GEOTECHNICAL INVESTIGATION

MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
SONOMA COUNTY, CALIFORNIA

Project No. 12225.01

March 12, 2013

Brunsing Associates, Inc.

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SANTA ROSA, CALIFORNIA

Project No. 12225.01

prepared for

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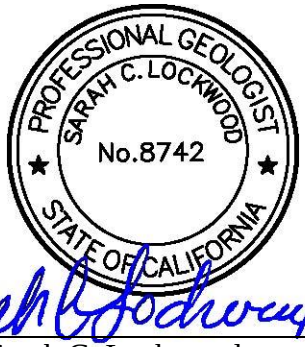

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1.0 INTRODUCTION

This report presents the results of a geotechnical investigation performed by Brunsing Associates, Inc. (BAI), for a proposed new fish screen and ladder system at the Mirabel inflatable dam on the Russian River, a diversion facility operated by the Sonoma County Water Agency. As shown on the Vicinity Map, Plate 1, the site is approximately 2700 feet downstream of Wohler Bridge.

The project will consist of a fish ladder, fish screen and intake, visitor viewing area with an Americans with Disabilities Act (ADA) accessible ramp, sheet pile retaining walls, staircase with lookout area, ADA parking area, and access road. The sheet pile retaining walls will have a free face up to 25 feet high. The fish ladder will be supported on 18-inch diameter driven pipe piles. Anticipated foundation loads for the fish screen and ladder are 65 tons per pile.

On April 11, 2011 our Senior Geotechnical Engineer, Keith Colorado, G.E., and our Project Geologist, Sarah Lockwood, P.G., visited the site with Mr. Mann (HDR) and Mr. Koldis and Mr. Brown with the Sonoma County Water Agency (SCWA) to discuss project design details. We reviewed the preferred configuration described in the Mirabel Fish Screen Reconfiguration Feasibility and Alternatives Study prepared by Prunuske Chatham, dated December 2009. We submitted two draft reports for review dated September 28, 2011 and December 8, 2011. On January 10, 2013, BAI, HDR and SCWA met at the site to further discuss geotechnical recommendations and modified design details. We reviewed the Mirabel Fish Screen and Fish Ladder Replacement preliminary 65 percent drawings prepared by HDR and dated August 9, 2012.

Our services included document review and research, subsurface exploration, aquifer testing, laboratory testing, and engineering and geologic analyses, to provide conclusions and recommendations regarding:

- Suitable foundation type(s) with design criteria and estimated settlement behavior
- Lateral earth pressures for design of walls below grade
- Anticipation and management of groundwater
- Soil material and compaction requirements for site fill, construction backfill, and structure support
- Temporary excavation
- Slope stability
- Geologic hazards, primarily liquefaction and associated hazards such as lurching and lateral spreading
- Seismic activity
- Erosion potential
- Construction considerations
- Additional geotechnical services

2.0 INVESTIGATION

Our investigation was performed in two phases. The results of the first phase were presented in draft reports dated September 28, 2011 and December 8, 2011. On April 11th 2012, we met with representatives of HDR and SCWA to review preliminary drawings prepared by HDR and discuss the need for supplemental geotechnical information. Our second phase investigation was performed November 6 and 13, 2012. On January 10, 2013, representatives of BAI, HDR, and SCWA met to discuss the consequences of earthquake induced liquefaction and approaches to mitigate this potential hazard. The results of both phases are presented in this report.

2.1 Document Review and Research

Our investigation was initiated by reviewing the following resources and published references:

- American Society of Civil Engineers (ASCE) and Southern California Earthquake Center (SC/EC), 2002, Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California.
- California Division of Mines and Geology (CDMG), 1998, Uniform Building Code, Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada: International Conference of Building Officials (ICBO).
- California Geological Survey (CGS), 2008, Guidelines for Evaluating and Mitigating Seismic Hazards in California.
- Cardwell, G.T., 1965, Geology and Ground Water in Russian River Valley Areas in Round, Laytonville and Little Lake Valleys, Sonoma and Mendocino Counties, California: U.S. Geological Survey: Water Supply Survey 1548.
- Delattre, M.P. and Koehler, R.D., 2009, Geologic Map of the Camp Meeker 7.5' Quadrangle Sonoma County, California – A Digital Database: California Geological Survey Preliminary Geologic Map – Version 1.0, website, *http://conservation.ca.gov/cgs/rghm/rgm/preliminary_geologic_maps.htm*.
- Freeze, R.A. and Cherry, J.A. 1979. *Groundwater*. New Jersey: Prentice Hall, Inc.
- Hazen, A. 1911. *Discussion of 'Dams on Sand Foundations',* by A.C. Koenig, Transactions, American Society of Engineers (ASCE).
- Huffman, M.E., and Armstrong, C.F., 1980, Geology for Planning in Sonoma County: California Division of Mines and Geology Special Report 120.
- Idriss, I.M. and Boulanger, R.W., 2008, Soil Liquefaction During Earthquakes
- Jennings, C.W. and Bryant, W.A., 2010, Fault Activity Map of California: California Geological Survey Geologic Data Map No. 6.
- MMI Engineering, Inc., 2011, Draft Geotechnical Data Report, Wohler-Mirabel Liquefaction Mitigation/Ground Improvement Study and Russian River-Cotati Intertie Crossing at the Russian River.
- Robertson, P.K., 2009, Performance Based Earthquake Design using the CPT.
- Sonoma County Water Agency, 1974, As-Built Plan Set for Russian River-Cotati Intertie Project Wohler Dam & Diversion.
- Sonoma County Water Agency, 1989, Official Plan Set for Mirabel Emergency Diversion.

- Su, G. W., Jasperse, J., Seymour, D., and Constantz, J., "Estimation of Hydraulic Conductivity in an Alluvial System Using Temperatures." *Ground Water* 42 (2004): 890-901.

2.2 Field Reconnaissance and Exploration

On April 11, 2011, Keith Colorado and Sarah Lockwood performed a reconnaissance of the site. Our Principal Engineering Geologist, Erik Olsborg, E.G., conducted a geologic reconnaissance on June 23, 2011. Both consisted of site observations, photography, and interpretation of geomorphic expressions along the stream channel.

BAI performed a subsurface exploration on June 21- 23, 2011 (Phase 1), and November 6 and 13, 2012 (Phase 2). It consisted of drilling, logging, and sampling four test borings, M-1 through M-4 and advancing three cone penetration tests (CPTs), CPT-7, CPT-8 and CPT-12 at the locations shown on the Site Plan, Plate 2. The borings were drilled with truck-mounted drill rigs (Marl M-11 and Mobile B-53) utilizing 8- and 7-inch outside diameter hollow stem augers and extended between 42 and 60 feet below the ground surface (bgs). The CPTs were advanced between 66 and 80 feet bgs, with a 20-ton truck-mounted CPT rig.

Our senior geotechnical engineer observed the CPT effort and logged the test borings and obtained relatively undisturbed samples of the soils encountered for visual classification and laboratory testing. The relatively undisturbed samples were obtained using a 2.0-inch outside diameter, SPT sampler and 3-inch outside diameter Modified California (CA) split-barrel sampler, driven by a 140-pound hammer falling 30 inches per blow. The samplers contained liners for retaining the soil materials. Blows required to drive the CA sampler were converted to Standard Penetration Test (SPT) blow counts for correlation with empirical test data, using a conversion factor of 0.64[1]. Once sampling reached the depth of groundwater, water was added to the hollow stem while removing the plug and inserting the sampler.

Graphic logs of test borings and CPT probes showing the materials encountered are presented in Appendix A. Soils were classified in accordance with the Unified Soil Classification System outlined on Plate A5. Soil properties used to describe the materials encountered are presented on Plate A6. The CPT test data were interpreted in accordance with Robertson method as shown in Appendix A.

At the conclusion of drilling, Borings M-3 and M-4 were converted to piezometers (groundwater monitoring wells) by installing 2-inch diameter perforated pipes with sand and fine gravel backfill. For well construction details, including screen intervals and seal depth, see the boring logs.

2.3 Aquifer Testing

BAI performed aquifer tests within the river bank west of the fish ladder to estimate the hydraulic conductivity of onsite soils and thus allow probable seepage rates of groundwater into

[1] SPT blow counts provide a relative measure of soil consistency and strength, and are utilized in our engineering analyses.

the fish ladder excavations to be estimated. The aquifer tests consisted of a pumping test and two slug tests.

Transducers were installed in piezometers M-3 and M-4, on November 6 and 13, respectively. The transducers recorded water levels in each well at one-minute intervals from their respective date of installation through conclusion of aquifer testing on November 27, 2012. During that time, the inflatable dam was lowered and the influence on the water table was recorded in the piezometers. After removing the transducers, our project hydrologist analyzed the gradient of the water table between our piezometers at different times.

Pumping and slug test procedures are summarized in the following paragraphs.

Pumping Test

On November 27, 2012, our project geologist performed a pumping test in monitoring well M-4. It consisted of lowering a submersible pump into the well, pumping water at a constant flow rate, and allowing the well to establish equilibrium with the flow rate. However, equipment limitations prevented any meaningful data from being obtained from the pump test.

Slug Tests[2]

On November 27, 2012, after allowing the well to recover from the pumping test, our project geologist performed slug tests in M-3 and M-4. Transducers measured groundwater levels as the aquifer came to equilibrium and the water level returned to its pre-test elevation. The slug was then removed quickly, causing a sudden drop in the water elevation. The time it took for the water to rise to original conditions was measured and recorded. The recovery time was used to estimate the in-situ hydraulic conductivity of the aquifer soils[3]. Results of the aquifer testing are presented and discussed in the following sections.

2.4 Laboratory Testing

Soil samples obtained during our subsurface exploration were transported to our laboratory and examined to confirm field classifications. Selected samples were tested to estimate their pertinent geotechnical engineering characteristics. Laboratory testing consisted of moisture content-dry density, classification (grain-size), unconsolidated-undrained triaxial compression and direct shear. Laboratory test results are presented in Appendix B and summarized on the boring logs.

[2] A slug test measures aquifer response under both rising head and falling head conditions. First, a weighted cylinder is lowered into the well, displacing a known volume of water and causing the water level in the well to rise. The water elevations are measured and time rates are recorded before the slug is placed, after placement, at equilibrium and after slug is removed.

[3] Hydraulic conductivity (K) describes the rate at which water can move through a permeable medium. It is measured in length per unit time such as centimeters per second (cm/s). It is also referred to as the coefficient of permeability (Fetter 95).

3.0 SITE GEOLOGY

Our investigation indicates the site is underlain by at least 80 feet (maximum depth investigated) of Quaternary alluvial deposits, comprised of unconsolidated gravel, sand, silt, and clay. These deposits are locally discontinuous. Bedrock was not encountered in our borings nor exposed in the nearby river banks. Bedrock in the surrounding area includes the Miocene-Pliocene Wilson Grove Formation sedimentary rocks, Cretaceous-Jurassic Franciscan Complex sedimentary, igneous and metamorphic rocks, and Cretaceous-Jurassic Great Valley Sequence sedimentary rocks. Our interpretation of the subsurface stratigraphy is presented on Cross Sections A-A' and B-B', Plates 3 and 4, respectively.

No evidence of slumping or other instability was observed along the river banks during our reconnaissance. No evidence of significant scour or eroding banks was observed in the immediate area.

No surficial evidence of the presence of active faults (those experiencing surface rupture or seismic activity within the past 11,000 years) was found at the site. The CGS 2010 Fault Activity Map shows Quaternary aged faults (active within the last 1.6 million years), trending to the northwest on either side of the site. The potentially active Mount Jackson Fault is located one-half mile south-southwest of the site. The potentially active Trenton Fault has two mapped traces; one trace is approximately one mile east of the site. The other trace is approximately one mile to the north. If the two traced are connected beneath the alluvium, the fault projection between the two traces would be approximately one-half mile north of the site. Older, inactive fault traces are located several miles north and northwest of the site.

The nearest known active fault is the Rodgers Creek Fault, approximately 7.1 miles east-northeast of the site. The most recent significant earthquake in the area occurred on October 1, 1969, when two moderate shocks (Richter Magnitude 5.6 and 5.7) caused localized damage to structures. The active San Andreas Fault is approximately 13.8 miles southwest of the site. The "potentially active" Mount Jackson Fault is located approximately one-half mile to the southwest. The site is not within a State of California Earthquake Fault (Alquist-Priolo) Zone. Fault locations can be seen on the Regional Fault Map, Plate 5.

Future damaging earthquakes could occur on these faults during the lifetime of the proposed structure. In general, the intensity of ground shaking at the site will depend on the distance to the causative earthquake epicenter, the magnitude of the shock, and the response characteristics of the underlying earth materials.

4.0 SITE CONDITIONS

The existing fish screen and ladder to be reconfigured are located on the western embankment of the river (Site Photograph, Plate 6). The proposed new structure will occupy the same location as the existing structure and will also extend further downstream. We have been informed that the existing dam structure, just east of the fish ladder, has sheet piles confining its foundation. North of the site, the river flows from north to south. At the fish screen location, the river flows generally south-southwest; the western shore is thus on the inside of a very gentle bend. South

of the site, the river bends further to the southwest to the river's confluence with Mark West Creek.

At the time of our field exploration, the dam was inflated, keeping the upstream water surface elevation at approximately 38 feet above Mean Sea Level (MSL). At the time of our aquifer testing, the dam had been deflated and the river elevation was just under 30 feet above MSL.[4] During our field exploration on June 23, 2011, groundwater was encountered at 14 feet below ground surface in boring M-1 and M-2. During our field exploration on November 6, 2012, groundwater was measured at 30 and 17 feet below ground surface in boring M-3 and M-4, respectively. Water elevations during exploration are presented on the boring logs.

The western bank above the existing structures is a cut slope averaging about 2.5 horizontal to 1 vertical (2.5H:1V). Upstream and downstream of the existing fish ladder, the submerged banks have been cut at 2H:1V and covered with filter material and rip rap. A graded service road descends the bank and provides access to the structure, including a level area that parallels the river (Plate 6). A diversion caisson and pump station is located at the top of the bank, directly upslope from the fish screen intake. Areas of the bank that have not been recently graded are heavily vegetated with brush and trees.

Our test borings and CPT probes generally encountered silty sand to clean[5] sand with some gravelly zones. Loose to medium dense, clean sands predominate. Although density generally increases with depth, variable densities were encountered throughout the depth of the borings.

5.0 DISCUSSION AND CONCLUSIONS

5.1 General

Based on the results of our reconnaissance and subsurface exploration, we conclude that the site is geotechnically suitable for the proposed new structure. The main geotechnical considerations include groundwater and surface water management, channel bank erosion/scour, and the consequences of strong seismic shaking from future earthquakes. The impact of these concerns can be minimized by following our recommendations.

5.2 Foundations

The new fish screen, ladder, and associated subsurface walls can be supported on driven, steel pipe piles. Provided the structure is protected from scour and the foundation is designed and constructed in accordance with our recommendations, we estimate that the maximum post-construction static settlement due to foundation loads will be less than ½ inch. We judge that post-construction differential static settlement will be less than ¼ inch between adjacent foundations.

[4] Thomas Jensen, SCWA, e-mail message to BAI, November 29, 2012.
[5] i.e. less than 5 percent passing the number 200 sieve

5.3 Aquifer Characteristics

The data gathered from the two slug tests were analyzed using Hvorslev (1951) method. Tables of the recovery times collected during the slug test are presented and discussed in Table 1 and 2, Appendix E. The results produced hydraulic conductivities of approximately 1 x 10^{-3} cm/sec. These results were judged to be low. To confirm this, we used the results of our grain size analysis to estimate the hydraulic conductivity. The Hazen method as described by Fetter (1988) was used for this calculation. On this basis, we estimate that the soils westerly adjacent to the planned construction area have an in-situ horizontal hydraulic conductivity (K_h) ranging from 1.1 x 10^{-2} to 7.6 x 10^{-2} centimeters per second (cm/s), a typical value for sands and gravels (Freeze & Cherry). These results are more representative of the local hydrogeologic conditions, and are in the same general range as values calculated during a nearby study of Russian River alluvium hydraulic conductivity (Su et al. 2004). We estimate that a vertical hydraulic conductivity value (K_v) an order of magnitude lower, or approximately 1.1 x 10^{-3} to 7.6 x 10^{-3} cm/sec, is appropriate.

5.4 Groundwater and Surface Water Management

Construction of the fish ladder and associated structures will require temporary diversion of the river. Since the construction area is partially in the river bed, water levels are anticipated to be at or above the existing ground surface after diversion of the river. Excavations are likely to encounter groundwater and will require temporary shoring and drainage to prevent caving. Consequently, dewatering will be necessary to create and maintain workable conditions within the construction area.

5.5 Slope Stability and Bank Erosion

Our slope stability analyses were performed to correspond to the guidelines by (1) ASCE and SC/EC and (2) CGS. These publications suggest a factor of safety (FS) greater than or equal to 1.5 for static conditions and 1.1 for pseudo-static conditions is necessary for a stable slope (horizontal seismic coefficient at 0.15).

Cross section A-A' (Plate 3) was created using contours shown on Plate 2. Seven soil units, with different density and strength parameters, were delineated within the slope for our stability analysis and are listed in Table 3 below.

Table 3. Soil Parameters

Unit	Wet Density (pcf)	Cohesion (psf)	Friction Angle (ϕ)
1	120	0	35
2	120	0	30
3	120	0	35
4	130	0	45
5	135	0	45
6	135	0	50
7	130	0	40

The above assigned strengths (cohesion and friction angle) are based on our laboratory test results and back-analysis from our slope stability calculations. Factors of safety were estimated using the computer program SLIDE 5.0 version 5.044 by Rocscience, Inc. employing the Bishop and Janbu Simplified methods. The results are presented in Appendix C.

In our analyses, we used a design flood elevation of 45 feet above MSL, according to Jonathon Mann, this represents the mean annual flood elevation for the site which is commonly maintained for several days or more during the winter[6].

The existing slopes and graded areas above the existing fish ladder are marginally stable as shown in our stability analysis on Plates C1 and C2. To prevent slope failures during severe storms or seismic events, unstable slopes should be mitigated by either over excavation, replacement, and compaction and/or in situ densification. Recommendations for each of these mitigation methods are discussed in following sections. We performed a stability analysis assuming an improvement area as shown on Plates C3 and C4. The analysis under these conditions indicates that the slope will be stable (FS>1.5 and FS>1.1) with the soil improvement.

Protection of the existing vegetation surrounding the existing/planned structure will reduce the risk of bank erosion. Best management practices during construction will help to reduce the impact on existing vegetation in order to maintain bank erosion/stability.

5.6 Seismicity, Faulting and Liquefaction

As discussed above, the site will be subject to strong ground shaking during future, nearby, large magnitude earthquakes originating on the active Rodgers Creek Fault, San Andreas Fault, or possibly other fault systems. The potential for surface fault rupture at the site is considered low. However, the potential for liquefaction exists.[7]

To evaluate liquefaction potential, we performed laboratory testing and liquefaction analysis of the soils. The results of our analysis indicate liquefaction will occur at the site during a design earthquake. To quantify liquefaction induced vertical settlement, we performed an analysis based on procedures by Idriss and Boulanger and CLiq version 1.7.1.14 software using the Robertson method. The results of our analysis are shown in Table 4 below. Liquefaction calculations were performed on the basis of a 7.3 maximum magnitude earthquake and peak ground acceleration of 0.4g for a design basis earthquake. We used a groundwater elevation of 45 feet above MSL, the mean annual flood elevation, in our liquefaction calculations.

Lateral spreading or lurching is generally caused by liquefaction adjacent to slopes. In these cases, the saturated soils move toward an unsupported face, such as a creek or river channel bank or body of water. Our analysis indicates that the overall probability for lateral displacement, during a

[6] HDR Inc., Via March 4, 2013 email from Jonathon Mann

[7] Liquefaction results in a loss of shear strength and potential soil volume reduction in saturated sandy, silty, silty/clayey, and coarse gravelly soils below the groundwater table from earthquake shaking. The occurrence of this phenomenon is dependent on many factors, including the intensity and duration of ground shaking, the soil age, density, particle size distribution, and position of the groundwater table.

design earthquake event, ranges from 39 to 75 percent. Estimated lateral displacements are shown in Table 4.

Table 4. Liquefaction Settlement and Lateral Displacement

Boring/CPT	Settlement (inches)	Lateral Displacement (inches)
M-1	5	52
M-2	2	4
M-3	5	0
M-4	1	19
CPT-07	1	10
CPT-08	5	65
CPT-12	4	60

BAI performed a liquefaction analysis to determine the minimum SPT blow count required with a FS of 2 to mitigate liquefaction potential. Minimum SPT blow counts required are discussed in a following section.

The liquefaction analysis results are presented in Appendix D.

5.7 Liquefaction Mitigation

The planned improvements must either be designed to resist the effects of liquefaction or mitigate its potential. The potential for and impacts of liquefaction were discussed with representatives of HDR and SCWA. It was decided that mitigating the potential for liquefaction was the most cost effective approach. At this time either the fish screen and ladder will be designed to resist the effects of vertical settlement and lateral spreading or the soils that have a potential for liquefaction will be improved by densification. Recommendations for both are provided below.

6.0 RECOMMENDATIONS

6.1 Site Grading

6.1.1 Clearing and Stripping

Areas to be graded should be cleared of existing vegetation, rubbish, and debris. After clearing, surface soils that contain organic matter should be stripped. In general, the depth of required stripping will be about 2 to 4 inches; deeper stripping and grubbing may be required to remove isolated concentrations of organic matter or roots. The cleared materials should be removed from the site or stockpiled for later use in landscape areas, as appropriate.

6.1.2 Structural Area Preparation

Within areas where new construction is planned existing weak soils should be removed for a depth of at least 1 foot below soil subgrade. In some areas, deeper excavations may be necessary to remove very weak soils, if encountered. BAI should observe the excavations to confirm

suitable materials are exposed. The exposed soils should then be scarified to about six inches deep; moisture conditioned to near optimum moisture content and compacted to at least 90 percent relative compaction.[8] These moisture conditioning and compaction procedures should be observed by BAI to check that the soil is properly moisture conditioned and the recommended compaction is achieved.

Fill material, either imported or on-site, should be free of perishable matter and rocks greater than three inches in largest dimension, and should be approved by a representative of BAI before fill placement. Fill for use in structural areas should be of relatively low expansion potential (i.e., Expansion Index of 30 or less). Our investigation indicates that most of the existing on-site soils to be excavated, less any organics and debris, are satisfactory for use as compacted fill. Fill should be placed in thin lifts (six to eight inches in thickness depending on compaction equipment), moisture conditioned to near optimum moisture content, and compacted to at least 90 percent relative compaction, to achieve planned grades.

6.1.3 Slopes and Shoring

Temporary cut slopes in native materials should be inclined no steeper than 2H:1V. Slopes steeper than 2H:1V may be acceptable to preserve existing uphill structures and utilities, and should be observed and approved by BAI during construction. If the materials exposed in the cuts are judged by BAI not stable at steeper inclinations, temporary shoring may be required. The cut slopes should be sloped in accordance with the most current State of California Safety Regulations and are the responsibility of the contractor. BAI should observe cut slopes during the excavation process to check for unanticipated weak or unstable zones.

Planned permanent cut and fill slopes should be inclined no steeper than 2H:1V. Fill slopes should be compacted by rolling and trimming, and be overfilled and trimmed back to planned grade, to expose a firm, smooth surface free of loose material. The onsite soils are highly erodible, so slopes should be planted with vegetation or protected from erosion by other measures (erosion control blankets, etc.), upon completion of grading.

