C.6 GEOLOGY AND SOILS

This section addresses the environmental setting and impacts related to the construction and operation of the Proposed Project and alternatives. Specifically, Section C.6.1 provides a description of the environmental baseline and regulatory settings, followed by an environmental impacts analysis of the Proposed Action in Section C.6.2. Impact analysis for the alternatives is provided in subsequent sections.

C.6.1 ENVIRONMENTAL BASELINE AND REGULATORY SETTING

Baseline geologic information was collected from geologic, seismic, and geotechnical literature covering the Proposed Project alignment and surrounding area. The literature review was supplemented by a field reconnaissance of the project alignment. The literature review and field reconnaissance focused on the identification of specific geologic hazards.

C.6.1.1 Environmental Setting

C. 6.1.1.1 *Physiography and Topography*

SFPP's proposed project extends from the City of Carson to the City of Norwalk. These cities are located on the south-central portion of an approximately 50 mile long by 20-mile wide lowland coastal plain. The coastal plain slopes gradually southward and westward toward the Pacific Ocean. The plain is interrupted by the Newport-Inglewood uplift, a regional anticline associated with the Newport-Inglewood fault zone. The Newport-Inglewood uplift is responsible for the formation of the Baldwin Hills, Rosecrans Hills, and Dominguez Hills.

The western end of the pipeline route begins immediately adjacent to the southeastern slopes of the Dominguez Hills. The topography along the proposed alignment is characterized by relatively low relief with elevations ranging from 25 to 80 feet above mean sea level. The proposed alignment crosses both the San Gabriel and Los Angeles Rivers, as well as Compton Creek. At the pipeline crossings the river channels are concrete lined and the levees are approximately 40 feet high and inclined at about 45 degrees. The Compton Creek channel bottom is unlined.

C.6.1.1.2 *Geology*

The Los Angeles Basin comprises a broad synclinal structure that contains a thick sequence of Holocene through early Cenozoic marine and non-marine sediments, deposited on a basement complex of granitic and metamorphic rocks, as the basin subsided. Holocene sediments in the project area consist of poorly consolidated alluvium deposited by the Los Angeles and San Gabriel Rivers. These sediments consist of gravel, sand, silt, and clay. The Holocene alluvium is underlain by more than 1,000 feet of early to middle Pleistocene gravel, sand, silt and clay. The early to middle Pleistocene sediments are subdivided into the marine San Pedro

Formation and the nonmarine to shallow marine Lakewood Formation. The San Pedro and Lakewood formations are exposed in the Baldwin Hills. Near the center of the basin, the San Pedro and Lakewood Formations are underlain by more than 20,000 feet of both marine and nonmarine, Tertiary to Cretaceous, sandstone, siltstone, and shale. These sediments are exposed in the Santa Monica Mountains and Repetto and Elysian Hills.

The Los Angeles Basin is one of the most prolific oil producing regions in the United States. The faults and folds associated with the Newport-Inglewood uplift form structural traps for the major oil fields along the Newport-Inglewood fault zone. One of the largest of these fields is the Inglewood Oil Field in the Baldwin Hills. In addition, the Potrero and Dominguez Oil Fields are located to the west of the project area.

C.6.1.1.3 *Faults and Seismicity*

The seismicity of southern California is dominated by the intersection of the northwest trending San Andreas fault system and the east-west trending Transverse Ranges fault system. The Los Angeles basin is located at the intersection of these two systems. Both systems are responding to strain produced by the relative motions of the Pacific and North American Tectonic Plates. The strain is relieved by right lateral strike slip faulting on the San Andreas and related faults and by vertical, reverse slip or left lateral, strike slip displacement on faults in the transverse ranges. The effects of this deformation include mountain building, basin development, deformation of Quaternary marine terraces, widespread regional uplift, and generation of earthquakes. Figure C.6-1 (Fault Map) depicts the location the proposed project in relation to known active and potentially active faults in the greater Los Angeles area.

The project area will be subject to strong ground shaking associated with earthquakes on faults of both the San Andreas and Transverse Ranges fault systems. Recently the Los Angeles Basin has been most severely shaken by thrust faults associated with the Transverse Ranges fault system. Active reverse or thrust faults in the Transverse Ranges include the blind thrust faults responsible for the 1987 Whittier Narrows Earthquake and the 1994 Northridge Earthquake and the frontal faults responsible for uplift of the Santa Monica and San Gabriel Mountains. The frontal faults include the Malibu Coast, Santa Monica-Hollywood, Raymond, and San Fernando-Sierra Madre, faults. Active right lateral strike slip faults in the Los Angeles area include the San Andreas, Whittier-Elsinore, Palos Verdes, Newport-Inglewood, and San Gabriel faults associated with the San Andreas fault system.

The proposed pipeline alignment crosses the northern end of the Alquist-Priolo Earthquake Fault Zone[1] for the Cherry Hills segment of the Newport-Inglewood fault, near the southeastern margin of the Dominquez Hills. The Cherry Hills fault is a part or a much longer Newport-Inglewood fault system that extends from north of the Baldwin Hills to south of Newport Beach.

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[1] Alquist-Priolo Earthquake Fault Zones are areas designated by the State of California as having high potential for fault movement.

