4.5 Geology, Soils, and Paleontology

This section of the PEIR describes the potential physical environmental effects related to the issues of geology, soils, and paleontology resulting from development of proposed CIP projects under the 2008 Master Plan. The paleontological analysis is based on the Paleontological Resources Evaluation prepared by George Burwasser, California Registered Geologist, attached to this PEIR as Appendix D.

4.5.1 Environmental Setting

4.5.1.1 Geology

The VWD service area is situated in the coastal foothill section of the Peninsular Ranges Geomorphic Province which extends approximately 900 miles from the Transverse Ranges and the Los Angeles Basin south to the southern tip of Baja California, and varies in width from approximately 30 to 100 miles. In general, the Peninsular Ranges Province consists of rugged mountains underlain by Jurassic metavolcanic and metasedimentary rocks, and Cretaceous igneous rocks of the southern California batholith. The Peninsular Ranges Province is traversed by a group of sub-parallel faults and fault zones trending roughly northwest (Ninyo & Moore 2008).

4.5.1.2 Faults

Active or potentially active faults are defined as faults that have exhibited evidence of ground displacement in the last 11,000 years and 2,000,000 years, respectively. Faults classified as inactive have not exhibited ground displacement in the last 2,000,000 years. Table 4.5-1 identifies active faults located within approximately 60 miles of the VWD service area, measured from the location of Palomar Community College District, San Marcos Campus. The approximate locations of the faults are shown on Figure 4.5-1. Movement on any of these faults may generate seismically induced ground shaking and surface rupture. Ground shaking can cover a wide area relative to the distance to the fault movement. Fault movement may result in a variety of seismic hazards, which are discussed below under Section 4.5.1.3.

Magnitude Scales

The Richter scale was developed in 1935 by Charles Richter for use in a study area in California to measure the strength of an earthquake. The more commonly used scale today is the moment magnitude (M_W) scale, developed at the U.S. Geological Survey (USGS) in 1978, which is a measure of the potential energy released on a fault expressed in whole numbers and decimals (e.g., 4.2). The M_W of an earthquake is defined relative to the seismic moment for an earthquake event. The magnitude of each earthquake varies with the recorded seismic moment. Each whole number increase in magnitude of an earthquake event represents an increase in amplitude of ten times and the energy released by approximately 31 times. The moment magnitude for active faults within 60 miles of the VWD service area is shown in Table 4.5-1.

Table 4.5-1 Active Faults within 60 miles of the VWD Service Area[1]

Fault	Moment Magnitude (M_W)[2]	Slip Rate (mm/yr)[3]	Fault Type[2]	Fault Movement[2]	Approximate Distance (miles)
Rose Canyon	7.2	1.5	B	SS-RL	12
Newport-Inglewood (Offshore)	7.1	1.5	B	SS-RL	14
Elsinore (Julian Segment)	7.1	5.0	A	SS-RL	18
Elsinore (Temecula Segment)	6.8	5.0	A	SS-RL	19
Coronado Bank	7.6	3.0	B	SS-RL	27
Earthquake Valley	6.5	2.0	B	SS-RL	35
Elsinore (Glen Ivy Segment)	6.8	5.0	A	SS-RL	35
San Jacinto (Anza Segment)	7.2	12.0	A	SS-RL	41
San Joaquin Hills	6.6	0.5	B	DS-R (23 SW)	42
San Jacinto (San Jacinto Valley Segment)	6.9	12.0	A	SS-RL	43
San Jacinto (Coyote Creek Segment)	6.8	4.0	A	SS-RL	44
Palos Verdes	7.3	3.0	B	SS-RL	45
Elsinore (Coyote Mountain Segment)	6.8	4.0	A	SS-RL	49
Chino Central Avenue (Elsinore Segment)	6.7	1.0	B	RL-R-O (65 SW)	52
Newport-Inglewood (L.A. Basin)	7.1	1.0	B	SS-RL	53
Whittier	6.8	2.5	A	RL-R-O (75NE)	55
San Jacinto (Borrego Segment)	6.6	4.0	A	SS-RL	58
San Jacinto (San Bernardino Segment)	6.7	12.0	A	SS-RL	60

(1) Measurements in this table were taken from the Palomar Community College District, San Marcos Campus, located along the western central boundary of the VWD service area.
(2) See text for definitions and explanations.
(3) Millimeters per year (mm/yr)
Source: Ninyo & Moore 2008

Fault Types

The California Department of Conservation, Division of Mines and Geology (CDMG) classify active surface faults into one of the following three categories:

- **Type A Faults.** Faults that exhibit a moment magnitude of 7.0 or greater, and have a slip rate of at least 5 millimeters per year.
- **Type B Faults.** Faults that exhibit a moment magnitude of 6.5 to 7.0, and have slip rates that vary depending on magnitude.
- **Type C Faults.** All other faults not classified as Type A or B.

The above listed classification of faults into Types A, B, and C is based on the potential energy released along a fault during displacement of the earth's crust in the form of earthquakes and in some cases, seismic creep. The classification type for active faults within 60 miles of the VWD service is shown in Table 4.5-1. The potential energy released along a fault is determined by four factors: the slip rate, the area (fault length multiplied by down-dip width), maximum magnitude (M_{MAX}), and the rigidity of displaced rocks. These factors in combination are used to calculate the moment magnitude (Ninyo & Moore 2008).

Fault Movement

Table 4.5-1 identifies three types of differential movement of faults within 60 miles of the VWD service area:

- **Strike-Slip Faults (SS)**. During strike-slip faulting, the sides of the fault move laterally relative to each other. These faults are predominantly described as right-lateral (RL) or left-lateral (LL).
- **Dip-Slip Faults (DS).** During dip-slip faulting, one side of the fault moves up or down relative to the other side. These faults are predominantly described as normal (N) or reverse (R).
- **Oblique-Slip Faults (O).** Oblique-slip faults have characteristics of both a strike-slip fault and dip-slip fault.

4.5.1.3 Seismic Hazards

Earthquake-related geologic hazards pose a significant threat to areas within San Diego County and can impact extensive regions of land. Earthquakes can produce fault rupture and strong ground shaking, and can trigger landslides, rockfalls, soil liquefaction, tsunamis, and seiches. In turn, these geologic hazards can lead to other hazards such as fires, dam failures, and toxic chemical releases.

Primary effects of earthquakes include violent ground motion, and sometimes permanent displacement of land associated with surface rupture. Earthquakes can snap and uproot trees, or knock people to the ground. They can also shear or collapse large buildings, bridges, dams, tunnels, pipelines and other rigid structures, as well as damage transportation systems, such as highways, railroads and airports. Secondary effects of earthquakes include near-term phenomena such as liquefaction, landslides, fires, tsunamis, seiches, and floods. Long-term effects associated with earthquakes include phenomena such as regional subsidence or emergence of landmasses and regional changes in groundwater levels (County 2009).

Fault Rupture

During earthquakes, the ground can rupture at or below the surface. Ground rupture occurs when two lithospheric plates heave past each other, sending waves of motion across the earth. Earthquakes can cause large vertical and/or horizontal displacement of the ground along the fault. Ground rupture can completely demolish structures by rupturing foundations or by tilting foundation slabs and walls, as well as damage buried and above ground utilities. Drinking water can be adversely affected, and the loss of water lines or water pressure can affect emergency services, including fire fighting ability. Research of historical earthquakes has shown that, although only a few structures have been ripped apart by fault rupture, this hazard can produce severe damage to structures built across active fault lines.

Ground Shaking

Ground shaking is the earthquake effect that produces the vast majority of damage. Several factors control how ground motion interacts with structures, making the hazard of ground shaking difficult to predict. Earthquakes, or earthquake induced landslides, can cause damage near and far from fault lines. The potential damage to public and private buildings and infrastructure can threaten public safety and result in significant economic loss. Ground shaking is the most common effect of earthquakes that adversely affects people, animals, and constructed improvements. The California Building Code (CBC) defines different Seismic Design Categories based on building occupancy type and the severity of the probable earthquake ground motion at the site. There are six Seismic Design Categories and designated as Categories A through F, with Category A having the least seismic potential and Category F having the highest seismic potential. All of San Diego County is located within Seismic Design Categories E and F (County 2009).

