FUGRO CONSULTANTS, INC.

GEOTECHNICAL REPORT
ARROYO GRANDE CREEK LEVEE IMPROVEMENTS
LOS BERROS CREEK TO OCEANO AIRPORT
SAN LUIS OBISPO COUNTY, CALIFORNIA

Prepared for:
Waterways Consulting, Inc.

October 5, 2012

October 5, 2012
Project No. 04.6212.0101

Waterways Consulting, Inc. (Waterways)
403B Swift Street
Santa Cruz, CA 95060

Attention: Mr. Jeremy Marello

Subject: Geotechnical Report, Arroyo Grande Creek Levee Improvements, Los Berros Creek to Oceano Airport, San Luis Obispo County, California

Dear Mr. Marello:

Fugro is pleased to submit this Geotechnical Report for the Arroyo Grande Creek Levee Improvements in San Luis Obispo County, California. This report was prepared in accordance with our proposal dated April 2, 2012, and authorized by Waterways Agreement for Services dated July 5, 2012.

This report presents design input based on the results of our evaluation of the seepage and stability conditions relative to the proposed north levee improvements along Arroyo Grande Creek. Our evaluation was based on site-specific exploration, our previous studies and other geotechnical studies in the site vicinity, review of published geologic information, project information provided by Waterways and the County of San Luis Obispo, and hydraulic and stream flow information provided by Waterways. Previous studies include a Fugro (2009) Preliminary Geotechnical Report that focused on evaluating liquefaction and other seismic related hazards that could impact the levee, and a Fugro (2012) Limited Geotechnical Report that focused on evaluating the seepage conditions along the existing north levee.

The purpose of this report is to provide input to the design team by evaluating seepage and slope stability conditions relative to the proposed north levee improvements along Arroyo Grande Creek. Our study included: an evaluation of the potential for underseepage within the levee foundation soils to cause boils - if excessive seepage forces exist at the levee landside toe; an evaluation of the potential for seepage through the levee (which could cause piping and erosion of the levee soils); and an evaluation of the levee slope stability for the proposed improvements relative to full flood and rapid drawdown conditions. This report includes a summary of the results of our seepage and stability evaluations, field and laboratory data collected, graphics showing the locations of explorations, supporting data from the slope stability and seepage analyses, design recommendations, and construction considerations.

Sincerely,

FUGRO CONSULTANTS, INC.

Gresham D. Eckrich, PE, PG, LEED AP
Project Engineer/Geologist

Jonathan D. Blanchard, GE 2312
Principal Geotechnical Engineer

Copies: 4 – Addressee (1 – pdf on CD ROM)

CONTENTS

PLATES

APPENDIX A – EXPLORATION LOGS

APPENDIX B – LABORATORY TEST RESULTS

APPENDIX C – GEOTECHNICAL PARAMETERS

APPENDIX D – GEOSTUDIO OUTPUT

1.0 SITE AND PROJECT UNDERSTANDING

The project generally consists of the design of approximately 2 miles of flood control improvements along both the northern and southern banks of Arroyo Grande Creek and the southern bank of Los Berros Creek near Oceano, California. Arroyo Grande Creek is mainly confined by levees west of Highway 1, and intermittently confined by levees east of Highway 1. Los Berros Creek is generally unconfined within the project extent. The location of the site and limits of the proposed levee improvement are shown on Plate 1, Site Map. All the elevations noted herein are relative to the NAVD88 datum.

1.1 EXISTING SITE

The site topography, exploration locations, cross section locations, and project stationing are shown on Plate 2, Field Exploration Plan. Note that stationing referenced herein corresponds to the stationing shown on Plate 2. Los Berros Creek flows west into Arroyo Grande Creek at the eastern terminus of the project. Arroyo Grande Creek then flows westerly to the Pacific Ocean, about 3½ miles downstream of Los Berros Creek. Concrete weirs and check dams are located within the Los Berros Creek channel, and rip-rap boulders associated with construction and maintenance of existing levees were observed along sections of variable length within the Arroyo Grande Creek channel. Bridges span Arroyo Grande Creek at Highway 1/Cienega Street, 22nd Street, and at the Union Pacific Railroad (UPRR) crossing. We understand that the County performs periodic tree trimming and vegetation removal from the channel as part of the levee system management and maintenance.

Existing site grades range from approximately elevation 11 feet (SH+G, 2008), at the west end of the project extent, to approximately elevation 65 feet, near the city limits of Arroyo Grande. The existing channel bottom consists mostly of gravel with vegetated banks and levee slopes. Sand and gravel bars have aggraded within the channel between the slopes of the levees. The existing land use adjacent to the south levee is predominantly agricultural land planted in irrigated row crops. The Cardoza (horse) Ranch is located south of the levee and west of Creek Road. The existing land use adjacent to the northern levee is a combination of the Oceano airport, South County Waste Water Treatment Plant, and residential and agricultural plots. Beyond the downstream limits of the project, the south levee is bordered by active sand dunes within the Oceano Vehicle Recreation Area operated by State Parks.

The levees and channelized Arroyo Grande Creek were constructed in the late 1950s as a U.S. Department of Agriculture, Soil Conservation Service project (USDA 1956). Portions of the creek were relocated as part of the construction of the levee system. Downstream of Highway 1, the levees consist of earthen berms. Review of the USDA (1956) plans show the levee embankments designed with 15-foot wide crests, with 1½h:1v to 2h:1v exterior slope inclinations, and 3h:1v interior slope inclinations. As-built plans provided by the County and cross sections developed with SH+G (2008) and San Luis Obispo County (2012) topographic data show that the interior slopes were constructed as steep as about 2h:1v. The interior height of the channel slopes indicated on the plans ranges from about 11 to 14 feet. Topographic data collected by Waterways (2012a) shows interior slope heights up to about 18 feet. The exterior slope height appears to have been designed about 5 to 12 feet above the adjacent grades downstream of Highway 1. However, upstream of Highway 1, the existing levee is less pronounced and more intermittent, with a design height generally less than about 3 feet above adjacent grades.

1.2 PROJECT DESCRIPTION

The limits of the proposed improvements, general layout and stationing for the project are shown on Plates 1 and 2. We understand that the levee improvements are an element of the County of San Luis Obispo Arroyo Grande Creek Waterways Management Program (WMP). In the project area, the Arroyo Grande Creek channel is managed through Zones 1 and 1A of the San Luis Obispo County Flood Control and Water Conservation District (Morro Group, 2008). As part of the WMP, flood control improvements will be provided along the northern and southern levees of Arroyo Grande and Los Berros Creeks. The program is intended to provide increased flood control benefits and riparian enhancement through vegetation management and sediment control within Arroyo Grande Creek channel. The Arroyo Grande Creek Waterways Management Program consists of flood protection improvements along Arroyo Grande Creek, from the city limits of Arroyo Grande and the confluence with Los Berros Creek to the upper edge of the Arroyo Grande Creek lagoon at the Pacific Ocean.

The levee improvements are funded by Propositions 1E and 84. The north levee improvements associated with the Proposition 84 project includes elements of the proposed Alternative 3a (Waterways, 2009a) improvement concepts. In addition, the improvements include fill placement and grading associated with the proposed Alternative 3a concept along the south levee, which is part of the Proposition 1E project.

North Levee Improvements. The north levee improvements will generally consist of raising the top of the between about Station 36+00 to about Station 109+50 and from about Station 122+00 to about Station 130+00, with floodwalls located in sections of the project extent with limited right-of-way. The three (3) concrete floodwalls are shown on the Alternative 3a plans from the 22nd Street Bridge to Station 73+23, from about Station 122+88 to Station 125+28, and from about Station 128+40 to Station 129+10. The design of north levee improvements is intended to improve flood protection in areas where existing residences border the north levee. We understand from the County that the existing north levee provides flood protection for a flood event with about a 5-year recurrence interval. The north levee is considered the main flood protection for residences that border the north side of Arroyo Grande Creek, particularly east of 22nd Street, between about Station 72+00 and 102+00, where existing homes are located in close proximity or encroach upon the levee, and as flood protection for the Oceano wastewater treatment plant site near Station 20+00.

The County has given priority to the north levee because of the high density residential areas, and the north levee is generally maintained at a slightly higher elevation than the south levee to encourage creek flows to breach the south levee before the water level in the creek would overtop the north levee. As part of that effort, we understand that the County recently raised sections of the north levee by placing about 1 foot or less of fill material between Stations 15+50 and 145+00, and placed temporary flood protection on sections of the south levee to help allow for overtopping of the south levee. The temporary flood protection consisted of visqueen covering both interior and exterior slopes, and sand bags along the levee crest. According to 2011 topographic data provided by the County (2012), levee crest elevations on the north and south levees range from 20.88 feet to 62.09 feet and 20.68 feet to 59.36 feet, respectively. As part of this project, topographic transects of the creek invert and lower levee slopes were surveyed by Waterways (2012a) at select stations along the project alignment.

South Levee Improvements. South levee improvements primarily consist of grade raises of about 3½ feet or less on the existing levee, and to fill areas where the profile of the existing levee crest is currently low or interrupted. The south levee improvements extend from about Station 37+00 to about Station 121+00 of Arroyo Grande Creek, and from about Station 15+00 to about Station 23+00 of Los Berros Creek. Specific analysis of seepage and slope stability conditions along the south levee was not a part of our scope of work for this study.

Hydraulic Conditions. The south levee improvements shown on the 30-percent Alternative 3a conceptual plans prepared by Waterways Consulting (2009) are designed to provide 2 feet of freeboard and flood protection for an estimated 10-year flood event, which corresponds to a peak flow of 5,400 cubic feet per second (cfs). Following submittal of the 30-percent Alternative 3a plans, we understand the County requested that the design of the north levee include crest elevations greater than the south levee along the entire project extent, to limit the likelihood that the north levee is overtopped during a flood event. As a result, the updated north levee improvements are designed to provide protection for water surface elevations corresponding to the 50-year flood event <u>or</u> water surface elevations one (1) foot above the south levee crest elevation, depending on which water surface elevation is lower along particular reaches of the project alignment (Waterways Consulting, 2012b). The recurrence interval for the flood event corresponding to the latter water surface elevations is greater than 10 years and less than 50 years.

According to Waterways Consulting (2012b), the finished ground elevation of the south levee at Station 80+00 is 36.2 feet, which corresponds to the estimated 10-year water surface elevation plus 2 feet of freeboard. As a result, the estimated maximum water surface elevation is 37.2 feet for the north levee in the vicinity of Station 80+00. Additionally, the finished ground elevation of the south levee at Station 124+00 is 53.6 feet, which is greater than the estimated 10-year water surface elevation plus 2 feet of freeboard. As a result, the proposed north levee floodwall will be designed to provide protection for the 50-year flood event, which corresponds to an estimated maximum water surface elevation of 53.8 feet in the vicinity of Station 124+00. We understand that the creek would likely not overtop the north levee during the design storm events because the south levee would likely breach, and water surfaces downstream of the breach would drop as a result.

The design storm events for Arroyo Grande Creek are generally considered to be relatively short duration (flashy) type floods that peak and recede below the base of the levee within 24 hours. The anticipated short storm durations were considered in our evaluation of the potential for steady-state seepage conditions to develop and the possibility that seepage forces would impact the exterior slope of the improved north levee. Peak water surface elevations are anticipated to remain stable for only a few hours before either the south levee would overtop in a storm event greater than the design storm event, or waters would eventually recede. We understand the County has monitored and observed the latter phenomenon during past flood events. Waterways estimates the duration of the 50-year flood event, which corresponds to a peak flow of approximately 13,485 cfs, is about 65 hours. However, during the 50-year flood event, the water surface elevation would rise above and fall below the peak elevations of the 10-year and 5-year flood events in approximately 9 and 14 hours, respectively. It should be noted the duration of the storm event considered in the steady-state seepage evaluation corresponds to the estimated time for steady-state seepage conditions to develop through the levee and result in phreatic surfaces emerging on the exterior levee slopes.

2.0 WORK PERFORMED

2.1 PURPOSE

The purpose of this report is to provide geotechnical recommendations for the design of the levee improvements based on the results of our field exploration, laboratory testing, and seepage and slope stability evaluations. The main geotechnical considerations that we have evaluated for this project are:

- Characterization of the subsurface conditions along the alignment of the levee, particularly the hydraulic conductivity and strength properties of levee fill material and underlying alluvium;
- An evaluation of the seepage vulnerability and stability of the proposed levee raise and floodwall improvements relative to full flood steady-state and rapid drawdown conditions;
- Providing grading and fill placement recommendations for construction of the proposed levee grade raises; and
- Providing foundation design and lateral earth pressure recommendations for the design of floodwalls.

2.2 SCOPE

To evaluate the geotechnical considerations for the project, we have executed the following scope of work:

- Meeting and consulting with Waterways Consulting and the County regarding our approach to providing geotechnical services for the project and to review the project objectives;
- Reviewing selected published geologic maps and reports, previous geotechnical studies performed along the levee and for bridges that span the creek channel, and as-built plans for the existing levee;

- Preparing a Health and Safety Plan, performing site visits to observe the general site conditions, obtaining well permits for selected borings, clearing utilities by contacting Underground Services Alert (USA), and coordinating the field exploration program;

- Field exploration consisting of drilling five (5) borings to depths of approximately 21½ to 41½ below the ground surface at selected locations along the north levee to characterize subsurface conditions and obtain samples for testing;

- Laboratory testing of selected samples obtained from the site to assist in characterizing the material properties of the levee fill and alluvium encountered;

- Preparing this Geotechnical Report that provides our opinions and recommendations regarding:

    - Geologic setting;

    - Soil and groundwater conditions encountered;

    - General condition, history, and material composition of the existing levees relative to seepage and stability;

    - Suitability of onsite soils for use as compacted fill;

    - Material requirements for on-site or imported fill and aggregates;

    - Site preparation and grading for flood wall areas;

    - Fill placement and compaction requirements for the levee improvements;

    - Slope stability and seepage considerations for the proposed north levee slopes and floodwalls based on the seepage conditions analyzed and the design flood event;

    - Bearing pressures, minimum foundation embedment and width, lateral load resistance, and estimated settlement for floodwall design;

    - Additional foundation embedment or width, if needed, to control seepage below the floodwall(s);

    - Need for and estimated depth of sheet-pile cutoff wall to mitigate seepage;

    - Subsurface drainage for control of seepage to mitigate adverse seepage through or beneath the levee (if needed); and

    - Construction considerations for temporary slopes, excavation, and subgrade preparation.

2.3 HISTORICAL AERIAL PHOTOGRAPHS

We reviewed selected historical aerial photographs obtained from Environmental Data Resources. The following is a table of the photographs reviewed as part of this study. Aerial Photography is presented on Plates 5a through 5c.

Summary of Historical Aerial Photograph Review

Date	Scale	Source	Notes on Arroyo Grande Creek
1939	1" = 1000'	Army	Downstream of about Station 85+00, the channel is relatively linear and nearly aligned with the present channel. Remnants of the pre-settlement Estero are apparent downstream of about Station 52+00. Between about Station 85+00 and Station 107+00, the channel is up to approximately 250 feet south of the present channel, and relatively young flood plain deposits are visible on both banks. Between about Station 107+00 and Station 140+00, the creek channel is slightly meandered and generally aligned with the present channel.
1949	1" = 1000'	Aero	Similar to 1939 photo, except channel between about 85+00 and Station 107+00 appears more linear. Pre-settlement Estero appears to have been filled and leveled downstream of about Station 52+00. Vegetation along the creek banks appears to have been cleared downstream of about Station 120+00.
1956	1" = 1000'	Hycon	Similar to 1949 photo, except channel between about 55+00 and Station 65+00 appears to have meandered approximately 50 feet north. Vegetation within the channel appears to have been cleared downstream of about Station 143+00.
1966	1" = 1000'	Mark Hurd	Present channel alignment established by construction of levee system. No vegetation is visible within the channel. Los Berros Creek confluence at about Station 143+00 has been constructed.
1972	1" = 1000'	Mark Hurd	Similar to 1966 photo, except more vegetation is visible within the channel.
1989	1" = 1000'	USGS	Similar to 1972 photo.
1994	1" = 1000'	USGS	Similar to 1989 photo.

Date	Scale	Source	Notes on Arroyo Grande Creek
2002	1" = 1000'	USGS	Similar to 1994 photo.

2.4 FIELD EXPLORATION

The drilling subcontractor for the exploratory borings was S/G Drilling Company of Lompoc, California. Field exploration consisted of drilling and sampling five (5) hollow-stem-auger borings on July 20, 2012. The logs for the borings are presented in Appendix A. The approximate locations of the borings performed for this study and previous explorations are shown on Plate 2, Field Exploration Plan.

S/G Drilling operated a CME85, truck-mounted drill rig to advance five (5) hollow-stem auger borings using 8-inch diameter hollow stem augers. The hollow-stem auger borings were advanced to depths of approximately 21½ to 41½ feet below the existing ground surface. The borings were sampled at selected depths using an unlined 2-inch outside diameter standard penetration test (SPT) split spoon sampler, a 3-inch outside diameter modified California split spoon sampler with brass liners, and a 3-inch outside diameter thin-walled (Shelby) tube. The split spoon samplers were driven into the material at the bottom of the drill hole using a 140-pound automatic trip hammer with a 30-inch drop. The blow count (N-value) is the number of blows from the hammer that were needed to drive the sampler 1 foot, after the sampler had been seated approximately 6 inches into the material at the bottom of the hole. Bulk samples were collected as drill cuttings retrieved from the auger flights.

2.5 LABORATORY TESTING

Laboratory tests for grain size distribution, plasticity (Atterberg limits), hydraulic conductivity, direct shear strength, triaxial compressive strength, and compaction (Proctor) were performed on selected samples recovered from the field exploration program. The tests were performed in general accordance with the applicable standards of ASTM. The results of the tests are presented in Appendix B.

2.6 PREVIOUS STUDIES

Fugro (2009) conducted a preliminary geotechnical investigation of the north and south levees. The investigation evaluated the potential for the site to be impacted by geologic hazards, analyzed static and seismic stability of levee slopes, and discussed geotechnical considerations for proposed levee raise alternatives. Field exploration activities consisted of advancing six (6) electric cone penetration test (CPT) soundings, collecting hand samples from the creek, and excavating a hand auger boring adjacent to the levee. The logs of the CPT soundings and hand auger boring are presented in the Fugro (2009) report, and the approximate locations of the explorations are shown on Plate 2. In addition, subsurface profiles summarizing Fugro's interpretation of the soil conditions encountered along the alignment of Arroyo Grande Creek within the project limits are shown in Fugro (2009).

Fugro (2012) prepared a limited geotechnical report addressing seepage conditions along the existing north levee. The report included an evaluation of the potential for steady-state flow conditions to result in seepage through and under the levee, instability of the levee slopes, the need for mitigation to address seepage conditions, and construction considerations relative to existing residences and land uses along the north levee. Field exploration activities consisted of drilling and sampling three (3) hollow-stem-auger borings. The logs of borings are presented in the Fugro (2012) report, and the approximate locations of the explorations are shown on Plate 2.

The U.S. Geological Survey (Holzer et al., 2004) has previously performed a geotechnical study in the project vicinity. The study focused on evaluating liquefaction and liquefaction-induced lateral spreading that occurred in Oceano in response to the 2003 San Simeon Earthquake. As part of that study, the USGS performed three CPT soundings (SOC 036, 035 and 037) on the Arroyo Grande Creek Levee within the project limits. The soundings were performed in this area of the levee because the USGS observed evidence of levee instability and liquefaction adjacent to the levee. The data from those CPT soundings were used to assist in our characterization of the subsurface conditions for this report. The logs of those CPT soundings performed by the USGS are included with the Fugro (2009) report. The approximate locations of the CPT soundings performed by the USGS are shown on Plate 2.

We reviewed logs of test borings from Caltrans (1956, 1984) and San Luis Obispo County (1984) as part of geotechnical investigations for the State Route 1 Bridge and 22nd Street Bridge, respectively. This boring information was used to help characterize the subsurface conditions at the site. The approximate locations of the bridge borings are shown on Plate 2.

2.7 GENERAL CONDITIONS

Fugro prepared the conclusions and professional opinions presented in this report in accordance with generally accepted geotechnical engineering principals and practices at the time and location this report was prepared. This statement is in lieu of all warranties, expressed or implied.

This report has been prepared for Waterways Consulting, Inc., and their authorized agents only. It may not contain sufficient information for the purposes of other parties or other uses. If any changes are made in the project as described in this report, the conclusions and recommendations contained in this report should not be considered valid unless Fugro reviews the changes and modifies and approves, in writing, the conclusions and recommendations of this report. The report and drawings contained in this report are intended for design-input purposes; they are not intended to act as construction drawings or specifications.

Soil and rock deposits will vary in type, strength, and other geotechnical properties between points of observation and exploration. Additionally, groundwater and soil moisture conditions can also vary seasonally or for other reasons. Therefore, we do not and cannot have complete knowledge of the subsurface conditions underlying the site. The conclusions and recommendations presented in this report are based upon the findings at the points of exploration, and interpolation and extrapolation of information between and beyond the points of observation, and are subject to confirmation based on the conditions revealed during construction.

The scope of services did not include any environmental assessments for the presence or absence of hazardous/toxic materials in the soil, surface water, groundwater, or atmosphere. Any statements or absence of statements, in this report or data presented herein regarding odors, unusual or suspicious items, or conditions observed are strictly for descriptive purposes and are not intended to convey engineering judgment regarding potential hazardous/toxic assessment.

3.0 SITE CONDITIONS

3.1 GEOLOGIC SETTING

The project is located in the Arroyo Grande and Cienega Valleys and within the Coast Ranges geologic and geomorphic province. The province consists of north-northwest-trending sedimentary, volcanic, and igneous rocks extending from the Transverse ranges to the south into northern California. Rocks of the Coast Ranges province are predominantly of Jurassic and Cretaceous age; however, the range is often flanked by pre-Jurassic, Paleocene-age to recent rocks that overlie older rock formations. The surficial geology in the project vicinity, as mapped by Hall et al. (1973), is shown on Plate 3, Regional Geologic Map.

The Arroyo Grande and Cienega Valleys and adjacent highlands composed of eolian (windblown) dune sand deposits are the dominant geomorphic features within the project vicinity. The valleys were formed during a period of low sea level (the Wisconsin glacial stage), as coastal streams adjusted to the drop in sea level by carving into the landscape. A subsequent rise in sea level produced a dynamic depositional environment reflected in the discontinuous and variable subsurface stratigraphy. Approximately 800 feet of interlayered and unconsolidated sediments have been deposited within the valleys, dip gently to the west, and are underlain by bedrock consisting of Pismo Sandstone or similar sedimentary rocks.

As shown on Plates 2 and 3, the predominant geologic units mapped in the study area are surficial sediments composed of dune sand deposits (Qs), older-stabilized dune sand deposits (Qos), and alluvium (Qal). Hall identified older dune sands as eolian deposits that have been stabilized and subsequently covered by vegetation. The alluvium is associated with floodplain, fluvial, and estuarine sediments that have been deposited along Arroyo Grande Creek and Los Berros Creek, and on the floor of the Arroyo Grande and Cienega Valleys. Surficial sediments are primarily underlain by weakly consolidated units of the age-equivalent of Paso Robles Formation and Careaga Sandstone.

Also depicted on Plate 2, a portion of the site along the creek was previously occupied by dune sand and an extensive pre-settlement Estero, according to an 1873-1874 map produced by the U.S. Coast Survey (Holzer et al., 2004). According to the USGS (2004) report, this area was subsequently “subdivided and turned into developable lots by leveling dunes and filling in swamp areas with dune sand in March 1927.” Presumably, the creek alignment was altered as a consequence of this development. The approximate limits of the Pre-Existing

Estero reported by Holzer et al. (2004) are noted on Plate 2. Apparently undeveloped remnants of the Estero are visible in the 1939 aerial photograph discussed above and shown on Plate 5a.

3.2 SUBSURFACE CONDITIONS

The subsurface conditions encountered generally consisted of artificial fill (Af) materials overlying alluvium deposits (Qal), with the exception of boring B-101, which only encountered alluvium deposits. Fill placed for flood protection is intermittent upstream of Highway 1, as creek channel banks are generally composed of alluvium deposits, with discontinuous sections of overlying levee fill and artificial fill presumably placed at level grade to expand adjacent residential and agricultural areas.

Logs of the borings for this investigation are presented in Appendix A. The locations of the borings are shown on Plate 2. A discussion of the geologic units encountered during the present study is provided below. Cross sections showing our interpretation of subsurface conditions at Stations 80+00 and 124+00 are shown on Plates 4a and 4b, respectively. All borings, except boring B-103, were drilled along the top of the existing levee. Our interpretation of subsurface conditions is based on boring logs, and is generally supplemented by logs of previous explorations (Fugro, 2009; USGS, 2004; Caltrans, 1956, 1984; San Luis Obispo County, 1984). Refer to Fugro (2009, 2012) for additional subsurface data and a profile interpretation of the subsurface conditions along the levee alignment.

Artificial Fill (Af). With the exception of boring B-101, all borings encountered artificial fill materials at the surface. The thickness of the fill materials encountered ranged from approximately 2 to 5 feet. The artificial fill consisted of medium dense to dense silty sand with gravel (SM), medium dense to dense clayey sand (SC) with gravel, and soft lean clay with sand (CL). For the purposes of seepage and stability analyses, the artificial fill was modeled as a uniform levee fill material.

Varying degrees of rodent burrows, vegetation, and loose surface soil were commonly observed along the interior and exterior of the existing levee slopes. Photographs of rodent burrows and loose surface soil on levee slopes are shown on Plate 6. We understand the County actively manages vegetation and rodent activity on the levee, which is common maintenance practice for hydraulic earth structures.

Alluvium Deposits (Qal). The alluvium encountered was composed of undifferentiated units of floodplain, fluvial, and estuarine sediments deposited along Arroyo Grande Creek. The alluvium was encountered at the surface in boring B-101 and below the artificial fill materials in the all other borings to the maximum depth explored, approximately 21½ to 41½ feet below the existing ground surface. The alluvium encountered during the Fugro (2009, 2012) field exploration programs was characterized as two predominant units of sandy alluvium (Qal_1, Qal_2), and three predominant units of fine-grained alluvium that were encountered at various depths within and below the sandy alluvium (Qal_3, Qal_4 and Qal_5). All of the alluvium units noted above were encountered in the borings drilled as part of this study, and are characterized below in a manner consistent with Fugro (2009, 2012).

For the purposes of seepage and stability analyses, the sandy alluvium units (Qal_1, Qal_2) were modeled as a uniform pervious foundation material. Additionally, the fine-grained alluvium units (Qal_3, Qal_4, Qal_5) were modeled as a uniform impervious foundation material. The sequence of the units does not necessarily progress downward from the ground surface or exist at each location that has been explored.