The face of the temporary cut slopes below and adjacent to the existing uphill structures should be no closer than 10 feet horizontal distance from the bottom, outer corner of the footings to the face of slope. The contractor should review as-built plans and pothole to determine the depth and type of foundation prior to cutting the slope in areas of existing structures.

6.2 Liquefaction Mitigation

To mitigate the potential for liquefaction to occur we recommend that vibro-replacement stone columns be used to densify saturated loose sand and gravels within the river embankment upslope of the proposed new fish screen and ladder. A schematic of vibro replacement is shown on Plate 7. Vibro-replacement stone columns are constructed using an electrically powered, eccentrically rotating cam, vibrating probe. The vibrating probe is approximately 18 inches in diameter, and its mechanized lead section is approximately 15 feet in length. Additional lengths

[8] Relative compaction refers to the in-place dry density of soil expressed as a percentage of the maximum dry density of the same material as determined by the ASTM D1557 laboratory test procedure.

of casing are added as needed to reach the full densification depth. A steel pipe welded longitudinally along the side of the unit delivers crushed stone to the tip of the probe once the probe reaches its design depth. The probe may either be hung from a crane or installed in the leads of a hydraulic drill rig to permit the probe to be pushed into the ground. As the probe is advanced into the ground, vibration imparted by the probe will densify the surrounding granular soils and drive the crushed stone delivered down the steel pipe to the tip of the probe into the native soils creating rigid columns of compacted crushed stone surrounded by stone intermixed with a densified soil matrix. The resulting soil matrix forms columns of compacted stone and soil. Soils surrounding these columns are also densified. The process reinforces and stabilizes the looser zones of soil to reduce liquefaction induced settlement and lateral spreading and increase shear strength of the soils, thereby improving the stability of the soils upslope of the proposed fish screen and ladder.

The following recommendations are appropriate for preliminary design of this project:

- Stone columns should be installed to an estimated depth of potentially liquefiable soils: between 25 and 40 feet below the ground surface.
- The minimum area to be densified is outlined on the Site Plan, Plate 2. Area may need adjusting based on tie-back lengths.
- Minimum SPT test blow count achieved should be at least 23.
- Minimum corrected normalized cone tip resistance achieved should be at least 150 ton per square foot (tsf).
- Estimated spacing of stone columns is approximately 8 feet on center; spacing is based on a square pattern.

The spacing of the stone columns is a variable that will need to be refined based on the results of a full scale field pilot test to be completed at the outset of the construction phase. Based on the results of in-situ field tests completed immediately after the test columns have been installed, appropriate production column spacing will be selected to provide the required degree of ground improvement.

6.3 Foundation Support

Structure and foundations should be protected from scour with the use of sheet piles or other alternative. Sheet piles should penetrate at least 5 feet below projected scour depths.

6.3.1 Driven Piles

The planned structures can be supported on driven steel pipe piles. On the basis of preliminary design loads provided by HDR, and utilizing the Federal Highway Administration computer program Driven 1.2 (2001), recommend pile tip elevations are summarized in Table 5. BAI was not able to drill a test boring or drive a probe within the river channel.

Table 5. Pile Capacity and Associated Tip Elevations

Type	Allowable Skin Friction (tons)	Allowable End Bearing (tons)	Allowable Total Capacity[9] (tons)	Tip Elevation[10] (ft)	Allowable Uplift Capacity[11] (tons)
18" dia. Pipe Pile 3/8" Thick Wall Open End	58.3	6.7	65	-24.0	38.9

During construction, piles should be checked for alignment and plumbness, or batter, as appropriate. The acceptable misalignment of a pile should be no more than 3 inches from the design location. The pile should be with two percent of the vertical, or batter line and be spaced no closer than 2.5 nominal pile diameters (center-to-center). Predrilling or jetting should not be performed.

The scale of the pile driving operation makes a traditional indicator pile program not practical. Instead, we recommend utilization of a pile driving analyzer (PDA) during installation of the first production pile. The PDA records data collected by a pair of accelerometers and strain gauges mounted near the top of the pile being driven, and provides real-time case method capacities. PDA data can then be analyzed using a software program such as CAPWAP (Case Pile Wave Analysis Program) which provides a rigorous numerical analysis which models pile and soil behavior to allow an analysis of PDA field data. The results produced provide total pile bearing capacity, resistance distribution, dynamic soil response and a simulated static load test. Pile settlement predictions obtained by CAPWAP have been extensively compared with static load tests, with good correlation between the two. If the design pile capacity is not realized during initial driving operations, we recommend PDA analysis be performed during restrike driving.

6.3.2 Lateral Capacity

Lateral pile analyses were performed for the replacement fish ladder and screen based on data collected during our investigation and our experience with similar subsurface conditions. Using the computer program L-Pile, BAI prepared shear and moment diagrams for piles subjected to lateral deflections of ¼-, ½-, 1-, and 2-inches, for both free and fixed-head conditions. The results are presented on Plates 8 through 13. Maximum and minimum bending moments for each condition is presented in Table 6. Results for different pile lengths and embedment conditions may differ from those presented.

[9] Capacity provided includes a factor of safety = 2.3 for skin friction and end bearing
[10] Tip elevation is based on elevation shown on Plate 2
[11] Uplift capacity should be limited to 2/3 of the allowable skin friction

Table 6: Bending Moments and Pile Deflection for Fixed and Free Head Conditions

	Pile Deflection (in)	Maximum Bending Moment (in-kips)	Minimum Bending Moment (in-kips)
Fixed	2”	2753	-5959
	1”	1479	-3142
	0.5”	800	-1669
	0.25”	433	-889
Free	2”	2281	-112
	1”	1220	-59
	0.5”	652	-31
	0.25”	347	-16

For lateral loading, piles in a group may be considered to act individually when the center-to-center spacing greater than 6D. Table 7 presents the lateral load reduction factors in accordance with Caltrans Guidelines (2011) to be applied for various pile spacing for in-line loading.

Table 7. Lateral Load Group Reduction Factors

Center to Center Pile Spacing for In-Line Loading	Group Efficiency (Ratio of Lateral Resistance of Pile in a Group to Single Pile)
5D	0.93
4D	0.84
3D	0.76

6.4 Seismic Design Criteria

The structures should be designed and/or constructed to resist the effects of strong ground shaking (on the order of Modified Mercalli Intensity IX) in accordance with current building codes. The California Building Code (CBC) 2010 edition indicates that the site classification for the property is Site Class F, due to the liquefiable soils. For design purposes BAI is using Site Class D. The CBC indicates that the following seismic design parameters are appropriate for the site:

Site Class = D
Mapped Spectral Response Acceleration at 0.2 sec Ss = 1.500g
Mapped Spectral Response Acceleration at 1.0 sec S_1 = 0.600g
Design Spectral Response Acceleration at 0.2 sec S_{DS} = 1.000g
Design Spectral Response Acceleration at 1.0 sec S_{D1} =0.600g
Design Acceleration $S_{DS}/2.5$ = 0.4g
Seismic Design Category = D

6.5 Retaining Walls

6.5.1 General

Retaining walls should be either provided with permanent back drainage to prevent buildup of hydrostatic pressure or designed to resist hydrostatic pressures. Back drain recommendations are presented on Plate 14. Quality, placement and compaction requirements for backfill behind retaining walls are the same as previously presented for fill material (Section 6.1.2). Light compaction equipment should be used near the wall to avoid overstressing the walls.

Retaining walls should be designed to resist the lateral pressures presented on Plate 15. Hydrostatic pressures are presented on Plate 15. Retaining walls with tie-backs should be designed to resist the lateral pressures presented on Plate 16. These pressures do not consider additional loads resulting from adjacent foundations, vehicles, or other downward surcharge loads. The lateral influence due to vehicle loads is illustrated on Plate 17. BAI can provide lateral pressures for other surcharge loads, if needed.

In addition to static loads, the retaining walls should be designed to resist potential seismic loads, in accordance with CBC requirements. For seismic loads, use a pressure increment equivalent to an inverted triangular distribution, varying from zero psf at the bottom of the wall to 18H psf at the top of the embedded portion, where “H” is the height of the embedded portion. The resultant dynamic thrust acts at 0.6H above the base of the wall.

If retained soils are not improved by densification, the retaining walls should be designed to resist lateral pressures due to liquefaction. For this condition, the retaining walls should be designed to resist an equivalent fluid pressure (triangular distribution) of 125 pcf.

6.5.2 Sheet Piles

Temporary or permanent sheet piles may be used in conjunction with temporary cut slopes during retaining and subsurface wall construction. Installation of sheet piles at the locations of retaining walls would create temporary shoring for slopes during construction and, depending on construction phasing, could then be removed and used elsewhere on site. Design requirements for sheet piles are the same as previously presented in Section 6.5.1. Existing soil parameters for design are presented in Table 8. Soil parameters for areas improved by densification are presented in Table 9. The final wall configuration, including depth of embedment, should be determined by the structural, shoring engineers and/or contractor in consultation with BAI.

Table 8. Existing Soil Parameters

Top (in)	Bottom (in)	γ (pcf)	ϕ (degrees)	c (psf)	k (pci)	Limiting Lateral Displacment (in)	Layer
0	48	135	32	0	225	0.5	1
48	168	120	30	0	90	0.5	2
168	252	132	33	0	20	0.5	3
252	396	135	35	0	60	0.5	4
396	456	130	33	0	125	0.5	5
456	576	125	32	0	60	0.5	6
576	648	125	33	0	125	0.5	7
648	672	120	0	1000	100	0.5	8
672	720	130	33	0	125	0.5	9
720	804	120	0	2000	500	0.5	10

Table 9. Predicted Densified Soil Parameters

Top (in)	Bottom (in)	γ (pcf)	ϕ (degrees)	c (psf)	k (pci)	Limiting Lateral Displacment (in)	Layer
0	48	135	40	0	225	0.5	1
48	168	135	40	0	225	0.5	2
168	252	135	40	0	125	0.5	3
252	396	135	40	0	125	0.5	4
396	456	130	33	0	125	0.5	5
456	576	125	32	0	60	0.5	6
576	648	125	33	0	125	0.5	7
648	672	120	0	1000	100	0.5	8
672	720	130	33	0	125	0.5	9
720	804	120	0	2000	500	0.5	10

As discussed in Section 5.4, sheet piles may also be utilized for temporary water diversion and cut off at grade after construction is complete. This method would provide the added benefit of scour protection along the base of the new structures.

6.5.3 Tie-backs

Tie-backs are in-situ, laterally installed reinforcing elements embedded in grout in boreholes drilled into supporting material. They consist of high-strength steel cables or rods that are post-tensioned onto steel base plates, placed into a grade beam or whaler system, after installation of the cables/rods within a sleeve in the laterally drilled borehole. If the soil upslope of the retaining walls is improved by densification, then tie-backs can be used. Tie-backs into existing liquefiable soils are prone to failure under seismic conditions.

Tie-backs should be inclined downward at about 15 degrees from horizontal. They should be at least 40 feet long (total length) with at least a 10 feet unbonded length, and a bore diameter of at least 8 inches. All tie-backs should be proof or performance tested to the load required by the structural engineer.

Design provisions for corrosion protection of the tie-backs would be required. For preliminary design of the tie-backs, use the following average, ultimate (no geotechnical factor of safety) soil parameter values. These values will be subject to further confirmation during soil densification/improvement.

- Average adhesion resistance, = 400 psf
- Average unit weight, "γ" 135 pcf

6.6 Asphalt Paved Areas

We have estimated that the near surface soils have an average R-value of about 30. Using an R-value of 30, assumed Traffic Indices (T.I.s.) of 5, 6 and 7, and Caltrans flexible pavement design procedures, our recommendations for minimum pavement section thicknesses are presented Table 10.

Table 10. Pavement Section Thickness

Area	T.I.	Thickness (inches) (1)	
		Asphalt Concrete Surfacing	Class 2 Aggregate Base
Driveway and Parking Areas	5.0	2.5	6.0
	6.0	3.0	8.0
	7.0	4.0	9.5

These thicknesses are the recommended minimums. Increasing asphalt concrete thickness in place of Class 2 Aggregate Base would increase the life and durability of the pavement section. If a different T.I. is determined for these pavement areas, BAI can provide additional pavement sections.

Class 2 Aggregate Base should have a minimum R-value of 78 and conform to the requirements contained in Section 26 of Caltrans (State of California) Standard Specifications, latest edition. Aggregate base should be placed in thin lifts and in a manner to prevent segregation; moisture conditioned to near optimum moisture content, and compacted to at least 95 percent relative compaction to provide a smooth unyielding surface. The upper 6 inches of subgrade soils should be compacted to at least 95 percent relative compaction to provide a smooth, unyielding surface. Weak soils within pavement areas should be removed and compacted to at least 90 percent relative compaction, as described in Section 6.1 of this report.

7.0 CONSTRUCTION CONSIDERATIONS

Depending on the depth of the existing sheet piles surrounding the dam foundation, planned excavations could reduce their lateral support capacity. Properly designed temporary shoring and/or underpinning may be necessary during demolition and construction.

Care should be taken to locate and protect existing underground utilities from damage during excavation and/or installation of sheet piles.

Excavations are likely to encounter groundwater and may require temporary shoring and dewatering. Accumulated water at the base of excavations can be removed by dewatering measures. During grading concentrated surface flows should be directed away from excavation areas.

Excavated soils should be stockpiled in areas so as not to surcharge cut slopes.

If sheet piles are utilized during retaining wall construction, careful location of the existing water diversion pipe will be critical. The sheet piles can be installed in sections to either side of the pipe and above it. Extreme care will be necessary to avoid damage to the pipe at and above the interface with the section to be demolished.

Placement of sheet piles into sand that has been densified may be difficult. Contractors will need to work together ensure efficient ground improvement and placement of sheet piles.

Caving may occur in tie-back holes, regardless of groundwater levels. Driller should be prepared to temporarily case the holes.

On site soils are cohesionless and as such are highly erodible, have a relatively high hydraulic conductivity and are susceptible to caving, especially when saturated.

8.0 ADDITIONAL SERVICES

During construction, after waters are diverted, BAI should observe the pile driving operations to check that conditions are as assumed and that our recommendations are applicable to the entire area. If significantly different conditions are observed, BAI may need to revise our recommendations. In addition, BAI should review the final grading and foundation plans and soil related specifications. This important step will allow us to check that the recommended design criteria were applied as we intended.

During soil improvement for liquefaction mitigation, BAI should observe, monitor and test the densification improvement. To check the densification, we will have to either perform CPT test and/or boring during the pilot test to evaluation the spacing and pattern for liquefaction mitigation.

During construction, BAI should observe soil conditions exposed during grading and excavations and foundation installation activities and perform the appropriate field and laboratory testing during site preparation and grading. Our observations and tests will allow us to check that the work is being performed in accordance with project guidelines, confirm that the soil conditions are as anticipated, and to modify our recommendations, if necessary.

9.0 LIMITATIONS

This geotechnical investigation was performed in accordance with the usual and current standards of the profession, as they relate to this and similar localities. No other warranty, either expressed or implied, is provided as to the conclusions and professional advice presented in this

report. Our conclusions are based upon reasonable geologic and engineering interpretation of available data.

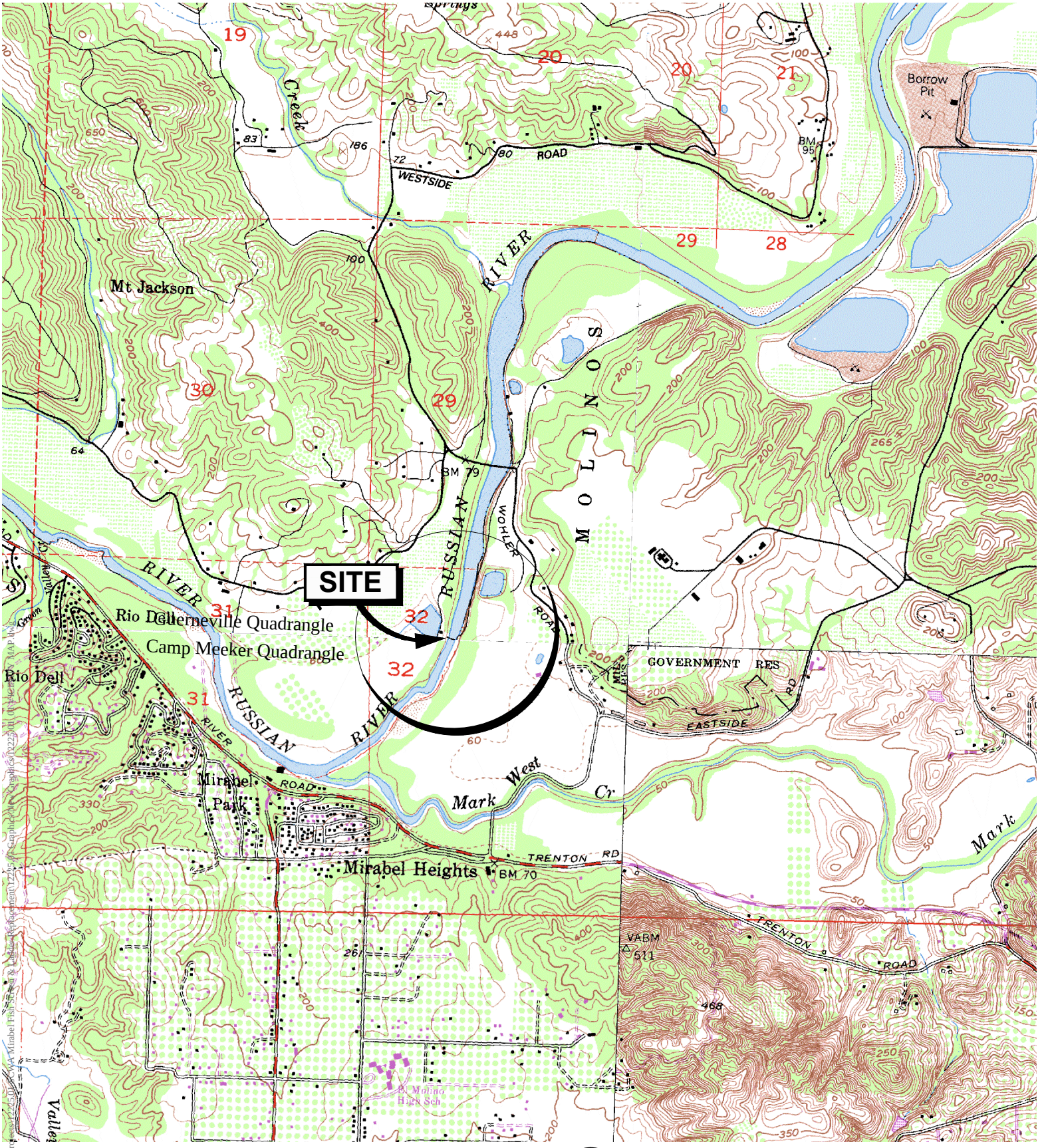
The samples taken and tested, and the observations made, are considered to be representative of the site; however, soil and geologic conditions may vary significantly between test borings, CPT's and across the site. As in most projects, conditions revealed during construction excavation may be at variance with preliminary findings. If this occurs, the changed conditions must be evaluated by BAI, and revised recommendations be provided as required.

This report is issued with the understanding that it is the responsibility of the Owner, or his/her representative, to insure that the information and recommendations contained herein are brought to the attention of all other design professionals for the project, and incorporated into the plans, and that the Contractor and Subcontractors implement such recommendations in the field. The safety of others is the responsibility of the Contractor. The Contractor should notify the owner and BAI if he/she considers any of the recommended actions presented herein to be unsafe or otherwise impractical.

Changes in the conditions of a site can occur with the passage of time, whether they are due to natural events or to human activities on this, or adjacent sites. In addition, changes in applicable or appropriate codes and standards may occur, whether they result from legislation or the broadening of knowledge. Accordingly, this report may become invalidated wholly or partially by changes outside our control. Therefore, this report is subject to review and revision as changed conditions are identified.

The recommendations contained in this report are based on certain specific project information regarding type of construction and structure location, which have been made available to us. If conceptual changes are undertaken during final project design, we should be allowed to review them in light of this report to determine if our recommendations are still applicable.

