APPENDIX E

Geotechnical Reports

Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

PRELIMINARY GEOTECHNICAL EVALUATION
REHABILITATION OF THE
EAST ALISO CREEK EMERGENCY SEWER (REACES)
MOULTON NIGUEL WATER DISTRICT
LAGUNA NIGUEL, CALIFORNIA
MNWD JOB #2002059

PREPARED FOR:
Moulton Niguel Water District
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Laguna Niguel, California 92607

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May 9, 2003
Project No. 202426002

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Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

May 9, 2003
Project No. 202426002

Mr. John H. Williams
Moulton Niguel Water District
27500 La Paz Road
Laguna Niguel, California 92607

Subject: Geotechnical Evaluation
Rehabilitation of the East Aliso Creek Emergency Sewer
Moulton Niguel Water District
Laguna Niguel, California
MNWD Job # 2002059

Dear Mr. Williams:

In accordance with your authorization, Ninyo & Moore has performed a preliminary geotechnical evaluation for the Rehabilitation of the East Aliso Creek Emergency Sewer project located in Laguna Niguel, California. The purpose of our evaluation was to make a preliminary assessment of slope stability along the alignment with regard to the existing pipelines. This report presents the results of our evaluation and our conclusions and preliminary recommendations regarding the rehabilitation of the existing pipelines along the alignment.

We appreciate the opportunity to be of service on this project. If you have any questions regarding this report, please contact the undersigned at your convenience.

Sincerely,
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1. INTRODUCTION

In accordance with your request and authorization, we have performed a preliminary geotechnical evaluation for the Rehabilitation of the East Aliso Creek Emergency Sewer (REACES) project located in Laguna Niguel, California (Figure 1). The purpose of our evaluation was to develop preliminary data regarding slope stability along the alignment with regard to the existing pipelines. Creek erosion and erosion control is being evaluated by others. This report presents the results of our evaluation and our conclusions and preliminary recommendations regarding the rehabilitation of the pipelines along the alignment.

We previously performed a geotechnical evaluation, including subsurface exploration, for the planning and design of a new replacement pipeline alignment generally located along the west side of Aliso Creek within the Aliso Canyon area. The results of our previous work were presented in a report dated December 19, 2000. In addition, supplemental subsurface exploration was performed for that proposed pipeline, the results of which were presented in our report dated December 19, 2001. Our previous work indicated that the proposed alignment along the west side of the creek is generally underlain by unconsolidated alluvium and slope wash sediments. The canyon area is bordered by steep slopes east and west of the creek channel, which are comprised of Tertiary age sedimentary rock units belonging to the San Onofre Breccia, and the Topanga and Monterey Formations. Relatively large landslides also border the canyon along both sides of the creek channel.

It is our understanding the District would like to evaluate the feasibility of rehabilitating the existing sewer pipelines along the east side of the creek. Existing pipelines include two 4-inch diameter ductile iron force sewer mains, one 18-inch-diameter VCP sewer line, and one 36 to 39-inch RCP ocean outfall effluent transmission main. Pipe bursting techniques will be considered to increase the capacity of the 4-inch-diameter sewer lines. An alternative to pipe bursting may consist of replacement of the two 4-inch force mains with 6-inch force mains along the existing dirt access road. The existing pipeline alignment extends from Alicia Parkway south along the base of the slopes bordering the east side of the Aliso Creek. The creek meanders along the canyon bottom and the distance between the creek and the closest pipeline varies along the alignment. In some places creek erosion is within approximately 10 feet or less to the existing pipelines. The distance between the pipelines and the canyon slopes is also variable. At some locations the pipelines are located adjacent to the steep canyon slopes. Due to erosion of the channel slopes, portions of the 18-inch line have been relocated away from the creek (Tetra Tech, 2002). A topographic survey of the current alignment is not available. We also understand that the rehabilitation project will include implementation of erosion control measures to protect the existing pipelines. The erosion control and feasibility evaluation is based on an approximately 10 year performance objective.

2. SCOPE OF SERVICES

Our scope of services for the geotechnical evaluation was performed in accordance with our proposal dated February 11, 2003 and included the following:

- Research and review of readily available pertinent geologic maps, geotechnical data, topographic maps, pipeline alignment and profile data, and existing aerial photographs.
- Performance of a geotechnical aerial photographic survey along the alignment. The geotechnical aerial photography was performed by our subconsultant, Geo-Tech Imagery International. The survey included relatively low-altitude, oblique, stereo photography. Color and false color infrared photographs were collected.
- Geologic mapping along the alignment, including an evaluation of geologic outcrops, slope erosion features, debris flows, ground cracking, and landslide areas. In addition, a reconnaissance along accessible areas of the creek channel to map embankment exposures and embankment slumps was performed.
- Review and interpretation of the field data, preparation of geologic cross sections, preliminary slope stability analyses and evaluation of the data with respect to rehabilitation of the pipelines.
- Coordination and consultation during the course of our work with District personnel and the erosion control consultant.
- Preparation of this preliminary geotechnical evaluation report presenting our findings along with our preliminary conclusions regarding slope stability hazards potentially impacting the existing pipelines.

3. SITE DESCRIPTION

The REACES project is located in the county of Orange, south of Aliso Viejo and west of the city of Laguna Niguel, adjacent to the east side of Aliso Creek (Figure 1). The existing pipeline alignment extends from Alicia Parkway down gradient along the east side of Aliso Creek to the existing S.C.C.W.D. Treatment Plant. According to the plans for the effluent transmission main, referred to as Reach E (Boyle Engineering, 1978), the existing pipelines from closest to farthest from the creek consist of one 18-inch-diameter VCP sewer line, two 4-inch diameter force sewer mains and one 36 to 39-inch RCP ocean outfall sewer line (Figure 2). The pipelines are roughly parallel and generally within 10 feet of each other. Manholes for the 18-inch VCP are numbered from 1 to 34 beginning near the treatment plant as referenced on the plan and profile sheets (Boyle Engineering, 1968). The force mains and outfall line trend away from the 18-inch line near Station 25+02 (Manhole No. 6) and roughly parallel the base of the canyon slopes. East of the 18-inch line at approximately Station 113+47 (Manhole No. 23), the force mains and outfall line trend parallel and within approximately 20 feet of the 18-inch line. Between approximately Stations 158+32 (Manhole No. 33) and 161+22, the force mains are shown within approximately 5 feet of the 18-inch sewer line. The depths of the pipelines are generally less than 10 feet deep. In areas where the force mains and outfall line are near the base of the canyon slopes, the depths of these utilities extend down to about 28 feet deep (between approximately Stations 78+30 and 79+30, Manhole No. 16B). The 36-inch RCP changes to a 39-inch RCP at approximately Station 70+52 (northeast of Manhole No. 14). In addition, an abandoned 18-inch PVC irrigation pipe is present roughly parallel to the east channel slopes of the creek, south of approximately Station 100+00. An additional abandoned 8-inch PVC pipe is present at the base of the hillside east of Manhole Nos. 18 and 19. The limits of the abandoned pipes are unknown.

The pipelines are generally located along the flood plain of Aliso Canyon. The canyon area is bordered by steep slopes east and west of the creek channel. The creek has incised below the valley bottom to depths of approximately 4 to 25 feet. Elevations along the creek bottom range from approximately 120 feet above mean sea level at the north end (Alicia Parkway) to approximately 32 feet above mean sea level at the south end (Treatment Plant). Some of the creek channel embankments are near vertical. At some locations channel slumping has occurred and rip-rap has been placed to control erosion. A graded dirt road is present along the east side of the creek. Several north-south trending drainage gulleys are present incising the canyon slopes. These gullies are interrupted by the graded road and/or drain to the creek. A concrete lined rip-rap gulley up to about 7 feet in depth crosses the dirt road at approximately Station 138+90 (east of Manhole No. 27). According to the pipeline profile (Boyle Engineering, 1968), the 18-inch pipeline at this location is just below the concrete. Smaller concrete lined drainage swales are also present crossing the road at approximately Stations 64+07 and 85+17. A concrete access road (drop structure) with a drainage culvert crosses the creek near approximately Station 102+00. Vegetation along the creek embankments and valley floor consist of moderate to thick cover of weeds, shrubs and some trees.

4. GEOLOGY AND SUBSURFACE CONDITIONS

A geologic reconnaissance was performed during the period of March 10 through 18, 2003 and consisted of geologic mapping along the east side of the Aliso Creek, including an evaluation of geologic outcrops, slope erosion features, debris flows, channel slumps and landslide areas. In addition, a geotechnical aerial photographic survey was performed by Geo-Tech Imagery International on March 1 and 7, 2003. The aerial photographs were used to evaluate topographic features, vegetation, groundwater, and soil moisture conditions as well as landslides, debris flows, seepage, and other geomorphic features. The photographic survey included relatively low-altitude, oblique, stereo photography along the alignment. Color and false color infrared photographs were also obtained. The results of the photographic survey are presented in Appendix A. The results of our geologic mapping utilizing the photographic data are presented on Figures 4 through 18. Due to the oblique nature of the photographs, the figures are not to scale. The 18-inch sewer line manholes and other cultural features are referenced on each figure.

4.1. Geologic Setting

The project site is situated in the San Joaquin Hills, within the northwestern portion of the Peninsular Ranges Geomorphic Province of California (Norris and Webb, 1990). The San Joaquin Hills consist of a series of generally northwest trending hills bounded by the Los

Angeles Basin on the north, the Pacific Ocean on the southwest, and the Santa Ana Mountains and San Juan Creek on the east and south. The existing sewer alignment follows the east side of Aliso Creek through a deep canyon surrounded by moderate to steeply sloped hillsides. Alluvium derived from the surrounding highlands has filled the bottom of the valley to variable depths and has been incised by the Aliso Creek to form paired stream terraces adjacent to the active stream channel.

Based on review of the referenced geologic maps of the area, the hillsides and areas surrounding the site are underlain by bedrock of the Miocene-aged Topanga and Monterey Formations, which consists of interbedded siltstones and sandstones (Figure 3). The San Onofre Breccia is also present in the hillside areas. A few natural slopes adjacent to the alignment include thick outcrops of resistant, strongly cemented sandstone. Regional mapping of the bedrock structure indicates that bedding of the Topanga Formation generally dips towards the south at approximately 8 to 22 degrees. Bedding surfaces of the Monterey Formation generally dip towards the east at approximately 8 to 25 degrees (Morton and others, 1974).

Materials that have washed and/or mass-wasted from the surface of the hills have collected at the base of the hills to form slope wash deposits. Debris flows are also common on the steeper hillsides in the area where an accumulation of weak soils become saturated and are gravity driven. Large ancient landslides composed of disturbed bedrock material have also been mapped along the sides of the canyon.

4.2. Geologic Units

In general, the alignment is underlain by variable thickness of Quaternary-age alluvium and slope wash deposits over bedrock materials of the Miocene-age Topanga and Monterey Formations. Large bedrock landslides are mapped adjacent to the pipelines near the middle portions of the alignment (Figure 3). Some minor fill soils associated with the graded access road and utility trenches along the base of the slopes are present. The fill soils appeared to be minor in aerial extent and were not evaluated for the purpose of this report. Approximate locations of the geologic contacts are presented on Figures 4 through 18. Generalized descriptions of the geologic units observed during our evaluation are presented below.

4.2.1. Debris Flows

Shallow slope creep and/or debris flows were observed along the hillsides east of the alignment. These materials typically consist of topsoil, colluvium, or weak, highly weathered bedrock materials that become saturated and are gravity driven along relatively short distances of the slopes. These materials do not appear to impact the alignment but their presence may have an impact on the surface drainage in the area.

4.2.2. Slope Wash

Slope wash deposits were typically observed in the limited exposures along the bank of the creek as well as road cuts adjacent to the access road. The slope wash deposits are typically interfingered and consist of mottled brown, grayish brown, and reddish brown, damp to moist, firm to hard, clay and silt with varying amounts of pinhole porosity and caliche veinlets.

4.2.3. Alluvium

Alluvium consisting of stream terrace and older stream deposits were observed within the near vertical slopes along the creek channel. The alluvium observed generally consisted of interbedded brown to dark brown and gray to black, moist to saturated, firm to hard, clay and silt; and lesser amounts of light yellowish and reddish brown, damp to saturated, loose to dense, clayey to silty sand and sand. The clay and silt deposits had variable amounts of pinhole porosity and caliche veinlets. Some recent slumping of the steep creek channel slopes were observed within the slope wash and alluvial deposits.

4.2.4. Landslides

Relatively large landslide complexes have been mapped along the alignment (Morton, 1974) and are evident in our photographic review and as well as during our reconnaissance between approximately Station 50+12 (Manhole No. 11A) and Station 76+01

(Manhole No.16B) and between Station 84+20 (near Manhole No.17) and Station 119+50 (between Manholes Nos. 24 and 25). We did not observe outcrop exposures or failure planes of the landslide masses along accessible areas of the creek channel. In addition, we did not observe ground cracks, scarps, seeps or other signs of recent landslide movement. Based on previous work and our recent reconnaissance, the landslide complexes are relatively ancient and consist of a variety of translational and/block type failures within the bedrock materials. The landslide complexes are covered with an unknown thickness of slope wash and/or alluvium. Based on our previous subsurface exploration along the canyon area, the basal failure planes of the landslides are expected to be relatively deep below the creek bottom. Shallower rupture surfaces and fracture planes may be present at relatively shallow depths, particularly where smaller landslides are mapped within large landslide features (Figure 3).

4.2.5. Topanga Formation

Based on regional mapping as well as our observations of limited exposures, the Topanga Formation is present south of approximately Station 84+20 (near Manhole No. 17). Where exposed, the formation consists of yellowish and orange brown, weakly to strongly cemented, sandstone and some reddish brown and gray, weakly to moderately indurated siltstone.

4.2.6. Monterey Formation

Based on regional mapping as well as our observations of limited exposures, the Monterey Formation is present north of approximately Station 119+50 (near Manhole Nos. 24 and 25). Where exposed, the formation consists of white to gray, weakly to moderately indurated, tuffaceous siltstones and gray, weakly to moderately cemented sandstone.

5. GROUNDWATER

No groundwater seepage or active springs were observed during our reconnaissance near the base of the canyon slopes or in accessible areas of the creek channel slopes. An artificial pond for an endangered turtle species was observed south of approximately Station 43+87 (Manhole No. 10). Groundwater levels along the alignment are expected to be relatively close to the adjacent creek bottom which ranges in elevations from approximately 120 feet above mean sea level near Alicia Parkway (Manhole No. 34) to approximately 32 feet above mean sea level near the Treatment Plant (Manhole No. 1). It should be noted that groundwater levels are influenced by seasonal variations in precipitation and runoff and are, therefore, subject to variation.

6. FAULTING AND SEISMICITY

The tectonic fabric of the Peninsular Ranges Geomorphic Province in which the site is located is dominated by northwest-trending, right-lateral, strike-slip fault systems. The site is considered to be in a seismically active area, as is the majority of southern California. There are, however, no known active fault traces crossing the alignment. Several older faults (pre-Pleistocene) are present in the vicinity of the alignment. A few of the faults cross the alignment near Station 76+01 (Manhole 16B). These faults are considered seismically inactive but may be a concern with regard to trench excavation stability.

Seismic hazards at the site are a consequence of ground shaking caused by events on nearby or distant, active faults. The closest active fault is the Newport-Inglewood fault located approximately 3 miles southwest of the alignment (Jennings, 1994). Table 2 lists selected known active faults in close proximity to the site, the maximum moment magnitude M_{max} as published by the California Department of Conservation, Division of Mines and Geology (1998) and the type of fault, as defined in Table 16-4 of the Uniform Building Code (International Conference of Building Officials, 1997).

Table 1 – Principal Active Faults

Fault	Approximate Fault to Site Distance miles (km)	Maximum Moment Magnitude^1 (M_{max})	Fault Type^2
Newport-Inglewood	3 (5)	6.9	B
Palos Verdes	18 (29)	7.1	B
Whittier-Elsinore (Glen Ivy)	21 (34)	6.8	B
Cucamonga	42 (67)	7.0	A
San Andreas – 1857 Rupture	56 (90)	7.8	A

Notes:
[1] CDMG, 1998.
[2] ICBO, 1997; CDMG, 1998.

In addition to the known faults included in Table 1, recent research suggests the San Joaquin Hills may have formed by folding and uplift in association with ongoing movement along a blind thrust fault in the southern Los Angeles basin. Grant and others (1999) have indicated the San Joaquin Hills blind thrust fault (not confirmed) may have the potential to generate up to a magnitude 7.3 earthquake.

6.1. Ground Motion

A probabilistic seismic hazard assessment that includes statewide estimates of peak horizontal ground accelerations has been conducted for California (Peterson and others, 1996). Based on our review of this report, and updated data available from the United States Geological Survey (1998), the peak horizontal ground acceleration (PGA) with a 10 percent probability of exceedance in 50 years is approximately 0.34g at the south end and 0.30g at the north end of the alignment.

6.2. Ground Rupture

The probability of damage due to surface ground rupture appears to be low due to the lack of known active faults crossing the site. Surface ground cracking related to shaking from distant events is not considered a significant hazard, although it is a possibility.

6.3. Liquefaction Potential

Liquefaction of soils can be caused by relatively strong vibratory motion due to earthquakes. Research and historical data indicate that loose, granular soils with fines content of less than 5 percent as well as low-plasticity fine-grain soils which meet the Chinese criteria (LL<35, Wu/LL>0.9 and CF<15%, where LL is the liquid limit, Wu is the in-situ water content and CF is the clay fraction defined as the portion of the grain size less than 0.005 mm) are susceptible to liquefaction (Youd, 2001), while the stability of the majority of plastic clayey silts, silty clays and clays is not adversely affected by vibratory motion. Liquefaction is generally known to occur in saturated or near-saturated cohesionless soils at depths shallower than about 50 feet. Based on our previous work we anticipate that the majority of the bedrock and alluvial deposits below groundwater at the site are relatively dense and/or contained a high proportion of silt and clay and, therefore, are considered to have a low liquefaction potential. However, beds of relatively loose, saturated, granular soils and low-plasticity fine-grained soils are expected at depths of less than 50 feet. The liquefaction potential in these materials is considered to be moderate.

6.4. Slope Stability

The existing alignment is situated adjacent to the active stream channel of Aliso Creek and is susceptible to damage by stream bank erosion and channel slumping. The erosion potential is relatively minor during the dry months, but may be relatively severe during the wet months and especially during large flood events. Erosion, (slow or catastrophic), poses a threat to the pipeline integrity. Rip-rap has been placed along steeper portions of the creek channel where the channel slopes are within approximately 20 feet of the 18-inch sewer line (see Figures 4 through 18). Additional rip-rap may be present in other areas which are currently obscured by vegetation. The rip-rap observed consists of granitic rock boulders up to approximately 2 to 3 feet in thickness. The actual thicknesses of the rip-rap layers are unknown.

In order to evaluate the stability of the existing pipelines, we initially located portions of the 18-inch pipeline that were relatively close to the creek channel (within approximately 30 feet). Within these sections, we tape measured the horizontal distance from the 18-inch pipeline to the top of the creek channel using the manholes for reference. At selected locations we measured the approximate profile of the channel embankment using a hand level and staff. In less accessible areas, conservative slope inclinations were estimated. This information was used with the pipeline profile data to prepare geologic cross sections. The approximate locations of the cross sections are presented on Figures 7, 9, 17 and 18.

Preliminary stability analysis of the creek channel slopes was performed using the PCSTABL6H computer program for Geologic Cross Sections A-A’, B-B’, C-C’ and D-D’ (Figure 19). The strength parameters selected for input into the analysis were based on our past experience with similar soil types and back calculating the factor of safety to 1.02 for the steeper existing slopes. In addition, for the purpose of our analysis, we assumed a thickness of existing rip rap of approximately 3 feet. Our stability analysis was performed using three potential environmental conditions, including relatively low water table (existing), an elevated water table and pseudo-static analysis to simulate seismic loading.

Based on the results of our analysis, it is our opinion that the pipeline stability with regard to the channel slopes can be categorized into four general conditions. Condition 1 includes the steep channel slopes where the 18-inch pipe is located within an imaginary plane of 1 to 1 (horizontal to vertical) extending up from the bottom of the creek and is represented by Cross Section A-A’. Our preliminary analysis of the slope in this area indicates a minimum factor of safety of approximately 1.02 under relatively dry conditions. In the event the water table was elevated above the current creek level, or seismic ground shaking occurs the factor of safety falls below 1.0 indicating a failure would occur. Condition 1 is relatively unstable. Based on our reconnaissance, Condition 1 occurs along the alignment from approximately Stations 145+50 to 148+00 (near Manhole Nos. 29 and 30).

Condition 2 includes a relatively steep channel slope (with partial rip rap protection) where the 18-inch pipe is situated within an approximately 2 to 1 (horizontal to vertical) imaginary plane from the creek bottom and is represented by Cross Section B-B’. Under dry conditions the stability at the pipeline with respect to the slope has a factor of safety of approximately

1.3. With an elevated water table or a seismic event the factor of safety is less than 1.0 and 1.1, respectively. Condition 2 areas are considered marginally stable under favorable environmental conditions, but unstable due to changes in groundwater, seepage conditions, or seismic shaking. Based on our reconnaissance Condition 2 occurs along the alignment from approximately Station 154+50 to 162+90 (Manhole No. 34).

Condition 3 includes the steep channel slopes (with partial rip rap protection) where the 18-inch pipe is located beyond an imaginary plane of 2 to 1 (horizontal to vertical) from the bottom of the creek and is represented by Cross Section C-C’. The stability of the slope in this area has a factor of safety of approximately 1.4 under relatively dry conditions. In the event the water table was elevated above the current creek level, or seismic shaking occurs the slope factor of safety decreases to approximately 1.2 and 1.1, respectively. The pipeline, however, is outside the potential failure planes in these conditions. Condition 3 areas have slopes that may become marginally stable due to changes in groundwater or seismic shaking, but the pipelines are relatively stable if further undermining does not occur. Based on our reconnaissance, Condition 3 occurs along the alignment from approximately Stations 11+12 to 15+00 (near Manhole Nos. 3 and 4) Stations 50+00 to 55+00 (near Manhole Nos. 9 and 10), approximately Stations 60+20 to 61+40 (Manhole No. 13A), approximately Stations 75+00 to 87+00 (near Manhole Nos. 16B and 17) and approximately Stations 98+00 to 99+60 (near Manhole No. 20).

Condition 4 includes moderately to relatively steep channel slopes where the 18-inch pipe is located greater than 30 feet from the creek and/or the elevation of the pipe is near the creek elevation as represented by Cross Section D-D’. The stability of the pipeline in this condition has factor of safety greater than 1.5, including elevated groundwater and seismic conditions. Condition 4 represents pipeline areas that are generally safe against mass instability provided that future severe undermining of the creek bank does not occur. Condition 4 represents those portions of the alignment outside areas of Conditions 1, 2, or 3.

7. PRELIMINARY FINDINGS

The purpose of our geotechnical evaluation was to develop preliminary information regarding slope stability along the alignment with regard to the feasibility of rehabilitating the existing pipelines. Erosion along the Aliso Creek has encroached portions of the alignment and continued erosion is likely to cause damage to pipelines along the length of the alignment. From a geotechnical standpoint, it is our preliminary opinion that rehabilitation of the existing pipelines is feasible, if suitable erosion protection measures are implemented. Erosion protection is being evaluated by Rivertech, Inc. Based on our evaluation, the pipelines along portions of the alignment are currently at risk due to creek channel failure and channel stabilization is appropriate (Condition 1 and 2). Potentially unstable areas include Condition 3 in the event of changes in groundwater, seismic shaking, or additional erosion. Stabilization and/or erosion protection of these areas is also appropriate. Other conditions that may impact the pipelines include slope creep, existing landslides, and tributary erosion. A summary of our preliminary findings is presented below.

- Based on our field measurements and preliminary stability analysis the existing 18-inch VCP sewer line between approximately Stations 145+50 and 148+00 (Condition 1) is close to the steep channel embankment, is relatively unstable, and should be stabilized. In general, stabilization of the pipeline may include relocating the pipe away from the channel embankment or embankment stabilization. Embankment stabilization or pipe relocation should be performed in this area. Relocation of the pipelines in this section of the alignment may be feasible. The 18-inch pipe should be relocated such that a horizontal distance of 30 feet is between the pipe and face of the channel slope. This may require relocating the utilities east of the 18-inch pipe.

- Our preliminary stability analysis indicated that the pipeline between approximately Stations 154+50 and 162+90 (Condition 2) may become unstable with changes in groundwater, seepage or seismic ground shaking. This section of the alignment is close to steep ascending slopes and relocation of pipes may not be feasible. However, microtunneling below steep slope areas could be considered. Embankment stabilization would likely involve some type of gravity retaining structure (gabion walls, rip rap, etc.) and/or reinforced earth slope construction. Slope stabilization should be designed and constructed along with the planned erosion protection system. The actual stabilization design should be based on further geotechnical evaluation including subsurface exploration and laboratory testing. Prior to the subsurface exploration, a detailed topographic survey of the alignment and slope areas should be performed.

- Condition 3 areas along the alignment were identified where the pipelines were within approximately 30 feet of the existing creek embankment, but where the depth of the pipeline with respect to the depth of the creek embankment resulted in a relatively stable condition. Additional erosion and/or slumping of the creek embankments would reduce the pipeline stability and erosion protection is imperative in these areas. Condition 3 areas include the pipelines from approximately Stations 11+12 to 15+00 (near Manhole Nos. 3 and 4), Stations 50+00 to 55+00 (near Manhole Nos. 9 and 10), Stations 60+20 to 61+40 (near Manhole No. 13A), Stations 75+00 to 87+00 (near Manhole Nos. 16B and 17), and Stations 98+00 to 99+60 (near Manhole No. 20).

- Portions of the pipeline alignment are located adjacent to or on steep slope areas and may be subject to slope creep. Slope creep generally consists of slow downhill movement of relatively weak soil in response to the forces of gravity and fluctuations in moisture and other slope conditions. The potential for slope creep impacting the pipelines depends of the subsurface soil conditions, pipe embedment depths, slope inclinations, etc. We understand that the pipelines have not been subject to significant deformation other than creek erosion damage. Erosion protection would reduce the potential for slope creep. Monitoring of existing pipelines may also be considered to evaluate slope creep.

- Relatively large landslides are present adjacent to portions of the pipeline alignment (Figure 3). Reactivation of landslides could damage/severe existing pipelines. During our recent field reconnaissance and review of aerial photographs we did not observe ground cracks, scarps, seepage, or other signs of recent landslide movement. We understand that the existing pipelines have not been damaged by landslide movement. Based on our previous work in the area we anticipate that the basal rupture surfaces of these large landslides are relatively deep below the creek bottom. Shallower rupture surfaces and fracture zones may be present, which could be relatively unstable. Excavations along the base of steep slope areas for trenching or other pipe improvements could expose rupture zones, fractured material, or other unstable conditions. Subsurface exploration should be performed to evaluate the potential risk of landslides impacting the existing pipelines.

- Drainage tributaries from the north facing slopes crossing the alignment may undermine pipelines and impact the stability of the embankments. Erosion protection should be considered where these tributaries cross the pipelines and monitored as needed.

- Due to the steepness of the creek bank slope, proximity of the pipelines to the creek slope face, and the potential of relatively shallow groundwater during a major earthquake, portions of the pipeline may be susceptible to liquefaction-induced lateral spreading.

8. ADDITIONAL STUDIES

Our preliminary geotechnical evaluation was performed for preliminary planning purposes. As indicated above it is our preliminary opinion that rehabilitation of the existing pipelines is feasible from a geotechnical perspective provided that erosion protection is implemented along with the recommended slope stabilization. Our work has not included subsurface exploration. Detailed topographic information along the existing creek area was not available at the time of our evaluation.

The existing pipelines are located adjacent to several large landslide areas and are subject to risk of damage if the landslides are reactivated (similar to the landslide risk for the proposed alignment west of the creek). Our preliminary evaluation did not indicate evidence of active landsliding or recent movement. Subsurface exploration should be performed to provide more information regarding the potential for landslide movement. In addition, the rehabilitation of existing pipelines may include relocation, slope stabilization, excavations for pipe bursting access, and/or trenching for new pipes. Prior to detailed design or construction, we recommend that geotechnical exploration be performed to evaluate the soil and geologic conditions, address potential landslide risks, and develop detailed design criteria for slope stabilization and pipeline construction. Current topographic information along the creek and adjacent slope areas should be prepared prior to additional geotechnical exploration.

9. LIMITATIONS

The field evaluation and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through subsurface exploration. Subsurface evaluation will be performed upon request.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site can change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

10. SELECTED REFERENCES

Boyle Engineering, 1968, Plans for Contract 1A-2 for Moulton Niguel Water District, 7 sheets, dated July.

Boyle Engineering, 1978, Construction Plans for Aliso Creek Effluent Transmission Main, Reach E, Contract No. PC-2-B-78-A, 18 sheets, dated September.

California Department of Conservation, Division of Mines and Geology, 1998, Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada: International Conference of Building Officials, dated February.

Grant, L. B., Mueller, K. J., Gath, E. M., Cheng, H., Edwards, L.R., Munro, R., and Kennedy, G.L., 1999, Late Quaternary Uplift and Earthquake Potential of the San Joaquin Hills, Southern Los Angeles Basin, California: Geology, November, Volume 27, No. 11, pp. 1031-1034.

International Conference of Building Officials, 1997, Uniform Building Code, dated May 1.

Jennings, C.W., 1994, Fault Activity Map of California and Adjacent Areas: California Division of Conservation, Division of Mines and Geology, Scale 1:750,000.

Peterson, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open File Report 96-08.

Morton, P.K., 1974, Geology and Engineering Geologic Aspects of the San Juan Capistrano Quadrangle, Orange County, California: California Division of Mines and Geology, Special Report 112. Scale 1:24,000.

Morton, P.K., 1976, Environmental Geology of Orange County, California: California Division of Mines and Geology Open File Report 79-8 LA, Scale 1:48,000.

Morton, P.K., Miller, R.V., and Tan, S.S., 1981, Geologic Map of Orange County, California, Showing Mines and Mineral Deposits: California Division of Mines and Geology, Bulletin 204, Scale 1:48,000.

Ninyo & Moore, 2000a, Limited Geotechnical Evaluation, Moulton Niguel Water District, Aliso Creek Emergency Sewer, Laguna Niguel, California, dated May 9.

Ninyo & Moore, 2000b, Geotechnical Evaluation, Moulton Niguel Water District, Aliso Creek Emergency Sewer, Laguna Niguel, California, dated December 19.

Ninyo & Moore, 2001a, Supplemental Geotechnical Recommendations for Slot Cuttings, Aliso Creek Emergency Sewer, Moulton Niguel Water District, Laguna Niguel, California, dated January 25.

Ninyo & Moore, 2001c, Supplemental Subsurface Exploration, Aliso Creek Emergency Sewer, Moulton Niguel Water District, Laguna Niguel, California, dated December 19.

Ninyo & Moore, 2003, Proposal for Geotechnical Consulting Services, Aliso Creek Emergency Sewer Alternative, Laguna Niguel, California, MNWD Project No. 2002059, dated February 11.

Tetra Tech, Inc., 2002, Site Plan and Photograph of Manholes, Aliso Creek Emergency Sewer, dated October.

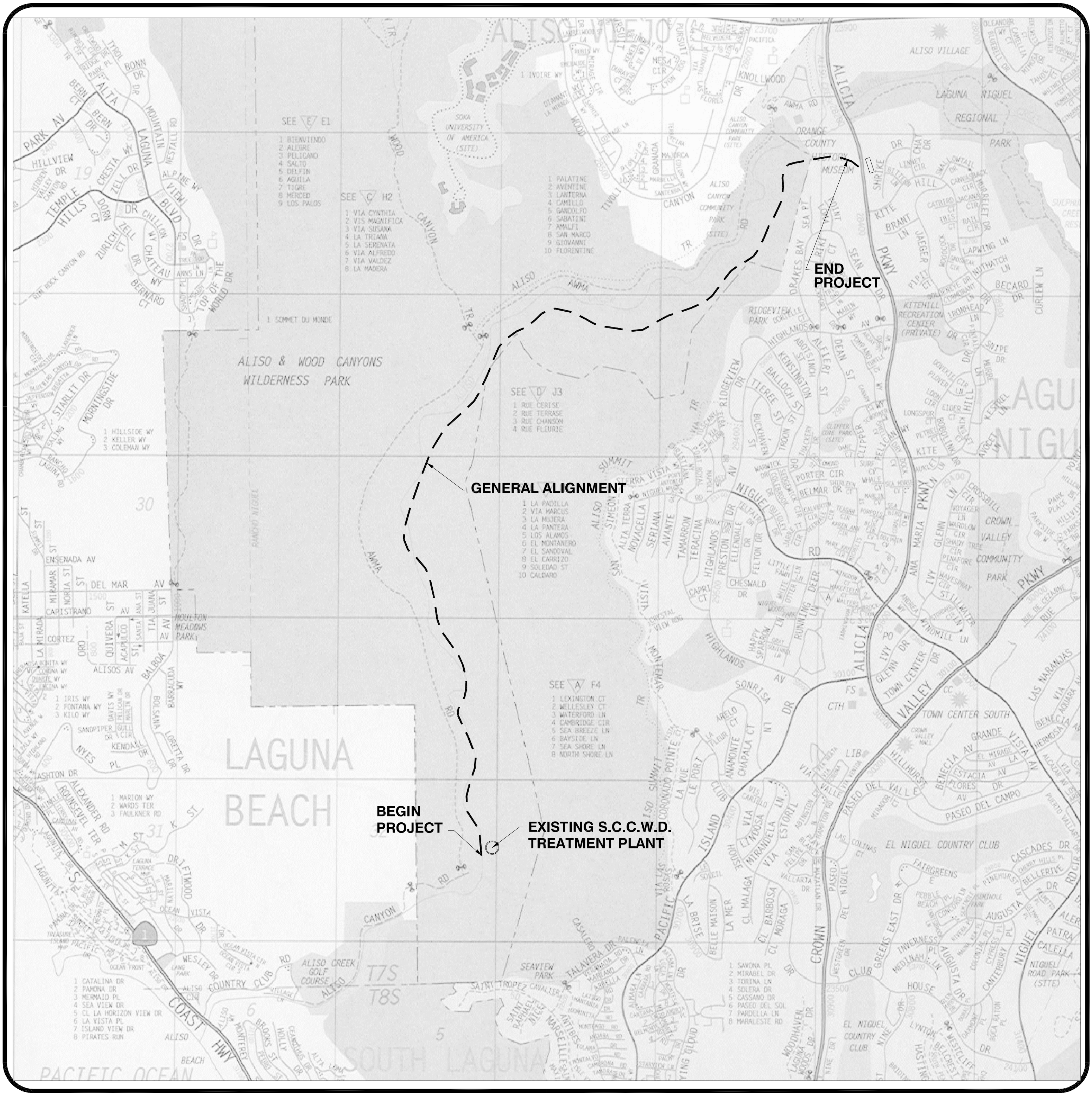
United States Geological Survey, 1968 (Photorevised 1981), San Juan Capistrano, California Quadrangle Map, 7.5 Minute Series: Scale 1:24,000.

Vedder, J.G., Yerkes, R.F., and Schoellhamer, J.E., 1957, Geologic Map of the San Joaquin Hills-San Juan Capistrano Area, Orange County, California: United States Geological Survey, Oil and Gas Investigations Map OM-193, Scale 1:24,000.

Youd, et. al., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, ASCE, Geot. J., Vol. 127, No. 10, pp. 817-833.

AERIAL PHOTOGRAPHS

Source	Date	Flight	Numbers	Scale
USDA	12-12-52	AXK-2K	130 through 134	1:20,000



REFERENCE: 2000 THOMAS GUIDE FOR LOS ANGELES/ORANGE COUNTIES, STREET GUIDE AND DIRECTORY

204260-A1.DWG

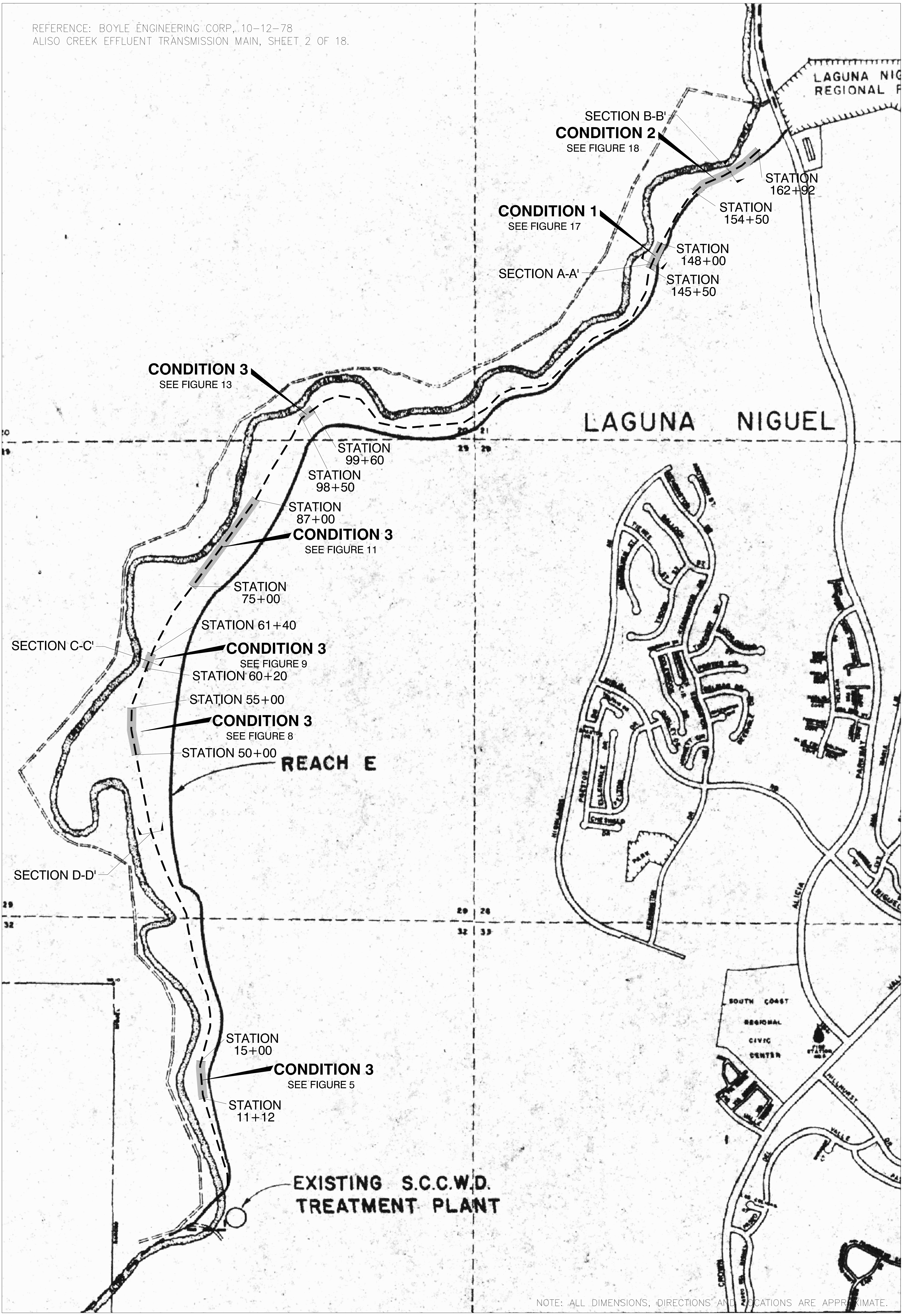
Ninyo & Moore

SITE LOCATION MAP

REACES
LAGUNA NUGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426001	5/2003	1

REFERENCE: BOYLE ENGINEERING CORP, 10-12-78
ALISO CREEK EFFLUENT TRANSMISSION MAIN, SHEET 2 OF 18.



NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

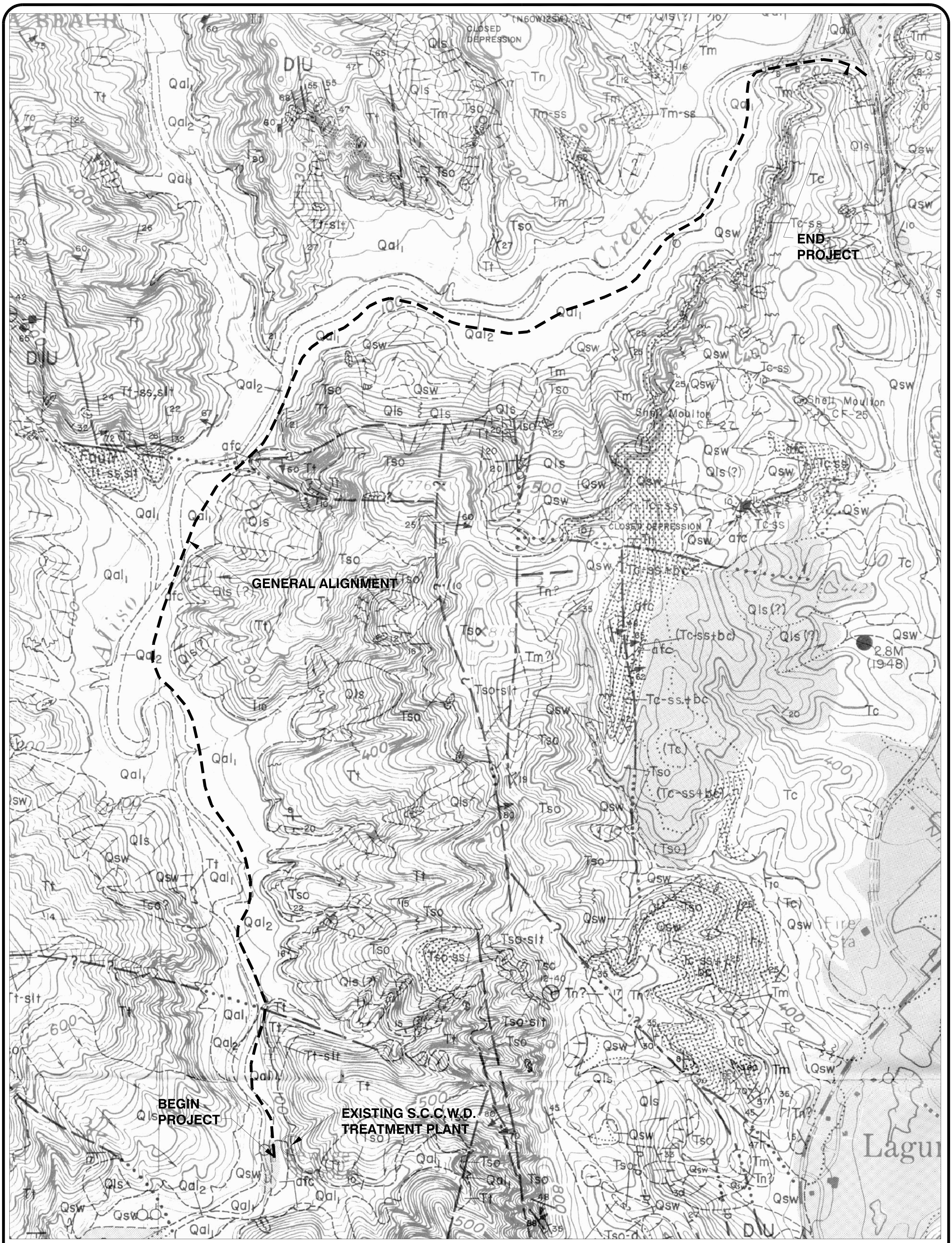
Ninyo & Moore

SITE PLAN

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	2

202426-B16.DWG



LEGEND

Qal	ALLUVIUM
Qsw	SLOPE WASH
Qls	BEDROCK LANDSLIDE
Tso	SAN ONOFRE BRECCIA
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION

GEOLOGIC CONTACT

FAULTS, DOTTED WHERE CONCEALED, QUERIED WHERE INFERRED

20 ATTITUDE OF BEDDING

APPROXIMATE ALIGNMENT OF EAST ALISO CREEK EMERGENCY SEWER

REFERENCE: GEOLOGIC MAP OF THE SAN JUAN CAPISTRANO QUADRANGLE, ORANGE COUNTY, CALIFORNIA, BY P.K. MORTON, W.J. EDINGTON, AND D.L. FIFE. DATE: 1974, SCALE: 1"=1000'.

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

N

0 1000

APPROXIMATE SCALE IN FEET

Ninyo & Moore

REGIONAL GEOLOGIC MAP

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	3

202426-B17.DWG

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426–B1.DWG

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 1-3

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	4

N

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
)Qls(	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
....——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←— · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
⑥	MANHOLE NO (18-INCH DIAMETER SEWER LINE)

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 3-6

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	5

202426-B2.DWG

N

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
⟩Qls⟨	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←— · · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
⑨	MANHOLE NO (18-INCH DIAMETER SEWER LINE)

Ninyo & Moore

AERIAL PHOTOGRAPH MANHOLE NOS. 6-9

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	6

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426-B3.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←— · · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
⑩	MANHOLE NO (18–INCH DIAMETER SEWER LINE)
D D'	APPROXIMATE LOCATION OF GEOLOGIC CROSS SECTION

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 6A - 10

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	7

202426-B4.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
)Qls(	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
—— ——?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
• • • • ——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
← · · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
12A	MANHOLE NO (18-INCH DIAMETER SEWER LINE)

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 9-12A

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2002	8

202426-B5.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— — ?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
← ·· —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
12A	MANHOLE NO (18–INCH DIAMETER SEWER LINE)
C ⌴ C'	APPROXIMATE LOCATION OF GEOLOGIC CROSS SECTION

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AERIAL PHOTOGRAPH
MANHOLE NOS. 12A-15A

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	9

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426-B6.DWG

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

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AERIAL PHOTOGRAPH
MANHOLE NOS. 14-16B

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	10

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←—·· —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←∿∿	SLOPE CREEP AND/OR DEBRIS FLOW
17	MANHOLE NO (18–INCH DIAMETER SEWER LINE)

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

AERIAL PHOTOGRAPH MANHOLE NOS. 16B-17

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	11

202426-B8.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
••••——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←· · ·—	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
⑲	MANHOLE NO (18–INCH DIAMETER SEWER LINE)

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 17-19

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	12

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426-B9.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— — —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←— · · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←~~~	SLOPE CREEP AND/OR DEBRIS FLOW
㉑	MANHOLE NO (18–INCH DIAMETER SEWER LINE)

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426–B10.DWG

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AERIAL PHOTOGRAPH
MANHOLE NOS. 19-21

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	13

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←·· —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
24	MANHOLE NO (18-INCH DIAMETER SEWER LINE)

Ninyo & Moore

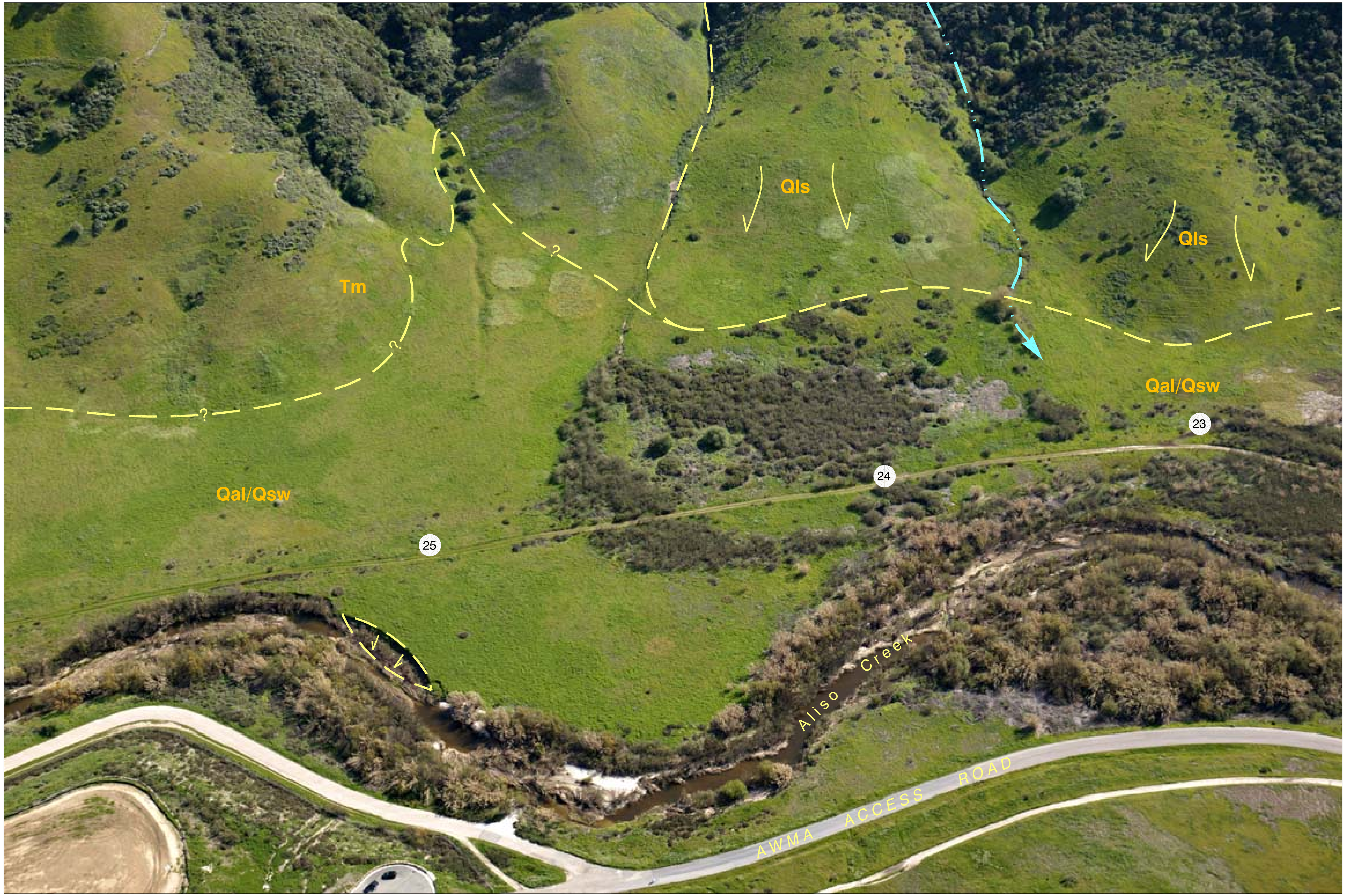
AERIAL PHOTOGRAPH
MANHOLE NOS. 21-24

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	14

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426-B11.DWG



DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— — ?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
···· ——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
← — · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←~~~	SLOPE CREEP AND/OR DEBRIS FLOW
25	MANHOLE NO (18–INCH DIAMETER SEWER LINE)

Ninyo & Moore

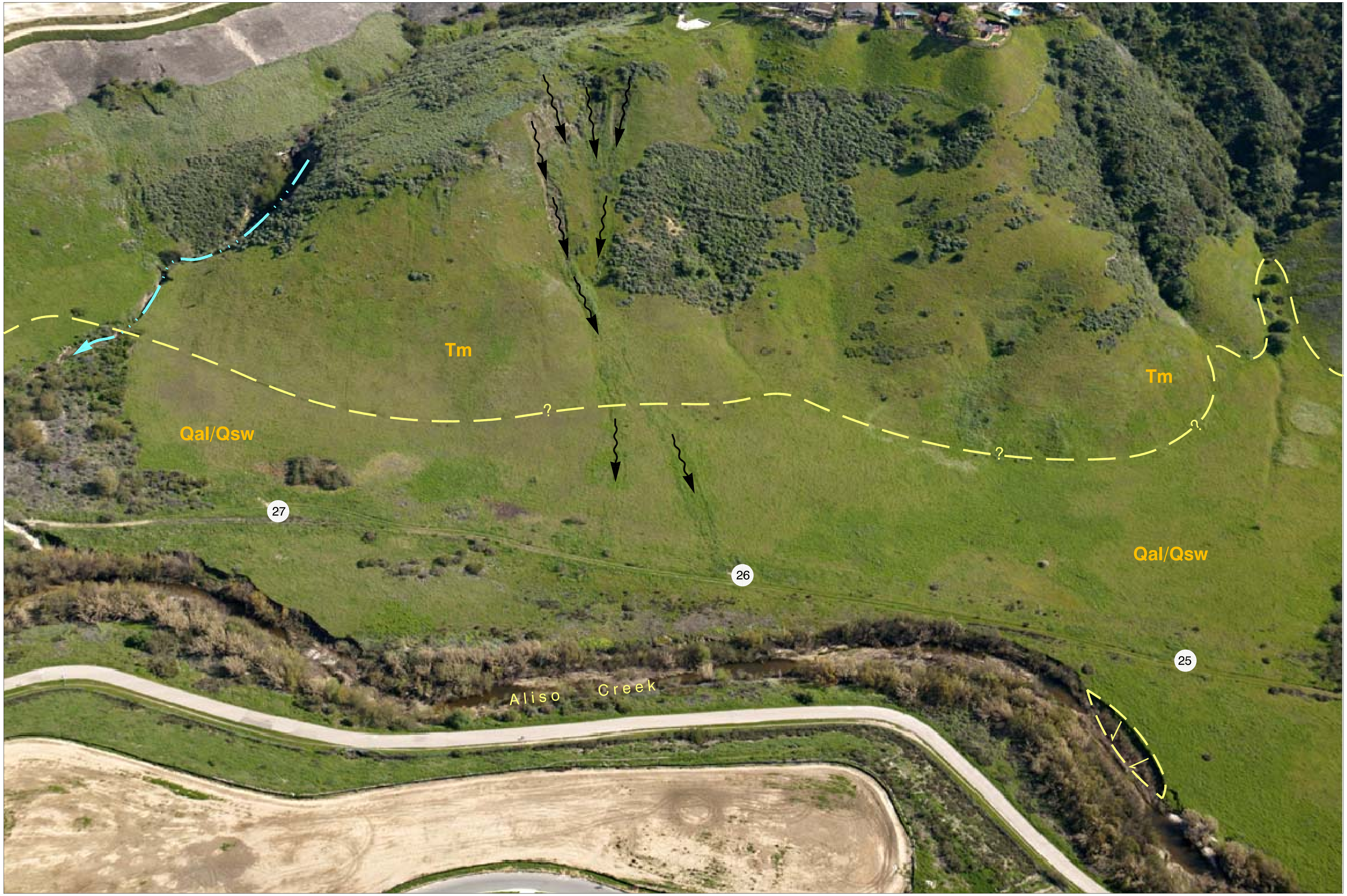
AERIAL PHOTOGRAPH
MANHOLE NOS. 23-25

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	15

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426–B12.DWG



DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····—	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
◄—··—	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
◄~~	SLOPE CREEP AND/OR DEBRIS FLOW
27	MANHOLE NO (18–INCH DIAMETER SEWER LINE)

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

202426–B13.DWG

Ninyo & Moore

AERIAL PHOTOGRAPH MANHOLE NOS. 25-27

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	16

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— —?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←·· —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←∿∿	SLOPE CREEP AND/OR DEBRIS FLOW
30	MANHOLE NO (18–INCH DIAMETER SEWER LINE)
A A'	APPROXIMATE LOCATION OF GEOLOGIC CROSS SECTION

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 27-30

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE
202426002	4/2003

FIGURE
17

202426–B14.DWG

DRAWING NOT TO SCALE

LEGEND

Qal/Qsw	ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED
Qls	LANDSLIDE DEPOSITS/CHANNEL SLUMP
Tt	TOPANGA FORMATION
Tm	MONTEREY FORMATION
— — ?	APPROXIMATE LOCATION OF GEOLOGIC CONTACT; QUERIED WHERE INFERRED
····——	APPROXIMATE LOCATION OF FAULT; DOTTED WHERE CONCEALED
←— · · —	APPROXIMATE LOCATION OF EXISTING DRAINAGE TRIBUTARY
←〰	SLOPE CREEP AND/OR DEBRIS FLOW
34	MANHOLE NO (18–INCH DIAMETER SEWER LINE)
B B'	APPROXIMATE LOCATION OF GEOLOGIC CROSS SECTION

NOTE: SCALE VARIES DUE TO OBLIQUE NATURE OF PHOTOGRAPH.
ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

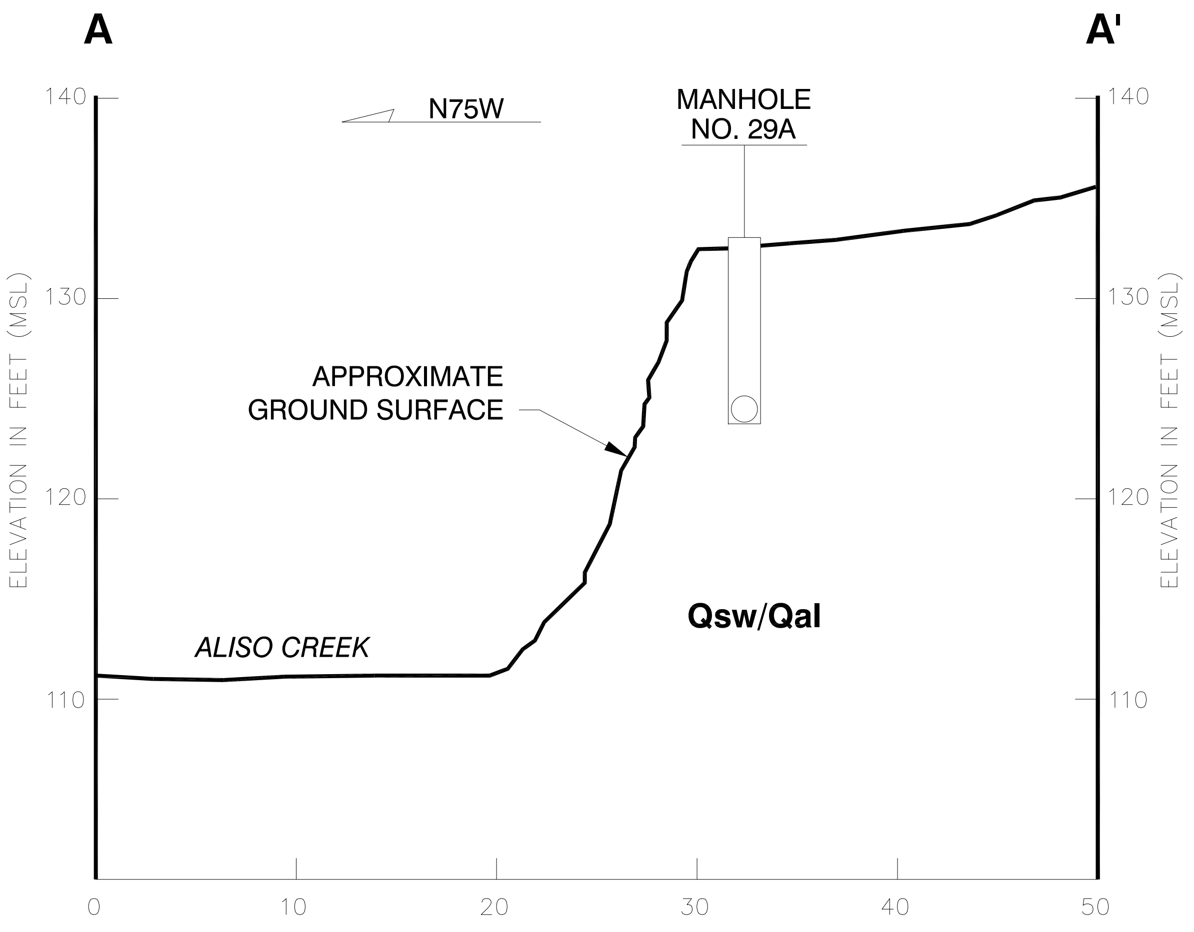
Ninyo & Moore

AERIAL PHOTOGRAPH
MANHOLE NOS. 30-34

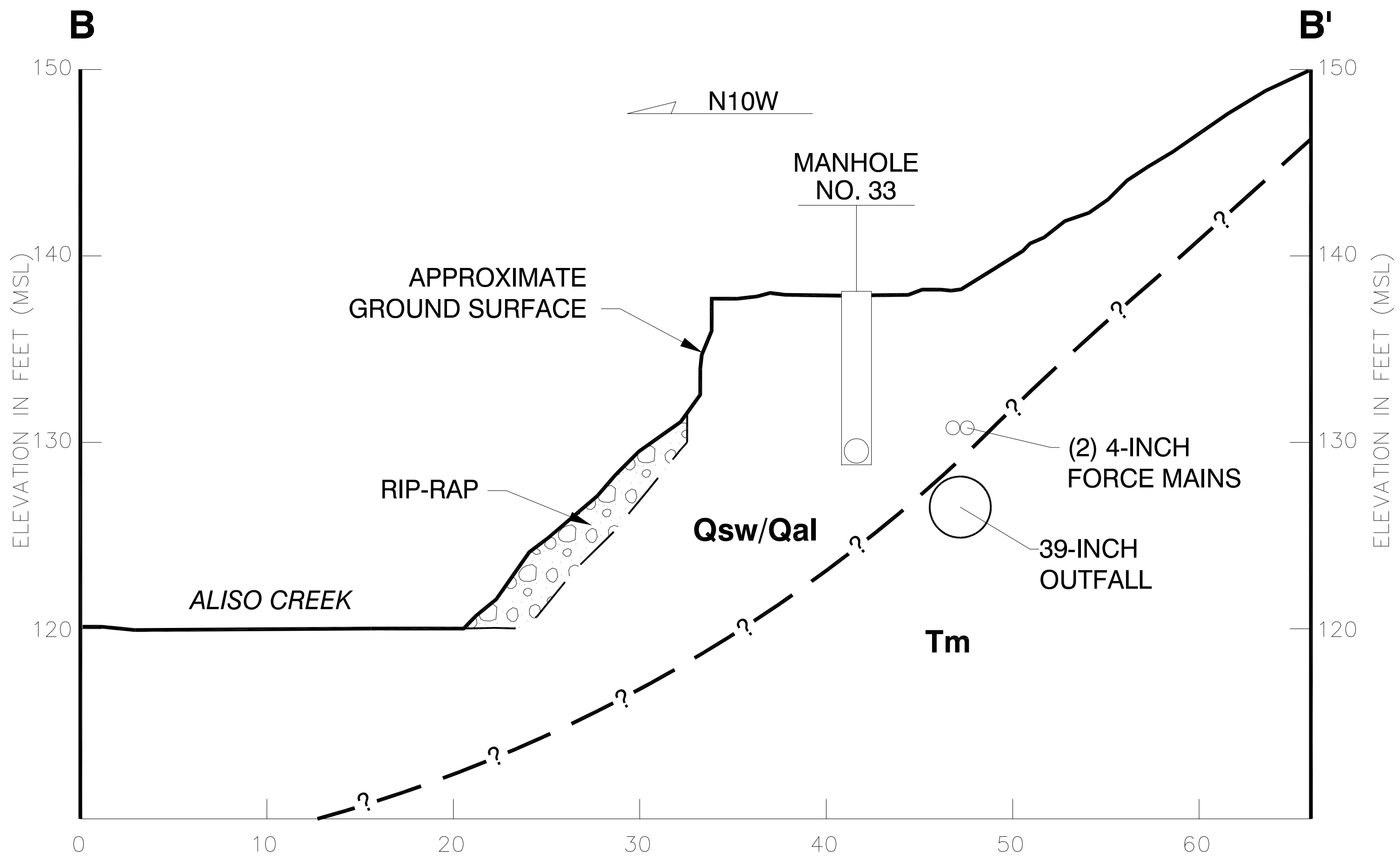
REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	18

202426-B15.DWG



STATION 146+11



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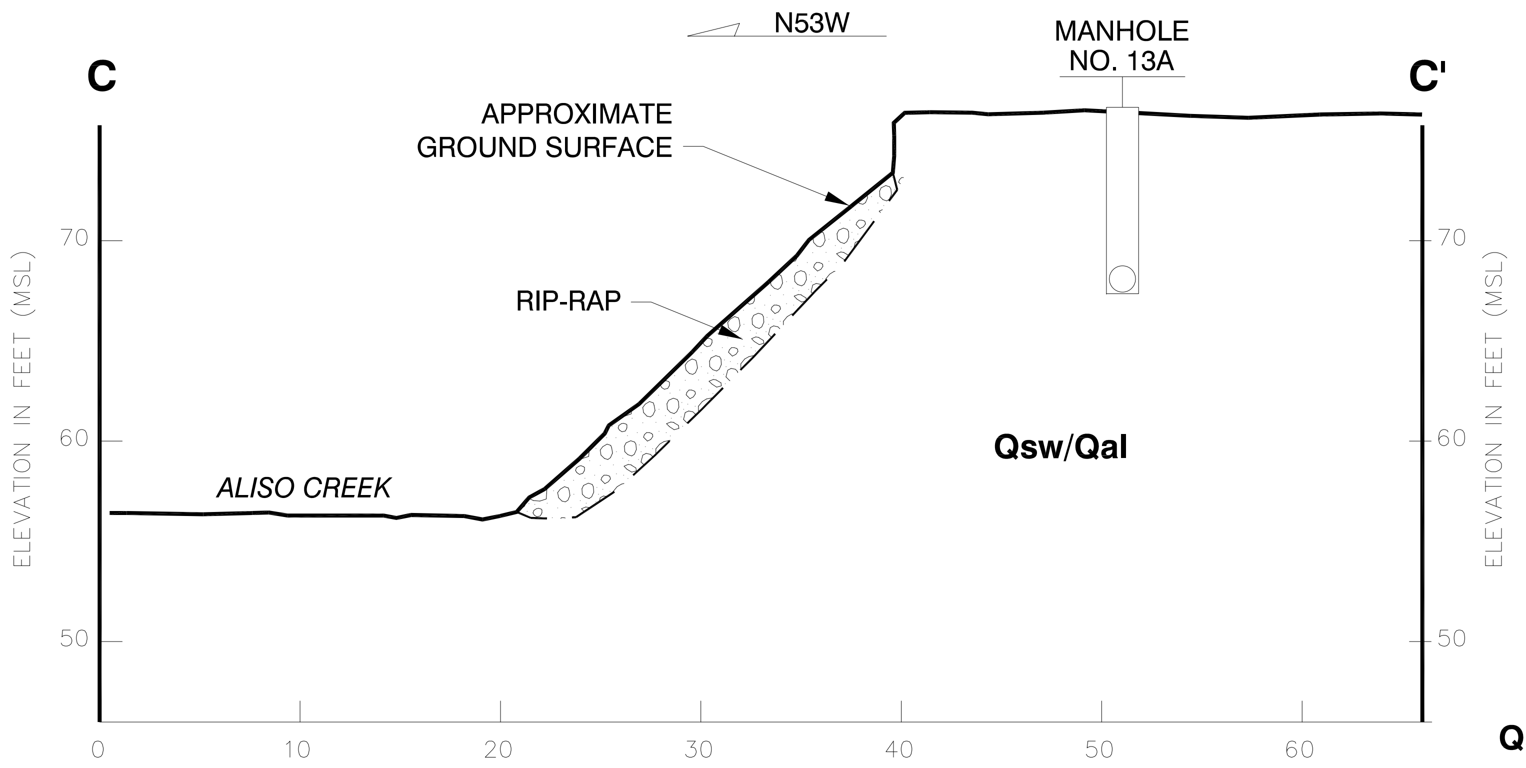