Liquefaction

Liquefaction occurs primarily in saturated, loose, fine, to medium-grained soils in areas where the groundwater table is generally 50 feet or less below the surface. When these sediments are shaken during an earthquake, a sudden increase in pore water pressure causes the soils to lose strength and behave as a liquid. In general, three types of lateral ground displacement are generated from liquefaction: 1) flow failure, which generally occurs on steeper slopes; 2) lateral spread, which generally occurs on gentle slopes; and 3) ground oscillation, which occurs on relatively flat ground. In addition, surface improvements on liquefiable areas may be prone to settlement and related damage in the event of a large earthquake on a regionally active fault. The primary factors that control the type of failure that is induced by liquefaction (if any) include slope, and the density, continuity, and depth of the liquefiable layer.

Landslides

A landslide is the down slope movement of soil and/or rock. Landslides can range in speed from very rapid to an imperceptible slow creep. Landslides can be caused by ground shaking from an earthquake or water from rainfall, septic systems, landscaping, or other origins that infiltrate slopes with unstable material. Boulder-strewn hillsides can pose a boulder-rolling hazard from ground shaking, blasting or a gradual loosening of their contact with the surface. The likelihood of a landslide depends on an area's geologic formations, topography, ground shaking potential, and influences of man. Improper or excessive grading can increase the probability of a landslide. Land alterations such as excavation, filling, removing of vegetative cover, and introducing the concentration of water from drainage, irrigation or septic systems may contribute to the instability of a slope and increase the likelihood of a landslide. Undercutting support at the base of a slope, or adding too much weight to the slope, can also produce a landslide.

Subsidence

Subsidence refers to elevation changes of the land, which can occur either gradually or suddenly. Subsidence can be caused by groundwater depletion, seismic activity, and other factors, and can cause a variety of problems including broken utility lines, blocked drainage, or distorted property boundaries and survey lines.

Expansive Soils

Certain types of clay soils expand when they are saturated and shrink when dried. These are called expansive soils, and can pose a threat to the integrity of structures built on them without proper engineering. Expansive soils are derived primarily from weathering of feldspar minerals and volcanic ash. The expansion and contraction of the soil varies with the soil moisture content (wet or dry), and can be aggravated by the way a property is maintained or irrigated. Human activities can increase the moisture content of the soils, and the threat of expansive soil damage. For example, a subdivision of homes that continually irrigates the landscaping or removes significant amounts of native vegetation could create this condition (County 2009).

Seiches and Tsunamis

A seiche is a standing wave in a completely or partially enclosed body of water. A seiche can occur from seismic ground shaking or by the sudden movement of a landslide into a reservoir. A seiche could result in localized flooding or damage to low lying areas adjacent to large bodies of water. Areas located along the shoreline of lakes or reservoirs are susceptible to inundation by a seiche. The size of a seiche and affected inundation area is dependent on different factors including size and depth of the water body, elevation, source, and if man made, the structural condition of the body of water in which the seiche occurs. A tsunami is a series of large waves in the open ocean that are caused by a sudden disturbance that displaces large volumes of water. The impacts on coastlines can be similar to those of a seiche, but can be much more devastating, causing loss of life and extensive property damage. Triggers for a tsunami include earthquakes, submarine landslides, volcanic eruptions, or meteor impacts (County 2009).

4.5.1.4 Paleontology

Paleontological resources are the remains or traces of prehistoric animals and plants. Fossils are important paleontological resources because of their use in documenting the presence and evolutionary history of particular groups of now-extinct organisms, reconstructing the environments in which those organisms lived, and determining the relative ages and geologic processes of the strata (sediment or rock layers) in which they occur. With few exceptions, fossils that are useful for these determinations are preserved in sedimentary rocks. There are three major categories of fossils: vertebrate animals, invertebrate animals, and plants. Each category represents a somewhat different set of conditions for preservation, although they often overlap. There are five sensitivity categories to classify the probability of finding paleontological resources within sedimentary rocks: High, Moderate, Low, Marginal, and No potential. These categories are described below.

High Sensitivity

High sensitivity is assigned to geologic formations known to contain paleontological localities with rare, well-preserved, and/or critical fossil materials for stratigraphic or paleoenvironmental interpretation, and fossils providing important information about the paleobiology and evolutionary history (phylogeny) of animal and plant groups. Highly sensitive formations are known to produce vertebrate fossil remains or are considered to have the potential to produce such remains.

Moderate Sensitivity

Moderate sensitivity is assigned to geologic formations known to contain paleontological localities with moderately preserved, common elsewhere, or stratigraphically long-ranging fossil material. The moderate-sensitivity category also is applied to geologic formations that are judged to have a strong but unproven potential for producing important fossil remains (e.g., Pre-Holocene sedimentary rock units representing low to moderate energy, of marine to non-marine depositional settings).

Low Sensitivity

Low sensitivity is assigned to geologic formations that, based on their relative youthful age and/or high energy depositional history, are judged unlikely to produce important fossil remains. Typically, low sensitivity formations may produce invertebrate fossil remains in low abundance.

Marginal Sensitivity

Marginal sensitivity is assigned to geologic formations that are composed of either volcanoclastic (derived from volcanic sources) or metasedimentary rocks, but that nevertheless have a limited probability for producing fossils from certain formations at localized outcrops. Volcanoclastic rock can contain organisms that were fossilized by being covered by ash, dust, mud, or other debris from volcanoes. Sedimentary rocks that have been metamorphosed by heat and/or pressure caused by volcanoes or plutons are called metasedimentary. If the sedimentary rocks had paleontological resources in them, those resources may have survived the metamorphism and still be identifiable in the metasedimentary rock, but because the probability of this occurring is so limited, these formations are considered only marginally sensitive.

No Potential

No potential is assigned to geologic formations that are composed entirely of volcanic or plutonic igneous rock, such as basalt or granite, and therefore do not have any potential for producing fossil remains. These formations have no paleontological resource potential; in other words, they are not sensitive.

4.5.2 Regulatory Framework

4.5.2.1 Federal

U.S. Geological Survey Landslide Hazard Program

In fulfillment of the requirements of Public Law 106-113, the U.S. Geological Survey (USGS) created the Landslide Hazard Program in the mid-1970s. The primary objective of the National Landslide Hazards Program (LHP) is to reduce long-term losses from landslide hazards by improving our understanding of the causes of ground failure and suggesting mitigation strategies. The federal government takes the lead role in funding and conducting this research, whereas the reduction of losses due to geologic hazards is primarily a state and local responsibility. In San Diego County, the Unified Disaster Council (UDC) is the governing body of the Unified San Diego County Emergency Services Organization. The primary purpose of the UDC and the Emergency Services Organization is to provide for the coordination of plans and programs designed for the protection of life and property in San Diego County.

American Antiquities Act

The American Antiquities Act prohibits appropriation, excavation, injury, or destruction of "any historic or prehistoric ruin or monument, or any object of antiquity" located on lands owned controlled, or funded by the federal government. The Act establishes penalties for such actions and sets forth a permit requirement for collection of antiquities on federally owned lands. Objects of antiquity are considered by a number of federal agencies to include fossils. The Act has been amended specifically to allow funding for paleontological mitigation. Natural or paleontological resources on privately owned land are currently not subject to federal law.

Paleontological Resources Conservation Act

The Paleontological Resources Conservation Act protects paleontological resources on federally owned lands and limits collecting vertebrate fossils and other rare and scientifically significant fossils on those lands to qualified researchers with a permit from the appropriate state or federal agency.

Paleontological Resources Preservation Act

The Paleontological Resources Preservation Act aims to manage and protect paleontological resources on federally owned lands and promotes the use of scientific principles and expertise and the development of plans for inventorying, monitoring, and deriving the scientific and educational use of such resources.

Omnibus Public Land Management Act – Paleontological Resources Preservation [Public Law 111-011. P.L. 111-011, Title VI, Subtitle D]

The Omnibus Public Land Management Act – Paleontological Resources Preservation (OPLMA-PRP) requires the Secretaries of the Interior and Agriculture to manage and protect paleontological resources on Federal land using scientific principles and expertise. The OPLMA-PRP includes specific provisions addressing management of these resources by the Bureau of Land Management (BLM), the National Park Service (NPS), the Bureau of Reclamation (BOR), the Fish and Wildlife Service (FWS), and the U.S. Forest Service (USFS) of the Department of Agriculture. The OPLMA-PRP affirms the authority for many of the policies the Federal land managing agencies already have in place for the management of paleontological resources such as issuing permits for collecting paleontological resources, curation of paleontological resources, and confidentiality of locality data. The statute establishes new criminal and civil penalties for fossil theft and vandalism on Federal lands. The OPLMA-PRP only applies to Federal lands and does not affect private lands. It provides authority for the protection of paleontological resources on Federal lands including criminal and civil penalties for fossil theft and vandalism.