Qal_1. This unit consisted of sandy material encountered at the surface in boring B-101 and below the levee fill in borings B-103 and B-105 to depths of approximately 9 to 32 feet below the surface. This upper sand unit consisted of loose poorly-graded sand (SP), very loose to dense poorly-graded sand with silt (SP-SM), medium dense well-graded sand with silt (SW-SM), very loose to very dense silty sand (SM), and medium dense silty sand with gravel (SM).

Qal_2. This unit consisted of sandy alluvium encountered just below the Qal_4 unit in boring B-104 at a depth of approximately 35½ feet below the existing ground surface. This lower sand unit consisted of medium dense silty sand (SM).

Qal_3. This unit of fine-grained alluvium consisted of relatively shallow strata composed of soft to very stiff fat clay (CH), stiff to hard sandy fat clay (CH), soft to hard lean clay (CL), medium stiff to very stiff sandy lean clay (CL), and soft lean clay with sand (CL) that were encountered below the levee fill in all borings B-102 and B-104, and interbedded with the Qal_1 unit in borings B-101, B-102 and B-105. The thickness of this unit ranged from approximately 1½ to 9 feet.

Qal_4. This unit consisted of very stiff to hard fat clay (CH) encountered in boring B-104. The 3½-foot-thick stratum was encountered below the Qal_1 unit to a depth of approximately 35½ feet below the existing ground surface.

Qal_5. This unit consisted of very stiff to hard fat clay (CH) encountered in boring B-104. The Qal_5 unit was encountered below the Qal_2 unit to the maximum depth explored, approximately 41 feet below the existing ground surface.

Geotechnical Properties. The results from selected laboratory tests and field data measured at the time of drilling are summarized below.

Summary of Selected Geotechnical Properties

Geologic Unit	Predominant Soil Types	SPT Field N-Value	Range of Dry Unit Weights (pcf)	Range of Moisture Contents (%)	Hydraulic Conductivity (cm/s)	Undrained Shear Strength (ksf)[1]
Af	SM, SC, CL	2-31	68-109	9-29	--	--
Qal_1	SP, SP-SM, SW-SM, SM	2-50	87-106	9-21	1.4×10^{-3}	--

[1] Denoted by the test used to estimate undrained shear strength: p = field pocket penetrometer; t = field torvane, uu = Unconsolidated, Undrained triaxial compression testing; cu – Consolidated, Undrained triaxial shear strength testing

Geologic Unit	Predominant Soil Types	SPT Field N-Value	Range of Dry Unit Weights (pcf)	Range of Moisture Contents (%)	Hydraulic Conductivity (cm/s)	Undrained Shear Strength (ksf)[1]
Qal_2	SM	26	--	--	--	--
Qal_3	CH, CL	4-15	80-94	18-39	1.8×10^{-6} - 6.4×10^{-7}	p = 1.3-4.5+
Qal_4	CH	26	--	--	--	p = 4.5+
Qal_5	CH	19	--	--	--	p = 4.5+

3.3 GROUNDWATER CONDITIONS

Groundwater was encountered in three (3) borings drilled during our July 2012 field exploration program at depths ranging from approximately 11½ feet (B-103) to approximately 13½ feet (B-104) below the ground surface. Groundwater was typically encountered at approximately the same elevation as the water elevation in Arroyo Grande Creek. During our field exploration program, the water in Arroyo Grande Creek was observed to be approximately ½ to 2½ feet deep. Variations in groundwater levels and soil moisture conditions will occur depending on changes in precipitation, runoff, tidal fluctuations, irrigation schedules, and other factors.

4.0 CROSS SECTIONS FOR ANALYSES

As part of our geotechnical investigation, two (2) cross sections were analyzed for seepage and slope stability. The locations of the cross sections, shown on Plate 2, correspond to Stations 80+00 and 124+00, respectively.

The ground surface profiles modeled in the stability analyses were estimated from SH+G (2008), San Luis Obispo County (2012), and Waterways (2012a) topography data, and levee improvement sections included in Waterways (2009a). For the purposes of our analyses, the subsurface conditions were generally modeled as levee fill overlying impervious foundation material and pervious foundation material. The ground surface profiles of the existing levee and proposed levee raise at Station 80+00 were estimated to be a uniformly graded embankment with a trapezoidal cross section. Dimensions of the proposed flood wall at Station 124+00 were estimated on the basis of standard wall design and discussions with Waterways Consulting.

5.0 GEOTECHNICAL ANALYSES

5.1 SEEPAGE EVALUATION

Seepage analyses were performed for the two (2) cross sections with the numerical modeling program SLIDE (Rocscience, 2010). Analyses were performed for steady-state and limited transient seepage conditions corresponding to the water surface elevations estimated by Waterways Consulting (2012b) for the design storm events within Arroyo Grande Creek.

Foundation underseepage refers to hydraulic flow beneath the levee that results when a higher water level (high gradient) in the creek infiltrates the creek bed, and then flows beneath the levee to the lower water level outside the levee (low gradient). Seepage daylighting on an unconfined exterior soil slope could potentially decrease the stability of the slope as a result of sloughing or internal, localized erosion of the embankment material. Sustained through-seepage and erosion can lead to piping, which typically consists of a tunnel-like void that forms within - and can undermine - the embankment when uncontrolled seepage daylights on the face of the exterior levee slope.

Steady-state Analyses. Steady-state seepage is defined as a stabilized water surface elevation in the creek channel, and stabilized seepage flow paths below and through the levee. As input to the seepage analyses, hydraulic conductivity values were selected based on a comparison of laboratory hydraulic conductivity test results, values estimated by the empirical grain size correlations presented in Chapuis (2004), and limited sensitivity analyses. Plates C-1 and C-2 show the estimated hydraulic conductivity values, including data from Fugro (2012), for the levee fill and foundation material, respectively. Both horizontal (k_h) and vertical hydraulic conductivity (k_v) values are input for modeling in SLIDE. Permeability values are assigned by inputting the saturated permeability in the horizontal direction and inputting the vertical to horizontal permeability ratio (k_v/k_h). Estimated k_v/k_h ratios and additional material properties are presented with the results of our seepage and stability analyses in Appendix D. It should be noted that the saturated hydraulic conductivity (k-saturation) values shown in Appendix D are presented in units of feet per second.

In addition, curves representing the variation of permeability (unsaturated permeability) versus matric suction were estimated for our seepage analyses. Without direct measurements, generalized curves based on soil type correlations were selected in SLIDE to estimate the unsaturated permeability of each material.

For the full flood steady-state seepage analyses, the landside extent of our models was defined by a distance of 2,000 feet from the creek centerline. To simulate the general hydrogeologic conditions we anticipate during a steady-state flood event, the phreatic surface was modeled at the landside ground surface.

To evaluate the potential for through-seepage to impact the north levee at Stations 80+00 and 124+00, we approximated the time for the phreatic surfaces estimated in our steady-state seepage analyses to develop and emerge on the levee exterior slopes. Based on our assumption that the levee embankment is uniform in composition, our estimate of the time needed for the phreatic surface to emerge on the landside slope compared the horizontal hydraulic conductivity (seepage velocity) of the levee fill and the length of an approximate through-seepage path within the embankment.

Transient Analyses. In an effort to model the development of seepage forces and phreatic surfaces during a full flood event that is representative of the Arroyo Grande Creek drainage, we conducted a limited transient seepage and stability analyses of the cross sections likely to develop through-seepage or critical underseepage, or sections with estimated factors of safety less than 1.0 relative to steady-state conditions. Cross sections with estimated steady-state analyses results that satisfied performance criteria were not evaluated in our transient analyses. The purpose of our transient analyses was to estimate if the conditions evaluated in our steady-state analyses are likely to develop during the projected duration of the 50-year flood event.

Input parameters applied to the limited transient seepage models were identical to those applied to the steady-state models, with the exception of the initial boundary conditions. For the transient seepage analyses, initial boundary conditions included water surface elevations and groundwater levels estimated on the basis of data collected during our field exploration efforts. In addition, volumetric water content values were estimated on the basis of laboratory results and assigned to subsurface materials to model the initial pore pressure conditions.

To estimate the effects of creek water surface elevations during the 50-yr flood event, we applied the peak water surface elevation to our model for a period of 14 hours. As noted above, during the 50-yr flood event, the water surface elevation would rise above and fall below the peak elevations of the 5-year flood event in approximately 14 hours, according to the hydrograph data defined by Waterways (2012b).

5.1.1 Seepage Criteria

The factor of safety for underseepage is defined as the critical gradient (i_{cr}) divided by the exit gradient (i_e). The critical gradient is defined as the effective unit weight (the difference between the saturated unit weight of soil at the landside toe and the unit weight of water) divided by the unit weight of water. The exit gradient is a measure of upward seepage force defined as the difference in hydraulic head at the top and bottom of a landside soil stratum, divided by the thickness of the soil stratum. Critical seepage conditions exist when the exit gradient equals the critical gradient. If the exit gradient exceeds the critical gradient, piping of the subsurface can erode foundation materials and potentially destabilize the embankment.

Typical performance criteria specify that underseepage beneath an existing levee is acceptable if the exit gradient is 0.5 or less, which would provide a factor of safety against underseepage-related failures of at least about 1.5 for a soil with a minimum submerged unit weight of 110 pcf. However, it should be noted that new levees are typically designed to provide a minimum factor of safety of about 5 or 6 to further reduce the potential for underseepage failure, as the consequences of piping and daylighting seepage adversely and severely impact the stability of a levee slope or foundation.

5.1.2 Results

The results of our seepage analyses for the two (2) cross sections are tabulated below, and presented graphically in Appendix D.

Table 5-1. Results of Seepage Analyses

Section	Design Storm Event Water Surface Elevation (feet)	Exit Gradient at Landside Toe		Factor of Safety		Estimated Time for Phreatic Surface to Emerge on Exterior Slope (hours)
		Steady-State	Transient	Steady-State	Transient	
80+00	**37.2**	**0.13**	**0.05**	**6.5**	**16.9**	**±22**
124+00	**53.8**	**0.03**	**----**	**28.1**	**----**	**+32**

5.2 SLOPE STABILITY

Slope stability analyses were performed for the two (2) cross sections using the numerical modeling program SLIDE (Rocscience, 2010). As input to the stability analyses, parameters including soil unit weight, and drained and undrained shear strength parameters (friction angle [phi] and cohesion) were estimated based on laboratory test results, and a review of the subsurface data and stability analyses included in Fugro (2009, 2012).

We performed stability analyses of the exterior slope for full flood conditions, with water surface elevations and seepage conditions corresponding to the design flood events. Additionally, we performed stability analyses of the interior slope for rapid drawdown conditions, which we anticipate arising as flood water recedes following the design flood events. The conditions evaluated and the results of our slope stability analyses are presented in Appendix D. Phreatic surfaces and pore pressures modeled in our stability analyses of full flood and rapid drawdown conditions were based on the results of our steady-state seepage analyses.

For our stability analyses of full flood conditions, drained shear strength parameters were assigned to the subsurface materials. Plates C-3 and C-4 show the estimated drained strength values, including data from Fugro (2012), for the levee fill and pervious foundation material, respectively. For our stability analyses of rapid drawdown, we conducted three-stage computations for the impervious foundation material. Input to the three-stage computations included both drained and undrained shear strength parameters, which were estimated according to the methods outlined in Appendix G of EM 1110-2-1902 (USACE, 2003) for rapid drawdown analyses.

As noted above, consolidated drained direct shear and consolidated, undrained triaxial strength testing was performed on relatively undisturbed samples collected during our field exploration program. The results of our direct shear and triaxial testing are presented in Appendix B.

5.2.1 Slope Stability Criteria

For the purpose of evaluating analysis results, the San Luis Obispo County (2005) Guidelines for Engineering Geology Reports considers slopes stable when the estimated factor of safety from slope stability analyses is at least 1.5 under static loading conditions. These values are consistent with local practice and California Geologic Survey (CGS 2008) guidelines for slope stability evaluations.

It should be noted that these publications do not specifically address slope stability analyses of full flood and rapid drawdown conditions. We therefore considered a minimum factor of safety equal to 1.4, as specified by the U.S. Army Corps of Engineers [USACE] (2000) for levee slope stability under long-term, steady seepage conditions. For rapid drawdown stability analyses, a minimum factor of safety equal to 1.0 is specified by the USACE (2000) for conditions where elevated water levels are unlikely to persist for long periods preceding drawdown.

In any case, a factor of safety of 1.0 represents the theoretical boundary below which a slope is no longer stable and experiences failure. Minimum factors of safety greater than 1.0, such as those stated above, are typically used to define stable slope conditions in practice to help account for uncertainties in characterizing subsurface conditions and limitations of analyses used to evaluate slope stability.

Previous studies by Fugro (2009) identified that the levee could be impacted by liquefaction and slope instability in response to an earthquake, and was observed near the Cardoza Ranch following the 2003 San Simeon Earthquake. As directed by the County, the scope of the improvements is for flood protection only, and no seismic criteria were considered in evaluating the stability of the levee slopes. We understand potential seismic hazards and repairs to the levees would be performed in response to a damaging seismic event as part of the County's operation and maintenance of the levee.

5.2.2 Results

The results of our slope stability analyses for the two (2) cross sections are tabulated below, and presented graphically in Appendix D.

Table 5-2. Results of Slope Stability Analyses

Section	Levee Slope	Factor of Safety		
		Seepage During Full Flood Event		Rapid Drawdown
		Steady-State	Transient	
80+00	Interior	-----	-----	1.39
	Exterior	1.01	2.0	-----
124+00	Interior	-----	-----	1.91
	Exterior	1.62	-----	-----

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY OF FINDINGS

- Soils encountered within the north levee generally consisted of levee fill material founded on alluvial sediment deposited along Arroyo Grande Creek. The alluvium was encountered to the maximum depths explored, approximately 41½ feet below the ground surface, and consists of interbedded very loose to very dense sandy soils and soft to hard fine-grained materials (see Plates 4a and 4b). Water was flowing in the creek at the time of our July 2012 field exploration program. Groundwater was encountered as shallow as approximately 11½ feet below the existing top of levee and about 7 feet below the exterior toe of the levee in borings drilled for this investigation, suggesting that the foundation soils beneath the levee are always saturated.
- The levee was designed and constructed by the Soil Conservation Service (USDA 1956), and based on blow count data and existing CPT data recorded in our explorations (present study, Fugro 2009, 2012), the levee fill consisted of predominantly medium dense to dense granular soil that appears to have been constructed as an "engineered" compacted fill material. Varying degrees of rodent burrows, vegetation, and loose surface soil were commonly observed along the interior and exterior of the existing levee slopes. Photographs of rodent burrows and loose surface soil on levee slopes are shown on Plate 6. We understand the County actively manages vegetation and rodent activity on the levee, which is common maintenance practice for hydraulic earth structures.
- The estimated factors of safety from our evaluation of the proposed north levee improvements suggest that there is a low potential for underseepage failure (piping or sand boils) relative to the design flow capacities and flood protection of the

proposed Arroyo Grande Creek channel improvements. As the water level in the creek rises, there is a greater head of water driving seepage through the soil and a greater potential for seepage to exit on the slope or destabilize the levee. However, relative to the design storm events and durations, water surfaces corresponding to that amount of flow would likely either recede before there was time for the seepage to exit on the levee slopes, or the south levee would overtop before water surfaces became high enough for critical seepage conditions to develop.

- Based on limited sensitivity analyses of the proposed north levee improvements, the susceptibility of the north levee to underseepage during a flood event is potentially influenced by the depth of the impervious foundation unit characterized as Qal_3 in this report and assumed to be present within the extent of the entire north levee. This unit of fine-grained alluvium was encountered near or just below the levee exterior toe in borings B-104 and B-105, and at an approximate depth of 8½ feet in boring B-105. In addition, the Qal_3 unit was encountered in borings B-101 and B-102 at or above the approximate elevation of the creek invert. Based on our analyses results, the Qal_3 unit helps to reduce the seepage pressures that can pass beneath the levee. In general, estimated exit gradients may exceed the typical performance criteria if the Qal_3 unit is present above the elevation of the levee exterior toe, or if the Qal_3 unit is not present (between our explorations) below the levee fill. Construction monitoring activities should consider the presence of this unit, and whether or not there are localized areas where the seepage conditions may be more critical than those analyzed. If the Qal_3 unit is not present in certain areas, additional seepage analyses should be performed to evaluate the need for mitigation in those areas.

- In the event that there was sufficient time for steady-state conditions to develop at the design water surface elevation, our evaluation of the proposed north levee improvements at Station 80+00 estimates that there would be a potential for seepage to exit on the exterior slope and instability of the exterior levee slope due to increased pore pressures (i.e. seepage pressures) within the levee fill material. However, on the basis of discussions with Waterways and review of hydrograph data for the 50-year flood event, the duration of the elevated water surfaces during the 50-year flood event is less than the estimated duration for steady-seepage conditions to develop within the levee fill. Based on the results of a limited transient analysis of the 50-year flood event at Station 80+00, there is low potential for through seepage and slope instability relative to the design flow capacities and flood protection of the proposed Arroyo Grande Creek channel improvements.

- As discussed in the Fugro (2009) report, alluvium encountered beneath the levee is vulnerable to being impacted by seismic hazards that could result in settlement and instability of the levee slopes. The levees were damaged by liquefaction of the alluvium in the vicinity of Stations 30+00 to 35+00 during the 2003 San Simeon Earthquake. Consideration of these seismic hazards was not a part of our evaluation, and we understand that the current design considerations of the Arroyo

Grande Creek Levee improvements are intended to improve the levee relative to flood control only.

6.2 SEEPAGE AND SLOPE STABILITY CONSIDERATIONS

For our seepage and stability analyses of the proposed levee improvements, we considered water surface elevations corresponding to flood events specific to the levee section evaluated, in accordance with the design proposed by Waterways (2012b). We understand historical flood events with peak flows approximately equal to 5,070 cfs have occurred since the construction of the Arroyo Grande Creek levee system, and that there have been no reports of seepage daylighting on the exterior levee slopes or sand boils having developed beyond the exterior toe of the levee.

The groundwater conditions encountered suggest that the foundation soils beneath the levee embankments are saturated to some extent by the normal dry-season water flow within the creek. As a result, it is possible that rising water levels within the channel may increase the rate of seepage beneath the embankment relatively quickly. Two general cases were evaluated: whether or not seepage through the proposed levee embankment could occur on the north side of Arroyo Grande Creek, and whether or not underseepage could reduce the proposed north levee improvement's stability due to piping, seepage, or sand boils developing near or beyond the exterior toe of the levee or floodwall footing.

Underseepage. Steady-state underseepage analyses of Stations 80+00 and 124+00 estimated exit gradients of 0.13 and 0.03, respectively, which correspond to factors of safety equal to about 6.5 and 28.1. These factors of safety exceed typical performance criteria for existing levees, and susceptibility to underseepage during the design flood events is generally not considered a potential deficiency of the proposed north levee improvements. In our opinion, no special mitigation measures for underseepage are needed for design of the proposed improvements.

Based on limited sensitivity analyses of the proposed north levee improvements, the susceptibility of the north levee to underseepage during a flood event is potentially influenced by the depth of the impervious foundation unit characterized as Qal_3 in this report and assumed to be present within the extent of the entire north levee. This unit of fine-grained alluvium was encountered near or just below the levee exterior toe in borings B-104 and B-105, and at an approximate depth of 8½ feet in boring B-105. In addition, the Qal_3 unit was encountered in borings B-101 and B-102 at or above the approximate elevation of the creek invert. Based on our analyses results, the Qal_3 unit helps to reduce the seepage pressures that can pass beneath the levee. In general, estimated exit gradients may exceed the typical performance criteria if the Qal_3 unit is present above the elevation of the levee exterior toe, or if the Qal_3 unit is not present (between our explorations) below the levee fill. Construction monitoring activities should consider the presence of this unit, and whether or not there are localized areas where the seepage conditions may be more critical than those analyzed. If the Qal_3 unit is not present in certain areas, additional seepage analyses should be performed to evaluate the need for mitigation in those areas.

Through Seepage. Through-seepage analyses estimated the time for steady-state seepage conditions to potentially develop and phreatic surfaces to emerge on the exterior slopes at Stations 80+00 and 124+00 to be approximately 22 and 32 hours, respectively. We understand the anticipated duration of elevated water surfaces during the 50-year flood event (and any flood event with a shorter recurrence interval) is less than the times noted above. Therefore, susceptibility to through-seepage during the design events is not considered a potential deficiency of the existing north levee. However, we expect the potential for through-seepage would increase for longer duration storm events. In our opinion, no special mitigation measures for through seepage are needed for design of the proposed improvements.

Slope Stability. With the exception of the exterior slope at Station 80+00, the slopes of the proposed north levee improvements appear to be stable relative to the steady-state full flood conditions. The exterior levee slope at Station 124+00 had an estimated factor of safety of 1.6 for steady-state full flood conditions. In addition, the interior slopes at Stations 80+00 and 124+00 had estimated factors of safety equal to about 1.4 and 1.9, assuming rapid drawdown conditions. These factors of safety meet or exceed typical performance criteria for new levees.

Our evaluation of the proposed north levee improvements at Station 80+00 suggest that the exterior slope is marginally stable (FS=1) during steady-state flood conditions. The estimated factor of safety is a result of increased pore pressures (i.e. seepage pressures) that develop within the levee fill material and decrease the shear strength of the material. However, based on discussions with Waterways and review of hydrograph data for the 50-year flood event, we understand that the duration of elevated water surfaces during the 50-year flood event is less than the estimated duration for steady-seepage conditions to develop within the levee fill.

As noted above, to estimate the effects of transient creek water surface elevations during the 50-yr flood event, we applied the peak water surface elevation to our model of Station 80+00 for a period of 14 hours. Based on our limited transient seepage analysis at Station 80+00, the seepage conditions estimated by our steady-state analyses are generally not representative of the anticipated design flood conditions at Arroyo Grande Creek. The exterior levee slope at Station 80+00 had an estimated factor of safety of 2.0 for transient full flood conditions. In our opinion, the potential for slope instability during the design flood events is low relative to the proposed north levee improvements.

Operations, Maintenance and Flood Inspection. In general, slope instability during the design flood events, and instability as water recedes immediately following those events (rapid drawdown), is not considered a potential deficiency of the proposed north levee improvements. Nevertheless, as part of their inspection efforts, the County should consider that if seepage were to exit on the exterior slopes of the levee, those conditions could destabilize the levee and the proposed levee would have no provisions to control seepage. The condition of the levee should be checked following major storm events to evaluate if there has been scour or erosion of the slopes that could adversely impact embankment stability.

6.3 SUGGESTED MATERIALS SPECIFICATIONS

The following are suggested materials specifications for materials that we have referenced in this report.

Compacted Fill shall consist of on-site or imported materials that are free of organics, oversized rocks (greater than 3 inches) trash, debris, corrosive and other deleterious material. Imported fill shall be reviewed by the geotechnical engineer prior to being brought to the site; however, imported fill materials shall comply with all specifications for material placed at the site. Fill materials shall comply with all specified material requirements for the area where the material is being placed.

Drainage Material shall conform to the Caltrans Standard Specification for Caltrans Class Type 1A Permeable Material or ASTM C-33 No. 8 coarse aggregate (pea gravel) provided the materials are enclosed in a geotextile.

Geotextile for separation (filter fabric) shall consist of material that conforms to the requirements outlined in the Caltrans Standard Specifications for Filter FabricClass C, Section 88-1.02.

Geotextile for subgrade stabilization shall conform to the requirements outlined in Caltrans Standard Specifications for Rock Slope Protection Fabric - Class 8, Section 88-1.02.

Retaining wall backfill material shall consist of either on-site or imported material conforming to Caltrans Standard Specifications for Structure Backfill, Section 19-3.02B.

6.3.1 Use of On-site Materials

Fill materials for the project are expected to include common borrow for constructing the levee berm, and structure backfill for floodwalls. On-site soil consisting of fill and alluvial deposits that is free of debris, organics, oversized rocks, and other deleterious materials should be suitable for use as compacted fill. The onsite materials encountered consisted of sandy clay, lean clay, fat clay, silty sand, clayey sand, sand with silt, and poorly graded sand with varying water contents. As excavated, the on-site soil may be too wet to be suitable for placement and compaction. If the material excavated can be hauled to an area where it can be spread out, disked, and dried to a compactable moisture content prior to placement, it is our opinion that excavated on-site soil can be used as compacted fill material. The project is in close proximity to the Pacific Ocean. Overcast and foggy weather may affect drying wet material.

Selected soils (silty sand [SM], sand with silt [SP-SM], and sand [SP]) may be suitable for use as structure backfill for floodwall construction. These materials maybe interbedded with fine grained soils that are not considered suitable for structure backfill. Segregation and processing of the on-site sandy materials may be needed to make the excavated material suitable for use as structure backfill.

6.4 GRADING - GENERAL

Fill placement and grading operations should be performed according to the recommendations of this report. We recommend that, unless otherwise recommended, fill and backfill materials be compacted to at least 90 percent relative compaction, as determined by the latest approved edition of ASTM Test Method D1557. Trench backfill, within 3 feet of finished grade, placed below pavement areas should be compacted to at least 95 percent relative compaction.

6.4.1 Clearing and Grubbing

Clearing and grubbing should be performed to initiate construction and prior to fill placement. Existing pavement, debris, organics, loose or disturbed materials, and other unsuitable materials should be excavated and removed prior to commencing fill placement. Demolition areas should be cleared of existing fill, vegetation, pavement, abandoned utilities, and soil disturbed during the clearing and grubbing process. Depressions left from the removal and demolition of materials should be replaced with compacted fill. Fill placement and compaction can then be performed according to the recommendations of this report.

6.4.2 Fill Placement

Fill should be placed and compacted to at least the minimum relative compaction recommended in this report. The moisture content of the fill should be suitable to achieve the recommended compaction, generally between approximately 2 percent below to 2 percent above the optimum. Each layer should be spread evenly and should be thoroughly blade-mixed during the spreading to provide relative uniformity of material within each layer. Jetting and ponding of water to assist with compaction should not be permitted for fill placement. Soft or yielding materials should be removed and be replaced with properly compacted fill material prior to placing the next layer.

Fill should be spread in lifts that will allow to the soil to be compacted to the specified compaction with the equipment being used, generally no thicker than approximately 8 inches prior to being compacted. Fill and backfill materials may need to be placed in thinner lifts to achieve the recommended compaction with the equipment being used

Rocks larger than 3 inches in diameter, organics, and other deleterious material should not be permitted within the fill material being placed. Rocks should not be nested, and voids should be filled with compacted material.