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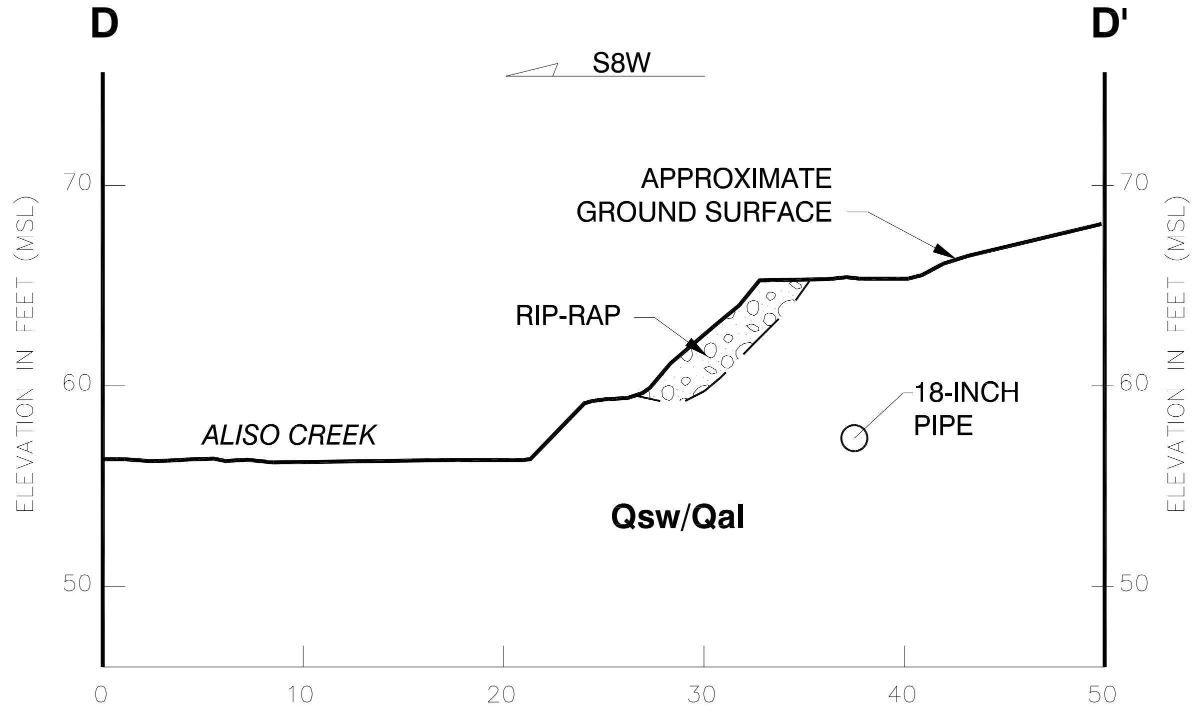


STATION 41+00

0 20 40

APPROXIMATE SCALE IN FEET

LEGEND

Qsw/Qal	SLOPE WASH AND/OR ALLUVIUM
Tm	MONTEREY FORMATION
—?—?—	APPROXIMATE GEOLOGIC CONTACT; QUERIED WHERE QUESTIONABLE

Ninyo & Moore

GEOLOGIC CROSS SECTIONS

REACES
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426002	5/2003	19

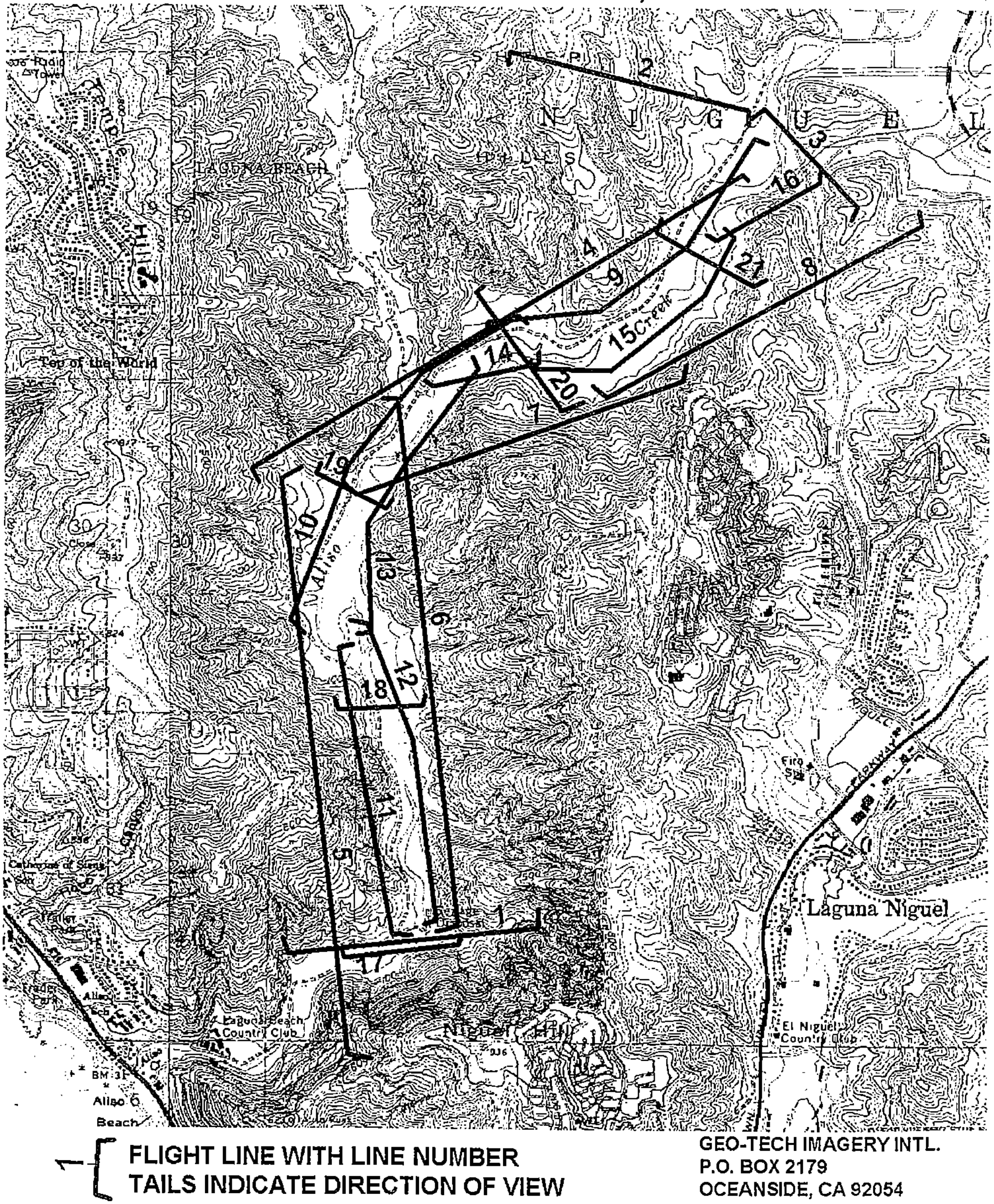
202426-B18.DWG

APPENDIX A

PHOTOGRAPHIC DOCUMENTATION

RESULTS OF GEOTECH IMAGERY INTERNATIONAL PHOTO SURVEY

FLIGHT LINES - MARCH 1, 2003



FLIGHT LINE WITH LINE NUMBER
TAILS INDICATE DIRECTION OF VIEW

GEO-TECH IMAGERY INTL.
P.O. BOX 2179
OCEANSIDE, CA 92054
760-754-8423
www.geo-tech-imagery.com

MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03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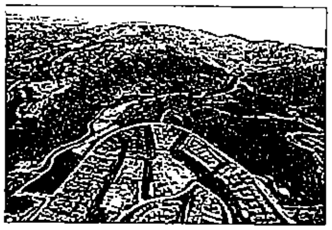
01MAR03_L01_F002.TIF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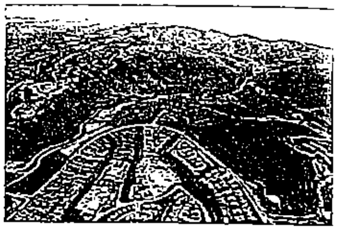
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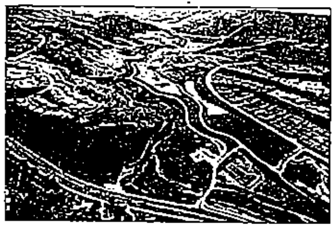
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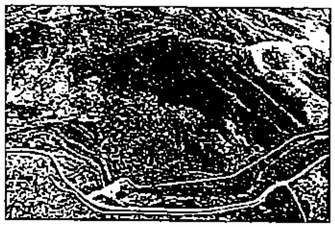
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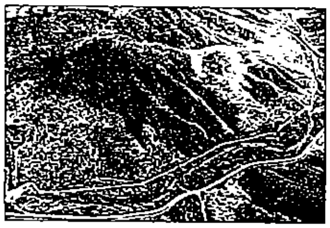
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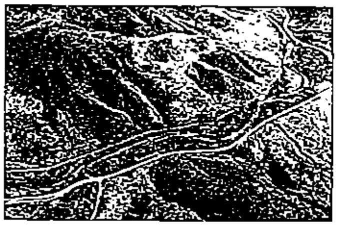
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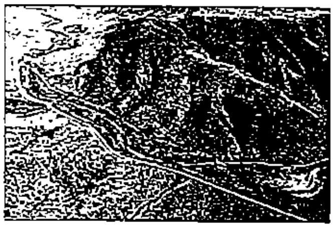
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MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03

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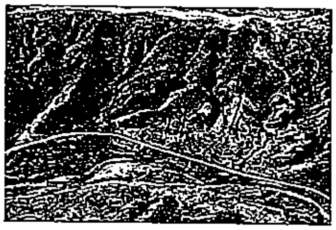

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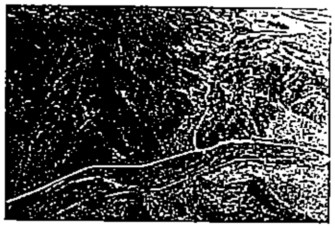

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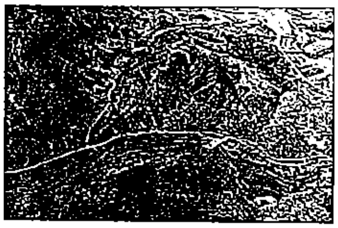

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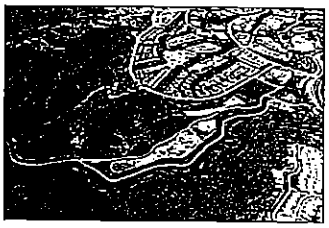

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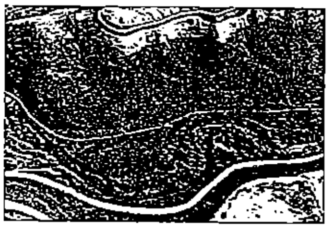

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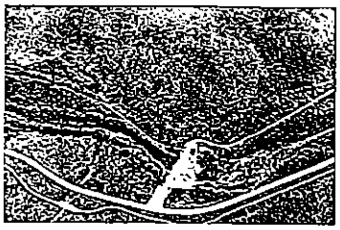
MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03



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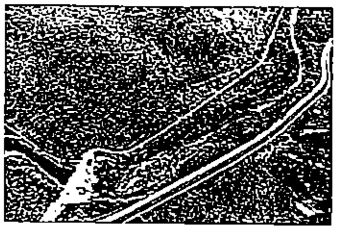

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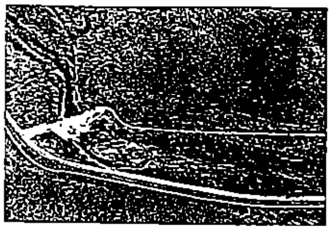

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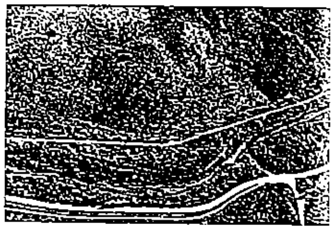

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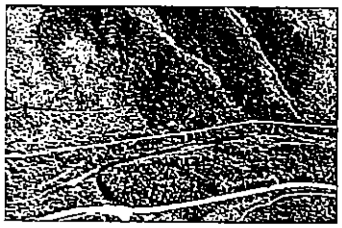

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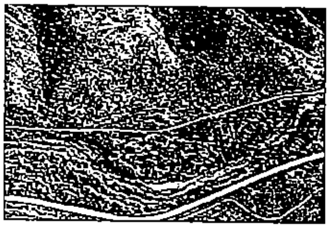

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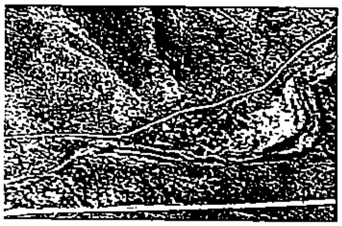

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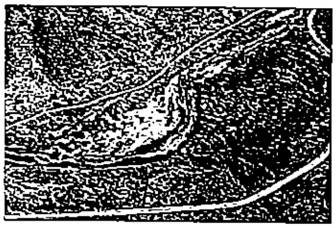

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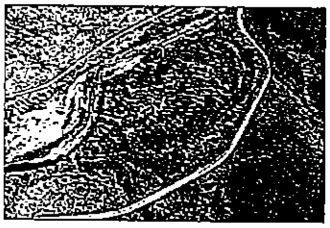

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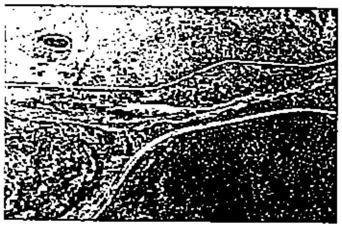

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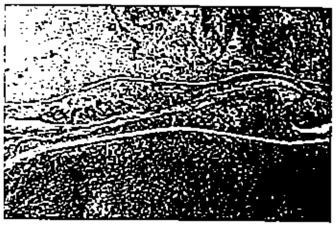

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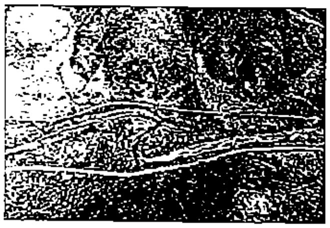

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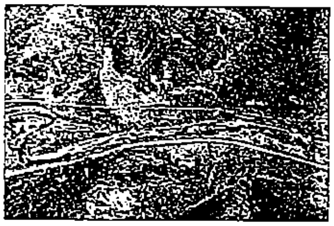

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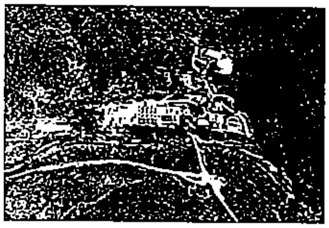

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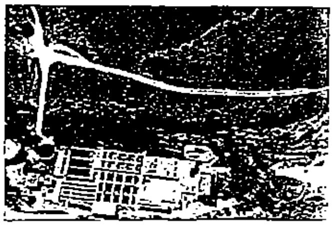

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MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03


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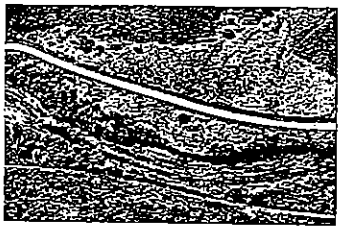
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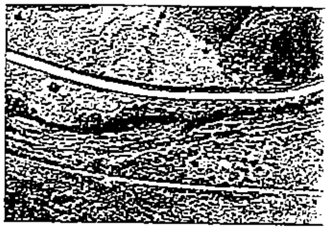
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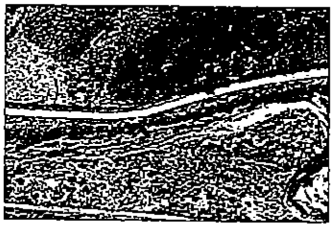
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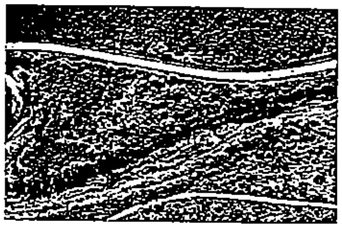
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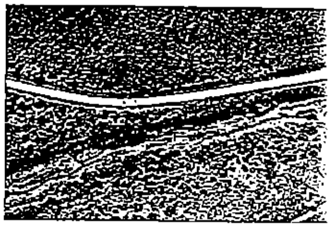
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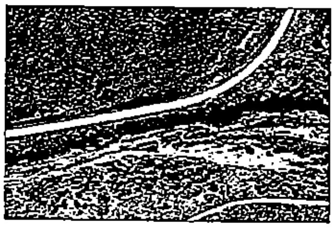
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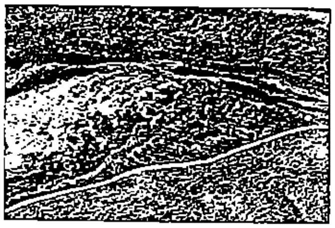
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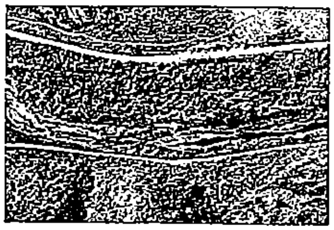
MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03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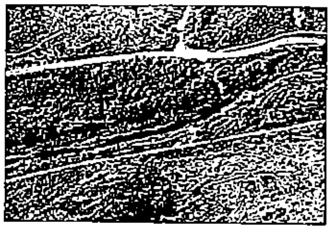
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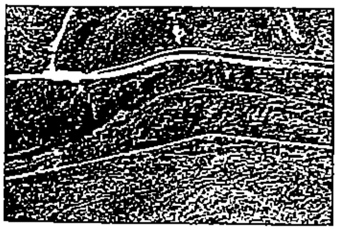
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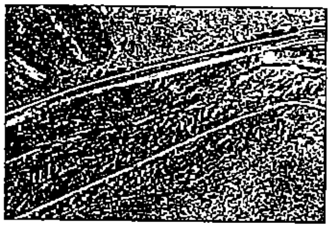
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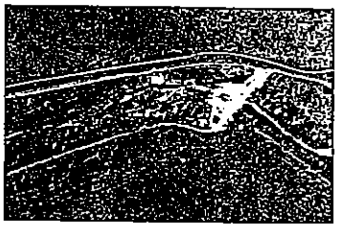
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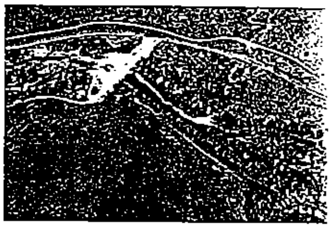
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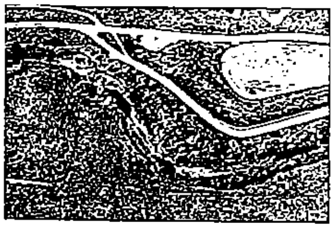
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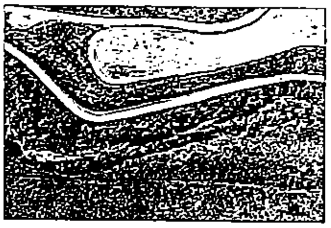
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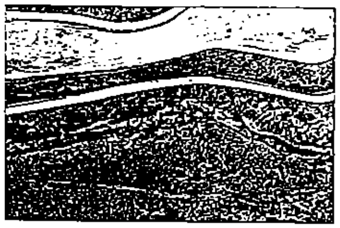
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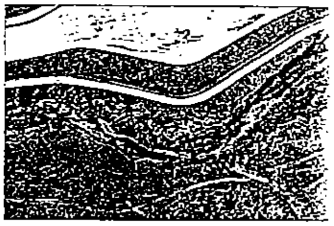
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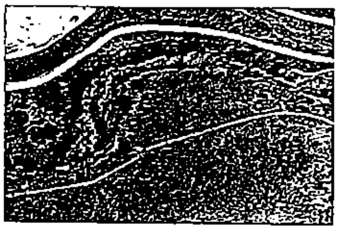
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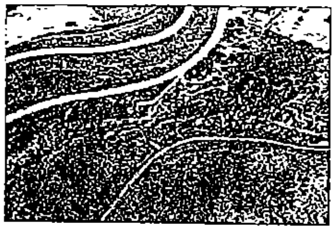
MOULTON NIGUEL WATER DIST. - ACES PROJ. 2002059 - 3-1-03



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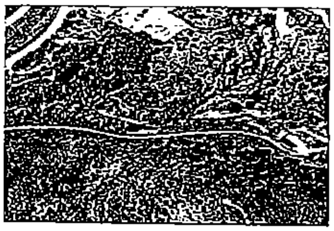

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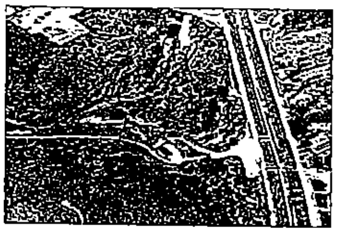

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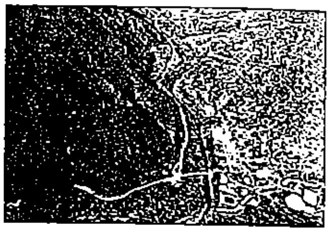

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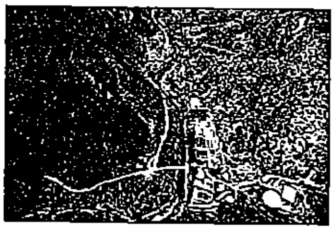

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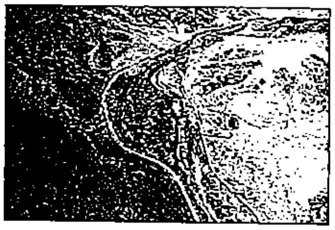

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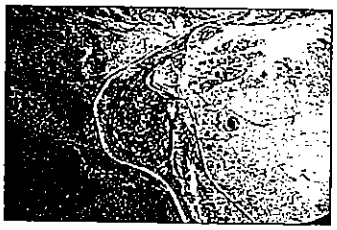

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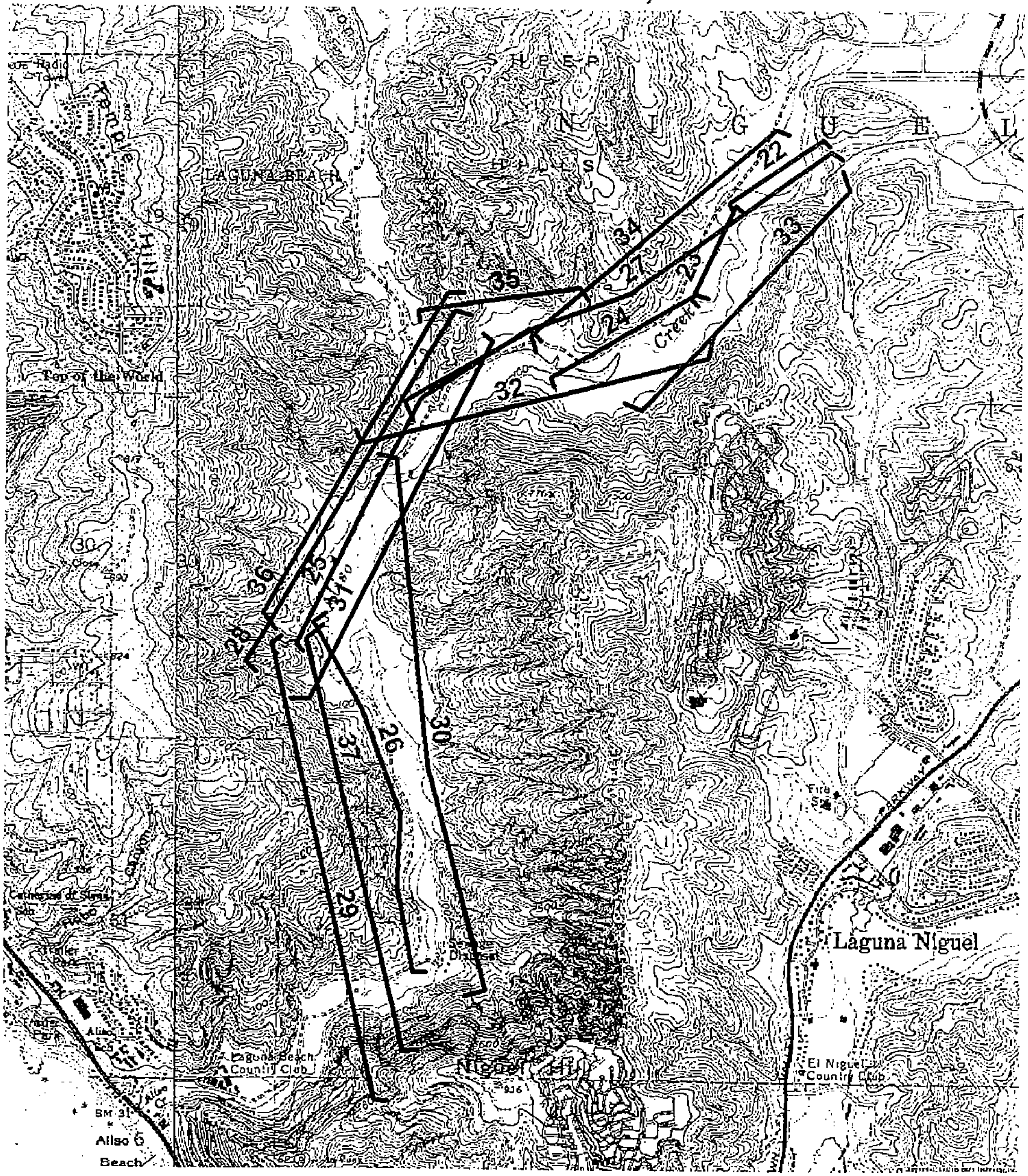
FLIGHT LINES - MARCH 7, 2003



FLIGHT LINE WITH LINE NUMBER
TAILS INDICATE DIRECTION OF VIEW

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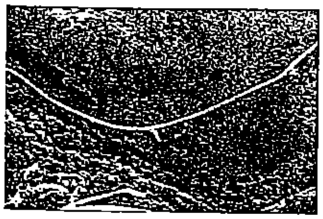

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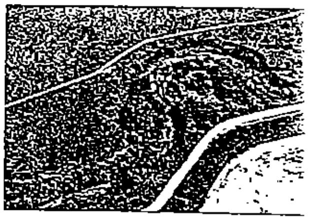

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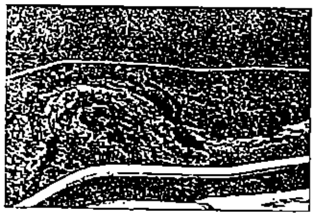

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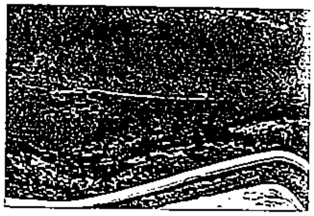

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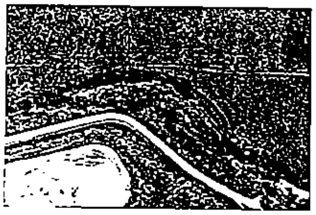

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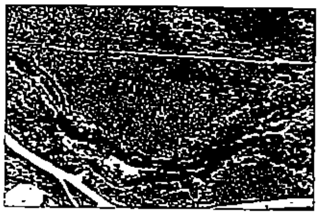

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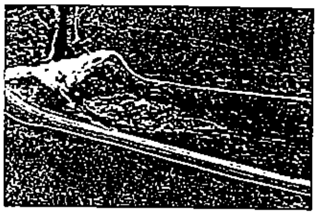

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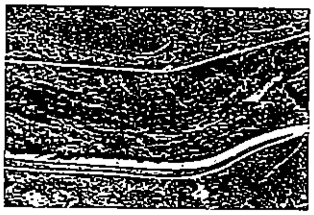

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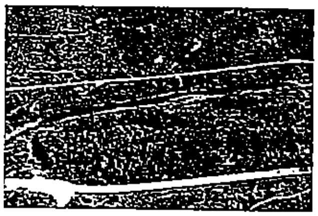

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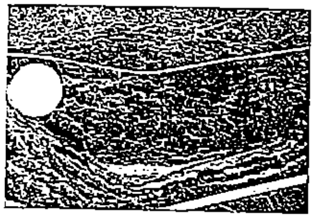

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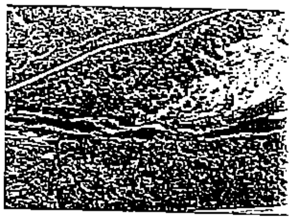

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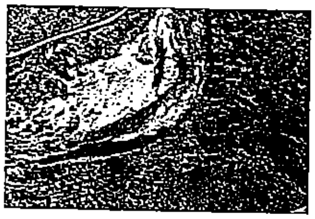

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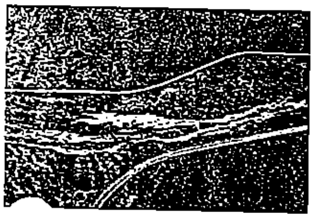

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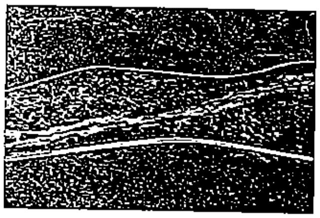

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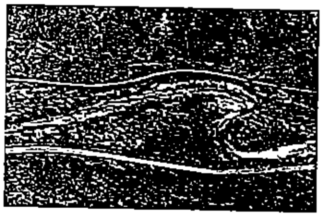

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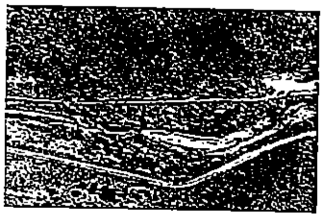

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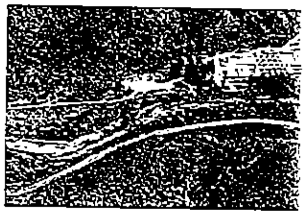

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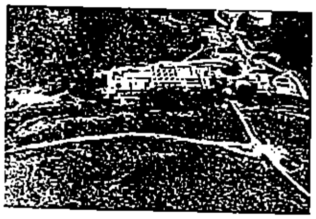

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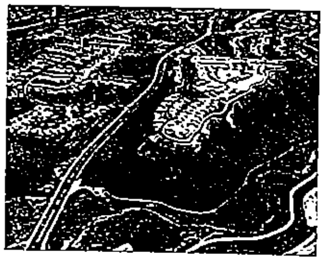

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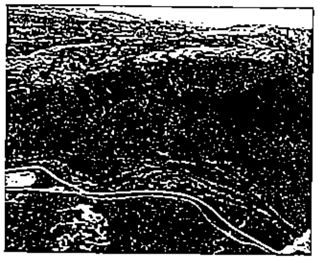
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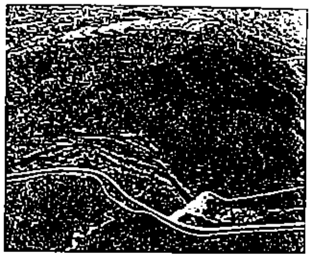
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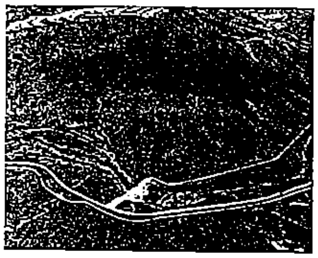
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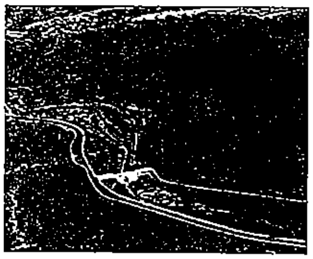
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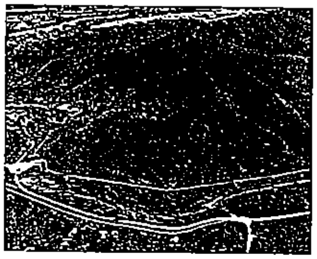
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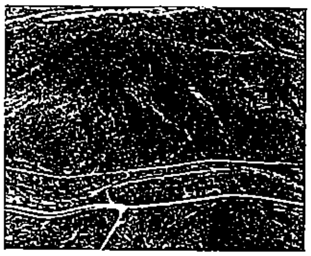
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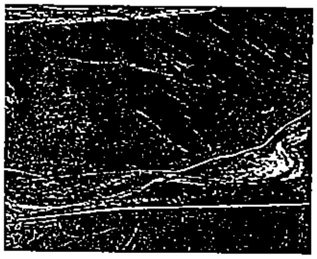
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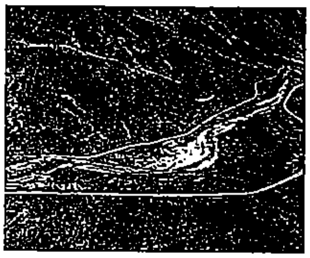
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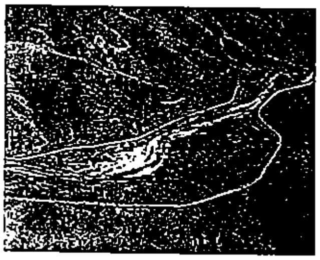
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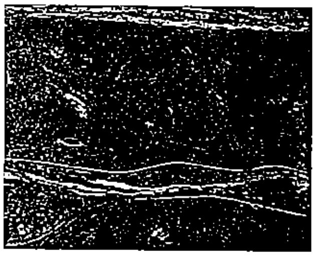
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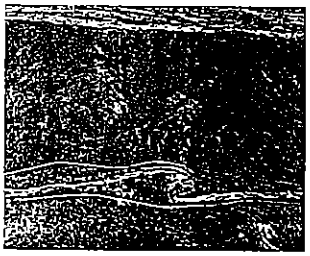
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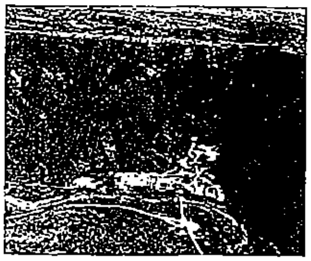
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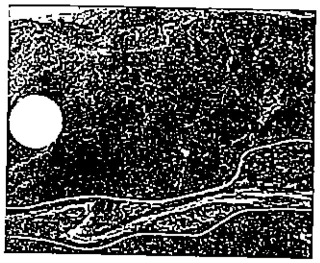
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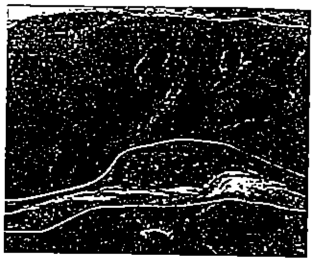
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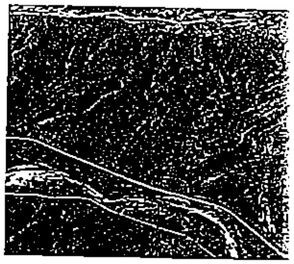
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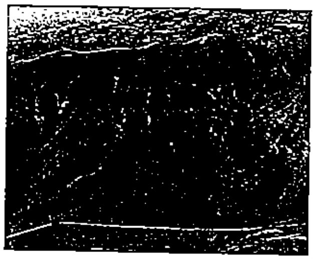
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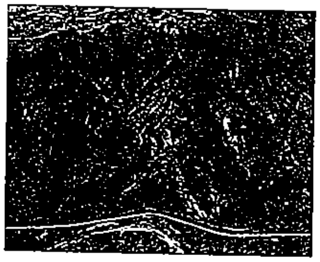
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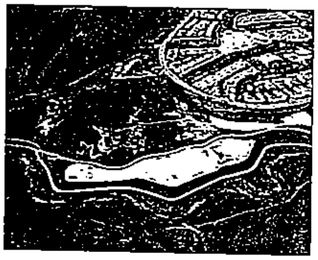
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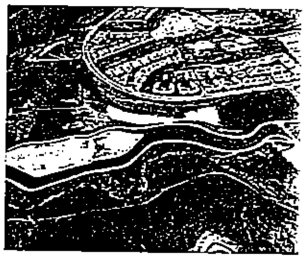
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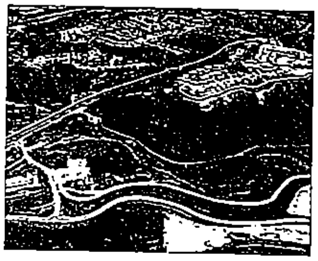
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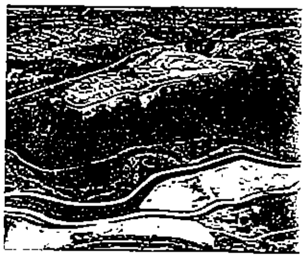
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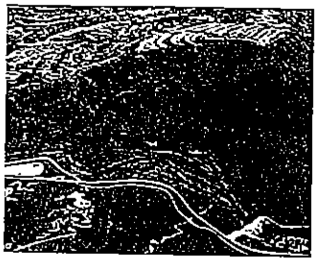
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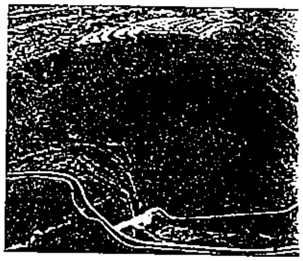
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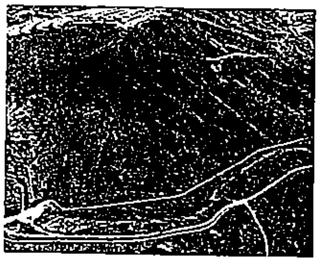
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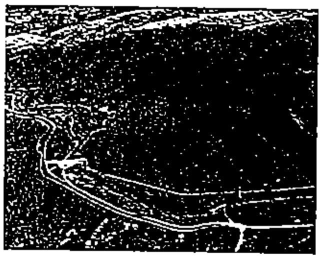
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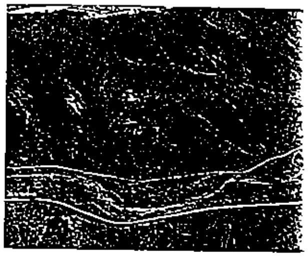
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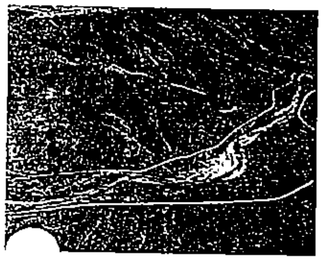
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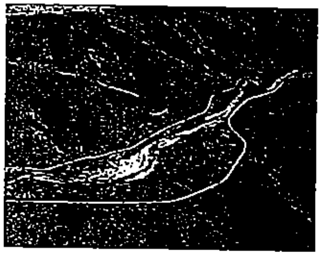
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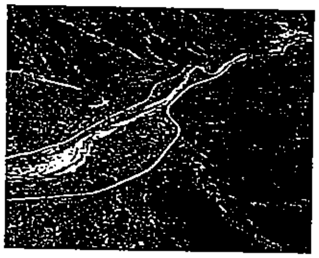
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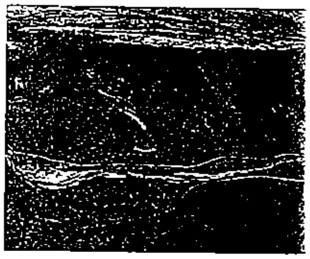
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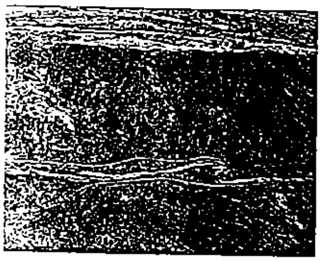
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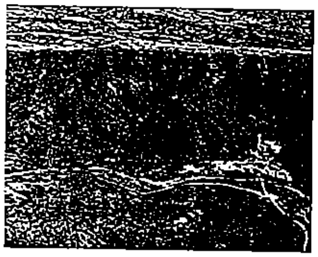
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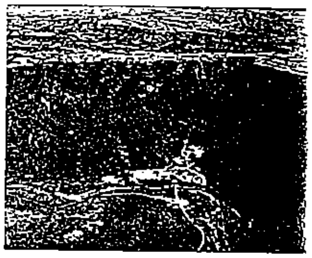
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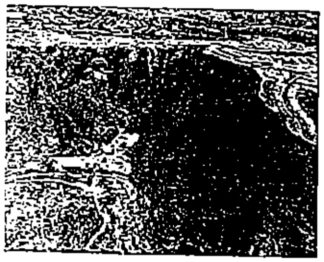
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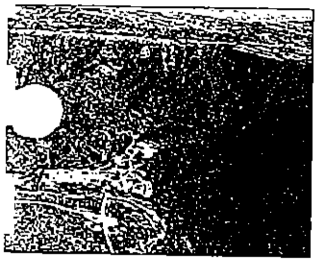

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Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

PRELIMINARY GEOTECHNICAL EVALUATION
COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
SOUTH ORANGE COUNTY
WASTEWATER AUTHORITY
LAGUNA NIGUEL, CALIFORNIA

PREPARED FOR:
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PREPARED BY:
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November 18, 2011
Project No. 202426005

Ninyo & Moore
Geotechnical and Environmental Sciences Consultants

November 18, 2011
Project No. 202426005

Mr. Ed Matthews
Dudek & Associates
750 Second Street
Encinitas, California 92024

Subject: Preliminary Geotechnical Evaluation
Coastal Treatment Plant Export Sludge System
South Orange County Wastewater Authority
Laguna Niguel, California

Dear Mr. Matthews:

In accordance with your authorization, Ninyo & Moore has performed a preliminary geotechnical evaluation for the preliminary design of the Coastal Treatment Plant Export Sludge System located in Laguna Niguel, California. The purpose of our geotechnical consulting services was to evaluate the soil and geologic conditions along the pipeline alignments and to provide geotechnical input to assist in the alignment selection and preliminary pipeline design.

We appreciate the opportunity to be of service on this project.

Sincerely,
NINYO & MOORE

James J Barton

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Senior Geologist

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CERTIFIED ENGINEERING GEOLOGIST
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Daniel Chu, PhD, PE, GE
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JJB/LTJ/DC/lr

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1. INTRODUCTION

In accordance with your request, we have performed a preliminary geotechnical evaluation for the preliminary design of the Coastal Treatment Plant Export Sludge Force System for the South Orange County Wastewater Authority (SOCWA). The purpose of our geotechnical services was to evaluate the soil and geologic conditions along the pipeline alignments and to provide geotechnical input to assist in the alignment selection and preliminary pipeline design.

The project includes alignment selection and preliminary design of a new sludge force main pipeline between the Coastal Treatment Plant and Alicia Parkway in the Aliso and Wood Canyons Wilderness Park area (Figure 1). The new pipeline will replace two existing deteriorating 4-inch sludge pipelines constructed along the east side of Aliso Creek in 1982. Replacement of the pipelines has been planned since the early 1990’s and the South Coast Water District constructed two of three phases of a replacement pipeline in early 2000. The third phase and final link of the replacement pipeline was not completed and the two pipelines constructed have not been placed into operation.

Several factors have impacted the design and construction of the replacement pipeline. In 2000, the replacement sludge force main pipeline was combined with the planned Aliso Creek Emergency Sewer (ACES) project along the west side of the Aliso Creek. This project was designed, but not constructed. In addition, the County of Orange has presented various plans for park improvements, which impact the pipeline construction and maintenance. The County of Orange and the Army Corps of Engineers are also involved in studies of environmental restoration in the wilderness park. Design and construction of these improvements is uncertain and SOCWA has decided to initiate the design process for the replacement sludge force main to replace the existing force mains.

The alignment alternatives currently considered include following the alignment of the existing force mains along the east side of the creek or following the existing AWMA Road on the west side of the creek to the Coastal Treatment Plant. The east side alignment would cross Sulphur Creek near Alicia Parkway and connect to the existing force main in Alicia Parkway. The preliminary design may consider a pipe bridge crossing the Sulphur Creek or an Arizona Crossing (concrete encasement) along the east side. The west side alignment would connect to the existing force main located in AWMA Road near the gated entry to the Wilderness Park. Depending on ground surface elevations, the invert of the pipe would generally be approximately 4 feet deep. In some areas, the pipe could be as deep as 24 feet. The pipe would generally be a 6-inch-diameter ductile iron pipe. Due to the depth of the pipe in some areas, direction drilling may be considered. If directional drilling is considered, the pipe would consist of 8-inch-diameter high density polyethylene pipe. The feasibility of pipe bursting the existing 4-inch mains will also be evaluated. The preliminary design will be performed to a level equivalent to a 30 percent design.

2. SCOPE OF SERVICES

Our scope of services for this geotechnical evaluation was performed in accordance with our proposal dated July 12, 2010, and included the following:

- Review of our files regarding previous work performed along the alignment area including geologic maps, topographic maps, aerial photographs, boring logs, laboratory test results, and existing pipeline plans.
- A field reconnaissance by our engineering geologist on September 22, 2011 of the project alignment to evaluate the current site conditions.
- Preparation of this report summarizing the geologic conditions along the alignment and the geotechnical aspects of the pipeline project. Geotechnical design and construction considerations are presented for preliminary planning purposes.

Our services included review and summary of previous work along the alignments. This report is intended as a preliminary geotechnical evaluation of the proposed pipeline alignment for planning purposes. Evaluation of creek erosion and its effects on the existing embankments adjacent to the force main alignments was not performed. We understand that creek erosion and the potential for seasonal flooding will be evaluated by others and mitigation recommendations will be developed at a later date. Detailed evaluation of landslides along the alignment was not included in the scope of work for this study.

3. BACKGROUND

Ninyo & Moore has performed several geotechnical evaluations along east and west sides of Aliso Creek between 2000 and 2009. Previous geotechnical evaluation reports are referenced in Section 13 of this report.

Our initial work was associated with the ACES project in 2000 and 2001. This work included three phases of subsurface exploration for a geotechnical evaluation of the planned pipeline alignment along the west side of Aliso Creek. In 2003 we performed a preliminary evaluation for the Rehabilitation of the East Aliso Creek Emergency Sewer (REACES) project. This evaluation included geologic mapping along the east side of Aliso Creek, preliminary assessment of the stability of the existing pipelines with regard to creek embankments, and an aerial photographic survey along the alignment. Subsurface exploration was not performed. A separate hydrologic study was performed by Rivertech, Inc. (2009), to evaluate stabilization of the east bank of the creek from the perspective of river mechanics. In 2005, a slope failure along the west side of the creek encroached into the existing AWMA Road. The road was realigned approximately 100 feet west of the failure (Ninyo & Moore, 2005). In 2009 we performed a preliminary evaluation for the Coastal Treatment Plant Access Road Realignment Study. This evaluation included limited subsurface exploration along the east side of Aliso Creek to provide geotechnical data for preliminary design considerations.

4. SITE DESCRIPTION

The project alignments are located in the Aliso Canyon Wilderness Park. The pipeline alignment generally parallels Aliso Creek which meanders through Aliso Canyon with relatively steep hillsides ascending to residential developments. Canyon slopes are on the order of 400 or more feet above the canyon floor. Aliso Creek is generally a north-south trending tributary. Near Alicia Parkway, the creek branches to the east-west trending Sulphur Creek. The slopes bordering the canyon include several smaller drainages which merge with Aliso Creek.

The creek has incised below the valley bottom to depths of approximately 4 to 25 feet. Elevations along the creek bottom range from approximately 120 feet above mean sea level (MSL) at the north end (near Alicia Parkway) to approximately 32 feet above MSL at the south end near the Coastal Treatment Plant (CTP). Some of the creek channel embankments are near vertical. At some locations channel slumping has occurred and rip-rap has been placed to mitigate erosion. Vegetation along the creek embankments and valley floor consist of moderate to thick cover of weeds, shrubs and some trees. A brief description of the east and west sides of the creek are presented below.

4.1. East Side

The east side of the creek includes an unpaved access road that roughly parallels the creek from Aliso Parkway to the CTP. The access road is gently inclined with an elevation of approximately 140 feet above MSL at the entrance from Alicia Parkway to approximately 50 feet MSL at the CTP. Several east-west trending drainage gulleys are present incising the canyon slopes. These gullies are interrupted by the access road and/or drain to the creek. A concrete lined rip-rap gulley up to about 7 feet in depth crosses the access road between Manholes 27 and 28 (Figure 2). Smaller concrete lined drainage swales are also present crossing the road. A concrete access road and drop structure, (ACWHEP Dam Access), crosses the creek near Manhole 21 (Figure 3). The drop structure descends from the road near the center of the creek approximately 20 feet. The unpaved access road is relatively close (within 20 feet) to the western edge of the creek embankment near Sulfur Creek and south of the drop structure at several locations (Figures 2 through 7).

Based on our review of available plans for existing pipelines along the east side of the creek, the pipelines from closest to farthest from the creek consist of one 18-inch-diameter VCP sewer line, two 4-inch diameter force sewer mains (sludge) and one 36- to 39-inch RCP ocean outfall sewer line (Boyle Engineering, 1978). The pipelines are roughly parallel and generally within 10 feet of each other. Manholes for the 18-inch VCP are numbered from 1 to 34 beginning near the treatment plant as referenced on the plan and profile sheets (Boyle Engineering, 1968). The force mains and outfall line trend away from the 18-inch line between Manhole Nos. 6A and 11A and roughly parallel the base of the canyon slopes (Figures 5 and 6). The force mains and outfall line trend parallel and within approximately 20 to 40 feet of the 18-inch line approximately between

Manhole Nos. 22 and 31 (Figures 2 and 3). The force mains are shown within approximately 5 feet of the 18-inch sewer line between Manhole Nos. 32 and 34 (Figure 2). The force main extends to depths generally ranging from 2 to 10 feet deep. In areas where the pipelines trend below the canyon slopes, the depth of the lines extends down to about 24 feet deep (between Manhole Nos. 16A and 16, Figure 4). The 36-inch RCP changes to a 39-inch RCP northeast of Manhole No. 14, (Figures 4 and 5). In addition, an abandoned 18-inch PVC irrigation pipe is present roughly parallel to the east channel slopes of the creek, south of Manhole 14 (Figure 5). An additional abandoned 8-inch PVC pipe is present at the base of the hillside east of Manhole Nos. 18 and 19 (Figure 4). The limits of the abandoned pipes are unknown.

4.2 West Side

The west side of the creek is bordered by an asphalt concrete paved access road referred to as AWMA Road. The road roughly parallels the creek from Woods Canyon to the CTP. North of the Woods Canyon, the road branches at a cul-de sac into a lower AWMA and upper AWMA Road. Topographically, AWMA Road is relatively flat from the cul de sac at an elevation of approximately 118 feet above MSL to approximately 83 feet near the base of the adjacent hillsides (Figure 5). The road then follows the base of the hillside with gentle slopes up and down to the CTP at an elevation of approximately 50 feet MSL. The area adjacent to the road is occupied by undeveloped parkland of the Aliso and Wood Canyons Wilderness Park. Existing sewer lines are present under the paved portion of the upper AWMA Road extending to the cul de sac where a gate is present. Details regarding the sewer lines were not available at the time of this report. Several storm drains consisting of 12 to 36-inch-diameter steel pipes cross the road from smaller drainage tributaries. In particular, three, 36-inch-diameter storm drains within a concrete apron cross the road near the Aliso Creek Trail (Figure 4). The slope below the outlet was covered with rip-rap extending down 15 or more feet along the east side of the road. At the time of our visit, water was flowing through the pipes. South of this drainage culvert, a 24-inch-diameter PVC pipe was exposed parallel to the east side of the road.

5. SUBSURFACE EXPLORATION AND LABORATORY TESTING

Subsurface exploration was previously conducted on both sides of the creek. The exploration consisted of several small and large diameter borings and continuous core borings to depths ranging from approximately 16½ to 85 feet below the ground surface with a truck-mounted drilling equipment. The approximate locations of the previous borings are shown on Figures 2 through 7. Logs of the borings are included in Appendix A.

6. GEOLOGY AND SUBSURFACE CONDITIONS

6.1. Geologic Setting

The project site is situated in the San Joaquin Hills, within the northwestern portion of the Peninsular Ranges Geomorphic Province of California (Norris and Webb, 1990). The San Joaquin Hills consist of a series of generally northwest trending hills bounded by the Los Angeles Basin on the north, the Pacific Ocean on the southwest, and the Santa Ana Mountains and San Juan Creek on the east and south. The roughly north-south Aliso Creek meanders through a deep canyon surrounded by moderate to steeply sloped hillsides. Alluvium derived from the surrounding highlands has filled the bottom of the valley to variable depths and has been incised by the Aliso Creek to form paired stream terraces adjacent to the active stream channel.

Based on our field reconnaissance and the referenced geologic maps of the area, the hillsides surrounding the site are underlain by bedrock of the Miocene-age Topanga, Monterey and Capistrano Formations, which consist of interbedded siltstones and sandstones (Figure 8). The San Onofre Breccia is also present in the hillside areas. A few natural slopes adjacent to the alignment include thick outcrops of resistant, strongly cemented sandstone. Regional mapping of the bedrock structure indicates that bedding of the Topanga Formation generally dips towards the south at approximately 8 to 22 degrees. Bedding of the Monterey Formation generally dips towards the east at approximately 8 to 25 degrees (Morton and others, 1974).

Materials that have washed and/or mass-wasted from the surface of the hills have collected at the base of the hills to form slope wash deposits. Debris flow deposits are also present on the steeper hillsides. Large ancient landslides composed of disturbed bedrock material have also been mapped along the sides of the canyon.

6.2. Site Geology

Based on the results of our previous work and recent subsurface exploration, the alignment is underlain by variable thickness of Quaternary-age older alluvium and slope wash deposits over bedrock materials of the Miocene-age Topanga and Monterey Formations. Large bedrock landslides are mapped near the middle portions of the project alignment and near the CTP (Figure 3, 4, 5 and 7). Some minor fill soils associated with the access roads, maintenance of the creek channel and utility trenches are also present. Generalized descriptions of the geologic units observed during our evaluation are presented below.

6.2.1. Debris Flows

Evidence of shallow debris flows (scars) were observed along the hillsides east of the creek. Deposits from debris flows typically consist of topsoil, colluvium, or highly weathered bedrock materials that flow down slope when saturated from seasonal precipitation. Debris flow deposits were not observed crossing the existing pipeline alignment.

6.2.2. Alluvium (Qal)

Alluvium, consisting of recent deposits of unconsolidated sand, silt and clay along the active drainage tributaries, were observed near the surface. These materials are expected to be relatively shallow (less than 10 feet) where they cross the proposed alignments.

6.2.3. Older Alluvium and/or Slope Wash (Qoal/Qsw); Undifferentiated

Older alluvium and/or slope wash deposits (undifferentiated) were observed in exposures along both sides of the creek, as well as road cuts and within borings adjacent to the roadways. The older alluvium and/or slope wash deposits typically consist of mottled brown, grayish brown, and reddish brown, gray to black, damp to moist, firm to hard, clay and silt and very loose to medium dense, clayey sand. The alluvium and/or slope wash is expected to extend to depths of approximately 20 or more feet below the ground surface. Some recent slumping of the steep creek channel slopes were observed within the alluvial deposits.

6.2.4. Landslides (Qls)

Relatively large landslide complexes have been mapped near the alignment (Morton, 1974) and were observed in our photographic review and during our reconnaissance (Figure 3, 4, 5, and 7). No known subsurface exploration has been performed within the landslide complexes along the east side of the creek. Our previous work on the west side of the creek included subsurface exploration near the base of two mapped landslides along the AWMA Road. Landslide rupture surfaces were not encountered within the depth of our previous exploration. Based on the results of our previous exploration, the basal rupture surface of these two landslides (if present) is situated below the depths of coring of approximately 80.0 and 85.0 feet. A comprehensive evaluation of the ancient landslides and stability analysis of the landslide masses was beyond the scope of our previous work.

We did not observe outcrop exposures or failure planes of the landslide masses along accessible areas of the creek channel. In addition, we did not observe ground cracks, scarps, seeps or other signs of recent landslide movement. Based on previous work and our recent reconnaissance, the landslide complexes are relatively ancient and consist of a variety of translational block type failures within the bedrock materials. The landslide complexes are covered with an unknown thickness of topsoil, slope wash and/or alluvium. We anticipate that the basal failure planes of the landslides are relatively deep below the creek bottom. Shallower rupture surfaces and fracture planes may be present at relatively shallow depths, particularly where smaller landslides are mapped within large landslide features.

6.2.5. Topanga Formation

Based on regional mapping as well as our observations of limited exposures, the Topanga Formation is generally present south of Manhole 17 (Figure 4). Topanga Formation has also been mapped in the slopes west of the creek and south of the fork between the upper and lower AWMA Road (Figure 3). Where exposed or encountered during the previous subsurface exploration, the formation consists of yellowish and orange brown, weakly to strongly cemented, sandstone and some reddish brown and gray, weakly to moderately indurated siltstone.

6.2.6. Monterey Formation

Based on regional mapping as well as our observations of limited exposures and previous subsurface exploration, the Monterey Formation is present north of Manhole 24 (Figure 3). Where exposed, the formation consists of white to gray, weakly to moderately indurated, tuffaceous siltstones and gray, weakly to moderately cemented sandstone.

7. GROUNDWATER

No groundwater seepage or active springs were observed during our reconnaissance near the base of the canyon slopes or in accessible areas of the creek channel slopes. Groundwater was previously encountered in borings drilled on the east and west sides of the creek at depths varying between 6½ and 39 feet at the time of the drilling. In general, groundwater is expected to be near the elevation of the adjacent stream level. Groundwater levels along the alignment can vary with seasonal storms, change in topography, stratigraphy, runoff and other environmental changes.

8. FAULTING AND SEISMICITY

The tectonic structure of the Peninsular Ranges Geomorphic Province is dominated by northwest-trending, right-lateral, strike-slip fault systems. The site is considered to be in a seismically active area, as is the majority of southern California. There are, however, no known active fault traces crossing the alignment. Several older faults (pre-Pleistocene) are present in the vicinity of the alignment. A few of the mapped faults cross near the middle and end of the realignment (Figures 4 and 6). These faults are considered seismically inactive, but may be a concern with regard to excavation stability. Regional faults are presented on Figure 9.

Table 1 lists selected principal known active faults that may affect the subject site and the maximum moment magnitude (M_{max}) as published by Cao, et al. (2003) for the California Geological Survey. The approximate fault-to-site distances were calculated using the computer program FRISKSP (Blake, 2001) based on a location near the midway point of the creek.

Table 1 – Principal Active Faults

Fault	**Approximate Fault to Site Distance miles[1] (km)**	**Maximum Moment Magnitude[2] (M_{max})**
San Joaquin Hills Blind Thrust	0.1 (0.2)	6.6
Newport-Inglewood (Offshore)	4.5 (7.2)	7.1
Newport-Inglewood (L.A. Basin)	11.9 (19.1)	7.1
Chino-Central Ave. (Elsinore)	18.1 (29.1)	6.7
Elsinore (Glen Ivy)	19.8 (31.8)	6.8
Palos Verdes	19.8 (31.9)	7.3
Coronado Bank	22.1 (35.5)	7.6
Whittier	22.2 (35.7)	6.8
Elsinore (Temecula)	23.2 (37.3)	6.8
Rose Canyon	34.1 (54.9)	7.2

Notes:
[1] Blake, 2001
[2] Cao, et al., 2003

The principal seismic hazards considered at the subject site are surface ground rupture, ground motion, liquefaction and slope stability. A brief description of these hazards and the potential for their occurrences on site are discussed below.

8.1. Surface Rupture

The probability of damage due to surface ground rupture is low due to the lack of known active faults crossing the site. Surface ground cracking related to shaking from distant events is not considered a significant hazard, although it is a possibility.

8.2. Ground Motion

The 2010 California Building Code (CBC) recommends that the design of structures be based on the horizontal peak ground acceleration (PGA) having a 2 percent probability of exceedance in 50 years which is defined as the Maximum Considered Earthquake (MCE). The statistical return period for PGA_{MCE} is approximately 2,475 years. The probabilistic PGA_{MCE} for the site was calculated as 0.61g using the United States Geological Survey (USGS, 2011) Ground Motion Calculator (web-based). The design PGA was estimated to be 0.41g using the USGS Ground Motion Parameter Calculator. These estimates of ground motion do not include near-source factors that may be applicable to the design of structures on site.

8.3. Liquefaction Potential

Liquefaction is the phenomenon in which loosely deposited granular soils with silt and clay contents of less than approximately 35 percent and non-plastic silts located below the water table undergo rapid loss of shear strength when subjected to strong earthquake-induced ground shaking. Ground shaking of sufficient duration results in the loss of grain-to-grain contact due to a rapid rise in pore water pressure, and causes the soil to behave as a fluid for a short period of time. Liquefaction is known generally to occur in saturated or near-saturated cohesionless soils at depths shallower than 50 feet below the ground surface. Factors known to influence liquefaction potential include composition and thickness of soil layers, grain size, relative density, groundwater level, degree of saturation, and both intensity and duration of ground shaking.

The California Seismic Hazards Zones Map indicates the Aliso Creek and alignment are potentially liquefiable (Figure 10). Based on our previous work and recent subsurface evaluation, we anticipate that the majority of the older alluvial deposits at the site contain a high proportion of silt and clay and, therefore, are considered to have a low liquefaction potential. However, some beds of relatively loose, saturated, granular soils are also anticipated along the alignment that may be liquefiable.

8.4. Slope Stability

The project is situated adjacent to the active stream channel of Aliso Creek and is susceptible to damage by stream bank erosion and channel slumping. The erosion potential is relatively low during dry months, but is relatively severe during wet months and especially during large flood events. Erosion, (slow or catastrophic), may impact the long-term performance of the proposed pipeline. The following is a brief description of the two sides of the creek.

The mapped landslides (Figures 3, through 7), are located along both sides of the creek. These slope areas are also mapped as potentially susceptible to landslide hazards during earthquakes (Figure 10). These landslides are considered to be relatively old with rupture surfaces (basal failure plane) generally below the level of the creek channel. Shallower rupture surfaces and fracture planes may be present at relatively shallow depths, particularly where smaller landslides are mapped within large landslide features.

8.4.1. East Side

Rip-rap has been placed along steeper portions of the creek channel where the channel slopes are within approximately 20 feet of the existing 18-inch sewer line. Additional rip-rap may be present in other areas which are currently obscured by vegetation. The rip-rap observed consists of granitic rock boulders up to approximately 2 to 3 feet in thickness. The actual thicknesses of the rip-rap layers are unknown.

Based on our review of the existing pipeline alignment, the active creek channel is in close proximity (approximately 30 feet or less) to the existing pipelines near Manhole Nos. 32-34, 29A, 21, 20, 17, 16, 14, 13A, 10, (Figures 2, 3, 4 and 5). These channel embankment areas are generally considered to be marginally stable. Erosion provisions and some type of embankment stabilization may be appropriate.

8.4.2. West Side

The west side of the creek ranges from approximately 5 to more than 200 feet from the existing paved AWMA Road. Minor erosion gulleys crossing the road are present. The area west of Manhole 15A (Figure 4) as well as west of Manholes 8, 6, 2 (Figures 6 and 7), the road is within approximately 5 to 10 feet of the west embankment. These channel embankment areas are generally considered to be marginally stable. Erosion provisions and some type of embankment stabilization may be appropriate.

9. PRELIMINARY CONCLUSIONS

Based on the results of our geologic reconnaissance and limited geotechnical evaluation, it is our preliminary opinion that the proposed project is feasible from a geotechnical perspective, but the project area is susceptible to several geologic hazards. Geologic hazards that could impact the pipeline include creek erosion, creek embankment stability, landslides and liquefaction. These conditions and other geotechnical aspects of the project are discussed in the following sections:

- The existing creek channel is in proximity to some segments of the existing pipelines along the east side of the channel and adjacent to AWMA Road on the west side. Creek channel erosion mitigation should be performed to protect the proposed pipeline, as well as existing pipelines and road. The stability of creek embankments should also be evaluated on a case-by-case basis where the pipeline is close to creek embankments. In general, the pipeline should maintain a horizontal distance away from the creek channel so that the pipeline is outside a 2:1 (horizontal to vertical) prism extending up from the bottom of the channel. Where this setback is not possible, additional stabilization may be appropriate. The north end of the alignment is along the edge of a relatively steep channel slope with some areas containing rip rap. Embankment stabilization will also be appropriate in this area.

- Our subsurface exploration indicates that the alluvium along the alignment is comprised predominantly of relatively clayey soils with a low potential for soil liquefaction. Some potentially liquefiable sandy alluvial layers are, however, anticipated at some locations. Seismic liquefaction may result in settlement and slumping of channel banks which could impact the pipeline. Creek bank stabilization may be performed to mitigate potential for seismic induced slope failures. Liquefaction may also result in soil settlement and sand boils.

- The alignments cross areas where large landslides have been mapped. The landslides are complex and considered to be relatively old features. The base of the slopes includes a mantle of slope wash and alluvial deposits. The landslides were not exposed in the current creek alignment. Two landslides were exposed along the western edge of the AWMA Road on the west side of the creek near the CTP. Our previous exploration of these landslide areas did not reveal landslide rupture surfaces to the depths explored. The toe of the landslides are expected to be below the creek channel.

