4.6 GEOLOGY AND SOILS

4.6.1 METHODOLOGY

This section discusses the potential seismic and geologic hazards that may adversely affect the City of Arcadia, as summarized from the *Seismic and Geologic Technical Background Report for the City of Arcadia General Plan Update, Arcadia, Los Angeles County, California*, prepared by Wilson Geosciences, Inc. in September 2008 and included in Appendix G of this EIR. In addition, information on local soils was summarized from the *Report and General Soil Map for Los Angeles County* prepared by the U.S. Department of Agriculture, Natural Resources Conservation Service.

The Seismic and Geologic Technical Background Report was developed to support the preparation of the Safety Element of the proposed General Plan Update and contains current information on the seismic and geologic conditions within and around the City that could affect persons and/or property in the event of a local geologic hazard or a major earthquake in Southern California. The report is based on information obtained from published regional reports and maps and site-specific grading, geotechnical, and engineering geology reports.

4.6.2 RELEVANT PROGRAMS AND REGULATIONS

Federal

International Building Code

The International Building Code (IBC) is the national model building code. The 2006 IBC is the most recent edition, which was incorporated into the 2007 California Building Code, and currently applies to all structures being constructed in California (ICC 2008). The national model codes are incorporated by reference into the building codes of local municipalities, such as the California Building Code and Arcadia's Building Code, as discussed below.

State

Alquist-Priolo Earthquake Fault Zoning Act

In response to the 1971 San Fernando Earthquake in Southern California, the Alquist-Priolo Special Studies Zones Act of 1972 was enacted. The Act was renamed in 1994 to the Alquist-Priolo Earthquake Fault Zoning (APEFZ) Act. The California Department of Mines and Geology's (CDMG) Special Publication 42 includes the provisions of the Act and an index to maps of Earthquake Fault-Rupture Zones (formerly Alquist-Priolo Special Study Zones), as well as current revisions to this document (including Supplements 1 and 2 added in 1999, and Supplement 3 added in 2003).

Earthquake Fault-Rupture Zones have been delineated along the traces of active faults to prevent the construction of urban development across the trace of active faults. The boundary of the fault zone is approximately 500 feet from major active faults and 200 to 300 feet from well-defined minor faults. The State Geologist defines an active fault as a fault that has previous surface displacement within the Holocene period (the last 11,000 years). A potentially active fault is defined as any fault that has surface displacement during Quaternary time (last 1,600,000 years) but not within the Holocene period.

Land subdivisions and habitable structures consisting of four units or more that are proposed within these zones are required to perform detailed fault investigations so that engineering geologists can mitigate the hazards associated with active faulting by identifying the location of the fault and allowing for a setback for structures for human occupancy from the zone of previous ground rupture.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 (*Public Resources Code*, Chapter 7.8, Section 2690–2699.6) directs the California Department of Conservation to identify and map areas subject to earthquake hazards, such as liquefaction, earthquake-induced landslides, and amplified ground shaking. Passed by the State legislature after the 1989 Loma Prieta earthquake, the Seismic Hazards Mapping Act was aimed at reducing the threat to public safety and minimizing potential loss of life and property in the event of a damaging earthquake event. A product of the resultant Seismic Hazards Mapping Program, Seismic Zone Hazard Maps identify Zones of Required Investigation. Most developments designed for human occupancy that are planned within these zones are required to conduct site-specific geotechnical investigations to identify the hazard and to develop appropriate mitigation measures prior to permitting by local jurisdictions.

Natural Hazards Disclosure Act

The Natural Hazards Disclosure Act (effective June 1, 1998) requires that sellers of real property and their agents provide prospective buyers with a disclosure statement when the property is located within one or more State-mapped hazard areas, including a Seismic Hazard Zone. The disclosure can be made as a Local Option Real Estate Transfer Disclosure Statement or a Natural Hazard Disclosure Statement.

California Building Code

The California Building Code (CBC) is promulgated under the *California Code of Regulations* (CCR), Title 24, Parts 1 through 12 (also known as the California Building Code), and is administered by the California Building Standards Commission (CBSC). The CBSC is responsible for administering California's building codes, including the adoption, approval, publishing, and implementation of codes and standards. The CBC is a compilation of three types of building standards from three different origins:

- Standards adopted by State agencies without change from the national model codes (e.g., the IBC).
- Standards adopted and adapted from the national model code standards to meet California conditions (e.g., most of California is Seismic Design Categories D and E).
- Standards authorized by the California legislature that constitute extensive additions not covered by the national model codes and adopted to address concerns particular to California (e.g., the specification of a "Certified Engineering Geologist" rather than an "engineering geologist").

The national model code standards adopted into Title 24 apply to all occupancies in California, except for modifications adopted by State agencies and local governing bodies. Facilities and structures such as power plants, freeways, emergency management centers (e.g., traffic management and 911 centers), and dams are regulated under criteria developed by various California and federal agencies. The current version of the CBC is the 2007 triennial edition (2007 CBC).

California Plumbing Code

Part 5 of the California Building Code (Title 24 of the Code of Regulations) is the California Plumbing Code, which provides standards for the design and construction of water and sewer systems, storm drains and recycled water system in buildings. It prohibits connection to a septic tank in areas served by a public sewer system and requires the proper abandonment of septic tanks, cesspools and seepage pits.

Regional

General Waste Discharge Requirements for Residential On-site Wastewater Treatment Systems

Order No. R4-2004-0146 of the Los Angeles Regional Water Quality Control Board (RWQCB) regulates discharges from residential on-site wastewater treatment systems throughout the entire Los Angeles Region (Los Angeles and Ventura counties). The General Waste Discharge Requirements (WDRs) apply to septic tanks proposed in areas with shallow groundwater, areas adjacent to water bodies listed as impaired pursuant to Section 303(d) of the Clean Water Act, areas where groundwater is used for domestic purposes, and areas with nitrogen or bacterial contamination of ground or surface waters. The general WDRs require dischargers to comply with all applicable Basin Plan provisions, including any prohibitions, water quality objectives and Total Maximum Daily Loads (TMDLs) governing the discharge. Discharge prohibitions and general provisions are outlined for compliance by dischargers that fall under the WDR, including regulations for the type of discharge, surface overflows, disposal of wastes in geologically unstable areas, odors, groundwater pollution, annual inspections, connection to public sewer system within six months of availability, and monitoring.

Local

Arcadia Building Regulations

Building regulations in Arcadia are specified in Article VIII, Sections 8010–8927 of the *Arcadia Municipal Code*, and include adoption of the 2007 California Building Code. Standard residential, commercial, and light industrial construction is governed by the CBC, which the City has amended to provide additions that make it more stringent and to address specific geologic and wildfire considerations in the City.

Arcadia Special Studies Geologic Zones Code

The City of Arcadia Special Studies Geologic Zones Code (Article III, Chapter 7 of the *Arcadia Municipal Code*) incorporates the Alquist-Priolo Special Studies Zones Map of the State Geologist. It designates the areas approximately 660 feet on either side of a fault for special study. The designated areas warrant special geologic investigations to confirm the presence or absence of active earthquake faults. The geologic investigations shall be prepared by or under the direction of a geologist registered in the State of California and in accordance with the guidelines of the State of California Board of Mines and Geology. Where a potentially active or an active fault trace is located, the following standards apply:

- No structure for human occupancy shall be built over the trace.
- A setback area of 50 feet shall be provided from the fault, unless the City's Geologist, after reviewing a geologic study, determines that either: (1) a lesser setback would not pose an unnecessary risk of structural damage due to surface rupture or (2) a setback

greater than 50 feet is needed for high risk structures (such as schools, hospitals, and buildings over 2 stories high).

- A seller of real estate or his agent shall disclose in writing to any prospective buyer the fact that the property is located within a Special Studies Zone, to be signed by the purchaser prior to entering escrow.

Geological Investigations

Section 9250.5.3 of the *Arcadia Municipal Code*, which is part of the City's Zoning Regulations, requires that every application for a development permit include, among other things, a report of an engineering geological investigation performed by a registered engineer and registered geologist, based on the plan for the work proposed under the permit. The engineering and geotechnical report should provide a description of the geology of the site and conclusions and recommendations regarding the effect of the geologic conditions, including consideration of seismic hazards and slope stability in natural materials. These reports are subject to review and approval by the City Engineer. Recommendations of the report should be incorporated into the design and construction of the proposed development.

Erosion Control

The City's Zoning Regulations require that every application for a development permit include erosion control planting or other protective devices. Development regulations for the Residential Mountainous Single Family Zone, as contained in the City's Zoning Regulations, require that all cut or fill slopes exceeding two meters (6.6 feet) in vertical height between two or more contiguous lots shall be planted with adequate plant material to protect the slope against erosion. The City's Building Regulations also prohibit irrigation systems or watering devices that cause soil erosion or saturate the soil to cause slope failure. Site topography or configuration that causes or will cause erosion, subsidence, surface water runoff problems, or other conditions which will, or may, be injurious to the public's health, safety, and welfare or to adjacent properties is considered a nuisance and subject to abatement under Section 9402 of the Municipal Code.

4.6.3 EXISTING CONDITIONS

<u>Regional and Local Geology</u>

The City of Arcadia is located at the boundary between the Peninsular Ranges geomorphic province (on the south) and the Transverse Ranges geomorphic province (on the north). The east-west trending San Gabriel Mountains, which underlie the northern part the City, are part of the Transverse Ranges. The City is located within the northwest portion of the San Gabriel Valley, which is bound on the north by the San Gabriel Mountains, on the west by the Repetto and Merced Hills, on the south by the Puente Hills, and on the east by the San Jose Hills. The San Gabriel Mountains are the result of uplift along a predominant fault line at the base of this steep mountain front. This fault line is a part of the Sierra Madre fault system that extends from the western San Fernando Valley to the City of Claremont on the east, where it joins the Cucamonga fault.

Erosion of the San Gabriel Mountains due to water and gravity have formed fan-shaped alluvial wedges that fill the San Gabriel Valley, providing a basin for groundwater storage and a geomorphic surface that has recorded younger (<12,000 year old) fault movements. Beneath the alluvial fan surface are hundreds of feet of alluvium composed primarily of sand, gravel, cobbles, and boulders, with some clay-rich deposits bordering the northern side of the Raymond fault, which generally runs northeast-southwest through the northern section of the City. Within the northern portions of the City, where the San Gabriel Mountains begin to rise steeply north of the Sierra Madre fault zone, Cretaceous-age crystalline "granitic" and metamorphic basement rock units underlie the City. Millions of years of tectonic uplift along the base of the San Gabriel Mountains have placed the very old crystalline basement rocks in the mountains on the north against the younger alluvial deposits of the San Gabriel Valley on the south.

