

3.8 GEOLOGIC HAZARDS

3.8.1 Regulatory Setting

3.8.1.1 State

Alquist-Priolo Earthquake Fault Zoning Act

This law initially was designated as the Alquist-Priolo Geologic Hazard Zones Act in 1972 (the Act). The Act was renamed the Alquist-Priolo Special Studies Zone Act, effective May 4, 1975, and, subsequently, the *Alquist-Priolo Earthquake Fault Zoning Act*, effective January 1, 1994. The original designation of “Special Studies Zones” was changed to “Earthquake Fault Zones” when the Act was last renamed.

The Alquist-Priolo Earthquake Fault Zoning Act is intended to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prohibit the location of developments and structures for human occupancy across the trace of active faults. Further, it is the intent to provide the citizens of California with increased safety and to minimize the loss of life during and immediately following earthquakes by facilitating seismic retrofitting to strengthen buildings, including historical buildings, against ground shaking.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 (Public Resources Code, Chapter 7.8, Division 2) directs the California Department of Conservation (DOC), Division of Mines and Geology (DMG) to delineate seismic hazard zones. The purpose is to reduce the threat to public health and safety and to minimize the loss of life and property by identifying and mitigating seismic hazards. Cities, counties, and state agencies are directed to use the seismic hazard zone maps in their land-use planning and permitting processes. This Act requires that site-specific geotechnical investigations be conducted prior to permitting most urban development projects within the hazard zones. Evaluation and mitigation of seismic hazards are to be conducted under guidelines established by the California State Mining and Geology Board and published by the California Geologic Survey (CGS, 2008).

3.8.1.2 Local

General Plan Policies and Ordinances

California Government Code Section 65300 requires each city and county to develop or adopt a general plan. General plans are intended to be foundations for city and county land use planning and development that incorporate resource management and projected growth. The state requires seven general plan elements, one of which is a Safety Element. The Safety Element requires the city and county to identify natural and human caused hazards that may affect the city or county and provide a protection plan from any unreasonable risks associated with these hazards

Grading Codes

The principal agencies having jurisdiction over grading, earthwork, and construction of new structures outside the existing rail rights-of-way are the individual cities and counties along the project alignment. Local jurisdictions often rely on building codes and ordinances as guidelines during the design review process. The purpose of the building and grading codes is to provide minimum standards to safeguard the

public's safety and welfare by regulating the design, construction, quality of materials, use, occupancy, location and maintenance of all structures, certain equipment, and grading.

Cities and counties all comply with the California Building Code (CBC), except where they may make changes or modifications in the requirements as determined to be reasonably necessary because of local climatic, geological, or topographical changes. In general, Chapter 18 of the CBC governs soil and foundation systems that are not subject to scour or water pressure by wind and by wave action. Foundation systems that are subject to such scour and water pressure loads are described in Chapter 16 of the CBC.

Prior to issuance of a grading permit as per existing city and county policies, geotechnical studies are required to be prepared to address site- and alignment-specific geotechnical considerations.

3.8.1.3 Existing Conditions

The Study Area is located along the Atchison, Topeka & Santa Fe railroad right-of-way in the San Gabriel Valley. The Study Area includes the existing rail alignment and the adjacent buffer zone, which extends 1,000 feet along both sides of the railroad. Most of the project alignment lies within areas of commercial and residential development.

3.8.1.4 Site Description

The project alignment is located on generally flat to gently inclined terrain along its 12.3-mile length. Elevations along the alignment range from approximately 610 feet above mean sea level in Glendora to 1,180 feet above mean sea level in Montclair. Elevations vary locally across major washes (intermittent streams) and rivers. The San Gabriel Mountains lie one to two miles north of the Study Area. Three isolated hills—South Hills, Way Hill, and the Puente Hills—are elevated above the valley south of the San Gabriel mountains along or north and south of the project alignment (Figure 3.8-1).

3.8.1.5 Regional and Local Geologic Setting

The project alignment is located in the Transverse Range geomorphic province of Southern California, which extends approximately 300 miles westward from the Mojave Desert to the Pacific Ocean. The Study Area lies within the northeastern portion of the Los Angeles Basin at the base of the San Gabriel Mountains. The Los Angeles Basin is a large trough, filled with marine and non-marine sediments. Deposition of marine sediments began approximately 65 million years ago in a deep, structural trough that existed off the coast of Southern California (Yerkes 1972). Over time, sedimentation slowly filled the trough with thousands of feet of sediments. About seven million years ago, as sedimentation continued, an eastward shift of the boundary between the Pacific and North American Plates began shaping the Los Angeles Basin from this deep trough. Deformation of the basin along contractional faults acted to shorten the basin in a north-south direction and uplift the bedrock units to form hills and mountains. Approximately two to five million years ago, the Elysian, Repetto, and Puente Hills were uplifted, predominately along northwest-trending faults (Shaw and Suppe 1996). Shortening of the Los Angeles Basin and San Gabriel Valley continues today along generally east-west trending faults (Shaw and Suppe 1996; Shaw et al. 2002; Fuis et al. 2001).

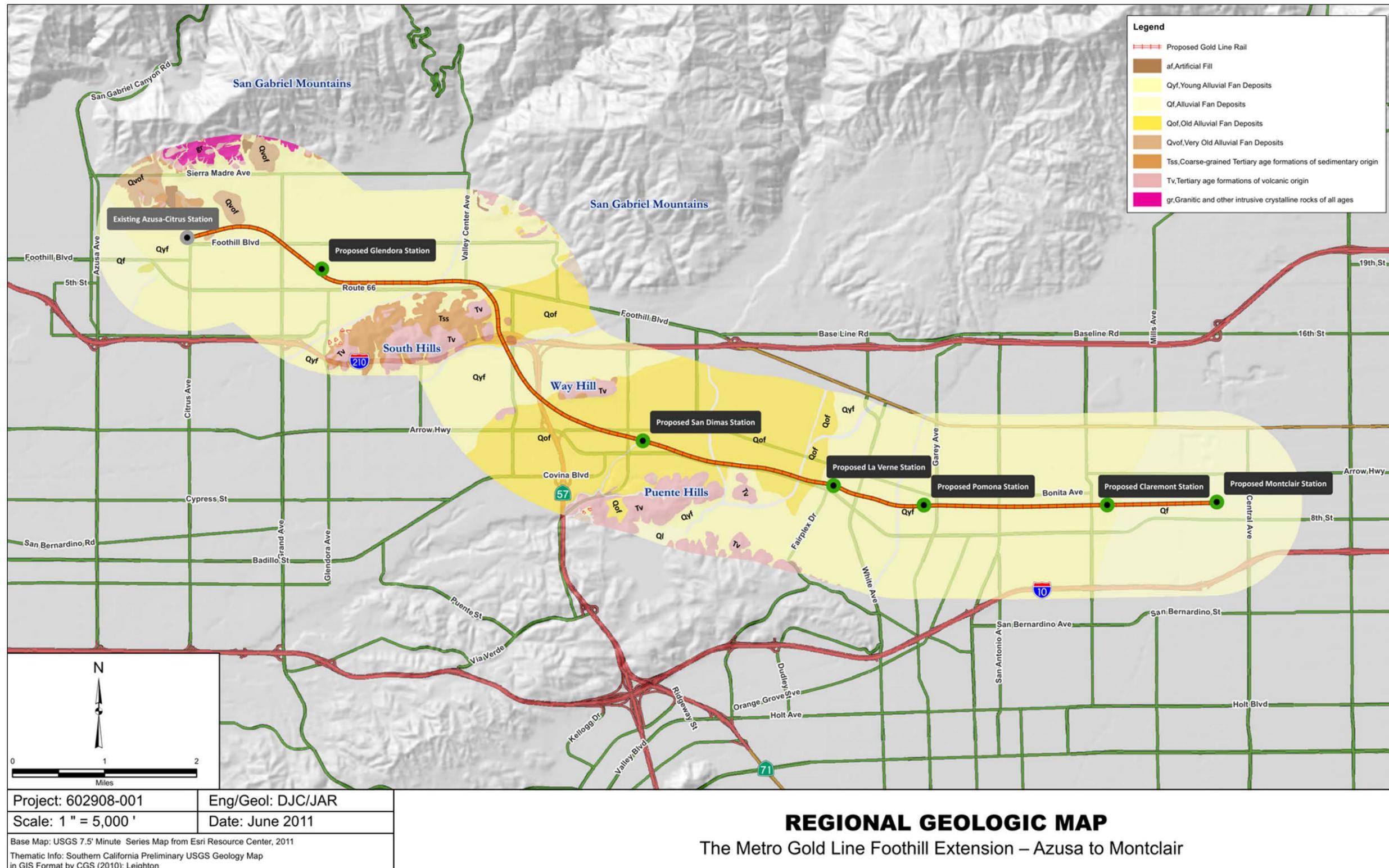


Figure 3.8-1. Regional Geologic Map (Los Angeles and San Bernardino Counties)

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Local Geology

The San Gabriel Valley is bound on the northwest by the Verdugo Mountains and Raymond Hill fault system, on the north by the San Gabriel Mountains, on the east by the San Jose Hills, on the south by the Puente Hills, and on the southwest by the Repetto Hills Elysian Park Anticline. The Repetto Hills are the surface expression of the Elysian Park Anticline, which is an elongated west-northwest trending fold belt in the shape of a dome.

