3.4 Geology, Soils, and Seismicity

3.4.1 Approach to Analysis

This section evaluates whether construction and operation of the proposed WTTIP would result in potential adverse impacts related to local geology, existing soil conditions, or seismicity. The analysis is based, in part, on review of various geologic maps and reports. The primary sources include:

- *Draft Geotechnical Impact Assessment, EBMUD Water Treatment and Transmission Improvements Program, AGS, Inc.* (AGS, Inc., 2005)
- *Draft Lamorinda Tunnel Conceptual Study, EBMUD Water Treatment & Transmission Improvement Program* (Jacobs Associates, 2005)
- *Seismic Stability Evaluation Report, Moraga Reservoir Dam* (EBMUD, 2003)
- Geologic and geotechnical reports and information from state and local agencies

The geotechnical evaluation of the project-level elements, the regional water treatment and major transmission system alternatives, and program-level projects considered in this section is also based on review of available geotechnical studies, subsurface boring data, and boring logs compiled by Caltrans for major freeway undercrossings in the vicinity of proposed facilities.

3.4.2 Setting

Regional Geology

The WTTIP study area lies within the geologically complex region of California referred to as the Coast Ranges geomorphic province.[1] The Coast Ranges province lies between the Pacific Ocean and the Great Valley province (Sacramento and San Joaquin Valleys) and stretches from the Oregon border to the Santa Ynez Mountains near Santa Barbara. Much of the Coast Ranges province is composed of marine sedimentary deposits and volcanic rocks that form northwest-trending mountain ridges and valleys, running roughly parallel to the San Andreas Fault Zone.

The project sites are generally located in the East Bay Hills, northwest-trending hills characterized by highly folded and deformed sedimentary rocks and alluvial-filled stream valleys. Bedrock consists primarily of the Great Valley Sequence, which is comprised of marine and nonmarine sedimentary rocks such as sandstones, siltstones, and claystones. The Great Valley Sequence has been further subdivided into different assemblages, which contain rocks deposited under similar conditions but during different time periods. Geologic units mapped at the various project sites contain rocks from these assemblages and include, from youngest to oldest, the Mulholland Formation, Contra Costa Group, Neroly Formation, Briones Formation, Rodeo Formation, Hambre Formation, Las Juntas Formation, Vine Hill Formation, and igneous rocks of

[1] A geomorphic province is an area that possesses similar bedrock, structure, history, and age. California has 11 geomorphic provinces (CGS, 2002a).

the Coast Range Ophiolite (AGS, Inc., 2005). With the exception of the igneous rocks, these units generally contain sandstones, mudstones, siltstones, shale, conglomerates, and/or claystones.

Topography

The topography within the study area is highly variable, as the project sites are located over a large area of Contra Costa County and a portion of Alameda County. Generally, the project sites are located either within the low-lying stream drainages or along ridge tops; exceptions are the proposed Moraga Road Pipeline alignment, which crosses from one stream valley to another over the intervening ridge tops, and the proposed Orinda-Lafayette Aqueduct, which includes a tunnel beneath the intervening ridges. Maps B1 through B7, presented at the end of Chapter 2, Project Description, show project locations on topographic base maps (U.S. Geological Survey [USGS] 7.5-minute quadrangles); and the D Maps (design drawings) include site-specific topography.

Improvements in the major stream valleys would be located at elevations ranging between about 200 and 425 feet above mean sea level (msl). Facilities in smaller tributary drainages would be located at elevations ranging from about 350 to 580 feet above msl. Facilities on ridgelines, mostly reservoirs, would be located at elevations ranging from about 540 feet to nearly 1,000 feet above msl. (See Table 2-10 in Chapter 2 for reservoir site elevations.)

Soils

The U.S. Department of Agriculture (USDA) Soil Conservation Service's *Soil Survey of Contra Costa County, California* (1977) was reviewed to determine soil conditions beneath the proposed project sites in Contra Costa County. The USDA Soil Conservation Service's *Soil Survey of Alameda County, California, Western Part* (1981) was reviewed for the Upper San Leandro WTP site. Table 3.4-1 provides a summary of the key engineering properties of soils at each site. Many of the proposed facilities would be constructed at developed sites where soil conditions have been altered by construction and utility installation.

The Lafayette WTP, Orinda WTP, Happy Valley Pumping Plant and Pipeline, and Leland Isolation Pipeline and Bypass Valve facilities are underlain by lowland soil associations (AGS, Inc., 2005). Most of the lowland soils exhibit slow permeability, moderate to high expansivity, corrosivity, and low erosivity. The Walnut Creek WTP, Upper San Leandro WTP, Ardith Reservoir/Donald Pumping Plant, Fay Hill Reservoir, Highland Reservoir and Pipelines, Moraga Reservoir, Sunnyside Pumping Plant and Pipeline, and Withers Pumping Plant facilities are underlain by upland soil associations. Upland soils generally have slow permeability, high expansivity, corrosivity, and moderate to high erosivity. The Sobrante WTP, Orinda-Lafayette Aqueduct, Fay Hill Pumping Plant and Pipeline Improvements, Glen Pipeline Improvements, Moraga Road Pipeline, and Tice Pumping Plant and Pipeline sites are underlain partially by lowland and partially by upland soils associations.

TABLE 3.4-1
SOIL PROPERTIES AT PROPOSED WTTIP PROJECT SITES (PROJECT LEVEL)

Location	Soil Type and Symbol	Slope	Erosion Hazard	Shrink/Swell Potential	Corrosivity
Lafayette WTP	Clear Lake clay (Cc)	0%	none	high	very high
Orinda WTP	Botella clay loam (BaC)	0–2%	slight	moderate	moderate
Walnut Creek WTP	Lodo clay loam (LcF)	30–50%	high	moderate	moderate
Sobrante WTP	Altamont–Fontana Complex (AcF)	30–50%	moderate to high	moderate to high	high
	Conejo clay loam (CeA)	0–2%	none	moderate	moderate
	Cropley clay (CkB)	2–5%	slight	high	high
	Cut-and-fill land, Los Osos Complex (CnE)	9–30%	high	high	high
	Diablo clay (DdE)	15–30%	moderate	high	high
Upper San Leandro WTP	Xerorthents–Altamont Complex (157)	30–50%	moderate	high	high
	Xerorthents–Los Osos Complex (158)	30–50%	moderate	high	moderate
Orinda-Lafayette Aqueduct	Botella clay loam (BaC)	0–2%	slight	moderate	moderate
	Clear Lake clay (Cc)	0%	none	high	very high
	Los Osos clay loam (LhE)	15–30%	moderate	high	high
Ardith Reservoir/ Donald Pumping Plant	Cut-and-fill land, Los Osos Complex (CnE)	9–30%	high	high	high
	Dibble silty clay loam (DeE)	15–30%	moderate	moderate to high	moderate to high
Fay Hill Pumping Plant and Pipeline Improvements	Cropley clay (CkB)	2–5%	slight	high	high
	Los Osos clay loam (LhF)	30–50%	moderate to high	high	high
Fay Hill Reservoir	Millsholm loam (MeF)	30–50%	high	low	high
Glen Pipeline Improvements	Clear Lake clay (Cc)	0%	none	high	very high
Happy Valley Pumping Plant and Pipeline	Cropley clay (CkB)	2–5%	slight	high	high
Highland Reservoir and Pipelines	Lodo clay loam (LcF)	30–50%	moderate to high	moderate	moderate
	Los Osos clay loam (LhF)	30–50%	moderate to high	high	high
Lafayette Reclaimed Water Pipeline	Lodo clay loam (LcF)	30–50%	moderate to high	moderate	moderate
	Clear Lake clay (Cc)	0%	none	high	very high

TABLE 3.4-1 (continued)
SOIL PROPERTIES AT PROPOSED WTTIP PROJECT SITES (PROJECT LEVEL)

Location	Soil Type	Slope	Erosion Hazard	Shrink/Swell Potential	Corrosivity
Leland Isolation Pipeline and Bypass Valves	Botella clay loam (BaA)	0–2%	slight	moderate	moderate
	Conejo clay loam (CeA)	0–2%	none	moderate	moderate
Moraga Reservoir	Los Osos clay loam (LhF)	30–50%	moderate to high	high	high
Moraga Road Pipeline	Alo clay (AaE)	15–30%	moderate	high	high
	Alo clay (AaF)	30–50%	moderate to high	high	high
	Clear Lake clay (Cc)	0%	none	high	very high
	Cropley clay (CkB)	2–5%	slight	high	high
	Los Osos clay loam (LhE)	15–30%	moderate	high	high
	Millsholm loam (MeG)	50–75%	very high	low	high
Sunnyside Pumping Plant	Diablo clay (DdF)	30–50%	moderate to high	high	high
Tice Pumping Plant and Pipeline	Botella clay loam (BaA)	0–2%	slight	moderate	moderate
	Clear Lake clay (Cc)	0%	none	high	very high
	Los Osos clay loam (LhE)	15–30%	moderate	high	high
	Tierra loam (TaD)	9–15%	moderate to high	low-moderate	high
Withers Pumping Plant	Altamont clay (AbE)	15–30%	moderate	high	high

SOURCE: USDA Soil Conservation Service, 1977 and 1981, as compiled by AGS, Inc. (AGS, Inc., 2005).

Seismicity

The San Francisco Bay Area is a region of high seismic activity with numerous active and potentially active faults.[2] Major earthquakes have affected the region in the past and are expected to occur in the near future on one of the principal active faults in the San Andreas Fault System. The USGS Working Group on California Earthquake Probabilities determined there is a 62 percent likelihood of one or more earthquakes of magnitude 6.7 or greater occurring in the San Francisco Bay Area region within the 30-year period from 2002 to 2032 (USGS, 2003).

2 An *active* fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 11,000 years). A *potentially active* fault is a fault that has shown evidence of surface displacement during the last 1.6 million years, unless direct geologic evidence demonstrates inactivity for the last 11,000 years or longer. This definition does not mean that faults lacking evidence of surface displacement are necessarily inactive. *Sufficiently active* is also used to describe a fault if there is some evidence that Holocene surface displacement occurred on one or more of its segments or branches (Hart, 1997).

