E. GEOLOGY AND SOILS

ENVIRONMENTAL SETTING

The project area is approximately four miles south of the city of Santa Monica, 1.5 miles north of the Los Angeles International Airport, five miles west of Culver City, and is bordered by Santa Monica Bay to the west. PDR is located within the city of Los Angeles, and MDR is within the county of Los Angeles. MDR is approximately two miles northwest of PDR, separated by the Ballona Wetlands and the MDR Channel.

Numerous consultants have conducted geological, geotechnical, and geophysical assessments at the project sites to evaluate the potential for migration of petroleum gases associated with the underlying oil bearing formations and the PDR Gas Storage Facility. This EIR analysis included review of reports prepared by Camp Dresser and McKee (CDM), Exploration Technologies, Inc. (ETI), Earth Consultants International (ECI), R.L. Hester, Davis and Namson Consulting Geologists, the U.S. Department of the Interior Minerals Management Service (United States Oil and Gas Resources Assessment of the Pacific Outer Continental Shelf Region), and the California Department of Water Resources (DWR) Bulletin 118 and Bulletin 104. The complete references for these sources are provided at the end of this section.

GEOLOGIC SETTING

Surface geologic features include the Playa del Rey Bluff, a prominent topographic feature in the project area, located five miles south of the Santa Monica Mountains and about five miles north of Palos Verdes Peninsula hills to the south. The Playa del Rey Bluff is a westerly extension of the Baldwin Hills and Fox Hills located 3 miles to the east and represents the southern flank of the ancestral Los Angeles River (now Ballona Creek) valley, which formerly flowed through this area. Geologically, the Los Angeles basin is a deep, sediment-filled structural depression with recent sedimentary deposits overlying older sedimentary rocks (i.e. sandstone). Beneath the sedimentary rocks are older crystalline basement rocks, consisting of schists (shales that are altered by heat and pressure).

Tectonic forces (those related to faults and earthquakes) beneath the earth uplifted, tilted, and folded the sedimentary rocks. These tectonic forces along both surface faults (e.g., the Newport-Inglewood and related faults) and buried (so-called "blind") thrust faults (e.g., Torrance-Wilmington, Elysian Park-Puente Hills, Las Cienegas-Coyote Hills, Los Angeles Basin, and Compton-Los Alamitos) formed the chain of hills extending northwest-southeast from north of Los Angeles to Long Beach.

Many subsurface geologic features within the Los Angeles Basin, such as depositional sequences and folds and faults in the rocks, produced geological structures that trapped and accumulated oil and gas, resulting in numerous oil and gas fields. The PDR gas field underlies most of the PDR and MDR area. Initially, this field was the site for oil development and then later, gas storage in this western location of the Los Angeles metropolitan region.

GEOLOGIC UNITS

Geologically recent river and floodplain deposits cover the MDR area, which is north of the Ballona escarpment, (a cliff formed by erosion) while south of the escarpment in PDR, older sand dunes are present as surface deposits. Underlying the surface deposits is a series of geologic units that extend thousands of feet below the project area and are not exposed at the surface. The commercial oil or gas producing zones and the PDR Gas Storage Facility are located within the deeper geologic formations. Geologic hazards, if any, on a particular lot could be attributed to near surface geologic materials such as the surface soils and the younger deposits immediately below the surface soils. Deeper geologic units and structures could influence seismic hazards depending on the geologic structure and underlying faults or the behavior of upward migration of subsurface gases, if it was to occur. **Table 4.E-1** presents the geologic column that lies beneath the project area (from geologically youngest to oldest) and briefly describes each unit and its relationship and relevance to potential impacts in the project area.

STRUCTURE AND SEISMICITY

Compression between the North American and Pacific plates creates tectonic forces that shape many of the surface features we see today. When forces along the plate boundary increase to the point of failure, earthquakes occur and often times, the displacement experienced deep in the earth where the failure occurs translates at the surface as surface fault rupture. Several active and potentially active faults are located within the project vicinity.[1] Regional tectonic stresses also uplifted, tilted, and folded sedimentary rock units in the project area, creating hills and related geologic structures. Geologic structures underlying many hills are often elongated domes or anticlines, similar to those underlying Fox Hills and Baldwin Hills. In the PDR project area, the thick sedimentary rock layers are gently folded into a broad anticline (elongated dome or convex upward folded geologic structure). Along with stratigraphic (depositional) confinement, the anticline forms a structural trap for oil and gas accumulation within the PDR oil field.

Faulting

Faults are fractures or lines of weakness in the earth's crust. Faults that allow landmasses to move horizontally past each other are strike-slip faults (e.g., San Andreas, San Jacinto, Elsinore, and Newport-Inglewood). In contrast, vertical movement occurs along thrust faults. Buried low angle thrust faults that do not rupture the surface are known as blind thrust faults. Earthquake research over the last decade has demonstrated that a complex array of buried, thrust faults underlie the Los Angeles area. Notable thrust fault systems include the Elysian Park Thrust Fault (also known as the Elysian Park Fold and Thrust Fault, the Elysian Park blind thrust fault) and Torrance-Wilmington Fold and Thrust Belt. Blind thrust faults generated the 1987 magnitude 5.9

1 An "active" fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 10,000 years). A "potentially active" fault is defined as a fault that has shown evidence of surface displacement during the Quaternary (last 1.6 million years), unless direct geologic evidence demonstrates inactivity for all of the Holocene or longer. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive

TABLE 4.E-1
GEOLOGIC UNITS UNDERLYING THE PDR AND MDR PROJECT AREA
(Listed geologically youngest to oldest)

