

4.6 GEOLOGY AND SOILS

This section summarizes information on geology, soils and seismic hazards for the project site, as well as potential area-wide geologic hazards and regional seismic characteristics that are relevant to development within the project site. An evaluation of the impacts of the proposed project with regard to these potential hazards and resources follows.

Two reports prepared by Lowney Associates for the project applicant were used for the following analysis of geology, soils and seismic hazards. The first report is the *Design-Level Geotechnical Investigation for the East Washington Place Retail Development*, dated May 28, 2004, and the second is the *Design-Level Geotechnical Investigation for East Washington Place* [the residential portion], dated April 28, 2004. City engineering staff reviewed the conclusions of the reports to ensure adequacy.

Lowney Associates had borings and cone penetration test (CPT) soundings performed in April and May of 2004 as part of their reports. A full copy of both reports are included as Appendix B.

A. Regulatory Framework

The State of California has established a variety of regulations and requirements related to seismic safety and structural integrity, including the California Building Code, the Alquist-Priolo Earthquake Fault Zoning Act and the Seismic Hazards Mapping Act.

1. State Regulations

a. California Building Code

The California Building Code (CBC) is included in Title 24 of the California Code of Regulations and is a portion of the California Building Standards Code. Under State law, all building standards must be centralized in Title 24 or they are not enforceable. The CBC incorporates the Uniform Building Code, a widely adopted model building code in the United States.

Through the CBC, the State provides a minimum standard for building design and construction. The CBC contains specific requirements for seismic safety, excavation, foundations, retaining walls and site demolition. It also regulates grading activities, including drainage and erosion control.¹ Petaluma is subject to the 2001 Uniform Building Code and the 2004 Electrical Code.

b. Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act² was passed in 1972 to mitigate the hazard of surface faulting to structures used for human occupancy. The main purpose of the Act is to prevent the construction of buildings used for human occupancy on top of active faults. The Act only addresses the hazard of surface fault rupture and is not directed toward other earthquake hazards, such as ground shaking or landslides.³

The law requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones or Alquist-Priolo Zones)⁴ around the surface traces of active faults, and to issue appropriate maps. The maps are distributed to all affected cities, counties, and State agencies for their use in planning and controlling new or renewed construction. Local agencies must regulate most development projects within the zones and there can generally be no construction within 50 feet of an active fault zone.⁵ The California Geologic

¹ California Code of Regulations, Title 24 (California Building Standards Code) summary page, http://www.bsc.ca.gov/title_24/t24_2001tried.html, accessed on November 30, 2005.

² Called the *Alquist-Priolo Special Studies Zones Act* until renamed in 1993.

³ California Geological Survey, Alquist-Priolo Earthquake Fault Zones, <http://www.consrv.ca.gov/CGS/rghm/ap/>, accessed on February 18, 2004.

⁴ Earthquake Fault Zones are regulatory zones around active faults. The zones vary in width, but average about ¼-mile wide. <http://www.consrv.ca.gov/cgs/rghm/ap/index.htm>, accessed on November 18, 2003.

⁵ California Geological Survey website, Alquist-Priolo Earthquake Fault Zones, <http://www.consrv.ca.gov/CGS/rghm/ap/affected.htm>, accessed on February 18, 2004.

Survey does not list the City of Petaluma on its list of cities affected by Alquist-Priolo Earthquake Fault Zones.⁶

c. Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act, passed in 1990, addresses non-surface fault rupture earthquake hazards, including liquefaction and seismically-induced landslides.⁷ Under the Act, seismic hazard zones are to be mapped by the State Geologist to assist local governments in land use planning. The Act states that “it is necessary to identify and map seismic hazard zones in order for cities and counties to adequately prepare the safety element of their general plans and to encourage land use management policies and regulations to reduce and mitigate those hazards to protect public health and safety.”⁸ Section 2697(a) of the Act additionally requires that “cities and counties shall require, prior to the approval of a project located in a seismic hazard zone, a geotechnical report defining and delineating any seismic hazard.” At the time of this report, Sonoma County had not yet been mapped under the Seismic Hazards Mapping Act because the State has targeted higher risk areas, such as the lower San Francisco Bay Area and the Los Angeles/Riverside areas.⁹

2. Local Regulations

Policies and programs included in the Community Health and Safety Element of the existing and proposed Petaluma General Plan that relate to the

⁶ California Geological Survey website, <http://www.consrv.ca.gov/CGS/rghm/ap/affected.htm>, accessed on May 9, 2005.

