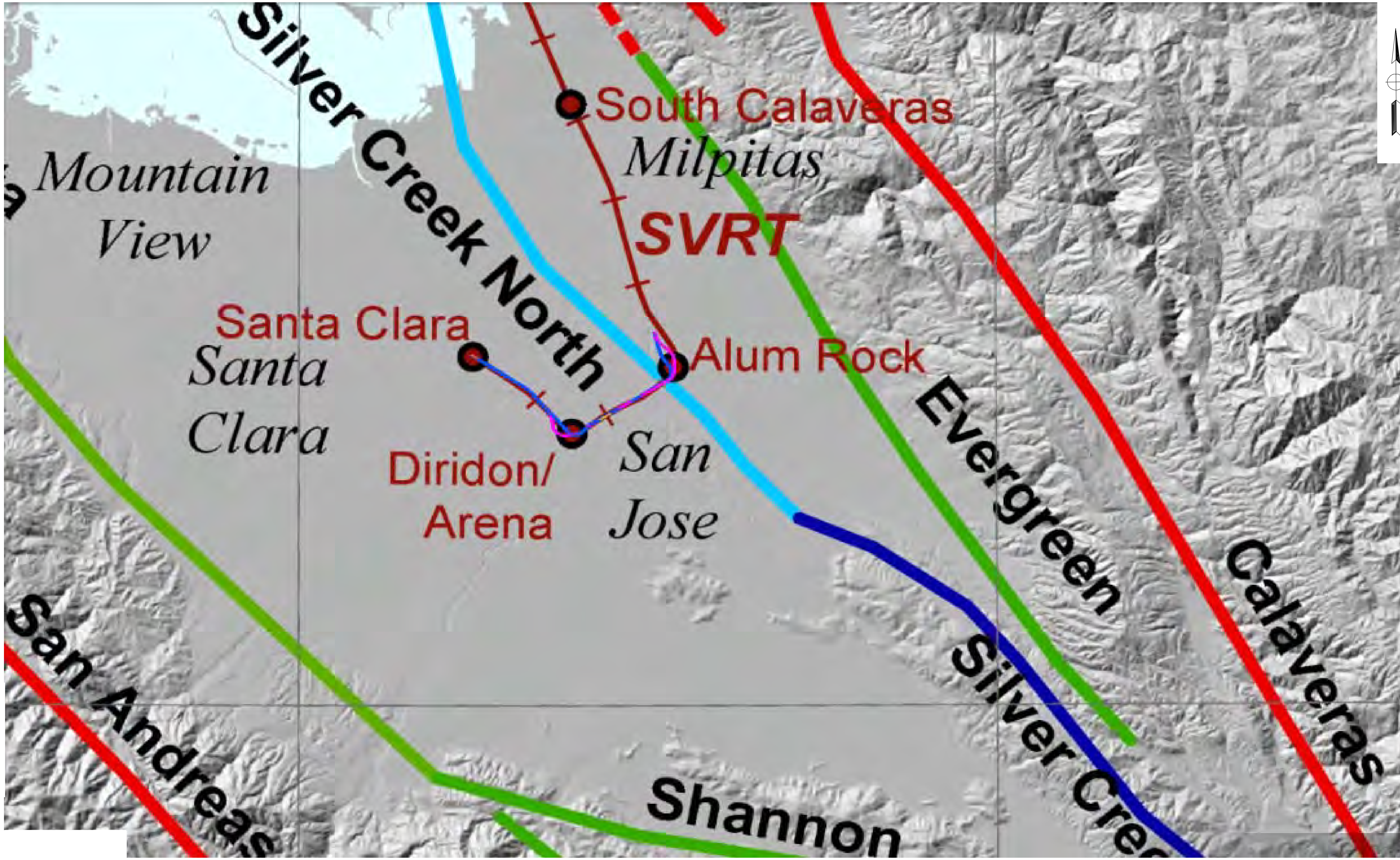
BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT

JOB NO.: 2013-131-PGR	FIGURE NO.: 3A



Explanation

- WG02 faults
- Alternative south end of the Hayward fault
- Santa Clara Valley Margin faults
- Silver Creek North (SS)
- Silver Creek South (Rv)