When the moisture content of the fill material is above or below that sufficient to achieve the recommended compaction, the material should be dried or wetted to near optimum moisture, and bladed and mixed to provide for relatively uniform moisture content throughout the material. Soft or yielding materials should be removed and replaced with properly compacted material prior to placing the next layer of fill. Fill and backfill materials may need to be placed in thinner lifts to achieve the recommended compaction with the equipment being used.

Graded slopes should be finished by placing compacted fill beyond the limits of the finished grade and then be cut back to expose compacted material at the slope face or the finished subgrade elevation below liners.

6.5 LEVEE EMBANKMENT IMPROVEMENTS

The existing levee embankments will be raised up to approximately 3½ feet or more above the existing levee crest elevations along most of the alignment. We understand that the typical embankment section will be approximately 15 feet wide at the top and constructed with interior and exterior slope inclinations of 2h:1v and 1.5h:1v to 2h:1v, respectively. Within sections of the project extent with limited right-of-way, improvements will generally be constructed with floodwalls, if necessary, or within the existing footprint of the levees utilizing slightly steeper inclinations than the existing slopes.

Settlement Considerations. We estimate that settlement of the proposed levee embankments resulting from static loads should generally be less than 1 inch. However, as noted in Fugro (2009), the proposed levee improvements are located in areas that may be prone to seismic settlement. Consideration of these seismic hazards was not a part of our evaluation, and we understand that the current design considerations of the Arroyo Grande Creek Levee improvements are intended to improve the levee relative to flood control only.

6.5.1 Grading for Levee Improvements

The recommended grading for unreinforced levee improvements is summarized on Plate 7. Fill material and placement should be performed according to the recommendations of this report. Where new embankment is constructed against an existing slope, the fill materials should be keyed and benched into the existing slope. As shown on Plate 6, we observed rodent burrows and could easily probe the fill by hand to depths of up to 4-feet on the existing levee slopes. To improve the existing embankment slopes impacted by rodent burrows, keying and benching should remove the outer 5 feet of the existing embankment materials, as shown on Plate 7. The upper 1-foot of the top of the embankment should be removed and the exposed subgrade scarified and recompacted to at least 90 percent relative compaction.

We recommend that the geotechnical engineer review the limits of excavation and benching during grading operations to evaluate whether or not existing loose material is removed prior to the placement of compacted fill. The project specifications should provide for variations in the limits of excavation, and for removal of additional loose or unsuitable material beyond the specified limits of keying and benching, if needed.

6.5.2 Subgrade Stabilization

Shallow groundwater and wet subgrade conditions are not anticipated during construction of the proposed levee raise. However, wet subgrade conditions may be encountered during construction of the three (3) concrete floodwalls shown on the Alternative 3a conceptual plans as measuring approximately 361 linear feet in total length. In addition, variations in groundwater levels and soil moisture conditions will occur depending on changes in precipitation, runoff, tidal fluctuations, irrigation schedules, and other factors. As a result, subgrade stabilization may become necessary during construction, and should be considered an option by the construction team.

Where wet subgrade conditions are encountered, we recommend that the bottom of the excavation be excavated using construction equipment that will reduce the potential for disturbance of the subgrade, such as an excavator operating outside the limits of the excavation. We recommend that at least 1 foot of drainage material wrapped in a geotextile (for stabilization) be placed in the bottom of the excavation to help stabilize the subgrade prior to placement of the subsequent fill and compaction. The gravel should be entirely encased in the geotextile prior to placing subsequent fill materials.

The project specifications should provide for geotechnical review of the subgrade conditions at the time of excavation, and for increasing gravel thickness and the depth of excavation, if needed, to remove additional loose or soft material.

6.6 SCOUR CONSIDERATIONS

Channel deposits encountered within Arroyo Grande Creek during the Fugro (2009) investigation consisted of silty sand, poorly-graded gravel with sand, and well-graded sand with gravel. Based on our field exploration in July 2012 and Fugro (2012), the existing levee fill material consists of silty sand with gravel, clayey sand, poorly-graded sand with silt and gravel, and lean clay with sand. Localized areas of scour and/or sloughing were observed on the existing interior levee slopes during the Fugro (2009) field exploration.

The exposed channel, estuarine deposits, and levee materials consisting of alluvial silts and fine sand are likely to scour at stream flow velocities of approximately 1.5 to 3.5 feet per second for clear and silty water conditions, respectively. On-going maintenance or other measures should be provided to reduce the potential for scour and erosion of the levee embankment.

6.7 FLOOD WALL DESIGN

The proposed flood walls can be supported on shallow foundations. Groundwater was encountered approximately 12½ feet below the existing top of levee in the vicinity of the proposed flood wall alignment. Depending on the final design plans, the proposed wall alignment may be underlain by loose, moist to wet sand materials that may be relatively difficult to excavate without dewatering the site. Based on discussions with Waterways, we understand the wall will likely be about 5 feet or more in height and will be supported on shallow foundations.

In additional to foundation support considerations, the design of floodwalls and hydraulic structures should also consider the potential for uplift forces to act on the base of the wall. Based on our analysis of the proposed floodwall at Station 124+00, we do not anticipate the need to control seepage below the wall. A schematic of the proposed flood wall dimensions modeled for our analysis is shown on Plate D-2a.

6.7.1 Shallow Foundation Design

Footing Preparation and Compaction. Footings should be embedded into relatively undisturbed existing soils at or below the elevation of the exterior slope toe. For the three (3) concrete floodwalls shown on the Alternative 3a plans, the following table lists the estimated minimum exterior slope toe elevations:

Approximate Location of Floodwall	Minimum Exterior Slope Toe Elevation (ft)
22nd Street Bridge to Station 73+23	27
Station 122+88 to Station 125+28	48
Station 128+40 to Station 129+10	52

The geotechnical engineer (Fugro) should review the foundation excavation during construction to evaluate if the foundation soils encountered appear suitable for support of the new footings. Based on the observations, we may recommend that the excavation(s) be deepened, if needed, to embed the footing below the existing fill or to remove loose or disturbed materials. The plans and specifications should include provisions for deepening the footing. Once the excavation is bottomed in suitable soil, the bottom of the excavation should be moisture conditioned and compacted to provide at least 95 percent relative compaction within the upper 1 foot of the footing excavation. Because the underlying soil may be relatively loose, it may take additional passes and compactive effort to achieve the recommended compaction. The backfill around the footing can consist of on-site sandy soil compacted to at least 95 percent relative compaction or 2-sack sand-cement slurry where the footings are located in close proximity to adjacent structures.

Spread Footing Design. Spread footings bearing on compacted fill or undisturbed alluvium can be designed using a maximum allowable bearing pressure of 2,500 pounds per square foot (psf). Spread footings should have a width of at least 4 feet and be embedded at least 3½ feet below the adjacent grade. Footings should be embedded deeper than 3½ feet, if needed, such that the top of the footing is setback at least 7 feet horizontal from the face of an adjacent slope. The recommended bearing pressure can be increased by 600 psf and 1,600 psf for each additional foot of footing width and embedment, respectively, to a maximum of 4,000 psf. The recommended bearing pressures are estimated for a factor of safety of 1.5.

Reinforcing of foundations should be designed by the structural engineer based on loading conditions and reinforced concrete design. The anticipated bearing materials and soil conditions encountered at the site are considered non-expansive, and therefore additional reinforcement to address expansive soil conditions does not need to be considered for foundation design.

Resistance to Uplift. The ultimate uplift resistance can be resisted by the dead weight of the footing plus the soil overburden pressure above the footing. The soil unit weight can be estimated as 110 pounds per cubic foot.

Settlement Considerations. We estimate that settlements resulting from static foundation loads should be approximately 1-inch total and approximately ¾-inch differential in 30 feet for foundation elements designed according to the recommendations of this report. As noted in Fugro (2009), the proposed floodwalls are located in areas that may also be prone to seismic settlement. Consideration of these seismic hazards was not a part of our evaluation, and we understand that the current design considerations of the Arroyo Grande Creek Levee improvements are intended to improve the levee relative to flood control only, with no mitigation measures for seismic settlement or liquefaction.

Resistance to Lateral Loads. Resistance to lateral loading can be provided by sliding friction acting on the base of spread footings combined with passive pressure acting on the sides of footings. We recommend that a coefficient of friction of 0.5 be used to estimate the sliding resistance along the bottoms of footings bearing in compacted soil. We recommend that a passive resistance of 250 pounds per cubic foot, equivalent fluid weight, be used to estimate the lateral resistance acting on the sides of footings or grade beams. One half of the recommended passive resistance should be used when considering that the foundation could be submerged. Passive resistance should not be used for the upper one foot of soil that is not constrained at the ground surface by slab-on-grade or pavement.

6.7.2 Construction Considerations

Groundwater and Dewatering. The site is located within a coastal riparian environment that is subject to flooding. Groundwater was encountered during our field exploration program at approximately 11½ feet or greater below the existing ground surface and was observed flowing within the creeks. Groundwater and water levels within the creeks are expected to fluctuate due to tidal changes, runoff and other factors. We expect that dewatering to control subsurface water may be needed as part of the construction of the proposed levee improvements. Depending on the time of construction, there is a potential for runoff or rainwater to enter the construction area. Pumps, temporary culverts or other methods to remove and/or divert water within the construction areas may be needed to control surface and/or groundwater during construction. Dewatering systems should be designed such that sumps and wells are properly filtered, and such that fines are not removed from foundation support soils during dewatering. Dewatering systems should be designed by a qualified registered professional. A dewatering plan and supporting analyses should be submitted to the geotechnical professional for review prior to mobilizing equipment to the site.

6.7.3 Lateral Earth Pressures

Our recommended equivalent fluid weights presented below are for conditions where the backfill material is placed level behind retaining walls. We recommend that the following lateral earth pressures (equivalent fluid weights) be used for the design of the proposed floodwalls:

Static Lateral Earth Pressures

Wall Loading Condition	Lateral Earth Pressure Condition	Equivalent Fluid Weight (pcf)
Free Standing	Active - Drained	40
Free Standing	Active - Undrained	20 + Water (62.4)

The recommended equivalent fluid weights do not account for surcharge loads acting on the backfill. The surcharge from foundation or surface loads can be neglected, provided the adjacent load is applied or setback behind a 1:1 line projected upward from the base of the wall. The lateral earth pressure from uniform surcharge loads can be estimated as 0.3 times the stress being applied at the ground surface. Traffic surcharges can be estimated as an additional 2 feet of soil cover, equal to a uniform pressure of 220 pounds per square foot. Fugro should provide additional recommendations if foundation loads act within the 1:1 line, or other surcharges to retaining walls are anticipated.

6.7.4 Seismic Considerations

Structures should be designed to resist the lateral forces generated by earthquake shaking in accordance with the building code and local design practice. This section presents seismic design parameters for use with the 2010 California Building Code (CBC). The USGS interactive website “Seismic Design Values for Buildings” (USGS 2008) was used to obtain seismic design criteria. Based on these criteria, the seismic data for use with code-based designs are:

California Building Code	Seismic Parameter	Value
Site Coordinates	Latitude, degrees	35.0938
	Longitude, degrees	-120.6027
Section 1613.5.1 Figure 1613.5	Ss , Seismic Factor, Site Class B at 0.2 sec	1.221
	S_1, Seismic Factor, Site Class B at 1 sec	0.446
	Site Class	S_D, Stiff soil
Section 1613.5.3 Table 1613.5.3(1)	Fa, Site Coefficient for Site Class	1.012
Section 1613.5.3 Table 1613.5.3(2)	Fv, Site Coefficient for Site Class	1.554
Section 1614A	S_{MS}, Site Specific Response Parameter for Site Class at 0.2 sec.	1.235
	SM1, Site Specific Response Parameter for Site Class D at 1 sec.	0.693
	$S_{DS} = 2/3\ S_{MS}$,	0.823
	$S_{D1} = 2/3\ S_{M1}$	0.462

As noted above, the soils encountered have a potential for liquefaction, and special considerations to address liquefaction or seismic settlement may be needed for design. Based on the seismic design parameters calculated by the USGS Hazard Calculator, and per 2007 CBC Section 1613A.5.6, structures of Occupancy Category I, II, III and IV (defined in 2007 CBC Table 1604.5) should be designed according to Seismic Design Category “D”.

6.8 CORROSION CONSIDERATIONS

Corrosivity testing was not performed as part of our investigation. However, according to the Caltrans Corrosion Guidelines, a corrosive area is defined where "…the soil and/or water contains more than 500 ppm of chlorides, more than 2,000 ppm of sulfates, has a minimum resistivity of less than 1,000 ohm-cm, or has a pH less than 5.5." Corrosion mitigation measures should be considered for reinforced concrete structures that are subject to a marine/estuarine environment with chloride levels exceeding 10,000 ppm. The selection of concrete types and cement contents, need for epoxy coating on rebar, and concrete density should be selected with consideration of the corrosion test results.

6.9 EROSION AND MAINTENANCE

During our field exploration program, areas of surficial erosion and sloughing were observed along the existing levee adjacent to the creek. Permanent erosion control measures or on-going maintenance of the levee should be provided as-needed to maintain stable slopes and repair erosion. Maintenance should include controlling and repairing rodent burrows within the levee, and inspecting the levee banks during and following storms events to identify any signs of seepage and erosion on the embankment.

7.0 CONTINUATION OF SERVICES

The geotechnical evaluation consists of an ongoing process involving the planning, design and construction phases of the project. To provide this continued service, we recommend that the geotechnical professional be provided the opportunity to review the project plans and specifications, and observe portions of the site grading, wall excavations, levee construction, and fill placement during construction.

Subsurface conditions, excavations and fill placement should be reviewed by the geotechnical professional during construction to evaluate if the subsurface conditions encountered and construction methods are consistent with those assumed for design. The geotechnical professional should also review the project plans and specifications prior to construction. The purpose of the review is to evaluate if the plans and specifications were prepared in general accordance with the recommendations of this report.

The exploration and evaluation of the site conditions is as much a part of earthwork construction as it is of design. Subsurface conditions, excavations and fill placement should be reviewed by the geotechnical professional during construction to evaluate if the subsurface conditions encountered and construction methods are consistent with those assumed for design. Construction observation should include materials testing to assess conformance of proposed materials with the approved plans and specifications. The geotechnical professional should also review the project plans and specifications prior to construction. The purpose of the review is to evaluate if the plans and specifications were prepared in general accordance with the recommendations of this report.

8.0 REFERENCES

California Department of Transportation (1956), Log of Test Borings, Arroyo Grande Creek Bridge As-Built Plans, Contract No. 5S-SVC22.

California Department of Transportation (1984), Log of Test Borings, Arroyo Grande Creek Bridge (Widen) As-Built Plans, Contract No. 05-200204.

California Geologic Survey (2008), *Guidelines for Evaluating and Mitigating Seismic Hazards in California*, Special Publication 117A, revised and re-adopted September 11, 2008.

Fugro (2009), *Preliminary Geotechnical Report, Arroyo Grande Creek Waterways Management Plan, Los Berros Creek to Near Oceano Airport, San Luis Obispo County, California*, dated April 22.

Fugro (2012), *Limited Geotechnical Report, Seepage Evaluation of the Existing Arroyo Grande Creek North Levee, San Luis Obispo County, California*, dated March 12.

GEO-SLOPE International, Ltd. (2010), "GeoStudio 2007 (Version 7.16, Build 4840)", Calgary, Alberta, Canada.

Hall, C.A. (1973), *Geologic Map of the Arroyo Grande 15' Quadrangle, San Luis Obispo County, California*, California Division of Mines and Geology, Map Sheet 24.

Holzer, T.L., Noce, T.E., Bennett, M.J., Di Allessandro, C., Boatwright, J., Tinsley III, J.C., Sell, R.W., and Rosenberg, L.I. (2004), *Liquefaction-Induced Lateral Spreading in Oceano California, During the 2003 San Simeon Earthquake*, United States Geological Survey, Open-File Report 2004-1269.

Morro Group (2008), "Flood Control Zones 1 & 1A Arroyo Grande Creek Waterway Management Program, Scope of Work Cost Estimate", dated March 17.

Rocscience Inc. (2010), "SLIDE (Version 6.005, Build Date: Sep 11 2010)" Toronto, Ontario, Canada.

San Luis Obispo County (1984), Log of Test Borings, 22nd Street Bridge Across Arroyo Grande Creek As-Built Plans, Job No. P12A2GI.

San Luis Obispo County (1999), "Safety Element, San Luis Obispo County General Plan", Department of Planning and Building, adopted December 14, 1999.

San Luis Obispo County (2005), Guidelines for Engineering Geology Reports, Department of Planning and Building.

San Luis Obispo County (2012), personal communication, email titled "RE: AG Channel Levee As-Builts", dated January 30.

Swanson Hydrogeology + Geomorphology (2008), Scope of Work Re: Arroyo Grande EIR, dated February 4.

U.S. Army Corps of Engineers (1995), Engineering Manual 1110-2-1911, *Construction Control for Earth and Rock-Fill Dams*, 30 September.

U.S. Army Corps of Engineers (2000), Engineering Manual 1110-2-1913, *Engineering and Design, Design and Construction of Levees*, 30 April.

U.S. Army Corps of Engineers (2003), Engineering Manual 1110-2-1902, *Engineering and Design, Slope Stability*, 31 October.

U.S. Department of Agriculture Soil Conservation Service (1956), Arroyo Grande Cr. Channel Improvement Plans, Arroyo Grande Watershed Project.

Waterways Consulting (2009a), Conceptual Plans, Arroyo Grande Creek Channel Levee Raise for Alternative 3A, dated September 15.

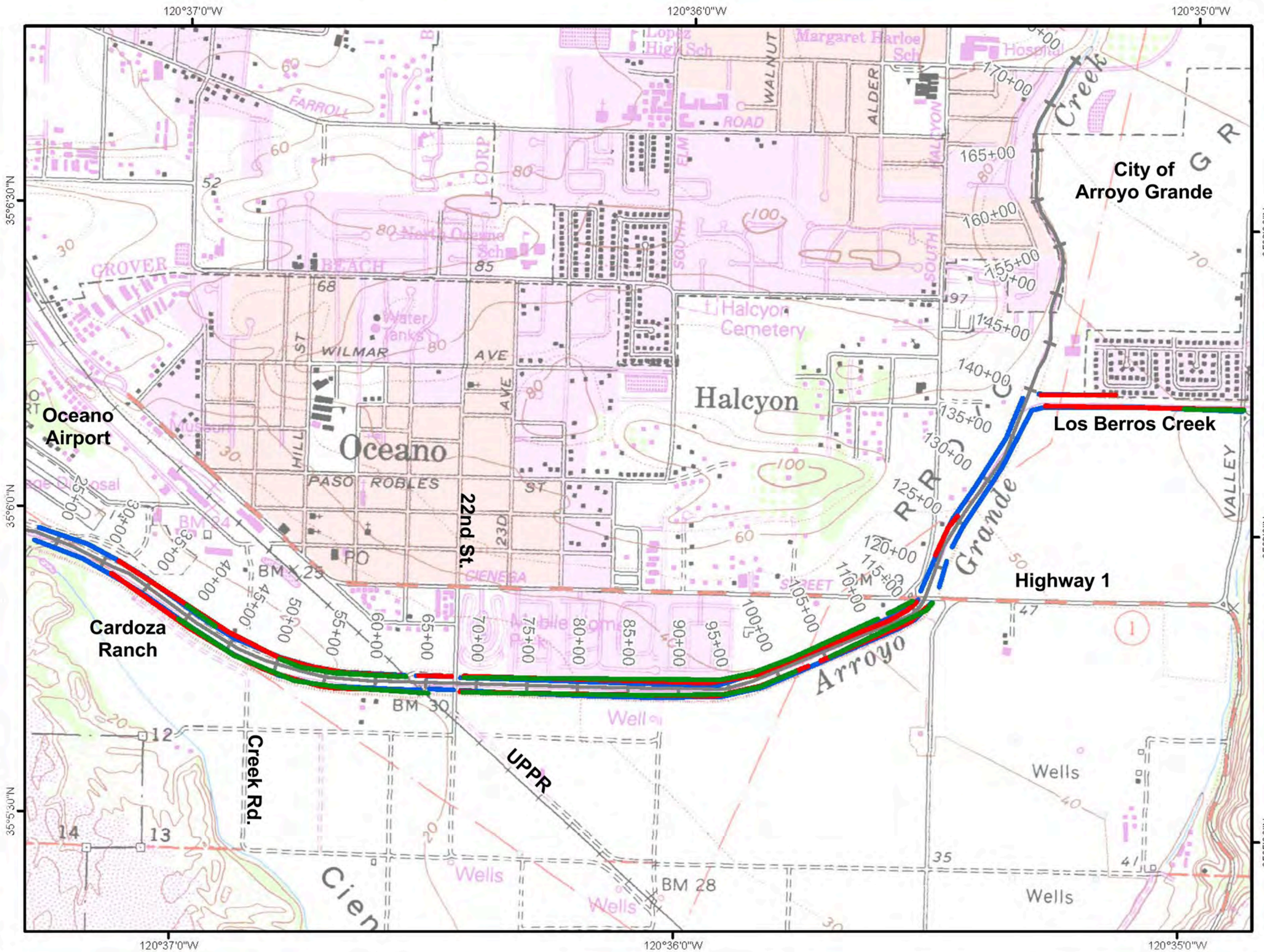
Waterways Consulting (2009b), Conceptual Plans, Arroyo Grande Creek Channel Levee Raise for Alternative 3C, dated September 15.

Waterways Consulting (2011), Technical Memorandum, Arroyo Grande Creek Hydraulic Analysis for Existing Conditions Levee Overtopping, dated September 30.

Waterways Consulting (2012a), Preliminary Arroyo Grande Creek Cross Sections, Arroyo Grande Creek Channel Analysis, dated August 1.

Waterways Consulting (2012b), personal communication, email titled "Arroyo Grande Creek Design Summary", dated September 7

PLATES



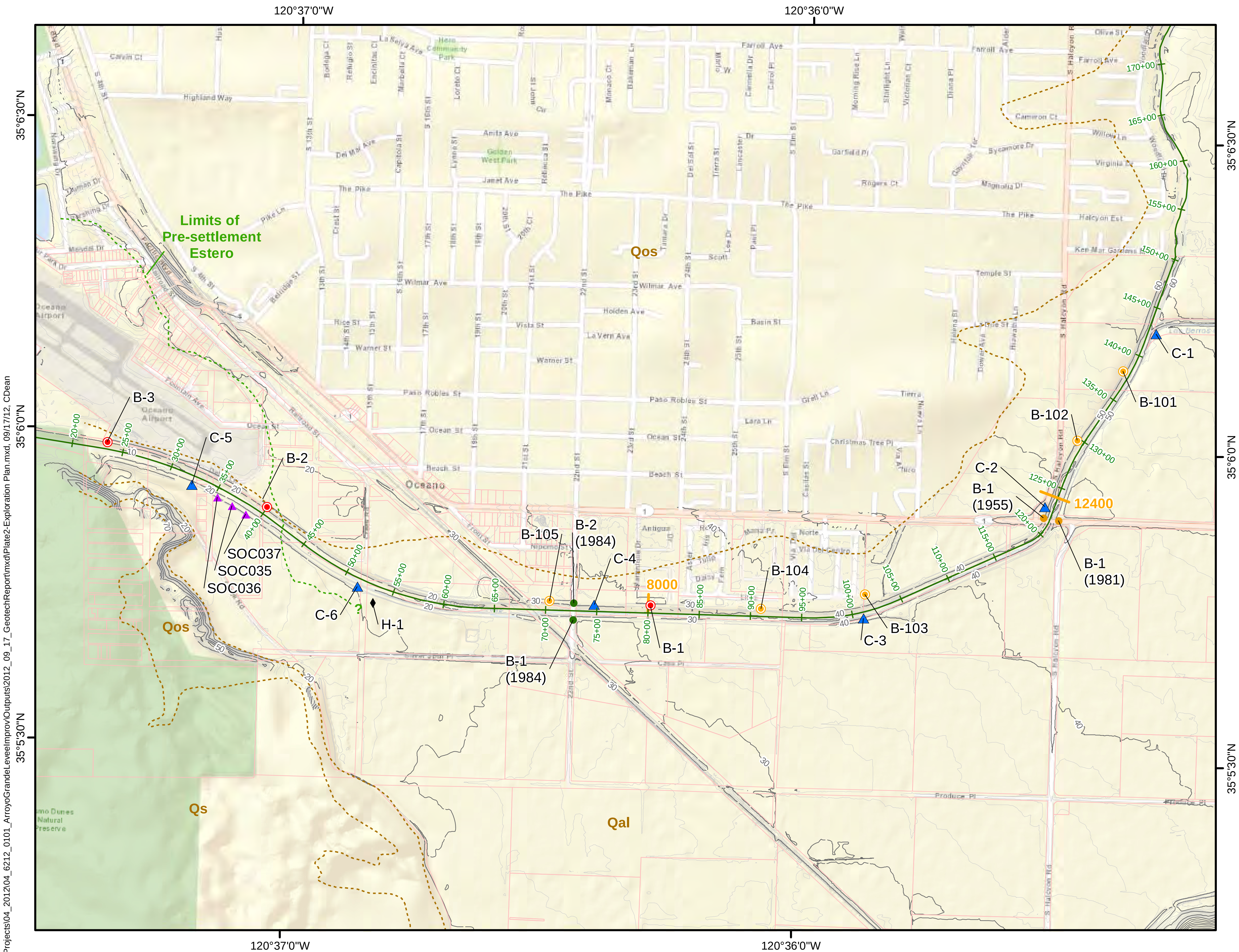
Legend

- Alt-3a Proposed levees
- Alt-3b Proposed levees
- Alt-3c Proposed levees
- Centerline Along Levee with Stationing

Horizontal Scale: 1:12,000

0 500 1,000 2,000 Feet

SITE MAP
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California



Legend

Approximate Exploration Locations

- 2012 Fugro Boring (July)
- 2012 Fugro Boring (January)
- 2008 Fugro CPT
- 2003 USGS SCPT
- Caltrans Boring (1955 and 1981)
- SLO County Boring (1984)
- 2008 Fugro Hand Auger Boring
- 8000 Cross Section Line
- 90+00 Centerline Along Levee with Stationing
- 10 foot contour
- 2 foot contour
- Parcels within Zones 1 and 1a

Geology

- Qal Alluvial Deposits
- Qs Sand Dune Deposits
- Qos Older Sand Dune Deposits
- Contact
- Limits of Pre-settlement Estero

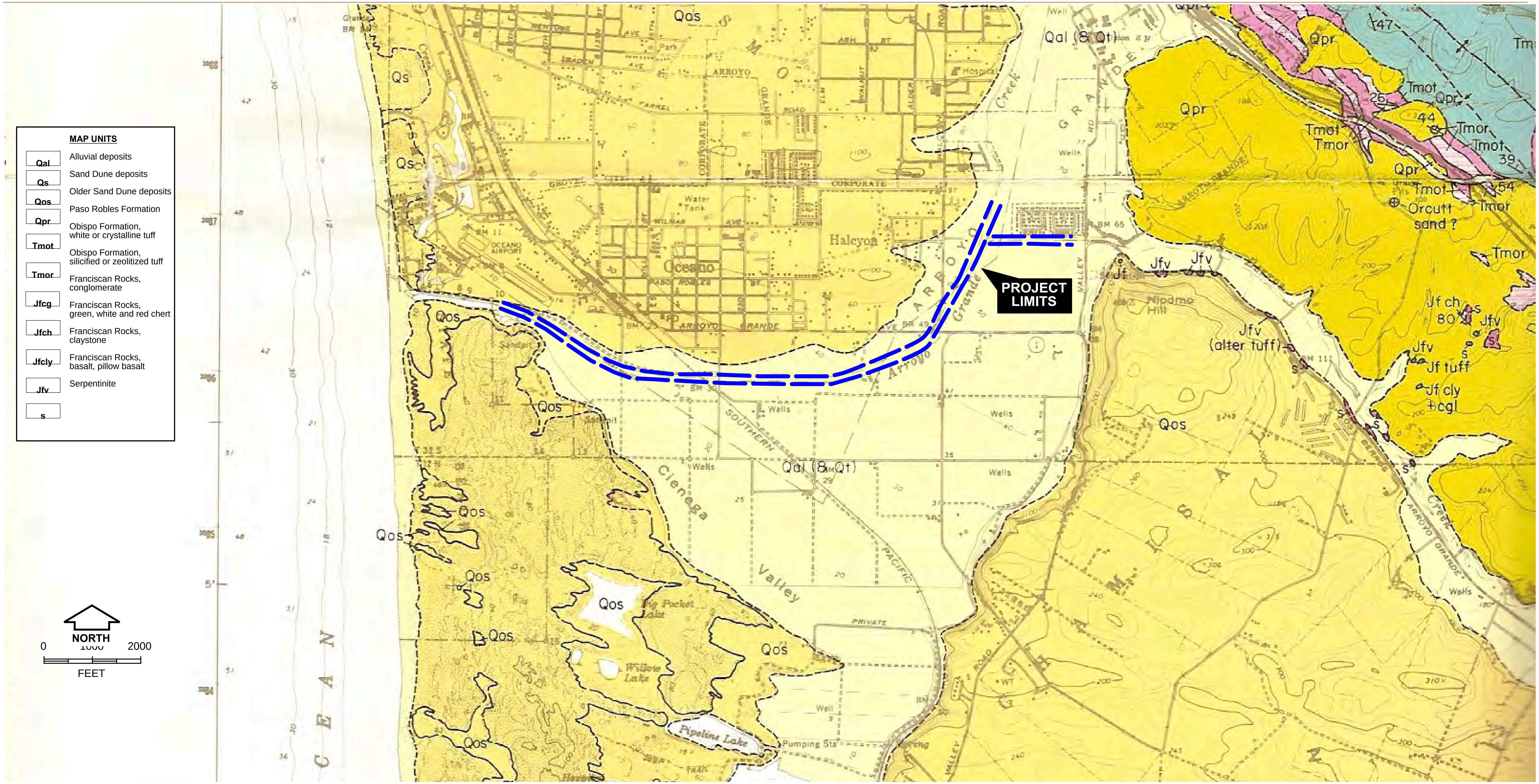
N

Horizontal Scale: 1:12,000

1,000 500 0 1,000 Feet

FIELD EXPLORATION PLAN
Arroyo Grande Creek
Levee Improvements
San Luis Obispo County, California

PLATE 2



BASE MAP SOURCE: Geology of the Arroyo Grande 15' Quadrangle, San Luis Obispo County (Hall, 1973).