⁷ California Geological Survey website, Alquist-Priolo Earthquake Fault Zones, <http://www.consrv.ca.gov/CGS/rghm/ap/affected.htm>, accessed on February 18, 2004.

⁸ California Public Resources Code, Division 2, Chapter 7.8, Article 7.8, Section 2691(c), <http://www.consrv.ca.gov/cgs/codes/prc/chap-7-8.htm>, accessed on February 19, 2004.

⁹ California Geological Survey website, [http://gmw.consrv.ca.gov/shmp/MapProcessor.asp?Action=SHMP&Location=All&Version=5&Browser=Net scape&Platform=Win](http://gmw.consrv.ca.gov/shmp/MapProcessor.asp?Action=SHMP&Location=All&Version=5&Browser=Net%20scape&Platform=Win), accessed on June 8, 2006.

proposed project are listed in Table 4.6-1. These policies and programs seek to ensure the safety of life and property from seismic and geologic hazards.

B. Existing Conditions

The background information necessary to determine the potential seismic and geologic impacts of the proposed project is provided below. This includes descriptions of the regional and local geology, and seismic activity relevant to the project site and surroundings.

1. Seismic Hazards

The San Francisco Bay Area is one of the most seismically active regions in the United States. The significant earthquakes that occur in the Bay Area are generally associated with crustal movement along well-defined, active fault zones of the San Andreas Fault system, which regionally follow in a north-westerly direction. In addition to faults that are apparent at the ground surface, the 1983 Coalinga and 1994 Northridge earthquakes have shown that “blind thrust faults” also present a hazard in certain areas of California. “Blind thrust faults” are inclined faults, where the earth on one side of the fault is pushed up and overrides the earth on the other side of the fault. These faults do not extend to the earth's surface.

The San Andreas Fault is located approximately 15 miles to the west and southwest of the project site. The Rodgers Creek Fault is located approximately 5 miles to the east of the project site. Other active faults in the area include the West Napa Fault and the Hayward Fault, located approximately 17 and 18 miles east and southeast of the site, respectively.¹⁰ Figure 4.6-1 depicts the location of the regional fault systems.

¹⁰ Lowney Associates, *Design-Level Geotechnical Investigation East Washington Place Retail Development*, 2004, page 3.

TABLE 4.6-1 **PETALUMA GENERAL PLAN POLICIES AND PROGRAMS —
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Policy/Program Number	Policies and Programs
Existing General Plan	
<i>Community Health and Safety Element</i>	
Policy 11	Establish acceptable levels of risk/life safety standards and bring buildings up to the same standard.
Program 10	Contract with a licensed geologist for independent review, analysis, and recommendations of geotechnical reports and development plans for projects in hazardous areas. Refer geologic/seismic investigations to the geologist for review and assessment.
Program 11	Record information on potential geologic hazards with parcel or subdivision maps.
Policy 14	The City shall continue to require soil and geologic investigations in areas prone to slope instability – or to mass movements associated with seismic activity – prior to development. Both on-site and off-site hazardous impacts should be considered by the City in its development review process.
Proposed General Plan	
<i>Community Health and Safety Element</i>	
Policy 3-P-1	Require geotechnical studies prior to development approval in geologic and/or seismic hazard areas. Require or undertake comprehensive geologic and engineering studies for critical structures regardless of location. Critical structures are those most needed following a disaster or those that could pose hazards of their own if damaged. They include utility centers and substations, water reservoirs, hospitals, fire stations, police and emergency communications facilities, and bridges and overpasses.
Policy 10-P-4	Adopt and amend as needed updated versions of the California Building Code (CBC) so that optimal earthquake-protection standards are used in construction and renovation projects. Earthquake-resistant design and materials must meet or exceed the current seismic engineering standards of the CBC Seismic Zone 4 requirements.

Policy/Program Number	Policies and Programs
Policy 10-P-5	Explore programs that would encourage, assist, or provide incentives to property owners to retrofit their buildings for seismic safety.