ILLUSTRATIONS



REFERENCE:
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Guerneville - 1993, Healdsburg - 1993
7.5 Minute Series, (Topographic), USGS

Latitude: 38.4998 N
Longitude: -122.8862 W

NORTH

APPROXIMATE SCALE (FEET)

0 1000 2000 4000

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Job No.: 12225.01
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Date: 03/12/13

VICINITY MAP
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
1

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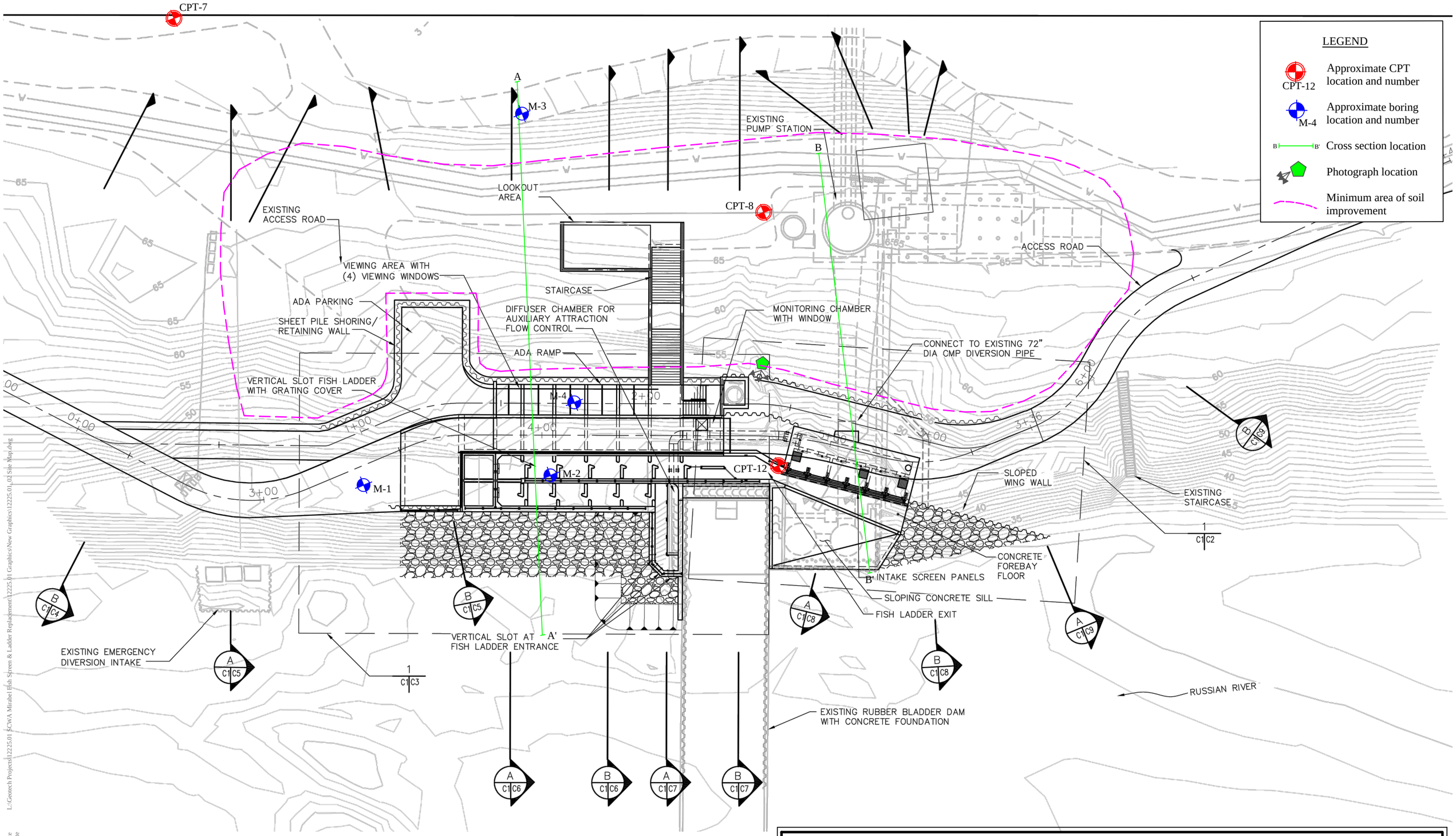

REFERENCE: Mirabel Fish Screen and Fish Ladder Replacement Overall Site Plan, Sheet C1, dated 8.9.2012, prepared by HDR Fisheries

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SITE PLAN
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE 2

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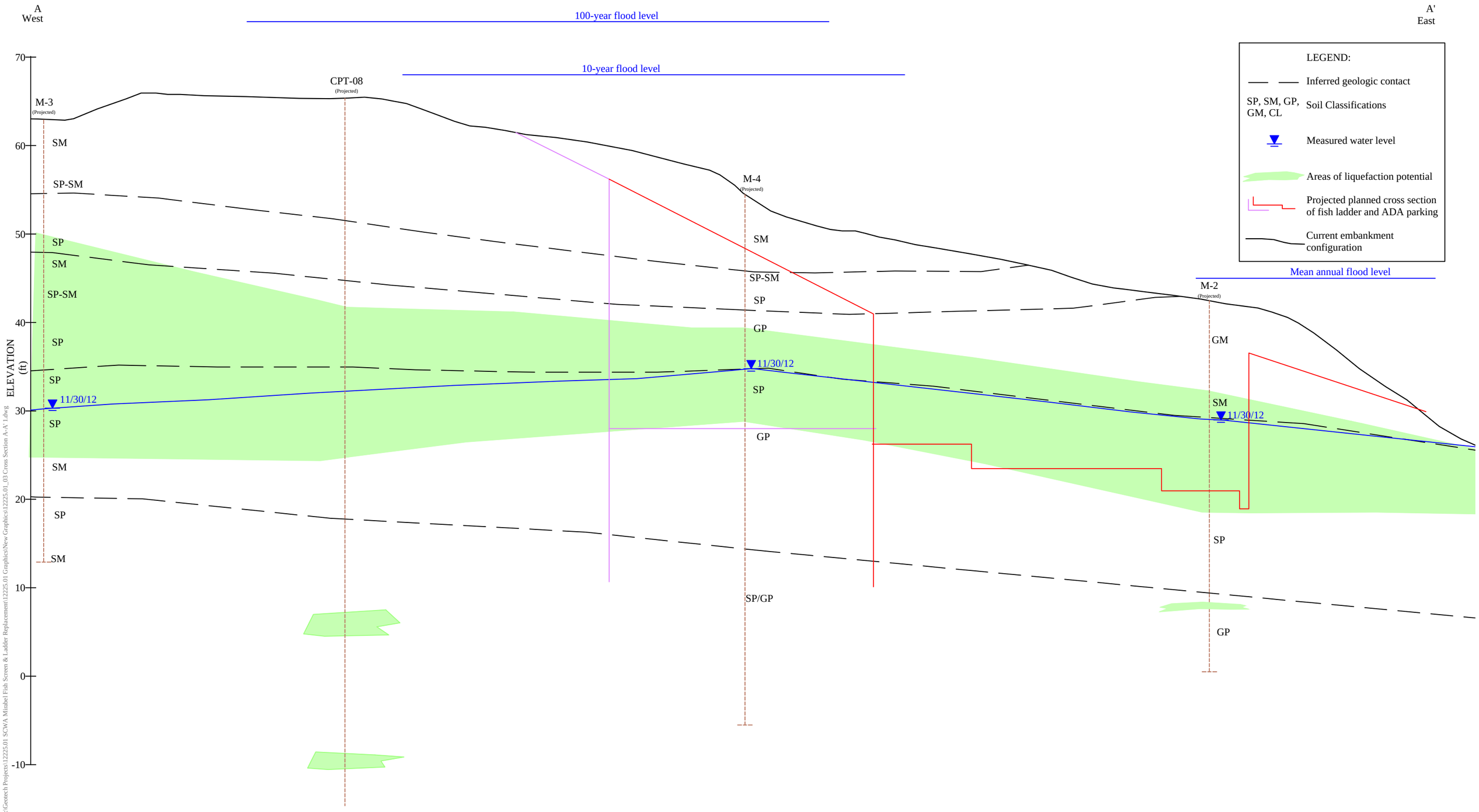

NOTE:
For explanation of soil classification abbreviations, see Appendix A, Plate A5.
Flood levels provided by Jon Mann, HDR
See Plate 2 for cross section location

REFERENCE: Mirabel Fish Screen and Fish Ladder Replacement
Overall Site Plan, Sheet C1, dated 8.9.2012, prepared by HDR Fisheries

APPROXIMATE VERTICAL AND HORIZONTAL SCALE (FEET)

0 5 10 20

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CROSS SECTION A-A'
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
3

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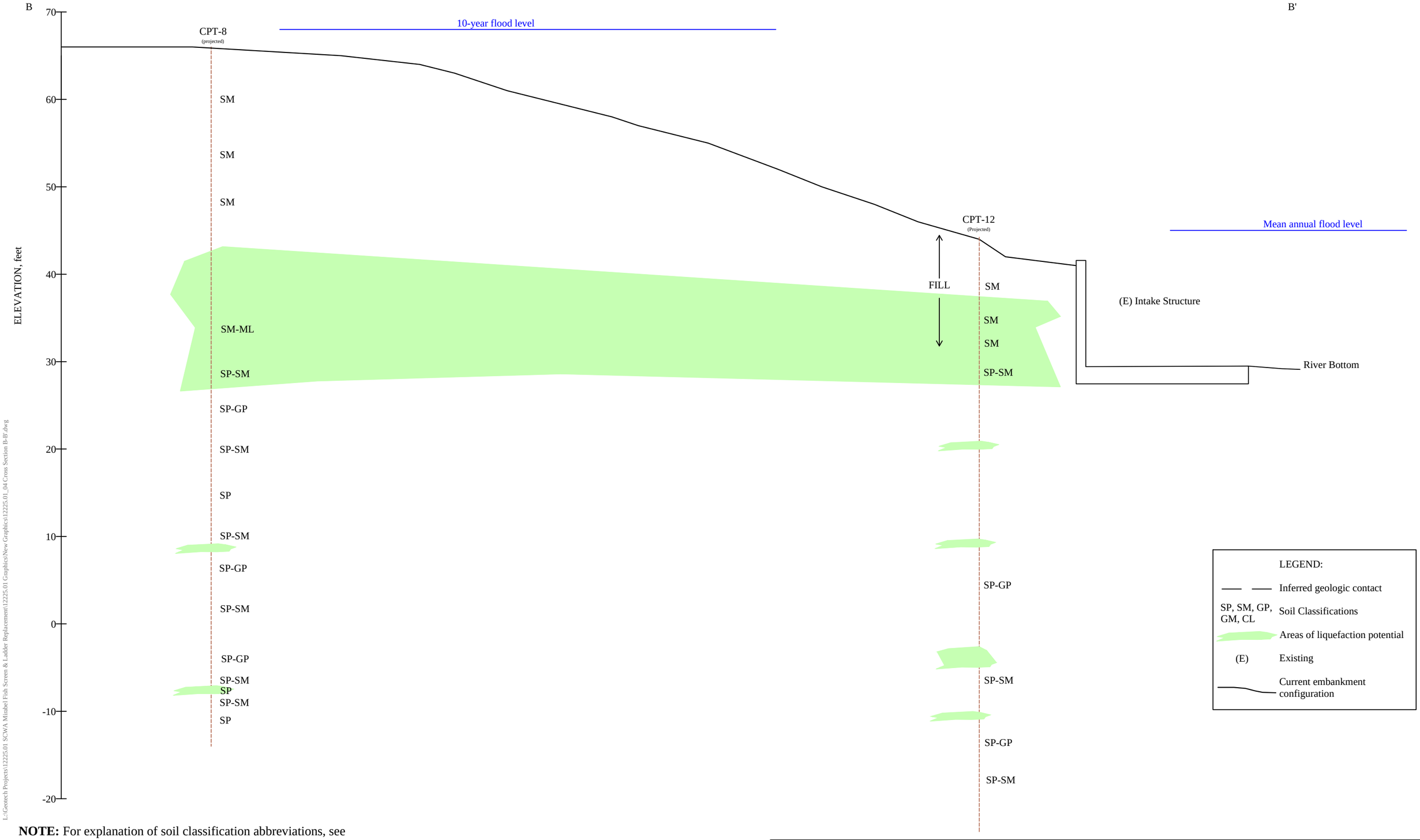

NOTE: For explanation of soil classification abbreviations, see Appendix A, Plate A5.

REFERENCE: Mirabel Fish Screen and Fish Ladder Replacement Overall Site Plan, Sheet C1, dated 8.9.2012, prepared by HDR Fisheries

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APPROXIMATE VERTICAL AND HORIZONTAL SCALE (FEET)

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CROSS SECTION B -B'
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
4

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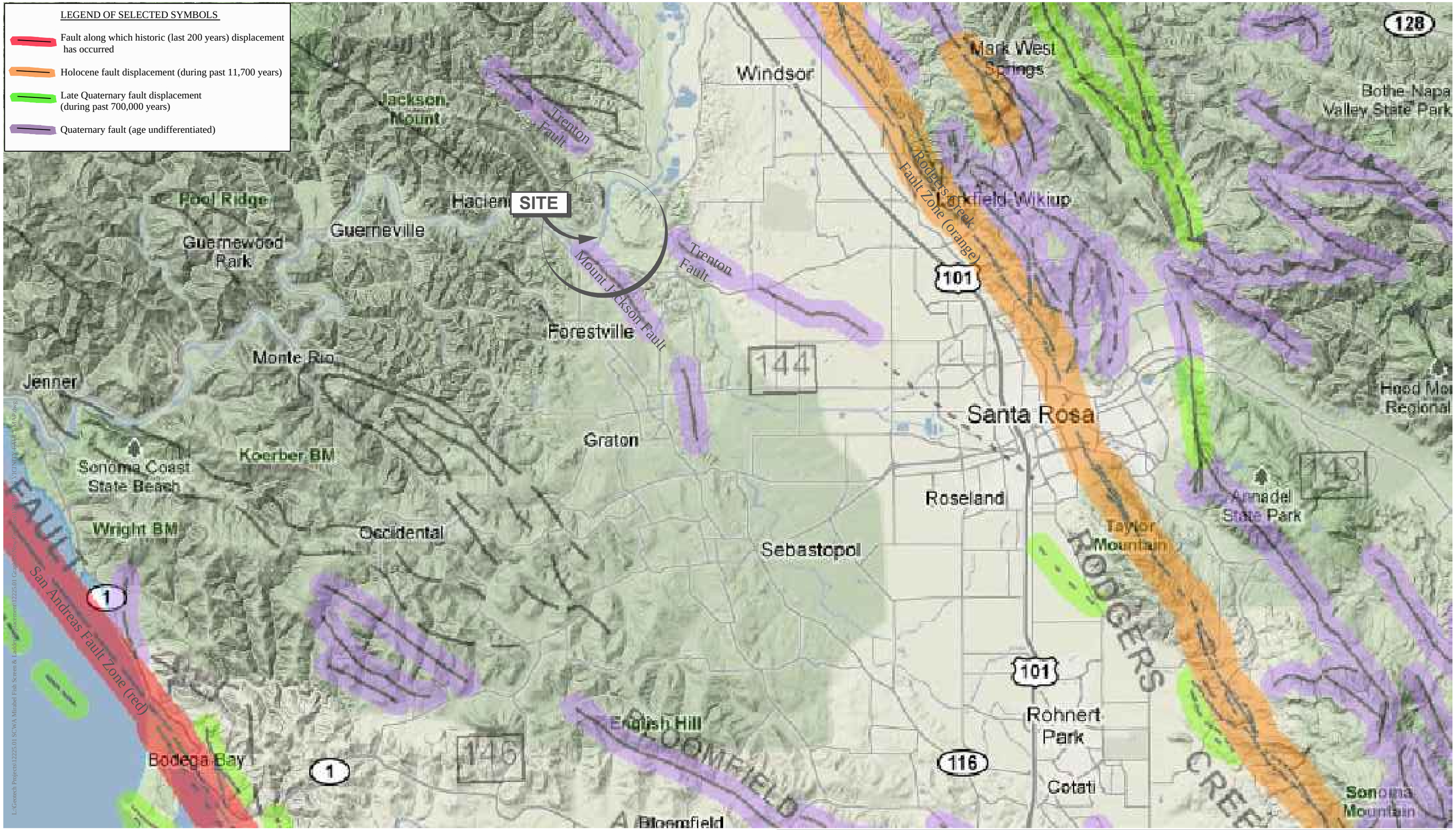

REFERENCE:
2010 Fault Activity Map of California. California Geological Survey, Geologic Data Map No. 6. Obtained at www.quake.ca.gov.
Selected fault names added by BAI.

NORTH

APPROXIMATE SCALE (FEET)
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REGIONAL FAULT MAP
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
5

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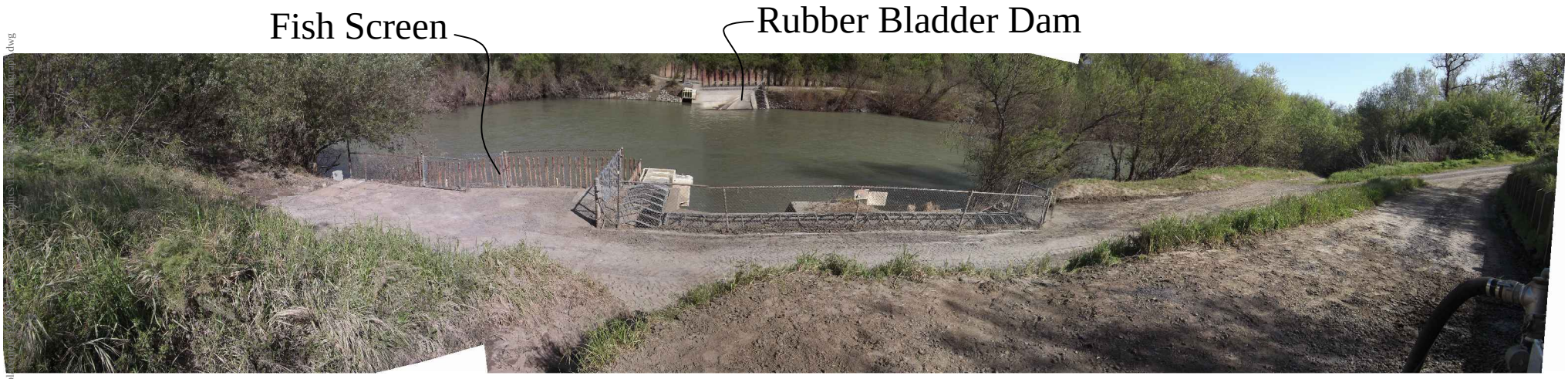

Looking East

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REFERENCE:
Site Photograph by Brunsing Associates, Inc., dated 4/11/11

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5468 Skylane Blvd., Suite 201
Santa Rosa, California 95403
Tel: (707) 838-3027

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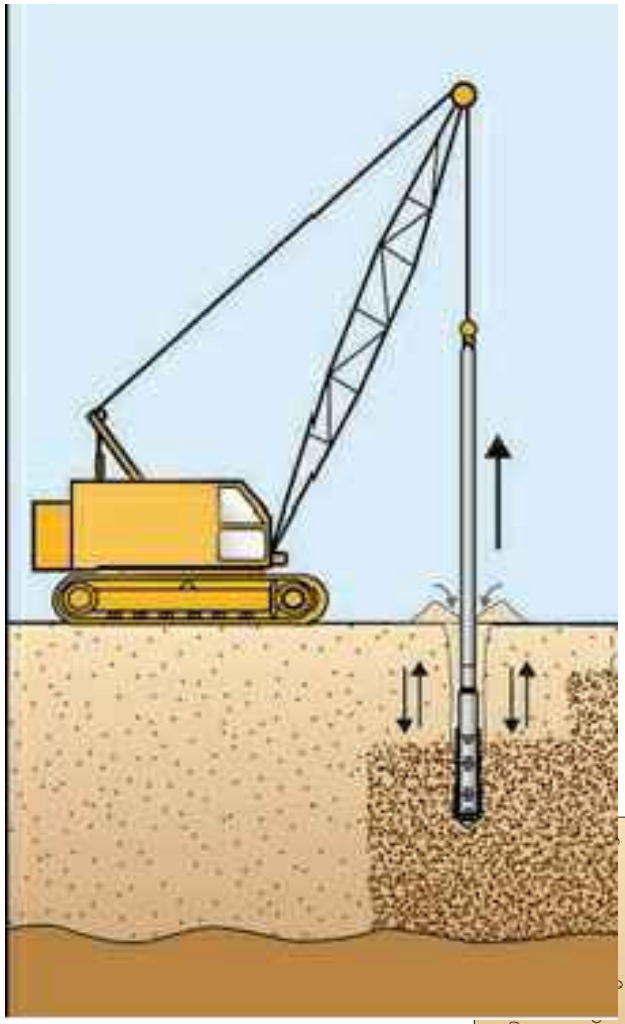
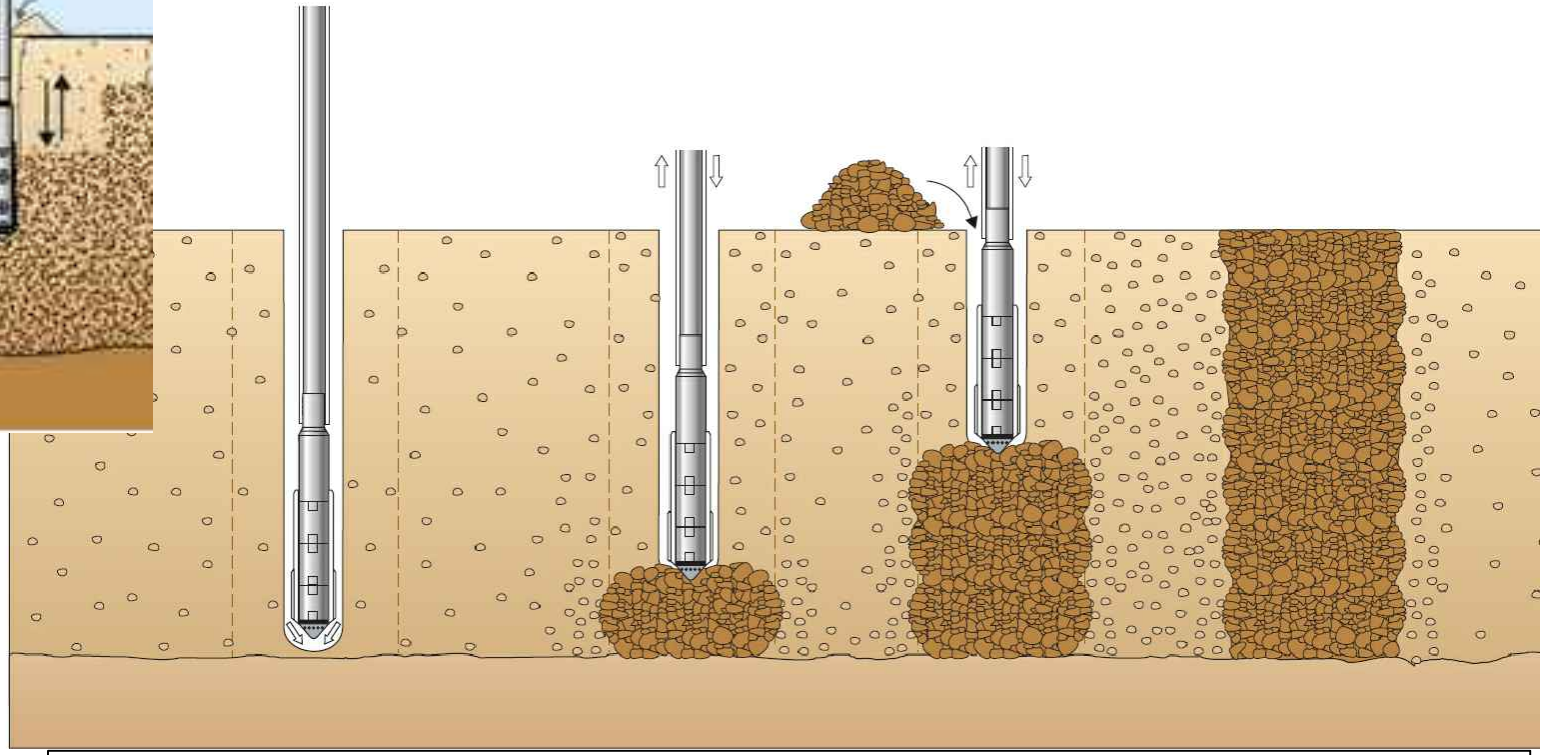
Date: 03/12/13

SITE PHOTOGRAPH
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
6





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VIBRO REPLACMENT SCHEMATIC

SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
7

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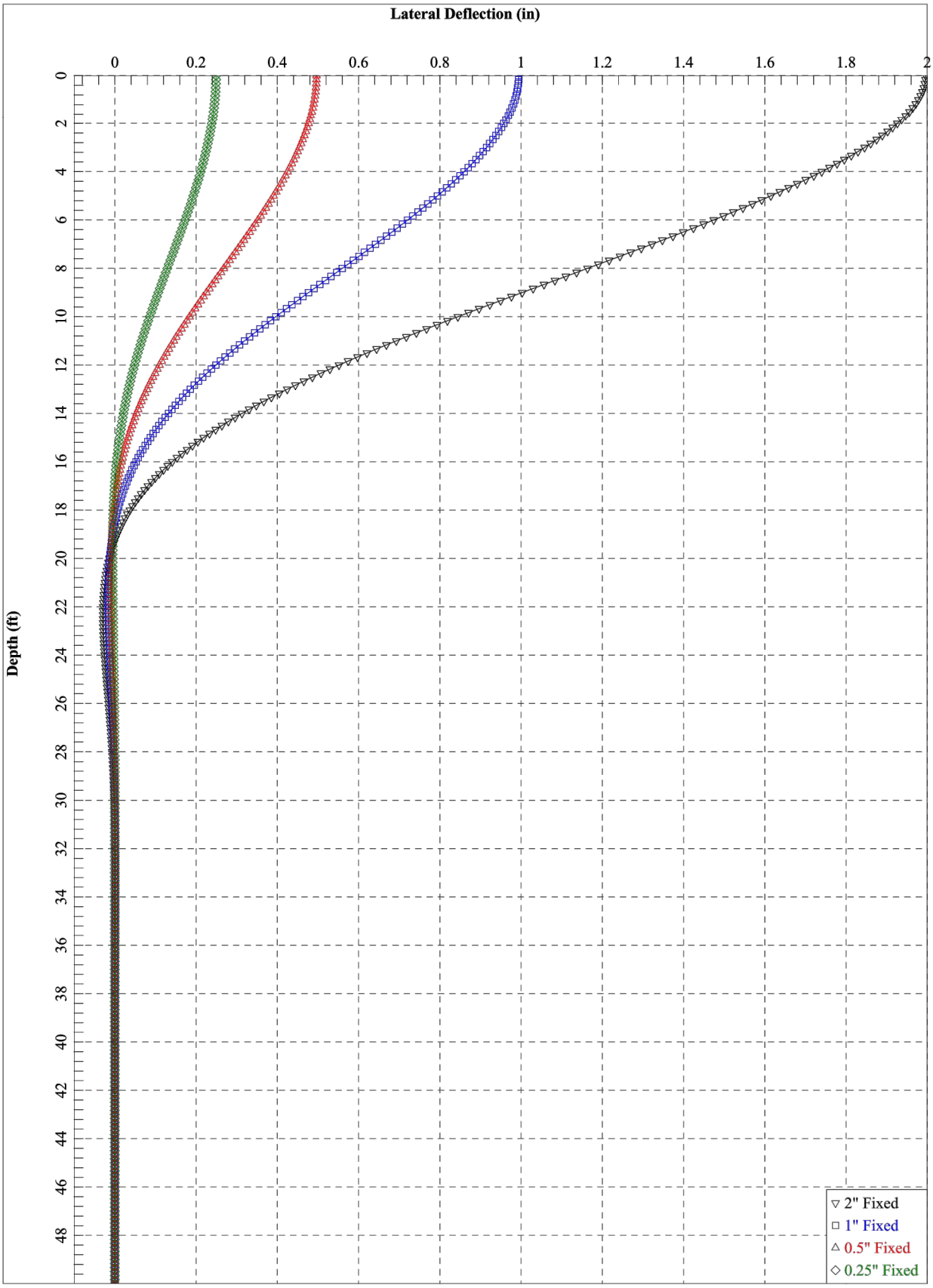