Reference: Geomatrix, 2004

Scale Bar

0 4 miles

FAULTS IN THE BAY REGION (CLOSE-UP OF CENTRAL PART OF PLATE 1A)

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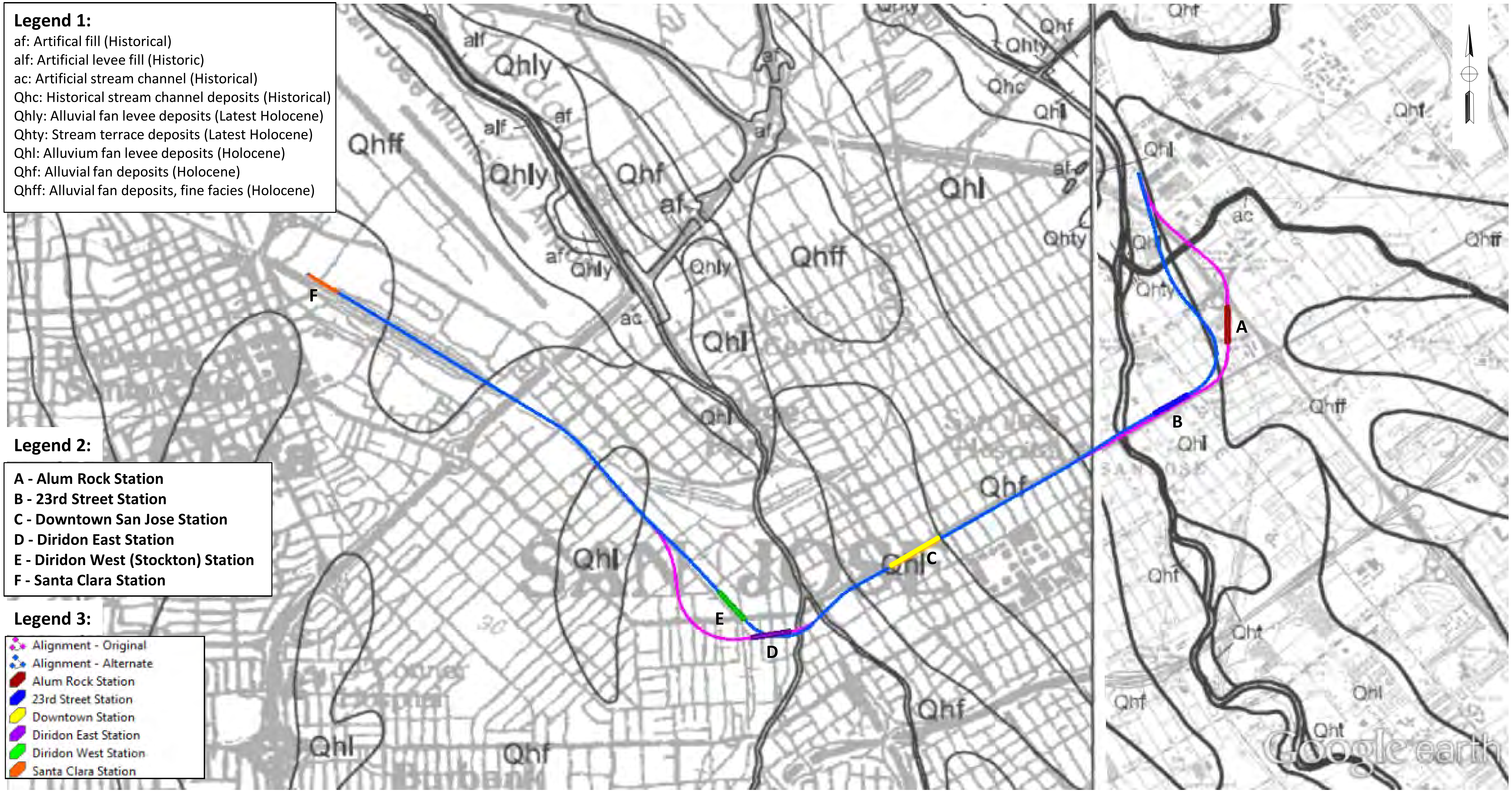
BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT	
JOB NO.: 2013-131-PGR	**FIGURE NO.: 3B**