Although research on earthquake prediction has greatly increased in recent years, seismologists cannot predict exactly when or where an earthquake will occur. The U.S. Geological Survey's Working Group on California Earthquake Probabilities (2002) determined that there is a 62 percent chance of at least one magnitude 6.7 or greater earthquake striking the San Francisco Bay region between 2003 and 2032.¹¹

a. Ground Rupture

Ground rupture generally occurs only along the fault zone that moves during the earthquake. As discussed in the Regulatory Framework section, the city of Petaluma has not been identified as being within an Alquist-Priolo fault zone. As a result, there is a low potential for ground rupture on the project site.

b. Ground Shaking

The major cause of earthquake damage is strong ground shaking which can damage or collapse weak structures throughout large areas. It can also trigger ground failures, which in turn damage or destroy structures. Ground shaking is most severe near the epicenter of an earthquake, and drops off away from the epicenter. The distance factor depends on the type of material underlying the area. Although there are no fault lines in the immediate vicinity of the project site, earthquakes in the general region could cause significant ground shaking within the project area.

¹¹ U.S. Geological Survey, *USGS Fact Sheet 039-03* 2003.

Lowney Associates performed a Deterministic Seismic Hazard Analysis (DSHA) of the project site to determine the maximum Moment Magnitude¹² (Mw) for the controlling faults, published attenuation curves, the shortest distance to the fault, and the site-specific response characteristics. Based on the attenuation methods of Campbell and Bozorgnia (1994), the mean peak ground acceleration (PGA) expected for the project site is 0.42g from a magnitude 7.0 Mw event on the Rodger's Creek Fault. A 7.9 Mw event on the San Andreas Fault would be expected to produce a PGA of 0.34g at the project site.¹³ The Probabilistic Seismic Hazard Analysis (PSHA) performed by the California Geologic Survey estimates a peak horizontal ground acceleration of 0.50g at the project site with a 10 percent probability of occurrence in 50 years. As these analyses show, strong ground shaking is expected at the project site during moderate to severe earthquakes in the San Francisco Bay Area.

c. Soil Liquefaction

Soil liquefaction is a process that occurs in water-saturated, unconsolidated sediment due to ground shaking. During liquefaction, soils lose strength and ground failure may occur, affecting structures. Soils most susceptible to liquefaction are loose to medium dense, saturated granular soils with poor drainage, such as silty sands or sands and gravels capped by or containing seams of low permeability sediment.

The borings on the southern portion of the project site encountered medium dense to dense granular soils, with several sand layers. Only relatively thin sand strata were encountered in the borings for the northern portion of the project site, where the retail uses are proposed. These sands also contained

¹² Moment magnitude is based on the seismic moment at the source, or hypocenter, of the earthquake. The moment magnitude scale is a way of rating the seismic moment of an earthquake with a simple, logarithmic numerical scale similar to the original Richter magnitude scale. Because it does not "saturate" the way local magnitude does, it is used for large earthquakes – those that would have a local magnitude of about 6 or larger.

¹³ Lowney Associates, 2004 *Design-Level Geotechnical Investigation East Washington Place Retail Development*, page 3.

significant amounts of silt and clay and were found to be medium dense to dense, meaning that the potential for liquefaction is relatively low.

Assuming a worst case scenario of groundwater within 5 feet of grade level, Lowney Associates estimated the potential for liquefaction in the southern portion of the project site. Based on the liquefaction analyses, some sand layers encountered, in the range of 10 to 20 feet deep, are theoretically liquefiable. There appears to be enough of a cap to contain the sand seams from causing ground surface rupture. Theoretical total liquefaction-induced settlements are estimated to be on the order of 0.5 to 1.5 inches. Liquefaction-induced differential settlements are estimated to range from 0.25 to 0.75 inches.

The probability of liquefaction occurring in the northern portion of the project site is relatively low because only thin sand strata with significant amounts of silt and clay were encountered there. Even if liquefaction did occur, the sands are overlain by 15 to 30 feet of stiff to very stiff clays, which would not be subject to liquefaction. As a result, the potential for liquefaction in the northern portion of the site consists of minor settlements, likely less than 0.25 inches at the ground surface. The liquefaction variation between the two portions of the site is not uncommon in alluvial soils around the Bay Area.¹⁴

d. Landslide Hazards

The project site is relatively flat and is not located adjacent to any hillsides. Thus, the landslide risk for the site during an earthquake, or other seismic or weather-related event, is low.

