C.5 GEOLOGY AND SOILS

C.5.1 ENVIRONMENTAL BASELINE AND REGULATORY SETTING

Baseline geologic information was collected from geologic, seismic, and geotechnical literature covering the proposed pipeline 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.5.1.1 Environmental Baseline

Physiography and Topography

SCWC's proposed pipeline alignment extends south from the City of Cypress through the City of Huntington Beach to the Bolsa Chica Mesa. 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 underlies Newport Mesa, Huntington Beach Mesa, Bolsa Chica Mesa, and Seal Beach Mesa.

The northern end of the proposed pipeline route begins within the Bolsa Chica Creek drainage basin while the southern end is located on Bolsa Chica Mesa. The topography along the proposed alignment is characterized by relatively low relief with elevations ranging from approximately 52 to 11 feet above mean sea level. The proposed alignment crosses both the Anaheim-Barber City and Westminster channels and parallels Bolsa Chica Channel along much of its length.

Geology

The coastal plain of Los Angeles-Orange County comprises a broad synclinal structure that contains a thick sequence of Holocene through early Cenozoic marine and non-marine sediments, which were deposited upon a basement complex of granitic and metamorphic rocks as the basement subsided. Holocene sediments in the project area consist of poorly consolidated alluvium deposited by the San Gabriel River and Coyote Creek. 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 non-marine to shallow marine Lakewood Formation. The Lakewood Formation is exposed at the surface on Bolsa Chica Mesa. Near the center of the basin, the San Pedro and Lakewood formations are underlain by more than 20,000 feet of both marine and non-marine, Tertiary to Cretaceous sandstone, siltstone, and shale. These sediments are exposed in the Puente, Chino, and San Juan Hills to the north and east.

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 Huntington Beach Oil Field, which underlies Huntington Beach and Bolsa Chica Mesas. However, none of these oil fields directly underlies the project alignment.

Faults and Seismicity

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 effects of this deformation include mountain building, basin development, deformation of Quaternary marine terraces, widespread regional uplift, and generation of earthquakes.

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. Active faults of the San Andreas system are predominantly strike-slip faults accommodating translational movement. The Transverse Ranges fault system consists primarily of blind reverse and thrust faults accommodating tectonic compressional stresses in the region. Blind faults have no surface expression and have been located using subsurface geologic and geophysical methods. This combination of translational and compressive stresses gives rise to diffuse seismicity across the region.

Active reverse or thrust faults in the Transverse Ranges include blind thrust faults responsible for the 1987 Whittier Narrows Earthquake, 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, all associated with the San Andreas fault system. Faults within 50 miles of the proposed site likely to produce damaging earthquakes are presented in Table C.5-1 – Significant Active Faults.

The southern end of the proposed pipeline is located approximately 500 feet east of the Alquist-Priolo Earthquake Hazard Zone[1] for the North Branch fault, part of the Newport-Inglewood fault zone. The fault zone comprises a series of short, discontinuous, northwest trending, en echelon[2] faults, and a complex pattern of subordinate folds and faults. The Newport-Inglewood fault zone lies along the southwest margin of the Los Angeles Basin and extends from north of the Baldwin Hills, roughly paralleling the coast to just south of Newport Beach. From Newport Beach the fault continues offshore and becomes the Newport-Inglewood – Rose Canyon fault zone.

Table C.5-1 Significant Active Faults

Fault Name	Closest Distance to Route (mi.)	Max. Credible Magnitude[a]	Site Intensity	Max. Probable Magnitude[b]	Site Intensity
Catalina Escarpment	35	7.0	VII	6.25	V

1 Alquist-Priolo Earthquake Fault Zones are areas designated by the State of California as having high potential for fault movement resulting in ground rupture.
2 Geologic features that are in an overlapping or staggered arrangement.