4.5.2.2 State

California Building Code

The CBC provides a minimum standard for building design. Chapter 16 of the 2010 CBC contains specific requirements for seismic safety. Chapter 18 of the 2010 CBC regulates excavation, foundations, and retaining walls. Chapter 33 of the 2010 CBC contains specific requirements pertaining to site demolition, excavation, and construction to protect people and property from hazards associated with excavation cave-ins and falling debris or construction materials. Appendix Sections J109 and J110 of the 2010 CBC regulate grading activities, including drainage and erosion control. Construction activities are subject to occupational safety standards for excavation, shoring, and trenching as specified in California

Occupational Safety and Health Administration (Cal/OSHA) regulations (Title 8 of the California Code of Regulations [CCR]) and in Appendix Sections J106 and J107 of the 2010 CBC.

California Alquist-Priolo (AP) Earthquake Fault Zoning Act [California Public Resources Code Sections 2621-2630]

The California Legislature passed this law in 1972 for the purpose of prohibiting the development of human-occupied structures within active fault areas, and to thereby mitigate the hazards associated with earthquake fault rupture.

California Seismic Hazards Mapping Act [California Public Resources Code Sections 2690-2699.6]

The California Geologic Survey, formerly the California Department of Conservation, Division of Mines and Geology (CDMG), provides guidance with regard to seismic hazards. Under CDMG's Seismic Hazards Mapping Act (1990), seismic hazard zones are identified and mapped to assist local governments in land use planning. The intent of this publication is to protect the public from the effects of strong groundshaking, liquefaction, landslides, ground failure, or other hazards caused by earthquakes. In addition, CDMG's Special Publications 117, "Guidelines for Evaluating and Mitigating Seismic Hazards in California," provides guidance for the evaluation and mitigation of earthquake-related hazards for projects within designated zones of required investigations.

National Pollution Discharge Elimination System Permits

In California, the State Water Resources Control Board (SWRCB) and its Regional Water Quality Control Board (RWQCB) administer the National Pollution Discharge Elimination System (NPDES) permit program. The NPDES permit system was established as part of the Clean Water Act (CWA), discussed in more detail in Section 4.7, Hydrology and Water Quality, of this PEIR, to regulate both point source discharges and nonpoint source discharges to surface waters of the U.S., including the discharge of soil eroded from construction sites. The NPDES program consists of characterizing receiving water quality, identifying harmful constituents (including siltation), targeting potential sources of pollutants (including excavation and grading operations), and implementing a comprehensive storm water management program. Construction and industrial activities typically are regulated under statewide general permits that are issued by the SWRCB. Additionally, the SWRCB issues Waste Discharge Requirements that also serve as NPDES permits under the authority delegated to the RWQCBs, under the CWA (see Section 4.7, Hydrology and Water Quality, of this PEIR).

4.5.2.3 Local

County of San Diego Grading Ordinance

Chapter 4 of the County of San Diego Grading Ordinance (Section 87.101 et seq.) includes requirements for the maximum slope allowed for cuts and fills, drainage terraces on cut or fill slopes exceeding 40 feet in height, expansive soils for cuts and fills, minimum building setbacks from cut and fill slopes, and a soil engineer's report which includes specific approval of the grading as affected by geological factors.

Section 87.430 of the County Grading Ordinance provides for the requirement of a paleontological monitor at the discretion of the County. In addition, the suspension of grading operations is required upon the discovery of fossils greater than 12 inches in any dimension. The Grading Ordinance also requires notification of the County Official (i.e., Permit Compliance Coordinator), and gives the County

Official the authority to determine the appropriate resource recovery operations, which shall be carried out prior to the County Official's authorization to resume normal grading operations. VWD is exempt from the requirements of the County grading permit. Therefore, the analysis of grading in this PEIR is for informational purposes and is set in the context of this exemption.

County of San Diego General Plan Safety Element

Policy 2 of the County of San Diego General Plan Public Safety Element (Part VII, page 14, 2008) states that the County will continue to pursue erosion control and landslide control programs through such measures as strict enforcement of the grading ordinance, continued support of the floodplain ordinance program, and by requiring soils and geologic reports in hazardous areas. Policy 4 of this Element states that the County will seek the cooperation and coordination of all jurisdictions and agencies involved in the mitigation of geologic hazards.

Policy 3.1 of the County of San Diego General Plan Seismic Safety Element (Part V, page 71, 1991) states that the County will survey all essential facilities (which include "lifeline" systems that provide water, sewers, electricity, fuel, and transportation to the community) in the region and report the results to the Board of Supervisors. Each essential facility shall be evaluated by a structural engineer, an engineering geologist, and a safety specialist with knowledge of the specific type of facility. The evaluation shall include the structural integrity of the building, the safety of its contents, and its disaster plan. Policy 4 of this Element states that the County will prohibit construction of essential facilities in any area subject to geologic or other hazards. If there are no feasible alternative sites, these facilities shall be designed to mitigate any seismic hazards associated with their sites. Policy 6 of this element states, in part, that the County will ensure that vulnerable lifeline systems such as fuel lines, water lines, and power lines and stations will either remain in operation or are quickly repairable.

4.5.3 Master Plan Impacts and Mitigation

4.5.3.1 Issue 1 – Exposure to Seismic and Geologic Hazards

Geology, Soils, and Paleontology Issue 1 Summary

Would implementation of the 2008 Master Plan expose people or structures to potential substantial adverse effects of a rupture of a known earthquake fault, strong seismic groundshaking, liquefaction, landslides, expansive or otherwise unstable soils?

Impact: Portions of the proposed CIP facilities could be located on geologic or soil units that are unstable and could result in damage from liquefaction, lateral spreading, subsidence, expansive soils, and/or landslides.	**Mitigation**: Site-specific Geotechnical Investigation (Geo-1).
Significance Before Mitigation: Significant.	**Significance After Mitigation**: Less than significant.

Standards of Significance

Based on Appendix G of the CEQA Guidelines, implementation of the 2008 Master Plan would have a significant impact if people or CIP facilities would be exposed to the substantial risk of loss, injury, or death as a result of:

1. Rupture of a known earthquake fault, as delineated on the most recent AP Earthquake Fault Zoning Map issued by the State Geologist for the area, or based on other substantial evidence of a known fault;
2. Strong seismic groundshaking;
3. Seismic-related ground failure;
4. Liquefaction;
5. Landslides; or
6. Expansive soils.

Impact Analysis

Fault Rupture

The AP Earthquake Fault Zoning Act identifies areas that are subject to fault rupture. None of the proposed CIP facilities involve human habitation. Therefore, the AP Earthquake Fault Zoning Act is not applicable to the 2008 Master Plan. Further, active faults in the region that could result in fault rupture include segments of the San Jacinto, Elsinore, and Rose Canyon. These faults are not located within the VWD service area. Therefore, the 2008 Master Plan CIP projects would not be subject to a significant risk of fault rupture.

Groundshaking

Groundshaking is the most common effect of earthquakes that adversely affects people and structures. The CBC defines different regions of the U.S. and ranks them according to their seismic hazard potential. All of San Diego County is located within Seismic Design Categories E and F, which have the highest seismic potential (County 2009). Therefore, proposed CIP projects may be subject to the adverse effects of seismic groundshaking. Although the 2008 Master Plan does not propose any facilities involving human habitation, seismic groundshaking has the potential to result in significant structural damage or facility failure. Structural damage or facility failure of a reservoir, pipeline, pump station or lift station could result in flooding, loss of potable drinking water and/or sewage spills. At the time of CIP project design, VWD would implement the relevant requirements of the 2010 CBC, as updated or amended, and CDMG's Special Publications 117. However, because CIP projects are within the areas of high seismic potential, they would remain at risk for damage from groundshaking. This is considered a potentially significant impact.

Liquefaction

Liquefaction is not known to have occurred historically in San Diego County. However, the potential exists for liquefaction to occur in areas with loose sandy soils combined with a shallow groundwater table, which typically are located in alluvial river valleys/basins and floodplains (County 2009). Figure 4.5-2, Geohazards, depicts soils within the District boundary that generally have a high potential for liquefaction, based on regional soil data. Many of the proposed CIP projects, such as the water and sewer pipelines, are located within areas of high liquefaction potential. This includes the land outfall, which is proposed along Encina Creek. These CIP projects could be subject to liquefaction, which may result in significant structural damage or facility failure. Structural damage or facility failure of a CIP project could result in flooding, loss of potable drinking water and/or sewage spills. At the time of proposed CIP project design, VWD would implement the relevant requirements of the 2010 CBC and CDMG's Special Publications 117. However, CIP projects that are within areas of high liquefaction potential would remain at risk for damage. This is considered a potentially significant impact.

