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4.3 GEOLOGY AND SOILS

4.3.1 INTRODUCTION

This section provides a discussion of the existing geologic and soils environment and an analysis of potential impacts from implementation of the proposed project. This section also addresses the potential for structural damage to occur due to the local geology underlying the Long Beach Sports Park project site, as well as slope stability, ground settlement, soil conditions, grading, and regional seismic conditions. The following geology and soils information is based on a technical study titled, "Geotechnical Evaluation in Support of Conceptual Design and Environmental Impact Report, Long Beach Sports Park, South and West of Spring Street and Orange Avenue, Long Beach, California," prepared by AMEC Earth and Environmental, Inc. (2004). The Geotechnical Evaluation is available for review at the City of Long Beach, Community Development Department.

4.3.2 EXISTING ENVIRONMENTAL SETTING

Geologic Setting and Topography

The City of Long Beach is located on the coastal margin of the Los Angeles Basin, which is underlain by over 15,000 feet of stratified sedimentary rocks of marine origin. The project site is located in the northwestern extremity of the Peninsular Ranges geomorphic provinces, near the seaward edge of the Los Angeles coastal plain/sedimentary basin. The dominant physiographic feature in the vicinity of the project site is a ridge-like topographic high that extends for three miles across the Cities of Signal Hill and Long Beach, reaching a maximum elevation of approximately 340 feet at the crest of Signal Hill.

This topographic high is part of a northwest-trending alignment of low hills and mesas that extend across the Los Angeles Coastal Plain between Newport Beach and Beverly Hills. This alignment of local highlands is the topographic expression of uplift, deformation, and faulting that has occurred along the Newport-Inglewood structural/fault zone (Barrow 1974). Faulting and ground deformation associated with this structural zone are believed to have begun during the Pleistocene Age (i.e., approximately 11,000 to 2 million years ago) and continue to the present day (Poland, et al, 1956).

The Los Angeles coastal plain on the northeast side of the Newport-Inglewood structural/fault zone is underlain by Recent or Holocene age alluvial sediments (i.e., sediments deposited less than 11,000 years ago) with a typical thickness of about 100 to 200 feet. These alluvial sediments consist of sand, gravel, silt, and some clay that were deposited in layers by the Los Angeles, San Gabriel, and Santa Ana Rivers. The Recent alluvium is, in turn, underlain by a much thicker succession of sedimentary stratas and unconsolidated sediments of Pleistocene age that are locally up to 3,000 feet in thickness (Poland et al., 1956). Although these sediments tend to have a higher degree of consolidation and/or weak cementation, the composition is generally similar to that of the overlying alluvium. These deposits consist of interfingered layers and lenses of sand, silt, gravel and minor clay, which are believed to be fluvial and/or near-shore marine in origin (Poland, et al 1956).

Tectonic forces have uplifted Pleistocene age sediments (i.e., deposited approximately 11,000 to 1.6 million years ago) that are now exposed on several of the local highlands present along this structural zone, including the area of the proposed project site. Pleistocene deposits extend to depths on the order of 200 to 500 feet beneath the ground surface of the project site (Poland 1956). A thin mantle of Recent or Holocene age native deposits (i.e., deposited less than 11,000 years ago) is also present and covers the older uplifted sediments in some areas. These deposits are typically less than 5 to 10 feet in thickness and occur as a thin mantle of slopewash/colluvium on the slopes. A relatively narrow band of Holocene alluvium up to about 25 feet in thickness has also been observed beneath the now mostly-buried natural drainage course that crosses the central portion of the site.

Previous grading beginning at some time in the late 1800s and continuing to the present day has affected essentially the entire site. Undocumented fills with varying thickness/depth from less than a foot to about 70 feet cover most of the natural topography. Figure 4.3.1 shows the present topography of the site and locally named or identifiable points.

The area of uplift along the Newport-Inglewood Fault Zone is manifest in the vicinity of the project site as a gently sloping terrace level on the northeast side of the structural zone with steeper slopes on the southwest side. These steeper slope areas reflect the presence of steeply inclined faults or surfaces of displacement in the sediments. The youngest or most recent evidence of faulting on the project site is, therefore, present on the southwest side of “Exxon Hill” crossing the southwest corner of the project site. This fault segment within the Newport-Inglewood Fault Zone is known as the Cherry Hill Fault and is discussed in greater detail below.

Review of available historic topographic maps shows an ancient drainage course that meanders in a general northeast-to-southwest direction across the ridge-like high that forms the topography of the local area. The available physiographic evidence suggests that this is an antecedent drainage course that was established prior to Pleistocene uplift along the Newport-Inglewood Structural/Fault Zone (Poland, et al., 1956). The most likely source of ancient flow along this relatively narrow channel/drainage course was as a local outlet for episodic flooding of the coastal plain by the nearby Los Angeles and/or San Gabriel Rivers. This episodic scouring and downcutting allowed the drainage to maintain its course through tectonic uplift of the local topography. Structure contouring on the top of the Pleistocene deposits/base of the alluvium suggests that the bottom of the eroded channel beneath the alluvium has a high point near the center of the project site along the alignment of Exxon Hill and the adjacent highland to the northwest. The ground surface elevations shown on available regional topographic maps suggest that this channel has not likely carried significant flood flows during historic time.

The available historic topographic maps and aerial photographs between 1921 and 1964 show this drainage course crossing through the north-central portion of the project site. The channel forms an “S”-shaped meander that enters the project site at Spring Street on the north and exits at about the mid-point of the western boundary along California Avenue. Adjacent highlands on the west and east extend up to elevations of 80 to 100 feet, and the flowline of the drainage channel shown on available historic topographic maps ranges from an elevation of approximately 50 feet near Spring Street to an elevation of 30 feet near California Avenue. The highest point on the property is at Exxon Hill in the southeast quadrant of the project site, which originally extended to an elevation of approximately 145 feet (see Figure 4.3.1).

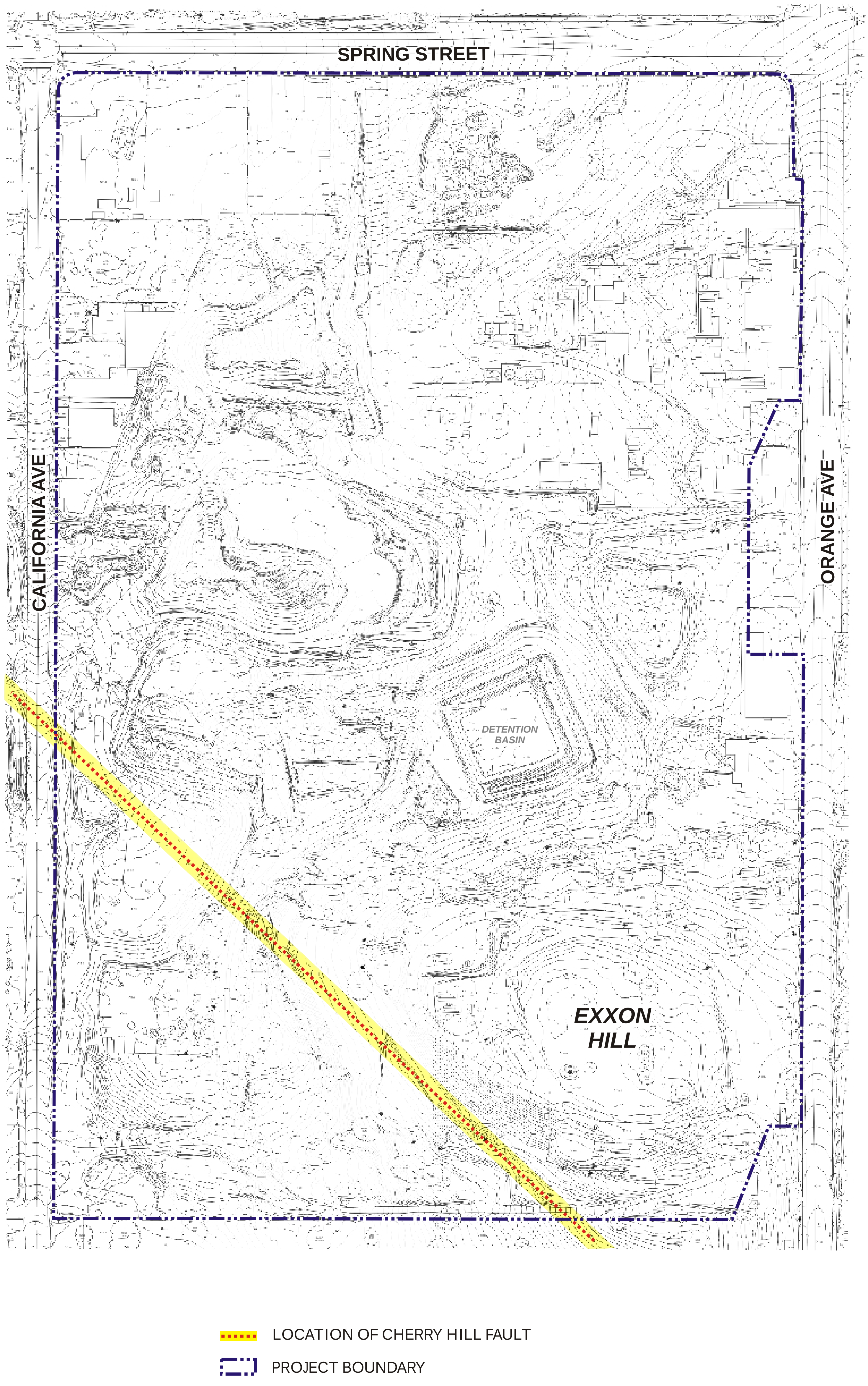

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FIGURE 4.3.1

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SOURCE: PBS&J

Long Beach Sports Park

Project Site Topography

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Previous Grading of the Project Site

The first significant grading of the project site appears to have occurred in 1891 in conjunction with construction of the "Los Angeles Terminal Railway" (Long Beach Water Department 1944). The rail line extended between Los Angeles and "east San Pedro" and was ultimately incorporated into the Union Pacific Railroad system. Review of a 1925 USGS topographic map indicates that the grading was accomplished by cutting or excavating a slot approximately 100 feet wide along a broad arc across the northwesterly portion of the project site. Grading for this portion of the rail line required construction of a narrow fill embankment across the drainage course that crossed through the center of the project site. This fill was presumably derived from the adjoining slot excavation to the north. Topographic maps indicate fill thickness up to about 30 to 35 feet was constructed in this area, presumably including installation of a culvert along the preexisting drainage course to carry surface drainage beneath the fill embankment. The remnant of the fill embankment for the railway is still present along the southwesterly extremity of the project site, but the original railway excavation has been obscured by subsequent fill placement.