Cucamonga	26	7.0	VII	6.25	VI
Elsinore	30	7.5	VIII	6.75	VII
Elysian Park Seismic Zone	17	7.0	VIII	5.75	VII
Malibu Coast	34	7.5	VII	6.50	VI
Newport-Inglewood	<1	7.0	X	5.75	IX
Palos Verdes	9	7.5	X	6.75	IX
San Andreas (Mojave)	45	8.3	VIII	8.00	VIII
San Andreas (San Bernardino Mtn.)	46	8.0	VII	6.75	VI
San Gorgonio-Banning	49	7.5	VI	7.00	VI
Sierra Madre-San Fernando	25	7.5	VIII	6.00	VI
Whittier	12	7.5	IX	6.00	VII

Notes: a) Maximum Credible Magnitude – the maximum earthquake that appears capable of occurring under the presently known tectonic framework.
b) Maximum Probable Magnitude – the maximum earthquake that is likely to occur during a 100-year interval.

The Palos Verdes fault zone is located offshore approximately nine miles southwest of the terminus of the pipeline. It is a major northwest trending, southwest dipping fault responsible for the uplift of the Palos Verdes Hills. The Palos Verdes fault zone has been mapped north into Santa Monica Bay and south into the Gulf of Santa Catalina, where it becomes the Palos Verdes - Coronado Banks fault zone.

Site intensity of an earthquake is 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 Modified Mercalli Scale is presented in Table C.5-2.

Fault Rupture

Fault rupture is a significant potential hazard to the southern portion of the proposed pipeline project, due to the proximity of the Newport-Inglewood fault zone. The proposed pipeline alignment approaches within one quarter-mile of the Alquist-Priolo zoned North Branch of the Newport-Inglewood fault. In addition, the proposed pipeline alignment crosses two potentially active faults. The Bolsa-Fairview fault crosses the pipeline alignment near the intersection of Bolsa Chica Road and Los Patos Avenue, and the projected trace of the Los Alamitos fault intersects the pipeline at the intersection of the 405 Freeway and Winchester Avenue. Figure C.5-1 depicts the location of the proposed pipeline alignment in relation to known active and potentially active faults in the project area.

Table C.5-2 Modified Mercalli Scale

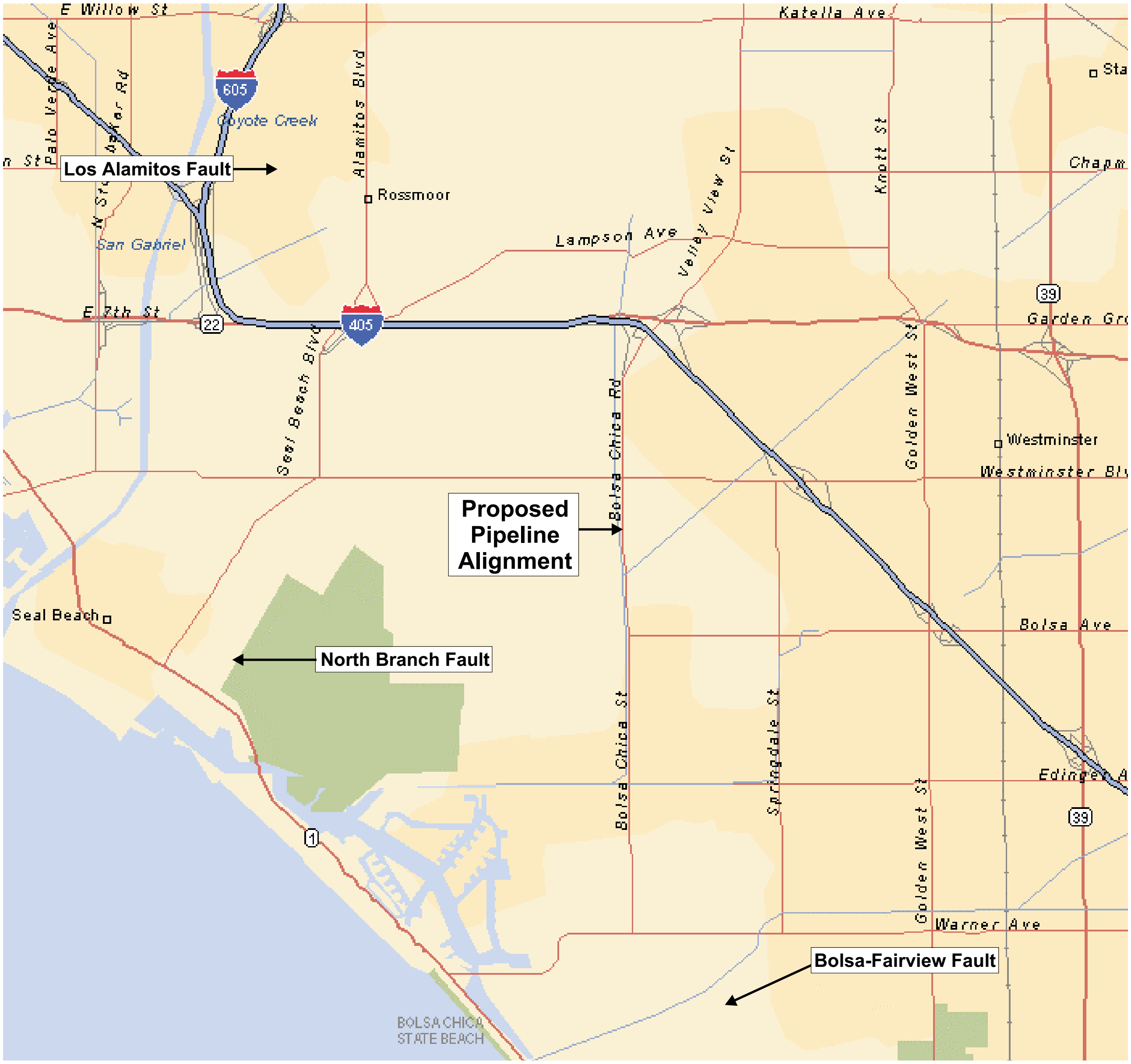
Intensity Scale	Effects
XII	Damage total or nearly total, practically all works of construction are greatly damaged or destroyed. Roads, rails, and underground utilities severely damaged.