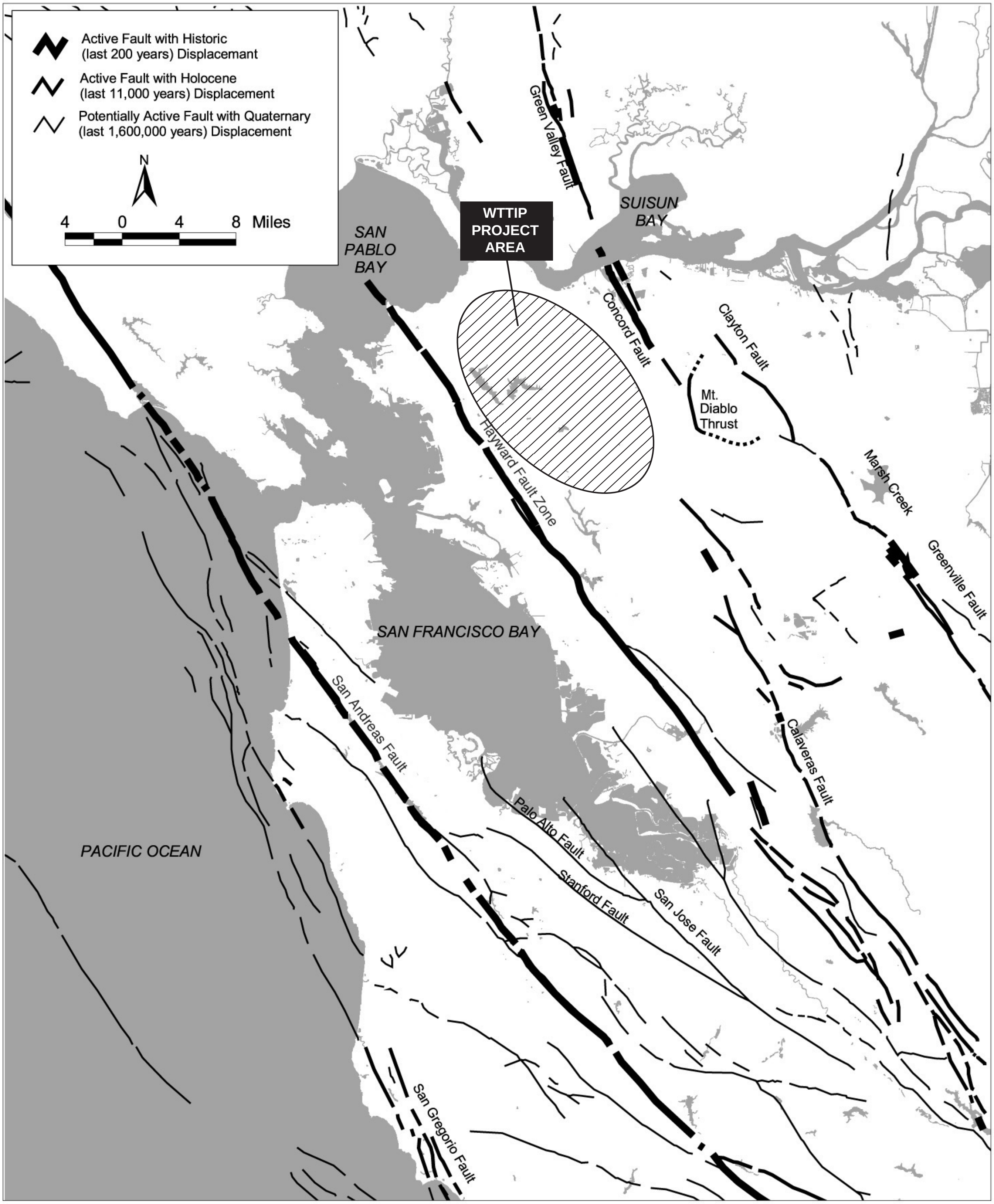
Richter magnitude (M) is a measure of the size of an earthquake as recorded by a seismograph. The reported Richter magnitude for an earthquake represents the highest amplitude measured by the seismograph at a distance of 100 kilometers from the epicenter. Richter magnitudes vary logarithmically, with each whole-number step representing a tenfold increase in the amplitude of the recorded seismic waves. Earthquake magnitudes are also measured by their moment magnitude (Mw), which is related to the physical characteristics of a fault, including the rigidity of the rock, the size of fault rupture, and the movement or displacement across a fault (CGS, 2002b).

The San Andreas Fault System forms the boundary between the North American and Pacific crustal plates and includes the San Andreas, Hayward, San Gregorio–Hosgri, Rodgers Creek–Healdsburg, Calaveras, Mt. Diablo Thrust, Marsh Creek–Greenville, and the Concord–Green Valley Faults (Figure 3.4-1). A number of these faults, such as the San Andreas and Hayward, have experienced significant activity during historic time (within the last 200 years). Table 3.4-2 lists the location of regionally active faults and potentially active faults significant to proposed WTTIP projects due to proximity, activity status, date of most recent motion, and maximum moment magnitude (Mmax). The Mmax is the strongest earthquake that is likely to be generated along a fault and is based on empirical relationships of surface rupture length, rupture area, and fault type, all of which are related to the physical size of fault rupture and displacement across a fault.

The Hayward (when combined with the Rodgers Creek) and the San Andreas Faults have the highest probabilities of generating an M 6.7 or greater earthquake before 2032 (USGS, 2003). The Hayward Fault is of particular concern because of the density of urban development along its length and the major infrastructure lines (water, electricity, gas, and transportation) that cross it. A characteristic feature of the Hayward Fault is its well-expressed and relatively consistent fault creep.[3] Although large earthquakes on the Hayward Fault have been rare since 1868, slow fault creep has continued to occur and has caused measurable offset across the fault trace. Fault creep on the East Bay segment of the Hayward Fault is estimated at 9 millimeters per year (mm/yr) (Peterson et al., 1996). However, a large earthquake could occur on the Hayward Fault with an estimated Mmax of 7.1 (Table 3.4-2).

The San Andreas Fault, although at least 19 miles from any of the project facilities, was the source of two major seismic events in recent geologic history that affected the San Francisco Bay region. The 1906 San Francisco earthquake, estimated at M 7.9, resulted in approximately 290 miles of surface fault rupture, the longest of any known to occur on a continental strike-slip fault. The more recent 1989 Loma Prieta earthquake, with a magnitude of M 7.1, resulted in widespread damage throughout the Bay Area.

[3] Fault creep is the slow, continuous deformation observed across a fault trace as a result of constant seismic stress.



SOURCE: ESA

EBMUD Water Treatment and Transmission Improvements Program . 204369

Figure 3.4-1
Active and Potentially Active Bay Area Earthquake Faults

TABLE 3.4-2
ACTIVE FAULTS IN THE PROJECT VICINITY

Fault	Location and Direction from Nearest WTTIP Project Site	Recency of Movement	Fault Classification[a]	Historical Seismicity[b]	Maximum Moment Magnitude Earthquake (Mmax)[c]
Concord–Green Valley	2.5 miles northeast (Walnut Creek WTP)	Historic (1955) Holocene	Active	Historic active creep	6.8
Mt. Diablo Thrust	1.9 miles northeast (New Leland Pressure Zone Reservoir)	Holocene	Active (Blind)	Many <M 4.5	6.65
Hayward	0.2 mile west (Upper San Leandro WTP; San Pablo Pipeline crosses fault)	Historic (1868 rupture) Holocene	Active	M 6.8, 1868 Many <M 4.5	7.1
Calaveras (northern)	6 miles south (Upper San Leandro WTP; St. Mary's Pipeline)	Historic (1861 rupture) Holocene	Active	M 5.6 to M 6.4, 1861 M 4 to M 4.5 swarms 1970, 1990	6.8
Marsh Creek–Greenville	11.9 miles southeast (New Leland Pressure Zone Reservoir)	Historic (1980 rupture) Holocene	Active	M 5.6, 1980	6.9
San Andreas	18.9 miles west (Upper San Leandro WTP)	Historic (1906; 1989 ruptures)	Active	M 7.1, 1989 M 7.9, 1906 M 7.0, 1838 Many <M 6	7.9

[a] Jennings, 1994, and Hart, 1997. An active fault is defined by the California Geological Survey as one that has had surface displacement within approximately the last 11,000 years. A potentially active fault is defined as a fault that has showed evidence of surface displacement during approximately the last 1.6 million years.
[b] Richter magnitude (M) and year for recent and/or large events. Richter magnitude scale reflects the maximum amplitude of a seismic wave measured at a distance of 100 kilometers from the epicenter.
[c] Moment magnitude is related to the physical size of a fault rupture and movement across a fault. The maximum moment magnitude (Mmax) is the strongest earthquake that is likely to be generated along a fault and is based on empirical relationships of surface rupture length, rupture area, and fault type.

SOURCE: Jennings, 1994; Hart, 1997, AGS, Inc., 2005.

The closest active faults to the various project sites are the Hayward, Mt. Diablo Thrust, and the Concord Faults. The Mt. Diablo Thrust and the Concord Faults are the faults with the least likelihood of causing an M 6.7 earthquake (USGS, 2003). The historical record indicates that no large earthquakes have occurred on the Mt. Diablo or Concord Faults; however, a moderate earthquake of M 5.4 occurred on the Concord Fault segment in 1955.

Other Regional Faults

Several smaller faults have been mapped in the vicinity of the project sites, including the Pinole, Franklin, Las Trampas, and Lauterwasser Faults. The California Geological Survey (CGS) does not consider these faults to be active, and they are therefore not zoned as Earthquake Fault Zones under the Alquist-Priolo Earthquake Fault Zoning Act.[4] Activity on these faults is much less

[4] The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act), signed into law in December 1972, requires the delineation of zones along active faults in California. As previously noted, an *active* fault is a fault that has had surface displacement within approximately the last 11,000 years.

likely to occur than movement on the principal active faults. If seismicity on these faults were to occur, the result would likely be occasional, small earthquakes (less than M 4) (AGS, Inc., 2005).

Seismic Hazards

Surface Fault Rupture

Seismically induced ground rupture is defined as the physical displacement of surface deposits in response to an earthquake's seismic waves. The magnitude and nature of fault rupture can vary for different faults, or even along different strands of the same fault. Ground rupture is considered more likely along active faults, which are referenced in Table 3.4-2.

None of the WTTIP project-level elements are within an Alquist-Priolo Earthquake Fault Zone, as designated through the Alquist-Priolo Earthquake Fault Zoning Act, and no mapped active faults are known to pass through the immediate project region. Therefore, the risk of ground rupture is low.

Of the program-level projects, only the proposed San Pablo Pipeline project is located on or near an active fault. The San Pablo Pipeline crosses the Hayward Fault and associated Alquist-Priolo Earthquake Fault Zone. Although the Alquist-Priolo Act requirements do not apply to this project because it would not include a surface building for human occupancy, there would be a potential risk of damage from ground rupture.

Groundshaking

Earthquakes in the Bay Area could produce strong groundshaking in the project region. Groundshaking intensity is partly related to the size of an earthquake, the distance to the site, and the response of the geologic materials that underlie a site. As a rule, the greater the earthquake magnitude and the closer the fault rupture to a site, the greater the intensity of groundshaking. Violent groundshaking is generally expected at and near the epicenter of a large earthquake; however, different types of geologic materials respond differently to earthquake waves. For instance, deep unconsolidated materials can amplify earthquake waves and cause longer periods of groundshaking.

While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the observed groundshaking effects at a particular location. The Modified Mercalli (MM) scale is commonly used to measure earthquake intensity due to groundshaking. Table 3.4-3 presents a description of the Modified Mercalli scale. The MM values for intensity range from I (earthquake not felt) to XII (damage nearly total). MM intensities ranging from IV to X can cause moderate to significant structural damage, although the damage will not be uniform. Some structures experience substantially more damage than others. The age, material, type, method of construction, size, and shape of a structure affect its performance in an earthquake.