- Reactivation of landslides could damage existing pipelines, as well as a new pipeline. During our recent field reconnaissance and review of aerial photographs we did not observe ground cracks, scarps, seepage, or other signs of recent landslide movement. We understand that the existing pipelines and access roads have not been damaged by landslide movement. Based on our previous work in the area we anticipate that the basal rupture surfaces of these large landslides are relatively deep below the creek bottom. Shallower rupture surfaces and fracture zones may be present, which could be relatively unstable. In general, we do not anticipate minor grading for the pipeline construction will impact the stability of the large landslides, but trenching for new pipeline could expose rupture zones, fractured material, or other unstable conditions.

- In order to further evaluate the landslides impacting the proposed pipeline alternative, subsurface exploration will be required in these areas. Depending on the subsurface conditions, it may be reasonable to design the improvements so as to reduce the impact of the new pipeline to the stability of the hillside. This would include limited excavations and fills as well as implementing suitable drainage provisions. Alternatives to trench excavations could be pipe bursting within the existing sludge lines or horizontal directional drilling through the landslide deposits.

- Grading is anticipated to include relatively shallow cuts and fills. In light of the potential slope stability hazards near mapped landslide areas, we recommend that the pipeline avoid excavations of more than 5 feet in these areas. As improvement plans become available, a detailed geotechnical evaluation of landslide areas may be performed to evaluate grading impacts. Future excavations and fill areas should be evaluated on a case-by-case basis.

- Drainage tributaries from the canyon slopes crossing the alignment may undermine the proposed pipeline and impact the stability of the creek embankments. Erosion protection and drainage improvements should be considered where tributaries cross the proposed pipeline improvement.

- Undocumented fill and loose natural soils are expected at the site. The fill and loose natural soils are considered to be potentially compressible under future loading from new fills or pipeline improvements. In order to provide suitable support of the pipeline, some removal and recompaction of potentially compressible soils below the pipeline may be appropriate.

- Groundwater was previously encountered depths ranging from approximately 6½ to 39 feet below the ground surface at the site. Groundwater levels along the alignment can vary with seasonal storms, change in topography, stratigraphy, runoff and other environmental changes.

10. PRELIMINARY GEOTECHNICAL CONSIDERATIONS

The following geotechnical conditions are presented for preliminary planning purposes. The design and planning of the pipeline improvement should be based on a detailed geotechnical evaluation. The evaluation should be based on proposed finish grade elevations and improvements within the pipeline alignment.

10.1. Seismic Ground Shaking

The project site is situated in a seismically active area. During the design life of the pipeline, strong ground shaking may occur. The closest active fault is the Newport Inglewood fault zone approximately 4½ miles south of the site. An estimated earthquake magnitude of 7.1 could occur on this fault zone. Our analysis indicated that a peak horizontal ground acceleration of 0.61g with a statistical return period of 2,475 years could occur at the project site. Accordingly, structural improvements, if any, should be designed in accordance with the appropriate CBC seismic criteria.

As discussed, seismic ground shaking may also cause seismic induced landsliding and liquefaction. Prior to the design, a subsurface geotechnical evaluation, including laboratory testing, should be performed to further evaluate the potential risks associated with these hazards and evaluate mitigation alternatives.

10.2. Earthwork

Earthwork for the project should be performed in accordance with the CBC and local grading ordinances, as appropriate. We recommend that fill and/or trench backfill be compacted to 90 percent relative compaction in accordance with American Society of Testing Materials (ASTM 1557).

Based on our understanding of the project, the earthwork on the project may consist of minor cuts and fills for construction access. Existing fill and natural soils generated from excavations should be generally suitable for use in fills, provided unsuitable debris or oversized rock (larger than 6 inches) that may be present is removed. Fill soils to be used for backfill around utilities should be compacted to 90 percent relative compaction. Detailed earthwork recommendations should be provided in the design geotechnical report.

10.3. Excavation Characteristics

Based on our previous field exploration and experience, we anticipate that excavations within the fill and alluvial materials along the alignment may be accomplished with conventional backhoe, excavators, or other trenching equipment in good condition. Based on the results of our subsurface exploration, we anticipate that the materials along the alignment will consist predominantly of clays and silts with lesser amounts of sands. In addition, gravel and cobbles may be encountered during the trenching and/or tunneling operations. Excavations in the bedrock materials (Topanga and Monterey Formations) as well as the bedrock landslides exposed in the slope areas could be difficult and may require heavy ripping or blasting.

10.4. Temporary Excavations

Temporary excavations above groundwater up to approximately 5 feet in depth should be generally stable. Excavations which expose friable, cohesionless sands, however, may be subject to caving. Excavations that appear unstable, or deeper than 5 feet, should be shored or the sides of the excavation laid back to slope inclinations of approximately 1½:1 (horizontal to vertical). Friable sand zones which are subject to caving may warrant continuous shoring. For planning purposes, we recommend that the on-site soil be considered at Type C soil in accordance with the OSHA soil classification.

Excavations for jacking and receiving pits (if designed) may include temporary slopes and/or vertical side walls. We anticipate that driven sheet pile or soldier pile with laggings shoring systems will be appropriate for these excavations. Details regarding shoring system should be based on a detailed geotechnical evaluation including site specific subsurface exploration.

Settlement of the ground may occur behind the shoring system wall during excavation. The amount of settlement depends on the type of shoring system, contractor’s workmanship, and soil conditions. Settlement may cause distress to adjacent structures, if present. Possible causes of settlement that should be addressed include vibration during installation of the sheet piling, excavation for construction, construction vibrations, dewatering, and removal of the support system. We recommend that the potential settlement distress be evaluated carefully by the contractor prior to construction.

10.5. Construction Dewatering

Groundwater was previously encountered at depths of approximately 6½ feet or more during exploratory drilling. Depending on the location of the alignment and depth to invert elevation, groundwater may be encountered. As details become available regarding planned excavations and tunneling (if designed), the potential for construction dewatering should be evaluated. Considerations for construction dewatering should include anticipated drawdown, volume of pumping, potential for settlement, and groundwater discharge. Disposal of groundwater should be performed in accordance with guidelines of the Regional Water Quality Control Board.

10.6. Exavation Bottom Stability

In general, we anticipate that the bottom of the excavation in areas of bedrock should provide suitable support to the new pipelines. Excavations that encounter soft fill and/or unconsolidated alluvium at the bottom may involve overexcavation and replacement with a compacted fill or gravel mat beneath the bottom of the excavation to thicknesses of approximately 1 to 3 feet. Recommendations for stabilizing excavation bottoms should be based on evaluation in the field by the geotechnical consultant at the time of construction.

10.7. Slope Stability

Creek erosion should be mitigated to protect the pipeline alignment. Where the creek is close to the proposed pipeline, embankment stabilization may be appropriate, in addition to erosion control. Embankment stabilization may involve some type of retaining structure (gabion walls, rip rap, etc.) and/or reinforced earth slope construction. Slope stabilization should be designed and constructed along with the planned erosion protection system. The actual stabilization design should be based on further geotechnical evaluation. Prior to the subsurface exploration, a detailed topographic survey of the alignment and slope areas should be performed. The survey should include planned finish grade elevations, locations of existing pipelines, and new improvements such as drainage structures, if appropriate.

We understand that the pipeline alternative on the east side between Manholes Nos. 32 and 34 may involve cuts into the adjacent hillside. Based on regional geologic mapping and review of aerial photographs, the geologic structure is considered favorable to neutral. Based on our reconnaissance, a wedge of slope wash is present in this area. The slope wash is situated at the base of a relatively steep slope, underlain by formational materials. In order to excavate in this area, an appropriate shoring system should be considered. Details regarding the shoring system should be provided when detailed plans are available. Additional subsurface exploration may be appropriate at that time.

Planned fill slopes should be generally stable if constructed at inclinations of 2:1 (horizontal to vertical) or flatter. In addition to the mapped landslides, other slopes bordering the proposed road are relatively steep and may be subject to instability. During the design phase, additional geotechnical evaluations should be performed to obtain soil and geologic data along the slope areas. Mitigation measures for slopes with marginal stability may include retaining structures, stabilization fills, soil-cement slopes, rip-rap and/or a combination of methods.

10.8. Horizontal Directional Drilling

Depending on the elevations of the pipeline alternatives, some horizontal directional drilling may be appropriate in lieu of trenching. The directional drilling would be expected to be in areas underlain by sands, silts and clays (older alluvial soils) and/or interbedded sandstones and siltstones (bedrock and/or landslide). The alluvial soils may also contain some gravel and cobbles. In areas underlain by bedrock, hard drilling will be encountered where well-cemented sedimentary rock is present. Mix-phases drilling condition (drilling from alluvium to sedimentary rock) may also be encountered during construction. Details regarding the parameters for the directional drilling should be evaluated with a subsurface evaluation of the location of the proposed directional drilling.

10.9. Corrosive Soils

A preliminary evaluation of the corrosion potential of the near-surface soils was previously performed based on laboratory testing of a representative sample of the near surface soils obtained from our exploratory borings. Laboratory testing was performed to evaluate pH, minimum electrical resistivity, chloride and sulfate content. The laboratory results are presented in Appendix B.

The pH of the tested samples ranges from 6.6 to 8.5, the electrical resistivity ranges from approximately 330 to 3,960 ohm-centimeters, the chloride content ranged from 50 to 215 parts per million (ppm), and the sulfate content ranged from approximately 0.001 percent (i.e., 10 ppm) to 0.192 percent (i.e. 1,920 ppm). Based on the laboratory test results and Caltrans (2003) corrosion criteria, the near surface soils can be classified as a non-corrosive site, which is defined as having earth materials with less than 500 ppm chlorides, less than 0.20 percent sulfates (i.e., 2,000 ppm), a pH of 5.5 or less.

Based on our past experience, the soils may vary along the proposed alignment. Accordingly, additional corrosivity testing of the on-site soils, however, should be performed during the design phase. Corrosivity testing may also need to be considered for soils that are imported for use as fill during construction. The corrosion potential of soils will influence the type of construction materials that may be used for structures and pipelines on the project. Where corrosive soils are present, selection of corrosion resistant material types for underground improvements and/or providing corrosion protection to surfaces in contact with corrosive soils may be used. Concrete protection against sulfate bearing soils may include the use of corrosive resistant cement type and limiting the water-cement ratio of the concrete mix.

11. ADDITIONAL STUDIES

This geotechnical evaluation was performed for preliminary planning purposes. As indicated, it is our preliminary opinion that the proposed pipeline is feasible from a geotechnical perspective provided that erosion protection along the creek channel is implemented along with proper planning and design of the grading and improvements. Our work included a limited subsurface evaluation. Current plans for the pipeline are conceptual. No detailed improvement plans illustrating planned finish grade elevations, existing and new pipelines and drainage structures were available at the time of this report.

The proposed pipeline is located adjacent to several large landslide areas and is subject to risk of damage if the landslides are reactivated. Our preliminary evaluation did not indicate evidence of active landsliding or recent movement. We recommend that additional geotechnical exploration be performed to evaluate the soil and geologic conditions, address potential landslide risks, and develop detailed design criteria for slope stabilization. Prior to the supplemental exploration, discussions with the interested parties for the project, including the appropriate review agency, should be conducted to evaluate the proposed program as well as anticipated analysis. Grading plans including planned elevations and proposed improvements should be prepared prior to additional geotechnical exploration.

12. LIMITATIONS

The field evaluation and geotechnical analyses presented in this geotechnical report have been conducted in general accordance with current practice and the standard of care exercised by geotechnical consultants performing similar tasks in the project area. No warranty, expressed or implied, is made regarding the conclusions, recommendations, and opinions presented in this report. There is no evaluation detailed enough to reveal every subsurface condition. Variations may exist and conditions not observed or described in this report may be encountered during construction. Uncertainties relative to subsurface conditions can be reduced through supplemental subsurface exploration. Subsurface evaluation will be performed upon request.

This document is intended to be used only in its entirety. No portion of the document, by itself, is designed to completely represent any aspect of the project described herein. Ninyo & Moore should be contacted if the reader requires additional information or has questions regarding the content, interpretations presented, or completeness of this document.

Our conclusions, recommendations, and opinions are based on an analysis of the observed site conditions. If geotechnical conditions different from those described in this report are encountered, our office should be notified and additional recommendations, if warranted, will be provided upon request. It should be understood that the conditions of a site can change with time as a result of natural processes or the activities of man at the subject site or nearby sites. In addition, changes to the applicable laws, regulations, codes, and standards of practice may occur due to government action or the broadening of knowledge. The findings of this report may, therefore, be invalidated over time, in part or in whole, by changes over which Ninyo & Moore has no control.

This report is intended exclusively for use by the client. Any use or reuse of the findings, conclusions, and/or recommendations of this report by parties other than the client is undertaken at said parties' sole risk.

13. REFERENCES

Boyle Engineering, 1968, Plans for Contract 1A-2 for Moulton Niguel Water District, 7 sheets, dated July.

Boyle Engineering, 1978, Construction Plans for Aliso Creek Effluent Transmission Main, Reach E, Contract No. PC-2-B-78-A, 18 sheets, dated September.

California Building Standards Commission, 2010, California Building Code: California Code of Regulations, Title 24, Part 2, Volumes 1 and 2, based on the 2009 International Building Code.

California Department of Conservation, Division of Mines and Geology, 1998, Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada: International Conference of Building Officials, dated February.

California Geological Survey, 2007, Seismic Shaking Hazards in California, Website http://www.consrv.ca.gov/cgs/rghm/pshamap/pshamain.html, last edited on June 11.

Google Earth, 2009, Satellite Imagery from Google Earth Pro, Version 5.0, site access dated 2008.

Grant, L. B., Mueller, K. J., Gath, E. M., Cheng, H., Edwards, L.R., Munro, R., and Kennedy, G.L., 1999, Late Quaternary Uplift and Earthquake Potential of the San Joaquin Hills, Southern Los Angeles Basin, California: Geology, November, Volume 27, No. 11, pp. 1031-1034.

Jennings, C.W., and Bryant, W.A., 2010, Fault Activity Map: California Geological Survey, California Geologic Data Map Series, Map No. 6, Scale 1:750,000.

Morton, P.K., 1974, Geology and Engineering Geologic Aspects of the San Juan Capistrano Quadrangle, Orange County, California: California Division of Mines and Geology, Special Report 112. Scale 1:24,000.

Morton, P.K., 1976, Environmental Geology of Orange County, California: California Division of Mines and Geology Open File Report 79-8 LA, Scale 1:48,000.

Morton, P.K., Miller, R.V., and Tan, S.S., 1981, Geologic Map of Orange County, California, Showing Mines and Mineral Deposits: California Division of Mines and Geology, Bulletin 204, Scale 1:48,000.

Ninyo & Moore, 2000a, Limited Geotechnical Evaluation, Moulton Niguel Water District, Aliso Creek Emergency Sewer, Laguna Niguel, dated May 9.

Ninyo & Moore, 2000b, Geotechnical Evaluation, Moulton Niguel Water District, Aliso Creek Emergency Sewer, Laguna Niguel, dated December 19.

Ninyo & Moore, 2001b, Supplemental Subsurface Exploration, Aliso Creek Emergency Sewer, Moulton Niguel Water District, Laguna Niguel, dated December 19.

Ninyo & Moore, 2003, Preliminary Geotechnical Evaluation, Rehabilitation of the East Aliso Creek Emergency Sewer (REACES), Moulton Niguel Water District, Laguna Niguel, California, MNWD Project No. 2002059, dated May 9.

Ninyo & Moore, 2005, Geotechnical Consulting Services, AWMA Access Road, Laguna Niguel, California, dated May 26.

Ninyo & Moore, 2009, Preliminary Geotechnical Evaluation, Coastal Treatment Plant, Access Road Realignment Study, South Orange County Wastewater Authority, Laguna Niguel, California, dated April 24.

Ninyo & Moore, 2010, Proposal for Geotechnical Consulting Services, Coastal Treatment Plant Export Sludge System, South Orange County Wastewater Authority, Laguna Niguel, California, dated July 12.

Peterson, M.D., Bryant, W.A., Cramer, C.H., Cao, T., Reichle, M.S., Frankel, A.D., Lienkaemper, J.J., McCrory, P.A., and Schwartz, D.P., 1996, Probabilistic Seismic Hazard Assessment for the State of California: California Department of Conservation, Division of Mines and Geology Open File Report 96-08.

Rivertech, Inc., 2004, Aliso Creek, Prioritizing Stabilization of the East Bank During Interim Period, dated February.

Tetra Tech, Inc., 2002, Site Plan and Photograph of Manholes, Aliso Creek Emergency Sewer, dated October.

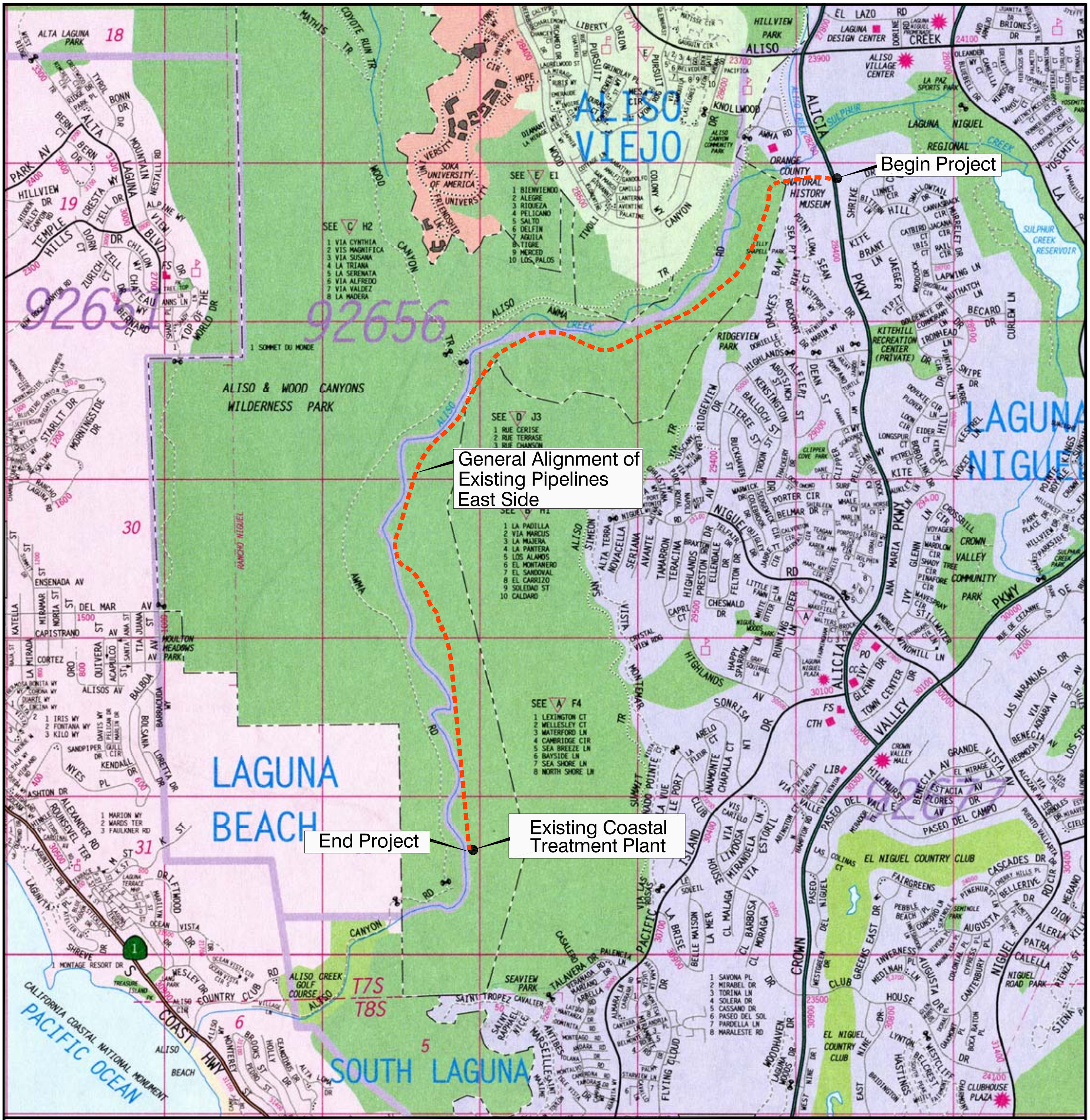
United States Geological Survey, 1968 (Photorevised 1981), San Juan Capistrano, California Quadrangle Map, 7.5 Minute Series: Scale 1:24,000.

Vedder, J.G., Yerkes, R.F., and Schoellhamer, J.E., 1957, Geologic Map of the San Joaquin Hills-San Juan Capistrano Area, Orange County, California: United States Geological Survey, Oil and Gas Investigations Map OM-193, Scale 1:24,000.

Youd, et. al., 2001, Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils, ASCE, Geot. J., Vol. 127, No. 10, pp. 817-833.

AERIAL PHOTOGRAPHS

Source	Date	Flight	Numbers	Scale
USDA	12-12-52	AXK-2K	130 through 134	1:20,000



REFERENCE: 2007 THOMAS GUIDE FOR LOS ANGELES/ORANGE COUNTIES, STREET GUIDE AND DIRECTORY

N

SCALE IN FEET

0 2400 4800

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Map © Rand McNally, R.L.07-S-129

202426_A1.DWG........GK

Ninyo & Moore

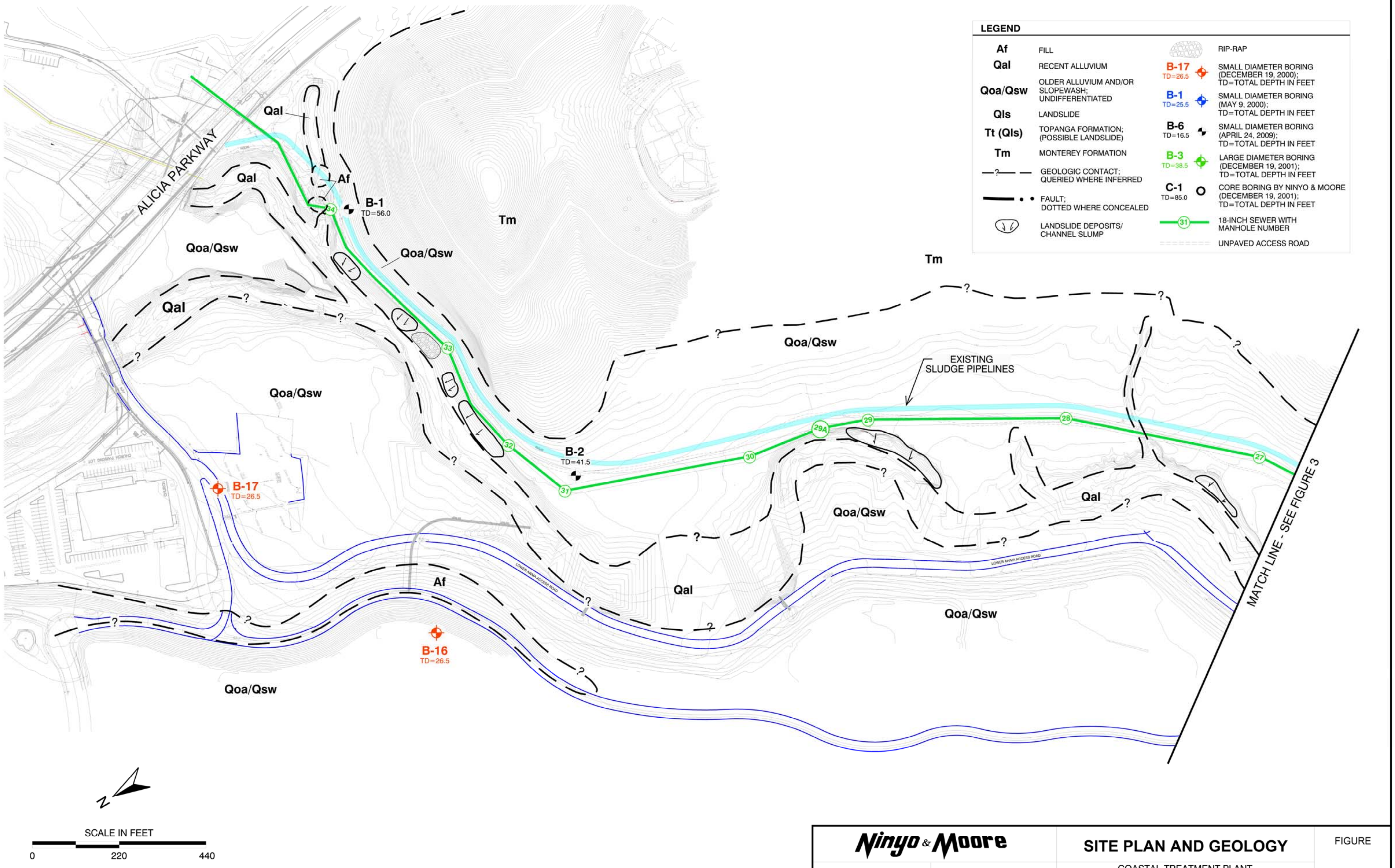
PROJECT NO.	DATE
202426005	11/11

SITE LOCATION

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

1



NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore

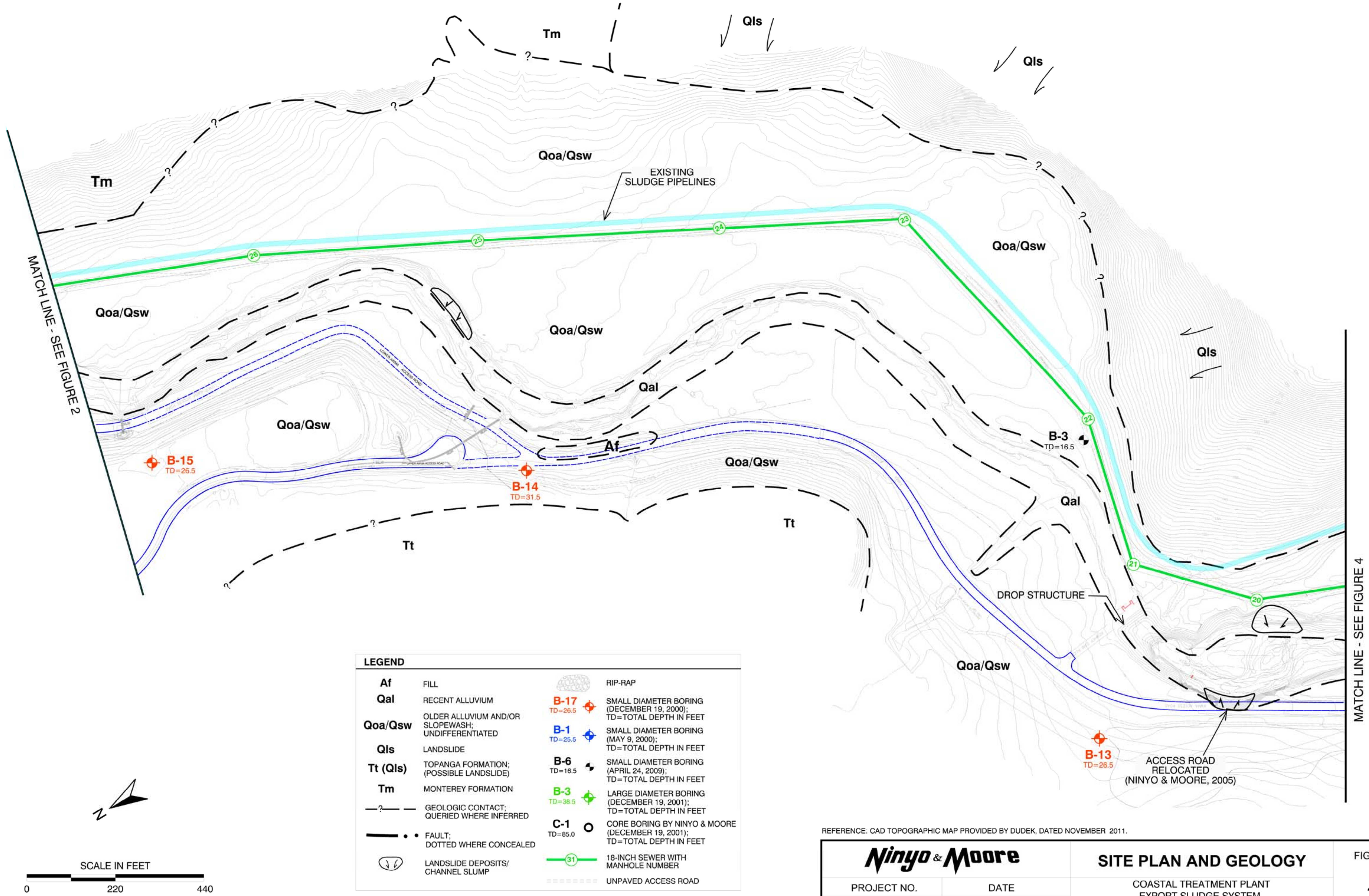
PROJECT NO.	DATE
202426005	11/11

SITE PLAN AND GEOLOGY

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

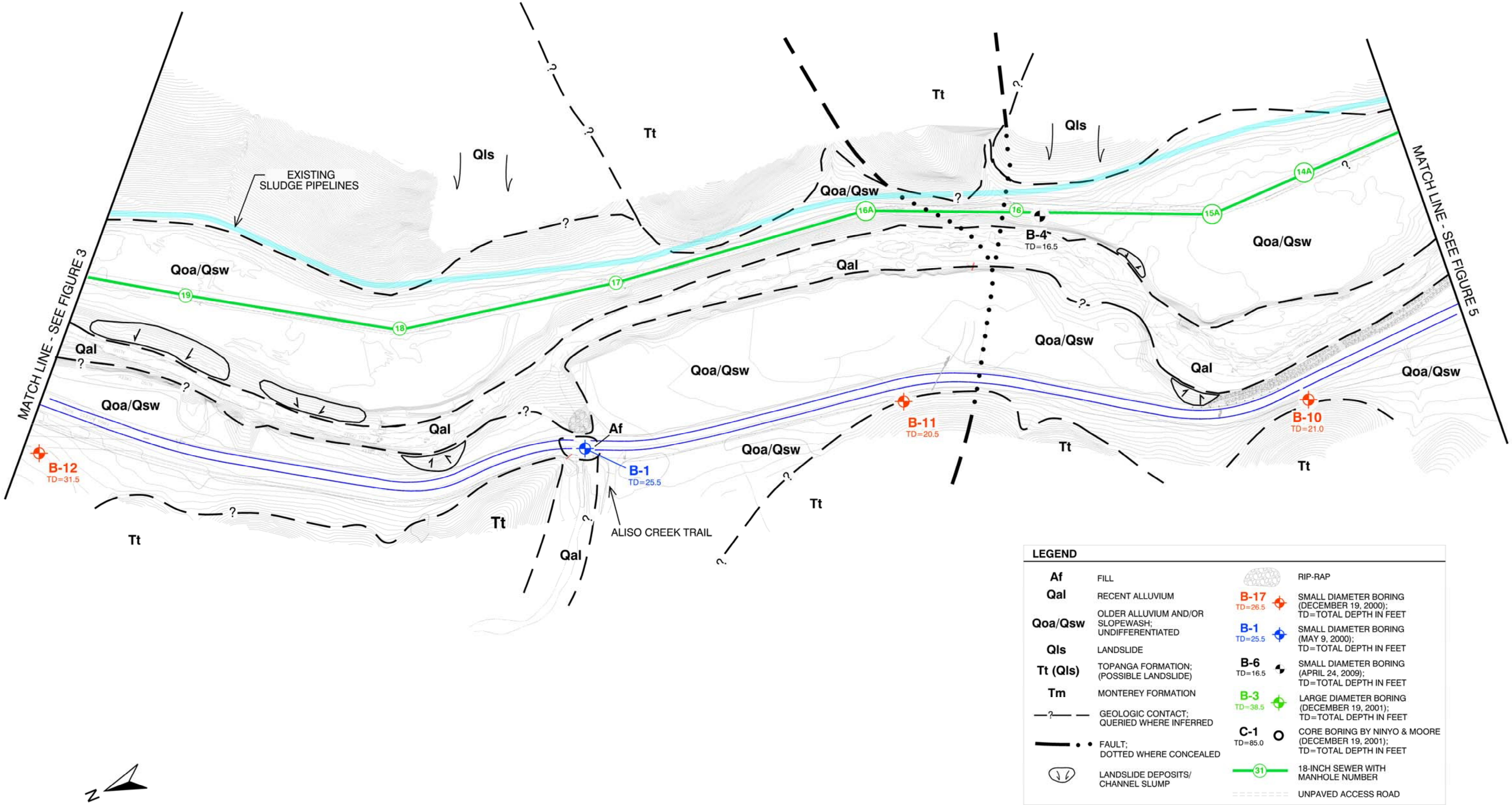
2



NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore		SITE PLAN AND GEOLOGY	FIGURE
PROJECT NO.	DATE	COASTAL TREATMENT PLANT EXPORT SLUDGE SYSTEM LAGUNA NIGUEL, CALIFORNIA	3
202426005	11/11		



SCALE IN FEET

0 220 440

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore

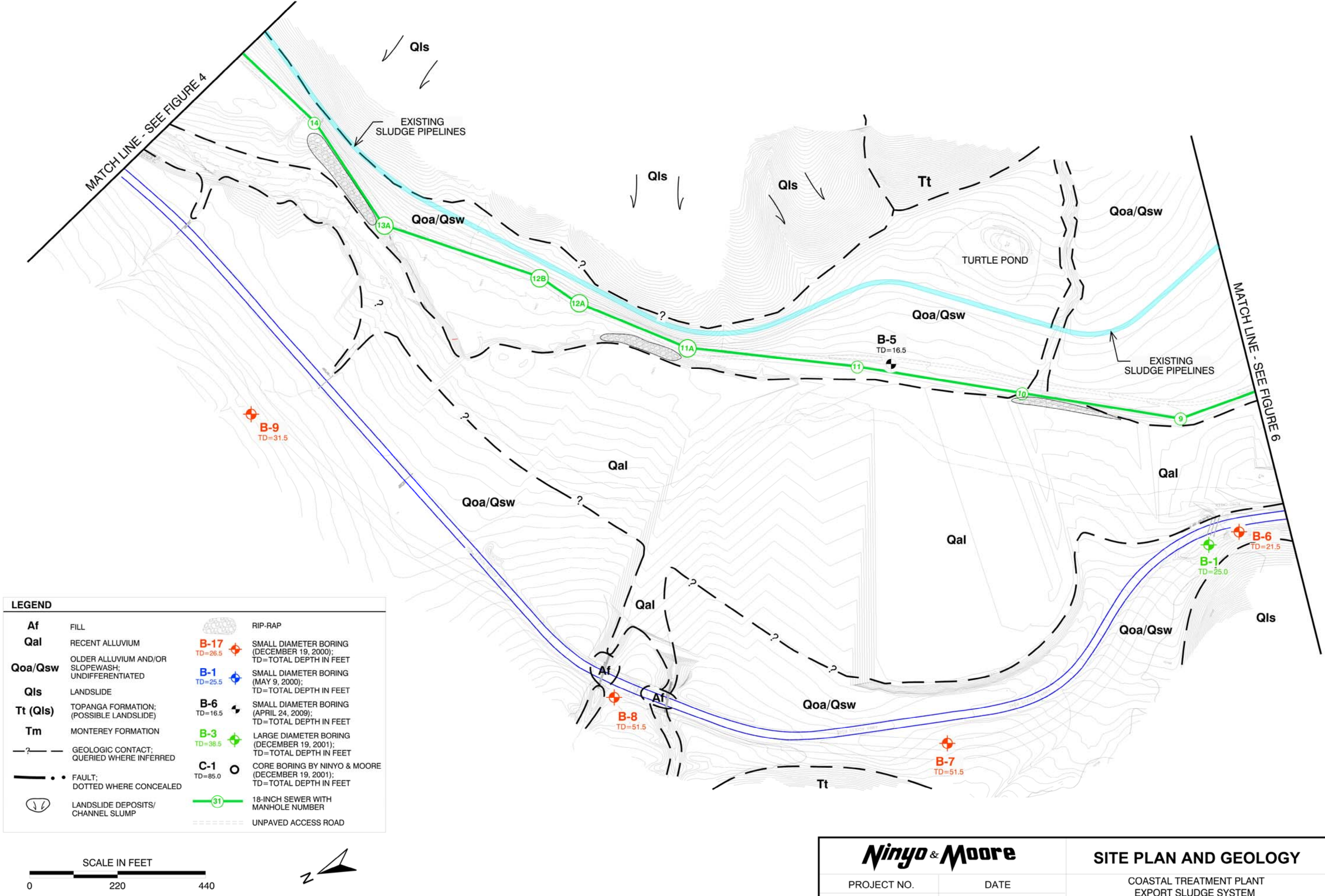
SITE PLAN AND GEOLOGY

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE
202426005	11/11

FIGURE

4



NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore

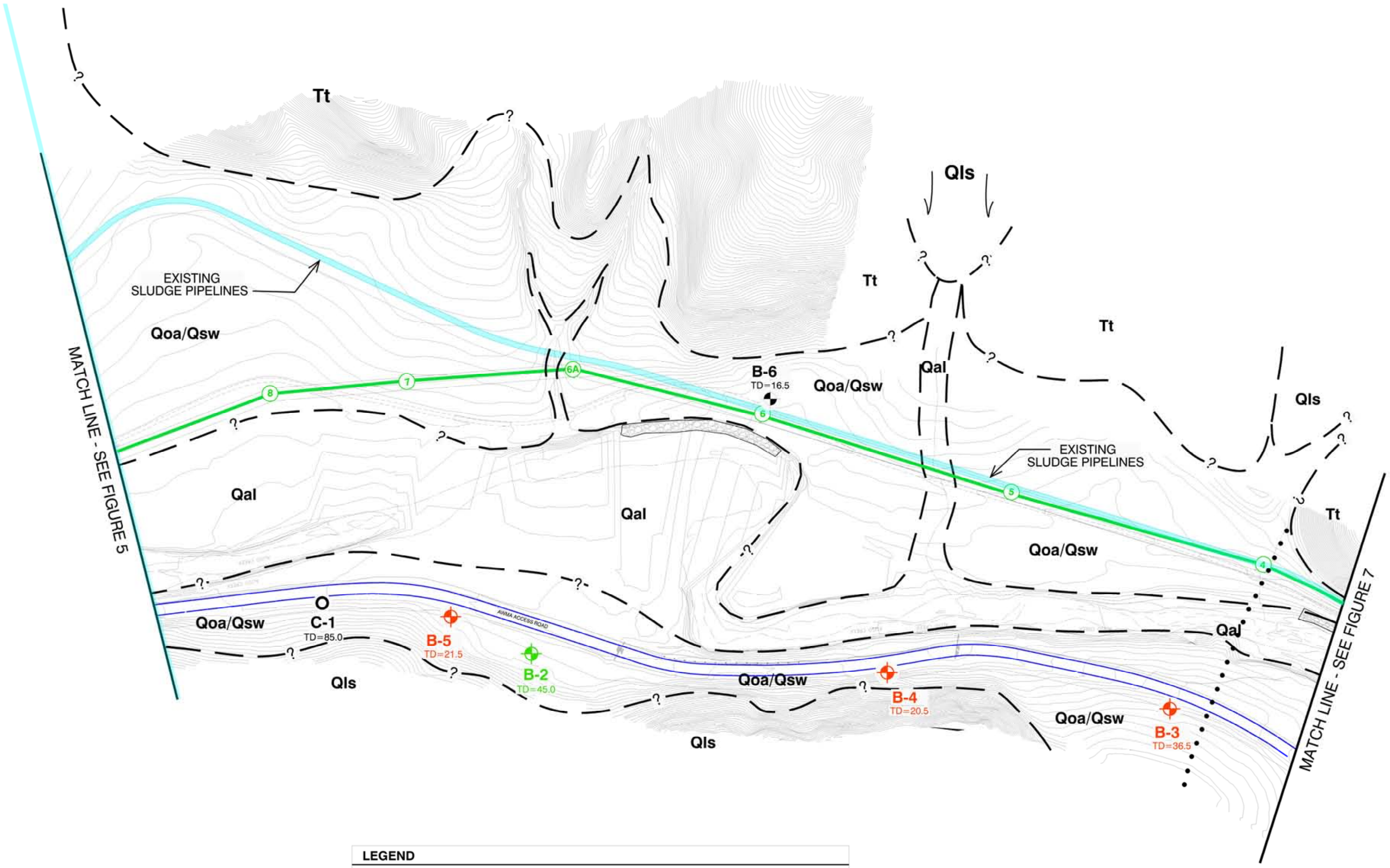
PROJECT NO.	DATE
202426005	11/11

SITE PLAN AND GEOLOGY

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

5



LEGEND

Af	FILL		RIP-RAP
Qal	RECENT ALLUVIUM	**B-17** TD=26.5 ⊕	SMALL DIAMETER BORING (DECEMBER 19, 2000); TD=TOTAL DEPTH IN FEET
Qoa/Qsw	OLDER ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED	**B-1** TD=25.5 ⊕	SMALL DIAMETER BORING (MAY 9, 2000); TD=TOTAL DEPTH IN FEET
Qls	LANDSLIDE	**B-6** TD=16.5	SMALL DIAMETER BORING (APRIL 24, 2009); TD=TOTAL DEPTH IN FEET
Tt (Qls)	TOPANGA FORMATION; (POSSIBLE LANDSLIDE)	**B-3** TD=38.5 ⊕	LARGE DIAMETER BORING (DECEMBER 19, 2001); TD=TOTAL DEPTH IN FEET
Tm	MONTEREY FORMATION	**C-1** TD=85.0 ○	CORE BORING BY NINYO & MOORE (DECEMBER 19, 2001); TD=TOTAL DEPTH IN FEET
—?— —	GEOLOGIC CONTACT; QUERIED WHERE INFERRED	—(31)—	18-INCH SEWER WITH MANHOLE NUMBER
━━ • •	FAULT; DOTTED WHERE CONCEALED	= = = =	UNPAVED ACCESS ROAD
	LANDSLIDE DEPOSITS/ CHANNEL SLUMP		

N

SCALE IN FEET

0 220 440

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore

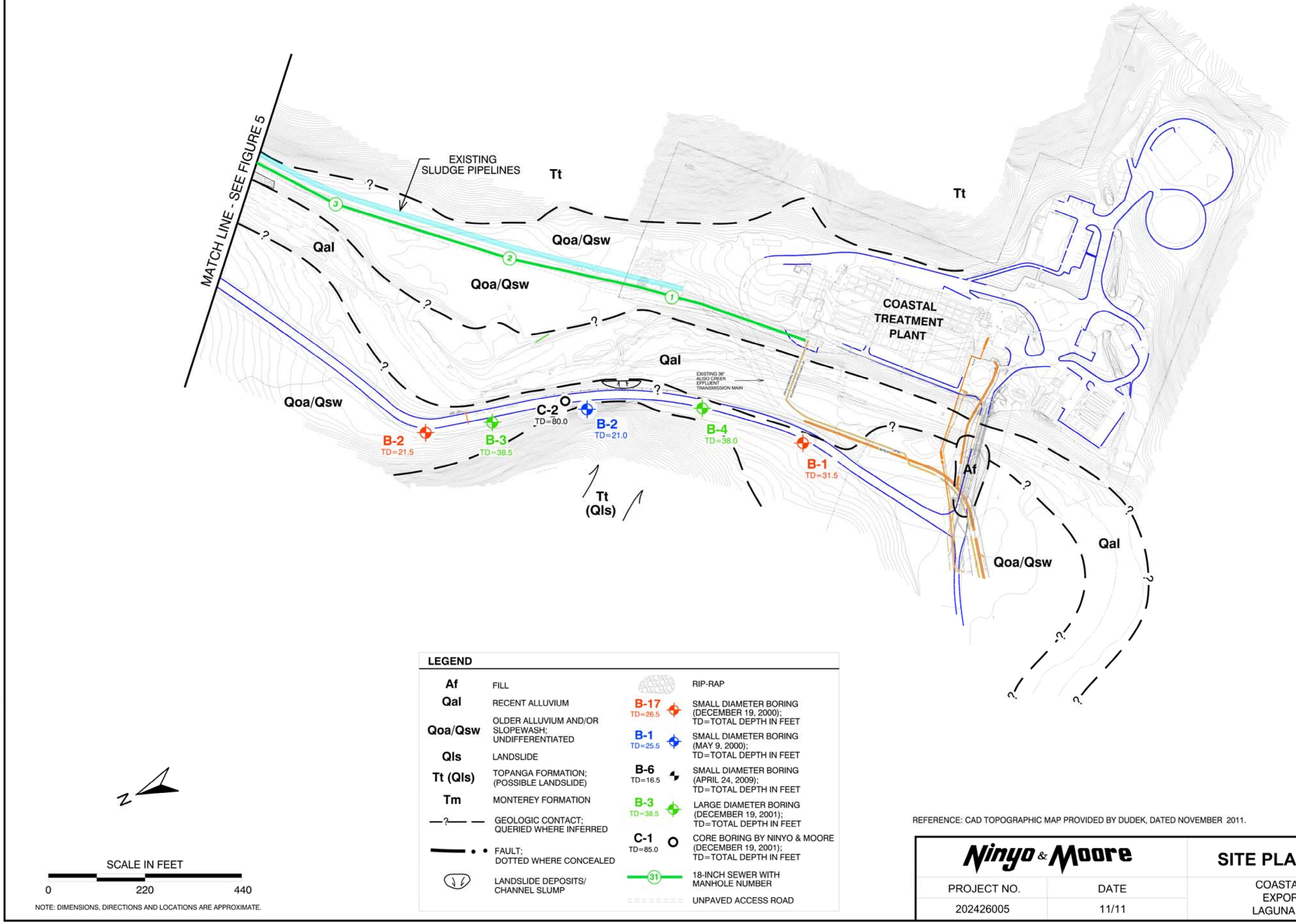
PROJECT NO.	DATE
202426005	11/11

SITE PLAN AND GEOLOGY

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

6



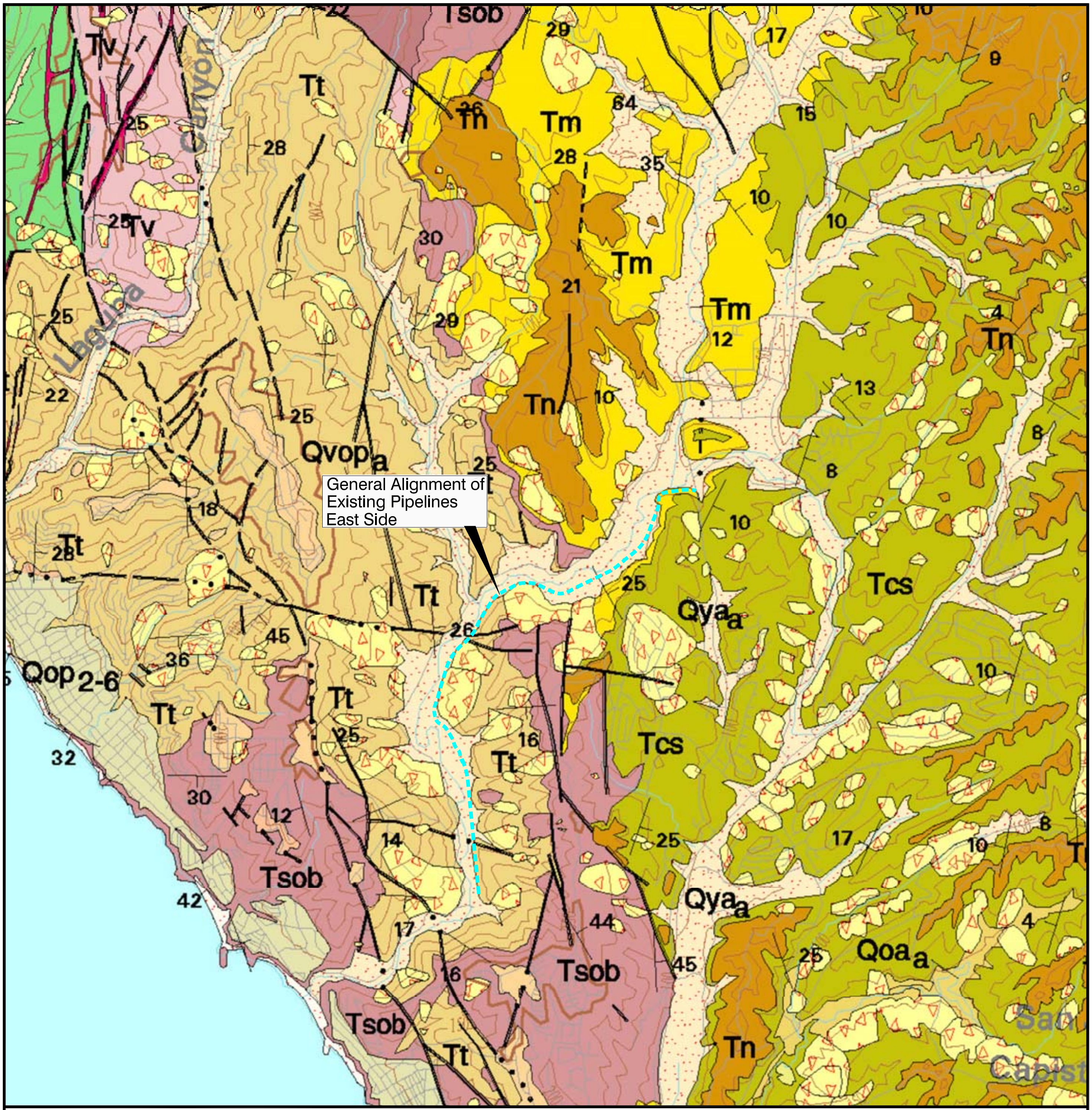
NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

Af	FILL		RIP-RAP
Qal	RECENT ALLUVIUM	**B-17** TD=26.5 ⊕	SMALL DIAMETER BORING (DECEMBER 19, 2000); TD=TOTAL DEPTH IN FEET
Qoa/Qsw	OLDER ALLUVIUM AND/OR SLOPEWASH; UNDIFFERENTIATED	**B-1** TD=25.5 ⊕	SMALL DIAMETER BORING (MAY 9, 2000); TD=TOTAL DEPTH IN FEET
Qls	LANDSLIDE	**B-6** TD=16.5 ◐	SMALL DIAMETER BORING (APRIL 24, 2009); TD=TOTAL DEPTH IN FEET
Tt (Qls)	TOPANGA FORMATION; (POSSIBLE LANDSLIDE)	**B-3** TD=38.5 ⊕	LARGE DIAMETER BORING (DECEMBER 19, 2001); TD=TOTAL DEPTH IN FEET
Tm	MONTEREY FORMATION	**C-1** TD=85.0 ○	CORE BORING BY NINYO & MOORE (DECEMBER 19, 2001); TD=TOTAL DEPTH IN FEET
—?— —	GEOLOGIC CONTACT; QUERIED WHERE INFERRED	—(31)—	18-INCH SEWER WITH MANHOLE NUMBER
——— • •	FAULT; DOTTED WHERE CONCEALED	= = = =	UNPAVED ACCESS ROAD
	LANDSLIDE DEPOSITS/ CHANNEL SLUMP		

REFERENCE: CAD TOPOGRAPHIC MAP PROVIDED BY DUDEK, DATED NOVEMBER 2011.

Ninyo & Moore		SITE PLAN AND GEOLOGY	FIGURE
PROJECT NO.	DATE	COASTAL TREATMENT PLANT EXPORT SLUDGE SYSTEM LAGUNA NIGUEL, CALIFORNIA	7
202426005	11/11		



General Alignment of Existing Pipelines East Side

REFERENCE: USGS, D.M. MORTON GEOLOGIC MAP OF THE SANTA ANA 30x60 QUADRANGLE; SOUTHERN CALIFORNIA, DATED 2004.

N

SCALE IN FEET

0 4,000 8,000

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

Tsob	SAN ONOFRE BRECCIA	Qoa	OLD AXIAL CHANNEL DEPOSITS
Tn	NIGUEL FORMATION	Qop	OLD PARELIC DEPOSITS
Tcs	CAPISTRANO FORMATION	Qvop	VERY OLD PARELIC DEPOSITS
Tm	MONTEREY FORMATION (MIOCENE)	Qya	YOUNG AXIAL CHANNEL DEPOSITS
Tt	TOPANGA FORMATION	△	LANDSLIDE DEPOSITS

Ninyo & Moore

PROJECT NO.	DATE
202426005	11/11

REGIONAL GEOLOGY

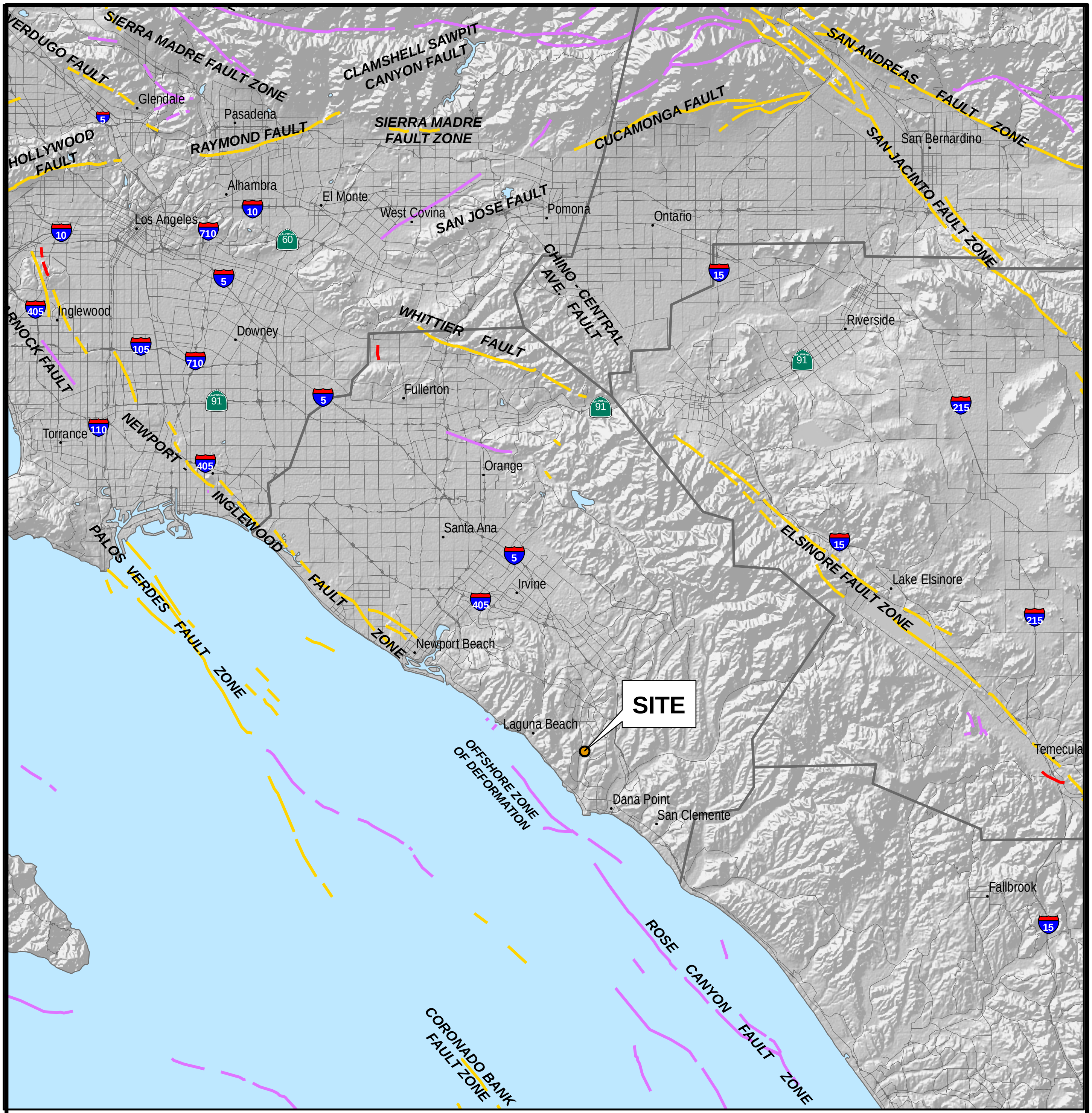
COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

8

202426_A3.DWG......GK

202426005_a4.Fault Loc.........GK



GIS DATA SOURCE: CALIFORNIA GEOLOGICAL SURVEY (CGS); ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE (ESRI)
REFERENCE: JENNINGS, 1994, FAULT ACTIVITY MAP OF CALIFORNIA AND ADJACENT AREAS

LEGEND

FAULT ACTIVITY:

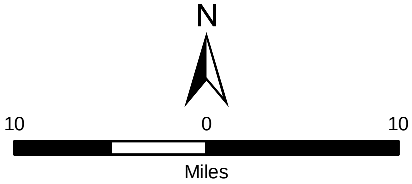
🟥 HISTORICALLY ACTIVE

🟨 HOLOCENE ACTIVE

🟩 LATE QUATERNARY (POTENTIALLY ACTIVE)

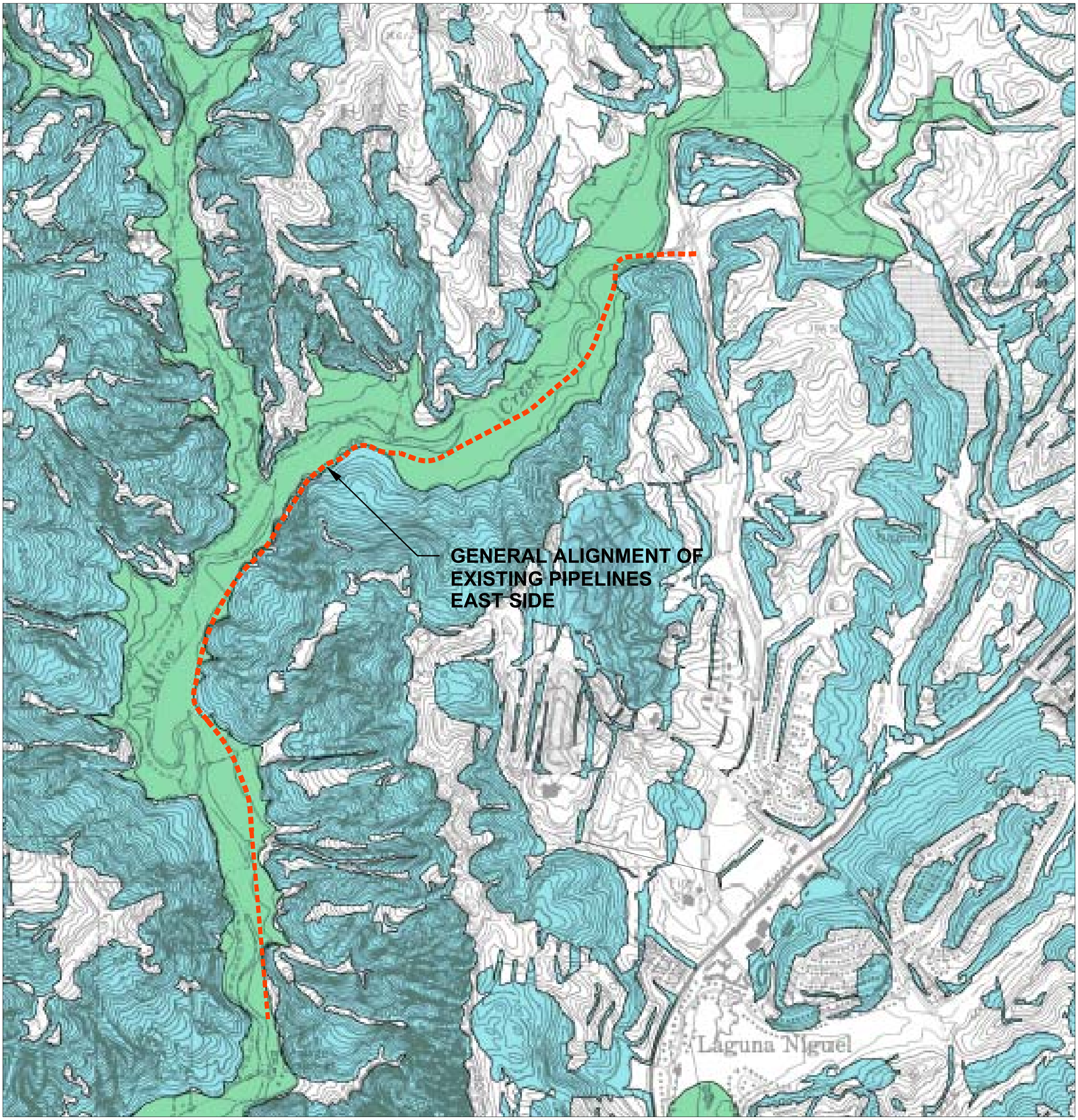
🟪 QUATERNARY (POTENTIALLY ACTIVE)

⬛ COUNTY BOUNDARIES



NOTE: DIMENSIONS, DIRECTIONS, AND LOCATIONS ARE APPROXIMATE

Ninyo & Moore		FAULT LOCATIONS	FIGURE
PROJECT NO.	DATE	COASTAL TREATMENT PLANT EXPORT SLUDGE SYSTEM LAGUNA NIGUEL, CALIFORNIA	9
202426005	11/11		



REFERENCE: STATE OF CALIFORNIA SEISMIC HAZARD ZONES, SAN JUAN CAPISTRANO QUADRANGLE, DATED DECEMBER 21, 2001.

SCALE IN FEET

0 2000 4000

N

NOTE: DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

LEGEND

🟩 Liquefaction
Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

🟦 Earthquake-Induced Landslides
Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

202426-A2.DWG.......GK

Ninyo & Moore

SEISMIC HAZARD ZONES

PROJECT NO.	DATE
202426005	11/11

COASTAL TREATMENT PLANT
EXPORT SLUDGE SYSTEM
LAGUNA NIGUEL, CALIFORNIA

FIGURE

10

APPENDIX A

BORING LOGS

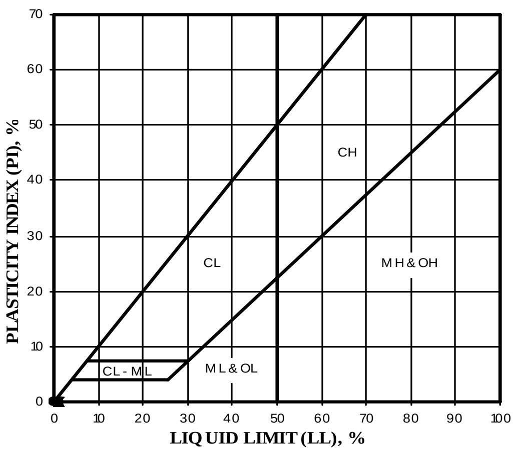
U.S.C.S. METHOD OF SOIL CLASSIFICATION

MAJOR DIVISIONS		SYMBOL		TYPICAL NAMES
COARSE-GRAINED SOILS (More than 1/2 of soil > No. 200 Sieve Size)	GRAVELS (More than 1/2 of coarse fraction > No. 4 sieve size	▨	GW	Well graded gravels or gravel-sand mixtures, little or no fines
		▨	GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
		▨	GM	Silty gravels, gravel-sand-silt mixtures
		▨	GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (More than 1/2 of coarse fraction < No. 4 sieve size	▨	SW	Well graded sands or gravelly sands, little or no fines
		▨	SP	Poorly graded sands or gravelly sands, little or no fines
		▨	SM	Silty sands, sand-silt mixtures
		▨	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (More than 1/2 of soil < No. 200 sieve size)	SILTS & CLAYS Liquid Limit <50	▨	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
		▨	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		▨	OL	Organic silts and organic silty clays of low plasticity
	SILTS & CLAYS Liquid Limit >50	▨	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		▨	CH	Inorganic clays of high plasticity, fat clays
		▨	OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soils

GRAIN SIZE CHART

CLASSIFICATION	RANGE OF GRAIN	
	U.S. Standard Sieve Size	Grain Size in Millimeters
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	306 to 76.2
GRAVEL	3" to No. 4	76.2 to 4.76
Coarse	3" to 3/4"	76.2 to 19.1
Fine	3/4" to No. 4	19.1 to 4.76
SAND	No. 4 to No. 200	4.76 to 0.075
Coarse	No. 4 to No. 10	4.76 to 2.00
Medium	No. 10 to No. 40	2.00 to 0.420
Fine	No. 40 to No. 200	0.420 to 0.075
SILT & CLAY	Below No. 200	Below 0.075

PLASTICITY CHART



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U.S.C.S. METHOD OF SOIL CLASSIFICATION

Updated Nov. 2011

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	BORING LOG EXPLANATION SHEET
0	■							Bulk sample.
		■						Modified split-barrel drive sampler.
		⊠						No recovery with modified split-barrel drive sampler.
		▮						Sample retained by others.
		◣						Standard Penetration Test (SPT).
5		⧄						No recovery with a SPT.
		▯	XX/XX					Shelby tube sample. Distance pushed in inches/length of sample recovered in inches.
		⧅						No recovery with Shelby tube sampler.
		▥						Continuous Push Sample.
				♀				Seepage.
10				▽				Groundwater encountered during drilling.
				▼				Groundwater measured after drilling.
						▦	SM	<u>MAJOR MATERIAL TYPE (SOIL)</u>: Solid line denotes unit change.
15						▨	CL	Dashed line denotes material change. Attitudes: Strike/Dip b: Bedding c: Contact j: Joint f: Fracture F: Fault cs: Clay Seam s: Shear bss: Basal Slide Surface sf: Shear Fracture sz: Shear Zone sbs: Shear Bedding Surface
20								The total depth line is a solid line that is drawn at the bottom of the boring.

BORING LOG

Explanation of Boring Log Symbols

PROJECT NO.	DATE	FIGURE
	Rev. 11/11	

DATE DRILLED 1/6/09 BORING NO. B-1
GROUND ELEVATION 139' ± (MSL) SHEET 1 OF 3
METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)
DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"
SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▨	CL	FILL: Dark brown, moist, stiff to very stiff, sandy CLAY.
5		■	14	12.3	109.0	▨	SC	ALLUVIUM: Dark brown, moist, medium dense, clayey SAND; scattered gravel.
10		◤	9			▨		
15		■	22	15.6	115.0	▨		
20		◤	1	▽		▨	SC	ALLUVIUM: (Continued) Brown to dark brown, saturated, very loose, clayey SAND.