LEGEND

Contact - Dashed where approximately located or inferred; queried where doubtful; dotted where concealed

High-angle fault - Dashed where approximately located or inferred; dotted where concealed and inferred; queried where uncertain. Arrows show relative direction of movement on cross sections when known; queried where uncertain.

Thrust or reverse fault - Dashed where approximately located or inferred, dotted where concealed and inferred; queried where concealed or doubtful. Sawteeth on upper plate. Dip of fault plane between 30° and 80°

Photo lineament - Queried where uncertain

Synform - Trace of axis at surface. Dashed where approximately located. Flanks coverate downward in folds and in rocks whose stratigraphic sequence is unknown.

Antiform - Trace of axis at surface. Dashed where approximately located. Flanks diverge downward in folds and in rocks whose stratigraphic sequence is unknown.

Strike and dip of beds uncertain

Marker beds

Conglomerate or gravel bed

Sandstone

Siltstone or diatomaceous siltstone

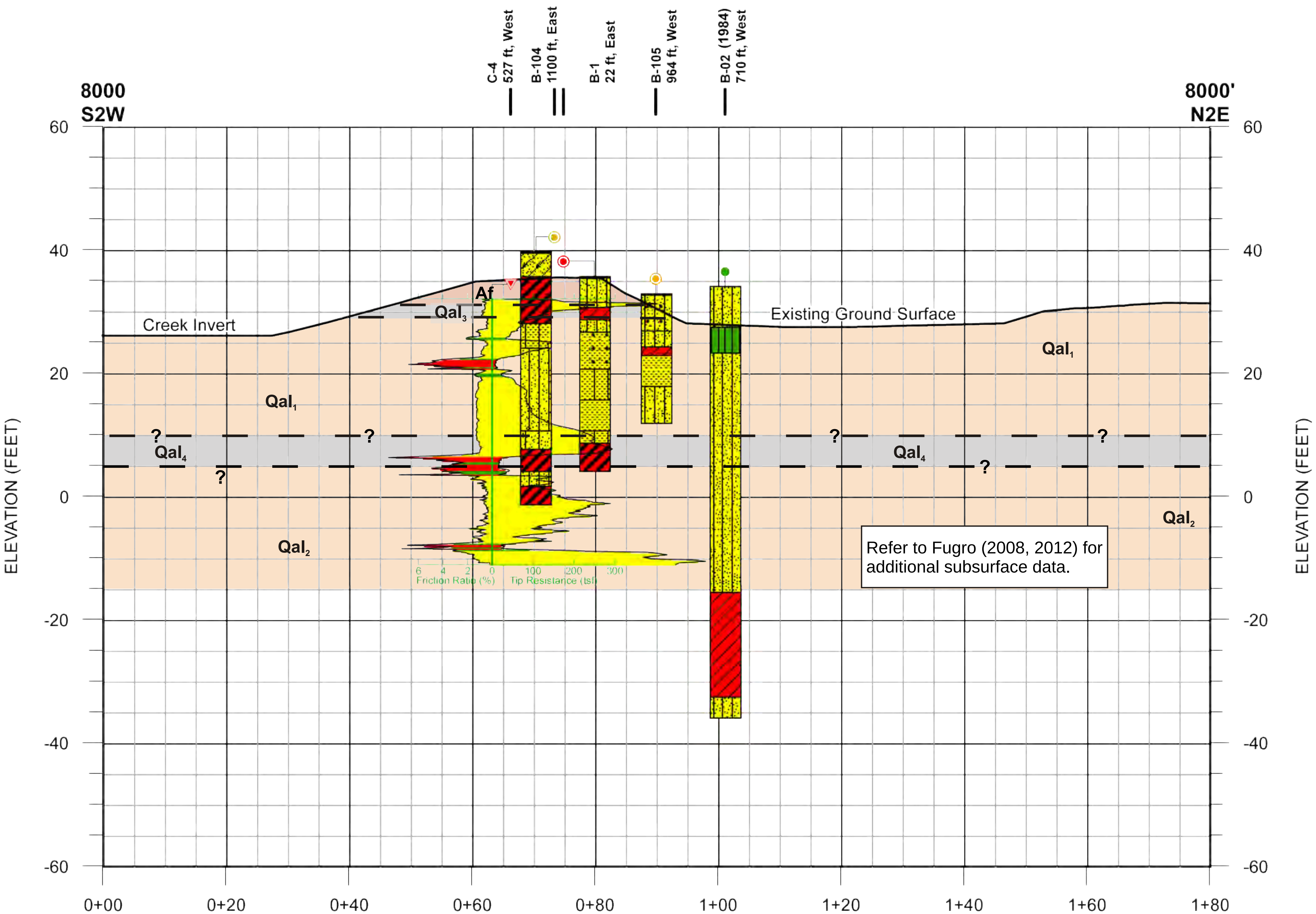
30 Strike and dip of flow banding

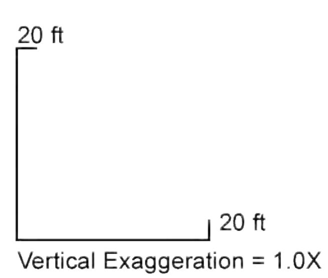
x 6193 Megafossil locality - U.C.L.A. locality number

Vollmer Ranch name/property owner

REGIONAL GEOLOGIC MAP

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

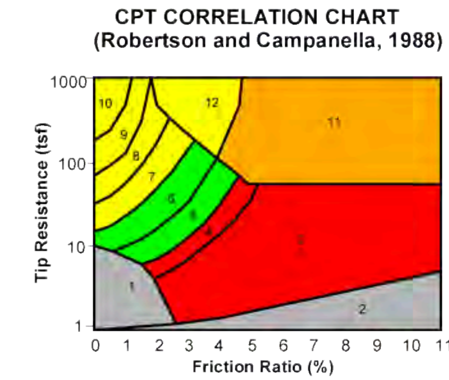




LEGEND

- Af — **Artificial Fill**
- Qal — **Sandy Alluvium**
- Qal — **Fine-grained Alluvium**

CPT Legend



Zone	Soil Behavior Type	U.S.C.S.
1	Sensitive Fine-grained	OL-CH
2	Organic Material	OL-OH
3	Clay	CH
4	Silty Clay to Clay	CL-CH
5	Clayey Silt to Silty Clay	MH-CL
6	Sandy Silt to Clayey Silt	ML-MH
7	Silty Sand to Sandy Silt	SM-ML
8	Sand to Silty Sand	SM-SP
9	Sand	SW-SP
10	Gravelly Sand to Sand	SW-GW
11	Very Stiff Fine-grained *	CH-CL
12	Sand to Clayey Sand *	SC-SM

*overconsolidated or cemented

Boring Legend

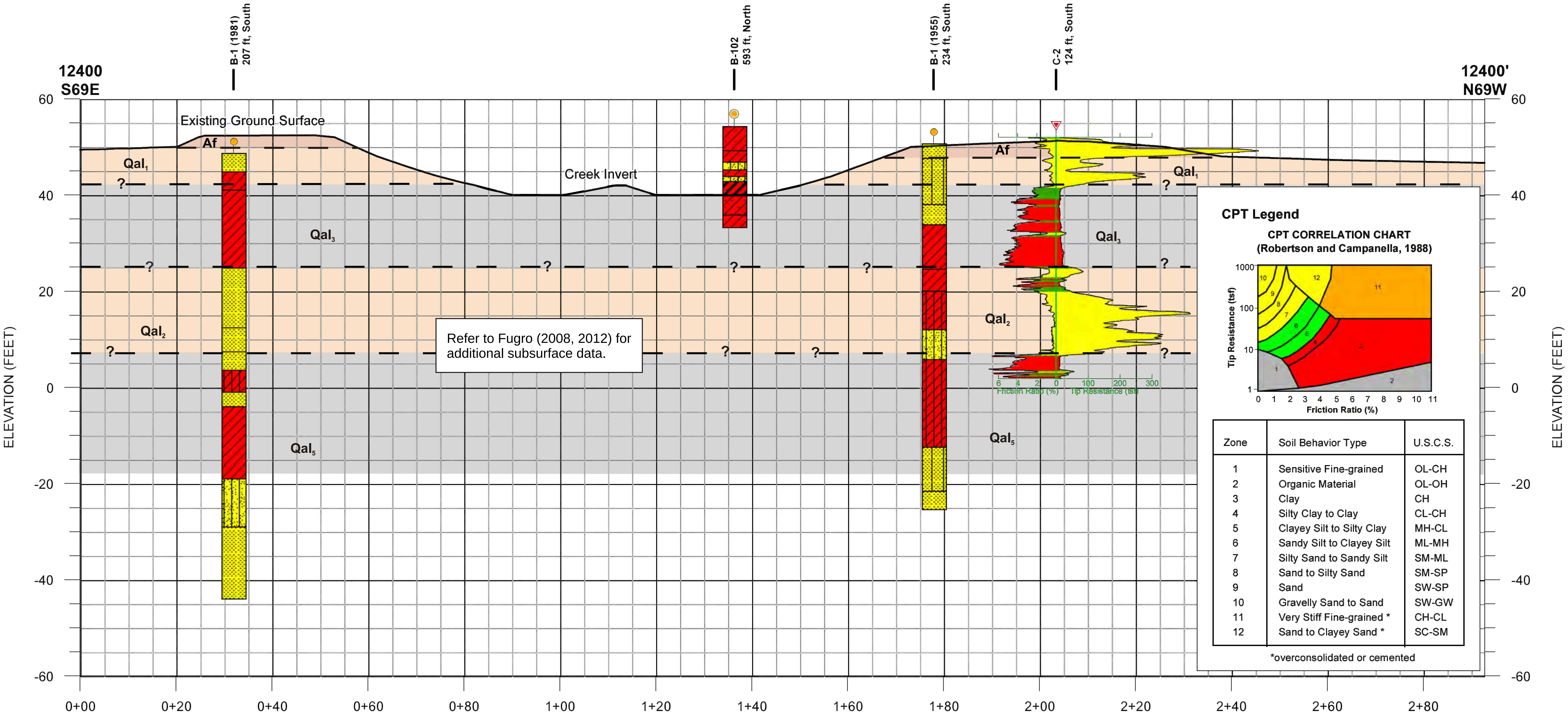
- Lean CLAY (CL)
- Sandy Lean Clay (CL)
- Fat CLAY (CH)
- Sandy Fat CLAY (CH)
- Silt (ML)
- Poorly-Graded SAND (SP)
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt (SW-SM)
- Gravelly, Clayey SAND (SC)
- Silty SAND (SM)
- Gravelly Silty SAND (SM)

CROSS SECTION 80+00
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE 4a

N:\Projects\04_2012\04_6212_0101_ArroyoGrandeLeveeImprov\Outputs\2012_09_04_GeotechReport\mxd\Plate4a_Profile08000.mxd, 09/04/12, CDean

Waterways, Inc.
Project No. 04.6212.0101



Zone	Soil Behavior Type	U.S.C.S.
1	Sensitive Fine-grained	OL-CH
2	Organic Material	OL-OH
3	Clay	CH
4	Silty Clay to Clay	CL-CH
5	Clayey Silt to Silty Clay	MH-CL
6	Sandy Silt to Clayey Silt	ML-MH
7	Silty Sand to Sandy Silt	SM-ML
8	Sand to Silty Sand	SM-SP
9	Sand	SW-SP
10	Gravelly Sand to Sand	SW-GW
11	Very Stiff Fine-grained *	CH-CL
12	Sand to Clayey Sand *	SC-SM

*overconsolidated or cemented

Boring Legend

- Lean CLAY (CL)
- Lean CLAY with Sand (CL)
- Fat CLAY (CH)
- Poorly-Graded SAND with Silt (SP-SM)
- Silty CLAY (CL-ML)
- Sandy Lean Clay (CL)
- Poorly-Graded SAND (SP)
- Silty SAND (SM)

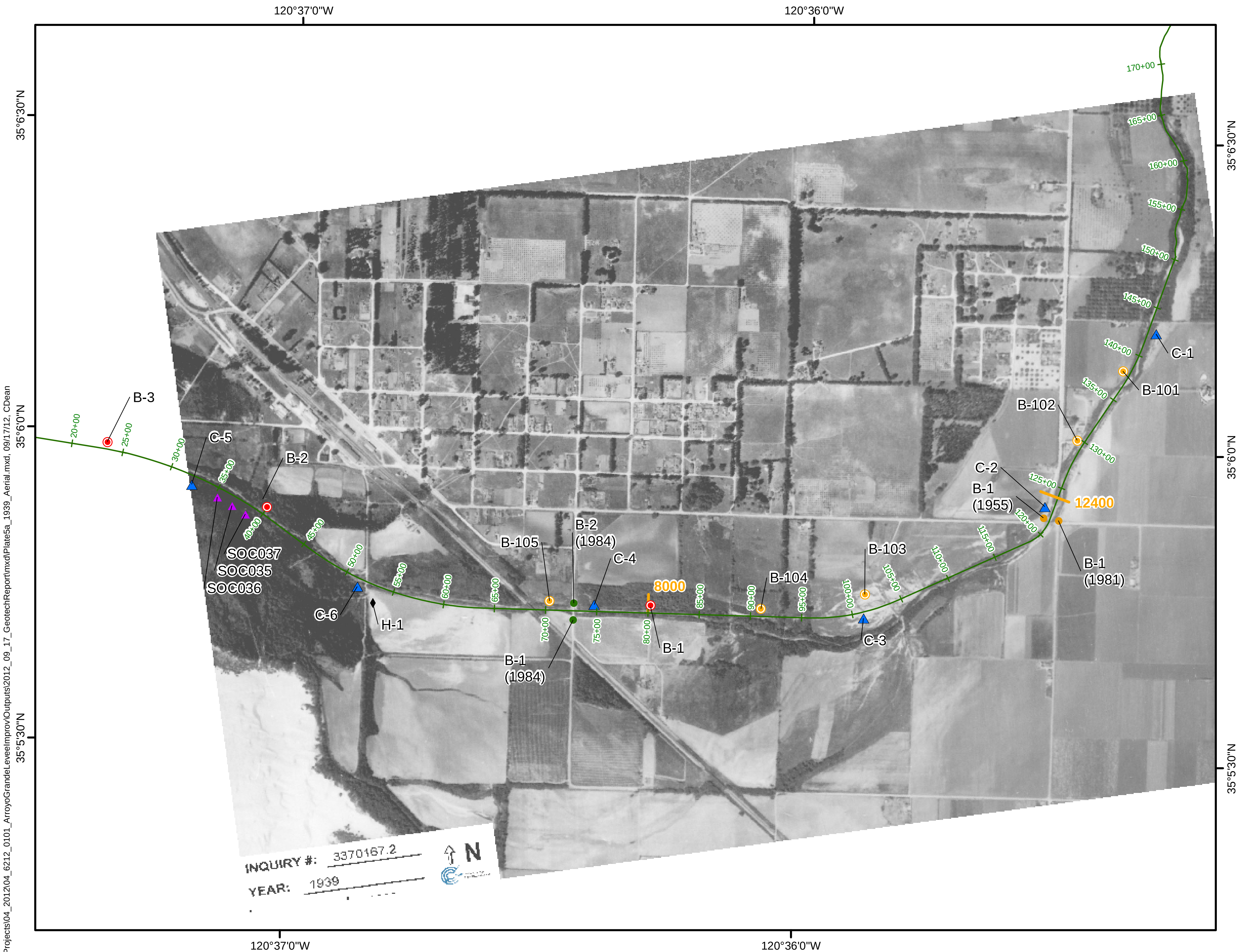
LEGEND

- Af — Artificial Fill
- Qal — Sandy Alluvium
- Qal — Fine-grained Alluvium

CROSS SECTION 124+00
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE 4b

N:\Projects\04_2012\04_6212_0101_ArroyoGrandeLeveeImprov\Outputs\2012_09_17_GeotechReport\mxd\Plate4b_Profile12400.mxd, 09/17/12, CDean



Legend

Approximate Exploration Locations

- 2012 Fugro Boring (July)
- 2012 Fugro Boring (January)
- 2008 Fugro CPT
- 2003 USGS SCPT
- Caltrans Boring (Year of Study)
- SLO County Boring (Year of Study)
- 2008 Fugro Hand Auger Boring
- 8000 Cross Section Line
- 90+00 Centerline Along Levee with Stationing

N

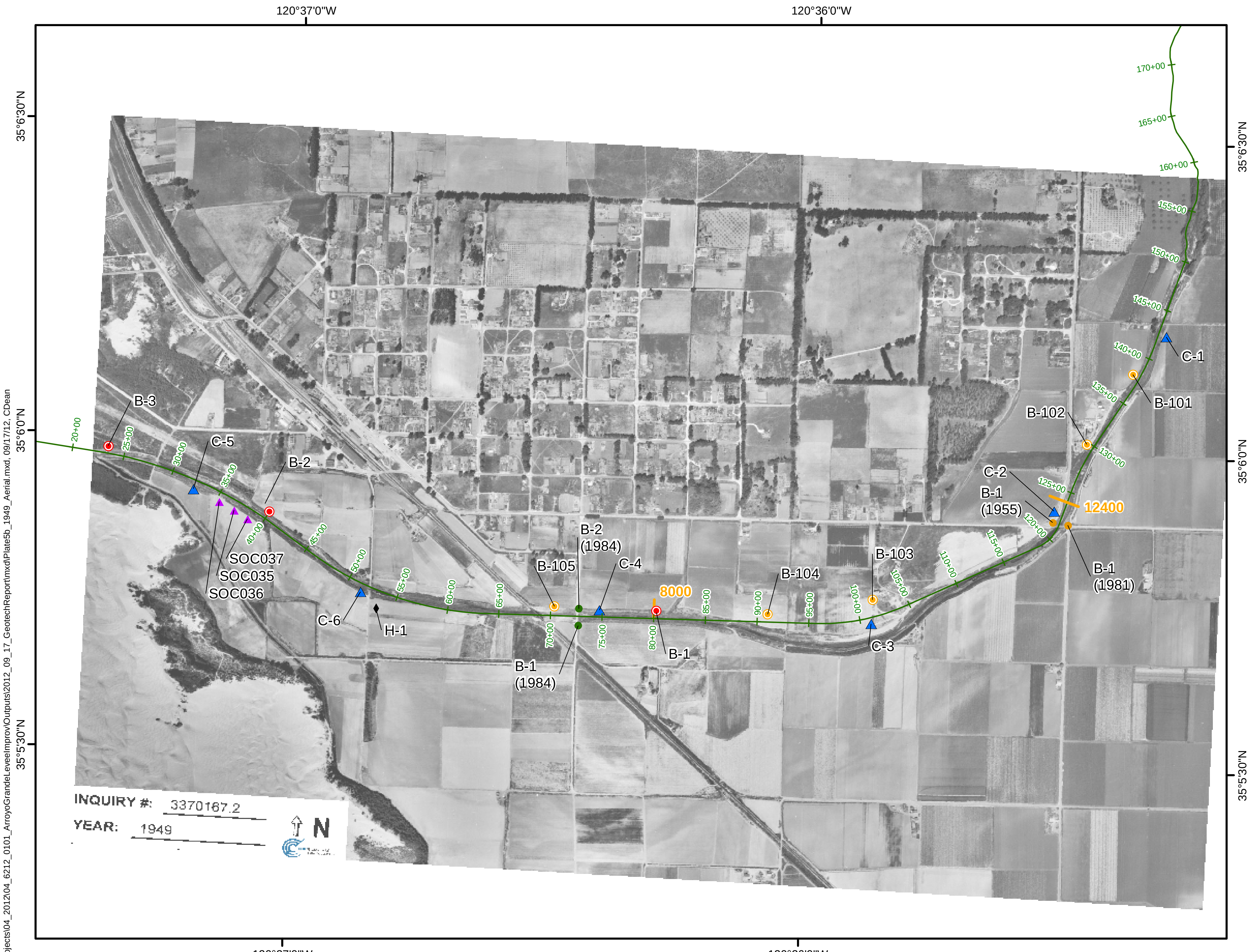
Horizontal Scale: 1:12,000

1,000 500 0 1,000 Feet

1939 AERIAL PHOTOGRAPH
Arroyo Grande Creek
Levee Improvements
San Luis Obispo County, California

N:\Projects\04_2012\04_6212_0101_ArroyoGrandeLeveeImprov\Outputs\2012_09_17_GeotechReport\mxd\Plate5a_1939_Aerial.mxd, 09/17/12, CDean

FUGRO



Legend

Approximate Exploration Locations

- 2012 Fugro Boring (July)
- 2012 Fugro Boring (January)
- 2008 Fugro CPT
- 2003 USGS SCPT
- Caltrans Boring (Year of Study)
- SLO County Boring (Year of Study)
- 2008 Fugro Hand Auger Boring
- 8000 Cross Section Line
- 90+00 Centerline Along Levee with Stationing

N

Horizontal Scale: 1:12,000

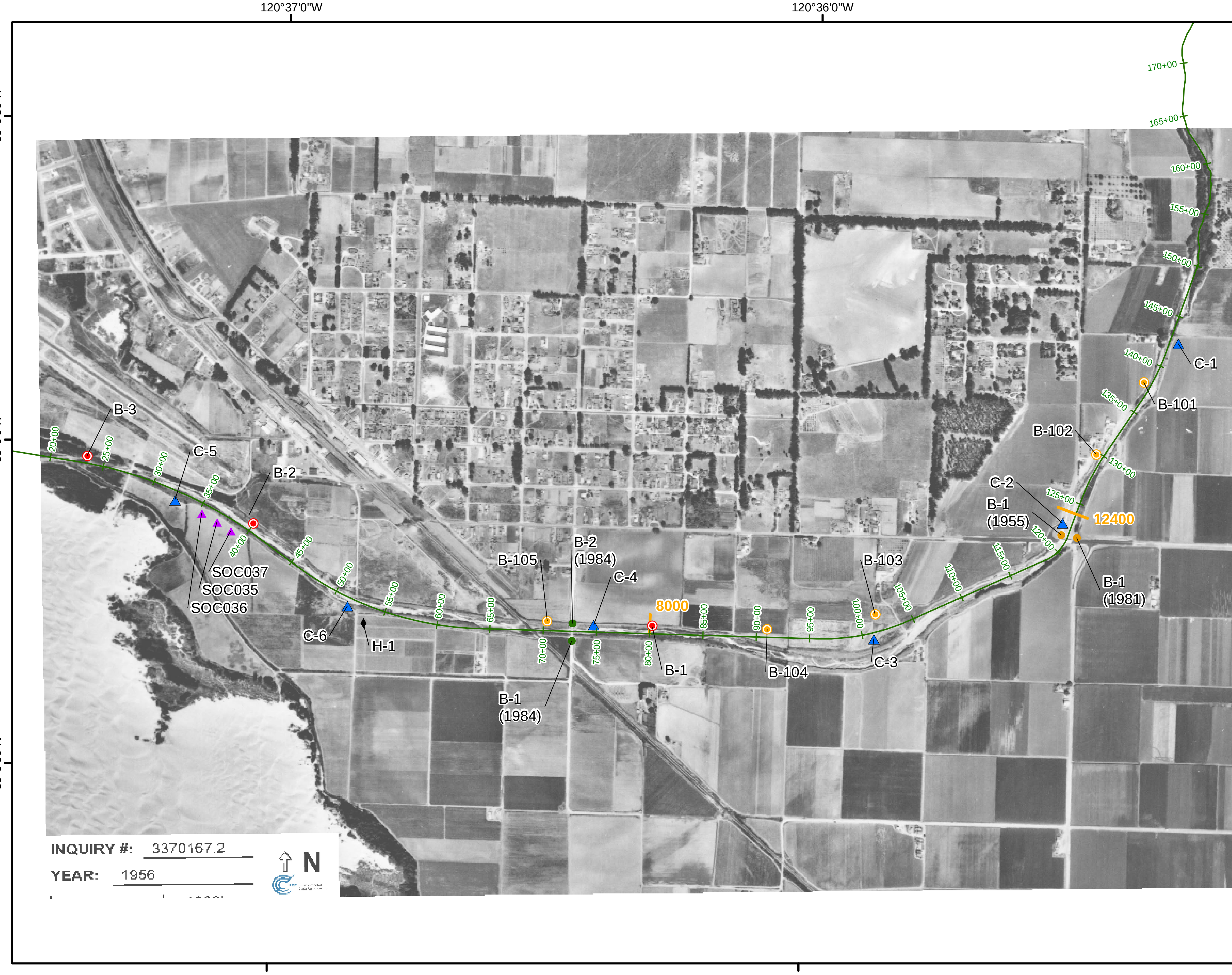
1,000 500 0 1,000 Feet

1949 AERIAL PHOTOGRAPH
Arroyo Grande Creek
Levee Improvements
San Luis Obispo County, California

PLATE 5b

N:\Projects\04_2012\04_6212_0101_ArroyoGrandeLeveeImprov\Outputs\2012_09_17_GeotechReport\mxd\Plate5b_1949_Aerial.mxd, 09/17/12, CDean