Ground elevations in the City range from approximately 1,800 feet above mean sea level (msl) at the northwestern corner (west of Santa Anita Canyon) to 320 feet above msl at the southeastern City boundary at Lower Azusa Road. The majority of the City has elevations between 350 and 800 feet above msl. Ground slopes are greater than 25 to 50 percent slopes in the hillsides and less than 10 percent on the higher alluvial fans (generally north of Foothill Boulevard). Slopes of less than two percent are found on the lower alluvial fans in the central and southern sections of the City.

Soils

Cretaceous and Proterozoic age crystalline "granitic" and metamorphic bedrock units are exposed in the northern and northeastern edges of the City, and underlie surficial alluvial soils in the remaining areas of the City. The bedrock formations form the core of the San Gabriel Mountains and range from Proterozoic (2.5 billion to 543 million years ago) to Paleozoic (543 to 248 million years ago) and Cretaceous (144 to 65 million years ago) in age.

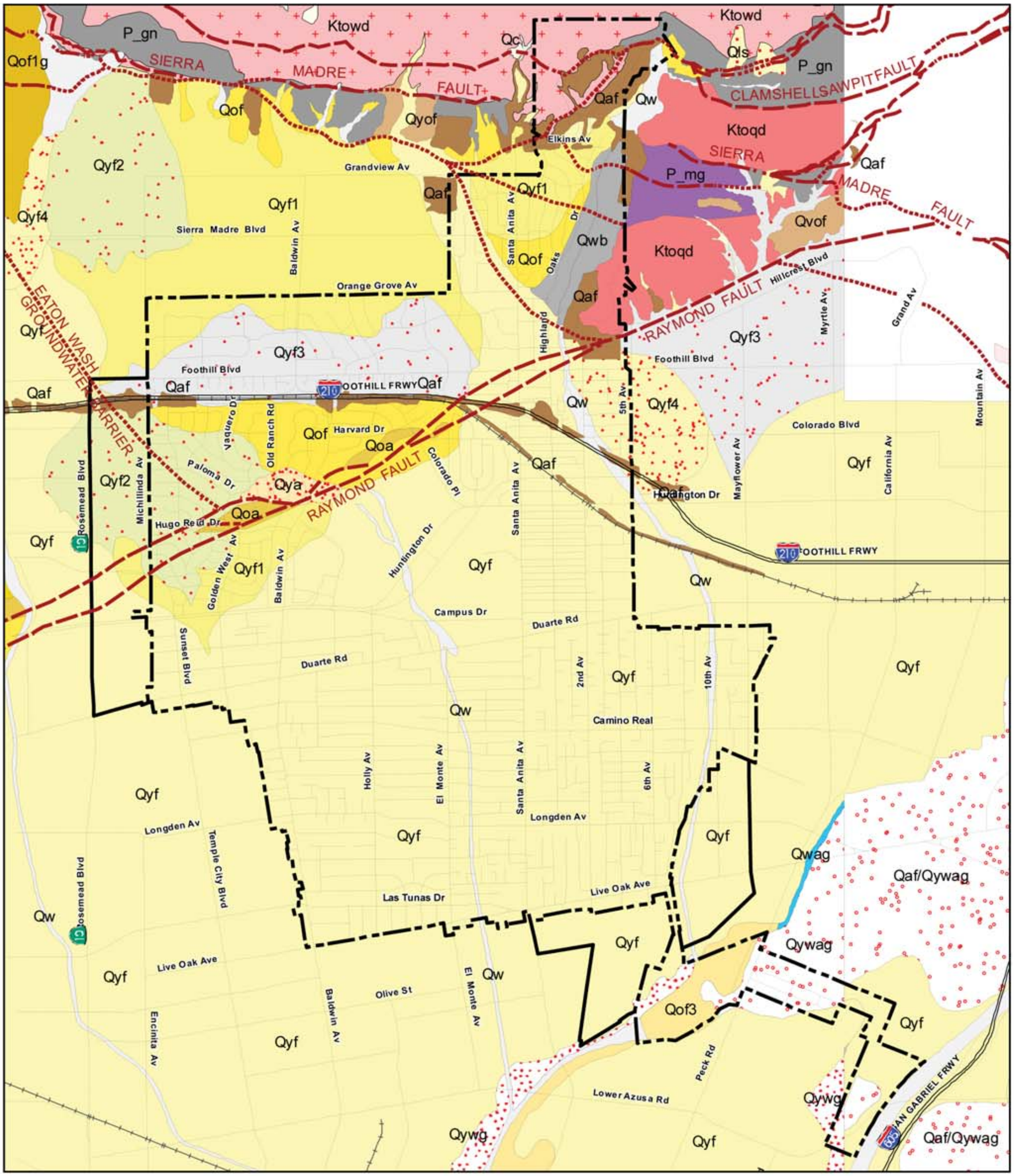
These bedrock units are susceptible to slope instability, which is commonly manifested as rock fall, debris slides, and surficial soil slumps, and rarely as large rotational landslides covering thousands of square feet. The northwestern portion of the City has been mapped to be underlain by a very large "probable Dormant-Old" landslide mass, where the landform has been highly eroded and is without evidence of historic movement. Excavation of these bedrock formations can be very difficult, requiring extensive ripping or blasting.

As previously discussed, surficial deposits in the City consist of relatively recent (geologically young) sediments formed by alluvial processes in streams on alluvial fans/basins located below Santa Anita/Little Santa Anita Canyons. A graphic depiction of the various soil types within and surrounding the City of Arcadia is presented in Exhibit 4.6-1, Area Geology Map.

The majority of alluvium within and immediately adjacent to the City is divided into three primary units. The youngest units are associated with more recent deposition from the Santa Anita and Little Santa Anita washes and the San Gabriel River. The oldest units underlie most of the younger deposits, but have a very limited map distribution along the flanks of Santa Anita Canyon and just north of the Raymond fault south of the I-210 Freeway.

The vast majority of deposits are of intermediate age, which is located north and south of the freeway and west of Baldwin Avenue. Older deposits were uplifted due to fault movements or broader regional uplift, while the younger sediments were being deposited on alluvial fans and in stream courses cutting through and around these elevated areas. It is estimated that young alluvial basin and fan deposits underlie at least three-quarters of the City.

The U.S. Department of Agriculture's (USDA's) Report and General Soil Map for Los Angeles County identifies soil associations in the City of Arcadia as consisting primarily of Hanford soils, with Vista Amargosa soils at the northeastern end and Tujunga-Soboba soils at the southeastern end (USDA 1969).



Legend

- City Boundary
- Sphere of Influence
- Approximate Fault Location
- Inferred or Possible Groundwater Barrier

Geological Units

Ktoqd, Ktowd, P_gn, P_mg, Qa, Qaf, Qaf/Qywag, Qc, Qls, Qoa, Qoa3a, Qof, Qof1g, Qof3, Qsw, Qvof, Qw, Qw1, Qwa, Qwag, Qwb, Qya, Qya3b, Qyf, Qyf1, Qyf2, Qyf3, Qyf4, Qyf5, Qywag, Qywg, Qyws

0 1,200 2,400 3,600 4,800 Feet

Source: Hogle-Ireland, Inc. 2010

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Area Geology Map

Exhibit 4.6-1

Arcadia General Plan Update

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Hanford soils are found on gently sloping alluvial fans. These soils are well-drained and have moderately rapid soil permeability. They are slightly acidic to mildly alkaline. Hanford soils have low shrink-swell potential and low corrosivity. They have slight limitations for shallow excavation and as septic tank filter fields. Erosion hazard is slight to moderate (USDA 1969).

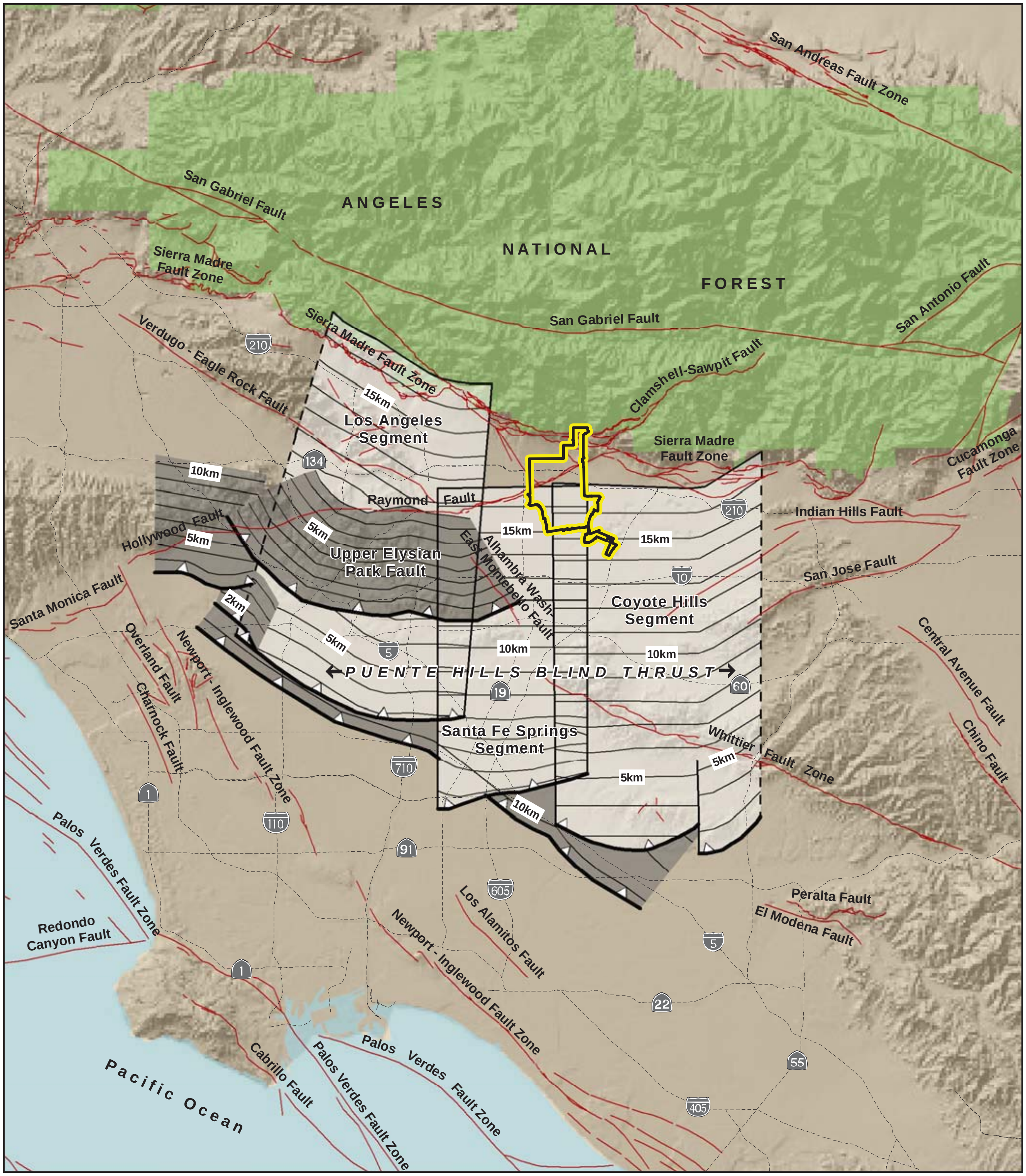
The Tujunga-Soboba soil association is made of up to 60 percent Tujunga soils and 30 percent Soboba soils, with the remaining 10 percent consisting of sandy and cobble material in the beds of intermittent streams. Tujunga soils have rapid soil permeability and are slightly acidic to mildly alkaline. Gravel and cobble make up 35 percent of the Soboba soils. Tujunga-Soboba soils have low shrink-swell potential and low corrosivity. Soil erosion hazard is slight to moderate from water and moderate to high from wind (USDA 1969).