Landslides

Certain lands within the VWD service area are subject to landslides. Generally, landslide potential is considered high for areas that contain slopes of 15 percent or greater, as shown in Figure 4.5-3. Specifically, the San Marcos General Plan Safety Element maps an area near the western edge of the city as having a potential for landslides (City of San Marcos 1983). Additionally, areas within the unincorporated county of San Diego communities of Bonsall, North County Metro and San Dieguito are identified as at high risk for landslides (County 2009). CIP projects most susceptible to landslide events include reservoirs, which are generally located at higher elevations for design purposes. Pump stations and lift stations located on slopes or hillsides would also be susceptible to landslide events. Therefore, the CIP projects proposed in the 2008 Master Plan would be susceptible to landslides, which could result in significant structural damage or facility failure. Structural damage or facility failure of a proposed CIP project could result in flooding, loss of potable drinking water and/or sewage spills. At the time of CIP project design, the VWD would implement the relevant requirements of the 2010 CBC and CDMG's Special Publications 117. However, CIP projects that are within high slope areas would remain at risk for damage from landslide potential, particularly areas within slopes of 15 percent or greater. This is considered a significant impact.

Expansive Soils

Certain types of clay soils expand when they are saturated and shrink when dried. These are called expansive soils, and can pose a threat to the integrity of structures built on them without proper engineering. If the moisture content and/or soil type differs at various locations under the foundation of a structure, localized or non-uniform (differential) movement may occur. This movement can cause damage to a CIP project's foundation and/or structure, which could result in flooding, loss of potable drinking water and/or sewage spills. Figure 4.5-2, Geohazards, depicts soils within the District boundary that contain soils with a high expansion potential (based on regional soil data). CIP projects that may be subject to expansive soils primarily include sewer pipelines, including the parallel outfall. At the time of CIP project design, the VWD would implement the relevant requirements of the 2010 CBC and CDMG's Special Publications 117. However, CIP projects that are within area of high soil expansion potential would remain at risk for damage. This is considered a significant impact.

Mitigation Measure

Implementation of the following mitigation measure would reduce the exposure of people and CIP facilities to substantial adverse effects associated with seismically induced groundshaking, liquefaction potential, landslides, and expansive soils to a less than significant level. CEQA analysis has been conducted separately for CIP projects R-1, R-7, SP-2, SP-3, SP-11, and SP-12; therefore, these projects are not subject to the mitigation measure identified below.

Geo-1 **Site-specific Geotechnical Investigation.** Prior to construction of proposed CIP projects, a site-specific geotechnical investigation will be conducted to determine whether geologic or other hazardous conditions exist and, if so, provide recommendations for construction that would reduce the damage potential. Areas of liquefaction; static or groundshaking-induced landslides, lateral spreading, subsidence; liquefaction, soil collapse, expansive soils and/or mudslide potential will be identified as part of the geotechnical investigation. The investigations will specifically address foundation and slope stability in liquefiable, landslide, expansive soils and mudslide areas proposed for construction. Recommendations made in conjunction with the geotechnical investigations will be implemented during construction, including (as appropriate) but not necessarily limited to the following actions:

1. Over-excavate unsuitable materials and replace them with engineered fill.
2. For thinner deposits, remove loose, unconsolidated soils and replace with properly compacted fill soils, or apply other design stabilization features (i.e., excavation of overburden).
3. For thicker deposits, implement applicable techniques such as dynamic compaction (i.e., dropping heavy weights on the land surface), vibro-compaction (i.e., inserting a vibratory device into the liquefiable sand), vibro-replacement (i.e., replacing sand by drilling and then vibro-compacting backfill in the bore hole), or compaction piles (i.e., driving piles and densifying surrounding soil).
4. Lower the groundwater table to below the level of liquefiable soils.
5. Perform in-situ densification of soils or other alterations to the ground characteristics.
6. For landslides, implement applicable techniques such as stabilization (i.e., construction of buttress fills, retaining walls, or other structural support to remediate the potential for instability of cut slopes composed of landslide debris); remedial grading and removal of landslide debris (e.g., over-excavation and recompaction); or avoidance (e.g., structural setbacks).
7. To minimize or avoid lateral spreading of on-site soils, remove compressible soils and replace them with properly compacted fill, perform compaction grouting or deep dynamic compaction, or use stiffened conventional foundation systems.
8. To minimize or avoid differential compression or settlement of on-site soils, manage oversized material (i.e., rocks greater than 12 inches) via off-site disposal, placement in non-structural fill, or crushing or pre-blasting to generate material less than 12 inches. Oversized material greater than 4 feet will not be used in fills, and will not be placed within 10 feet of finished grade, within 10 feet of manufactured slope faces (measured horizontally from the slope face), or within 3 feet of the deepest pipeline or other utilities.
9. Locate foundations and larger pipelines outside of cut/fill transition zones and landscaped irrigation zones.

As part of the geotechnical investigation, a database search of hazardous materials sites pursuant to Government Code Section 65962.5 will be performed within a one-mile radius surrounding the proposed CIP site. If the database search identifies hazardous material sites within the search parameters, a Phase I environmental assessment will be required. In the event hazardous materials sites are identified within the database search and a Phase I environmental assessment is required, VWD will retain a registered environmental assessor to perform a Phase I Environmental Site Assessment. The Phase I Environmental Site Assessment will follow the current ASTM standard and the recommendations contained within the Phase I Environmental Site Assessment will be implemented according to standard regulatory procedures.

4.5.3.2 Issue 2 – Soil Erosion or Topsoil Loss

Geology, Soils, and Paleontology Issue 2 Summary

Would implementation of the 2008 Master Plan result in substantial soil erosion or the loss of topsoil?

Impact: Construction activities associated with CIP projects could result in soil erosion or loss of topsoil.

Mitigation: Construction-Related Erosion Control Plan (Geo-2).

Significance Before Mitigation: Significant.

Significance After Mitigation: Less than significant.

Standards of Significance

Based on Appendix G of the CEQA Guidelines, implementation of the 2008 Master Plan would have a significant impact if CIP construction projects would result in substantial soil erosion or loss of topsoil.

Impact Analysis

Earth-disturbing activities associated with the construction of CIP facilities would expose soils that could be subject to erosion during rain and wind events. Grading, excavation, on-site soils balancing and soil stockpiling operations would have the potential to expose soils to wind erosion and substantial erosion or topsoil loss during a rain event. Soil removal associated with grading and excavation activities would reduce soil cohesion, which could accelerate erosion. Increased erosion and soil loss could impact soil stability, in addition to causing indirect effects on communities and sensitive biological resources downstream of the proposed CIP project site. Indirect effects of soil erosion include the deposition of pollutants and sediment to watershed outlets, an increase in polluted runoff to surface and groundwater receiving bodies, and an increase in flood potential downstream. Therefore, construction activities associated with CIP facilities would have the potential to result in substantial soil erosion or loss of topsoil. This would be considered a significant impact.

Upon completion of construction for a proposed CIP facility, no exposed soils would remain on site that would be susceptible to the effects of wind erosion. For the CIP projects constructed in undeveloped areas (R-7, R-10, R-11, PS-1, PS-2) an increase in impermeable surfaces would occur. However, all CIP projects would comply with the requirements of the local MS4 permit requirements regarding storm water discharge, which require no net increase in storm water runoff when compared to existing conditions. Compliance with the applicable MS4 requirements would result in less than significant impacts related to topsoil loss or increased erosion from CIP operational activities.

Mitigation Measure

Implementation of mitigation measure Geo-2 would reduce construction-related impacts associated with soil erosion or loss of topsoil to a less than significant level. CEQA analysis has been conducted separately for CIP projects R-1, R-7, SP-2, SP-3, SP-11, and SP-12; therefore, these projects are not subject to the mitigation measures identified below.

Geo-2 **Construction-Related Erosion Control Plan.** The construction bid documents for each proposed CIP project will include either a 90 percent Erosion Control Plan (for projects that would result in less than one acre of land disturbance) or a 90 percent Storm Water Pollution Prevention Plan (SWPPP) (for projects that would result in one acre or greater of land disturbance). The Erosion Control Plan will comply with the storm water regulations or ordinances of the local agency jurisdiction within which the proposed CIP project occurs; the SWPPP will comply with the NPDES General Construction Permit. These plans will be based on site-specific hydraulic and hydrologic characteristics, and identify a range of Best Management Practices (BMPs) to reduce impacts related to storm water runoff, including sedimentation BMPs to control soil erosion. The Erosion Control Plan or SWPPP will identify the specific storm water BMPs to be implemented during the construction phase of a given CIP project. Typical BMPs to be implemented as part of the Erosion Control Plan or SWPPP may include, but may not be limited to, the actions listed below.