18" Diameter Pipe Pile with 3/8" Thick Wall

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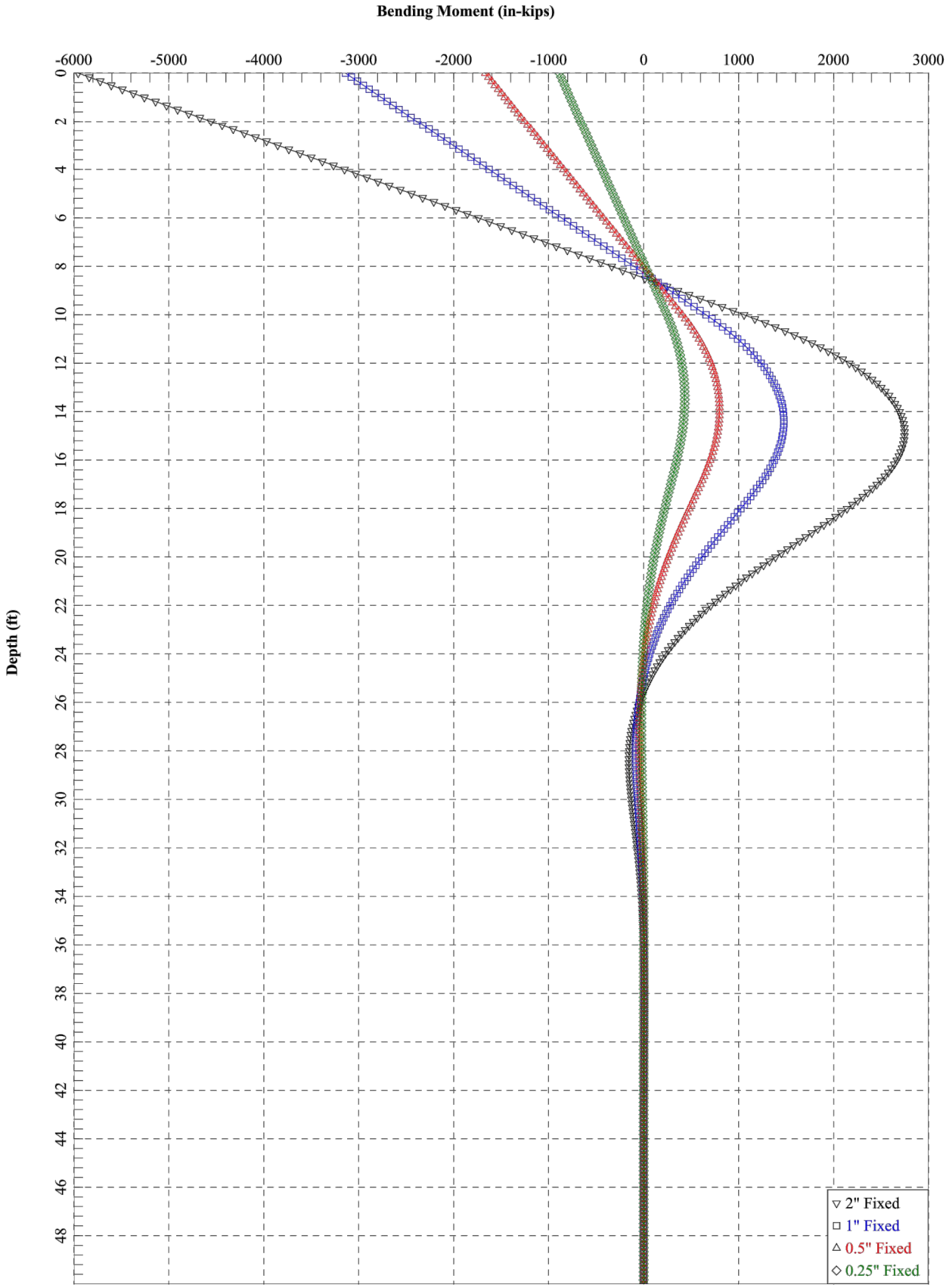
Appr.: KAC
Date: 03/12/13

LPILE ANALYSIS
FIXED HEAD CONDITION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
8



18" Diameter Pipe Pile with 3/8" Thick Wall

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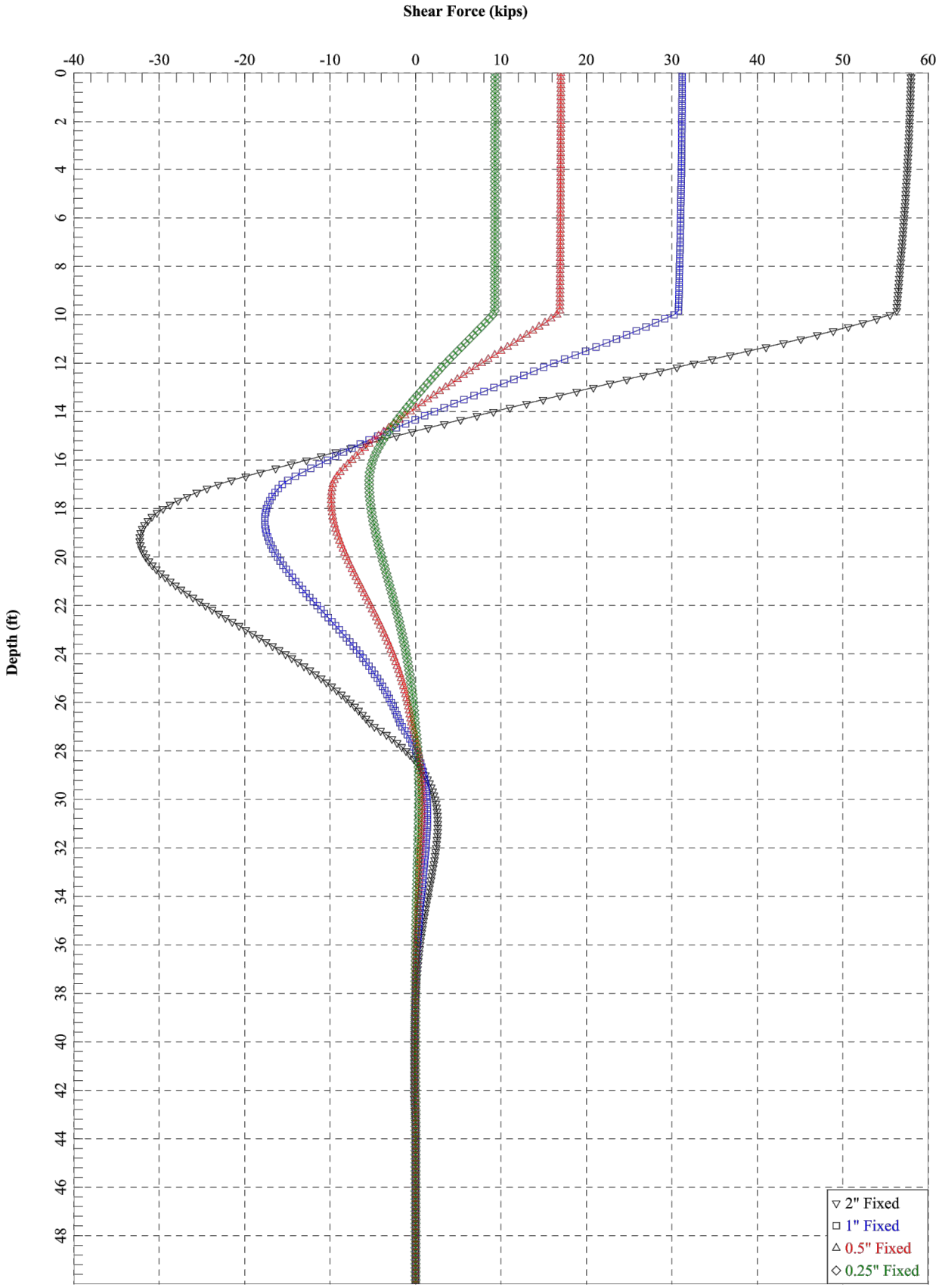
5468 Skylane Blvd., Suite 201
Santa Rosa, California 95403
Tel: (707) 838-3027

Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LPILE ANALYSIS
FIXED HEAD CONDITION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
9



18" Diameter Pipe Pile with 3/8" Thick Wall

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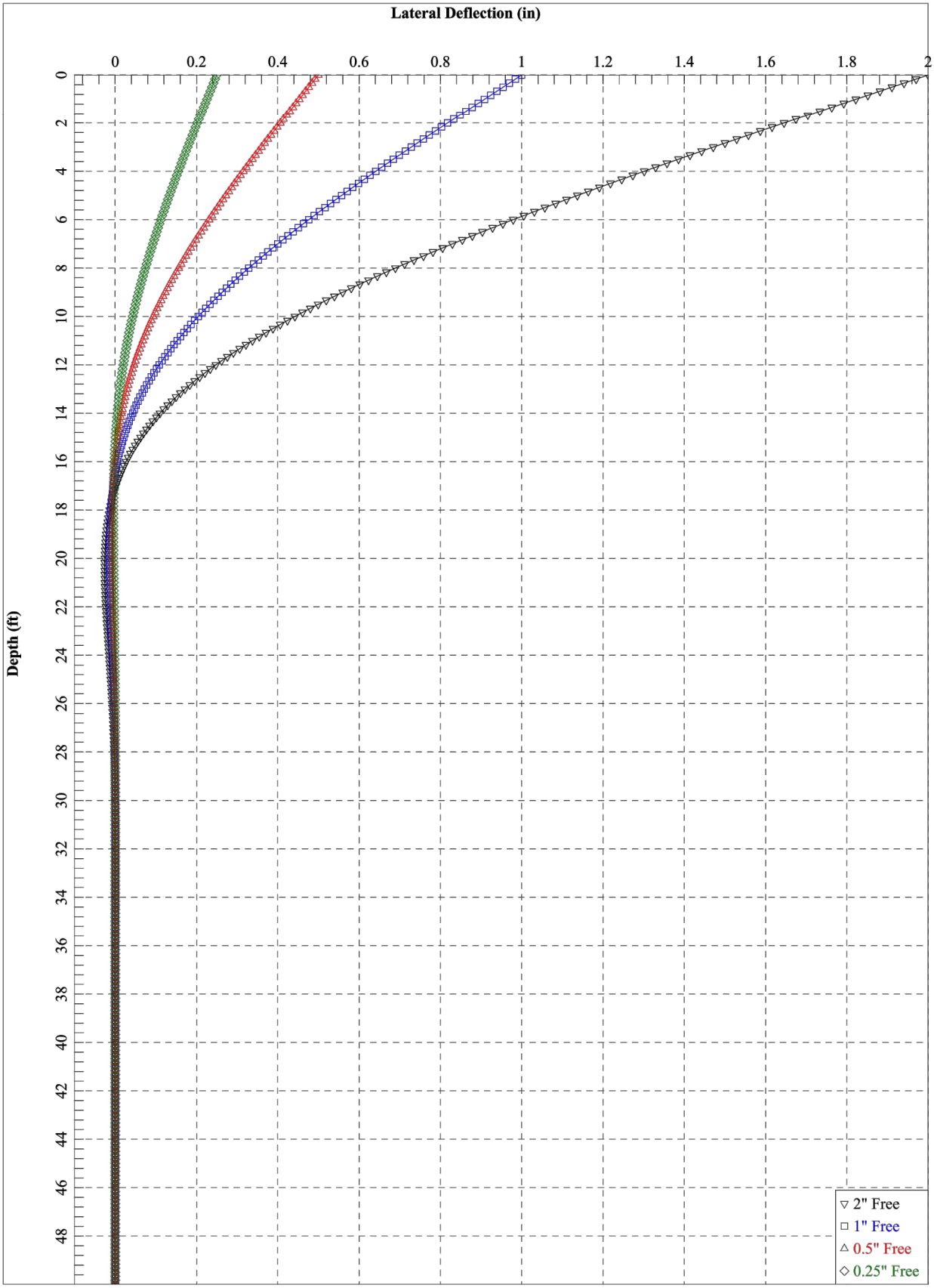
Tel: (707) 838-3027

Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LPILE ANALYSIS
FIXED HEAD CONDITION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
10



18" Diameter Pipe Pile with 3/8" Thick Wall

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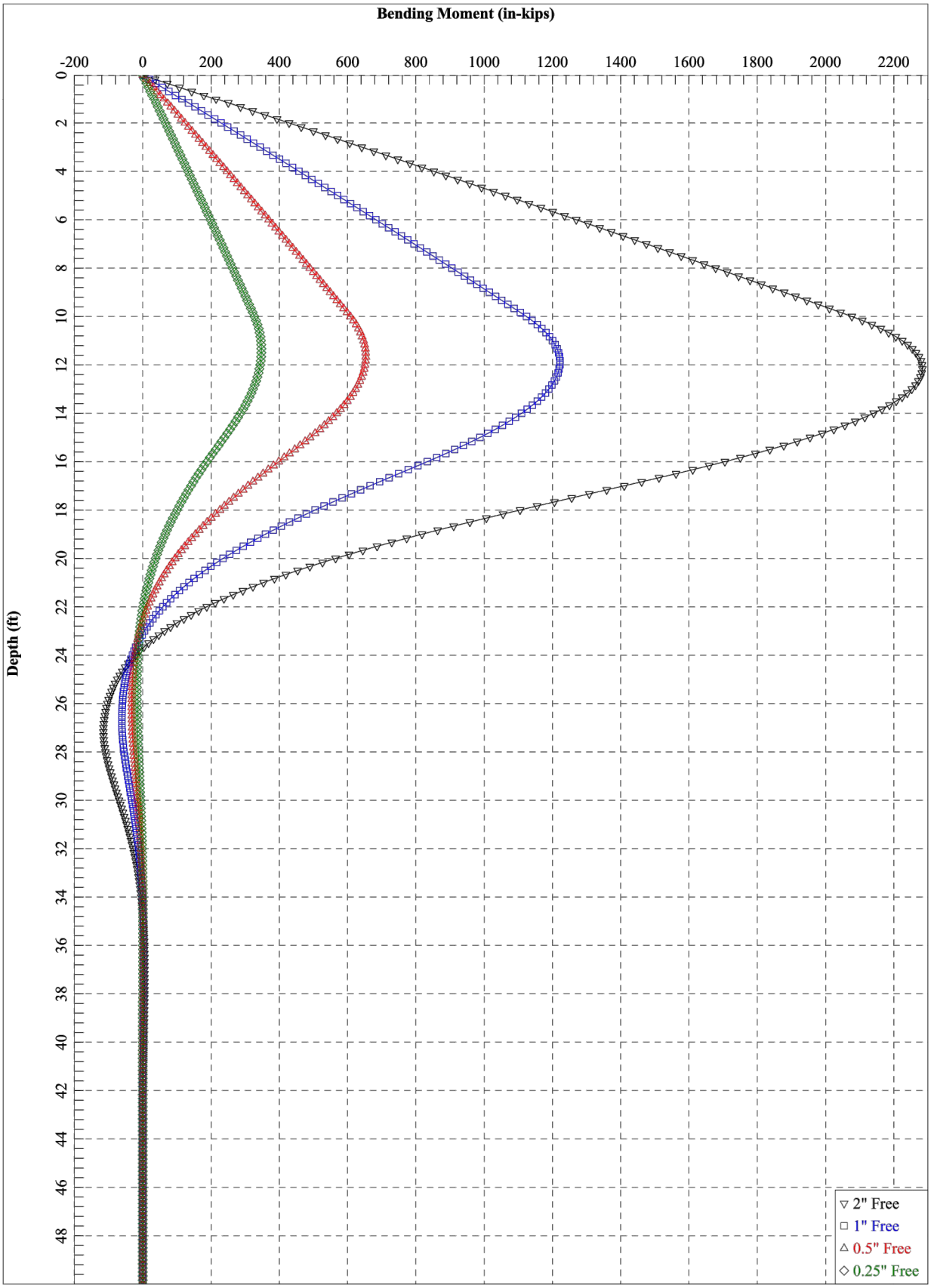
Job No.: 12225.01
Appr.: KAC
Date: 03/12/13

LPILE ANALYSIS
FREE HEAD CONDITION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
11



18" Diameter Pipe Pile with 3/8" Thick Wall

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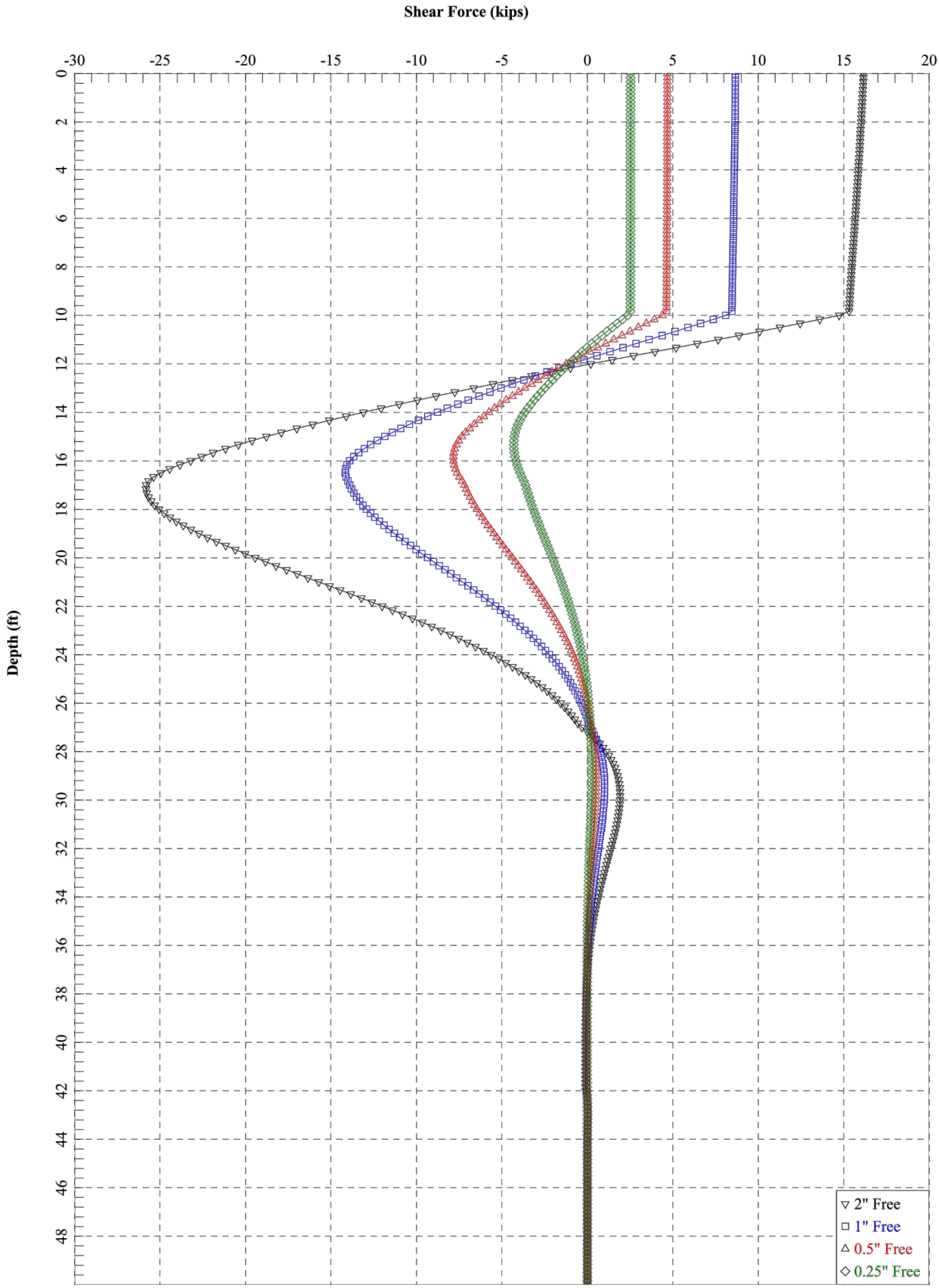
LPILE ANALYSIS
FREE HEAD CONDITION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
12



18" Diameter Pipe Pile with 3/8" Thick Wall

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LPILE ANALYSIS
FREE HEAD CONDITION
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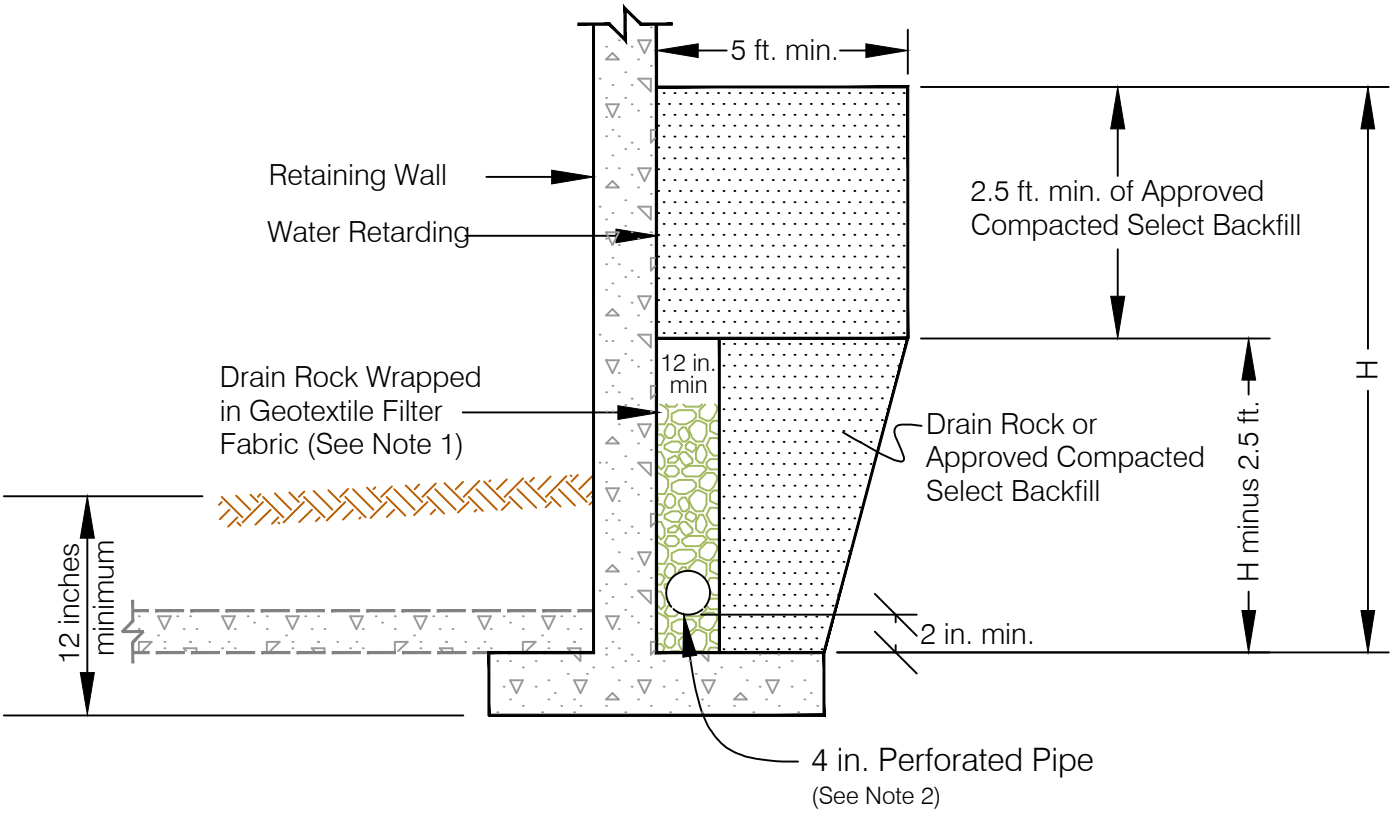
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
13



RETAINING WALL DRAINAGE DETAIL
(Not to Scale)

(1) Drain rock should be clean, free-draining material graded in size between the No. 4 and 3/4 inch sieves and should be wrapped in a non-woven geotextile filter fabric (Mirafi 140N or equivalent).