XI	
X	Major damage, including partial to complete collapse of weak masonry and frame buildings and moderate damage of stronger structures.
IX	
VIII	Moderate damage including toppled chimneys, cracked stucco, frames shifted on foundations. Damage more severe to weak walls and masonry.
VII	
VI	Minor damage including cracks in chimneys and walls. Furniture moved and items knocked off shelves.
V	Felt by most people, some awakened from sleep. Some objects are moved. No structural damage.
IV	
III	Felt indoors by some people.
II	Not generally felt by people.
I	

The likelihood of fault rupture in the area where potentially active and active strands of the Newport-Inglewood fault cross and are near the proposed pipeline is difficult to assess because of the character of the fault, the youthful alluvial surficial deposits in this area, and its urban setting. Therefore, while active strands of the Newport-Inglewood fault zone have not been documented crossing the pipeline alignment, the possibility of fault rupture cannot be ruled out.

Strong Ground Shaking

The proposed SCWC pipeline is located in a region that has a history of strong seismic activity. Any of the faults listed in Table C.5-1 could potentially generate earthquakes with magnitudes greater than 6.0, resulting in strong ground shaking. A review of historic earthquake activity from 1850 to 1993 indicates that ten earthquakes of magnitude 6.0 or greater have occurred within a 50 miles of the proposed site. Distance from the site, magnitude, and site intensity for each of these seven earthquake events are presented Table C.5-3 – Historic Earthquakes. In addition, there have also been seven earthquakes with magnitudes between 5.5 and 6.0 within 50 miles of the site.



