3.8 GEOLOGY, SOILS, AND MINERALS

3.8.1 Introduction

This section addresses issues associated with geology, soils, faults and seismicity, and minerals. Construction of the Species Conservation Habitat (SCH) Project alternatives would affect soils and minerals and the structures that would be built could be affected by local faults and seismic and geothermal activity. The compatibility of the SCH Project with future geothermal development is addressed in Section 3.13, Land Use. The study area for geology, soils, and minerals comprises the proposed alternative sites, seismically active areas in the surrounding Salton Basin (refer to Figure 3.8-1 for locations of nearby faults), and local sources of rock and gravel used during construction.

Table 3.8-1 summarizes the impacts of the six Project alternatives on geology, soils, and minerals, compared to both the existing conditions and the No Action Alternative.

Table 3.8-1 Summary of Impacts on Geology and Soils

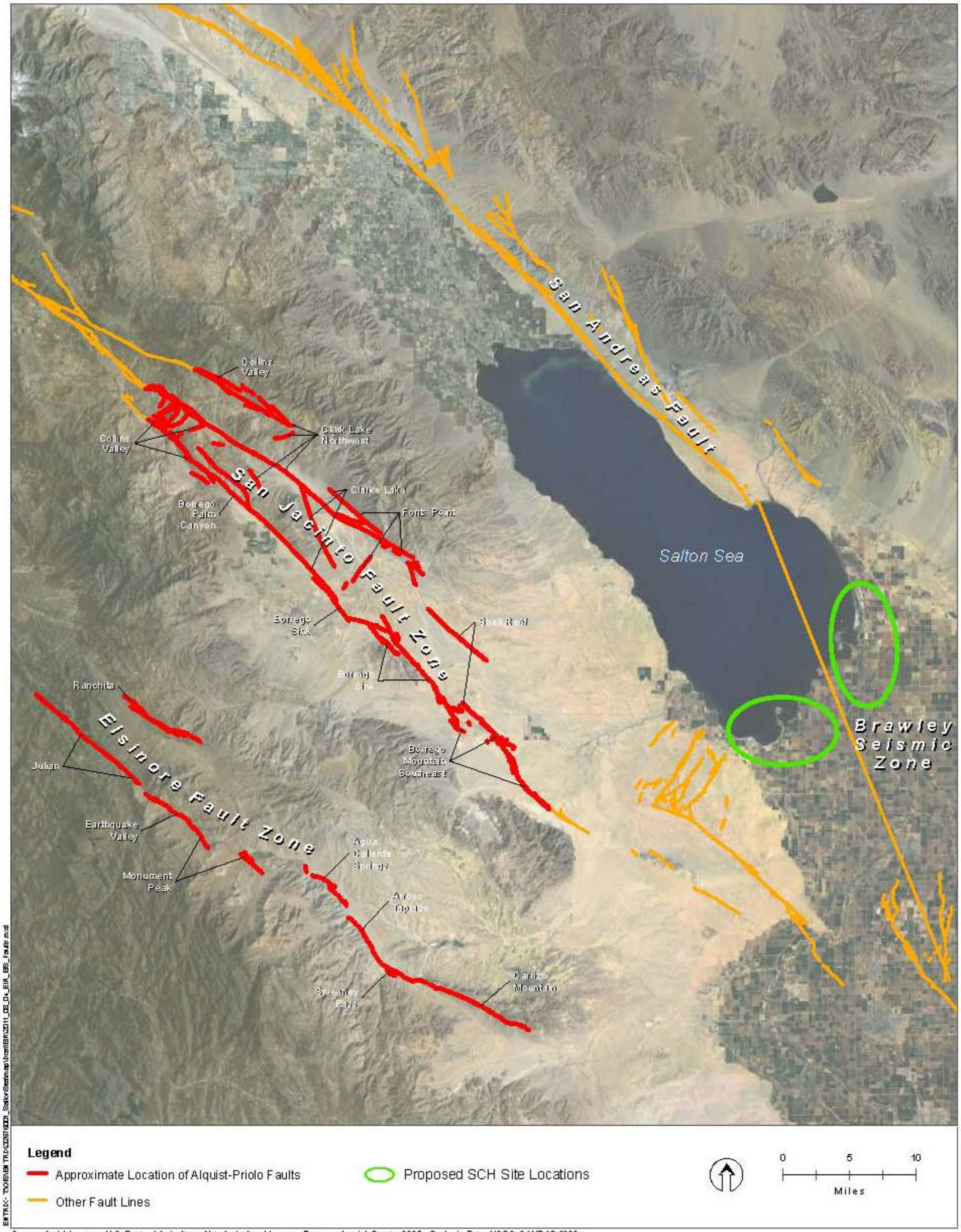
Impact	Basis of Comparison	Project Alternative						Mitigation Measures
		1	2	3	4	5	6	
Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures.	Existing Condition	L	L	L	L	L	L	None required
	No Action	L	L	L	L	L	L	None required
Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction.	Existing Condition	L	L	L	L	L	L	None required
	No Action	L	L	L	L	L	L	None required
Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms.	Existing Condition	L	L	L	L	L	L	None required
	No Action	L	L	L	L	L	L	None required
Impact GEO-4: Construction would require the use of rock as riprap or pond substrate.	Existing Condition	L	L	L	L	L	L	None required
	No Action	L	L	L	L	L	L	None required

Note:
O = No Impact
L = Less-than-Significant Impact
S = Significant Impact, but Mitigable to Less than Significant
U = Significant Unavoidable Impact
B = Beneficial Impact

3.8.2 Regulatory Requirements

Alquist-Priolo Earthquake Fault Zone Act

The Alquist-Priolo Earthquake Fault Zone Act (Public Resources Code sections 2621 et seq.) was passed in 1972 to prevent buildings from being constructed over active faults. The Act is designed to mitigate surface fault rupture by preventing construction of buildings for human occupancy across an active fault. It requires state zoning of active faults, and local review and regulation of development within the zones. The proposed Project sites are not located within an Alquist-Priolo special study zone.