Scale Bar
0 5000 ft

Reference: Witter; 2006

QUATERNARY DEPOSITS MAP

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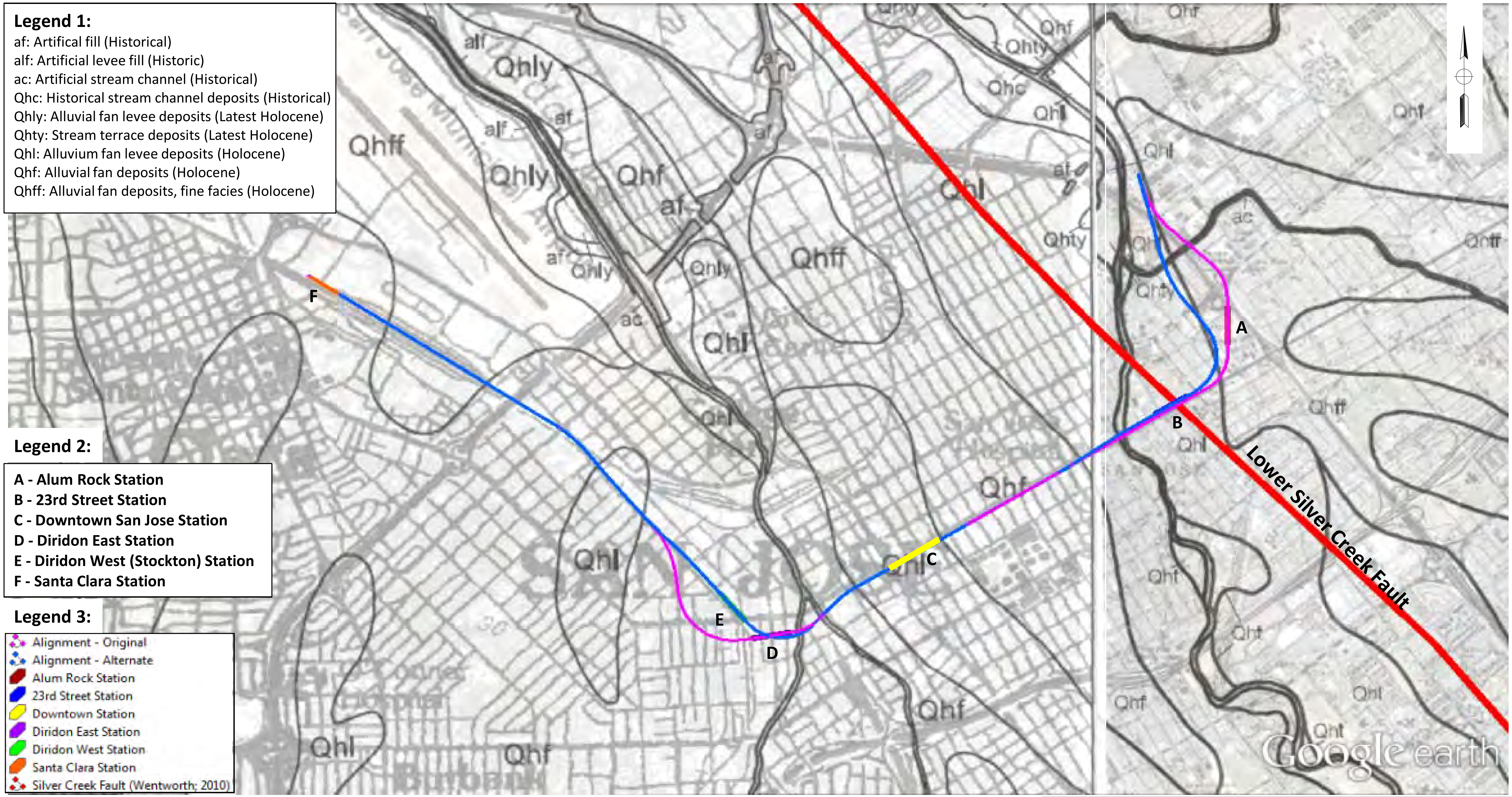
BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT

JOB NO.: 2013-131-PGR	**FIGURE NO.: 4A**



Scale Bar
0 5000 ft

Reference: Witter et al; 2006 and Wentworth et al; 2010

QUATERNARY DEPOSITS MAP WITH SILVER CREEK FAULT

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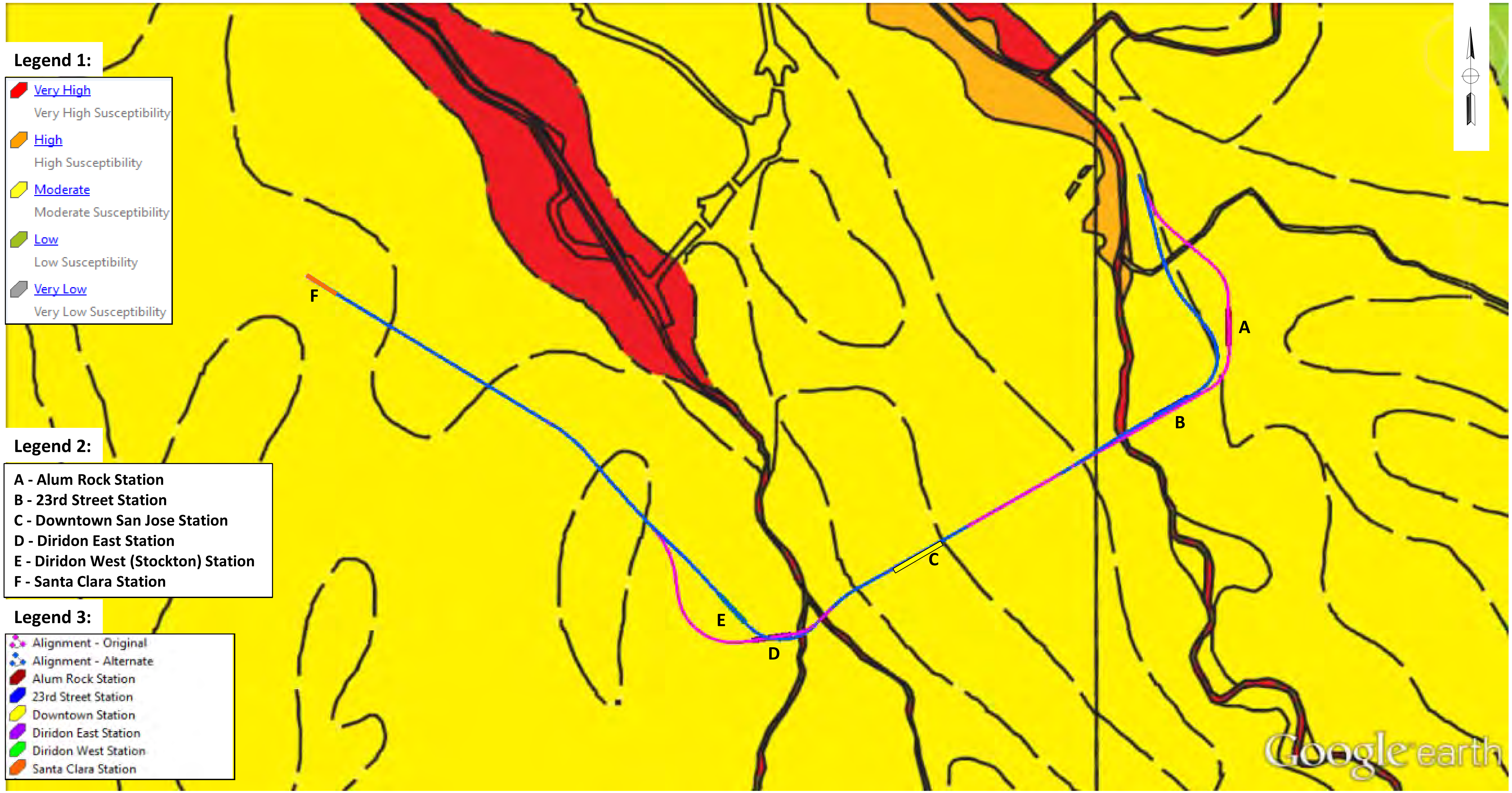
BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT

JOB NO.: 2013-131-PGR

FIGURE NO.: 4B



Scale Bar 0 5000 ft

Reference: Witter et al; 2006

LIQUEFACTION SUSCEPTIBILITY MAP

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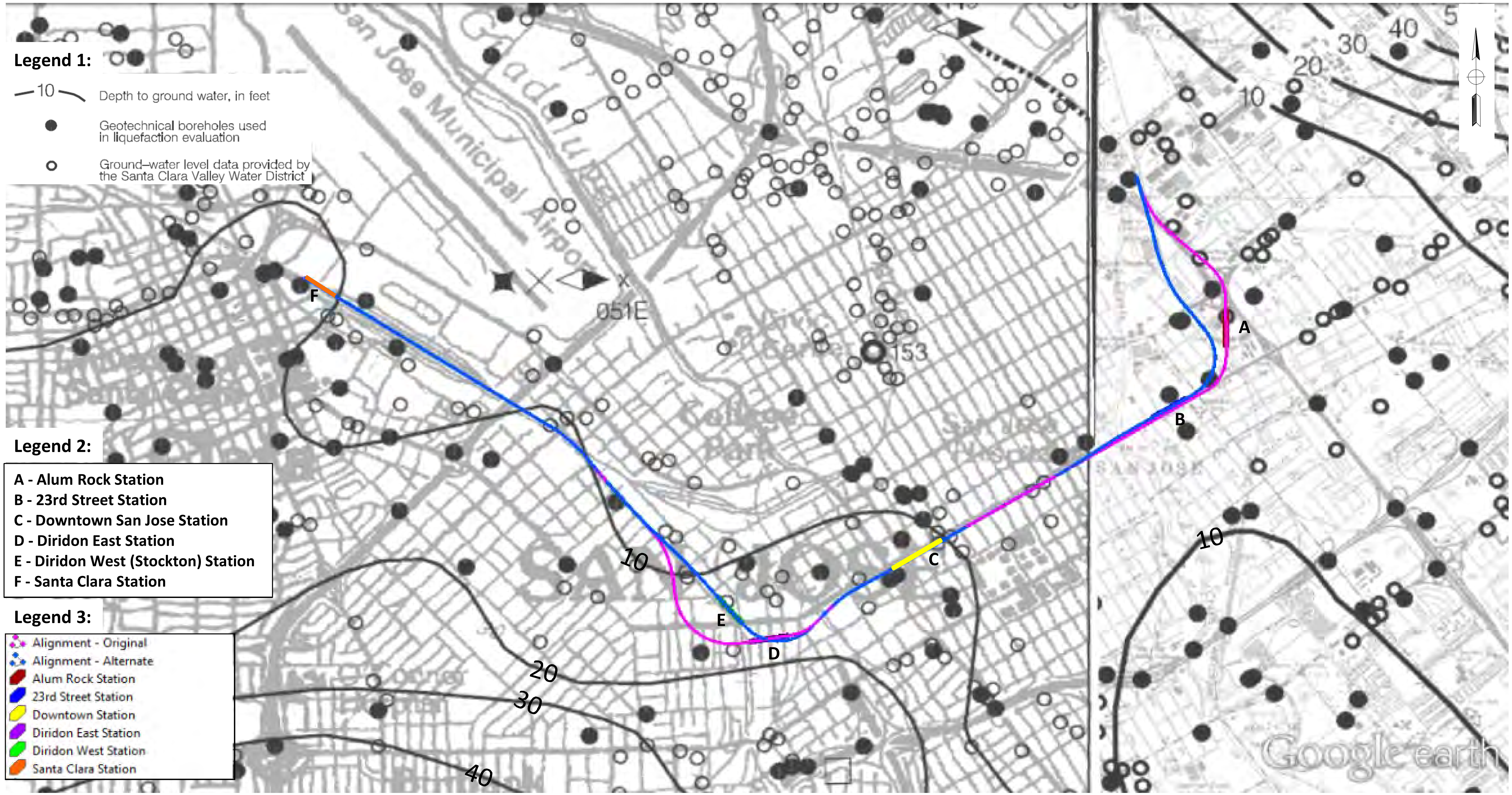
BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT

JOB NO.: 2013-131-PGR

FIGURE NO.: 5



Scale Bar 0 5000 ft

Reference: California Geological Survey; 2000 & 2002

HISTORIC GROUNDWATER CONTOURS

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BART SILICON VALLEY PHASE II SANTA CLARA EXTENSION PROJECT

JOB NO.: 2013-131-PGR	FIGURE NO.: 6

APPENDIX A

APPENDIX A

DISCUSSION OF EVIDENCE FOR MAPPING OF SILVER CREEK FAULT

Wentworth et al (2010) delineated the Silver Creek Fault as the western basement boundary of the Evergreen Basin in the fashion begun by Taylor (1956) and Chapman (California Department of Water Resources, 1967), but using the current array of gravity stations and the basin-thickness inversion of gravity, which sharpens the gravity depiction of the basin boundaries. The western boundary of the basin is relatively straight, and the principal issue in locating the fault is just how high on the steeply east-dipping basin boundary in the gravity inversion to place the bedrock trace. There is no convincing evidence for the location of the fault on the alluvial surface, but two independent lines of evidence indicate that the trace lies at the top of the gravity boundary. A steep gradient in an InSAR image (Ikehara and others, 1998; Galloway and others, 1999 and 2000) marks an abrupt subsidence boundary with as much as 2.5 cm of recoverable annual subsidence west of the Silver Creek Fault that results from groundwater pumping. This subsidence boundary requires a groundwater boundary in the water-bearing section, which we take to mark the shallow expression of the Silver Creek Fault. Independent confirmation of a basement-bounding Silver Creek Fault and its location is provided by the Evergreen seismic reflection profile. The eastward termination of the basement reflection at the Silver Creek Fault in that profile occurs directly beneath the location of the InSAR boundary. We thus place the bedrock trace of the Silver Creek Fault along the top of the basin boundary in the gravity inversion, extending northwestward from its intersection with the Calaveras Fault.

The strongest evidence for any continued activity along the northern Silver Creek Fault beneath the alluvial plain is recorded in the Evergreen seismic reflection profile, which was collected in 2002 by Williams and others (2002) using a minivibroseis source. The survey yielded reflections from depths of about 50 m to 1.2 km within the Evergreen Basin.

The Silver Creek Fault can be confidently traced upward from the 500-m-deep bedrock tip of the fault to and slightly above the mid-Quaternary unconformity. Above that the deformation is much less distinct, although here also we suggest that the fault has broken the shallow section and offset individual reflections by less than a cycle. The reflections in the shallow section define distinct structural sag across the Silver Creek Fault that, near the surface, is about 750 m wide with amplitude of about 30 m. This amplitude decreases downward, as does the width of the sag, with the sag still distinct as deep as almost 300 m. The sag is evident as shallow as about 50 m, above which no coherent reflections were obtained. The structural sag is marked by numerous steps and bends in the reflections of less than a cycle that imply small faults, with both normal and reverse separations.

These characteristics of the structural sag—an upward spreading synformal structure marked by faults of both normal and reverse separation above a strike-slip fault—are typical of negative flower structures (Harding, 1985; Harding and others, 1985). This is a simple example with poorly developed marginal faults that occurs above a straight, single-stranded fault having an earlier history of strike slip. It is also a very shallow example (less than about 300 m) developed in unconsolidated sediments. Wentworth and others take this flower structure to indicate continuing strike slip on the Silver Creek Fault in the late Quaternary. Equivalent reflections on either side of the flower structure are at about the same depth, so during this younger period the fault would have experienced strike slip with cross-fault extension, but no dip slip.

Wentworth and others estimated the age of the sediment at the shallowest imaging of the flower structure (50 m) by projecting stratigraphy downstream and parallel to the Silver Creek Fault from well CCOC to the seismic profile. This places the 50- m-deep, 138,000 years old base of alluvial cycle 2 at the shallowest expression of the flower structure, which indicates that the synformal (downward folding) deformation is at least as young as about 140,000 years.

Wentworth and others (2010) suggest, in the absence of good evidence to the contrary, that the Silver Creek Fault probably continues to absorb the kind of right slip that produced the negative flower structure, but at so slow a rate that the shallow faulting, diffused across the width of the flower structure, is not evident at the ground surface, which along the northern part of the fault is within an active depositional system. In their 2004 Summary Discussion for Silver Creek Fault - Silicon Valley Rapid Transit System, Geomatrix concluded that the available data are permissive that an active fault extends northwest-ward along the mapped trace of the Silver Creek fault and beneath/through the SVSX tunnel alignment between the planned Civic Center/SJSU and Alum Rock stations. The available data show that faulting may extend through the Quaternary sediments to a shallow depth, possibly less than 30 m.