Waterways Consulting, Inc.
Project No. 04.6212.0101



Legend

Approximate Exploration Locations

- 2012 Fugro Boring (July)
- 2012 Fugro Boring (January)
- 2008 Fugro CPT
- 2003 USGS SCPT
- Caltrans Boring (Year of Study)
- SLO County Boring (Year of Study)
- 2008 Fugro Hand Auger Boring
- 8000 Cross Section Line
- 90+00 Centerline Along Levee with Stationing

N

Horizontal Scale: 1:12,000

1,000 500 0 1,000 Feet

1956 AERIAL PHOTOGRAPH
Arroyo Grande Creek
Levee Improvements
San Luis Obispo County, California

PLATE 5c

N:\Projects\04_2012\04_6212_0101_ArroyoGrandeLeveeImprov\Outputs\2012_09_17_GeotechReport\mxd\Plate5c_1956_Aerial.mxd, 09/17/12, CDean

Photo 1: Rodent burrows observed on exterior levee slope at about Station 71+50

Photo 2: Depth of burrow approximately 2½ feet at about Station 71+50

Photo 3: Depth of burrow approximately 4 feet at about Station 71+50 (only probe handle visible)

Photo 4: Rodent burrows observed on exterior levee slope at about Station 91+00

SITE PHOTOGRAPHS

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

APPENDIX A

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: The drill hole location referencing local landmarks or coordinates

SURFACE EL: Using local, MSL, MLLW or other datum

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	BLOW COUNT / REC"/DRIVE"	MATERIAL DESCRIPTION	
-12	2	1	25	Well graded GRAVEL (GW)	COARSE GRAINED
-14	4	2	(25)	Poorly graded GRAVEL (GP)	
-16	6			Well graded SAND (SW)	
-18	8	3	(25)	Poorly graded SAND (SP)	
-20	10	4	(25)	Silty SAND (SM)	
-22	12	5	18"/ 30"	Clayey SAND (SC)	
-24	14	6		Silty, Clayey SAND (SC-SM)	
-26	16			Elastic SILT (MH)	FINE GRAINED
-28	18	7		SILT (ML)	
-30	20	8	20"/ 24"	Silty CLAY (CL-ML)	
-32	22	9	(25)	Fat CLAY (CH)	
-34	24	10	30"/ 30"	Lean CLAY (CL)	
-36	26			CONGLOMERATE	ROCK
-38	28	11	20"/ 24"	SANDSTONE	
-40	30	12		SILTSTONE	
-42	32	13		MUDSTONE	
-44	34			CLAYSTONE	
-46	36			BASALT	
-48	38			ANDESITE BRECCIA	
				Paving and/or Base Materials	

General Notes

Soil Texture Symbol

Sloped line in symbol column indicates transitional boundary

Samplers and sampler dimensions
(unless otherwise noted in report text) are as follows:

Symbol for:

1	SPT Sampler, driven 1-3/8" ID, 2" OD
2	CA Liner Sampler, driven 2-3/8" ID, 3" OD
3	CA Liner Sampler, disturbed 2-3/8" ID, 3" OD
4	Thin-walled Tube, pushed 2-7/8" ID, 3" OD
5	Bulk Bag Sample (from cuttings)
6	CA Liner Sampler, Bagged
7	Hand Auger Sample
8	CME Core Sample
9	Pitcher Sample
10	Lexan Sample
11	Vibracore Sample
12	No Sample Recovered
13	Sonic Soil Core Sample

Sampler Driving Resistance

Number of blows with 140 lb. hammer, falling 30" to drive sampler 1 ft. after seating sampler 6"; for example,

Blows/ft	Description
25	25 blows drove sampler 12" after initial 6" of seating
86/11"	After driving sampler the initial 6" of seating, 36 blows drove sampler through the second 6" interval, and 50 blows drove the sampler 5" into the third interval
50/6"	50 blows drove sampler 6" after initial 6" of seating
Ref/3"	50 blows drove sampler 3" during initial 6" seating interval

Blow counts for California Liner Sampler shown in ( )

Length of sample symbol approximates recovery length

Classification of Soils per ASTM D2487 or D2488

Geologic Formation noted in bold font at the top of interpreted interval

Strength Legend

- Q = Unconfined Compression
- u = Unconsolidated Undrained Triaxial
- t = Torvane
- p = Pocket Penetrometer
- m = Miniature Vane

Water Level Symbols

- Initial or perched water level
- Final ground water level
- Seepages encountered

Rock Quality Designation (RQD) is the sum of recovered core pieces greater than 4 inches divided by the length of the cored interval.

KEY TO TERMS & SYMBOLS USED ON LOGS

PLATE A-1

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: Approximately 900' northeast of B-102, Station 138+50

SURFACE EL: 58.5 ft +/- (rel. NAVD88 datum)

ELEVATION, ft: 58, 56, 54, 52, 50, 48, 46, 44, 42, 40, 38, 36, 34, 32

DEPTH, ft: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26

SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
A		**ALLUVIUM (Qal_1)** Poorly graded SAND with silt (SP-SM): very loose, light grayish brown, moist							
1	(4)								
2	7	**Qal_3** Lean CLAY with sand (CL): soft, dark brown, moist, trace fine sand	118	94	14 26	10			
		Qal_1 Silty SAND (SM): loose, light brown, moist, fine sand							
3A	(11)	Poorly graded SAND with silt (SP-SM): loose, light brown, moist, medium to coarse sand							
3B			97	87	13	8			
4	4	Silty SAND (SM): very loose, light brown, moist, lenses of silty CLAY (CL-ML) with oxidation staining, trace gravel				24			
5	(6)	**Qal_3** Fat CLAY (CH): soft to stiff, black, moist	111	80	39		64	44	p 1.5
6	(17)	- stiff to hard							p 4.0
		Lean CLAY (CL): stiff to hard, light brown, moist, oxidation mottling							
7	(16)								p 3.0

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: Not Encountered
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-101

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-2

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: Approximately 760' north of and 160' east of westerly intersection of SR-1 and Halcyon Road, Station 130+00

SURFACE EL: 54.5 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
54		A		**ARTIFICIAL FILL (af)** Lean CLAY with sand (CL): soft, very dark brown to black, moist, scattered subangular to angular gravel up to 1"				57			
	2	1	(4)		88	68	29	79			
52		2	2								
50	4										
	6	3A	(8)	**ALLUVIUM (Qal_3)** Lean CLAY (CL): medium stiff to hard, brownish gray, moist, trace fine sand							p 1.8
48		3B			115	89	29		45	27	p 3.0
	8	4A, 4B	4	**Qal_1** Silty SAND (SM): very loose, light gray, moist							
46											
	10	5	(11)	**Qal_3** Lean CLAY (CL): soft to very stiff, gray, moist							p 2.0
44											p 1.8
		6	5	**Qal_1** Silty SAND (SM): loose, light gray, moist							
42	12			**Qal_3** Fat CLAY (CH): soft to very stiff, black, moist							p 1.3, p 1.8
40	14	7		Sandy lean CLAY (CL): very dark grayish brown, moist							
38	16				114	91	25		44	29	
36	18			Lean CLAY (CL): very stiff, brownish gray, moist, oxidation mottling							
34	20	8	(23)								p 3.3
32	22										
30	24										
28	26										

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: Not Encountered
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-102

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-3

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: Approximately 1200' east of B-104, approximately 75' north of Arroyo Grande Creek Levee, Station 101+00

SURFACE EL: 43 ft +/- (rel. NAVD88 datum)

DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
0–2	A		**ARTIFICIAL FILL (af)** Silty SAND with gravel (SM): reddish brown, dry, subangular gravel up to approximately 1"							
2–4.5	1	(8)	**ALLUVIUM (Qal_1)** Poorly graded SAND with silt (SP-SM): loose, black, moist, abundant organics	104	96	9	10			
	2	7								
4.5–9.5	3A	(11)	Silty SAND (SM): loose, reddish brown, moist, fine sand							
	3B			99	91	10	20			
	4	9	- light brown, trace rounded gravel up to 1"							
9.5–14	5	(21)	Silty SAND with gravel (SM): medium dense, light brown, moist, fine to coarse sand, subangular to well-rounded gravel							
14–21	6A	(47)	Silty SAND (SM): dense, yellowish brown to reddish yellow, wet, abundant oxidation staining							
	6B									
	7	(50)								

ELEVATION, ft: 42, 40, 38, 36, 34, 32, 30, 28, 26, 24, 22, 20, 18
DEPTH, ft: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: 11.5 ft
BACKFILLED WITH: Native cuttings
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-103

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-4

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: Approximately 1840' east of 22nd Street Bridge, Station 91+40

SURFACE EL: 39.8 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
		A		**ARTIFICIAL FILL (af)** approximately 2.5" base material							
38	2	1	(47)	Clayey SAND with gravel (SC): dense, brown to light brown, dry, subrounded to well-rounded gravel up to approximately 1"	119	109	9	19			
36	4	2	15	- medium dense							
34	6	3		**ALLUVIUM (Qal_3)** Sandy Fat CLAY (CH): stiff to hard, dark brown to black, dry, trace oxidation staining, fine to medium sand, subrounded gravel	116	91	27		54	35	p 4.5+
32	8	4	(19)								p 4.5
30	10	5	(17)								p 2.8
28	12			**Qal_1** Poorly graded SAND with silt (SP-SM): dense, reddish orange, wet							
26	14	6A	(52)					7			
24	16	6B		Silty SAND (SM): dense, reddish orange, wet	128	106	21				
22	18										
20	20	7A	(50/6")								
		7B		- yellowish brown, very dense							
18	22										
16	24	8	(25)								
14	26			- medium dense, trace subangular gravel up to ½"							

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 41.0 ft
DEPTH TO WATER: 13.5 ft
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-104

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE A-5a

LOCATION: Approximately 1840' east of 22nd Street Bridge, Station 91+40

SURFACE EL: 39.8 ft +/- (rel. NAVD88 datum)

ELEVATION, ft	DEPTH, ft	MATERIAL SYMBOL	SAMPLE NO.	SAMPLERS	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
12	28												
10	30		9A		(36)	Well-graded SAND with silt and gravel (SW-SM): medium dense, brown to yellowish brown, angular gravel				7			
			9B				126	106	18				
8	32					**Qal$_4$** Fat CLAY (CH): very stiff to hard, light gray, wet							
6	34												
			10A		(40)								p 4.5+
4	36		10B			**Qal$_2$** Silty SAND (SM): medium dense, light gray, wet, fine sand							
2	38					**Qal$_5$** Fat CLAY (CH): very stiff to hard, bluish gray, wet							p 4.5+
0	40		11		(27)								
-2	42												
-4	44												
-6	46												
-8	48												
-10	50												
-12	52												

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 41.0 ft
DEPTH TO WATER: 13.5 ft
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-104

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

Waterways Consulting, Inc.
Project No. 04.6212.0101

LOCATION: Approximately 160' west of 22nd Street Bridge, Station 71+00

SURFACE EL: 33 ft +/- (rel. NAVD88 datum)

ELEVATION, ft: 32, 30, 28, 26, 24, 22, 20, 18, 16, 14, 12, 10, 8

DEPTH, ft: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26

SAMPLE NO.	SAMPLER BLOW COUNT	MATERIAL DESCRIPTION	UNIT WET WEIGHT, pcf	UNIT DRY WEIGHT, pcf	WATER CONTENT, %	% PASSING #200 SIEVE	LIQUID LIMIT, %	PLASTICITY INDEX, %	UNDRAINED SHEAR STRENGTH, S_u, ksf
A		**ARTIFICIAL FILL (af)** approximately 2.5" base material				22			
1	(28)	Silty SAND with gravel (SM): medium dense, brown to light brown, dry, subrounded to well-rounded gravel up to 1.5"							
2	14								
3	(19)	- moist							
4	6	**ALLUVIUM (Qal_1)** Silty SAND (SM): loose, brown, moist							
5A	(10)								
5B		**Qal_3** Sandy lean CLAY (CL): medium stiff to very stiff, brown to gray brown, moist, oxidation mottling	98	83	18				
6A	7					54			p 1.5
6B		**Qal_1** Poorly graded SAND (SP): loose, light yellowish brown to brown, moist							
7A	(15)								
7B			115	101	14	4			
8	(27)	Silty SAND (SM): medium dense, light yellowish brown to brown, wet							
9	(13)	- loose, yellowish brown, wet							

The log and data presented are a simplification of actual conditions encountered at the time of drilling at the drilled location. Subsurface conditions may differ at other locations and with the passage of time.

COMPLETION DEPTH: 21.0 ft
DEPTH TO WATER: 12.5 ft
BACKFILLED WITH: 2-sack slurry
DRILLING DATE: July 20, 2012

DRILLING METHOD: 8-inch-dia. Hollow Stem Auger
HAMMER TYPE: Automatic Trip
DRILLED BY: S/G Drilling Company
LOGGED BY: G Eckrich
CHECKED BY: J Blanchard

LOG OF BORING NO. B-105

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

APPENDIX B

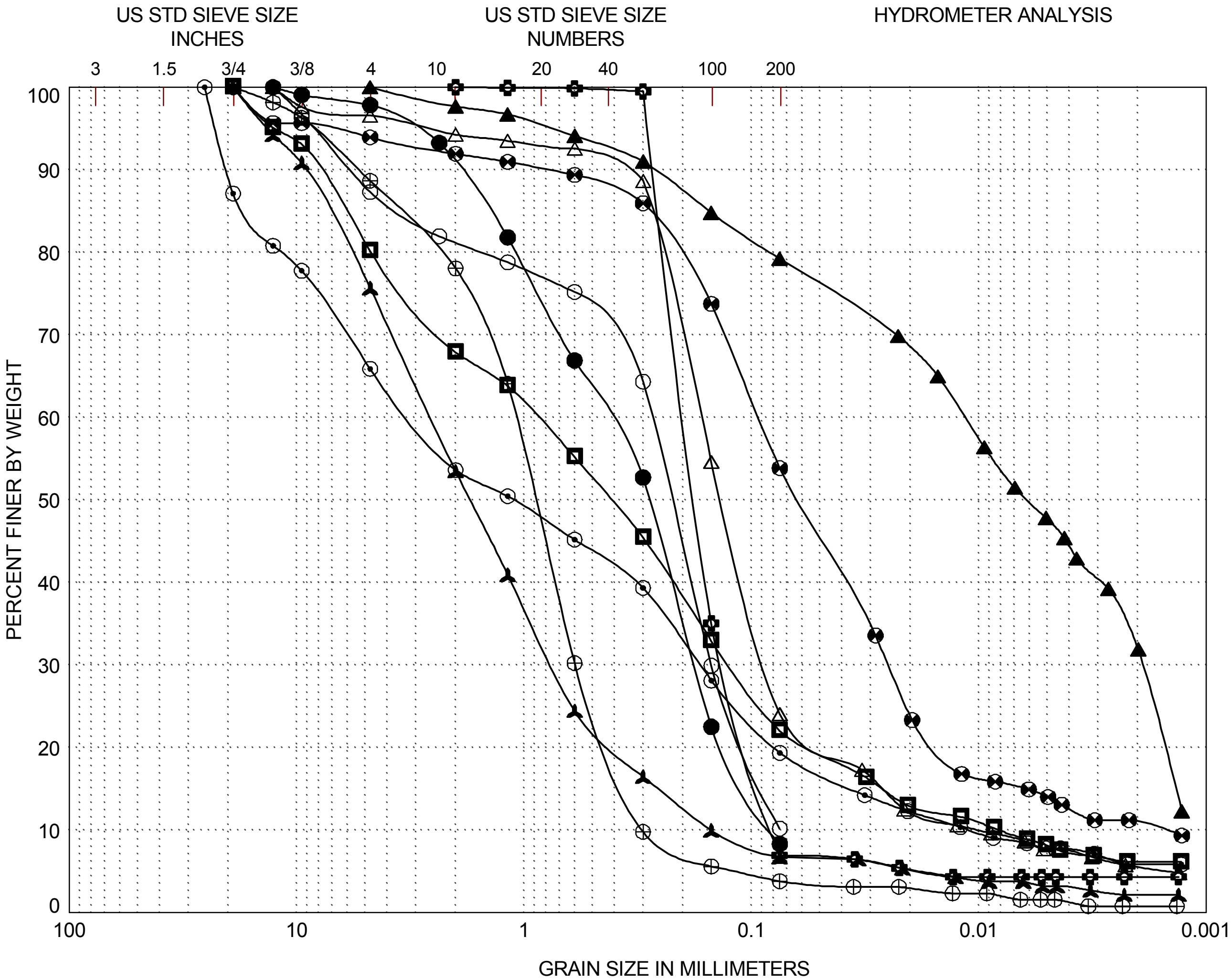
Waterways Consulting, Inc.
Project No. 04.6212.0101

DRILL HOLE	DEPTH, ft	SAMPLE NUMBER	MATERIAL DESCRIPTION	UWW pcf	UDW pcf	MC %	FINES %	ATTERBERG LIMITS		COMPACTION TEST		DIRECT SHEAR		COMPRESSIVE STRENGTH TESTS		CORROSIVITY TESTS				R-VALUE	EXPANSION INDEX	SAND EQUIVALENT (SE)	SPECIFIC GRAVITY
								LL	PI	MAX DD pcf	OPT MC %	C ksf	PHI deg	Qu, ksf	S_u (Cell Prs.) ksf	R	pH	Cl	So_4 (%)				
B-101	2.0	1	Poorly graded SAND with silt (SP-SM)			14	10																
B-101	2.3	1	Lean CLAY with sand (CL)	118	94	26																	
B-101	5.5	3B	Poorly graded SAND with silt (SP-SM)	97	87	13	8																
B-101	6.0	4	Silty SAND (SM)				24																
B-101	10.5	5	Fat CLAY (CH)	111	80	39		64	44														
B-102	0.1	A	Lean CLAY with sand (CL)				57			115.0	13.8												
B-102	1.5	1	Lean CLAY with sand (CL)	88	68	29	79																
B-102	6.5	3A	Lean CLAY (CL)	115	89	29		45	27														
B-102	15.9	7	Sandy Lean CLAY (CL)	114	91	25		44	29														
B-103	3.0	1	Poorly graded SAND with silt (SP-SM)	104	96	9	10																
B-103	7.0	3B	Silty SAND (SM)	99	91	10	20																
B-104	3.0	1	Clayey SAND with gravel (SC)	119	109	9	19																
B-104	6.7	3	Sandy Fat CLAY (CH)	116	91	27		54	35														
B-104	14.5	6A	Poorly graded SAND with silt (SP-SM)				7																
B-104	15.5	6B	Silty SAND (SM)	128	106	21																	
B-104	29.5	9A	Well graded SAND with silt and gravel (SW-SM)				7																
B-104	30.5	9B	Well-graded SAND with gravel (SW)	126	106	18																	
B-105	0.0	A	Silty SAND with gravel (SM)				22			123.0	9.8												
B-105	8.5	5B	Silty SAND (SM)	98	83	18																	
B-105	9.0	6A	Sandy Lean CLAY (CL)				54																
B-105	11.5	7B	Poorly graded SAND (SP)	115	101	14	4																

SUMMARY OF LABORATORY TEST RESULTS
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE B-1

LAB SUMMARY TABLE VENTURA_F:\FUGRO SLO GEOTECH DOCUMENTS\GINT\GINT PROJECTS\04.6212.0101.GPJ_ 9/6/12 10:54 AM-cab



GRAVEL		SAND			SILT or CLAY
Coarse	Fine	Coarse	Medium	Fine	

LEGEND (location)	(depth,ft)	CLASSIFICATION	Cc	Cu
○ B-101	2.0	Poorly graded SAND with silt (SP-SM)	1.1	3.7
● B-101	5.5	Poorly graded SAND with silt (SP-SM)	0.9	5.3
△ B-101	6.0	Silty SAND (SM)	4.3	16.4
▲ B-102	1.5	Lean CLAY with sand (CL)		
⊙ B-104	3.0	Clayey SAND with gravel (SC)	0.8	283.9
✿ B-104	14.5	Poorly graded SAND with silt (SP-SM)	1.1	2.4
⅄ B-104	29.5	Well graded SAND with silt and gravel (SW-SM)	1.5	17.1
▣ B-105	0.0	Silty SAND with gravel (SM)	2.2	107.6
⊗ B-105	9.0	Sandy Lean CLAY (CL)	4.3	59.9
⊕ B-105	11.5	Poorly graded SAND (SP)	1.1	3.6

GRAIN SIZE CURVES
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE B-2

SAMPLE ID

Boring Number	B-101
Sample Number	3B
Sample Depth, ft	5.5
Classification	Poorly-graded SAND with silt (SP-SM): dark yellowish brown, moist

SAMPLE PROPERTIES

	Intial	Final
Mass, g	587.78	---
Water Content, %	12.6%	---
Dry Density, pcf	86.5	---
Saturation, %	37%	---
Void Ratio	0.91	---
Diameter, in	2.42	---
Height, in	5.00	---
Area, in^2	4.60	---
Volume, in^3	23.00	---

CLASSIFICATION

Sieve Size	% Passing
3/8-in. (9.5mm)	99
#4 (4.75mm)	98
#16 (1.18mm)	82
#30 (0.6mm)	67
#100 (0.150mm)	22
#200 (0.075mm)	8

Other Parameters	
Liquid Limit	---
Plastic Limit	---
Plasticity Index	---
Estimated Gs	2.65

TEST SUMMARY

Sample Type	MCA
Permeant	Deaired Tap-Water
Pipette Area, cm^2	0.971
k_{avg} 20ºC, cm/s	1.4E-03
Tested By	JC

REMARKS

Test Method: ASTM D5084 (Method C)

Test performed in conjunction with staged triaxial CU; final properties after permeation are not availible.

PERMEATION DATA

Trial	Date	Time, sec	$Temp_{Avg}$, ºC	σ', ksf	μ, ksf	i_o	i_f	k_t, cm/s
1	8/3/12	314	22.1	0.3	7.2	0.2	0.1	1.5E-03
2	8/3/12	326	22.2	0.3	7.2	0.2	0.1	1.4E-03
3	8/3/12	304	22.2	0.3	7.2	0.2	0.1	1.5E-03
4	8/3/12	306	22.2	0.3	7.2	0.2	0.1	1.5E-03
5								
6								

SAMPLE IMAGES

HYDRAULIC CONDUCTIVITY

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

SAMPLE ID

Boring Number	B-102
Sample Number	3A
Sample Depth, ft	6.5
Classification	Lean CLAY (CL): dark grayish brown, moist

CLASSIFICATION

Sieve Size	% Passing
3/8-in. (9.5mm)	---
#4 (4.75mm)	---
#16 (1.18mm)	---
#30 (0.6mm)	---
#100 (0.150mm)	---
#200 (0.075mm)	---

Other Parameters	
Liquid Limit	45
Plastic Limit	18
Plasticity Index	26
Estimated Gs	2.65

SAMPLE PROPERTIES

	Intial	Final
Mass, g	136.78	139.18
Water Content, %	28.9%	31.2%
Dry Density, pcf	89.0	90.3
Saturation, %	89%	100%
Void Ratio	0.86	0.83
Diameter, in	2.41	2.41
Height, in	0.99	0.98
Area, in^2	4.58	4.55
Volume, in^3	4.54	4.47

TEST SUMMARY

Sample Type	MCA
Permeant	Deaired Tap-Water
Pipette Area, cm^2	0.0314
Annulus Area, cm^2	0.7671
k_{avg} 20ºC, cm/s	1.8E-06
Tested By	JC

REMARKS

Test Method: ASTM D5084 (Method F)
Estimated Gs provides final saturation of 100%.

PERMEATION DATA

Trial	Date	Time, sec	$Temp_{Avg}$, ºC	σ', ksf	μ, ksf	i_o	i_f	k_t, cm/s
1	8/1/12	74	24.3	0.4	7.2	10.5	5.2	2.0E-06
2	8/1/12	70	24.3	0.4	7.2	10.5	5.2	2.1E-06
3	8/1/12	72	24.3	0.4	7.2	10.5	5.2	2.0E-06
4	8/1/12	71	24.3	0.4	7.2	10.5	5.2	2.0E-06
5								
6								

SAMPLE IMAGES

HYDRAULIC CONDUCTIVITY
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

SAMPLE ID

Boring Number	B-104
Sample Number	3
Sample Depth, ft	6.7
Classification	Fat CLAY (CH): very dark grayish brown, moist

CLASSIFICATION

Sieve Size	% Passing
3/8-in. (9.5mm)	---
#4 (4.75mm)	---
#16 (1.18mm)	---
#30 (0.6mm)	---
#100 (0.150mm)	---
#200 (0.075mm)	---

Other Parameters	
Liquid Limit	54
Plastic Limit	19
Plasticity Index	34
Estimated Gs	2.65

SAMPLE PROPERTIES

	Intial	Final
Mass, g	1143.86	---
Water Content, %	27.4%	---
Dry Density, pcf	91.2	---
Saturation, %	89%	---
Void Ratio	0.81	---
Diameter, in	2.87	---
Height, in	5.80	---
Area, in^2	6.47	--
Volume, in^3	37.52	---

TEST SUMMARY

Sample Type	TWT
Permeant	Deaired Tap-Water
Pipette Area, cm^2	0.0314
Annulus Area, cm^2	0.7671
k_{avg} 20ºC, cm/s	6.4E-07
Tested By	JC

REMARKS

Test Method: ASTM D5084 (Method F)

Test performed in conjunction with staged triaxial CU; final properties after permeation are not availible.