Vista-Amargosa soils are found in steep mountainous areas. Vista soils make up 45 percent of the association, with Amargosa soils making up 40 percent. The remaining 15 percent consist of 5 percent Godde soils, 5 percent Saugus soils, and 5 percent rock land. Vista soils are well drained and have moderately rapid soil permeability. Sheet and rill erosion are moderate on Amargosa soils, which has led to the removal of 25 or 40 percent of the surface soils, with rock outcrops covering 2 to 10 percent of the surface. Vista-Amargosa soils have low shrink-swell potential and low corrosivity. Soil erosion hazard is high to very high (USDA 1969).

Faults and Seismicity

Within Los Angeles County, numerous regional and local faults are capable of producing severe earthquakes (magnitude [M] of 6.0 or greater). Exhibit 4.6-2, Regional Fault Map, shows the relative location and general extent of faults in and near the City of Arcadia. Table 4.6-1 lists the major faults in the area, their distances from the Arcadia City Hall, and their associated maximum potential earthquakes.

Active and potentially active faults that cross the City of Arcadia include the Raymond fault (also known as the Raymond Hill fault), the Sierra Madre fault, and Eaton Wash groundwater barrier, with the Upper Elysian Park blind thrust and Puente Hills blind thrust underlying areas that could cause folding and uplift in the City. Others faults located near the City (within ten miles) include the Clamshell-Sawpit, Verdugo-Eagle Rock, Alhambra Wash, Whittier, and San Jose faults.



Arcadia City Boundary

Freeway/Highway

Potential Earthquake Faults (See Table)

Blind Thrust Faults

Faults are buried below the surface; small triangles indicated fault dip direction (north) and thin gray lines indicate the depth contours (e.g., 5 km = 5 kilometers deep) on the fault surface (Shaw et al, 2002).

Surface Faults

Faults exposed at the ground surface; solid where well located, dashed where approximate, and dotted where conceled (Bryant, 2005).
Not all Faults in Table are shown on Figure .

Source: Hogle-Ireland, Inc. 2010

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Regional Fault Map

Exhibit 4.6-2

Arcadia General Plan Update

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TABLE 4.6-1
MAJOR FAULTS WITHIN 50 KILOMETERS OF THE CITY OF ARCADIA

Fault Name (in Order of Nearest Distance from the Site)	Approximate Distance from Site [mi (km)]	Fault Length (km)	Fault Dip and Direction (Where Applicable)	Slip Rate (mm/yr.)	Type of Fault (Sense of Slip)	Magnitude (Mw) of Maximum Earthquake	Age and Evidence of Latest Surface Faulting
Raymond	0.6 (0.9)	23	80° NE	0.5 to 2.5	Reverse Oblique	6.5	Historic (1988 M4.9 Pasadena EQ)
Sierra Madre	2.7 (4.3)	85	55° N	1.0 to 3.0	Reverse	7.2	Holocene and Late Quaternary
Puente Hills Blind Thrust	2.9 (4.7)	40	27° N	0.3 to 1.0	Reverse	7.1	No documented surface faulting
Clamshell-Sawpit	3.6 (5.8)	16	45° N	0.5 to 1.0	Reverse	6.5	Recent Seismicity
Upper Elysian Park Blind Thrust	4.7 (7.5)	34	22° NE	0.9 to 1.7	Blind Thrust – Reverse	6.4	Historic (1987 Whittier Narrows EQ)
Verdugo-Eagle Rock	5.2 (8.4)	27	45°– 60° NE	0.5 to 1.0	Reverse Oblique	6.9	Holocene
Whittier	8.5 (13.6)	38	75° NE	1.5 to 3.5	Strike Slip	6.8	Late Quaternary NW of Brea Canyon
San Jose	9.4 (15.1)	22	75° N	0.5 to 1.0	Reverse Oblique	6.4	Late Quaternary
Hollywood	11.0 (17.7)	19	65°– 70° N	0.5 to 1.5	Reverse Oblique	6.4	Late Quaternary
Cucamonga	16.0 (25.8)	25	50° N	3.0 to 7.0	Reverse	6.9	Late Quaternary; Historic
Chino-Central Avenue (Elsinore)	16.4 (26.4)	28	60°– 65° SW	1.0	Reverse Right Oblique	6.8	Late Quaternary
Sierra Madre (San Fernando)	17.6 (28.3)	18	45° N	1.0 to 3.0	Reverse	6.7	Late Quaternary; possible Holocene
San Gabriel	18.6 (30.0)	72	90°	0.5 to 1.5	Strike Slip	7.1	Late Quaternary
Newport-Inglewood (Los Angeles Basin)	20.7 (33.3)	66	90°	0.5 to 1.5	Strike Slip	7.1	Historic (1933 Long Beach EQ)
Santa Monica	22.1 (35.6)	28	75° N	0.5 to 1.5	Reverse Oblique	6.6	Late Quaternary; Holocene
Northridge (East Oak Ridge)	23.2 (37.4)	31	42° S	0.5 to 2.5	Reverse	7.0	Historic (1994 Northridge Earthquake)
San Andreas (Carrizo-Big Bend)	23.8 (38.3)	345	90°	31.0 to 37.0	Strike Slip	7.8	Historic (1857) SE to Wrightwood
San Andreas (San Bernardino)	23.8 (38.3)	192	90°	16.0 to 28.0	Strike Slip	7.5	Late Quaternary; Holocene

TABLE 4.6-1 (Continued)
MAJOR FAULTS WITHIN 50 KILOMETERS OF THE CITY OF ARCADIA

Fault Name (in Order of Nearest Distance from the Site)	Approximate Distance from Site [mi (km)]	Fault Length (km)	Fault Dip and Direction (Where Applicable)	Slip Rate (mm/yr.)	Type of Fault (Sense of Slip)	Magnitude (Mw) of Maximum Earthquake	Age and Evidence of Latest Surface Faulting
San Andreas (Mojave North/South)	23.8 (38.3)	337	90°	22.0 to 36.0	Strike Slip	7.1	Holocene
Malibu Coast	28.5 (45.9)	37	75° N	0.1 to 0.5	Reverse Oblique	6.7	Late Quaternary
Palos Verdes	29.1 (46.9)	96	90°	2.0 to 4.0	Strike Slip	7.3	Holocene
Santa Susana	29.1 (46.9)	27	55° N	3.0 to 7.0	Reverse	6.7	Late Quaternary
Elsinore (Glen Ivy)	30.2 (48.6)	190	90°	3.0 to 7.0	Strike Slip	7.5	Late Quaternary; Holocene
San Joaquin Hills	31.1 (50.1)	28	23° S	0.3 to 0.7	Blind Thrust – Reverse	6.6	Late Quaternary uplift San Joaquin Hills

Mi: mile(s); km: kilometer(s); mm/yr: millimeters per year; Mw: moment magnitude

The primary source of information: Wills, and others, 2008. Fault distances based on Blake 2002; faults beyond about 50 kilometers were not deemed critical to the earthquake risk in the City. Local active or potentially active faults discussed in the text that are not in this table (e.g., Alhambra Wash, Eaton Canyon groundwater barrier) have much less known about their earthquake potential or they are part of a larger zone that is evaluated.

Source: Wilson Geosciences 2008.

Raymond (also Raymond Hill) Fault

The east-west trending Raymond fault passes through the northern portion of the City of Arcadia, as well as the cities of San Marino, Pasadena, South Pasadena, and Los Angeles. On the west, the fault is thought to connect to the Hollywood fault. Topographically, the fault has a distinct south-facing scarp along much of its length, as well as linear depressions and sag ponds, shutter/pressure ridges, offset drainages, and back-tilted erosional surfaces. These features indicate relatively recent fault movement affecting near-surface deposits. This fault is considered “active” and the California Geological Survey (CGS) has established an Alquist-Priolo Earthquake Fault Zone on the entire segment, which extends approximately 500 feet on each side of the fault. Exhibit 4.6-3, Alquist-Priolo and Fault Hazard Management Zone, depicts the extent of the Alquist-Priolo Earthquake Fault Zone for the Raymond fault.

The Raymond fault is predominantly a left-lateral strike-slip fault and is thought to be capable of a 6.5 magnitude earthquake. Surface fault ground rupture (net slip) for the Raymond fault could be approximately 3 to 6 feet and the related ground deformation zone could be over ¼ mile wide, mostly north of the fault location. Slip rates for the Raymond fault vary from a minimum of 1.5 millimeters per year (mm/yr), with an uncertainty of ±1.0 mm/yr, and an average recurrence interval of about 3,000 years.