Source: Aerial Imagery: U.S. Dept. of Agriculture, Nat. Agricultural Imagery Program, Imerial County, 2005. Geologic Data: USGS, SANDAG 2008.

Figure 3.8-1 Location of Faults near the Salton Sea

California Code of Regulations, Title 24

California Code of Regulations, Title 24, Chapters 16 and 17 include standards for structural and seismic design of structures. As defined by the California Code of Regulations, the Salton Sea is located in Seismic Zone 4; therefore, the seismic performance objectives include:

- To sustain minimal or no damage under minor earthquake ground motion;
- To limit damage to nonstructural features under moderate level earthquake ground motion; and
- To limit damage to structural and nonstructural features without collapse under major level earthquake ground motion.

California Water Code, Division 3

Division 3 of the California Water Code establishes standards and provisions related to dams and reservoirs under the jurisdiction of the California Department of Water Resources (DWR). This regulation delineates general and administrative provisions; powers of DWR including maintenance of operation of water infrastructure, emergency work, investigations and studies, and general procedures; applications for new dams and alterations to existing dams; as well as inspection and approval processes to ensure the safeguard of life and property from dam failure. Section 6025.6 states that "the civil engineer supervising a dam pursuant to subdivision (a) of section 6025.6 shall take into consideration, in determining whether or not a dam constitutes, or would constitute, a danger to life or property, the possibility that the dam might be endangered by seepage, earth movement, or other conditions that exist, or might occur, in any area in the vicinity of the dam."

The Division of Safety of Dams (DSOD), which operates under Division 3 of the California Water Code, reviews plans and specifications for the construction of new dams or for the enlargement, alteration, repair, or removal of existing dams. DSOD must grant written approval before construction can proceed on any new dam (assuming it falls within DSOD jurisdiction). The berms proposed for the Species SCH Project would be constructed using local materials and impound water that is no more than 6 feet from the water surface to the berm's downstream toe. This design consideration places the berms outside the DSOD's jurisdiction (personal communication, D. Gutierrez 2011).

Imperial County General Plan

The Seismic and Public Safety Element of the Imperial County General Plan (1993) contains goals and policies for protection of geologic features, soil resources, and avoidance of geologic hazards. Building codes and grading ordinances establish specific regulations for construction procedures, including erosion control measures.

3.8.3 Affected Environment

The following description of the study area depicts the regional geologic environment, the geologic history of the study area, faulting and seismicity, soils, geologic hazards within the region, and mineral resources.

3.8.3.1 Regional Geologic Environment

The descriptions of the regional geologic environment, geologic history, faults, and historical earthquakes are taken from the *Salton Sea Ecosystem Restoration Program Final Programmatic Environmental Impact Report* (PEIR) (DWR and California Department of Fish and Game [DFG] 2007) and updated as appropriate. The Salton Sea occupies a portion of the interior-draining Salton Basin. This basin's southern end has been blocked by the deposition of deltaic sediments from the Colorado River, effectively preventing drainage from the basin to the Gulf of California. The several subbasins that drain into the Salton Sea include the Whitewater River from the San Bernardino, Little San Bernardino, and San Jacinto ranges to the north-northwest, Salt Creek from the Orocopia and Chocolate Mountains to the east, and San Felipe Creek, which drains the Peninsular Range to the West. The largest flow into the Salton Sea comes from the Imperial Valley to the south via the New and Alamo rivers. These rivers primarily convey drainage flows from irrigated lands.

The Salton Basin is located in the Salton Trough, a deep north-west trending structural depression that extends from San Gorgonio Pass to the Gulf of California. The Salton Trough is the northern portion of the rift zone that occurs where the North American (east) and Pacific (west) plates converge. The rift zone includes the Salton Trough, the Colorado River Delta, and the Gulf of California. The rift zone, a low-lying area that occurs because of the downward movement of land between two fault zones, formed during late Cenozoic time. The accumulation of the Colorado River Delta sediments separates the trough from the southern Gulf of California.

The Salton Trough is bounded to the north by the Transverse Ranges geomorphic province, to the northeast by the Mojave Desert geomorphic province, and to the west by the Peninsular Ranges geomorphic province. Northwest-trending faults and associated folding cross the Salton Basin, the Imperial Valley, and the mountains to the west. These faults are predominately right-lateral and can be divided into three main fault zones: the San Andreas, San Jacinto, and Elsinore. These faults are discussed in the "Faults" section below.

