4.4 GEOLOGY & SOILS

4.4.1 ENVIRONMENTAL SETTING

IN THIS SECTION:

- Regulatory Setting
- Regional and Site Geology
- Seismic and Geologic Hazards
- Site Soils Conditions

The following section is based on geotechnical reports and reviews prepared for the proposed project by Miller Pacific Engineering Group in 2006; supplemental reviews were conducted in July 2009, August 2011, January 2013 and December 2013. The 2011 review provided an update to the 2006 report based on review of site and grading plans developed at that time. A subsequent review in January 2013 reviewed foundation recommendations for future structures and underground utilities, and a supplemental review was conducted in December 2013 that examined current grading plans and onsite settlement issues. All geotechnical project studies, reports and memos are included in Technical Appendix C-4, which is available on the DEIR CD, on the City of Petaluma website at http://cityofpetaluma.net/cdd/riverfront.html, and on file for review at the City of Petaluma Community Development Department, Planning Division, located at 11 English Street in Petaluma between the hours of 8 AM to 12 PM and 1 PM to 5 PM Monday through Thursday.

The section also draws from analyses contained in the City of Petaluma *General Plan 2025* Environmental Impact Report (EIR) that was certified on May 19, 2008. The City's General Plan and EIR are also available for review at the Planning Division office and online at: http://cityofpetaluma.net/cdd/plan-general-plan.html.

The principle geologic hazards and soils constraints identified at the site are differential settlement and strong seismic ground shaking with a potential for localized liquefaction and moderate expansive potential of near-surface soil. Shallow groundwater may be present during and after construction. A full discussion is provided below.

REGULATORY SETTING

State Regulations

ALQUIST-PRIOLO EARTHQUAKE FAULT ZONING ACT

The Alquist-Priolo Earthquake Fault Zoning Act was passed by the state of California in 1972 to prevent the construction of buildings used for human occupancy over the surface trace of

active faults. The Act requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults and to issue appropriate maps. Local agencies must regulate most development projects within the zones. Before a project can be permitted, cities and counties must require a geologic investigation to demonstrate that proposed buildings will not be constructed across active faults. The Act provides for special seismic design considerations if developments are planned in areas adjacent to active or potentially active faults. There are no state-delineated Alquist-Priolo fault zones within the City of Petaluma's Urban Growth Boundary.

SEISMIC HAZARDS MAPPING ACT

The Seismic Hazards Mapping Act (SHMA) addresses non-surface fault rupture earthquake hazards, including strong ground shaking, liquefaction, and seismically induced landslides. The goal is to mitigate seismic hazards to protect public health and safety. Pursuant to the SHMA, the state Department of Conservation is directed to provide local governments with seismic hazard zone maps that identify areas susceptible to amplified shaking, liquefaction, and earthquake-induced landslides or other ground failures. Site-specific geotechnical hazard investigations are required by SHMA when construction projects fall within these areas. The Act has resulted in the preparation of maps delineating Liquefaction Zones and Earthquake-Induced Landslide Zones of Required Investigation, but mapping has not yet been extended to the USGS 7.5-minute quadrangles that encompass Petaluma.

CALIFORNIA BUILDING CODE

Title 24 of the California Code of Regulations, known as the California Building Code (CBC), sets forth minimum requirements for building design and construction in public buildings and a large percentage of private buildings. In the context of earthquake hazards, the CBC design standards have a primary objective of ensuring public safety and a secondary goal of minimizing property damage and maintaining function during and following a seismic event. The CBC prescribes seismic design criteria for different types of structures. The CBC also requires analysis of liquefaction potential, slope-instability, differential settlement, and surface displacement due to faulting or lateral spreading for various categories of construction. Recognizing that the risk of severe seismic ground motion varies from place to place, the California Building Standards Code seismic code provisions vary depending on location (Seismic Zones 0, 1, 2, 3, and 4—with 0 being the least stringent and 4 being the most stringent). The City of Petaluma is located in Seismic Zone 4.