Sierra Madre Fault Zone

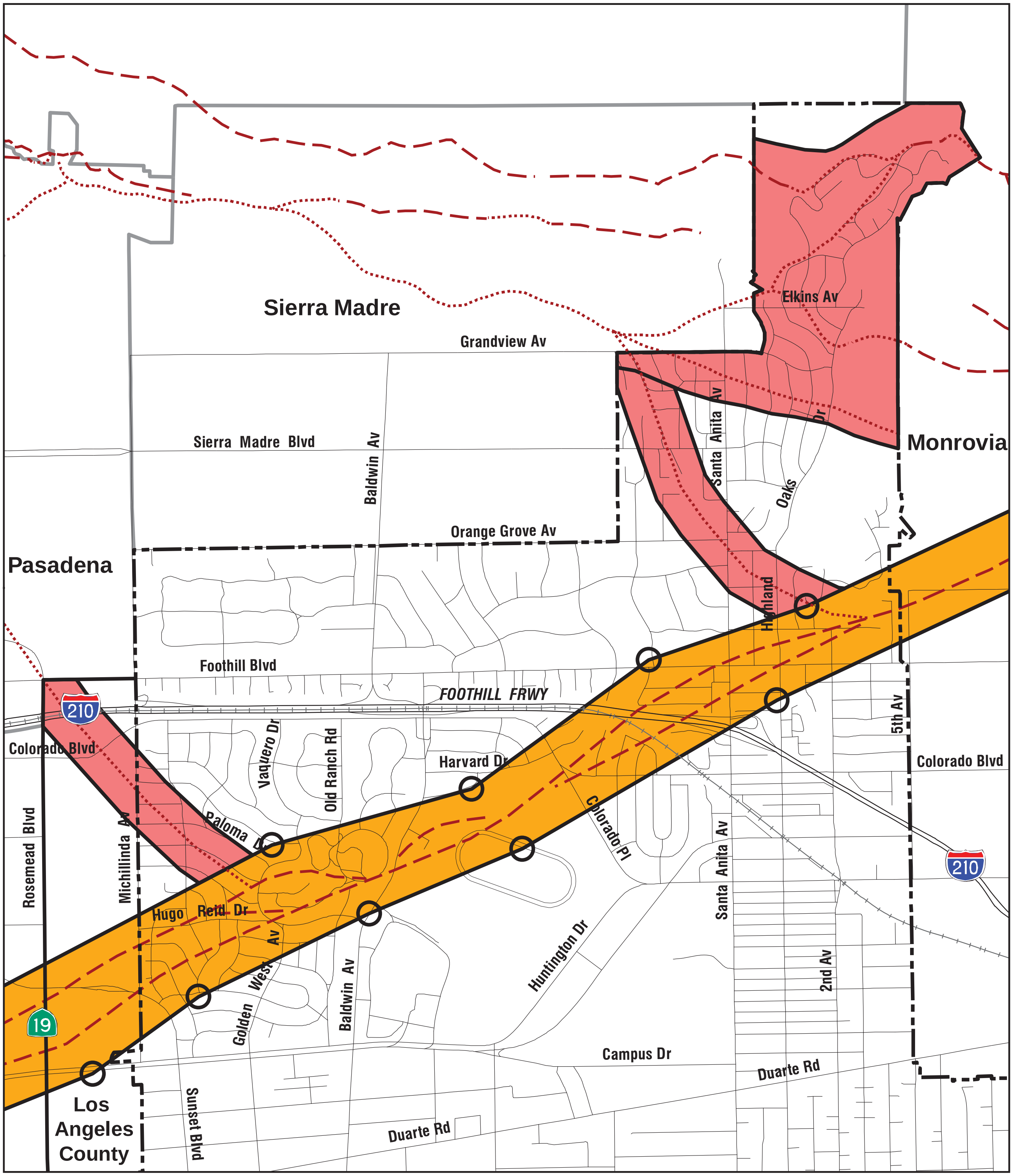
The Sierra Madre fault zone extends from the City of San Fernando on the west to the City of Claremont on the east, defining the southern edge of the Transverse Ranges geomorphic province. This fault is considered responsible for thousands of feet of vertical and significant left-lateral offset that has thrust the San Gabriel Mountains southward up and over the San Gabriel Basin. It connects to the San Fernando fault on the west and to the Cucamonga fault on the east. The Sierra Madre fault crosses the northern end of the City of Arcadia, following the base of the San Gabriel Mountains in a generally west-northwest direction.

The Sierra Madre fault is thought to be capable of a 7.2 magnitude earthquake. Estimated fault net slip (reverse north over south with some left-lateral component) could be 10 to 30 feet with related ground deformation over ¼ mile wide. The reverse fault slip rate for the Sierra Madre fault is assumed to be in the range of 2 to 4.5 mm/yr and the average recurrence interval for large earthquakes is around 3,000 to 4,000 years.

The CGS has an active program to determine if the Alquist-Priolo Earthquake Fault Zone should be further defined on the Sierra Madre fault between the Mount Baldy quadrangle and the San Fernando faults west of the City of La Cañada-Flintridge. No firm timetable for release of preliminary Alquist-Priolo Earthquake Fault Zone maps for the Arcadia area is available at this time.

Upper Elysian Park Blind Thrust and Puente Hills Blind Thrust

“Blind” thrust earthquakes have no, or very subtle, surface expressions. Depending upon the type of source fault, the depth of the energy release, and the magnitude of the earthquake, surface fault rupture may occur, causing ground displacements within the near surface geologic and soil formations. Alternatively, there may be co-seismic folding and uplift where a localized area near a buried fault is raised with respect to a larger surrounding region, such as area-wide and regional uplift associated with the 1987 Whittier Narrows earthquake and 1994 Northridge earthquake events. The blind thrusts are quite deep (several thousand feet beneath the City), and they do not interfere with groundwater nor do they present a surface deformation threat to



Fault Location

- Approximate
- Inferred or Possible Groundwater Barrier
- Alquist-Priolo Earthquake Fault Zone
- Fault Hazard Management Zone
- Turning Point
- City Boundary
- Sphere of Influence

0 1,200 2,400 3,600 4,800 Feet

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Source: Hogle-Ireland, Inc. 2010

Alquist-Priolo and Fault Hazard Management Zone

Exhibit 4.6-3

Arcadia General Plan Update

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(Rev 05/27/10 JFG) Projects\Hogle\J010\Graphics\Ex4.6-3_alquistPriolo.pdf the City. The Upper Elysian Park Blind Thrust is located southwest of the City and the Puente Hills Blind Thrust is located to the south along the Puente Hills.

Eaton Wash Groundwater Barrier

Groundwater data indicate aquifers underlying the western portion of the City, north of the Raymond fault, are separated by a groundwater barrier that is presumed to be a buried fault. This so-called Eaton Wash groundwater barrier affects groundwater movement in the area, forming groundwater barriers or causing groundwater cascades. This barrier has a general northwest-southeast trend and connects to the Raymond fault at the western section of the City. The 1928 Sierra Madre topographic map (1925 survey) shows a marked change in topographic form roughly parallel to and about three blocks northeast of the mapped Eaton Wash groundwater barrier.

In the northern end of the City, groundwater barriers are also mapped within the Sierra Madre fault zone, suggesting that groundwater-bearing sediments in small sub-basins are separated by buried faults. Since the mapped groundwater barriers associated with the Eaton Wash barrier and the Sierra Madre fault are not exposed at the surface, their existence and locations are considered very uncertain.

Groundwater Depth

Studies prepared by the CDMG provide groundwater depth maps compiled from multiple sources that indicate historically highest groundwater levels (shallowest depths) at about 10 feet to over 150 feet in the City. Water shallower than 30 to 40 feet, if it exists, would be found along the northern side of the Raymond fault or in the southeastern portion of the City, although most areas of the City have water depths greater than 100 feet.

Areas with shallow groundwater are generally subject to liquefaction hazards. Shallow groundwater was present (1) in the southern part of the City along Live Oak Avenue between Santa Anita and Tenth Avenue and all areas of the City south of Live Oak Avenue; (2) along the recent alluvial wash areas of Santa Anita Canyon north of the Raymond fault; and (3) in an area 1,550 to 4,400 feet wide located north of the Raymond fault (roughly a line connecting Second Avenue and Foothill Boulevard with Michillinda Avenue and California Boulevard).

Surface water from Santa Anita Canyon is first impounded behind Santa Anita Dam, where it is allowed to percolate into the porous alluvium to recharge the extensive aquifer system that underlies the City and the Main San Gabriel Basin. This also occurs on the San Gabriel River at Santa Fe Dam on the eastern side of the City. The spreading process is a form of groundwater management that captures surface flow that may otherwise be lost (e.g., to the ocean or to evaporation) from productive uses. This practice maintains shallow water in the southeastern portion of the City and along the Raymond fault near Santa Anita Wash. There are other smaller spreading basins upstream from the City in Sierra Madre, Pasadena, and Monrovia.

Liquefaction

Liquefaction is defined as the transformation of a granular material from a solid state into a liquid state with vibration (most commonly seismic shaking) in the presence of water. It is a phenomenon that tends to occur in areas with shallow groundwater and where the soils are composed of loosely compacted granular materials. During an earthquake, saturated, cohesionless soil particles tend to decrease in volume (condense) because the vibration causes smaller particles to shift and fill in the voids (pores) between larger soil particles normally filled with water. As the soil condenses, less space is left for water, causing an increase in pore water pressure.[1] If the pore water pressure increases sufficiently, the soil loses its strength and transforms into a liquid state. This condition can lead to damage of overlying structures caused by loss of bearing, settlement, or subsidence of the soil; severe settlement of aboveground structures; and, in some cases, uplift of buried structures (e.g., large pipelines).

Exhibit 4.6-4, Liquefaction Hazards and Historically High Groundwater, depicts areas within and adjacent to the City of Arcadia that are subject to liquefaction and earthquake-induced landslide hazards. Surficial deposits that are susceptible to liquefaction include very loose to loose deposits (Qw, Qf, Qa), and loose to moderately dense deposits (Qyf4 and Qya4), which are normally unconsolidated and poorly to slightly cemented. Historically high groundwater (less than 30 feet deep) is present in some areas of the City, and liquefaction and dynamic settlement potential is highest where the younger deposits (Qw, Qa, Qf, and Qyf/Qya deposits) are primarily sand and silty sand with low density. High ground shaking intensity potential would also be associated with these deposits.

Dry to partially saturated sediments that are not susceptible to liquefaction may be susceptible to dynamic consolidation and local ground subsidence. This consolidation or densification occurs in loose, cohesionless sediments as the empty spaces are filled due to intense seismic shaking. In general, the youngest alluvium would be the most susceptible to dynamic consolidation effects. Older alluvium are less susceptible.

Artificial fill (Qaf) deposits are susceptible to dynamic consolidation and subsidence in areas where Qaf may have been placed without proper engineering controls and inspections. This may be a concern in areas where thick artificial fill masses have been placed in reclaimed sand and gravel mines, such as the 85-acre Rodeffer Inert Landfill at 12321 Lower Azusa Road. This quarry was excavated to a depth of 150 to 165 feet and then filled with inert materials no larger than 12 inches (maximum dimension), with continued landfilling at the site.