Ninyo & Moore

BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-1

DATE DRILLED 1/6/09 BORING NO. B-1

GROUND ELEVATION 139' ± (MSL) SHEET 2 OF 3

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▒		@20': Groundwater encountered during drilling.
				▼		▒		@23.75': Groundwater measured at the end of drilling.
25		■	16	20.0	108.1	▒		Medium dense; scattered gravel.
30		◣	2			▒		Olive brown; very loose.
35		■	11			▒		Light olive brown; loose.
40		◣	1	31.1		▨	CL	ALLUVIUM: (Continued) Olive and brown, saturated, very soft, sandy CLAY.

Ninyo & Moore

BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-2

DATE DRILLED 1/6/09 BORING NO. B-1
GROUND ELEVATION 139' ± (MSL) SHEET 3 OF 3
METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)
DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"
SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
45		■	5	33.0	85.8	▨		Light olive brown; firm.
						▒		MONTEREY FORMATION: Dark brown, saturated, hard, sandy weathered SILTSTONE.
50		◤	63			▒		
55		■	70/10"			▒		Caliche.
								Total Depth = 56 feet. Groundwater encountered during drilling at approximately 20 feet. Groundwater measured at the end of drilling at approximately 23.75 feet. Backfilled with on-site soils on 1/6/09. Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
60								

Ninyo & Moore

BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-3

DATE DRILLED 1/6/09 BORING NO. B-2

GROUND ELEVATION 139' ± (MSL) SHEET 1 OF 3

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					░	SC	FILL: Medium brown, damp, medium dense, clayey SAND.
5		◣	8			░		Reddish brown and olive; scattered construction debris (woven fabric).
10	■		34			░	SC	ALLUVIUM: Dark brown, damp, medium dense, clayey SAND with sandy CLAY lenses; caliche.
15		◣	2	23.2		▨	CL	Mottled olive and brown, damp to moist, soft, CLAY; caliche.
20	■		11	22.0	102.7	▨	CL	ALLUVIUM: (Continued) Dark brown, moist, stiff, sandy CLAY with scattered sandy SILT.

Ninyo & Moore

BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-4

DATE DRILLED 1/6/09 BORING NO. B-2
GROUND ELEVATION 139' ± (MSL) SHEET 2 OF 3
METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)
DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"
SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■				▨		
25		◣	4	▽		▨		@25': Groundwater encountered during drilling. Gray; wet to saturated; firm.
30		■	9			▨	SC	Gray, saturated, loose, clayey SAND.
				▼		▨		@33.3': Groundwater measured after completion of drilling.
						▨		MONTEREY FORMATION: Light yellowish brown, saturated, moderately soft, clayey SILTSTONE.
35		◣	7			▨		
40		■	39			▨		MONTEREY FORMATION: (Continued) Light yellowish brown, saturated, moderately hard, clayey SILTSTONE.
								Total Depth = 41.5 feet.

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-5

DATE DRILLED 1/6/09 BORING NO. B-2

GROUND ELEVATION 139' ± (MSL) SHEET 3 OF 3

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								Groundwater encountered during drilling at approximately 25 feet. Groundwater measured at the completion of drilling at approximately 33.3 feet. Backfilled with soil cuttings on 1/6/09. <u>Note</u>: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
45								
50								
55								
60								

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-6

DATE DRILLED 1/6/09 BORING NO. B-3
GROUND ELEVATION 103' ± (MSL) SHEET 1 OF 1
METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)
DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"
SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▨	CL	FILL: Dark brown, damp to moist, soft to firm, sandy CLAY.
5		■	6	22.8	98.9	▨	CL	ALLUVIUM: Dark brown to black, moist, firm to stiff, sandy CLAY with gravel.
				▼		▨		@6.5': Groundwater measured after completion of drilling.
10		◣	21			▨		Dark olive brown and dark reddish brown; saturated; very stiff.
						▨		Occasional cobble.
15		■	18			▒	SC	Light yellowish brown, saturated, medium dense, clayey SAND; scattered gravel.
								Total Depth = 16.5 feet. Groundwater measured at approximately 6.5 feet at the end of drilling. Backfilled with on-site soils on 1/6/09. Note: Groundwater, though not encountered at the time of drilling, may rise to a higher level due to seasonal variations in precipitation and several other factors as discussed in the report.
20								

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-7

DATE DRILLED 1/6/09 BORING NO. B-4

GROUND ELEVATION 89' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▦	SM	ALLUVIUM: Yellowish brown to brown, damp to moist, medium dense, silty SAND with scattered sandy clay lenses.
	■	■	20	10.0	108.0	▦		
5		◣	3			▨	CL	Dark yellowish brown, damp to moist, soft to firm, sandy CLAY; rootlets.
10		■	24	16.1	102.0	▨		Very stiff; caliche; rootlets.
15		◣	6			▨		Mottled yellowish brown and olive brown; firm to stiff.
								Total Depth = 16.5 feet. No groundwater encountered during drilling. Backfilled with on-site soils on 1/6/09. Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
20								

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-8

DATE DRILLED 1/6/09 BORING NO. B-5

GROUND ELEVATION 75' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▨	CL	FILL: Brown, dry to damp, stiff, sandy CLAY.
5		◣	15	12.7	103.8	▨	SC	ALLUVIUM: Dark brown, damp, medium dense, clayey SAND; caliche.
10		◣	5			▨		Yellowish brown; loose.
15		■	21			▨		Very stiff sandy clay lens.
								Total Depth = 16.5 feet. No groundwater encountered during drilling. Backfilled with on-site soils on 1/6/09. Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.
20								

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-9

DATE DRILLED 1/6/09 BORING NO. B-6

GROUND ELEVATION 63' ± (MSL) SHEET 1 OF 1

METHOD OF DRILLING 8 inch Hollow-Stem Auger (Martini Drilling)

DRIVE WEIGHT 140 lbs. (Auto. Trip Hammer) DROP 30"

SAMPLED BY MCP LOGGED BY MCP REVIEWED BY JJB

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					▨	SC	ALLUVIUM: Light yellowish brown, dry to damp, medium dense, clayey SAND with sandy CLAY; scattered gravel; rootlets.
	■	■	16	8.2	112.2	▨		
5		■	7			▨		Caliche; loose to medium dense.
10		■	11			▨		Loose; scattered gravel.
15		◣	3			▧	CL	Reddish brown, damp, soft to firm, sandy CLAY; rootlets.
20								Total Depth = 16.5 feet. No groundwater encountered during drilling. Backfilled with on-site soils on 1/6/09. Note: Groundwater may rise to a level higher than that measured in borehole due to seasonal variations in precipitation and several other factors as discussed in the report.

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BORING LOG

COASTAL TREATMENT PLANT ACCESS ROAD REALIGNMENT
LAGUNA NIGUEL, CALIFORNIA

PROJECT NO.	DATE	FIGURE
202426004	4/09	A-10

DATE DRILLED 11/15/01 BORING NO. B-1

GROUND ELEVATION 62' ± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY LTJ LOGGED BY LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	SLOPE WASH/ALLUVIUM: Light brown, damp, loose, silty SAND.
							SC	Brown, moist, medium dense, clayey SAND with few gravel.
	■			16.8				
5								
	■			15.2				Light yellowish brown, scattered cobble to small boulder size sandstone and siltstone fragments.
10								
							SC+CL	Light yellowish brown, moist, medium dense, clayey SAND and sandy CLAY with few cobble size siltstone/sandstone fragments.
15	■			19.2				
				▽				@ 17.0': Groundwater encountered during drilling; boring subject to caving; saturated.
	■			20.5				Mottled olive brown and orangish brown.
20							SC+CL	SLOPE WASH/ALLUVIUM: Mottled olive brown and orangish brown, moist,

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. B-1

GROUND ELEVATION 62' ± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY LTJ LOGGED BY LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
	■					▨	CL	dense, clayey SAND and sandy CLAY. @ 20.0': Cobble and boulder size siltstone fragments. Brown, saturated, stiff, sandy CLAY with gravel and cobbles.
	■					▤		<u>TOPANGA FORMATION (LANDSLIDE DEPOSITS)</u>: Light olive, moist, moderately weathered SILTSTONE. @ 22.0': difficult drilling; switched to bullet tooth flight auger bit; strongly cemented.
25								Total Depth = 25.0 feet. Drilling refusal in strongly cemented siltstone. Groundwater encountered during drilling at approximately 17.0 feet. Boring downhole logged to approximately 18.0 feet; caving and seepage encountered. Backfilled on 11/15/01.
30								
35								
40								

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. B-2

GROUND ELEVATION 54' ± (MSL) SHEET 1 OF 3

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY GMC LOGGED BY GMC/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▥	ML	FILL: Light brown to brown, damp, firm, clayey SILT; abundant rootlets.
						▨	CL	SLOPE WASH/ALLUVIUM: Brown, damp to moist, firm, sandy CLAY; trace coarse sand and gravel; abundant rootlets.
5	■			9.6		▨		
10	■			22.4		▨		Moist to wet.
				▽		▨		@ 14.0': Groundwater encountered during drilling; saturated.
15	■			22.1		▨		@ 14.0 to 17.0': Borehole caving; downhole logging terminated.
20						▨		SLOPE WASH/ALLUVIUM (CONTINUED): Brown, saturated, firm, sandy CLAY; trace coarse sand and

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. B-2

GROUND ELEVATION 54' ± (MSL) SHEET 2 OF 3

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY GMC LOGGED BY GMC/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
	■							gravel; abundant rootlets.
25							SC	Light brown and reddish brown, saturated, medium dense, clayey SAND; few to little gravel; few cobbles of reddish brown, strongly cemented, fine grained sandstone.
30 35	■							<u>TOPANGA FORMATION (LANDSLIDE DEPOSITS)</u>: Yellowish brown, saturated, moderately cemented, moderately weathered, silty fine to medium-grained SANDSTONE; trace coarse sand and pebbles.
	■							Reddish brown and grayish brown, moderately indurated SILTSTONE.
40								Bluish gray and white, weakly cemented, slightly weathered, fine to medium grained SANDSTONE; friable. <u>TOPANGA FORMATION (LANDSLIDE DEPOSITS)(CONTINUED)</u>: Bluish gray, white and gray, weakly cemented, fresh to slightly weathered, fine to medium grained SANDSTONE; friable; planar and convoluted laminations.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. B-2

GROUND ELEVATION 54' ± (MSL) SHEET 3 OF 3

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY GMC LOGGED BY GMC/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
						▨		
45								Total Depth = 45.0 feet. Groundwater encountered during drilling at approximately 14.0 feet. Borehole downhole logged to approximately 15.0 feet; seepage and caving encountered. Backfilled on 11/15/01.
50								
55								
60								

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/14/01 BORING NO. B-3
GROUND ELEVATION 45.5' ± (MSL) SHEET 1 OF 2
METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)
DRIVE WEIGHT NA DROP NA
SAMPLED BY TPO LOGGED BY TPO/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▨	SC	FILL: Gray, moist, medium dense, clayey SAND with trace gravel and fine roots.
	■			8.7		▨		
						▧	CL	SLOPEWASH/ALLUVIUM: Olive brown, moist, stiff, sandy CLAY.
5	■			20.2		▧		
10	■			24.5		▧		
15	■			24.0		▧		@ 15.0': Few scattered lenses of fine sand.
				▽		▧		@ 18.0': Groundwater encountered during drilling, saturated. @ 18.0' to 24.0': Borehole caving; downhole logging terminated at approximately 19.0 feet.
20	■			22.6		▧	CL	SLOPE WASH/ALLUVIUM (CONTINUED): Olive brown, moist, stiff, sandy CLAY.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/14/01 BORING NO. B-3
GROUND ELEVATION 45.5' ± (MSL) SHEET 2 OF 2
METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)
DRIVE WEIGHT NA DROP NA
SAMPLED BY TPO LOGGED BY TPO/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
	■					▨		
						▦	SM	Light gray, saturated, medium dense, silty SAND.
						▨	CL	Olive brown, saturated, stiff, sandy CLAY with trace gravel.
25	■					▨		
30	■					▨		
						▨		@ 33.0': Boulders.
35	■					▨		
	■					░		<u>TOPANGA FORMATION (LANDSLIDE DEPOSITS)</u>: Gray, slightly weathered, very hard, strongly cemented SANDSTONE.
								Total Depth = 38.5 feet. Drilling refusal in strongly cemented sandstone. Groundwater encountered at approximately 18.0 feet during drilling. Boring downhole logged to approximately 19.0 feet; caving and seepage encountered. Backfilled on 11/14/01.
40								

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/14/01 BORING NO. B-4

GROUND ELEVATION 48.0' ± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY TPO LOGGED BY TPO/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SC	FILL: Grayish brown, damp, clayey SAND with trace gravel; trace root hairs;
	■			8.4			SC	SLOPE WASH/ALLUVIUM: Olive brown, moist, medium dense, clayey SAND with little gravel, cobbles.
5	■			6.0				
							CL	Dark brown, moist, stiff, sandy CLAY with cobble to boulder size shale fragments.
								TOPANGA FORMATION (LANDSLIDE DEPOSITS): Yellowish brown, moderately weathered, weakly to moderately cemented, silty fine-grained SANDSTONE.
10	■			14.0				@ 10.5': Becomes strongly cemented; orange oxidation; bedding massive.
								@ 14.0': Fracture; N60°E, 60°NW; planar with approximately 1/16-inch clay infilling.
15	■			13.0				
								Brown and gray, moderately weathered, clayey SHALE. @ 16.5': Bedding, N50°E;12°S @ 17.0': Fracture, N30°W, 60°NE; planar with approximately 1/16-inch clay infilling; fracture terminated between 16.5' and 18.0'.
								Gray to dark gray, strongly cemented, fine-grained SANDSTONE; moderately weathered; moderately cemented, massive.
20	■							TOPANGA FORMATION (LANDSLIDE DEPOSITS): Gray to dark gray, strongly cemented, fine-grained SANDSTONE; moderately

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/14/01 BORING NO. B-4

GROUND ELEVATION 48.0' ± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 30" Bucket Auger (San Diego Drilling)

DRIVE WEIGHT NA DROP NA

SAMPLED BY TPO LOGGED BY TPO/LTJ REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								weathered; moderately cemented, massive.
								@ 21.5': Approximately 1-inch-thick brown shale layer: N60°W, 12°S.
								@ 22.0': Scattered discontinuous vertical fractures; tight.
								@ 22.5': Slight seepage.
25								
								@ 25.5': Bedding, N30°W, 10°SW.
								@ 26.0': Fracture, N30°W, 85°SW, tight.
								@ 26.5': Fracture, N20°W, 85°SW, tight.
								@ 29.0': Fracture, N30°W, 50°SW; planar, tight, seepage becomes heavy.
30								@ 30.0': Drilling becomes difficult; alternating between bucket auger bit and bullet tooth flight auger.
								@ 31.0': Bedding, N30°E, 7°SW.
35								
								Total Depth = 38.0 feet. Refusal encountered during drilling in strongly cemented sandstone. Groundwater seepage encountered during drilling from approximately 22.5 to 33.0 feet. Backfilled on 11/14/01.
40								

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. C-1

GROUND ELEVATION 56.0' ± (MSL) SHEET 1 OF 5

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	SLOPE WASH/ALLUVIUM: Light brown, light gray, moist, medium dense, silty SAND; thin bands of reddish brown oxidation.
5		◣	17					
10		◣	5					Loose.
15		◣	12	▽				@ 15.0': Groundwater encountered during drilling. Brown, saturated, medium dense.
							SC	Brown, saturated, loose, clayey SAND; few coarse sand.
20		◣	5				SC	SLOPE WASH/ALLUVIUM (CONTINUED): Brown, saturated, loose, clayey SAND; few coarse sand.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. C-1

GROUND ELEVATION 56.0' ± (MSL) SHEET 2 OF 5

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		▮				▨		
25		▮	15			▨		Light brown; medium dense; few thin interbeds of brown clay and light brown silty sand.
30		▮	10			▨		Brown to dark brown; mottled with reddish oxidation; increase in clay content; few coarse sand.
35		▮	20			▨		Dark reddish brown; few specks of reddish oxidation; trace organics.
						▨	SC	Dark grayish brown, saturated, very stiff, sandy CLAY; trace fine gravel, few thin interbeds of light brown and brown, clayey fine sand.
40		▮	17			▨	SC	SLOPE WASH/ALLUVIUM (CONTINUED): Dark grayish brown, saturated, very stiff, sandy CLAY; trace fine gravel; few thin interbeds of light brown and brown, clayey fine sand; few medium sand; gradational contacts.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. C-1

GROUND ELEVATION 56.0' ± (MSL) SHEET 3 OF 5

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
45			125					TOPANGA FORMATION (LANDSLIDE DEPOSITS): Light brown, saturated, weakly cemented, intensely weathered, soft SANDSTONE; interbedded with few thin beds of brown to dark brown, strongly indurated, moderately hard claystone and siltstone.
								Bluish gray, saturated, slightly weathered to fresh, moderately indurated, moderately soft SILTSTONE. Core Run @ 46.5' to 48.0'; Approximately 20% recovery; no RQD; sample disturbed during drilling. Core Run @ 48.0'to 50': Approximately 8% recovery; no RQD; sample disturbed during drilling. Reddish brown, strongly cemented, extremely hard, sandstone in core shoe.
50								Gray, fresh, strongly indurated, moderately hard; trace shells. Core Run @ 50.0' to 55.0': Approximately 89% recovery; RQD of 89%.
								Bluish gray, saturated, fresh, unfractured, moderately cemented, moderately hard, silty fine-grained SANDSTONE; few random shells; bioturbated.
55								Core Run @ 55.0'to 58.0': Approximately 67% recovery; RQD of 67%; very slightly fractured. @ 57.8': fracture; slightly open, smooth, planar, infilled with very thin clay at approximately 60 degrees. @ 58.0' to 63.0': 98% recovery; RQD of 98%.
60								TOPANGA FORMATION (LANDSLIDE DEPOSITS) CONTINUED: Bluish gray, saturated, fresh, unfractured, moderately cemented, moderately hard, silty fine-grained SANDSTONE; few random shells; bioturbated. Decrease in silt.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DEPTH (feet) | SAMPLES Bulk Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S.

DATE DRILLED 11/15/01 BORING NO. C-1

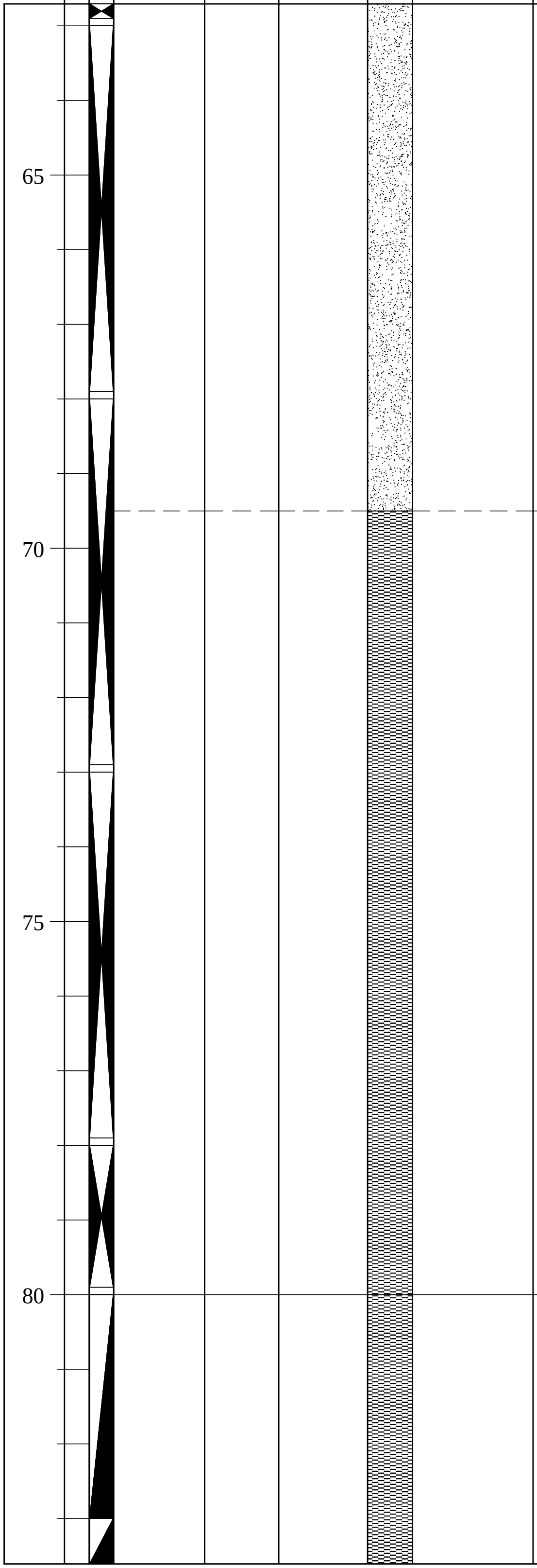
GROUND ELEVATION 56.0' ± (MSL) SHEET 4 OF 5

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DESCRIPTION/INTERPRETATION



Core run @ 63.0'-68.0': Approximately 98% recovery; RQD of 90%.
Light gray, strongly cemented, hard.

Gray, moderately cemented, moderately hard, trace coarse sand and shells; trace black laminae aproximately hairline to 1/32-inch thick.

Core @ 68.0' - 73.0': Aproximately 100% recovery; RQD of 92%.

Gray, fresh, strongly indurated, moderately hard, unfractured SILTSTONE.

Core Run @ 73.0'-78.0': Approximately 100% recovery; RQD of 100%.

@ 74.0'-75.5': Trace fine sand.

Light gray.

Core Run @ 78.0' to 83.0': Approximately 95% recovery; RQD of 95%.

@ 79.0' to 80.0': Sandy.

TOPANGA FORMATION (CONTINUED):
Light gray and gray, strongly indurated, moderately hard, unfractured SILTSTONE; few trace shells.

Core run @ 83.0'-85.0': Approximately 100% recovery; RQD approximately

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/15/01 BORING NO. C-1

GROUND ELEVATION 56.0' ± (MSL) SHEET 5 OF 5

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▒		100%.
85								Total Depth = 85.0 feet. Groundwater encountered at approximately 15.0 feet during drilling. Backfilled on 11/16/01.
90								
95								
100								

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/12/01 BORING NO. C-2

GROUND ELEVATION 46.5' ± (MSL) SHEET 1 OF 4

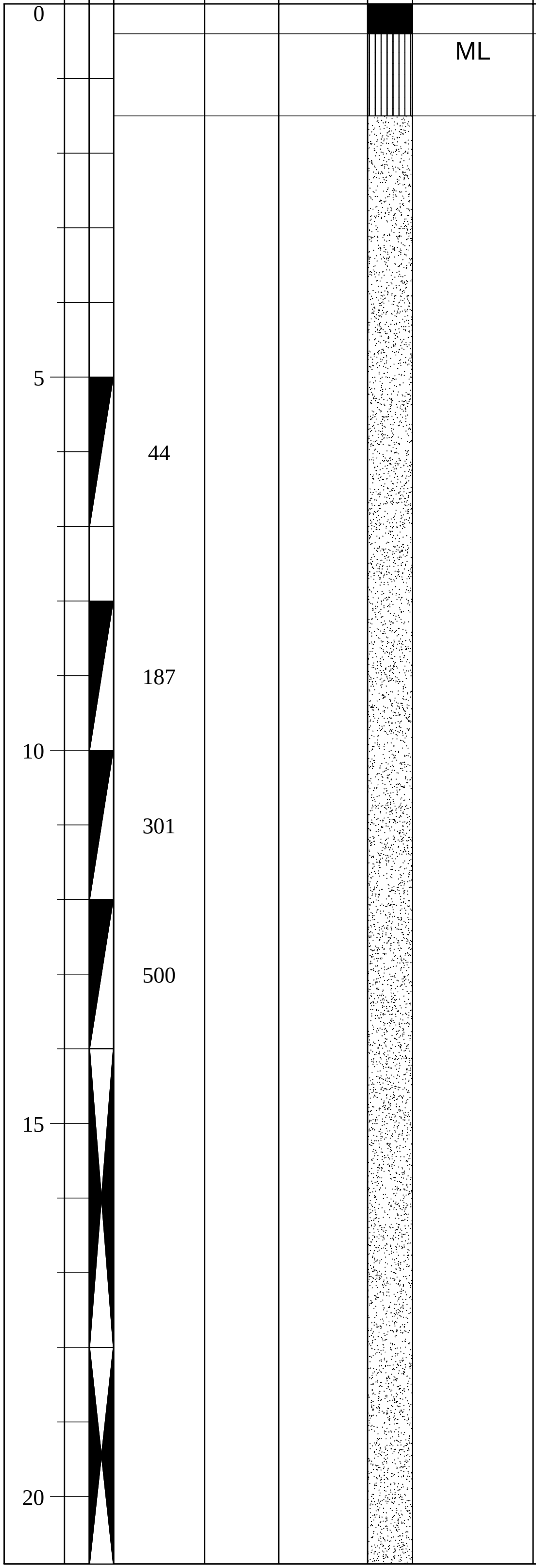
METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet) | SAMPLES: Bulk, Driven | BLOWS/FOOT | MOISTURE (%) | DRY DENSITY (PCF) | SYMBOL | CLASSIFICATION U.S.C.S.

DESCRIPTION/INTERPRETATION



ASPHALT CONCRETE:
Approximately 4 inches thick.

FILL:
Reddish brown, moist, medium dense, sandy SILT.

TOPANGA FORMATION (LANDSLIDE DEPOSITS):
Light yellowish brown, damp to moist, weakly cemented, moderately weathered, soft, silty fine SANDSTONE; few bands of orangish oxidation; dark red to black fracture surfaces; few fractures.

Few thin interbeds of light grayish brown, moderately to strongly cemented, very hard, silty fine sandstone.

Core Run @ 14.0'-18.0': Approximately 20% recovery; No RQD, sample disturbed during drilling.

Grayish brown; moderately cemented.
Core Run @ 18.0'-23.0': Approximately 27% recovery; RQD of 23%.

TOPANGA FORMATION (LANDSLIDE DEPOSITS):
Yellowish brown, moderately weathered, weakly cemented, soft, silty fine

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/12/01 BORING NO. C-2
GROUND ELEVATION 46.5' ± (MSL) SHEET 2 OF 4
METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)
DRIVE WEIGHT 140 lbs. DROP 30"
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								SANDSTONE; abundant reddish oxidation banding.
								Core run @ 23-28.0': Approximately 13% recovery; no RQD, sample disturbed during drilling. Light brown, moderately weathered, moderately cemented, moderately soft.
25								
								Gray to dark gray, moderately weathered, moderately cemented, moderately soft, SILTSTONE, trace fossils. Core Run @ 28-32.5': Approximately 77% recovery; RQD of approximately 20%, sample disturbed during drilling.
30								
								Bluish gray, slightly weathered, moderately to strongly cemented, moderately hard, moderately fractured SANDSTONE.
								Gray, moderately weathered, moderately cemented, moderately hard SILTSTONE. Core Run @ 32.5-35.0': Changed coring system,approximately 73% recovery; RQD of 62%. @ 33.5': fracture; slightly open, rough, undulating, dipping approximately 50 degrees.
35								@ 35.0-40.0': Approximately 100% recovery; RQD of 67%. Fresh, very thin interbed of strongly cemented, hard, fine-grained sandstone at top of core.
								@ 35.0-39.0': Intensely to moderately fractured.
40								TOPANGA FORMATION (LANDSLIDE DEPOSITS) CONTINUED): Light gray, fresh, moderately to strongly cemented, moderately hard, intensely to moderately fractured, fine sandy SILTSTONE; fractures are subvertical, hairline to 1/32 inch wide, infilled with quartz, moderately

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.

DATE DRILLED 11/12/01 BORING NO. C-2

GROUND ELEVATION 46.5' ± (MSL) SHEET 3 OF 4

METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)

DRIVE WEIGHT 140 lbs. DROP 30"

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DESCRIPTION/INTERPRETATION

spaced, slightly open, rough undulating, dipping approximately 55 to 60 degrees.
Core Run @ 40-50.0': Approximately 92% recovery; RQD of 92%.

45

Gray, fresh, moderately to strongly cemented, moderately hard, moderately fractured, fine-grained SANDSTONE; fractures are infilled with very thin dark gray silt, fractures dip approximately 50 to 80 degrees.
@ 47.0': fracture; slightly open, moderately rough, planar fracture with polished surface, dipping at approximately 50 degrees.

50

Moderately fractured; trace pebbles.
Core Run @ 50.0'-55.0': Approximately 97% recovery; RQD of 95%.

Light gray; strongly cemented; hard; silty.

55

Gray; few subvertical to 60 degree fractures; tight to slightly open, smooth, planar, and infilled with very thin silt and quartz.
Core Run @ 55.0'-60.0': Approximately 92% recovery; RQD of 92%.

Subvertical, hairline to 1/16 inch-wide-fractures, infilled with quartz.

60

TOPANGA FORMATION (LANDSLIDE DEPOSITS) (CONTINUED):
Dark gray, strongly cemented, moderately hard, fine-grained SANDSTONE; subvertical hairline to 1/8 inch wide fracture, closed and filled with quartz, few medium to coarse grains; trace pebbles.
Core Run @ 60.0-65.0': Approximatley 98% recovery; RQD of 89%; slightly fractured.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 11/12/01 BORING NO. C-2
GROUND ELEVATION 46.5' ± (MSL) SHEET 4 OF 4
METHOD OF DRILLING 8" Hollow Stem Auger/Rock coring (Spectrum Drilling)
DRIVE WEIGHT 140 lbs. DROP 30"
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY LTJ/CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
65								Core Run 65.0-70.0': Approximately 93% recovery; RQD of approximately 93%. Moderately hard, trace shells. @ 67.0-69.0': Subvertical fracture, tight.
70								@ 69.5'; fracture dipping approximately 45 degrees, with approximately 1/16-inch clay infill. Core Run @ 70.0-75.0': Approximately 92% recovery; RQD of 86%. Hard; unfractured; trace coarse sand, no pebbles.
75								Core Run @ 75.0-80.0': Approximately 64% recovery; RQD of 57%.
80								Total Depth = 80.0 feet. No groundwater encountered during drilling. Backfilled on 11/15/01.

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BORING LOG

Moulton Niguel Water District, Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426001	12/2001	

DATE DRILLED 3/16/00 BORING NO. B-1a
GROUND ELEVATION 87± (MSL) SHEET 1 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (THF Drilling)
DRIVE WEIGHT 140 lbs DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■						SM	FILL: Dark brown, moist, medium dense, silty SAND.
								Brown.
							SP	STREAM TERRACE DEPOSITS: Light brown, moist, medium dense, SAND.
5		■	27	17.2	112.2			
							SC/CL	Mottled, dark brown and grayish brown, moist to wet, very stiff, fine sandy CLAY to clayey SAND; trace veinlets of reddish oxidation.
							SP	Light brown, wet, dense, SAND.
10		■		▽				@ 10': Groundwater encountered during drilling. Sharp contact.
	■		33				SC	Light grayish brown, saturated, dense, clayey SAND.
15		☒	70/6"					TOPANGA FORMATION: Saturated, strongly cemented, SILTSTONE and SANDSTONE.
20		☒						TOPANGA FORMATION (CONTINUED): Saturated, strongly cemented, SILTSTONE and SANDSTONE.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	5/2000	

DATE DRILLED 3/16/00 BORING NO. B-1a

GROUND ELEVATION 87± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (THF Drilling)

DRIVE WEIGHT 140 lbs DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
						▨		
25		◣	80/5"			▨		Refusal at approximately 25.5 feet. Total Depth = 25.5 feet. Groundwater encountered during drilling at approximately 10.0 feet. Backfilled on 3/16/00.
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	5/2000	

DATE DRILLED 3/16/00 BORING NO. B-2a

GROUND ELEVATION 48± (MSL) SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (THF Drilling)

DRIVE WEIGHT 140 lbs DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0	■					ML	FILL: Light brown, moist, loose, sandy SILT.
	■					GP	Brown, moist, medium dense, poorly-graded GRAVEL; few sand.
	■						TOPANGA FORMATION: Light yellowish brown, moist, moderately to strongly cemented, silty fine SANDSTONE.
5	■	■	100/3"	12.7	90.0		
	■						Light grayish brown, moist, strongly cemented, fine, sandy SILTSTONE.
10		◤	84/6"				Light reddish brown; moderately cemented; few yellowish oxidation.
							Light reddish brown, moist, strongly cemented, silty fine SANDSTONE; trace veinlets of black oxidation.
15		■	100/5"	13.9	86.5		
20		◤	70/5"				TOPANGA FORMATION (CONTINUED): Light gray, moist, strongly cemented, fine sandy SILTSTONE.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	5/2000	

DATE DRILLED 3/16/00 BORING NO. B-2a

GROUND ELEVATION 48± (MSL) SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (THF Drilling)

DRIVE WEIGHT 140 lbs DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								Refusal at approximately 21.0 feet. Total Depth = 21.0 feet. No groundwater encountered. Backfilled on 3/16/00.
25								
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	5/2000	

DATE DRILLED 10/4/00 BORING NO. B-1

GROUND ELEVATION 49 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	OLDER ALLUVIUM: Brown, moist, medium dense, silty SAND; trace gravel.
			15					
5			23					
10			16				CL	Brown to dark brown, moist, very stiff, silty CLAY; few fine sand.
15			29				SM/ML	Brown, moist, medium dense, silty SAND to fine sandy SILT.
20			8				CL	OLDER ALLUVIUM (CONTINUED): Brown, moist, firm to stiff, silty CLAY; trace fine sand.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-1
GROUND ELEVATION 49 ±MSL SHEET 2 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■				▨		
				▽		▨		@ 24': Groundwater encountered during drilling.
25		■	31			▨		Hard; few to some sand.
30		■	19			▨		Very stiff.
								Total Depth = 31.5 feet. Groundwater encountered during drilling at approximately 24.0 feet. Backfilled on 10/4/00.
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-2

GROUND ELEVATION 46 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▦	SM	<u>FILL</u>: Light brown, damp, loose, silty fine SAND; abundant grass.
						▨	CL	<u>OLDER ALLUVIUM</u>: Brown and dark brown, moist, stiff CLAY; mottled; few caliche stringers.
5	■	■	16			▨		
10		◣	4			▨		Soft to firm.
						▨		Wet.
15		■	9			▨		Firm; trace pinhole porosity.
						▨		Stiff.
20		◣	10			▨	CL	<u>OLDER ALLUVIUM (CONTINUED)</u>: Brown and dark brown, moist to wet, stiff, silty CLAY; mottled; trace

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-2

GROUND ELEVATION 46 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▨		pinhole porosity.
								Total Depth = 21.5 feet. No groundwater encountered. Backfilled on 10/4/00.
25								
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-3

GROUND ELEVATION 64 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▥	ML	FILL: Dark brown, damp, loose, fine sandy SILT; abundant rootlets.
						▨	CL	COLLUVIUM/SLOPE WASH: Reddish brown, moist, firm, silty CLAY; trace caliche veinlets and pinhole porosity; interbedded with few thin beds of silty sand.
	■					▦	SM	Brown, moist, loose, silty SAND.
5	■	■	10	15.8	99.6	▨	CL	Reddish brown, moist, firm to stiff, silty CLAY; trace caliche veinlets and pinhole porosity.
10		◣	6			▨		Firm; few caliche veinlets.
15		■	9			▨		Brown.
20		◣	7			▨	CL	COLLUVIUM/SLOPE WASH (CONTINUED): Brown, moist, firm, silty CLAY; few caliche veinlets; trace pinhole

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-3

GROUND ELEVATION 64 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								porosity.
25			11					Stiff wet.
							CL	Cobbles of brown and olive brown, moist, highly weathered, weakly to moderately indurated, silty claystone.
30			12				CL+ML	Dark brown, wet, stiff CLAY interbedded with reddish brown SILT.
35			11					
				▽			SC	@ 36': Groundwater encountered during drilling. Brown, saturated, loose, clayey SAND.
								Total Depth = 36.5 feet. Groundwater encountered during drilling at approximately 36.0 feet. Backfilled on 10/4/00.
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-4

GROUND ELEVATION 53 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							ML	COLLUVIUM/SLOPE WASH: Dark brown, moist, loose, SILT.
		■	19					
5	■	■	15					Medium dense.
10		■	30					Moist to wet; few pieces of light brown friable sandstone; trace shells.
15	■	■	28				SM	Orange-brown and bluish gray, moist, medium dense, silty fine SAND.
								TOPANGA FORMATION: Orange-brown, moist, weakly cemented, fine-grained SANDSTONE.
20		■	50/2"					TOPANGA FORMATION (CONTINUED): Orange-brown, damp to moist, weakly cemented, fine-grained SANDSTONE.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-4

GROUND ELEVATION 53 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								Total Depth = 20.5 feet. No groundwater encountered. Backfilled on 10/4/00.
25								
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-5

GROUND ELEVATION 54 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							GP	FILL: Gray, damp, medium dense, poorly graded GRAVEL.
							SM	OLDER ALLUVIUM: Brown to dark brown, moist, loose, silty SAND; large pinhole voids up to approximately 2 millimeters in diameter.
5		■	10					
	■							
10		◣	9				CL	Dark brown, moist, stiff, silty CLAY.
15	■	■	26				SM	Brown, moist, medium dense, silty SAND.
							SC	Light yellowish brown, moist, medium dense, clayey SAND.
20		◣	22				SC/CL	OLDER ALLUVIUM (CONTINUED): Light yellowish brown, moist, medium dense, clayey SAND.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-5

GROUND ELEVATION 54 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▨	CL	Yellowish brown, moist, very stiff, sandy CLAY.
								Total Depth = 21.5 feet. No groundwater encountered. Backfilled on 10/4/00.
25								
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-6
GROUND ELEVATION 62 ±MSL SHEET 1 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	FILL: Light brown, damp, loose, silty SAND; abundant rootlets; grass.
							CL	OLDER ALLUVIUM: Olive to reddish brown, moist, hard, sandy CLAY; few pinhole voids; trace gravel of grayish brown, weakly indurated Siltstone.
5	■	■	55	13.3	117.3			
							CL+SM	Brown, moist, very stiff CLAY; interbedded with thin beds of reddish brown, medium dense, silty SAND.
10		◣	20					
							CL+SC	Reddish brown and yellowish brown, moist, stiff CLAY; finely laminated; interbedded with thin beds of yellowish brown and gray, loose, clayey SAND.
15		■	17					
				▼			SM+SP	Brown, saturated, medium dense, silty fine SAND to poorly graded SAND. @ 18.5': Groundwater measured after drilling completed.
20		◣	17				SM+SP	OLDER ALLUVIUM (CONTINUED): Brown, saturated, medium dense, silty fine SAND to poorly graded SAND.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-6

GROUND ELEVATION 62 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▨		TOPANGA FORMATION: Reddish brown and gray, moist, moderately indurated, SILTSTONE. Total Depth = 21.5 feet. Groundwater measured after drilling at approximately 18.5 feet. Backfilled on 10/4/00.
25								
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-7

GROUND ELEVATION 105 ±MSL SHEET 1 OF 3

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	<u>OLDER ALLUVIUM</u>: Light yellowish brown, damp to moist, dense, silty fine SAND.
5		■	78					Pinhole voids; rootlets.
10	■	⧄	50/1"					No recovery; rock encountered.
								Trace to few gravel.
15		■	19	5.8	113.5			Loose.
								Light brown.
20		◣	31				SM	<u>OLDER ALLUVIUM (CONTINUED)</u>: Light brown, moist, dense, silty fine SAND.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-7

GROUND ELEVATION 105 ±MSL SHEET 2 OF 3

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
25			32					Rock in upper part of sample.
30			12					Medium dense; white stringers.
35			20					Loose; clayey; few coarse sand and fine gravel.
							ML/SM	Brown, moist, medium dense, fine sandy SILT to silty fine SAND.
40			18				ML/SM	OLDER ALLUVIUM (CONTINUED): Brown, moist, medium dense, fine sandy SILT to silty fine SAND.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-7

GROUND ELEVATION 105 ±MSL SHEET 3 OF 3

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
45		■	32			▨	CL	Brown, moist, very stiff, fine sandy CLAY.
50		◣	17			▨		
								Total Depth = 51.5 feet. No groundwater encountered. Backfilled on 10/4/00.
55								
60								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-8

GROUND ELEVATION 104 ±MSL SHEET 1 OF 3

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							ML	OLDER ALLUVIUM: Olive brown, damp, loose, SILT; few sand; trace caliche stringers.
	■							
5	■	■	10					Moist; little sand.
10		◢	6					
	■							
15	■	■	24	12.6	105.4			Medium dense; few gravel.
								Grayish brown; fine sand.
20		◢	8				ML	OLDER ALLUVIUM (CONTINUED): Grayish brown, moist, loose, fine sandy SILT; few caliche stringers; few

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-8
GROUND ELEVATION 104 ±MSL SHEET 2 OF 3
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣						interbeds of dark brown, clayey SILT; fine laminations.
							CL+SC	Dark reddish brown, moist, very stiff CLAY; trace medium sand; interbedded with clayey SAND and SILT.
25		■	26	13.6	116.7			
							CL+ML	Reddish brown, moist, very stiff, silty CLAY; interbedded and gradational with thin beds of SILT.
30		◣	16					
35		■	18	20.2	105.8			Stiff; wet; trace black organics.
				▽				@ 39': Groundwater encountered during drilling.
40		◣	10				CL+ML	<u>OLDER ALLUVIUM (CONTINUED)</u>: Reddish brown, saturated, stiff, clayey SILT to silty CLAY; trace black organics.

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BORING LOG
Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-8

GROUND ELEVATION 104 ±MSL SHEET 3 OF 3

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
							SM+ML	Reddish to yellowish brown, saturated, medium dense, silty fine SAND; interbedded with few very thin beds of SILT.
45			40					
							ML	Reddish brown, saturated, medium dense, fine sandy SILT; few clayey SILT beds.
50			20					
								Total Depth = 51.5 feet. Groundwater encountered during drilling at approximately 39.0 feet. Backfilled on 10/4/00.
55								
60								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-9

GROUND ELEVATION 88 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							ML	<u>OLDER ALLUVIUM</u>: Brown, moist, loose, fine sandy SILT.
5		■	15					Rootlets; pinhole voids.
10		◤	8					
15	■	■	20					
20		◤	8				ML	<u>OLDER ALLUVIUM (CONTINUED)</u>: Brown, moist, loose SILT; trace clay.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-9

GROUND ELEVATION 88 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■				▥		
25		■	10			▨	ML/CL	Brown, moist, loose, clayey SILT to firm to stiff, silty CLAY.
30		■	11			▨		Medium dense to stiff.
								Total Depth = 31.5 feet. No groundwater encountered. Backfilled on 10/4/00.
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-10
GROUND ELEVATION 80 ±MSL SHEET 1 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▨	CL	COLLUVIUM/SLOPE WASH: Brown, damp to moist, firm CLAY; trace sand.
5	■	■	10	18.3	105.5	▨		Firm to stiff; moist.
						▒		TOPANGA FORMATION: Grayish brown, moist, weakly indurated, SILTSTONE.
10		◤	15			▒		
15		■	80/9"			▒		Sandy; moderately weathered; some reddish oxidation.
20		◤	65/11"			▒		TOPANGA FORMATION (CONTINUED): Grayish brown, moist, moderately indurated, SILTSTONE; moderately

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.

DATE DRILLED 10/4/00 BORING NO. B-10

GROUND ELEVATION 80 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DESCRIPTION/INTERPRETATION

weathered; few thin interbeds of white, strongly indurated, SILTSTONE and light brown, moderately cemented, SANDSTONE.

Total Depth = 21.0 feet.
No groundwater encountered.
Backfilled on 10/4/00.

25

30

35

40

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-11

GROUND ELEVATION 84 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	COLLUVIUM/SLOPE WASH: Light brown, damp, loose, silty SAND; some organics.
							CL	Brown, moist, stiff CLAY; trace mottling; trace black organics and pinhole porosity.
5		■	15					Stiff to very stiff.
							SC/SM	Reddish brown mottled with gray, moist, medium dense, clayey to silty SAND; mottled with gray.
								TOPANGA FORMATION: Yellowish brown, moist, moderately cemented, fine- and medium-grained SANDSTONE; interbedded with few very thin beds of grayish brown, moderately indurated, SILTSTONE.
10		■	50/5"					
15		■	50/5"					
				▽				@ 18': Groundwater encountered during drilling.
20			50/4"					TOPANGA FORMATION (CONTINUED): Yellowish brown, saturated, moderately cemented, fine- and medium-

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.
25							
30							
35							
40							

DATE DRILLED 10/4/00 BORING NO. B-11

GROUND ELEVATION 84 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DESCRIPTION/INTERPRETATION

grained SANDSTONE; interbedded with few very thin beds of grayish brown, moderately indurated, SILTSTONE.

Total Depth = 20.5 feet.
Groundwater encountered during drilling at approximately 18.0 feet.
Backfilled on 10/4/00.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-12

GROUND ELEVATION 102 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▥	ML	OLDER ALLUVIUM: Brown, damp to moist, medium dense SILT; trace sand.
5	■	■	11			▥		Thin, white stringers.
10		■	16			▥		Loose; clayey.
15		■	21			▨	CL+SP	Dark brown, moist, very stiff, CLAY; interbedded with brown, moist, medium dense, poorly graded, fine SAND; trace coarse sand.
						▥	ML	Brown, moist, stiff, clayey SILT.
20		■	15			▥	ML	OLDER ALLUVIUM (CONTINUED): Brown, moist, stiff to very stiff, clayey SILT.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/4/00 BORING NO. B-12
GROUND ELEVATION 102 ±MSL SHEET 2 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY DD LOGGED BY DD REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
25			7					Firm.
30			12	▽				@ 30': Groundwater encountered during drilling. Stiff; saturated.
								Total Depth = 31.5 feet. Groundwater encountered during drilling at approximately 30.0 feet. Backfilled on 10/4/00.
35								
40								

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-13

GROUND ELEVATION 105 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							ML	OLDER ALLUVIUM: Brown, damp, stiff, SILT.
5		■	19					Reddish brown; moist; few find sand.
	■							
	■						CH	Brown, moist to wet, stiff, silty CLAY; mottled with light brown; trace rootlets; abundant pinhole porosity.
10		◣	10					
							ML	Brown to reddish brown, wet, stiff, clayey SILT; few grayish brown gravel of moderately indurated, Siltstone.
15		■	13	25.8 ▼	99.1			@ 16': Groundwater encountered during and measured after drilling; saturated.
							CL	Reddish brown, saturated, firm, silty CLAY.
20		◣	8	22.8	94.8		CL	OLDER ALLUVIUM (CONTINUED): Redddish brown, saturated, firm to stiff, silty CLAY.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-13
GROUND ELEVATION 105 ±MSL SHEET 2 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◤				▨		
25		■	27			▨		Very stiff.
								Total Depth = 26.5 feet. Groundwater encountered during and measured after drilling at approximately 16.0 feet. Backfilled on 10/5/00.
30								
35								
40								

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BORING LOG
Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-14

GROUND ELEVATION 118 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▦	SM	FILL: Light brown, damp, dense, silty SAND; little gravel; few grass.
						▨	CL	COLLUVIUM/SLOPE WASH: Dark grayish brown, moist, hard CLAY; abundant pinhole porosity; trace rootlets; trace coarse sand; trace caliche stringers.
5		■	39			▨		
10	■	■	34	30.9	88.1	▨		Very stiff.
						▨	CL	OLDER ALLUVIUM: Reddish brown, moist, very stiff, silty CLAY; abundant pinhole porosity.
15	■	■	33			▨		Hard; trace reddish oxidation; trace caliche stringers.
				▽		▨		@ 19': Groundwater encountered during drilling. Saturated; very stiff.
20		■	22	22.8	94.8	▨	CL	OLDER ALLUVIUM (CONTINUED): Reddish brown, saturated, very stiff, silty CLAY; abundant pinhole

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-14
GROUND ELEVATION 118 ±MSL SHEET 2 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■				▨		porosity; trace reddish oxidation; trace caliche stringers.
25		■	18			▨		Few thin interbeds of silt.
30		☒	31			▨		
								Total Depth = 31.5 feet. Groundwater encoutered during drilling at approximately 19.0 feet. Backfilled on 10/5/00.
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-15

GROUND ELEVATION 132 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							CL	OLDER ALLUVIUM: Reddish brown, moist, stiff CLAY.
5	■	■	44					Hard; silty.
10		◣	22					Cobble of light gray, moist, moderately indurated SILTSTONE.
							SM	Brown, moist, medium dense, silty SAND.
15		■	26					
							SC	Reddish brown to brown, moist, medium dense,clayey fine SAND.
20		◣	17				SC	OLDER ALLUVIUM (CONTINUED): Reddish brown to brown, moist, medium dense, clayey fine SAND.

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-15

GROUND ELEVATION 132 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		▼				▨		Wet.
				▽		▨	ML+CL	@ 24': Groundwater encountered during drilling. Reddish brown, saturated, loose, fine sandy SILT; interbedded with CLAY.
25		▼	9			▨		
								Total Depth = 26.5 feet. Groundwater encountered during drilling at approximately 24.0 feet. Backfilled on 10/5/00.
30								
35								
40								

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-16

GROUND ELEVATION 144 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▒	SM	FILL: Reddish brown, moist, medium dense, silty SAND; abundant grass and rootlets.
						▥	ML	OLDER ALLUVIUM: Reddish brown, moist, dense, sandy SILT.
5		■	74			░	ML+SM	Dark grayish brown, moist, dense, SILT; trace organics; few sand; interbedded with few beds of silty SAND.
10	■	◣	27			░		Black; medium dense; little sand.
						▨	SC+CL	Gray and grayish brown, wet, medium dense, clayey SAND; mottled; few pinhole porosity; trace rootlets; few interbeds of CLAY.
15		☒	26			▨		
						▨	CL	Dark gray and gray, moist to wet, stiff CLAY; mottled; few organics and pinhole porosity.
20		◣	10			▨	CL	OLDER ALLUVIUM (CONTINUED): Dark gray and gray, moist to wet, firm to stiff, CLAY; mottled; few

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BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-16

GROUND ELEVATION 144 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■				▨		organics and pinhole porosity; few sandy interbeds.
						▨	SC+CL	Dark gray to black, wet, medium dense, silty SAND; interbedded with CLAY and clayey SAND.
25		■	25	▽		▨		@ 25': Groundwater measured during drilling; saturated.
30		■	9			▨		Loose.
								Total Depth = 31.5 feet. Groundwater measured during drilling at approximately 25.0 feet. Backfilled on 10/5/00.
35								
40								

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-17

GROUND ELEVATION 145 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0							SM	FILL: Light brown, damp, dense, silty SAND; few to little gravel.
							ML	OLDER ALLUVIUM: Dark reddish brown, damp, medium dense, fine sandy SILT.
							SC	Grayish brown, moist, medium dense, clayey SAND.
5			18	▽ ▼				@ 6': Groundwater encountered during drilling. Saturated. @ 6.5': Groundwater measured after drilling.
							SM-SC	Grayish brown, saturated, very loose to loose, silty SAND; interbedded with brown clayey SAND.
10			4					
							CL	Gray, light brown and reddish brown, saturated, stiff, CLAY; convoluted laminations; trace pinhole porosity.
15			13					
							ML	Reddish brown and brown, saturated, stiff, SILT; trace caliche stringers.
20			15				ML	OLDER ALLUVIUM (CONTINUED): Reddish brown and brown, saturated, stiff to very stiff, SILT; trace

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-17

GROUND ELEVATION 145 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		■						caliche stringers.
						▨	CL	Dark grayish brown, saturated, stiff to very stiff, silty CLAY; trace caliche stringers; trace pinhole porosity.
25		☒	55			▨		Hard.
								Total Depth = 26.5 feet. Groundwater encountered during drilling at approximately 6.0 feet. Groundwater measured after drilling at approximately 6.5 feet. Backfilled on 10/5/00.
30								
35								
40								

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-18

GROUND ELEVATION 151 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						▒	SM	FILL: Light brown, damp, medium dense, silty SAND.
	■					▒	SM	OLDER ALLUVIUM: Dark reddish brown, moist, medium dense, silty SAND.
5		■	18	6.7	102.5	▒		Yellowish brown; loose.
				▽		▒		@ 8': Groundwater encountered during drilling.
						▨	SC+CL	Brown, saturated, loose, clayey SAND; interbedded with dark grayish brown, firm CLAY.
10		◣	6			▨		
				▼		▨		@ 11.5': Groundwater measured after drilling.
						▨	CL	Reddish brown, brown and gray, saturated, stiff, silty CLAY; mottled; trace pinhole porosity.
15		■	14	26.4	97.3	▨		
						▨	SC+CL	Brown, saturated, medium dense, clayey SAND; interbedded with reddish brown, stiff, CLAY; trace pinhole porosity.
20		◣	12			▨	SC+CL	OLDER ALLUVIUM (CONTINUED): Brown, saturated, medium dense, clayey SAND; interbedded with reddish

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-18
GROUND ELEVATION 151 ±MSL SHEET 2 OF 2
METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)
DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches
SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
								brown, stiff CLAY; trace pinhole porosity.
25			30					
							SC+SM	Brown, saturated, dense, clayey SAND; interbedded with yellowish brown, silty SAND.
30			40					
								Total Depth = 31.5 feet. Groundwater encountered during drilling at approximately 8.0 feet. Groundwater measured after drilling at approximately 11.5 feet. Backfilled on 10/5/00.
35								
40								

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-19

GROUND ELEVATION 159 ±MSL SHEET 1 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
0						■		ASPHALT CONCRETE: Approximately 4½ inches thick.
						⁘	GP	AGGREGATE BASE: Light brown, moist, dense, poorly graded GRAVEL; little to some sand; approximately 5 inches thick.
						▨	CL	COLLUVIUM/SLOPE WASH: Dark grayish brown to black, moist, stiff, silty CLAY; trace sand; trace rootlets and caliche.
5	■	■	13			▨		
						▨	CL	OLDER ALLUVIUM: Reddish brown and brown, moist, very stiff, silty CLAY; mottled trace coarse sand.
10		◢	18			▨		Few thin sandy interbeds.
15		■	10	22.3	102.2	▨		Brown, wet, firm to stiff, sandy CLAY.
				▼		▨		@ 18.5': Groundwater measured after drilling.
						▨	CL+SC	Brown, saturated, stiff, sandy CLAY; interbedded with few thin beds of clayey SAND.
20		◢	9			▨	CL+SC	OLDER ALLUVIUM (CONTINUED): Brown, saturated, stiff, sandy CLAY; interbedded with few thin beds of

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

DATE DRILLED 10/5/00 BORING NO. B-19

GROUND ELEVATION 159 ±MSL SHEET 2 OF 2

METHOD OF DRILLING 8" Hollow Stem Auger (Cal Pac Drilling)

DRIVE WEIGHT 140 lbs. (Spooling Cable) DROP 30 inches

SAMPLED BY GMC LOGGED BY GMC REVIEWED BY CAP

DEPTH (feet)	SAMPLES Bulk	SAMPLES Driven	BLOWS/FOOT	MOISTURE (%)	DRY DENSITY (PCF)	SYMBOL	CLASSIFICATION U.S.C.S.	DESCRIPTION/INTERPRETATION
		◣				▨		clayey SAND.
				▽		▨		@ 23': Groundwater encountered during drilling.
25		■	28			▨		Very stiff.
						▨	ML+CL	Reddish brown and brown, saturated, medium dense, sandy SILT; interbedded with thin beds of sandy CLAY.
30		◣	12			▨		
35		☒	30			▨		
								Total Depth = 36.5 feet. Groundwater encountered during drilling at approximately 23.0 feet. Groundwater measured after drilling at approximately 18.5 feet. Backfilled on 10/5/00.
40								

Ninyo & Moore

BORING LOG

Aliso Creek Emergency Sewer
Laguna Niguel, California

PROJECT NO.	DATE	FIGURE
202426-01	12/2000	

South Orange County Wastewater Authority

Lower Aliso Creek Erosion Assessment

County of Orange, California

April 2012

Prepared by:

TETRA TECH

Lower Aliso Creek Erosion Assessment

County of Orange, California

April 2012

Prepared for:

South Orange County Wastewater Authority

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Disclaimer

These documents have been prepared for a specific project and shall neither be altered nor reused for any other purpose. Also, these documents do not represent as-built conditions. If these documents are altered intentionally or unintentionally, or are reused without the design engineer's written approval, it will be at the sole risk and responsibility of the user. The act of altering or reusing is construed as indemnifying and holding the design engineering firm and its employees harmless from all claims, damages, and expenses, including attorney fees, arising out of such act.

Executive Summary

As part of the ongoing preparation of an environmental impact report (EIR) the South Orange County Wastewater Authority (SOCWA) is currently considering alternatives for the Coastal Treatment Plant (CTP) Export Sludge Force Main Replacement Project. The potential for erosion along lower Aliso Creek between the CTP Bridge crossing and the AWMA Road Bridge crossing has been identified as a key consideration relative to the Export Sludge Force Main Replacement planning process. This report documents the erosion assessment conducted to categorize the vulnerability of the proposed infrastructure in/along both the east bank and west bank of the creek over a 50-year planning period. This assessment was specifically conducted to aid SOCWA in the evaluation of alternatives for the replacement of the existing Export Sludge force mains. These alternatives include two options for the installation of a new force main (Alternatives FM 1 and FM 2) and for the trucking of liquid sludge over the existing paved access road (Alternative TR 1). The erosion assessment documented in this report focuses only on the two alternatives for the installation of a new force main.

The assessment began with field reconnaissance to document recent and historical erosion areas, including modes of failure and conditions which promote failure, as well as conditions that have promoted stable banks. Hydraulic modeling was performed to quantify and categorize hydraulic conditions that control fluvial processes most likely to initiate or maintain bank erosion. A bank energy index (BEI) was calculated, and quartiles were used to rank bank energy as a basis for identifying specific locations along the channel where erosion potential is greatest. To better interpret the BEI, factors affecting resistance to erosion were considered (i.e., bank materials, clay in the toe of the bank, woody vegetation along the toe of the bank, and depositional berms along the banks). Bank materials were categorized based on available boring log profiles, because available geologic and soils mapping do not differentiate the composition of the soils throughout the valley bottom in which lower Aliso Creek is contained. Slope stability modeling was carried out to evaluate the influences of various types of soils and stratification, slope geometry, and groundwater conditions on stable slope geometry using limit equilibrium for desired factors of safety.

The vulnerability of the infrastructure along the channel to bank erosion was rated considering: 1) fluvial erosion potential (*High, Moderate,* or *Low*), 2) geotechnical erosion risk (*High, Moderate,* or *Low*), and 3) the erosion risk associated with bend migration (*High, Moderate* or *Low*). The *High*-rated combined erosion risk, based on the analyses conducted for this assessment, indicates that the proposed pipeline alignment will likely be impacted by bank erosion over the 50-year planning period, so pipeline realignment or bank protection measures are recommended. A *Moderate*-rated erosion risk indicates, based on the analyses conducted, that the pipeline alignment could be impacted over the planning period, so bank erosion should be monitored on a regular basis (i.e., after all floods) and bank protection measures installed if necessary. A *Low*-rated erosion risk indicates, based on the analyses conducted, that the pipeline alignment is unlikely to be impacted by bank erosion over the planning period, so occasional monitoring is recommended (i.e., every few years, or after major floods, whichever occurs first).

The proposed FM 1 alignment along the east (left) bank is potentially subject to approximately 3,300 feet of *High* erosion risk and approximately 1,250 feet of *Moderate* erosion risk; the remaining 12,050 feet of the proposed alignment is along banks with erosion risk rated *Low*.

The proposed FM 2 alignment along the west (right) bank is potentially subject to approximately 1,200 feet of *High*-rated erosion risk and approximately 850 feet of *Moderate*-rated erosion risk; the remaining 17,350 feet of the existing and proposed alignment is along banks with erosion risk rated *Low*.

Additional factors related to erosion along lower Aliso Creek that may affect the erosion risk ratings (and thus the stability of the proposed pipelines) were considered. These factors include: 1) locations where concentrated surface runoff and tributary channels cross the proposed alignments, 2) the reliability of existing bank protection measures that may not have been designed because they were installed as emergency protection, 3) the potential for seepage induced bank failures associated with abandoned pipelines in the banks, 4) the potential for localized vertical degradation of the channel bottom, and 5) the reliability of the CTP and AWMA Bridges.

This erosion assessment was undertaken to evaluate the impacts of potential channel erosion on proposed alternatives for the replacement of the Export Sludge system. However, this assessment also has implications for existing infrastructure. The proposed route of the FM 1 pipeline is roughly the same alignment as the existing Export Sludge force mains and the Effluent Transmission Main (ETM). The ETM is buried below the existing force mains and the proposed FM 1 pipeline, so it is likely less vulnerable to channel erosion. However, the erosion risk to the ETM can be roughly equated to the erosion risk posed to the proposed FM 1 pipeline. The AWMA Road (upon which the TR 1 alternative is dependent) is roughly the same alignment as the proposed FM 2 pipeline, but the road is at greater elevations than the proposed pipeline. Therefore, the erosion risk to the AWMA Road is likely to be greater than the erosion risk to the proposed FM 2 pipeline.

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1 Introduction

This report presents the methods used and results from an erosion assessment along lower Aliso Creek in support of the assessment of proposed alternatives associated with ongoing preparation of an environmental impact report (EIR) for the South Orange County Wastewater Authority (SOCWA) Coastal Treatment Plant (CTP) Export Sludge Force Main Replacement Project.

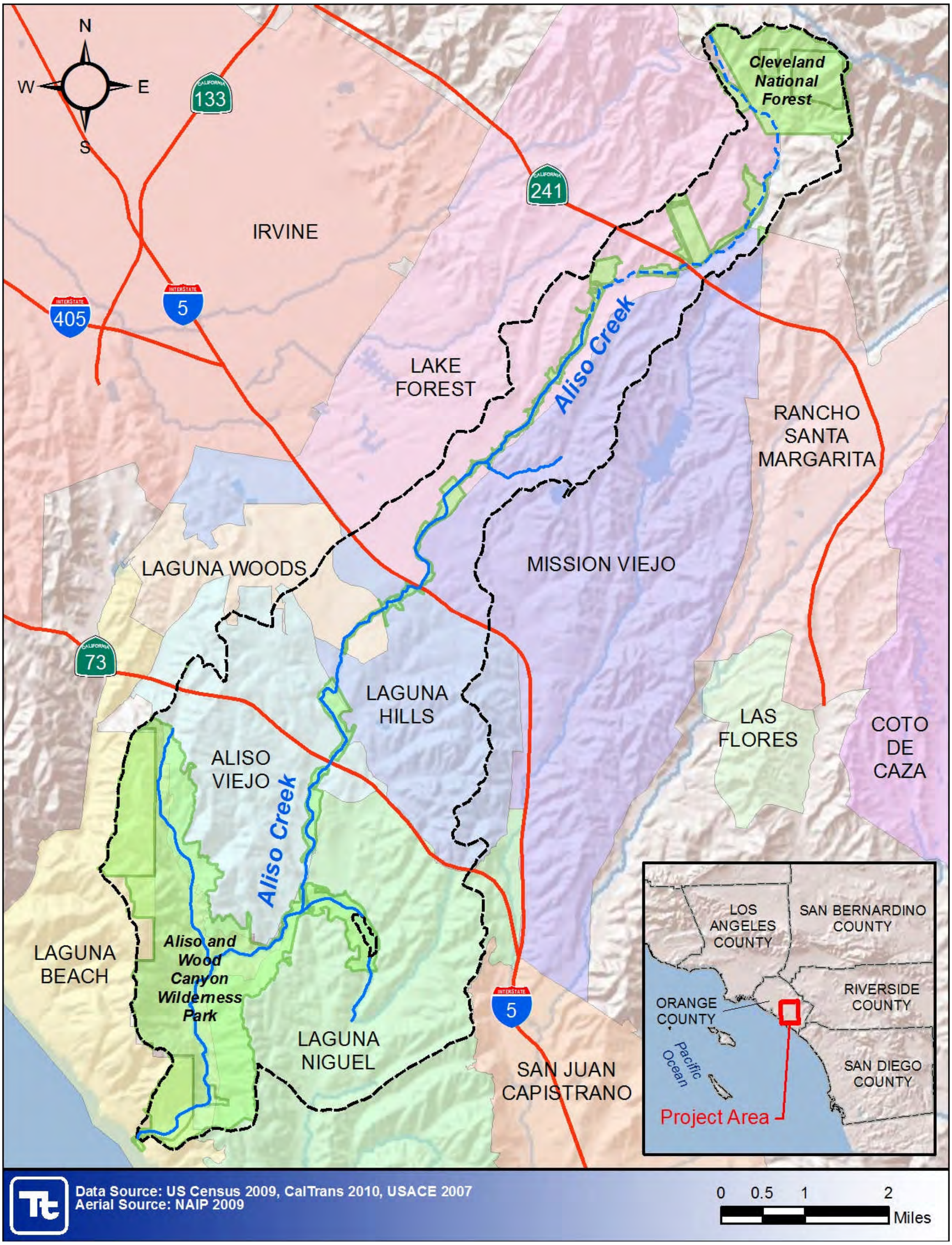
1.1 Study Area

The Aliso Creek watershed is located in the County of Orange in southern California, approximately 40 miles southeast of the City of Los Angeles. As shown in **Figure 1-1**, the creek drains a long, narrow coastal watershed, with its headwaters in the Cleveland National Forest and its mouth at the Pacific Ocean. The drainage area is 34.6 square miles, and the mainstem of the creek is approximately 19.5 miles in length.

Except for a small portion of the Cleveland National Forest in the upper watershed, and the Aliso and Wood Canyons Wilderness Park in the lower watershed, the Aliso Creek watershed is nearly fully developed. Portions of the following municipalities are located in the watershed: Lake Forest, Aliso Viejo, Mission Viejo, Laguna Niguel, Laguna Hills, and Laguna Beach. The drainage systems associated with this development are typically more efficient hydraulically, and in places, the creek channel has been realigned and or modified.