The San Gabriel Valley floor is composed primarily of unconsolidated recent alluvial fan and stream deposits, consisting predominately of sands and gravels derived from the surrounding mountains and hills, with finer clays and silts deposited over the broad floodplain of the rivers and streams that flow into the basin. These recent deposits are underlain by a thick sequence of late Cretaceous- to Pleistocene-age marine and non-marine sedimentary rock units that are locally intruded by middle Miocene-age volcanic rocks. The sedimentary sequence that overlies the basement complex ranges from Miocene-age plutonic rocks in the eastern portion of the San Gabriel Valley to Precambrian-age plutonic rocks in the northern San Gabriel Valley. The bedrock units within the San Gabriel Valley are exposed at the base of the mountains and foothills north and south of the project alignment.

The San Gabriel Valley is an almost-enclosed basin drained by the Rio Hondo and San Gabriel Rivers. The deepest part of the San Gabriel Basin lies beneath the San Gabriel River where approximately 4,000 to 6,000 feet of Upper Pleistocene- to Holocene-age (approximately one million years ago to recent) sediments are deposited.

Local Geologic Units

The aerial extent of the geologic units (surficial and bedrock) along the project alignment is shown on Figure 3.8-1. The geologic units presented in Table 3.8-1 are a compilation of many mapped units described in California Geologic Survey Open-File Reports (98-12, 98-13, 98-15, 98-16, 98-20, 98-21, 98-23, and 2000-06).

Table 3.8-1. Geological Units in the Study Area

	Type	Map Symbol*
Surficial Units	Artificial Fill	Af
	Quaternary Young Alluvial Fan Deposits	Qyf
	Quaternary Alluvial Fan Deposits	Qf
	Quaternary Old Alluvial Fan Deposits	Qof
	Quaternary Very Old Alluvial Fan Deposits	Qvof
Bedrock Units	Topanga Formation	Tss
	Topanga Formation—Basalt	Tv
	Granitic Intrusive Bedrock, Undifferentiated	gr

* See Figure 3.8-1.

3.8.1.6 Regional Faulting and Seismicity

The two principal seismic considerations for most sites in Southern California are surface rupture along active fault traces and damage to structures caused by to seismically induced ground shaking. Surface rupture occurs during an earthquake when movement along an active fault breaks the ground surface. Strong ground shaking may also affect any area of Southern California to varying degrees because of the proximity and earthquake potential of nearby active faults, and because of the local geologic and

topographic conditions that can either amplify or attenuate the seismic waves. Seismic hazards that may affect the project alignment include primary hazards from surface rupturing of the ground surface along active fault traces, and secondary hazards resulting from strong ground shaking.

Surface Rupture

Surface rupture can devastate structures built across an active fault. A fault is considered active if there is evidence of movement (either directly observable or inferred) along one or more of its segments in the last 11,000 years. Figure 3.8-2 shows the project alignment and the active and potentially active faults in the region. To protect structures from the hazard of ground-surface rupture along a fault line, the California Geological Survey (CGS), under the State-mandated *Alquist-Priolo Earthquake Fault Zoning Act*, has delineated “earthquake fault zones” along well-defined active or potentially active faults. No earthquake fault zone crosses the project alignment; however, the Duarte and San Jose Faults and other local faults are known to cross the project alignment, and many active and potentially active faults are located in the region (Figure 3.8-2). Ground rupture from these faults and strong ground shaking from an earthquake on one of these regional faults could adversely affect the Study Area.

Seismic Shaking

The Study Area is likely to experience strong ground shaking during its lifetime. The intensity of ground shaking at a given location along the project alignment would depend primarily upon the earthquake’s magnitude, faulting mechanism, distance from the seismic source (focus), and the site response characteristics (Petersen et al. 1998). The intensity of shaking is generally amplified in areas underlain by deep deposits of loose, unconsolidated soils. The most common effects of strong seismic shaking include liquefaction and its related ground deformations, dynamic settlement, and landsliding (Section 3.8.2.2 provides a detailed discussion of these terms).

Peak Horizontal Ground Acceleration (PGA) is generally used to evaluate the intensity of ground motion. For a general evaluation of the project alignment, a deterministic seismic hazard analysis was performed. The analysis estimated the expected PGA values along the alignment based on a maximum earthquake magnitude along any of the faults in the region. In addition to the earthquake magnitude, PGA values are affected by the type of material that underlies the site. For this evaluation, it was assumed, based on the information presented in Figure 3.8-1, that alluvium underlies the Study Area and, therefore, the attenuation relationship for alluvium was used to calculate the PGA expected along the alignment (United States Geological Survey Open-File Report 2010-1296).

For probabilistic analysis, information from the United States Geological Survey website was used. Figure 3.8-3 presents the PGA values estimated along the alignment. The values of the PGA contours are for a 2 percent probability of exceedance in 50 years (average return period of 2,475 years) using a 0.05g interval.¹

Another way of describing the intensity of an earthquake at a particular site is based on the observations of individuals during and after the earthquake. This represents the severity of shaking, as perceived by those who experienced it. It is also based on observations of damage to structures, movement of furniture, and changes in the earth’s surface as a result of tectonic deformation during the earthquake. The Modified Mercalli Intensity Scale is commonly used to quantify intensity descriptions. The intensity scale ranges from I to XII (Table 3.8-2).

¹ PGA is expressed as a percentage of the acceleration due to gravity (g).

