4.5 GEOLOGY

The following analysis is partially based on the literature review and geotechnical investigation of the project area conducted by LGC Valley, Inc., dated March 29, 2011, the City of Rancho Palos Verdes General Plan Conservation and Open Space Element and Safety Element (2018), and additional data regarding landslide conditions compiled by the City of Rancho Palos Verdes Public Works Department from 2007 to 2017. The LGC Valley geotechnical review conducted by LGC Valley, Inc. is contained in its entirety in Appendix D.

4.5.1 Setting

a**. Regional Geology.** As described in the Rancho Palos Verdes General Plan Conservation and Open Space Element, the Palos Verdes Peninsula bedrock is composed of a metamorphic core blanketed by sequences of younger sedimentary rock. The structure is complicated by smaller-scale folding, and schist (rocks that split into layers) and sedimentary rocks have been intruded by irregular masses of basaltic volcanic rocks. This entire block has been uplifted by movement on two sub-parallel bounding faults: the Palos Verdes Fault on the northeast and the San Pedro Fault offshore on the southwest. The most widely exposed rocks and the most significant in terms of slope stability is the Miocene Monterey Formation. The Monterey Formation is more than 2,000 feet thick on the Palos Verdes Peninsula. It has been divided into three members on the basis of rock type: the Altamira Shale, the Valmonte Diatomite (fossilized remains of diatoms, a type of hard-shelled algae), and the Malaga Mudstone (from oldest to youngest). Altamira Shale consists largely of thin-bedded sedimentary rocks formed by the deposition of successive layers of clay, along with numerous layers of tuff (volcanic ash) that have been largely altered to weak clays. Thick layers of volcanic ash deposited millions of years ago were compressed over time into bentonite. In the presence of water, bentonite becomes very slippery and has been a major contributing factor for landslides in Rancho Palos Verdes (Rancho Palos Verdes General Plan 2018).

The faulting and seismicity of Southern California is dominated by the compressionary regime associated with the "Big Bend" of the San Andreas Fault Zone. The San Andreas Fault Zone separates two of the major tectonic plates that comprise the Earth's crust. The Pacific Plate lies west of the San Andreas Fault Zone. The North American Plate lies east of the San Andreas Fault Zone. The relative movement between the two plates is the driving force of fault ruptures in the region. The San Andreas Fault generally trends northwest-southeast. However, north of the Transverse Ranges Province, the fault trends in an east-west direction (the Big Bend), causing the fault's right-lateral strike-slip movement to produce north-south compression between the two plates. This compression has produced rapid uplift of many of the mountain ranges in Southern California. North-south compression in southern California has been estimated to be 5 to 20 millimeters per year (SCEC, 1995).

b. Project Area Geology. The proposed ordinance revisions would apply to the approximately 112-acre Zone 2 Landslide Moratorium Area, located north of the intersection of Palos Verdes Drive South and Narcissa Drive in the Portuguese Bend area of the Palos Verdes Peninsula. This area, located on the hills above the south-central coastline of the City, is within the City's larger (approximately 1,200-acre) Landslide Moratorium Area (LMA). Zone 2 is geologically interconnected to the rest of the LMA.

The project area is located on Middle Miocene to Early Pliocene Monterey formation, which constitutes the exposed bedrock over most of the Palos Verdes Peninsula. The Altamira Shale Member of the Monterey formation is the lowest of three distinct phases of the Monterey formation in the area and is the source of the Ancient Portuguese Bend Landslide (APBL), and all subsequent landslides within the APBL including the Recent Portuguese Bend Landslide (PBL) and the Abalone Cove Landslide (ACL). The Altamira Shale is further subdivided into three distinct lithofacies, or zones of distinct deposition and thus rock types. These are the Portuguese Tuff, the Cherty Lithofacies and the Phosphatic Lithofacies. Of these three, the Portuguese Tuff is the most prominent and encountered unit in the area, and is typically used as a reference point in discussing stratigraphy. Because of its thickness, estimated between 50 feet and 75 feet, and its composition (an altered ash tuff to bentonite clay), it is also commonly considered to have the greatest potential to affect the slope stability of the local area (LGC Valley, Inc, 2011).

Geologic Units. The main geologic units in Zone 2 and the connected surrounding area are the Monterey formation and ancient and recent landslide deposits. Surficial units of marine and non-marine terrace soils, along with alluvium, colluvium and fill mantle the thicker deposits of landslide and bedrock (LGC Valley, Inc. 2011). Each of these materials is discussed below.

Artificial Fill. Local areas of artificial fill are found throughout the Zone 2 area. Fill soil thickness is variable from a few inches to ten feet or more in response to the filling of low points, swales or grabens from ancient land flow events in order to create roads and/or pads. According to the March 2011 Geotechnical Study prepared by LGC Valley, Inc., it is possible that some of the minor cracking observed in roadways, trenches and in lots in the Zone 2 area are due to settlement of poorly compacted fill soils.

Colluvium. Colluvium is located at the ground surface in areas unaffected by grading activities and is the in-situ development of soil from the underlying materials. The colluvium or topsoil is composed of dark brown to black silty clay and clayey silt and is prone to shrinkage and cracking when drying. The colluvium is thicker in low areas such as swales and thinner on steep hillsides. The colluvium has an average thickness of approximately three feet for gently dipping surfaces in the project area (LGC Valley, Inc. 2011).

Alluvium. Alluvium is the down slope migration of particles by moving water that is typically confined within the elongated troughs of streams and canyons. Alluvium may be fine to coarse-grained and even consist of cobbles and boulders. Alluvium is generally confined to the active stream channels that cut across the southern flank of the peninsula and are interpreted at approximately ten feet or less in thickness in the adjacent Altamira and Portuguese Canyons. Thinner deposits are interpreted within the short streams that feed into these primary canyons.

Landslides. Landslides have occurred throughout the peninsula, but none are more prominent than those of the approximately 900-acre Ancient Portuguese Bend Landslide complex and surrounding areas. In general, these landslides are the result of inclined bedding to the south that becomes unsupported due to erosion from beach waves and intrusion from water runoff. As landslides move down-slope into the beach zone due to loss of support from erosion, the material up-slope from these areas loses support and becomes susceptible to landsliding as well. Further instability comes from the now fractured nature of the landslide material, which allows more water to infiltrate into the landslide mass, adding weight, creating buoyancy and further decreasing clay strength, while erosion from beach processes at the toe restrict the landslide masses from natural buttressing. The overall effect is a series of landslides that "shingle" up slope nearly to the crest of the anticline that forms the backbone of the peninsula.

According to the LGC Valley, Inc. Geotechnical Study (2011), the initial landsliding that occupies the bulk of the area observed today occurred approximately 120,000 years ago with possibly initial movements as early as 500,000 years ago. Landslides in the South Shore occurred approximately 16,200 years ago, and historical landsliding of the Portuguese Bend Landslide (PBL) and Abalone Cove Landslide (ACL) indicate that mass movements still occur in the area today. Thus, it is reasonable to conclude that landsliding occurs nearly continuously, at least in geologic terms, throughout the APBL complex and that landsliding will continue into the future.

Overall, the various landslides are interpreted or known to be founded on the weak bentonite clay beds that comprise within the Altamira Shale (LGC Valley, Inc. 2011). All landslides appear to fail in a down slope direction toward the ocean. Because of numerous land movements, head scarps and grabens of varying length, height and arc occur throughout the APBL area. Over time, erosion wore down these initially sharp angled features into subdued hills and depressions. Coupled with the formation of terraces over time, the APBL has a gently rolling, hilly appearance except in the areas of recent landsliding.

The APBL moved as a translational-type landslide along a pre-existing weak layer(s) composed of bentonite clay that is inclined toward the ocean (LGC Valley, Inc. 2011). Some geologic reviewers interpret the data as indicating that the APBL initially moved as a single sheet, in part because of the lateral continuity of the entire landslide complex, and then broke into smaller landslides shortly thereafter. Others hypothesize that landsliding occurred in several relatively smaller stages that then migrated up-slope as a series of landslides as successive parcels of land became unsupported from the down-slope failures.