In 1898, seven years after construction of the railroad, a 1.28-million-gallon reservoir was constructed on the project site by the Long Beach Development Company at the crest of what is now locally known as Exxon Hill (previously known as Reservoir Hill) (Long Beach Water Department 1944). The reservoir reportedly had an elevation of 144 feet and was designed as a circular concrete tank that was constructed in an excavation and/or was partially buried. No information is available regarding the service life of the reservoir tank, but historic aerial photographs indicate that by 1945 it was no longer being used for water storage. The concrete tank was demolished and removed from the site by the City of Long Beach Department of Oil Properties near the end of 2000 and the beginning of 2001. The current ground surface elevation of the former tank site is approximately 135 feet.

A second reservoir was constructed on the project site in 1909 at the site of wells that supplied the Long Beach townsite with water in the 1880s (Long Beach Water Department 1944). The reservoir was constructed by the Long Beach Water Company and had a capacity of 4.28 million gallons. The reservoir was constructed in the bottom of the drainage course that crossed the central portion of the site. Grading construction appears to have consisted of building fill embankments on the downstream and upstream sides of the planned reservoir, and then excavating an approximately square basin in the area between the embankments. Excavation of the basin area also appears to have included significant removals and steepening of the ascending slope on the southerly side of the reservoir. The bottom and walls of the excavated basin were lined with concrete to minimize uncontrolled outflow. The elevation contours indicate that the structure would have impounded surface drainage to the north, along the upstream portion of the previously existing drainage course. The difference in elevation between the top of the reservoir embankment and the adjoining flowline indicates up to 15 feet of water could potentially have been impounded upstream of the reservoir. Graphic notations on a 1921 survey plan show marshland varying in width from about 50 feet up to about 180 feet along the upstream portion of the drainage channel. The reservoir remained in service for about 20 years and was abandoned for use by the City Water Department around 1928. The reservoir structure was ultimately converted to a detention basin that is currently part of the regional storm water facilities.

The oil-producing potential of the Newport-Inglewood structural/fault zone was discovered in the early 1920s. Grading associated with the oil fields, which have been in continuous operation for about 80 years, included construction of roads, drill pads, building pads, sumps, and installation of numerous pipelines. This grading affected essentially the entire site to some degree, but the associated depth of excavation and thickness of fill does not appear to typically exceed 10 to 20 feet. In general, construction on the project site during this time period appears to have generally conformed to the existing ground contours. Associated grading, therefore, included primarily local redistribution of the earth materials present on site, and significant areas of imported fill are not apparent from the available historic documentation of the physiographic conditions.

Previous reports by Dames and Moore (3/30/88 and 5/18/88) and Pacific Soils Engineering (8/19/92) have indicated that demolition debris was placed on site from the 1933 Long Beach earthquake and possibly from the Hancock Oil Refinery fire in 1958. This information is reportedly based on personal recollections of people who live or work in the area. However, the available historic documentation and observations from extensive subsurface exploration of the project site do not support the conclusion that a significant volume of demolition debris was deposited on the property in the time frame 1925 to 1964. Recent discussions with Mr. Don Clarke, a Division Engineer with the City's Department of Oil Properties, indicate that previous recollections of earthquake demolition debris disposal may have confused the project site with the area adjacent to what is currently referred to as "Reservoir Hill," which is located about two miles away on the southeast side of Signal Hill. The area in the vicinity of this more recently named Reservoir Hill site was apparently used for disposal of demolition debris from the 1933 earthquake.

Until the late 1960s most of the grading on site appears to have primarily consisted of redistribution of materials present on the site, and significant areas of imported fill are not apparent from the available historic documentation (i.e., from historic aerial photos and topographic maps). However, subsequent to preparation of the USGS topographic map in 1968, significant quantities of imported fill appear to have been deposited in several areas of the project site. The most prominent of these fill areas include:

- Railway fill embankment constructed in 1891.
- Imported fill constructed by the Long Beach Water Department sometime between 1963 and 1972 prior to construction of overlying light industrial buildings in the east-central portion of the project site.
- Imported soils placed sometime between about 1963 and 1990 to fill the existing natural drainage course and the remnant of the railway slot excavation.
- Imported concrete and asphalt stockpile of demolition debris, and resulting crushed aggregate product on Sully Miller/Hansen leasehold.
- Imported fill stockpile placed by the Long Beach Water Department sometime between approximately 1990 and 1997 in the southwest-central portion of the project site.
- Imported fill stockpile placed by the Long Beach Water Department sometime between approximately 1990 and 2002, including partial filling of the remaining railway slot excavation in the northwest-central portion of the project site.
- Imported silica sand piles within and around the MacPherson Sandblasting leasehold.
- Concrete rubble stockpile on the old gas processing plant property, reportedly placed by Signal Hill Petroleum sometime between the late 1900s and the present.

The approximate location and extent of existing fill areas is shown on Figure 4.3.2. With the probable exception of the old railway embankment fill, these areas of existing fill appear to have been imported to the project site. Existing artificial fills at the project site generally consist of mixtures of sand, silt, and clay with scattered gravel and fragments of concrete.

In summary, existing fills cover much of the project site. Many of these fills were associated with redistribution of the on-site soils during previous oil field operations, and are typically less than 10 to 20 feet in thickness. However, during the more recent site history (i.e., after 1968) imported fill was placed in several areas of the site. No engineering documentation regarding construction, compaction, or other grading control of the existing fills is known to be available. The absence of any geotechnical control of the fill construction does not allow appropriate characterization of the engineering properties or of the anticipated future deformation potential of on-site fills.

Seismic Environment

Reasonably well established historic records of earthquakes in California have been compiled for approximately the past two hundred years. More accurate instrumental measurements have been available since 1933. As demonstrated by historic seismicity, earthquakes generated by displacement along nearby regional faults within an approximate 62-mile (100 kilometer) radius area are considered capable of generating ground shaking of engineering significance at a particular site. A summary of significant earthquakes (i.e., Magnitude 4.0 or greater) within a 62-mile radius of the project site has been compiled from the available historic records and is shown in Appendix D of the Geotechnical Evaluation prepared by AMEC.

Although there are some earthquakes in the earlier portion of the historic records that were larger, the most significant previous earthquake with regard to the project site was the magnitude 6.3 Long Beach Earthquake on March 11, 1933. This earthquake occurred along the Newport-Inglewood structural/fault zone at a location about 18 miles to the southeast, offshore from Newport Beach.

The project site is located approximately 48 miles southwest of the active San Andreas Fault Zone (Mohave Section). Other active or potentially active faults of seismic concern in the region include the Newport-Inglewood Fault Zone (Los Angeles Basin), the Palos Verdes Fault, the Whittier/Elsinore Fault System, the Compton Blind Thrust Fault, and the Elysian Park Blind Thrust Fault. Figure 4.3.3 shows the project site proximity to surrounding fault systems.

A fault is described as the area where two tectonic or continental plates meet. An “active” fault is defined by the State of California (Hart 1997) as having had surface displacement within the Holocene time (i.e., within the last 11,000 years). The San Andreas Fault, where the western Pacific plate meets with the eastern North American plate, is the State’s largest and most active fault. Seismologists have determined that the San Andreas Fault is moving at a rate of approximately two inches per year. A “potentially active” fault is defined as showing evidence of surface displacement during the Quaternary time (i.e., during the last 1.6 million years). These terms are, however, used by the State primarily for use in evaluating the potential for surface rupture along faults and are not intended to describe possible seismic activity associated with displacement along a fault. These definitions are not applicable to blind thrust faults that have only limited, if any, surface exposures. A brief discussion of each of the fault systems pertinent to the proposed project site is presented below.