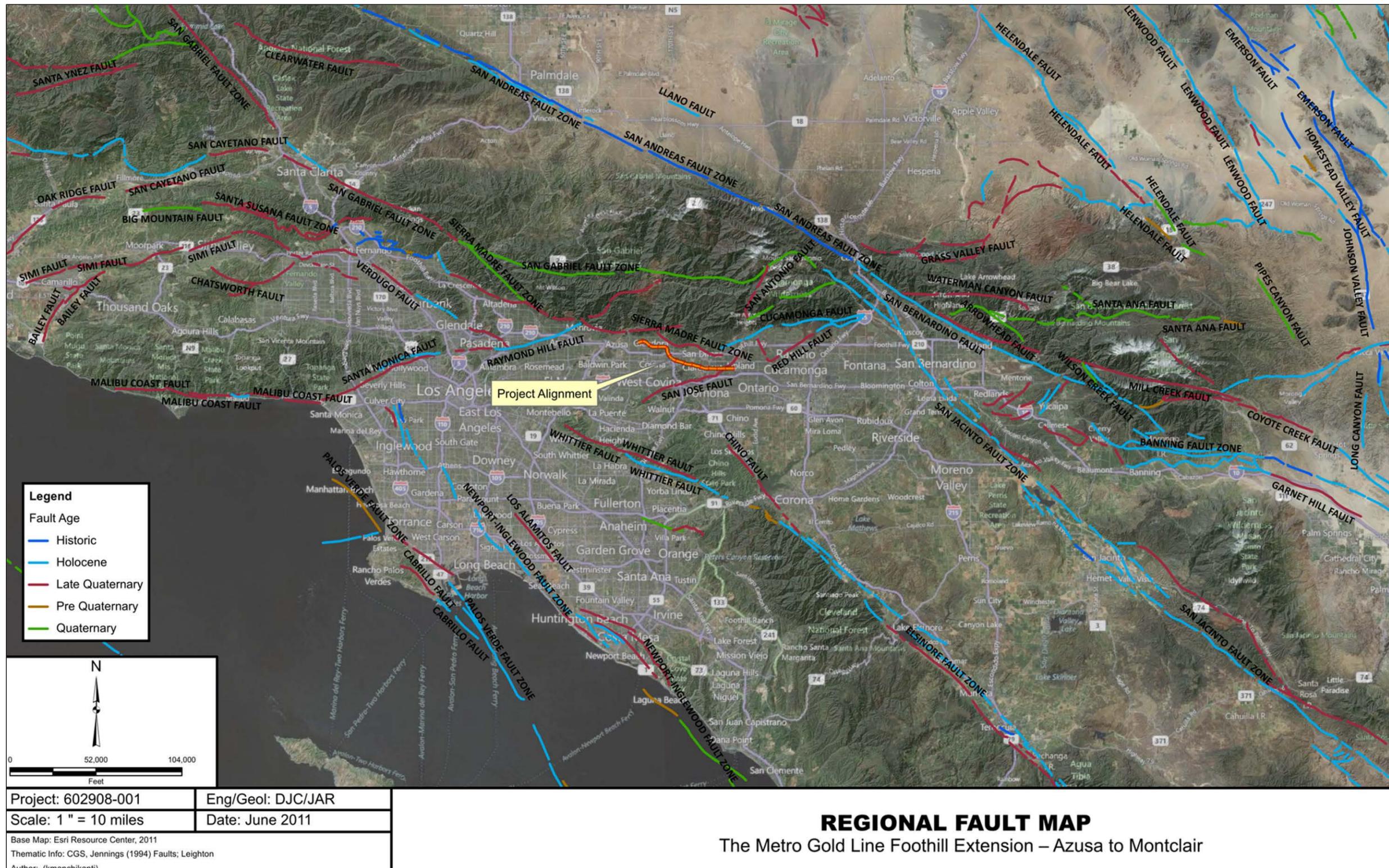


Figure 3.8-2. Regional Fault Map

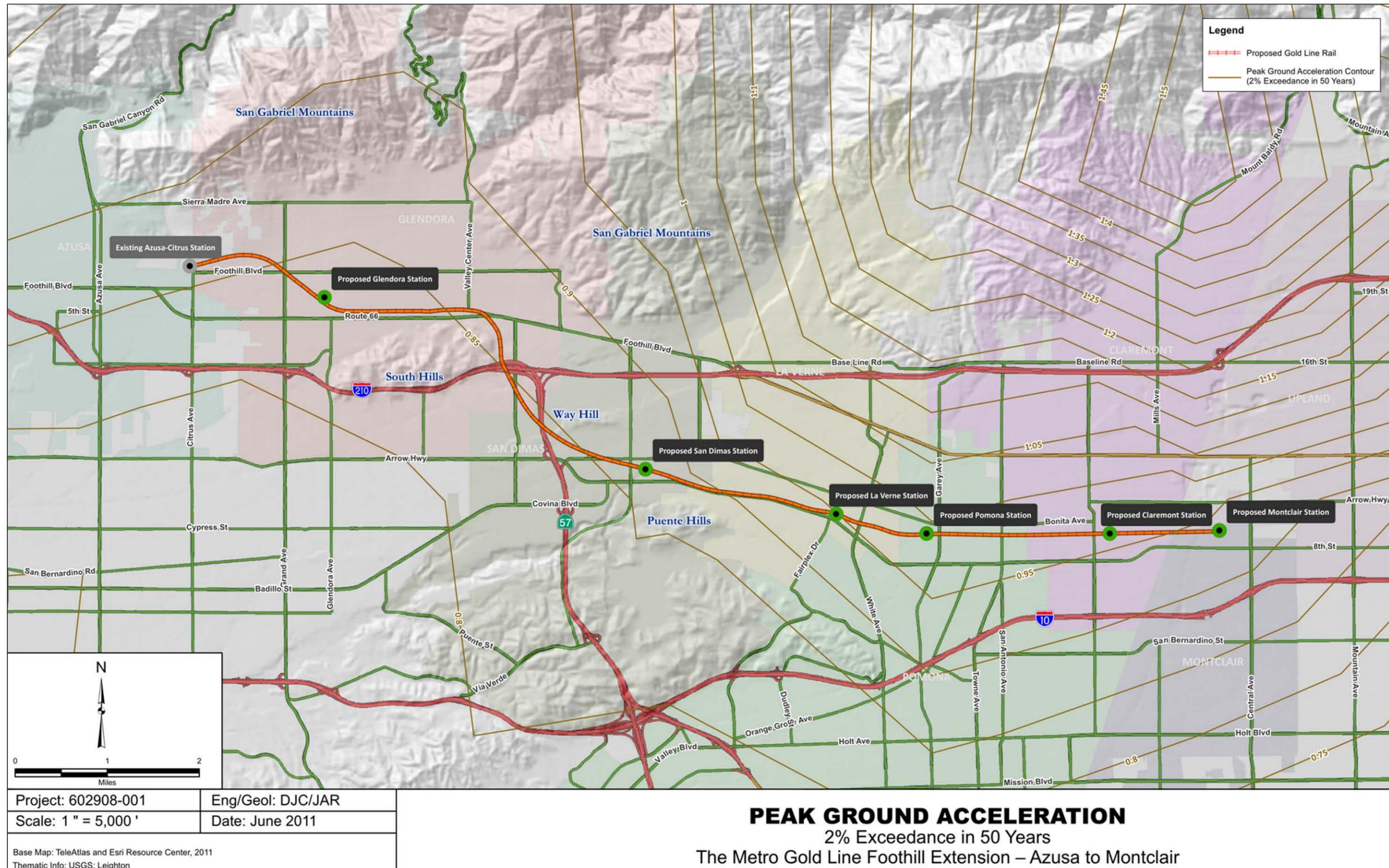


Figure 3.8-3. Peak Ground Acceleration

Table 3.8-2. Modified Mercalli Intensity Scale

I	Not felt by people, except under especially favorable circumstances. However, dizziness or nausea may be experienced. Sometimes birds and animals are uneasy or disturbed. Trees, structures, liquids, bodies of water may sway gently, and doors may swing very slowly.
II	Felt indoors by a few people, especially on upper floors of multistory buildings and by sensitive or nervous persons. As in Level I, birds and animals are disturbed, and trees, structures, liquids, and bodies of water may sway. Hanging objects swing, especially if they are delicately suspended.
III	Felt indoors by several people, usually as a rapid vibration that may not be recognized as an earthquake at first. Vibration is similar to that of a light truck, or lightly loaded trucks passing nearby, or heavy trucks some distance away. Duration may be estimated in some cases. Movements may be appreciable on upper levels of tall structures. Standing cars may rock slightly.
IV	Felt indoors by many, outdoors by few. Awakens a few individuals, particularly light sleepers, but frightens no one except those apprehensive from previous experience. Characterized by vibration like that due to passing of heavy or heavy loaded trucks, sensation like a heavy body striking building, or the falling of heavy objects inside. Dishes, windows, and doors rattle; glassware and crockery clink and clash. Walls and house frames creak, especially if intensity is in the upper range of this level. Hanging objects often swing. Liquids in open vessels are disturbed slightly. Stationary cars rock noticeably.
V	Felt indoors by practically everyone, outdoors by most people. Direction can often be estimated by those outdoors. Awakens many or most sleepers. Frightens a few people, with slight excitement; some persons run outdoors. Buildings tremble throughout. Dishes and glassware break to some extent. Windows crack in some cases, but not generally. Vases and small or unstable objects overturn in many instances, and a few fall. Hanging objects and doors swing open or close abruptly. Pendulum clocks stop, or run fast or slow. Small objects move, and furnishings may shift to a slight extent. Small amounts of liquids spill from well-filled open containers. Trees and bushes shake slightly.
VI	Felt by everyone, indoors and outdoors. Awakens all sleepers. Frightens many people; results in general excitement, and some persons run outdoors. Persons move unsteadily. Trees and bushes shake slightly to moderately. Liquids are set in strong motion. Small bells in churches and schools ring. Poorly built buildings may be damaged. Plaster falls in small amounts. Other plaster cracks somewhat. Many dishes and glasses, and a few windows, break. Knickknacks, books, and pictures fall. Furniture overturns in many instances. Heavy furnishings move.
VII	Frightens everyone. General alarm, and everyone runs outdoors. People find it difficult to stand. Persons driving cars notice shaking. Trees and bushes shake moderately to strongly. Waves form on ponds, lakes, and streams. Water is muddied. Gravel or sand banks along streams cave in. Large church bells ring. Suspended objects quiver. Damage is negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, and considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up with mortar), spires, etc. Plaster and some stucco fall. Many windows and some furniture break. Loosened brickwork and tiles shake down. Weak chimneys break at the roofline. Cornices fall from towers and high buildings. Bricks and stones are dislodged. Heavy furniture overturns. Concrete irrigation ditches are considerably damaged.
VIII	General fright, and alarm approaches panic. Persons driving cars are disturbed. Trees shake strongly, and branches and trunks break off (especially palm trees). Sand and mud erupt in small amounts. Flow of springs and wells is temporarily and sometimes permanently changed. Dry wells renew flow. Temperatures of spring and well waters vary. Damage is considerable in ordinary substantial buildings, with some partial collapse, and heavy in some wooden houses, with some tumbling down. Panel walls break away in frame structures. Decayed pilings break off. Walls fall. Solid stone walls crack and break seriously. Wet grounds and steep slopes crack to some extent. Chimneys, columns, monuments, and factory stacks and towers twist and fall. Very heavy furniture moves conspicuously or overturns.

Table 3.8-2. Modified Mercalli Intensity Scale (continued)

IX	General panic. Ground cracks conspicuously. Damage is great in masonry structures and buildings, with some collapsing in large part. Some wood frame houses built especially to withstand earthquakes are thrown out of plumb; others are shifted wholly off foundations. Reservoirs are seriously damaged, and underground pipes sometimes break.
X	Most masonry and frame structures and their foundations are destroyed. Ground, especially where loose and wet, cracks up to widths of several inches; fissures up to a yard in width run parallel to canal and stream banks. Landsliding is considerable from riverbanks and steep coasts. Sand and mud shift horizontally on beaches and flat land. Water level changes in wells. Water is thrown on banks of canals, lakes, rivers, etc. Dams, dikes, and embankments are seriously damaged. Well-built wooden structures and bridges are severely damaged and some collapse. Dangerous cracks develop in excellent brick walls. Railroad rails bend slightly. Pipelines buried in earth tear apart or are crushed endwise. Open cracks and broad wavy folds open in cement pavements and asphalt road surfaces.
XI	Few masonry structures remain standing. Disturbances in ground are many and widespread, varying with the ground material. Broad fissures, earth slumps, and landslips develop in soft, wet ground. Water charged with sand and mud is ejected in large amounts. Sea waves of significant magnitude may develop. Damage is severe to wood frame structures, especially near epicenter, and great to dams, dikes and embankments, even at long distances. Supporting piers or pillars of large, well-built bridges are wrecked. Wooden bridges that “give” are less affected. Railroad rails bend greatly and some thrust endwise. Pipelines buried in earth are put completely out of service.
XII	Damage is nearly total. Practically all works of construction are damaged greatly or destroyed. Disturbances in the ground are great and varied, and numerous shearing cracks develop. Landslides, rockfalls, and slumps in riverbanks are numerous and extensive. Large rock masses are wrenched loose and torn off. Fault ruptures develop in firm rock, and horizontal and vertical displacements are noted. Water channels, both surface and underground, are disturbed and modified greatly. Lakes are dammed, new waterfalls are produced, rivers are deflected, etc. Surface waves are seen on ground surfaces. Lines of sight and level are destroyed. Objects are thrown upward into the air.

Magnitude (Moment Magnitude) and Intensity (Modified Mercalli Intensity Scale) measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake; intensity is determined from the effects on people, human structures and natural environment. A comparison of Magnitude and Intensity for the faults at each station is provided in the Construction-Period Impacts section.