Local Regulations

The City of Petaluma has adopted the California Building Code as set forth in Section 17.04.010 of the City's Municipal Code. Chapter 18 of the California Building Code requires a geotechnical foundation investigation during the project-planning phase for new construction intended for human occupancy. The detailed geotechnical and foundation investigations

include site preparation and earthwork, grading, drainage, pavements, foundation types, retaining walls, seismic design, and slope protection. The investigations must be performed by California-licensed geologists and engineers as part of the design phase of a project, and the report would be required prior to the time of building permit issuance. At a minimum, the investigations must provide information and recommendations for the following items:

- Characteristics of the soil materials below the construction site;
- Most appropriate type of foundation for the proposed structure;
- Static and dynamic design criteria for the recommended foundation type;
- Estimated foundation settlement rate;
- Necessary subgrade preparation for the foundation;
- Lateral pressures for retaining walls;
- Design slopes for cut and fill sections; and
- Suitability of on-site soils for use as backfill.

The recommendations of the foundation and structural reports prepared for the construction of the project or equivalent measures are normally incorporated in the final design of each structure. Earthquake-resistant design and materials must meet or exceed the current seismic engineering standards of the CBC Seismic Zone 4 requirements.

The City's Grading and Erosion Control Ordinance #1576, Title 17, Chapter 17.31 of the Petaluma Municipal Code) regulates grading in order to: control erosion; control sedimentation; protect water quality; reduce pollutants in stormwater to the maximum extent practicable; and safeguard health, safety, and the public welfare. The regulations establish administrative procedures to carry out these regulations. An erosion and sediment control plan will be required for the subdivision grading plans.

REGIONAL AND SITE GEOLOGY

The site is located within the Coast Range Geomorphic Province of California. The regional bedrock geology consists of complexly folded, faulted, sheared, and altered sedimentary, igneous, and metamorphic rock of the Jurassic-Cretaceous age (65 to 190 million years ago) Franciscan Complex. Northwest-southeast trending mountain ridges formed from previous tectonic activity characterizes the regional topography. Extensive faulting during the Pliocene Age (1.8 to 7 million years ago) formed the uneven depression that is now the San Francisco Bay. More recent tectonic activity is concentrated along the San Andreas Fault zone, a complex group of generally parallel faults (Miller Pacific Engineering Group, March 2006).

According to the geotechnical report, regional geologic mapping by the California Geological Survey and the California Division of Mines and Geology indicate the site is underlain by highly compressible Bay Mud deposits over as much as 300 feet of unconsolidated alluvium.

This mapping shows the Bay Mud beginning near the north end of the property and thickening towards the Petaluma River (Miller Pacific Engineering Group, March 2006).

SEISMIC AND GEOLOGIC HAZARDS

The site is located within a region subject to a high level of seismic activity, and could experience strong seismic ground shaking during the lifetime of the proposed project. The three closest known potentially active faults are the Rodgers Creek, San Andreas, and Hayward faults. An active fault is one that shows displacement within the last 11,000 years and, therefore, is considered more likely to generate a future earthquake than a fault that shows no sign of recent rupture. Due to their close proximity, the Rodgers Creek and San Andreas faults present the highest potential for severe ground shaking. The Rodgers Creek fault is closest to the site as shown on Table 4.4-1. The Richter Magnitude Scale provides a method to deduce the magnitude of an earthquake from seismologic instruments, which is also shown on Table 4.4-1.

The project site is not located within an Alquist-Priolo Earthquake Fault Zone, and no known active faults traverse the site. Therefore, the risk of ground rupture within the limits of the site is considered to be low (Miller Pacific Engineering Group, March 2006).

TABLE 4.4-1: Summary of Significant Regional Earthquake Activity

Fault	Historic Richter Magnitude	Year	Distance to Project Site	Peak Site Acceleration
San Andreas	8.3	1906	59 km	0.25 g
Rodgers Creek	6.2	1898	19 km	0.24 g
Rodgers Creek	5.7	1969	26 km	0.16 g
Rodgers Creek	5.1	1893	18 km	0.15 g
West Napa	5.2	2000	24 km	0.13 g
SOURCE: Miller Pacific Engineering Group, March 2006				

According to the City's *General Plan 2025* EIR, the project site is located within an area that is mapped as having a very high liquefaction potential (City of Petaluma, September 2006 – Map 3.7-5). Liquefaction refers to the sudden, temporary loss of soil strength during strong ground shaking. Liquefaction-related phenomena include settlement, flow failure, and lateral spreading.