The oldest exposed rocks in the region surrounding the Salton Trough are Precambrian gneisses, anorthosites, and schists, as shown on Figure 3.8-2. Younger Paleozoic to Cenozoic plutonic rocks in turn intrude on these rocks. The sediments within the Salton Trough range in age from Miocene to Holocene. The Salton Trough is a large structural depression that has filled with about 19,500 feet or 3.7 miles of sediment since the late Cenozoic.

The oldest sediments are coarse clastic sediments derived from the surrounding crystalline rocks. These deposits are overlain by essentially continuous deposits of volcanics, lacustrine, evaporites, marine, fluvial, and deltaic sediments. The greatest source of sediment is from the Colorado River.

The only marine formation, the Imperial Formation, was deposited during a marine incursion that occurred not long after the initiation of the opening of the Gulf of California about 5,000,000 years ago. Discontinuous outcrops of the formation are found from just south of the international border to San Gorgonio Pass. This formation may be as old as late Miocene but is generally considered to be Pliocene. The marine rocks at the formation's northern end are thought to be Miocene and may not be correlative with the marine rocks found to the south. These rocks may predate the opening of the Gulf of California and represent a proto-Gulf.

3.8.3.2 Geologic History

The Salton Trough is located in a tectonically complex area. Prior to the formation of the present-day Salton Trough, the region was landward of a back arc resulting from the subduction of the Farallon plate beneath the North American plate. Volcanics formed during this time are found today in the highlands that define the present day rift zone, as well as Precambrian metamorphics. Units exposed in the mountain ranges near the Salton Trough include the San Gorgonio complex, the Chuckwalla complex, and the Orocopia schist. Deposition of early Tertiary sedimentary units occurred in the region prior to the opening of the present day rift basin. These units are consolidated and primarily nonmarine in origin. Major units include the Coachella fanglomerate and the Hathaway, Imperial, and Mecca formations.

Eon	Era	Period		Epoch	Age in Million Years Before Present
Phanerozoic	Cenozoic	Quaternary		Recent (Holocene)	0 to 0.01
				Pleistocene	0.01 to 2
		Neogene	Tertiary	Pliocene	2 to 5
				Miocene	5 to 24
		Paleogene		Oligocene	24 to 37
				Eocene	37 to 58
				Paleocene	58 to 66
	Mesozoic	Cretaceous			66 to 144
		Jurassic			144 to 208
		Triassic			208 to 245
	Paleozoic	Permian			245 to 286
		Carboniferous	Pensylvanian		286 to 320
			Mississippian		320 to 360
		Devonian			360 to 408
		Silurian			408 to 438
		Ordovician			438 to 505
		Cambrian			505 to 570
Precambrian	Proterozoic				570 to 2,500
	Archean				2,500 to 3,800
	Pre-Archean				3,800 to 4,600

Figure 3.8-2 Geologic Time Scale

Interlayered with some of the sedimentary units, such as the Coachella fanglomerate, may be intervals of basalt, probably originating from the volcanism associated with the back arc setting. The Imperial Formation is the only major marine sedimentary unit exposed in the Salton Trough and preserves the occurrence of the proto-Gulf of California. It is up to 3,700 feet thick and was deposited 5,000,000 to 7,000,000 years ago.

The rift basin that occurs today from the San Gorgonio Pass south into the Gulf of California formed about 4,000,000 years ago. It is bounded on both sides by a series of fault zones. The downward movement of the land between the fault zones and the subsequent infilling of the trough has resulted in a thick sequence of highly variable sediments. Once the rift basin formed, sediments were deposited originating from the Colorado River, which has flowed both south (its current course) and north into the rift valley, as well as from alluvial material eroded from the surrounding mountain ranges. As a result of this periodic inundation of the rift valley and subsequent evaporation of the lakes, lacustrine (lake) evaporites (deposits) are the dominant sediment type in the northern Salton Trough. Downward percolation of water through these saline units has resulted in the occurrence of rift basinal brines, which characterize the Salton Sea and Brawley geothermal systems.

Most recent geologic units are lacustrine and alluvial sediments originating from the uplands adjacent to the rift basin. Wind action frequently influences surficial units, often resulting in dunes such as the Sand Hills, a 40-mile-long by 5-mile-wide series of wind-blown deposits extending along the Coachella

Canal's eastern side from the United States-Mexico border and the Tule Wash dune located west of the Salton Sea.

Lake Cahuilla is a collective name representing the numerous times the Salton Trough has been flooded by water from the Colorado River. The Colorado River has drained the interior of the North American plate since before the formation of the current rift zone. Because of the natural deposition of sediments at the delta that formed where the Colorado River enters the rift zone, thick accumulations of sediments near the delta's upper zones could result in the river changing course. When this change happened, the river would flow into the rift valley until the river again changed course. The occurrence of the deltaic sediments also prevents the Gulf of California from inundating the Salton Trough, which is below sea level.

The sedimentary record within the Salton Trough documents well the previous occurrences of Lake Cahuilla. Deposition of light-colored calcium carbonate along the cliffs of the present day valley shows that the most recent shoreline was about 40 feet above sea level. Anthropologic, geologic, and freshwater mollusk data indicate that Lake Cahuilla first appeared about 700 and occupied the basin until about 300 years ago. At its largest, the lake is estimated to have been 6 times the size of the current Salton Sea – 100 miles long and 35 miles across. Although Salton Sink was a dry lakebed when Europeans first explored the valley in 1774, the Colorado River is known to have flooded the area at least 8 times between 1824 and 1904 resulting in earlier versions of the Salton Sea.