1. Development of a written plan that includes sequencing of construction activities and the implementation of erosion control and sediment control BMPs that will take local climate (rainfall, wind, etc.) into consideration. The purpose of the written plan is to reduce the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking, and to perform the construction activities and control practices in accordance with the planned schedule.
2. Preserve existing vegetation to minimize the potential of removing or injuring existing trees, vines, shrubs, and grasses that protect soil from erosion.
3. Use hydraulic mulch on disturbed soils to provide a layer of temporary protection from wind and water erosion.
4. Temporarily protect exposed soils from erosion by water and wind by applying hydraulic seeding, hydroseeding, or other appropriate soil cover.
5. Divert runoff or channel water to a desired location by constructing earth dikes or drainage swales. A drainage swale is a shaped and sloped depression in the soil surface used to convey runoff to a desired location. Earth dikes and drainage swales are used to divert off site runoff around the construction site, divert runoff from stabilized areas and disturbed areas, and direct runoff into sediment basins or traps.
6. Prevent scour of the soil caused by concentrated, high velocity flows by providing outlet protection; a physical device composed of rock, grouted riprap, or concrete rubble, which is placed at the outlet of a pipe or channel.
7. Apply a compost blanket to slopes and earth disturbed areas to prevent erosion, and in some cases, increase infiltration and/or establish vegetation. The compost blanket can be applied by hand, conveyor system, compost spreader, or pneumatic delivery (blower)

system. The blanket thickness is determined from the slope steepness and anticipated precipitation. A compost blanket protects the soil surface from raindrop erosion, particularly rills and gullies that may form under other methods of erosion control.

8. Detain sediment-laden water, promoting sedimentation behind a silt fence. A silt fence is made of a woven geotextile that has been entrenched, attached to supporting poles, and sometimes backed by a plastic or wire mesh for support.
9. Contain sediment-laden runoff in a sediment trap, allowing sediment to settle out before the runoff is discharged. Sediment traps are formed by excavating or constructing an earthen embankment across a waterway or low drainage area.
10. Place fiber rolls at the toe and on the face of slopes along the contours. Fiber rolls intercept runoff, reduce its flow velocity, release the runoff as sheet flow, and provide removal of sediment from the runoff (through sedimentation). By interrupting the length of a slope, fiber rolls can reduce sheet and rill erosion until vegetation is established.
11. Intercept or divert sheet flows with a sandbag barrier on a level contour. Sandbag barriers placed on a level contour pond sheet flow, allowing sediment to settle out.
12. Construct a straw bale barrier to pond sheet-flow runoff and allow sediment to settle out. A straw bale barrier is a series of straw bales placed on a level contour to intercept sheet flows.

4.5.3.3 Issue 3 – Paleontological Resources

Geology, Soils, and Paleontology Issue 3 Summary

Would implementation of the 2008 Master Plan directly or indirectly destroy a unique paleontological resource or site?

Impact: Construction of CIP projects proposed within the Santiago formation has the potential to disturb or destroy paleontological resources.	**Mitigation:** Paleontological Resources Investigation (Geo-3).
Significance Before Mitigation: Significant.	**Significance After Mitigation:** Less than significant.

Standards of Significance

Based on Appendix G of the CEQA Guidelines, implementation of the 2008 Master Plan would have a significant impact if CIP construction projects would directly or indirectly destroy a unique paleontological resource or site. Because paleontological resources are typically buried and, therefore, not apparent until revealed by excavation, significant impacts to paleontological resources are often determined based on the geologic formations that would be disturbed and the potential for those geologic formations to contain fossils.

Impact Analysis

To evaluate 2008 Master Plan impacts, a paleontological resources evaluation was conducted for the VWD service area. This evaluation was performed by a registered geologist at PBS&J and is included as Appendix D of this PEIR. According to the paleontological resources evaluation, the VWD service area contains one geologic unit of high paleontological sensitivity: the Santiago formation. The Santiago formation is located along the southern portion of the VWD service area's western boundary.

The Santiago formation is sandstone and conglomerate throughout most of its exposed area. This formation is finer-grained and muddier in the southern part of San Diego County. Petrified wood of avocado and other types of trees and terrestrial mammals (e.g. horses, rodents, insectivores, etc.) indicate a coastal lowland paleo-environment. Thousands of vertebrate specimens have been recovered and catalogued from this formation, attesting to the significance of this geologic unit. This formation has produced so much paleo-environmental information that the County of San Diego Department of Land Use and Planning has assigned it to the special category of Very High Sensitivity. Excavation and construction activities associated with proposed CIP projects located within the Santiago formation have the potential to disturb or destroy paleontological resources. The location of the Santiago formation within the VWD service area is identified in Figure 4.5-4. A portion of the parallel land outfall will also be located within areas containing the Santiago formation (Burwasser 2011). Proposed CIP projects located within or near the Santiago formation include SP-2, SP-3, SP-6, SP-11, SP-12, SP-13, SP-15, SP-19, SP-20, SP-23, SP-28, SP-29, R-1, R-3, R-7, and the parallel land outfall. The other geologic units within the VWD service area consist of unconsolidated Quaternary deposits (low paleontological sensitivity) in the valleys and on the lower hillsides and the more ancient hill and ridge rocks of igneous (no paleontological potential) or meta-volcanic (marginal paleontological sensitivity). Other than the Santiago formation, other geologic units in the VWD service area are not expected to contain recoverable paleontological resources. Therefore, for proposed CIP projects that are within or near the Santiago formation, impacts are considered potentially significant (Burwasser 2010).

Mitigation Measures

Implementation of mitigation measure Geo-3 would reduce potential impacts associated with disturbance of paleontological resources to a less than significant level. CEQA analysis has been conducted separately for CIP projects R-1, SP-2, SP-3, SP-11, and SP-12; therefore, these projects are not subject to the mitigation measures identified below.

Geo-3 **Paleontological Resources Investigation.** For proposed CIP projects located within the Santiago formation (potentially SP-6, SP-13, SP-15, SP-19, SP-20, SP-23, SP-28, SP-29, R-1, R-3, R-7, and the parallel land outfall), a project-level paleontological resources investigation will be conducted by a qualified professional paleontologist in cooperation with the County of San Diego and the San Diego Natural History Museum. The paleontological resources investigation will include:

1. A review of the records search performed in the Paleontological Resources Evaluation for the VWD Service Area (Appendix C of this EIR) and, if necessary, an updated records search;

2. Project-level pedestrian surveys of portions of the proposed CIP site where paleontological resources could be encountered based on presence and depth of sensitive formations;
3. Formal evaluation of any potentially affected paleontological resources to determine whether they qualify as unique paleontological resources; and
4. Recommended measures to avoid, where feasible, impacts on unique paleontological resources, such as preservation in place, planning construction to avoid unique paleontological sites, placing paleontological sites into permanent conservation easements, or planning parks, green space, or other open space to incorporate paleontological sites. Where avoidance or preservation in place is not feasible, excavation and curation may be recommended as mitigation.

The results of the paleontological resources investigation will be compiled into a technical report or memorandum and submitted to VWD for further coordination with the County of San Diego Department of Planning and Land Use and the San Diego Natural History Museum, as necessary.

4.5.4 Cumulative Impacts

Geology, Soils, and Paleontology Cumulative Issue Summary

Would implementation of the 2008 Master Plan have a cumulatively considerable contribution to cumulative geology/soils impacts considering past, present, and probable future projects?

Cumulative Impact	Significant?	Proposed Master Plan Contribution
Localized soil erosion or loss of topsoil in affected watersheds due to development.	Yes	Not cumulatively considerable with implementation of Geo-2.
Regional loss of paleontological resources.	Yes	Not cumulatively considerable with implementation of Geo-3.

Impacts relative to seismic hazards and other geologic/soil conditions (i.e., fault rupture, groundshaking, ground failure, liquefaction/collapse, landslides, lateral spreading, subsidence, and expansive soils) are generally site-specific. Impacts that may occur geoseismically at one site would not contribute cumulatively with another site unless the sites are contiguous, identical geoseismically or pedologically, and the geoseismic or pedologic stressor is identical for both sites. The likelihood of this occurrence is extremely rare (Burwasser 2011). Therefore, these issues are not subject to a cumulative impact analysis, and are not addressed in this section.