TABLE 3.4-3
MODIFIED MERCALLI INTENSITY SCALE

Intensity Value	Intensity Description	Average Peak Acceleration (% g[a])
I	Not felt except by a very few persons under especially favorable circumstances.	< 0. 17
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	0.17–1.4
III	Felt noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly, vibration similar to a passing truck.	0.17–1.4
IV	During the day felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	1.4–3.9
V	Felt by nearly everyone, many awakened. Some dishes and windows broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles may be noticed. Pendulum clocks may stop.	3.5–9.2
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; and fallen plaster or damaged chimneys. Damage slight.	9.2–18
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving.	18–34
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.	34–65
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked. Underground pipes broken.	65–124
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from riverbanks and steep slopes. Shifted sand and mud. Water splashed over banks.	> 124
XI	Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.	> 124
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.	> 1.24

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

SOURCE: ABAG, 2003; CGS, 2003.

As a comparison, the 1906 San Francisco earthquake, with an M 7.9 on the San Andreas Fault, produced shaking intensities modeled to range from moderate (MM VI) to strong (MM VII) within the project area. The 1989 Loma Prieta earthquake, with an M 7.1 near the San Andreas Fault, produced light (MM V) to moderate (MM VI) shaking intensities (AGS, Inc., 2005).

Ground motion during an earthquake can also be described using the motion parameters of acceleration, velocity, and duration of shaking. A common measure of ground motion is the peak ground acceleration (PGA). The PGA for a given component of motion is the largest value of horizontal acceleration obtained from a seismograph. PGA is expressed as the percentage of the acceleration due to gravity (g), which is approximately 980 centimeters per second squared. For comparison purposes, the maximum peak acceleration value recorded during the Loma Prieta earthquake was in the vicinity of the epicenter, near Santa Cruz, at 0.64 g. The lowest recorded value was 0.06 g in the bedrock on Yerba Buena Island. The highest value measured in the Contra Costa County area was 0.13 g (CDMG, 1990). However, an earthquake on the nearby Hayward Fault would likely produce far more severe groundshaking in the project area than was observed during the Loma Prieta earthquake. As Table 3.4-4 shows, calculations indicate that the PGA could reach as high as 0.93 g in the project region (AGS, Inc., 2005).[5]

An Mmax 7.1 earthquake on the Hayward Fault yields the highest calculated PGA for the Orinda WTP, Sobrante WTP, Upper San Leandro WTP, Orinda-Lafayette Aqueduct, Ardith Reservoir/Donald Pumping Plant, Happy Valley Pumping Plant and Pipeline, Highland Reservoir and Pipelines, Sunnyside Pumping Plant and San Pablo Pipeline sites (AGS, Inc., 2005). An Mmax 6.7 earthquake on the Mt. Diablo Thrust Fault yields the highest calculated PGA for the Lafayette WTP, Walnut Creek WTP, Fay Hill Pumping Plant and Pipeline Improvements, Fay Hill Reservoir, Glen Pipeline Improvements, Highland Reservoir and Pipelines, Moraga Reservoir, Moraga Road Pipeline, New Leland Pressure Zone Reservoir and Pipeline, and Tice Pumping Plant and Pipeline sites. An Mmax 6.65 earthquake on the Concord–Green Valley fault yields the highest calculated PGA for the Withers Pumping Plant facility. Calculated PGAs for earthquakes on other regionally active faults were less than those shown in Table 3.4-4. It should be noted that the values shown in the table are based on minimum distances from each facility to the respective faults. For pipeline alignments, multiple locations were analyzed to determine the PGA for the entire pipeline length.

After the Loma Prieta earthquake in 1989, EBMUD initiated a seismic evaluation program to evaluate the performance of essential components of the water system following a major earthquake, and to identify and evaluate projects to improve the system's post-earthquake performance. The seismic evaluation program studied three faults passing through or close to the

5 PGA values were calculated using a deterministic seismic hazard assessment approach. First, the faults near a site are identified and assessed for activity. Then, for each seismic source, an earthquake scenario consisting of the maximum magnitude a fault is capable of generating at the closest distance to the site is used to determine the ground motion estimate.

TABLE 3.4-4
ESTIMATED PEAK GROUND MOTIONS, PROJECT-LEVEL ELEMENTS

Facility Name	Distance to Hayward Fault (km)	Peak Ground Acceleration[a] (g)	Distance to Mt. Diablo Thrust Fault (km)	Peak Ground Acceleration[b] (g)	Distance to Concord Fault (km)	Peak Ground Acceleration[c] (g)
Lafayette WTP	9	0.43	9	**0.46**	13	0.28
Orinda WTP	5	**0.59**	14	0.33	17	0.22
Walnut Creek WTP	15	0.29	5	**0.66**	6	0.47
Sobrante WTP	3	**0.71**	24	0.20	20	0.19
Upper San Leandro WTP	<0.5	**0.93**	17	0.28	22	0.18
Orinda-Lafayette Aqueduct	5	**0.59**	9	0.46	13	0.28
Ardith Reservoir/ Donald Pumping Plant	6	**0.54**	10	0.43	15	0.25
Fay Hill Pumping Plant and Pipeline Improvements	8	0.46	7	**0.54**	12	0.29
Fay Hill Reservoir	8	0.46	7	**0.54**	12	0.29
Glen Pipeline Improvements	10	0.39	8	**0.50**	11	0.32
Happy Valley Pumping Plant and Pipeline	6	**0.54**	14	0.33	15	0.25
Highland Reservoir and Pipelines	8	**0.46**	9	**0.46**	13	0.28
Lafayette Reclaimed Water Pipeline	8	**0.46**	9	**0.46**	13	0.28
Moraga Reservoir	8	0.46	7	**0.54**	12	0.29
Moraga Road Pipeline	8	0.46	7	**0.54**	12	0.29
Sunnyside Pumping Plant	8	**0.46**	13	0.35	14	0.26
Tice Pumping Plant and Pipeline	13	0.32	4	**0.73**	7	0.43
Withers Pumping Plant	16	0.27	9	0.46	6	**0.47**

Values in **Bold** indicate the highest calculated PGA for that project location.

[a] Average PGA value calculated using Mmax of 7.1 for the Hayward–Rodgers Creek Fault taken from three different sources.
[b] Average PGA value calculated using Mmax of 6.65 for Mt. Diablo Thrust Fault taken from three different sources.
[c] Average PGA value calculated using Mmax of 6.7 for Concord–Green Valley Fault taken from three different sources.

km = kilometers
g = gravity

SOURCE: AGS, Inc., 2005.

service area: the Hayward, Calaveras, and Concord.[6] The seismic evaluation studies, conducted between 1991 and 1994, involved investigations to:

- Establish target levels of service (service goals) for post-earthquake conditions
- Assess site seismic hazards (groundshaking, liquefaction, landslides, and surface faulting)
- Evaluate the structural integrity of facilities
- Develop seismic scenarios
- Prioritize improvements
- Prepare cost estimates
- Estimate total system recovery times and achievement of service goals

The seismic evaluation program was designed to identify and prioritize those facilities most prone to seismic damage that would cause an unacceptable level of service, life safety hazard, and/or cost to customers. The service goals were developed to help define what constituted unacceptable service and addressed the system as a whole as well as water needs for firefighting, hospitals and disaster centers, and domestic and other water users. As a result of the seismic evaluation program, many of the WTPs and other facilities received seismic upgrades.

Secondary Earthquake Hazards

Secondary earthquake hazards in the project region include earthquake-induced landsliding, settlement, and liquefaction. Strong ground motions that occur during earthquakes are capable of inducing landslides and related forms of ground failure. Settlement is the gradual downward movement of an engineered structure (such as a building) due to the compaction of unconsolidated material below the foundation. Settlement accelerated by earthquakes can result in vertical or horizontal separations of structures or portions of one structure; cracked foundations, roads, sidewalks, and walls; and, in severe situations, building collapse and bending or breaking of underground utility lines. Soil liquefaction (a phenomenon in which soils lose strength) can result in ground failure. The soils most susceptible to liquefaction are clean, loose, uniformly graded, saturated, fine-grained soils that occur close to the ground surface, usually at depths of less than 50 feet. In general, upland areas have a low liquefaction potential, except where significant alluvium is present in creek bottoms or swales.

Other Geologic Hazards

Landslides and Slope Failure

Slope failures, commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. A slope failure is a mass of rock, soil, and debris displaced downslope by sliding, flowing, or falling. Exposed rock slopes undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and deep-seated rotational slides. Landslides may occur on slopes of 15 percent or less; however, the

[6] The seismic evaluation program evaluated both “probable” and “maximum” earthquakes on the Hayward Fault, and the maximum-level earthquakes on the Calaveras and Concord Faults. Other likely earthquake events, such as an earthquake along the San Andreas Fault, are not expected to produce as much damage to the water system.

probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. Landslide-susceptible areas are characterized by steep slopes and downslope creep of surface materials. Debris flows consist of a loose mass of rocks and other granular material that, if saturated and present on a steep slope, can move downslope. The rate of rock and soil movement can vary from a slow creep over many years to a sudden mass movement. Landslides occur throughout the state of California, but the density of incidents increases in zones of active faulting.

Slope stability can depend on a number of complex variables. The geology, structure, and amount of groundwater in the slope affect slope failure potential, as do external processes (i.e., climate, topography, slope geometry, and human activity). The factors that contribute to slope movements include those that decrease the resistance in the slope materials and those that increase the stresses on the slope. Slope failure under static forces occurs when those forces initiating failure overcome the forces resisting slope movement. For example, a soil slope may be considered stable until it becomes saturated with water (e.g., during heavy rains or due to a broken pipe or sewer line). Under saturated conditions, the water pressure in the individual pores within the soil increases, reducing the strength of the soil. Cutting into the slope and removing the lower portion, or slope toe, can reduce or eliminate the slope support, thereby increasing stress on the slope.

Earthquake motions can induce significant horizontal and vertical dynamic stresses in slopes that can trigger failure. Earthquake-induced landslides can occur in areas with steep slopes that are susceptible to strong ground motion during an earthquake. The 1989 Loma Prieta earthquake triggered thousands of landslides over an epicentral area of 770 square miles. The Oakland-Berkeley Hills could experience some earthquake-induced rockfalls, slumps, and debris flows during an event on the Hayward Fault or other active Bay Area fault capable of generating strong ground motion.

Squeezing Ground

Squeezing ground is a tunneling term used to describe the slow advancement of exposed, low-strength rock surfaces into the tunnel. This slow creep of the rock material is often imperceptible at the time of construction, but ultimately causes a reduction in the tunnel cross-section and a convergence of installed support. Squeezing conditions are often associated with materials that have a low swelling capacity and high overburden pressure.[7] The degree of squeezing ground potential is a significant factor in the selection of appropriate excavation methods and equipment and in the development of tunnel support systems.

Mineral Resources

The CGS has classified lands within the San Francisco Bay region into four Mineral Resource Zones (MRZs). The classification of MRZs is based on guidelines adopted by the California State Mining and Geology Board, as mandated by the Surface Mining and Reclamation Act of 1975. MRZ-1 zones are areas where adequate information indicates that no significant mineral deposits

7 Overburden pressure is the vertical pressure from overlying materials.

are present, or where it is judged that little likelihood for their presence exists. MRZ-2 zones, which were not found on any of the project sites, are areas where adequate information indicates significant mineral resources are present, or where it is judged that a high likelihood for their presence exists. MRZ-3 zones are considered to have potential mineral deposits, but their significance cannot be evaluated from available data. MRZ-4 zones are areas where available information is inadequate for assignment to any other MRZ category. The various project sites are mapped by the CGS as MRZ-1, MRZ-3, or MRZ-4 zones (Stinson et al., 1987).