Figure C.6-1 Regional Fault Map

(To Download this map please see List of Figures on the table of contents)

The Newport-Inglewood fault zone lies along the southwest margin of the Los Angeles Basin and coincides with a structural break between a relatively shallow depositional shelf to the southwest and a deep depositional basin to the northeast. The fault zone comprises a series of short, discontinuous, northwest trending, en echelon faults and a complex pattern of subordinate folds and faults. Several of these fault segments, including the Avalon-Compton fault located to the north of the Dominquez Hills and the Cherry Hill fault, have been assigned Alquist-Priolo Earthquake Fault Hazard Zones by the California Division of Mines and Geology. However, the California Division of Mines and Geology has not assigned an Alquist-Priolo Earthquake Fault Hazard Zone to the gap between the Avalon-Compton fault and the Cherry Hills fault. This gap, which generally coincides with the Dominguez Hills, is believed to represent a left step in the fault system. Figure C.6-2 shows the location of the Alquist Priolo Fault Zone for the Newport-Inglewood Fault, showing its trend towards and across the proposed pipeline route.

Fault Rupture

Fault rupture is a significant potential hazard to the western portion of the proposed pipeline project, due to the presence of the Newport-Inglewood fault. The State of California's Alquist Priolo Earthquake Fault Zone maps depicts surface traces of the Cherry Hills fault approaching the western end of the proposed alignment from the southeast, but does not depict the Cherry Hills fault crossing the project alignment. The fault zone appears to be stepping to the left from the Cherry Hill fault to the Avalon-Compton fault. The potential for fault rupture in the area where the trend of the Newport-Inglewood fault crosses the pipeline alignment is very difficult to assess because of the character of the fault, the youthful fluvial deposits in this area, and its urban setting. Therefore, while active strands of the Newport-Inglewood fault have not been documented at the pipeline crossing, numerous short splay faults are often present in set-over areas between en-echelon segments and the presence or absence of active faults traces can not be precluded based on surface mapping alone.

Strong Ground Shaking

Earthquakes are classified by their magnitude (M), the amount of energy released. Earthquakes of M 6.0 to 6.9 are classified as moderate. Earthquakes between M 7.0 and 7.9 are classified as major. Earthquakes of M8.0 or more are classified as great. The 1933 M 6.3 Long Beach Earthquake was caused by a rupture of the Newport-Inglewood fault that extended from offshore of Newport Beach to south of the Dominguez Hills. This event resulted in major damage to many parts of the Los Angeles Basin, including subsidence or settlement of saturated sandy soils in the coastal area (Toppozada et al., 1988). In addition, two small earthquakes (M 4.5 and 4.4) occurred in the Dominguez Hills on June 18, 1944. Damage to 16 oil wells in the Rosecrans Oil Field during these earthquakes was attributed to movements along an east west trending, south-dipping, reverse fault.

Figure C.6-2 Newport-Inglewood Fault zone

Regionally damaging earthquakes may also occur on other known faults in Southern California. In addition, it is very important to note that earthquake activity from unmapped subsurface faults is a distinct possibility that is currently not predictable. For example, both the 1987 Whittier Narrows M 5.9 earthquake and the 1994 Northridge M 6.7 earthquake occurred on blind thrust faults that have no surface exposure. The location and seismogenic characteristics of the Elysian Park and Northridge blind thrust faults, which were responsible for these events, were not well defined prior to the earthquakes they produced. Evidence from investigations for petroleum resources and seismology data suggest an additional blind thrust fault is present in the project area. This fault has been designated as the Compton Thrust by the California Division of Mines and Geology (1996). Surface rupture attributable to these deep seated seismic sources does not appear to be likely, but their presence in the Los Angeles Basin will influence the exposure levels of the proposed project to strong seismic shaking during future earthquakes generated by these faults.

The intensity of earthquake induced ground motions can be described using peak site accelerations, represented as a fraction of the acceleration of gravity (g), or the Modified Mercalli Scale. The maximum credible peak ground acceleration for proposed project can be calculated from the distance of the proposed alignment to the most critical fault and the maximum credible earthquake for that fault, using any of a number of attenuation relationships. The Modified Mercalli Scale is a subjective numerical index describing the severity of the earthquake in terms of its observed effects on humans, man-made structures, and the earth's surface. The Modified Mercalli (MM) intensity scale is shown on Table C.6-1.

In a study of earthquake hazards of the Los Angeles region, Evernden and Thomson (1985) predicted maximum Modified Mercalli Intensities due to what they consider to be characteristic earthquakes on 87 late Quaternary faults in the region. The application of the Evernden and Thomson study is that Modified Mercalli Intensities of about VII to IX can be expected along the proposed alignment. In addition, recent maps published by the California Division of Mines and Geology (1996) estimated the peak ground acceleration with a 10% probability of exceedance in 50 years would be between 0.4 and 0.6g for the project area. The characteristics of significant local faults that would contribute to the seismic shaking hazards along the proposed project are listed in Table C.6-2, Fault Activity.