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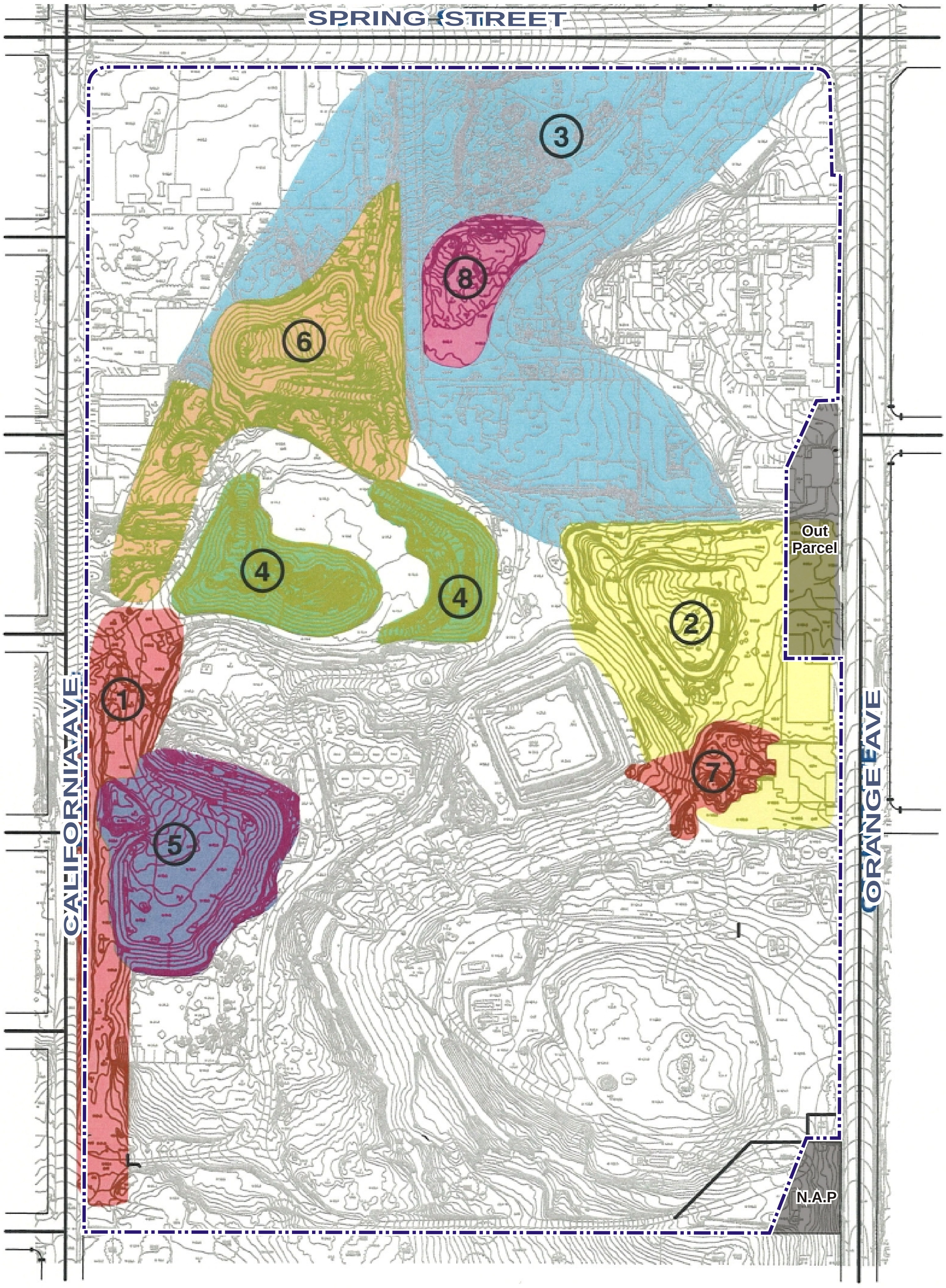

APPROXIMATE LOCATION AND EXTENT OF SIGNIFICANT FILL AREAS

Shallow fill ranging in depth from about 1 to 70 feet covers essentially the entire site. The delineated fills are considered significant because of their thickness and areal extent. With the probable exception of the old railway embankment (1), all of the delineated fill areas appear to be materials that were imported to the site

1. Railway fill embankment constructed in 1891 (LBWD, 1944).
2. Imported fill reportedly constructed by the Long Beach Water Department sometime between 1963 and 1972, prior to construction of overlying light industrial buildings.
3. Imported soils placed sometime between about 1963 and 1990 to fill the existing natural drainage course and the remnant of the railway slot excavation.
4. Imported concrete and asphalt stockpile of demolition debris, and resulting crushed aggregate product on Sully Miller/Hanson leasehold.
5. Imported fill stockpile reportedly placed by the Long Beach Water Department sometime between approximately 1990 and 1997.
6. Imported fill stockpile reportedly placed by the Long Beach Water Department sometime between approximately 1990 and 2002, including partial filling of the remaining railway slot excavation.
7. Imported silica sand piles within and around the MacPherson Sandblasting leasehold.
8. Concrete rubble stockpile on the old gas processing plant property, reportedly placed by Signal Hill Petroleum, Inc.

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PROJECT BOUNDARY

FIGURE 4.3.2

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SOURCE: PBS&J

Long Beach Sports Park

Areas of Existing Fill

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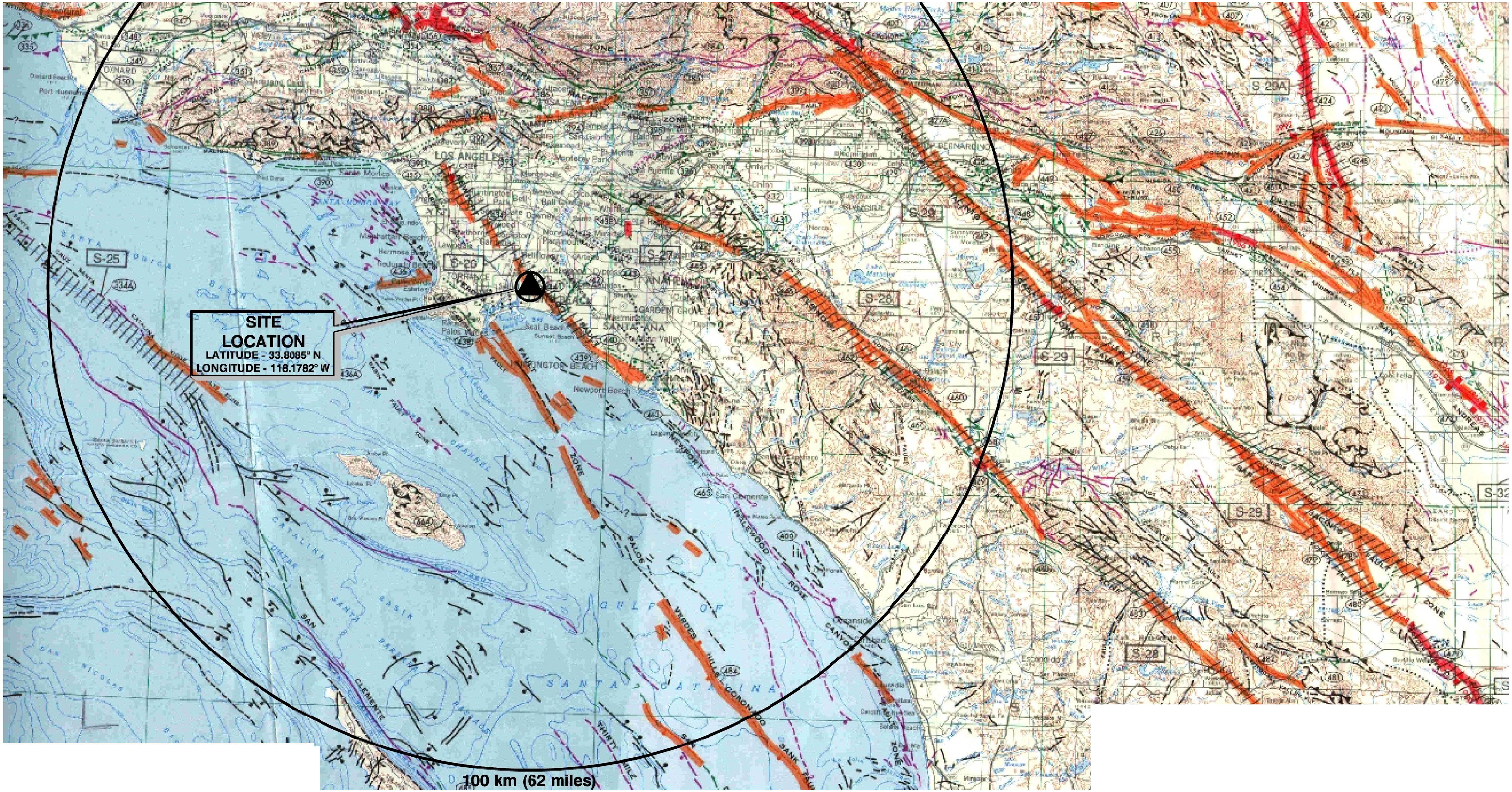

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FIGURE 4.3.3

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SOURCE: CDMG GEOLOGIC DATA MAP No.6 (JENNINGS, 1994)

Long Beach Sports Park
Fault Map

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Newport-Inglewood Fault Zone. The project site is located within a region that contains three primary traversing faults within the larger Newport-Inglewood Fault system, including the Cherry Hill Fault, the Northeast Flank Fault, and the Reservoir Hill Fault. This fault system is northwest-trending and generally right lateral. The fault consists of several near vertical breaks traceable from the Santa Monica Mountains, southeast to off-shore from Newport Beach. This zone of deformation extends offshore to the southeast, approximately paralleling the coastline. Individual faults at or near the surface within the zone form short, discontinuous, generally left-stepping patterns like the mapped trace of the Cherry Hill Fault that crosses the southwestern corner of the project site. The Cherry Hill Fault is considered the most recently active segment of the Newport-Inglewood Fault Zone in the immediate vicinity of the project site. Based on historic earthquakes and evidence of Holocene activity, the fault zone is considered active.

Palos Verdes Fault. The northwest-trending Palos Verdes Fault Zone is located about six miles southwest of the project site and extends from the Santa Monica Bay across the northeast side of the Palos Verdes Peninsula to a location offshore from San Clemente, a distance of about 60 miles. Holocene activity is indicated along this fault zone.

Whittier/Elsinore Fault System. The Whittier/Elsinore Fault System consists of several steep to near-vertical faults along a zone as much as one-half mile wide. The inferred sense of movement along these faults is predominately reverse slip west of the Chino area, and right lateral strike slip to the east. Offset of Holocene sediments and historic seismicity indicates that the fault system is active.