2. Hazards Associated with Soil Characteristics

Soil characteristics can create engineering difficulties and hazards for development due to varying abilities for soils to handle pressure, as well as differ-

¹⁴ John Dye, Senior Project Engineer, Lowney Associates. Personal communication with Jennifer Phelps, DC&E, March 20, 2006.

ing external forces and environmental changes. For example, a building built on a site with sections of soils of different load-bearing characteristics could crack or tilt over time, due to an earthquake or changed environment, such as extremely wet conditions over an extended period, as the sections of soils compact or expand at different rates. The following section describes different conditions that could prove hazardous to development on the project site. Liquefaction, discussed above, is also a soil quality-related hazard.

a. Lateral Spreading

Lateral spreading of soil typically occurs as a form of horizontal displacement of relatively flat-lying alluvial soil material toward an open or “free” face, such as an open body of water, channel or excavation. While the project site is relatively flat, there are no creeks or open bodies of water within an appropriate distance from the project site, so the potential for lateral spreading to occur is low.

b. Existing Undocumented Fill

Several borings encountered approximately 1.5 to 3.5 feet of undocumented fill on the northern portion of the project site. Although the existing fill appeared to be relatively stiff, data regarding the original compaction and lateral extent of the fill is not available.

c. Shallow Groundwater

Shallow groundwater can impact grading and underground construction since shallow groundwater may result in potentially wet and unstable subgrade soils, difficulty achieving compaction, and difficult underground utility installation. Groundwater was encountered at depths ranging from 6 to 18 feet, but it is anticipated that the groundwater, especially in the southern portion, could rise seasonally to approximately 5 feet.

d. Corrosive Soils

Soils low in pH and/or with high sulfate concentrations can corrode materials used for proposed surface and subsurface improvements. Low pH soils can severely deteriorate buried metal pipelines and other metallic improve-

ments. High sulfate content soils can deteriorate concrete and prevent complete curing of concrete, reducing its strength considerably. These soil units generally coincide with saline soil deposits, such as rock salt, gypsum, and anhydrite, and which may occur within the project area. The preliminary review of soils revealed that the soils have a moderate or severe potential to corrode buried metallic improvements constructed within the native clayey soils located on the southern portion of the site. The northern portion of the site may also be subject to corrosion, but the soils in the retail area were not studied for corrosion potential.

e. Differential Compaction

If near-surface soils differ in composition both vertically and horizontally, strong earthquake shaking can cause non-uniform compaction of soil strata, resulting in movement of near-surface soils. The subsurface soils on the project site are generally stiff to very stiff clays and medium dense sands that do not appear to change in thickness or consistency abruptly over short distances. As a result, the potential for differential compaction is low.

f. Erosion

The site is relatively flat, without slopes or bodies of water, and therefore potential for erosion is low.

g. Expansive Soils

Expansive soils can undergo significant volume change with changes in moisture content. They shrink and harden when dried, and expand and soften when wetted. This expansive nature can damage building foundations and other construction, such as sidewalks and concrete flatwork, if not properly engineered. Moderately to very highly expansive soils were found to be blanketing much of the site.

3. Hazards Associated with Existing Development

The project site has previously been used for urban uses. As a result, there are existing structures and supporting underground infrastructure throughout the site. In addition, there are some mature trees and other vegetation.

Foundations, underground infrastructure and roots disturb the underlying soil compaction and can create hazards to new development if not removed properly. Hazards are associated with the potential risk of settlement of improperly filled areas and risk of collapse or erosion of existing utilities if abandoned in place.

C. Standards of Significance

The proposed project would result in a significant geologic or seismic impact if it would:

- ◆ Expose people or structures to potential substantial adverse effects, including the risk of loss, injury or death involving:
 - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault.
 - Strong seismic ground shaking.
 - Seismic-related ground failure, including liquefaction.
 - Landslides, mudslides or other similar hazards.
- ◆ 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, collapse, or affect the stability of structures.
- ◆ Result in substantial soil erosion or the loss of topsoil.
- ◆ Be located on expansive soil, creating substantial risks to life or property.
- ◆ Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

D. Impact Discussion

The East Washington Place project proposes to construct retail and residential uses on the project site. As a result, there would be an increase in human occupancy and new structures on the site. For the following analysis, both the existing and proposed General Plans were reviewed to determine whether there would be different conclusions under either Plan. Unless otherwise stated below, the following impact analysis and its conclusions would apply under either General Plan scenario.