Liquefaction Potential

Liquefaction is the phenomenon in which saturated granular sediments temporarily lose their shear strength during periods of strong, earthquake induced, ground shaking. The susceptibility of a site to liquefaction is a function of the depth, density, and water content of the granular sediments and the magnitude and frequency of earthquakes in the surrounding region. Saturated, unconsolidated silts, sands, and silty sands within 50 feet of the ground surface are most susceptible to liquefaction.

Table C.6-1 Modified Mercalli Intensity Scale

Intensity. A subjective measure of the force of an earthquake at a particular place as determined by its effects on persons, structures, and earth materials. The principal scale used in the United States today is the Modified Mercalli, 1956 version as defined below (modified from, Richter, 1958, p. 137-138):	
I.	Not felt.
II.	Felt by persons at rest, on upper floors, or favorably place.
III.	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.	Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing automobiles rock. Windows, dishes, doors rattle. Wooden walls and frame may creek.
V.	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	Felt By all. Many frightened and run outdoors. Persons walk unsteadily. Window, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off wall. Furniture moved or overturned. Weak plaster and masonry D cracked.
VII.	Difficult to stand. Noticed by drivers of automobiles. Hanging objects quiver. Furniture broken. Weak chimneys broken at roof line. Damage to masonry D, including cracks, fall of plaster, loose bricks, stone, tiles and unbraced parapets. Small slides and caving in along sand or gravel banks. Large bells ring.
VIII.	Steering of automobiles affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall to stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted of foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground and liquefaction.
X.	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.	Rails bent greatly. Underground pipelines completely out of services.
XII.	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.
See Uniform Building Code for specifications on quality of masonry construction on ground shaking in Holocene to Plio-Pleistocene sediments.	

Liquefaction related phenomena include lateral spreading, ground oscillation, flow failures, loss of bearing strength, subsidence, and buoyancy effects (Youd, 1978). Lateral spreading comprises the lateral displacement of surficial blocks of sediment as a result of liquefaction, and commonly occurs on gentle slopes between 0.3° and 3° (Ziony, 1985). The areas along the pipeline alignment most susceptible to lateral spreading would be where the pipeline crosses the levees of the Los Angeles and San Gabriel Rivers.

In addition, densification of the soil resulting in vertical settlement of the ground can also occur. Lateral spreading and liquefaction were responsible for most of the pipeline failures in San Francisco during the 1989 Loma Prieta Earthquake and in the San Fernando Valley during the 1994 Northridge earthquake. Damage induced by lateral spreading and liquefaction is generally most severe when liquefaction occurs within 15 to 20 feet of the ground surface.

Based on our review, the proposed project overlies flood plain deposits. Since these soils typically contain sands and silts, they may be potentially liquefiable, if they are saturated.

Table C.6-2 Fault Activity

Fault/Fault Segment Name	Fault Style (1)	Assume Fault/Segment Length (km)	Assumed Fault Slip Rate (mm/yr)	Notable Historic Surface Wave Magnitude, Ms (year in parentheses)	Estimated "Upper Bound" Moment Magnitude (M)
Blind Thrust Faults					
Compton	TH	39	1.5		6.8
Elysian Park	TH	34	1.5	5.9 (1987)	6.7
Northridge	TH	31	1.5	6.7 (1994)	6.9
West Los Angeles	TH	16	1.5		6.7
Newport Inglewood	RL	64	1.0	6.3 (1933)	6.9
Palos Verdes	OBL	96	3.0	3.9 (1972)	7.1
Raymond	OBL	21	0.5	4.9 (1988)	6.5
San Andreas System					
Multi-segmented Model (1857 Rupture) Cholame +Carrizo + Mojave	RL	345	34	8 (1857)	7.8
San Gabriel	RL	72	1.0		7.0
Santa Monica Mountains System					
Hollywood	OBL	17	1.0	6 (1855)	6.4
Santa Monica	OBL	28	1.0	5 (1979, 1989)	6.6
Malibu Coast	OBL	37	0.3		6.7
Blind thrust	TH	75	0.1 – 1		7.2
Sierra Madre System					
San Fernando	R	18	2	6.4 (1971)	6.7
Sierra Madre	R	57	3	5.8 (1991)	7
Verdugo	R	29	0.5		6.7
Whittier – North Elsinore	RL	37	2.5		6.8

Notes: (1) Fault Styles: RL = Right Lateral; R = Reverse; TH = Thrust; OBL = Oblique

Source: Fault data from CDMG Open File Report 96-08

Tinsley et. al. (1985) modeled the liquefaction potential in the Los Angeles Basin. Their model suggests that based on 1960 to 1975 ground water levels, the liquefaction potential in the project area is moderate high near the northeastern and southwestern ends of the proposed pipeline and low to very low elsewhere. However, based on 1905 to 1927 groundwater levels, their model suggests the liquefaction potential along most of the proposed alignment is very high. Therefore, if the basin recovers to historic levels during wet winters and periods of high runoff, the liquefaction potential along the project alignment may be very high.