Geologic Unit Name	Geologic Description	Location and Proximity to Project Lots	Relevance to Project Lots
Surface Soils	Only disturbed, semi-natural soils remain in the project area with limited depths. Consist of clay sand and silt mixtures.	Disturbed and semi natural soils occur on the surface of MDR and PDR project lots	Due to the past development, original soil resources are disturbed. Most, if not all project lots are not overlain by intact, native soil profiles.
Recent Alluvium	Recent river and floodplain alluvium and near-shore deposits consisting of gravels, sand, silt, and clay.	Recent alluvium underlies surface materials in the MDR.	The primary exposed material, other than soil, on MDR project lots. Could be attributable to geologic and seismic hazards. Include deposits that are known locally as the "50-Foot Gravel"[1]
Older Dune Sand	Older dune sand deposits cover ancient marine terraces and consist of sand, although also contain silt, clay, and gravel lenses.	Older sand dunes underlie the surface materials in the PDR project area.	Primary geologic unit exposed on the 34 PDR lots other than soil and could be the cause of geologic and seismic hazards.
Lakewood Formation	Approximately 100-feet thick and consists of sand, silt, and gravel.	Not exposed at surface but underlies the Bluffs area of PDR.	No direct influence on potential geologic and seismic hazards on the lots.
San Pedro Formation	Consists of sand deposits with lenses of gravel, silt, and clay.	Not exposed at surface. 50 feet deep in the MDR area and 150 feet deep in the PDR area.	Intermediate geologic unit. No direct influence on potential geologic and seismic hazards on the lots.
Pico Formation	Marine sandstone, siltstone, and shale, interbedded with marine gravels (DWR, 1961)	Occurs at a depth of about 400 to 500 feet below the surface in the project area	Shale units form impervious caps or barriers to upward movement of water, oil, and gas, trapping the hydrocarbon below.
Repetto Formation	Siltstone and shale with layers of sandstone and conglomerate.	Approximately 3,000 feet below the surface.	Sandstone beds within the upper and middle Repetto Formation form the upper oil producing zone found in the MDR area (Davis, 2000).
Puente Formation	Shale devoid of major sand-bearing units.	Underlies MDR and PDR at depths generally over 5,000 feet	The thick shale interval is impermeable and forms the primary cap or seal for the PDR oil field and the gas storage zone (Davis, 2000)
The Topanga Formation	Comprised of sandstone and conglomerate weathered material from the underlying Catalina Schist.	Does not underlie the entire project area. Depth is about 6,000 feet.	The schist conglomerate is the primary reservoir for the PDR oil field and the gas storage zone.
Santa Monica Schist or Catalina Schist	Basement rock at depths greater than 6,000 feet	Underlying the project area and most of the Los Angeles Basin	No direct influence on geology or geologic Hazards on lots.

1 The "50-foot gravel" was thought to provide preferential pathways for subsurface gas migration to the surface. The total thickness of recent alluvium varies from several feet to about 60 feet. According to a subsurface investigation conducted for this EIR, the Ballona Aquifer does not underlie the project sites (Brown and Caldwell, 2004)

Whittier Narrows earthquake and the 1994 magnitude 6.7 Northridge earthquake. Because of these recent events, blind thrusts are considered a future earthquake risk, especially in the Los Angeles basin. In the PDR project area, the Compton blind thrust fault is about 20,000 to 30,000 feet below the site; well below the gas storage zone. Faults that exhibit both vertical and horizontal movement are known as oblique faults (e.g., Santa Monica-Hollywood, Cucamonga, Palos Verdes, and Raymond Faults and Fault Zones). Other faults defined within a 5 mile radius of the site include the northwesterly-trending Newport-Inglewood, Palos Verdes, Overland Avenue, and Charnock faults. Major fault zones in Southern California within approximately 25 miles of the site are summarized in **Table 4.E-2**.

Within the PDR Gas Storage Facility area and the Storage Zone Area of Influence (within one mile of the main facility), investigators Metzner (1935), Hodges (1944), and Riegle (1953) interpreted two sets of minor faults that appeared to displace Catalina Schist and Topanga Formation schist conglomerate at depths greater than 4,000 ft below ground surface (Davis, 2000a). Subsequent analysis by Hester (1986) and Davis (2000) did not find conclusive evidence for the existence of these minor faults and the studies determined that if the faults did exist, they are short, minor offsets at depths greater than 4,000 feet that have probably not experienced displacement within the last 14 million years and certainly not in the last 3 to 4 million years (Davis, 2000a)[2].

The Charnock fault, the nearest fault in the project vicinity, is located about 1.5 miles east of the PDR and MDR area and extends southeast from near Venice Boulevard toward the City of Gardena. The Charnock fault displaces lower aquifers acting as a partial barrier to groundwater movement (DWR, 1961). This fault was thought to be a six-mile long vertical thrust with the northeast side downthrown relative to the southwest side. The Los Angeles County Seismic Element (1990, Plate 1) and the California state fault map (Jennings, 1995) classifies the Charnock fault as a potentially active fault. However, detailed 3-dimensional seismic survey data revealed no evidence of the Charnock fault in the vicinity of the PDR and MDR project area (Davis, 200b).

The Lincoln Boulevard Fault, initially proposed by ETI (2000) to explain the presence of methane gas found during soil-gas surveys at the project sites, was thought to be located east of and parallel to Lincoln Boulevard (ETI, 2000). Subsequent seismic studies conducted by ETI (2000), ECI (2000), and Davis (2000) evaluated the potential for faulting near the intersection of Lincoln and Jefferson Boulevards at the Playa Vista site. These studies, that included subsurface drilling and seismic surveys, did not find evidence of the Lincoln Boulevard fault and could not confirm the presence of local faulting. The postulated Lincoln Boulevard fault is inconsistent with the existing geophysical and geologic data from the Playa Vista area (Davis, 2000b).