(2) Pipe should be SDR 35, or equivalent, placed with perforations down, and sloped at 1% to drain to gravity outlet or sump with automatic pump.

(3) A clean-out pipe with cap should be installed at the up-slope end of perforated pipe, pipe elbows should be 45 degrees or less (for "snake" access).

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RETAINING WALL DRAINAGE DETAIL
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
14

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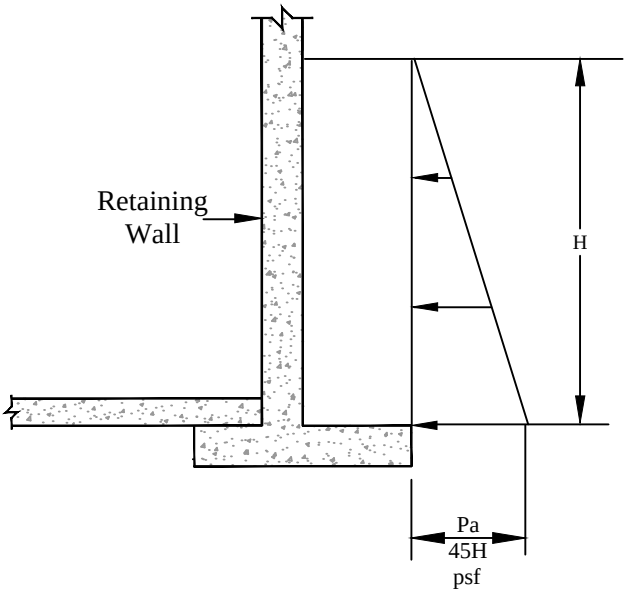
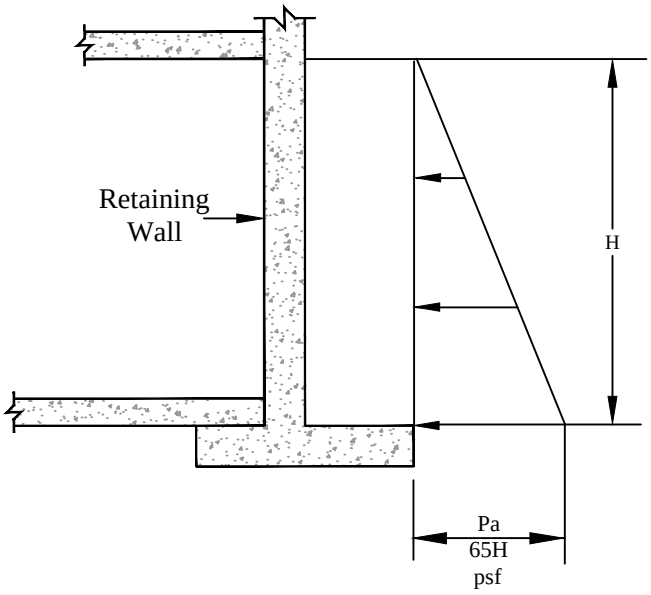


ACTIVE SOIL PRESSURE DIAGRAM

For walls that are free to rotate (See Note 2)



AT-REST SOIL PRESSURE DIAGRAM

For braced walls of substantial rigidity (See Note 2)

NOTES:

(1) The above are soil pressures only and do not include lateral loads resulting from such as traffic, floor loads, adjacent foundations or other vertical loads.

(2) If the wall at surface of the backfill cannot yield about 0.1% of its' height, at-rest soil pressures should be used.

(3) The above pressures assume a drained condition. See Plate 14 for drainage and backfill details. If wall back drains are not provided for retaining walls, use the following combined earth and hydrostatic equivalent fluid pressures (triangular distributions).

Wall Condition	Equivalent Fluid Pressure
Active	70 pcf
At-Rest	90 pcf

(4) The above pressures should be used where backfill slope is flatter than 3 horizontal to 1 vertical (3H:1V). Where backfill slope is between 3H:1V and 1.5H:1V, use active pressure of 55H psf and at-rest pressure of 85H psf, use equivalent active pressure of 80 pcf and at-rest pressure of 110 pcf for undrained conditions.

(5) For design seismic pressures see the Retaining Walls Section of this report.

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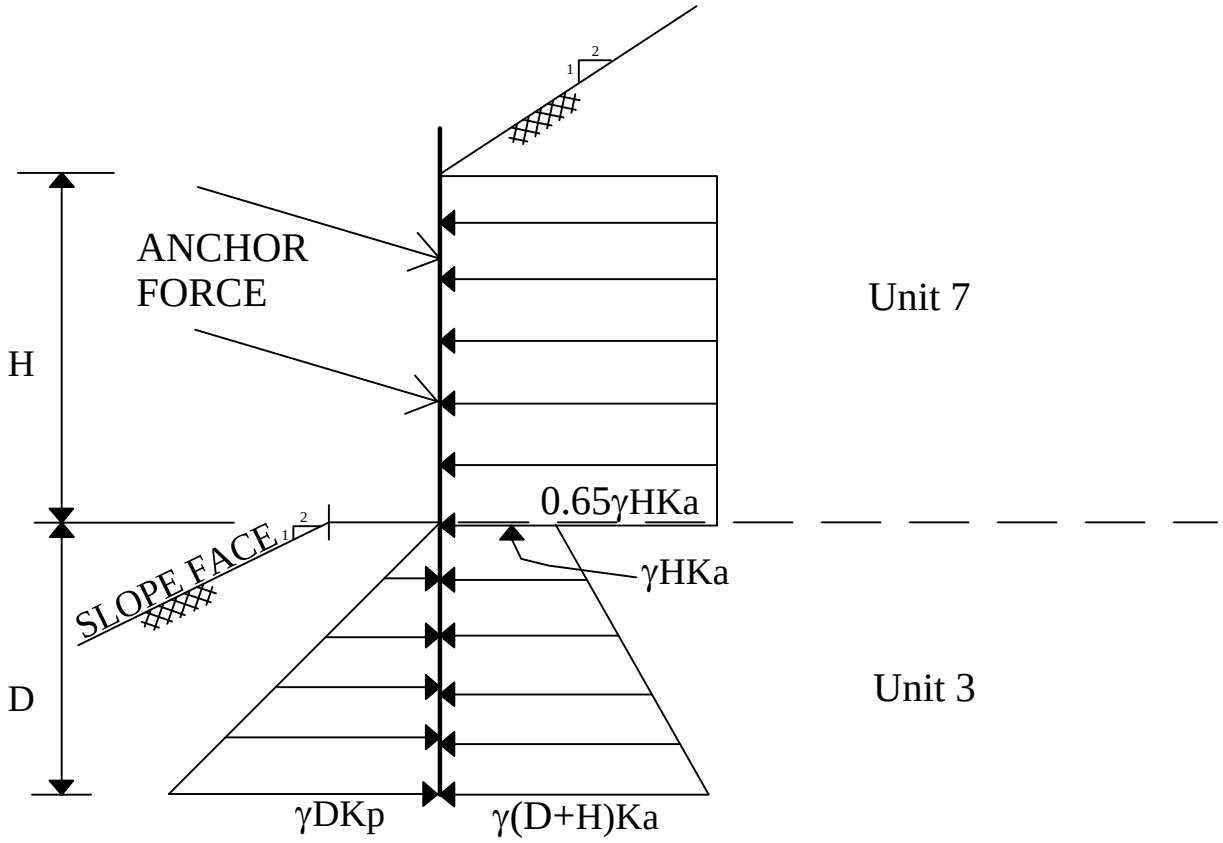
RETAINING WALL LATERAL EARTH PRESSURES
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
15



NOT TO SCALE

γ - UNIT WEIGHT OF SOIL (pcf)

Ka - COEFFICIENT OF ACTIVE EARTH PRESSURE

Kp - COEFFICIENT OF PASSIVE EARTH PRESSURE

H - HEIGHT OF EXPOSED RETAINING WALL

D - EMBEDMENT DEPTH

NOTES:

1. THE PRESSURE DIAGRAM PRESENTED IS FOR COHESIONLESS SOIL.
2. ACTIVE EARTH PRESSURE ACTS OVER ENTIRE WALL SURFACE.
3. VERTICAL COMPONENTS OF ANCHOR FORCES MUST RESISTED BY EMBEDDED LENGTH OF SOLDIER PILES BELOW ZONE OF ASSUMED EXCAVATION.

INPUT PARAMETERS			
SOIL UNIT	γ (pcf)	Ka	Kp
3	120	0.38	1.50
7	130	0.28	1.80

REFERENCE: A Cost Effective Method for the Design & Construction of Permanently Anchored Retaining Walls, Nicholson Construction Company

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DESIGN PRESSURE DIAGRAM
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
16

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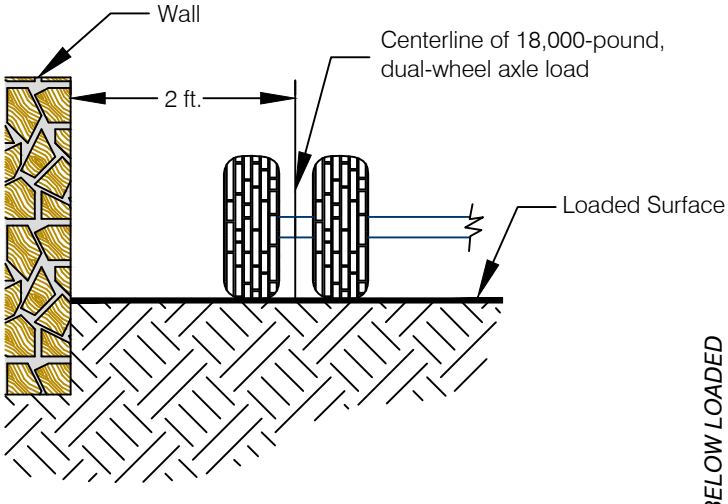

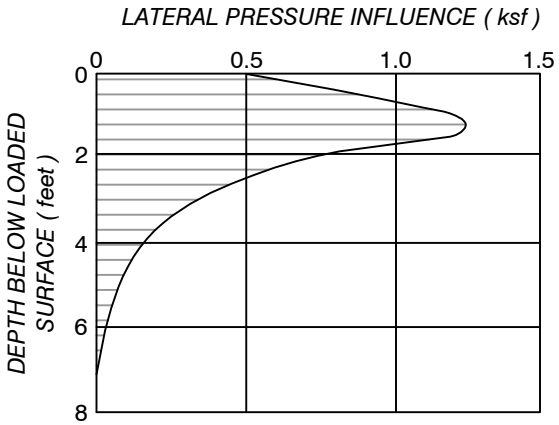

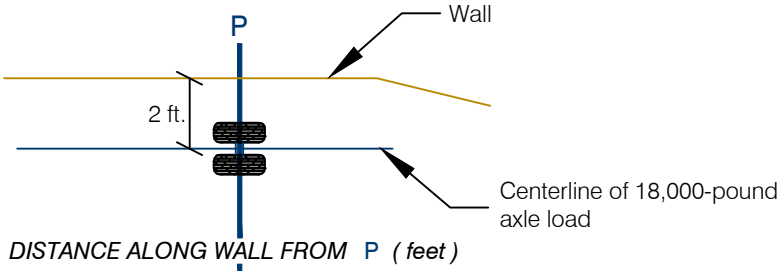

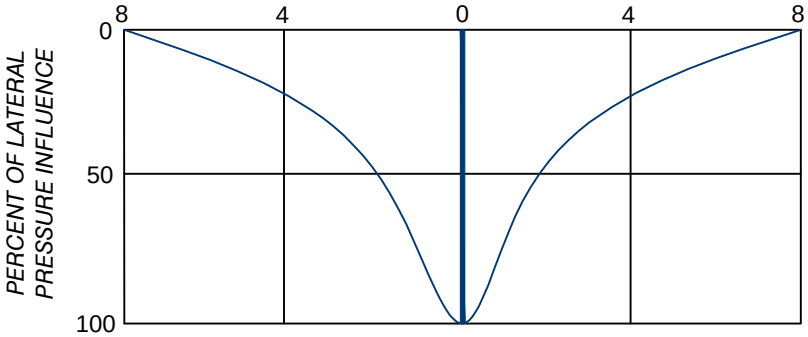

NOTES:

(1) Reference for truck load: Highway Research Bulletin 141.

(2) Lateral influence pressures for other truck wheel loads located behind a wall would be linearly proportioned to those shown for a dual-wheel truck 18,000 pound axle load.

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LATERAL PRESSURE INFLUENCE DIAGRAMS
FOR DUAL-WHEEL TRUCKLOADS
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACMENT PROJECT
Sonoma County, California

PLATE
17

APPENDIX A
Test Borings and CPT Logs

Log of Boring M-1

Equipment: MARL M11; 8-inch hollow stem auger

Date: 6/23/11

Logged By: KAC **Elevation:** 43 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Description
					1	GRAY BROWN SILTY SANDY GRAVEL (GM) dense, dry
					2	
					3	
	SPT			57	4	OLIVE-BROWN SILTY SAND (SM) medium dense to dense, damp
					5	
					6	BROWN SILTY FINE SAND (SM) with gravel medium dense, damp
Tx 1191 (720) 29% Passing #200 84% Passing #4	CA	11.7	109	8**	7	
					8	
					9	BROWN SAND (SP) with gravel medium dense, moist
	SPT			13	10	
					11	BROWN SAND (SP) with gravel loose, moist
					12	
	CA			5**	13	
					14	
					15	GRAY COARSE SAND (SP) very loose, saturated
	SPT			2	16	
					17	BROWN FINE SAND (SP) very loose, saturated
					18	BROWN POORLY GRADED SAND (SP) medium dense, saturated
Tx 2450 (1440) 3% Passing #200 86% Passing #4	CA	19.9	110	20**	19	
					20	
					21	GRAY COARSE SAND (SP) medium dense, saturated
	SPT			18	22	GRAY GRAVEL (GP) with sand medium dense, saturated
					23	
					24	BROWN POORLY GRADED GRAVEL (GP) with sand medium dense, saturated
3% Passing #200 51% Passing #4	CA	8.8	131	25**	25	
					26	
					27	BROWN POORLY GRADED SAND (SP) medium dense, saturated
	SPT			14	28	
					29	

Fill

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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LOG OF BORING M-1
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE A1

Log of Boring M-1

Equipment: MARL M11; 8-inch hollow stem auger
Date: 6/23/11
Logged By: KAC **Elevation:** 43 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Description
5% Passing #200 91% Passing #4	CA	19.6	109	24**	31	BROWN SILTY SANDY GRAVEL (GM) medium dense, saturated
	SPT			40	33	GRAY-BROWN SAND (SP) dense, saturated
	SPT			38	35	BROWN SAND (SP) dense, saturated
					37	BROWN SILTY SANDY GRAVEL (GM) dense, saturated
	SPT			41	39	BROWN SAND (SP-SM) with silt medium dense, saturated
					43	BROWN SAND (SP) medium dense, saturated
	SPT			16	48	BROWN SILTY SAND (SM) dense, saturated
	SPT			61	51	

Notes:
1. Free water encountered at about 14 feet below ground surface during drilling
2. Boring caved while removing hollow stem auger

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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Date: 03/12/13

LOG OF BORING M-1
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE A1
SHEET 2 of 2

Log of Boring M-2

Equipment: MARL M11; 8-inch hollow stem auger

Date: 6/23/11

Logged By: KAC **Elevation:** 44 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Sample	
					1		BROWN SILTY SANDY GRAVEL (GM) medium dense, damp
					2		
					3		
					4		
					5		Fill
	SPT			40	6		
					7		
					8		
					9		
					10		
Tx 1070 (1008) 38% Passing #200 98% Passing #4	CA	17.9	105	12**	11		BROWN SILTY SAND (SM) medium dense, damp to saturated
					12		
					13		
					14		
					15		BROWN SAND (SP) with gravel medium dense, saturated
	SPT			21	16		
					17		
					18		
					19		GRAY-BROWN POORLY GRADED SAND (SP) with gravel medium dense, saturated
					20		
4% Passing #200 78% Passing #4	CA	10.2	86	20**	21		
					22		
					23		
					24		BROWN SAND (SP) medium dense, saturated
					25		
	SPT			26	26		
					27		
					28		
					29		BROWN POORLY GRADED SAND (SP)

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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LOG OF BORING M-2
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE A2

Log of Boring M-2

Equipment: MARL M11; 8-inch hollow stem auger

Date: 6/23/11

Logged By: KAC **Elevation:** 44 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Sample	
					30		loose, saturated
2% Passing #200 100% Passing #4	CA	23.9	76	10**	31		
					32		
					33		
					34		BROWN COARSE SAND (SP) with gravel dense, saturated
					35		
	SPT			38	36		
					37		
					38		
					39		BROWN FINE SAND (SP) dense, saturated
					40		
3% Passing #200 49% Passing #4	CA	4.6	107	61/11"**	41		BROWN GRAVEL (GP) with sand dense, saturated
					42		

Notes:
1. Free water encountered at about 14 feet below ground surface during drilling

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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LOG OF BORING M-2
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A2
SHEET 2 of 2

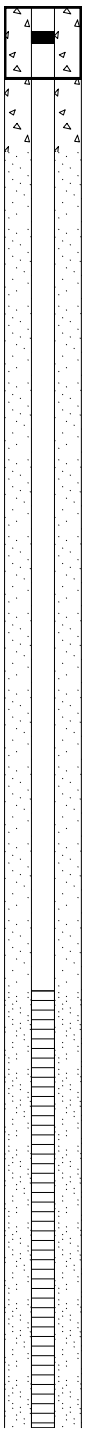
Log of Boring and Well Detail M-3

Equipment: Mobile B-53; 7-inch hollow-stem auger

Date: 11/6/12

Logged By: KAC **Elevation:** 62 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Sample	Description
					1		OLIVE-BROWN SILTY SAND (SM) soft to medium stiff fine sand
					2		
					3		
	CA			26/9"**	4		
					5		LIGHT OLIVE-BROWN SAND (SP-SM) with silt medium dense, damp fine sand
					6		
	CA			23**	7		Fill
					8		
		17.7	97		9		
	CA			7**	10		
					11		
					12		
					13		BROWN SAND (SP) loose, moist
					14		
	CA			5**	15		OLIVE-BROWN SILTY SAND (SM) loose, moist fine sand
					16		
					17		OLIVE-BROWN FINE SAND (SP-SM) with silt loose, moist
					18		
		14.9	88		19		
	CA			6**	20		
					21		
					22		
					23		BROWN FINE SAND (SP) loose, moist
					24		
	SPT			10	25		
					26		
					27		
					28		
					29		GRAY BROWN MEDIUM SAND (SP) medium dense, moist



* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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LOG OF BORING and WELL DETAIL M-3
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE A3

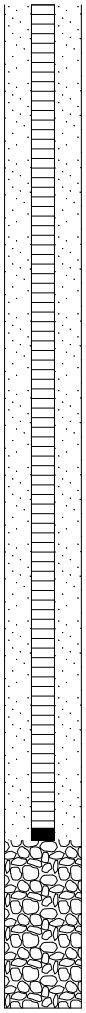
Log of Boring and Well Detail M-3

Equipment: Mobile B-53; 7-inch hollow-stem auger

Date: 11/6/12

Logged By: KAC **Elevation:** 62 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Sample	
	SPT			25	30		
					31		
					32		
					33		GRAY MEDIUM TO COARSE SAND (SP) medium dense, saturated coarse gravel in sampler shoe
DS 555 (500) DS 1268 (1000) DS 2304 (1500)	CA			21**	34		
					35		
					36		
					37		
					38		GRAY SILTY GRAVELLY SAND (SM) medium dense, saturated coarse gravel in sampler shoe
					39		
	SPT			31	40		
					41		
					42		
					43		GRAY-BROWN GRAVELLY SAND (SP) dense, saturated
					44		
	SPT			40	45		
					46		
					47		
					48		GRAY-BROWN FINE SOIL (SP)
					49		GRAY-BROWN COARSE SAND (SP)
	SPT			46	50		BROWN SAND (SP-SM) with silt



Notes
1. Free water encountered at about 33 feet below ground surface during drilling
2. Free water measured at 30 feet below ground surface 5 hours after drilling completed
3. Hollow stem became clogged around 35 feet below ground surface, advanced to 50 feet to install piezometer

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

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LOG OF BORING and WELL DETAIL M-3
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE A3

Log of Boring and Well Detail M-4

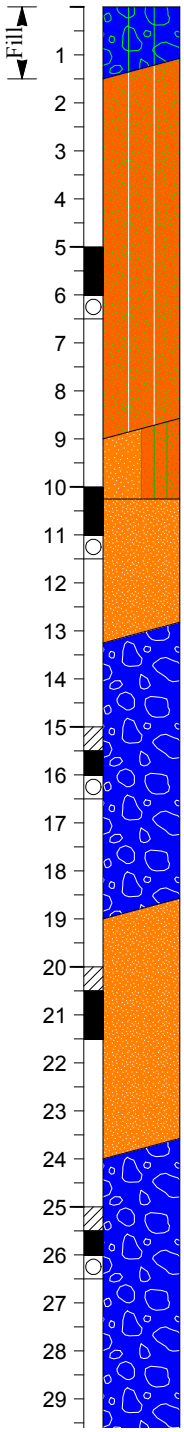
Equipment: Mobile B-53; 7-inch hollow-stem auger

Date: 11/6/12

Logged By: KAC **Elevation:** 49 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot
	CA			25**
35% Passing #200		14.5	108	
	CA			13**
2% Passing #200		4.0	111	
	CA			15**
2% Passing #200	CA	8.4	122	13**
	SPT			24

Depth (ft.) / Sample



GRAY SILTY SANDY GRAVEL (GM)
dense, dry

BROWN SILTY GRAVELLY SAND (SM)
dense, damp

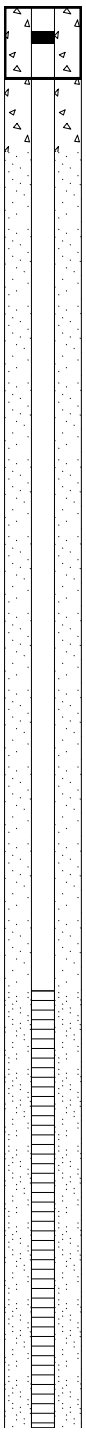
BLUE GRAY FINE SAND (SP-SM) with silt
medium dense, damp

BROWN SAND (SP)
medium dense, damp
fine grained sand

BROWN POORLY GRADED GRAVEL (GP) with sand
medium dense, wet

GRAY MEDIUM SAND (SP)
medium dense, saturated

GRAY BROWN SANDY GRAVEL (GP)
medium dense, saturated



* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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LOG OF BORING and WELL DETAIL M-4
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MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A4
SHEET 1 of 2

Log of Boring and Well Detail M-4

Equipment: Mobile B-53; 7-inch hollow-stem auger

Date: 11/6/12

Logged By: KAC **Elevation:** 49 feet ***

Laboratory Tests	Sampler Type*	Moisture Content (%)	Dry Density (pcf)	Blows/foot	Depth (ft.)	Sample	
	SPT			34	30–31		BROWN SANDY GRAVEL (GP) medium dense, saturated
					32		
					33		
					34		Slotted Casing
					35		
					36		
					37		
					38		
					39		
					40		
					41		
					42		
					43		
					44		
					45		
					46		
					47		
					48		End Cap
					49		Slough
					50		

Notes
1. Free water encountered at about 19 feet below ground surface during drilling
2. Free water measured at 17.7 feet below ground surface on November 13, 2012

* See Soil Classification Chart & Key to Test Data
** Equivalent "Standard Penetration" Blow Counts.
*** Elevations interpolated from Mirabel Fish Screen and Fish Ladder Replacment Overall Site Plan, dated 11.4.2011, prepare by HDR Fisheries.