4.5.4.1 Soil Erosion

The geographic context for the analysis of cumulative impacts relative to soil erosion encompasses the Carlsbad and San Luis Rey watersheds directly downstream from proposed CIP construction sites. This is because rainfall erosion of soils exposed by land disturbance activities can lead to downstream sedimentation effects, as sediment-laden runoff is carried along drainage facilities and natural water courses by storm water flows. Land disturbance activities may include agricultural practices, cattle grazing and land development (e.g., vegetation clearing, grading, excavation, trenching), and these activities are expected to continue in the vicinity of the Carlsbad and San Luis Rey watersheds. Even with the promulgation of storm water regulations, land disturbance associated with development activities throughout these watersheds continues to contribute, however incrementally, to the overall sedimentation problems observed in runoff flows that discharge into watercourses, lagoons, and eventually the Pacific Ocean. Therefore, the baseline cumulative impact to the Carlsbad and San Luis Rey watersheds (i.e., local cumulative impact areas) caused by downstream sedimentation effects from soil erosion associated with basin-wide land disturbance activities is significant.

As described in Section 4.5.3.2 above, construction and operational activities associated with proposed CIP projects could result in soil erosion or loss of topsoil. Implementation of mitigation measure Geo-2 would reduce construction impacts to a level below significance and compliance with MS4 permit requirements would reduce post-construction (operation) impacts to a level below significance. Therefore, the 2008 Master Plan would not result in a cumulatively considerable contribution to downstream sedimentation effects from soil erosion within the local cumulative impact areas.

4.5.4.2 Paleontological Resources

The geographic context for the analysis of cumulative impacts to paleontological resources encompasses the paleontologically sensitive geologic formations within the VWD service area. Excavation activities associated with land development within these areas could have significant impacts to paleontological resources. Therefore, the baseline cumulative impact to paleontological resources caused by excavation activities associated with future land development within the regional cumulative impact area is significant. As described in Section 4.5.3.3 above, excavation activities associated with proposed CIP project construction and located within the Santiago formation have the potential to disturb or destroy paleontological resources. Implementation of mitigation measure Geo-3 would reduce this impact to a level below significance. Therefore, excavation and construction activities associated with CIP construction projects SP-2, SP-3, SP-6, SP-11, SP-12, SP-13, SP-15, SP-19, SP-20, SP-23, SP-28, SP-29, R-1, R-3, R-7, and the parallel land outfall, would not result in a cumulatively considerable contribution to the loss of paleontological resources within the regional cumulative impact area.

4.5.5 CEQA Checklist Items Deemed Not Significant or Not Applicable to the 2008 Master Plan

Would the planning area have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of waste water?

The 2008 Master Plan would not involve the use of septic tanks or other alternative wastewater disposal systems and no impact would occur. No further evaluation is necessary.

4.5.6 References

Burwasser, George J. 2010. Paleontological Resources Evaluation for Vallecitos Water District, San Diego County, California. October 28.

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City of San Marcos. 1983. San Marcos General Plan. Prepared 1983, Amended 1997.

Ninyo & Moore. 2008. Limited Geologic and Soils Evaluation, Palomar Community College District, San Marcos Campus Master Plan EIR. April 11.

URS Corporation (URS). 2004. Multi-Jurisdiction Hazard Mitigation Plan, San Diego County. Prepared for the County of San Diego, Office of Emergency Services. March 15, 2004. Available at www.co.san-diego.ca.us/oes/docs/HazMit_Plan.pdf

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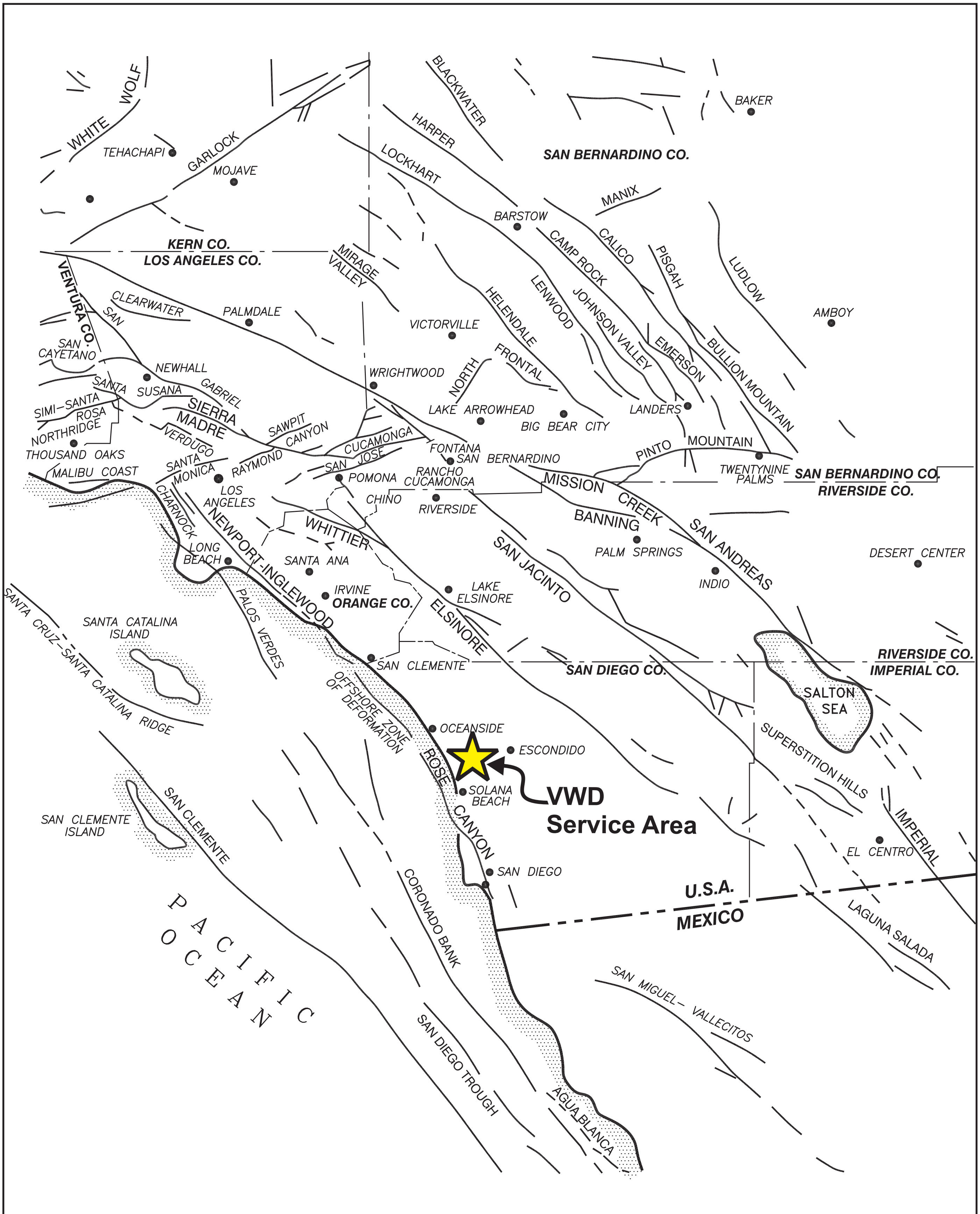


Note: All dimensions, directions and locations are approximate.