C.6.1.1.4 *Soils*

The United States Soil Conservation Service (SCS) (now called the Natural Conservation Service) publishes soil survey reports for nearly all regions of California. The reports include detailed, qualitative and quantitative descriptions of soil characteristics including color, texture, thickness, engineering properties, and the soil's suitability for specific crops. The soil descriptions presented in this section were compiled from data published by the SCS for Los Angeles County (SCS, 1969). Soils within the Los Angeles Basin vary from well-drained soils present in the alluviated plains and terraces to poorly drained soils. However, since most of the basin is urbanized, most native soils have been disturbed or removed.

The soil characteristic which may have the most significant impact on the design and operation of the Proposed Project is the soil's corrosivity. The corrosivity of a soil is an estimate of the potential for soil-induced chemical action that dissolves or weakens the pipeline. Corrosion potential is based mainly on the sulfate content, texture, and acidity of the soil. The corrosion potential in the native soils is high throughout most of the project area. Significant soil characteristics for the soil associations encountered within the basin are summarized below.

Hanford Association. These soils occur on alluvial fans with slopes of 2-5 percent and on the Los Angeles River flood plain. Hanford soils typically comprise coarse brown sandy loam surface layers underlain by yellow brown coarse sandy loam and gravelly loamy coarse sand substratum. These soils are over 60 inches deep, are well drained, and have moderately rapid subsoil permeability

Chino Association. These soils comprise loams, silt loams or clay loams and are present on 0 to 2 percent slopes, are usually over 60 inches deep and are somewhat poorly drained. These soils are present in the Ballona Gap and in the flood plain just east of the Baldwin Hills. They are calcareous throughout and have some areas with high water tables.

Ramona-Placentia Association. The soils of this association occur on the slopes of the low foothills associated with the Newport-Inglewood fault zone and on the coastal terrace. Ramona soils are characteristically red brown dense loam, clay loam or sandy loam. They are typically over 60 inches deep and are well drained. Placentia soils are over 18 inches deep. They are characterized by a well drained loam or sandy loam surface layer underlain by a poorly drained, dark red brown, clay loam subsoil.

C.6.1.2 Applicable Laws, Regulations, and Standards

Geologic resources and geotechnical hazards are governed primarily by local jurisdictions. The conservation elements and seismic safety elements of city and county General Plans contain policies for the protection of geologic features and avoidance of geologic hazards, but do not specifically address pipeline construction. Local grading ordinances establish detailed procedures for excavation and earthwork required during pipeline construction. In addition, building codes in each jurisdiction establish standards for construction of above ground structures.

C.6.2 ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: PROPOSED PROJECT

C.6.2.1 Significance Criteria

Geologic and soil conditions were evaluated with respect to the impacts the project may have on the local geology, as well as the impact specific geologic hazards may have upon the pipeline and its related facilities. The significance of these impacts was determined on the basis of CEQA statutes, guidelines and appendices, thresholds of significance developed by local agencies, government codes and ordinances, and requirements stipulated by California Alquist-Priolo statutes. Significance criteria and methods of analysis were also based on standards set or expected by agencies for the evaluation of geologic hazards.

The impact assessment was developed based on a geologic, soils, and geotechnical engineering evaluation of the proposed project. The assumptions and justification for site-specific assessments are explained in the text.

Impacts of the Proposed Project on the geologic environment would be considered significant if:

- Unique geologic features or geologic features of unusual scientific value for study or interpretation would be disturbed or otherwise adversely affected by the pipeline alignment and consequent construction activities
- Known mineral and/or energy resources would be rendered inaccessible by pipeline construction
- Agricultural soils would be converted to non-agricultural uses
- Geologic processes, such as landslides or erosion, could be triggered or accelerated by construction or disturbance of landforms
- Substantial alteration of topography would be required or could occur beyond that which would result from natural erosion and deposition.

Impacts of the following geologic hazards on the Proposed Project would also be considered significant:

- High potential for ground rupture due to presence of an active earthquake fault crossing along the pipeline route with attendant potential for damage to the pipeline or other project structures
- High potential from earthquake-induced ground shaking to cause liquefaction, settlement, lateral spreading and/or surface cracking along the route, resulting in probable attendant damage to the proposed pipeline or other project structures

- Potential for failure of construction excavations due to the presence of loose saturated sand or soft clay
- Corrosive soils would damage the pipeline.

C.6.2.2 Applicant Proposed Measures

SFPP proposes to reduce potential impacts by completing appropriate geotechnical/geologic investigations and incorporating the recommendations of those investigations in the design and construction of the pipeline. Measures considered by SFPP include shifting the alignment to avoid high risk areas identified during the geotechnical investigations; installing automatic shut off valves on the flanks of high risk areas; local ground strengthening measures; and using pipeline, alignment and pipe trench designs that allow sufficient flexibility to accommodate fault displacements. Specifically, SFPP has committed to implementation of the following measures to reduce potential impacts related to geology and geologic hazards.

- Increasing the pipe wall thickness, as necessary, to withstand greater stress from ground movement
- Complying with pipeline design and construction codes and specifications
- Designing aboveground structures to withstand the predicted level of ground shaking as well as site-specific foundation conditions
- Placing the pipe below liquefiable materials
- Installing a cathodic protection system to prevent corrosion
- Installing shutoff valves beyond the limits of potential lateral spreading.