The greatest impact of an earthquake is usually in the epicenter, with lower intensities occurring in zones outward from the epicenter. The quality of construction and variation of geologic conditions also affect the distribution of intensity. Some buildings are safer than others, depending on design, foundation, location, and furnishings. Most buildings constructed on bedrock suffer less damage than those constructed on thick alluvium (unconsolidated sediments) or fill.

Nearby Active Faults

Numerous active and potentially active faults lie within a few miles of the Study Area. Descriptions of the more prominent faults near the site and a few that cross the alignment are provided below. The descriptions indicate the type of fault, approximate distance to the proposed alignment, maximum potential earthquake in terms of magnitude (M). M is a measurement of an earthquake’s magnitude based on area of the fault, amount of movement during the earthquake, and the strength of the rocks ruptured during the earthquake.

Chino Fault

The Chino Fault, located about 4.5 miles east of the eastern terminus of the Study Area, is the northward extension of the Elsinore Fault Zone, which is north of the Puente Hills (Figure 3.8-2). Offset drainages, fault scarps, and trench excavations show that this is an active fault with predominately right-lateral strike-slip motion (Dolan et al. 2001). It has been estimated that the Chino Fault could generate a maximum magnitude 6.7 earthquake.

Clamshell-Sawpit Fault

The Clamshell-Sawpit Fault is located approximately six miles northwest of the eastern end of the project. It is a 10-mile-long, north-to-northeast dipping fault zone that branches northeastward from the Sierra Madre Fault Zone (Cao et al. 2003, Leighton 1990). It has a slip rate of 0.06 to 0.1 inch per year and could produce a magnitude 6.5 earthquake (Cao et al. 2003, Dolan et al. 1995).

Duarte Fault

The Duarte Fault is a southern splay of the main Sierra Madre Fault trace that is adjacent to the Study Area (Figure 3.8-2), approximately 1.0-mile west of the proposed Glendora Station, in Azusa. It has been mapped (Morton 1973, Crook et al. 1987) as scarps within the older and younger alluvial fan deposits emanating from Bradbury, Spinks, and Monrovia Canyons north of Duarte and Azusa. Multiple groundwater barriers north of Azusa indicate the presence of an Upper Duarte Fault, which has an inferred trace a few thousand feet north of the Duarte Fault (Crook et al. 1987). The Upper Duarte and Duarte Faults have not been zoned under the Alquist-Priolo Act because the timing of their latest movements has not been determined; however, the Duarte Fault is considered active by the County of Los Angeles (Leighton 1990). The CGS has not delineated the Duarte Fault as active at this time.

Puente Hills Blind-Thrust Fault

Movement on the Puente Hills Blind-Thrust Fault caused the 1987 Whittier Narrows earthquake. Blind-thrust faults are located in the subsurface with no mapped fault trace at the ground surface. The focus of the 1987 event was approximately eight miles below the San Gabriel Valley near Whittier Narrows. This fault does not reach the surface, and a fold has formed above the fault at or just below the ground surface (Shaw and Shearer 1999; Pratt et al. 2001; Christofferson et al. 2001; Dolan et al. 2003). To the north of the 1987 focus, the fault flattens and continues beneath the San Gabriel Mountains and merges with the Sierra Madre-Cucamonga Fault system (Fuis et al 2001). The Puente Hills Blind-Thrust Fault is located in the subsurface west of the Study Area and could produce a maximum 7.1 M earthquake (Cao et al. 2003; Petersen et al. 1996).

Raymond Hill Fault

The Raymond Hill Fault extends across the Los Angeles Basin from the Los Angeles River to the foot of the San Gabriel Mountains west of the Study Area. Its trace trends roughly east-west at the western portion, then curves to an east-northeast trend in the eastern portion (Figure 3.8-2). This fault has been delineated as an earthquake fault zone under the Alquist-Priolo Act (Bryant and Hart 2007).

Indications that the Raymond Hill Fault is a predominately a left-lateral strike-slip fault are its left-lateral offset of a basement ridge at its eastern termination, and a suite of geomorphic observations, including pressure ridges, sag ponds, and left-lateral stream deflections along its trace (Crook et al. 1987; Jones et al. 1990; Weaver and Dolan 2000). Seismic evidence and aftershock analyses indicate that the 1988 Pasadena earthquake occurred on the Raymond Hill Fault (Jones et al. 1990). This fault could produce a magnitude 6.5 M earthquake, and has a slip rate of 0.06 to 0.04 inch per year (Marin et al. 2000).

Evidence from fault trenching (Crook et al. 1987; Weaver and Dolan 2000) suggests the most recent surface-rupturing event occurred more than 1,000 years ago.

San Andreas Fault Zone

The San Andreas Fault is the longest and most well-known fault in California. Its activity is known from historic earthquakes—most notably the 1857 and 1906 earthquakes—and from many fault studies that have shown that the San Andreas offsets (or displaces) recently deposited alluvial sediments. The closest portion of the San Andreas Fault to the Study Area is the San Bernardino segment, which is located about 16 miles to the east-northeast and is considered the most active segment of the San Andreas Fault system. This segment could produce a maximum magnitude 7.1 earthquake (Petersen et al. 1996; Cao et al. 2003).

San Jacinto Fault Zone

The San Jacinto Fault Zone extends more than 124 miles northwest from El Centro to Cajon Pass, California, where it intersects with the San Andreas Fault. Movement along this fault is predominately right-lateral strike-slip with minor amounts of dip-slip displacement. This fault zone is segmented along its entire length into smaller sub-parallel strands and cross faults. The closest segment to the Study Area is the San Bernardino segment, which is approximately 12.5 miles from the eastern terminus of the project alignment. The San Jacinto Fault Zone has produced more moderate to large earthquakes than any other fault zone in Southern California (Petersen and Wesnousky 1994). The most recent earthquake occurred November 24, 1987, on the Superstition Hills Fault segment, approximately 90 miles east of San Diego. Up to approximately 5 inches of surface displacement was observed for this magnitude 6.2 seismic event. Along the length of the fault, slip rate data are variable, ranging from approximately 0.08 to almost 0.8 inch per year. The slip rate for the San Bernardino segment is unknown, but the fault could produce a maximum magnitude 6.7 earthquake (Petersen et al. 1996; Cao et al. 2003).

San Jose Fault

The San Jose Fault is an 11- to 14-mile-long fault that splays west-southwest from the Cucamonga-Sierra Madre Fault Zone in the Upland area and continues southwest along the southern boundary of the San Jose Hills. The fault crosses the project alignment approximately 0.5-mile west of the proposed Claremont Station. The fault has been mapped based on a water barrier near the Study Area that reportedly impedes the flow of groundwater, with groundwater levels on the north side of the fault higher than water levels on the south side of the fault (Tinsley et al. 1985; Los Angeles County Department of Public Works 1996).

Two Upland earthquakes of 1988 and 1990 have been attributed to this fault (Hauksson and Jones 1991). Analyses of these earthquakes indicate the San Jose Fault has left-lateral strike-slip motion on a northeast-oriented fault plane. However, apparent dip-slip separation of a buried aquifer offset across the fault, plus subsurface mapping suggest the San Jose Fault may be a reverse fault (Yeats 2001; Hauksson and Jones 1991). An earthquake on this fault, rupturing the entire length of the fault, could produce a maximum magnitude 6.5 earthquake (Cao et al. 2003), with the potential to cause offset to the project alignment.

Sierra Madre-Cucamonga Fault Zone

The Sierra Madre-Cucamonga Fault Zone includes several fault segments that extend more than 86 miles along the southern margin of the San Gabriel Mountains. The two main portions of this fault zone include the Sierra Madre Fault to the west and the Cucamonga Fault to the east. The fault zone is inclined to the north, dipping below the San Gabriel Mountains and uplifting them above the Los Angeles Basin. The 1971 San Fernando earthquake near the town of Sylmar is attributed to movement along the San Fernando Fault, a splay of the Sierra Madre Fault Zone. The Sierra Madre Fault Zone passes through the northern portions of Glendora, and portions of San Dimas. The Sierra Madre Fault is less than one mile at its closest point to the project alignment north of Glendora. This fault segment could produce a maximum magnitude 7 earthquake (Cao et al. 2003; Petersen et al. 1996).

The Cucamonga Fault is the eastern extent of the Sierra Madre Fault Zone and lies to the north of Pomona, Claremont, and Montclair. It is located 2.2 miles north of Claremont at its closest point to the Study Area. This segment of the Sierra Madre-Cucamonga Fault Zone could produce a maximum magnitude 7 earthquake (Cao et al. 2003; Petersen et al. 1996).

Upper Elysian Park Blind-Thrust Fault

The Upper Elysian Park Blind-Thrust Fault does not intersect with the ground surface. This fault is expressed as an elongated group of low hills (Elysian Park Hills, Repetto Hills and Monterey Hills) extending approximately 12.4 miles from northern Los Angeles to San Gabriel (Dolan et al. 2001). These hills are Pliocene to Quaternary-aged (approximately two million years old) folded sediments that have been uplifted and folded along the northeast-dipping fault. The Elysian Park Blind-Thrust Fault has a slip rate of 0.04 to 0.07 inch per year and could produce a maximum magnitude 6.4 earthquake (Cao et al. 2003, Oskin et al. 2000). It is located west of the Study Area.

Whittier Fault

The Whittier Fault is the northwestward extension of the Elsinore Fault Zone, a 155-mile-long fault zone traced from Los Angeles, California, to northern Baja California, Mexico. The Whittier segment is approximately 24.8 miles long and extends from the Whittier Narrows section of the San Gabriel River southeastward to the Santa Ana River. Although no major historical earthquakes have been attributed to the Whittier Fault, studies (most of which included trenching) completed by several investigators have documented movement on this fault in the last 11,000 years (Leighton et al. 1987, Rockwell et al. 1988, Gath et al. 1992, Patterson and Rockwell 1993). The closest section of the Whittier Fault lies approximately 10.5 miles southwest of the Study Area. A maximum 6.8 M earthquake has been estimated for this fault (Cao et al. 2003, Petersen et al. 1996).