Recent historical movement and groundwater data such as that identified in the ACL and recent PBL, among others, generally supports this later interpretation as these slides occurred along seaward dipping strata, that appears to have begun within the beach zone with shallower groundwater levels up-slope. Reports that leach fields, seepage pits and cesspools were in common use for residences atop the APBL indicate primary sources for groundwater build-up, which would be a primary catalyst for movement (LGC Valley, Inc. 2011).

Though both of these slides generally moved "at once," surface monument data as well as historical data indicate that the first and greater movement occurred at the toe of the slide and then decreased up-slope such that the slides "shingle" up-slope with the toe area showing a greater "rubble" appearance than those areas higher up (LGC Valley, Inc. 2011). Thus, the material near the toe of the landslide has a distinctly different and chaotic structure with very low strength as compared to the landslide debris higher uphill, which is more intact and has a greater inherent strength.

As indicated above, the movement of lower land masses subsequently decreases support of the land up-slope, creating distinct zones within each landslide that are progressively less broken-up, and therefore stronger up-slope. The larger uphill masses provide significant support to up-slope property because it remains fairly intact.

Abalone Cove Landslide. The ACL is the re-activation of part of the APBL complex and abuts Zone 2 immediately to the south. Movement of the ACL initiated in 1974 and continued until 1985, encompassing a total of approximately 85 acres (LGC Valley, Inc. 2011).

Beginning in 1994, a series of survey monuments were installed across the ACL and Zone 2. The monuments were set up to be reviewed through Global Positioning Satellite networks (GPS) and recordings have been collected through 2006. The data from these monuments indicates that small amounts of movement have occurred up to the most recent known readings in 2006. Interpretations vary as to causation of the movement, ranging from slope creep, stress relaxation of the landslide from the primary movement that occurred between 1974 and 1985, continued creep movement along the basal rupture surface of the landslide, effects from high rainfall, damage or disturbance to monuments, to possible error in data points or some combination thereof (LGC Valley, Inc. 2011). These systems are designed to look primarily for lateral movements, which are easier to detect than vertical movements and give a sense of the direction of movement. The vertical component in these systems is the hardest and least accurate to obtain. Further, due to the rise over run basic of slopes, lateral movement more clearly identifies movement (i.e., it is easier to determine relative disturbance if the lateral is, for example, several inches versus the vertical component, which may be tenths or hundredths of an inch). Thus, for landslides, lateral movement is more sensitive and more readily identifiable.

From 1994 to 2006, movement of the ACL indicated the magnitude of displacement at the toe of the ACL to be approximately 1.9 feet, the mid-portion 0.8 feet, and the head area approximately 0.6 feet (LGC Valley, Inc. 2011). This movement roughly correlates to a yearly slip of 1.9 inches, 0.8 inches and 0.6 inches, respectively, though the movement is not steady on a year-to-year basis. Instead, the data appears to indicate that movement occurs in pulses typically regulated by rainfall. This movement is not considered to be a hazard to life and limb as long as the abatement activities (groundwater dewatering and monitoring) within the ACL continue. Monuments within Zone 2 indicate average movement of approximately 0.3 inches per year or three inches every 10-year period. Additional data collected by the City of Rancho Palos Verdes Public Works Department from 2007 to 2017 shows relatively little movement in much of the project area over that time, but indicates more substantial movement (up to about 1.4 inches per year) along the eastern edge of Zone 2 where a few of the remaining vacant lots are located.

Because the ACL area contained numerous home sites and the boundaries were unclear at the time of initial and even continued landsliding, a Landslide Moratorium Ordinance was adopted in 1978. This ordinance was adopted because it was uncertain whether the slide could be controlled or prevented from spreading beyond the area characterized by visible surface cracks.

Shortly after the adoption of the Landslide Moratorium Ordinance, a geotechnical investigation of the ACL was sponsored by the City. The subsequent report by Robert Stone and Associates (1979) provided recommendations for removal of groundwater and noted the lack of youthful landslides uphill of the ACL, in Zone 2 of the area subject to the Landslide Moratorium

Ordinance. The report indicated that there were only two naturally occurring processes capable of destabilizing the slides uphill from the active ACL. One was loss of support on the downhill side as a result of movement of the ACL, and the other was a rise in the groundwater table. From these conclusions, the report recommended against further development in Zone 2 until slide movement was stopped within the ACL, the water table was lowered and surface drainage was improved.

Portuguese Bend Landslide. The 260-acre active Portuguese Bend Landslide (PBL) has been moving continuously since re-activation in 1956. Like the ACL, the PBL is a portion of the much larger APBL complex; however, its rate of movement is estimated at approximately three feet per year versus the 0.6 to 1.9 inch per year rate for the ACL (LGC Valley, Inc. 2011).

The landslide displaced Palos Verdes Drive South, eliminated the extension of Crenshaw Boulevard, damaged a pier just east of Inspiration Point, and affected approximately 160 homes, of which about 134 were destroyed. The remaining homeowners moved to nearby areas that were more stable or adapted to account for ground movements through methods such as continuous use of hydraulic jacks and timbers to keep their foundations relatively level.

Excavation shafts explored by geologists into the PBL located the basal rupture surface on a sheared bentonite clay bed located about 30 to 40 feet above the Portuguese Tuff. The western margin of the PBL moves over inactive landslide debris of the APBL while the eastern portion moves over in-place bedrock (LGC Valley, Inc. 2011).

Similar to the ACL, the PBL is composed of rubble within the toe areas and numerous large blocks up-slope that move at different rates. Like the ACL, the seaward portion of the slide mass moves at a faster rate than those parcels further away from the coast and all parcels accelerate after periods of high rainfall. The rate of movement of the landslide reached 1.5 inches per day after seasons of high rainfall. Only through continued redistribution of landslide mass in three distinct pulses between 1986 and 1995 did the movement decrease to 0.05 inches per day. However, lapses in maintenance, increased infiltration of water into the landslide, weight at the head of the slide due to other landslides and additional weight due to alluvial build-up led to additional failures (LGC Valley, Inc. 2011).

Over several decades, numerous attempts to stabilize the landslide have failed. These include the installation of 23 steel-reinforced concrete caissons; earth re-distribution across the landslide; the installation of dewatering wells, attempts to control beach erosion through the installation of gabions, drainage improvements, and the sealing of fissures.

Groundwater. The current source of groundwater is primarily rainfall. However, supplemental water may also be present due to infiltration from adjacent canyons and up-slope areas and water pipes broken due to landsliding.

Groundwater was concluded to be the most likely agent responsible for the slide movement of the 80-acre ACL (LGC Valley, Inc. 2011). The ACL landslide is the re-activation of part of the APBL complex and is relevant for the Zone 2 area because it abuts Zone 2 immediately to the south. Movement of the ACL initiated in 1974 and continued substantial movement until 1985, encompassing a total of approximately 85 acres.

A dewatering system was installed in the ACL and was effective in lowering the groundwater table and slowing the rate of land movement. Correlations between groundwater pumping and a decline in the rate of movement of the slide began immediately after the start of dewatering. Subsequent wells appear to have further reduced movement to negligible amounts.

Early in the development of the Portuguese Bend area, septic systems, leach lines and cesspools installed as part of residential development on the APBL contributed high volumes of water directly into the landslide and were likely catalysts for inception of movement.

In their report for the City of Rancho Palos Verdes, Robert Stone & Associates (RSA 1979) clearly described three ways in which groundwater negatively affects a landslide mass. First, the water increases the plasticity of clay gouge along the slide surface and allows it to deform more freely with less frictional resistance. Once saturation occurs along a slide surface, the further accumulation of water decreases stability through the action of water pressure. The buoyancy effect of water reduces the weight of solid material pushing down on the slide surface, thus reducing frictional resistance to sliding. At the same time, fluid pressure acting in the direction of slide movement provides an additional driving force similar to water behind a dam. For the ACL, RSA (1979) concluded that evaluation of the driving force produced by the groundwater head indicates it is the controlling factor causing the slide movement.