Scale: 1" = 4'

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Date: 03/12/13

LOG OF BORING and WELL DETAIL M-4
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE A4

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE-GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVELS AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (Less than 5% fines)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (Greater than 12% fines)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS 50% OR MORE OF COARSE FRACTION PASSING THROUGH NO. 4 SIEVE	CLEAN SANDS (Less than 5% fines)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (Greater than 12% fines)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE-GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMOUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

KEY TO TEST DATA

Consol - Consolidation
LL - Liquid Limit
PI - Plasticity Index
EI - Expansion Index
SA - Sieve Analysis

■ Sample Retained
▨ Sample Recovered, Not Retained
⊠ Bulk Sample
◯ Sample Not Recovered
CA - California Modified Split Barrel Sampler 3.0-inch O.D.
CM - California Modified Split Barrel Sampler 2.5-inch O.D.
SPT - California Split Barrel Sampler 2.0-inch O.D.
SH - Shelby Tube
RC - Rock Coring

Shear Strength, psf	Confining Pressure, psf	
Tx	320 (2600)	- Unconsolidated Undrained Triaxial
TxCU	320 (2600)	- Consolidated Undrained Triaxial
DS	2750 (2600)	- Consolidated Drained Direct Shear
FVS	470	- Field Vane Shear
UC	2000	- Unconfined Compression
PP	2000	- Field Pocket Penetrometer
Sat		- Sample saturated prior to test

▽ Groundwater Level Reading
▼ Second Groundwater Level Reading

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SOIL CLASSIFICATION CHART & KEY TO TEST DATA

SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE A5

RELATIVE DENSITY OF COARSE-GRAINED SOILS

Relative Density	Standard Penetration Test Blow Count (blows per foot)
Very loose	4 or less
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	More than 50

CONSISTENCY OF FINE-GRAINED SOILS

Consistency	Identification Procedure	Approximate Shear Strength (psf)
Very soft	Easily penetrated several inches with fist	Less than 250
Soft	Easily penetrated several inches with thumb	250 to 500
Medium stiff	Penetrated several inches by thumb with moderate effort	500 to 1000
Stiff	Readily indented by thumb, but penetrated only with great effort	1000 to 2000
Very stiff	Readily indented by thumb nail	2000 to 4000
Hard	indented with difficulty by thumb nail	More than 4000

NATURAL MOISTURE CONTENT

Dry	No noticeable moisture content. Requires considerable moisture to obtain optimum moisture content* for compaction.
Damp	Contains some moisture, but is on the dry side of optimum.
Moist	Near optimum moisture content for compaction.
Wet	Requires drying to obtain optimum moisture content for compaction.
Saturated	Near or below the water table, from capillarity, or from perched or ponded water. All void spaces filled with water.

* Optimum moisture content as determined in accordance with ASTM Test Method D1557, latest edition.

Where laboratory test data are not available, the above field classifications provide a general indication of material properties; the classifications may require modification based upon laboratory tests.

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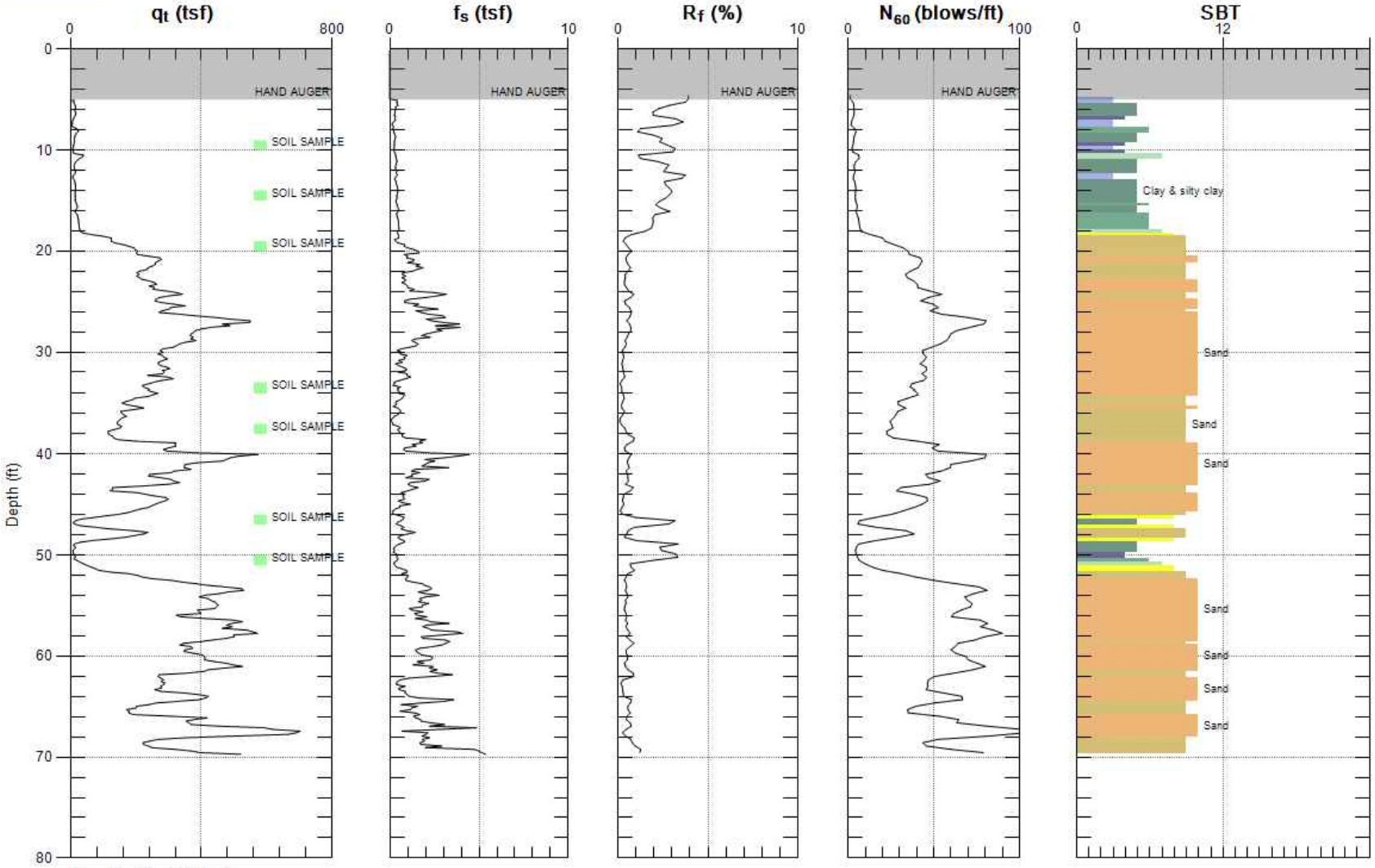
SOIL DESCRIPTIVE PROPERTIES
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A6

GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC07 Date: 6/21/2011 01:58



Max. Depth: 69.718 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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Job No.: 12225.01

Appr.: KK

Date: 03/12/13

CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

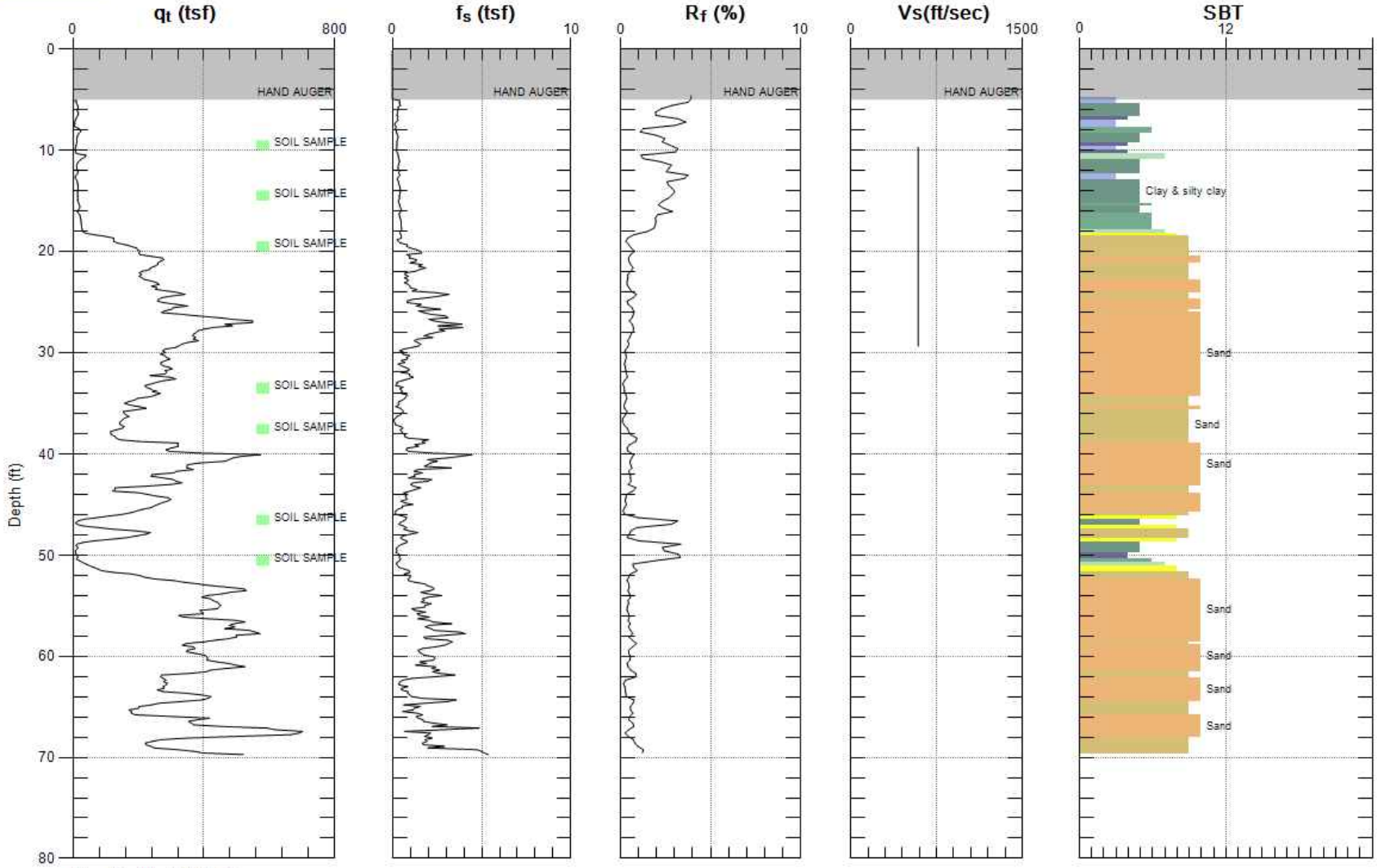
PLATE
A7
SHEET 1 of 3

L:\Geotech Projects\12225.01 SCWA Mirabel Fish Screen & Ladder Replacement\12225.01 Graphics\New Graphics\12225.01_A7-A16.dwg
3/8/2013 10:47:29 AM save date
3/12/2013 9:09:07 AM plot date

GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC07 Date: 6/21/2011 01:58



Max. Depth: 69.718 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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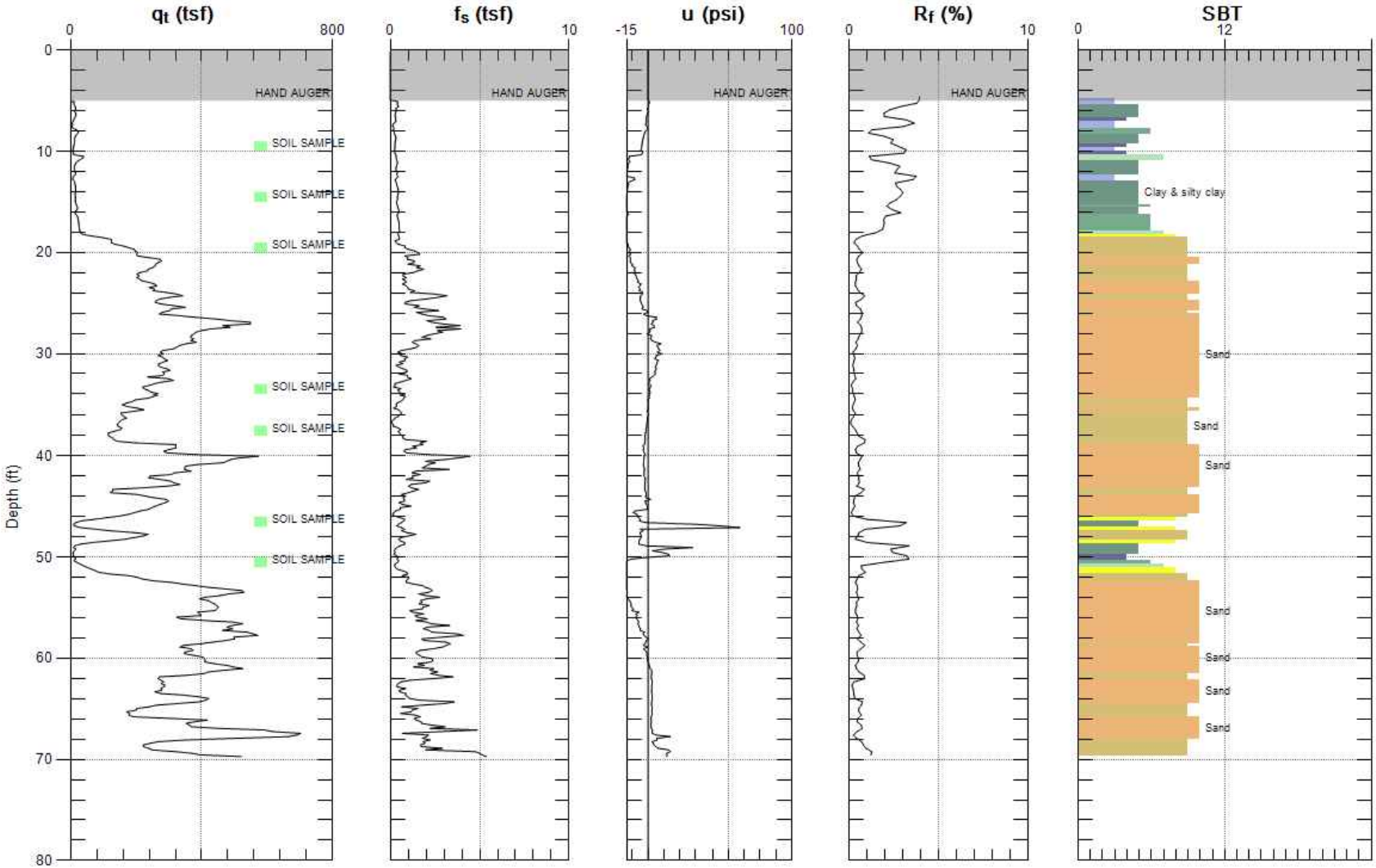
CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A7
SHEET 2 of 3

GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC07 Date: 6/21/2011 01:58



Max. Depth: 69.718 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A7
SHEET 3 of 3

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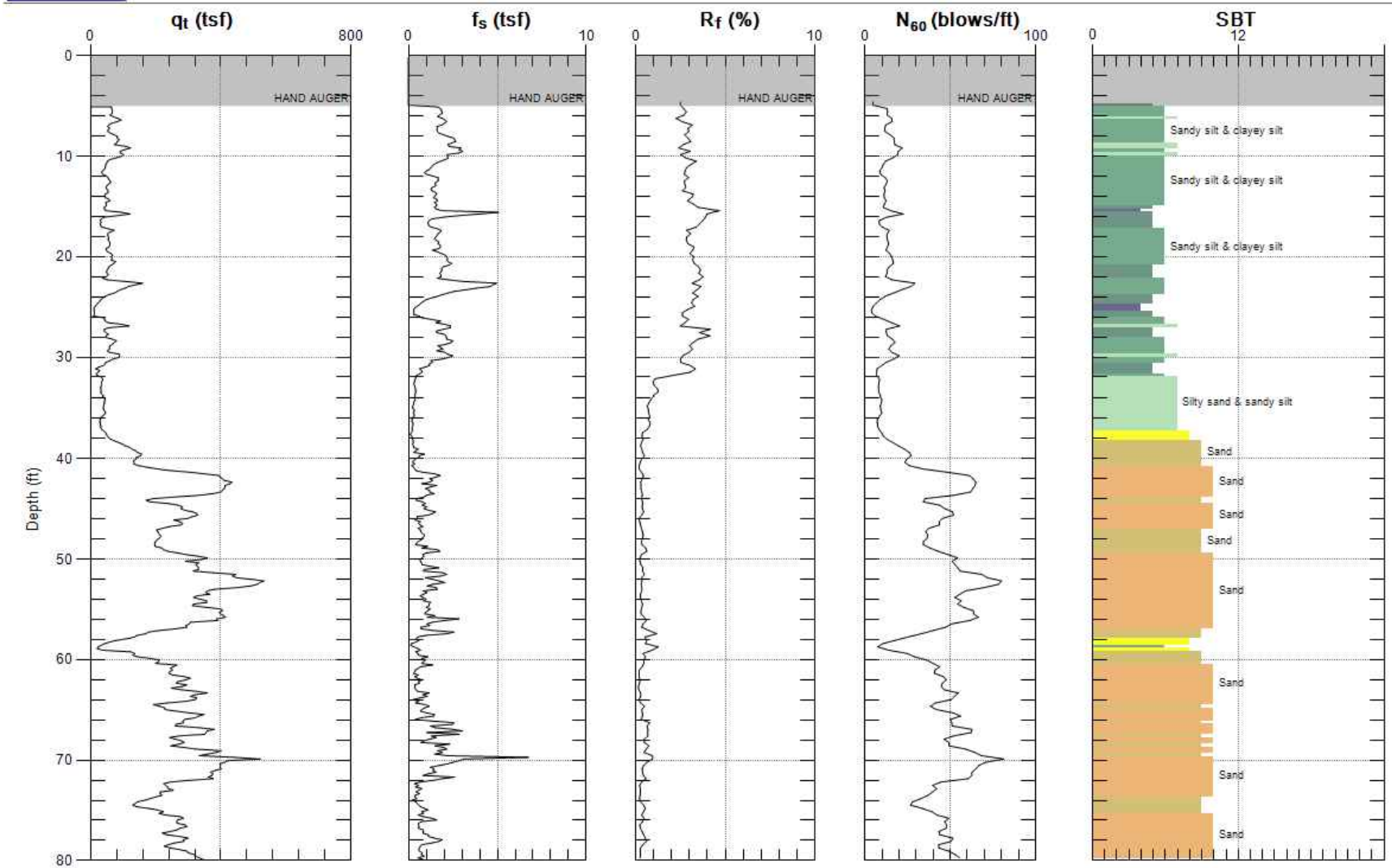
Sounding: CPT-GSC08 Date: 6/22/2011 10:35



Max. Depth: 80.052 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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CONE PENETRATION TEST LOG
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MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
A8
SHEET 1 of 3

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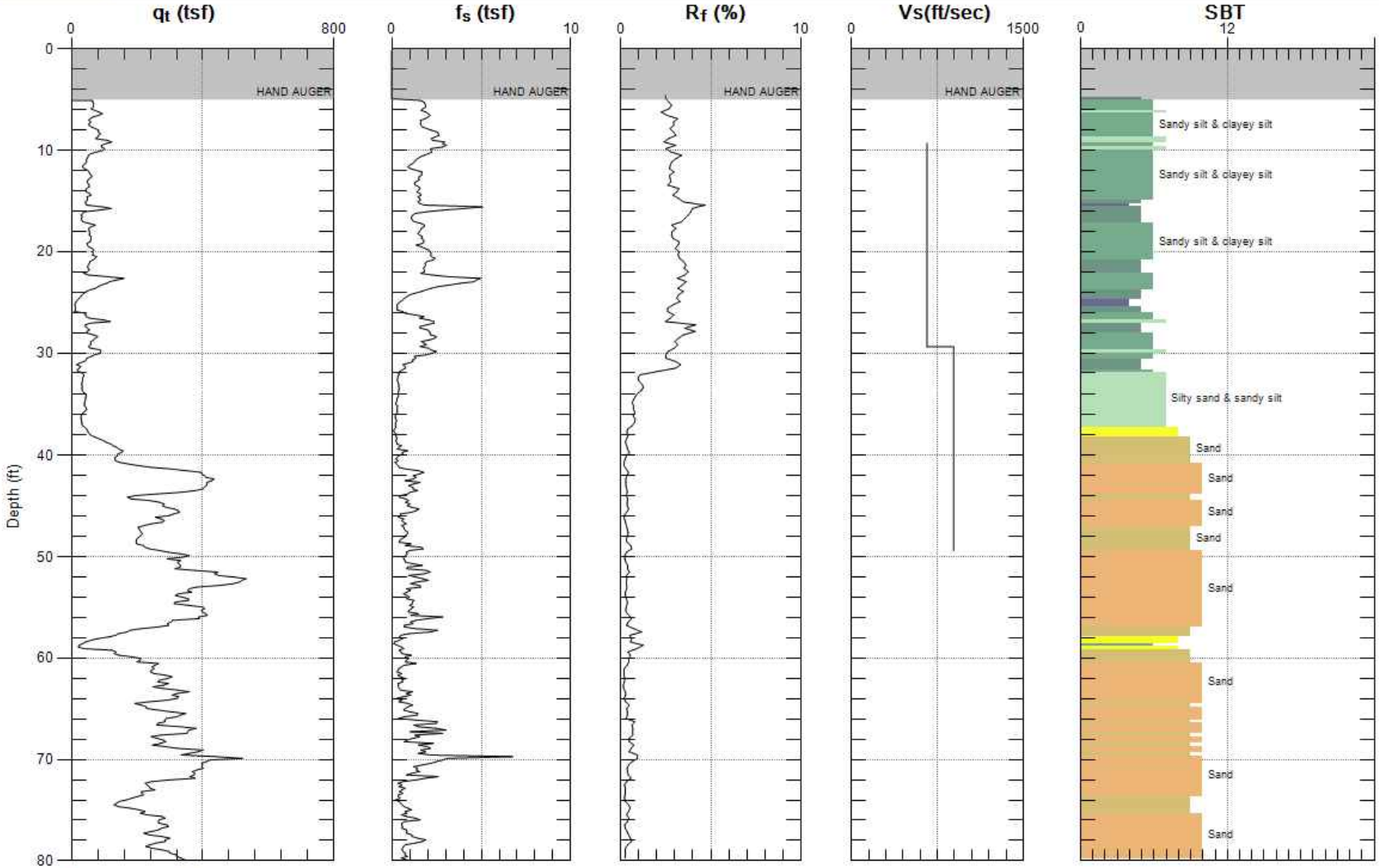
GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC08 Date: 6/22/2011 10:35