Local Faults

Local faults include short, inferred faults that cross the Study Area and either are not considered active, or their activity has yet to be determined because of their inaccessibility (i.e., buried). In the northeastern San Gabriel Valley, three faults have been identified based on groundwater barriers observed by the California Department of Water Resources. The San Jose Fault (discussed above) is oriented northeast-southwest along the southern edge of the San Jose Hills and has been determined to be the causative fault of the 1988 and 1990 Upland earthquakes (Hauksson and Jones 1991). Walnut Creek Fault has an inferred location on the north side of the San Jose Hills and is oriented roughly parallel to the San Jose Fault. The Indian Hill Fault, also called the Way Hill-Lone Hill Fault, is known to exist based on differences in groundwater levels across this part of the San Gabriel Valley (California Department of

Water Resources 2003 and 1966). This fault has been mapped along the trend of Way and Lone Hills east to the Cucamonga Fault.

3.8.1.7 Subsidence

In California, subsidence related to human activities has been attributed to withdrawal of subsurface fluids, such as oil and groundwater; oxidation of subsurface organic material, such as peat and coal; and by hydroconsolidation (from excessive irrigation) of loose, dry soils in a semi-arid climate.

Withdrawal of groundwater has occurred in the San Gabriel Valley and along the project alignment for past agricultural activities. This practice has been greatly reduced over the years because of urbanization. As a result, groundwater elevations in the San Gabriel Valley have risen or remained constant in recent years (California Department of Water Resources 2003). A majority of the San Gabriel Valley and the project alignment is underlain by alluvial deposits that can include isolated organic-rich soils and floodplain deposits. Subsidence due to oxidation of these deposits is possible. The extent or exact locality of such subsidence would be determined during standard geotechnical investigations for the proposed stations and alignment. Given that groundwater withdrawal is highly regulated, subsidence is not expected to be a substantive concern.

3.8.1.8 Volcanic Hazards

Hazards from nearby volcanic activity may include surface rupture, lava flows, and ash falls. Amboy Crater is the closest potentially active volcano to the Study Area and lies approximately 100 miles northeast of the alignment. The Study Area is not within the potential hazard area of the Amboy Crater volcanic area. Accordingly, impacts related to volcanic hazards would be considered minimal.

3.8.1.9 Slope Stability

Most of the project alignment is located on flat terrain. The few slopes that exist are those constructed for railroad bridges to cross above local roads and streams. These manmade slopes appear in good, stable condition. However, within the alignment buffer zone there are a few areas where slope instability could exist, particularly during an earthquake. These areas are mapped as potential seismically induced landslide zones on the Seismic Hazard Zones Maps and Reports (Figure 3.8-4) (California Division of Mine and Geology 1999a, 1999b, 1999c, and 1999d; Perez et al. 1998; Schlosser and Wills 1998a and 1998b). A seismically induced landslide zone is an area where previous landslides have occurred or an area where conditions exist for potential permanent ground displacement such that mitigation (as defined in Public Resources Code Section 2693(c)) would be required. These areas include the northern slopes of the South Hills and Puente Hills. In these areas, seismically induced landslides could occur if shaking from an earthquake were to cause preexisting landslides to reactivate or trigger new landslides along planes of weakness. For the rest of the alignment, which is not within the seismically induced landslide zones, the potential for this hazard is low.

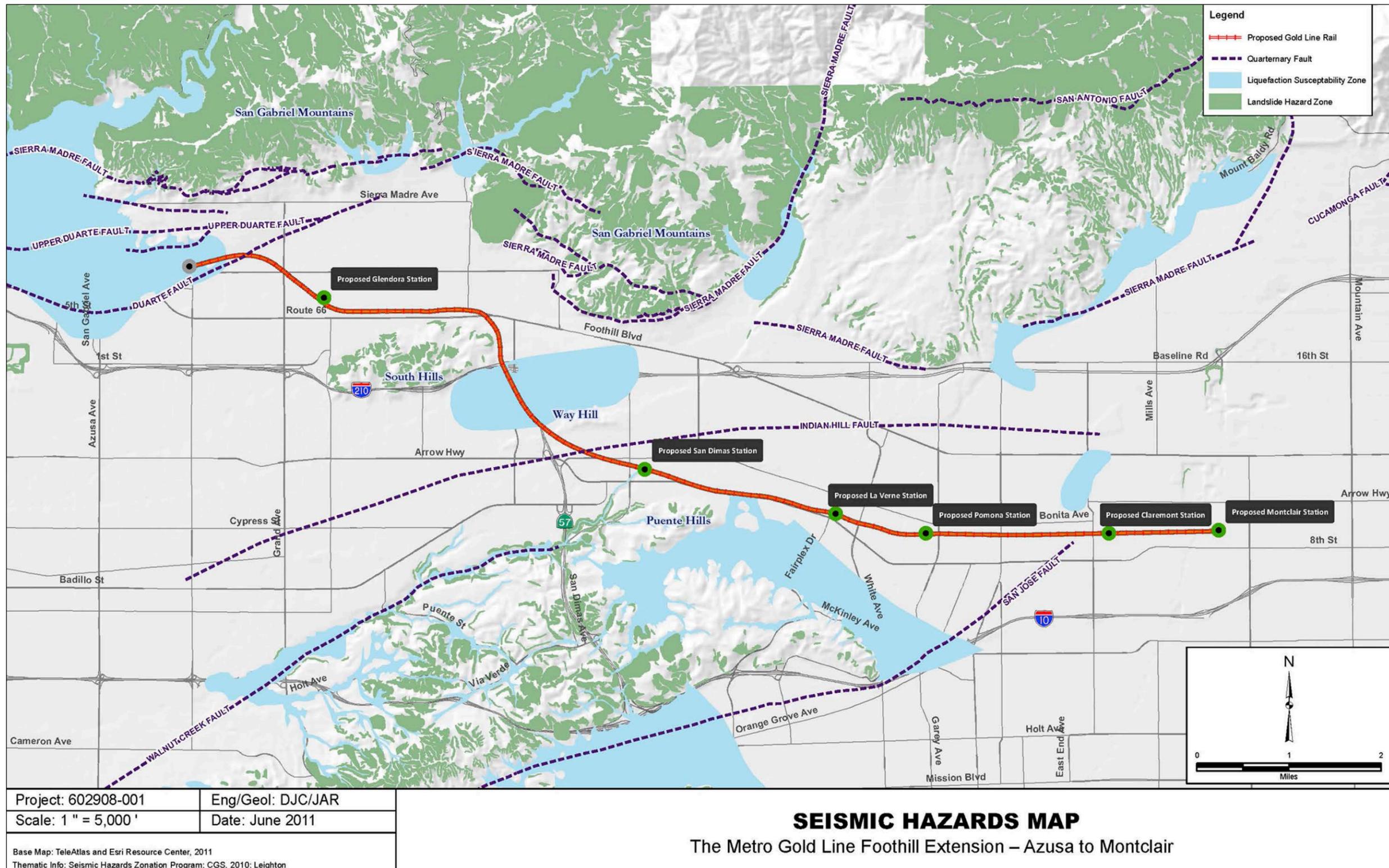


Figure 3.8-4. Seismic Hazards Map—Los Angeles and San Bernardino Counties

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3.8.1.10 Groundwater

The San Gabriel Valley Groundwater Basin is structurally bound by the Raymond Fault and Sierra Madre-Cucamonga Fault Zone to the north and northwest, the Puente and Repetto Hills to the south, and the San Jose and Chino Faults to the southeast. Groundwater is contained in the older and more recent alluvium shed from the San Gabriel Mountains and is transported to the basin mainly by the Rio Hondo and San Gabriel river drainage systems and associated tributaries (California Department of Water Resources 2003).

Historically high groundwater levels vary across the basin, which is due, in part, to faults that act as groundwater barriers and depth of sediments contained in the intervening valleys bounded by range fronts and smaller hills within the basin. Generally, groundwater depth ranges from 10 feet below ground surface (bgs) to 200 feet bgs near the western end of the Study Area. As the alignment trends southeast, groundwater rises, ranging from 150 to 100 feet bgs near the Glendora Station, and rises southerly until the alignment crosses the southeastern portion of South Hills where groundwater is only 30 to 50 feet bgs. Between the South Hills and Puente Hills to the southeast, groundwater again deepens to 100 feet bgs near the San Dimas Station, and rises as the alignment nears the northwestern slopes of the Puente Hills where groundwater elevations again rise to 30 to 50 feet bgs. As the alignment trends southeasterly from the flanks of the Puente Hills, groundwater deepens to 250 feet near the inferred San Jose and Indian Hill Faults, which act as groundwater barriers that impede flow, resulting in contrastingly different elevations across the inferred faults. Southerly of Claremont Station and west of San Antonio Creek, groundwater elevations across the faults vary by as much as 300 feet.

In general, depth to groundwater should be expected to vary significantly across the project alignment. The alignment predominately spans alluvial sediments deposited from varying formations with contrastingly different lithology. The nature of alluvial deposition (sedimentation) is such that permeable and less permeable sedimentary structures exist at varying depths below the alignment, allowing for perched groundwater conditions to develop during periods of extended rainfall or persistent irrigation. Based on interpretation of historically highest groundwater contours and borehole log data locations within the Glendora, Baldwin Park, San Dimas, and portions of the Ontario Quadrangles, groundwater can be anticipated to be shallowest (approximately 10 feet bgs) near the western end of the Study Area and deepest (approximately 250 feet bgs) near the Claremont Station. However, the reported levels are associated with historically high groundwater levels compiled from multiple well soundings and borings drilled over many years. Current groundwater levels in Southern California are generally not near their historically high levels generally because of human activities such as groundwater pumping, paving, and stormwater diversion channels.