Proposed Pipeline

Bolsa-Fairview and
Los Alamitos Faults

North Branch Fault of the
Newport-Inglewood Fault Zone

Bolsa Chica Water Line and Wastewater Project

Figure C.5-1

Known Active and Potentially Active Faults

Aspen Environmental Group

Table C.5-3 Historic Earthquakes

Date	Closest Distance to Site (mi.)	Quake Magnitude (M)	Site Intensity (MM)
July 11, 1855	21	6.30	VII
December 16, 1858	34	7.00	VII
December 19, 1880	48	6.00	V
April 4, 1893	48	6.00	V
July 30, 1894	43	6.00	V
July 22, 1899	46	6.50	V
May 15, 1910	37	6.00	VI
July 23, 1923	47	6.25	V
March 11, 1933	8	6.30	IX
February 9, 1971	47	6.40	V

Earthquakes are classified by their magnitude (M), a measure of the amount of energy released during the event. Earthquakes of M 6.0 to M 6.9 are classified as moderate. Earthquakes between M 7.0 and M 7.9 are classified as major, and earthquakes of M 8.0 or greater are classified as great. The 1933 M 6.3 Long Beach Earthquake occurred along the Newport-Inglewood fault zone. Although there was no surface rupture associated with the earthquake, it resulted in 120 deaths and over $50 million in property damage. Many school buildings were destroyed. This earthquake led to the passage of the Field Act, which gave the State Division of Architecture authority and responsibility for approving design and supervision of construction of public schools. Building codes were also improved as a result of this earthquake.

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 granular sediments, and the magnitude and frequency of earthquakes in the surrounding region. Saturated, unconsolidated silt, sand, and silty sand within 50 feet of the ground surface are most susceptible to liquefaction.

Liquefaction related phenomena may include lateral spreading, ground oscillation, loss of bearing strength, subsidence, and buoyancy effects (Tinsley, 1986). Lateral spreading comprises of surficial blocks of sediment due to liquefaction, and commonly occurs on gentle slopes of 0.3° and 3°. The southern end of the pipeline would be the most susceptible to lateral spreading as it crosses onto the Bolsa Chica Mesa. 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.

Previous studies in the project area indicate that the surficial soils are comprised of interbedded layers of unconsolidated sand, silty sand, and clay. Groundwater levels along the alignment vary from elevation –30 to +16 feet from the southern end of the alignment to the northern end. The shallow levels near the northern end of the project area appear to be the result of perched groundwater and may vary seasonally. The California Division of Mines and Geology (CDMG) Seismic Hazard Zone Maps for the Los

Alamitos and Seal Beach quadrangles characterize the soils in the project area as prone to liquefaction. In addition, the liquefaction potential in the Los Angeles basin has been modeled by Tinsley et al. (1986). Their model suggests that the liquefaction potential varies from very high to moderate along most of the pipeline alignment. The liquefaction potential of the southern portion of the alignment, located in the Bolsa Chica Mesa, is low.

Soils

Soils within the project area consist predominantly of well-drained soils consisting of alluvial and terrace deposits. Previous studies in the project area indicate that the surficial soils can be expected to be comprised of interbedded layers of unconsolidated sand, silty sand, and clay. The soil characteristic that could have significant impact on design and operation of the pipeline are corrosivity. Limited soil testing along the alignment by Ductile Iron Pipe Research Association in 1997 revealed that soils found at expected excavation depths are potentially corrosive to ductile iron pipe. Use of polyethylene encasement of the ductile iron pipe would mitigate potential corrosion.

C.5.1.2 Regulatory Setting

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 aboveground structures.

C.5.2 ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

C.5.2.1 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 potential impacts to the pipeline and its related facilities for specific geologic hazards. The significance of these impacts was determined based on CEQA statutes, guidelines and appendices, thresholds of significance developed by local agencies, government codes and ordinances, and requirements stipulated by the 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 adjustments 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.

- 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 of a known active earthquake fault or of a known potentially active fault, as delineated on an Alquist-Priolo Earthquake Fault Zone Map, crossing along the pipeline route with attendant potential for damage to the pipeline or other project structures.

- High potential for earthquake-induced strong ground shaking to cause liquefaction, settlement, lateral spreading and/or surface cracking along the alignment, 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.

- The presence of corrosive soils which would damage the pipeline.

C.5.2.3 Impacts and Mitigation Measures for Pipeline Construction

Since the proposed alignment is located in city streets and existing ROWs, there are no known soils, geologic, or paleontologic conditions or resources in the project area that would be significantly impacted by 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.