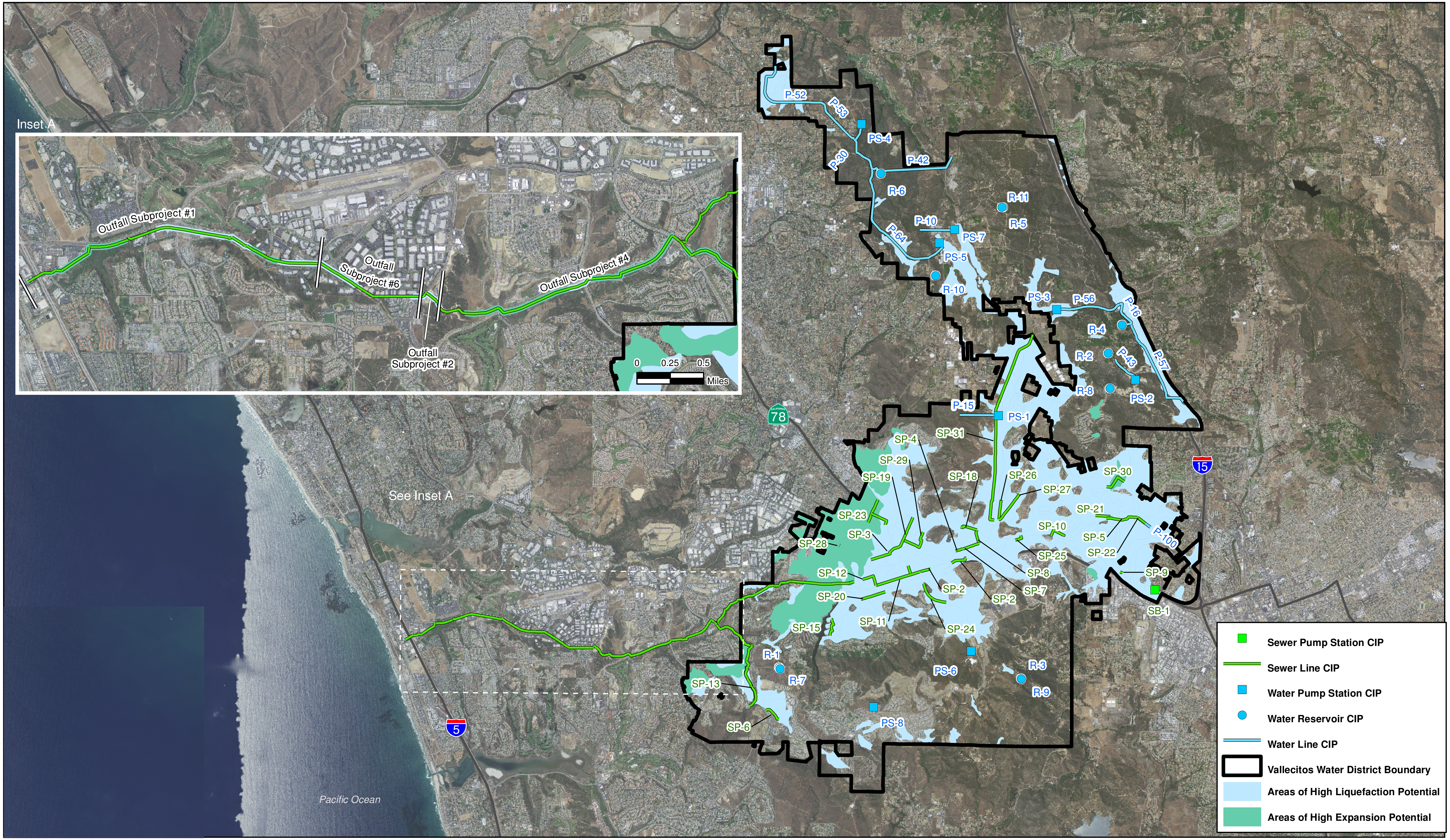
Source: Ninyo & Moore, 2008

PBS&J

0 15 30
Miles

N

FAULT LOCATION MAP
FIGURE 4.5-1



3/31/2011 TH SD Z:\Projects\I\S\VallecitosWaterDistrict\2008MasterPlan\mxd\Env\Geohazards.mxd

Source: NRCS, 2011; SanGIS, 2010; ESRI, 2010; VWD, 2010

PBS&J

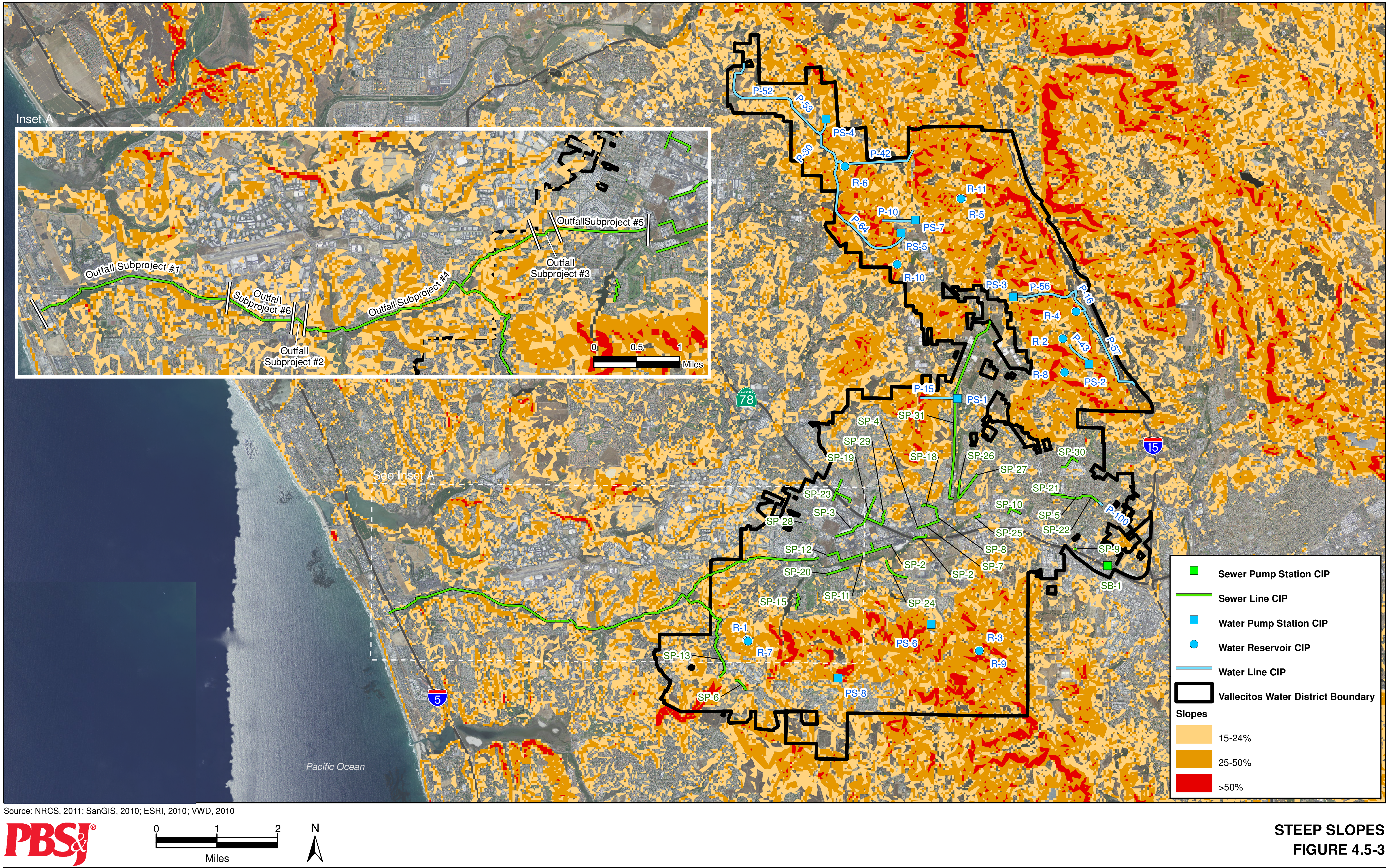
0 1 2
Miles

N

This figure is for planning purposes only and is not intended to replace site-specific geotechnical investigations. The figure is based on information from the US Department of Agriculture's Soil Survey Geographic (SSURGO) Database. SSURGO information is developed through testing a limited number of samples and extrapolating the results to represent the attributes of regional soil units. Polygons in this figure were created using Geospatial Information System (GIS) data layers available through SSURGO. The polygons show units wherein soil attributes related to Liquid Limits, Plasticity Index, and Linear Extensibility Percent are coded to represent the units' potential for liquefaction or expansion.