Currently, groundwater is interpreted as the controlling factor in initiating slide movement. It is also the only factor that can be reasonably manipulated to minimize slide movement for all areas within the APBL complex.

c. Seismic Hazards. The project area is located within the Peninsular Ranges Geomorphic Province, a seismically active area of Southern California. The Peninsular Ranges are characterized by northwest-trending blocks of mountain ridges and thick sequences of sediment-floored valleys cut longitudinally by young northwest trending fault zones and local low angle thrust faults. Numerous active faults occur within this region, and the nearby Palos Verdes, Newport-Inglewood and Santa Monica faults are the most significant faults from a seismic hazards perspective.

The project area is located outside an Alquist-Priolo Earthquake Fault Zone as defined by the Alquist-Priolo Special Studies Zone Act of 1972 (now the Alquist-Priolo Earthquake Fault Zoning Act), which regulates development near active faults (LGC Valley, Inc. 2011). Thus the potential for ground rupture to adversely affect the project area from an active fault is low.

However, the project area is expected to experience strong ground shaking from both near and distant earthquake sources. The type and magnitude of the seismic shaking hazard are dependent on the distance from the causative fault and the intensity and magnitude of the seismic event. Primary seismic hazards can be divided into two general categories: hazards due to ground rupture and hazards associated with ground shaking.

<u>Potential for Ground Rupture</u>. In general terms, an earthquake is caused when strain energy in rocks is suddenly released by movement along a plane of weakness. In some cases, fault movement propagates upward through the subsurface materials and causes displacement at the ground surface as a result of differential movement. Surface rupture usually occurs along

traces of known or potentially active faults, although many historic events have occurred on faults not previously known to be active.

The California Geologic Survey (CGS) establishes criteria for determining faults as active, potentially active or inactive. Active faults are those that show evidence of surface displacement within the last 11,000 years (Holocene age). Potentially active faults are those that demonstrate displacement within the past 1.6 million years (Quaternary age). Faults showing no evidence of displacement within the last 1.6 million years are considered inactive for most structures, except for critical or certain life safety structures. In 1972, the Alquist-Priolo Special Studies Zone Act (now known as the Alquist-Priolo Earthquake Fault Zoning Act, 1994) was passed into law, to prohibit the location of most structures for human occupancy across the traces of active faults and to thereby mitigate the hazard of fault rupture. The Alquist-Priolo Earthquake Fault Zoning Act requires the State Geologist to delineate Earthquake Fault Zones along known active faults in California, and provides policies for cities and counties to regulate developments within Earthquake Fault Zones.

Ground rupture caused by movement along a fault could result in catastrophic structural damage to buildings constructed along the fault trace. Consequently, the State of California via the Alquist-Priolo Special Studies Zone Act prohibited the construction of occupied "habitable" structures within the designated active fault zone. The term "structure for human occupancy" is defined as any structure used or intended for supporting or sheltering any use or occupancy, which is expected to have a human occupancy rate of more than 2,000 person-hours per year. Unless proven otherwise, an area within 50 feet of an active fault is presumed to be underlain by active branches of the fault. Local government agencies may identify additional faults, in addition to those faults identified by the State, for which minimum construction setback requirements must be maintained.

Several active and potentially active faults are located in the region. These include the Elysian Park fold and thrust belt, the Torrance-Wilmington fold and thrust belt, the Newport-Inglewood fault and the Santa Monica fault among others. The Palos Verdes Fault is located approximately four miles from the project area and is considered to have the most substantial effect on the site from a probabilistic design standpoint. In addition, other large faults in the Southern California area have the potential to affect the site. These include the San Andreas Fault, San Gabriel Fault and other undefined large blind thrust faults. However, based on the geotechnical report prepared by LGC Valley, Inc., no known active or potentially active faults underlie the project area. Therefore, the potential for surface ground rupture in the project area is low.

Potential for Ground Shaking. The energy released during an earthquake propagates from its rupture surface in the form of seismic waves. The resulting strong ground motion from the seismic wave propagation can cause significant damage to structures. At any location, the intensity of the ground motion is a function of the distance to the fault rupture, the local soil/bedrock conditions, and the earthquake magnitude. Intensity is usually greater in areas underlain by unconsolidated material than in areas underlain by more competent rock. Earthquakes are characterized by a moment magnitude, which is a quantitative measure of the strength of the earthquake based on strain energy released during the event. The magnitude is independent of the site, but is dependent on several factors, including the type of fault, rock-type, and stored energy. Moderate to severe ground shaking would be experienced in the project area if a large magnitude earthquake occurs on one of the nearby faults.

Ground shaking is primarily a function of the distance between a site and the seismic source, the type of materials underlying the site and the motion of fault displacement. The 1994 Northridge earthquake showed how peculiarities in basin effects could play a substantial role in ground accelerations at particular areas. For instance, ground accelerations exceeding 1.0 g were recorded at areas far from the epicenter of the Northridge earthquake.

The number or frequency of large magnitude earthquakes that may occur during the life of the project cannot be predicted. However, it is probable the project area will experience at least one major earthquake during the next 50 years.

d. Secondary Seismic Hazards from Ground Shaking. Potential hazards resulting from the secondary effects of ground shaking include: liquefaction, lateral spreading, seismic settlement, and earthquake induced landslides. Secondary hazards are discussed below.

<u>Liquefaction</u>. Soil liquefaction results from the temporary buildup of excess pore pressures, which can result in a condition of near zero effective stress and temporary loss of strength. Several factors influence a soil's potential for liquefaction during an earthquake, including magnitude and proximity of the earthquake; duration of shaking; soil types; grain size distribution; clay fraction content; soil density; particle angularity; effective overburden; location of the groundwater table; cyclic loading; and soil stress history. Saturated, loose to medium dense, near surface cohesionless soils exhibit the highest liquefaction potential, while dry, dense, cohesionless soils and cohesive soils exhibit low to negligible liquefaction potential. With increasing overburden, density and increasing clay content, the likelihood of liquefaction decreases. Liquefaction often occurs in earthquake prone areas underlain by young alluvium where the groundwater table is higher than 50 feet below ground surface.

Based on a review of the Seismic Hazard Zone Maps (CGS, 1999a, 1999b) for the Redondo Beach and San Pedro Quadrangles, the project area is not located within a Seismic Hazards Zone for Liquefaction. Previous geotechnical studies indicate the project area is underlain by ancient landslide deposits consisting generally of the Altamira Shale with lesser deposits of various surficial soils. The shale is not considered susceptible to liquefaction; however, the thin surficial soils may be susceptible. Based on the general distribution and interpreted thicknesses of surficial soils in the subject area, liquefaction potential in the project area is anticipated to be very low to nil.

<u>Lateral Spreading</u>. Lateral spreading, closely related to liquefaction, occurs when level or nearly level soil masses slide laterally on a liquefied layer and gravitational and inertial forces cause the layer and the overlying non-liquefied material to move toward a free face. The magnitude of lateral spreading movement depends on the magnitude of the seismic event, distance between the site and the seismic event, thickness of the liquefied layer, ground slope, fines content, average particle size of the materials comprising the liquefied layer, and the standard penetration rates of the materials. Because the project area is hilly and the potential for liquefaction is very low to nil, the potential for lateral spreading on the project area is also considered very low to nil.

Seismic Settlement. Seismic settlement occurs when cohesionless materials (sands) densify as a result of ground shaking. Uniform settlement beneath a given structure would cause minimal damage; however, because of variations in distribution, density, and confining conditions of the soils, seismic settlement is generally non-uniform and can cause serious structural damage. Dry and partially saturated soils as well as saturated granular soils are subject to seismic settlement.

The project area is underlain by ancient landslide material composed of Altamira Shale and locally thin surficial deposits such as non-marine terrace soils and colluvium or alluvium. Based on a review of LME applications and soils reports for the first 16 undeveloped lots completed to date, the foundations for the undeveloped lots will be founded into newly placed fill over landslide soils or directly into the landslide material. Based on those studies, the underlying landslide material would not be prone to settlement. Due to the minimal thickness of proposed engineered fill beneath foundations, the potential for seismically-induced settlement is very low.