The mainstem of Aliso Creek originates in the Santiago Hills and flows south for a distance of 1.5 miles within the Cleveland National Forest. It flows from the National Forest under the Foothills Transportation Corridor and through highly developed areas in Mission Viejo and Lake Forest. Further southwest, the creek flows through a fully urbanized area along the I-5 corridor and the City of Laguna Hills. Upstream of Pacific Park Drive, Aliso Creek enters a floodwater retarding basin; downstream of Pacific Park Drive the creek flows through an engineered channel toward the confluence of Sulphur Creek and the upstream end of the Aliso and Wood Canyons Wilderness Park. Sulphur Creek conveys runoff from an 8.9-square-mile watershed, nearly half of which first flows into Sulphur Creek Reservoir (also called Laguna Niguel Lake) before draining into Aliso Creek. Downstream of the Sulphur Creek confluence (approximately 14.5 miles downstream from the origin and 5 miles upstream from the mouth), the Park opens into a coastal canyon that is nearly undeveloped. Aliso Creek continues approximately 1.5 miles to the diversion structure for the Aliso Creek Wildlife Habitat Enhancement Project (ACWHEP). Roughly 0.3 miles downstream of the ACWHEP structure is the confluence of Wood Canyon Creek, a right bank (west) tributary draining nearly 4 square miles largely within the park. The combined flows continue to the southwest through the narrow canyon. Approximately 1 mile upstream from the Pacific Ocean, Aliso Creek flows out of the Wilderness Park and enters the private Aliso Creek Golf Course located in the confined valley. Just upstream of the ocean, the creek passes through a narrow strip of development along the Pacific Coast Highway in the City of Laguna Beach.

The study area (**Figure 1-2**) focuses on lower Aliso Creek (a distance of approximately 4 river miles), specifically the reach from the CTP to the Aliso Water Management Agency (AWMA) Road Bridge over Aliso Creek and the reach on Sulphur Creek from the Alicia Parkway culvert crossing to the confluence with Aliso Creek.



Data Source: US Census 2009, CalTrans 2010, USACE 2007
Aerial Source: NAIP 2009

Figure 1-1. Aliso Creek Watershed

Figure 1-2. Study Area – Lower Aliso Creek

1.2 Project Background

SOCWA pumps sludge generated at the CTP (approximately RM 1.2) to their Regional Treatment Plant (RTP) for digestion and dewatering. The sludge is pumped approximately 4.5 miles through two parallel 4-inch diameter ductile-iron pipelines from the CTP, north along the eastern side of Aliso Creek to the RTP located upstream of Sulphur Creek Reservoir (Dudek 2011). The dual Export Sludge force mains were placed into service more than 30 years ago; at that time they were designed to be constructed as far from the eastern bank of Aliso Creek as reasonably possible (Dudek 2011). The pipelines have deteriorated through corrosion and internal deposition to the point they need to be replaced, or risk future sewage spills in the environmentally sensitive Aliso and Wood Canyons Wilderness Park. The ongoing erosion of the Aliso Creek channel poses a threat to proposed alternatives for the replacement of the Export Sludge system as well as to existing infrastructure. Past storms have resulted in erosion that has caused the failure of the Moulton Niguel Water District (MNWD) 18-inch sewer line in Aliso Canyon (**Figure 1-3**). Erosion from storm events has not caused past failures of either the SOCWA 4-inch diameter Export Sludge force mains or the Effluent Transmission Main (ETM). However, past storm events have caused SOCWA to install riprap along threatened embankments. Various historical floods have washed out portions of the west bank of Aliso Creek and AWMA Road (**Figure 1-4**), the only paved access road connecting the CTP to Alicia Parkway. Due to the risk of undermining proposed Export Sludge force main or the existing AWMA Road (for trucking of liquid sludge), SOCWA is evaluating the potential for the further erosion of Aliso Creek as part of the analysis of alternatives for the replacement of the Export Sludge system.

Figure 1-3. East (left) Bank Erosion along Aliso Creek Showing Undermined MNWD Pipeline (photo courtesy of SOCWA, appears to be near RM 1.60)

Figure 1-4. Emergency Repair of West (right) Bank of Aliso Creek (photo courtesy of SOCWA, appears to be near RM 1.85)

In a 2006 study for SOCWA, Dudek identified five alternative Export Sludge force main alignments, including two along the eastern side of Aliso Creek, two along the western side, and one that crossed from west to east. The recommended alignment was along the west side of Aliso Creek.

A Pre-Design Report is currently being prepared for SOCWA that evaluates two alternatives for a new Export Sludge force main (Alternatives FM 1 and FM 2) and an option involving the hauling of liquid sludge (Alternative TR 1). Alternative FM 1 follows the existing SOCWA easement along the east side of Aliso Creek (**Figure 1-5**). Alternative FM 2 will follow a new alignment located west of Aliso Creek primarily following the AWMA Road (**Figure 1-5**). Alternative TR 1 involves trucking of liquid sludge to the Regional Treatment Plant using the AWMA Road. Due to the location of the AWMA Road at greater elevations along the banks of Aliso Creek than the proposed elevations of the FM 2 pipeline, the erosion risk posed to the AWMA Road is likely greater than the erosion risk posed to the FM 2 pipeline. This report documents only the erosion risk to the proposed FM 1 and FM 2 alignment.

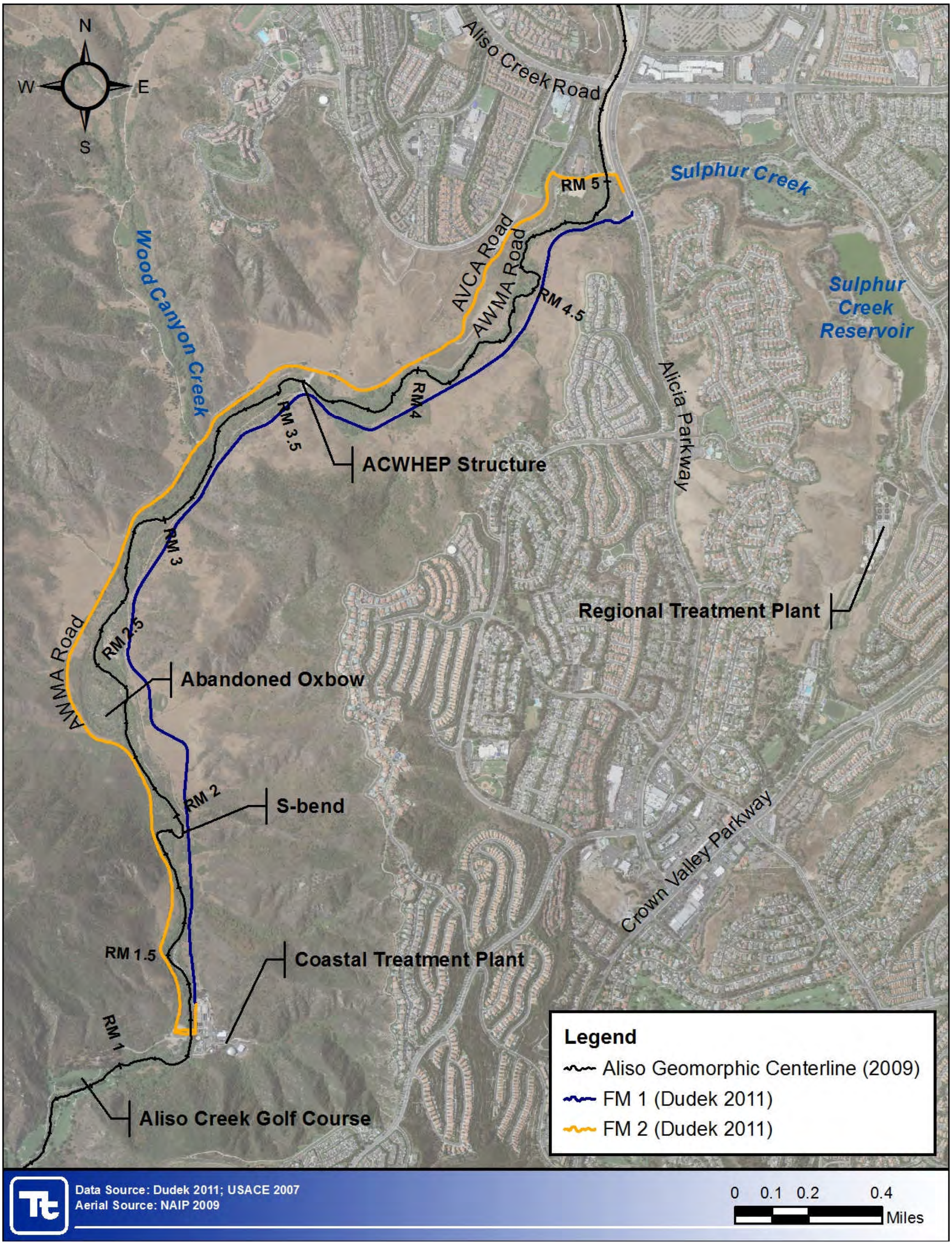


Figure 1-5. Proposed Force Main Alignments between the CTP and Alicia Parkway

1.3 Study Objective

The potential for erosion along Aliso Creek has been identified as a key consideration relative to the Export Sludge force main replacement planning process (Dudek 2011). The objective of this study was to conduct an erosion assessment of lower Aliso Creek to categorize the vulnerability of the proposed FM 1 and FM 2 alignments along the east (left) bank and west (right) bank, respectively. The assessment includes the identification and evaluation of locations where erosion of the channel, floodplain, banks, and hillslopes along lower Aliso Creek and Sulphur Creek could lead to exposure/undermining of the proposed pipelines. The purpose of this study is to aid SOCWA in the evaluation of preliminary alignments of proposed alternatives for the replacement of the Export Sludge force mains.

1.4 Study Approach

The following framework was established to achieve the study objective:

- Characterize the geomorphic conditions of Aliso Creek and Sulphur Creek within the study area.
- Compile available geotechnical data to provide a basis for evaluating the potential for bed and bank resistance to erosion.
- Conduct field reconnaissance to: observe and document recent and historical erosion areas, assess identified erosion areas (e.g., failure mode, physical properties of the bank, and bank materials and stratification), observe conditions that have promoted stable banks, and consider any factors that may minimize/exacerbate impacts of erosion on the stability of proposed force main alignments.
- Simulate flood event hydraulics to quantify the potential for flows to exert erosive energy on the banks, and to remove mass wasted bank materials along the toes of the banks. Specifically, the channel hydraulics and the radii of curvature for bends in the channel were used to calculate a Bank Energy Index (BEI) (Harvey and Mussetter 1993).
- Perform preliminary slope stability calculations to determine stable angles for banks identified during the field reconnaissance as geotechnically unstable. The stable bank angles establish a means for comparing risk of future bank instabilities to the location of proposed pipeline alignments.
- Calculate erosion risk associated with bend migration using the BEI values and the offset between calculated stable bank slopes and the proposed pipeline alignments.
- Combine results to categorize the vulnerability of the proposed pipeline alignments to erosion of the Aliso Creek and Sulphur Creek channels.

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2 GEOMORPHOLOGY

The stability of the easements associated with the proposed FM 1 and FM 2 pipeline alignments for the Export Sludge Force Main Replacement Project is dependent upon to geomorphic condition of lower Aliso Creek. Previous studies were reviewed to provide a general characterization of recent historical, existing, and likely future geomorphic conditions.

2.1 Previous Studies

Previous studies have focused on the geologic setting of lower Aliso Creek, as well as the aspects of fluvial geomorphology that affect the existing physical character, and likely future characteristics, of lower Aliso Creek. A few studies have specifically focused on fluvial geomorphology as it pertains to the infrastructure (i.e., pipelines and access roads) along lower Aliso Creek. The results/conclusions of these studies are summarized briefly to provide context for the efforts undertaken in this study; citations for the studies are provided if further details are of interest.

Jack G. Raub Company. 1980. *Aliso Viejo Refined Runoff Management Plan.* Prepared for Aliso Viejo Company. Costa Mesa, California.

In January 1980, the County of Orange Board of Supervisors conditionally approved the Aliso Viejo Plan (i.e., the construction of 20,000 dwelling units and an 800-acre industrial/commercial center on the upland portions of a 6,619-acre parcel of land between Laguna Beach and the Saddleback Valley). One of the concerns raised during the review process was the impact of Aliso Viejo runoff on erosion and sedimentation problems in Wood Canyon and Aliso Creek, including existing flood levels in Laguna Canyon. To address this issue, the Board of Supervisors conditioned approval of the Aliso Viejo Plan on the submission of a concept plan for diverting urban runoff away from sensitive environmental areas and for assuring the runoff would not contribute unacceptably to the Laguna Canyon flood problem. The *Aliso Viejo Refined Runoff Management Plan* (AVRRMP) outlined a runoff management program including diversions, desilting basins, retention basins, channel stabilization, landscaping, and erosion control.

Camp Dresser & McKee, Inc. 1982. *Sediment Discharge and Mechanics of Aliso Creek.* Prepared for Jack G. Raub Company. Newport Beach, California.

This report is a supplement to the *AVRRMP* (Jack G. Raub Company 1980). It was conducted to evaluate the channel stabilization measures recommended for Aliso Creek in the *AVRRMP*; results showed that fewer structures were required. Construction of the structures recommended in this report was expected to aggravate the existing bank erosion problems along Aliso Creek because the reduction of the bed slope due to construction of grade control structures was noted as having the tendency to alter the stream's meandering pattern and to cause attacks on the bank. Thus, selection of appropriate corrective and preventative measures was recommended (i.e., piling revetment with wire fence, tree revetment, jetted willow poles, jacks, brush mats, and riprap); the selection of the exact measure would depend on the severity of the problem and the risk involved. The cause of the bank erosion was attributed to the storms of 1978, 1979, and 1980, which produced the greatest three-year storm volume of record in most Southern California watersheds. The problem of bank erosion was particularly noticeable at the outer bank of stream bends. The report includes predicted limits of vertical degradation of the Aliso Creek channel, corresponding to ultimate watershed development conditions. The impact of vertical degradation and bank instabilities is referenced throughout the report.

Rivertech, Inc. 1999. *Aliso Creek Stream Instability Countermeasures, For the Protection of: AWMA's Effluent Transmission Main / Land Outfall.* Prepared for Aliso Water Management Agency (AWMA). Laguna Hills, California.

In the years subsequent to the publication of *Sediment Discharge and Mechanics of Aliso Creek* (CDM 1982), bank erosion and channel degradation continued along Aliso Creek. [NOTE: although not included in this report, it was during this period (i.e., the early 1990s) that the Mission Viejo Company constructed a riprap drop structure along Aliso Creek, upstream of the confluence with Wood Canyon, as part of a mitigation banking project.] While channel degradation and bank erosion continued, the AWMA (predecessor to SOCWA) had to maintain and operate its facilities along Aliso Creek, requiring emergency measures to avoid damage to pipelines and spillage of wastewater into the creek (e.g., addition of riprap to the east embankment of Aliso Creek at the confluence with Sulphur Creek during the El Nino storms of 1998). This mode of operation was excessively costly and imposed a significant financial burden on the AWMA. To minimize the cost of operating and maintaining its facilities, the AWMA retained Rivertech, Inc. to analyze future improvements that might need to be implemented to protect infrastructure along Aliso Creek. It was not feasible for the AWMA to construct and maintain the recommended counter measures without the participation of other agencies (Rivertech, Inc. 2003), so the AWMA awaited the completion of the U.S. Army Corps of Engineers *Aliso Creek Watershed Management Study / Plan*.

U.S. Army Corps of Engineers, 2002. *Aliso Creek Watershed Management Study / Plan*. Los Angeles, California.

This study performed a general review of existing conditions, and identified problems and opportunities within the watershed as a whole. Identified problems included instability of Aliso Creek channel and associated erosion damage, poor water and environmental quality, and flooding damages. A range of structural and non-structural solutions (measures) were identified as potential means to address the identified problems, followed by an evaluation and screening process to arrive at recommendations. The study also included an assessment of a potential restoration effort for the mainstem Aliso Creek utilizing a hydrology, hydraulics and sediment transport model, and a habitat assessment numerical classification.

Ninyo & Moore. 2003. *Preliminary Geotechnical Evaluation, Rehabilitation of the East Aliso Creek Emergency Sewer (REACES).* Prepared for Moulton Niguel Water District. Irvine, California.

This report was not available for review; the following information attributed to the report is provided in Rivertech, Inc. (2004). Ninyo & Moore performed a preliminary geotechnical evaluation of the creek alignment to assess the geological conditions and potential slope stability hazards to the existing pipelines (i.e., along the east (left) bank only). The report presents the results of the geotechnical evaluation (which did not include subsurface exploration). The figures in Rivertech, Inc. (2004) are not to scale (due to the oblique nature of the background aerial photographs), and tabular lengths of results of the ranked slope stability hazards by evaluated subreach are not available. However, Ninyo & Moore did provide categorical risk rankings as presented in Rivertech, Inc. (2004); these ratings are summarized below:

- <u>Condition 4:</u> Generally safe against slope stability hazards provided that future severe undermining of the creek bank does not occur (4 of 14 subreaches, approximately 25 percent of the evaluated subreach length).

- Condition 3: Relatively stable if further erosion does not occur (8 of 14 subreaches, approximately 60 percent of the evaluated subreach length).
- Condition 2: Marginally stable (1 of 14 subreaches, approximately 10 percent of the evaluated subreach length).
- Condition 1: Unstable (1 of 14 subreaches, approximately 5 percent of the evaluated subreach length).

Rivertech, Inc. 2003. *Aliso Creek Feasibility Analysis of Stabilizing the East Bank during Interim Period.* Prepared for Moulton Niguel Water District. Laguna Hills, California.

The Moulton Niguel Water District (MNWD) was evaluating the feasibility of rehabilitating the East Aliso Creek Emergency Sewer (EACES) – a series of pipelines situated along the east floodplain of Aliso Creek between Alicia Parkway and the CTP. Due to persistent channel degradation and instability of Aliso Creek, it was noted that the channel had widened and banks had the tendency to slump into the channel such that continuation of these geomorphic processes would cause failure of the EACES. MNWD retained Rivertech, Inc. to identify cost-effective solutions to protect the pipelines against bank failures caused by channel degradation. The report describes four alternative plans and their conceptual-level estimated costs.

Rivertech, Inc. 2004. *Prioritizing Stabilization of the East Bank during Interim Period.* Prepared for Moulton Niguel Water District. Laguna Hills, California.

The purpose of this study was to prioritize the recommendations for the alternatives presented in Ninyo & Moore (2003) and Rivertech, Inc. (2003). The prioritization considered evaluations of instability based on river mechanics (Rivertech, Inc. 2003) and evaluations of geotechnical processes (Ninyo & Moore 2003). These evaluations were combined with considerations of bend effects, bank slopes, vegetative cover, and availability of riprap (i.e., presence of existing riprap) to generate an integrated grade for prioritizing the stabilization measures. The tabular summary of the integrated grades does not include subreach lengths, and the figures on which the subreaches are shown is not to scale (due to the oblique nature of the background aerial photographs). However, as estimated from the not-to-scale figures, the integrated grades for the evaluated subreach are summarized below (using a scale of 0 to 10, with 0 indicating least stable conditions and 10 indicating most stable conditions):

- Grade 5: 1 of 14 subreaches, approximately 5 percent of the evaluated subreach length.
- Grade 4: 6 of 14 subreaches, approximately 35 percent of the evaluated subreach length.
- Grade 3: 4 of 14 subreaches, approximately 40 percent of the evaluated subreach length.
- Grade 2: 2 of 14 subreaches, approximately 15 percent of the evaluated subreach length.
- Grade 1: 1 of 14 subreaches, approximately 5 percent of the evaluated subreach length.

The report notes the prioritization is based on qualitative analyses, and straight averaging of the river mechanics rankings and the geotechnical rankings produced the integrated grades.

Tetra Tech, Inc. 2006. *DRAFT Aliso Creek Concept Plan Report.* Submitted to County of Orange Resources & Development Management Department. Irvine, California.

The County of Orange Resources and Development Management Department (RDMD) contracted with Tetra Tech, Inc. to perform an analysis of alternatives for restoration of stream stability. The study focuses on stream stability as a priority project goal. The project is identified as the Aliso SUPER (i.e.,

Stabilization, **U**tility **P**rotection, and **E**nvironmental **R**estoration). Three stream stability alternatives were considered, and each is evaluated in part based on protection provided to the utilities located along the maintenance road east of the main channel. Due to the conceptual level of the restoration alternative designs, it was recommended that proximity to utility pipelines and potential for channel migration into the utility corridor should be considered during more advanced design efforts.

Collison, A. and N. Garrity. 2009. *Memorandum: Aliso Creek Stabilization Project Review.* Submitted to Kenneth Frank, City of Laguna Beach. Prepared by Philip Williams & Associates (PWA). San Francisco, California.

The memorandum documents, in part, a one-day field geomorphic reconnaissance of Aliso Creek and a review of Orange County's *DRAFT Aliso Creek Concept Plan Report.* The report concludes that the high degree of channel incision and widening has resulted from urbanization in the watershed and that future widening threatens infrastructure that runs alongside the creek (i.e., the AWMA Road and the utility pipelines) if they are left in the current locations and no action is taken. Field observations made suggest that for the last ten years at least (as evidenced by the age of the trees on the inset floodplain) the channel has been vertically stable or slightly aggradational (progressive raising/increasing in elevation through alluvial deposition). This is consistent with the actively eroding banks: aggrading systems tend to exhibit more rapid rates of lateral migration and bank erosion as sedimentation and vegetation establishment on point bars promotes meander migration.

Tetra Tech, Inc. 2010. DRAFT *Aliso Creek F4 Geomorphic Assessment.* Prepared for the U.S. Army Corps of Engineers, Los Angeles District. Irvine, California.

Tetra Tech, Inc. conducted a geomorphic assessment of Aliso Creek to provide a basis for interpreting the hydraulic engineering work associated with the comparison of alternative environmental restoration plans, and specifically to provide a rational basis for prediction of future geomorphic conditions associated with the no-action plan. The assessment builds on numerous earlier hydrologic, hydraulic, geotechnical, and geologic studies and investigations conducted in the Aliso Creek watershed.

Key findings relative to bank erosion/bank stability are as follows:

- The nature and distribution of bed material in lower Aliso Creek are a function of historical colluvial inputs (e.g., landslides) that led to blockages of the creek and subsequent upstream deposition of clay materials. The clay layers are influential in controlling streambank strength and the resistance to channel widening.
- Colluvial inputs and outcrops of coarse materials (e.g., San Onofre Breccia) are being concentrated into natural grade controls that limit the potential for future degradation of the channel bed.
- Hydraulic modeling analyses confirmed existing hydraulic conditions are incapable of mobilizing the cobble-sized materials that are concentrated in natural grade controls.
- Due to nearly built-out development conditions, there is low potential for future land cover-induced changes to the flood regime (i.e., future flood hydrology will be similar to existing flood hydrology).
- A geomorphic model was developed and tested to explain the potential for future changes in channel morphology. Results confirmed that future vertical adjustments of the bed profile will be limited because: 1) the widened channel and decreased channel bed slope have decreased

unit discharge and bed material transport capacity, and 2) the concentrations of coarse sediments have increased the critical flows required to mobilize these materials.

- An Incised Channel Evolution Model (ICEM) was applied on a reach-by-reach basis to both categorize existing geomorphic conditions and provide a means for predicting future geomorphic conditions, particularly with regarding to bed degradation and channel widening.
- System-wide continuation of upper bank failures is likely along much of lower Aliso Creek, particularly where banks are nearly vertical, composed of non-cohesive alluvium, and contain tension cracks. However, field observations suggest that mass-failed bank materials are not consistently being removed from the toe of the bank by fluvial entrainment. Retention of the failed material is enhanced by the high density of the riparian vegetation that is supported by greater base flows in the channel. In contrast, at locations where failed materials are removed from the toe of the bank by fluvial entrainment, or at locations where the channel locally impinges against the base of the terrace, continuing erosion and retreat of that bank is likely.
- Continuation of both localized (colluvial) and more widespread (fluvial) deposition of sediment on the inset floodplain will reduce the effective heights of the banks to the point where they no longer exceed the critical height for geotechnical stability. This, combined with reduced bank angles, will ultimately lead to bank stabilization.
- Despite the natural progression toward stable banks, stabilization measures may be required for those locations where infrastructure (e.g., AWMA Road, buried pipelines) is at risk from continuing bank erosion.

The results of this analysis provide the foundation for the continued analyses presented in this current study.

2.2 Geomorphic Characterization of Lower Aliso Creek

The previous studies of the geomorphology of lower Aliso Creek illustrate the following common themes:

- Development of the Aliso Creek watershed has led to changes in runoff hydrology such that the morphology of the channel has adjusted to accommodate greater peaks rates of runoff and runoff volumes. Space for future watershed development is now so limited, that there is minimal potential for future changes to flood hydrology.
- Degradation of the bed of the channel and subsequent bank erosion/channel widening are the two primary manifestations of the channel response to the altered hydrology.
- Continuation of systemic bed degradation does not appear likely; however, localized incision and degradation may occur.
- Channel width appears to have reached a point where unit discharges have decreased enough to allow bed material deposition to form berms and inset floodplains.
- Due to excessive bank height, non-cohesive bank materials, tension cracking in the upper banks, and the absence of mature woody vegetation on the banks, bank erosion is expected to continue at some locations.
- Bank erosion is driven by two types of processes: 1) flow impingement on bank materials and fluvial entrainment of eroded bank materials along the toe, and 2) bank slumping and slab/block failures of upper bank materials due to geotechnically unstable conditions.

- Geomorphic instabilities of the channel poses risks to the infrastructure (e.g., AWMA Road and sewer pipelines) located along both banks of Aliso Creek.

3 Erosion Assessment

An erosion assessment along lower Aliso Creek was conducted to provide a technical basis for evaluating the potential erosion risk posed to the proposed FM 1 and FM 2 pipeline alignments, assuming no new erosion protection measures are implemented over a 50-year planning period.

3.1 Erosion Assessment Approach

Various approaches for conducting an erosion assessment were considered and the following was selected.

Tetra Tech, Inc. staff conducted field reconnaissance along both banks of lower Aliso Creek. The reconnaissance was performed to observe and document conditions and factors present at erosional areas as well as conditions and factors that promote bank stability. Observations indicated bank erosion is primarily gravity driven (e.g., mass failures of bank materials), but the stability of the banks was linked to whether failed materials at the toe of the bank were being removed by fluvial processes. Thus, technical analyses focused on the erosion potential/erosion resistance. Hydraulic analyses were carried out to quantify the potential for fluvial erosion to contribute to destabilizion of banks and contribute to the undermining of proposed infrastructure. These analyses were conducted at individual sites along the creek. Geotechnical erosion resistance was characterized by compiling and categorizing subsurface boring logs recorded along both banks of Aliso Creek. Geotechnical erosion processes were evaluated using slope stability analyses. These analyses quantified the stable bank slope depending on bank materials and bank height. The risk of erosion associated with bend migration was categorized using the hydraulic erosion potential and the offsets between calculated stable bank slopes and the proposed pipeline alignments. The various indices of erosion risk were considered together to generate a combined erosion risk for the proposed FM 1 and FM 2 alignments.

3.2 Field Reconnaissance

In December 2011 and January 2012 field reconnaissance was conducted along both banks of lower Aliso Creek as well as along the left bank of Sulphur Creek below Alicia Parkway. On December 26, 2011, the fluvial geomorphologist and hydraulic engineer started at Alicia Parkway and walked downstream along the south (left) bank of Sulphur Creek. The day's efforts continued downstream along the east (left) bank of Aliso Creek, to approximately river mile 3.21 – about 2,100 feet downstream from the ACWHEP diversion structure. The remainder of the east (left) bank was surveyed on December 27th. Hasan Nouri of FluvialTech (previously of Rivertech, Inc.) provided a briefing the morning of December 27th of work he performed related to stabilization studies along Aliso Creek. The morning of December 28, the inspection team worked upstream along the west (right) bank of Aliso Creek, from the downstream limit at the CTP to the ACWHEP diversion structure. The remainder of the west (right) bank was surveyed on January 25, 2012.

The objectives of the field reconnaissance included:

- Observe and document recent and historical erosion areas that have the potential to destabilize/expose infrastructure.
- Assess the identified erosion areas (e.g., failure mode, physical properties of the bank, and bank materials and stratification).
- Observe and quantify conditions that have promoted stable banks, including the development of depositional berms along the toe, the presence of cohesive clay materials in the toe of the bank, graded upper banks without tension features (i.e., near vertical cracks along the top of

bank parallel to the bank face), the influence of woody vegetation, and the presence and condition of existing protection measures.

- Consider any factors that may minimize/exacerbate impacts of erosion on the stability of proposed pipeline alignments.

Features of interest that were observed during the reconnaissance were located with hand-held mapping grade GPS units, and digital photographs were taken. Field notes were subsequently compiled with the location information and photographs to spatially relate the information. Appendix A includes figures and photographs documenting the field reconnaissance. The figures illustrate the spatial relationships between the Aliso Creek centerline, the extents of existing bank protection measures, the proposed FM 1 and FM 2 alignments, as well as locations preliminarily rated *High* or *Moderate* in regard to erosion risk to infrastructure (a de facto preliminary rating of *Low* was assumed for all locations not preliminarily rated *High* or *Moderate*). Locations where conditions were observed that promote stable banks are noted as *Stable.* These preliminary ratings were based only on the field reconnaissance, prior to the initiation of all technical analyses. Selected photographs representative of these various areas follow the figures in Appendix A.

To illustrate some of the observed/inferred fluvial and geotechnical processes affecting bank stability and risk to proposed infrastructure, a series of eight cross section schematics has been prepared (Appendix B). Each figure contains notes that describe the processes illustrated in the schematic.

- Bank Slumping due to Geotechnically Unstable Slope – **Figure B-1**
- Over-steep Existing Riprap Revetment – **Figure B-2**
- Stable Bank Angle – **Figure B-3**
- Establishment of Inset Floodplain – **Figure B-4**
- Bank Instability due to Flow Impingement and Potential Bend Migration – **Figure B-5**
- Bank Erosion due to Concentrated Runoff along AWMA Road – **Figure B-6**
- Existing Exposure of East (Left) Bank Infrastructure – **Figure B-7**
- Bank Erosion Exacerbated by Concentrated Upland Runoff – **Figure B-8**

Table 3-2 and **Table 3-3** note the presence/absence of geomorphic features observed to have controlling influences on limiting the potential for bank erosion. The features include:

- Clay-bearing materials or bedrock in the toe of the bank
- A depositional berm along the toe of the bank
- Substantial woody vegetation established along the toe of the bank
- Existing bank protection measures

3.3 Fluvial Erosion Potential

As documented in Section 2.1, previous studies consistently make reference to the destabilizing effects of flood flows on the morphology of the lower Aliso Creek channel, and the impacts on the stability of the valley bottom. The lateral stability of the channel banks is of particular interest in this erosion assessment due to the potential for destabilizing/undermining the proposed pipeline alignments. This section presents: 1) the methodology used to quantify the potential for fluvial erosion to destabilize stream banks, and 2) the categorization of fluvial erosion potential.

3.3.1 Methodology for Quantifying Fluvial Erosion Potential

The potential for bank erosion and removal of mass-failed bank material driven by fluvial processes needs to consider both the magnitude of hydraulic stresses applied on the banks during a flood event as well as the duration of the flood event. To incorporate the effects of both magnitude and duration, the potential for fluvial processes to contribute to erosion of the banks along lower Aliso Creek was quantified using the Bank Energy Index (BEI) (Harvey and Mussetter 1993). The BEI is based on the concept of total energy (E) applied to the banks. Energy is defined as the product of the stream power expended on the banks and the incremental time over which it is applied (**Equation 1**). Bank stream power is the product of the average main channel velocity (V_{ch}) and the shear stress applied on the bank (τ_b) (**Equation 2**).

$$E = \int_0^t (V_{ch} * \tau_b)\ dt \qquad \textbf{Equation (1)}$$

where

E = total energy applied at a specific bank location
V_{ch} = average main channel velocity
τ_b = shear stress applied on the bank
dt = incremental time for discretizing the flood event hydrograph

$$\tau_b = K_b * \gamma * d_h * S_f \qquad \textbf{Equation (2)}$$

where

τ_b = shear stress applied on the bank at a specific location
K_b = factor that accounts for the effect of channel curvature on the shear stress acting on the outside of a channel bend (**Figure 3-1**)
γ = unit weight of the water-sediment mixture flowing in the channel (62.4 lbs/ft^3)
d_h = hydraulic depth in the channel
S_f = slope of the energy grade line

Equation (1) and **Equation (2)** were solved for a given flood event by discretizing flood hydrographs into a series of five-minute times-steps, calculating hydraulics for each time-step, and integrating the resulting energies at each time step over the duration of the flood hydrograph. The BEI was calculated for a flood event by normalizing the total energy applied at specific bank locations by the median energy applied at all cross sections.

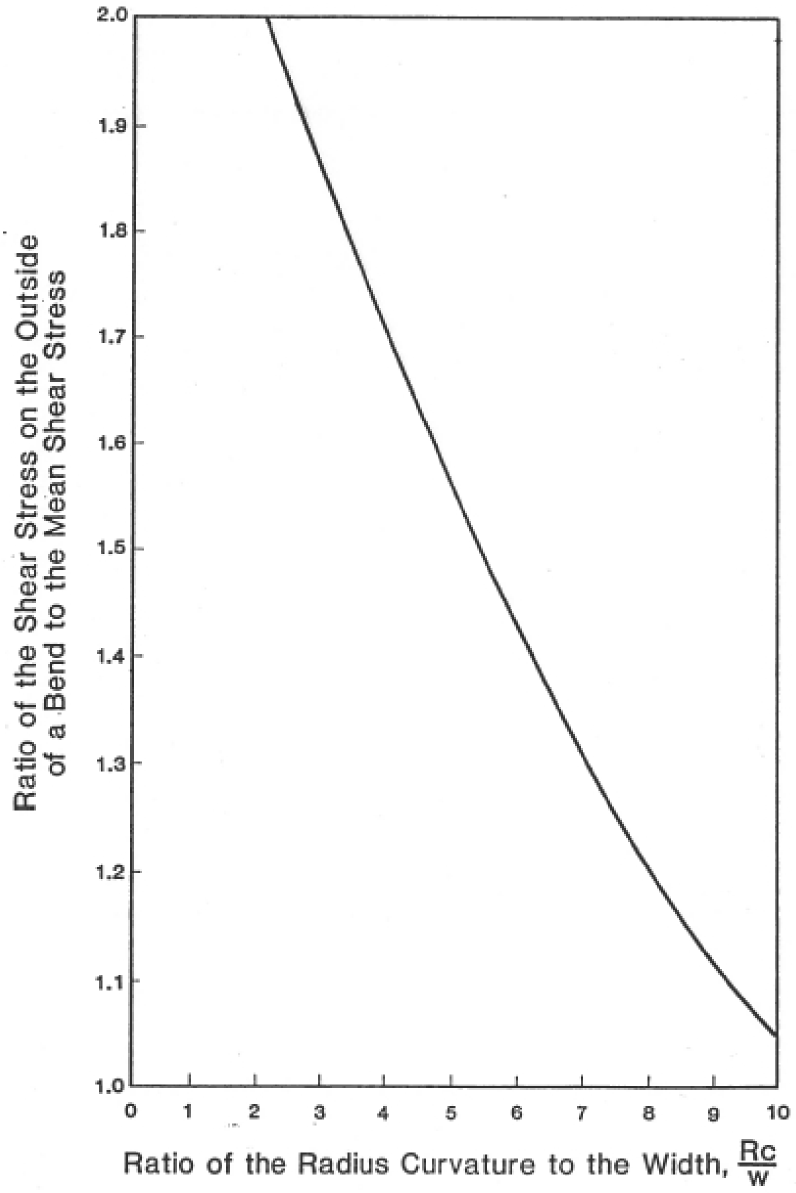


Figure 3-1. SCS (1977) Relation for Calculating the Increase in Shear Stress on the Outside of a Bend

Flood event hydrographs have been previously simulated at various locations along lower Aliso Creek (USACE 2000). The hydrographs were generated using the U.S. Army Corps of Engineers HEC-1 computer software (USACE 1998). Details regarding the setup, testing, and calibration of the HEC-1 models are available in USACE (2000). Hydrographs were simulated for the following average annual recurrence interval floods: 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year.

Channel hydraulics (i.e., velocity (V_{ch}), top width (W_{ch}), hydraulic depth (d_h), and slope of the energy grade line (S_f)) were simulated using the HEC-RAS model developed for Aliso Creek (USACE 2009). The refined and calibrated version of this model (Tetra Tech, Inc. 2010) was applied for this study; however only the portion of the model between the Pacific Ocean and the AWMA Road Bridge crossing of Aliso

Creek was used. Additional cross sections were added for the portion of Sulphur Creek between the Alicia Parkway culvert and the confluence with Aliso Creek. **Figure A-1** to **Figure A-4** in Appendix A show the locations of the cross sections included in the model. The hydraulics were calculated for a range of flows, up to the peak discharge of the 100-year flood, for the development of various rating curves that were then integrated over the flood hydrographs.

After normalizing the calculated energies for each flood event at each cross section, the resulting BEI values were categorized using quartiles. The BEI values in the first quartile (Q1) represent the locations along the channel where the lowest relative energy is applied to the banks; the BEI values in the fourth quartile (Q4) represent the greatest relative energy applied to the banks. **Table 3-1** presents the categories assigned to the various quartiles. When compared across flood events, consistency was observed in the categorization of a particular cross section by quartile.

Table 3-1. Fluvial Erosion Potential by BEI Quartile

	Q1	Q2	Q3	Q4
Fluvial Erosion Potential	*Low*	*Low*	*Moderate*	*High*

The BEI values were calculated as an indication of the relative potential for fluvial processes to initiate/maintain bank erosion. The quartile rankings were compared to observations made during the field reconnaissance as an informal check of the rankings. In general, the locations categorized in Q4 or Q3 were either 1) locations where active bank erosion was observed during the field reconnaissance, 2) locations where mass wasted bank materials were not being retained along the toe of the bank, 3) locations along the outside of bends, or 4) were locations where existing bank protection measures were observed. This indicates the BEI is a reasonable indicator of locations where fluvial processes contribute to bank erosion, or where these processes historically presented such a risk that bank protection measures were installed (commonly on an emergency basis in response to erosion that posed a threat to infrastructure). Locations categorized in Q1 tended to be cross sections that exhibited some combination of graded banks, relatively wider channels, large radii of curvature or straight reaches, inset floodplains, and hydraulically-connected overbank areas. Consequently, the categorization of the fluvial erosion potential by quartile produced results that were in general agreement with observations of existing conditions. The BEI quartiles are provided in **Table 3-2** and **Table 3-3** along the east (left) and west (right) banks, respectively. Greater potential for fluvial processes to erode the banks and/or remove the products of mass failure of the banks is not the only factor contributing potential for destabilization of the proposed pipeline alignments; incorporation of the fluvial erosion potential along with other factors in rating the risk to the proposed pipeline alignments is addressed in Section 3.5.

3.3.2 Categorization of Fluvial Erosion Potential

The potential for fluvial processes to initiate or maintain bank erosion processes was categorized using the BEI quartiles and observations made during the field reconnaissance. The BEI was calculated to categorize fluvial energy exerted on a bank, so this is the primary basis in the categorization of fluvial erosion potential. However, comparison of fluvial erosion potential across sites using the BEI quartiles is most meaningful when conditions that resist fluvial erosion are similar (e.g., vegetation, presence and condition of bank protection measures, bank materials, stratification of bank materials). The field reconnaissance indicated that bank conditions affecting erosion resistance vary widely along the proposed FM 1 and FM 2 pipeline alignments.

3.3.2.1 Erosion Resistance Provided by Bank Materials

The resistance of the bank materials to fluvial erosion was investigated by reviewing available mapping and compiling boring logs from previous subsurface investigations along lower Aliso Creek.

3.3.2.1.1 Review of Geologic Mapping

According to geologic mapping of the San Juan Capistrano Quadrangle, in which the lower Aliso Creek watershed is included, the valley bottom containing Aliso Creek is composed of alluvium (Morton et al. 1974). Alluvium is typified as unconsolidated to poorly consolidated, fine to coarse sand and gravel, with very high erodibility on slopes greater than five degrees (about 11.4H:1V), and poor to fair slope stability. More recently, digital geologic mapping of the Santa Ana Quadrangle was compiled (Morton 2004) and this mapping classifies the valley bottom containing Aliso Creek as young axial channel deposits (Holocene and late Pleistocene) (**Figure 3-2**). This mapping unit (*Qyaa*) is typified by fluvial deposits along canyon floors, consisting of unconsolidated sand, silt, and clay-bearing alluvium. The hillslopes from the CTP to approximately the ACWHEP diversion structure are mapped as Topanga Formation (*Tt*); hillslopes from approximately the ACWHEP diversion structure to the AWMA Road Bridge are mapped as Monterey Formation (*Tm*). Both of these mapping units are typified by marine siltstones and sandstones. The only other mapping unit bordering the valley bottom is young landslide deposits (Holocene and late Pleistocene). This mapping unit (*Qyls*) contains a range of highly fragmented to largely coherent landslide deposits (unconsolidated to consolidated). Many of these landslides in part reactivated during the late Holocene. The mapping units include both the scarp areas as well as the slide deposit.

At a regional scale, the available geologic mapping (Morton et al. 1974, Morton 2004) categorizes the alluvium that makes up the channel boundaries of undifferentiated gravel, sand, silt, and clay. These materials exhibit varying degrees of resistance to fluvial erosion, and varying properties that affect geotechnical slope stability.

The NRCS soil survey of Orange and Western Part of Riverside Counties (2008) was reviewed to evaluate whether surface soils mapping is more refined than the geologic mapping. Unfortunately, much of the valley bottom is generally classified as *Riverwash* which is composed of various sandy, silty, and clayey loams. Little information is provided to distinguish the locations with clay-bearing materials versus silts and sands.

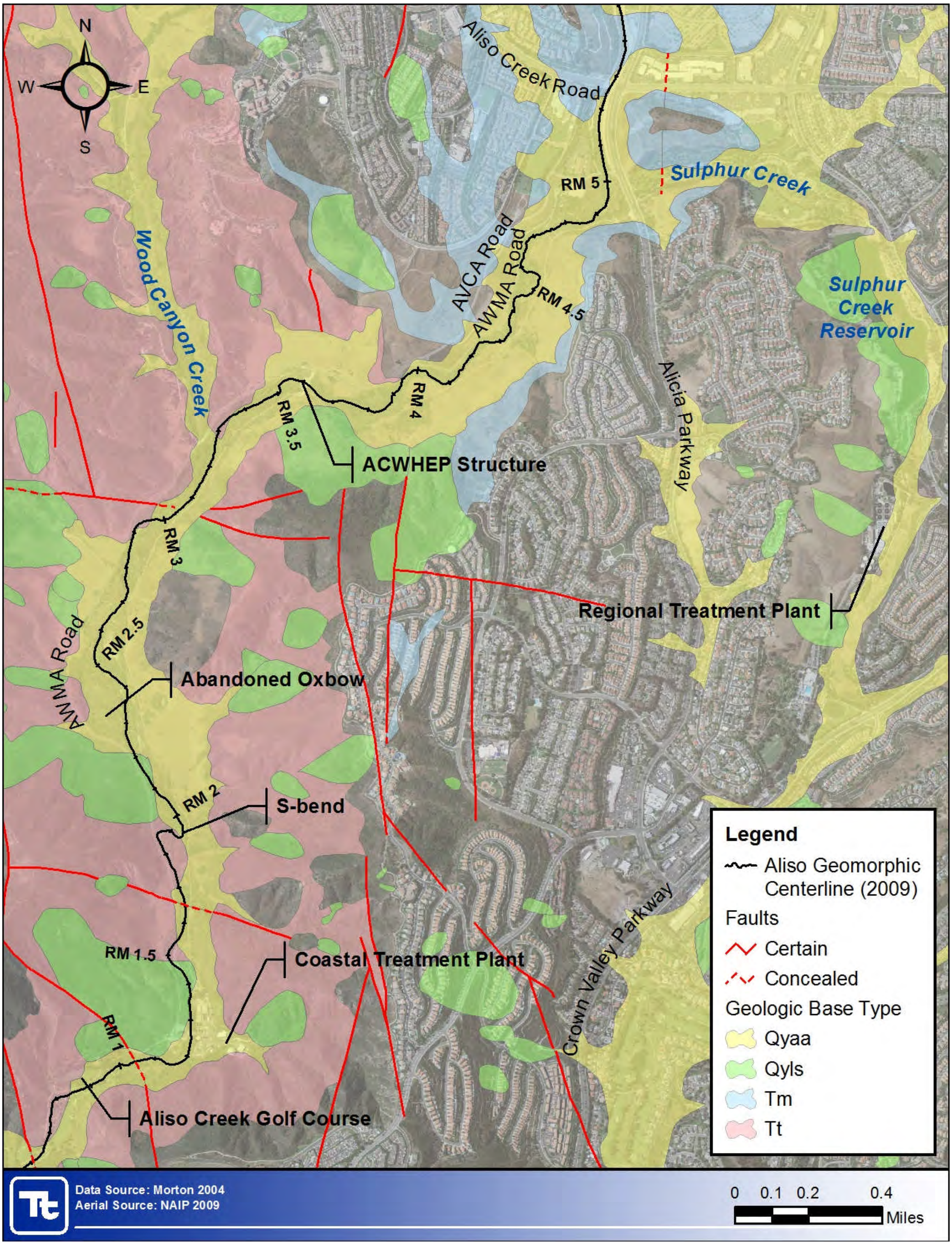


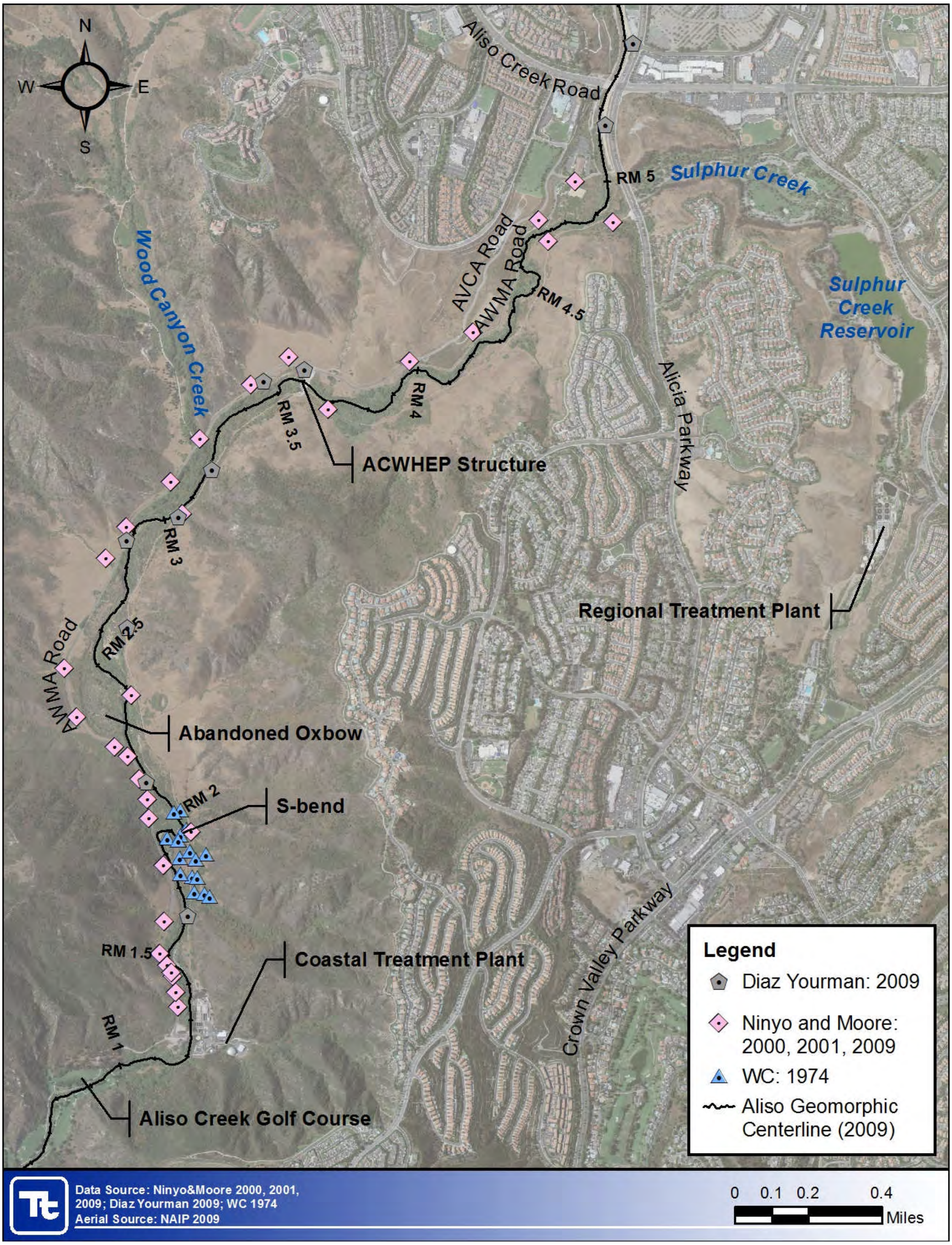
Figure 3-2. Geologic Mapping in the Lower Aliso Creek Watershed (Morton 2004)

3.3.2.1.2 Compilation of Subsurface Exploration Data

While the regional geologic mapping is not of fine enough resolution to differentiate 1) the potential resistance of the bank material to fluvial erosion, and 2) the potential differences in geotechnical properties that affect slope stability, previous studies (Woodward-Clyde Consultants 1975, Ninyo & Moore 2009, Diaz Yourman & Associates 2009, Ninyo & Moore 2011) have documented subsurface explorations. These studies include boring logs that include USCS classifications (ASTM D2487-11) of soil type. The locations of these borings along lower Aliso Creek are shown in **Figure 3-3**.

To facilitate comparisons of the geotechnical influence on erosion resistance, the borings were grouped by their bank location (i.e., east or west). The approximate station along the Aliso Creek centerline was assigned to each boring. A common symbology was developed for the various USCS classifications, and the symbols were plotted along the longitudinal profile of Aliso Creek. Clay-bearing, cohesive materials that provide greater resistance against erosion are colored green (e.g., CL, CH, SC). Low to non-cohesive, silty and granular materials that are more susceptible to erosion are colored red (e.g., SP, SM, ML, MH). Materials with a mix of clay-bearing and silty materials are colored yellow (e.g., SC-SM, CL-ML, CL-SM). The east (right) bank data is presented in **Figure 3-4** and the west (left) bank data in **Figure 3-5**. The channel thalweg and top of bank profiles are included for reference.

Figure 3-4 and **Figure 3-5** illustrate the variability in the distribution of clay-bearing alluvium throughout the valley bottom. Thus, the influence of the bank materials and stratification on resistance to erosion was considered only on a case-by-case basis; the profiles are too varied to make reach-based generalizations.



Data Source: Ninyo&Moore 2000, 2001, 2009; Diaz Yourman 2009; WC 1974
Aerial Source: NAIP 2009

Figure 3-3. Available Geotechnical Boring Locations

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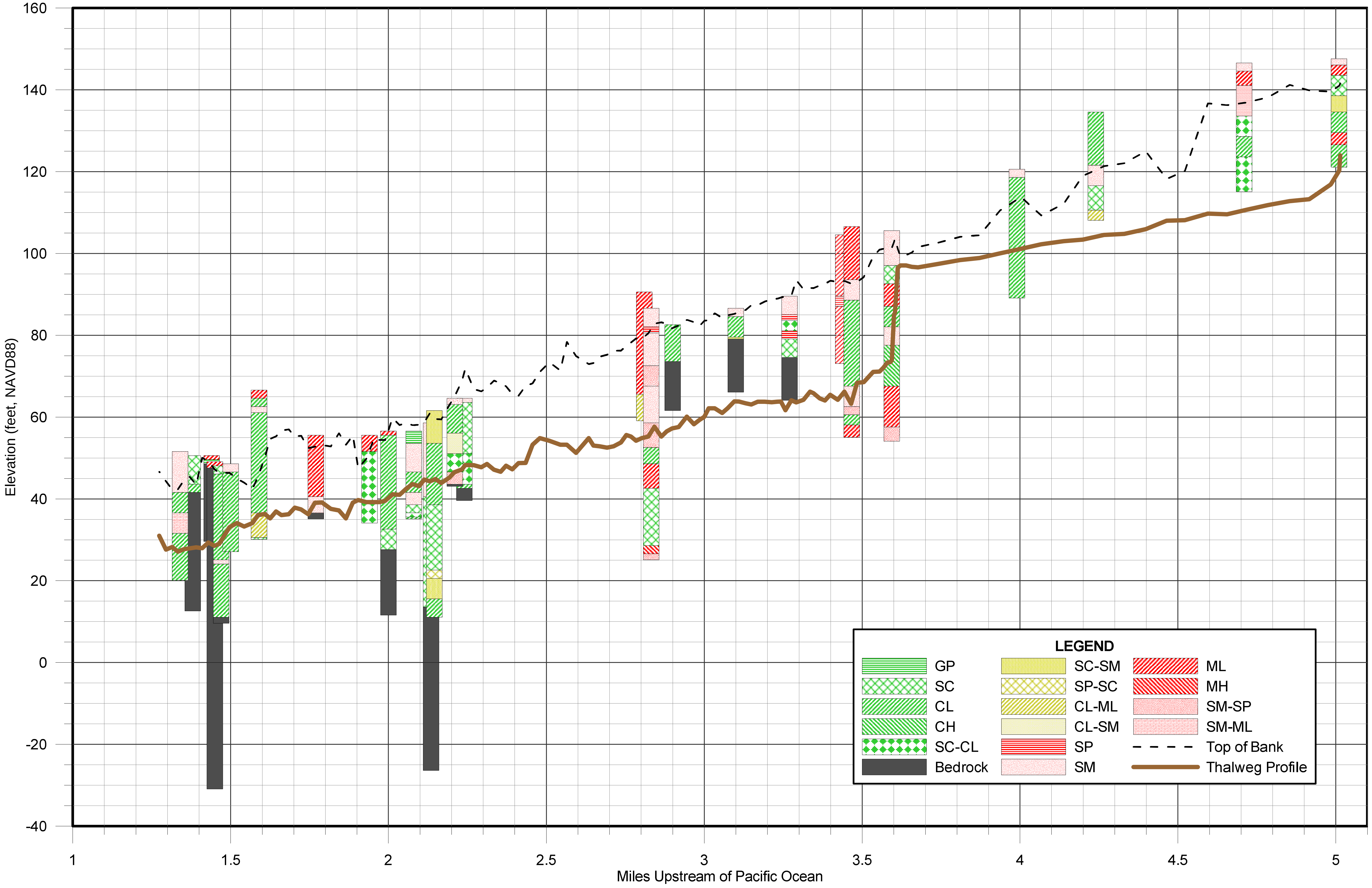

Figure 3-4. East (Right) Bank Geotechnical Boring Profiles

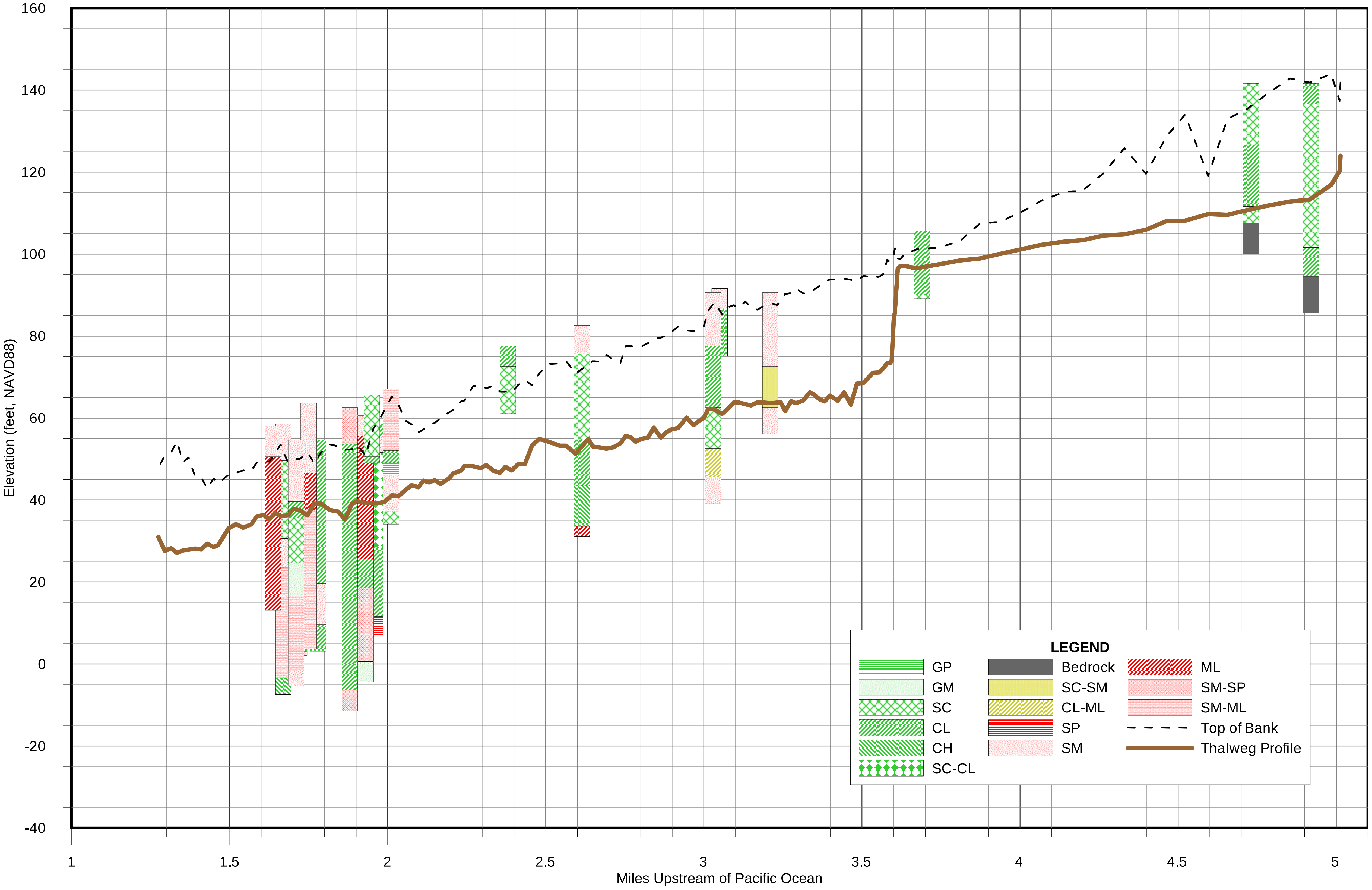

Figure 3-5. West (Left) Bank Geotechnical Boring Profiles

3.3.2.2 Fluvial Erosion Categorization

While the BEI provides a basis for comparing the potential for fluvial forces to contribute to destabilization of the banks along lower Aliso Creek, physical factors observed during the field reconnaissance (i.e., clay or bedrock in the toe of bank, a depositional berm along the toe, woody vegetation established along the toe, and existing bank protection measures in good condition) can mitigate some of the erosion potential. **Figures B-3** and **B-4** in Appendix B show examples of stable banks. **Table 3-2** and **Table 3-3** summarize the combined influence of the BEI and these physical factors on the fluvial erosion potential for the east (left) and west (right) banks, respectively. Each cross section included in the hydraulic model is categorized for fluvial erosion potential (i.e., *H* = high; *M* = moderate; *L* = low). The categories generally follow the BEI categories, unless physical factors are present that would reduce this potential. It was assumed that the physical factors were sufficient to reduce the BEI one category (e.g., *High* to *Moderate*, *Moderate* to *Low*). When a cross section is located along the inside of a bend – these areas are frequently low energy and promote deposition – these location were assigned a fluvial erosion potential of *Low* since the BEI values are not representative of conditions along the inside of a bend.

Table 3-2. Summary of Fluvial Erosion Potential along East (Left) Bank

River Mile	**Bank Along Outside of Bend**	**Bank Along Inside of Bend**	**BEI Quartile**	**BEI Category**	**Physical Factors Decreasing Fluvial Erosion Potential**				**Fluvial Erosion Potential**
					Clay/ Bedrock in Toe	**Depositional Berm At Toe**	**Woody Vegetation Along Toe**	**Existing Bank Protection in Good Condition**	
Sulphur Creek									
0.120			3	Mod.					M
0.105	X		4	High					H
0.088	X		1	Low					L
0.067			4	High					H
0.036			4	High					H
0.023			3	Mod.					M
Aliso Creek									
4.854			3	Mod.				X	L
4.785			3	Mod.					M
4.717		X							L
4.656		X							L
4.595		X							L
4.522	X		3	Mod.					M
4.464		X							L
4.398			1	Low					L
4.330	X		2	Low		X	X		L
4.266		X							L
4.199			1	Low					L
4.138	X		3	Mod.		X	X		L
4.067			4	High					H
4.003		X							L
3.937			3	Mod.					M

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
3.872	X		2	Low			X		L
3.810			3	Mod.					M
3.741		X							L
3.677	X		2	Low	X		X		L
3.657			2	Low					L
3.639			3	Mod.					M
3.621			4	High					H
3.613			3	Mod.					M
3.604			4	High					H
3.601			4	High					H
3.594		X							L
3.589		X							L
3.580		X							L
3.567		X							L
3.555		X							L
3.535		X							L
3.505	X		3	Mod.		X	X		L
3.484			4	High					H
3.465			1	Low					L
3.444			3	Mod.					M
3.423			2	Low					L
3.399			2	Low					L
3.382			1	Low					L
3.366		X							L
3.346		X							L
3.335		X							L
3.314		X							L
3.291		X							L
3.276		X							L
3.257	X		1	Low			X		L
3.243	X		2	Low			X		L
3.231	X		1	Low			X		L
3.214	X		1	Low			X	X	L
3.191	X		1	Low		X	X		L
3.169	X		2	Low		X	X	X	L
3.149	X		1	Low		X	X	X	L
3.131	X		2	Low		X	X	X	L
3.110	X		4	High		X	X	X	M
3.095	X		4	High		X	X	X	M
3.074	X		3	Mod.					M
3.057	X		3	Mod.					M
3.033	X		3	Mod.	X				L

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
3.014	X		4	High					H
3.000	X		4	High					H
2.985	X		1	Low					L
2.967		X							L
2.945		X							L
2.919		X							L
2.898			4	High					H
2.881			3	Mod.					M
2.864			3	Mod.					M
2.842			4	High					H
2.823			2	Low					L
2.802			2	Low				X	L
2.784			1	Low				X	L
2.768	X		2	Low		X	X	X	L
2.753	X		2	Low		X	X	X	L
2.736	X		1	Low				X	L
2.713	X		2	Low					L
2.692	X		2	Low					L
2.668	X		1	Low					L
2.649			1	Low					L
2.634			2	Low					L
2.594			1	Low					L
2.565		X							L
2.544		X							L
2.509		X							L
2.479		X							L
2.456	X		4	High					H
2.434	X		2	Low					L
2.412	X		2	Low					L
2.392	X		1	Low					L
2.372	X		2	Low					L
2.355		X							L
2.334		X							L
2.312		X							L
2.294		X							L
2.270		X							L
2.243		X							L
2.233		X							L
2.208		X							L
2.193		X							L
2.167			2	Low					L
2.149			3	Mod.					M

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
2.131			3	Mod.					M
2.113			4	High					H
2.097			2	Low					L
2.076			3	Mod.					M
2.056			4	High					H
2.035			3	Mod.					M
2.013			4	High					H
1.989			3	Mod.				X	L
1.971	X		4	High				X	M
1.955	X		4	High	X				M
1.930	X		2	Low	X				L
1.904		X							L
1.887		X							L
1.865		X							L
1.843			1	Low					L
1.817			2	Low					L
1.789			3	Mod.					M
1.767			4	High					H
1.746			1	Low					L
1.723			1	Low					L
1.703	X		2	Low		X	X		L
1.684	X		3	Mod.	X	X	X		L
1.661	X		3	Mod.	X	X	X	X	L
1.644	X		3	Mod.				X	L
1.625	X		3	Mod.				X	L
1.608	X		4	High				X	M
1.586	X		4	High					H
1.569	X		3	Mod.					M
1.543	X		2	Low					L
1.520		X							L
1.496		X							L
1.464	X		2	Low		X			L
1.449	X		2	Low		X			L
1.429	X		2	Low		X			L
1.410	X		1	Low		X			L
1.391	X		1	Low					L
1.370	X		1	Low					L
1.353			1	Low					L
1.333			1	Low					L
1.315			1	Low					L
1.295			1	Low					L

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
1.274			3	Mod.				X	L

Table 3-3. Summary of Fluvial Erosion Potential along West (Right) Bank

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
Sulphur Creek									
Not Applicable									
Aliso Creek									
5.014		X							L
5.011		X							L
4.984		X							L
4.916		X							L
4.854		X							L
4.785			3	Mod.					M
4.717	X		3	Mod.	X		X		L
4.656	X		2	Low			X		L
4.595	X		4	High			X		M
4.522		X							L
4.464	X		4	High					H
4.398			1	Low					L
4.330		X							L
4.266	X		3	Mod.			X		L
4.199			1	Low					L
4.138		X							L
4.067			4	High					H
4.003	X		3	Mod.	X				L
3.937			3	Mod.					M
3.872		X							L
3.810			3	Mod.					M
3.741	X		4	High			X		M
3.677		X							L
3.657			2	Low					L
3.639			3	Mod.					M

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
3.621			4	High					H
3.613			3	Mod.					M
3.604			4	High					H
3.601			4	High					H
3.594	X		4	High	X				M
3.589	X		4	High	X				M
3.580	X		4	High					H
3.567	X		4	High					H
3.555	X		4	High					H
3.535	X		4	High					H
3.505		X							L
3.484			4	High					H
3.465			1	Low					L
3.444			3	Mod.					M
3.423			2	Low					L
3.399			2	Low					L
3.382			1	Low					L
3.366	X		2	Low		X	X		L
3.346	X		2	Low		X	X		L
3.335	X		3	Mod.		X	X		L
3.314	X		3	Mod.		X	X		L
3.291	X		1	Low		X	X		L
3.276	X		1	Low	X	X	X		L
3.257		X							L
3.243		X							L
3.231		X							L
3.214		X							L
3.191		X							L
3.169		X							L
3.149		X							L
3.131		X							L
3.110		X							L
3.095		X							L
3.074		X							L
3.057		X							L
3.033		X							L
3.014		X							L
3.000		X							L
2.985		X							L
2.967	X		1	Low					L
2.945	X		4	High				X	M
2.919	X		3	Mod.	X			X	L

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
2.898			4	High					H
2.881			3	Mod.					M
2.864			3	Mod.					M
2.842			4	High					H
2.823			2	Low					L
2.802			2	Low					L
2.784			1	Low					L
2.768		X							L
2.753		X							L
2.736		X							L
2.713		X							L
2.692		X							L
2.668		X							L
2.649			1	Low					L
2.634			2	Low					L
2.594			1	Low					L
2.565	X		1	Low					L
2.544	X		1	Low					L
2.509	X		3	Mod.					M
2.479	X		4	High					H
2.456		X							L
2.434		X							L
2.412		X							L
2.392		X							L
2.372		X							L
2.355	X		1	Low					L
2.334	X		1	Low					L
2.312	X		1	Low					L
2.294	X		2	Low					L
2.270	X		3	Mod.					M
2.243	X		4	High	X				M
2.233	X		2	Low	X				L
2.208	X		4	High				X	M
2.193	X		2	Low				X	L
2.167			2	Low					L
2.149			3	Mod.					M
2.131			3	Mod.					M
2.113			4	High					H
2.097			2	Low					L
2.076			3	Mod.					M
2.056			4	High					H
2.035			3	Mod.					M

River Mile	Bank Along Outside of Bend	Bank Along Inside of Bend	BEI Quartile	BEI Category	Physical Factors Decreasing Fluvial Erosion Potential				Fluvial Erosion Potential
					Clay/ Bedrock in Toe	Depositional Berm At Toe	Woody Vegetation Along Toe	Existing Bank Protection in Good Condition	
2.013			4	High					H
1.989			3	Mod.					M
1.971		X							L
1.955		X							L
1.930		X							L
1.904		X							L
1.887	X		2	Low					L
1.865	X		1	Low					L
1.843			1	Low				X	L
1.817			2	Low					L
1.789			3	Mod.					M
1.767			4	High					H
1.746			1	Low					L
1.723			1	Low					L
1.703		X							L
1.684		X							L
1.661		X							L
1.644		X							L
1.625		X							L
1.608		X							L
1.586		X							L
1.569		X							L
1.543		X							L
1.520	X		4	High					H
1.496	X		4	High	X				M
1.464			2	Low		X			L
1.449		X							L
1.429		X							L
1.410		X							L
1.391		X							L
1.370		X							L
1.353			1	Low					L
1.333			1	Low					L
1.315			1	Low					L
1.295			1	Low					L
1.274			3	Mod.				X	L

3.4 Geotechnical Erosion Risk to Proposed Pipeline Alignments

The bank materials and stratification characterized in Section 3.3.2.1 influence not only the resistance to fluvial erosion, they also affect the potential for gravity driven geotechnical forces to initiate and continue erosion of geotechnically unstable banks. As part of the process for assessing the overall risk of bank erosion to impact proposed pipeline alignments, an evaluation of the geotechnical stability of existing bank slopes was performed. The geotechnical data contained in previous subsurface investigation reports were used to characterize the soil types and basic engineering properties of the alluvial soils encountered along lower Aliso Creek. These data generally consisted of boring logs and a limited amount of laboratory testing of soil samples taken from the borings.