Failure of the trench walls during construction activities would not represent a significant impact. Unstable slopes can be braced using standard construction techniques; and in areas with shallow groundwater, slopes can be stabilized by shoring and dewatering (see Section B.7.1 for proposed shoring activities).

C.5.2.4 Impacts and Mitigation Measures for Project Operation

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 southern end of the Proposed Project, where the alignment crosses the Newport-Inglewood fault zone. The State of California's Alquist-Priolo Earthquake Fault Zone Maps (CDMG, 1986) suggest that an active trace of the Newport-Inglewood fault zone approaches the southern end of the alignment from the southwest, but does not cross the proposed pipeline alignment (see Figure C.5-1). In this area, motion along the Newport-Inglewood fault zone appears to be concentrated on the center strand, known as the North Branch fault. However, the potential for fault motion on adjacent potentially active strands of the fault cannot be ruled out.

Pipelines can be designed to withstand substantial fault movement without rupture when the direction and magnitude of anticipated offset are well defined. However, because of the uncertainties regarding direction and magnitude of anticipated offsets, and because fault crossing designs have not been thoroughly tested by nature, the fault crossings at the potentially active Bolsa-Fairview and Los Alamitos faults are designated as significant unavoidable (**Class I**) impacts.

Impact: Potential rupture of the pipeline by any of the faults listed in Table C.5-1 **(Class I)**.

Mitigation Measure:

G-1 Prior to final design, the SCWC shall conduct geologic/geotechnical investigations to document the location, orientation, and direction of anticipated offset for the North Branch, Bolsa-Fairview, and Los Alamitos faults, and, as appropriate, incorporate design recommendations to mitigate fault rupture. The investigation may be conducted in conjunction with the investigations described in Mitigation Measures G-2, G-3, and G-4.

Strong Ground Shaking

Strong earthquake induced ground shaking could be triggered by seismic activity on any of the faults listed in Table C.5-1. Strong earthquake-induced ground shaking 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 soft or very soft to stiff soils. However, the Modified Mercalli Intensities along the alignment adjacent to the Newport-Inglewood fault zone range from VIII to IX. An intensity of IX could cause damage to underground utilities. The effect of strong ground shaking on the proposed alignment is therefore designated as a significant, but mitigable (**Class II**) impact.

Impact: Strong ground shaking induced by a large event on the Newport-Inglewood fault zone could cause collapse or rupture of the pipeline **(Class II)**.

Mitigation Measure:

G-2 Proper seismic design allows structures to withstand intense ground shaking without collapse. Design of the project facilities shall conform to current codes and specifications. A complete geotechnical engineering investigation shall be completed, and the findings thereof considered, before preparation of final design of the pipeline. The investigation may be conducted in conjunction with the investigations described in Mitigation Measures G-1, G-3, and G-4.

Liquefaction Potential/Differential Settlement

Liquefaction often results in the 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 occur within the soil mass, allowing structures to settle and tilt. Damage caused by liquefaction phenomena is generally most severe when liquefaction occurs within 15 to 20 feet of the ground surface.

Previous studies in the project area indicate that the surficial soils are comprised of interbedded layers of unconsolidated sand, silty sand, and clay with groundwater levels varying from approximately 7 to more than 40 feet below ground surface, from north to south along the alignment. Shallow groundwater near the northern end of the project area appears to be the result of perched groundwater and may vary seasonally. The liquefaction potential along most of the alignment has been mapped as varying from moderate to very high. The liquefaction potential of the southern most portion of the alignment, located on the Bolsa Chica Mesa, is low. The potential for liquefaction and lateral spreading damage to the pipeline is designated as a significant, but mitigable (**Class II**) impact.

In addition, the portion of the pipeline that crosses onto the Bolsa Chica Mesa may be susceptible to earthquake induced differential settlement where looser and younger sediments border denser and older deposits. Areas with potential differential settlement are designated as a significant, but mitigable (**Class II**) impact.

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

Mitigation Measure:

G-3 Geotechnical investigations shall be completed in areas classified as having moderate to very high liquefaction potential and areas of potential differential settlement and the findings thereof considered before final design of the Proposed Project. Liquefaction can be mitigated by several methods including dynamic densification, ground improvement, grouting, or removal of suspect soils. The investigation may be conducted in conjunction with the investigations described in Mitigation Measures G-1, G-2, and G-4.