In their 2004 Summary Discussion for Silver Creek Fault - Silicon Valley Rapid Transit System, Geomatrix concluded that the available data are permissive that an active fault extends northwest-ward along the mapped trace of the Silver Creek fault and beneath/through the SVSX tunnel alignment between the planned Civic Center/SJSU and Alum Rock Stations. The available data show that faulting may extend through the Quaternary sediments to a shallow depth, possibly less than 30 m. Therefore, rupture on a potential shallow fault trace could affect the SVSX tunnel and the 23rd Street Station alternate.

Further evaluation of the Silver Creek fault is necessary to assess the location, extent, and recency of movement on the fault, in order to make a preliminary assessment of the extent of displacement that may occur during a potential earthquake originating on the Silver Creek fault.

The 23rd Street Station site is situated within the sag in recent alluvial deposits (identified by seismic reflection profiling) directly over the Silver Creek Fault escarpment in the buried bedrock surface.

APPENDIX B

APPENDIX B

POTENTIAL FOR FAULT RUPTURE AND FAULT DISPLACEMENT AT THE SVRT TUNNEL ALIGNMENT (Geomatrix 2004)

The available data are permissive that an active fault extends northwest-ward along the mapped trace of the Silver Creek fault and beneath/through the SVRT tunnel alignment between the planned Civic Center/SJSU and Alum Rock stations. The available data show that faulting may extend through the Quaternary sediments to a shallow depth, possibly less than 30 m. Therefore, rupture on a potential shallow fault trace could affect the SVRT tunnel.

Although further evaluation of the buried fault trace is necessary to assess the location, extent and recency of movement on the fault, it is possible to make a preliminary assessment of the extent of displacement that may occur during a potential earthquake on the Silver Creek fault. The potential amount and distribution of fault displacement on an active fault can be evaluated using both a deterministic and a probabilistic approach.

In a deterministic approach, the maximum displacement can be assessed based on observed/measured coseismic displacements on the fault or based on the maximum size (length/ magnitude) of a potential earthquake occurring on the fault. No reliable data on previous fault displacement or rupture length is available for the northern reach of the Silver Creek fault, thus, the potential displacement is estimated from the assessed maximum magnitude for the fault. The maximum magnitude is assessed to range from **M** 6.5 to 6.9, with a mean of **M** 6.7. Based on empirical relationships between moment magnitude (**M**) and surface fault displacement for strike slip earthquakes (Wells and Coppersmith, 1994), the range of maximum displacements is estimated at 0.5 to 1.2 m (1.6 to 3.9 feet), and the mean estimate is 0.74 m (2.4 feet) for the mean maximum magnitude of **M** 6.7. These estimates should be viewed as preliminary in nature pending further assessment of the fault source characteristics. The potential displacement is assessed as predominantly strike slip, but also may include a subordinate vertical component of slip. Further, although the maximum displacement is assumed to occur on a single narrow fault trace (width of less than several meters), it is possible that the deformation could be accommodated over a wider zone, on the order of several meters to 10’s of meters, with discrete displacements distributed on parallel fault traces in the zone of deformation.

A more detailed evaluation could consider several other factors that will affect the expected surface displacement at a specific site along the northern reach of the Silver Creek fault. These include the likelihood that the maximum surface displacement along the rupture will occur at the tunnel crossing, and possible effects of the thick Quaternary sediments overlying bedrock on the amount and distribution of fault displacement during an earthquake. Considering these factors, probabilistic and/or deterministic fault displacement hazard levels can be defined for a potential fault crossing of the SVRT tunnel alignment using a similar approach as that used for evaluating ground motion levels (Coppersmith and Youngs, 2000; Youngs and others, 2003). The displacement is estimated using empirical relationships between earthquake magnitude and maximum fault displacement (such as Wells and Coppersmith, 1994), and can be expressed as median (50th percentile) and median plus log sigma (84th percentile) displacements. The displacement levels would be evaluated from a maximum credible earthquake for a deterministic assessment, and from a probabilistic distribution of maximum magnitude (based on a logic tree assessment of fault rupture parameters for the Hayward fault) to evaluate the probability of exceeding specific amounts of fault displacement.