According to the project geotechnical report, the project site is underlain by highly compressible Bay Mud deposits, which is not the type of soil that is typically susceptible to liquefaction, although ancient stream meanders are occasionally found in bay mud and can leave isolated deposits of saturated sands that could liquefy during strong seismic shaking.

An approximately nine-foot thick layer of loose sandy soil was encountered in one boring in the center of the site, and this sandy soil may be subject to liquefaction and seismic settlement in the event of strong ground shaking. It is thought that the sandy deposit represents an old channel meander associated with the Petaluma River based on a map of the river dated 1860. The channel meander is generally shaped like a horseshoe, with a width of ranging from approximately 70 feet to 120 feet, and traverses the southern portion of the project site. The channel meander location is shown on Figure 4.4-1. The geotechnical investigation indicated that given the localized nature of the channel meanders, widespread liquefaction-related settlements and other related phenomenon are not anticipated at the project site (Miller Pacific Engineering Group, March 2006).

Lurching and lateral spreading can occur during strong ground shaking. Lateral spreading generally occurs on slopes and near the tops of slopes where stiff soils are underlain by soft liquefiable deposits. Lurching and spreading along the bank of the Petaluma River, directly adjacent to the southern end of the property, is a potential hazard. However, the geotechnical investigated concluded that the approximately 100-foot wide planned park between the river and the proposed development would provide an adequate setback from the river that should effectively mitigate any lurching or spreading hazard.

SITE SOILS CONDITIONS

Soils

As indicated above the project site is underlain by highly compressible Bay Mud deposits. The principle soil constraints of the site are related to total and differential settlement. Shallow groundwater may be present during and after construction.

The geotechnical investigation included five test borings and lab testing. To the depths explored, the subsurface profile consists of artificial fill, bay mud, and alluvial soils consisting of sand, silt, and clay with minor intermittent gravels. Over the northern one third to one half of the site, the soil probes encountered approximately five feet of sandy artificial fill over the natural bay mud and alluvial soil. The thickness of the compressible bay mud layer varies across the site. The geotechnical exploration indicates that the bay mud is between 15 and 20 feet thick beneath the northern half of the site and thickens to between 35 to 40 feet at the southern end of the site, adjacent to the Petaluma River. An approximately nine-foot thick layer of loose, natural sandy soil was encountered above the bay mud near the center of the site (Boring 3). As indicated above, this deposit is likely a filled-in old stream meander, which are occasionally found in bay mud and can leave isolated deposits of saturated sands. Old fill and stockpiles of soil and aggregate are present over much of the northern half of the site.

Beyond the limits of the bay mud, near-surface native soils in the area are commonly relatively weak and expansive alluvial clays. The soil borings conducted as part of the project

geotechnical investigation did not identify the presence of highly plastic silts or clays near-surface soil at the site, although some pockets of moderate plasticity clays and/or silts with low to moderate expansive characteristics may exist. Subsequent review in 2009 of the northern portion of the site proposed for commercial development indicated that potentially expansive soils are present in this area.

Erosion Potential

Sandy soils on moderate slopes or clayey soils on steep slopes are susceptible to erosion when exposed to concentrated surface water flows. Because site topography at the project site is generally flat, and evidence of significant erosion problems was not observed during the geotechnical investigation, the potential hazard to the site from erosion was determined to be low.

4.4.2 IMPACTS AND MITIGATION MEASURES

CRITERIA FOR DETERMINING SIGNIFICANCE ANALYSIS

In accordance with the California Environmental Quality Act (CEQA), State CEQA Guidelines (including Appendix G), City of Petaluma plans, policies and/or guidelines, and agency and professional standards, a project impact would be considered significant if the project would:

- 4a Expose people or structures to potential substantial adverse effects including the risk of loss, injury, or death resulting from the rupture of a known earthquake fault, seismic ground shaking, landslides, or seismic-related ground-failure, including liquefaction,
- 4b 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 an onsite or offsite landslide, lateral spreading, subsidence, or slope failure/ instability;
- 4c Be located on an expansive soil, as defined by the Uniform Building Code (1997) or subject to other soil constraints that might result in deformation of foundations or damage to structures, creating substantial risks to life or property; or
- 4d Result in substantial soil erosion or the loss of topsoil and subsequent sedimentation into local drainage facilities and water bodies.