Regulatory Framework

California Building Code

The California Building Code (CBC) has been codified in the California Code of Regulations (CCR) as Title 24, Part 2, which is a portion of the California Building Standards Code. The California Building Standards Commission is responsible for coordinating building standards under Title 24. Under state law, all building standards must be centralized in Title 24 or they are not enforceable. The purpose of the CBC is to provide minimum standards to safeguard property and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location, and maintenance of building and structures within its jurisdiction. The Uniform Building Code (UBC), published by the International Conference of Building Officials, is a widely adopted building code in the United States. The CBC is based on the 1997 UBC, with necessary California amendments. These amendments include significant building design criteria that have been tailored for California earthquake conditions.

The project region is located within Zone 4, one of the four seismic zones designated in the United States. Zone 4 is expected to experience the greatest effects from earthquake groundshaking and therefore has the most stringent requirements for seismic design. The national standards adopted into Title 24 apply to all occupancies in California, except for modifications adopted by state agencies and local governing bodies.

In addition, EBMUD has its own seismic design standards that in some areas can be more conservative than the CBC due to the criticality of providing water service following a seismic event.

Division of Safety of Dams

Since 1929, the State of California has supervised the construction and operation of dams to prevent failure and to safeguard life and property. The California Department of Water Resources, Division of Safety of Dams (DSOD) supervises the construction, enlargement, alteration, repair, maintenance, operation, and removal of dams and reservoirs. The DSOD has jurisdiction over all dams in the state that are not federally owned, that are 25 feet or higher (regardless of storage capacity), and that have a storage capacity of 50 acre-feet of water or greater (regardless of height). Dams that are 6 feet or less in height (regardless of storage capacity) or dams with a storage capacity of 15 acre-feet or less (regardless of height) are not under the jurisdiction of the DSOD.

The DSOD has jurisdiction over the existing Moraga Reservoir, Fay Hill Reservoir, and Leland Reservoir. The circular tanks proposed for the project are not considered to be dams (California Water Code, Section 6004a) and are not under DSOD jurisdiction. None of the proposed reservoirs are expected to meet the criteria for DSOD jurisdiction.

3.4.3 Impacts and Mitigation Measures

Significance Criteria

For the purpose of this EIR and consistent with Appendix G of the CEQA Guidelines, a geologic or seismic impact is considered significant if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault
  - Strong seismic groundshaking
  - Seismic-related ground failure, including liquefaction
  - Landslides
- Result in substantial soil erosion or the loss of topsoil;
- Be located on a geologic unit or soil that is unstable or that would become unstable as a result of the project, and potentially result in onsite or offsite landslide, lateral spreading, subsidence (i.e., settlement), liquefaction, or collapse;
- Be located on expansive soil, as defined in Table 18-1-B of the 1994 Uniform Building Code, creating substantial risks to life or property;
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater;
- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state; or
- Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan.

Based on the proposed construction of the various project elements and the geologic environment in the project area, the proposed WTTIP would not result in impacts related to fault rupture, soil erosion, settlement from tunneling, wastewater disposal, or mineral resources. No impact discussion is provided for these topics for the following reasons:

- *Fault Rupture*. The faults most susceptible to earthquake rupture are active faults, which are faults that have experienced surface displacement within the last 11,000 years. There are no active faults that cross any of the project-level sites, and the nearest project facility to an active fault is at least 0.2 mile away. Therefore, the potential for fault rupture to affect the proposed project elements is very low. Of the program-level projects, the San Pablo Pipeline would cross the active Hayward Fault and is therefore discussed below in the program-level projects discussion.

- *Soil Erosion*. Construction work would incorporate best management practices for erosion control, in accordance with applicable local policies and/or stormwater pollution prevention plan requirements (see Section 3.5, Hydrology and Water Quality). These erosion control measures would reduce the potential for short- or long-term structural damage to fills, foundations, and other engineered structures.

- *Settlement from Tunneling*. The tunnel shafts at either end of the proposed tunnel would extend from 75 to 220 feet deep for the east-end shaft and the west-end shaft, respectively. The entire length of the tunnel would be located within bedrock materials, which would reduce the potential for surface settlement. In addition, interior tunnel supports, successfully used in the nearby Lafayette Tunnel No. 2, installed as tunneling progresses, will reduce the potential for subsidence to affect overlying structures.

- *Corrosivity*. Despite the identification of corrosive soils at some project sites, modern pipeline construction materials and methods include measures to reduce the potential for corrosion to a less-than-significant level.

- *Wastewater Disposal*. None of the project elements require the use of septic or other alternative disposal wastewater systems, and therefore no impact associated with this hazard would result.

- *Mineral Resources*. None of the project elements would alter, destroy, or limit access to any existing significant mineral resources.

Impacts and Mitigation Measures

Table 3.4-5 provides a summary of geologic and seismic impacts by project facility.

Impact 3.4-1: Potential injury and/or damage resulting from unstable slopes.

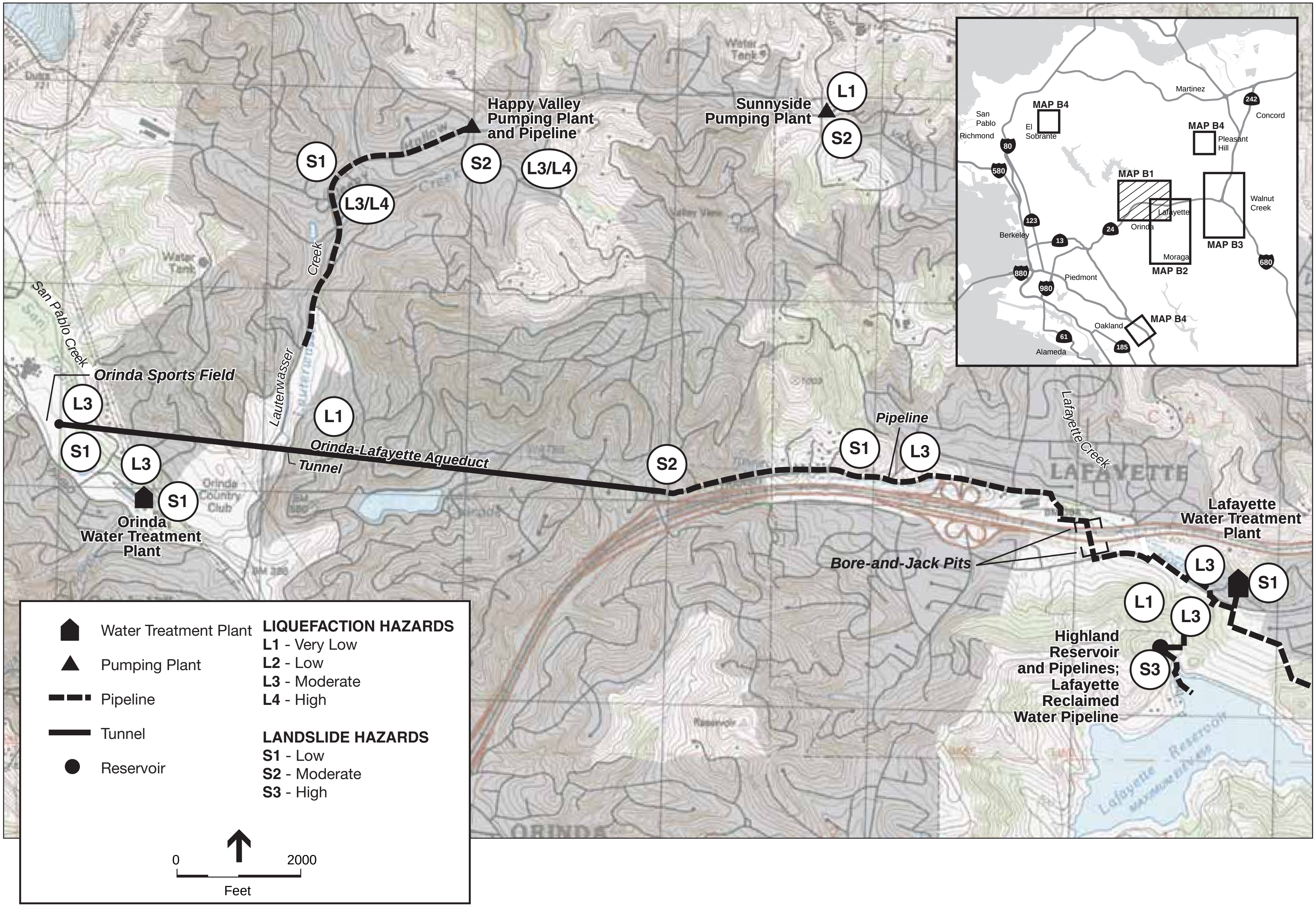
Figures 3.4-2 through 3.4-5 identify a potential slope stability hazard associated with proposed WTTIP project sites evaluated at a project level of detail. The designations shown in the figures (S_1, S_2, and S_3) are based on site-specific reports reviewed by AGS, Inc. and on resources from the Association of Bay Area Governments. Sites with the S_1 designation are considered to have the lowest potential for slope stability hazards, and sites with the S_3 designation are considered to have the highest potential for slope stability hazards because of previously identified slope failures on or near the subject site. WTTIP sites assigned the S_3 designation include the following:

- Walnut Creek WTP
- Highland Reservoir and Pipelines
- Moraga Road Pipeline
- Fay Hill Reservoir

TABLE 3.4-5
SUMMARY OF POTENTIAL PROJECT-LEVEL GEOLOGY, SOILS, AND SEISMICITY IMPACTS

Facility	Impact 3.4-1 Slope Stability	Impact 3.4-2 Ground-shaking	Impact 3.4-3 Expansive Soils	Impact 3.4-4 Liquefaction	Impact 3.4-5 Squeezing Ground
Lafayette WTP					
Alternative 1	LTS	SM	SM	SM	–
Alternative 2	LTS	SM	SM	LTS	–
Orinda WTP					
Alternative 1	LTS	SM	SM	SM	–
Alternative 2	LTS	SM	SM	SM	–
Walnut Creek WTP					
Alternative 1 or 2	SM	SM	SM	LTS	–
Sobrante WTP					
Alternative 1 or 2	SM	SM	SM	LTS	–
Upper San Leandro WTP					
Alternative 1 or 2	LTS	SM	SM	LTS	–
Orinda-Lafayette Aqueduct					
Alternative 2 only	SM	SM	SM	SM	SM
Ardith Reservoir/ Donald Pumping Plant	SM	SM	SM	LTS	–
Fay Hill Pumping Plant and Pipeline Improvements	LTS	SM	SM	LTS	–
Fay Hill Reservoir	SM	SM	SM	LTS	–
Glen Pipeline Improvements	LTS	SM	SM	SM	–
Happy Valley Pumping Plant and Pipeline	SM	SM	SM	SM	–
Highland Reservoir and Pipelines	SM	SM	SM	SM	–
Lafayette Reclaimed Water Pipeline	SM	SM	SM	SM	--
Leland Isolation Pipeline and Bypass Valves	LTS	SM	SM	SM	--
Moraga Reservoir	SM	SM	SM	LTS	–
Moraga Road Pipeline	SM	SM	SM	SM	–
Sunnyside Pumping Plant	SM	SM	SM	LTS	–
Tice Pumping Plant and Pipeline	SM	SM	SM	SM	–
Withers Pumping Plant	SM	SM	SM	LTS	–