3.8.1.11 Soils

Soils in the study area have been heavily disturbed by urban development, which often includes the importation of soils for fill. Since soils underlying the Study Area have proven capable of supporting rail infrastructure for over 100 years, no analysis of their characteristics was undertaken. All areas proposed for stations and parking have been previously developed; nonetheless, individual sites will be evaluated as part of the permitting processes to demonstrate that structural requirements are met (such as constructing on expansive soils) with the use of construction techniques that meet current state and federal requirements and compliance with applicable building codes.

Of concern in California is whether soils are prone to liquefaction during seismic events. Liquefaction often occurs in earthquake-prone areas underlain by young alluvium where the groundwater table is

within 50 feet of the ground surface. Section 3.8.2.4 discusses the issues of liquefaction soils for each station/parking location and the capability of soils to adequately support the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater for each station/parking location.

3.8.2 Environmental Impacts

This section addresses potential geotechnical impacts that could affect the project. The impact and severity of potentially significant hazards will differ along the alignment and are addressed below for specific locations within each city in the Study Area. Potential impacts from subsidence, tsunamis, and volcanic hazards are not anticipated because the project alignment is not near significant bodies of water or active volcanic areas and, therefore, are not discussed further.

3.8.2.1 Evaluation Methodology

This preliminary geotechnical assessment was conducted according to the guidelines set forth by the CGS, Note 52 for preparation of Environmental Impact Reports (California Division of Mines and Geology 1982 and 2001). These guidelines identify geologic problems (e.g., earthquake damage, loss of mineral resources, slope instability, erosion, and flooding) that must be evaluated for their potential impact to proposed development. The assessment includes:

- Review of available published documents and unpublished reports, including each city's general plan, and vintage historical aerial photographs from numerous flights between 1928 and 1979.
- Evaluation and review of data collected during previous geotechnical investigations of the site.
- Discussion of the geologic, seismic, groundwater, and soil engineering aspects of the site.
- Deterministic seismic hazard analysis for the major active and potentially active faults in the region. The analysis is a site-specific evaluation of the potential ground motion expected for the site, which would be caused by the maximum earthquake expected to occur along any fault within about a 62.5-mile radius of the site. The seismic hazard analysis estimates the PGA values to be expected along the alignment, based on the shortest distance to the fault, the maximum expected earthquake magnitude, and the attenuation of the seismic energy.
- Probabilistic seismic analysis for a 2 percent probability of exceedance in 50 years (return period of 2,475 years). The expected PGA values along the alignment have been contoured and are shown on Figure 3.8-3.

3.8.2.2 Impact Criteria

Impact on geologic and seismic resources is considered significant if the project would:

- Expose people or structures to potential substantial adverse effects involving rupture of a known earthquake fault, strong seismic ground shaking, or landslides
- Be located in an area of erosive soils, liquefaction, and expansive soils

These hazards are described below.

Fault-Induced Ground Rupture

During a moderate to large earthquake, differential movement of blocks of the earth's crust along a fault can cause the ground surface to break. This results in a localized area of intense cracking and offset of surface features such as buildings and roads.

Seismic Shaking

During an earthquake, ground shaking at a given location depends primarily on the earthquake magnitude, the distance from the earthquake focus to the site, and the response characteristics of the soils or bedrock units. Seismic shaking is described by the PGA relative to the gravitational constant of the earth (e.g., 0.5g represents a PGA of 0.5 times gravity). Table 3.8-3 to Table 3.8-9 summarize faults, fault distances, magnitudes, expected PGA values, and estimated intensity values (Modified Mercalli) for each proposed station.

Secondary Effects of Seismic Shaking

Secondary effects of seismic shaking are non-tectonic processes that are directly related to strong seismic shaking (Yeats et al. 1997). Ground deformation (including fissures, settlement, and displacement) and the resulting loss of bearing strength are common expressions of these processes and are leading causes of damage to structures during a moderate to large earthquake. Secondary effects leading to ground deformation include liquefaction, lateral spreading, landsliding, and settlement.

Liquefaction

Liquefaction occurs when loose, cohesionless, water-saturated soils (generally fine-grained sand and silt) are subjected to strong seismic ground motion of significant duration (generally one-half to one minute or more). These soils essentially behave similar to liquids, losing bearing strength. Structures built on these soils may tilt or sink when the soils liquefy. Liquefaction more often occurs in earthquake-prone areas underlain by young alluvium where the groundwater table is within 50 feet of the ground surface. Areas where possible liquefaction can occur have been mapped as potential liquefaction zones on the Seismic Hazard Zones Maps and Reports by the CGS. A liquefaction zone is an area where historic liquefaction has occurred or an area where conditions exist for potential permanent ground displacement such that mitigation as defined in Public Resources Code Section 2693(c) would be required. Figure 3.8-4 delineates possible liquefaction zones.

Lateral Spreading

Lateral spreading is a phenomenon where large blocks of intact, non-liquefied soil move down-slope on a continuous liquefied layer (Yeats et al. 1997; Tinsley et al. 1985). The mass moves toward an unconfined area, such as a descending slope or stream-cut bluff, and is known to move on slope gradients as gentle as one degree.

Seismically Induced Landslides

Marginally stable slopes (including existing landslides) may be subject to landsliding caused by seismic shaking. The seismically induced landslide hazard depends on many factors, including existing slope stability, shaking potential, and presence of existing landslides. Figure 3.8-4 delineates possible seismically induced landslide zones.

Seismically Induced Settlement

Strong ground shaking can cause settlement by allowing sediment particles to become more tightly packed, thereby reducing pore space. Unconsolidated, loosely packed granular alluvial deposits are especially susceptible to this phenomenon. Poorly compacted artificial fills may also experience seismically induced settlement.

Seismically Induced Inundation

Strong seismic ground motion can cause dams and levees to fail, resulting in damage to structures and properties located downstream. Flood control and water-storage facilities can also fail as a result of flaws not recognized in their feasibility studies, design or construction phases of the facilities.

Soil Properties

Certain soils are incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems in areas where sewers are not available for the disposal of wastewater.

3.8.2.3 Short-term Construction Impacts

No Build Alternative

The No Build Alternative does not include construction and would not be expected to experience adverse effects or significant impacts related to geologic or seismic resources underlying the cities in the region or the Study Area. Under the No Build Alternative, the Study Area would be subject to the same geologic and seismic influences as are present under existing conditions.

Transportation Systems Management (TSM) Alternative

The TSM Alternative does not include construction and would not have any elements that would affect geologic-seismic resources. However, TSM Alternative elements would be subject to geologic and seismic influences. All construction would be in accordance with the latest federal and state seismic requirements.

Build Alternative

The Build Alternative project would not have any elements that would affect geologic-seismic resources during construction, which would be in accordance with the latest federal and state seismic requirements. However, project elements would be subject to geologic and seismic influences during the construction period.

3.8.2.4 Long-Term Impacts

No Build Alternative

No elements of the No Build Alternative would be expected to experience significant impacts related to geologic or seismic resources underlying the cities in the region or the Study Area. With the No Build Alternative, the Study Area would be subject to the same geologic and seismic influences as occur under existing conditions.

Transportation Systems Management (TSM) Alternative

The operations of the TSM Alternative's rapid buses would be in accordance with policies and procedures developed by Caltrans, Metro, and other transit agencies that recognize the possibility of seismic events.

No elements of the TSM Alternative would have long-term geologic or seismic impacts in any of the cities within the Study Area.

Build Alternative

All project facilities would be constructed in accordance with the latest federal and state seismic requirements. The operations of the LRT would be in accordance with policies and procedures developed by Caltrans, Metro, and other transit agencies that recognize the possibility of seismic events. No elements of the Build Alternative would have significant long-term geologic or seismic impacts in any of the cities within the Study Area.

City of Glendora

The proposed alignment has three major bends as it passes through Glendora. It changes orientation from roughly east-west to southeast-northwest at Grand Avenue, and returns to an east-west orientation near Glendora Avenue, then turns once again to a southeast-northwest orientation as the railroad passes around the eastern end of the South Hills. The Study Area is underlain by predominately sand and gravel deposits of the Glendora Fan, which is a fan-shaped accumulation of sediments deposited by rivers emanating from mountain canyons to the north. The South Hills are the dominant topographic feature south of the mountain front within the Glendora area, and comprise marine sandstone and siltstone deposits of the Tertiary-aged Topanga Formation and the andesitic tuffs and breccias of the Glendora Volcanics (Figure 3.8-1) (Morton 1973).