The Raymond fault serves as a groundwater barrier, evidenced by significant differences in groundwater level across the fault. In addition, artesian conditions and ponded surface water have been observed north of the fault. This has made the area north of the fault prone to liquefaction and the potential for permanent ground displacement. Aside from this area, liquefaction potential is also present in the southeastern section of the City, as mapped in the Seismic Hazard Zone Maps for the Mount Wilson and El Monte Quadrangles prepared by the CGS. These areas generally correspond to areas with alluvial deposits (Qya and Qyf) and historically shallow groundwater.

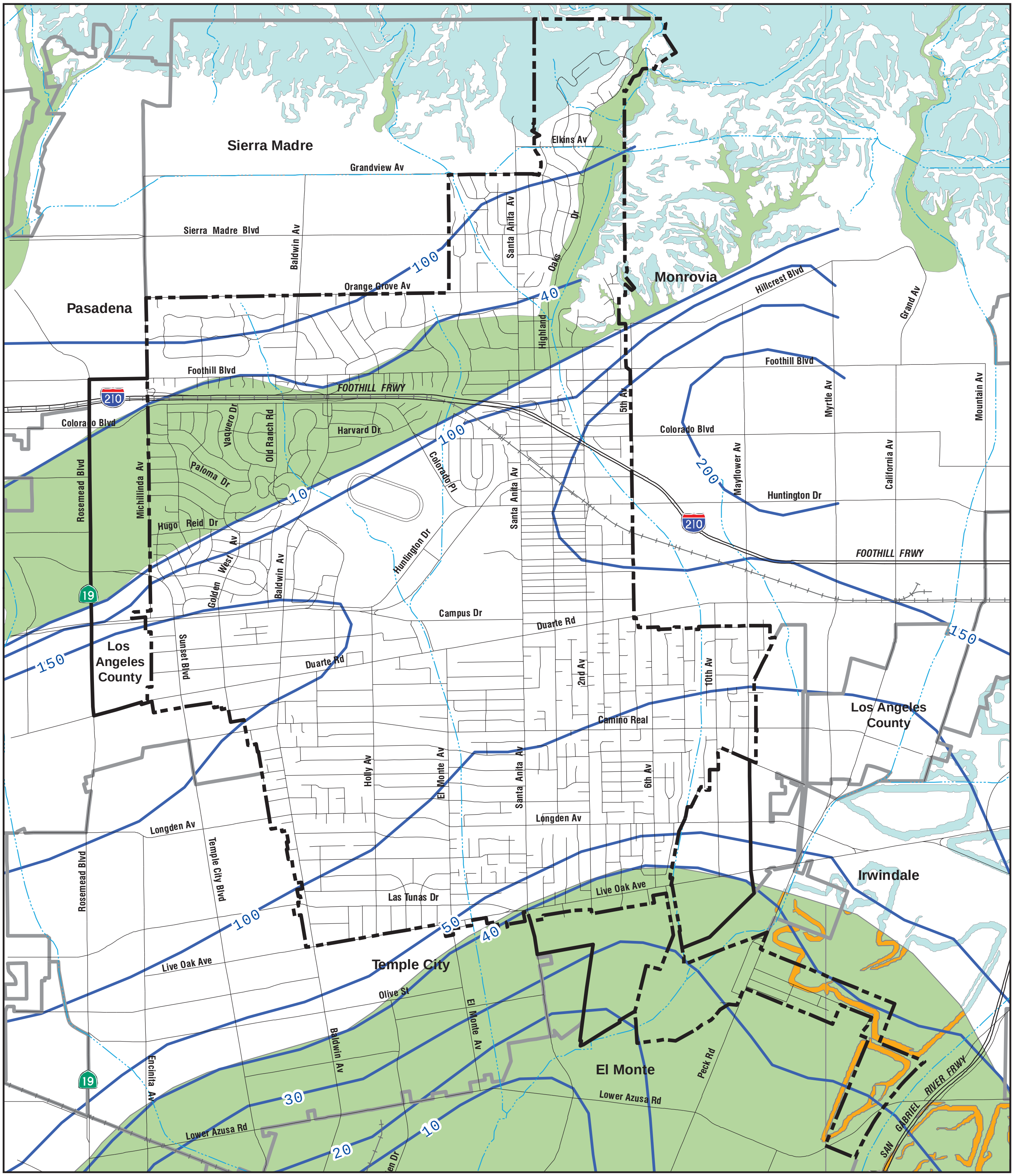
4.6.4 THRESHOLDS OF SIGNIFICANCE

The following significance criteria are derived from Appendix G of the State CEQA Guidelines. A project would result in a significant adverse impact related to geology and soils if it would:

Threshold 4.6a: Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving: (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Hazard Fault Map issued by the State Geologist for the area or based on other substantial evidence of a known fault, (ii) strong seismic ground shaking, (iii) seismic-related ground failure, including liquefaction, or (iv) landslides;

Threshold 4.6b: Result in substantial soil erosion or the loss of topsoil;

[1] Pore water is the water existing in the pores, or spaces, between grains in sedimentary materials.



Zones of Required Investigation

- Liquefaction Zone
- Earthquake-Induced Landslides
- Overlapping Liquefaction and Earthquake-Induced Landslides

Historically Highest Groundwater Contours

- Depth to groundwater in feet
- City Boundary
- Sphere of Influence

0 1,200 2,400 3,600 4,800 Feet

Source: Hogle-Ireland, Inc. 2010

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Liquefaction Hazards and Historically High Groundwater

Exhibit 4.6-4

Arcadia General Plan Update

N W E S

BonTerra CONSULTING

(Rev 05/27/10 JFG) Projects\Hogle\J010\Graphics\Ex4.6-4_liquefaction.pdf

Threshold 4.6c: Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse;

Threshold 4.6d: Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property; and/or

Threshold 4.6e: 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.

4.6.5 GENERAL PLAN GOALS, POLICIES, AND IMPLEMENTATION ACTIONS

A number of goals and policies in the Safety Element of the updated *Arcadia General Plan* address geology and soil issues as well as seismicity in the City. Implementation of these goals and policies would reduce seismic and geologic hazards to existing and future developments. These include:

> ***Policy LU-3.6:*** *Encourage preservation of the natural topography of a site and existing mature trees.*

Goal S-1: *Minimized potential for loss of life, physical injury, and property damage resulting from earthquakes and geologic hazards.*

> ***Policy S-1.1:*** *Explore the creation of a fault hazard management zone for the Sierra Madre fault.*

> ***Policy S-1.2:*** *Emphasize carefully planned development within seismic and geologic hazard areas to minimize potential hazards risk as the City's preferred hazards management strategy.*

> ***Policy S-1.3:*** *Require detailed geologic investigations to accompany development proposals for sites that lie within known or suspected seismic and geologic hazard areas. Require that such investigations and reports conform to accepted professional standards and any applicable State and City requirements.*

> ***Policy S-1.4:*** *Monitor activities of the California Geological Survey and other relevant agencies and organizations to stay informed regarding new mapping and reports that advance the state of knowledge of seismic and geologic hazards affecting Arcadia.*

> ***Policy S-1.5:*** *Continue enforcing the most rigorous building and grading codes which govern seismic safety.*

> ***Policy S-1.6:*** *Require the removal or retrofit, as appropriate, of any hazardous or substandard structures that may collapse in the event of an earthquake.*

A number of implementation actions are included in the revised General Plan that would reduce impacts related to geology and soils. These are provided in Appendix D and include:

> ***Implementation Action 2-15:*** *Site Planning*
>
> ***Implementation Action 8-1:*** *Earthquake Preparedness*
>
> ***Implementation Action 8-2:*** *Seismic Hazards Mapping*

Implementation Action 8-3: *Geotechnical Investigations*

Implementation Action 8-4: *Seismic Safety Considerations in Building Codes*

Implementation Action 8-5: *Siting of Critical Facilities*

4.6.6 STANDARD CONDITIONS

There are existing regulations that reduce geologic and seismic hazards to structures and infrastructure, as discussed above. Compliance by existing and future development with these standard conditions (SCs) would reduce the potential for personal injury and property damage associated with geologic and seismic hazards in the City. Existing regulations that promote public safety during major earthquake events or prevent exposure to local geologic hazards include:

SC 4.6-1: All future development projects within the City shall comply with Article VIII, Sections 8010–8927 of the *Arcadia Municipal Code*, which incorporates by reference the 2007 California Building Code (2007 CBC), and any applicable ordinances set forth by the City, or the most recent City building and seismic codes in effect at the time the grading plans are approved.

SC 4.6-2: All future development projects within the designated Alquist-Priolo Earthquake Fault Zone for the Raymond fault shall prepare a geologic investigation in compliance with the Alquist-Priolo Earthquake Fault Zone Act, which shall include but not be limited to literature and aerial photo review, field mapping, possible geophysics and/or trench excavations, and alluvial deposit age dating for land subdivisions and habitable structures consisting of four units or more that are proposed within this zone. As required by CGS Note 48, all essential facilities, public schools, hospitals, and other facilities deemed critical or important shall be judged to higher standards than residential developments.

SC 4.6-3: All future development projects within 660 feet on either side of the Raymond fault shall be subject to special geologic investigations to confirm the presence or absence of hazardous faults in that area in compliance with the City's Special Studies Geologic Zones Code. The geologic report shall be prepared by or under the direction of a Geologist registered in the State of California and in accordance with the guidelines of the State of California Board of Mines and Geology. The requirements of this code include the following:

- No structure for human occupancy shall be built over a potentially active or an active fault trace.
- A setback area of 50 feet shall be provided from a potentially active, or an active fault trace, unless the City's Geologist, after reviewing a geologic study, determines that either (1) a lesser setback would not pose an unnecessary risk of structural damage due to surface rupture or (2) a setback greater than 50 feet is needed for high risk structures (such as schools, hospitals, and buildings over 2 stories high).
- A seller of real estate or his agent shall disclose in writing to any prospective buyer the fact that the property is located within a Special Studies Zone, to be signed by the purchaser prior to entering escrow.

SC 4.6-4: In accordance with the Natural Hazards Disclosure Act, agents and sellers of real property located within a designated Alquist-Priolo Earthquake Hazard Zone shall disclose to any prospective purchaser that the property is within an Earthquake Hazard Zone pursuant to the requirements of this Act.