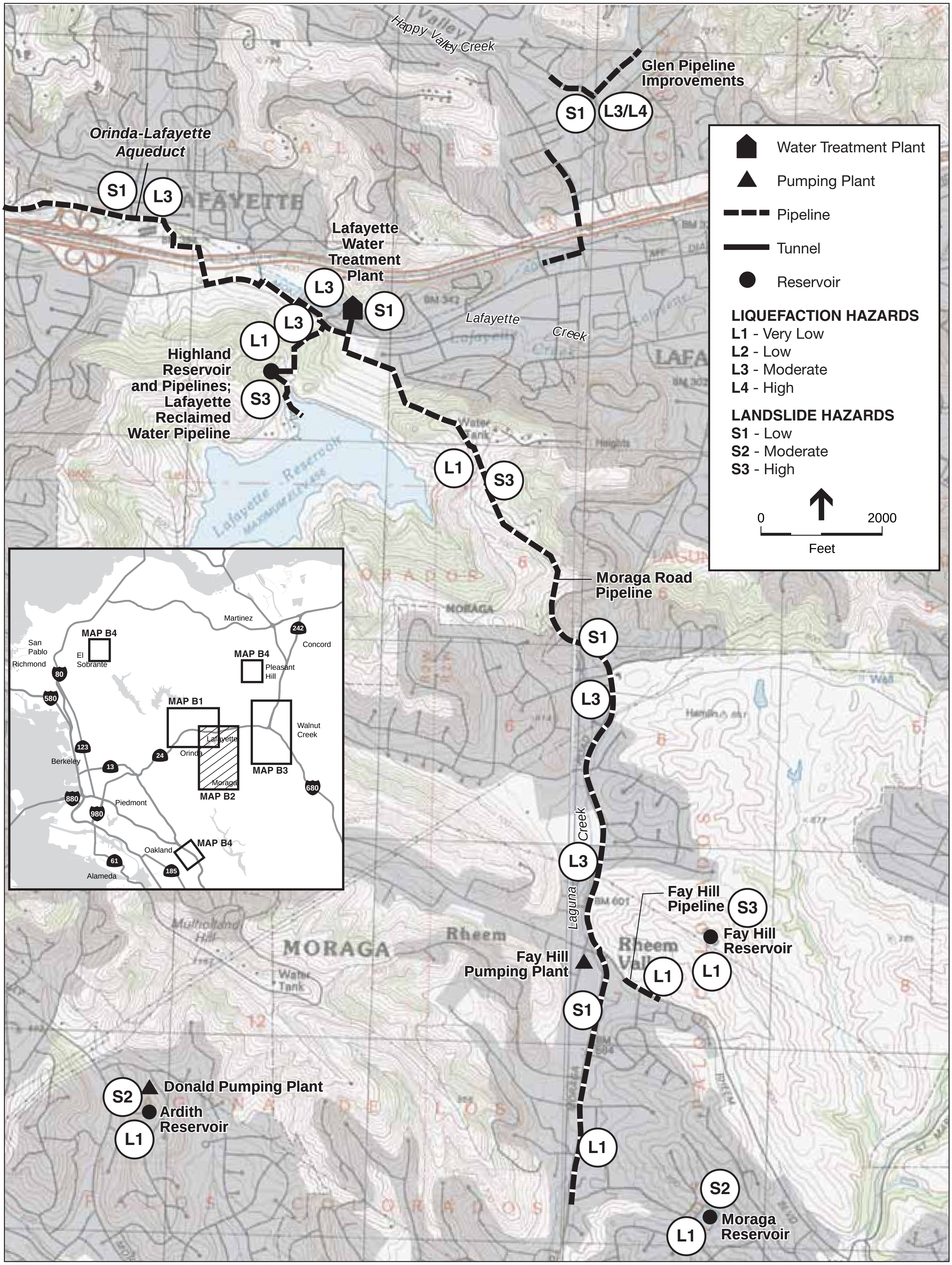
SM = Significant Impact, Can Be Mitigated
SU = Significant Impact, Unavoidable
LTS = Less-Than-Significant Impact
– = No Impact



SOURCE: USGS; ESA

EBMUD Water Treatment and Transmission Improvements Program . 204369

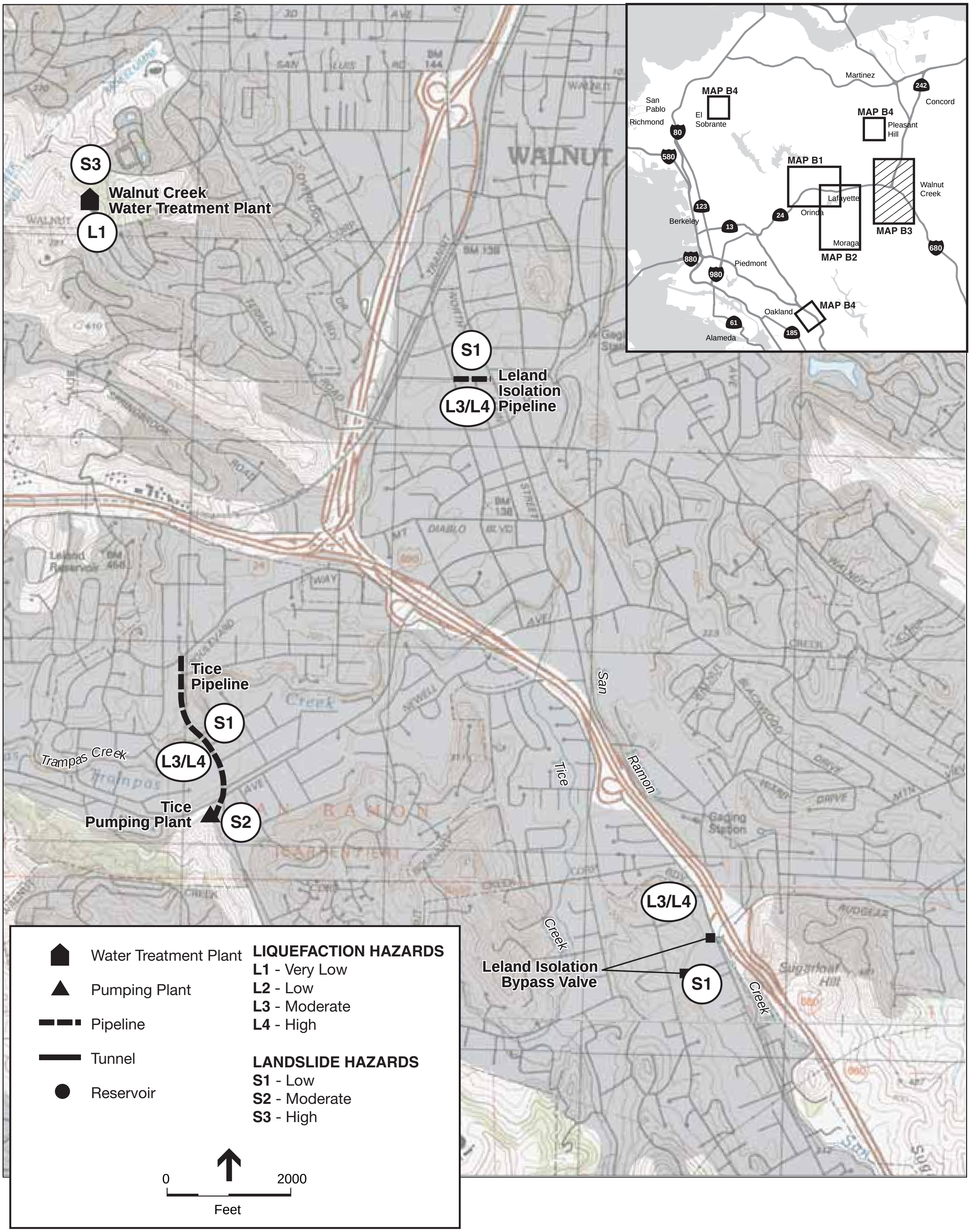
Figure 3.4-2
Potential Geologic Hazard Locations



SOURCE: USGS; ESA

EBMUD Water Treatment and Transmission Improvements Program . 204369

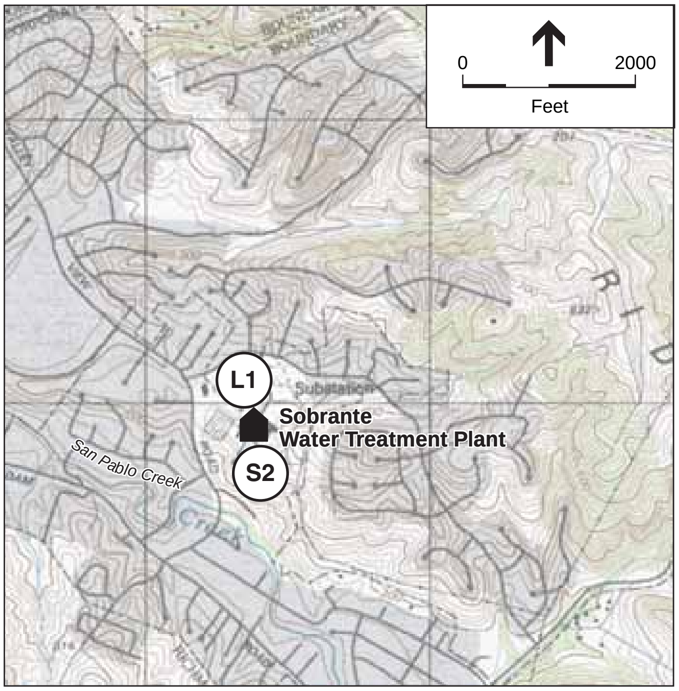
Figure 3.4-3
Potential Geologic Hazard Locations