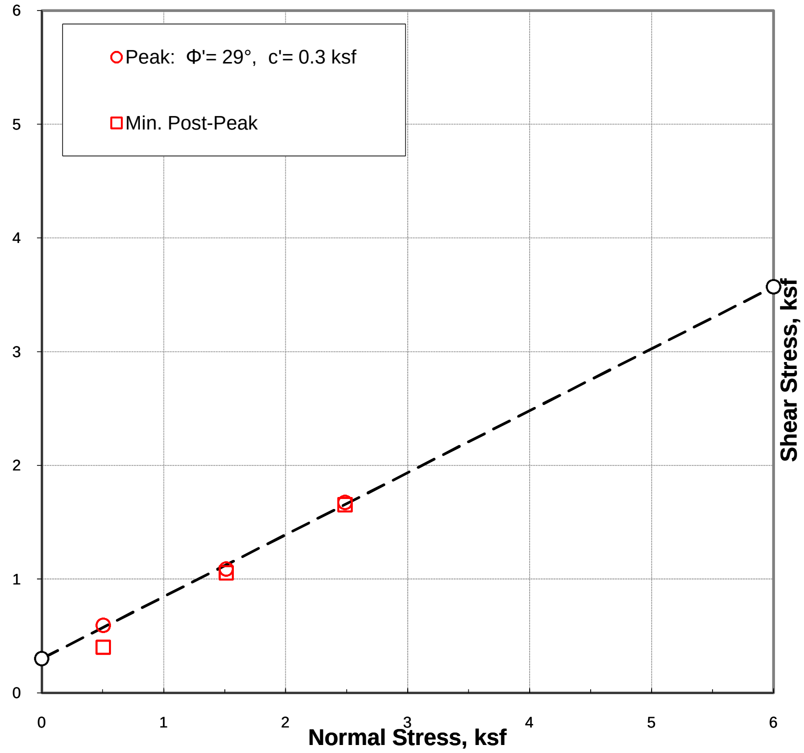
PERMEATION DATA

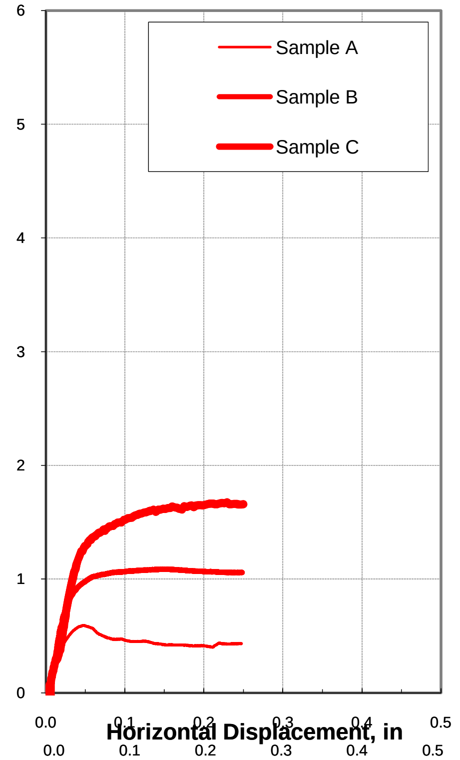
Trial	Date	Time, sec	$Temp_{Avg}$, ºC	σ', ksf	μ, ksf	i_o	i_f	k_t, cm/s
1	8/2/12	729	24.7	0.3	7.2	3.6	1.7	8.7E-07
2	8/2/12	846	24.7	0.3	7.2	3.6	3.6	7.0E-07
3	8/2/12	789	24.7	0.3	7.2	3.6	1.8	7.5E-07
4	8/2/12	1109	24.7	0.3	7.2	3.6	1.7	5.7E-07
5	8/3/12	304	22.1	0.3	7.2	3.6	2.7	8.0E-07
6	8/3/12	436	22.1	0.3	7.2	3.6	2.7	5.6E-07

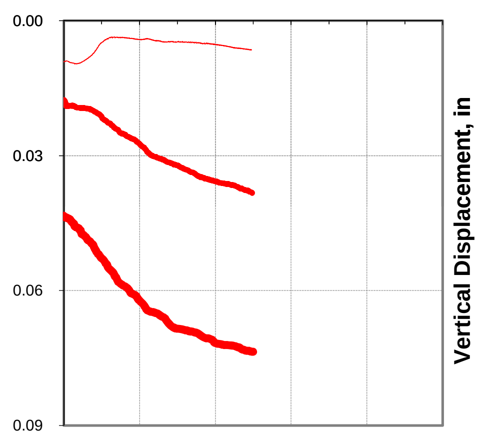
SAMPLE IMAGES

HYDRAULIC CONDUCTIVITY

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California







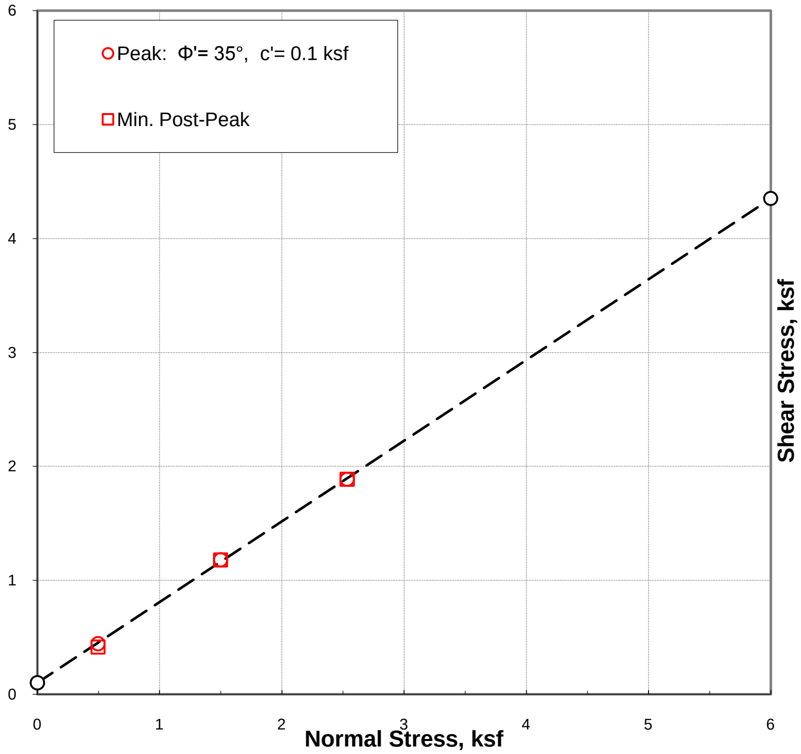
SAMPLE ID		
	Boring Number:	B-102
	Sample Number:	7
	Sample Depth:	15.9 ft
	USCS Classification:	Lean CLAY (CL): very dark grayish brown, moist

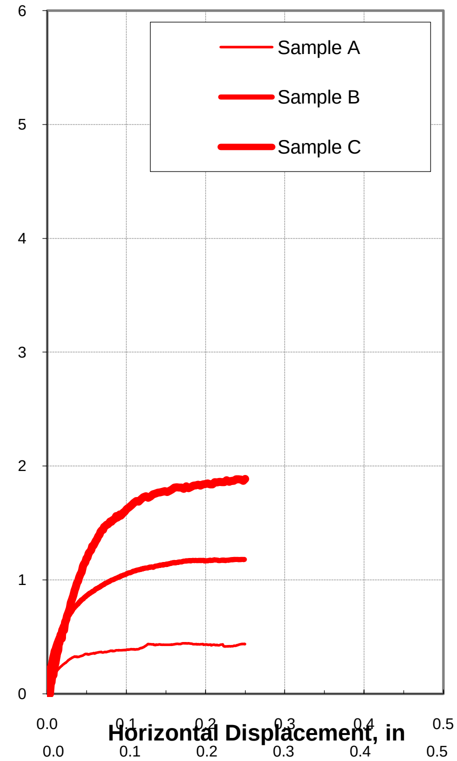
	Sample No.	A	B	C	D
INITIAL	Water Content, %	25.2%	25.2%	25.2%	
	Dry Unit Weight, pcf	90.8	90.0	91.1	
	Saturation, %	81%	80%	82%	
	Void Ratio	0.82	0.84	0.82	
	Diameter, in	2.41	2.41	2.41	
	Height, in	0.89	0.88	0.89	
FINAL	Water Content, %	29.8%	31.4%	27.7%	
	Dry Unit Weight, pcf	89.1	88.1	94.0	
	Void Ratio	0.86	0.88	0.76	
TEST SUMMARY	Displacement at Peak, in	0.05	0.15	0.23	
	Displacement Rate, in/min	0.000	0.000	0.000	
	Normal Stress, ksf	0.5	1.5	2.5	
	Peak Shear Stress, ksf	0.59	1.09	1.67	
	Min. Post-Peak Stress, ksf	0.40	1.05	1.65	
REMARKS	Test Method: ASTM D3080				

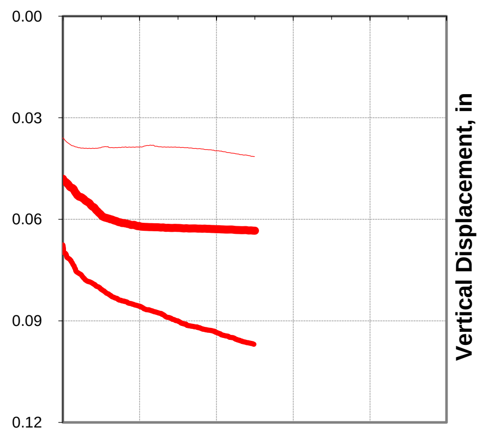
CLASSIFICATION	Sieve Size	% Passing
	3/8-in. (9.5mm)	---
	#4 (4.75mm)	---
	#16 (1.18mm)	---
	#30 (0.6mm)	---
	#100 (0.150mm)	---
	#200 (0.075mm)	---
	Atterberg Limits	
	Liquid Limit, %	44
	Plastic Limit, %	15
	Plasticity Index, %	28
	Estimated Gs	2.65
	k_{avg} 20ºC, cm/sec	---

DIRECT SHEAR TEST RESULTS
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

Waterways Consulting, Inc.
Project No. 04.6212.0101







SAMPLE ID	Boring Number:	B-103			
	Sample Number:	3B			
	Sample Depth:	7.0 ft			
	USCS Classification:	Silty SAND (SM): dark yellowish brown, moist			
INITIAL	Sample No.	A	B	C	D
	Water Content, %	9.7%	9.7%	9.7%	
	Dry Unit Weight, pcf	93.5	90.6	92.9	
	Saturation, %	33%	31%	33%	
	Void Ratio	0.77	0.82	0.78	
	Diameter, in	2.42	2.42	2.42	
	Height, in	1.00	1.00	1.00	
FINAL	Water Content, %	23.4%	22.7%	20.9%	
	Dry Unit Weight, pcf	101.5	102.5	105.7	
	Void Ratio	0.63	0.61	0.56	
TEST SUMMARY	Displacement at Peak, in	0.17	0.24	0.25	
	Displacement Rate, in/min	0.001	0.001	0.001	
	Normal Stress, ksf	0.5	1.5	2.5	
	Peak Shear Stress, ksf	0.44	1.18	1.89	
	Min. Post-Peak Stress, ksf	0.41	1.18	1.89	
REMARKS	Test Method: ASTM D3080				

CLASSIFICATION

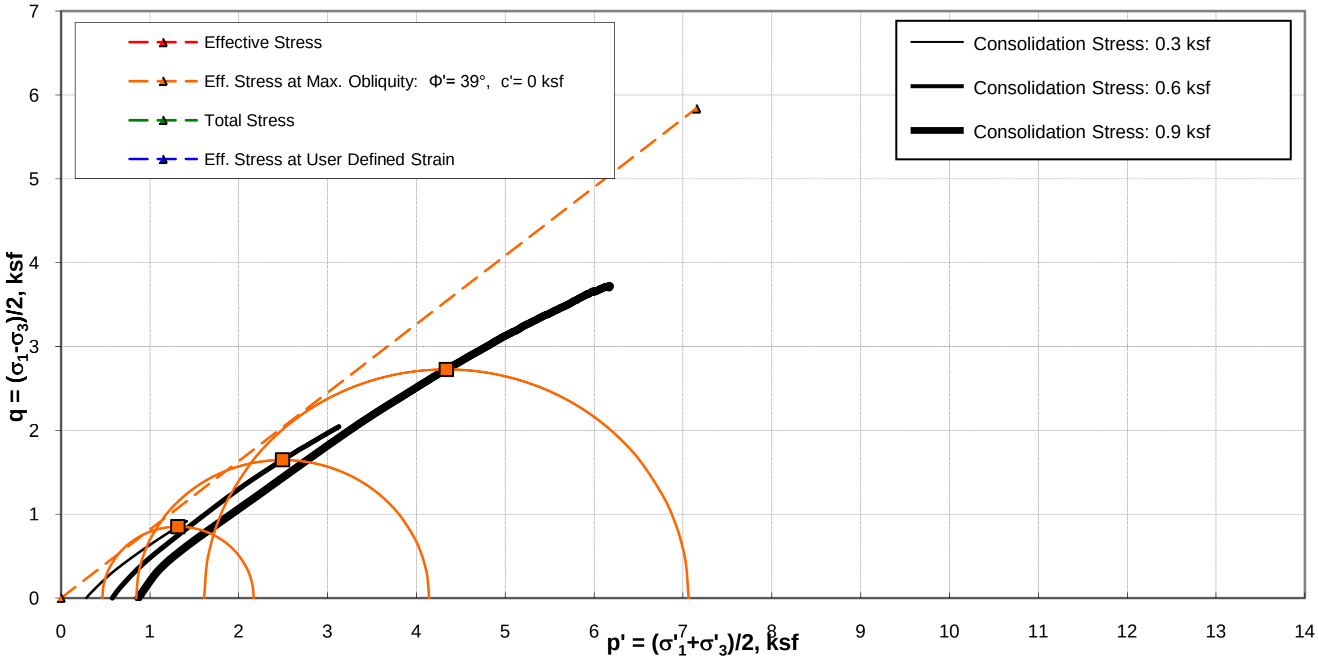
Sieve Size	% Passing
3/8-in. (9.5mm)	---
#4 (4.75mm)	---
#16 (1.18mm)	---
#30 (0.6mm)	---
#100 (0.150mm)	---
#200 (0.075mm)	20.5

Atterberg Limits	
Liquid Limit, %	---
Plastic Limit, %	---
Plasticity Index, %	---
Estimated Gs	2.65
k_{avg} 20°C, cm/sec	---

DIRECT SHEAR TEST RESULTS

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE B-4b



SAMPLE ID

Boring Number.:	B-101
Sample Number.:	3b
Sample Depth:	5.5 ft
USCS Classification:	Poorly-graded SAND with silt (SP-SM): dark yellowish brown, moist

	Sample No.	A	B	C
INITIAL	Water Content, %	12.6%	30.5%	30.1%
	Dry Unit Weight, pcf	86.5	91.5	92.0
	Saturation, %	37%	100%	100%
	Void Ratio	0.91	0.81	0.80
	Diameter, in	2.42	2.38	2.41
	Height, in	5.00	4.87	4.76
PRE-SHEAR	Water Content, %	30.5%	30.1%	29.4%
	Dry Unit Weight, pcf	91.5	92.0	92.9
	Saturation, %	100%	100%	100%
	Void Ratio	0.81	0.80	0.78

REMARKS

Test Method: ASTM 4767

CLASSIFICATION

Sample No.	A
Liquid Limit	---
Plastic Limit	---
Plastic Index	---
Passing #4 (4.75 mm)	97.8%
Passing #200 (0.075 mm)	8.3%
Estimated Gs	2.65

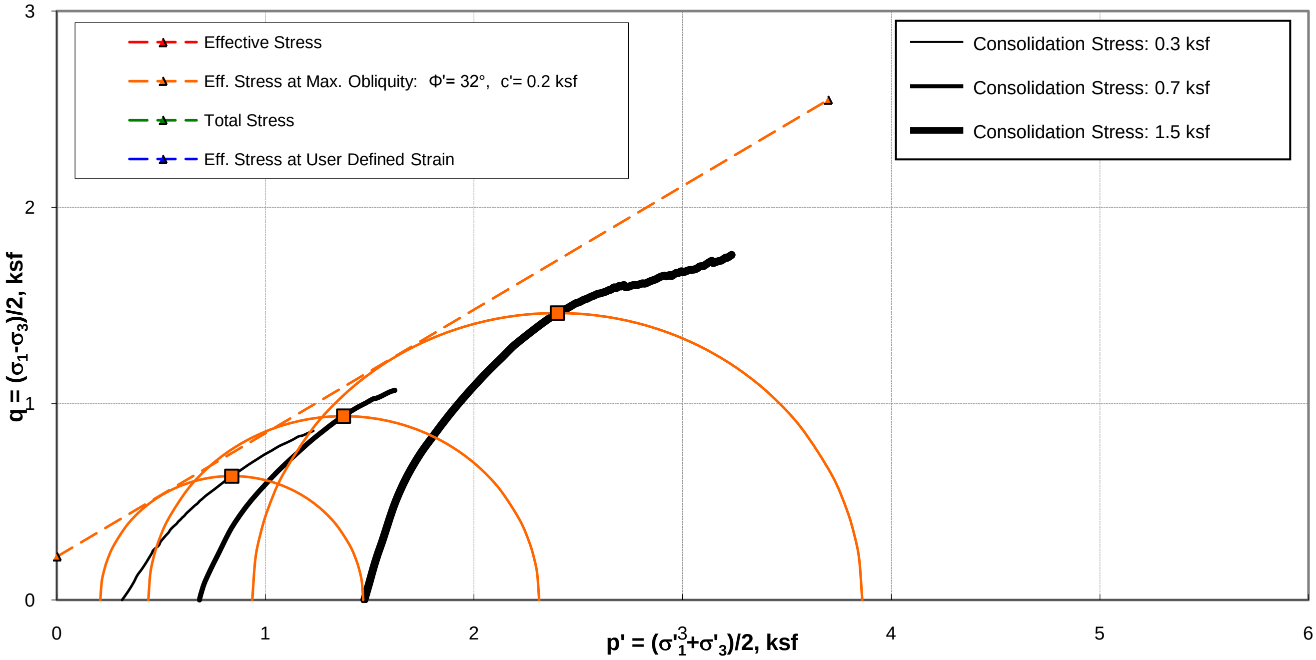
TEST SUMMARY

Sample No.	A	B	C
B-Parameter	0.95	0.95	0.95
t_{50}, minutes	N/A	N/A	N/A
Strain Rate, %/min	0.30	0.30	0.30
Cell Pressure, ksf	7.5	7.7	8.1
Back Pressure, ksf	7.2	7.1	7.2
Consolidation Stress, ksf	0.3	0.6	0.9
Deviator Stress @ Failure, ksf	1.7	3.3	5.4
Axial Strain @ Failure, %	2.8	4.3	7.3
σ'_{1F}, ksf	2.1	4.1	7.0
σ'_{3F}, ksf	0.5	0.8	1.6
Tested By:	JC	JC	JC
Date Tested:	8/3/12	8/6/12	8/7/12

ISOTROPICALLY CONSOLIDATED, UNDRAINED TRIAXIAL TEST WITH PORE WATER PRESSURE MEASUREMENTS

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

Waterways Consulting, Inc.
Project No. 04.6212.0101



SAMPLE ID				
Boring Number.:	B-104			
Sample Number.:	3			
Sample Depth:	6.7 ft			
USCS Classification:	Sandy fat CLAY (CH): very dark grayish brown, moist			

INITIAL	Sample No.	A	B	C
	Water Content, %	27.4%	31.2%	30.8%
	Dry Unit Weight, pcf	91.2	90.6	91.0
	Saturation, %	89%	100%	100%
	Void Ratio	0.81	0.83	0.82
	Diameter, in	2.87	2.87	2.88
	Height, in	5.80	5.84	5.76
PRE-SHEAR	Water Content, %	31.2%	30.8%	30.2%
	Dry Unit Weight, pcf	90.6	91.0	91.8
	Saturation, %	100%	100%	100%
	Void Ratio	0.83	0.82	0.80

REMARKS

Test Method: ASTM 4767

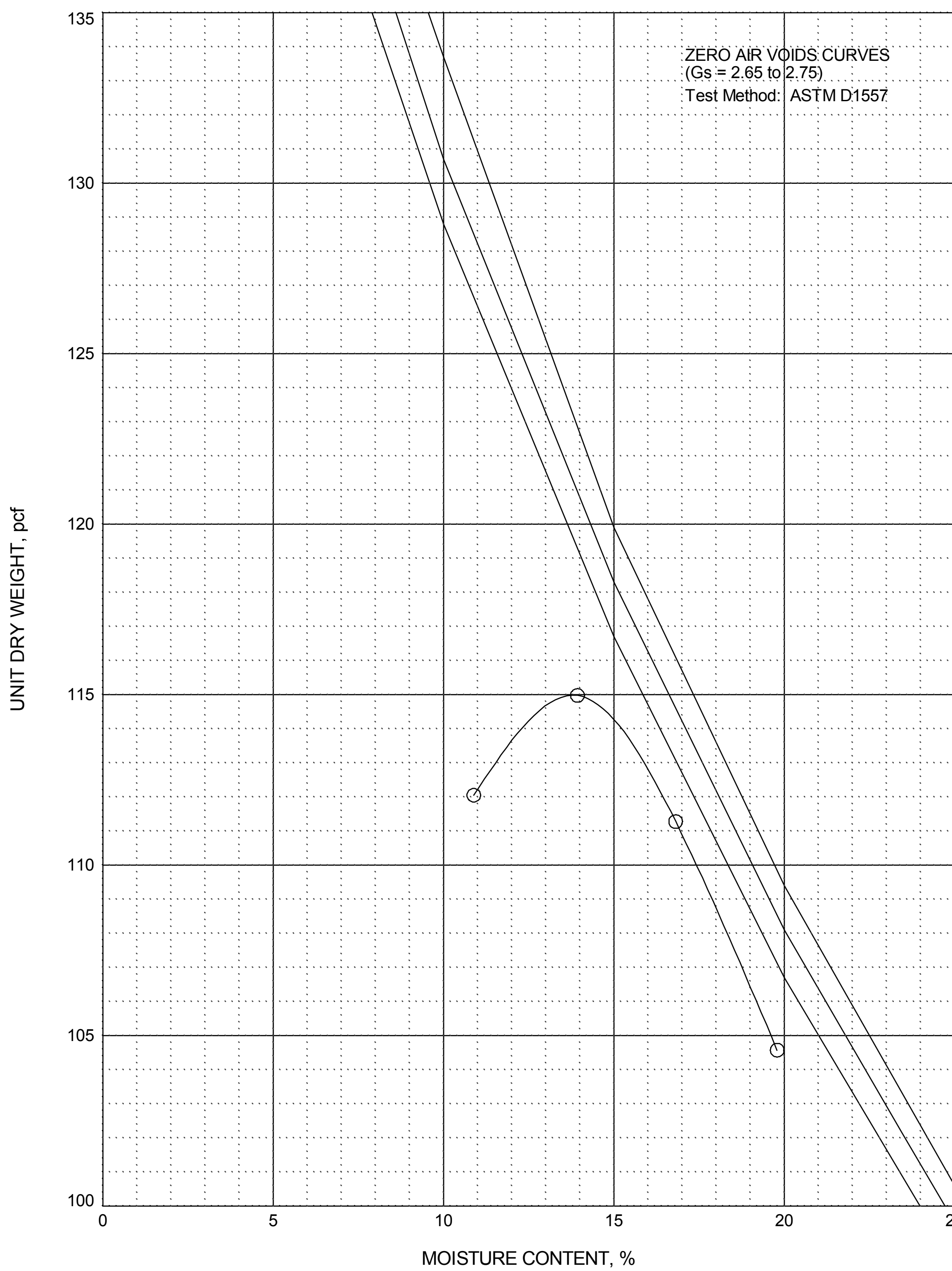
CLASSIFICATION	
Sample No.	A
Liquid Limit	54
Plastic Limit	19
Plastic Index	34
Passing #4 (4.75 mm)	---
Passing #200 (0.075 mm)	---
Estimated Gs	2.65

TEST SUMMARY			
Sample No.	A	B	C
B-Parameter	0.97	0.97	0.97
t_{50}, minutes	N/A	N/A	N/A
Strain Rate, %/min	0.01	0.01	0.01
Cell Pressure, ksf	7.5	8.0	8.7
Back Pressure, ksf	7.2	7.3	7.2
Consolidation Stress, ksf	0.3	0.7	1.5
Deviator Stress @ Failure, ksf	1.2	1.9	2.9
Axial Strain @ Failure, %	1.0	2.3	4.1
σ'_{1F}, ksf	1.5	2.3	3.8
σ'_{3F}, ksf	0.2	0.4	0.9
Tested By:	JC	JC	JC
Date Tested:	8/3/12	1/0/00	8/7/12