1. Seismic-Related Hazards

Since the project site is located in a region subject to seismic activity, the residents and structures of the East Washington Place project would be exposed to seismic hazards. The following provides a discussion of impacts that could be caused by earthquakes in the general region.

a. Ground Rupture

Because there are no known Alquist-Priolo faults in Petaluma, ground rupturing is not anticipated. Therefore, there would be *no impact*.

b. Ground Shaking

Due to the project site's proximity to faults in the larger region, and the 62 percent chance that there will be a strong earthquake on one of those faults by 2032, it is likely that any development in the area would be affected by strong ground shaking. This would be a *significant impact*.

c. Soil Liquefaction

As discussed in the Existing Conditions section, there is a moderate to high potential for localized liquefaction on the southern portion of the project during a major earthquake. Settlement estimates indicate that liquefaction-induced settlement of around 0.5 to 1.5 inches could occur in localized areas across the site during strong ground shaking. As a result, during an earthquake there is the potential that structures would be damaged as the underlying soils settled. This would be a *significant impact*.

d. Landslides, Mudslides or Other Similar Hazards

The site is relatively flat, and therefore is not at risk for a landslide or mudslide. Therefore, there would be *no impact*.

2. Hazards Associated with Soil Characteristics

a. Lateral Spreading

Since there are no creeks or open bodies of water within an appropriate distance from the project site, the probability of lateral soil spreading occurring at the site is low. Therefore, *no impact* related to lateral spreading is anticipated.

b. Existing Undocumented Fill

Since the engineering properties of undocumented fill are unknown, they pose potential engineering hazards to new construction. Differences in expansive levels of soils can damage building foundations and other construction if not properly engineered. This is considered a *significant impact*.

c. Shallow Groundwater

Groundwater was encountered at depths ranging from 6 to 18 feet, and could rise seasonally to approximately 5 feet. This would be a *significant impact*.

d. Corrosive Soils

Due to the presence of soil with a moderate or severe potential to corrode buried metallic improvements constructed in the project site, this is considered a *significant impact*.¹⁵

e. Differential Compaction

The probability of significant differential compaction occurring on the project site is low due to the types and consistency of the soil across the project area. This would be a *less-than-significant impact*.

¹⁵ Dye, John, Senior Project Engineer, Lowney Associates. Personal e-mail communication with Jennifer Phelps, DC&E, March 20, 2006.

f. Erosion

Because the project site is relatively flat and not near any water bodies, there would be *no impact* with regard to erosion.

g. Expansive Soils

During the boring tests, moderately to very highly expansive soils were found to be blanketing much of the site. These could cause damage to the new residential and retail structures if appropriate engineering design is not utilized. This would be a *significant impact*.

3. Cumulative Impacts

A list-based approach has been used for this cumulative analysis. The analysis considers the development projects listed in Appendix C (Cumulative Projects) and whether this project would have significant cumulative impacts related to geology and soils in combination with the cumulative projects.

Cumulative growth in the region would expose buildings and people to geologic hazards. However, most impacts would be mitigated at an individual project level, through incorporation of engineering design features and compliance with local and State building codes. Given that the immediate area of the project site is relatively flat, there is low potential for the project to cumulatively contribute to erosion or landslides. In addition, the project will reduce its potential geologic hazards to a less-than-significant level. Therefore, the project would *not contribute to a significant cumulative impact* regarding geological and soil concerns.

E. Impacts and Mitigation Measures

Impact GEO-1: Large earthquakes could generate strong to violent ground shaking at the site and could cause damage to buildings and infrastructure and threaten public safety. This is considered a *significant impact*.

Mitigation Measure GEO-1: All construction activities should meet the California Building Code regulations for seismic safety (i.e. enforcing perimeter and/or load-bearing walls, bracing parapets, etc.).

Significance After Mitigation: *Less than significant.*

Impact GEO-2: The proposed project facilities on the southern portion of the site could be damaged by liquefaction and resulting localized differential settlement. This is considered a *significant* impact.

Impact GEO-3: The undocumented fills could undergo settlement that could cause damage to foundations and pavements. This is considered to be a *significant* impact.

Impact GEO-4: The presence of relatively shallow groundwater could impact grading and underground construction and equipment. This is considered to be a *significant* impact.

Impact GEO-5: Due to the presence of soil with a moderate or severe potential to corrode buried metallic improvements constructed in the project area, this is considered to be a *significant* impact.

Impact GEO-6: Expansive soils could cause damage to foundations and pavements. This is considered to be a *significant* impact.

Mitigation Measure GEO-2-6: The geotechnical recommendations for mitigation of liquefaction and resulting localized differential settlement, undocumented fills, shallow groundwater, corrosive potential and expansive soils, that are contained in the Lowney Associates geotechnical reports dated April 28 and May 28, 2004, should be implemented.

Significance After Mitigation: *Less than significant.* Implementation of the above mitigation measure would address all of the geotechnical Impacts GEO-2 through GEO-6.