C.6.2.3 Impacts and Mitigation Measures for Pipeline Construction

Since the proposed alignment is located in city streets, there are no known soils, geologic, or paleontologic conditions and/or resources in the project area that would be significantly impacted by the construction of a pipeline in this urban setting. In addition, since slopes along the proposed alignment are very gentle, construction of the proposed project is not expected to substantially alter the topography, trigger slope failures, or accelerate erosion.

C.6.2.4 Impacts and Mitigation Measures for Station Modifications

Station modifications are not expected to impact soil, geologic, or paleontologic conditions and/or resources in the project area; substantially alter the topography; trigger slope failures; or accelerate erosion.

C.6.2.5 Impacts and Mitigation Measures for Project Operation

C.6.2.5.1 *Fault Rupture*

Large abrupt differential fault displacements comprise the most severe earthquake hazard for a buried pipeline.

Rupture or severe distortion of the proposed pipeline may occur at the active and potentially active fault crossings along the project alignment.

Fault rupture is a significant potential hazard near the western end of the proposed project, where the alignment crosses the active Newport-Inglewood fault zone. The State of California's Alquist Priolo, Fault Rupture Hazard Zone Maps (CDMG, 1984), suggest that active traces of the Newport-Inglewood fault zone approach the western end of the proposed project from both the southeast and the northwest, but do not cross the proposed pipeline alignment (see Figure C.6-1). In this area, the Newport-Inglewood fault zone appears to be stepping to the left from the Cherry Hill fault to the Avalon-Compton fault. The potential for surface rupture where the trend of the Newport-Inglewood fault zone crosses the pipeline alignment is very difficult to assess, because of the character of the fault, and the youthful fluvial deposits in this area and the urban setting. Therefore, although no active strands of the fault have been mapped, with confidence, where the proposed alignment crosses the Newport-Inglewood trend, they may still exist.

Oil pipelines can be designed to withstand substantial fault movement without rupture when the direction and magnitude of anticipated offset is well defined. However, because of the uncertainties regarding direction and magnitude of anticipated offset and because fault crossing designs have not been thoroughly tested by nature, the Newport-Inglewood fault crossing is designated as a significant unavoidable **(Class I)** impact. Anticipated fault offset at the active Newport-Inglewood fault crossing ranges from three to six feet.

The proposed project includes the use of pipeline and trench designs that will allow sufficient flexibility to accommodate fault displacements and the use of block and check valves on the flanks of high risk areas. This comprises a dual level seismic design philosophy that typically includes, orientation of the pipeline to avoid large compressive strains during faulting and the use of thick walled, ductile steel pipe that will be capable of moving laterally, vertically, and longitudinally without failing during fault rupture; coupled with a system for monitoring and controlled shutdown of the pipeline should rupture occur. The proposed project also includes geologic/geotechnical investigations, as appropriate, and incorporation of the design recommendation of these reports in the project design. However, SFPP has not specified which areas will be investigated.

Mitigation Measure for Fault Rupture

Impact: Potential rupture of the pipeline in the Newport-Inglewood fault zone **(Class I)**.

G-1 Based on existing information, SFPP shall prepare a report documenting the location, orientation and direction of anticipated offset for the Newport-Inglewood fault. Based on this information, SFPP shall develop and justify design elements for the fault crossing, including consideration of vibration sensors, thicker-walled pipe, consideration of additional block valves, or other items. SFPP shall submit this report to the State Fire Marshal, the CPUC, and the Los Angeles County Public Works Department for review and approval prior to finalizing construction plans.

C.6.2.5.2 *Strong Ground Shaking*

Southern California is subject to strong ground shaking resulting from seismic activity on any of the faults depicted on Figure C.6-1. The characteristics of significant local faults that would contribute to the seismic shaking hazards along the proposed project are listed in Table C.6-2.

Strong earthquake-induced ground shaking can result in significant damage to above ground structures. However, it generally only impacts buried structures when the shaking induces ground failure, such as settlement or liquefaction, or when the buried structure spans an abrupt change from stiff to soft or very soft soils. The impacts of settlement and liquefaction on the proposed project are discussed below. Damage attributable to a transition from stiff to soft soils is not anticipated along the proposed alignment.

No new above ground facilities are included in the proposed project. Existing above ground structures will be modified to provide additional pumping capability and/or additional piping. These structures include the Watson Station, Norwalk Station, Industry Station, and Colton Terminal.

Table C.6-3 depicts the estimated maximum Modified Mercalli Intensities for these facilities. This data was derived from maps compiled by Evernden and Thomson (1985).

Table C.6-3 Modified Mercalli Intensities

Location	Modified Mercalli Intensities
Watson Station	VIII
Norwalk Station	VII+
Industry Station	VII
Colton Station	VII to VIII

Proper seismic design allows structures to withstand intense ground shaking without collapsing. For example, many structures located immediately adjacent to the San Fernando fault were still standing after the 1971 San Fernando Earthquake. Since the proposed project will comply with construction codes and specifications, the impacts of strong ground shaking on modifications to the above ground facilities will be mitigated by designing the modifications in accordance with the Uniform Building Code's earthquake design criteria for Seismic Zone 4. Therefore, the effect of strong ground shaking on the proposed project is designated as an adverse, but non-significant (**Class III**) impact.