SC 4.6-5: In accordance with Section 9250.5.3 of the *Arcadia Municipal Code*, every application for a development permit shall include, among other things, a report of an engineering geological investigation, which shall provide a description of the geology of the site and conclusions and recommendations regarding the effect of the geologic conditions, including consideration of seismic hazards and slope stability in natural materials on the proposed development. The Report shall be conducted in compliance with the published guidelines and implementation procedures from the Seismic Hazards Mapping Act, which requires registered professionals (California Registered Civil Engineer or Certified Engineering Geologist) to conduct liquefaction evaluations; establish the site-specific mitigation; and participate in the implementation process. Recommendations of the report, as they pertain to structural design and construction recommendations for earthwork, grading, slopes, foundations, pavements, and other necessary geologic and seismic considerations, should be incorporated into the design and construction of the proposed development.

SC 4.6-6: In accordance with the City's Zoning Regulations and Building Regulations, every application for a development permit within the Residential Mountainous Single-Family Zone shall include plans for erosion control planting or other protective devices. Irrigation systems or watering devices that cause soil erosion or saturate the soil to cause slope failure are prohibited. Site topography or configuration that causes or will cause erosion, subsidence, surface water runoff problems, or other conditions that may affect adjacent properties or the public health, safety, and welfare are prohibited.

SC 4.6-7: All existing and future development within the City shall be conducted in compliance with Los Angeles RWQCB Order No. R4-2004-0146, which regulates discharges from residential on-site wastewater treatment systems throughout the entire Los Angeles Region (Los Angeles and Ventura Counties). The General Waste Discharge Requirements (WDRs) apply to septic tanks proposed in areas with shallow groundwater, areas adjacent to water bodies listed as impaired pursuant to Section 303(d) of the Clean Water Act, areas where groundwater is used for domestic purposes, and areas with nitrogen or bacterial contamination of ground or surface waters.

SC 4.6-8: All future development within the City shall be conducted in compliance with the California Plumbing Code (Part 5 of the California Building Code), which provides standards for the design and construction of water and sewer systems, storm drains and recycled water systems in buildings, and which prohibits connection to a septic tank in areas served by a public sewer system. It also requires the proper abandonment of septic tanks, cesspools, and seepage pits.

4.6.7 ENVIRONMENTAL IMPACTS

Future development pursuant to the General Plan Update would be exposed to geologic and seismic hazards present in the City.

Seismic Hazards

Threshold 4.6a: Would the proposed 2010 General Plan Update expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving: (i) 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, (ii) strong seismic ground shaking, (iii) seismic related ground failure, including liquefaction, or (iv) landslides?

Surface Rupture

As presented in Table 4.6-1, numerous active and potentially active faults cross within and near the City. A potential for surface fault rupture hazard exists along the faults underlying the City. “Active” faults (demonstrated offset of Holocene materials [less than 10,000–12,000 years ago] or significant seismic activity) and “potentially active” (Pleistocene [greater than 12,000 but less than 1,600,000 years ago]) faults (as defined by the CGS) must be considered as potential sources for fault rupture.

The potential for damaging earthquakes in the City is typical of most Southern California cities. With faults in and near the City, severe local earthquakes could occur within a relatively short distance and would most likely occur aligned with major strike-slip or reverse faults with recognizable surface features (e.g., the Raymond, Sierra Madre, Clamshell-Sawpit, Cucamonga, Whittier, and San Andreas faults), but also on less understood blind thrust faults (e.g., the Puente Hills and Upper Elysian Park blind thrusts), which have more subtle surface expressions.

In general, the younger the last movement is on a fault, the higher the potential for future movement on that fault. Five documented faults, fault zones, or groundwater barriers that may be faults directly underlie the City. Each fault or barrier has a different potential for surface rupture and damage-generating potential. These faults are:

- Raymond fault;
- Sierra Madre fault zone and associate groundwater barriers;
- Puente Hills (blind thrust);
- Upper Elysian Park (blind thrust); and
- Eaton Wash groundwater barrier.

The Raymond, Sierra Madre, and Puente Hills faults pose the most substantial threat related to surface rupture for the City. Depending upon the type of fault, the depth of the energy release, and the magnitude of the earthquake, ground displacements could occur within the near surface geologic and soil formations accompanied by co-seismic folding, ground tilting, and/or uplift above the Raymond and Sierra Madre faults.

An earthquake with a magnitude (M) of 6.5 on the Raymond fault could cause ground rupture offsets in the range of 5 to 6 feet. An earthquake with a magnitude of 7.2 on the Sierra Madre fault could result in very large ground rupture movements of possibly 10 feet or more. Ground rupture movements of this magnitude could cause severe damage to structures overlying the faults. Movement on a buried fault could likely cause regional uplift. Earthquakes under M 6 (unless very shallow) are not expected to cause significant fault offset or uplift.

The surface rupture and strong ground shaking potential of the Raymond fault presents a seismic hazard to the existing and future developments near the fault. Fault rupture hazards do not change for existing land uses and would not change under the General Plan Update. However, future development may be exposed to these hazards if located on the fault traces. Under the proposed Land Use Policy Map, new development may occur on vacant lots along and near the Sierra Madre fault at the northern end of the City and along the Raymond fault near Santa Anita Wash. When combined with strong ground shaking, rupture is a very serious hazard. Rupture can result in damage to structures, utility infrastructure, and streets.

A number of existing regulations prevent development over a fault trace or protect structures and infrastructure from surface rupture hazards. Specifically, compliance with seismic design criteria in the CBC (SC 4.6-1) would promote the structural integrity of structures and infrastructures near faults. Compliance with AP Zone requirements for detailed fault investigations (SC 4.6-2) would identify the presence of a fault trace on a development site. Setbacks from the zone of previous ground rupture is required by the City's Special Studies Geologic Zones Code (SC 4.6-3) would preclude the development of structures intended for human occupancy over a potentially active, or an active fault trace, and require a setback requirement of at least 50 feet or greater for high risk structures, such as schools, hospitals, and buildings over 2 stories high. Disclosure of a site's location within a Special Studies Zone during real estate transactions (SC 4.6-4) would also reduce risks to development.

While the State has not designated the Sierra Made fault an Alquist-Priolo Earthquake Fault Zone, the City has included Policy S-1.1, which calls for exploring the creation of a fault hazard management zone for the Sierra Madre fault. Policy S-1.2 calls for careful planning of development within seismic and geologic hazard areas, and Policy S-1.3 requires detailed geologic investigations to accompany development proposals for sites that lie within known or suspected seismic and geologic hazard areas. Implementation of these policies will further reduce surface rupture hazards in the City.

Implementation Actions in the General Plan Update would also reduce the potential for surface rupture hazards. Implementation of SC 4.6-1 through SC 4.6-4, General Plan Policies S-1.1 and S-1.2, and the Implementation Actions along with the long recurrence interval between large earthquake events (approximately 3000 years), would reduce surface rupture hazards to future development pursuant to the General Plan Update to less than significant levels.

Seismic Ground Shaking

Earthquake-related hazards have the potential to cause serious damage if the seismic event is large enough to generate short-duration, high peak ground accelerations or long-duration, moderate to high ground accelerations. Potential earthquake effects on structures and facilities within the City would depend upon the size and location of the earthquake in relation to a specific location and its geologic conditions.

Earthquake shaking from regional earthquakes have affected the City relative to the distance of the epicenter to the City. The recent San Fernando, Northridge, Upland, and Landers/Big Bear earthquake events were felt in the City but did little damage. However, the 1991 "Sierra Madre" earthquake (M 5.6) and aftershocks occurring approximately 5.5 miles north of the City of Arcadia was substantially more destructive for the City.

Ground shaking from an earthquake on any given fault will depend primarily on its distance from individual sites and the size of the earthquake (amount of energy release). The severity of ground shaking is presented as the percentage of the force of gravity.[2] The effects of ground shaking are based on the intensity value, as described by the Modified Mercalli Intensity (MMI) scale. Table 4.6-2 is the Modified Mercalli Intensity scale and Table 4.6-3 shows the maximum magnitude, peak ground acceleration (g), and MMI for major faults within 25 miles of the Arcadia City Hall.

In general, the more distant the fault and the smaller the potential earthquake, the less the ground shaking effect. However, local geology (e.g., thick alluvium versus shallow bedrock) and sedimentary basin geometry can affect seismic waves to be more extensive than amplifications and resonances caused by near surface soft alluvium alone.

The Sierra Madre fault has the potential to affect fewer properties than the Raymond fault due to its location at the northern end of the City. However, it has a greater surface fault rupture potential (approximately 10 feet or more) and very strong ground shaking potential (MMI approximately XI) during the maximum earthquake (M 7.2), presenting seismic hazards to existing and future developments in the northern section of the City. Strong seismic ground shaking can cause general ground cracking, ridgetop spreading, and deformation of fill slopes.

Unreinforced masonry (URM) buildings are especially hazardous, as they structurally fail with ground shaking or ground movement. However, as of 2005, the City of Arcadia’s 22 URMs had either been seismically reinforced (19) or demolished (3). Thus, no URMs remain in the City.

Future development pursuant to the General Plan Update will be subject to ground shaking hazard during earthquake events. The severity of ground shaking will depend on the magnitude of the earthquake, its distance to the City, and site geologic conditions. Local differences in subsurface conditions (e.g., density, water content, grain size, subgrade soil profile classification) could increase the effective shaking above the levels stated in Table 4.6-3 below. Therefore, site-specific geological, geotechnical, and earthquake engineering studies are mandatory for evaluating critical, sensitive, or high-occupancy structures (SC 4.6-5).

In areas subject to potentially strong ground shaking, compliance with seismic design criteria in the CBC (SC 4.6-1) allows these structures to withstand seismic ground shaking to an acceptable degree and prevents hazards to persons and property. Future developments at the northern end of the City where there are sites with steep terrain or where ridgetops or fill slopes are present may be exposed to ridgetop spreading and deformation of fill slopes from strong seismic shaking. Site-specific geologic investigations (SC 4.6-6) would identify these hazards and provide appropriate construction recommendations.

[2] Ground shaking is measured relative to the force of gravity (g), with “1g” for one unit of gravitational force, or 100 percent gravity. Therefore, 0.50g is 50 percent the force of gravity.