3.4.1 Slope Stability Analysis Methodology

Slope stability analyses were performed through simulations using SLIDE computer software (Version 6.011, released May 10, 2011) developed by Rocscience, Inc. The software can simulate the influences of various types of soil stratification, slope geometry, and groundwater conditions using limit equilibrium to calculate the factor of safety for various scenarios. The factor of safety is defined as the ratio of resisting forces to driving (destabilizing) forces. The factor of safety of various bank slope heights and slope angles were evaluated in order to estimate the required setback from the stable bank slope associated with different tolerances for risk.

3.4.1.1 Limitations of Slope Stability Analyses

As identified in Section 2.1, available documentation indicates only cursory slope stability analyses have previously been applied along the banks of lower Aliso Creek. Given the lack of extensive soil strength data that are typically required for detailed slope stability analyses, the results presented in this study are subject to the following limitations:

- The slope stability analyses performed as part of the geotechnical assessment of bank instabilities were based on the existing conditions and very limited soil strength data.
- The analyses were based on generalized estimates regarding soil stratigraphy and strength properties. In locations where the proposed pipeline alignments are categorized as *High* risk due to the proximity to a currently unstable slope bank, additional detailed geotechnical analyses should be performed during subsequent design phases.
- The current study only addressed stability issues with regard to alluvial soils exposed in the creek banks. The regional geologic conditions include numerous landslides in the bedrock formations along both banks of lower Aliso Creek. In any area where bedrock or landslide materials are exposed or found to be in the near-surface within the channel bed and/or banks, additional detailed study should be performed.
- The current study included fairly conservative assumptions regarding groundwater conditions and surface cracking; however, field observations indicate that surface runoff from upland areas has been problematic at various locations along the creek alignment. Areas where surface erosion of the bank is occurring due to concentrated upland runoff should be evaluated, and appropriate remedial drainage measures and/or slope protection should be implemented.

3.4.1.2 Model Input Data

Due to the lack of soil strength data typically available for detailed slope stability analyses, several simplifications regarding soil and slope conditions were applied for the slope stability analyses.

Previous geologic studies, observations made during field reconnaissance, and regional geologic mapping confirm substantial variation of soil types within the alluvial valley bottom containing Aliso

Creek. Further, these sources confirm interbedded stratification of different soil types. As described in Section 3.4.1.2, bank materials can generally be categorized into two groups: 1) soils bearing cohesive clays or 2) low cohesive silty soils. The clayey soils are typically low plasticity clays and clayey sands whereas the silty soils are typically silty sands and sandy silts. Localized layers of more coarse grained sands and gravels were encountered in some of the borings logs but comprise a fairly small portion of the overall stratigraphy. Therefore, the slope stability analyses were run for only two types of bank materials: clayey soils and silty soils. By grouping the various soils into these two classes, the influence of stratification was not further considered. For simplicity, the slope stability analyses were performed without consideration of stratification of clayey and silty soils.

Strength and density properties of the two soil categories were estimated based on Standard Penetration Test (SPT) (ASTM 1586-11) blow-counts (N-values) and on data from the two direct shear tests available from the existing geotechnical data (MACTEC Engineering and Consulting, Inc. 2007, Ninyo & Moore 2009). A summary of the assumed soil parameters is presented in **Table 3-4**.

Table 3-4. Estimated Values of Selected Bank Material Properties

Bank Material Type	Total Unit Weight (lbs/ft^3)	Cohesion (lbs/ft^2)	Angle of Internal Friction (degrees)
Clayey Soils (Silty Clays/Clayey Sands)	130	100	27
Silty Soils (Sandy Silts/Silty Sands)	130	50	30

Historical records of flows in Aliso Creek indicate that water-surface elevations rise and recede relatively quickly due to the flashy nature of the urban hydrology. The peak water-surface elevations during the 100-year flood, as calculated using the HEC-RAS model (Section 3.3), are around 10 feet above the channel bottom. To account for potential unbalanced water pressure within the banks following periods of rapid hydrograph recession (i.e., drawdown), a residual piezometric surface five feet above the toe of slope was incorporated in the model. This piezometric surface is considered a conservative allowance for unbalanced water pressure because the full rising limb of flood hydrographs including sustained peak flows are of relatively short duration (i.e., up to 18 hours during the 100-year flood). As a result, the depth of saturation into the slope face is anticipated to be limited.

Field observations of existing slope failures and instabilities along lower Aliso Creek indicate that tension features (i.e., near-vertical cracks) parallel to the top of slope appear to be a contributing cause of bank instability. These cracks initially develop as a result of desiccation of the upper soils above the slope and/or stress fractures due to slope deformation of the bank (creep). These open fissures can fill with surface water during rains, increasing the destabilizing forces on the portion of the slope riverward of the tension crack. The initial tension features typically extend several feet below the ground surface; however, as failure of the slope progresses these tension cracks develop into deep shear fractures which can extend to the basal plane of the failure wedge. Conservatively, a depth of initial tension cracking equal to one-quarter of the overall slope height was incorporated into the SLIDE simulations.

3.4.1.3 Results of Slope Stability Analyses

The results of the slope stability analyses are presented by bank material in **Figure 3-6** (clayey soils) and **Figure 3-7** (silty soils). For clayey soils, curves relating calculated factors of safety to stable bank slopes are shown for various overall slope heights (10 to 30 feet). For silty soils, simulation results confirmed that the factor of safety is not substantially influenced by slope height; thus, only one curve representative of all slope heights is shown. The curves are used to identify a stable slope for a desired factor of safety (i.e., tolerance for risk) given the bank materials and bank height. Typically a minimum factor of safety of 1.5 is utilized for slope stability considerations, and this value is identified in both **Figure 3-6** and **Figure 3-7**. A factor of safety of 1.0 is indicative of incipient failure, so for comparison purposes, this value is also shown in **Figure 3-6** and **Figure 3-7**. Building codes frequently specify minimum setbacks from stable slopes for permanent construction. The California Building Code specifies a minimum foundation setback of one-third of the slope height, up to a maximum setback of 40 feet, from the top of a stable slope (California Building Standards Commission 2010). In cases where a proposed pipeline is located at an elevation below the top of slope, this setback was applied at the elevation of the proposed pipeline.

Figures B-1, B-2, B-5, B-6, B-7, and **B-8** in Appendix B show examples of the projected stable slope as compared to the current existing bank slope.

The other key factor in assessing appropriate setback from the existing bank slope is the establishment of the effective toe of slope. The toe is the anchor point that determines the reference location for application of the stable slope provided in **Figure 3-6** and **Figure 3-7**. The effective toe of slope should be established at no higher an elevation than the expected maximum extent of vertical degradation and no farther riverward than the expected extent of lateral erosion/migration of the bank. The degradation and erosion potentials are described in Section 3.3.

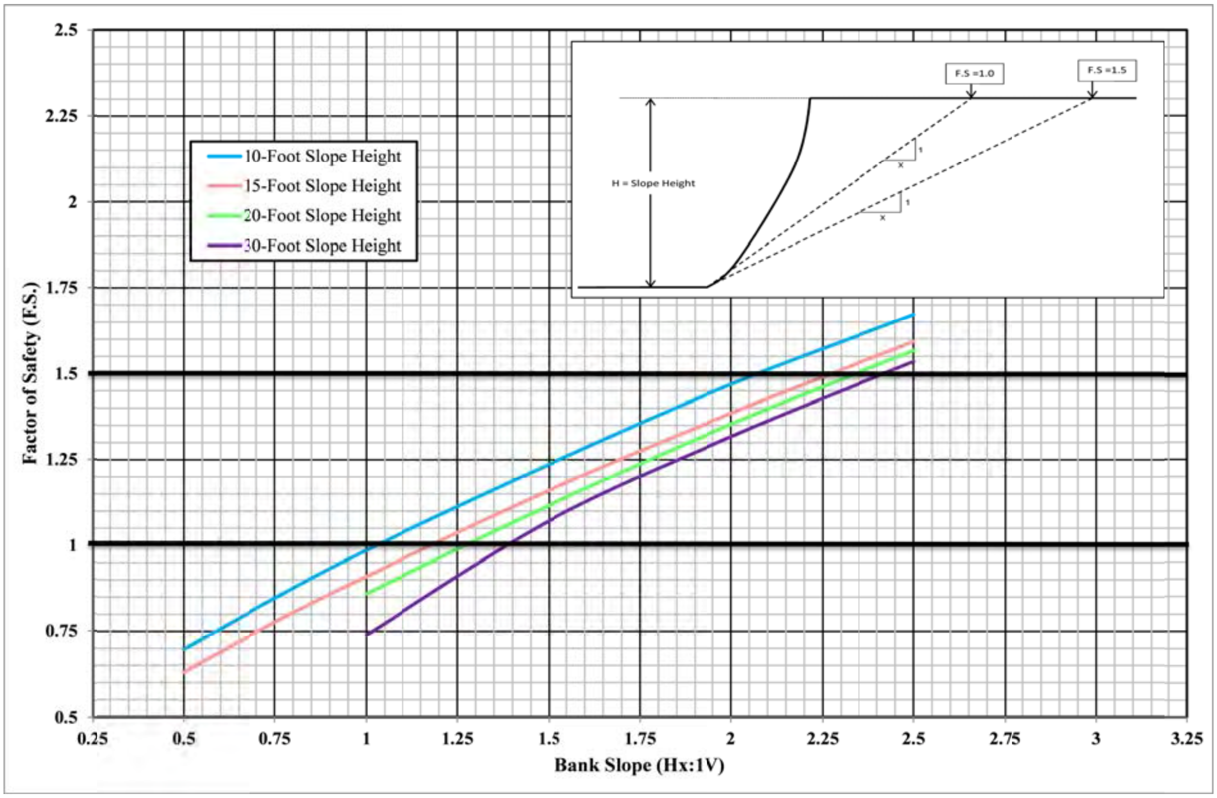

Figure 3-6. Equilibrium Slope Relationships for Clayey Bank Materials

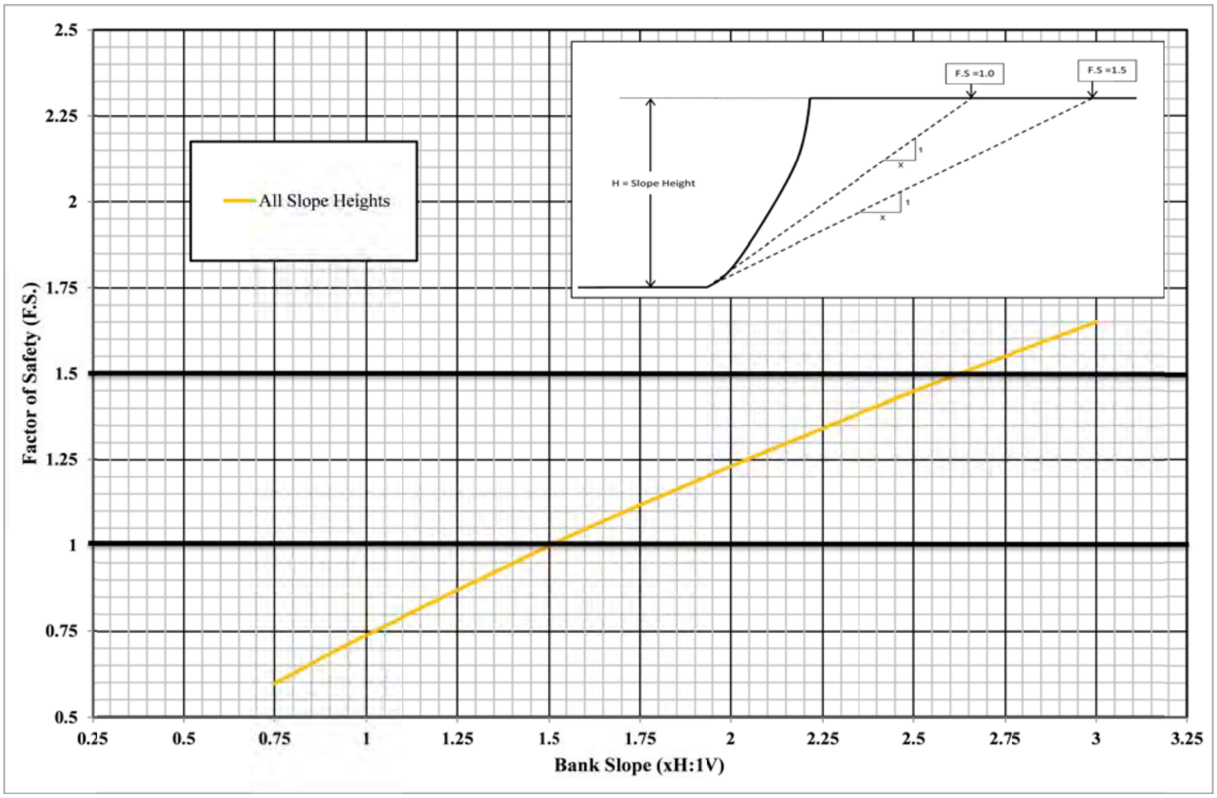

Figure 3-7. Equilibrium Slope Relationships for Silty Bank Materials

3.4.2 Categorization of Geotechnical Erosion Risk to Proposed Pipeline Alignments

Existing bank heights and slopes in many locations along lower Aliso Creek are geotechnically unstable, and geotechnical failures of the banks (e.g., mass wasting) will continue to erode the banks. The results of the slope stability analyses (Section 3.4.1) were used to categorize predicted geotechnically stable bank slopes relative to the proposed pipeline alignments. This was done as a two-step process. The first step was to screen, in a conservative manner, locations where the proposed alignment is likely to be outside the influence of future geotechnical bank failures. A buffer was delineated along the existing top of banks (**Figure 3-8**) using an estimated maximum bank height of 35 feet, the stable slope of 2.6H:1V for silty materials applying a factor of safety of 1.5, and the setback distance based on California Building Code of one-third of the slope height. This results in a buffer width of approximately 100 feet. The alignment of the proposed FM 1 and FM 2 pipelines was compared to the extents of the bank buffers. If the alignments were within the buffers, site-specific calculations using actual bank heights and bank materials were required; if the alignments were outside the buffers, the potential for geotechnical instabilities of the banks to impact the stability of the proposed pipelines was automatically categorized as *Low* (**Figure 3-9**).

Where site-specific calculations were required to assess the risk of geotechnical erosion on the proposed pipelines, bank heights were calculated using the cross section geometry in the hydraulic model. Where the geotechnical borings show the banks contain clay-bearing materials, bank heights were rounded up to the categories shown in **Figure 3-6**. If geotechnical boring data indicated clay-bearing materials in the bank, the bank slope curves presented in **Figure 3-6** were used; if the borings indicated silty materials, or if no information was available, the curve for silty material shown in **Figure 3-7** was used. Locations within the 100-foot top of bank buffer are discretely located along the length of the banks (**Figure 3-8**); for simplification, the site specific calculations were conducted on the critical section at each location. The critical section was identified by evaluating the following factors: slope height, slope angle, bank materials, and the distance between the existing bank and the proposed pipeline alignments. Appendix C includes schematics illustrating the stable slope calculations applied to the critical sections. After applying the recommended setback of one-third of the bank height to the stable bank slope, the geotechnical erosion potential was categorized as illustrated in **Figure 3-9**.

Despite the frequent observations made during the field reconnaissance of geotechnically unstable banks, the proposed pipeline alignments are generally landward of the stable bank angles (F.S. = 1.5) including the recommended setback distance of one-third the slope height. The geotechnical erosion risk is rated *Low* along both proposed alignments except for a single reach along the east (left) bank (FM 1 pipeline alignment) from approximately RM 4.49 to RM 4.55 that is rated *Moderate*.

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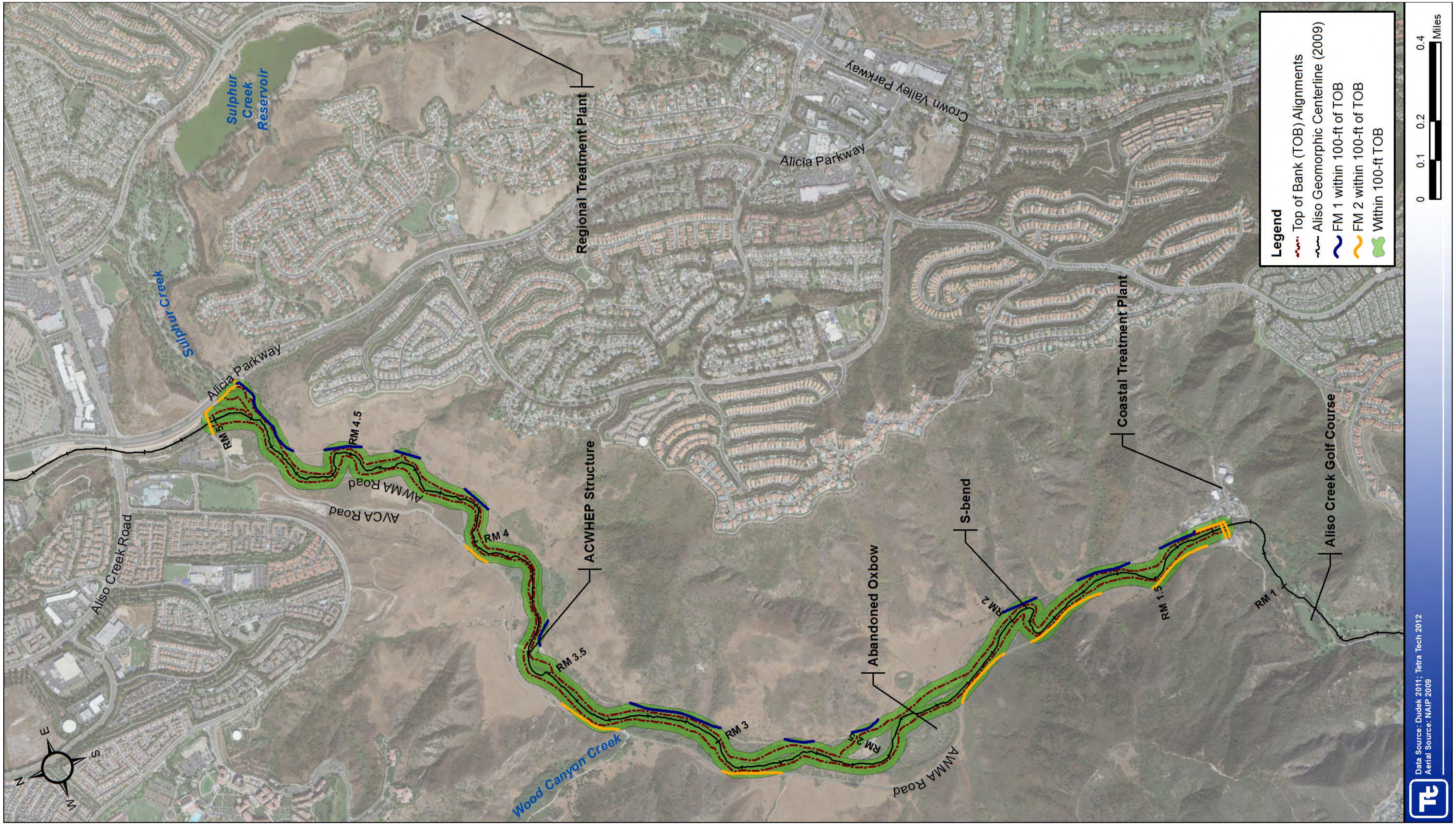

Figure 3-8. Screening of Proposed Pipeline Alignments for Areas Potentially Impacted by Geotechnically Unstable Banks

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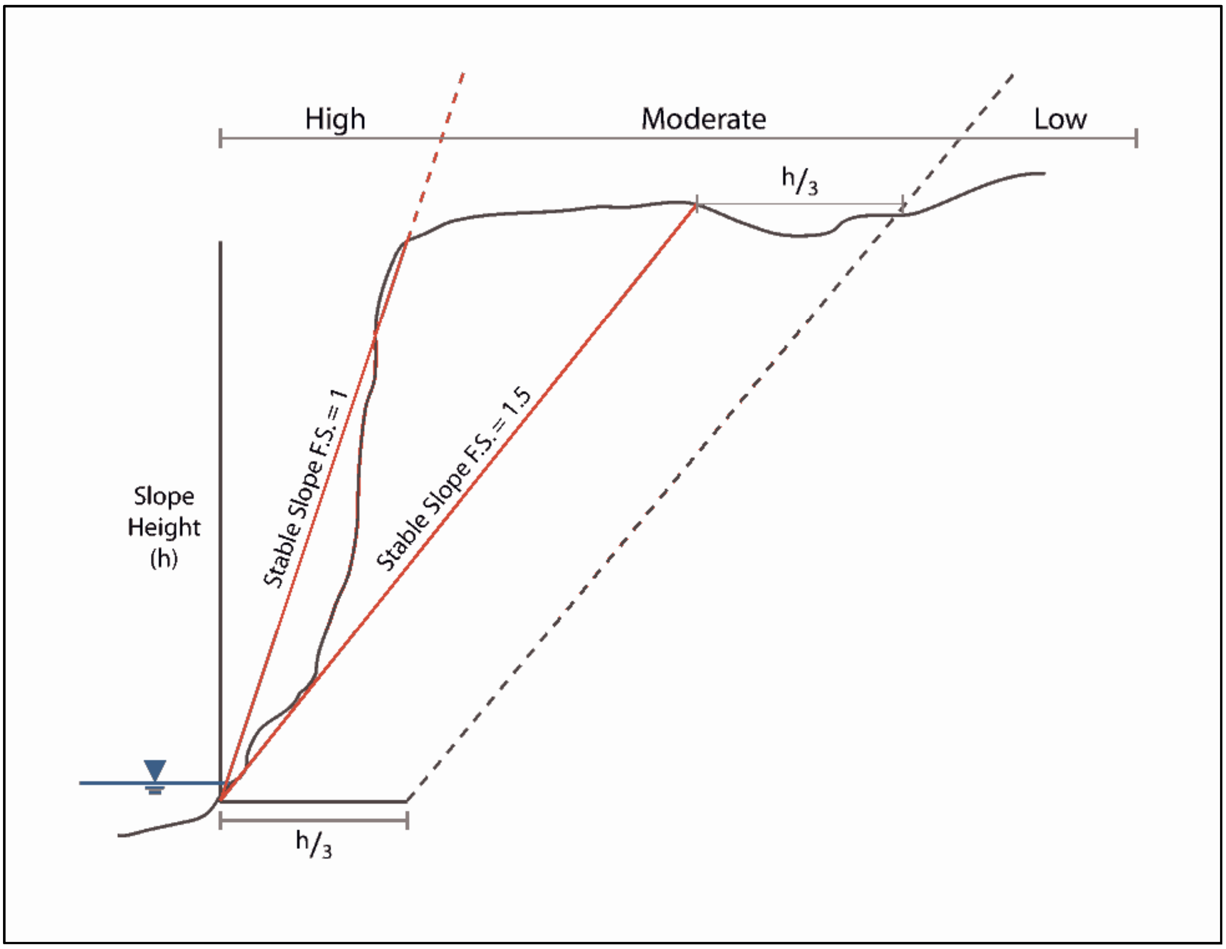

Figure 3-9. Categories of Geotechnical Erosion Risk

3.5 Erosion Risk Associated with Bend Migration

As addressed at the end of Section 3.4.1.3, the evaluation of risk posed to the proposed pipelines depends in part on the establishment of the toe of the bank. While the geomorphic characterization (Section 2.2) provides a basis for expecting limited future systemic channel incision and widening, localized changes from existing conditions are likely. One such change could be the landward translation of the toe of a bank along the outside of a bend due to bend migration. The valley bottom containing lower Aliso Creek is alluvial, so there is the potential for bank erosion along the outside of bends to migrate toward the proposed alignments. Fluvial removal of failed bank materials from the toe of banks along the outside of bends keeps the bank slopes near-vertical, and this continues the mass wasting erosional processes. Such a lateral translation of the bank will cause the predicted stable bank slopes to move landward a distance equivalent to any landward migration of the toe of slope. Data to quantify historical rates of bend migration are not available for lower Aliso Creek. In the absence of such data, the 2009 centerline delineation has been overlaid on 1939 aerial photography to illustrate the consistency in the planform of the channel (**Figure 3-10**). Of approximately two dozen bends along lower Aliso Creek, comparison of the 1939 centerline to the 2009 centerline shows about half of these bends have migrated. Where the banks along the outside of the bends have not been protected, average rates of migration range from approximately 0.5 to 1.3 feet per year, with an average of approximately 0.9 feet per year. While the planform of lower Aliso Creek has generally persisted since 1939, the cross sectional-area of the channel has enlarged approximately eight-fold between the early 1970s and the late 1990s (Tetra Tech, Inc. 2010) as shown on **Figure B-1**. Bend migration is a common occurrence in alluvial rivers, but the comparison illustrated in **Figure 3-10** doesn't indicate substantial bend migration processes occurring in lower Aliso Creek, despite the highly dynamic processes of downcutting and channel widening, over this period of approximately 70 years.

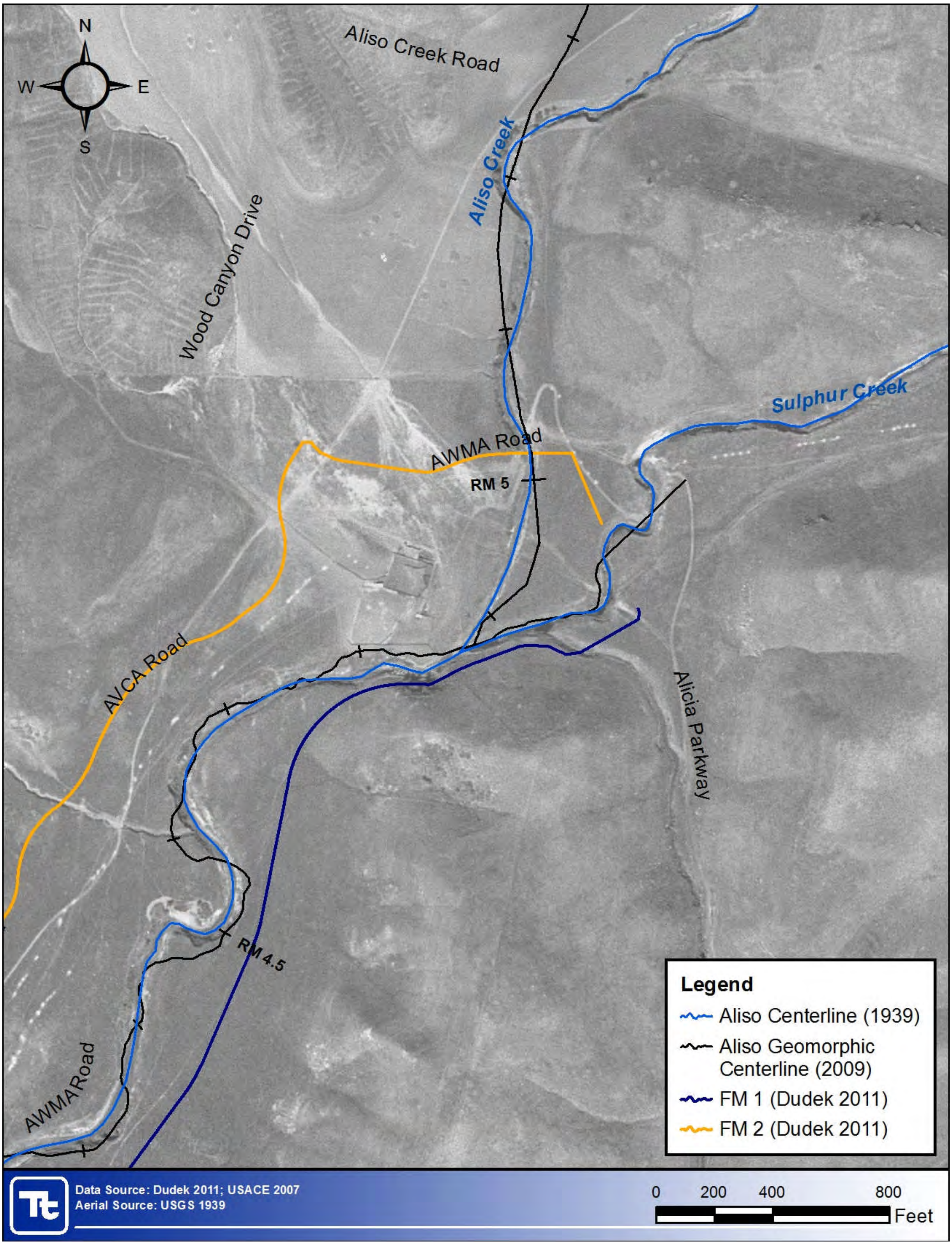

Figure 3-10 (Map 1 of 5). 2009 Channel Alignment Overlaid on 1939 Aerial Photography

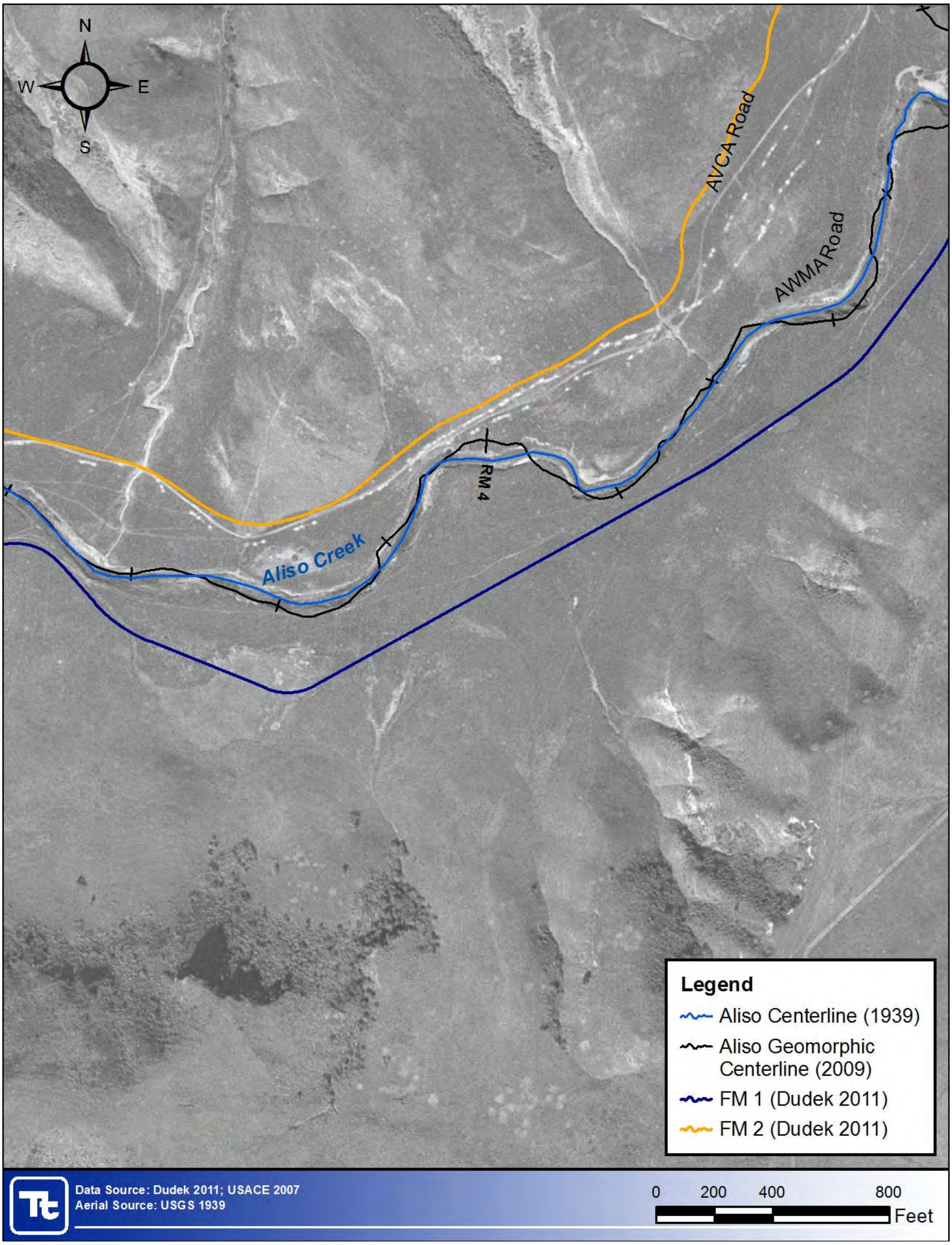

Figure 3-10 (Map 2 of 5). 2009 Channel Alignment Overlaid on 1939 Aerial Photography

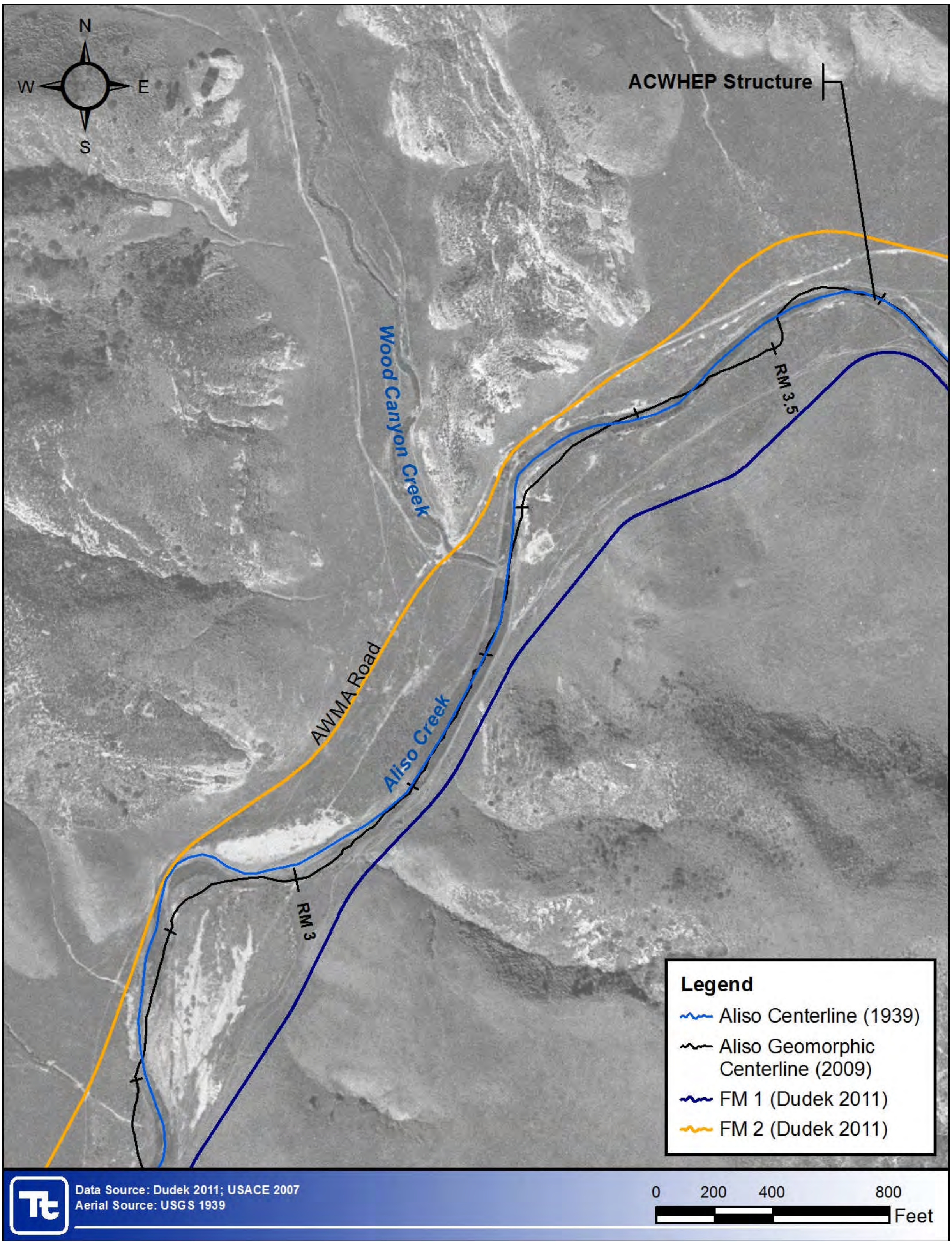

Figure 3-10 (Map 3 of 5). 2009 Channel Alignment Overlaid on 1939 Aerial Photography

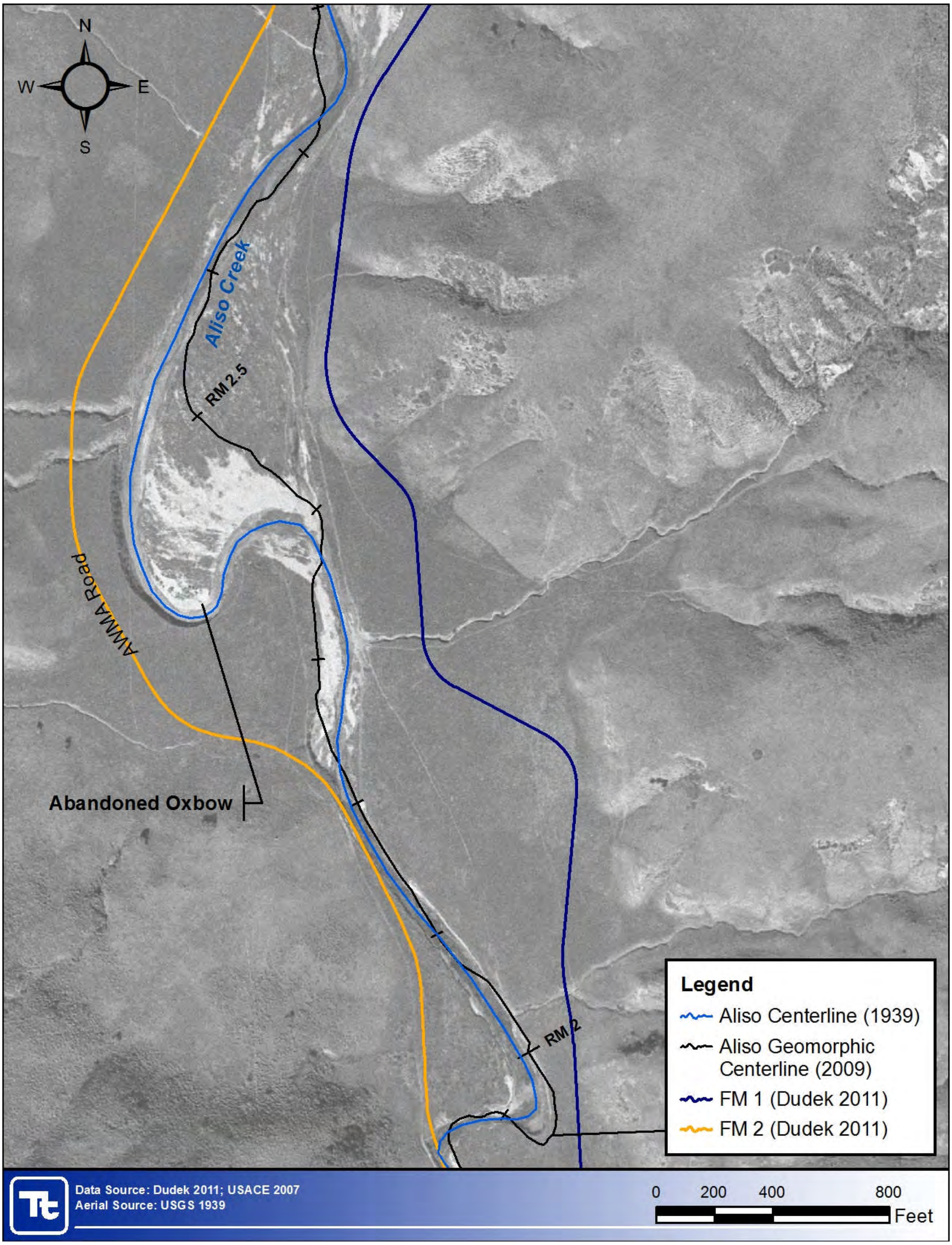

Figure 3-10 (Map 4 of 5). 2009 Channel Alignment Overlaid on 1939 Aerial Photography

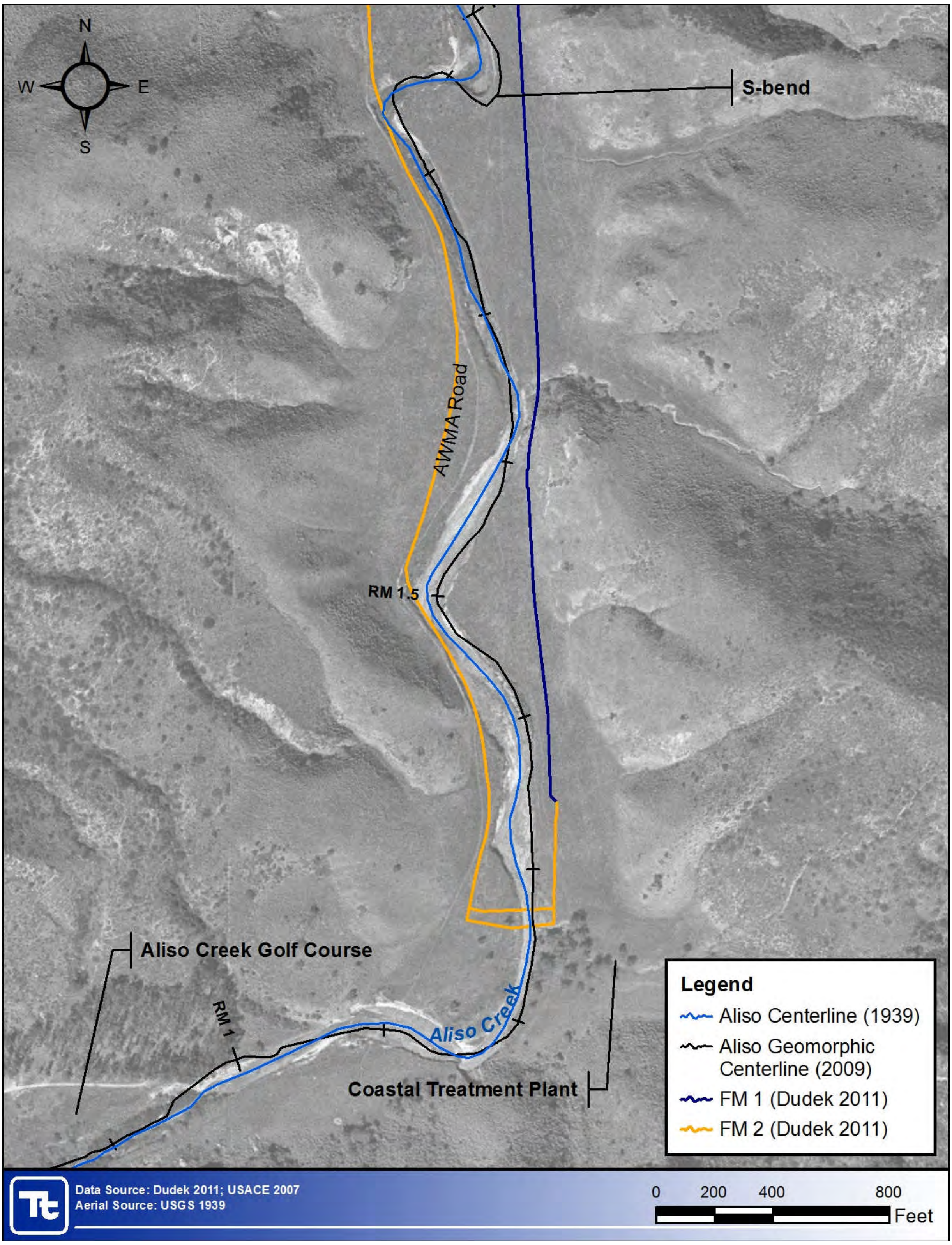

Figure 3-10 (Map 5 of 5). 2009 Channel Alignment Overlaid on 1939 Aerial Photography

Even though the historical record indicates a limited propensity for bend migration, the potential impact on the proposed pipeline alignments of bank erosion induced by bend migration was assessed. The fluvial erosion potential was evaluated along the outside of bends (**Table 3-5** and **Table 3-6**). If the fluvial erosion potential is rated *Moderate* or *High*, bend migration is more likely to occur over the 50-year planning period. This potential for migration could be mitigated by the presence of properly designed and installed bank protection measures maintained in good condition; however, due to the absence of engineering designs associated with the installation of existing emergency bank protection measures, it was assumed there would be limited effectiveness for these measures to mitigate the long-term potential for bend migration. Using the results from the slope stability analyses, the distance was calculated between the predicted stable bank slope (including the setback equal to one-third of the slope height) and the proposed pipeline at the proposed elevation of the pipeline (Appendix C). These calculations were made for critical sections (taken to be applicable to conditions along the outside of a bend of interest).

For sites where the distance between the predicted stable bank slope and the proposed pipeline is less than 50 feet and the fluvial erosion potential (based on the highest rating of any section within the full extent of the bend) is rated *High* or *Moderate*, the risk to the proposed pipelines of bank erosion associated with bend migration was rated *High*. Since the comparison of the 2009 channel centerline to the 1939 centerline revealed that unprotected banks along the outside of bends along lower Aliso Creek have migrated at an average rate of about 1.0 feet per year, a distance of 50 feet was selected to represent an estimate a reasonable threshold of bend migration over the 50-year planning period. If the fluvial erosion potential is *Low*, the erosion potential due to bend migration was rated *Moderate*.

For sites where the distance between the calculated stable bank slope (including the setback equal to one-third the slope height) and the proposed pipeline is greater than 50 feet, the risk to the proposed pipelines of bank erosion induced by bend migration is rated *Low* – independent of the fluvial erosion potential.

The results of this analysis are presented in **Table 3-5** and **Table 3-6** for the east (left) bank and west (right) bank, respectively.

Table 3-5. Erosion Risk Associated with Bend Migration along the East (Left) Bank

Approximate Bend Extents (RM)	Critical Section (RM)	Fluvial Erosion Potential	Approximate Offset from Stable Slope[1] (feet)	Erosion Risk Associated with Bend Migration
0.105 – 0.074[s]	0.088[s]	High	30	High
4.88 – 4.83	4.854	Low	10	Mod.
4.56 – 4.464	4.522	Mod.	0	High
4.36 – 4.29	4.330	Low	65	Low
4.138 – 4.08	4.138	Low	85	Low
3.71 – 3.657	3.677	Low	70	Low
3.257 – 2.985	3.095	High	5	High
2.768 – 2.668	2.713	Low	65	Low
2.58 – 2.479	2.509	Low	15	Mod.
1.989 – 1.91	1.989	Mod.	35	High
1.703 – 1.56	1.608	High	30	High
1.44 – 1.353	1.370	Low	10	Mod.

Note:

[s] Indicates river mile is measured upstream along Sulphur Creek from the Aliso Creek confluence.

[1] Offset is estimated as the distance between the setback of one-third the slope height from the stable slope and the proposed pipeline alignment.

Table 3-6. Erosion Risk Associated with Bend Migration along the West (Right) Bank

Approximate Bend Extents (RM)	Critical Section (RM)	Fluvial Erosion Potential	Approximate Offset from Stable Slope[1] (feet)	Erosion Risk Associated with Bend Migration
4.03 – 3.937	4.003	Mod.	100	Low
3.580 – 3.505	3.555	High	90	Low
3.366 – 3.291	3.346	Low	20	Mod.
2.967 – 2.89	2.898	High	10	High
2.26 – 2.167	2.193	Mod.	5	High
1.90 – 1.817	1.817	Low	10	Mod.
1.52 – 1.464	1.449	High	5	High

Note:

[1] Offset is estimated as the distance between the setback of one-third the slope height from the stable slope and the proposed pipeline alignment.

4 Erosion Assessment Summary

The analyses described in this report were conducted in support of the ongoing preparation of an EIR for the SOCWA CTP Export Sludge Force Main Replacement Project. Previous studies and historical infrastructure maintenance along lower Aliso Creek have highlighted the key influence bank erosion plays in the stability of roads and pipelines adjacent to the channel. The following sections summarize the combined influence of fluvial erosion potential, geotechnical erosion risk, and risk of bank erosion associated with bend migration to the stability of proposed force main alignments for the 50-year planning period.

The combined erosion risk rating was assigned based primarily on the risk to the stability of the proposed pipeline alignments of bank erosion induced by bend migration, with consideration given to the risk of bank erosion due to geotechnical instabilities. The combined erosion risk rating was assigned based on the higher erosion risk rating assigned to either the geotechnical erosion or the bend migration. A *High* erosion risk implies, based on the analyses conducted, that the proposed pipeline alignment will likely be impacted by bank erosion over the 50-year planning period, so pipeline realignment or bank protection measures are recommended. A *Moderate* risk implies, based on the analyses conducted, that the pipeline alignment could be impacted over the planning period, so bank erosion should be monitored on a regular basis (i.e., after all floods) and bank protection measures installed if necessary. A *Low* risk implies, based on the analyses conducted, that the pipeline alignment is unlikely to be impacted by bank erosion, so occasional monitoring is recommended (i.e., every few years, or after major floods, whichever occurs first).

4.1 Proposed FM 1 Alignment

The proposed FM 1 alignment along the east (left) bank is potentially subject to approximately 3,300 feet of *High* erosion risk and approximately 1,250 feet of *Moderate* erosion risk; the remainder of the proposed alignment (approximately 12,050 feet) is rated *Low* risk. The locations associated with these ratings are shown in **Table 4-1** as well as in **Figure 4-1**. The Fluvial Erosion Potential is presented for reference in **Table 4-1** but was not directly incorporated into the combined erosion risk rating since it was previously factored into the bend migration risk ratings. For ease of interpreting **Table 4-1** and to highlight potential areas of concern, the *Low* ratings are not shown.

Table 4-1. Summary of Erosion Risk to the Proposed FM 1 Alignment along the East (Left) Bank

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
Sulphur Creek				
0.120	M			
0.105	H		H	H
0.088	L		H	H
0.067	H			
0.036	H			
0.023	M			
Aliso Creek				
4.854	L		M	M
4.785	M			
4.717	L			
4.656	L			
4.595	L			
4.522	M	M	H	H
4.464	L		H	H
4.398	L			
4.330	L			
4.266	L			
4.199	L			
4.138	L			
4.067	H			
4.003	L			
3.937	M			
3.872	L			
3.810	M			
3.741	L			
3.677	L			
3.657	L			
3.639	M			
3.621	H			
3.613	M			
3.604	H			
3.601	H			
3.594	L			
3.589	L			
3.580	L			
3.567	L			
3.555	L			
3.535	L			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
3.505	L			
3.484	H			
3.465	L			
3.444	M			
3.423	L			
3.399	L			
3.382	L			
3.366	L			
3.346	L			
3.335	L			
3.314	L			
3.291	L			
3.276	L			
3.257	L		H	H
3.243	L		H	H
3.231	L		H	H
3.214	L		H	H
3.191	L		H	H
3.169	L		H	H
3.149	L		H	H
3.131	L		H	H
3.110	M		H	H
3.095	M		H	H
3.074	M		H	H
3.057	M		H	H
3.033	L		H	H
3.014	H		H	H
3.000	H		H	H
2.985	L		H	H
2.967	L			
2.945	L			
2.919	L			
2.898	H			
2.881	M			
2.864	M			
2.842	H			
2.823	L			
2.802	L			
2.784	L			
2.768	L			
2.753	L			
2.736	L			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
2.713	L			
2.692	L			
2.668	L			
2.649	L			
2.634	L			
2.594	L			
2.565	L		M	M
2.544	L		M	M
2.509	L		M	M
2.479	L		M	M
2.456	H			
2.434	L			
2.412	L			
2.392	L			
2.372	L			
2.355	L			
2.334	L			
2.312	L			
2.294	L			
2.270	L			
2.243	L			
2.233	L			
2.208	L			
2.193	L			
2.167	L			
2.149	M			
2.131	M			
2.113	H			
2.097	L			
2.076	M			
2.056	H			
2.035	M			
2.013	H			
1.989	L		H	H
1.971	M		H	H
1.955	M		H	H
1.930	L		H	H
1.904	L			
1.887	L			
1.865	L			
1.843	L			
1.817	L			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
1.789	M			
1.767	H			
1.746	L			
1.723	L			
1.703	L		H	H
1.684	L		H	H
1.661	L		H	H
1.644	L		H	H
1.625	L		H	H
1.608	M		H	H
1.586	H		H	H
1.569	M		H	H
1.543	L			
1.520	L			
1.496	L			
1.464	L			
1.449	L			
1.429	L		M	M
1.410	L		M	M
1.391	L		M	M
1.370	L		M	M
1.353	L		M	M
1.333	L			
1.315	L			
1.295	L			
1.274	L			

Note:

Ratings of *L* not shown to facilitate interpretation of results in the table, and to highlight potential problem areas.

Figure 4-1 (Map 1 of 4). Combined Erosion Risk To Proposed FM 1 and FM 2 Alignments

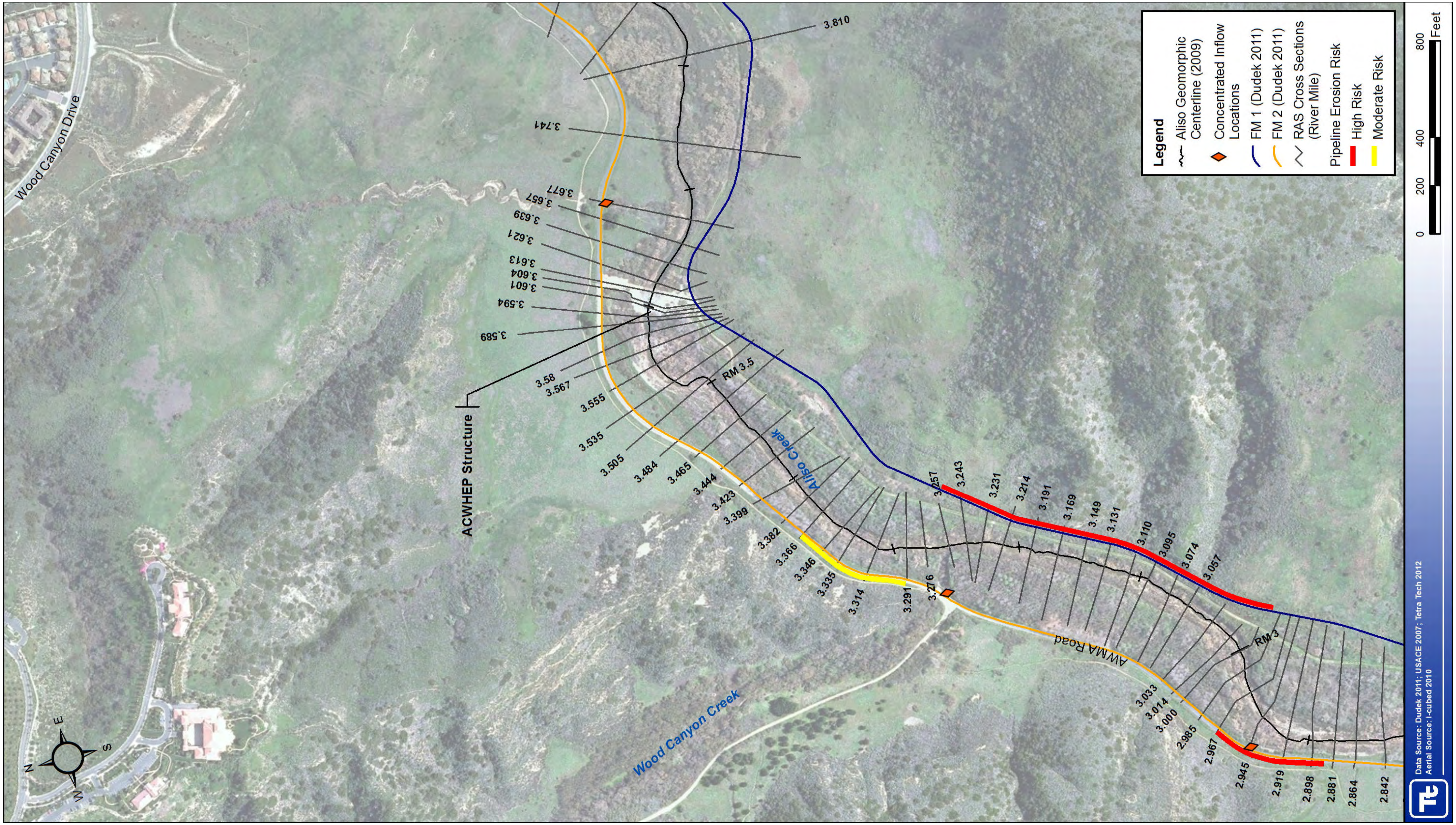

Figure 4-1 (Map 2 of 4). Combined Erosion Risk To Proposed FM 1 and FM 2 Alignments

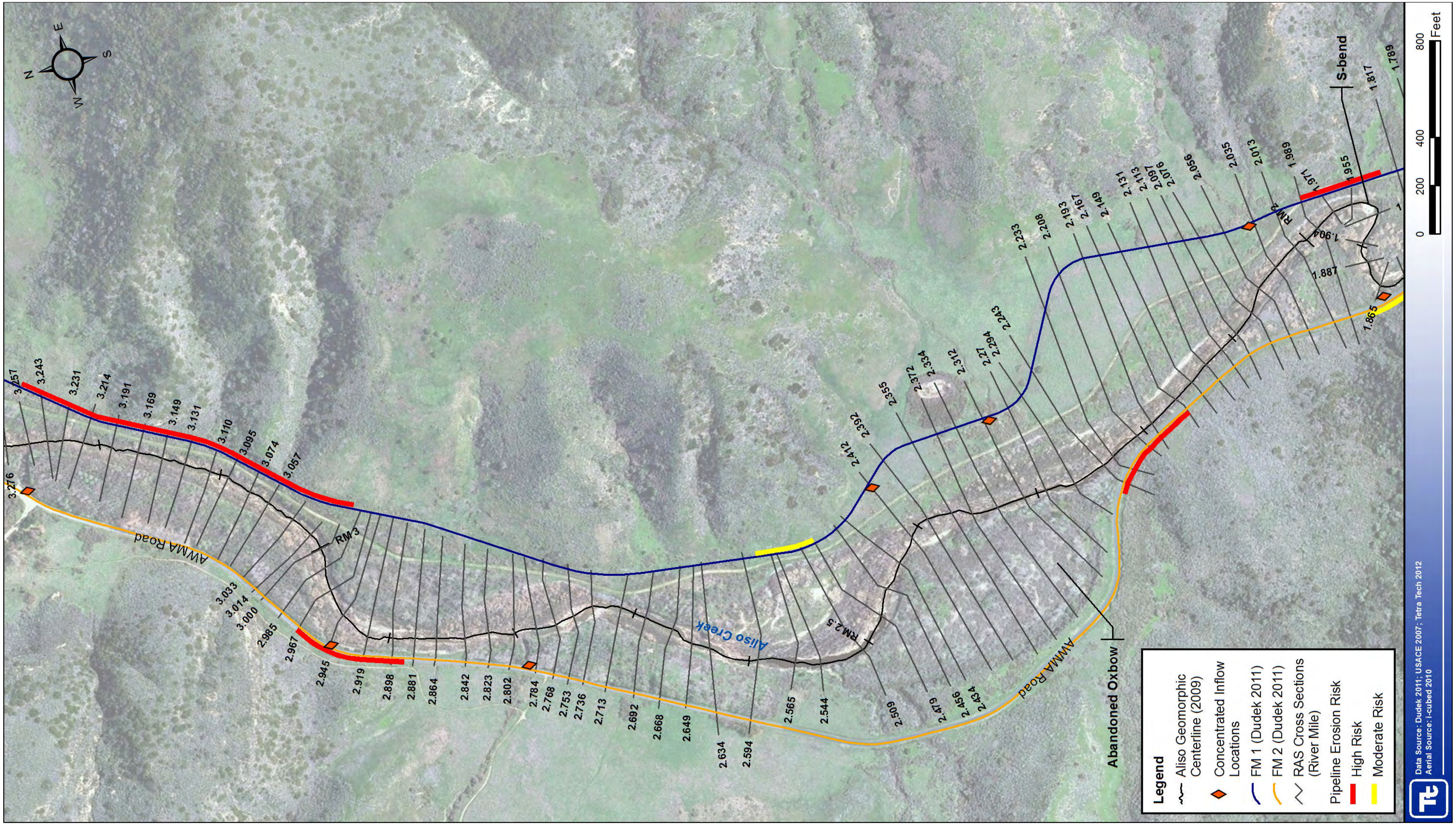

Figure 4-1 (Map 3 of 4). Combined Erosion Risk To Proposed FM 1 and FM 2 Alignments

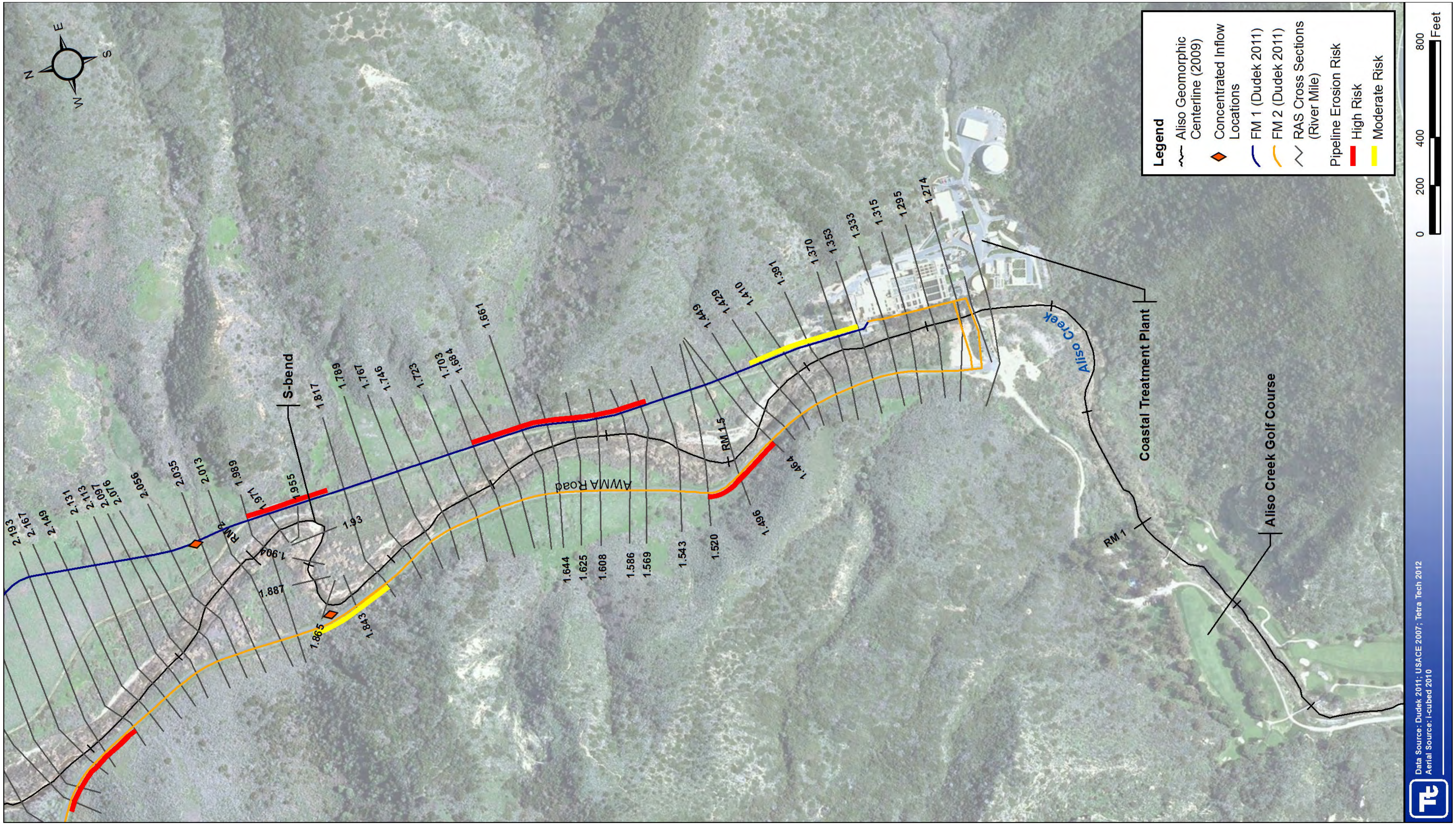

Figure 4-1 (Map 4 of 4). Combined Erosion Risk To Proposed FM 1 and FM 2 Alignments

4.2 Proposed FM 2 Alignment

The proposed FM 2 alignment along the west (right) bank is potentially subject to approximately 1,200 feet of *High* erosion risk and 850 feet of *Moderate* erosion risk; the remainder of the proposed and existing alignment (approximately 17,350 feet) is rated *Low* risk. The locations associated with these ratings are shown in **Table 4-2** as well as on **Figure 4-1**. The Fluvial Erosion Potential is presented for reference in **Table 4-2** but was not directly incorporated into the combined erosion risk rating since it was previously factored into the bend migration risk ratings. For ease of interpreting **Table 4-2** and to highlight potential problem areas, the *Low* ratings are not shown.