Geologic hazards within Glendora, as described in the Safety Element of the Glendora General Plan/Community Plan 2025 (City of Glendora ~~1999~~2008), include landslides and other slope failures, faulting, seismic shaking, and expansive soils. Numerous landslides have been mapped along the slopes of the San Gabriel Mountains front and the South Hills. The Sierra Madre Fault Zone extends along the San Gabriel Mountains front into Glendora and presents a possible ground rupture hazard to specific areas of the city and a potential for large ground accelerations (i.e., PGA values) during seismic events on nearby faults (Leighton 1973, City of Glendora ~~1999~~2008). Soils are not a concern as wastewater disposal in Glendora is provided by the sanitary sewer collection system managed by the City's public works department

Fault-induced ground rupture is a potentially significant hazard because of the Duarte Fault. The fault crosses the project alignment near Barranca Avenue, coincident with the liquefaction zone boundary (Figure 3.8-4). This fault is not considered active by the state; however, it is considered active by the County of Los Angeles. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Liquefaction is a potentially significant hazard in two locations at the Study Area in Glendora. Figure 3.8-4 shows that the potential for liquefaction extends from Citrus Avenue to just west of Barranca Avenue, and from just north of I-210 into San Dimas (California Division of Mines and Geology 1999b, Lloyd and Wills 1998c). Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including reinforced foundations, bridge abutments and deep foundations, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismically induced inundation is a potentially significant impact to the Study Area. Failure of the Big Dalton Dam has a flood area that would extend from Little Dalton Wash to San Dimas Wash. This possible flood would inundate the Study Area from Grand Avenue to Lone Hill Avenue in less than 30 minutes (Los Angeles County Flood Control District 1973c). If flooding of the alignments were to occur, there would be a significant impact. Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismic shaking for the portion of the Study Area in Glendora is summarized in Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.80g to 0.85g. Table 3.8-3 provides a summary of the fault parameters and deterministic PGA values for the proposed Glendora Station. The Sierra Madre Fault is the closest fault to the proposed station. The maximum magnitude 7.2 earthquake could produce a 0.51g PGA at the proposed station, which would correlate to an approximate Modified Mercalli Intensity of X. Typical characteristics are described in Table 3.8-2.

Table 3.8-3. Glendora Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
Sierra Madre	1.5	7.2	0.51	X
San Jose	4.9	6.4	0.35	IX
Clamshell-Sawpit	6.4	6.5	0.28	IX
Cucamonga	7.4	6.9	0.32	IX
Raymond	7.5	6.5	0.25	IX
Puente Hills Blind Thrust	8.8	7.1	0.47	X

In a seismic event, if one or more of the above phenomena occur, there would be a significant impact to the proposed alignment in Glendora. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

City of San Dimas

The project alignment has a south-southeast orientation as it enters San Dimas. After it passes between Way Hill and Lone Hill, it turns to a more easterly direction. Both older and younger alluvial fan deposits underlie the Study Area. Bedrock units of the Topanga Formation and the Glendora Volcanics are exposed nearby on Way Hill and in the San Jose Hills (Figure 3.8-1). The Sierra Madre Fault passes through the northern portion of the city, north of Foothill Boulevard.

The *City of San Dimas General Plan* (1991) identifies a number of geologic conditions that pose a significant hazard to particular parts of the city. Landslide risk is noted in the San Jose Hills and along the San Gabriel Mountain front as well as seismic risks, including ground rupture, liquefaction, and differential settlement. Soils are not a concern as wastewater disposal in San Dimas is served by a sanitary sewer collection system managed by the City’s public works department.

At the Study Area there are no faults zoned under the Alquist-Priolo Act (Hart and Bryant 1999). However, the Indian Hill-Way Hill Fault is mapped crossing the alignment near the proposed San Dimas Station (Jennings 1994; Leighton 1972). The Indian Hill-Way Hill Fault location is not clear at the surface and is inferred by the presence of a groundwater barrier and the volcanic ridge (Way Hill) in the alluvial valley.

Fault-induced ground rupture is a potentially significant geologic hazard in San Dimas because the Indian Hill Fault is mapped (Morton and Miller 2003) as crossing the project alignment at approximately Bonita Avenue near the proposed station (Figure 3.8-4). Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Liquefaction is a potentially significant geologic hazard north of the Way Hill fault at the Study Area. The CGS indicates a liquefaction hazard north of the fault, which is due to the shallow groundwater condition that saturates loose, granular alluvial fan deposits at the Study Area (Figure 3.8-4) (California Division of Mines and Geology 1999d; Loyd 1998). Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including reinforced foundations, bridge abutments and deep foundations, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismically induced inundation is a potentially significant hazard because of the location of San Dimas Dam upstream of the city. Failure of San Dimas Dam would result in inundation of the Study Area from the Foothill Freeway south of South Hills to approximately Amelia Avenue (Los Angeles County Flood Control District 1973h). If flooding of the alignments were to occur, there would be a significant impact. Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismic shaking for the portion of the Study Area in San Dimas is summarized on Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.85g to 0.90g. Table 3.8-4 provides a summary of the fault parameters and deterministic PGA values for the proposed San Dimas Station. The Sierra Madre Fault is the closest fault to the proposed station. The estimated maximum magnitude 7.2 earthquake could produce a 0.53g PGA at the proposed station, which would correlate to an approximate Modified Mercalli Intensity of X.

In a seismic event, if one or more of the above phenomena occur, there would be a significant impact to the proposed alignment in San Dimas. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Table 3.8-4. San Dimas Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
Sierra Madre	1.7	7.2	0.53	X
San Jose	2.5	6.4	0.52	X
Cucamonga	4.7	6.9	0.37	X
Chino-Central Ave	6.1	6.7	0.26	IX
Puente Hills Blind Thrust	8.6	7.1	0.50	X
Clamshell-Sawpit	9.2	6.5	0.18	VIII

City of La Verne

The project alignment is located on the north side of Arrow Highway, which passes near the northeastern extent of the San Jose Hills. Bedrock exposures of the Glendora Volcanics are within 1,000 feet of the Study Area. The underlying surficial units, however, are silt and sand alluvial fan sediments (Figure 3.8-1). Soils are not a concern, as wastewater disposal in La Verne is served by a collection system managed by the City's public works department.

Liquefaction is a potentially significant geologic hazard as mapped on the San Dimas Quadrangle Seismic Hazard Zones Map and accompanying report (California Division of Mines and Geology 1999d, Loyd 1998). The zone of potential liquefaction is located on the southern margin of the Study Area between Damien and Wheeler Avenues (Figure 3.8-4). Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including reinforced foundations, bridge abutments and deep foundations, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismically induced inundation is a potentially significant hazard to a small portion of the Study Area if the Live Oak Reservoir dam were to fail. Failure of the dam would inundate the portion of the Study Area approximately between Wheeler Avenue and D Street (Los Angeles County Flood Control District 1973i) and would cover the area from Wheeler Avenue to Thompson Creek Wash (Los Angeles County Flood Control District 1973i). Flooding of the rail alignment could result in delays and other service disruption. The extent of flooding would depend on the degree to which the dam is breached and the water level in the reservoir at that time. Since the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismic shaking for the portion of the Study Area in La Verne is summarized on Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.90g to 0.95g. Table 3.8-5 summarizes the fault parameters and deterministic PGA values for the proposed La Verne station. The San Jose Fault is the closest fault to the proposed station. The maximum magnitude 6.4 earthquake could produce a 0.59g PGA at the station that would result in a Modified Mercalli Intensity of X. Typical characteristics are described in Table 3.8-2.

Table 3.8-5. La Verne Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
San Jose	1.4	6.4	0.59	X
Sierra Madre	1.9	7.2	0.52	X
Cucamonga	3.0	6.9	0.42	X
Chino-Central Ave	4.6	6.7	0.31	IX
Puente Hills Blind Thrust	9.5	7.1	0.42	X
Clamshell-Sawpit	10.7	6.5	0.16	VIII

In a seismic event, if one or more of the above phenomena occur, there would be a significant impact to the proposed alignment in La Verne. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

City of Pomona

As the project alignment enters Pomona at Fulton Avenue, it turns slightly and takes on an east-west orientation. Younger alluvial fan deposits consisting mostly of sand underlie the Study Area. However, shallow groundwater conditions have not been identified at the Study Area, and no active or potentially active faults have been mapped along the project alignment. As a result, liquefaction is not considered a potential hazard along this portion of the alignment (Figure 3.8-4).

Seismically induced inundation presents a potentially significant geologic hazard. Flooding due to failure of the San Antonio Dam could inundate the Study Area with approximately 4 to 7 feet of water (United States Army Corps of Engineers 1986). This would likely result in schedule delays and service disruption. The extent of flooding would depend on the degree to which the dam is breached and the water level in the reservoir at that time. Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Soils, are not a concern, as wastewater disposal in Pomona is served by a sanitary sewer collection system managed by the City's water/wastewater operations division.

Seismic shaking for the portion of the Study Area in Pomona is summarized on Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.95g to 0.98g. Table 3.8-6 provides a summary of the fault parameters and deterministic PGA values for the proposed Pomona station. The San Jose Fault is the closest fault to the proposed station. An estimated maximum magnitude 6.4 earthquake on the San Jose Fault could produce 0.60g PGA at the proposed station, which would correlate to an approximate Modified Mercalli Intensity of X. Typical characteristics are described in Table 3.8-2.

Table 3.8-6. Pomona Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
San Jose	0.9	6.4	0.60	X
Sierra Madre	2.0	7.2	0.51	X
Cucamonga	2.5	6.9	0.45	X
Chino-Central Ave	4.2	6.7	0.33	IX
Puente Hills Blind Thrust	10.0	7.1	0.39	IX
Clamshell-Sawpit	11.4	6.5	0.15	VII

In a seismic event, if one or more of the above phenomena occur, there would be a significant impact to the proposed alignment in Pomona. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

City of Claremont

In Claremont, the project alignment has an east-west orientation and is underlain by unconsolidated alluvial fan sediments with rock fragments up to boulder size (Figure 3.8-1). Shallow groundwater conditions have not been identified at the Study Area (Lloyd 1998). Because of the absence of shallow groundwater, liquefaction is not considered a potential hazard along this portion of the alignment (Figure 3.8-4). Soils are not a concern, as wastewater disposal in Claremont is served by a sanitary sewer collection system managed by the City's community services department.