TABLE 4.6-2
MODIFIED MERCALLI INTENSITY SCALE

Average Peak Velocity (cm/sec)	Intensity Value	Description	Average Peak Acceleration (%gravity)
<0.1	I	Not felt except by a very few under especially favorable circumstances.	<0.17
0.1–1.1	II	Felt only by a few persons at rest, especially on upper floors of high-rise buildings; delicately suspended objects may swing.	0.17–1.4
0.1–1.1	III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake; standing automobiles may rock slightly, vibration like passing of truck; duration estimated.	0.17–1.4
1.1–3.4	IV	During the day, felt indoors by many, outdoors by few; at night, some awakened; dishes, windows, doors disturbed; walls make creaking sound; sensation like a heavy truck striking building; standing automobiles rock noticeably.	1.4–3.9
3.4–8.1	V	Felt by nearly everyone, many awakened; some dishes, windows and so on broken; cracked plaster in a few places; unstable objects overturned; disturbances of trees, poles, and other tall objects sometimes noticed; pendulum clocks may stop.	3.9–9.2
8.1–16	VI	Felt by all, many frightened and run outdoors; some heavy furniture moved; a few instances of fallen plaster and damaged chimneys; damage slight.	9.2–18
16–31	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 cars.	18–34
31–60	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, and walls; heavy furniture overturned; sand and mud ejected in small amounts; changes in well water; persons driving cars disturbed.	34–65
60–116	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 creaked conspicuously; underground pipes broken.	65–124
>116	X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked; rails bent; landslides considerable from river banks and steep slopes; shifted sand and mud; water splashed, slopped over banks.	>124
>116	XI	Few, if any, masonry buildings 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
>116	XII	Damage total; waves seen on ground surface; lines of sight and level distorted; objects thrown into air.	>124

cm/sec: centimeters per second

Source: Wilson Geosciences 2008.

TABLE 4.6-3
DETERMINISTIC EARTHQUAKE GROUND SHAKING PARAMETERS FOR ELEVEN POTENTIALLY CRITICAL EARTHQUAKE FAULTS WITHIN 25-MILES OF ARCADIA CITY HALL[A]

Fault Name	Distance Miles (Kilometers)	Maximum Magnitude	Peak Horizontal Ground Acceleration	Modified Mercalli Intensity[b]
Raymond	0.6 (0.9)	6.5	0.57	X
Sierra Madre	2.7 (4.3)	7.2	0.69	XI
Puente Hills Blind Thrust	2.9 (4.7)	7.1	0.64	X
Clamshell-Sawpit	3.6 (5.8)	6.5	0.43	X
Upper Elysian Park Blind Thrust	4.7 (7.5)	6.4	0.36	IX
Verdugo-Eagle Rock	5.2 (8.4)	6.9	0.45	X
Whittier	8.5 (13.6)	6.8	0.26	IX
San Jose	9.4 (15.1)	6.4	0.24	IX
Hollywood	11.0 (17.7)	6.4	0.21	VIII
Cucamonga	16.0 (25.8)	6.9	0.21	VIII
San Andreas -1857 Rupture	23.8 (38.3)	7.8	0.21	VIII

[a] Blake, T.F., 2002, EQFAULT Computer Program for Earthquake Assessments, update of 1989 program; attenuation relationship Boore and others. (1997) Horizontal – NEHRP D (250), median value. Latitude 34.1373, Longitude 118.0386

[b] Bolt, B.A., 1993, Abridged Modified Mercalli Intensity Scale, *Earthquakes – Newly Revised and Expanded*, Appendix C, W.H. Freeman and Co., 331 pp.

Source: Wilson Geosciences 2008.

Goal S-1 in the Safety Element of the proposed General Plan Update calls for minimizing the potential for loss of life, physical injury, and property damage resulting from earthquakes and geologic hazards. The supporting policies of this goal include Policy S-1.1, which will explore the creation of a fault hazard management zone for the Sierra Madre fault; Policy S-1.2, which calls for careful planning of development within seismic and geologic hazard areas; Policy S-1.3, which requires detailed geologic investigations for developments on sites that lie within known or suspected seismic and geologic hazard areas; Policy S-1.4, which calls for staying informed on the state of knowledge of seismic and geologic hazards affecting Arcadia; Policy S-1.5, which calls for enforcing the most rigorous building and grading codes for seismic safety; and Policy S-1.6, which requires the removal or retrofit of hazardous or substandard structures that may collapse in the event of an earthquake.

Implementation Actions for these policies will further reduce ground shaking hazards in the City. Implementation of SC 4.6-1, SC 4.6-5, and SC 4.6-6; General Plan Policies S-1.2, S-1.3, S-1.4, S-1.5, and S-1.6; and associated Implementation Actions would reduce ground shaking hazards to future development pursuant to the General Plan Update to less than significant levels.

Ground Failure and Liquefaction

Secondary seismic hazards include several types of ground failure that can occur as a result of severe ground shaking. These hazards include landslides, ground subsidence, ground lurching, shallow ground rupture, liquefaction, and soil strength loss. The probability for each type of ground failure depends on the severity of the earthquake, the site's distance from the fault, the local topography, and subsoil and groundwater conditions, among other factors.

Areas susceptible to liquefaction have been identified north of the Raymond fault, along Santa Anita Wash, and in the southern section of the City, as shown in Exhibit 4.6-4. Future development pursuant to the General Plan Update in these areas would be exposed to liquefaction hazards.

The CBC and the City's Building Regulations (SC 4.6-1) provide the appropriate building design criteria needed to protect the structural integrity of structures and infrastructure against liquefaction. The City requires the preparation of a geotechnical investigation for individual developments (SC 4.6-5), which would include research and soil borings to determine the presence of shallow groundwater and the potential for liquefaction. The geologic investigation would be conducted in compliance with the Seismic Hazards Mapping Act, which requires developments designed for human occupancy and proposed in seismic hazard zones to conduct site-specific geotechnical investigations to identify the hazard and to develop appropriate mitigation measures prior to permitting by local jurisdictions. Implementation of SC 4.6-1 and SC 4.6-5 would reduce liquefaction hazards to be less than significant.

Landslides

Landslides typically consist of shallow failures involving surficial soils and the underlying highly weathered bedrock in moderate to steep terrain. Intermediate to large boulders dislodged from high steep slopes may travel as far as 100 feet from the base of a slope across adjacent, gently sloping surfaces. Structures, roadways, utilities, and the general population located on or below these hazard areas could be subject to severe damage or injury.

Based on the California Seismic Hazard Mapping Program, areas susceptible to earthquake-induced landslides and other slope failures (e.g., rock falls) are present at the northeastern end of the City, along the eastern slopes of Santa Anita Canyon, and in the southeastern end of the City. These areas have experienced earthquake-induced slope failure during historic earthquakes and landslide movement (including both landslide deposits and source areas). Other areas include those where the CGS's analysis indicates ground slope and geologic materials are susceptible to earthquake-induced slope failure.

Slope instability in the hillside and mountain areas of the City has been documented as one landslide in an area underlain by a very large "probable Dormant-Old" landslide mass, where the landform has been highly eroded but there is no evidence of historic movement. The southeastern area of the City has manufactured slopes within mining pits at the quarries, but the former quarry site in the City has since been filled up with inert materials. Reclamation of the quarry site at the southern end has eliminated steep slopes at this former mining pit. The quarry currently has a relatively flat slope and is not expected to feature major slopes when it is finally re-used for future industrial and commercial uses, as planned by the proposed Land Use Policy Map. Potential rock fall hazards exist along Santa Anita Canyon Road within the Wilson Diorite. Bedrock landslides and mudslides are not expected in the flatter areas of the City, where most of the future development is expected.

However, new residential development on vacant lots at the northern end of the City would be exposed to landslide hazards. Compliance with the CBC and the City's Building Regulations (SC 4.6-1) would provide for the structural integrity of homes that may be built in this area. Site-specific geologic investigations (SC 4.6-6) would identify these hazards and provide appropriate construction recommendations.

Goal S-1 in the Safety Element of the General Plan Update calls for minimizing the potential for loss of life, physical injury, and property damage resulting from earthquakes and geologic hazards. Several policies support this goal, as discussed above. Policy LU-3.6 calls for the preservation of the natural topography of a site. Goal RS-8 calls for balanced use of hillside properties that respects the natural environment and private property rights. Its supporting policies include Policy RS-8.1, which calls for site-specific investigations and use of available information for determining environmental sensitivity; Policy RS-8.2, which requires detailed biological and other appropriate environmental resource and hazard studies for properties within the foothills and appropriate mitigation; and Policy RS-8.3, which calls for potential use of hillside areas within Arcadia as habitat mitigation/banking sites.

Implementation of SC 4.6-1, SC 4.6-6, General Plan Goals S-1 and RS-8 and their supporting policies, Policy LU-3.6, and associated Implementation Actions would reduce seismic hazards in the City. Impacts associated with landslide hazards would be less than significant, and no mitigation is required.

Soil Erosion

Threshold 4.6b: Would the proposed 2010 General Plan Update result in substantial soil erosion or the loss of topsoil?

Erosion potential over the majority of the City, which is underlain by Hanford soils, is slight to moderate. Erosion at the northeastern section is high to very high, as this area is underlain by Vista-Amargosa soils. Erosion along the San Gabriel River at the southeastern section ranges from slight to high in areas underlain by Tujunga-Soboba soils. Future development would lead to ground disturbance, including grading and excavations, which may be subject to wind or water erosion.

Erosion control measures are required by the City's Zoning Regulations and Building Regulations, especially for cut and fill slopes in the Residential Mountainous Single-Family Zone (SC 4.6-6). In addition, future development projects are required to implement erosion control Best Management Practices (BMPs), in compliance with the National Pollutant Discharge Elimination System (NPDES) Construction General Permit. Erosion control measures would prevent eroded soils from entering adjacent properties and minimize sediments and loose soils from entering the City's roadways, storm drain system, and adjacent areas. Compliance with this permit is discussed in Section 4.8, Hydrology and Water Quality, and is set forth in SC 4.8-1.

Additionally, upon completion of future development projects, the conversion of bare soils through the introduction of pavements, roads, buildings, and landscaping is expected to reduce soil erosion potential from both wind and water. Implementation of SC 4.6-6 and SC 4.8-1 would prevent future development pursuant to the General Plan Update from resulting in significant adverse impacts associated with substantial soil erosion or loss of topsoil. Impacts relating to erosion would be temporary and less than significant. No mitigation is required.

Geologic Hazards

Threshold 4.6c: Would future development pursuant to the proposed 2010 General Plan Update be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?

Geologic hazards include slope instability (landslides, mudslides, and debris flows), poor geotechnical/soils engineering properties (expansive, collapsible, and corrosive), shallow groundwater, flooding from tsunami and seiche, and subsidence. These hazards and surface fault rupture, in contrast to seismic ground motion hazards, are more susceptible to direct observation and testing for determining the degree of significance and specifying a remediation or avoidance strategy.

Landslide

Landslide hazards were previously discussed under Threshold 4.6a. Geologic hazards in the City include landslide potential on steep slopes found at the northern end of the City and in local quarries. As discussed above, bedrock landslides and mudslides are not expected in the flatter areas of the City, where most of the future development pursuant to the General Plan Update is expected to occur. Future development may occur at the northern end of the City near the Angeles National Forest, where potential landslide hazards are present. Reclamation of the quarry site at the southern end has eliminated steep slopes at this former mining pit. The quarry currently has a relatively flat slope and is not expected to feature major slopes when it is re-used for future commercial uses, as planned by the proposed Land Use Policy Map.