San Andreas Fault. Extending more than 700 miles, the San Andreas Fault is the longest and most significant system in California. Within and south of the Transverse Ranges, the strike of the fault trends west-northwest, within a nearly vertical dip. Motion along the fault is right lateral with post Oligocene (i.e., less than 22 million years) offset of more than 150 miles. Historic seismicity, sag ponds, offset channels, and linear geomorphic features indicate that this fault system is active.

Compton Blind Thrust Fault. The Compton Blind Thrust Fault is not exposed at the ground surface and has been hypothesized on the basis of seismologic modeling and studies of underlying structural geology. The Compton Blind Thrust Fault is believed to extend beneath the Newport-Inglewood and Palos Verdes Faults and is manifested by the location and trend of the overlying Compton and Torrance-Wilmington fold systems. The California Geological Survey (CGS) recently removed the Compton Blind Thrust Fault from the list of potential seismic sources due to lack of evidence for Late Quaternary displacement (i.e., during the last 15,000 to 20,000 years).

Elysian Park Blind Thrust Fault. The Elysian Park Blind Thrust Fault was hypothesized on the basis of mapped folding of relatively young sediments along the northeasterly edge of the

Los Angeles basin that is believed to be associated with nearby earthquakes that show thrust-type mechanisms. Seismic information recorded for the 1987 Whittier Narrows earthquake was a primary impetus in the development of a blind thrust model in this area. More recent geologic studies and seismologic analysis have revised the originally-hypothesized model to include two shallower detachment surfaces known as the Upper Elysian Park blind thrust and the Puente Hills blind thrust. The CGS recently removed the Elysian Park Blind Thrust Fault from the list of potential seismic sources and replaced it with estimated seismic parameters for these two shallower structures.

One method of measuring the magnitude of earthquakes is the Magnitude Scale. This scale measures the magnitude of energy released by an earthquake on a logarithmic scale, and is the most common scale used to compare the "size" of earthquakes, as it is an objective measure based on the energy released by a particular earthquake. The measured magnitude of an earthquake is independent of the location or proximity to a project site. The Modified Mercalli Intensity (MMI) scale is a subjective index that is used to generally quantify the effects of an earthquake at a particular location. Assignment of an MMI to a particular area is typically based on a broad compilation of earthquake observations following a seismic event. The MMI scale ranges from I for earthquakes barely perceptible by human beings to XII for the "ultimate catastrophe." Table 4.3.A describes the generalized relationship of Richter magnitude and Modified Mercalli intensity scales for a nearby earthquake.

Table 4.3.A: Relationship of Magnitude and Modified Mercalli Intensity Scales to Expected Earthquake Damage for a Nearby Earthquake

Richter Magnitude	Modified Mercalli Scale	Expected Earthquake Damage
2	I-II	Usually detected only by instruments.
3	III	Felt indoors. May not be recognized as an earthquake.
4	IV-V	Felt by most people; structures shake; windows and dishes rattle; wooden walls and frame creak; slight damage to unsecured objects.
5	VI-VII	Felt by all; many frightened and run outdoors; glassware breaks; items fall off shelves; furniture moves; cracks occur in unreinforced masonry; chimneys, cornices, and other unreinforced architectural ornaments fall; some small slides can occur.
6	VII-VIII	Difficult to stand; steering of autos is affected; potentially moderate to major damage occurs to structures; frame houses move off foundations if not bolted; branches break off trees; elevated structures such as chimneys and water towers collapse.
7	IX-X	General panic; major total damage to masonry structures; underground pipes break; frame structures seriously damaged; cracks occur in ground; large landslides likely; serious damage occurs to dams, dikes, embankments.
8+	X-XII	Major and total damage to buildings and infrastructure.

Source: California Division of Mines and Geology, "CDMG Notes," after Charles F. Richter, 1958, *Elementary Seismology*.

Peak ground motion parameters that might be generated at the project site by the maximum earthquake (equivalent to maximum credible earthquake) have been estimated for active faults within the 62-mile search radius for the project site. The Cherry Hill Fault, which comprises the nearby portion of the Newport-Inglewood Fault Zone, is considered to be the critical fault structure with regard to deterministic seismic parameters for the project site. Figure 4.3.4 shows the approximate location of the project site within the Newport-Inglewood Structural/Fault Zone. The largest ground motion at the project site would be associated with a magnitude 6.9 along the underlying Cherry Hill Fault. A peak horizontal site acceleration of 0.58g was estimated.

These deterministic seismic parameters provide a means for evaluating the relative importance of potential nearby seismic sources, but are not generally used for development of design criteria or for seismic hazard evaluations. Probabilistic analyses that consider the seismic potential of the project area are considered a more valid approach to seismic hazard analyses.

Beginning in 1997, the California Division of Mines and Geology (CDMG) has produced “Seismic Hazard Evaluation Reports” for the areas shown on selected U.S. Geological Survey (USGS) topographic maps (7.5 minute series) within the State of California. The stated purpose of these reports/maps is to identify potential seismic hazards for use by city and county planning agencies in their permitting and land use planning processes. CDMG’s probabilistic seismic hazards analysis (1998) estimates that a PGA of 0.49g is applicable to the project site conditions with a 10 percent probability of exceedence in 50 years (475 year return period). The predominant earthquake that contributes most to the ground shaking hazard at 10 percent probability of exceedence in 50 years is a magnitude 6.8 event on the nearby portion of the Newport-Inglewood Fault Zone.

Geologic Materials

The soils found on the project site can be divided into four geologic units. In order of decreasing age, they are: 1) the Lower Pleistocene age San Pedro formation (Qsp), 2) undifferentiated Upper Pleistocene terrace deposits (Qpu), 3) Recent or Holocene age alluvium/colluvium (Qal/Qcol) and 4) artificial fill (af). The abbreviations shown in parenthesis correspond to the map symbols for the stratigraphic units shown on Plate III of the technical evaluation prepared by AMEC (2004). A brief summary of the general characteristics and engineering properties of each of these geologic units is presented below.

San Pedro Formation. The San Pedro Formation underlies the entire site and extends to a depth of at least 200 to 500 feet below the ground surface. Surface exposures of the San Pedro formation are present on the small cut slope on the southerly side of the existing detention basin and in local outcrops immediately to the northwest of the basin. This unit was also encountered in many of the previous exploratory excavations. The San Pedro formation locally consists of unconsolidated to semiconsolidated mixtures of silt and sand, with minor local clay and gravel. These sediments were deposited primarily in a near-shore marine lagoon-like and/or fluvial environment during the Lower Pleistocene Age. The internal structure of this unit tends to be generally massive or crudely stratified, although local intervals described as thinly interbedded siltstone and fine sandstone were in a few of the previous exploratory excavations. Stratification and local bedding planes within the San Pedro Formation are typically flat-lying, although deformation in the vicinity of the Cherry Hill fault has produced local bedding orientations that are inclined to the southwest at 30 to 60 degrees. This geologic unit will provide the base for construction of proposed compacted fill, and/or possibly the base for in-situ treatment or deep foundations for support of proposed

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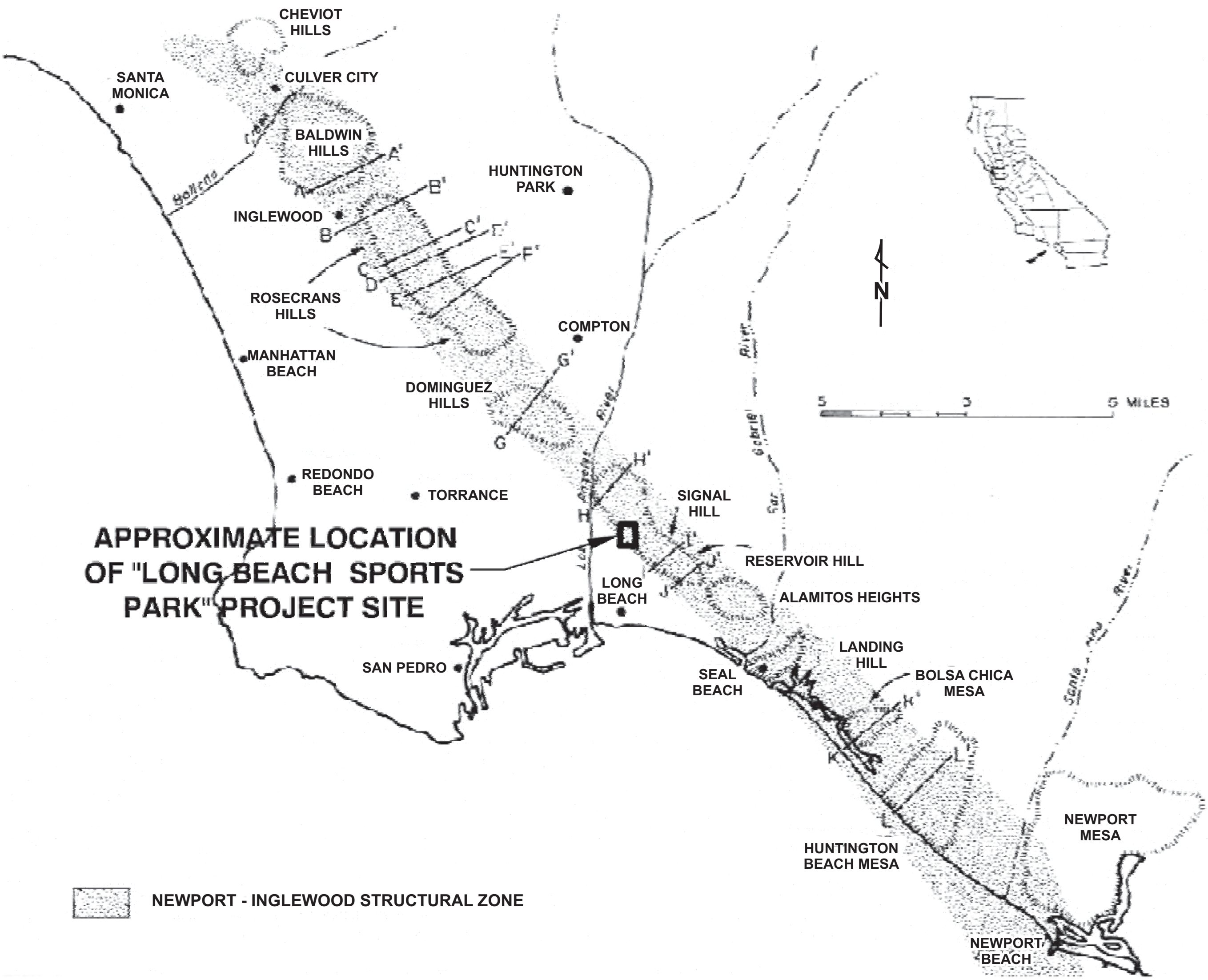

GENERAL SITE LOCATION SHOWING THE NEWPORT-INGLEWOOD STRUCTURAL ZONE DESCRIBED BY BARROW, 1974 (EXCERPT OF P. 3).