3.8.3.3 Faults

The Salton Sea Trough has three main fault zones (San Andreas, San Jacinto, and Elsinore). The Coachella Segment of the San Andreas Fault forms the northeastern boundary of the Salton Trough. The fault is evident on the ground surface from north of the Salton Sea to just north of Bombay Beach located on the Salton Sea's eastern shore, but is not evident on the ground surface to the southeast of the Salton Sea. The latest break on this segment is likely greater than 300 years ago. With an estimated accumulated strain of about 25 millimeters/year, a possibility exists that this segment could produce an earthquake with a magnitude of about 7.5 or larger with over 20 feet of offset. The San Jacinto Fault Zone is located just to the west of the Salton Sea and is composed of a complex system of faults including the San Jacinto, San Felipe Hills, Santa Rosa, San Felipe, Superstition Hills, Superstition Mountain, Coyote Creek, and Imperial. The Imperial Valley, located just south of the Salton Sea, is one of the most seismically active regions in Southern California. The Imperial Fault produced a magnitude 6.9 earthquake in 1940. The Elsinore Fault Zone is located west of the San Jacinto Fault Zone and borders the southwestern face of the Coyote Mountains. These fault zones are discussed in more detail below and shown on Figure 3.8-1. The Brawley Seismic Zone also is discussed below.

San Andreas Fault

The San Andreas Fault enters the Salton Trough at the Coachella Valley's northwestern end. This fault system constitutes the main structural boundary between the Pacific and North American plates. Today, the San Andreas Fault Zone is traceable from the Gulf of California northward to Shelter Cove Coast in Humboldt County. Regionally, it is traceable from the town of Niland east of the Salton Sea northward through San Gorgonio Pass. The fault zone continues southward into Mexico as the Sand Hills and Algodones Fault. The San Andreas Fault is right-lateral with an approximate offset of 200 miles. The offset in Southern California is estimated to have begun in the late Miocene and early Pliocene (5,000,000 to 10,000,000 years ago).

San Jacinto Fault Zone

The San Jacinto Fault Zone is a major strand of the San Andreas Fault System. It extends southeastward from Cajon Pass as a series of splays into the Salton Trough. The San Jacinto Fault is an extremely active system. Right lateral displacement on the San Jacinto Fault Zone is about 19 miles. Vertical separations along the zone exceed 8,000 feet in the Santa Rosa Mountains. The San Jacinto Fault is thought to be Plio-Pleistocene based on vertebrate and plant remains but may be younger than 1,000,000 years as indicated by lateral offset of the late Pleistocene Ocotillo Conglomerate.

Elsinore Fault Zone

The Elsinore Fault Zone extends from the northern Peninsular Range southward to the Gulf of California. The fault zone is parallel and west of the San Jacinto Fault Zone. Right lateral displacement along the main fault trace is about 30 miles. Vertical displacement and relief features along this fault reach as much as 9,000 feet. The Elsinore Fault Zone is considered to be older than the San Jacinto Fault, between 1,800,000 and 2,700,000 years ago.

Brawley Seismic Zone

The Brawley Seismic Zone is comprised of the Imperial-Brawley fault system and is a zone of high seismicity extending from the Imperial Fault's northern reach northwest into the Salton Sea. This zone is marked by parallel or near-parallel, closely spaced, step-like, right-lateral faults that trend northwest and are linked by conjugate left-lateral structures. The Sand Hills Seismicity Lineament extends southeast from the San Andreas Fault's southern tip within this seismic zone and may represent the San Andreas Fault's southern extension.

3.8.3.4 Historical Earthquakes

The Imperial Valley portion of the Salton Trough has had more small to moderate earthquakes than any other portion of the San Andreas Fault system. In addition to these smaller earthquakes, 9 earthquakes with magnitudes of 6.0 or greater have occurred along the San Jacinto Fault and 3 of greater than 6.0 have occurred along the Imperial Fault between 1890 and 1972. Two additional earthquakes with magnitudes greater than 6.0 have occurred since 1972. One was on the Imperial Fault (magnitude 6.5, 1979) and the other was on the Superstition Hill Fault (magnitude 6.6 in 1987). Two strong earthquakes (both magnitude 7.1) have been recorded on the Cerro Prieto Fault in Mexicali Valley. These earthquakes occurred in 1915 and 1934. Although earthquakes also occur in the Coachella Valley, the northern Salton Trough is less active seismically than its southern portion. The area also experienced a magnitude 7.2 earthquake in 2010 that was centered in Mexicali, Mexico, approximately 57 miles southeast of the Salton Sea.

3.8.3.5 Soils

Soils Adjacent to the Salton Sea

Soil units within the Salton Trough have formed on fine-grained sediments associated with the occurrence of Lake Cahuilla and alluvial fans from the adjacent highlands. A wide range of desert and alluvial soil types are present, including well-drained sands to silty clay loams in the area adjacent to the Salton Sea. The preliminary geotechnical report prepared for the SCH Project provides additional detail regarding the soils in the area where the proposed ponds would be constructed (Appendix C).