IMPACT ANALYSIS

The following impact analyses address potential exposure to seismic hazards (4a), location on unstable geologic unit (4b), location on expansive soils or subject to other soils constraints (4c), and erosion (4d).

Seismic Hazards

Impact 4.4-1 – *Exposure to Seismic Hazards*: Future project structures, residents and occupants at the site would be subject to strong seismic shaking and liquefaction hazards. This is considered a *potentially significant* impact.

The proposed project would result in subdivision of the project site with subsequent future development of a mix of residential, hotel, commercial and office uses. Exposure to seismic shaking from an earthquake on regional faults could result in potential injury to people or damage to structures and improvements. Additionally, according to the geotechnical investigation, there is potential for localized liquefaction with seismic-induced ground settlement in the area of an old, approximate nine-foot deep stream meander. The stream meander is generally shaped like a horseshoe, with a width ranging from approximately 70 feet to 120 feet, and traverses the southern portion of the project site. The channel meander location is shown on Figure 4.4-1.

Ground shaking can induce settlement of loose granular soils above the water table. As indicated above, one boring (boring 3) did encounter a channel meander deposit, which depending on the time of year could be unsaturated. Otherwise, these types of soils at the site were not encountered at the site, and seismically induced ground settlement is considered to be a minor potential hazard at the site (Miller Pacific Engineering Group, 2011).

Lurching and lateral spreading can occur during strong ground shaking. Lateral spreading generally occurs on slopes and near the tops of slopes where stiff soils are underlain by soft liquefiable deposits. Lurching and lateral spreading along the bank of the Petaluma River, directly adjacent to the southern end of the property, is a potential hazard. However, preliminary plans show an approximately 100-foot wide "Civic Space" parkway zone between the river and new lots that would support future development. The geotechnical investigation concluded that this level of setback from the river should effectively mitigate any lurching, lateral spreading or slope instability hazard.

As indicated in the PROJECT DESCRIPTION (Chapter 3.0) section of this EIR, the proposed subdivision includes creation of a 0.16-acre parcel (Parcel D) that will be dedicated to the City of Petaluma for future construction of an approximate 15,000 square foot building to store approximately 100 small boats. The southernmost boundary of this parcel is located about 120+ feet from the Petaluma River as shown on Figure 1-2. However, the site plan (Figure 1-4) shows a structure less than 100-feet from the Petaluma River, and, thus future development of a boathouse would conflict with the recommended 100-foot setback from the river, which as indicated above would effectively mitigate potential lurching and lateral spreading hazards. (It is noted that the conceptual rendering shown on Figure 1-4 shows the boathouse structure extending onto adjacent state-owned lands. Any encroachment onto the adjacent lands would require a lease with and approval from the State Lands Commission.)

Although not part of the project, it is the opinion of the project geotechnical engineer that the development of structures within 100 feet of the Petaluma River is feasible from a geotechnical standpoint. The foundations for future structures near the river bank can be designed to take into account the risk of lateral spreading. Structures along the river bank may need to be supported on deep foundations extending through the Bay Mud to mitigate the lateral spreading risk. (Miller Pacific Engineering Group, December 2013).

Future buildings will be required to be designed in accordance with the latest version of the California Building Code. Construction in accordance with requirements of the California Building Code will reduce potential impacts to structures due to seismic shaking. The City's General Plan 2025 EIR indicates that based on an existing regulatory framework that addresses earthquake safety issues and adherence to the requirements of the Building Code, seismically induced ground shaking would not be a substantial hazard in the City's planning area.