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FIGURE 4.3.4

Long Beach Sports Park

Newport-Englewood Structural/Fault Zone

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structures throughout the project site. The compression/consolidation characteristics of this geologic unit are within acceptable limits, although near-surface samples show a minor potential for hydrocompression. This unit generally exhibits a very low expansion potential.

Undifferentiated Terrace Deposits. Undifferentiated terrace deposits are present overlying the San Pedro Formation across the crest of Exxon Hill in the southeast quadrant of the project site. This unit is locally referred to as the Lakewood Formation and essentially includes all the materials deposited during the Upper Pleistocene Age. Terrace deposits exposed in borings at the project site consist primarily of brown-to-orange brown fine silty and/or clayey sand that was deposited during the Upper Pleistocene Age on an ancient coastal plain and/or wave cut platform. Terrace deposits have characteristic reddish or orange-brown coloration due to iron oxide coating of the soil particles. Local exposures also tend to have a higher clay content than the underlying San Pedro formation. Bedding within the terrace deposits is indistinct and is manifest primarily as crude stratification of material types. The soil shows no adverse compression characteristics and tends to have a very low expansion potential.

Alluvium and/or Colluvium. Alluvium and/or colluvium are near-surface soils that have been deposited and/or have accumulated due to local fluvial processes and/or from erosion and downslope movement of soils from adjacent highlands. Residual soils that have developed in-situ from deep weathering of the underlying geologic units are also included in the alluvium/colluvium. These near-surface native or natural deposits are generally present as at least a thin mantle beneath all existing remnants of the original natural ground surface. Accordingly, surface exposures of these materials are generally limited to those portions of the slopes surrounding Exxon Hill that are in an essentially natural condition. The thickest intervals of alluvium/colluvium are present near the base of the existing and previously-existing natural slopes, including the area along the now mostly-buried drainage course that crosses the central portion of the project site. The alluvium/colluvium consists of massive to thinly-interfingered layers and lenses of fine silty and clayey sand with local intervals of clay and silt that contain abundant decaying plant material (i.e., peat). These alluvial/colluvial soils were deposited during Recent or Holocene time. Scattered traces of decaying wood fragments and/or other decomposed plant material are characteristic of this unit. These peat-rich intervals are believed to be associated with former marshlands that previously existed along the now mostly-buried drainage course. The soil generally tends to have a very loose to loose consistency and is moderately to highly compressible.

Undocumented Artificial Fill. Undocumented fill is present and covers much of the existing ground surface. It was encountered in the upper portion of all but 2 of 25 exploratory borings recently excavated on the project site. The thickness of fill ranges from 1 foot to about 70 feet. The existing artificial fill on the project site generally consists of mixtures of sand, silt, and clay with scattered gravel and fragments of concrete. Construction of undocumented fills on the property did not apparently include any specific verification testing of ground preparation to receive fill, and as briefly discussed above, excessively compressible alluvium/peat intervals are present beneath the fill in some areas. Also, the material properties of the fill itself, including primarily the compaction/density and soil moisture content were apparently not controlled and/or tested during fill construction/placement. This absence of any geotechnical control does not allow appropriate characterization of the anticipated engineering properties of these materials or projection of the testing results, thus precluding accurate estimates or forecasts of their future deformation potential. The existing fills are, therefore, considered unsuitable in their current condition for the support of proposed fills and associated project structures/improvements.

Groundwater

On the basis of review of nearby water wells, the highest groundwater levels comprising the local groundwater resource were estimated to range from about 50 feet to 80 feet below sea level. However, perched near-surface groundwater was observed during exploratory borings on the project site. Soil moisture measurements in samples below the observed seepage zones at three of these locations indicated unsaturated conditions, confirming the interpretation of perched groundwater conditions. Most of the borings that encountered perched groundwater occurred in areas that were once part of the natural drainage course that crosses the central portion of the project site or within the broad lowland or basin in the southwestern quadrant of the project site. Additionally, closed depressions in the topography, as evidenced by local ponding after rainfall, will tend to promote infiltration of surface water and the occurrence of local shallow groundwater.

Seepage and/or saturated conditions observed in the borings were typically encountered within 5 to 10 feet above or below the former ground surface, which in most of these areas has been buried by variable amounts of undocumented fill. Perched groundwater has, therefore, primarily been observed within the lower portions of the fill or in the native deposits immediately below the fill. These groundwater observations are locally inconsistent and are likely to fluctuate in proportion to the volume of rainfall and with the quality of the local surface drainage provisions.

Possible Geotechnical Constraints

Primary Seismic Effects.

Ground Shaking and Surface Fault Rupture. The primary seismic effects associated with earthquakes are ground shaking and surface fault rupture.

Ground or seismic shaking would typically be considered to be the greatest potential for damage associated with earthquakes. Seismic shaking is characterized by the physical movement of the land surface during and subsequent to an earthquake. Seismic shaking has the potential to cause destruction and damage to buildings and property, including damage resulting from damaged or destroyed gas or electrical utility lines; disruption of surface drainage; blockage of surface seepage and groundwater flow; changes in groundwater flow; dislocation of street alignments; displacement of drainage channels and drains; and possible loss of life. In addition, groundshaking can induce several kinds of secondary seismic effects, including liquefaction, differential settlement, landslides, and seiching, all of which are described below.

The intensity of seismic shaking during an earthquake depends largely on geologic foundation conditions of the materials comprising the upper several hundred feet of the earth's surface. The greatest amplitudes and longest durations of ground shaking occur on thick water-saturated unconsolidated alluvial sediments that may lead to liquefaction (further described below). Ground shaking can also cause ground failure or deformation due to lurching and liquefaction.

Surface fault rupture refers to the displacement of the ground surface along a fault, which can occur during strong earthquakes.

As previously stated, the Cherry Hill Fault crosses the southwesterly corner of the project site and is considered the most recently-active segment of the Newport-Inglewood Fault Zone in the immediate vicinity of the project site. The Newport-Inglewood Fault Zone, of which the Cherry Hill Fault is a part, is within a designated an Alquist-Priolo Earthquake Fault Zone and is therefore subject to the requirements and conditions of the 1994 “Alquist-Priolo Earthquake Fault Zoning Act” with regard to the potential for surface fault rupture. This Act requires that proposed development of habitable structures be set back from the surface trace of “active” faults to avoid the potential hazard of surface fault rupture. The State of California defines an “active” fault as one that exhibits evidence of surface displacement during recent or Holocene time (i.e., during approximately the last 11,000 years).

Secondary Seismic Effects.

Liquefaction. Seismic ground shaking of relatively loose granular soils that are saturated or submerged can cause the soils to liquefy and temporarily behave as a dense fluid. This loss of support can produce local ground failure such as settlement or lateral spreading that may damage overlying improvements. Liquefaction is caused by sudden temporary increases in pore water pressure due to seismic densification or other displacement of submerged granular soils. Intervals of loose sand may, therefore, be subject to liquefaction if these materials are or were to become submerged and are also exposed to strong seismic ground shaking.

The location of the preexisting now mostly-buried drainage course that crosses the central portion of the project site approximately coincides with a zone that is considered potentially susceptible to liquefaction as designated by the State of California on the “Seismic Hazard Zone Map, Long Beach Quadrangle” (March 25, 1999). Geotechnical evaluation of the subsurface data indicated that local intervals of saturated loose sand in the vicinity of the previously-existing channel will likely have a significant potential for liquefaction under conditions of strong seismic ground shaking.

Seismically-Induced Ground Settlement. This type of secondary seismic effect can result in damage to property when an area settles to different degrees over a relatively short distance. The sinking or settlement of a structure, fill prism, or other imposed load is usually the result of compaction or consolidation of the underlying soil. Extensive undocumented fills and underlying alluvial deposits on the project site have the potential to compress or “settle” during seismically-induced ground shaking. Local intervals of peat materials observed within the alluvium are also considered to be compressible. Construction of additional fill thicknesses and/or local increases in the subsurface moisture content will tend to increase the potential for future differential settlement of the overlying surface and associated improvements.

Seismically-Induced Landslides/Slope Instability. The downslope movement of loose rock or soil is also a potential secondary seismic effect that can occur during strong ground shaking. With the possible exception of shallow slumping of loose surficial soils present on some of the slopes on the project site and shallow slumping or landsliding possibly attributed to downslope movement of fill generated by previous grading on Exxon Hill, there are no existing landslides present on the property. Although the project site is shown on the "Seismic Hazard Zone Map, Long Beach Quadrangle" (March 25, 1999) published by the California Division of Mines and Geology, the map does not identify any areas or zones on the project site that are considered potentially susceptible to seismically-induced landsliding. However, seismically-induced landslides and slope instability are considered a potential constraint or impact within the project area due to its location in the Newport-Inglewood Fault Zone.