Ground Lurching. Lurching occurs when certain soils have been observed to move in a wave-like manner in response to intense seismic ground shaking, thereby forming ridges or cracks on the ground surface. Areas underlain by thick accumulations of slopewash (colluvium) and alluvium are more susceptible than bedrock to ground lurching. Under strong seismic ground motion, lurching can be expected within loose, cohesionless soils, or in clay-rich soils with high moisture content. Generally, only lightly loaded structures such as pavement, fences, pipelines, and walkways are damaged by ground lurching; more heavily loaded structures appear to resist such deformation. Because deposits of loose terrace sands and slopewash were not indicated in geotechnical reports for proposed residential locations, ground lurching is not expected to occur.

Earthquake Induced Landslides and Rock Topple. Landslides occur when slopes become unstable and masses of earth material move down slope. Landslides are generally rapid events, often triggered during periods of rainfall or by earthquakes. Mudslides and slumps are typically more shallow types of landslides that affect the upper soil horizons, and are not bedrock features. Mudslides and slumps commonly occur during or soon after periods of rainfall, and rock fall and rock avalanches are common during large earthquakes.

The size of a seismically-induced landslide can vary from minor rock falls to large hillside slumps and avalanches. The underlying geology including bedrock bedding planes, degree of water saturation of a material, steepness of a slope and general strength of the soil all contribute to the stability of a hillside. Basal erosion caused by water or human-induced modifications to the natural contour of a hill, including grading, have the potential to aid in destabilizing a hillside during an earthquake.

The stability of a soil is influenced by many factors, including grain size, moisture content, organic matter content, degree of slope, and soil type. Unstable soils can be subject to landslides, debris flows, and rock falls. All of these phenomena are manifestations of gravity driven flows of earth materials due to slope instability. Hillsides naturally have a tendency to fail. Unless engineered properly, development in hillside areas tends to increase the potential for slope failures. Slope modifications by grading, changes in infiltration of surface water, and undercutting of slopes can create unstable hillsides, resulting in landslides or debris flows. Rock falls occur in virtually all types of rocks and especially on slopes steeper than 40 degrees where the rocks are weakly cemented, intensely fractured, or weathered. It should be noted that the addition of homes on the project area would not alter the potential for seismic slope failure. Rock fall landslides are commonly triggered by seismically-induced ground shaking. Rock topple involves the rotation of columns or blocks of rock about some fixed base, and rock topples can occur when these blocks of rock are subject to shaking during an earthquake. Generally, vertical or near vertical slopes are most subject to this process, however slopes with a gradient greater than 3:1 (horizontal to vertical) are more susceptible to rock topple than slopes of lower angles. A ground acceleration of at least 0.10 g in steep terrain is necessary to induce earthquake-related rock falls, although exceeding this value does not guarantee that rock falls will occur (Wilson and Keefer, 1985). Steep terrain does occur north and west of Zone 2 and, based on the local rock types, terrain, and ground accelerations indicated in the LGC Valley report (2011) which exceed those indicated by Wilson and Keefer (1985), these areas may be subject to rock topple and rock fall during a seismic event.

As defined by the California Geological Survey, the project area is located within a Seismic Hazard Zone for earthquake induced landslides. The project area is within the boundaries of the APBL, and the area is upslope of the well investigated, studied and mapped ACL and PBL landslides. Depending on the intensity of seismic shaking, seismically-induced landsliding could occur in the project area if ground shaking is very high. The probability of seismically-induced landslides is considered moderate (LGC Valley, Inc. 2011).

e. Geotechnical Hazards.

Expansive Soils. Expansive soils swell or heave with increases in moisture content and shrink with decreases in moisture content and clays are most susceptible to expansion. Foundations for structures constructed on expansive soils require special design considerations (CBC, 2008). Within the Zone 2 area, the upper area soils consist of fill, colluvium, and landslide material that contain expansive soils. Laboratory testing performed as a part of individual lot investigations indicated the expansion potential is medium to high (LGC Valley, Inc. 2011).

Hydroconsolidation. Hydroconsolidation occurs when soil layers collapse (settle) when water is added under loads. Natural deposits susceptible to hydroconsolidation are typically aeolian, alluvial, or colluvial materials, with high apparent strength when dry. The dry strength of the materials may be attributed to the clay and silt constituents in the soil and the presence of cementing agents (i.e., salts). Capillary tension may tend to act to bond soil grains. Once these soils are subjected to excessive moisture and foundation loads, the constituency, including soluble salts or bonding agents, is weakened or dissolved, capillary tensions are reduced and collapse occurs, resulting in settlement. The site is predominantly underlain by dense bedrock-derived landslide deposits, and surficial soils are relatively thin and anticipated to be removed prior to construction of single-family homes; therefore, the potential for hydroconsolidation is considered very low.

Subsidence and Settlement. Subsidence is the sinking of the ground surface caused by the compression of soil layers. This may be caused by groundwater, oil or gas withdrawal, oxidation of organics, or the placement of additional fill over compressible layers.

Layers susceptible to compression settlement can be exacerbated by increased loading, such as from the construction of buildings or the placement of additional fill over compressible layers. Settlement can also result solely within improperly placed artificial fill and structures built on soils or bedrock materials with differential settlement rates. Settlement can be mitigated prior to development through the removal and recompaction of loose soils, and proper placement of engineered fill during site grading.

Slope Stability. Slope stability refers to the relative stability of a slope in terms of driving forces versus resisting forces. If the driving forces are greater than the resisting forces, the slope will move or fail in the down slope direction. If the resisting forces are greater than the driving forces, the slope will not move but remain in a state of stability. If the forces are equal, the slope is on the verge of failure.

The standard of practice in Southern California is to achieve a factor of safety in which the resisting forces are 1.5 times greater than the driving forces (factor of safety of 1.5). The purpose of achieving a factor of safety of 1.5 is to account for those portions of the data set that are inconsistent or poorly understood. In this way, a "safety factor" is applied to the slope being reviewed.Generally speaking, a factor of safety of 1.5 is the condition to achieve for development projects on slopes in the project area. However, based on past studies of the area, the site has a range of slope stability factors of safety due to the various methods of analysis performed by various reviewers. These are discussed further below.

Gross Slope Stability. The geotechnical report prepared by LGC Valley, Inc. included a review of geotechnical studies, investigations, and reviews of the APBL, PBL, and ACL by numerous geotechnical professionals who determined the factor of safety of the ancient and active landslides within the project area based on their data set and methods of analysis. Because of the abundance and diversity of data along with variable interpretation of the data, there are varying opinions regarding the overall stability within Zone 2. These opinions range from the area being at unity (i.e., factor of safety at or just below 1.0) (GeoKinetics 2007), a factor of safety that is probably greater than 1.0 and less than 1.5 (Cotton Shires 2001) to a factor of safety of greater than 1.5 (Leighton, 2001 and 2006).

The primary factors used in determining a factor of safety for a site are: the profile of the ground surface; the geologic structure of the underlying bedrock or soils; the groundwater table; and the strength of the soil column, plus the method of analysis. Secondary factors are also considered. For the project area, these include: previous earthwork and redistribution of land mass; erosion along the beach zone and a reduction in support to up-slope areas; and control of run-off and potential infiltration of water into the slide mass through ground fractures and other avenues.

Based on the review by LGC Valley, Inc., there appears to be general agreement among geologists and geotechnical engineers who have studied the topography of the area regarding groundwater levels used in the slope stability analyses, the strength of the various soil units, the general location of the various rupture surfaces and the overall structure of site bedrock at depth. There is also general consensus that erosion along the beach zone contributes to instability, that instability generally decreases away from the beach zone and that control of groundwater is fundamental for minimizing long term instability. Further, there is additional agreement between the various reviewers that any future development that may occur in the geologic hazard area should be bound by a set of conditions that range from becoming a part of the community abatement district to the control of run-off from roofs.