2 Davis (2000) used five different geologic and geophysical methods to evaluate the possibility of faulting beneath the Playa Vista Site. These included geologic data review, construction of subsurface maps and cross section data, review of pre-existing seismic reflection data, 2-dimensional high resolution seismic reflection along Jefferson Boulevard, 3-dimensional seismic survey over the entire site, and off-shore geophysical data (Davis, 2000b)

Historic Seismicity

The moment magnitude (Mw) provides a physically meaningful measure of the size of a faulting event and is currently accepted by the scientific community as the measure of earthquake energy released during a seismic event. While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the ground-shaking effects at a particular location. Ground movement during an earthquake can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and type of geologic material. A common measure of ground motion is the peak ground acceleration (PGA), which expressed as the percentage of the acceleration due to gravity (g) or approximately 980 centimeters per second squared. The Modified Mercalli (MM) intensity scale, ranging from MM intensity of I to XII, is commonly used to measure earthquake ground motion intensity and is based on whether people can feel the earthquake and the observed effects of ground shaking. The MM intensity values ranging from I to II are typically not felt by people while intensity values between III and VII are felt by most and result in some damage. MM intensity values from VIII to the maximum value of XII represent strong to violent ground shaking and result in considerable structural damage and/or collapse.[3] The estimated moment magnitudes (Mw) shown in **Table 4.E-2** represent *characteristic* earthquakes on particular faults.[4] **Table 4.E-2** lists the major earthquake faults located within 25 miles of the PDR and MDR project areas and includes the expected size and intensity of a maximum earthquake on each of the faults.

During the past 230 years (1769 to 1999), Southern California has experienced about 20 notable earthquakes (Mw 6.0 or greater; where Mw is the moment magnitude). Six of these events equaled or exceeded Mw 7.0. The three largest earthquakes that occurred within the Los Angeles Basin during recent time are the January 17, 1994, Mw 6.7 Northridge earthquake; the October 1, 1987, Mw 5.9 Whittier-Narrows earthquake; and the February 9, 1971, Mw 6.4 San Fernando earthquake. The shortest distance from the site to the energy release zone (site-to-source distance) in these earthquakes is about 18, 22, and 31 miles, respectively.

Peak horizontal ground acceleration (PHGA) estimates indicate that the earthquake-induced ground motion would be generated by an Mw 6.9 event on the underlying Compton Thrust fault or an Mw 7+ event on the Newport-Inglewood fault. The California state-planning scenario for a major earthquake on the Newport-Inglewood fault zone assumes that an Mw 7 earthquake could subject the project area to seismic MM intensity of VIII+ to IX (Toppozada, et al, 1988). In 1933, the project site area experienced an intensity of VII+ during the 6.3 magnitude Long Beach earthquake. Even though no specific analysis has been conducted to determine actual values, a future earthquake on the buried Compton thrust fault may generate higher ground motion intensity than experienced during the 1933 event.

3 The damage level represents the estimated overall level of damage that will occur for various MM intensity levels. The damage, however, will not be uniform. Not all buildings perform identically in an earthquake.

4 The concept of “characteristic” earthquake means that we can anticipate, with reasonable certainty, the actual earthquake that can occur on a fault.

**TABLE 4.E-2
EARTHQUAKE SITE PARAMETERS
WITHIN 25 MILES OF THE PROJECT AREA**

		Estimated Maximum Earthquake		
			Mean Values	
Abbreviated Fault Name	**Approximate Distance** Miles (Kilometers)	**Maximum Earthquake Magnitude** (Mw)	**Peak Ground Acceleration** (g.)	**Estimated Site Intensity (MMI)**
Palos Verdes	4.1 (6.6)	7.1	0.424	X
Newport-Inglewood (L. A. Basin)	5.9 (9.5)	6.9	0.340	IX
Compton Thrust	6.2 (9.9)	6.8	0.591	X
Santa Monica	6.3 (10.2)	6.6	0.362	IX
Malibu Coast	7.2 (11.6)	6.7	0.346	IX
Hollywood	8.6 (13.8)	6.4	0.272	IX
Elysian Park Thrust	14.1 (22.7)	6.7	0.307	IX
Anacapa-Dume	14.8 (23.8)	7.3	0.260	IX
Raymond	16.6 (26.7)	6.5	0.156	VIII
Verdugo	18.0 (28.9)	6.7	0.161	VIII
Northridge (E. Oak Ridge)	18.0 (29.0)	6.9	0.270	IX
Sierra Madre	21.4 (34.5)	7.0	0.160	VIII
Sierra Madre (San Fernando)	22.6 (36.4)	6.7	0.126	VIII
Whittier	24.1 (38.8)	6.8	0.102	VII
Santa Susana	24.2 (39.0)	6.6	0.109	VII

SOURCE: EQFAULT Computer Program (Blake, 2000)

GEOLOGIC AND SEISMIC HAZARDS

Surface Fault Rupture

Surface fault rupture can occur in cases where earthquakes are large or occur at shallow depths. With the exception of the Compton Thrust Fault and the low angle Elysian Park Thrust Fault, which lies at 8,000 to 10,000 feet beneath the storage zone, no known active faults capable of causing surface offset underlie the project area and the Storage Zone. A major, near-vicinity earthquake could possibly cause minor movement (probably < 1.0 foot) at depth within the storage zone, but such offset is unlikely to propagate to within several hundred feet of the surface. Because surface fault rupture is more likely on active faults, the State of California, through the Alquist-Priolo Earthquake Zoning Fault Act, places active faults in zones that restrict development. No Alquist-Priolo zones traverse the project area and the potential for surface fault rupture at the site is considered very low. Presently, documentation indicates that the storage zone contains no fault offsets. As discussed above, previous reports infer various faults in other areas of the field, but these reports do not provide evidence of their presence (Davis, 2000).