C.6.2.5.3 *Liquefaction Potential/Differential Settlement*

Liquefaction often results in loss of ground bearing capacity and/or lateral spreading, both of which can result in damage to engineered structures. During loss of ground bearing capacity, large deformations can occur within the soil mass, allowing buildings to settle and tilt. If structures are buoyant, they may float upward. However, lateral spreading represents the most serious liquefaction related hazard for the proposed project.

Lateral spreading consists of the lateral displacement of surficial, typically competent blocks of sediment as a result of liquefaction within the underlying soils, and commonly occurs on slopes as gentle as 0.3 and 3 degrees (Ziony, 1985). Lateral spreading can extend several hundred feet back from a slope and displacements of tens of feet may occur if soil conditions are especially favorable for liquefaction and if earthquake shaking is of sufficient duration. A good example of lateral spreading occurred during the 1971 San Fernando Earthquake, when an area of almost 163 acres moved down a 2.5 percent slope. In addition, lateral spreading was responsible for most of the pipeline failures in San Francisco during the 1989 Loma Prieta Earthquake and in the San Fernando Valley during the 1994 Northridge Earthquake. Lateral spreading is particularly likely in the vicinity of unlined stream and river channels or other sloping locations. Damage induced by lateral spreading and liquefaction is generally most severe when liquefaction occurs within 15 to 20 feet of the ground surface.

Tinsley, et. al. (1985) developed a series of maps of the liquefaction potential in the Los Angeles Region, using an evaluation of (1) the age and type of surficial soil deposits, (2) the looseness of granular sediments, and (3) 1960 to 1975 data on the depth to groundwater. Based on this data, and as shown on Figure C.6-3, areas of moderate to high liquefaction potential along the Proposed Project alignment include:

- The area from Woodruff Avenue, on the west side of the San Gabriel River, to the Norwalk Station
- An area bounded by Artesia Boulevard on the south, Walnut Street on the North, Cherry Avenue on the west, and Lakewood Boulevard on the east
- The area west of Alameda Street and immediately adjacent to and south of Watson Station.

The remainder of the pipeline alignment and the Industry and Colton Stations are within areas which have low to very low susceptibilities to liquefaction. However, when 1905 and 1927 groundwater data are used, these areas also exhibit a moderate to high liquefaction potential. As a result, extended periods of heavy rainfall may significantly increase the area susceptible to liquefaction. The potential for liquefaction and lateral spreading damage to the pipeline is designated as a significant, but mitigable (**Class II**) impact.

The location of the pipeline near the flank of the Dominguez Hills creates the potential for earthquake induced differential settlement where looser and younger sediments border denser and older deposits. Areas of potential differential settlement represent a significant, but mitigable (**Class II**) impact.

Placeholder for Figure C.6-3, Liquefaction areas

SFPP's Applicant Proposed Measures include reduction of liquefaction hazards by placing the pipe below liquefiable materials. Burial of the pipeline in competent soil below the liquefiable soil layers prevents any liquefaction hazard to the pipeline. However, liquefiable soils often extend down to a depth of 20 to 50 feet. Therefore, it may be impractical to implement this measure. SFPP also states that geologic/geotechnical investigations will be completed, as appropriate, and incorporation of the design recommendation of these reports in the project design. However, SFPP has not specified which areas will be investigated. The impacts of lateral spreading in areas where the pipeline is buried in a competent layer above the zone of liquefiable soil can be mitigated through the use of the same design considerations that apply at fault crossings

Mitigation Measures for Liquefaction

Impact: Liquification, lateral spreading, and differential settlement could cause pipeline rupture (**Class II**).

G-2 SFPP shall conduct geotechnical investigations in the areas classified as having moderate to high liquefaction potential and areas of potential differential settlement during final design of the proposed project. In addition, SFPP shall request information from local jurisdictions on the specific locations of perched aquifers. If these locations or classifications are confirmed by geotechnical analyses, then site-specific mitigation should be implemented. Techniques considered shall include the following:

- Buried pipelines crossings areas of liquefiable soils will either be located below, within, or above the zone of liquefiable soil.
- Burial of the pipeline within the liquefiable layer often results in uplift forces on the pipeline. The impact of uplift on the pipeline can be mitigated through the use of densification techniques, such as stone columns, vertical anchors (tension piles), or by use of thick-walled, ductile steel pipe.
- Additional block valves to isolate the liquefiable area.
- Burial of the pipeline within the liquefiable layer often results in uplift forces on the pipeline. The impact of uplift on the pipeline can be mitigated through the use of densification techniques, such as stone columns, vertical anchors (tension piles), or by use of thick-walled, ductile steel pipe.
- Additional block valves to isolate the liquefiable area.

C.6.2.5.4 *Failure of Construction Excavation*

Failure of construction excavations along the proposed alignment does not represent a significant impact. Unstable slopes can be braced using standard construction techniques. In addition, at the Compton Creek crossing, slopes can be stabilized by dewatering, as appropriate.

C.6.2.5.5 *Corrosive Soils*

Since most of the soils along the proposed project alignment are derived from marine sediments, the potential for steel corrosion is high throughout the entire length of the alignment. The presence of corrosive soils is a potentially significant impact that is reduced to non-significance because SFPP will install a cathodic protection system to protect the pipeline from corrosion.