Seiching. This phenomenon occurs when seismic groundshaking induces standing waves (seiches) inside water retention facilities, such as reservoirs and water tanks. Such waves can cause retention structures to fail and flood downstream properties. With the possible exception of the existing detention basin near the center of the property, no confined bodies or water are present on or in close proximity to the project at the present time. The proposed project does call for a storm water detention basin to be located in the southwest portion of the project site; however, the shallow depth of the water (7–8 feet) would limit the height of a seiche. The probability that a significant seismic event would coincide with an extreme storm event is considered relatively low. Development of a seiche also depends on a complex set of variables that include the period or length of the seismic waves, the strength and direction of the ground motion, and the corresponding period or size and shape of the confined water body. In consideration of the required coincidence of a complex set of variables, including most importantly an extreme storm event and a significant earthquake, the probability that a significant seiche could develop on the project site during the probable design life of the project is considered very low. The risk associated with possible seiche waves is therefore not considered a potential constraint or a potentially significant impact of the project.

Tsunamis. Tsunamis are sea waves induced by earthquakes, or less frequently, by very large submarine landslides. The proposed project is located a significant distance from the ocean shoreline and has a minimum proposed ground surface elevation of 45 feet. The risk associated with tsunamis is therefore not considered a potential hazard or a potentially significant impact.

Non-Seismic Geologic Constraints.

Mudslides. Mudslides and slumps are described as a shallower type of slope failure, usually affecting the upper soil mantle or weathered bedrock underlying natural slopes and triggered by surface or shallow subsurface saturation. Characteristics related to mudslide (mudflow) risks are 1) depth and type of soil; 2) direction and angle of slope; 3) surface drainage configuration; and

4) type and condition of natural ground cover. Historically, mudslides are most common during or shortly after a heavy rainfall or series of rainfalls.

Erosion. Erosion typically occurs from concentrated runoff or unprotected slopes or along unlined channels that are underlain by relatively erosion-prone earth materials (e.g., topsoil, soft alluvium, uncemented sandstone). Proposed fills and exposed cut surfaces will typically consist of mixtures of silt and sand and will also tend to be easily eroded under conditions of uncontrolled, concentrated surface runoff.

Subsidence. The phenomenon of widespread land sinking, or subsidence, is generally related to substantial overpumping of groundwater or petroleum reserves from deep underground reservoirs. Subsidence due to oil extraction is not considered a significant problem in the Signal Hill area, including the project site, because of the relatively stiff structure of the uplifted older sediments comprising the local portion of the Newport-Inglewood structure/fault zone. Periodic survey monitoring of the oil field areas is conducted by the City of Long Beach, Department of Oil Properties.

Expansive Soils. Expansive soils contain types of clay minerals that occupy considerably more volume when they are wet or hydrated than when they are dry or dehydrated. Volume changes associated with changes in the moisture content of near-surface expansive soils can cause uplift or heave of the ground when they become wet or, less commonly, cause settlement when they dry out. Repeated cycles of wetting and drying in the vicinity of slopes composed of expansive soils can produce incremental lateral and downslope movements known as “slope creep.” Potential variability in the soil moisture content typically decreases with increasing depth, and the weight of overlying soil also tends to reduce the amount of volume change that can occur. Therefore, the deeper portion of the foundation soil profile tends to be less problematic with regard to expansive soils.

Regulatory Setting Relative to Structural and Seismic Safety Design

Prior to the issuance of building permits, the City ensures that structural design shall comply with the current edition of the Uniform Building Code (UBC) and City Building Codes applicable to structure design and construction in order to minimize the potentially damaging effect of severe ground shaking originating from earthquakes in the region.

Prior to the issuance of grading permits, the City’s engineering department ensures that rough and final grading plans and overexcavation plans incorporate the recommendations of required final geotechnical investigation reports. Standard City plan approval processes require that recommendations in the final geotechnical report are reflected in the notes of the grading plan and shall be implemented as conditions of any grading and/or construction permit.

4.3.3 METHODOLOGY

This section addresses the potential for structural damage to occur due to the local geology underlying the proposed project site, as well as slope instability, ground settlement, unstable soil conditions, and regional seismic conditions. Geologic/geotechnical conditions affecting the site are summarized from compiled information and analyses, including referenced documents/publications and a site- specific program of geotechnical exploration, sampling, and laboratory testing. The scope and content of the geotechnical investigation for the proposed project are primarily based on guidelines for environmental impact reports published by the California Division of Mines and Geology (CDMG, Note 46, 1982; now known as the California Geological Survey, [CGS]). The Geotechnical Evaluation prepared by AMEC Earth and Environmental, Inc. (2004) is available for review at the City of Long Beach, Community Development Department.

4.3.4 THRESHOLD OF SIGNIFICANCE CRITERIA

Project implementation would result in a significant impact to or from geologic resources and soils if it would:

- expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving rupture of a known earthquake fault as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault, strong seismic ground shaking, and seismic-related ground failure, including liquefaction or landslides;
- create substantial soil erosion or the loss of topsoil;
- be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on-site or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse;
- be located on expansive soil, as defined in Table 18-1-B of the UBC (1994), creating substantial risks to structures or life; or
- be incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

4.3.5 IMPACTS AND MITIGATION MEASURES

The following impacts of the proposed project have been identified based on project characteristics, statutory requirements, and the significance thresholds defined above. Some of the impacts are considered less than significant; others are considered potentially significant. Both types of impacts are identified and discussed below.

Less than Significant Impacts

Subsidence. Land subsidence in this context refers to broad scale changes in the elevation of the land that occur in response to the pumping of oil wells, water wells, or other mineral extraction. The phenomenon of widespread land sinking, or subsidence, is generally related to substantial overpumping of groundwater or petroleum reserves from deep underground reservoirs. Subsidence due to oil extraction is not actively monitored in the Signal Hill area, including the project site, because of the relatively stiff structure of the uplifted older sediments comprising the local portion of the Newport-Inglewood structure/fault zone. Although active water wells in the earlier part of the 1900s dramatically lowered local groundwater levels, modern management of the underlying groundwater resources has tended to stabilize current levels. Although measurable vertical elevation changes have occurred during historic time, these changes affect broad areas and are not considered a significant constraint or impact of the proposed project.

On-Site Sewage Disposal Systems. An existing trunk sewer crosses the central portion of the project site. As a part of the proposed project, the existing trunk sewer will be relocated on or in close proximity to the project site. The proposed project will utilize the existing sewer system, and no on-site sewage disposal systems are planned. There is no impact with regard to utilization of on-site sewage disposal systems.

Potentially Significant Impacts

Ground Shaking. Strong seismic ground shaking is considered a potentially significant impact to the proposed project unless appropriate mitigation measures are implemented as a part of project design and construction.

As with all of Southern California, the project site is subject to strong ground motion resulting from earthquakes on nearby faults, including the underlying Cherry Hill Fault. The project site is located in the Long Beach 7.5 minute quadrangle, and the Seismic Hazard Zone Evaluation report for this area is Open-File Report 98.19. As previously stated, the peak horizontal ground acceleration (PGA) is a commonly-used parameter to represent the level of observed and/or estimated ground shaking at a particular site. Peak ground motion parameters that might be generated at the project site by the maximum earthquake (equivalent to maximum credible earthquake) have been estimated for active faults within the 62-mile search radius for the project site. The Cherry Hill Fault, which comprises the nearby portion of the Newport-Inglewood Fault Zone, is considered to be the critical fault structure with regard to deterministic and probabilistic seismic parameters for the project site. CDMG's probabilistic seismic hazards analysis (1998) estimates that a PGA of 0.49g is applicable to the project site conditions, with a 10 percent probability of exceedance in 50 years (475 year return period) and the predominant earthquake being a magnitude 6.8 event on the nearby portion of the Newport-Inglewood Fault Zone.

Ground shaking generated by the fault movement is considered a potentially significant impact that may potentially affect the proposed project. Implementation of Mitigation Measure 4.3.1 will reduce this potential impact to a less than significant level.

Surface Fault Rupture. An Alquist-Priolo Special Studies/Earthquake Fault Zone that crosses the southwesterly corner of the project site has been delineated by the State Geologist. As previously stated, the fault is commonly referred to as the Cherry Hill Fault, and is part of the Newport-Inglewood Fault Zone. To assure that homes and other structures for human occupancy are not built on active faults, the Alquist-Priolo Earthquake Fault Zoning Act also requires that a site-specific geological investigation of the fault be performed before a local government can approve development projects within the zones. Through compliance with this Act during the permitting process as required by State law, seismic hazards associated with surface fault rupture are mitigated to the extent feasible. Incorporation of a recommended setback of 50 feet from the fault zone will reduce potential seismic hazards resulting from surface fault rupture to acceptable levels.

Implementation of Mitigation Measure 4.3.2 will reduce the potential for surface fault rupture affecting an occupied structure on the project site to a less than significant level.

Liquefaction. Liquefaction of local intervals of sandy alluvium is considered a potentially significant impact unless appropriate mitigation measures are implemented as a part of project design and construction.

A preexisting but now mostly buried drainage course crosses beneath the central portion of the project site. The location of this drainage course approximately coincides with a zone considered potentially susceptible to liquefaction, as designated by the State of California on the "Seismic Hazard Zones Map, Long Beach Quadrangle" dated March 25, 1999. Review of historic aerial photos and topographic maps of the project site indicate that marshlands and/or ponded water were periodically present in closed depressions caused by construction of fill embankments along the drainage course. Geotechnical evaluation of the subsurface data indicates that local intervals of saturated loose sand in the vicinity of the previously existing drainage channel will likely have a significant potential for liquefaction under conditions of strong seismic ground shaking.