Considering the absence of active faults capable of causing surface fault rupture, the potential for fault rupture at the project sites is low and is therefore not evaluated further in this document.

Earthquake Ground Shaking

The numerous active earthquake faults within 50 miles of the project area will continue to subject the southwestern Los Angeles Basin and the project area to strong seismic shaking during large earthquakes. Earthquakes are unavoidable and will occur throughout the useful life of the project. Earthquakes in the region could generate long duration ground shaking capable of causing injury and severe structural damage. The potential for activity on a blind thrust is possible and if it were to occur, the ground motion could be higher than some buildings could tolerate. Earthquakes that generate strong ground shaking could trigger movement on other nearby fault zones. Estimated PHGA generated by earthquakes on the San Andreas Fault, Newport-Inglewood, and Elysian Park Thrust Fault should range from about 0.1 g to 0.7 g. These earthquakes would generate enough energy and have a sufficiently long duration, to damage project facilities, adjacent structures, and area residences.

Induced Seismicity

Microseismic activity, with magnitude from 0 to 1 Mw, often occurs during injection and extraction operations (Terralog Technologies, 2000). Activity of this magnitude can be anticipated at PDR during operations, and is not significant relative to natural daily seismicity in the Los Angeles area. Earthquakes in this magnitude range would not cause subsurface fault movement of more than an inch and would not be felt at the surface and therefore, the impacts would remain less than significant and microseismicity is not evaluated further in this EIR.

Slope Stability

Slope failures, also commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Exposed rock slopes undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and deep-seated rotational slides. Landslides may occur on slopes of 15 percent or less; however, the probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. Landslides typically occur within slide-prone geologic units that contain excessive amounts of water, are located on steep slopes, or where planes of weakness are parallel to the slope angle.

The MDR area is located on low-relief topography along the coastline north of the bluffs and therefore slope instability is not an issue or a potential impact at the MDR sites. Areas along the northern boundary of PDR are delineated by the State of California as Seismic Hazard Zones for earthquake-induced landslides (see *Applicable Regulations, Plans, and Policies* below). The five lots making up Clusters 10 and 11 in the PDR area have steep slope angles with slope heights of more than 50 feet in Quaternary marine terrace deposits. However, these areas are not included in the areas designated as Seismic Hazard Zones.

Liquefaction and Other Secondary Earthquake Effects

Liquefaction is a phenomenon whereby unconsolidated and/or near-saturated soils lose cohesion and are converted to a fluid state as a result of severe vibratory motion. The relatively rapid loss of soil shear strength during strong earthquake shaking results in temporary, fluid-like behavior of the soil. Soil liquefaction causes ground failure that can damage roads, pipelines, underground cables, and buildings with shallow foundations. Liquefaction can occur in areas characterized by water-saturated, cohesionless, granular materials at depths less than 40 feet. The depth to groundwater influences the potential for liquefaction; the shallower the groundwater, the higher potential for liquefaction.

Young, unconsolidated dune sand and lagoon sediments underlie the MDR area over a shallow, tidally-influenced groundwater table. Because of the shallow underlying geologic materials and the groundwater conditions, the MDR is delineated by the State of California as a Seismic Hazard Zone for liquefaction (see *Applicable Regulations, Plans, and Policies* below) The materials in this area, namely saturated sands and coarse grain lagoon sediments could fail and liquefy during a major earthquake. Liquefaction hazard at the PDR sites is not an impact due to the location and presence of geologic materials not susceptible liquefaction.

Subsidence

Removal of oil and gas (or other fluids) from poorly consolidated geologic formations can cause surface subsidence. These fluid withdrawal processes can leave void spaces at depth. Unless refilled with fluids by re-pressurization techniques, poorly consolidated sediments may collapse causing subsidence in the shallower earth layers. The same general process can occur when groundwater is withdrawn from unconsolidated aquifers. There is no indication that groundwater withdrawal is taking place in the project area, therefore the potential for subsidence is low and not evaluated further in this EIR.

In October 2000, the City of Los Angeles, Department of Public Works (LADPW) evaluated surface elevation changes in the PDR project area. During the period from 1975 to 2000, the maximum surface subsidence observed on one location was 2.66 inches. This occurred at an elevation marker placed in the curb of Manchester Boulevard at the intersection of Hastings Avenue. LADPW concluded that area surface subsidence identified during their evaluation was likely associated with settlement of curbs, sidewalks and gutters along major streets and not localized or regional subsidence.

Although the oil storage zone is well-consolidated, complete withdrawal of all storage gas (including cushion gas) may cause minor surface subsidence. No specific studies for the PDR field indicate this level of subsidence. For the Montebello Field (with somewhat similar geology) studies estimate two inches of subsidence distributed over a broad area (Terralog Technologies, 2000). Since the field will remain in operation, measurable surface subsidence is not anticipated. The potential damage to surface structures attributable to minor amounts of subsidence is not significant and therefore not evaluated further in this EIR.

Expansive Soils

Expansive soils possess a "shrink-swell" behavior. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Structural damage may occur over a long period of time, usually the result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils. There may be portions of the project area that could contain expansive soils. Adverse effects due to expansive soils, such as those that could damage a building foundation or road, can be overcome by adequate investigation and engineering design.