Thus, based on LGC Valley's work, the item most in contention did not include the fundamental parameters into which a slope stability analysis is considered. Rather it was the method of analysis that created the greatest disparities between various geotechnical firms and reviewers. These methods are complex and premised in a deep understanding of soil behavior and the complex interactions that occur between rock, soil, water, discontinuities (known, and predicted) and gravity. Thus, there are various ways of interpreting and combining the geologic data, to obtain a range of conclusions regarding site stability, from site failure (factor of safety less than 1.0) to stable (factor of safety of 1.0 or greater). Based on their review and geotechnical expertise, LGC Valley, Inc. concluded that site slope stability is likely somewhere higher than 1.0, but less than 1.5. This conclusion is based on: (1) the fact that, with the exception of the eastern end of Zone 2, much of the Zone 2 area of review is not moving or not moving at a rate that would be considered due to deep-seated ancient landslide movement (creep, expansive soils and other factors may be at play); (2) soil strengths of the weakest layers, the configuration of the geology and the shape of the land; and (3) the fact that the area is atop the APBLC and thus has a history of movement, which suggests that it could move again. The location atop an already failed landslide suggests that the factor-of-safety is roughly 1.25, which is a common result after reviewing landslide movement after failure and is a typical starting point for beginning landslide relative slope stability analysis. It should be noted that this conclusion is predicated on a number of downhill factors that could result in movement in this area should they "fail" over time. However, the probability of failure is considered low since numerous measures are in place and proposed to help achieve a positive, non-failing result (the primary one being keeping groundwater levels low).

LGC Valley, Inc. also concludes that the development of the 31 undeveloped lots in Zone 2 would not have a negative effect on the overall stability of the ancient or active landslides or the remainder of Zone 2, provided that development on the lots is designed within the guidelines of the conditions of approval and in accordance with the city of Rancho Palos Verdes and the latest adopted building codes, and provided additional measures with respect to control of groundwater, reduction in infiltration of water and limiting of earth grading are taken into consideration during development.

Surficial Slope Stability. Surficial failures consist of a variety of failures ranging from shallow slumps to debris flows. Generally, debris flows are a mixture of water-saturated soil that moves down slope, while slumps do not mix much but move as a more intact piece of soil. Surficial landslide failures form when generally loose masses of poorly consolidated soil or weathered bedrock become saturated and then become unstable due to the increase in pore pressure along the soil/rock interface, the increase in weight to the soil from water and a decrease in the soil's strength, which reduces the soil's ability to resist the driving forces. Typically, these events occur during or shortly after periods of long duration and/or high intensity rainfall. Surficial slope stability may be a potential hazard to some of the proposed home sites in the project area due to the presence of small local slopes on individual lots that would need to be assessed and remediated on a case-by-case basis.

f. Regulatory Setting

Public Resources Code, Section 2621. The Alquist-Priolo Act of 1972 (now the Alquist-Priolo Earthquake Fault Zoning Act, Public Resources Code 2621, Division 2, Chapter 7.5) established criteria and policies to assist cities, counties, and State agencies in the exercise of their responsibility to prohibit the location of developments and structures for human occupancy across the trace of active faults, as defined by the State Mining and Geology Board. Under the Act, the State Geologist is required to delineate active faults ("special study zones") in California and the State Mining and Geology Board provides regulations to guide cities and counties in their implementation of the law. The Act also requires that, prior to approval of a project, a geologic study be conducted to define and delineate any hazards from surface rupture. Unless proven otherwise, the area within 50-feet of an active fault is presumed to be underlain by active branches of the fault. As discussed above, the project area is not located in an Alquist-Priolo Earthquake Fault Zone.

Other State Regulatory Requirements. State Government Code requires cities and counties to adopt and enforce the Uniform Building Code (UBC). The City has adopted the California Building Code (CBC), 2016 Edition (Part 2 of Title 24 of the California Code of Regulations), including Chapter 1 and Appendices F,and J, which incorporates and amends the International Building Code, 2015 Edition, published by the International Code Council, as the Building Code of the City of Rancho Palos Verdes. The project area would be subject to Public Resources Code Section 2699, which directs cities to take into account the information provided in available seismic hazard maps when it adopts or revises the safety element of any land-use planning or permitting ordinances. The Department of Conservation, Division of Mines and Geology, Special Publication a117Aa sets forth guidelines under the Geologic Hazards Mapping Act for evaluating and mitigating seismic hazards. Recommendations for mitigating landslide hazards are included in this publication and may be used in the project area, as necessary.

Rancho Palos Verdes General Plan. The City of Rancho Palos Verdes General Plan (2018) includes the following policies for public health/safety related to the natural environment:

1. *Permit development within the Sea Cliff Erosion Area (RM1), only if demonstrated through detailed geologic analysis, that the design and setbacks are adequate to insure public safety and to maintain physical, biologic, and scenic resources. Due to the sensitive nature of RM 1, this area is included as an integral part of the Coastal Specific Plan.*
2. *Allow only low intensity activities within Resource Management Districts of extreme slopes (RM 2).*
3. *Require any development within the Resource Management Districts of high slopes (RM 3) and dormant landslide area (RM 5) to perform at least one, and preferably two, independent engineering studies concerning the geotechnical, soils, and other stability factors (including seismic considerations) affecting the site following established geological industry standards.*
4. *Require a more detailed definition of the limits and composition of any Resource Management District when reviewing any development proposal that contains one or more Resource Management District.*
5. *Develop and enforce a grading ordinance with detailed controls and performance standards to insure both engineering standards and the appropriate topographic treatment of slopes based upon recognized site planning and landscape architecture standards.*

6. *Prohibit activities that create excessive silt, pollutant runoff, increase canyon wall erosion, or potential for landslide, within Resource Management Districts containing hydrologic factors (RM 6).*

The Rancho Palos Verdes General Plan (2018) also includes the following policy for Flood Control/Storm Drain System:

47. *Require that all flood control/natural water source interfaces and systems minimize erosion.*

<u>Landslide Moratorium Ordinance</u>. The project area is within the 1,200-acre Landslide Moratorium Area (LMA), established in 1978 in response to potential unstable soil conditions and active landslide movement (Chapter 15.20 of the Rancho Palos Verdes Municipal Code). In general, properties within the LMA that are currently developed with residential structures are permitted to make limited improvements if the City grants a Landslide Moratorium Exception (LME). New construction (except for the 16 Monks lots) is not permitted on properties in the LMA that are not currently developed with residential structures. A Moratorium Exclusion (ME) may be requested, and if granted, effectively removing the properties from the LMA. As discussed in Section 2.0 *Project Description*, the proposed project would amend this chapter of the Municipal Code to allow the 31 undeveloped lots within Zone 2 to be developed by amending Exception Category "P".

<u>Rancho Palos Verdes Municipal Code</u>. The California Building Code (2016 Edition) was adopted by the City as the Building Code of the City of Rancho Palos Verdes (see Section 15.04.010 of the Municipal Code - Building Code adopted of the City's Municipal Code).

Section 15.20.050 of the RPVMC requires appropriate landslide abatement measures as conditions of a landslide moratorium exception permit within the landslide moratorium area. Conditions imposed by the City shall include, but not be limited to, the following:

A. *If lot drainage deficiencies are identified by the director of public works, all such deficiencies shall be corrected by the applicant.*
B. *If the project involves additional plumbing fixtures, or additions of habitable space which exceed two hundred square feet, or could be used as a new bedroom, bathroom, laundry room or kitchen, and if the lot or parcel is not served by a sanitary sewer system, septic systems shall be replaced with approved holding tank systems in which to dispose of on-site waste water. The capacity of the required holding tank system shall be subject to the review and approval of the city's building official. For the purposes of this subsection, the addition of a sink to an existing bathroom, kitchen or laundry room shall not be construed to be an additional plumbing fixture. For those projects which involve additions of less than two hundred square feet in total area and which are not to be used as a new bedroom, bathroom, laundry room or kitchen, the applicant shall submit for recordation a covenant specifically agreeing that the addition of the habitable space will not be used for those purposes. Such covenant shall be submitted to the director for recordation prior to the issuance of a building permit. For lots or parcels which are to be served by a sanitary sewer system on or after the effective date of the ordinance codified in this section (July 6, 2000), additional plumbing fixtures may be permitted and the requirement for a holding tank may be waived, provided that the lot or parcel is to be connected to the sanitary sewer system. If a sanitary sewer*

system is approved and/or under construction but is not yet operational at the time that a project requiring a landslide moratorium exception permit is approved, the requirement for a holding tank may be waived, provided that the lot or parcel is required to be connected to the sanitary sewer system pursuant to Section 15.20.110 (Required Connection to Operational Sanitary Sewer System) of this chapter, or by an agreement or condition of project approval.