In-Sea Soils

In-Sea soils consist of soils derived from lacustrine (lake) evaporites (deposits) and are summarized below (DWR and DFG 2007):

- **Sea Floor Deposits –** The first layer, Salton Sea Floor Deposits, is composed of recently deposited, very soft to loose, highly plastic clays to silty fine sands. The thickness of this layer ranges from zero to 21 feet with the greatest thickness occurring in the southern and mid-Sea areas.
- **Soft Lacustrine Deposits –** The Soft Lacustrine Deposits were found to underlie the seafloor deposits over much of the Salton Sea's area. These materials consist of highly plastic, soft to very soft clays ranging in thickness from zero to 26 feet. The thickest deposits were found in the Whitewater River delta and the mid-Sea's easterly area.
- **Upper Alluvial Deposits –** The Upper Alluvial Deposits are interspaced between the Soft and Stiff Lacustrine Deposits and are predominant near the Salton Sea's perimeter. These deposits are described as composed of loose to dense silty fine sands with interbedded silt and sand lenses ranging in thickness from zero to 26 feet. The thickest deposits were found in the Salton Sea's northeastern, southwestern, and west-central margins.
- **Upper Stiff Lacustrine Deposits –** The Upper Stiff Lacustrine Deposits underlying both the Soft Lacustrine and Upper Alluvial Deposits, are composed of predominantly stiff to very stiff, highly plastic clays ranging in thickness from four to 31 feet. The thickest deposits were found in the mid-Sea's eastern and southeastern areas, the latter near the Alamo River delta.
- **Lower Alluvial Deposits –** The Lower Alluvial Deposits are similar to the Upper Alluvial Deposits except that their density is greater, ranging in consistency from medium dense to dense. These deposits were predominant in the southern Salton Sea, ranging from zero to 22 feet in thickness.
- **Lower Stiff Lacustrine Deposits –** The Lower Stiff Lacustrine Deposits likely underlies the entire Salton Sea having a thickness much greater than 100 feet. This layer is primarily hard plastic clay.

3.8.3.6 Geologic Hazards

Geologic hazards that may occur in the Salton Trough include the potential for earthquake rupture or shaking (discussed under "Faults" above), subsidence as a result of groundwater overdraft, liquefaction of loose saturated soils during earthquakes, landslides in areas of steep topography, lateral spreading, seiches, and volcanic hazards. These hazards are described below.

Subsidence

Subsidence can occur when pore pressure within a groundwater system is reduced (usually as a result of groundwater extraction) to the point that the aquifer framework compresses. This process is more common in systems where finer-grained sediments such as clay or silt dominate the aquifer framework. Subsidence can also occur as a result of tectonic activity or reservoir loading.

Recent subsidence investigations in the Coachella Valley have focused on its southern portion near the Salton Sea. Increased groundwater pumping to meet increasing water demands makes the area susceptible to subsidence. Subsidence of up to 0.5 foot has occurred for the period 1928 to 1996. Additional subsidence of up to 0.13 foot may have occurred between 1996 and 1998.

Recent investigations in the Imperial Valley evaluated potential subsidence due to geothermal energy generation activities along the southern Salton Sea shoreline. These studies determined that subsidence was not occurring in as a result of geothermal development because the water was being reinjected following energy generation. Subsidence due to other factors is occurring in the southern Salton Sea at a rate of about 10 millimeters per year.

Liquefaction

Liquefaction may occur when shallow (less than 50 feet below grade), saturated, unconsolidated material is subjected to shaking. The shaking causes porewater pressure to increase, and the material to lose its structural integrity and behave as a liquid. It commonly occurs where shallow groundwater occurs, near surface water bodies, or in filled areas. Shallow groundwater occurs in extensive areas of the Salton Trough, and liquefaction is considered to be a hazard in both the Imperial and Coachella valleys.

Landslides

Landslides most commonly occur in areas of and adjacent to steep slopes. Earthquakes may often trigger them. Within the Salton Trough region, landslide potential is greatest along the valley margins. It could also occur on a minor scale along embankments that often occur along canals. Because of the broad, low-lying character of the study area, landslide potential throughout the area is low.

Lateral Spreading

Lateral spreading is the separating or rupturing of the ground surface as a result of strong ground shaking. Lateral spreading commonly occurs along drainage banks, cliffs, or other areas with steep or nearly vertical slopes, where generally loose sediments collapse due to lack of lateral support. Lateral spreading does not necessarily take place along an active fault, but rather is generally associated with liquefaction caused by seismically induced ground shaking. Within the study area, lateral spreading is most likely to occur along river, creek, and drain banks. The potential for lateral spreading to occur along the steep channel slopes of the New and Alamo rivers in the more southern study area is moderate to high. However, the potential for lateral spreading to occur in areas near the Salton Sea is relatively low as the rivers, creeks, and drains tend to have generally gentle to moderately sloping banks near the Salton Sea.

Seiches

Seiches are large waves in lakes produced by either wind or seismic activity. No occurrences of seiches are documented at the Salton Sea. However, because of the Salton Sea's shallowness and the fact that the region is seismically active, the potential exists for a seiche to occur in the Sea.

Volcanic Hazards

Volcanoes, rhyolite domes, geothermal fields, mud pots, and hot springs are indicators that volcanism exists in the Salton Trough. These features are located primarily in the Mexicali and Imperial valleys.