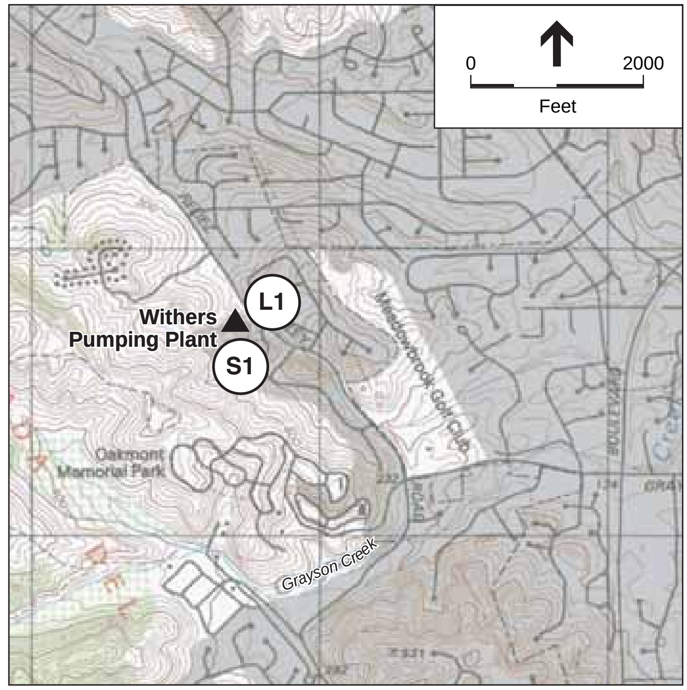


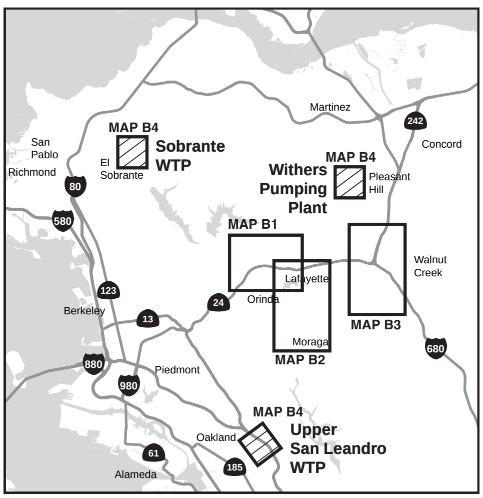
SOURCE: USGS; ESA

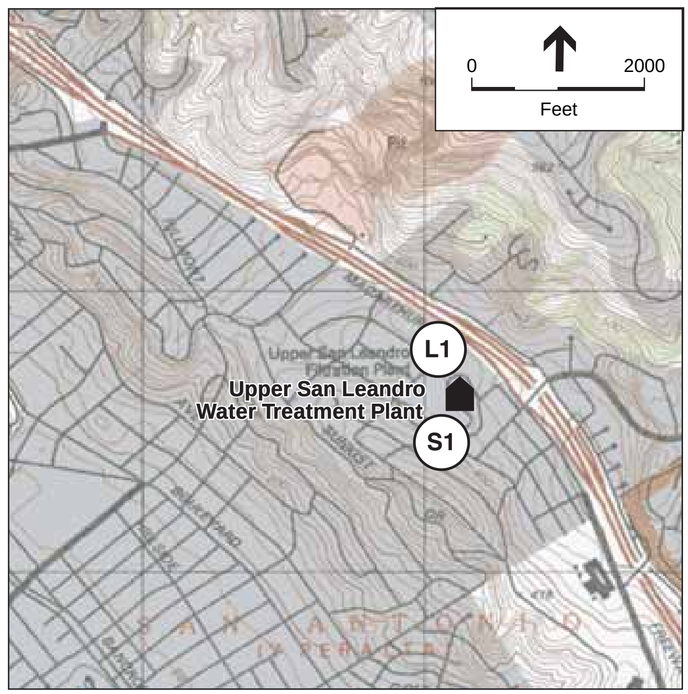
EBMUD Water Treatment and Transmission Improvements Program . 204369

Figure 3.4-4
Potential Geologic Hazard Locations









Water Treatment Plant

Pumping Plant

LIQUEFACTION HAZARDS
L1 - Very Low
L2 - Low
L3 - Moderate
L4 - High

LANDSLIDE HAZARDS
S1 - Low
S2 - Moderate
S3 - High

SOURCE: USGS; ESA

EBMUD Water Treatment and Transmission Improvements Program . 204369

Figure 3.4-5
Potential Geologic Hazard Locations

Lafayette WTP – Alternative 1 or 2

The Lafayette WTP site has been previously graded for development and is relatively level. The majority of the proposed project elements would be located in the previously developed area or in an area that would not present a hazard associated with unstable slopes (also see the discussion under the Lafayette Reclaimed Water Pipeline, below). Therefore, the potential impact at this site would be less than significant.

Orinda WTP – Alternative 1 or 2

The Orinda WTP site has been previously graded for development and is relatively level. The proposed project elements would be located in the previously developed area or in an area that would not present a hazard associated with unstable slopes. Therefore, the potential impact at this site would be less than significant.

Walnut Creek WTP – Alternative 1 or 2

The Walnut Creek WTP is located near a ridgeline in an area of relatively steep terrain. Recent geotechnical studies identified unstable slopes in this area and recommended mitigation measures that were incorporated into the design of improvements currently being completed at the WTP. The proposed new filters would be located within the developed portion of the WTP by the operations building in an area with a low potential for slope instability. The proposed Leland Pumping Plant No. 2 would be located towards the northern end of the WTP where the slopes become greater. With implementation of Measure 3.4-1, below, the potential impact associated with unstable slopes would be less than significant.

Sobrante WTP – Alternative 1 or 2

The Sobrante WTP is located in a relatively level area, with the exception of the parcel situated west of Valley View Drive. The proposed backwash water equalization basins and sedimentation units would be sited at this location, where the relatively steep slopes are showing signs of soil instability (e.g., failure of an asphalt walkway). As part of the project, EBMUD would convert the existing basins into equalization basins and install a new basin and new sedimentation units to the south. With implementation of Measure 3.4-1, below, the potential impact associated with unstable slopes would be less than significant.

Upper San Leandro WTP – Alternative 1 or 2

The topography of the Upper San Leandro WTP is characterized by gentle slopes. The proposed project elements would be located in the previously developed area or in an area that would not present a hazard associated with unstable slopes. Therefore, the potential impact at this site would be less than significant.

Orinda-Lafayette Aqueduct – Alternative 2

The only near-surface features of the tunnel would be the two vertical shafts installed for entry and exit purposes during construction. The tunnel itself would be located sufficiently deep into the bedrock (between 75 feet and 400 feet, see Map D-OLA-4 for profile) and would not present a potential hazard due to slope instability. The pipeline alignments at either end of the tunnel shafts would generally be located in gently sloping areas and would not be subject to slope stability hazards. The west shaft would be located in a relatively level area that would also not be susceptible to unstable slopes. The east shaft would be located in a moderately sloping area. In consideration of the above and with implementation of Measure 3.4-1, the potential impact would be less than significant.

Ardith Reservoir and Donald Pumping Plant

The Ardith Reservoir site is located on moderate to steep topography that could potentially be susceptible to slope instability. A previous geotechnical investigation for this site (formerly referred to as the Moraga Reservoir site), indicated that there was evidence of shallow surface soil slides on the eastern slope of the site (Marliave, 1955). Although the existing Donald Pumping Plant is located in an area of level terrain, the project would relocate the plant to the downhill (western) side of the site, which would require measures to ensure slope stability. With implementation of Measure 3.4-1, the potential impact would be less than significant.

Fay Hill Pumping Plant and Pipeline Improvements

The Fay Hill Pumping Plant site is located within a relatively level area adjacent to a roadway. The potential impact due to slope instability at this site would be less than significant.

Fay Hill Reservoir

As with the Walnut Creek WTP, the Fay Hill Reservoir is located in an area of relatively steep terrain with previously identified unstable slopes. Slope stabilization improvements have been implemented to the north of the existing reservoir. Previous geotechnical reports indicate that landslides have affected only shallow soils, because the bedrock is found at shallow depths (AGS, Inc., 2005). With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Glen Pipeline Improvements

The proposed pipeline improvements would not be located in any areas of unstable slopes. Therefore, the potential impact would be less than significant.

Happy Valley Pumping Plant and Pipeline

The proposed location of the Happy Valley Pumping Plant is near the convergence of two surface water drainages. The topography is nearly level at the proposed plant location and becomes moderately steep toward the drainages. Evidence of soil instability was observed along the southern end of the property, adjacent to the creek.

Along the proposed pipeline route, numerous small landslides along Lombardy Lane and Miner Road have affected the adjacent slopes; however, the pipeline would be buried within the roadway and would not be affected by these deposits (AGS, Inc., 2005). With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Highland Reservoir and Pipelines

The topography at the Highland Reservoir site consists of a moderate slope at the crest of an eastward-facing ridge, with moderate to steep slopes in unpaved areas along the pipeline alignment. The proposed access road to the reservoir site is moderate to very steep in inclination. Landslides have been identified on the northern and southern slopes of the ridgeline. One of the previously identified landslides coincides with the location of the proposed access road; however, none of the landslides are within 300 feet of the proposed reservoir site or overflow pipeline, or within 100 feet of the joint pipe alignment (EBMUD, 2006). Colluvial deposits have been identified along the roadway to the southeast of the reservoir site along the proposed pipeline alignment.[8] There is evidence of some bank failure at the Lafayette Creek crossing of the proposed Highland Reservoir Pipelines; however, any support structures for the pipeline would be located at a sufficient distance away from the edge of the stream bank. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Lafayette Reclaimed Water Pipeline

Similar to the Highland Reservoir Pipelines, there is evidence of some bank failure at the Lafayette Creek crossing of the proposed Lafayette Reclaimed Water Pipeline; however, any support structures for the pipeline would be located sufficiently away from the creekbank edge[9]. As discussed above for the Highland Reservoir, there are known landslides in the upland areas of the pipeline alignment. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Leland Isolation Pipeline and Bypass Valves

The Leland Isolation Pipeline alignment would be located in relatively level areas within existing roadways. Therefore, the potential impact due to slope instability at this site would be less than significant.

Moraga Reservoir

The topography at the Moraga Reservoir site consists of moderate slopes that have been altered by grading and fill associated with the original construction of the reservoir. Previous studies identified shallow landsliding to the northwest and east. The EBMUD *Seismic Stability Evaluation Report, Moraga Reservoir Dam* (2003) did not identify areas of slope instability in the immediate area, other than minor areas of soil cracking attributed to expansive clay soils. Two trenches excavated for the seismic evaluation did not indicate that landslides are affecting the immediate vicinity of the reservoir. The proposed replacement reservoir tank would be located

8 Colluvial deposits refer to loose, heterogeneous, and incoherent masses of soil material deposited by rainwash, sheetwash, or slow continuous downslope creep at the base of gentle slopes or hillsides.

9 The proposed pipeline would cross above Lafayette Creek from the WTP before entering a trench the remainder of the length to the Lafayette Reservoir.

entirely within the footprint of the existing open-cut reservoir, with a valve pit structure located on the hillside southwest of the proposed tank. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Moraga Road Pipeline

The topography along the proposed Moraga Road Pipeline alignment consists of gentle slopes in the vicinity of the Lafayette WTP to the north and along Moraga Road to the south. The slopes become moderately steep in the central portion as the alignment passes through the Lafayette Reservoir Recreation Area. Previous studies have identified numerous areas of landslide deposits along the pipeline alignment between Lafayette Reservoir and Moraga Road (AGS, Inc., 2005). Numerous small landslide deposits along the upper narrow portion of Moraga Road have affected the adjacent slopes; however, the southern portion of the pipeline would be buried within the roadway and would not be affected by these shallow soil deposits. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Sunnyside Pumping Plant

The proposed Sunnyside Pumping Plant site is located near the crest of a hillside that moderately slopes towards the southeast. The proposed location is currently used for grazing and has little established vegetation. Although there are no known landslides at the proposed pumping plant site, other slides have been mapped in the immediate area (URS, 1999). With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Tice Pumping Plant and Pipeline

The proposed Tice Pumping Plant site is located at the foot of a moderate- to steep-sloping hillside. There is evidence of soil instability along this hillside. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Withers Pumping Plant

The topography at the Withers Pumping Plant site consists of a moderately sloping hillside adjacent to the existing Grayson Reservoir. Regional planning maps indicate that the site has a slope stability rating of generally stable, and no landslides were identified at the site (AGS, Inc., 2005). However, the proposed construction on this slope could potentially increase instability. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Mitigation Measure

> **Measure 3.4-1:** During the design phase for all WTTIP project components that require ground-breaking activities (excluding pipelines), the District will perform site-specific design-level geotechnical evaluations to identify adverse slope instability conditions and provide recommendations to reduce and eliminate potential slope hazards in the final design and if necessary, throughout construction. For all pipelines located in landslide hazard areas, appropriate piping material with the ability to deform without rupture (e.g.

ductile steel) will be used. For large diameter pipes (greater than 12 inches diameter) located in high landslide hazard areas, a geotechnical evaluation will be conducted. The geotechnical evaluations will include detailed slope stability evaluations, which could include a review of aerial photographs, field reconnaissance, soil testing, and slope stability modeling. Slope stability evaluations would be completed for the Fay Hill Reservoir, Walnut Creek WTP, Sobrante WTP, Ardith Reservoir/Donald Pumping Plant, Happy Valley Pumping Plant, Highland Reservoir, Lafayette Reclaimed Water Pipeline, Moraga Reservoir, Moraga Road Pipeline, Sunnyside Pumping Plant, Tice Pumping Plant, and Withers Pumping Plant. Facilities design and construction will incorporate the slope stability recommendations contained in the geotechnical analysis. Slope stabilization measures may include the following:

- Appropriate slope inclination (not steeper than 2 horizontal to 1 vertical)
- Slope terracing
- Fill compaction
- Soil reinforcement
- Surface and subsurface drainage facilities
- Engineered retaining walls
- Buttresses
- Erosion control measures

Mitigation measures included in the geotechnical report will be incorporated into the project construction specifications and become part of the project.