Soil Erosion

Erosion is the wearing away of soil and rock by processes such as mechanical or chemical weathering, mass wasting, and the action of waves, wind, and underground water. Soils containing high amounts of silt or clay can be easily erodable while sandy soils are less susceptible. Excessive soil erosion can eventually lead to building foundation and roadway damage. At the project sites, areas that are underlain by fine grained material and areas where the soil is exposed during the construction phase are susceptible to erosion.

The shallow (within a few feet of the ground surface) soil, alluvium, and bedrock formations underlying the project will have varying susceptibility to soil erosion due to their unconsolidated nature and/or level of compaction. Running water and steep slopes are the primary components that trigger erosion of unprotected soil surfaces.

APPLICABLE REGULATIONS, PLANS, AND POLICIES

This section presents a discussion of applicable laws and regulations that address geologic hazards in California, applicable to the project site.

STATE

Alquist-Priolo Earthquake Hazards Zone Act of 1972

The Alquist-Priolo Earthquake Hazard Zone Act (formerly the Alquist-Priolo Special Studies Zones Act), signed into law in December 1972 [5] requires the identification of zones along sufficiently active and well-defined faults. Development is limited in areas defined as Earthquake Hazard Zones, and structures for human occupancy are generally not permitted. Development proposals for both public and private structures in an Earthquake Hazard Zone require detailed geologic/seismic hazard evaluations before a use permit is issued. No active faults capable of generating surface fault rupture traverse the project area and therefore this act does not apply to the lots proposed for sale.

Seismic Hazards Mapping Act[6]

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5 California Public Resource Code, Section 2621.
6 California Public Resource Code, Section 2690.

The Seismic Hazards Mapping Act of 1990 was developed to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. The Act requires the property owner of a parcel within a designated seismic hazard zone to conduct an appropriate geological/geotechnical investigation in accordance with the *California Geological Survey Guidelines for Evaluating and Mitigating Seismic Hazards* (CGS Special Publication 117). This investigation must be completed before the lead agency grants the building permit[7].Appropriate mitigation measures must be incorporated into the project design. Seismic hazard zone maps outline areas that are considered susceptible to liquefaction and earthquake-induced landslides. MDR, including the lots proposed for sale, is designated under the Seismic Hazards Mapping Act as a liquefaction hazards zone by CGS (CGS, 1999). . Limited areas along the north bluffs of PDR are steeply sloped and have been designated in accordance with the Seismic Hazard Mapping Act as areas with a potential for earthquake-induced landslides (CGS, 1999). The lots are not within the areas designated as seismic hazard zones because the gradient, geologic material, and the expected response to ground shaking at the lots do not represent a potential seismically-induced slope failure hazard. If the slope areas that are designated Seismic Hazard Zones do fail during an earthquake, the lots are not close enough to be affected.

California Building Code

The California Building Code (CBC) is another name for the body of regulations known as the California Code of Regulations (CCR), Title 24, Part 2, which is a portion of the California Building Standards Code. Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable (Bolt, 1988).

Published by the International Conference of Building Officials (ICBO), the Uniform Building Code (UBC) is a widely adopted model building code in the United States. The CBC incorporates by reference the UBC with necessary California amendments. About one-third of the text within the CBC has been tailored for California earthquake conditions (ICBO, 1997). The national model code standards that include Title 24 apply to all occupancies in California except for more stringent modifications adopted by state agencies and local governing bodies.

The project area is located within Seismic Zone 4, as delineated under the UBC and CBC. This area is one of the four seismic zones designated in the United States, and is considered an area with greatest earthquake risk. This region is expected to experience damaging ground shaking effects from earthquake and therefore has the most stringent requirements for seismic design. For sites within Zone 4, the CBC and UBC require additional earthquake ground motion analysis and more conservative construction criteria to avoid structural collapse during the characteristic earthquakes possible within this zone.

7 Lead agency is the state agency, city, or county with the authority to approve projects (CCR Title 14, Section 3721b)]

California Division of Oil, Gas and Geothermal Resources

The California Division of Oil, Gas & Geothermal Resources (DOGGR) regulates production of oil and gas, as well as geothermal resources, within the state of California. DOGGR regulations are defined in CCR, Title 14, Chapter 4 (see Appendix F). DOGGR regulations define well design and construction standards, surface production equipment and pipeline requirements, and well abandonment procedures and guidelines.

- DOGGR regulates well abandonment procedures to ensure they are conducted safely and are effective. These regulations require procedures designed to prevent future migration of oil and gas from a producing zone to shallower zones, and to protect groundwater.
- DOGGR oversees well operations. When an operator ceases well operation or production, state law requires the well is abandoned within a reasonable period of time.
- Regulations require well operators to maintain detailed records of abandonment operations and file copies with DOGGR.
- DOGGR also regulates environmentally sensitive pipelines within 300 feet of any public recreational area, or a building intended for human occupancy (residences, schools, hospitals, and businesses) that is not necessary to the production operation.

LOCAL

County of Los Angeles, Department of Public Works

For projects involving site grading and earthmoving, the County of Los Angeles, Department of Public Works (DPW), Building and Safety Division, has jurisdiction to ensure the safety of workers during construction and the public once the project is constructed. DPW, City of Los Angeles grading and earthmoving requirements are specified in the County Building Code (including the latest version of the Uniform Building Code (UBC) and the procedures outlined in the County Hydrology Manual.

City of Los Angeles

The City of Los Angeles, Building and Safety Department, regulates design and construction of commercial and high occupancy structures located over areas with potential for gas reaching the surface. These areas typically include oil and gas resource areas (active and abandoned oil and gas fields), landfills, and other areas where shallow subsurface gas has been documented.