C.6.2.6 Secondary Impacts and Mitigation Measures of Project Operation

The secondary impacts of this project are associated with increasing the throughput in existing pipelines, and increased trucking. No new impacts to geologic resources or impacts from geologic hazards would occur; however the increased pipeline throughput would result in a potentially larger spill if pipeline rupture was caused by an earthquake in Arizona, Nevada, or southern California.

C.6.2.7 Cumulative Impacts and Mitigation Measures

Potential cumulative geologic impacts are limited to loss of unique geologic features or known mineral and/or energy resources, substantial alteration of the topography, or triggering or acceleration of slope failures the proposed project and one or more future projects. Seismic impacts comprise the impact of the geologic environment on the project and are not cumulative. Construction of the proposed project would contribute only a negligible increase to the potential cumulative geologic impacts. Any future impacts associated with cumulative projects in the immediate vicinity of the pipeline would be primarily attributable to those other projects.

C.6.2.8 Significant Unavoidable Impacts

The crossing of the active Newport-Inglewood fault zone is an unavoidable significant impact. Even with the implementation of Mitigation Measure G-1, the potential for damage to the pipeline during fault rupture can be reduced, but not completely eliminated.

C.6.3 SANTA FE ALTERNATIVE SEGMENT

Geologic impacts for the Santa Fe Alternative would include, fault rupture, potential differential settlements during strong ground shaking, and the presence of corrosive soils. These impacts would be the same as for the segment of the Proposed Project that this alternative would replace. Mitigation Measures G-1 and G-2 would apply to both the Santa Fe Alternative and the segment of the Proposed Project it would replace.

C.6.4 CHERRY ALTERNATIVE SEGMENT

Geologic impacts for the Cherry Alternative would include liquefaction potential along the Artesia Boulevard segment of this alternative, but none along the Cherry Avenue portion. Areas of moderate liquefaction potential are not present along the segment of the proposed project that this alternative would replace; therefore, the proposed route segment is preferred over this alternative. Mitigation Measure G-2 would apply to the areas of moderate liquefaction potential. However, if only the Cherry Avenue portion of this segment is used, in combination with the Paramount Alternative, a large area of moderate liquefaction potential adjacent to the proposed route on Artesia Boulevard could be avoided.

C.6.5 PARAMOUNT ALTERNATIVE SEGMENT

Geologic impacts for the Paramount Alternative would include a small area of moderate liquefaction potential east of Cherry Avenue. A large area of moderate liquefaction potential is present along the segment of the proposed project that this alternative would replace; therefore, this alternative is preferred to the proposed route segment with respect to liquefaction potential. Mitigation Measure G-2 would apply to the areas of moderate liquefaction potential.

C.6.6 ALONDRA ALTERNATIVE SEGMENT

Geologic impacts for the Alondra Alternative would include the potential for liquefaction and lateral spreading. However, while approximately 3.4 miles of the Alondra Alternative traverses areas classified as having a moderate to high liquefaction potential, the segment of the Proposed Project that this alternative would replace traverses nearly 5 miles of soils with this classification. Mitigation Measure G-2 would apply to both the Alondra Alternative and the segment of the Proposed Project it would replace.

C.6.7 BELLFLOWER RAIL ALTERNATIVE SEGMENT

Geologic impacts for the Bellflower Rail Alternative would include the potential for liquefaction and lateral spreading. Approximately 0.75 miles of the Bellflower Rail Alternative traverses areas classified as having a moderate to high liquefaction potential, while the segment of the Proposed Project that this alternative would replace traverses approximately 0.5 miles of soils with this classification. Mitigation Measure G-2 would apply to both the Bellflower Rail Alternative and the segment of the Proposed Project it would replace.

C.6.8 ARTESIA ALTERNATIVE SEGMENT

Geologic impacts for the Artesia Alternative would include the potential for liquefaction. These impacts would be the same as for the segment of the Proposed Project that this alternative would replace. Mitigation Measure G-2 would apply to both the Artesia Alternative and the segment of the Proposed Project it would replace.

C.6.9 SHOEMAKER ALTERNATIVE SEGMENT

Geologic impacts for the Shoemaker Alternative would include the potential for liquefaction. However, the Shoemaker Alternative is approximately one mile longer than the segment of the proposed project that it would replace and therefore, increases the pipeline's exposure to areas of moderate to high liquefaction potential. Mitigation Measure G-2 would apply to both the Shoemaker Alternative and the segment of the Proposed Project it would replace.

C.6.10 NO PROJECT ALTERNATIVE

Under the No Project Alternative, increased trucking of petroleum products and increased use of the Phoenix-West Pipeline would occur. Increased throughput in the pipeline could result in a larger spill if an earthquake caused a pipeline rupture.

C.6.11 MITIGATION MONITORING PROGRAM

Table C.6-4 presents the mitigation monitoring program for geology and soils.