The geotechnical report includes recommendations to address liquefaction hazards. Once specific building layouts and designs are established, additional geotechnical investigation(s) will be required for structural development that would require further soil borings and laboratory testing to determine the extent of liquefiable deposits. Detailed geotechnical recommendations for grading and foundations will then be developed, as needed, to mitigate potential impacts to structures and improvements in accordance with requirements of the California Building Code, such as incorporation of geotechnical recommendations into building plans. Most buildings will likely require structural foundation systems, such as mat slabs or rigid interconnected grade beams that are able to resist the anticipated strong ground shaking and potential for differential movement caused by liquefaction and/or consolidation of the bay mud discussed in the Impact 4.4-2 analysis below (Miller Pacific Engineering Group, 2011). Depending on the thickness of the liquefiable sand layer and the thickness of the non-liquefiable bay mud and fill cap, there may not be any ground surface manifestations even if liquefaction of localized loose sand layers does occur. If needed, mitigation measures to address liquefaction potential could include soil improvement (i.e. densification or grouting), use of deep foundation systems that provide support below the potential liquefiable layer, or use of stiff mat slab or rigid, interconnect grade beam foundations designed to withstand potential liquefaction induced ground settlements (Miller Pacific Engineering Group, 2006, December 2013). It is noted that the typical mitigation measures used to control the effects of liquefaction are similar to those measures used to design for settlement of bay mud, which is addressed in the following impact discussion. The project geotechnical engineer has indicated that the use of stiff, shallow foundation systems for light residential structures constructed over Bay Mud deposits has been a standard engineering practice in the Bay Area for many years (Miller Pacific Engineering Group, December 2013).

Mitigation Measures

Compliance with the California Building Code regulations and implementation of Mitigation Measure GEO-1 below will reduce the impact of exposure to seismic and geologic hazards to a less-than-significant level.

> GEO-1: Require implementation of all recommendations as set forth in the geotechnical investigations and updates prepared for the subject property by Miller Pacific Engineering Group (dated March 2006, July 2009, August 2011, January 2013, December 2013), including but not limited to recommendations for site and soil preparation, foundation designs, drainage and installation of utilities. Buildings shall require the following: a) structural foundation systems, such as mat slabs or rigid interconnected grade beams, able to resist the anticipated strong ground shaking and potential for differential movement caused by liquefaction and/or consolidation of the bay mud, b) soil improvement, c) deep foundation systems, or d) other engineering techniques as recommended in additional geotechnical investigations of liquefaction hazards. All structures shall meet the California Building Code regulations and design requirements for seismic safety.

Geologic/Soils Constraints

Impact 4.4-2 – *Soil Settlement*: Future structures at the project site would be subject to soil settlement with potential damage to structures and utilities. This is a *potentially significant* impact.

The proposed project would result in subdivision of the project site with subsequent future development of a mix of residential, hotel, commercial and office uses. Site improvements will be subject to settlement due to consolidation of the bay mud under new foundations and/or fill loads. Geotechnical review of a former grading site plan in 2006 and 2011 indicated that settlement would vary across the site and identified the magnitude of potential settlement on the site. The former plan showed fills up to 10 feet on the southern portion of the site, which could have subjected structures to as much as two feet of total settlement due to the new loading of the bay mud deposits. Where fills of three feet or less are planned, total settlements of up to one foot could still be expected. Consolidation of bay mud occurs at a decreasing rate over several decades, and as much as 50 percent of the total settlement would likely occur within the first five years after the fill load is applied.

The principal hazards associated with the anticipated settlement include distress to new residential structures, disruption of underground gravity flow utilities (storm drain and sanitary sewer), and distress to new pavements and flatwork. Common mitigation for settlement of new improvements include:

a) use of deep foundations (driven piles or drilled piers) which gain support below the compressible layer;

b) preloading of the development area (i.e., with stockpiles) to force the estimated settlement in an accelerated time frame in advance of construction;

c) improvement of the compressible soil layer (through use of Rammed Aggregate Piers (RAP[1]) or other densification method) to limit future settlements to tolerable levels;

d) use of stiffened foundation systems to withstand the effects of the anticipated settlement; or

e) a combination of two or more of the above. The geotechnical investigation indicated that the rate of settlement can be significantly increased through the use of vertical wick drains installed through the bay mud layer, which reduce the drainage path distance for the dissipation of pore water pressure and accelerate the consolidation of the bay mud (Miller Pacific Engineering Group, March 2006).