The City of Los Angeles Fire Department prohibits construction of dwellings closer than 50 feet from an operating oil well. The Fire Commission may grant variances not exceeding 10 percent of the required clearances. Any substantial reduction in clearances should impose additional safeguards from fire and fire exposure. Upon completion of well abandonment procedures, the Los Angeles Fire Department conducts a final inspection of the well site.

Along with the DPW, the City issues permits for project-related grading activities within the city, monitors project-related construction activities if applicable, and ensures compliance with permit requirements. The City issues final project approvals and a certificate of occupancy (if applicable) when they receive verification of compliance to inspections and requirements.

SIGNIFICANCE CRITERIA

A soils or geologic impact would be considered significant if it would result in any of the following, which are adapted from CEQA Guidelines, Appendix G:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault;
  - Strong seismic ground shaking;
  - Seismic-related ground failure, including liquefaction; or
  - Landslides
- Result in 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- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse;
- Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property; or
- Underlying geology produces preferential pathways for trapped subsurface gases to migrate to the surface resulting in adverse conditions and substantial risk to future residents and customers or commercial establishments.

Certain topics related to geology and seismicity are not discussed in this analysis because they are not considered potential impacts of or to the project. These topics are discussed below.

- The project area is not located in a low-lying area or adjacent to a large body of water where tsunami and seiches could cause inundation and damage.
- The project would not alter or destroy a unique geologic feature such as an unusual rock formation (with limited distribution), fossil location, geologic structure (such as a cave), or a significant mineral occurrence.
- The project will not include the use of septic tanks or alternative wastewater disposal systems because municipal wastewater systems would provide sewage service.

ENVIRONMENTAL IMPACTS AND MITIGATION

This impact analysis considers impacts related to the geologic and seismic hazards that could be affected by or affect the reasonably foreseeable future development of the 36 lots. Actual transfer of property ownership of the 36 PDR and MDR lots from SCG to new owners would not result in geologic or seismic impacts. However, development of the site would attract more people to the project area thereby exposing more people to hazards related to seismicity and unstable soil and slope conditions. The proposed development could affect geology by reducing natural slope stability through construction grading or could lead to additional erosion and soil loss due to construction activities.

Impact E.1: If commercial or residential development occurs on the project lots and a major earthquake occurs in the region, seismic ground shaking could potentially injure people residing or visiting the project lots and could cause collapse or damage to structures if placed on the lots. An earthquake could cause damage to abandoned or unknown well casings. (Less than significant with recommended mitigation)

Surface Damage from Earthquakes

The numerous active earthquake faults within 50 miles of the project area will continue to subject the southwestern Los Angeles Basin and the project area to strong seismic shaking during large earthquakes. Earthquakes are unavoidable and may occur throughout the useful life of the project. Earthquakes in the region could occur on one of the numerous faults in the Los Angeles Area and generate long duration ground shaking capable of causing injury and severe structural damage. Blind thrust faults (discussed previously in setting section), although not likely to cause ground rupture, have the potential to cause a moderate to large earthquake sometime in the future as Los Angeles experienced in 1987 and 1999. If a blind thrust fault generated a moderate to high magnitude event, the ground motion could be higher than some buildings could tolerate. Earthquakes that generate strong ground shaking could also trigger movement on other nearby fault zones.

Because the Los Angeles is located within one of the most seismically regions in the United States, it is likely that the project area may experience at least one major earthquake (Mw 6.7 or higher) within the life of the development that would result from the project. The intensity of such an event would depend on the causative fault and the distance to the epicenter, the moment magnitude, and the duration of shaking. A seismic event in this region could produce high ground acceleration and MM intensities ranging from strong (MM-VIIX) to very violent (MM-X). Based on the MM intensity scale, an earthquake of this intensity would cause considerable structural damage, even in well-designed structures. Substantial cracks could appear in the ground, and the shaking could cause other secondary damaging effects, such as the failure of underground pipes.

Damage to Well Casings

The magnitude of impact from seismic ground motion on the former oil reservoir and PDR Gas Storage Facility area is uncertain considering that it is unknown whether changes in the underlying geology, such as bedrock fractures, could develop preferential gas migration to the surface, especially through unabandoned, abandoned, or unknown well casings. Gas migration to the surface due to seismically-induced changes to the underlying strata or earthquake damage to a well casing would only be a significant impact if the gas that leaked to the surface represented an adverse impact to human health or the environment. Refer to Section 4.F, *Public Health* and

Section 4.G, *Public Safety* for additional discussion and analysis on human health and safety impacts associated with exposure to subsurface gas sources.

Post-1933 earthquakes within the Newport-Inglewood zone reportedly have damaged wells and well casings and a moderate earthquake on October 21, 1941damaged wells at a depth of 5,000 to 6,000 feet in the West Dominguez oil field (Toppozada et al, 1988). Although this may suggest that under certain seismic conditions and depths, earthquakes can damage well casings accessing the gas storage zone, the response of the well to seismic activity, and the magnitude of the resulting damage during an earthquake cannot be certain or predicted.

The PDR Gas Storage reservoir is about 6,000 feet deep and overlain by a thick and impermeable sequence of bedrock that provides a seal for oil and gas. There is no evidence that this sealing section is offset by through-going fractures. In addition, oil production and gas injection has produced an inverse pressure gradient that is present between the overlying seal and the PDR Gas Storage reservoir. The impermeable seal produced by the thick bedrock and the inverse pressure gradient make upward migration of hydrocarbons from the PDR Gas Storage Facility highly unlikely (Davis, 2000a).