C. *Roof runoff from all buildings and structures on the site shall be contained and directed to the streets or an approved drainage course.*

D. *If required by the city geotechnical staff, the applicant shall submit a soils report, and/or a geotechnical report, for the review and approval of the city geotechnical staff.*

E. *If the lot or parcel is not served by a sanitary sewer system, the applicant shall submit for recordation a covenant agreeing to support and participate in existing or future sewer and/or storm drain assessment districts and any other geological and geotechnical hazard abatement measures required by the city. Such covenant shall be submitted to the director prior to the issuance of a building permit.*

F. *If the lot or parcel is not served by a sanitary sewer system, the applicant shall submit for recordation a covenant agreeing to an irrevocable offer to dedicate to the city a sewer and storm drain easement on the subject property, as well as any other easement required by the city to mitigate landslide conditions. Such covenant shall be submitted to the director prior to the issuance of a building permit.*

G. *A hold harmless agreement satisfactory to the city attorney promising to defend, indemnify and hold the city harmless from any claims or damages resulting from the requested project. Such agreement shall be submitted to the director prior to the issuance of a building permit.*

H. *The applicant shall submit for recordation a covenant agreeing to construct the project strictly in accordance with the approved plans; and agreeing to prohibit further projects on the subject site without first filing an application with the director pursuant to the terms of this chapter. Such covenant shall be submitted to the director for recordation prior to the issuance of a building permit.*

I. *All landscaping irrigation systems shall be part of a water management system approved by the director of public works. Irrigation for landscaping shall be permitted only as necessary to maintain the yard and garden.*

J. *If the lot or parcel is served by a sanitary sewer system, the sewer lateral that serves the applicant's property shall be inspected to verify that there are no cracks, breaks or leaks and, if such deficiencies are present, the sewer lateral shall be repaired or reconstructed to eliminate them, prior to the issuance of a building permit for the project that is being approved pursuant to the issuance of the moratorium exception permit.*

K. *All other necessary permits and approvals required pursuant to this code or any other applicable statute, law or ordinance shall be obtained.*

4.5.2 Environmental Impact Analysis

a. Methodology and Thresholds of Significance. This evaluation is based in part on the geotechnical evaluation of the project area that was conducted by LGC Valley, Inc. This document is available in its entirety in Appendix D.

It should be noted that the proposed project’s impacts in the following issue areas were found to be less than significant in the Initial Study (see Appendix A):

- *Rupture of a known earthquake fault*
- *Seismic-related ground failure, including liquefaction*
- *Soils incapable of adequately supporting the use of septic tanks*

Because impacts related to these issues were found to be less than significant in the Initial Study, further discussion of these issues in the EIR is not warranted. Therefore, this EIR analysis focuses on potential impacts related to:

- *Strong seismic ground shaking*
- *Landslides*
- *Soil erosion or the loss of topsoil*
- *The potential to be located on a geologic unit or soil that is unstable as a result of the project, and potentially result in lateral spreading, subsidence, liquefaction, or collapse*
- *The potential to be located on expansive soils, creating substantial risks to life or property*

The proposed project's impact is considered potentially significant if it would directly or indirectly cause potential substantial adverse effects involving strong seismic ground shaking, landslides, seismic-related ground failure, seismically-induced landslides, and soil hazards such as expansive soils, based on regional or site-specific conditions.

b. Project Impacts and Mitigation Measures.

Impact GEO-1 **Seismically-induced ground shaking could result in the exposure of people and structures that could be introduced to the area as a result of the proposed ordinance revisions to adverse effects. However, mandatory compliance with applicable CBC requirements would reduce impacts to a Class III, *less than significant*, level.**

Given the highly seismic character of the Southern California region and the project area's proximity to known active and potentially active faults, severe ground shaking is anticipated during the life of the new residences that could be built under the proposed ordinance revisions. As discussed in *setting* above, several active and potentially active faults are located in the region. These include the Elysian Park fold and thrust belt and the Torrance-Wilmington fold and thrust belt, the Newport-Inglewood fault and the Santa Monica fault, among others. The Palos Verdes Fault is located approximately four miles from the project area and is considered to have the most substantial effect on the site from a probabilistic design standpoint. No known active or potentially active faults underlie the project area. However, earthquakes along any of the faults in the region could potentially damage buildings and pose risks to human health and safety. Any new construction of habitable structures that could be facilitated by the proposed ordinance revisions would be required to comply with CBC standards. CBC standards require that structures are built to resist forces generated by ground shaking during an earthquake. With mandatory compliance with CBC standards, impacts from ground shaking would be less than significant.

Mitigation Measures. Impacts would be less than significant without mitigation.

Significance after Mitigation. Impacts would be less than significant.

Impact GEO-2 **Construction on individual lots in Zone 2 facilitated by the proposed ordinance revisions could cause or accelerate erosion, such that slope failure could occur. Operation of the project, which would allow for 31 single-family homes to be developed in the project area, could potentially cause or accelerate downstream erosion. However, with implementation of Mitigation Measure HWQ-1 and Mitigation Measure HWQ-3(a and b) identified in Section 4.8, *Hydrology and Water Quality*, impacts would be Class II, *less than significant with mitigation incorporated.***

During construction of individual residences, topsoil would be exposed and potentially removed from individual properties. The exposure or removal of topsoil could cause accelerated erosion on the project area. Topsoil eroded from the project area would be retained in stormwater that drains into Altamira Canyon. This soil would become sediment and result in sedimentation downstream of the project area. Construction impacts would be potentially significant.

Over the longer term, changes to surface hydrology could potentially occur in portions of the project area, which may be caused by increased impervious surfaces on individual lots, modified runoff patterns, or inadequate drainage facilities. Adverse surface drainage could cause or accelerate erosion, which could undermine proposed structures and lead to surficial slope failures on either manufactured or natural slopes.

In addition, any increase in runoff from the subject lots could increase drainage into Altamira Canyon. Altamira Canyon, a natural drainage course that traverses the Zone 2 area, currently experiences erosion due to runoff from the existing areas that are tributary to the canyon. A number of factors currently contribute to erosion in Altamira Canyon, including the steep gradient of the canyon, storm and operational runoff from existing developments within the watershed, and the types of soil within the streambed.

Development of the 31 lots would result in an increase in impervious area, and consequently, an increase in runoff rates and volume. The increase in impervious area would result in a change in the water balance in the project area. While the total rainfall for any given storm will remain constant, the increase in runoff would result in a corresponding reduction in infiltration in the project area. As discussed in Section 4.8 *Hydrology and Water Quality*, the increase in peak runoff rates as a result of cumulative development of the 31 lots for the design storm events (10-, 25-, 50-year, and Capital Storm) ranges from 0.5% to 1% for the entire watershed and 2.9% to 4.5% for the project area (Zone 2) (see Table 4.8-1 and Table 4.8-2). Thus, based upon the total runoff quantities and the proposed project's relatively small contribution to the overall amount of runoff into Altamira Canyon that is a factor in the ongoing erosion, impacts due to the project would be less than significant with the mitigation identified below. These measures would minimize increases in the quantity, duration, and frequency of runoff through the use of detention facilities and the application of low impact development principles in the development of the lots, such as, but not limited to, detaining peak flows and use of cisterns, bio-retention areas, green roofs (which are roofs with vegetation and a growing medium, planted over a waterproofing membrane), and permeable hardscape. With release of runoff from the Zone 2 lots in a controlled manner, Altamira Canyon would experience little or no measurable incremental increase in erosion directly attributable to the 31 lots.

It should be noted that, because Altamira Canyon currently experiences erosion and will continue to experience erosion with or without adoption of the proposed ordinance revisions, the City has explored other measures to address the existing erosion as part of the Final Feasibility Study for the Portuguese Bend Landslide Complex (July 2018) prepared for the City by Daniel B. Stephens & Associates, Inc. As discussed in detail in Section 4.8, *Hydrology and Water Quality*, that study addresses land movement and slope failure issues in the area and identifies a number of technologies as options for achieving storm water control and groundwater extraction to achieve manageable and sustainable land stability. The study was adopted by the City and the Public Works Department is in the process of implementing the study's recommendations.