The project geotechnical consultant also has indicated that a reduction in fill will reduce the magnitude of potential settlement (Miller Pacific Engineering Group, December 2013). Review of the current grading plan by the project geotechnical engineer indicates that, in general, the grading plan shows that the existing grades on the northern half of the project site will be lowered by one to two feet. The current grading plan indicates that new fills planned for the southern roughly one half of the project site will typically be limited to two feet or less in thickness. The one exception is a localized area near the southern end of the proposed Caulfield Lane extension, where up to ten feet of new fill is planned to accommodate a possible future bridge over the Petaluma River beyond the southern edge of the project. This area includes the southern segment of the road and a number of adjoining lots (#5-11, 144, 32-37). It is also noted that even with a potential predicted ground settlement of one to two feet, the resulting ground level elevations (ranging between approximately 14 and 15 feet) would be well above the identified 100-year flood level elevation of (Ibid.), which is 9.0-10.0 feet (NAVD 1988 Datum). (See the HYDROLOGY AND WATER QUALITY [CHAPTER 4.6] section of this EIR for further discussion of flood hazards.)

The current grading plan (dated February 1, 2013) and settlement issues were reviewed by the project geotechnical engineer (Miller Pacific Engineering Group, December 2013). According to this review, the grading plan has now been designed to limit the thickness of new fills placed on areas of the site underlain by deeper Bay Mud deposits. (The grading plan is shown on Figure 1-9.) By limiting the thickness of new fills, both total and differential settlement due to bay mud consolidation will be minimized. Where fills of two feet or less are planned, consolidation of the bay mud will result in total settlement of less than one foot over the life of the project; where 10 feet of new fill is planned in a localized area at the southern end of the

[1] RAP are compacted aggregate base columns, constructed in pre-drilled holes. Hole diameters are typically 20 to 30 inches and maximum practical depths for RAP are on the order of 20 to 30 feet.

proposed Caulfield Lane extension, up to two feet of total settlement will occur over the life of the project (Miller Pacific Engineering Group, December 2013). Light weight fill can be utilized in localized areas to equalize new fill loading and thereby equalize new total settlements (limit differential settlements). Light weight fill could be used at the south end of the Caulfield Lane extension, for example, where variable new fill thicknesses are required at the future bridge approach (Ibid.). Since the proposed Caulfield Lane extension will experience some settlement post construction, the geotechnical engineer recommends that the roadway elevation should be planned so the elevation will match the proposed bridge elevation after the predicted roadway settlement has occurred. It may be necessary to adjust the elevation of the roadway in a short transition zone at the time that the bridge is constructed (Ibid.).

Bay Mud thickness typically changes very gradually across the site. As discussed, the grading plan has been designed to limit the amount of new fill and to keep the new fill thickness relatively uniform within a given area of the site. Due to the gradual changes in Bay Mud thickness and gradual changes in new fill loads, future differential settlement is limited, and is spread out over long horizontal distances. The key issue for reducing the risk of damage to future improvements is to limit the amount of differential vertical settlement that occurs per unit of horizontal distance (Miller Pacific Engineering Group, December 2013).

In conjunction with limiting consolidation settlement of the Bay Mud by limiting the thickness of new fills, new residential structures will be supported on stiff, structural foundation systems consisting of either stiff mat slabs or rigid, interconnected grade beams. These types of stiff, shallow foundation systems can be designed to accommodate the amount of total and differential settlement predicted for the subject project without experiencing damage or distress (Ibid.). It is noted that the use of stiff, shallow foundation systems for light residential structures constructed over Bay Mud deposits has been a standard engineering practice in the Bay Area for many years (Ibid.). The 2006 geotechnical investigation did not find the use of deep foundations to be a cost-effective option for the planned residential structures, but indicated that a combination of the other three options will likely provide the most practical solution for the settlement hazard. Preloading and the use of wick drains are not proposed.

For the northern portion of the site, where previously placed fill will be removed, the geotechnical investigation indicates that the settlement hazard will be lessened but not eliminated, and ground improvement with RAP may be a cost-effective mitigation option for this area (Miller Pacific Engineering Group, 2006). It is anticipated that the larger, heavier commercial structures proposed for the development in the northern portion of the site, where located in areas underlain by Bay Mud deposit, will be supported on deep foundations (driven piles or drilled piers) that extend through the bay mud and gain support in the stiff underlying soil (Miller Pacific Engineering Group, December 2013).