DOGGR developed and enforces well abandonment standards to ensure that all wells are abandoned in a consistent manner to protect oil and gas zones, to prevent degradation of usable waters, to protect surface conditions, and for public health and safety.[8] DOGGR standards require that the wells be filled with impermeable plugs to seal and isolate gas zones. These requirements to fill and seal the wells with concrete, or other comparable sealing material, and its inspection and testing of the abandonment process, ensures that wells will seal existing and potential preferential gas migration pathways. Each of the wells associated with the lots were abandoned to DOGGR standards under supervision of the district deputy and therefore the potential is low that they could become a conduit or preferential pathway for gas migration to the surface after abandonment.

During an earthquake, the cement seal in the well could be damaged allowing a preferential pathway to form and gas to migrate to the surface. It is possible but not necessarily probable that earthquake ground motion could fracture the hardened concrete within the well to the extent that a continuous fracture would could form and allow gas migration. Furthermore, because of the inverse pressure gradient discussed above, even in the event that a well seal was fractured, there is a low potential for gas to escape to the surface.

The past uses of the wells are also considered in analyzing whether gas migration is possible when the well is damaged by an earthquake. With the exception of the Troxel 1 well, most of the wells associated with the lots proposed for sale did not have extended, direct contact with the storage reservoirs, as listed below:

- Abandoned wells, Joyce 1, Samarkand 1, 23-1, 29-1, and 29-2 in PDR were part of fluid recovery systems that were used in water removal and not directly involved with the gas storage area.

8 California Code of Regulations, Title 14, Article 3, Section 1723

- The Anglo American Champ No.1 and O&M-1 well in PDR were not involved in storage operations.
- Hisey 1, Lor Mar 1, Merrill 1, and 13-1 in PDR were located in a smaller, separate reservoir that became saturated with water in the 1970s and was not used. The presence of water would significantly reduce, if not eliminate, contact with subsurface gas.

Brown and Caldwell conducted soil gas surveys and subsurface exploration studies to support the analysis for this EIR (Brown and Caldwell, 2004). Results of Brown and Caldwell's recent soil gas sampling verify the absence of soil gas in the shallow soils on the project parcels indicating that there is no leakage occurring from the project site well casings and surrounding geology. As discussed above, the migration of gas to the surface would only be an impact if that gas represented an adverse health hazard to the public on the associated lots. (Refer to Section 4.F, *Public Health* and Section 4.G, *Public Safety* for additional discussion and analysis on human health and safety impacts associated with exposure to subsurface gas sources.)

Based on the above analysis, it is not likely that earthquake ground shaking could damage the seal within an abandoned well to the point that quantities of subsurface gas could escape and represent a health and safety hazard and therefore, impacts related to this occurrence would remain less then significant.

Once the 36 project lots are developed, there would remain a high potential that seismic ground shaking could expose people to injury and property to damage in the event of a large regional earthquake. Although earthquakes are unavoidable, there are feasible measures and structural design to reduce the level of injury and building damage during an earthquake. The California Building Code (CBC) requires special seismic design criteria for commercial and residential structures in Seismic Zone 4 in California. Prior to design and construction, future development of the 36 project lots would require design under the CBC, which includes necessary geotechnical study to develop adequate soil strength data. Under the CBC, structures would be designed and constructed to withstand the maximum magnitudes of the characteristic earthquakes on the regional faults. Mitigation Measure E.1 below is recommended by this EIR for future site development to ensure that impacts related to injury and structural damage in the event of an earthquake remain less than significant.

Recommended Mitigation Measure E.1: A site-specific, design level geotechnical investigation for each building (which is typical for any large development project) shall be required as part of this project. Each investigation shall include an analysis of expected ground motions at the site. The analyses shall be in accordance with applicable City ordinances and policies and consistent with the 1997 UBC (or any more recent version of the UBC adopted by the City of Los Angeles), which requires structural design that incorporates ground accelerations expected from known active faults. In addition, the investigations will determine final design parameters for the walls, foundations, and foundation slabs. The investigations shall be reviewed by a registered geotechnical engineer. All recommendations by the project engineer and geotechnical engineer shall be included in the final design. Recommendations that are applicable to foundation design, earthwork, and site preparation that were prepared prior to or during the project design phase shall be incorporated into the project. The final seismic considerations for the site

shall be submitted to and approved by the City of Los Angeles Department of Public Works. (Recommended for Future Development)

Significance after Recommended Mitigation: Less than Significant.

Impact E.2: In the event of a major earthquake in the Los Angeles region, the 36 lots proposed for sale would be subjected to seismic ground shaking and depending on the site-specific geologic conditions and level of ground motion, may be subjected to earthquake-induced, secondary ground failures including liquefaction, earthquake-induced landslides, and earthquake-induced settlement. (Less than significant with recommended mitigation)

As discussed above, ground shaking from earthquakes can cause certain types of soils and slopes to fail resulting in landslides and soil collapse. In the MDR area, seismic-induced ground failure could occur due to the unconsolidated alluvial material and high groundwater. Because of this, the MDR area is designated by the State of California as a Seismic Hazard Zone (see Regulatory Setting discussion above) for liquefaction. Liquefaction at the site could result in loss of bearing pressure, lateral spreading, sand boils (liquefied soil exiting at the ground surface), and other potentially damaging effects. The PDR area is not designated as a liquefaction zone because the underlying geology is more consolidated than the sediments in the MDR and the groundwater is deeper.

Unlike the MDR, some areas of the PDR are designated as a Seismic Hazard Zone for earthquake-induced landslides. In these areas, the combination of topography, underlying geology, and potential seismic response during an earthquake represent an area susceptible to slope failure during an earthquake, especially in saturated or overdeveloped slopes. There is also some limited potential for slope instability in natural slopes that could fail due to static forces. In other areas, development requiring new cut slopes, road building, or grading of terraces could reduce the overall stability of natural slopes leading to slope failure. The potential for slope failure is only present on lots within Clusters 10, 11, and 12. Slopes on these lots could fail under static or seismically-induced movement, or if grading would require terraces and cut slopes. Any unstable slopes that may be present locally could experience problems with or without future development of the lots.