Corrosive Soils

Previous studies in the project area indicate that the surficial soils can be expected to be comprised of interbedded layers of unconsolidated sand, silty sand, and clay with local perched aquifers. Limited soil testing along the alignment by the Ductile Iron Pipe Research Association in 1997 revealed that soils found at expected excavation depths are potentially corrosive to ductile iron pipe. They recommended use of polyethylene encasement of the ductile iron pipe to mitigate any potential corrosion. However, their testing did not cover the entire length of the pipeline and did not account for potential corrosion in areas of saturated soils. Potential damage to the pipeline from corrosive soils is designated as a significant, but mitigable (**Class II**) impact.

Impact: Damage to the pipeline from corrosive soils **(Class II)**.

Mitigation Measure:

G-4 A thorough geotechnical investigation to fully characterize the presence, extent, and corrosion potential of the soils along the pipeline alignment shall be completed prior to final design. Based on the results, appropriate measures can be designed to minimize potential impacts from corrosion. The investigation may be conducted in conjunction with the investigations described in Mitigation Measures G-1, G-2, and G-3.

C.5.2.5 Summary of Impacts

A summary of geologic impacts to the proposed route and the applicable mitigation measures is presented in Table C.5-4.

Table C.5-4 Impact and Mitigation Summary – Geology and Soils

Impact	Class	Mitigation Measure
Potential rupture of the pipeline by strands of the Newport-Inglewood fault zone or by the potentially active Los Alamitos fault	I	G-1
Strong ground shaking induced by a large event on the Newport-Inglewood could cause collapse or rupture of the pipeline.	II	G-2
Liquefaction, lateral spreading, and differential settlement could cause pipeline rupture	II	G-3
Damage to the pipeline from corrosive soils.	II	G-4

C.5.3 REFERENCES

Blake, Thomas F. 1993. EQSearch – A Computer Program for the Estimation of Peak Horizontal Acceleration from California Historical Earthquake Catalogs.

_____. 1995. EQFAULT – A Computer Program for the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults.

CDMG (California Division of Mines and Geology). 1962. Geologic Map of California, Long Beach Sheet, Scale 1:250,000.

_____. 1965. Geologic Map of California, Santa Ana Sheet, Scale 1:250,000.

_____. 1975. Recommended Guidelines for Determining the Maximum Credible and the Maximum Probable Earthquakes, CDMG Note No. 43.

_____. 1986. Alquist-Priolo Earthquake Fault Zone Map, Seal Beach Quadrangle, Scale 1:24,000.

_____. 1994. Fault Activity Map of California and Adjacent Areas, interpretation and compilation by C.W.Jennings.

_____. 1999. Seismic Hazard Zone Map, Los Alamitos Quadrangle, Scale 1:24,000.

_____. 1999. Seismic Hazard Zone Map, Seal Beach Quadrangle, Scale 1:24,000.

Ductile Iron Pipe Research Association. 1997. Soil Investigation Report, Huntington Beach Project – Bolsa Chica Pipeline, Huntington Beach, California.

NEIC (National Earthquake Information Center). 1999. Web Page http://www.neic.cr.usgs.gov/neis. Accessed February.

SCEC (Southern California Earthquake Center). 1999. Web Page http://www.scecdc.scec.org/, October.

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 Angels Region – An Earth-Science Perspective, U.S. Geological Professional Paper 1360.

Toro International. 1998. Preliminary Geotechnical Investigation, Bolsa Chica Pipeline Segment 1, Huntington Beach, California.

Toro International. 1998. Geotechnical Memorandum, Proposed Pipe Jacking Underneath Freeways 405 and 22, Bolsa Chica Pipeline Segment 2.

USGS (United States Geologic Survey). 1981. Los Alamitos Quadrangle, 7.5 Minute Series, Scale 1:24,000.

_____. 1981. Seal Beach Quadrangle, 7.5 Minute Series, Scale 1:24,000.

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