Impact 3.4-2: Facility damage or service interruptions resulting from strong groundshaking.

Groundshaking is an unavoidable hazard for structures and associated infrastructure within the entire project region. Project-related improvements would likely experience at least one major earthquake (greater than M 6.7) sometime during the operational lifetime of the project components (USGS, 2003). Most structures, including buried pipelines, clearwells, pumping plants, and associated appurtenances, are subject to damage from earthquakes. In comparison to above-ground structures, underground pipelines and buried clearwells are generally less susceptible to damage from strong groundshaking because they are imbedded in compacted backfill that can tolerate more seismic wave motion. The degree of hazard depends on the geologic conditions of each site, construction materials, and construction quality. The intensity of such an event depends on the causative fault and the distance to the epicenter, the moment magnitude, and the duration of shaking. The 1989 Loma Prieta earthquake reportedly caused more than 60 water pipeline breaks in Santa Cruz, the nearest urbanized area to the epicenter (CDMG, 1990). As a result, EBMUD initiated a seismic evaluation program to identify seismic safety concerns of the water system and develop facility improvements throughout the system. As a result of the seismic evaluation program, EBMUD has reduced the overall susceptibility to significant damage from a major earthquake. According to the California Division of Mines and Geology (now the CGS), a major earthquake on the Hayward Fault would likely damage EBMUD facilities throughout the district, but it is unlikely that the entire system would be incapacitated (CDMG, 1987). Modern standard engineering and construction practices include design criteria to mitigate potential damage from an earthquake, and any potential interruption of service would likely be temporary in nature. With implementation of the measure identified below, this impact would be reduced to a less-than-significant level.

Mitigation Measure

Measure 3.4-2: During the design phase for all WTTIP project components that require ground-breaking activities (excluding pipelines), the District will perform site-specific, design-level geotechnical evaluations to identify potential secondary ground failure hazards (i.e., seismically-induced settlement) associated with the expected level of seismic ground shaking. The geotechnical analysis would provide recommendations to mitigate those hazards in the final design and, if necessary during construction. The site-specific design-level geotechnical evaluations, based on the site conditions and location and professional opinion of the geotechnical engineer, could include subsurface drilling, soil testing, and analysis of site seismic response. The geotechnical engineer would review the seismic design criteria of facilities to ensure that facilities are designed to withstand the highest expected peak acceleration, set forth by the CBC for each site. Recommendations resulting from findings of the geotechnical study will be incorporated into the design and construction of proposed facilities. Design and construction for buildings will be performed in accordance with the District's seismic design standards, which meet and/or exceed design standards for Seismic Zone 4 of the Uniform Building Code.

Impact 3.4-3: Facility damage resulting from settlement or uplift caused by expansive or compressible soils.

Proposed project elements could be damaged due to settlement of weak or saturated subsurface soils. Underlying soils at the proposed project sites may also have a high potential for expansion. The "shrink-swell"[10] capacity of expansive soils can cause damage to foundations and pipelines. Many of the project sites have been previously studied and developed and the underlying soils replaced with engineered fill. However, whether a previous geotechnical evaluation needs minor updating or the site requires initial analysis, implementation of the measures identified below would reduce the potential hazard to a less-than-significant level.

Mitigation Measures

Measure 3.4-3a: During the design phase for all WTTIP project components that require ground-breaking activities (excluding pipelines), the District will perform site-specific design-level geotechnical evaluations to identify geologic hazards and provide recommendations to mitigate those hazards in the final design and during construction. The geotechnical evaluations will include site-specific investigations, which may include, if necessary, soil sampling and testing to determine the presence and characteristics of potentially compressible soils, the engineering properties of the proposed foundation material, the depth and thickness of soil layers, and the depth to groundwater. The findings of the investigations would formulate adequate measures to correct adverse soil conditions

10 "Shrink-swell" refers to the cyclical expansion and contraction that occurs in fine-grained clay sediments from wetting and drying.

that result in ground settlement or uplift due to ground swelling. Feasible mitigation measures, as listed below, are standard engineering practice and are common engineering design strategies used to overcome problematic soil conditions.

- Removal and replacement of problematic topsoil
- Installation of deep foundations (i.e., piles, drilled piers)
- Deep mixing of compressible or expansive soils with stabilizing agents

Mitigation measures included in the geotechnical evaluations will be incorporated into the project design specifications and would become part of the project.

Measure 3.4-3b: The District will include in the contract specifications that any fill will be selected, placed, compacted, and inspected in accordance with plans and specifications prepared by a licensed professional engineer.

Impact 3.4-4: Potential facility damage resulting from a major earthquake in areas susceptible to liquefaction.

The following analysis of liquefaction potential relies on conclusions presented in the geotechnical impact assessment performed by AGS, Inc. (2005). AGS, Inc. based its assessment of liquefaction potential on a review of available geotechnical studies for various project sites as well as information from the Association of Bay Area Governments regarding liquefaction potential. In addition, this information was also compared to liquefaction susceptibility mapping that was compiled by the US Geological Survey in combination with the California Geological Survey (USGS, 2006)

Figures 3.4-2 through 3.4-5 identify a potential liquefaction hazard associated with proposed WTTIP project sites evaluated at a project-level of detail. The designations (L_1, L_2, L_3 and L_4) are based on resources from the Association of Bay Area Governments. Sites with the L_1 designation are considered to have the lowest potential for liquefaction hazards, and sites with the L_4 designation are considered to have the highest potential for liquefaction because of soil types and probable groundwater depths. Sites assigned the L_4 designation include the following:

- Happy Valley Pumping Plant
- Glen Pipeline Improvements
- Leland Isolation Pipeline
- Tice Pumping Plant

Lafayette WTP

Alternative 1

The Lafayette WTP is underlain by alluvium. Alluvial soils are considered to have a moderate liquefaction potential. The foundations of the proposed clearwells nos. 1 and 2 would be constructed in consolidated sedimentary rock, as would foundations for the new Leland and Bryant Pumping Plants; therefore, these structures are considered to have very low potential for liquefaction (AGS, Inc., 2005). For other structures with shallow foundations, implementation of Measures 3.4-4, identified below, would reduce this impact to a less-than-significant level.

Alternative 2

Under Alternative 2, the Lafayette WTP would receive improvements within an existing building constructed on soils with a moderate liquefaction potential. However, the building was designed and built according to standards that would minimize the potential damage from liquefaction.

Orinda WTP

Alternative 1

The Orinda WTP is underlain by alluvium; however, the foundations of the proposed clearwells, pumping plants, and sedimentation basins would be constructed in consolidated sedimentary rock, which has a very low potential for liquefaction (AGS, Inc., 2005). For other structures with shallow foundations, implementation of Measure 3.4-4, identified below, would reduce this impact to a less-than-significant level.

Alternative 2

As stated above, the Orinda WTP is underlain by alluvium which has a moderate liquefaction potential for structures with shallow foundations. With implementation of Measure 3.4-4, identified below, this impact would be reduced to a less-than-significant level.

Walnut Creek WTP – Alternative 1 or 2

The Walnut Creek WTP is underlain by bedrock, and the liquefaction potential is considered to be very low. Therefore, the potential impact related to liquefaction would be less than significant.

Sobrante WTP – Alternative 1 or 2

Consolidated sedimentary rocks underlie the Sobrante WTP. Based on site conditions, including the depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Upper San Leandro WTP – Alternative 1 or 2

Crystalline volcanic rocks underlie the Upper San Leandro WTP. Based on site conditions, including the depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Orinda-Lafayette Aqueduct – Alternative 2

The trenched segment of the Orinda-Lafayette Aqueduct alignment is partially underlain by alluvium and is considered to be potentially liquefiable (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Ardith Reservoir and Donald Pumping Plant

Consolidated sedimentary rocks underlie the Ardith Reservoir and Donald Pumping Plant site. Based on geology and depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Fay Hill Pumping Plant and Pipeline Improvements

Both the Fay Hill Pumping Plant site and the pipeline alignment are underlain by unconsolidated alluvium. However, the pipeline improvements would be located within the existing roadway. Based on the site conditions, including the depth of groundwater, these sites are considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Fay Hill Reservoir

Consolidated sedimentary rocks underlie the Fay Hill Reservoir site. Based on geology and depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Glen Pipeline Improvements

Alluvium underlies the length of the Glen Pipeline Improvements, and the entire alignment is considered to have moderate to high liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Happy Valley Pumping Plant and Pipeline

Alluvium underlies the pumping plant site and the entire length of the pipeline alignment. Based on site conditions, including the depth of groundwater, the alignment is considered to have a moderate to high liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Highland Reservoir and Pipelines

Consolidated sedimentary rocks underlie the proposed reservoir site and the higher portion of the pipeline alignment (generally covering the alignment south of Mt. Diablo Boulevard). The lower portion of the pipeline alignment, extending from northeast of the proposed reservoir site to the Lafayette WTP, is underlain by unconsolidated alluvium and some shallow landslide deposits. Based on these site conditions, including the depth of groundwater, the portion of the pipeline alignment underlain by alluvium in the vicinity of the Lafayette WTP is considered to have a moderate liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Lafayette Reclaimed Water Pipeline

Consolidated sedimentary rocks underlie the proposed reservoir site and the higher portion of the pipeline alignment (generally covering the alignment south of Mt. Diablo Boulevard). The lower portion of the pipeline alignment is underlain by unconsolidated alluvium and some shallow landslide deposits. Based on these site conditions, including the depth of groundwater, the portion of the pipeline alignment underlain by alluvium in the vicinity of the Lafayette WTP is considered to have a moderate liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Leland Isolation Pipeline and Bypass Valves

The Leland Isolation Pipeline and Bypass Valve sites are underlain by unconsolidated alluvium and are considered to have a moderate to high liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Moraga Reservoir

Consolidated sedimentary rocks underlie the Moraga Reservoir site. Based on site conditions, the depth of groundwater, and the seismic stability evaluation performed at this site, there is a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Moraga Road Pipeline

Consolidated sedimentary rocks underlie a majority of the pipeline alignment, except in the immediate vicinity of the Lafayette WTP and along Moraga Road south of Campolindo Drive where the alignment is underlain by alluvium. Based on site conditions, including the depth of groundwater, the portions of the pipeline alignment underlain by alluvium are considered to have a moderate liquefaction potential (AGS, Inc., 2005). The central portion of the pipeline alignment is underlain by consolidated rocks that are considered to have a very low liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Sunnyside Pumping Plant

Consolidated sedimentary rocks underlie the Sunnyside Pumping Plant and pipeline site. Based on site conditions, including the depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Tice Pumping Plant and Pipeline

The Tice Pumping Plant and Pipeline sites are underlain by alluvium between Olympic Boulevard and Las Trampas Creek; this area is considered to have a moderate to high liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

Withers Pumping Plant

Consolidated sedimentary rocks underlie the Withers Pumping Plant site. Based on geology and depth of groundwater, this site is considered to have a very low potential for liquefaction (AGS, Inc., 2005). Therefore, the potential impact would be less than significant.