The strength, density, consistency, and other engineering properties of the San Pedro formation indicate that these material would generally not be susceptible to liquefaction. However, local intervals of the San Pedro formation within one to seven feet of the existing or former ground surface (i.e., beneath existing fills) exhibited a loose consistency that could be problematic under conditions of strong seismic ground shaking. Proposed grading will remove essentially all of the terrace deposits that are present across the crest of Exxon Hill. These deposits were observed to have a medium dense consistency and are located above an elevation that is likely to become submerged in the future. Therefore, the terrace deposits are not considered a potential problem with regard to liquefaction.

The typical Standard Penetration Test (SPT) blow count data for the alluvium and for existing fill is considered indicative of a loose to very loose consistency for sandy or granular materials that are present within these units. Intervals of perched groundwater have been observed locally within the alluvium and within the lower portions of the existing fills. Future landscape watering and local inundation of the planned detention basin will likely produce similar local intervals of perched groundwater after development of the project site. Sandy intervals within these units are considered to represent a significant potential for liquefaction in the event they are saturated/submerged and exposed to strong seismic ground shaking. The estimated extent of the local intervals of potentially liquefiable soils approximately conforms with the zone shown on the State of California's "Seismic Hazard Zones Map, Long Beach Quadrangle" (March 25, 1999).

Implementation of Mitigation Measure 4.3.3 requiring remedial treatment of existing fills and/or alluvium will reduce the potential for liquefaction to a less than significant level.

Landslides and Slope Instability. Potential landslides and slope instability that could affect project improvements and structures are a potential significant impact of the project unless appropriate mitigation measures are implemented as a part of project design and construction.

With the possible exception of local shallow slumping of loose surficial soils present on some slopes within the project site and probable downslope movement of fill generated from previous grading on Exxon Hill, no existing landslides are present on the property. Proposed grading for the project will extend over essentially the entire site and is primarily intended to produce level grades for planned playing fields, parking lots, and building areas. The proposed grading configuration will, therefore, substantially reduce the height and extent of slopes on the project site. The potential for future slope instability will be limited to proposed cut-and-fill slopes that will be manufactured as part of the proposed grading.

Existing fills and other potentially compressible soils extend to significant depths at several locations on the project site. Remedial grading required for removal and recompaction of these materials will produce temporary construction slopes of substantial height in some areas. The presence of local perched groundwater in these temporary excavations will tend to have an adverse impact on the local slope stability conditions during construction phases.

Proposed permanent slopes will consist of both cut and fill materials, although significant cut slopes will likely be limited to the immediate area of the existing topographic highland in the southeast quadrant of the project site (i.e., Exxon Hill). A typical slope gradient of 2:1 (horizontal:vertical) is planned, although local gradients ranging from about 3:1 to 6:1 are also planned. Proposed slopes typically range in height from a few feet up to about 14 feet. The highest proposed slopes are in the proposed soccer field/detention basin area, with a maximum height of 35 feet that ascends from the northeastern edge of the planned small detention basin at the north end of the soccer fields. The planned compacted fill slope in this area extends to a maximum height of 45 feet. Inundation and subsequent drainage of the toe area will occur during or shortly after extreme storm events, producing saturated conditions in the lower portion of the slope face. Temporary local groundwater conditions will therefore need to be considered in stability evaluations of slopes around the detention basins to avoid slope failure.

Materials comprising both the proposed cut and fill slopes will consist of mixtures of silt and sand that exhibit moderately high frictional shear strengths. The combination of relatively high shear strengths and low-to-moderate slope heights and surface gradients will tend to minimize the risk of possible future gross or deep-seated slope failures. However, the local presence of groundwater and/or saturated soil conditions, including periodic inundation of the lower portion of slopes in the planned detention basins, could have an adverse impact on the site slope stability conditions. The primarily granular character of the on-site soils will also tend to make the surficial soils more susceptible to erosion and possibly shallow failure under conditions of uncontrolled drainage and/or local saturation.

Implementation of Mitigation Measures 4.3.4 through 4.3.6 and building code requirements will provide stabilized engineered fill and slope faces. These measures will reduce the potential impact of landslides and slope instability to a less than significant level.

Erosion. Under conditions of uncontrolled concentrated surface runoff, erosion of the graded areas on the project site is considered a potential significant impact unless mitigation measures are implemented as a part of project design and construction.

The graded areas on the project site will consist primarily of compacted fill with an area of cut in the San Pedro formation in the vicinity of Exxon Hill. The intent of the grading is to create large areas of level ground to accommodate proposed playing fields, parking lots, and building areas. The lack of relief tends to minimize the potential for erosion and should limit any significant potential for future erosion to the intervening slope areas. However, foundation soils involved in the grading will consist primarily of mixtures of silt and sand, with only a limited amount of cohesive clays. Mixtures of silt and sand will tend to be easily eroded under conditions of uncontrolled concentrated surface runoff. Periodic inundation of the lower portions of slopes in the planned detention basins will also tend to have an adverse impact on the local slope stability/erosion conditions. Erosion of graded areas is, therefore, consisted a potentially significant impact.

Implementation of Mitigation Measure 4.3.7 will reduce and minimize potential for erosion, slope failure, and surficial soil instability. Impacts related to erosion will be reduced to a less than significant level with mitigation.

Ground Settlement. Lack of control or documentation for the existing fills on the project site preclude accurate prediction of the future deformation behavior of these materials. These undocumented fills and underlying alluvial deposits are considered excessively compressible and represent a significant risk of differential settlement and ground deformation. Local intervals of peat observed within the alluvium are also considered problematic in this regard. Construction of additional fill thickness and/or local increases in the subsurface moisture content that will likely occur with project development due to landscape watering and presence of storm water in the detention basin and periods of inundation of the detention basin areas will tend to increase the potential for future differential settlement of the overlying ground surface and project improvements, including walkways and structures.

The Pleistocene age deposits (San Pedro formation and terrace deposits) are considered to present a low potential for seismically-induced ground settlement because of the medium dense to very dense consistency of these materials. Similarly, controlled compacted fill to be placed as a part of the proposed grading construction can be expected to exhibit a low potential for seismically-induced settlement.

The possibility for seismically-induced settlement, slope, and/or foundation instability associated with the excessive compression of undocumented fill and alluvium present on-site is considered a potentially significant impact. Implementation of Mitigation Measure 4.3.3, which requires remedial treatment of highly compressible soils that would support proposed structures and associated improvements (e.g., subdrains) will substantially reduce the potential for ground settlement. These required improvements will reduce this potential impact to a less than significant level.

Expansive Soils. Soils observed at the project site consist primarily of mixtures of silt and sand, and only minor amounts of clay appear to be present. Expansion testing of samples representing the general geologic units present at the project site indicates a “very low” to “low” expansion potential in accordance with UBC Table 18-1-B, 1997. Expansive soils are, therefore, considered unlikely to be a significant design constraint for most of the project area. However, much of the materials that will be involved in the grading activity consist of undocumented fills with locally variable soil types that may include expansive clays. Local intervals within the alluvium consists of clay that will likely exhibit a significant expansion potential.

The possibility of slope and/or foundation instability associated with expansive soils on the project site cannot be ruled out on the basis of the available test data, and is, therefore, considered a potentially significant impact. Implementation of Mitigation Measure 4.3.8 will provide engineered soil conditions below project structures so as to reduce the potential impact from expansive soils to a less than significant level.

Uncontrolled Groundwater Seepage. As previously discussed, perched groundwater levels have been observed in borings at many locations on the site. The distribution of the borings that encountered shallow groundwater was primarily limited to the former lower elevations on the project site, which tended to show evidence of historic ponding of surface water. Most of these observations occurred along portions of the original natural drainage that crosses the central portion of the project site and/or within the broad lowland or basin in the southwestern quadrant of the project site (i.e., in the area of the proposed detention basin). Seepage and/or saturated conditions observed in the borings were typically encountered within five to ten feet above or below the former ground surface, which in most of these areas has been buried by variable amounts of undocumented fill. Perched groundwater has, therefore, primarily been observed within the lower portions of the fill or in native deposits immediately below the fill. The lower portions of the temporary excavations for remedial grading will, therefore, likely encounter groundwater seepage at some locations. The relatively sporadic occurrence of much of the observed groundwater seepage suggests water is limited in volume and will not likely be a significant construction constraint on most of the project site. However, in the vicinity of the previously- excavated drainage course near Spring Street in the north and California Street in the west, the previous seepage observations were relatively consistent. The occurrence of shallow groundwater at these locations may, therefore, be a construction constraint that will require local dewatering. In the event a significant volume of perched groundwater is encountered, the water can be pumped to temporary reservoirs for use in dust control, moisture conditioning of fills for compaction, and/or other construction-related uses.

Landscape irrigation associated with development may tend to create localized perched groundwater conditions and/or raise the local groundwater levels. Inundation of the proposed detention basins and associated infiltration will also contribute to the local shallow groundwater conditions. The presence of shallow groundwater can have a deleterious effect on the stability and deformation potential of nearby slopes and foundations. For this reason, it is standard practice to install appropriate subdrain provisions in order to maintain possible future groundwater levels below acceptable elevations and in an attempt to minimize variations in the moisture context of foundation soils. The serviceability of the planned soccer fields in the proposed large detention basin is also an important consideration. Saturated conditions of the near-surface soils will tend to increase the maintenance and limit use of the fields for possibly long periods of time in the absence of an appropriate subdrain or underdrain system.

Possible uncontrolled groundwater flow is considered a potentially significant impact both during construction and after construction of the proposed project. Implementation of Mitigation Measures 4.3.9 and 4.3.10 will provide control of groundwater conditions to reduce this potential impact to below a level of significance.

Mitigation Measures

The following mitigation measures are incorporated to offset potentially significant adverse impacts of the proposed project.