Volcanoes, Mud Volcanoes, and Mud Pots

The Cerro Prieto volcano is located southeast of Mexicali, near the Cerro Prieto Fault and the Cerro Prieto geothermal field. The volcano is a prominent feature in the area, but is not related to the geothermal field. The volcano last erupted between 10,000 and 100,000 years ago. Mud pots, mud volcanoes, geysers, and fumaroles also occur near the Cerro Prieto volcano. An active geyser occurred in the area for several months as recently as 1991.

Mud pots and mud volcanoes are located southeast of the Salton Sea near Niland. The mud volcanoes that occur in this area are 3 to 6 feet in height and up to 10 feet wide. The mud pots are smaller than the mud volcanoes (no more than a couple of feet high or wide). The mud in the mud volcanoes is generally hotter than in the mud pots. Anecdotal observations from local residents report variations in carbon dioxide and temperature variation that may be controlled by seasonal changes or earthquake activity. Mud pots are present adjacent to and within the Project area east of the Alamo River in Morton Bay. Several other sites are currently under water in the Sea near Mullet Island (personal communication, N. Driscoll 2010).

Holocene Rhyolite Domes

Extrusive rhyolite domes are located near the mud pots along the Salton Sea's southern edge. Obsidian Butte is the largest and southernmost rhyolite dome and is estimated to be between 2,400 and 8,500 years old. It is located on the Salton Sea's shoreline and is composed of rhyolite, obsidian, and pumice. Ancestral shorelines of Lake Cahuilla can be observed at Obsidian Butte. The other domes are located at Rock Hill, Red Island, and Mullet Island.

Hot Springs

Hot springs are located in several areas throughout the Salton Trough. They are often associated with the spreading centers of major regional faults.

One prominent area of hot springs occurs to the east of Bombay Beach, on the Salton Sea's eastern shore. The area is referred to as the Hot Mineral Spa Geothermal Resource Area. Numerous wells have been drilled in the area, several of which exhibit artesian flow. Water produced at these wells is from a common source, are meteoric, and are produced from a narrow band of sediments located between the crystalline bedrock of the Chocolate Mountains and the Hot Spring Fault.

Hot springs occur throughout the region, including near Jacumba, Holtville, Canon de Guadalupe, and the city of Desert Hot Springs.

3.8.3.7 Mineral Resources

Minerals found throughout Imperial County include gold, gypsum, sand, gravel, lime, clay, and stone. These resources are extracted through commercial enterprises (County of Imperial 1993). Industrial materials are also extracted commercially, including kyanite, mineral fillers (clay, limestone, sericite, mica, and tuff), salt, potash, calcium chloride, manganese, and sand. A variety of mining/reclamation areas exist in Imperial County, but they are not located in the immediate study area (County of Imperial 1993).

The Project area is located in the Salton Sea Known Geothermal Resource Area (County of Imperial 2006). A Known Geothermal Resource Area is defined as:

> An area in which the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary of the Interior, engender a belief in those who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose (30 USC [United States Code] section 1001).

Brine produced by geothermal activities contains minerals, although the recovery is dependent upon production costs and market price. At the Salton Sea Known Geothermal Resource Area, the brine is very high in minerals such as sodium, arsenic, antimony, mercury, selenium, potassium, iron, tin, manganese, chlorine, boron, bromine, potash, and zinc. Precious metals, such as silver, gold, and platinum, are present in trace concentrations. Studies of brine in the Salton Sea area have shown substantial differences in the trace element compositions even from relatively closely spaced wells. The total dissolved solids and mineral concentrations in the brine can also change with the well flow rate (County of Imperial 2006).

Since the geothermal brines of the Salton Sea Known Geothermal Resource Area have a greater concentration of valuable minerals, this area's resource is being developed. Cal Energy is operating a zinc extract plant near the Salton Sea. Some of the minerals being extracted from geothermal brines, such as manganese and tin, have strategic value for national defense (County of Imperial 2006).

3.8.4 Impacts and Mitigation Measures

3.8.4.1 Impact Analysis Methodology

The impact assessment for geology and soils is based on the proximity of active faults, frequency and types of seismic events, existing ground acceleration data and models, and the type of existing soils. In addition, the susceptibility and/or contribution of the alternatives to geologic hazards are described in terms of their potential impact on the public. The preliminary geotechnical investigation for the SCH Project conducted by Hultgren-Tillis Engineers (Appendix C) was also reviewed. Impacts on minerals were evaluated through consideration of whether the Project alternatives would preclude the development of geothermal resources in the Project area and the potential for the Project alternatives to result in the loss of important mineral resources.

3.8.4.2 Thresholds of Significance

Significance Criteria

Impacts on geology and soils would be significant if the SCH Project would:

- Have the potential to expose people, property, or structures to 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 from soil liquefaction; and
  - 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 alternatives, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, seiche, or collapse;
- Be located on expansive or unstable soils, as defined in the Uniform Building Code, creating substantial risks to life or property; or
- Be located in soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.

Impacts on mineral resources would be significant if the SCH Project would:

- Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state; or
- Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan; or
- Result in the loss of access to a known geothermal resource area that would substantially affect existing and future resource extraction activities.