As previously discussed, Implementation of SC 4.6-1, SC 4.6-5, General Plan Goals S-1 and RS-8 and their supporting policies, Policy LU-3.6, and associated Implementation Actions would reduce seismic hazards in the City. Impacts associated with landslide hazards would be less than significant, and no mitigation is required.

Subsidence

Subsidence is the compaction of the ground when large amounts of ground water or oil have been withdrawn from fine-grained sediments or when underlying limestone deposits dissolve. Subsidence may cause differential settlement of the overlying structure and substantially more damage than if the structure were to settle evenly throughout. Large-scale subsidence due to fluid withdrawal (water or oil) has not been reported in or near the City. However, sections of the City with young alluvial deposits and thick artificial fill masses are potentially susceptible to settlement or subsidence although no specific areas of past subsidence have been identified. Consolidation potential of 2 to 6 percent may occur on younger alluvium, increasing to 12 to 36 inches in areas overlain by 50 feet of young alluvium and even proportionately greater in areas overlain by thick non-engineered fill.

The CBC and the City's Building Regulations (SC 4.6-1) provide the appropriate building design criteria needed to protect the structural integrity of structures and infrastructure against subsidence and soil settlement. The City requires the preparation of a geotechnical investigation for individual developments (SC 4.6-5), which would include research and soil borings to determine the presence of subsidence hazards and the potential for soil settlement. Implementation of SC 4.6-1 and SC 4.6-5 would reduce subsidence hazards to less than significant levels.

Liquefaction-Induced Ground Failure

Liquefaction-induced ground failure includes ground fissures, sand boils, ground settlement, loss of bearing strength, buoyancy effects, ground oscillation, flow failure, and lateral spreading. Ground fissures are linear features that open to widths of a few to several inches, but which may or may not exhibit differential vertical movement. Sand boils are built-up sand accumulations (often up to three feet across) that result from ejected sand and water forced from the subsurface under pressure. Ground settlement often occurs as liquefied sand deposits consolidated after ejection of water. Loss of bearing strength can cause surface structures to settle, either evenly or differentially, causing tilting. Buoyancy caused by rapid upward movement of water through sandy soils can cause buried structures to rise (float) when they are founded in the liquefied layer.

Ground oscillation may not cause permanent ground displacement, but may damage rigid structures beyond the effects of severe ground shaking in a non-liquefied zone. Flow failure is found in steeper terrain where liquefied soils near the ground surface flow as a viscous mass down slope, similar to a mudflow in rain-saturated soils. Lateral spread is a liquefaction-induced landslide of a fairly coherent block of soil and sediment deposits that moves laterally (along the liquefied zone) by gravitational force, sometimes in the order of 10 feet, often toward a topographic low (such as a depression or a valley area).

These types of ground failure can cause damage to surface and subsurface structures in areas with liquefaction hazards (north of the Raymond fault and southern end of the City). In addition, since liquefaction-induced lateral spread failures are more prevalent adjacent to topographic depressions or valley areas that form unsupported slopes or “free faces”, it is possible that slopes into the Santa Anita Wash, the Rio Hondo, and the San Gabriel River would be the most susceptible to a lateral spread landslide failure.

As previously discussed, compliance with the CBC and the City’s Building Regulations (SC 4.6-1) would provide the building design criteria needed to protect the structural integrity of structures and infrastructure against these hazards. Additionally, preparation of a geotechnical investigation for individual developments (SCs 4.6-5) would include identification and mitigation of potential liquefaction and ground failure hazards to future development projects in the City. Implementation of SC 4.6-1 and SC 4.6-5 would reduce impacts related to liquefaction-induced ground failure to less than significant levels, and no mitigation is required.

Collapsible Soils

Collapsible soils undergo a volume reduction when the pore spaces become saturated with water, causing loss of grain-to-grain contact and possibly dissolving of interstitial cement holding the grains apart. The weight of overlying structures can cause uniform or differential settlement and damage to foundations and walls. The most likely locations for collapsible soils in the City are the current and pre-development washes and drainage channels, which cover much of the City and Santa Anita Wash. Compliance with the CBC and the City’s Building Regulations (SC 4.6-1) and preparation of a geotechnical investigation for individual developments (SC 4.6-5) would identify collapsible soil hazards and protect the structural integrity of structures and infrastructure against these hazards.

Future development pursuant to the General Plan Update would be exposed to geologic hazards, which include landslides, subsidence, liquefaction, and collapsible soils. As previously discussed, Implementation of SC 4.6-1, SC 4.6-5, General Plan Goals S-1 and RS-8 and their supporting policies, Policy LU-3.6, and associated Implementation Actions would reduce collapsible soil hazards in the City to less than significant levels, and no mitigation is required.

Expansive Soils

Threshold 4.6d: Would future development pursuant to the proposed 2010 General Plan Update be located on expansive soil, as defined in Section 1802.3.2 of the 2007 California Building Code, creating substantial risks to life or property?

Expansive soils are generally associated with soils, alluvium, and bedrock formations that contain clay minerals susceptible to expansion under wetting conditions and contraction under drying conditions. Depending upon the type and amount of clay present in a geologic deposit, volume changes (shrink and swell) can cause severe damage to slabs, foundations, and concrete flatwork.

Hanford, Vista Amargosa, and Tujunga-Soboba soils that underlie the City do not have high shrink-swell potential and thus, are not considered expansive. However, due to the granular (sandy) nature of the alluvium in the flatter areas of the City, expansive clays would most likely be present in older alluvial, bedrock formation soils in the hillside areas, and in sag-pond areas (e.g., the Los Angeles Arboretum and Santa Anita Racetrack areas) caused by past impoundments along the northern side of the Raymond fault.

Soil expansion hazards to future development pursuant to the General Plan Update would be identified during the preparation of required geotechnical investigations for individual developments (SC 4.6-5), with recommendations on the soil expansion index that needs to be considered in the design and construction of structures and infrastructure. Additionally, the CBC and the City's Building Regulations (SC 4.6-1) provide the appropriate building design criteria needed to protect the structural integrity of structures and infrastructure against soil expansion. Implementation of SC 4.6-1 and SC 4.6-5 would reduce soil expansion hazards to less than significant levels. No mitigation is required.

Septic Tank Limitations

Threshold 4.6e: Does the City 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?

The vast majority of the City is served by the public sewer system. Future development would be required to connect to the public sewer system where existing sewer lines are available, as required under the California Plumbing Code (SC 4.6-7). While the majority of the City is served by the public sewer system, there are septic tanks that remain. Redevelopment of a site with a septic tank would require abandonment of the septic tank and connection to the public sewer system under the California Plumbing Code.

Compliance with Order No. R4-2004-0146 of the Los Angeles RWQCB is required to regulate the type of discharge; surface overflows; disposal of wastes in geologically unstable areas; odors; and groundwater pollution, including annual inspections, connection to public sewer system within six months of availability, and monitoring (SC 4.6-8). The regulations protect shallow groundwater and adjacent water bodies.

Hanford and Tujunga-Soboba soils that underlie the majority of the City do not have severe limitation for use of septic tank filter fields. However, Vista-Amargosa soils have severe limitations for shallow excavation and as septic tank filter fields. Therefore, future development that would occur at the northern end of the City underlain by Vista-Amargosa soils could not be adequately served by septic systems. Since there are no sewer lines at the northern edge of the City and on-site soils could not support septic systems, future development in the area generally north/northwest of Canyon Road would need to include extension of sewer lines to the development sites (MM 4.6-1). Implementation of SC 4.6-7, SC 4.6-8, and Mitigation Measure (MM) 4.6-1 would reduce impacts related to the operation or decommissioning of septic systems to be less than significant.

4.6.8 CUMULATIVE IMPACTS

Geology and soils impacts are generally site specific and there is typically little, if any, cumulative relationship between the development of individual projects on separate sites. As such, one development would not alter geologic events or soil features/characteristics (such as groundshaking, seismic intensity, or soil expansion) at another site, nor change geologic conditions or hazards at off-site locations.

However, geological and seismic conditions are regional in nature and affect large areas, rather than individual parcels. Therefore, future development pursuant to the General Plan Update, as well as development within the San Gabriel Valley, would be subject to geologic hazards including development potentially affected by faults, ground shaking, surface rupture, liquefaction, landslides, subsidence, soil collapse, expansive soils, and other geologic issues.

Compliance with applicable State and local regulations would be required of all development within the San Gabriel Valley. Individual projects would be designed and built in accordance with applicable standards in the CBC and the individual building regulations of local jurisdictions, including pertinent seismic design criteria. Site-specific geologic hazards would be addressed by the geotechnical investigation required by individual cities and the County for each development proposal. Geologic investigations would identify the geologic and seismic characteristics on a site and provide guidelines for engineering design and construction to provide for the structural integrity of proposed development. Compliance with applicable State and local regulations and standard engineering practices related to seismic and geologic hazard reductions would prevent significant adverse impacts associated with geologic hazards and impacts associated with the General Plan Update would not be cumulatively considerable.

Development projects in the San Gabriel Valley would connect to the public sewer system where available but may utilize septic tanks or alternative wastewater disposal systems in areas without sewer service. Compliance with the Los Angeles RWQCB regulations and the California Plumbing Code would prevent hazards associated with soils incapable of supporting septic systems. Therefore, compliance with applicable State and local regulations and standard engineering practices related to septic hazard reductions would prevent significant adverse impacts. Impacts associated with the General Plan Update would not be cumulatively considerable.

4.6.9 MITIGATION MEASURES

In addition to implementation of the relevant goals, policies, and implementation actions in the updated General Plan and compliance with the standard conditions, potential adverse impacts related to soils incapable of supporting septic systems may occur with future development at the northern edge of the City. The following mitigation measure is required:

MM 4.6-1: Future development at the northern edge of the City (generally north/northwest of Canyon Road) shall provide for the extension of sewer lines to serve the proposed project in order to avoid hazards associated with soils incapable of supporting septic tank systems.

4.6.10 LEVEL OF SIGNIFICANCE AFTER MITIGATION

Seismic Hazards

Less Than Significant Impact

Soil Erosion

Less Than Significant Impact

Geologic Hazards

Less Than Significant Impact

Expansive Soils

Less Than Significant Impact

Septic Tank Limitations

Less Than Significant Impact With Mitigation

Cumulative Impacts

Less Than Significant Impact