Max. Depth: 80.052 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
A8
SHEET 2 of 3

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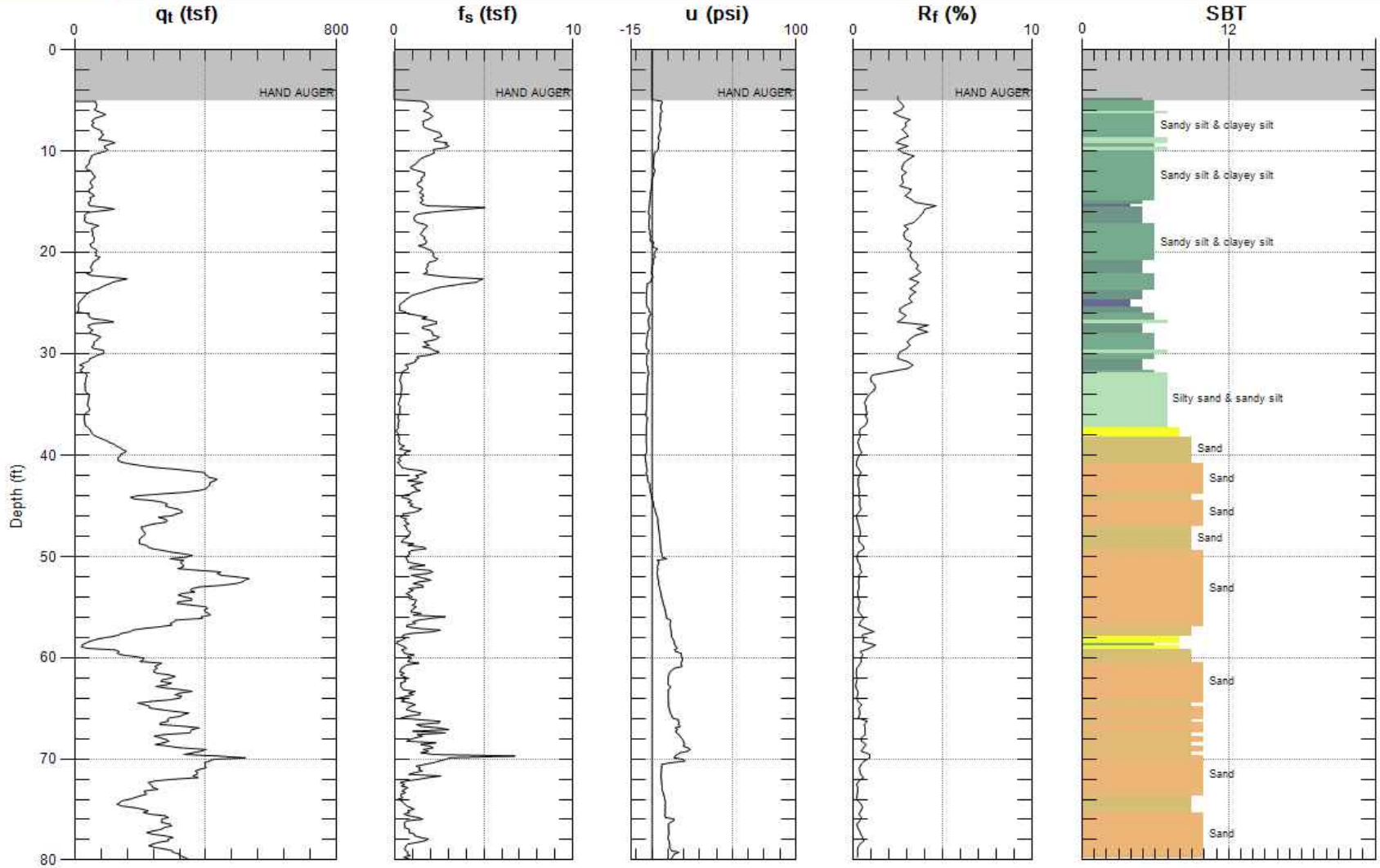
Sounding: CPT-GSC08 Date: 6/22/2011 10:35



Max. Depth: 80.052 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
A8
SHEET 3 of 3

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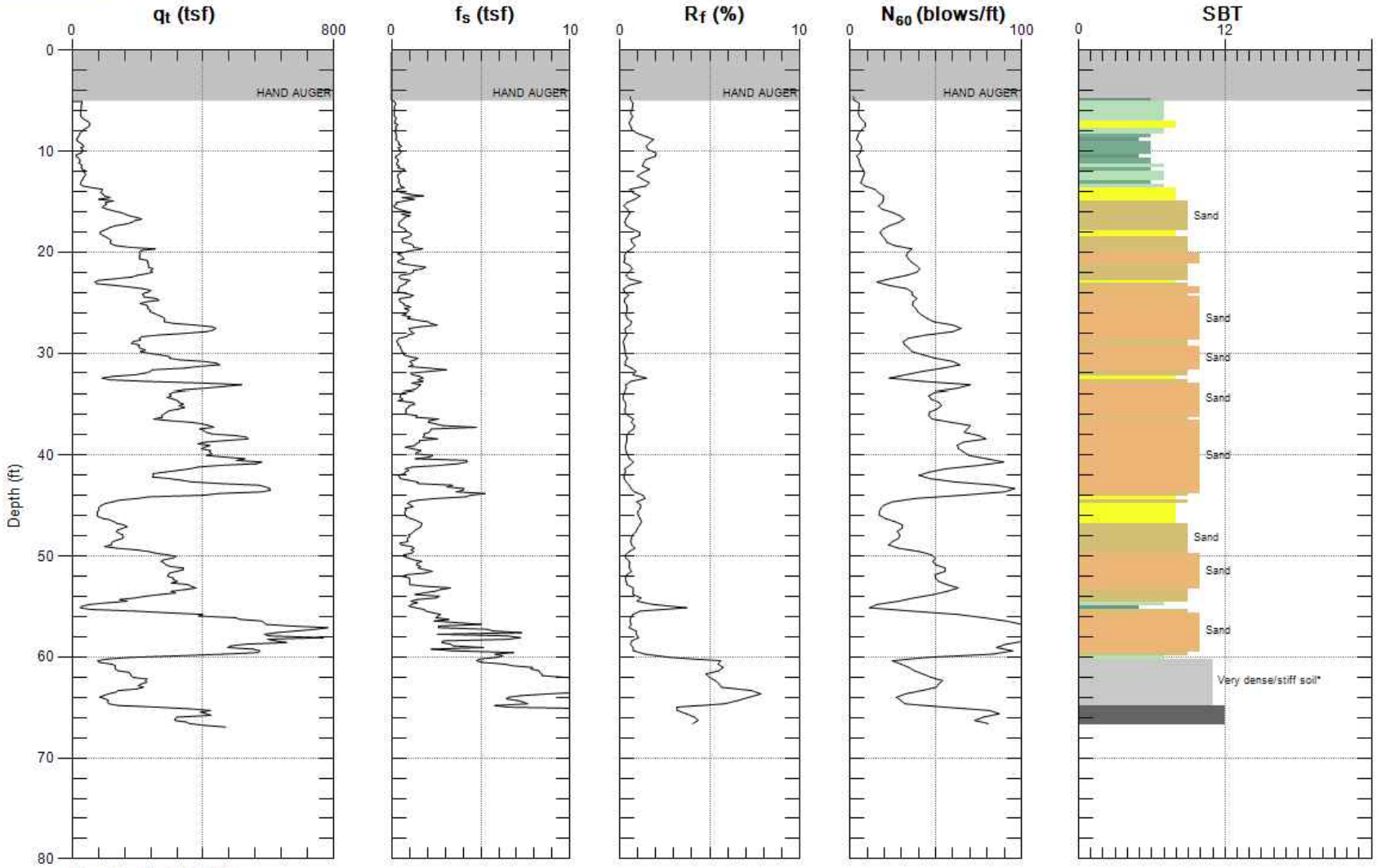
GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC12 Date: 6/23/2011 02:09



Max. Depth: 66.929 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
A9
SHEET 1 of 2

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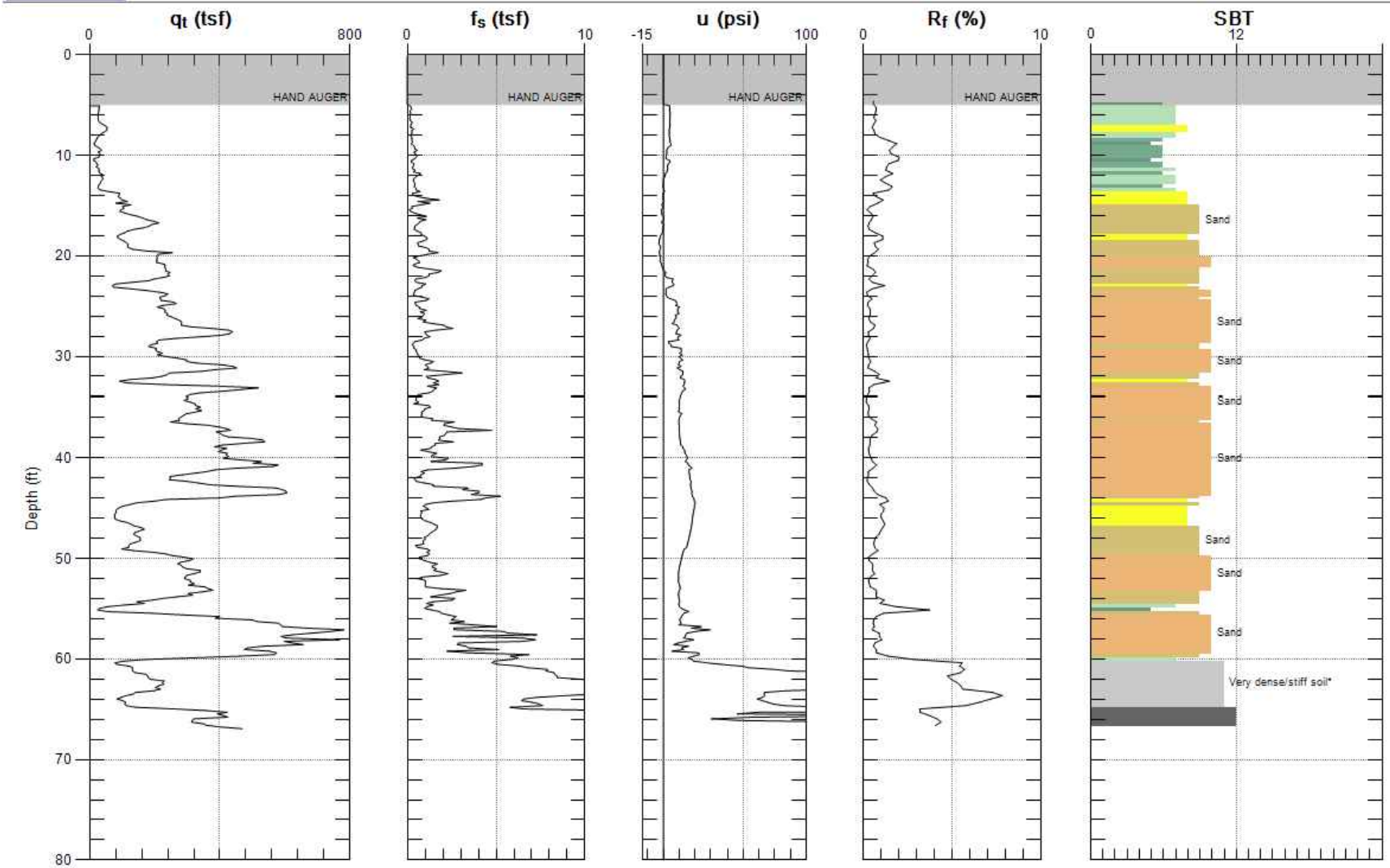
GREGG GEOSYNTEC

Site: SONOMA RUSSIAN RIV. Engineer: JESSICA B.

Sounding: CPT-GSC12 Date: 6/23/2011 02:09



Max. Depth: 66.929 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

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CONE PENETRATION TEST LOG
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
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PLATE
A9
SHEET 2 of 2

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Cone Penetration Testing Procedure (CPT)

Gregg Drilling carries out all Cone Penetration Tests (CPT) using an integrated electronic cone system, *Figure CPT*. The soundings were conducted using a 20 ton capacity cone with a tip area of 15 cm^2 and a friction sleeve area of 225 cm^2. The cone is designed with an equal end area friction sleeve and a tip end area ratio of 0.80.

The cone takes measurements of cone bearing (q_c), sleeve friction (f_s) and penetration pore water pressure (u_2) at 5-cm intervals during penetration to provide a nearly continuous log. CPT data reduction and interpretation is performed in real time facilitating on-site decision making. The above mentioned parameters are stored on disk for further analysis and reference. All CPT soundings are performed in accordance with revised (2007) ASTM standards (D 5778-07).

The cone also contains a porous filter element located directly behind the cone tip (u_2). It consists of porous plastic and is 5.0mm thick. The filter element is used to obtain penetration pore pressure as the cone is advanced as well as Pore Pressure Dissipation Tests (*PPDT's*) during appropriate pauses in penetration. It should be noted that prior to penetration, the element is fully saturated with oil under vacuum pressure to ensure accurate and fast dissipation.

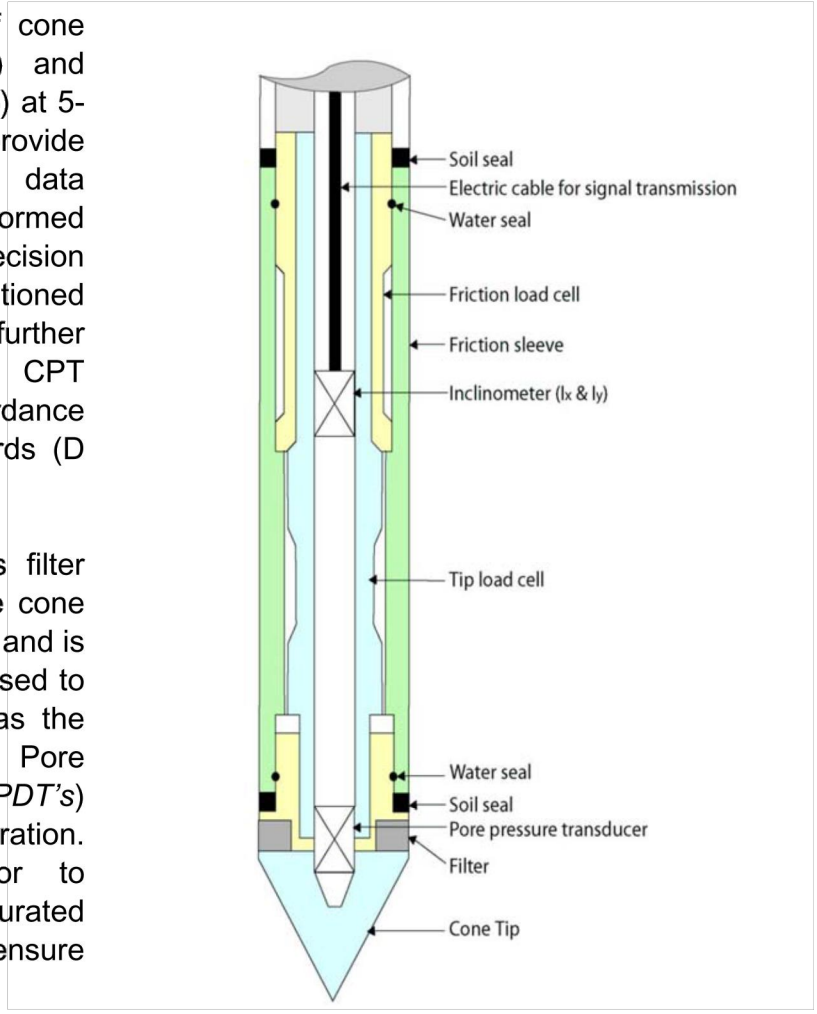

Figure CPT

The cone has the following accuracy:
1 tsf for q_c, 0.02 tsf for f_s and 0.5 psi for u_2. In soft clays, a lower capacity cone should be used for improved accuracy.

When the soundings are complete, the test holes are grouted. The grouting procedures generally consist of pushing a hollow tremie pipe with a "knock out" plug to the termination depth of the CPT hole. Grout is then pumped under pressure as the tremie pipe is pulled from the hole. Disruption or further contamination to the site is therefore minimized.

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CONE PENETRATION TESTING PROCEDURE
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
A10

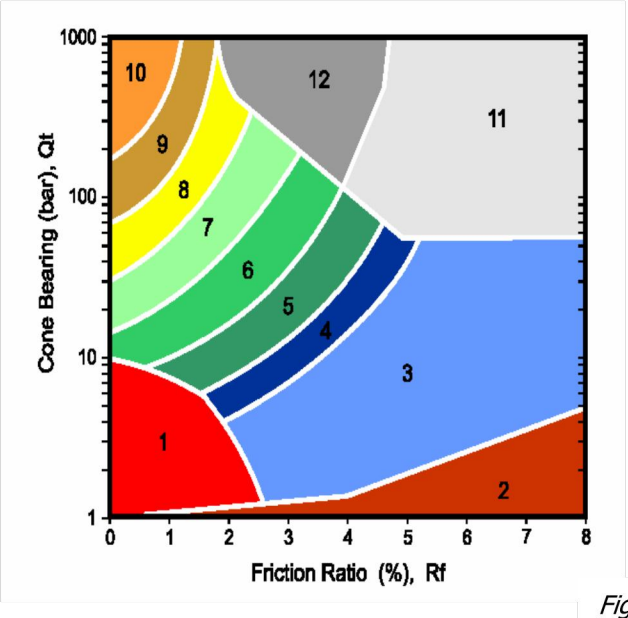
Cone Penetration Test Data & Interpretation

The Cone Penetration Test (CPT) data collected from your site are presented in graphical form in the attached report. The plots include interpreted Soil Behavior Type (SBT) based on the charts described by Robertson (1990). Typical plots display SBT based on the non-normalized charts of Robertson et al (1986). For CPT soundings extending greater than 50 feet, we recommend the use of the normalized charts of Robertson (1990) which can be displayed as SBTn, upon request. The report also includes spreadsheet output of computer calculations of basic interpretation in terms of SBT and SBTn and various geotechnical parameters using current published correlations based on the comprehensive review by Lunne, Robertson and Powell (1997), as well as recent updates by Professor Robertson. The interpretations are presented only as a guide for geotechnical use and should be carefully reviewed. Gregg Drilling & Testing Inc. do not warranty the correctness or the applicability of any of the geotechnical parameters interpreted by the software and do not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used in the software.

Some interpretation methods require input of the groundwater level to calculate vertical effective stress. An estimate of the in-situ groundwater level has been made based on field observations and/or CPT results, but should be verified by the user.

A summary of locations and depths is available in Table 1. Note that all penetration depths referenced in the data are with respect to the existing ground surface.

Note that it is not always possible to clearly identify a soil type based solely on q_t, f_s, and u_2. In these situations, experience, judgment, and an assessment of the pore pressure dissipation data should be used to infer the correct soil behavior type.