Application of Significance Criteria

Significance criteria have been applied to each alternative. The following list summarizes the overall methodology in the application of the criteria to the alternatives:

- **Expose people, property, or structures to substantial adverse effects from seismic events –** The primary risks associated with seismic activity are related to berm failure or SCH water supply pipeline rupture. While berms would be designed and constructed in accordance with California Building Code requirements, the potential for risk to life and property in the event of collapse is discussed. The potential for conveyance pipeline rupture as a result of seismic events, leading to associated flooding hazards, also is discussed. Landslides are not considered a potential risk in the Project area because of the generally flat topography and are not discussed further.
- **Substantial soil erosion or loss of topsoil** – The potential for substantial soil erosion to occur during construction and release of hydrostatic test water is considered, as is the potential for the erosion to occur in or around the river diversion system. The potential loss of topsoil during pipeline installation also is addressed. The diversion facilities (both pumped and gravity) would be built into the river bank and would not project into the channel; thus, they would not be expected to increase erosion. In addition, the area around the diversion facilities would be treated with riprap or similar material to avoid erosion. Thus, this impact is not addressed further.
- **Location on a geologic unit or soil that is unstable, or that would become unstable** – The existing soils are considered expansive and unstable, and this issue is discussed below. Areas within the Project footprint may have liquefiable and expansive soils and be subject to subsidence and volcanic hazards.
- **Location on expansive or unstable soils, creating substantial risks to life or property –**.Refer to the preceding criterion.
- **Location in soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems** – The Project alternatives would not require the use of septic tanks, nor would residential or related uses be proposed that would require the need for wastewater disposal systems. Therefore, this significance criterion is not addressed further.
- **Loss of availability of a locally or statewide important mineral resource**. The primary loss of such mineral resources would result from the use of rock for pond substrate and well as the loss of access any minerals that may underlie the SCH facilities.
- **Loss of access to a known geothermal resource area.** The potential for conflicts with geothermal activities in general is discussed in Section 3.13, Land Use. As discussed, the Project would not preclude geothermal development and, thus, would not preclude the extraction of minerals from brine should geothermal development be implemented in the Project vicinity.

3.8.4.3 No Action Alternative

The description of the impacts of the No Action Alternative that is included in the PEIR (DWR and DFG 2007) is applicable to the SCH Project and summarized below. This alternative would involve construction and operations and maintenance activities associated pupfish channels, and relocating recreational facilities as the Salton Sea recedes, which could result in short-term construction impacts associated with erosion. No soil/bedrock mineral resources were identified along the shoreline. Specific information related to mineral resources in the Salton seabed was not found during the PEIR's preparation; however, mineral resources may be present. The disturbance of about 35,800 acres of land, and the use of 5,050,000 cubic yards of seabed soils could result in loss of mineral resources in the seabed.

3.8.4.4 Alternative 1 – New River, Gravity Diversion + Cascading Ponds

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). As noted above in Section 3.8.3.4, three main fault zones (San Andreas, San Jacinto, and Elsinore) are located in the Salton Sea Trough. In addition to the San Andreas Fault, which runs beneath the seabed, the San Jacinto Fault Zone is located immediately west of the Sea and is composed of a complex system of faults (DWR and DFG 2007; U.S. Geological Survey 2010). Large seismic events have occurred at the Salton Sea approximately every 200 years, although it has been over 335 years since the last significant earthquake was recorded (Monroe 2007). For these reasons, the potential for ground shaking and rupture within the Project area is high.

No seismically induced safety impacts would result from berm or pipeline failure during construction. Once the ponds and pipelines were filled with water, a berm failure could release water directly to the Salton Sea or onto exposed playa where it would then flow to the Sea. The topography in the ponds' vicinity slopes toward the Salton Sea, and water released from the ponds would flow in this direction rather than inundate the surrounding area. Thus, water released from the ponds as a result of seismic events would not expose people, property, or structures to substantial adverse effects, and impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative. In addition, the SCH's maximum water surface elevation would be -228 feet. This elevation is at or below the elevation of the land to the south of the Project area, making it difficult for adjacent land to be flooded in the event of an SCH berm failure.

Under this alternative, the sedimentation basin would be located upstream at the gravity diversion. The basin elevation would be at an elevation of about -222 feet. This water elevation is below the ground elevation at the basin (i.e., the basin would be dug into the native ground. No risk exists of berm failure that would send water onto adjoining properties.

Although a potential exists for seismic events to damage the water pipelines, they would be constructed of plastic, which would minimize the potential for rupture. Moreover, the pipelines leading from the river would be buried at a depth of approximately 15 feet, which would further minimize the potential for flooding because some water, at least, would be absorbed into the ground and the soil would impede the release of water. The pipelines carrying saline water would be located in the seabed, and any water released from them would flow back into the Salton Sea. Water released from the pipelines as a result of seismic events would not expose people, property, or structures to substantial adverse effects, impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). As discussed in Section 2, best management practices would be implemented during construction to minimize the potential for erosion and sedimentation. They would be part of the Stormwater Management Pollution Prevention Plan and would include such measures as preservation of existing vegetation to the extent feasible, installation of silt fences, use of wind erosion control (e.g., geotextile or plastic covers on stockpiled soil), and stabilization of site ingress/egress locations to minimize erosion. Given the implementation of these best management practices, impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative.

Water would be used to perform a hydrostatic test of the saltwater and brackish water pipelines before they were put into service. The test water from the pipelines would be released into either the sedimentation basin or one of the SCH ponds. The water would be released in a controlled manner to minimize the potential for erosion, and any erosion that did occur would be contained within the basin or the pond. Impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative.