The potential liquefaction hazard could directly impact the MDR development and seismically-induced landslides could impact the PDR development (in certain areas). Typically, potential liquefaction and landslide hazards, if adequately investigated, can be reduced with appropriate engineering. Areas within a designated Seismic Hazard Zone must undergo prescribed evaluation and mitigation prior to development. Because appropriate and accepted investigation and engineering techniques are available to mitigate potential liquefaction and landslide hazards, this impact would remain less than significant with mitigation recommended for future development, as discussed below.

Recommended Mitigation Measure E.2: A site-specific, design level geotechnical investigation shall be required for all lots prior to development, especially those lots that may be susceptible to secondary seismic ground failure. The investigation shall consider the proposed development designs and provide engineering recommendations for mitigation of liquefiable soils and seismically-induced ground failure resulting in landslides or soil collapse. These recommendations shall become part of the future project. Where applicable, prior to incorporation into the project, geotechnical engineering recommendations from previous investigations regarding the mitigation and reduction of liquefaction, landslides, and ground failure for each site shall be reviewed for compliance with California Geological Survey's (CGS) *Geology Guidelines for Evaluating and Mitigating Seismic Hazards (CGS Special Publication 117, 1997).* (Recommended for Future Development)

Significance after Recommended Mitigation: Less than Significant.

Impact E.3: If eventually developed for commercial or residential uses, some of the 36 project lots that are proposed for sale may be subject to geologic hazards attributable to expansive or settled soils and erosion. These hazards could cause risks to life and property. (Less than significant with recommended mitigation)

Soil conditions are variable throughout the MDR and PDR project areas and site-specific conditions on each of the 36 lots proposed for sale would not be determined without testing each lot. For this reason, there may be portions of the development area that could contain moderately to highly expansive soils or be porous and subject to consolidation under building loads. Adverse effects due to expansive soils typically occur in the first few feet of the soil column and can damage foundations, pavements, and utilities through cyclic shrink-swell behavior. Adverse effects can generally be overcome by adequate investigation and engineering design. Ground settlement that causes localized areas of the surface to settle beyond what a building can tolerate may be present on certain project lots. Over time, settlement could occur on the project site as a result of increased foundation loads from overlying structures being placed on semi-consolidated deposits, such as disturbed surface soils, the older sand dune deposits in PDR and the alluvial deposits underlying the MDR area. Settlements could potentially occur from static loads and possibly half of the settlement would take place during construction or shortly thereafter. Differential settlement could occur between column or floor slabs due to variability of underlying soil conditions. The recommended mitigation measure presented below would ensure potential impacts associated with expansive soils and settlement would remain less than significant.

Construction activities such as backfilling, grading, and compaction can expose areas of loose soil that, if not properly stabilized, could be subjected to soil loss and erosion by wind and storm water runoff. Concentrated surface water flows, occurring temporarily during construction activities or over the long-term after development, if not managed or controlled, can eventually result in significant erosion and soil loss. The City and County of Los Angeles require site grading and earthmoving projects to comply with the Department of Public Works requirements and the procedures outlined in the County Hydrology Manual to avoid erosion and loss of topsoil.

These requirements and procedures include the development of Best Management Practices to reduce erosion and sedimentation. As discussed in Section 4.H, *Hydrology and Water Quality*, the NPDES permitting program, as implemented by the State of California, addresses measures to reduce sedimentation and erosion in stormwater discharges for construction activities. Examples of protection measures include diversion dikes, silt fences, sediment traps or sediment basins, and mulching. Compliance with local grading codes, the requirements of the NPDES process, and required runoff controls for construction, such as Best Management Practices, would ensure that erosion hazards remain less than significant.

Recommended Mitigation Measure E.3: A site-specific, design level geotechnical investigation shall be required for all of the lots proposed for sale to determine the presence or absence of expansive soils or those soils that could not accommodate building loads. Such geotechnical investigations and reports shall include generally accepted and appropriate engineering techniques. Engineering recommendations shall become part of the future project. In addition, future developers shall adhere to local grading and construction policies to reduce the potential for geologic hazards, including differential settlement and soil erosion. All construction activities and design criteria shall comply with applicable codes and requirements of the California Building Codes and applicable local construction and grading ordinances. (Recommended for Future Development)

Significance after Recommended Mitigation: Less than Significant.

CUMULATIVE IMPACTS

Impact E.4: Future development of the 36 project lots, when combined with other foreseeable development in the vicinity, could result in cumulative impacts with respect to geology. (Less than significant)

As the future development of the lots proposed for sale and other redevelopment projects[9] in the MDR and PDR area near completion, additional people that would be subjected to seismic risks and hazards will come into the area. While the number of people visiting, living, and working in the area will increase incrementally exposing additional people to seismic and geological hazards over a short term, the trends of redevelopment in these areas will likely decrease the risk to people and property by upgrading or demolishing older buildings that are seismically unsafe. Older buildings will likely be seismically retrofitted and newer buildings will be constructed to stricter building codes. Thus, there are no expected cumulatively significant geology effects, nor would the project's contribution to any such effects be cumulatively considerable.

Mitigation: None required.

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9 These projects include, the Village at Playa Vista, Mountain Gate, Paradise Landmark Condominium Project, Brentwood Project, and Westside Medical Park. See Section 3.6 for more information about these cumulative projects.

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