GEOHAZARDS

FIGURE 4.5-2

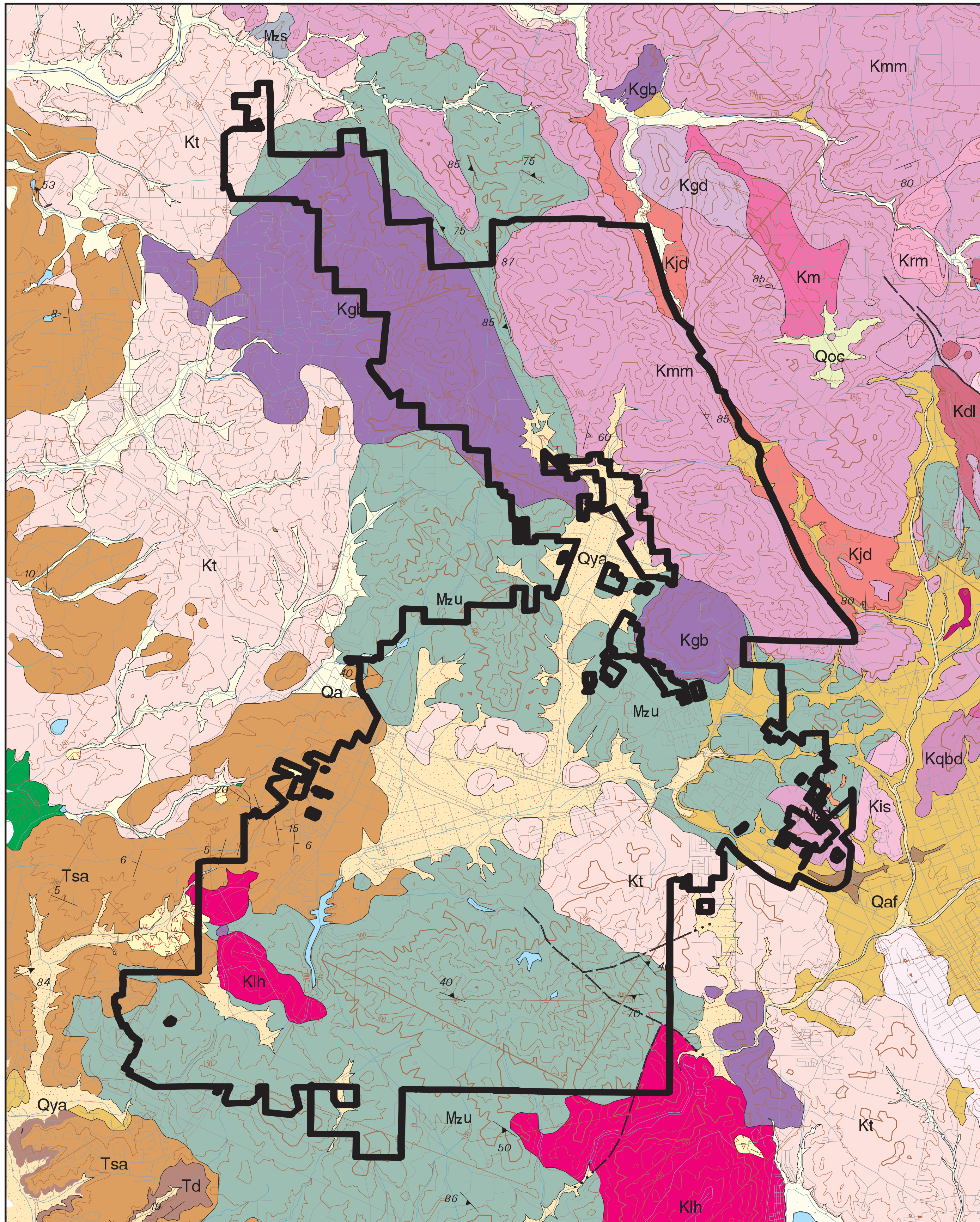


3/28/2011 TH SD Z:\Projects\S\VallecitosWaterDistrict\2008MasterPlan\mxd\Env\Slope.mxd

Source: NRCS, 2011; SanGIS, 2010; ESRI, 2010; VWD, 2010

PBSJ

STEEP SLOPES
FIGURE 4.5-3



Source: California Department Conservation, Geologic Map, Oceanside CA 30'x60' Quad, 2005

0 .75 1.5
Miles
N

DESCRIPTION OF MAP UNITS
Approximate stratigraphic relationships

MODERN SURFICIAL DEPOSITS
Sediment that recently has been transported and deposited in channels and washes, on surfaces of alluvial fans and alluvial plains, and on hill slopes and in artificial fills. Soil profile development is non-existent. Includes:

af **Artificial fill (late Holocene)** – Deposits of fill resulting from human construction, mining, or quarrying activities, includes compacted engineered and non-compacted non-engineered fill. Some large deposits are mapped, but in some areas no deposits are shown.

Qa **Alluvial floodplain deposits (late Holocene)** – Active and recently active floodplain deposits. Consists of unconsolidated sandy, silty, or clay-bearing alluvium. Does not include alluvial fan deposits at distal ends of channels.

Qya **Young alluvial floodplain deposits (Holocene and late Pleistocene)** – Poorly consolidated, poorly sorted, permeable floodplain deposits of sandy, silty or clay-bearing alluvium.

OLD SURFICIAL DEPOSITS
Sediments that are moderately consolidated and slightly to moderately dissected. Older surficial deposits have upper surfaces that are capped by moderate to well-developed pedogenic soils. Includes:

Qoa **Old alluvial floodplain deposits, undivided (late to middle Pleistocene)** – Fluvial sediments deposited on canyon floors. Consists of moderately well consolidated, poorly sorted, permeable, commonly slightly dissected gravel, sand, silt, and clay-bearing alluvium. Where more than one number is shown (e.g., Qoa_{2-6}) those deposits are undivided.

SEDIMENTARY AND VOLCANIC BEDROCK UNITS

Tsa **Santiago Formation (middle Eocene)** – There are three distinctive parts. A basal member consisting of buff and brownish-gray, massive, coarse grained, poorly sorted arkosic sandstone and conglomerate (sandstone generally predominating). In some areas the basal member is overlain by a central member that consists of gray and brownish-gray (salt and pepper) soft, medium grained, moderately well sorted arkosic sandstone. The upper member consists of gray, coarse grained arkosic sandstone and grit. Vertically and laterally throughout the formation there exists greenish-brown, massive claystone interbeds, tongues and lenses of often fossiliferous, lagoonal claystone and siltstone. The lower part of the Santiago formation interfingers with the Delmar Formation and Torrey Sandstone in the Encinitas quadrangle. Named by Woodring and Popenoe (1945) for Eocene deposits of northwestern Santa Ana Mountains.

UNNAMED CRETACEOUS ROCKS OF THE PENINSULAR RANGES BATHOLITH

Kt **Tonalite, undivided (mid-Cretaceous)** – Massive, coarse grained, light gray hornblende-bottle tonalite.

Kgb **Gabbro, undivided (mid-Cretaceous)** – Massive, coarse grained, dark gray and black biotite-hornblende-hypersthene gabbro.

NAMED CRETACEOUS ROCKS OF THE PENINSULAR RANGES BATHOLITH

Kis **Granite of Indian Springs (mid-Cretaceous)** – Fine grained biotite granite. Similar in appearance to Kdl.

Klh **Leucogranodiorite of Lake Hodges (mid-Cretaceous)** – Massive, coarse and medium grained biotite-hornblende, leucogranodiorite.

Kmm **Monzogranite of Merriam Mountain (mid-Cretaceous)** – Massive, medium to coarse grained, leucocratic hornblende-biotite monzogranite.

Kjd **Granodiorite of Jesmond Dean (mid-Cretaceous)** – Massive, fine grained, dark gray and black granodiorite.

PREBATHOLOTHIC AND SYNBATHOLITHC METAMORPHIC ROCKS

Mzu **Metamorphosed and unmetamorphosed volcanic and sedimentary rocks, undivided (Mesozoic)** – Wide variety of unmetamorphosed and low to high metamorphic grade volcanic and sedimentary rocks. They include prebatholithic (metamorphosed) and synbatholithic (unmetamorphosed) rocks (Santiago Peak Volcanics) of Larsen (1948), metasedimentary rocks (Bedford Canyon Formation) of Larsen (1948), metasedimentary rocks (Bedford Canyon Formation) of Larsen (1948), volcanic, metavolcanic, sedimentary and metasedimentary rocks (Black Mountain Volcanics) of Hanna (1926). These rocks include a Cretaceous subaerial island-arc volcanic sequence consisting of basalitic andesite, andesite, dacite, rhyolite, volcaniclastic breccias, welded tuff and epiclastic rocks (Herzig 1991). They are comagmatic with the oldest Cretaceous plutons of the Peninsular Ranges batholiths (Herzig and Kimbrough 1991; Anderson 1991).

Mzd **Metavolcanic dikes (Mesozoic)** – Very find grained, dark gray, massive dikes within Mzu.

Mzs **Schist with minor amphibolites and marble (Mesozoic)** – Quartz-mica schist, quartz-mica-amphibole schist, and feldspathic amphibole schist.

GEOLOGIC FORMATIONS
FIGURE 4.5-4