Table C.6-4 Geology and Soils Mitigation Monitoring Plan

Impact	Mitigation Measure	Location	Monitoring/Reporting Action	Effectiveness Criteria	Responsible Agency	Timing
PROPOSED PROJECT & SANTA FE ALTERNATIVE SEGMENT						
Potential rupture at active Newport Inglewood fault crossing (Class I)	**G-1** The Applicant shall conduct a fault study at the Newport Inglewood fault crossing to define the fault plane orientation and direction and magnitude of anticipated offset and refine fault crossing parameters.	Near the Intersection of Laurel Park Road and Santa Fe Avenue	Review and approve fault report	Fault crossing design recommendations should be consistent with standard engineering practice.	CPUC, Los Angeles Co. Department of Public Works	Prior to start of construction
PROPOSED PROJECT AND ALL ALTERNATIVE SEGMENTS *						
Liquefaction Potential/ Differential Settlement (Class II)	**G-2** The Applicant shall conduct geotechnical studies of areas with moderate to high liquefaction potential and define areas with the potential for perched aquifers. Site specific mitigation shall be identified in the geotechnical report.	Proposed Route: • Adjacent to Watson Station • Artesia Blvd between Paramount and Lakewood Blvds • Between Woodruff Ave. and Norwalk Station • Differential Settlement Potential adjacent to the Dominguez Hills	Review and approve geotechnical report. The report's design recommendations should be consistent with standard geotechnical engineering practice.	Liquefaction does not cause pipeline rupture	CPUC, Los Angeles Co. Department of Public Works	Prior to project construction

*** Locations of potential liquefaction on alternative segments:**

Santa Fe Alternative:	Adjacent to the Dominguez Hills
Cherry Alternative:	Along the Artesia Blvd section of this alternative
Paramount Alternative:	Along the Garfield Avenue section of this alternative
Alondra Alternative:	Lakewood Blvd between Artesia Blvd and Walnut Street; Between Woodruff Ave. and Norwalk Station
Bellflower Rail Alternative:	Between Woodruff and Artesia Boulevards
Artesia Alternative:	Throughout the entire length of this alternative segment
Shoemaker Alternative:	Throughout the entire length of this alternative segment

C.6.12 REFERENCES

1991. FRISK89 Version 2.0, A Computer Program for the Probabilistic Estimation of Seismic Hazard Using Faults as Earthquake Sources

1991. Deterministic Estimates of Strong Ground Motion for the Proposed Low-Level Radioactive Waste Repository, Hudspeth County, Texas; Draft Consultant Report prepared by Dames and Moore for the Texas Low-Level Radioactive Waste Disposal Authority

Blake, T.F. 1992. EQFAULT Version 2.0, A Computer Program For the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults.

California Division of Mines and Geology. 1996. Probabilistic Seismic Hazard Assessment for the State of California, CDMG Open-File Report 96-08/USGS Open-File Report 96-706.

Campbell, K.W. 1990. Empirical Prediction of Near-Source Soil and Soft-Rock Ground Motion for the Diablo Canyon Power Plant Site, San Luis Obispo County, California; consultant report prepared by Dames and Moore for Lawrence Livermore National Laboratory.

Campbell, K.W. and Y. Bozorgnia. 1994. Near Source Attenuation of Peak Horizontal Acceleration from Worldwide Accelerograms Recorded from 1957 to 1993; in Proceedings of the Fifth U.S. National Conference on Earthquake Engineering, Vol III.

Dobry R., I.M. Idriss, and E. Ng. 1978. Duration Characteristics of Strong-Motion Earthquake Records; Bulletin of the Seismological Society of America, vol. 68, no. 5.

Evernden, J.F. and J.M. Thomson. 1985. Predicting Seismic Intensites, in Evaluating Earthquake Hazards in the Los Angeles Region- An Earth-Science Perspective, U.S. Geological Survey Professional Paper 1360.

Naeim, F. and J.C. Anderson. 1993. Classification and Evaluation of Earthquake Records for Design; Earthquake Engineering Research Institute NEHRP Professional Fellowship Report.

Ploessel M.R. and J.E. Slosson. 1974. Repeatable High Ground Accelerations from Earthquakes; California Geology, vol. 27, no. 9.

Sadigh, K., C.Y. Chang, F. Makdisi, and J. Egan. 1989. Attenuation Relationships for Horizontal Peak Ground Acceleration and Response Spectral Acceleration for Rock Sites (abstract), Seismological Research Letters, Volume 60.

Seed H.B., et al. 1985. Influence of SPT Procedures in Soil Liquefaction Resistance Evaluations; Journal of Geotechnical Engineering, ASCE, Vol 111, No. 12.

Tinsley, J.C., T.L. Youd, D.M. Perkins, and A.T.F. Chen. 1986. Evaluating Liquefaction Potential; in Evaluating Earthquake Hazards in the Los Angeles Region- An Earth-Science Perspective, U.S. Geological Survey Professional Paper 1360.

Youd, T.L. and D.M. Perkins. 1978. Mapping Liquefaction Induced Ground Failure Potential, Proceedings of the American Society of Civil Engineers, Journal of the Geotechnical Engineering Division v 104, no. GT 4.

Ziony, J.I., ed. 1985. Evaluating Earthquake Hazards in the Los Angeles Region-An Earth Science Perspective, U.S. Geological Survey Professional Paper 1360