Table 4-2. Summary of Erosion Risk to the Proposed FM 2 Alignment Along the West (Right) Bank

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
Sulphur Creek				
Not Applicable				
Aliso Creek				
5.014	L			
5.011	L			
4.984	L			
4.916	L			
4.854	L			
4.785	M			
4.717	L			
4.656	L			
4.595	M			
4.522	L			
4.464	H			
4.398	L			
4.330	L			
4.266	L			
4.199	L			
4.138	L			
4.067	H			
4.003	L			
3.937	M			
3.872	L			
3.810	M			
3.741	M			
3.677	L			
3.657	L			
3.639	M			
3.621	H			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
3.613	M			
3.604	H			
3.601	H			
3.594	M			
3.589	M			
3.580	H			
3.567	H			
3.555	H			
3.535	H			
3.505	L			
3.484	H			
3.465	L			
3.444	M			
3.423	L			
3.399	L			
3.382	L			
3.366	L		M	M
3.346	L		M	M
3.335	L		M	M
3.314	L		M	M
3.291	L		M	M
3.276	L			
3.257	L			
3.243	L			
3.231	L			
3.214	L			
3.191	L			
3.169	L			
3.149	L			
3.131	L			
3.110	L			
3.095	L			
3.074	L			
3.057	L			
3.033	L			
3.014	L			
3.000	L			
2.985	L			
2.967	L		H	H
2.945	M		H	H
2.919	L		H	H
2.898	H			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
2.881	M			
2.864	M			
2.842	H			
2.823	L			
2.802	L			
2.784	L			
2.768	L			
2.753	L			
2.736	L			
2.713	L			
2.692	L			
2.668	L			
2.649	L			
2.634	L			
2.594	L			
2.565	L			
2.544	L			
2.509	M			
2.479	H			
2.456	L			
2.434	L			
2.412	L			
2.392	L			
2.372	L			
2.355	L			
2.334	L			
2.312	L			
2.294	L			
2.270	M			
2.243	M		H	H
2.233	L		H	H
2.208	M		H	H
2.193	L		H	H
2.167	L		H	H
2.149	M			
2.131	M			
2.113	H			
2.097	L			
2.076	M			
2.056	H			
2.035	M			
2.013	H			

River Mile	Fluvial Erosion Potential	Geotechnical Erosion Risk[1]	Bend Migration Risk[1]	Combined Erosion Risk[1]
1.989	M			
1.971	L			
1.955	L			
1.930	L			
1.904	L			
1.887	L		M	M
1.865	L		M	M
1.843	L		M	M
1.817	L		M	M
1.789	M			
1.767	H			
1.746	L			
1.723	L			
1.703	L			
1.684	L			
1.661	L			
1.644	L			
1.625	L			
1.608	L			
1.586	L			
1.569	L			
1.543	L			
1.520	H		H	H
1.496	M		H	H
1.464	L		H	H
1.449	L			
1.429	L			
1.410	L			
1.391	L			
1.370	L			
1.353	L			
1.333	L			
1.315	L			
1.295	L			
1.274	L			

Note:
Ratings of *L* not shown to facilitate interpretation of results in the table, and to highlight potential problem areas.

4.3 Additional Considerations

The previous tables focus on the potential risk impacting the pipeline from bank erosion; however, other factors may influence the potential for bank erosion to destabilize/undermine the proposed pipeline alignments. The following sections identify additional considerations that apply to both the pipeline alignments and should be considered as part of the overall understanding of potential erosion impact at the pipelines.

4.3.1 Concentrated Runoff and Tributaries

Along the length of Aliso Creek, runoff from upland areas is conveyed into the river. This occurs via concentrated overland flow, storm drains, drainage channels, and tributaries. At many of these inflow points, there is the potential for localized bank erosion. **Figures B-6** and **B-8** in Appendix B illustrate the impacts associated with concentrated surface runoff. Where the inflows, particularly concentrated runoff and tributaries, cross the proposed pipeline alignments (**Table 4.3** and **Figure 4-1**), there is the potential that the localized erosion could propagate landward from the bank and expose the pipeline. Thus, the crossings should be addressed as part of the pipeline replacement design.

Table 4-3. Concentrated Inflow Locations along Lower Aliso Creek

River Mile	Type of Inflow
FM 1 Alignment	
Sulphur 0.050	Tributary channel
4.522	Concentrated surface runoff
4.340	Tributary channel
2.412	Concentrated surface runoff
2.312	Tributary channel
2.040	Tributary channel
FM 2 Alignment	
3.677	Tributary channel
3.257	Tributary (Wood Canyon)
2.945	Concentrated surface runoff
2.784	Tributary channel
1.858	Concentrated surface runoff

Special consideration of the inflow from Wood Canyon Creek is warranted. The existing confluence of Wood Canyon Creek with Aliso Creek has undergone considerable erosion downstream of the AWMA Road crossing. This crossing has been protected with a riprap revetment, but observations indicate the protection is being flanked. The Wood Canyon watershed contains numerous recreational crossings of the creek, as well as environmental resources (e.g., the Wood Canyon Emergent Wetland) that could be impacted if the grade control provided by the crossing is lost. Additionally, downcutting that would propagate upstream from the crossing would contribute a substantial volume of sediment to Aliso Creek that could exacerbate bank erosion and lead to avulsions that could threaten existing and proposed pipeline alignments. Thus, the stability of this crossing is imperative from various perspectives.

4.3.2 Existing Bank Protection

Prior the field reconnaissance conducted for this study, the locations and extents of existing bank protection were not well documented. Where vegetation permitted access for observation, the extents and condition of bank protection measures were recorded. Due to the emergency conditions under which much of these protection measures were installed, standard engineering designs were likely not performed. Rather, the material is commonly dumped from the top of bank down the slope. In some instances, the riprap revetments appear to be in good condition. In these cases, the protection may limit future bank erosion over the 50-year planning period for the proposed pipelines. However, since specifications for factors such as toedown depths, layer thickness, rock durability, gradation, and filter blankets are not available, the existing good condition may not persist. Degradation (e.g., slumping, displacement, and weathering of older riprap) of the bank protection was observed during the field reconnaissance in places along both banks. While credit for mitigating fluvial erosion potential was provided for existing bank protection measures in good condition, it is necessary that these measures be maintained over the project planning period. The emergency measures may need to be replaced with engineered features designed for site specific locations along lower Aliso Creek.

4.3.3 Abandoned Pipelines

The ACWHEP structure was installed in the early 1990s to divert flow into irrigation pipes to restore floodplain vegetation. Between the diversion structure (RM 3.6) and the downstream end of the abandoned oxbow (RM 2.3), the PVC irrigation pipelines still exist in/on both banks of Aliso Creek. Due to breaks in the pipes near the diversion structure, the irrigation system is no longer operational; however, the pipes have simply been abandoned in place. Additionally, portions of 18-inch diameter VCP in the east (left) bank have been undermined; fixes primarily entail bypassing the exposed/broken reach. Both the abandoned irrigation and sewer pipes create flowpaths for seepage into and through the banks that can promote unstable conditions, resulting in bank failures. An extreme example of this process was observed along the east bank near RM 3.014 (represented in **Figure B-7** in Appendix B). Field observations indicate that high flows entered the open end of the irrigation pipe, traveled to a break in the pipe, and leaked into the bank materials contributing to the observed bank erosion and slumping. No attempt has been made to predict where this type of bank failure could occur; without a thorough understanding of the location of all abandoned pipes this type of failure should be considered as one that can and will occur randomly along the extents of the abandoned pipelines.

4.3.4 Vertical Channel Degradation

The processes discussed throughout this report focus on the potential for bank erosion and bend erosion to destabilize the proposed pipeline alignments. It should be noted that isolated potential for vertical degradation exists in the system (Tetra Tech, Inc. 2010). The only location where future vertical degradation is expected within the study area is between approximately RM 2.75 and RM 3.25. Various lengths of both channel banks in this reach have been identified as having a *High* combined erosion risk. If measures were taken to stabilize the channel bank in this reach, the potential for approximately 1 – 4 feet of additional vertical degradation (Tetra Tech, Inc. 2010) near RM 3.25 should be considered during design of the measures (the additional expected vertical degradation tapers to 0 feet at RM 2.75).

Previous studies (Tetra Tech, Inc. 2010) have noted the importance of the integrity of the ACWHEP diversion structure to the geomorphology of lower Aliso Creek. The diversion structure provides grade control to the bed of Aliso Creek, and the influence of this grade control extends considerable distances both upstream and downstream. If the functionality of this structure to hold grade is not maintained, substantial changes in channel morphology (e.g., upstream propagation of downcutting and downstream deposition) may occur.

4.3.5 Bridges

The proposed FM 2 alignment requires crossings of Aliso Creek at two bridges: 1) the CTP Bridge, and 2) the AWMA Bridge. The reliability of these bridges directly affects the vulnerability of this alternative over the 50 year planning period. Assessments of the erosion risk to the integrity of the bridges and evaluations of the structural integrity of the bridges were not conducted within this study; however, more detailed analyses are recommended in the future for further consideration of this alternative.

4.4 Limitations

The summaries of risk previously presented are dependent on the following key limitations:

- Simulations of future flood hydrology show peak flows are likely to be similar to recent historical conditions. However, differences between simulated flood hydrographs and actual flood hydrographs (e.g., flood duration and flood frequency) could exacerbate bank erosion.
- Flood hydrology in lower Aliso Creek is episodic. Therefore, changes in channel morphology are unlikely to change gradually over time; rather, the morphology of the channel (particularly the geotechnical stability of bank slopes and bend migration) will be episodic and flood driven.
- The assessment of the geomorphic stability of lower Aliso Creek is critically dependent upon the stability of the ACWHEP diversion structure. If this structure is not maintained to perform in its current capacity, major changes in channel morphology (including bank erosion, bend migration, and channel avulsions) may occur.
- It was assumed no new bank protection measures installed by any entity would be constructed over the project life, but that the existing condition of observed bank protection measures in good condition would be maintained.
- The slope stability analyses are dependent on limited soil strength data, so locations where likely future erosion risks are greatest may require additional geotechnical testing and analyses during later design phases.
- The geometry of the channels, floodplains, and terraces is based on: 1) 2006 surveys of channel morphology between the CTP and the ACWHEP structure, or 2) topographic mapping collected in 1998. Changes in morphology more recent that these dates are not reflected in the analyses carried out in this study.
- The influence of regional geologic conditions (e.g., landslides in bedrock formations along both banks of lower Aliso Creek) on the stability of the proposed pipeline alignments were not specifically quantified in this study.
- Seismic evaluation of the proposed pipeline alignments was beyond the scope of this current study. Later phases of design of the selected pipeline alignment may require evaluation of potential bank deformation due to earthquake loading, including 1) slope deformation due to seismic shaking and 2) ground subsidence and lateral spreading due to soil liquefaction.

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5 References

California Building Standards Commission. 2010. *California Building Code, California Code of Regulations.* Title 24, Part 2 (First Printing), Chapter 18, Section 1808, 1808.7. http://publicecodes.citation.com/st/ca/st/b200v10/st_ca_st_b200v10_18_sec008_par012.htm Accessed March 20, 2012.

Diaz Yourman & Associates. 2009. *Geotechnical Data Report Aliso Creek Environmental Restoration Project.* Prepared for U.S. Army Corps of Engineers, Los Angeles District. Santa Ana, California.

Dudek. 2006. *Coastal Treatment Plant Export Sludge Forcemain Replacement Study.* Prepared for South Orange County Wastewater Authority. Encinitas, California.

Dudek. 2011. *Coastal Treatment Plant Export Sludge Pipeline Alignment Study.* Prepared for South Orange County Wastewater Authority. Encinitas, California.

ESRI. 2009. *ArcGIS ArcMap.* Computer software, Version 9.3.1, Build 4000. Redlands, California.

Harvey, M.D. and R.A. Mussetter. 1993. *Geomorphic, Sediment Engineering, and Channel Stability Analyses, American and Sacramento River, California Project.* Prepared by Resources Consultants & Engineers, Inc. Prepared for the U.S. Army Corps of Engineers, Sacramento District. Fort Collins, Colorado.

MACTEC Engineering and Consulting, Inc. 2007. *Final Report of Geotechnical Evaluation for Environmental Impact Report, Appendix C Geophysical Surveys.* Irvine, California.

Morton, D.M. 2004. *Preliminary Digital Geologic Map of the Santa Ana 30’ X 60’ Quadrangle, southern California, version 2.0.* U.S. Geological Survey, Western Surficial Processes Team. Department of Earth Sciences, University of California. Riverside, California.

Morton, P.K., Edgington, W.J, and D.L Fife. 1974. *Geology and Engineering Geologic Aspects of the San Juan Capistrano Quadrangle, Orange County, California.* California Division of Mines and Geology, . Prepared in cooperation with the County of Orange, Department of Building Safety, Road Department, and the Orange County Flood Control District. Sacramento, California.

NRCS. 2008. *Soil Survey Geographic (SSURGO) Database for Orange & Western Part of Riverside Counties, California.* U.S. Department of Agriculture, Natural Resources Conservation Service. Fort Worth, Texas.

Ninyo & Moore. 2009. *Preliminary Geotechnical Evaluation Coastal Treatment Plant Access Road Realignment Study, South Orange County Wastewater Authority, Laguna Niguel, California.* Prepared for Tetra Tech, Inc. Irvine, California.

Ninyo & Moore. 2011. *Preliminary Geotechnical Evaluation Coastal Treatment Plant Export Sludge System, South Orange County Wastewater Authority.* Prepared for Dudek & Associates. Irvine, California.

Rocscience, Inc. 2011. *SLIDE.* Computer software, Version 6.011. Toronto, Ontario.

SCS. 1977. Design of Open Channels. U.S. Department of Agriculture, Soil Conservation Service (SCS), Engineering Division. Washington, D.C.

Tetra Tech, Inc. 2010. *DRAFT – Aliso Creek F4 Geomorphic Assessment.* Prepared for the U.S. Army Corps of Engineers, Los Angeles District. Irvine, California.

USACE. 1998. *HEC-1 Flood Hydrograph Package.* Generalized Computer Program, Version 4.1. U.S. Army Corps of Engineers (USACE), Hydrologic Engineering Center. Davis, California.

USACE. 2000. *Aliso Creek Watershed Study, Orange County, California, Hydraulic and Sediment Analysis Appendix.* Prepared by Simons, Li, and Associates. Prepared for the U.S. Army Corps of Engineers (USACE), Los Angeles District. Irvine, California.

USACE. 2009. *Aliso Creek Mainstem Ecosystem Restoration Study, Orange County, California, Hydrology and Hydraulics Appendix.* Prepared by Tetra Tech, Inc. Prepared for the U.S. Army Corps of Engineers (USACE), Los Angeles District. Irvine, California.

Woodward-Clyde Consultants. 1975. *Phase II Geotechnical Investigation for the Proposed AWMA Wastewater Treatment Plant, Aliso Canyon, Orange County, California.* Prepared for VTN Consolidated, Inc. Orange, California.

APPENDIX A – FIELD RECONNAISSANCE MAPPING AND PHOTOGRAPHS

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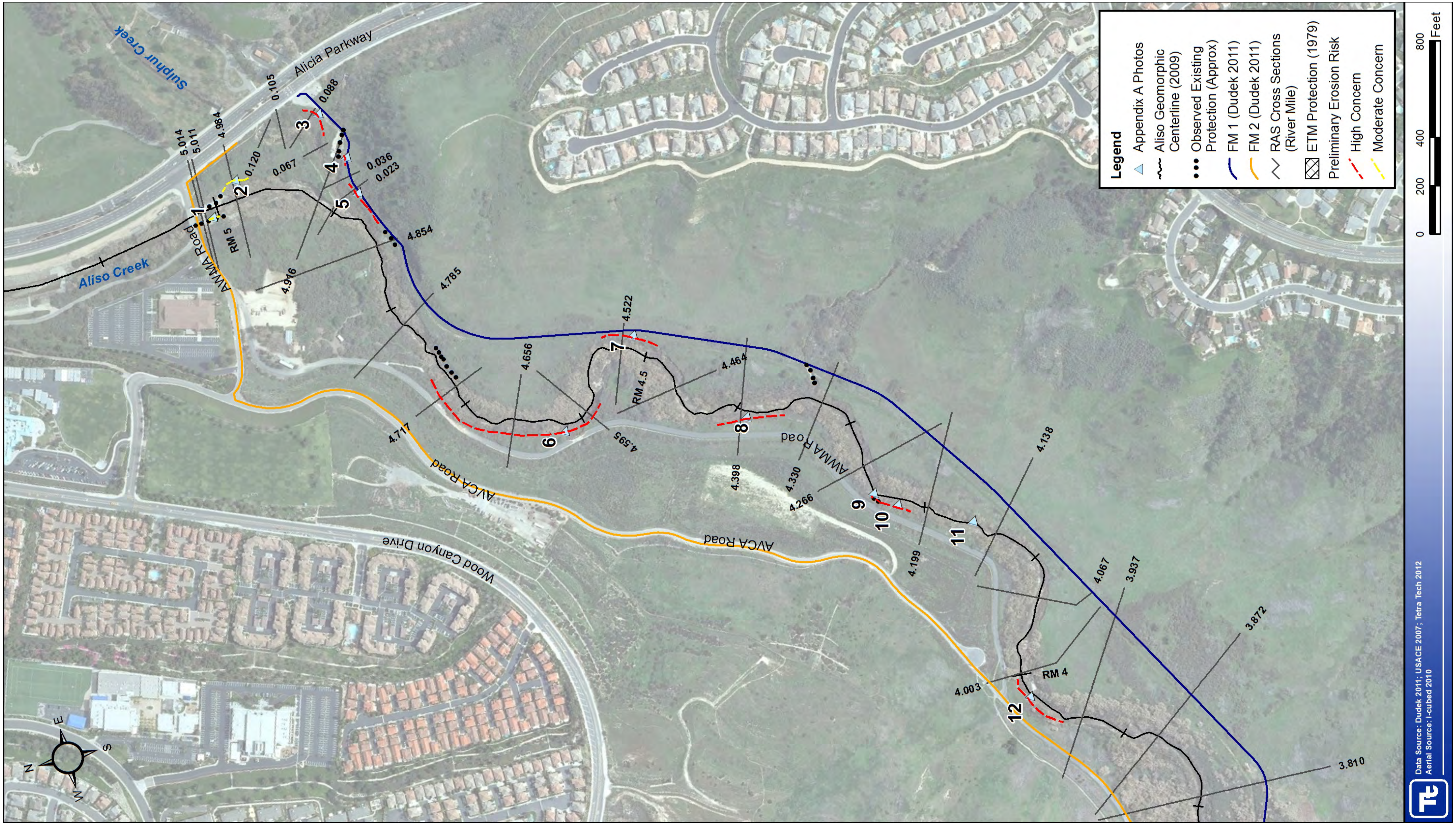
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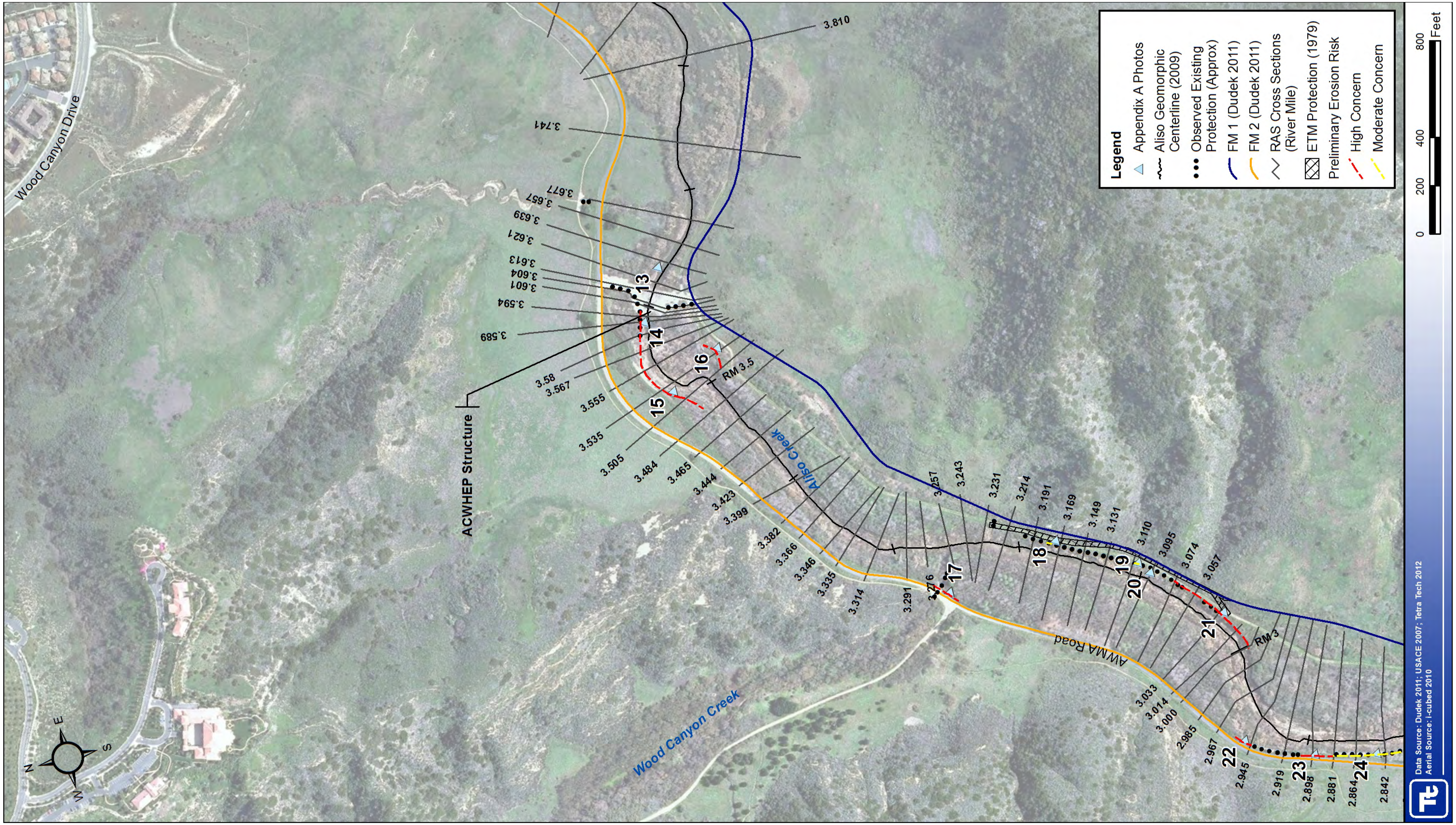
Alicia Parkway
Aliso Creek
AWMA Road
AVCA Road
Wood Canyon Drive
RM 5
RM 4.5
RM 4
5.014
5.011
4.984
4.916
4.854
4.785
4.717
4.656
4.595
4.522
4.464
4.398
4.330
4.266
4.199
4.138
4.067
4.003
3.937
3.872
3.810
0.120
0.105
0.088
0.067
0.036
0.023
1
2
3
4
5
6
7
8
9
10
11
12
Legend
Appendix A Photos
Aliso Geomorphic Centerline (2009)
Observed Existing Protection (Approx)
FM 1 (Dudek 2011)
FM 2 (Dudek 2011)
RAS Cross Sections (River Mile)
ETM Protection (1979)
Preliminary Erosion Risk
High Concern
Moderate Concern
0
200
400
800
Feet
N
S
E
W
Data Source: Dudek 2011; USACE 2007; Tetra Tech 2012
Aerial Source: i-cubed 2010

Figure A-1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Appendix A Photos
Aliso Geomorphic Centerline (2009)
Observed Existing Protection (Approx)
FM 1 (Dudek 2011)
FM 2 (Dudek 2011)
RAS Cross Sections (River Mile)
ETM Protection (1979)
Preliminary Erosion Risk
High Concern
Moderate Concern
0
200
400
800
Feet
Data Source: Dudek 2011; USACE 2007; Tetra Tech 2012
Aerial Source: i-cubed 2010
Wood Canyon Drive
ACWHEP Structure
Aliso Creek
Wood Canyon Creek
AWMA Road
RM 3.5
RM 3
N
E
S
W
3.810
3.741
3.677
3.657
3.639
3.621
3.613
3.604
3.601
3.594
3.589
3.58
3.567
3.555
3.535
3.505
3.484
3.465
3.444
3.423
3.399
3.382
3.366
3.346
3.335
3.314
3.291
3.276
3.257
3.243
3.231
3.214
3.191
3.169
3.149
3.131
3.110
3.095
3.074
3.057
3.033
3.014
3.000
2.985
2.967
2.945
2.919
2.898
2.881
2.864
2.842
13
14
15
16
17
18
19
20
21
22
23
24

Figure A-2

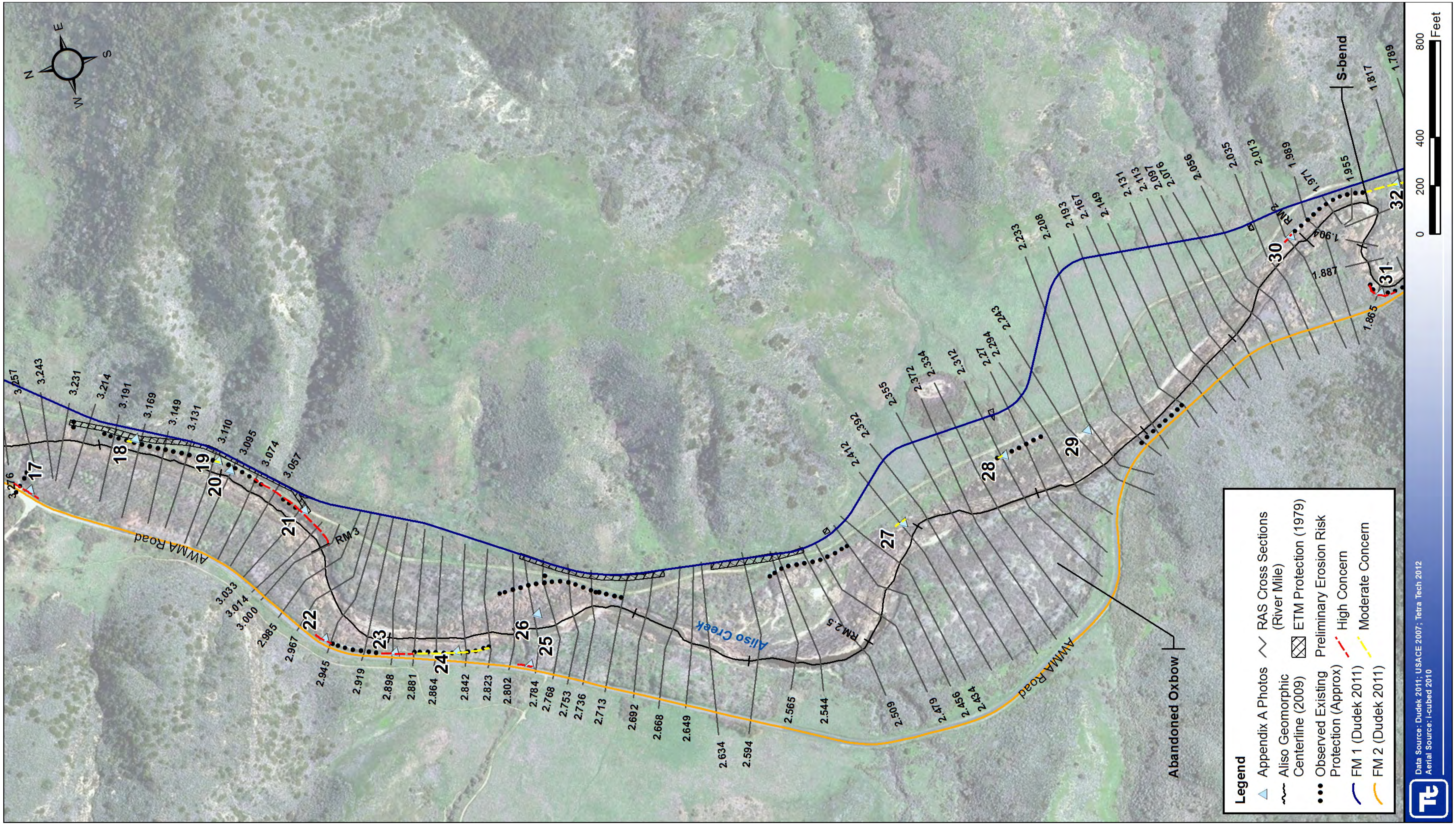
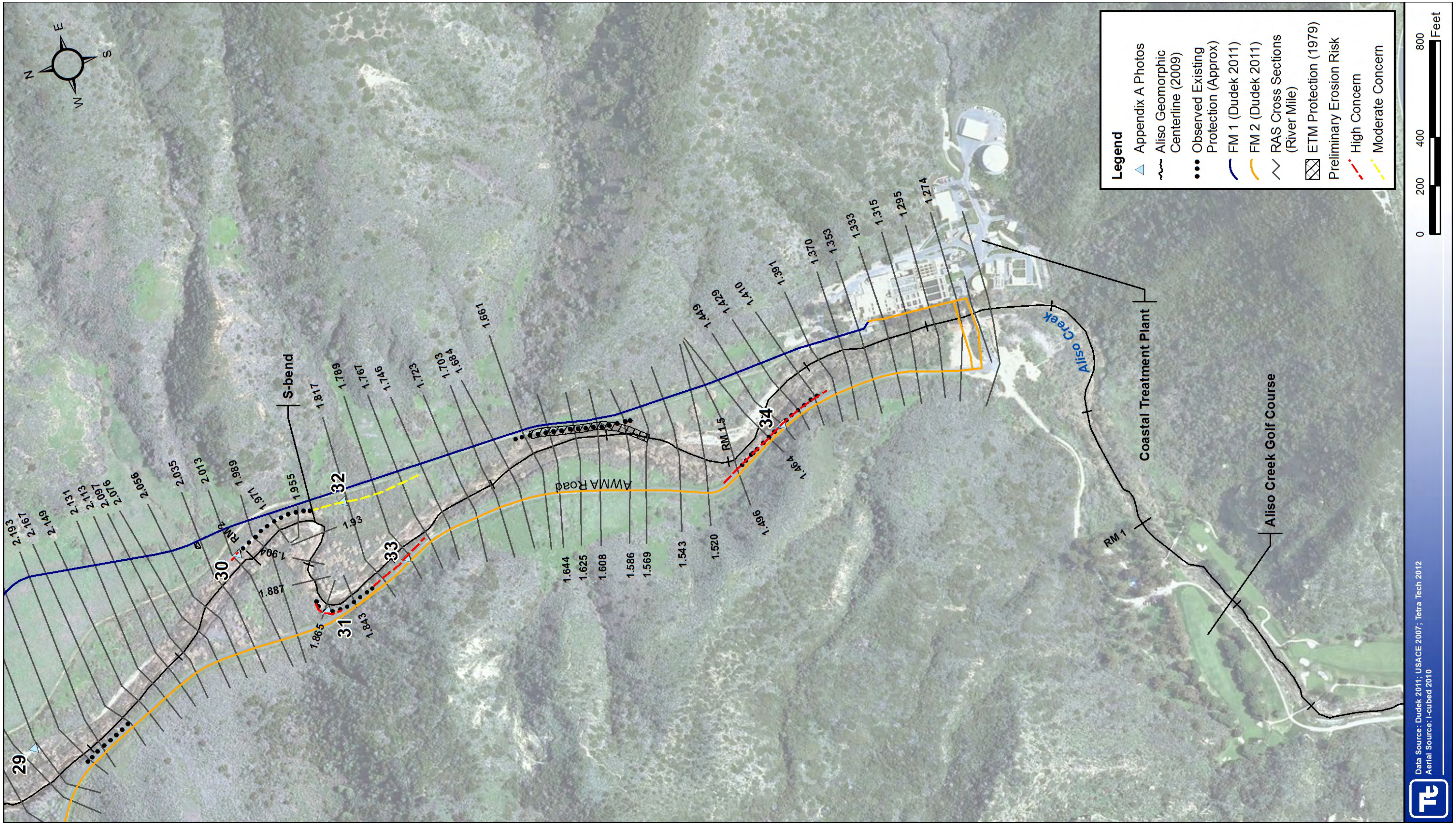

N
E
S
W
Legend
Appendix A Photos
RAS Cross Sections (River Mile)
Aliso Geomorphic Centerline (2009)
ETM Protection (1979)
Observed Existing Protection (Approx)
Preliminary Erosion Risk
High Concern
Moderate Concern
FM 1 (Dudek 2011)
FM 2 (Dudek 2011)
Data Source: Dudek 2011; USACE 2007; Tetra Tech 2012
Aerial Source: i-cubed 2010
0
200
400
800
Feet
S-bend
Abandoned Oxbow
AWMA Road
AWMA Road
Aliso Creek
RM 3
RM 2.5
RM 2
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
3.276
3.257
3.243
3.231
3.214
3.191
3.169
3.149
3.131
3.110
3.095
3.074
3.057
3.033
3.014
3.000
2.985
2.967
2.945
2.919
2.898
2.881
2.864
2.842
2.823
2.802
2.784
2.768
2.753
2.736
2.713
2.692
2.668
2.649
2.634
2.594
2.565
2.544
2.509
2.479
2.456
2.434
2.412
2.392
2.372
2.355
2.334
2.312
2.294
2.27
2.243
2.233
2.208
2.193
2.167
2.149
2.131
2.113
2.097
2.076
2.056
2.035
2.013
1.989
1.971
1.955
1.904
1.887
1.865
1.817
1.789

Figure A-3


Legend
Appendix A Photos
Aliso Geomorphic Centerline (2009)
Observed Existing Protection (Approx)
FM 1 (Dudek 2011)
FM 2 (Dudek 2011)
RAS Cross Sections (River Mile)
ETM Protection (1979)
Preliminary Erosion Risk
High Concern
Moderate Concern
0
200
400
800
Feet
N
E
S
W
Coastal Treatment Plant
Aliso Creek Golf Course
Aliso Creek
S-bend
AWMA Road
RM 1
RM 1.5
RM 2
29
30
31
32
33
34
2.193
2.167
2.149
2.131
2.113
2.097
2.076
2.056
2.035
2.013
1.989
1.971
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1.93
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1.865
1.843
1.817
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1.586
1.569
1.543
1.520
1.496
1.464
1.449
1.429
1.410
1.391
1.370
1.353
1.333
1.315
1.295
1.274
Data Source: Dudek 2011; USACE 2007; Tetra Tech 2012
Aerial Source: i-cubed 2010

Figure A-4

34
Oversteep / Undercut Riprap

(looking u/s) Emergency rock placement? Near-vertical rock on bank. Stable toe. Geotechnically stable bank?

33
Oversteep Bank, Narrow Setback

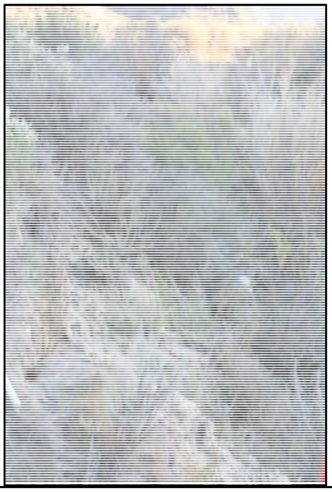
(looking d/s) Potential for continued fluvial erosion. Bank not geotechnically stable. Top of unstable bank within 15 feet of AMWA Road.

32
Probable Future Incision

(looking d/s toward bend) Active erosion in chute (red shovel). Bend persists since pre-1930. Clay in toe of bank reduces rate of erosion/migration.

31
Flow Impingement, Narrow Setback

Active flow impingement above elevation of riprap revetment along bank. Narrow setback. Also concentrated runoff down the bank.



30
Flow Impingement

(looking d/s) Flood flows in Aliso Creek erode bank material upstream of existing riprap revetment.

29
Stable Bank

Downstream view of left bank, 2.5H:1V bank slope. Woody shrubs established across bank, stable toe along high flow chute.

No Photo Available

28

Tributary Crossing

Displacement of existing riprap allows headcut to propagate up the tributary.

27

Concentrated Runoff

(looking d/s) Concentrated runoff from upland areas enters Aliso Creek by spilling across the bank, causing erosion.

26

Stable Bank

Landward view of inset floodplain with dense growth of tree-willows and sycamores. Approximately 100-foot buffer to toe of bank.

25

Tributary Crossing

Landward view up tributary channel incised 20 feet. Incision “checked” by culvert; road embankment and proposed alignment is geotechnically unstable.

24

Oversteep Riprap

(lookding d/s) Emergency rock placement? Near-vertical rock on bank. Geotechnically stable bank? Established trees and depositional berm minimize fluvial energy applied on the bank.

23

Slumping

(looking u/s) Slumping of full bank height into Aliso Creek.

22
Concentrated Runoff

(looking u/s) Wood Canyon overflow down AMWA Road enters Aliso Creek by spilling down the bank. A headcut is propagating up the flowpath toward the proposed alignment.

21
Leakage along Abandoned Pipe, Slumping, Impingement

(looking d/s) Leakage into abandoned irrigation line promotes slumping. Bank erosion exacerbated by flow impingement.

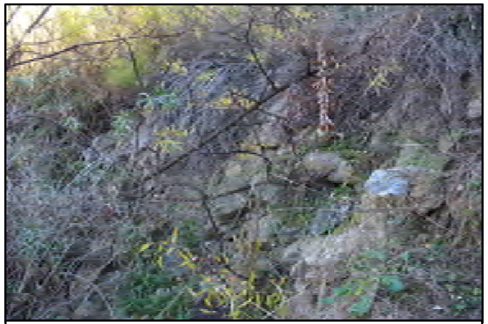
20
Stable Bank

Landward view of depositional berm and vegetation along toe of riprap revetment. Stable bank angle. Sycamore and tree-willows along toe.

No Photo Available

19
Slumping

Local displacement of riprap revetment.

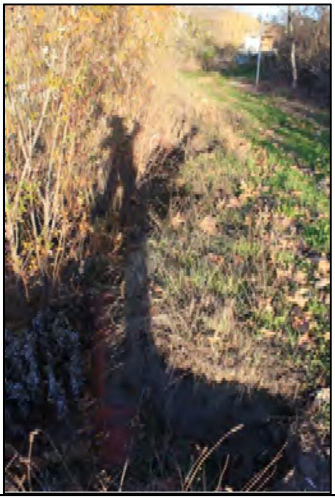


18
Slumping

(looking u/s) Slumping bank displaces riprap along upper bank; lower bank stabilized by depositional berm.

17
Wood Canyon

Riverward view of area scoured by flows overtopping AMWA Road crossing.



16
VCP Exposed, Slumping

(looking u/s) Slumping due to pipe leakage or geotechnical instability; exposed sewer line.

15
Flow Impingement, Slumping

(looking d/s) Direct impingement of flood flows; slumped material at toe.

14
Undercut Riprap

Threatening ACWHEP diversion structure.

13
Stable Bank

(looking u/s) Low bank height, connected floodplain. Well-vegetated floodplain.

12
Flow Impingement

(looking d/s) Outside bend upstream of ACWHEP backwater influence, unstable bank.

11
Stable Bank

(looking u/s) Stability promoted by 6-foot high, vegetated, depositional berm along toe of bank. Floodplain connected, stable bank angle.

10

Upper Bank Instability

(looking u/s) Close proximity to alignment. Lower bank stable and vegetated, scarp along upper bank.

9

Impingement, Weathered Riprap

(looking u/s) Riprap revetment to protect against impingement is breaking down.

8

Upper Bank Geotechnical Instability

(looking u/s) Close proximity to pipe alignment, further widening as upper bank stabilizes.

7

Impingement & Concentrated Runoff

(Riverward view) Fluvial energy cutting into toe of alluvial fan; concentrated upland runoff contributes to bank failure.
Steep high bank actively failing.

6

Upper Bank Geotechnical Instability

(looking d/s) 30-ft high bank, nearly vertical. Close proximity to AMWA Road.

5

Slumping

(looking d/s) No woody vegetation at toe to hold failed material. No room to lay back slope.

4

Local Scour

(looking d/s) Turbulence from water spilling off grouted rock is locally scouring the bank.

3

Flow Impingement

Riverward view of bend in Sulphur Creek where flood flows directly impinge on bank slope.

2

Upper Bank Geotechnical Instability

(looking u/s) Lower bank stabilized by dense woody vegetation; upper bank will continue to erode to achieve a stable bank angle.

1

Undercut Grouted Riprap

Likely due to scour over bridge drop; grout prevents rock from conforming to scour hole.

APPENDIX B – CROSS SECTION SCHEMATICS

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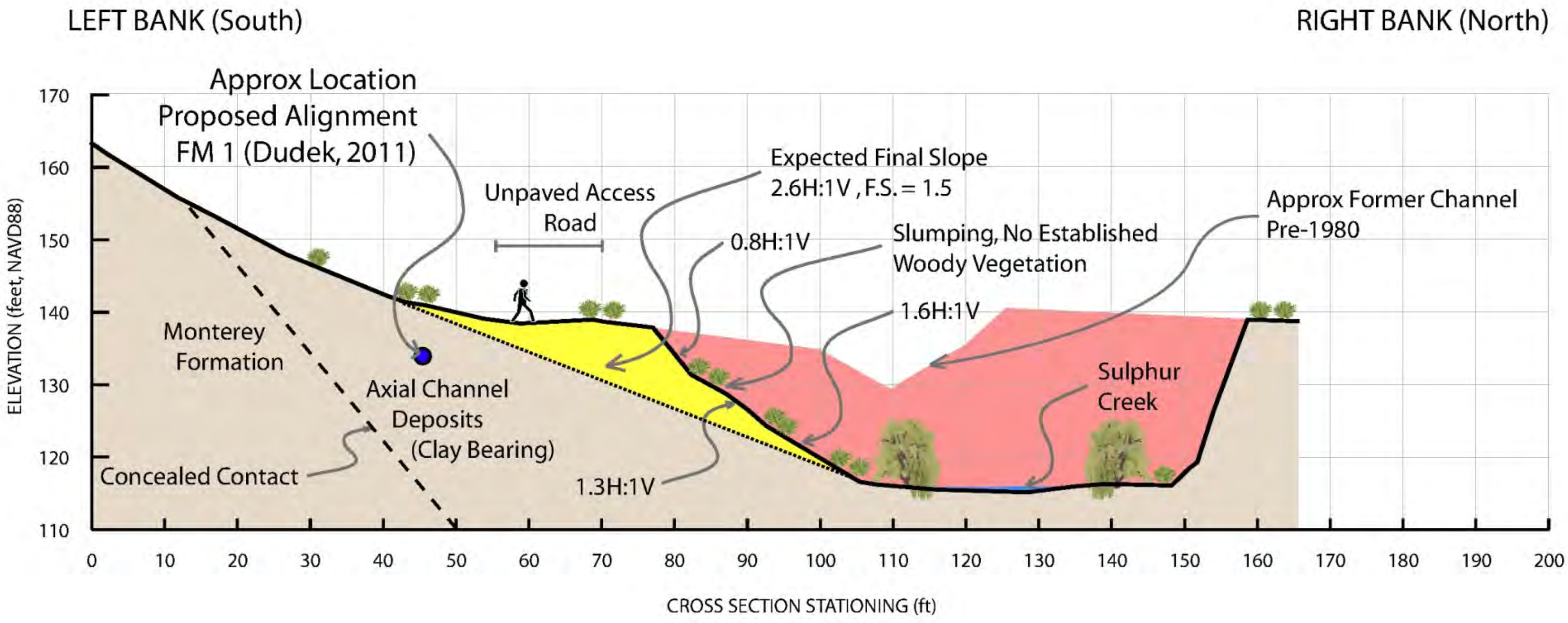

Figure B-1: Bank Slumping due to Geotechnically Unstable Slope

NOTES: Cross Section shown is of Sulphur Creek, 0.023 miles upstream of the Aliso Creek Confluence.

The left (south) bank is slumping due to geotechnical instabilities resulting from channel incision. Factors such as an overly steep bank slope, a slope height of around 20 feet, and a near absence of established woody vegetation along the slope (and particularly along the toe) contribute to the existing unstable bank. It is expected that further erosion of the bank will continue until the slope flattens to approximately 2.6H:1V. Using a factor of safety of 1.5, the stable bank slope is approximately 10 feet from the proposed pipeline alignment, and this distance is further reduced when the recommended setback equal to one-third the bank height is incorporated.

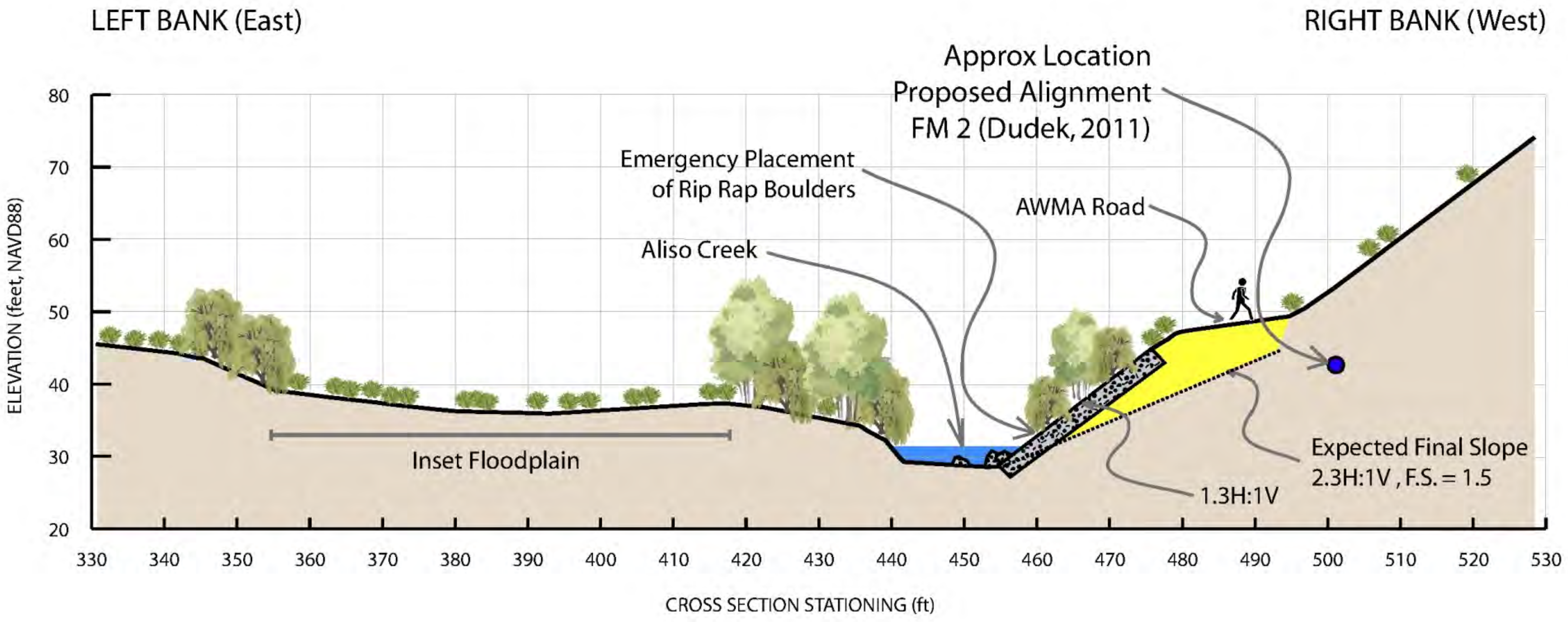

Figure B-2: Over-Steep Existing Riprap Revetment

NOTES: Cross Section shown is of Aliso Creek, 1.449 miles upstream of the Pacific Ocean.

Many of the existing bank protection measures appear to have been installed during emergency situations. For riprap revetments, this means the rock was probably dumped from top of bank, likely without any formal engineering design. As shown here, this can lead to measures that may not provide long-term protection to the bank or the proposed pipelines. Monitoring and maintenance of the protection is recommended as the future pipe alignment could be endangered if bank protection fails. In this example, if the protection was to fail, a stable bank slope would be within approximately 5 feet of the proposed alignment. This situation is representative of conditions at cross sections 1.496 to 1.410 (see **Table 3-3** in the main body of the report).

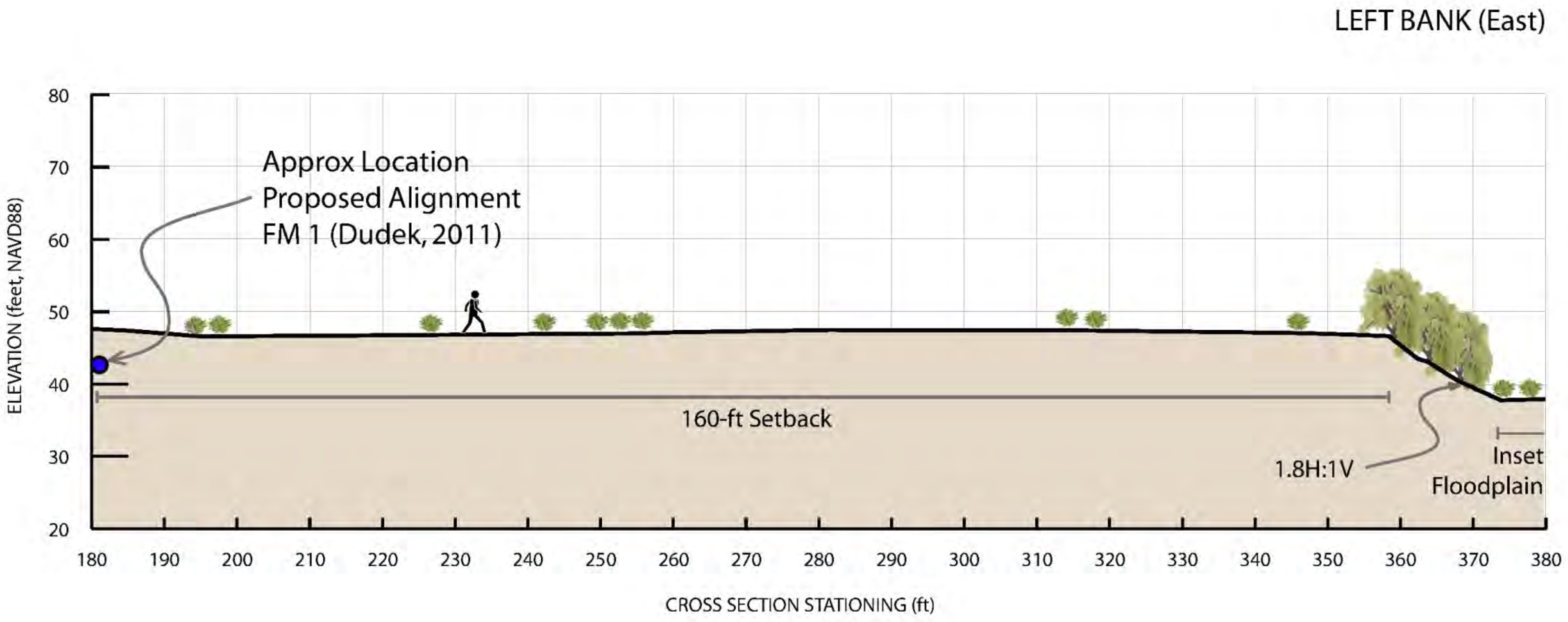

Figure B-3: Stable Bank Angle

NOTES: Cross Section shown is of Aliso Creek, 1.520 miles upstream of the Pacific Ocean.

The proposed FM 1 alignment is setback 160 feet from the relatively stable left bank, as indicated by its low slope height, established woody vegetation, flatter slope angle, and the inset floodplain. Considering historical locations of the channel, there is low potential for the channel to avulse/migrate to a location that would threaten the future integrity of the proposed pipeline. This situation is representative of conditions at cross sections 1.543 to 1.449 (see **Table 3-2** in the main body of the report).

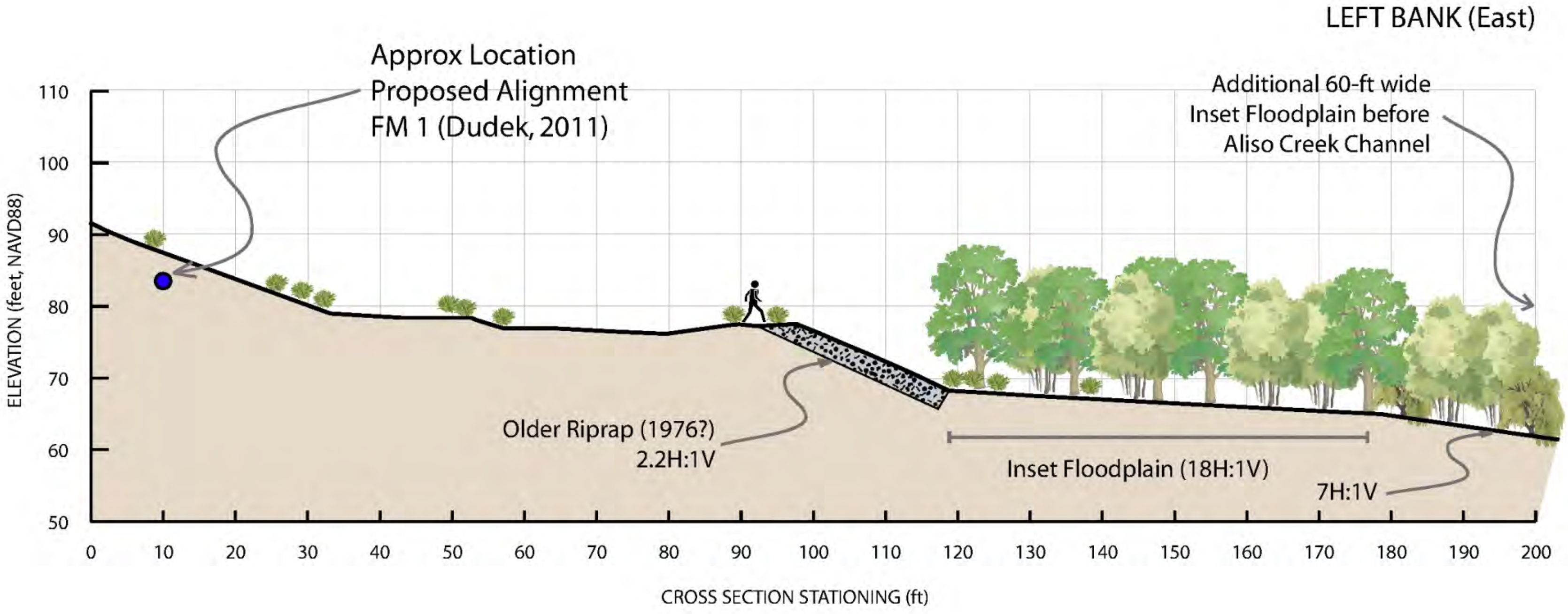

Figure B-4: Establishment of Inset Floodplain

NOTES: Cross Section shown is of Aliso Creek, 2.768 miles upstream of the Pacific Ocean.

Two inset floodplains are have developed between the channel and the toe of the riprap protection. These floodplains support established woody vegetation (e.g., tree willows and sycamore). The riprap was constructed at a stable slope. The proposed pipeline alignment is setback 90 feet from the top of the riprap protection. The potential for channel avulsions and bank erosion is low, so there is low long-term risk of pipeline damage from channel erosion. This situation is representative of conditions at cross sections 2.842 to 2.736 (see **Table 3-2** in the main body of the report).

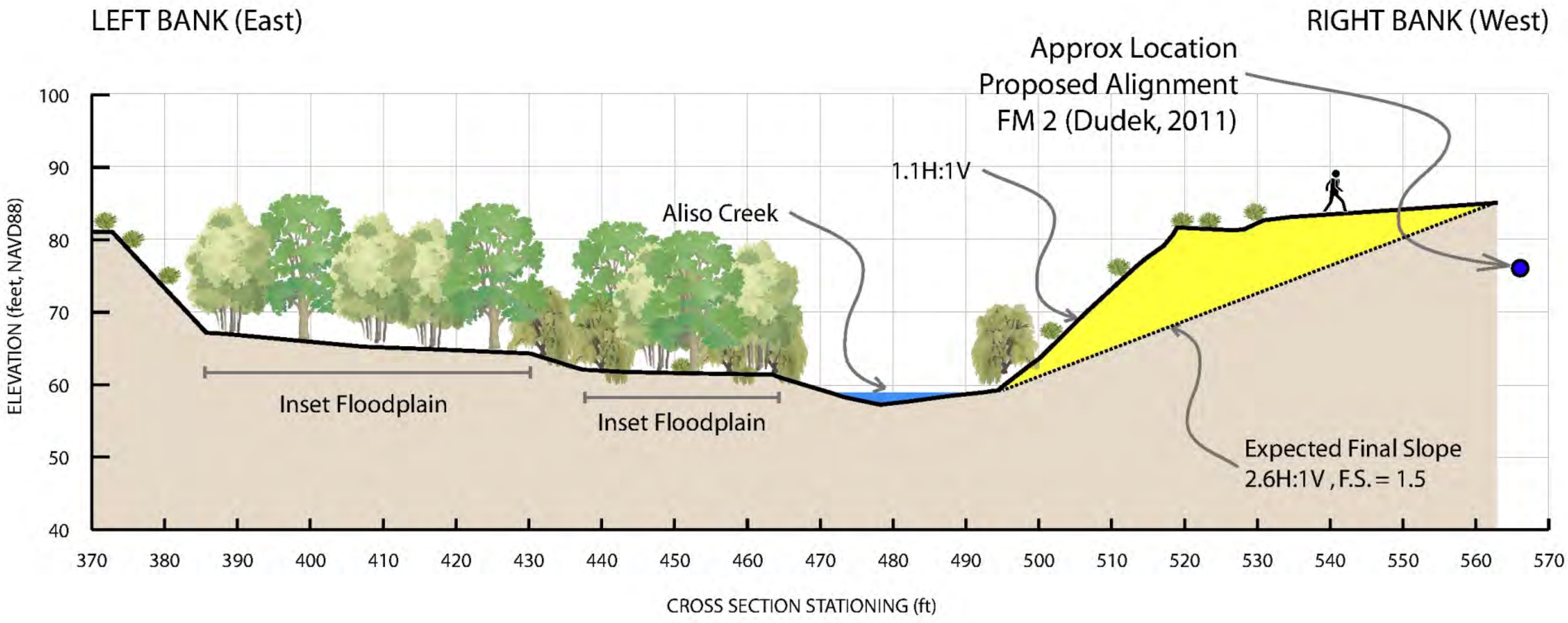

Figure B-5: Bank Instability due to Flow Impingement and Potential Bend Migration

NOTES: Cross Section shown is of Aliso Creek, 2.898 miles upstream of the Pacific Ocean.

The right bank is located along the outside of a bend. Flood flows impinge on the bank, and erode material from the toe. Failed material from the overly steep upper bank is not retained at the toe, so a berm that could reduce effective bank height cannot get established. The bank slope will continue to fail until a stable angle is reached. The new top of bank is projected to be within 10 feet of the proposed FM 2 alignment. If fluvial erosion causes the bend to migrate landward, the calculated stable top of bank location will translate an equal distance to any migration of the toe. The combined influences of geotechnical instabilities and bend migration present *High* erosion risk to the long-term integrity of the proposed FM 2 alignment.

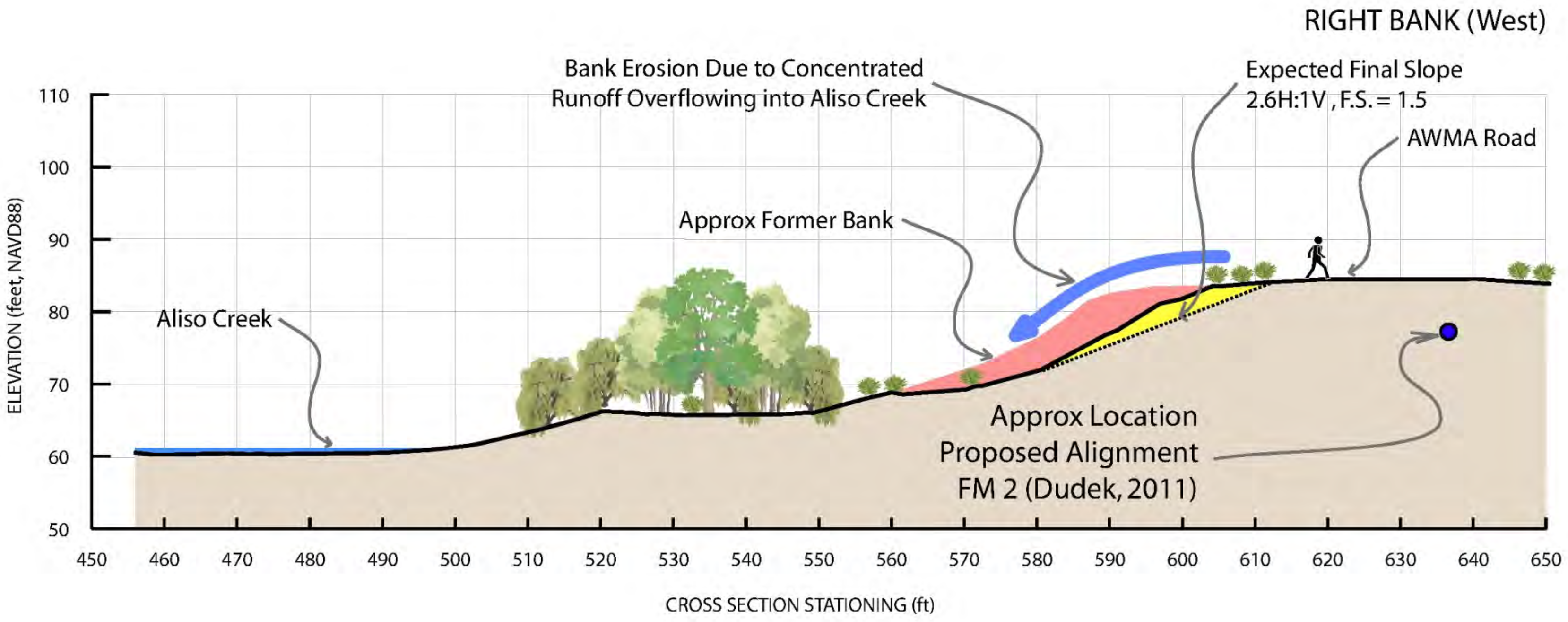

Figure B-6: Bank Erosion due to Concentrated Runoff along AMWA Road

NOTES: Cross Section shown is of Aliso Creek, 2.941 miles upstream of the Pacific Ocean.

Concentrated runoff flowing down AWMA Road spills over the bank into Aliso Creek. The runoff is concentrated on the road by a berm along one of the abandoned ACWHEP irrigation lines. The right bank is expected to continue eroding due to concentrated runoff flowing over the top of bank. Bank retreat may migrate into the FM 2 alignment without bank protection or diversion of the runoff. The geotechnically stable top of bank is projected to be within 25 feet of the proposed FM 2 alignment, but this distance does not account for additional erosion caused by the runoff.