Streets and utilities can be designed to accommodate total and differential settlements of the magnitude predicted for the subject project. Flow gradients for surface drainage and gravity pipelines are checked before and after the predicted settlements to ensure continued proper

functioning throughout the life of the project. Flexible couplings and connections can be used for the various piping systems to allow for some movement (Miller Pacific Engineering Group, December 2013).

Mitigation Measures

Implementation of recommendations in project geotechnical reports as set forth in the Mitigation Measure GEO-1 above as well as Mitigation Measures GEO-2 and GEO-3 below will reduce the impact of exposure to geotechnical hazards to a less-than-significant level. Additionally, geotechnical investigations will be required for each development phase in accordance with requirements of the California Building Code and City policies and requirements.

> GEO-2: Implement the recommendations of the project geotechnical investigations and updates prepared for the subject property by Miller Pacific Engineering Group (dated March 2006, July 2009, August 2011, January 2013, December 2013), except as modified based on site-specific refinements. Settlement mitigation measures shall include use of structural foundation systems (such as mat slabs or rigid interconnected grade beams) for residential structures, which can withstand the potential total and differential settlements in accordance with recommendations of the geotechnical investigations and deep foundations (driven piles or drilled piers) for heavier structures planned in the northern portion of the site. Ground improvement, such as with the use of Rammed Aggregate Piers (RAP), may also be appropriate at certain locations within the site.
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> GEO-3: The Geotechnical Reports prepared by Miller Pacific Engineering shall be subject to third party peer review in order to verify that recommended measures to address differential settlement of bay mud associated with thicker fills up to ten feet near the Future Caulfield Lane Bridge are adequate to accommodate potential settlement. The applicant shall be responsible for the cost of the peer review and the City's Public Works Department shall coordinate the scope of service and approve findings of the peer review prior to the issuance of grading permits.

Expansive Soils

Impact 4.4-3 – *Expansive Soils*: Future structures at the project site would be subject to expansive soils with potential damage to structures and utilities. This is a *potentially significant* impact.

The proposed project would result in subdivision of the project site with subsequent future development of a mix of residential, commercial and office uses. Moderate and highly plastic silts and clays, when located near the ground surface, can exhibit expansive characteristics (shrink-swell) that can be detrimental to structures and flatwork during periods of fluctuating

soil moisture content. The probes and borings drilled during the geotechnical investigation did not indicate the presence of highly plastic silts or clays, although some pockets of moderate plasticity clays and/or silts with low to moderate expansive characteristics may exist.

Highly expansive soils are not anticipated at the site. Near surface soil at final design subgrade elevations at portions of the site will likely be clayey, weak, and plastic (expansive). Several options to provide an improved subgrade for these conditions are available, including treatment of onsite material, use of fill, and moisture conditioning and recompacting existing soils. Subsequent geotechnical investigations that will be required at the structural design stage of future development phases would include exploration and laboratory testing to more precisely determine the extent and degree of potential expansion of near surface soil within the building pad areas and to provide specific engineering design recommendations, if needed, to protect structures and improvements.

Mitigation Measures

Compliance with the California Building Code regulations and implementation of the Mitigation Measure GEO-1 in the preceding impact discussion will reduce the impact of potential structural damage due to expansive soils to a less-than-significant level.

Erosion

Impact 4.4-4 – *Erosion*: Grading at the project site could result in inadvertent erosion or soil transport into the Petaluma River. This is a *potentially significant* impact.

Project plans indicate that mass grading of the entire site will be conducted to redistribute onsite soils, creating a balanced mass grading of the site. The planned mass grading will enable completion of all subdivision improvements and better accommodate future development phases. Total site grading would consist of approximately 146,000 cubic yards of cut, of which about 75,000 cubic yards will be hauled offsite for Caltrans use in its Highway 101 improvement project that is currently underway. The site grading could result in inadvertent erosion or transport of sediments into the Petaluma River if not properly controlled. This is a potentially significant impact that would primarily lead to potential water quality degradation in the Petaluma River. This impact is further addressed in the HYDROLOGY and WATER QUALITY (Chapter 4.6) section of this EIR.

Mitigation Measures

Implementation of Mitigation Measures HYDRO-2, HYDRO-3 and HYRDRO-4 in the HYDROLOGY & WATER QUALITY (Chapter 4.6) section of this EIR will reduce the impact of potential erosion to a less-than-significant level.