ISOTROPICALLY CONSOLIDATED, UNDRAINED TRIAXIAL TEST WITH PORE WATER PRESSURE MEASUREMENTS

Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

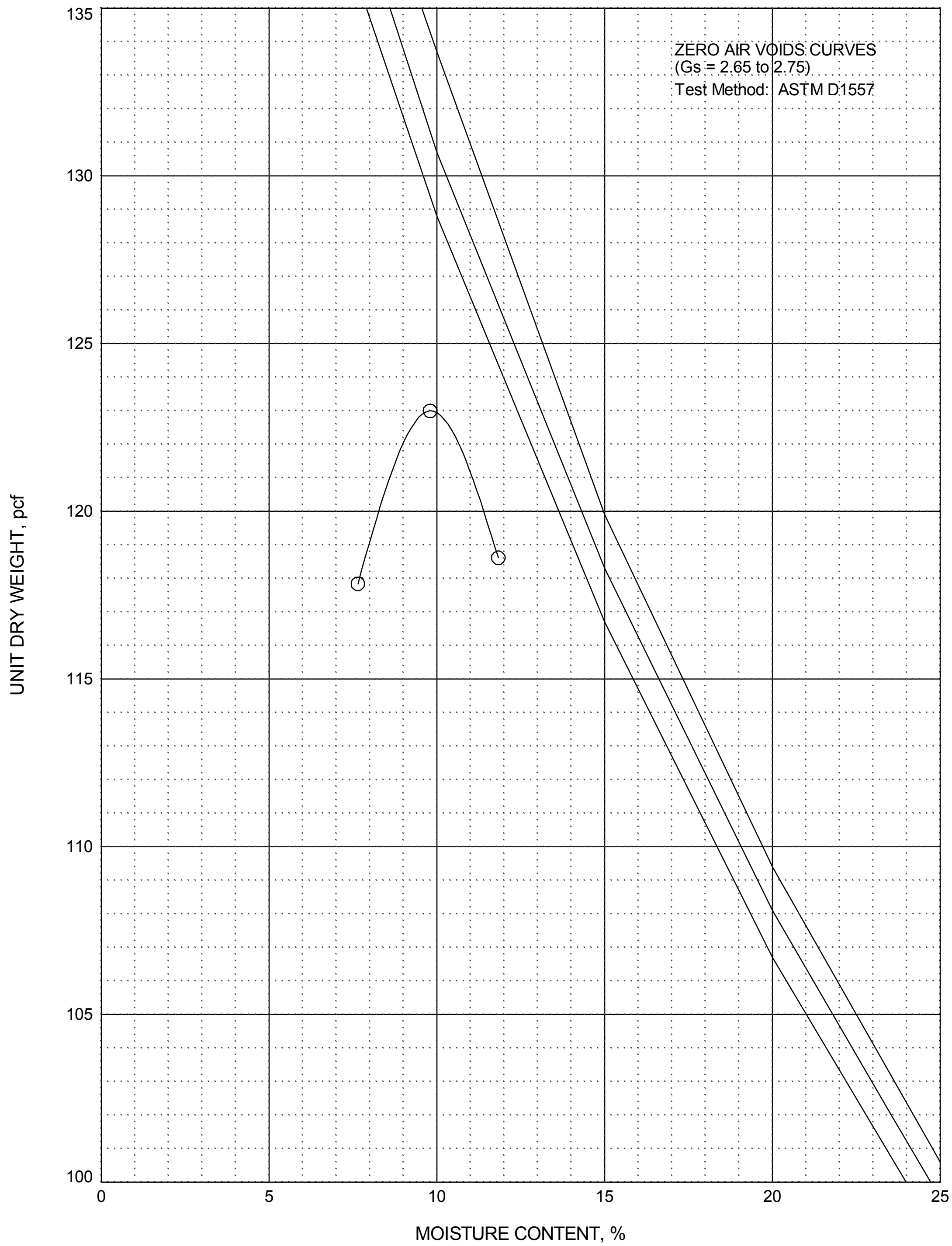
PLATE B-5b



LEGEND (location)	depth, ft	CLASSIFICATION	MAXIMUM UNIT DRY WEIGHT, pcf	OPTIMUM WATER CONTENT, %
○ B-102	0.1	Lean CLAY with sand (CL)	115.0	13.8

COMPACTION TEST RESULTS
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

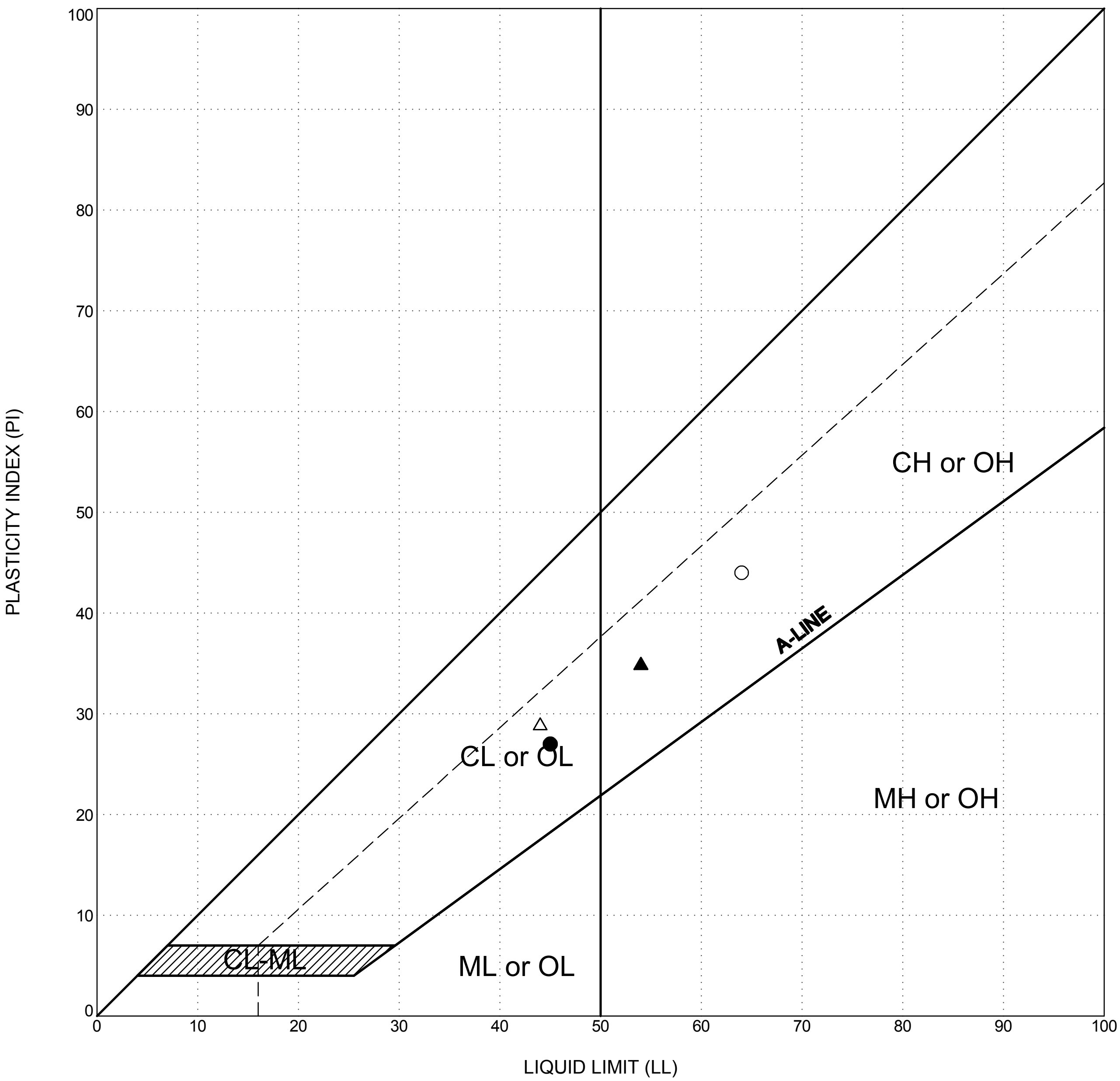
PLATE B-6a



LEGEND (location)	depth, ft	CLASSIFICATION	MAXIMUM UNIT DRY WEIGHT, pcf	OPTIMUM WATER CONTENT, %
○ B-105	0.0	Silty SAND with gravel (SM)	123.0	9.8

COMPACTION TEST RESULTS
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE B-6b



ATTERBERG LIMITS TEST RESULTS

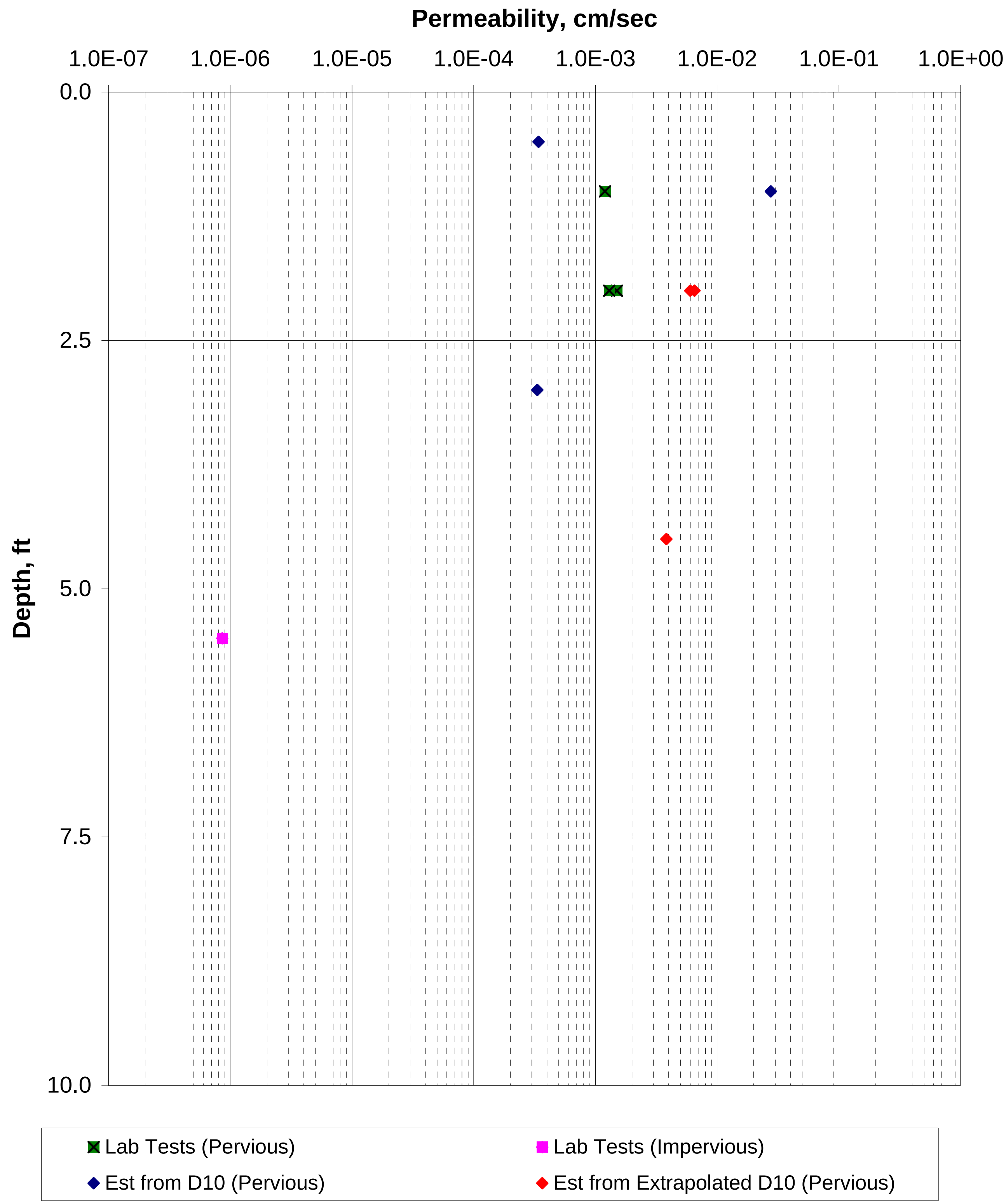
LEGEND location	depth, ft	CLASSIFICATION	LIQUID LIMIT(LL)	PLASTIC LIMIT(PL)	PLASTICITY INDEX (PI)
○ B-101	10.5	Fat CLAY (CH)	64	20	44
● B-102	6.5	Lean CLAY (CL)	45	18	27
△ B-102	15.9	Sandy Lean CLAY (CL)	44	15	29
▲ B-104	6.7	Sandy Fat CLAY (CH)	54	19	35

PLASTICITY CHART
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE B-7

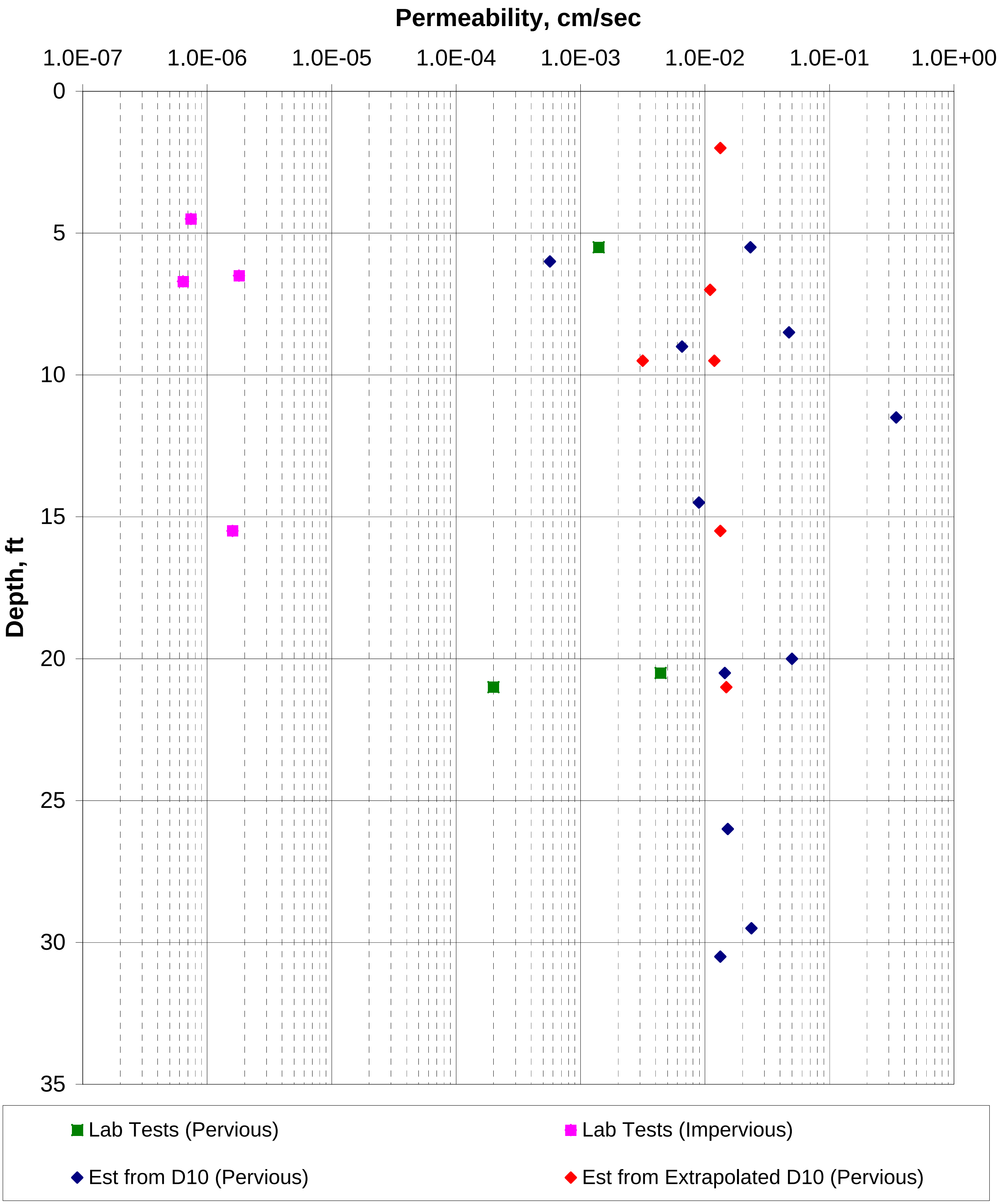
APPENDIX C

Levee Fill

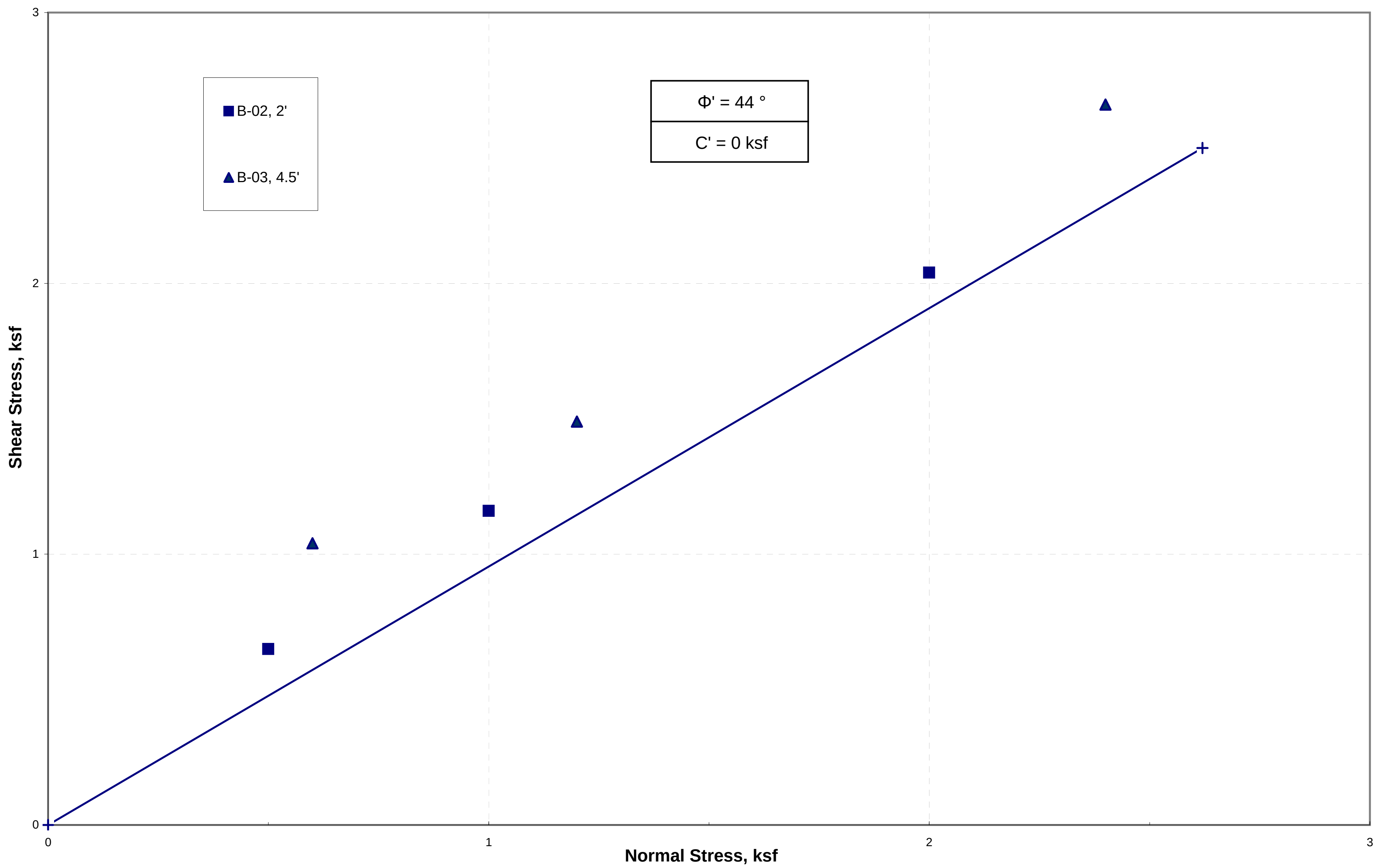


LEVEE FILL HYDRAULIC CONDUCTIVITY ESTIMATES
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

Foundation Material

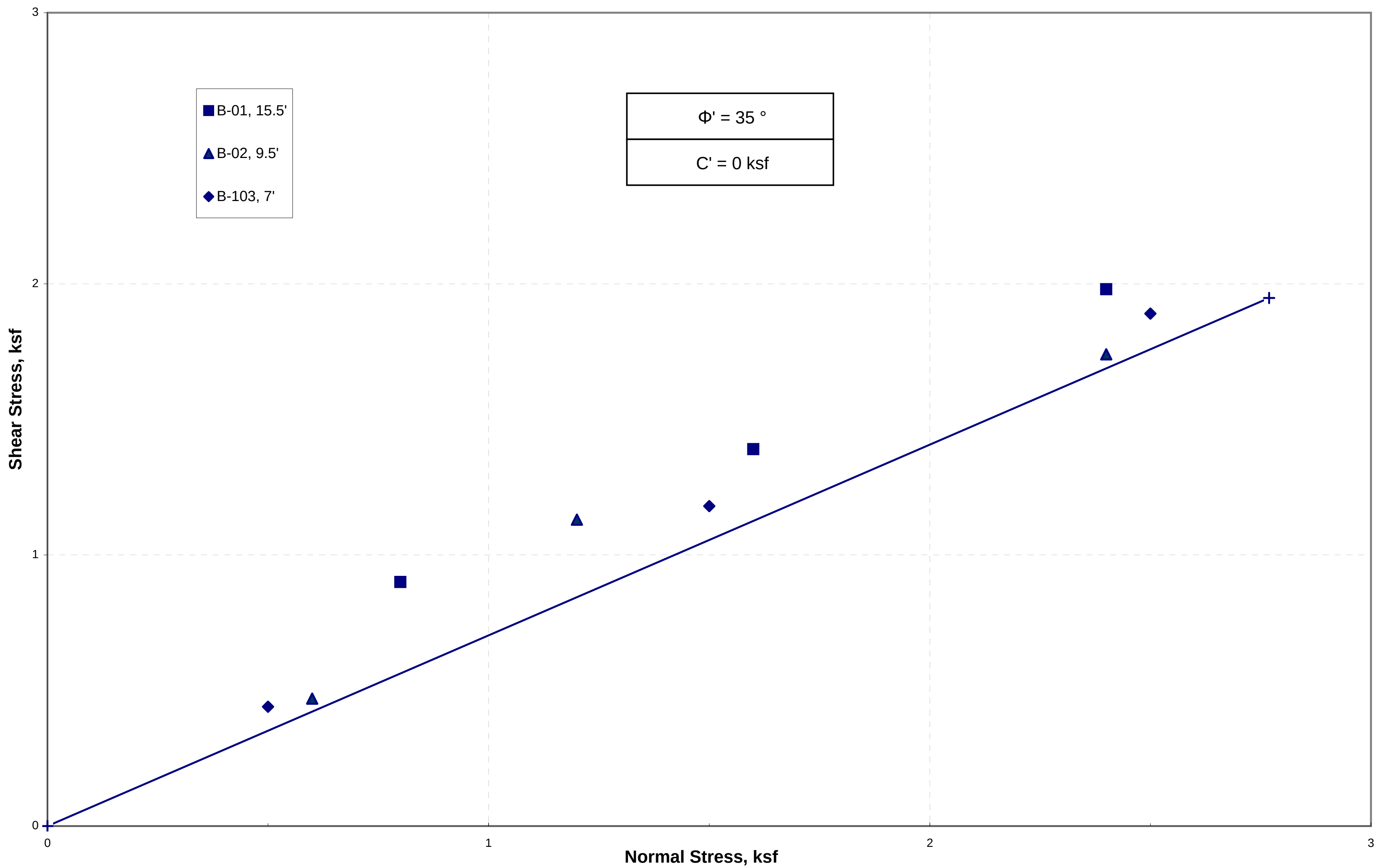


FOUNDATION HYDRAULIC CONDUCTIVITY ESTIMATES
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California



LEVEE FILL DRAINED STRENGTH ESTIMATES
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

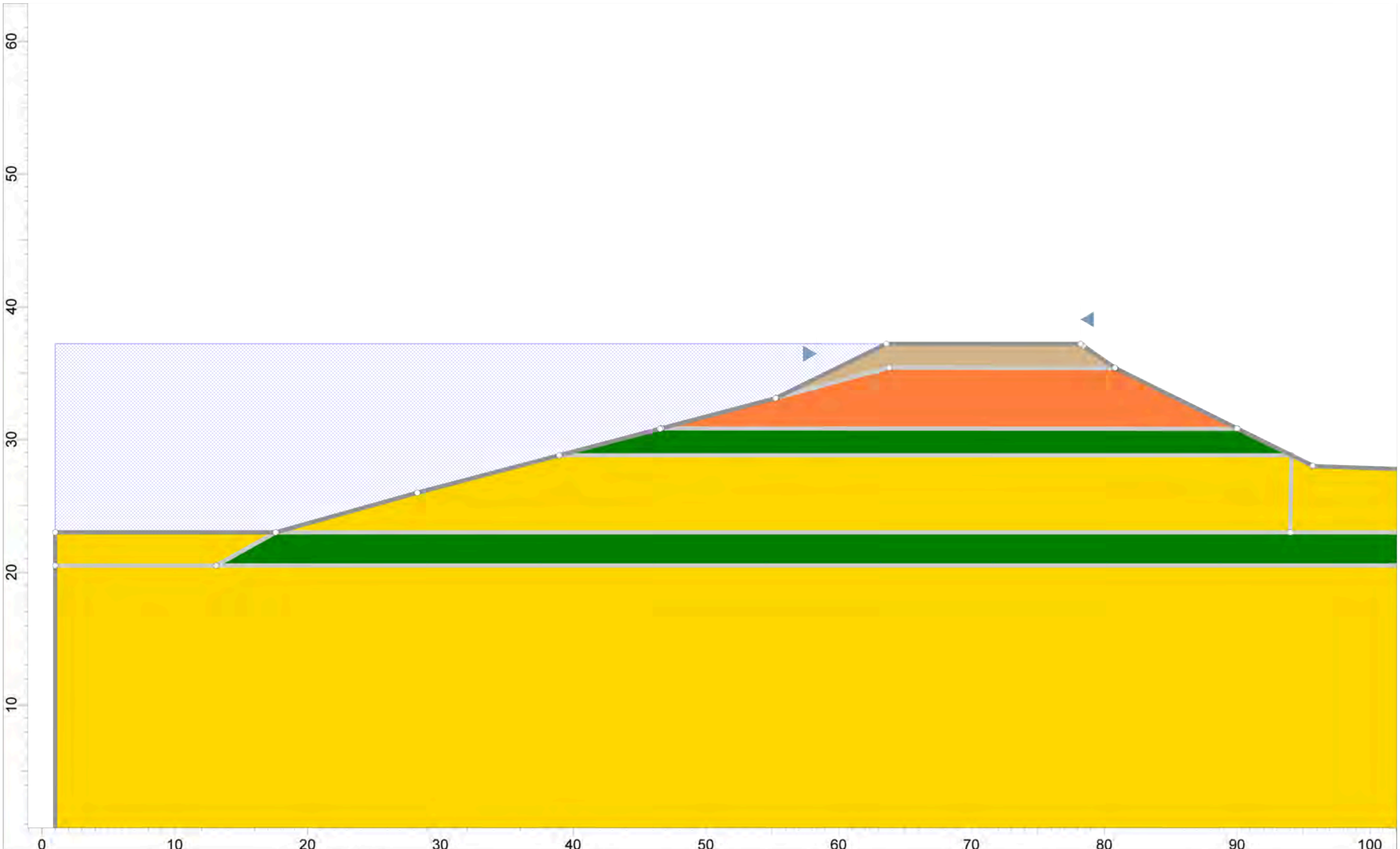
PLATE C-3



PERVIOUS FOUNDATION DRAINED STRENGTH ESTIMATES
Arroyo Grande Creek Levee Improvements
San Luis Obispo County, California