Mitigation Measure

Measure 3.4-4: During the design phase for all WTTIP project components that require ground-breaking activities (excluding pipelines), the District will perform site-specific design-level geotechnical evaluations to identify geologic hazards and provide recommendations to mitigate those hazards in the final design and during construction. The design-level geotechnical evaluations will include the collection of subsurface data for determining liquefaction potential. When site-specific testing indicates that conditions are present that could result in significant liquefaction and damage to project facilities, appropriate feasible measures will be developed and incorporated into the project design. For all pipelines located in liquefaction hazard areas, appropriate piping material with the ability to deform without rupture (e.g. ductile steel) will be used. For large diameter pipes (greater than 12 inches diameter) located in high liquefaction hazard areas, a geotechnical evaluation will be conducted. The performance standard to be used in the geotechnical evaluations for mitigating liquefaction hazards will be minimization of the hazards. Measures to minimize significant liquefaction hazards could include the following, unless the site-specific soils analyses dictate otherwise:

- Densification or dewatering of surface or subsurface soils
- Construction of pile or pier foundations to support pipelines and/or buildings
- Removal of material that could undergo liquefaction in the event of an earthquake, and replacement with stable material

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Impact 3.4-5: The effects of squeezing ground during tunnel construction, which could damage interior supports.

Orinda-Lafayette Tunnel – Alternative 2

Tunnel engineers confronted squeezing ground in the existing Lafayette Tunnels No. 1 and No. 2 as well as in two BART tunnels located in the Orinda/Berkeley region. Based on this previous experience of the geologic materials in the region, the onset of squeezing ground could occur days to years after excavation (Jacobs Associates, 2005). Repairs to Tunnel No. 1 were made 10 years after construction. Approximately 5 percent of the total length of Tunnel No. 2 is estimated to be affected by squeezing ground (Jacobs Associates, 2005).

Squeezing ground is a common construction challenge for tunnel projects, especially in heavily deformed materials such as those expected during the excavation of the proposed tunnel. Although the effects of squeezing ground can damage a tunnel's interior support structure and sometimes injure workers, there are remedies that can reduce the potential for this phenomenon to compromise the structural integrity of the tunnel structure. Although squeezing ground could become an issue during or after the construction of the tunnel, implementation of the following mitigation measure would reduce this impact to a less-than-significant level.

Mitigation Measure

Measure 3.4-5: The contractor will monitor for squeezing ground through the use of tunnel convergence reference points. The tunnel excavation will be reinforced throughout by either steel rib-type supports and blocking or a precast concrete segmental lining system. For a steel rib-type support system, support spacing will decrease in less competent materials. Immediate face, roof, and sidewall support will likely be required for stability in squeezing ground. The need for immediate support will require the application of active support elements and/or the use of pre-excavation support, especially at the crown (top) of the tunnel. Shotcrete will be used to strengthen sidewalls and faces when the tunnel excavation is not advanced within about a day.

Table 3.10-6 provides a summary of the applicable mitigation measures discussed above.

Program-Level Elements

Lafayette WTP

As stated above, the Lafayette WTP is located on relatively level terrain within an alluvial valley that has a moderate potential for liquefaction. Under Alternative 1, several treatment improvements could be constructed at the WTP. As described above for the project-level elements, new structures at the Lafayette WTP could be susceptible to the effects of groundshaking, underlying soil properties (i.e., expansive soils), and liquefaction. With implementation of mitigation measures similar to Measures 3.4-2, 3.4-3a, 3.4-3b, and 3.4-4, the potential impacts from these geologic hazards would be less than significant.

Orinda WTP

Proposed program-level improvements at the Orinda WTP include construction of treatment facilities such as a large (350 feet in diameter) underground clearwell. The Orinda WTP is located on relatively level terrain within an alluvial valley that has a moderate potential for liquefaction. Therefore, future improvements at the Orinda WTP could be susceptible to the effects of liquefaction, groundshaking, and underlying soil properties (i.e., expansive soils). Facilities such as the underground clearwell would be less susceptible to the effects of liquefaction because its foundation would likely be located beneath liquefiable layers; however, other improvements with shallow foundations would be more susceptible. With implementation of mitigation measures similar to Measures 3.4-2, 3.4-3a, 3.4-3b, and 3.4-4, the potential impacts from these geologic hazards would be less than significant.

TABLE 3.4-6
SUMMARY OF APPLICABLE MITIGATION MEASURES – IMPACTS 3.4-1 THROUGH 3.4-5

Facility	Measure 3.4-1 Slope Stability Evaluations	Measure 3.4-2 Subsurface Exploration/ Review of Seismic Design Criteria	Measure 3.4-3a Reduce Settlement or Uplift	Measure 3.4-3b Fill will be in Accordance with Geotechnical Engineer Plans	Measure 3.4-4 Minimize Significant Liquefaction	Measure 3.4-5 Monitor for Squeezing
Lafayette WTP						
Alternative 1	–	✓	✓	✓	✓	–
Alternative 2	–	✓	✓	✓	–	–
Orinda WTP						
Alternative 1	–	✓	✓	✓	✓	–
Alternative 2	–	✓	✓	✓	✓	–
Orinda-Lafayette Aqueduct						
Alternative 2	–	✓	✓	✓	✓	✓
Walnut Creek WTP						
Alternative 1 or 2	✓	✓	✓	✓	–	–
Sobrante WTP						
Alternative 1 or 2	✓	✓	✓	✓	–	–
Upper San Leandro WTP						
Alternative 1 or 2	–	✓	✓	✓	–	–
Ardith Reservoir and Donald Pumping Plant	✓	✓	✓	✓	–	–
Fay Hill Pumping Plant and Pipeline Improvements	–	✓	✓	✓	–	–
Fay Hill Reservoir	✓	✓	✓	✓	–	–
Glen Pipeline Improvements	–	✓	✓	✓	✓	–
Happy Valley Pumping Plant and Pipeline	✓	✓	✓	✓	✓	–
Highland Reservoir and Pipelines	✓	✓	✓	✓	✓	–
Lafayette Reclaimed Water Pipeline	✓	✓	✓	✓	–	–
Leland Isolation Pipeline and Bypass Valves	–	✓	✓	✓	✓	–
Moraga Reservoir	✓	✓	✓	✓	–	–
Moraga Road Pipeline	✓	✓	✓	✓	✓	–
Sunnyside Pumping Plant	✓	✓	✓	✓	–	–
Tice Pumping Plant and Pipeline	✓	✓	✓	✓	✓	–
Withers Pumping Plant	✓	✓	✓	–	–	–

✓ = Applicable Impact
– = No Impact

Walnut Creek WTP

The Walnut Creek WTP is located along the ridge top surrounded by relatively steep topography. Under both Alternative 1 and 2, several treatment improvements could be constructed at the WTP. As described above for the project-level elements, new structures at the Walnut Creek WTP could be susceptible to the effects of slope instability, groundshaking, and underlying soil properties (i.e., expansive soils). The potential for liquefaction, however, is very low at the Walnut Creek WTP. With implementation of mitigation measures similar to Measures 3.4-1, 3.4-2, 3.4-3a, and 3.4-3b, the potential impacts from these geologic hazards would be less than significant.

Leland Reservoir Replacement

With its hilltop location, the Leland Reservoir site is likely to have a low potential for liquefaction, but could be subject to slope instability. The DSOD has determined that the embankment could become unstable during an earthquake. Therefore, replacement of the reservoir with tanks engineered to current standards would be a beneficial impact. However, proposed facilities at this site could still be susceptible to the effects of slope instability and underlying soil properties (i.e., expansive soils). With implementation of mitigation measures similar to Measures 3.4-1, 3.4-3a, and 3.4-3b, the potential impacts from these geologic hazards would be less than significant.

New Leland Pressure Zone Reservoir and Pipeline

The topography at the New Leland Pressure Zone Reservoir consists of nearly level areas west of I-680, and moderate to steep slopes east of I-680 along the pipeline alignment approaching the reservoir site on Sugarloaf Hill. Adjacent slopes have been cut into the sandstone bedrock and benched at approximately 20-foot intervals. With implementation of Measure 3.4-1, the potential impact due to slope instability would be less than significant.

Consolidated sedimentary rocks underlie the New Leland Pressure Zone Reservoir site and a portion of the pipeline alignment. The remainder of the pipeline alignment is underlain by alluvium and is considered to have a moderate to high liquefaction potential (AGS, Inc., 2005). With implementation of Measure 3.4-4, this impact would be reduced to a less-than-significant level.

St. Mary's Road/Rohrer Drive Pipeline

Upgrading the size of the existing pipeline under this project would be an overall beneficial impact with regard to potential geologic hazards. The new pipeline would be designed, constructed, and engineered according to current standards and would provide an improvement in structural integrity. Although still susceptible to the effects of groundshaking, an unavoidable impact, the new pipeline would likely perform better than the existing pipeline. With implementation of a mitigation measure similar to Measures 3.4-2, the potential impacts from any identified geologic hazards would be less than significant.

San Pablo Pipeline

The proposed pipeline would be located along the shoreline of the San Pablo Reservoir up to the San Pablo Tunnel, where the existing tunnel would be converted for use to convey the treated water. Near the reservoir, the groundwater is likely to be relatively shallow, resulting in the potential for liquefaction along this route. In addition, the pipeline could be susceptible to the effects of slope instability (if located at the base of a steep slope) as well as underlying soil properties (i.e., expansive soils) throughout the alignment.

The pipeline would consist of a steel pipe placed within the existing tunnel. The existing tunnel, which crosses the active Hayward Fault, could potentially be damaged from fault rupture. However, the proposed pipeline would be used for backup purposes only. Consequently, failure of the pipeline due to fault rupture would not disrupt water service.

With implementation of mitigation measures similar to Measures 3.4-1, 3.4-2, 3.4-3a, 3.4-3b, and 3.4-4, the potential impacts from these geologic hazards would be less than significant.

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