Exposed playa that was recently submerged would be used to construct the berms. It is highly saline and not considered topsoil. Topsoil would be removed during construction of the pipeline leading from the river to the ponds, but it would be stockpiled and replaced in its original location. Thus, any loss of topsoil would be temporary, and the impact would be less than significant when compared to both the existing environmental setting and No Action Alternative.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). In general, the lacusterine soils on the Sea bed are weak and may be subject to erosion, piping, settling, and spreading during the life of the Project. These factors would be considered during the geotechnical design and accommodated by allowing for settling in the design and placement of soil, adding features such as a cutoff wall to avoid seepage, and using flatter side slopes on the berms to reduce seepage and add stability. The preliminary geotechnical investigation (Appendix C) showed that the Sea sediments at the pond sites are predominantly fine-grained soils with low strength. These types of soils will readily erode when exposed to even light wave action and are also dispersive in fresh water. (Their performance in brackish water is yet to be evaluated). Compressibility, seepage, and expansion potential are also issues that would need to be addressed through appropriate design. If seepage developed through a berm, the dispersive nature of the soils could lead to the loss of the embankment. Additional geotechnical analysis would be performed prior to construction, however, and the berms would be constructed following appropriate site-specific soil construction techniques, including the use of specialized equipment and flat to moderate slopes. The Project would not cause instability in the surrounding area, and should berm failure occurring during the life of the Project, this would be addressed by repairing the failed section, relocating a section of berm, or changing the berm cross section. As discussed in Impact GEO-1, berm failure would not result in the exposure of people, property, or structures to substantial adverse effects, and impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative.

Impact GEO-4: Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The Project would require rock or gravel from local sources to be used as substrate or riprap for the ponds, but these materials are in ready supply, and their use would not result in the loss of availability of a mineral resource that is of local or statewide important. Thus, impacts would be less than significant when compared to both the existing environmental setting and No Action Alternative.

3.8.4.5 Alternative 2 – New River, Pumped Diversion

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative, except the pipelines from the New River would not be required, and the sedimentation basin would be located within the ponds at a maximum water surface elevation of -228 feet. This water elevation is below the ground elevation at the basin. That is, the basin is dug into the native ground. No risk exists of berm failure that would send water onto adjoining properties.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative except no topsoil would be removed during pipeline construction.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

Impact GEO-4. Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

3.8.4.6 Alternative 3 – New River, Pumped Diversion + Cascading Ponds

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). The discussions under Alternatives 1 and 2 are applicable to this alternative.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). The discussions under Alternatives 1 and 2 are applicable to this alternative.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). The discussions under Alternatives 1 and 2 are applicable to this alternative.

Impact GEO-4: Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The discussions under Alternatives 1 and 2 are applicable to this alternative.

3.8.4.7 Alternative 4 – Alamo River, Gravity Diversion + Cascading Pond

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative with the exception of the presence of mud pots east of the Alamo River in Morton Bay. The area of current mud pot exposure would be avoided when locating and constructing Project berms. It is possible, however, that new mud pots could open up during the Project's life. If such a vent were to open up under an existing berm, the release of carbon dioxide gas could erode and undermine the berm, causing it to fail. If the failed berm were located between two ponds (where the water surface elevation would be similar), the water in the two ponds would equilibrate at a new lower level based on the combined volume of water and volume of the ponds. No water would rush between the ponds. If the failed berm were an exterior berm, the water would be released to the Salton Sea or exposed playa. The severity of the release would depend on several factors including the speed at which the failure progressed and the elevation differential between the pondwater surface elevation and the elevation of the Sea or playa. The worst-case elevation differential would be 6 feet. However, no structures downstream of the berm would be at risk. The berm could be rebuilt and at different location to avoid the newly exposed vent. This impact is less than significant when compared to both the existing environmental setting and the No Action Alternative.

Impact GEO-4: Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

3.8.4.8 Alternative 5 – Alamo River, Pumped Diversion

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative, except the pipeline from the Alamo River would not be required, and the sedimentation basin would be located within the ponds at a maximum water surface elevation of -228 feet. This water elevation is below the ground elevation at the basin. That is, the basin would be dug into the native ground. No risk exists of berm failure that would send water onto adjoining properties.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative except no topsoil would be removed during pipeline construction.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). The discussions under Alternatives 1 and 4 are applicable to this alternative.

Impact GEO-4: Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

3.8.4.9 Alternative 6 – Alamo River, Pumped Diversion + Cascading Ponds

Impact GEO-1: A seismic event could cause the berms to fail and damage the water diversion/conveyance structures (less-than-significant impact). The discussions under Alternatives 1 and 5 are applicable to this alternative.

Impact GEO-2: Best management practices would be used to prevent soil erosion and the loss of topsoil during construction (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative except no topsoil would be removed during pipeline construction.

Impact GEO-3: The Project would be located on unstable soils, potentially affecting the stability of the berms (less-than-significant impact). The discussions under Alternatives 1 and 4 are applicable to this alternative.

Impact GEO-4: Construction would require the use of rock or gravel as riprap or pond substrate (less-than-significant impact). The discussion under Alternative 1 is applicable to this alternative.

3.8.5 References

California Department of Water Resources (DWR) and California Department of Fish and Game (DFG). 2007. Salton Sea Ecosystem Restoration Program Final Programmatic Environmental Impact Report.

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3.8.6 Personal Communications

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