4.3.1 Appropriate seismic design provisions shall be implemented with project design and construction in accordance with governing building codes. Unless superseded by other regulatory provisions or standards, seismic design criteria shall be developed on the basis of the requirements of the current UBC and reviewed and approved by the City Building Official prior to issuance of building permits. The following UBC design parameters are based on the 1997 UBC, Volume 2, Chapter 16, Divisions IV and V. These parameters are considered applicable for the seismic design evaluation of proposed structures pending any more recent updates of the UBC, or unless more site-specific design values are required by the project structural engineer (e.g., response spectra or site period), as approved by the City Building Official.

Project Site Seismic Design Parameters

Seismic Zone Factor Z:	0.4
Soil Profile Type:	S_D
Design Fault:	Newport Inglewood
Fault Distance:	<1.24 miles (2 kilometers)

Prior to issuance of building permits, the City of Long Beach Building Official (or designee) is required to review and approve final design plans to ensure that all structures are designed to resist earthquake forces as defined by the UBC for a Seismic Zone 4.

4.3.2 All habitable structures shall be set back a minimum of 50 feet from the current Alquist-Priolo Special Studies Zone or the Special Studies Zone as modified by the project geotechnical consultant based upon additional soil and fault study. Final foundation setback recommendations shall be based on in-grading review and mapping of the fault trace by the project geotechnical consultant, including appropriate projection of the exposed conditions. All recommendations for final foundation setback shall be reviewed and approved by the City Building Official prior to issuance of building permits.

4.3.3 Remedial treatment shall be required for any of the existing fills and/or underlying alluvium that are comprised of loose sandy soils that may become saturated in the future and are also intended for support of planned structures, slopes, and associated improvements. In general, foundation soils that are within a 1:1 (45-degree) downward projection from the perimeter of proposed structures, slopes, and associated improvements shall be considered as supporting these improvements. Remedial treatment of highly compressible soil and/or undocumented/unengineered fill that are intended for the support of planned improvements shall be performed, as required by the City of Long Beach Building Official. Removal and replacement of these unsuitable soils as compacted fill is considered the most straightforward method of remedial treatment. Alternative remediation measures, such as in-situ densification and/or installation of deep foundations, may be used in areas of the site where existing constraints make removal and compaction cost-prohibitive or difficult due to property line constraints. Site-specific final design evaluation and grading plan review shall be performed by the project geotechnical consultant, including assessment of possible remedial alternatives prior to the start of grading construction. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final written report, subject to review by the City of Long Beach Building Official prior to issuance of grading permits.

4.3.4 Proposed permanent cut and fill slopes shall not exceed a surface gradient of 2:1 (horizontal:vertical). Pending future final design evaluations, granular soils shall be excluded from the outer 10 to 12 feet of any proposed slope face within the anticipated inundation area of planned detention basins, and/or this portion of the slope can be reinforced appropriately. Additional site-specific final design evaluations shall be performed by the project geotechnical consultant to evaluate the stability conditions of proposed slopes, including the surficial stability/erosion potential, and with particular regard to slopes within the planned detention basins. Grading plan review shall also be performed by the project geotechnical consultant prior to the start of grading to verify that the recommendations developed during the geotechnical design evaluation have been appropriately incorporated into the project plans. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the City of Long Beach Building Official prior to issuance of grading permits.

4.3.5 In general, proposed temporary cut slopes shall not exceed a gradient of 1:1 (horizontal:vertical). Pending future site-specific final design evaluations, planned construction slope excavations at a 1:1 gradient (45-degree angle) shall not exceed a height of 16 feet, and those excavated at a 1.5:1 gradient shall not exceed a height of 37 feet. Proposed temporary slope excavations in undocumented fill and alluvium adjacent to Spring Street and California Avenue shall be subject to additional site-specific exploration, testing, and stability evaluations by the project geotechnical consultant to refine and enhance the preliminary recommendations. Grading plan review shall also be performed by the project geotechnical consultant prior to the start of grading to verify that the recommendations developed during the geotechnical design evaluation have been appropriately incorporated into the project plans. Temporary construction slopes shall be reviewed by the project geotechnical consultant during excavation to assess and mitigate potential unanticipated structural anomalies and/or unforeseen groundwater conditions. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the City of Long Beach Building Official prior to issuance of grading permits.

4.3.6 Unreinforced fill slopes shall not exceed a gradient of 2:1 (horizontal:vertical). Any portion of a proposed slope with gradients steeper than 2:1 shall require appropriate reinforcement and/or installation of a retaining wall. The project geotechnical consultant shall perform additional site-specific final design evaluations of the proposed retaining walls to refine and enhance the preliminary recommendations. These evaluations shall address wall drainage and surficial stability/erosion potential of the adjoining sections of the fill slope. Geotechnical evaluations of proposed retaining walls within planned detention basins shall also include development of the appropriate geotechnical criteria for the wall design under rapid draw-down groundwater conditions. Grading plan review shall also be performed by the project geotechnical consultant prior to the start of grading to verify that the recommendations developed during the geotechnical design evaluation have been appropriately incorporated in the project plans. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the City of Long Beach Building Official prior to issuance of grading permits.

4.3.7 The surficial stability/erosion potential of the proposed graded slopes shall be evaluated by the project geotechnical consultant as a part of the geotechnical design evaluation. Best management practices (BMPs) shall be employed during construction to minimize the potential for erosion, and the project shall conform to applicable National Pollution Discharge Elimination System (NPDES) requirements and regulations. Appropriate landscape planting shall be installed as soon as is practical after completion of grading, particularly in the graded slope areas. Erosion control recommendations and design provisions shall be developed and incorporated into grading plans prepared by the project civil engineer for implementation during construction. Grading plans shall be reviewed and approved by the project geotechnical consultant prior to the start of grading construction. BMP development and implementation should be closely coordinated with the water quality requirements of the project construction and operation standard urban storm water mitigation plans [SUSMP]. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the City of Long Beach Building Official prior to issuance of grading permits.

4.3.8 Proposed grading shall be implemented to provide relatively uniform soil conditions in the upper portion of the building areas. A moderate level of moisture shall be installed and maintained in the fill/foundation soils to minimize future volume changes. Appropriate drainage provisions as designed and/or recommended by the project civil engineer and geotechnical consultant shall be implemented to minimize future soil moisture changes. Subsurface drainage improvements shall be approved by the City of Long Beach Building Official prior to issuance of grading permits. On-site inspection during grading shall be conducted by the Building Official or a designee to ensure compliance with City-approved drainage design and soil mixture and recompaction.

Additional site testing and final design evaluations regarding the possible presence of significant volumes of expansive soils on site shall be performed by the project geotechnical consultant to refine and enhance the preliminary recommendations. Grading plan review shall also be performed by the project geotechnical consultant prior to the start of grading to verify that the recommendations developed during the geotechnical design evaluation have been appropriately incorporated in the project plans. Final design and recommendations regarding expansive soils shall be based on testing and analyses of the near-surface soils following the completion of grading. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the Building Official prior to issuance of grading permits.

4.3.9 Subdrains shall be installed behind all fill slopes and retaining walls and shall be considered and evaluated for installation in other areas where the proposed ground surface is near the buried surface of the underlying San Pedro formation. Pending future additional site-specific evaluations, canyon-type subdrains shall be installed along the flanks of the previously existing drainage course at elevations that will daylight at the northeasterly perimeter of the planned large detention basin. Some consideration shall also be given to installation of a central canyon type subdrain within the planned compacted fill along an approximation of the original flowline alignment. The recommended subdrain shall be constructed with a minimum drainage gradient of one percent. Design of underdrain systems for the playing fields shall be undertaken by a specialized consultant with specific expertise in this type of design. These measures shall conform to the recommendations of the project geotechnical consultant and the project civil engineer. As recommended by the project geotechnical consultant in a final report, proposed subdrain systems shall be integrated with planned storm drains (see also Section 4.4, Water Resources), as approved by the Building Official prior to issuance of grading permits.

Site-specific final design evaluation and grading plan review shall be performed by the project geotechnical consultant prior to the start of grading to verify that recommendations developed during the geotechnical design process are appropriately incorporated in the project plan. The project geotechnical consultant shall review construction excavations during excavation to assess possible unforeseen groundwater conditions and to approve as-built locations and construction materials/methods for recommended subdrains. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the Building Official prior to issuance of grading permits.

4.3.10 Surface drainage provisions for the project shall be evaluated and designed by the project civil engineer and shall be reviewed and approved by the project geotechnical consultant prior to the start of grading activities. Design and grading construction shall be performed in accordance with the requirements of the UBC applicable at the time of grading, appropriate local grading regulations, and the recommendations of the project geotechnical consultant as summarized in a final report, subject to review by the Building Official prior to issuance of grading permits.

4.3.6 CUMULATIVE IMPACTS

For Geology and Soils, the study area considered for the cumulative impact of other projects consisted of 1) the area that could be affected by proposed project activities; and 2) the areas affected by other projects whose activities could directly or indirectly affect the geology and soils of the proposed project site. In general, only projects occurring adjacent to or very close to the project site were considered. Neither the proposed project nor any of the identified projects with potential cumulative impacts entailed activities that would affect geology and soils at significant distances from the site (i.e., projects requiring significant structural blasting or drilling, high vibration activities, deep excavation, etc.).

The analysis indicated that there would be no significant cumulative impact of the proposed project related to geology and soils. This conclusion is based on the following:

- There are no rare or special geological features or soil types on the project site that would be affected by project activities.
- There are no other known activities or projects with activities that affect the geology and soils of this site.

4.3.7 LEVEL OF SIGNIFICANCE AFTER MITIGATION

The mitigation measures described above will reduce the potential geologic, seismic, and soil-related impacts to below a level of significance. Therefore, there are no significant unavoidable adverse impacts of the proposed project related to geology and soils.