Fault-induced ground rupture is a potentially significant geologic hazard at the Study Area because the San Jose Fault crosses the Study Area between Carnegie Avenue and Indian Hill Boulevard (Figure 3.8-2) (Morton and Miller 2003). Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismically induced inundation presents a potentially significant geologic hazard. Flooding due to failure of the San Antonio Dam would inundate the Study Area with approximately 4 to 7 feet of water (U.S. Army Corps of Engineers 1986). This would likely result in schedule delays and service disruption. The extent of flooding would depend on the degree to which the dam is breached and the water level in the reservoir at that time. Since the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismic shaking for the portion of the Study Area in Claremont is summarized on Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.95g to 0.98g. Table 3.8-7 provides a summary of the fault parameters and deterministic PGA values for the proposed Claremont Station. The San Jose Fault is the closest fault to the proposed station. The estimated maximum

magnitude 6.4 earthquake could produce a 0.61g PGA at the proposed station, which would correlate to a Modified Mercalli Intensity of X. Typical characteristics are described in Table 3.8-2.

Table 3.8-7. Claremont Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
San Jose	0.0	6.4	0.61	X
Cucamonga	2.3	7.2	0.47	X
Sierra Madre	2.4	6.9	0.48	X
Chino-Central Ave	4.5	6.7	0.32	IX
Puente Hills Blind Thrust	11.4	7.1	0.33	IX
Clamshell-Sawpit	12.5	6.5	0.14	VII

In a seismic event, if either or all of the above phenomena occur, there would be a significant impact to the proposed alignment in Claremont. Since all project facilities and systems would be constructed in compliance with most current seismic regulations and requirements and incorporate all required seismic safety features, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

City of Montclair

The project alignment is oriented in an east-west fashion. Gravel and boulder-rich sediments carried from the San Gabriel Mountains by the San Antonio River make up the alluvial fan deposits that underlie the Study Area. The Sierra Madre-Cucamonga Fault Zone lies less than one mile to the north of the Study Area (Figure 3.8-2). Shallow groundwater conditions have not been identified at the Study Area (Lloyd 1998) and no active or potentially active faults have been mapped along the project alignment. Because of the absence of shallow groundwater, liquefaction is not considered a potential hazard along this portion of the alignment (Figure 3.8-4). Soils are not a concern, as wastewater disposal in Montclair is served by a sanitary sewer collection system managed by the City's public works engineering division.

Seismically induced inundation is a potentially significant impact due to possible failure of the San Antonio Dam located north of the Study Area. Flooding caused by a total failure of the San Antonio Dam would inundate the Study Area with 7 to 8 feet of water (U.S. Army Corps of Engineers 1986). The actual extent of flooding would depend on the degree to which the dam is breached and the water level in the reservoir at that time. Such an event would result in schedule delays and service disruption. Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate safety features, including constructing the alignment above the floodwater and the station and parking areas designed with floodwater diversion devices, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

Seismic shaking for the portion of the Study Area in Montclair is summarized on Figure 3.8-3. The PGA value for a 2 percent probability of exceedance in 50 years ranges from 0.92g to 0.95g. Table 3.8-8 provides a summary of the fault parameters and deterministic PGA values for the proposed Montclair station. The San Jose Fault is the closest fault to the proposed station. The estimated maximum magnitude 6.4 earthquake on the fault could produce a 0.52g PGA at the proposed station, which would correlate to a Modified Mercalli Intensity of X. Typical characteristics are described in Table 3.8-2.

Table 3.8-8. Montclair Station Seismic Summary

Fault Name	Approximate Distance (miles)	Maximum Earthquake Magnitude (M)	Peak Ground Acceleration (g)	Estimated Site Modified Mercalli Intensity
San Jose	0.8	6.4	0.52	X
Cucamonga	2.7	7.2	0.44	X
Sierra Madre	3.3	6.9	0.43	X
Chino-Central Ave	5.1	6.7	0.30	IX
Puente Hills Blind Thrust	12.3	7.1	0.30	IX
Clamshell-Sawpit	13.3	6.5	0.13	VII

In a seismic event, if one or more of the above phenomena occur, there would be a significant impact to the proposed alignment in Montclair. Since all of the project facilities and systems would be constructed in compliance with most current regulations and requirements and incorporate seismic safety features, including structural setbacks for buildings, flexible railroad tracks with provisions for realignment, this impact would be reduced to the applicable current safety standards (see specific design guidelines in Table 3.8-9).

3.8.2.5 Cumulative Impacts

The Southern California Association of Governments' (SCAG) *2012-2035 Regional Transportation Plan/Sustainable Communities Strategy* (RTP/SCS) Final EIR provides a regional cumulative impact assessment for transportation improvements (including the project) through the year 2035. The 2004 RTP analysis concludes that significant cumulative impacts could occur because of hazardous geologic conditions in certain locations where transportation projects are planned. However, the project is not expected to result in any significant geologic or seismic hazards and, thus, would not contribute to this significant cumulative impact identified by SCAG.

3.8.2.6 Impacts Addressed by Regulatory Compliance

Construction-Period Impacts

Impacts that would arise during construction of the Build Alternative project were identified in Section 3.8.2.3 (e.g., seismically induced ground rupture, liquefaction, inundation, seismic shaking). Elimination or reduction of these construction impacts would occur through strict compliance with local, state, or federal regulations or permits as listed in Section 3.8.1 that have been developed by regulatory agencies to manage geologic and seismic concerns during construction.

Long-term Impacts

Mandatory compliance with current seismic safety and geotechnical safety requirements and regulations, including safety design standards would result in *less than significant* impacts related to geologic and seismic concerns. Table 3.8-9 lists design guidelines for compliance with existing regulations.

3.8.3 Mitigation Measures

3.8.3.1 Short-term Construction Mitigation Measures

Construction period impacts would be reduced to a less than significant level by complying with state and local regulatory requirements and/or permits identified in Section 3.8.1. No additional mitigation measures are necessary.

3.8.3.2 Long-term Mitigation

Because there are many functioning railroad facilities in the Los Angeles region that have been designed with similar geologic and seismic considerations, it is anticipated that strict compliance with seismic safety regulations and standards, including design standards incorporating safety features and proper construction procedures, would result in *less than significant* impacts. Table 3.8-9 lists design guidelines and recommendations addressing seismic and geological concerns.

3.8.4 Level of Impact after Mitigation

With strict compliance with seismic safety regulations and standards, including design standards incorporating safety features and proper construction procedures listed in Table 3.8-9, impacts would be *less than significant*.

Table 3.8-9. Summary of Design Guidelines for Potentially Significant Geologic Hazards

Location	Geologic Hazard	Geologic Condition	Design Guidelines
Glendora			
Barranca Avenue	Fault-Induced Ground Rupture	Duarte fault inferred to cross Study Area, Holocene rupture not yet determined.	Structural setback for buildings
Citrus to Barranca Avenues	Liquefaction	Shallow ground water (less than 40 feet bgs) within the loose, granular alluvial fan sediments deposited in this area.	Reinforce all station and parking foundations, bridge abutments and railway tracks; support structures on deep foundations.
Grand Avenue to Lone Hill Avenue	Seismically Induced Inundation	Presence of the Big Dalton Dam located topographically higher than the Study Area.	Construct alignment higher than floodwater; design floodwater diversion devices for stations and parking areas.
San Dimas			
South of Gladstone Avenue to North of 210 Freeway	Liquefaction	Shallow ground water (less than 40 feet bgs) within the loose, granular alluvial fan sediments deposited in this area	Reinforce all station and parking foundations, bridge abutments and railway tracks; support structures on deep foundations.
Bonita Avenue	Fault-Induced Ground Rupture	The Indian Hill Fault is inferred to cross the Study Area. Its activity has not been confirmed.	Structural setback for buildings; flexible railroad tracks with provisions for realignment.
210 Freeway to Highland Place	Liquefaction	Shallow ground water (less than 40 feet bgs) within the loose, granular alluvial fan sediments deposited in this area.	Reinforce all station and parking foundations, bridge abutments and railway tracks; support structures on deep foundations.
Foothill Freeway to Amelia Avenue	Seismically Induced Inundation	Presence of the San Dimas Dam located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.
La Verne			
Damien to Wheeler Avenues	Liquefaction	Shallow ground water (less than 40 feet bgs) within the loose, granular alluvial fan sediments deposited in this area.	Reinforce all station and parking foundations, bridge abutments and railway tracks; support structures on deep foundations.
Wheeler Avenue to D Street	Seismically Induced Inundation	Presence of the Live Oak Reservoir located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.
Wheeler Avenue to Thompson Creek Wash	Seismically Induced Inundation	Presence of the Live Oak Dam located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.

Table 3.8-9. Summary of Design Guidelines for Potentially Significant Geologic Hazards (continued)

Location	Geologic Hazard	Geologic Condition	Design Guidelines
Pomona			
Fulton Road to Carnegie Avenue	Seismically Induced Inundation	Presence of the San Antonio Dam located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.
Claremont			
Carnegie Avenue to Indian Hill Boulevard	Fault-Induced Ground Rupture	The inferred trace of the San Jose Fault crosses the Study Area.	Structural setback for buildings; flexible railroad tracks with provisions for realignment.
Carnegie Avenue to Claremont Boulevard	Seismically Induced Inundation	Presence of the San Antonio Dam located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.
Montclair			
Claremont Boulevard to Central Avenue	Seismically Induced Inundation	Presence of the San Antonio Dam located topographically higher than the Study Area.	Construct alignment higher than flood water; design floodwater diversion devices for stations and parking areas.

Source: Leighton Consulting, Inc., 2011