The hydrologic analysis conducted as part of the Drainage Report (Appendix E) performed for the project was aimed at determining the overall hydrological impact of buildout in Zone 2. Each of the individual property owners would need to prepare a detailed hydrologic analysis to demonstrate compliance with the mitigation measures listed below. The mitigation measures address individual site development impacts due to flooding and erosion. Although some portion of the project area currently experience flooding and erosion issues during periods of heavy precipitation, future project area development is responsible for mitigating only its incremental increase in flooding and erosion, not for mitigating for existing conditions that are the result of past project area developments. While it may be desirable to resolve the site flooding and erosion in Altamira Canyon and other natural drainage courses, this existing condition affecting the larger area would need to be addressed separately from these proposed ordinance revisions.

<u>Mitigation Measures</u>. All project area development would be required to comply with the Chapter 18.50 of the RPVMC, which includes water-efficient landscape standards intended to promote water conservation. The standards would limit water runoff and infiltration by limiting irrigation requirements. In addition, Mitigation Measure HWQ-1 in Section 4.8, *Hydrology and Water Quality*, would be required to reduce erosion during construction to a less than significant level. In addition, pursuant to Mitigation Measure HWQ-3<u>(a and b)</u> in Section 4.8, *Hydrology and Water Quality*, each individual developer would be required to comply with the following, pursuant to the review and approval by the City Building Official:

- *Illustrate that point flow on each of the properties is either normalized, attenuated adequately, or will reach an acceptable conveyance such as a storm drain, channel, or natural drainage course. All runoff shall be directed to an acceptable conveyance and shall not be allowed to drain to localized sumps or catchment areas with no outlet.*
- *Maintain existing drainage patterns and outlet at historical outlet points*
- *Minimize changes to the character of the runoff at property lines. Changes in character include concentration of flow outletting onto adjacent properties or increasing the frequency or duration of runoff outletting onto adjacent properties*
- *Reduce increases in runoff by utilizing appropriate and applicable low impact development principles such as, but not limited to, detaining peak flows and use of cisterns, bio-retention areas, green roofs and permeable hardscape*
- *Provide on-site detention facilities or conveyance to acceptable off-lot conveyance devices*
- *Minimize "Dry Weather" runoff which could add to the total infiltration from the project*

Significance After Mitigation. Impacts would be less than significant with implementation of measures HWQ-1 and HWQ-3(a and b) in Section 4.8, *Hydrology and Water Quality*. These measures reduce the volume and velocity of runoff from the project area, which in turn reduces the potential for soils to erode and become retained in runoff.

Impact GEO-3 **The project area is located on a geologic unit that could be unstable or could potentially become unstable as a result of development facilitated by the proposed ordinance revisions. With implementation of mitigation measures GEO-3(a) and GEO-3(b), impacts would be Class II, *less than significant with mitigation incorporated.***

The project area and surrounding areas are within the boundaries of the APBL and the area is upslope of the well investigated, studied and mapped Abalone Cove and Portuguese Bend landslides. In addition, as discussed in the *Setting*, the project area is within an identified earthquake-induced landslide area. The underlying bedrock bedding planes, groundwater level, steepness of slope, and shear strengths of the soils all influence the stability of the hillsides in the project area. Lateral erosion caused by natural or human-induced modifications to the contour of a hill, which includes grading, have the potential to destabilize a hillside. As discussed in the *Setting*, the standard of practice in Southern California is to achieve a factor of safety in which the resisting forces are 1.5 times greater than the driving forces (factor of safety of 1.5). However, the slope stability in the project area is likely between 1.0 and 1.5. Therefore, the 1.5 factor of safety standard is not met. As a result, structures constructed on these slopes could potentially succumb to slope failure or structural damage. Impacts could extend to surrounding off-site structures depending on the size of the slope instability. Impacts would be potentially significant.

Grading for residences and accessory structures would be required to adhere to grading practices as outlined in the County of Los Angeles and City of Rancho Palos Verdes grading ordinances in order to address issues specific to each lot's surficial slope stability. Due to the unique circumstances in the project area, impacts related to large deep-seated landslides would be potentially significant and further mitigation in terms of ground water control is warranted.

As discussed in Section 4.8, *Hydrology and Water Quality*, portions of the additional runoff that would be added to the existing drainage system for the project area would be directed to Altamira Canyon. Groundwater recharge is a landslide concern because an increase in infiltration could affect the stability of existing landslides in the project area and vicinity. Adding water to the landslide material adds weight, creates buoyancy, and further reduces clay strength on the existing slopes, which could lead to slope failure. However, the portions of Altamira Canyon that would receive drainage from the project area are generally steep, and as such do not contribute substantially to groundwater recharge as water moves quickly over the land surface, minimizing infiltration. Therefore, the incremental increase in surface water from the project area as a result of the development of an additional 31 lots would not substantially increase infiltration in Altamira Canyon or related effects on landslide potential (LGC Valley, Inc. 2011). Because adding impervious surfaces in the project area would reduce infiltration on the subject lots, that aspect of the potential new development would not contribute to groundwater-related landslide concerns.

Mitigation Measures. Mitigation measures GEO-3(a) and GEO-3(b) would be required to address impacts related to soil instability and landslides.

GEO-3(a) **Geotechnical Recommendations.** Prior to issuance of any grading permit or building permit, individual project applicants shall comply with all recommendations contained in the Geotechnical Study prepared by LGC Valley, Inc., dated March 29, 2011, including the following, which shall be reflected in the geotechnical/soils reports for individual projects:

- *Conform to applicable requirements of the City of Rancho Palos Verdes Landslide Moratorium Ordinance (Rancho Palos Verdes Municipal Code Chapter 15.20.050), some of which are outlined below.*
- *Limit grading to less than 1,000 cubic yards (cut and fill combined including export and import) per lot, with no more than 50 cubic yards of imported fill per lot and 1,000 cubic yards of export.*
- *Agree to participate in the Abalone Cove Landslide Abatement District and/or other recognized or approved districts whose purpose is to maintain the land in a geologically stable condition. No proposed building activity may cause lessening of stability in the zone.*
- *Submit a geotechnical report to the City indicating what, if any, lot-local and immediately adjacent geologic hazards must be addressed and/or corrected prior to, or during construction. Said report shall specify foundation designs based on field and laboratory studies and must be approved by the City's geotechnical reviewers.*
- *Limit post-construction lot infiltration and runoff rates and volume to pre-construction levels through use of appropriate low impact development principles such as, but not limited to, detaining peak flows and use of cisterns, holding tanks, detention basins, bio-retention areas, green roofs, and permeable hardscape.*
- *Connect all houses to a public sanitary sewer system and maintained at the property owner's expense. Any necessary easements shall be provided.*
- *Correct all lot drainage deficiencies, if any, identified by the Director of Public Works.*
- *Collect runoff from all buildings and paved areas not infiltrated or retained/detained on-site to match existing pre-construction conditions and direct runoff to the street or to an approved drainage course as approved by the Director of Public Works.*
- *Comply with all other relevant building code requirements.*

GEO-3(b) **Covenant.** Individual project applicants shall submit for recordation a covenant agreeing to construct the project strictly in accordance with the approved plans and agreeing to prohibit further development on the subject site without first filing an application with the Director pursuant to the terms of Chapter 15.20 of the RPVMC. Such covenant shall be submitted to the Director for recordation prior to the issuance of any grading or building permit.

Significance After Mitigation. Impacts would be reduced to below a level of significance under CEQA with implementation of mitigation measure GEO-3(a) and GEO-3(b) and compliance with applicable requirements of the most recent CBC. With these requirements, although the 1.5 factory of safety standard likely cannot be met in all cases, development of the 31 undeveloped lots in Zone 2 would not have a negative effect on the overall stability of the ancient or active landslides or the remainder of Zone 2. Thus, development of the 31 lots would not exacerbate the overall landslide hazard in the project area and the environmental impact under CEQA would be less than significant.