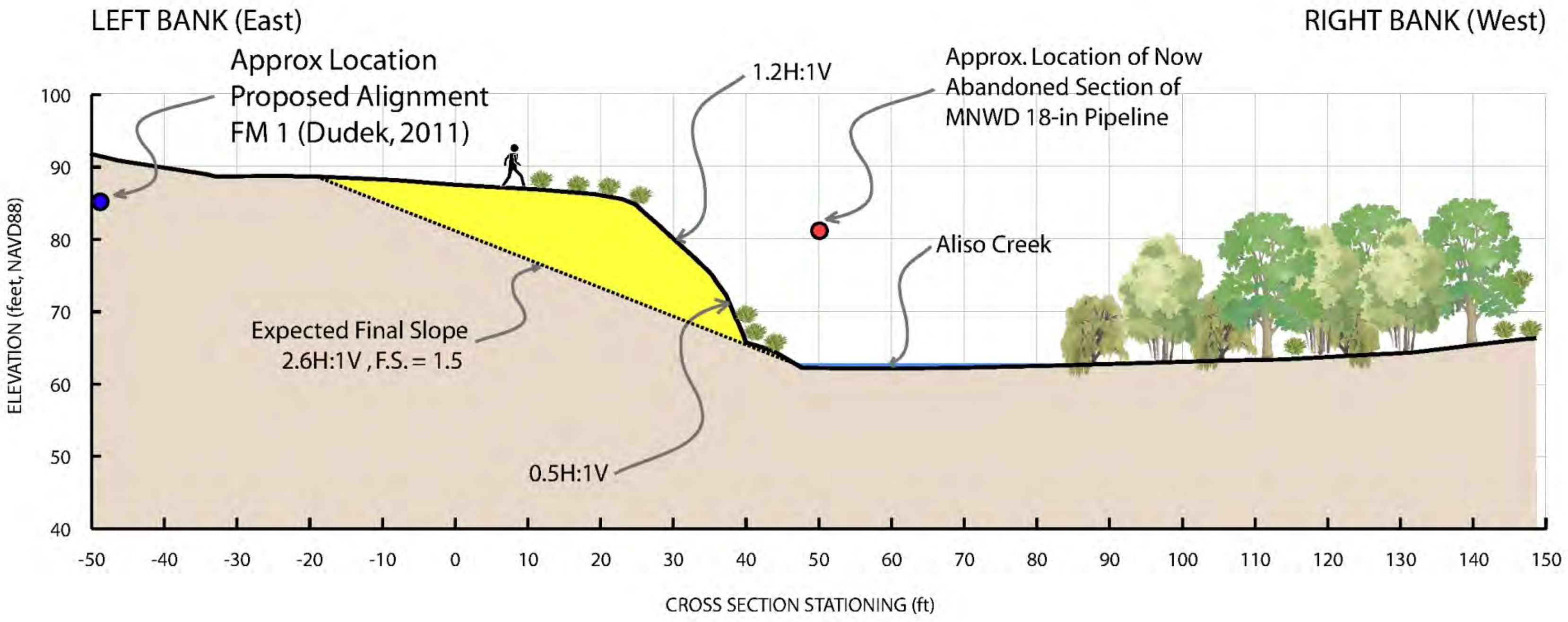

Figure B-7: Existing Exposure of East (Left) Bank Infrastructure

NOTES: Cross Section shown is of Aliso Creek, 3.014 miles upstream of the Pacific Ocean.

The abandoned ACWHEP irrigation pipelines in the left bank appear to have provided seepage pathways into the bank. Slump failures apparently initiated by seepage from the pipeline were observed. The left bank is expected to lay back to a stable slope of 2.6H:1V. Due to fluvial erosion potential it is expected that there will be continued erosion along outside of bend in the channel, progressing towards the proposed FM 1 alignment. Active erosion has already eroded a section of the 18-inch diameter vitrified clay pipe sewer line; a new line has been installed and the eroded section has been abandoned in place. This situation is representative of conditions at cross sections 3.033 to 3.000 (see **Table 3-2** in the main body of the report).

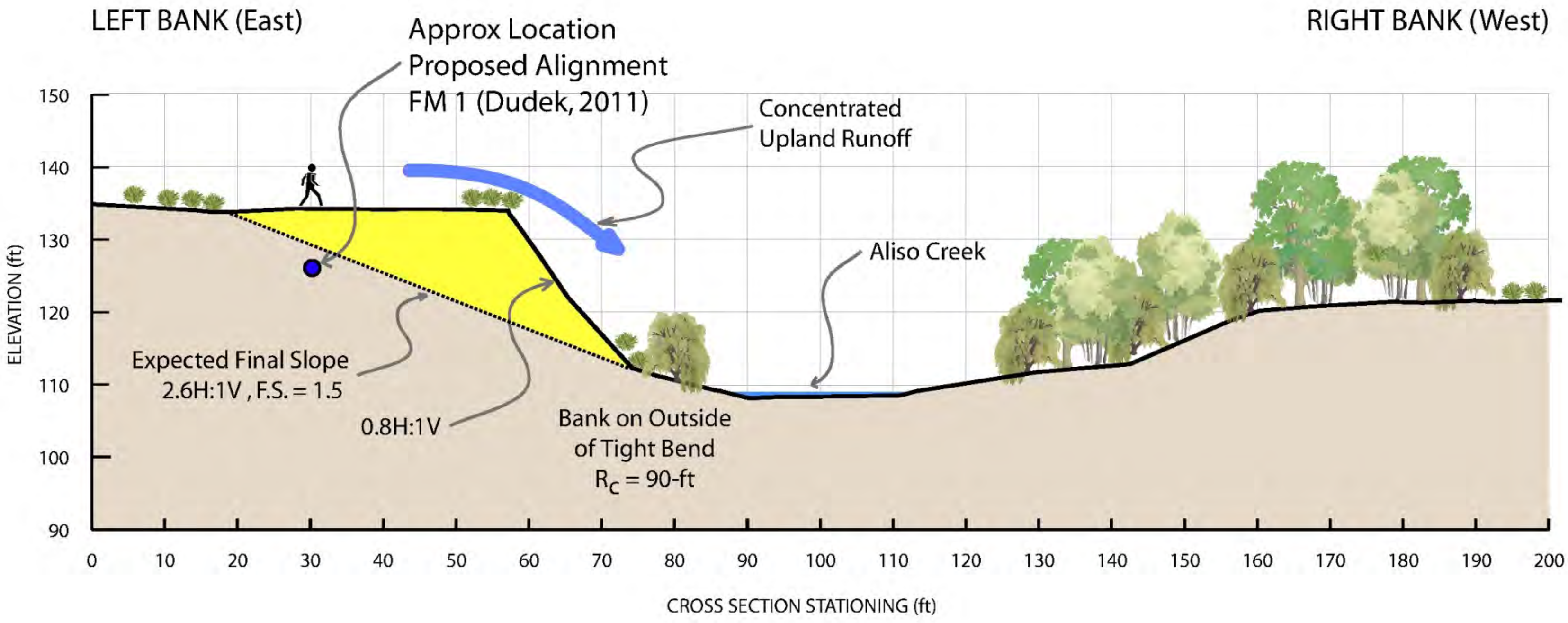

Figure B-8: Bank Erosion Exacerbated by Concentrated Upland Runoff

NOTES: Cross Section shown is of Aliso Creek, 4.522 miles upstream of the Pacific Ocean.

Instability of the left bank is caused by unstable geotechnical conditions, fluvial erosion around the outside of a bend, and concentrated upland runoff spilling down the bank. The left bank is being cut into alluvial fan deposits, and the concentrated runoff flowing across the fan spills into Aliso Creek over the top of bank. The left bank is expected to fail geotechnically to a stable slope of 2.6H:1V. The proposed FM 1 alignment is at the calculated stable bank slope plus the recommended setback. The risk of geotechnical erosion is *Moderate*, but when coupled with the upland runoff and the potential for bend migration into the fan deposits, the erosion risk over the 50-year design life of the proposed FM 1 alignment is *High*.

APPENDIX C – SITE SPECIFIC CALCULATIONS OF GEOTECHNICAL SLOPE STABILITY

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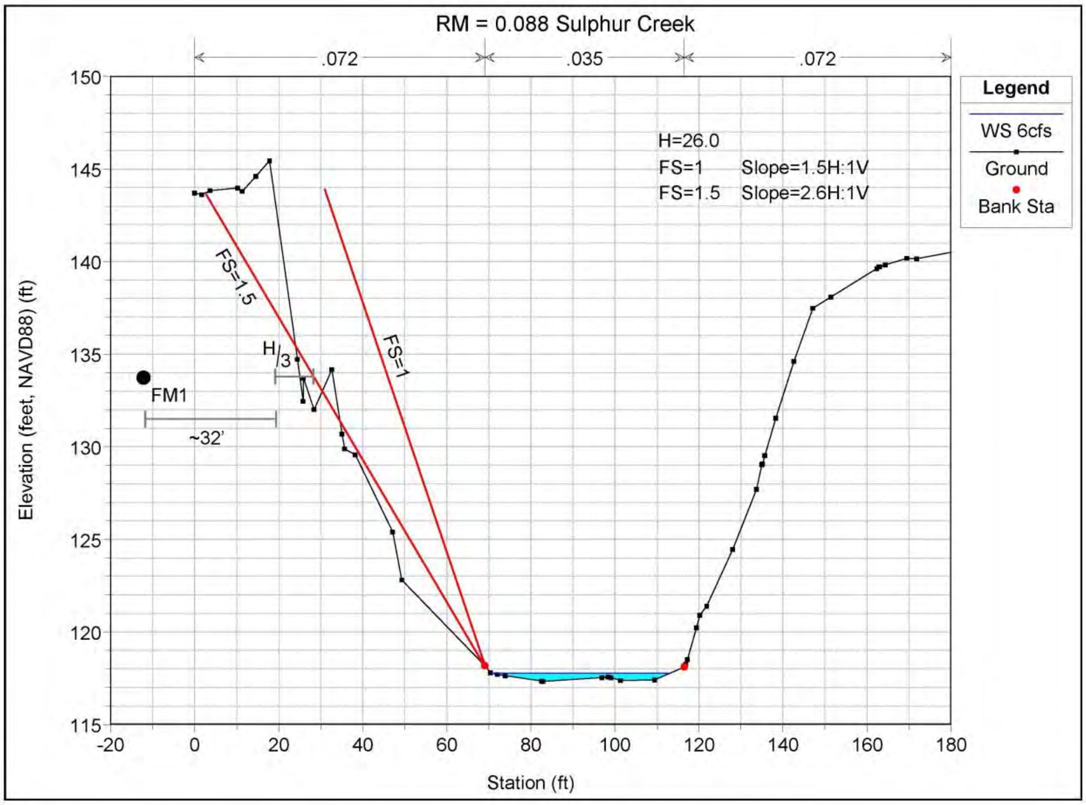
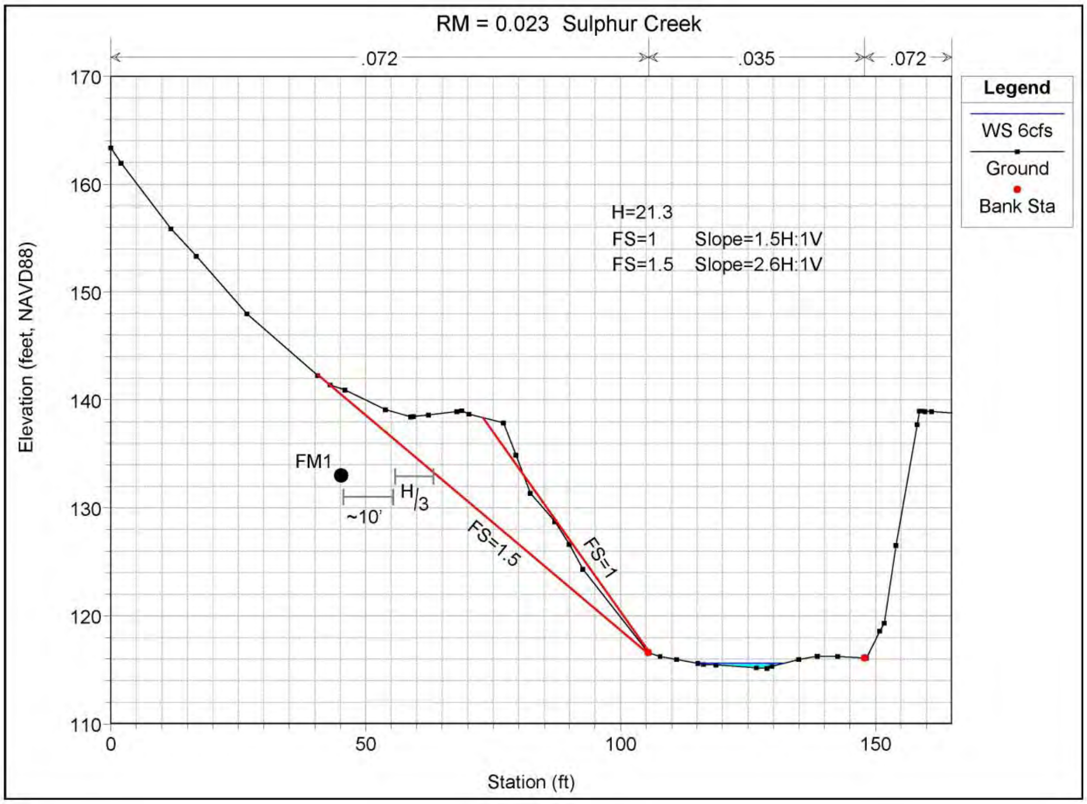
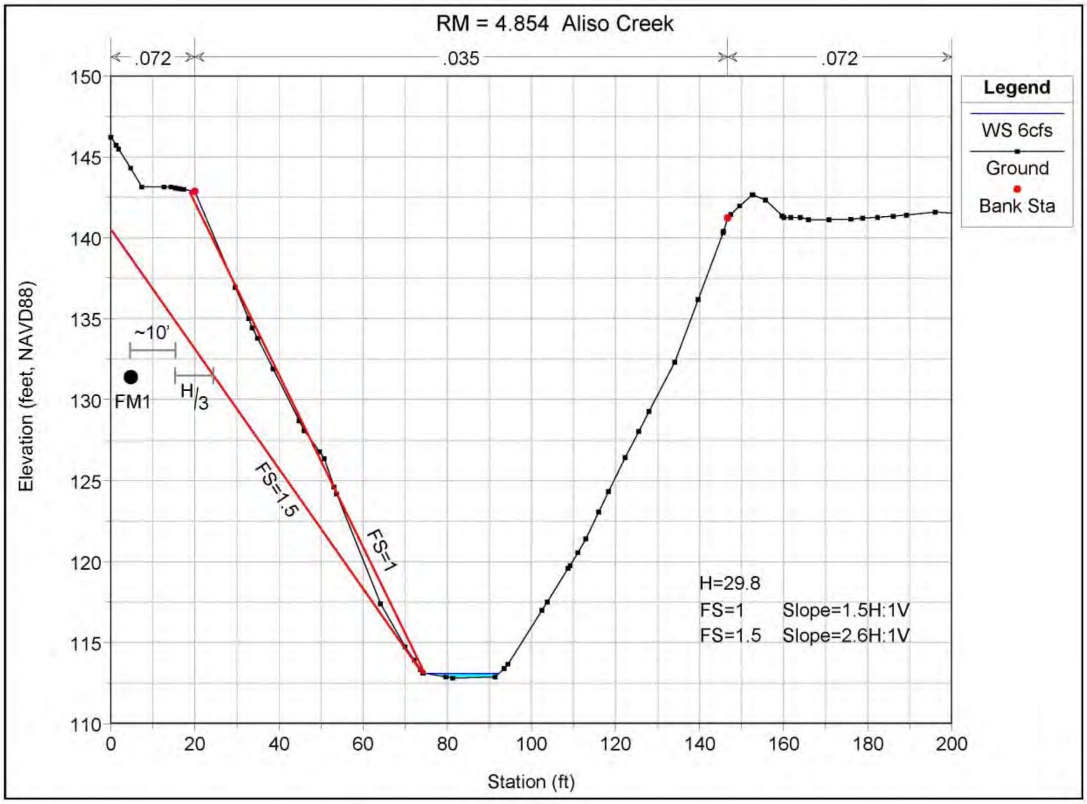
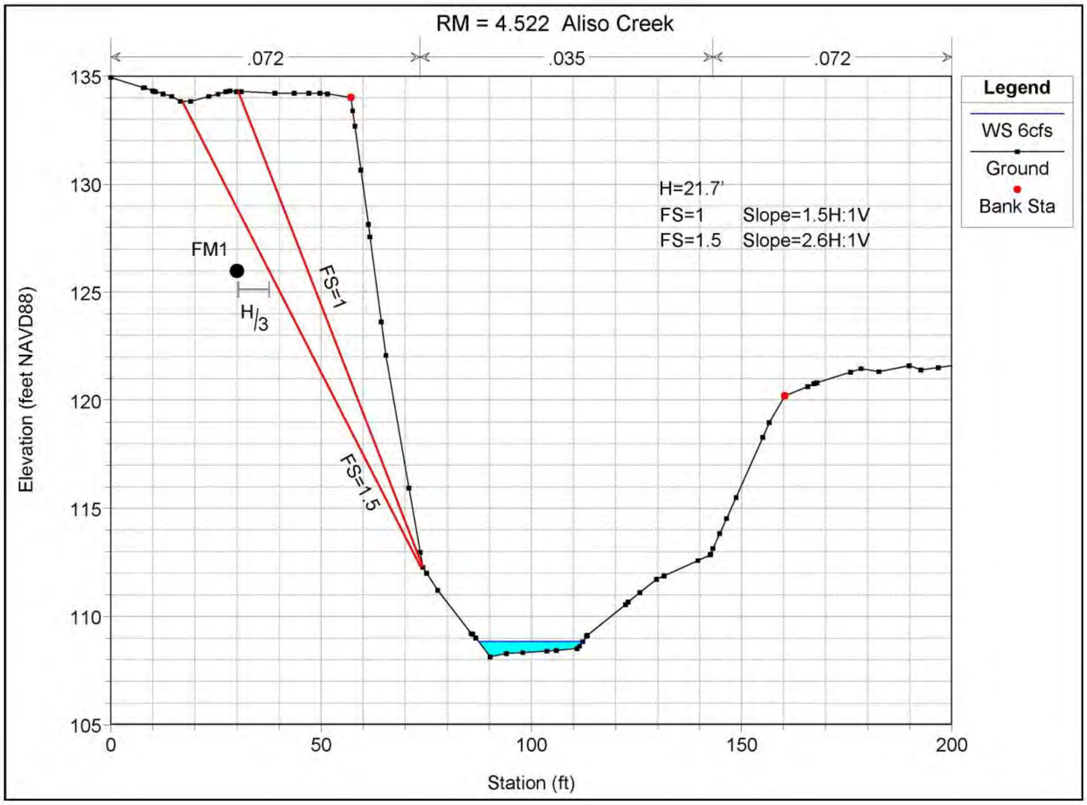
EAST (LEFT) BANK – PROPOSED FM 1 ALIGNMENT






RM = 4.854 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet, NAVD88)
Station (ft)
~10'
FM1
H/3
FS=1.5
FS=1
H=29.8
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
110
115
120
125
130
135
140
145
150
0
20
40
60
80
100
120
140
160
180
200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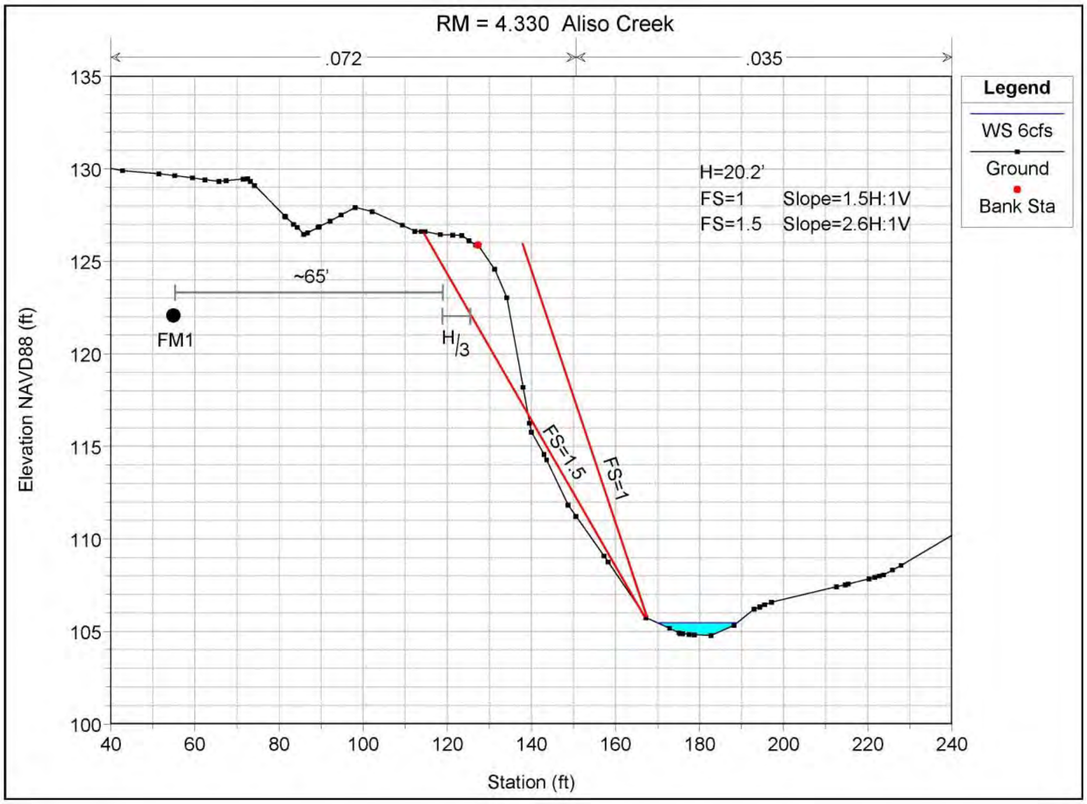
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet NAVD88)
Station (ft)
H=21.7'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FM1
H/3
FS=1
FS=1.5
105
110
115
120
125
130
135
0
50
100
150
200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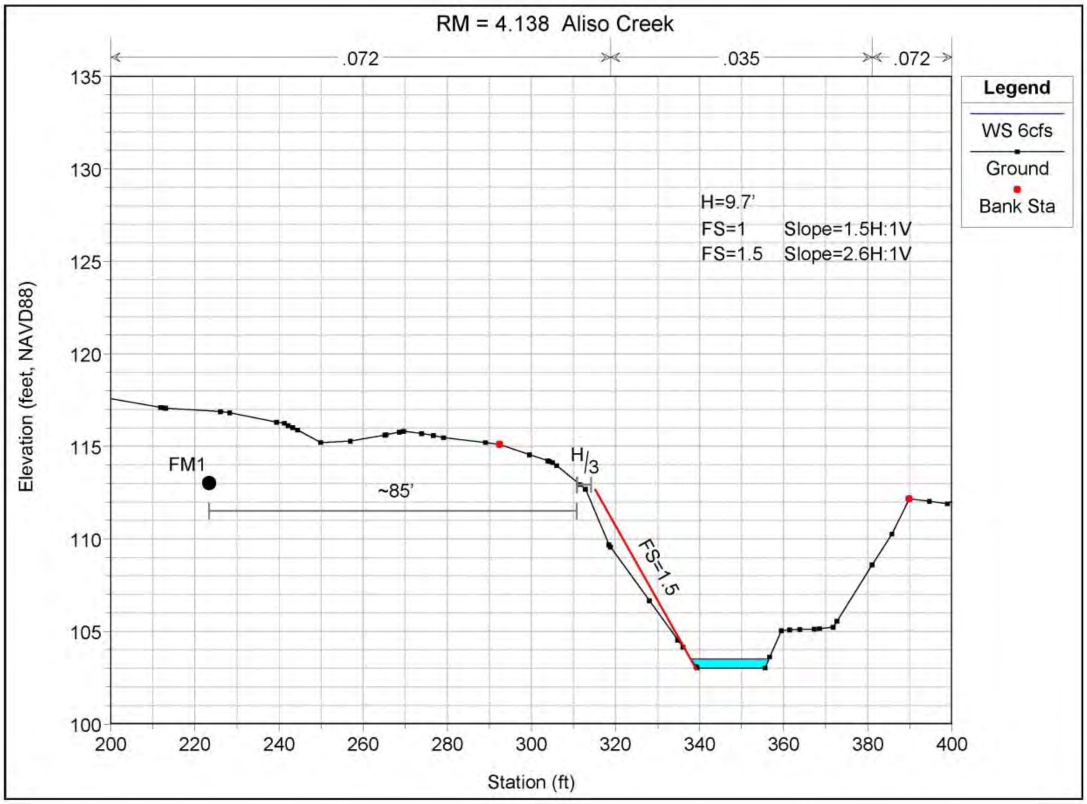
.072
.035
Legend
WS 6cfs
Ground
Bank Sta
H=20.2'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
~65'
FM1
H/3
FS=1.5
FS=1
Elevation NAVD88 (ft)
Station (ft)
135
130
125
120
115
110
105
100
40
60
80
100
120
140
160
180
200
220
240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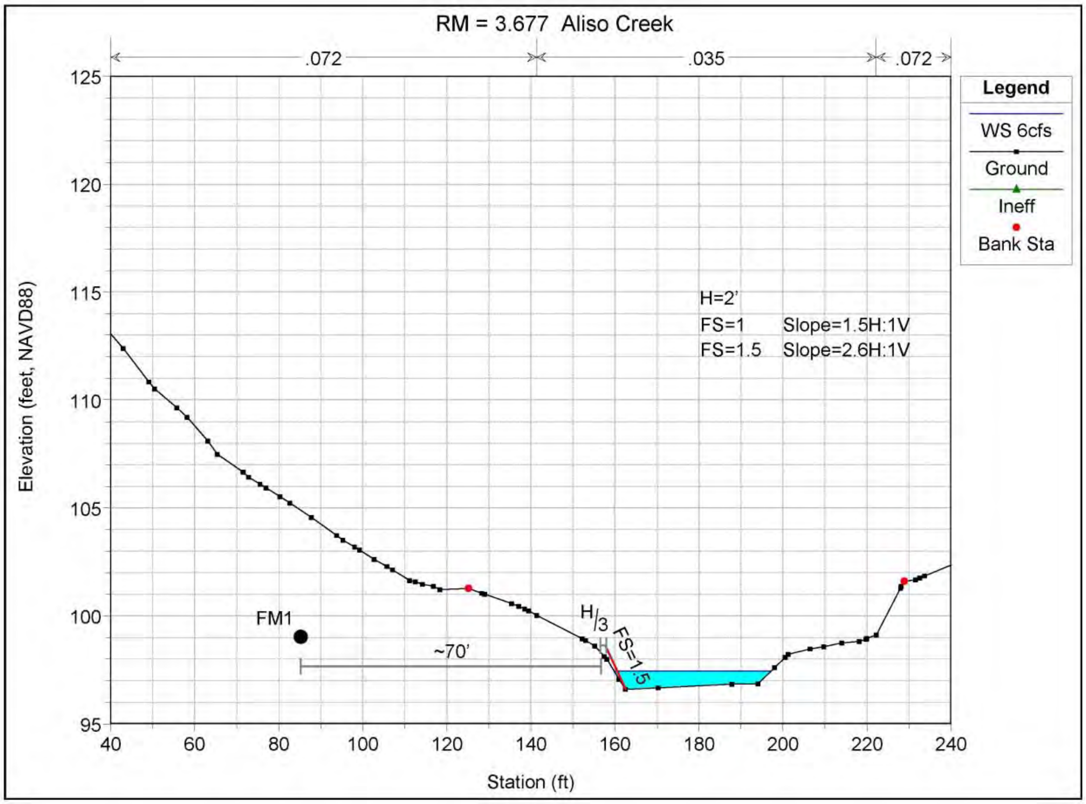
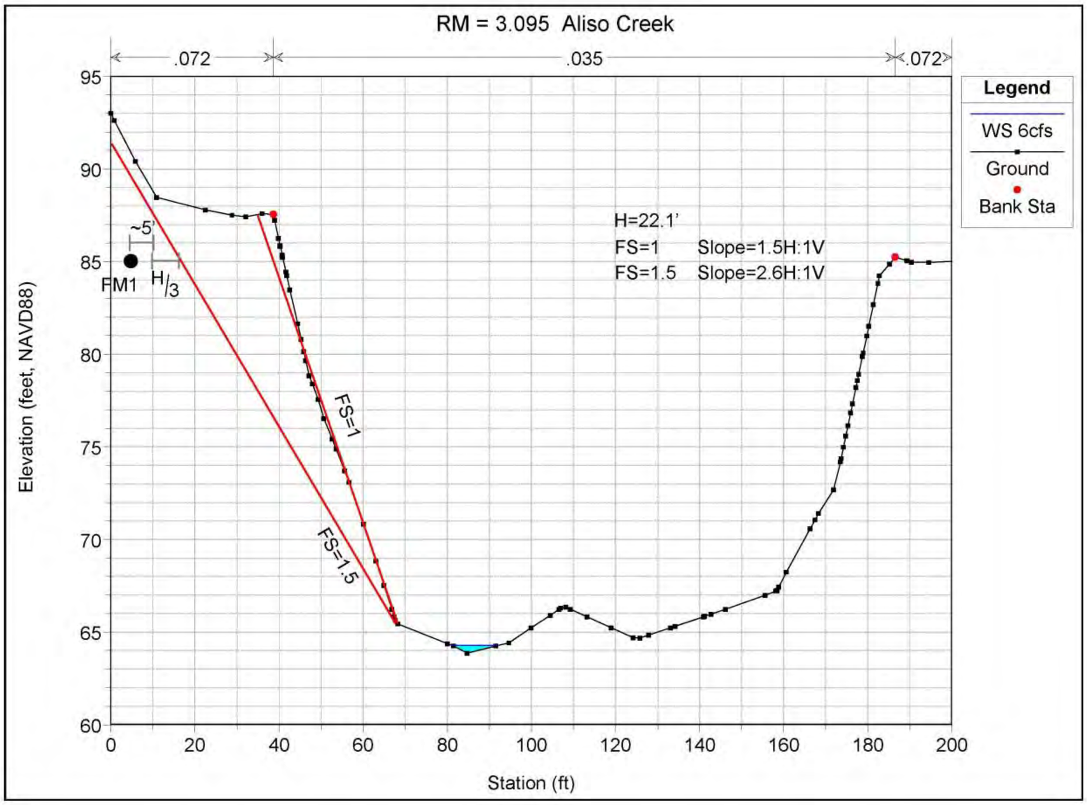
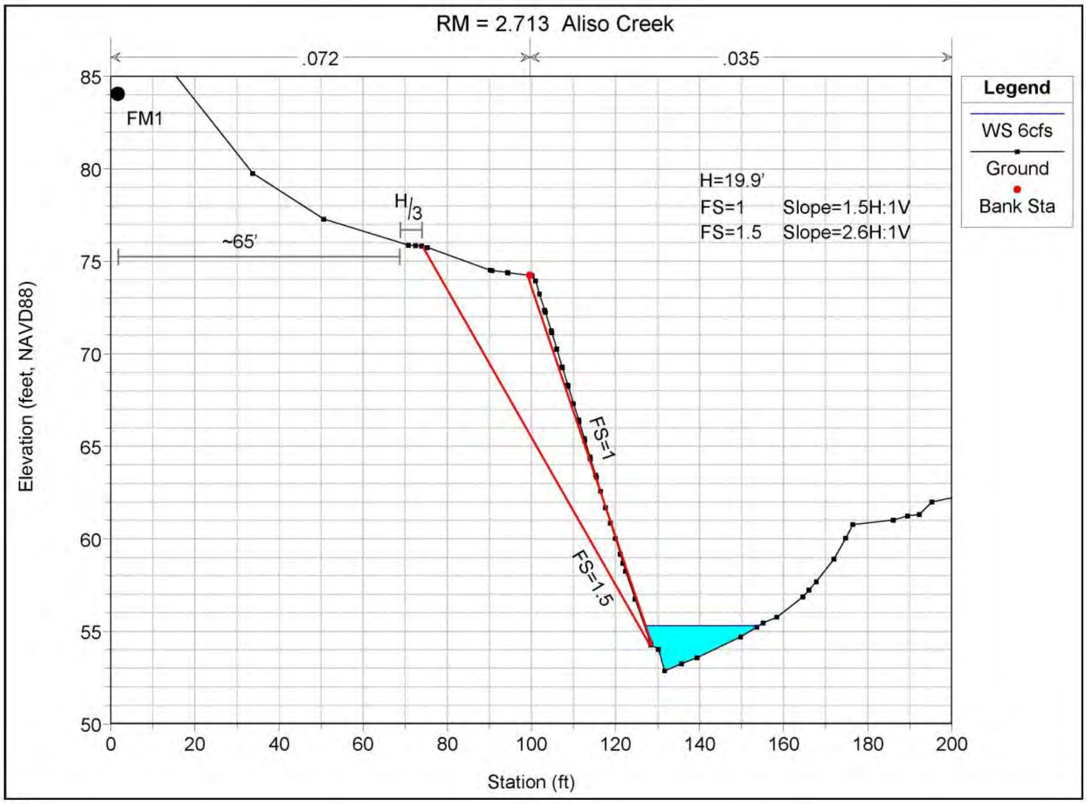
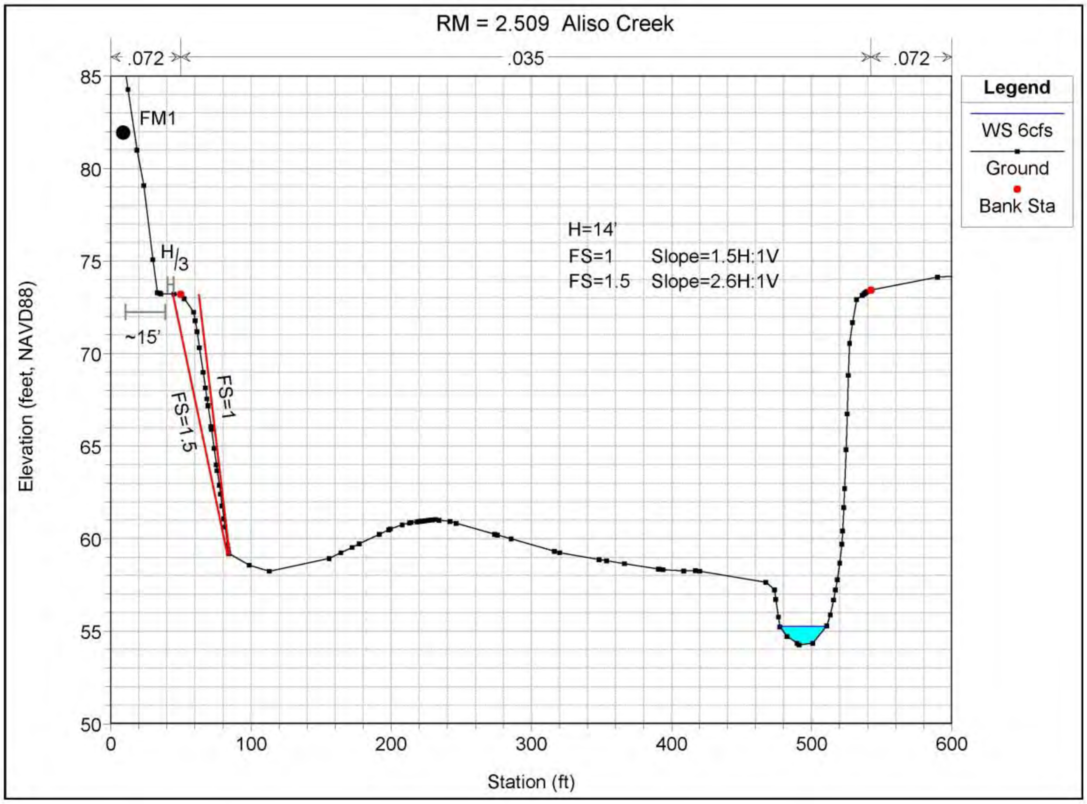
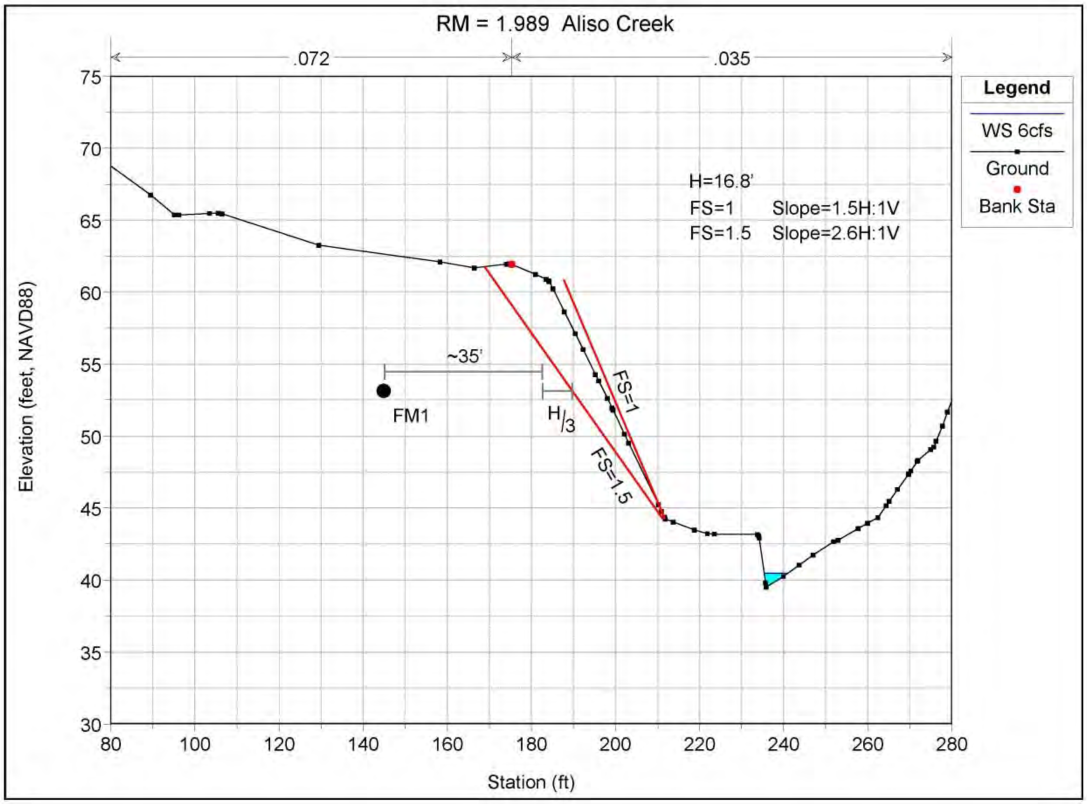
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=9.7'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FM1
~85'
H/3
FS=1.5
Elevation (feet, NAVD88)
Station (ft)
135
130
125
120
115
110
105
100
200
220
240
260
280
300
320
340
360
380
400

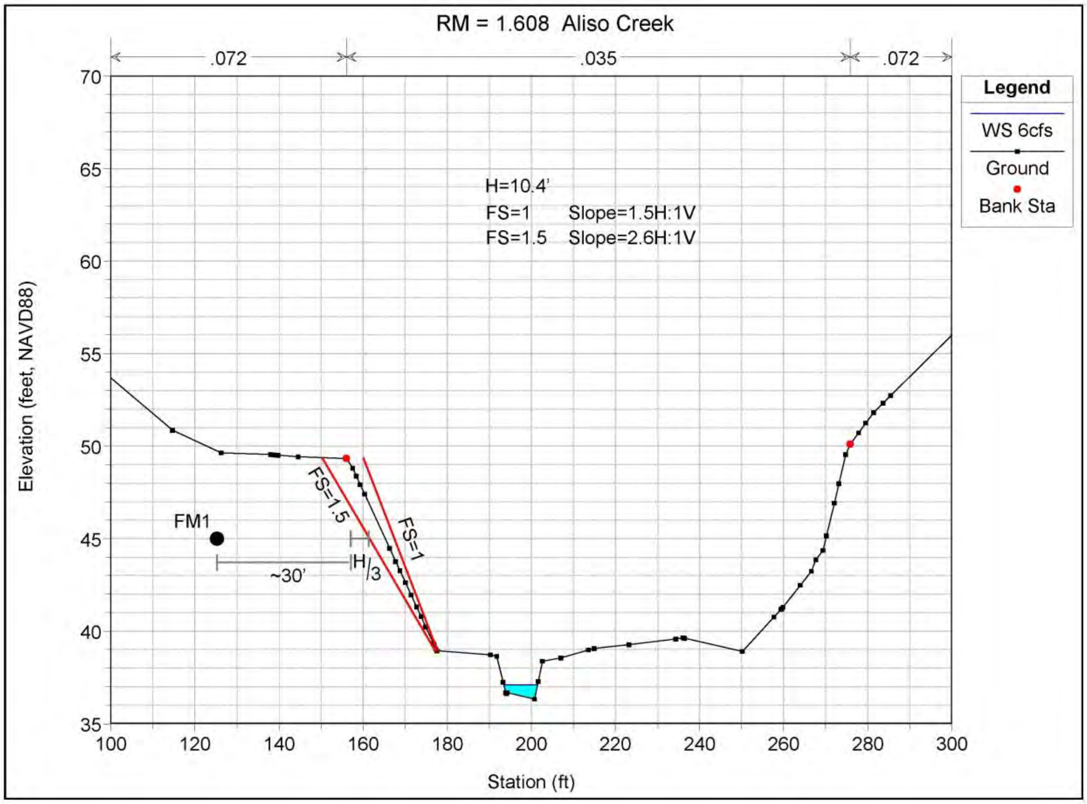

RM = 3.677 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Ineff
Bank Sta
H=2'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FM1
~70'
H/3
FS=1.5
Elevation (feet, NAVD88)
Station (ft)
125
120
115
110
105
100
95
40
60
80
100
120
140
160
180
200
220
240

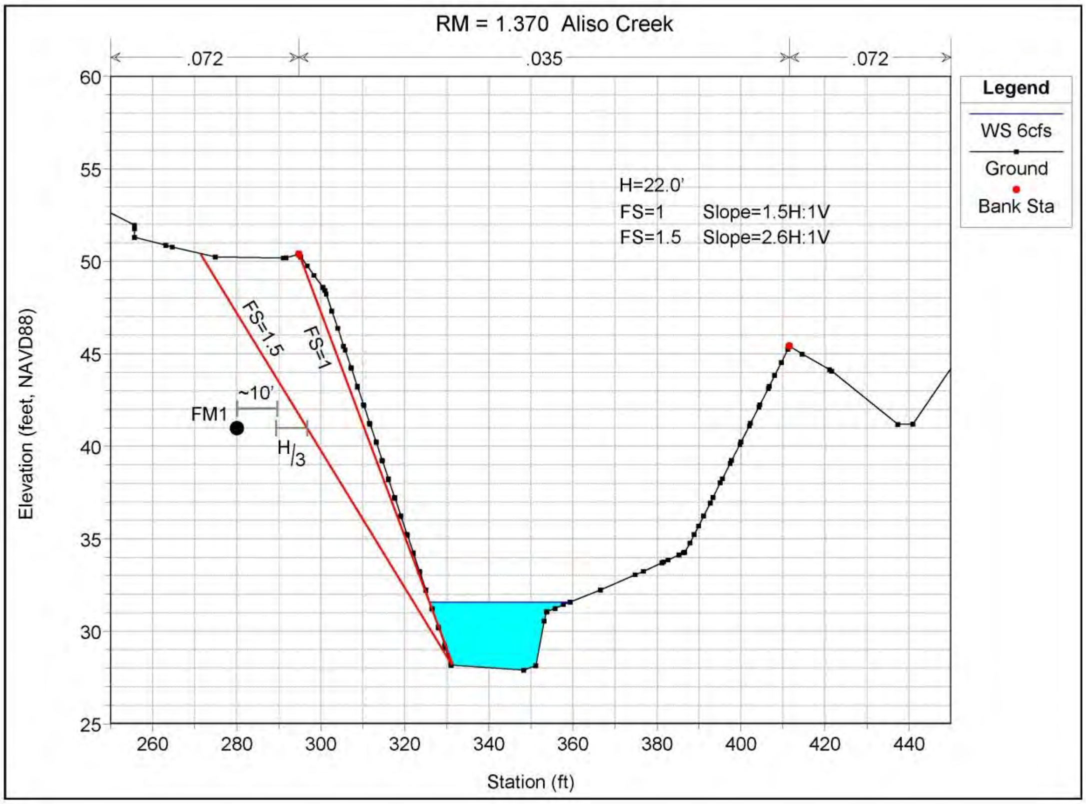

RM = 3.095 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=22.1'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
~5'
FM1
H/3
FS=1
FS=1.5
Elevation (feet, NAVD88)
Station (ft)
95
90
85
80
75
70
65
60
0
20
40
60
80
100
120
140
160
180
200


RM = 2.713 Aliso Creek
.072
.035
FM1
H/3
~65'
H=19.9'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FS=1
FS=1.5
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet, NAVD88)
Station (ft)
85
80
75
70
65
60
55
50
0
20
40
60
80
100
120
140
160
180
200

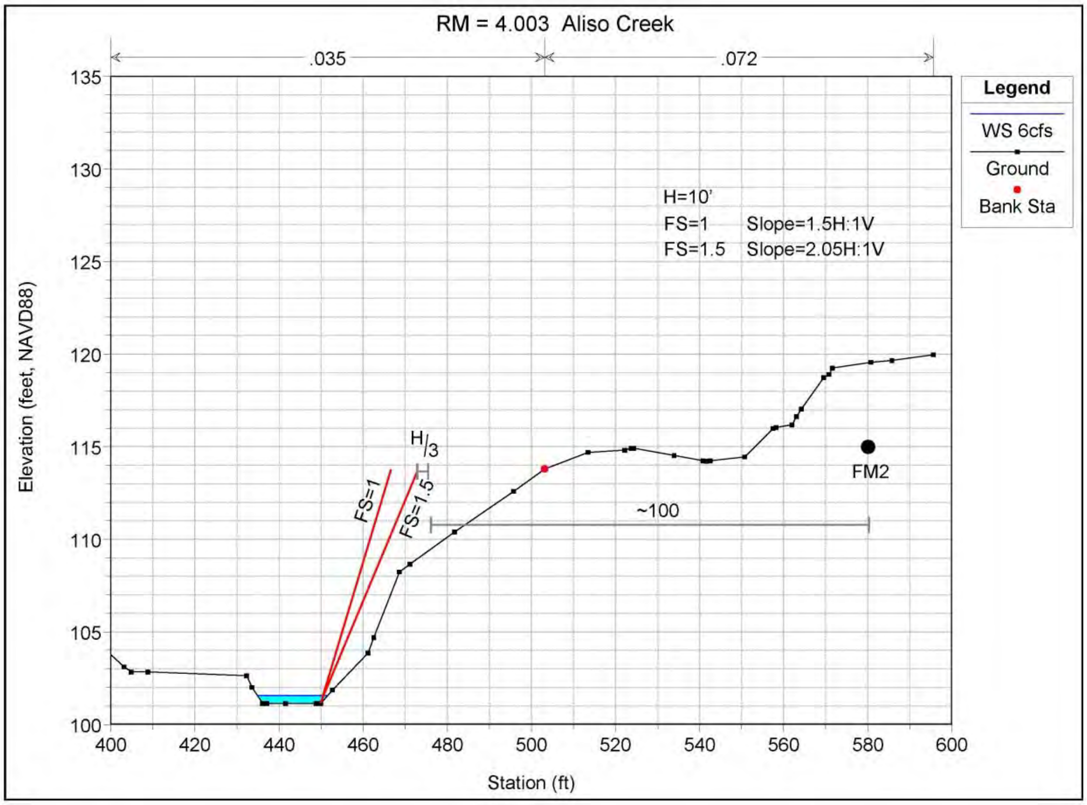

RM = 2.509 Aliso Creek
.072
.035
.072
FM1
H/3
~15'
H=14'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FS=1
FS=1.5
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet, NAVD88)
Station (ft)
85
80
75
70
65
60
55
50
0
100
200
300
400
500
600

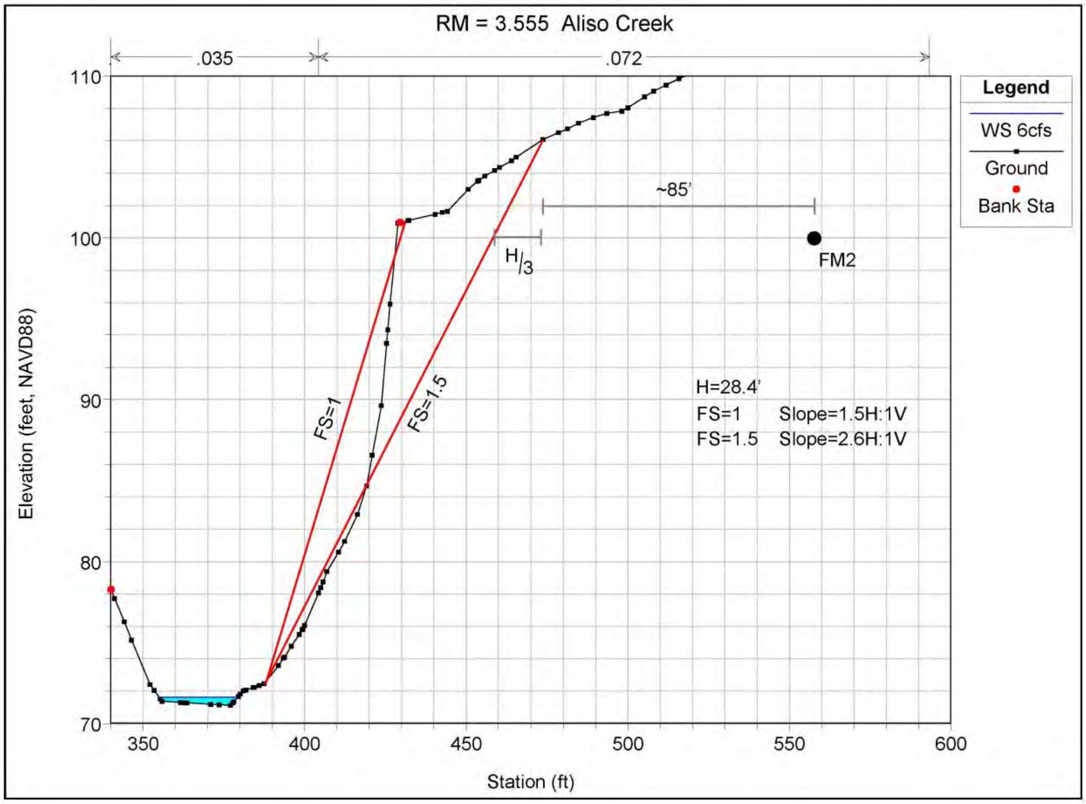

RM = 1.989 Aliso Creek
.072
.035
Legend
WS 6cfs
Ground
Bank Sta
H=16.8'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
~35'
FM1
H/3
FS=1
FS=1.5
Elevation (feet, NAVD88)
75
70
65
60
55
50
45
40
35
30
80
100
120
140
160
180
200
220
240
260
280
Station (ft)

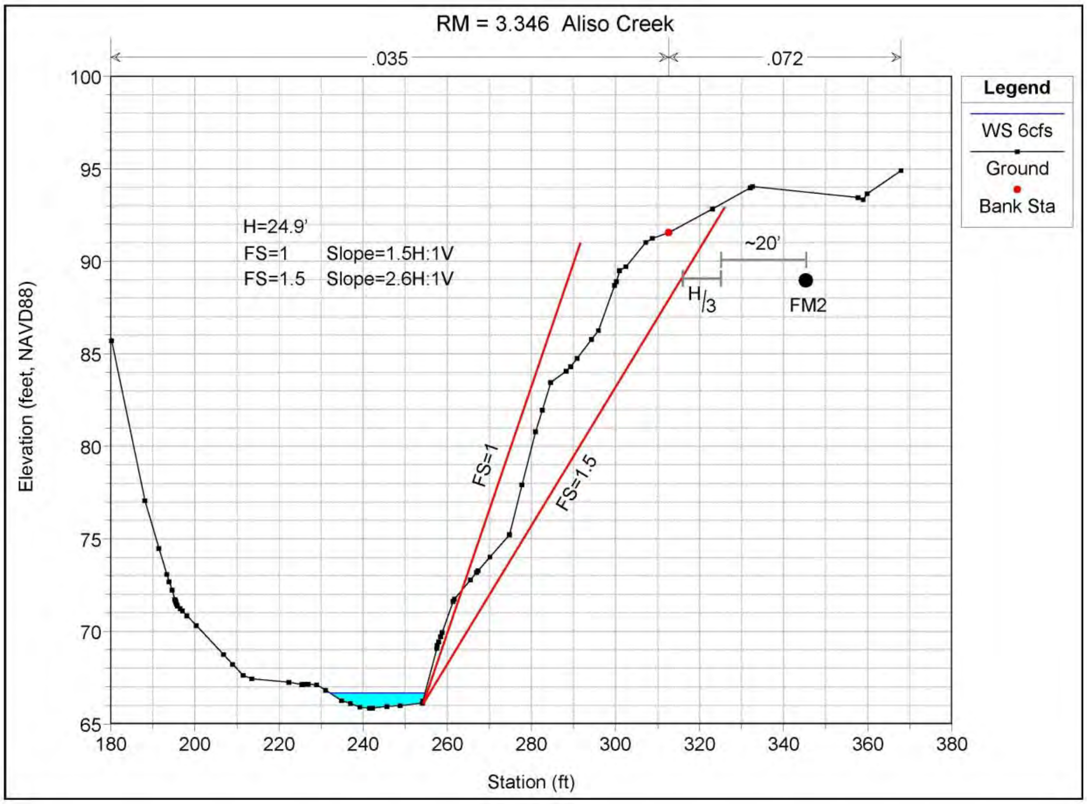

RM = 1.608 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=10.4'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FM1
~30'
H/3
FS=1.5
FS=1
Elevation (feet, NAVD88)
70
65
60
55
50
45
40
35
100
120
140
160
180
200
220
240
260
280
300
Station (ft)

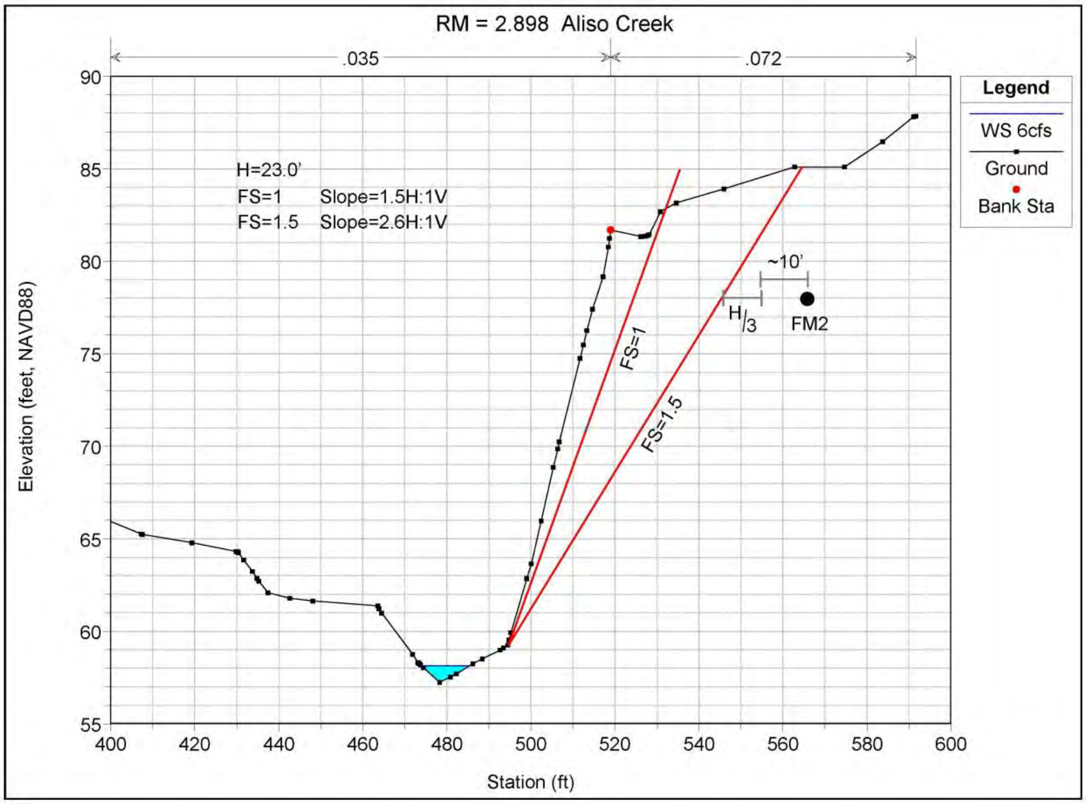

RM = 1.370 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=22.0'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FS=1.5
FS=1
~10'
FM1
H/3
Elevation (feet, NAVD88)
60
55
50
45
40
35
30
25
260
280
300
320
340
360
380
400
420
440
Station (ft)

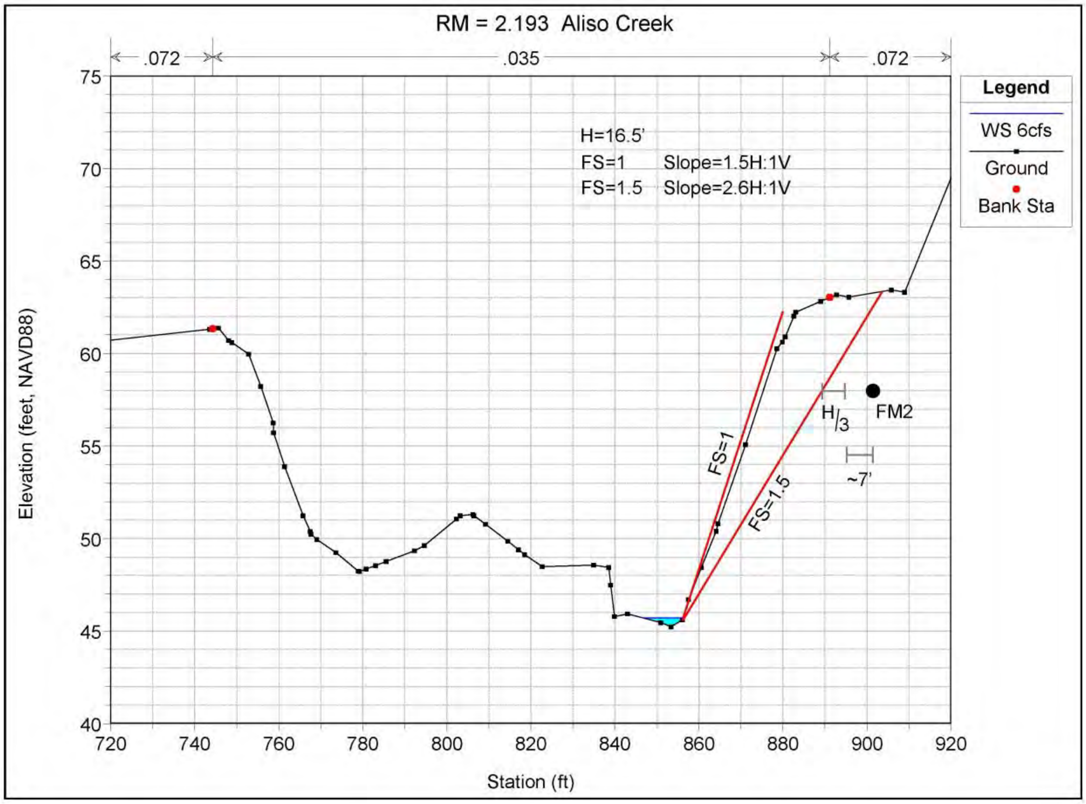
WEST (RIGHT) BANK – PROPOSED FM 2 ALIGNMENT

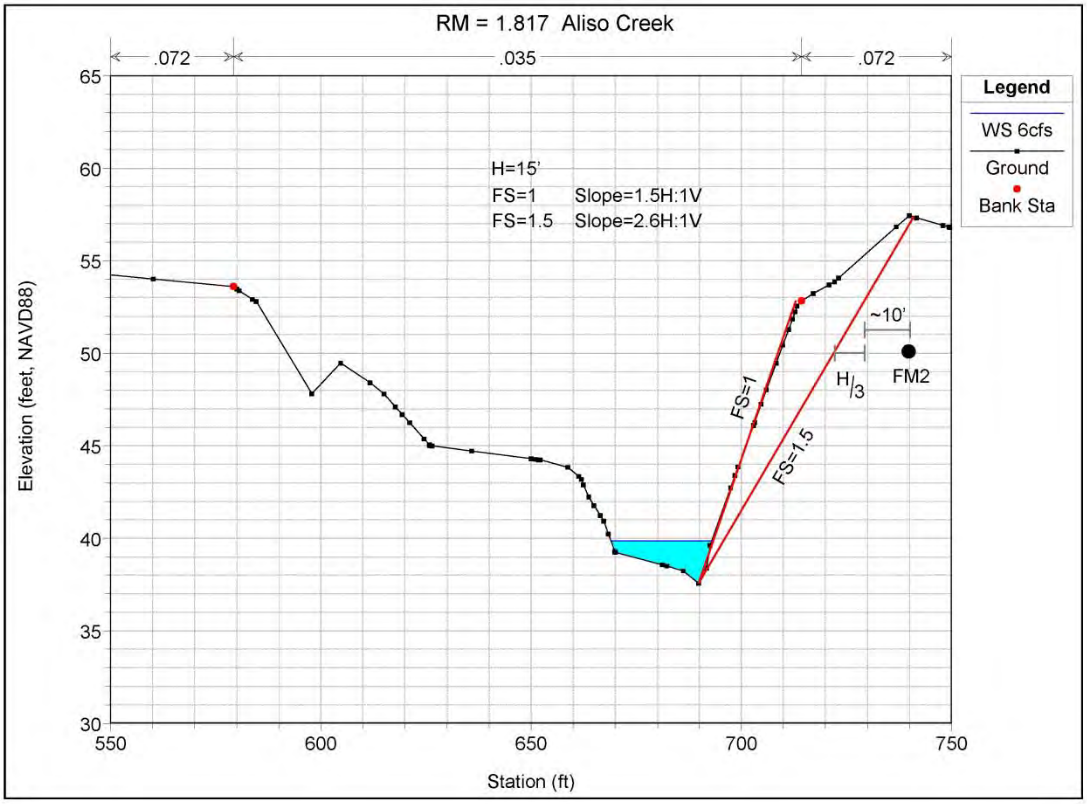


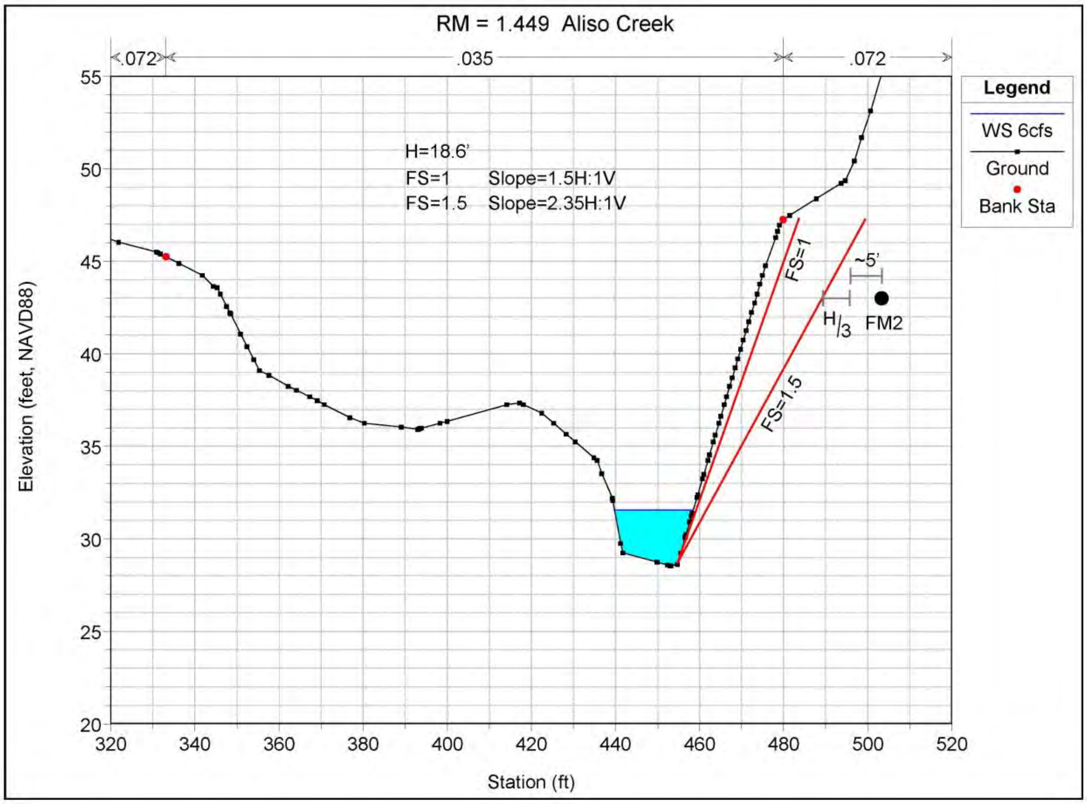



RM = 3.346 Aliso Creek
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=24.9'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FS=1
FS=1.5
~20'
H/3
FM2
Elevation (feet, NAVD88)
Station (ft)
100
95
90
85
80
75
70
65
180
200
220
240
260
280
300
320
340
360
380


RM = 2.898 Aliso Creek
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=23.0'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
FS=1
FS=1.5
~10'
H/3
FM2
Elevation (feet, NAVD88)
Station (ft)
90
85
80
75
70
65
60
55
400
420
440
460
480
500
520
540
560
580
600


RM = 2.193 Aliso Creek
.072
.035
.072
H=16.5'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
H/3
FM2
~7'
FS=1
FS=1.5
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet, NAVD88)
Station (ft)
40
45
50
55
60
65
70
75
720
740
760
780
800
820
840
860
880
900
920


RM = 1.817 Aliso Creek
.072
.035
.072
H=15'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.6H:1V
~10'
H/3
FM2
FS=1
FS=1.5
Legend
WS 6cfs
Ground
Bank Sta
Elevation (feet, NAVD88)
Station (ft)
30
35
40
45
50
55
60
65
550
600
650
700
750


RM = 1.449 Aliso Creek
.072
.035
.072
Legend
WS 6cfs
Ground
Bank Sta
H=18.6'
FS=1 Slope=1.5H:1V
FS=1.5 Slope=2.35H:1V
FS=1
FS=1.5
~5'
H/3
FM2
Elevation (feet, NAVD88)
Station (ft)
20
25
30
35
40
45
50
55
320
340
360
380
400
420
440
460
480
500
520