PLATE C-4

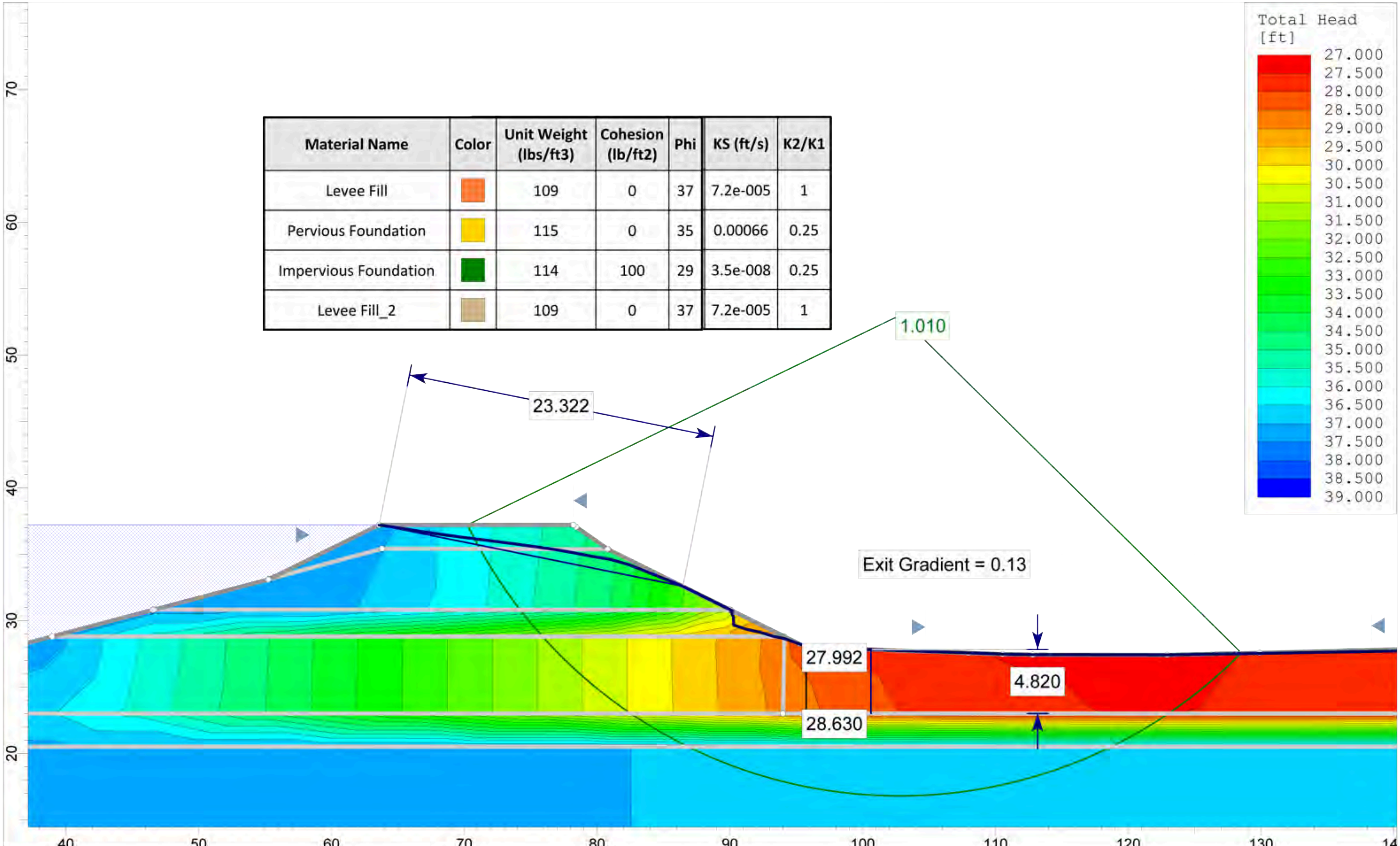
APPENDIX D



Project	Arroyo Grande Creek Levee Improvements			
Analysis Description	STA 80+00 Levee Raise			
Drawn By	GDE	Scale 1:120	Company	Fugro Consultants
Date	August, 2012		File Name	STA 80+00_N Levee_Raise.slim

SLIDE 6.005

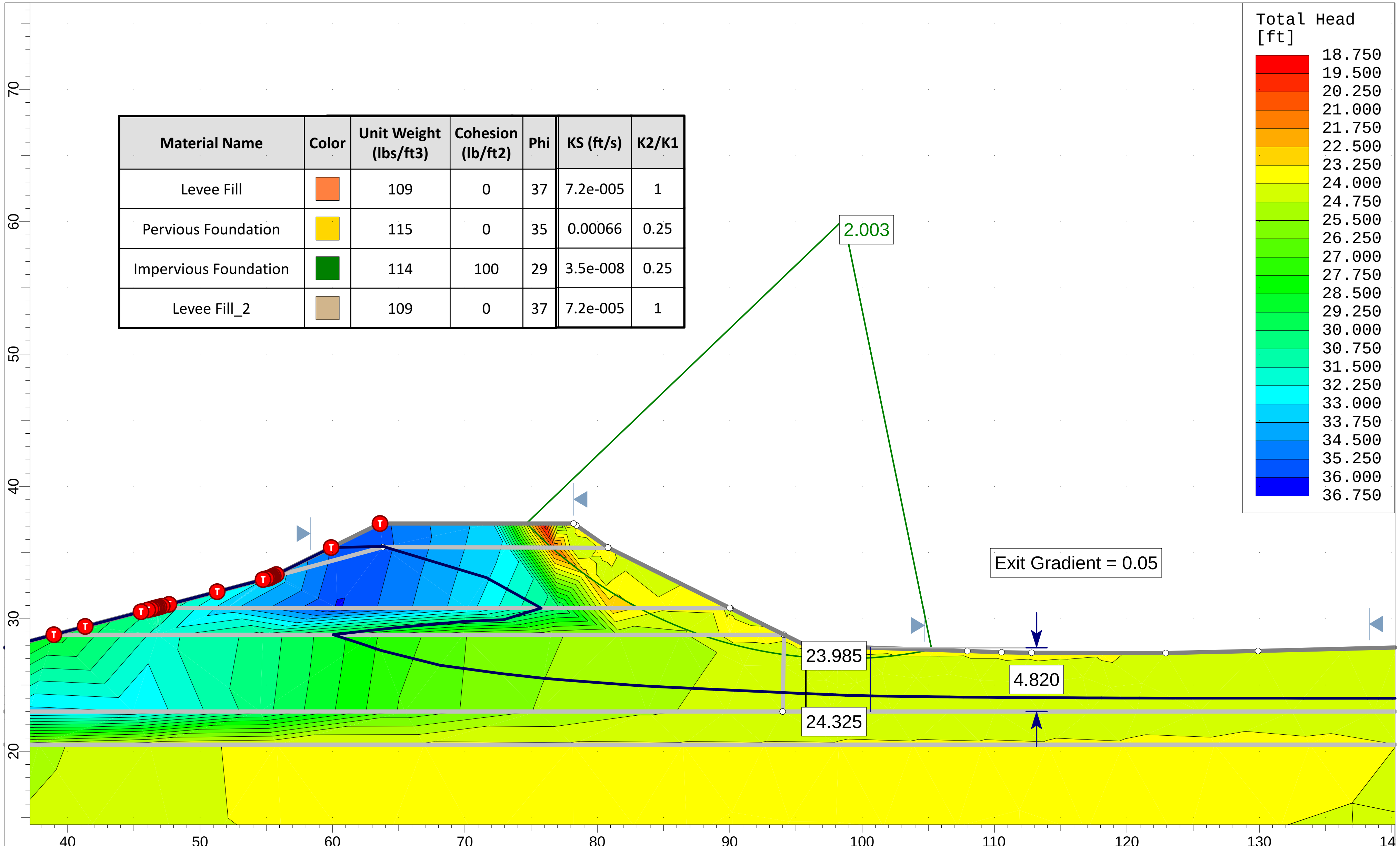
PLATE D-1a



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (lb/ft2)	Phi	KS (ft/s)	K2/K1
Levee Fill		109	0	37	7.2e-005	1
Pervious Foundation		115	0	35	0.00066	0.25
Impervious Foundation		114	100	29	3.5e-008	0.25
Levee Fill_2		109	0	37	7.2e-005	1

rocscience	*Project* Arroyo Grande Creek Levee Improvements		
	Analysis Description STA 80+00 Levee Raise		
	Drawn By GDE	*Scale* 1:120	*Company* Fugro Consultants
SLIDEINTERPRET 6.005	*Date* August, 2012		*File Name* STA 80+00_N Levee_Raise.slim

PLATE D-1b



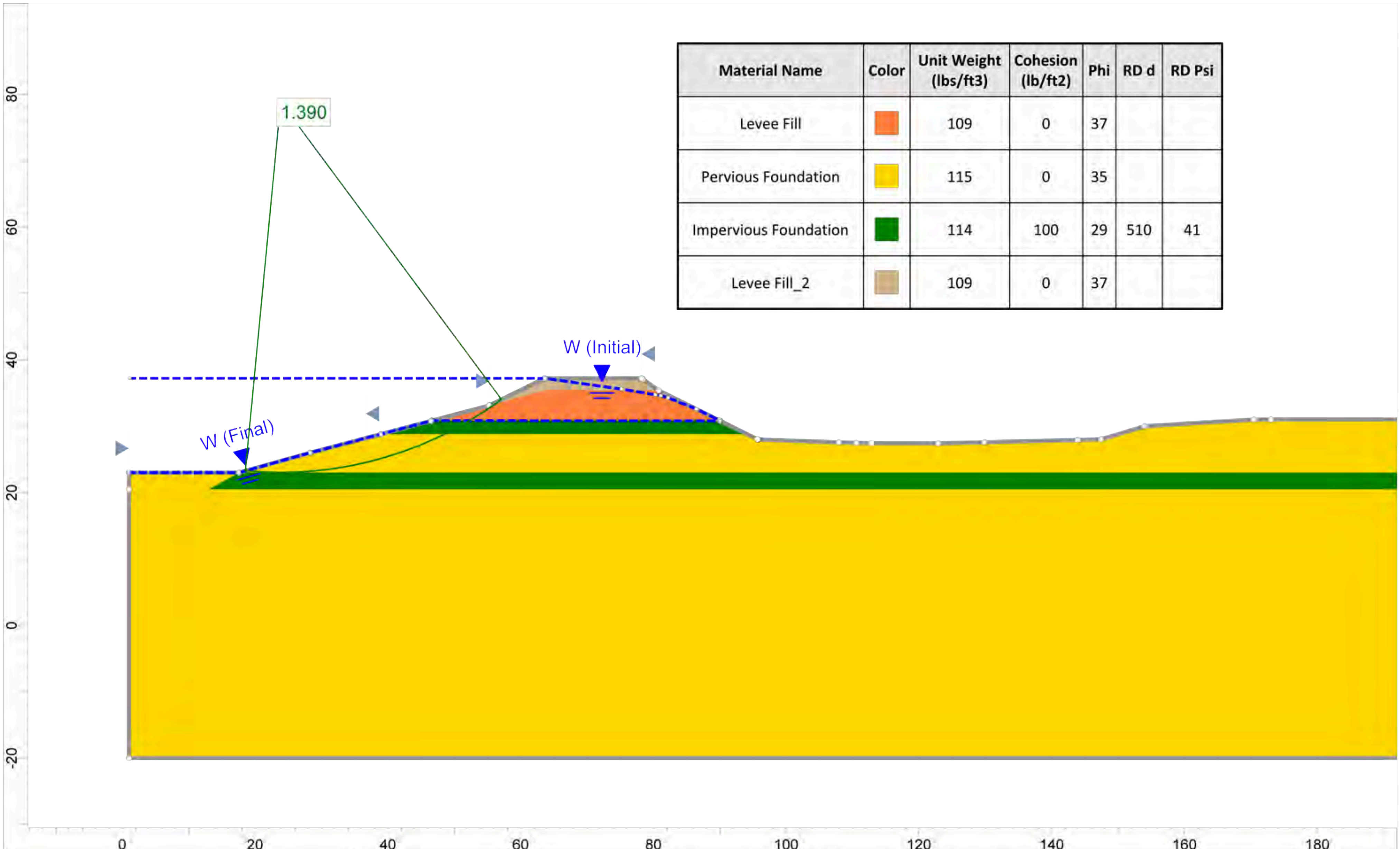
Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (lb/ft2)	Phi	KS (ft/s)	K2/K1
Levee Fill		109	0	37	7.2e-005	1
Pervious Foundation		115	0	35	0.00066	0.25
Impervious Foundation		114	100	29	3.5e-008	0.25
Levee Fill_2		109	0	37	7.2e-005	1

rocscience

SLIDEINTERPRET 6.005

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 80+00 Levee Raise_Transient		
Drawn By GDE	*Scale* 1:120	*Company*	Fugro Consultants
Date	August, 2012	*File Name*	STA 80+00_N Levee_Raise_Transient.slim

PLATE D-1c

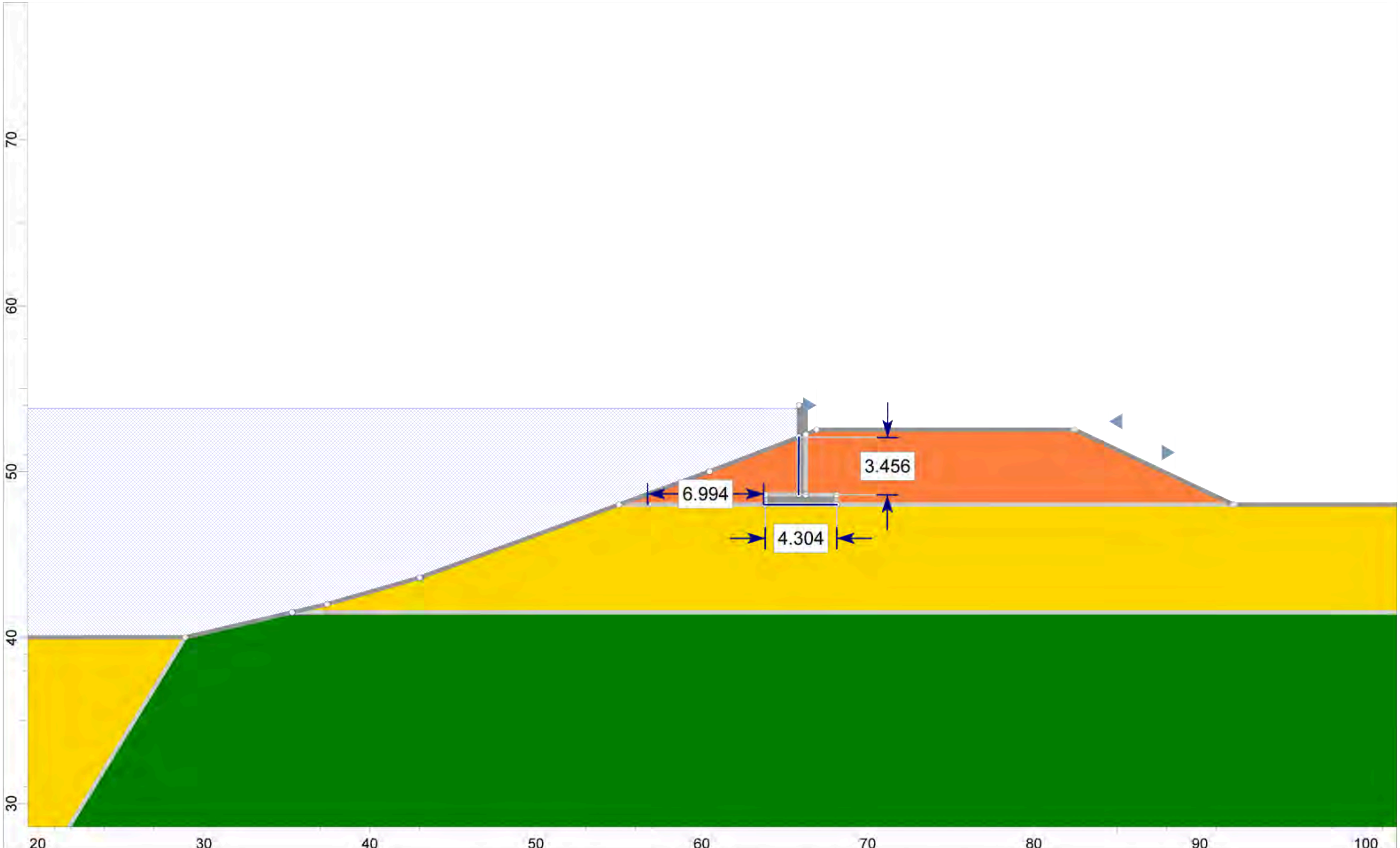


Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (lb/ft2)	Phi	RD d	RD Psi
Levee Fill		109	0	37		
Pervious Foundation		115	0	35		
Impervious Foundation		114	100	29	510	41
Levee Fill_2		109	0	37		

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 80+00 Levee Raise_Rapid Drawdown		
Drawn By GDE	*Scale* 1:240	*Company*	Fugro Consultants
Date	August, 2012	*File Name*	STA 80+00_N Levee_Raise_RD.slim

SLIDEINTERPRET 6.005

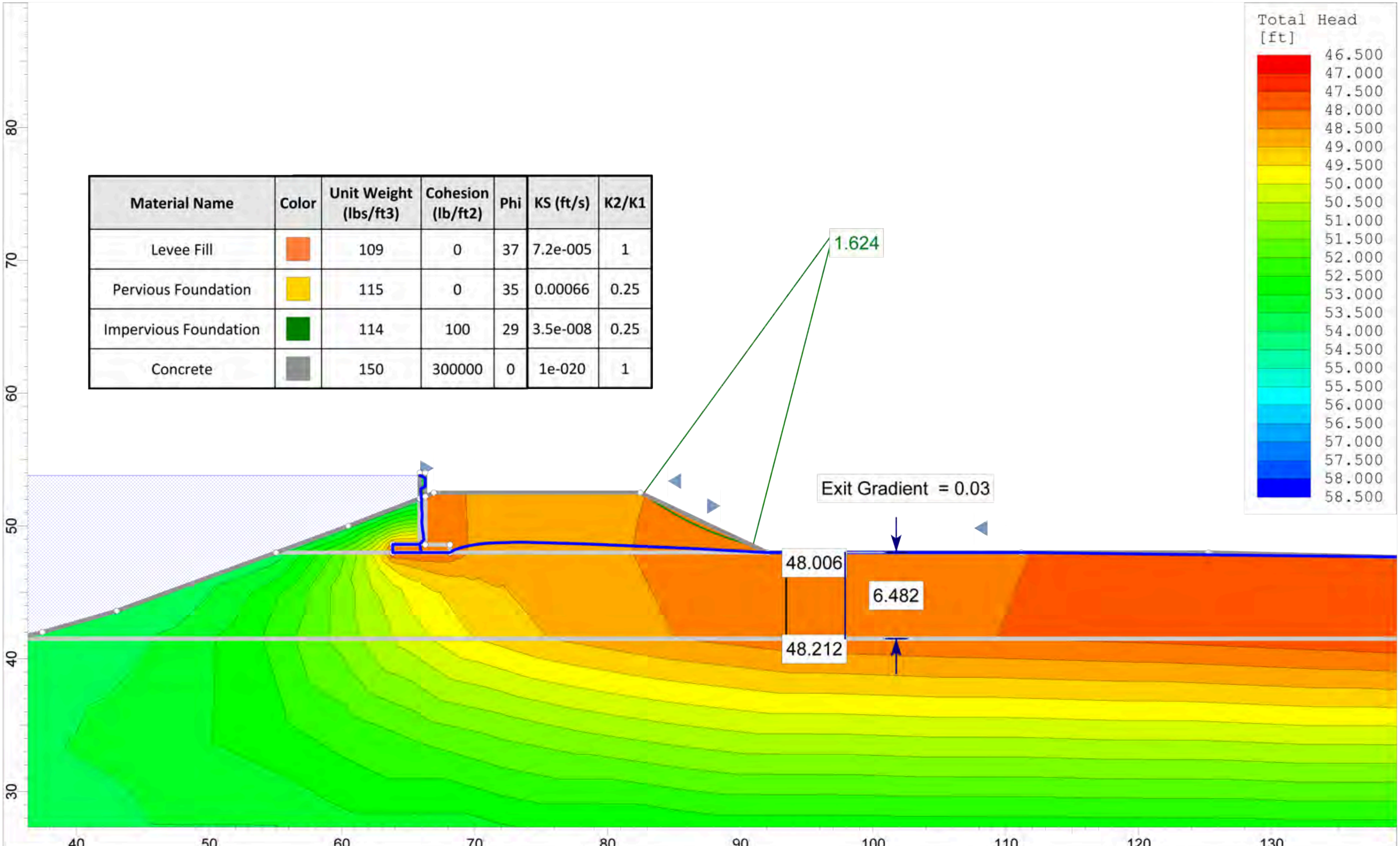
PLATE D-1d



Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 124+00 Levee Floodwall		
Drawn By GDE	*Scale* 1:96	*Company*	Fugro Consultants
Date	September, 2012	*File Name*	STA 124+00_N Levee_Floodwall.slim

SLIDE 6.005

PLATE D-2a



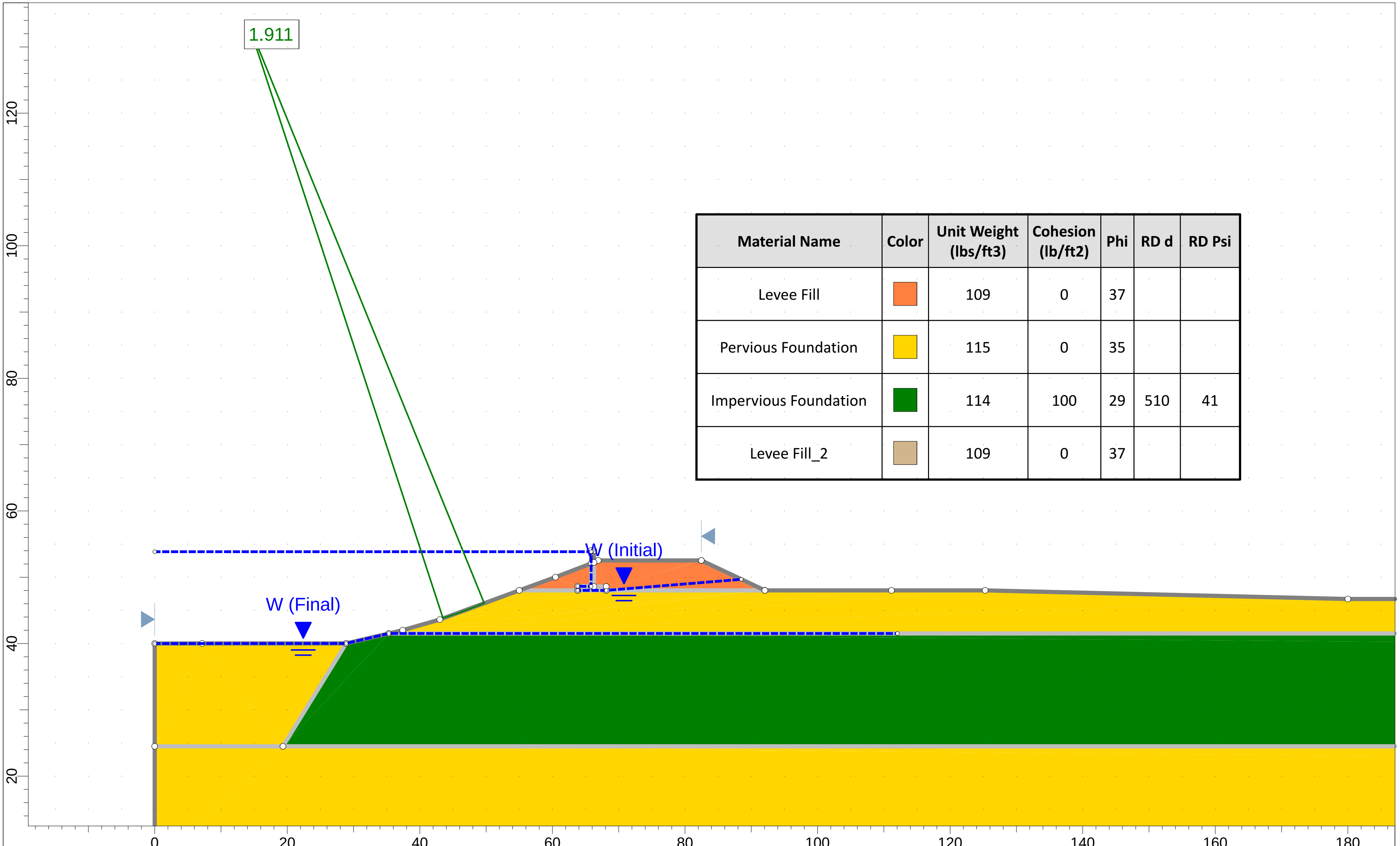
Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (lb/ft2)	Phi	KS (ft/s)	K2/K1
Levee Fill		109	0	37	7.2e-005	1
Pervious Foundation		115	0	35	0.00066	0.25
Impervious Foundation		114	100	29	3.5e-008	0.25
Concrete		150	300000	0	1e-020	1

rocscience

SLIDEINTERPRET 6.005

Project	Arroyo Grande Creek Levee Improvements		
Analysis Description	STA 124+00 Levee Floodwall		
Drawn By GDE	*Scale* 1:120	*Company*	Fugro Consultants
Date	September, 2012	*File Name*	STA 124+00_N Levee_Floodwall.slim

PLATE D-2b



Material Name	Color	Unit Weight (lbs/ft3)	Cohesion (lb/ft2)	Phi	RD d	RD Psi
Levee Fill		109	0	37		
Pervious Foundation		115	0	35		
Impervious Foundation		114	100	29	510	41
Levee Fill_2		109	0	37		

SLIDEINTERPRET 6.005

Project	Arroyo Grande Creek Levee Improvements
Analysis Description	STA 124+00 Levee Floodwall_Rapid Drawdown
Drawn By	GDE
Scale	1:240
Company	Fugro Consultants
Date	September, 2012
File Name	STA 124+00_N Levee_Floodwall_RD.slim

PLATE D-2c