Impact GEO-4 **The project area is in a Seismic Hazard Zone for earthquake-induced landslides. Therefore, project area development would inherently be subject to risks associated with seismically-induced landslides. However, with implementation of mitigation measures GEO-3(a) and GEO-3(b) requiring design of potential new construction on each lot in compliance with site-specific geotechnical recommendations, impacts would be Class II, *less than significant with mitigation incorporated.***

The project area is located in a Seismic Hazard Zone for earthquake-induced landslides. Seismic Hazard Zones are regulatory zones identified by the State of California that encompass areas prone to liquefaction and earthquake-induced landslides. In Seismic Hazard Zone areas, the state has determined that weak soil and/or rock may be present beneath the site. If present, these weak materials can fail during an earthquake and, unless proper precautions are taken during grading and construction, can cause damage to structures.

Landslides occur when slopes become unstable and masses of earth material move down slope. Landslides are generally rapid events, often triggered during periods of rainfall or by earthquakes. The size of a landslide can vary from minor slope scars to hundreds of acres of hillside land movement. The underlying bedrock bedding planes, groundwater level, steepness of a slope, and shear strengths of the soils all contribute to the stability of a hillside. The Palos Verdes Fault is located approximately four miles from the site and is considered to have the most substantial effect on the project area from a probabilistic design standpoint.
Although development of the 31 residences that could occur as part of the proposed project would not eliminate existing landslide hazards in the area, the possible exposure of development to an existing hazard is not a significant environmental effect under CEQA. Moreover, potential for seismically-induced landsliding would not change substantially with the addition of the 31 residences that would be accommodated in the project area. The 31 subject lots are primarily in areas of gentle slopes, whereas the seismic hazard concern is for the more steeply inclined areas. Grading quantities would be limited by the proposed ordinance revisions and any loose soils that are replaced with compacted fill could actually improve conditions. Nonetheless, depending on the intensity of seismic shaking, seismically-induced landsliding could occur in the project area during a seismic event, which is a potentially significant impact.

Mitigation Measures. Mitigation measures GEO-3(a) and GEO-3(b) above would be required to reduce impacts to a less than significant level. In particular, Mitigation Measure GEO-3(a) would require each applicant to submit a geotechnical report for review and approval by the City's geotechnical reviewers indicating any geologic hazards that need to be addressed and/or corrected prior to construction. In addition, Mitigation Measure GEO-3(b) would require each individual project applicant to record a covenant agreeing to construct the project strictly in accordance with the approved plans. Because each individual single-family residential site would be required to prepare a geotechnical report and would be required to construct the project strictly according to approved plans, potential seismically-induced landsliding effects would be addressed on a site-specific basis.

Significance After Mitigation. Impacts would be reduced to below a level of significance under CEQA with incorporation of mitigation measures GEO-3(a) and GEO-3(b). However, as discussed in the geotechnical study (LGC Valley, Inc. 2011), the project area will continue to have the potential for instability due to the presence of the Abalone Cove and Portuguese Bend landslides. Therefore, as is the case in any landslide prone area, development within the project area is subject to inherent risks associated with seismically-induced landslides.

Impact GEO-5 The project area is not susceptible to liquefaction, ground lurching, lateral spreading or seismic settlement. Impacts would be Class III, *less than significant*.

As discussed in *Setting*, the project area is underlain by ancient landslide material composed of Altamira Shale and locally thin surficial deposits such as non-marine terrace soils and colluvium or alluvium. The Seismic Hazard Zone maps for the Redondo Beach and San Pedro quadrangles show that the project area is not within a liquefaction zone. Liquefaction potential in the project area is very low (LGC Valley, Inc. 2011). Because the project area is not susceptible to liquefaction, the potential for lateral spreading is low.

Areas underlain by thick accumulations of slope wash and alluvium are more susceptible than bedrock to ground lurching. Under strong seismic ground motion, lurching can be expected within loose, cohesionless soils, or in clay-rich soils with high moisture content. Generally, only lightly loaded structures such as pavement, fences, pipelines, and walkways are damaged by ground lurching; more heavily loaded structures appear to resist such deformation. Because deposits of loose terrace sands and slope wash are not present in the project area, the potential for ground lurching is nil.

Based on a review of LME applications and soils reports for the first 16 undeveloped lots in the project area completed to date, the underlying landslide material in the project area would not be prone to settlement. Due to the minimal thickness of proposed engineered fill beneath foundations, the potential for settlement is low.

Design of the proposed structures in accordance with the provisions of the most recent CBC would minimize the potential effects of ground shaking. Therefore, adverse effects associated with liquefaction, ground lurching, lateral spreading and/or seismic settlement during a ground shaking event would not be expected. Impacts would be less than significant.

Mitigation Measures. Mitigation is not required.

Significance After Mitigation. Impacts would be less than significant without mitigation.

Impact GEO-6 Soils in the project area are moderately to highly expansive. With implementation of mitigation measures GEO-3(a) and GEO-3(b), impacts related to expansive soils would be Class II, *less than significant with mitigation incorporated.*

As discussed in *Setting*, expansive soils swell or heave with increases in moisture content and shrink with decreases in moisture content. Clays are most susceptible to expansion. Foundations for structures constructed on expansive soils require special design considerations (CBC, 2016). Within the Zone 2 area, the upper site soils consist of fill, colluvium, and landslide material that contain expansive soils. Laboratory testing performed as part of individual lot investigations indicates that expansion potential is medium to high (LGC Valley, Inc. 2011). Expansive soils could result in distress in the form of cracking and/or differential uplift of concrete footings and floor slabs when soils become wet. This distress would be localized and limited to the structures constructed on the expansive soils. Structures in the project area would be required to comply with the most recent California Building Code, which would reduce the potential for expansive soil effects. Nonetheless, impacts related to expansive soils would be potentially significant.

Mitigation Measures. Implementation of mitigation measures GEO-3(a) and GEO-3(b) would be required to reduce impacts related to expansive soils. Mitigation Measure GEO-3(a), as described above, requires that the project conform to the City of Rancho Palos Verdes Landslide Moratorium Ordinance, grade up to 1,000 cubic yards per lot, participate in ACLAD and/or other recognized or approved districts whose purpose is to maintain the land in a geologically stable condition, and submit a geotechnical report to the City's geotechnical reviewers prior to construction. Further, Mitigation Measure GEO-3(b) would ensure that these geotechnical report recommendations are actually implemented into the project by requiring individual project applicants to record a covenant agreeing to construct the project strictly in accordance with the approved plans. With implementation of the recommendations contained in the geotechnical report as required by Mitigation Measure GEO-3(a) and by constructing the project strictly according to approved plans as required by Mitigation Measure GEO-3(b), impacts related to expansive soils would be reduced to a less than significant level.

Significance After Mitigation. Impacts would be less than significant with implementation of mitigation measures GEO-3(a) and GEO-3(b).

c. Cumulative Impacts. Cumulative development in and around the City would include approximately 2,232 residences and 219,646 square feet of non-residential development, as shown in Table 3-1 in Section 3.0, *Environmental Setting*. Proposed development, in conjunction with other cumulative projects proposed in Rancho Palos Verdes and surrounding areas (including adjacent areas within the LMA), would expose people and property to seismically related hazards that are present throughout the region. Planned and pending projects would be subject to various geologic hazards that are site-specific in nature, but would not create additive effects that are cumulative in nature. Impacts related to slope stability, destabilization of hillsides due to excavation, landsliding, seismically induced ground shaking, liquefaction, soil settlement and expansive soils would be similar to what is described for the project and would be addressed on a project-by-project basis through compliance with existing building codes and any site-specific mitigation measures for individual projects. Compliance with applicable code requirements and the recommendations of site-specific geotechnical evaluations on a case-by-case basis would reduce cumulative impacts relating to geologic hazards to a less than significant level. Regarding erosion in Altamira Canyon, as discussed above, based upon the total runoff quantities and the proposed project's relatively small contribution to the drainage that is a factor in ongoing erosion, the project's contribution as mitigated would not be cumulatively considerable and project area development would not increase instability in adjacent areas.