(After Robertson, et al., 1986)

ZONE		SBT
1		Sensitive, fine grained
2		Organic materials
3		Clay
4		Silty clay to clay
5		Clayey silt to silty clay
6		Sandy silt to clayey silt
7		Silty sand to sandy silt
8		Sand to silty sand
9		Sand
10		Gravely sand to sand
11		Very stiff fine grained*
12		Sand to clayey sand*

*over consolidated or cemented

Figure SBT

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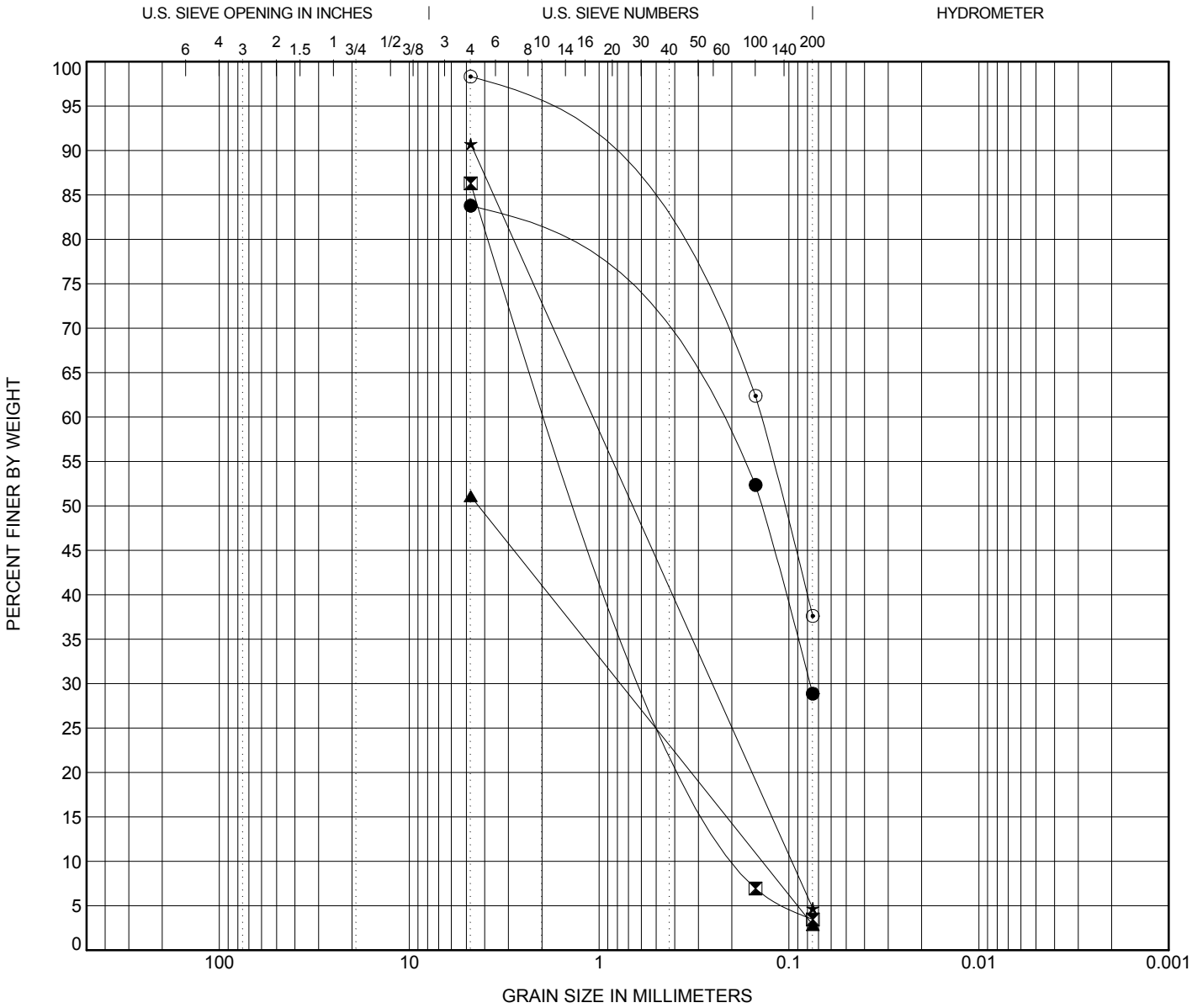
CONE PENETRATION TEST DATA & INTERPRETATION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
A11

APPENDIX B
Laboratory Test Data



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	M-1	6.5 ft	**BROWN SILTY FINE SAND (SM) with gravel**					
⧗	M-1	19.0 ft	**BROWN POORLY GRADED SAND (SP)**				**0.65**	**8.81**
▲	M-1	25.0 ft	**BROWN POORLY GRADED GRAVEL (GP) with sand**					
★	M-1	30.5 ft	**BROWN POORLY GRADED SAND (SP)**				**0.62**	**11.14**
⊙	M-2	10.5 ft	**BROWN SILTY SAND (SM)**					

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	M-1	6.5 ft	**4.75**	**0.347**	**0.078**			**54.9**	**28.9**	
⧗	M-1	19.0 ft	**4.75**	**1.511**	**0.409**	**0.171**		**82.9**	**3.5**	
▲	M-1	25.0 ft	**4.75**		**0.774**	**0.139**		**48.3**	**2.8**	
★	M-1	30.5 ft	**4.75**	**1.079**	**0.254**	**0.097**		**86.0**	**4.7**	
⊙	M-2	10.5 ft	**4.75**	**0.14**				**60.7**	**37.6**	

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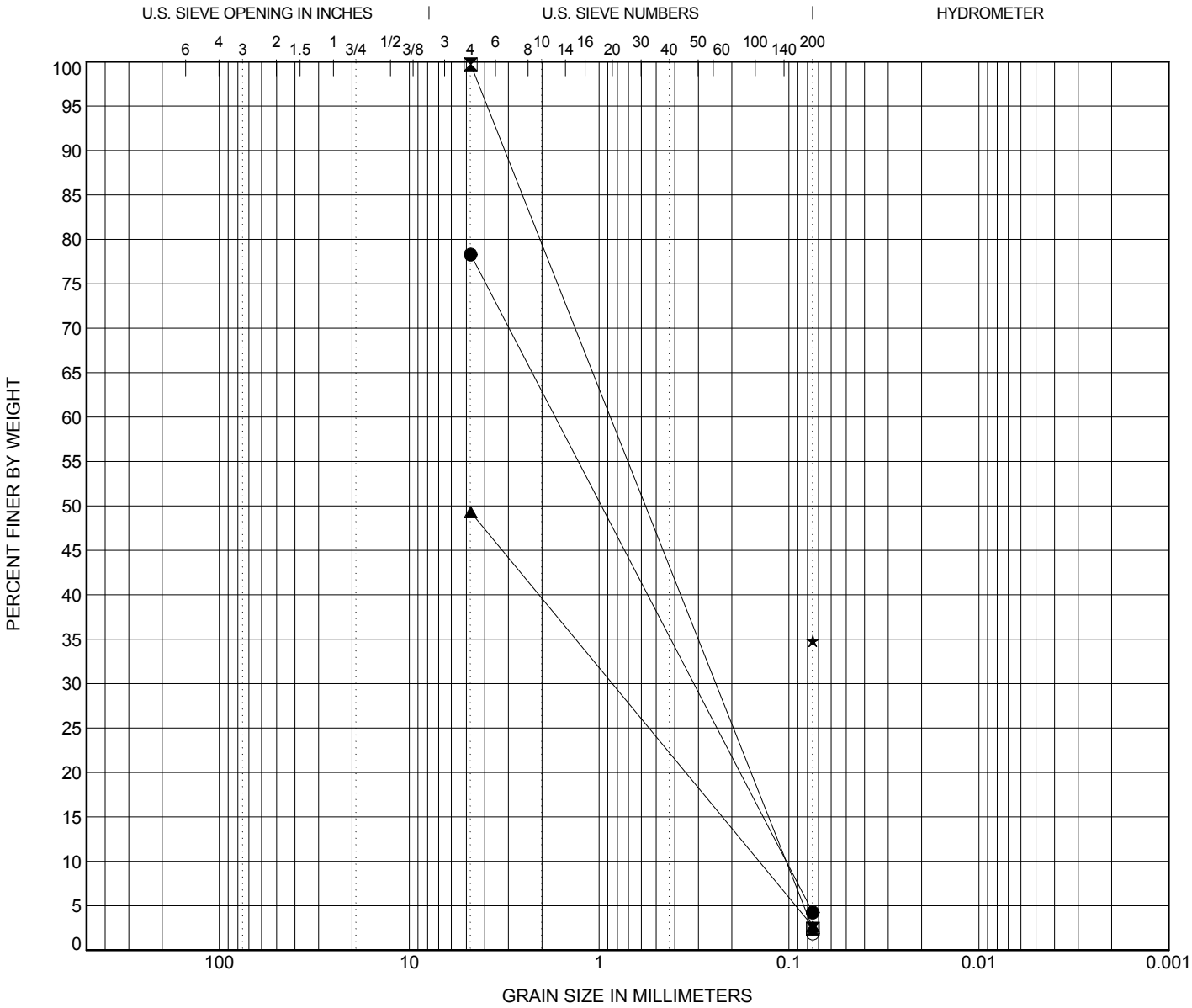
GRAIN SIZE DISTRIBUTION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
B1



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	M-2	20.5 ft	GRAY-BROWN POORLY GRADED SAND (SP) with gravel				0.57	16.46
⧗	M-2	30.5 ft	BROWN POORLY GRADED SAND (SP)				0.65	8.44
▲	M-2	41.0 ft	BROWN GRAVEL (GP) with sand					
★	M-4	10.0 ft	BLUE GRAY FINE SAND (SP-SM) with silt					
⊙	M-4	15.5 ft	BROWN POORLY GRADED GRAVEL (GP) with sand					

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	M-2	20.5 ft	4.75	1.705	0.317	0.104		74.0	4.2	
⧗	M-2	30.5 ft	4.75	0.874	0.243	0.104		97.3	2.4	
▲	M-2	41.0 ft	4.75		0.854	0.144		46.6	2.7	
★	M-4	10.0 ft	0.075						34.8	
⊙	M-4	15.5 ft	0.075						1.9	

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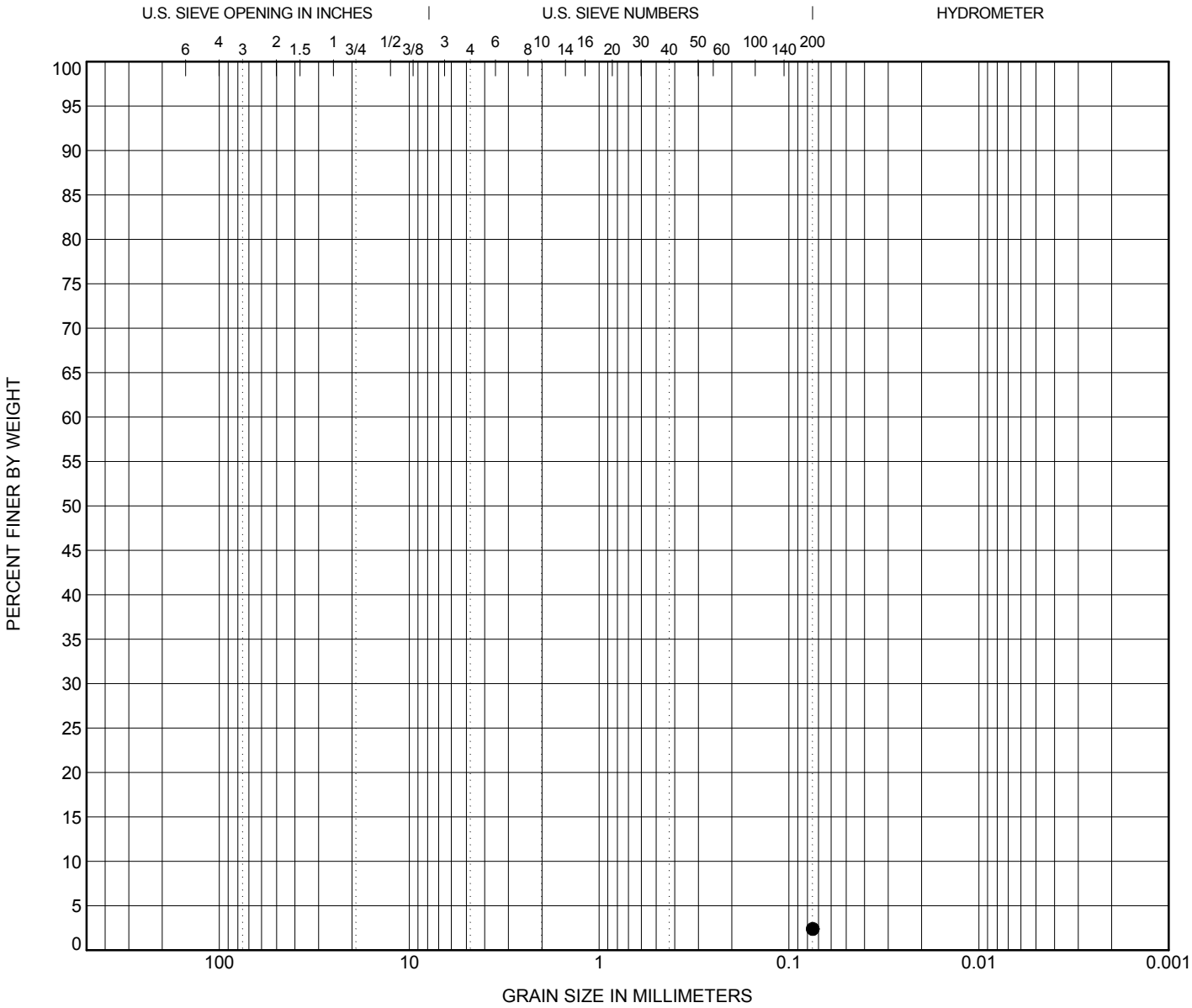
Appr.: KAC
Date: 03/12/13

GRAIN SIZE DISTRIBUTION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
B2



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● M-4	21.0 ft	**GRAY MEDIUM SAND (SP)**					

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● M-4	21.0 ft	**0.075**						**2.4**	

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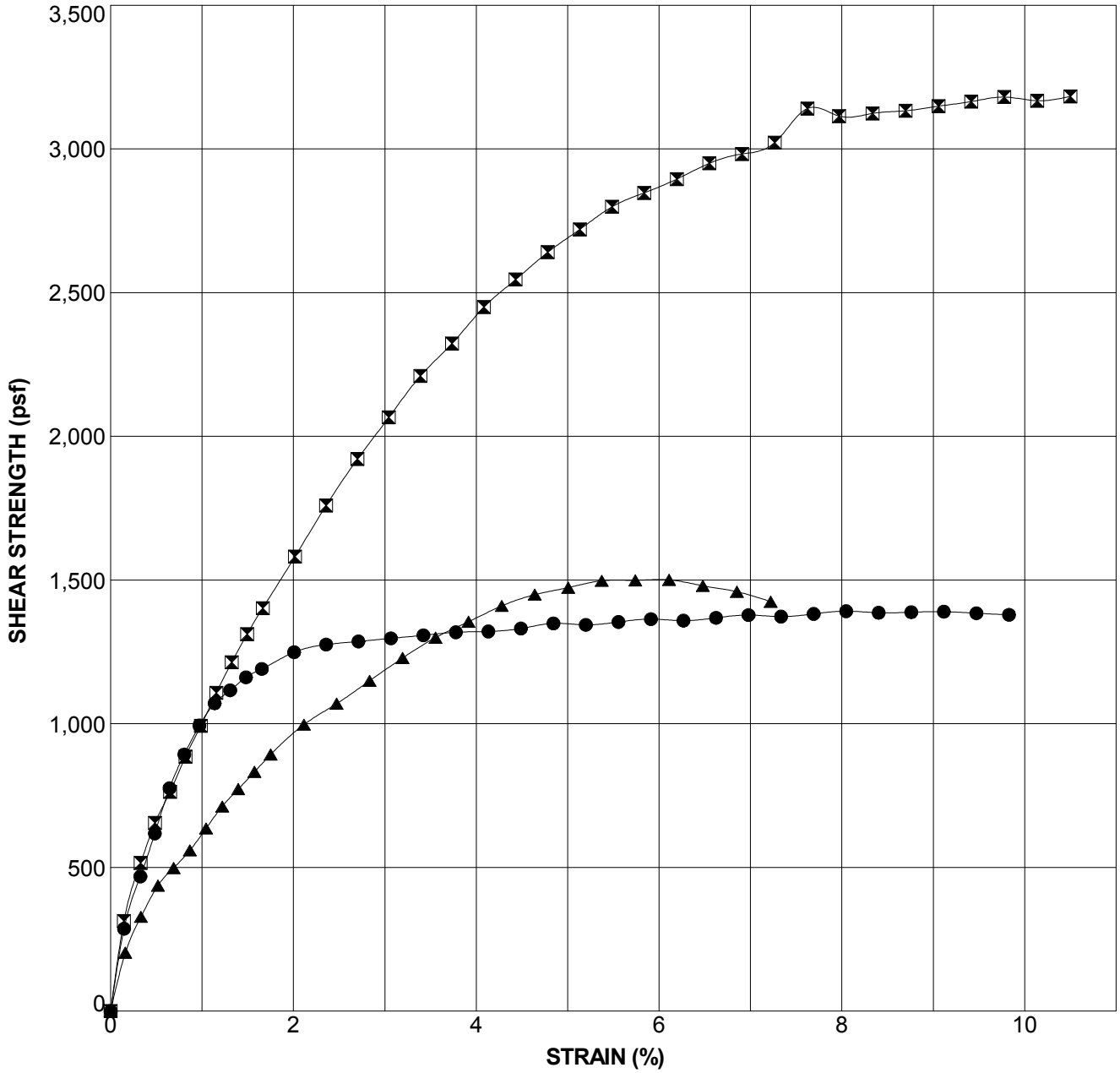
GRAIN SIZE DISTRIBUTION
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
B3



Sample Source	Classification	Confining Pressure (psf)	Yield Strength (psf)	Strain (%)	Dry Density (pcf)	Moisture Content (%)
● M-1 at 6.5 ft	BROWN SILTY FINE SAND (SM) with gravel	720	1191	1.7	109	11.7
⊠ M-1 at 19 ft	BROWN POORLY GRADED SAND (SP)	1440	2450	4.1	110	19.9
▲ M-2 at 10.5 ft	BROWN SILTY SAND (SM)	1008	1070	2.5	105	17.9

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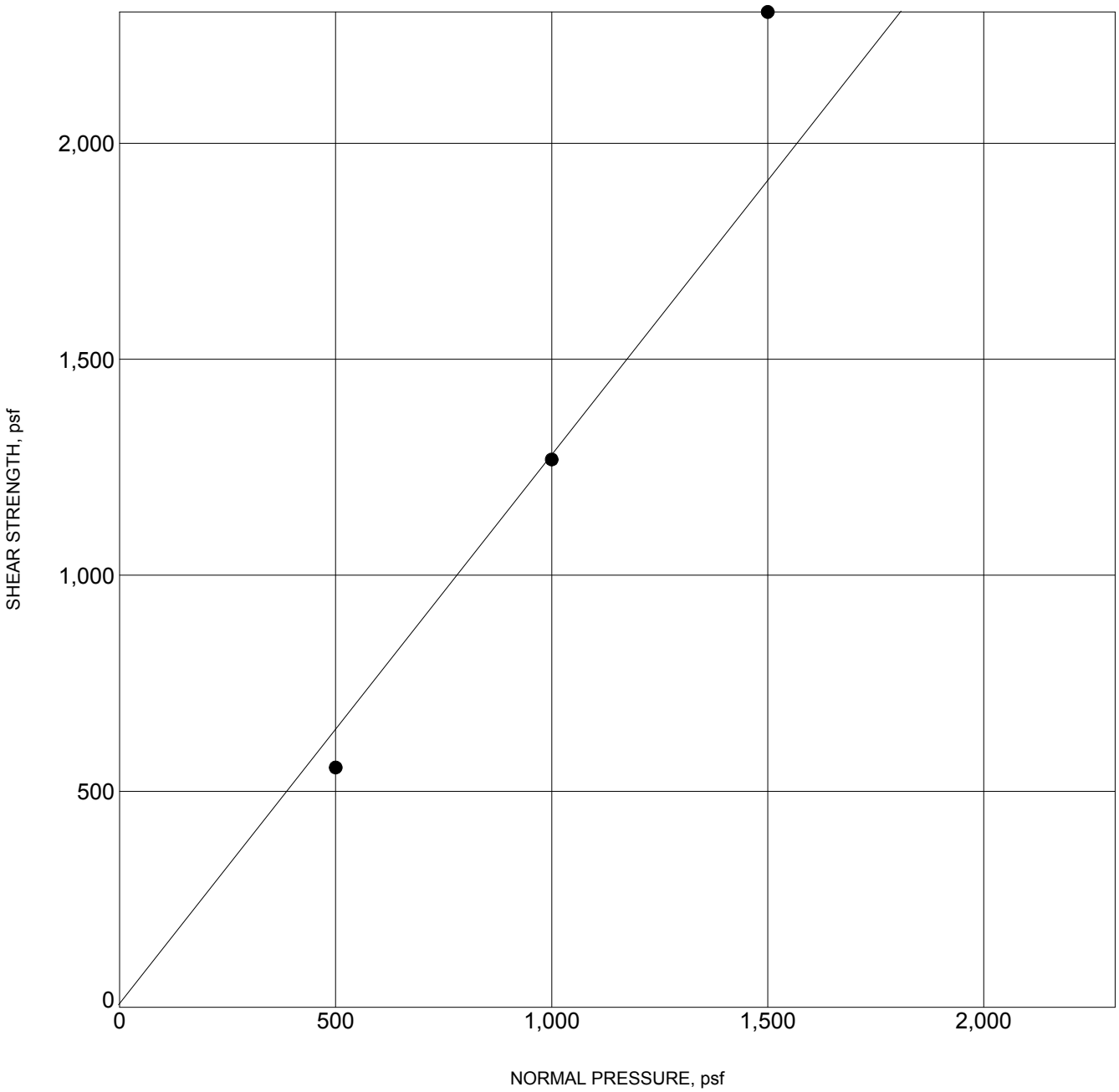
UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
B4



Specimen Identification				Classification	γ_d	MC%	c	ϕ (degree)
●	**M-3**	**at**	**34.0 ft**	**GRAY MEDIUM TO COARSE SAND (SP)**	**133**	**10.9**	**0**	**52**

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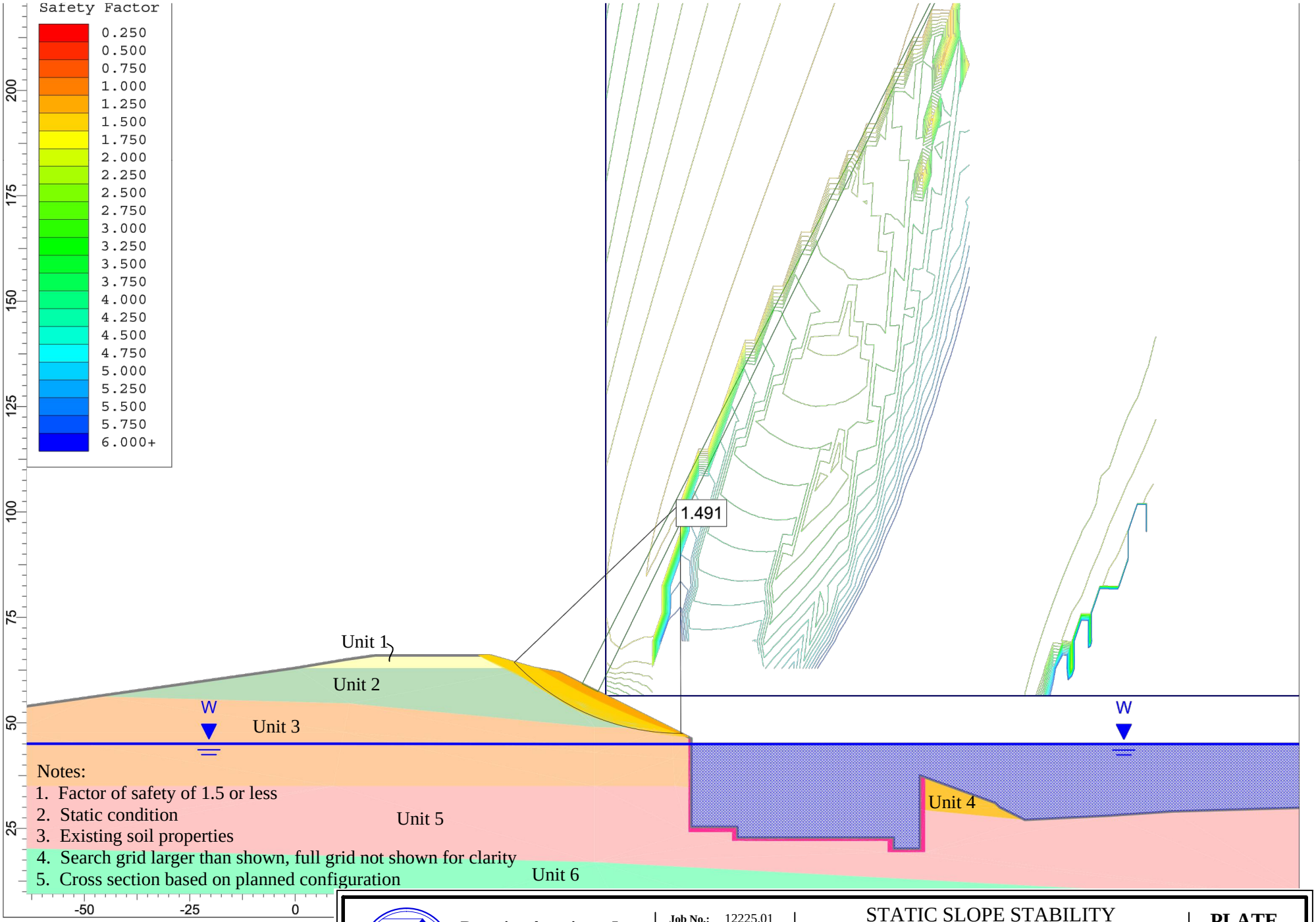
DIRECT SHEAR TEST RESULTS
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
B5

APPENDIX C
Slope Stability SLIDE 5.0 Data



Notes:
1. Factor of safety of 1.5 or less
2. Static condition
3. Existing soil properties
4. Search grid larger than shown, full grid not shown for clarity
5. Cross section based on planned configuration

APPROXIMATE SCALE (FEET)

0 15 30 60

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STATIC SLOPE STABILITY
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
C1

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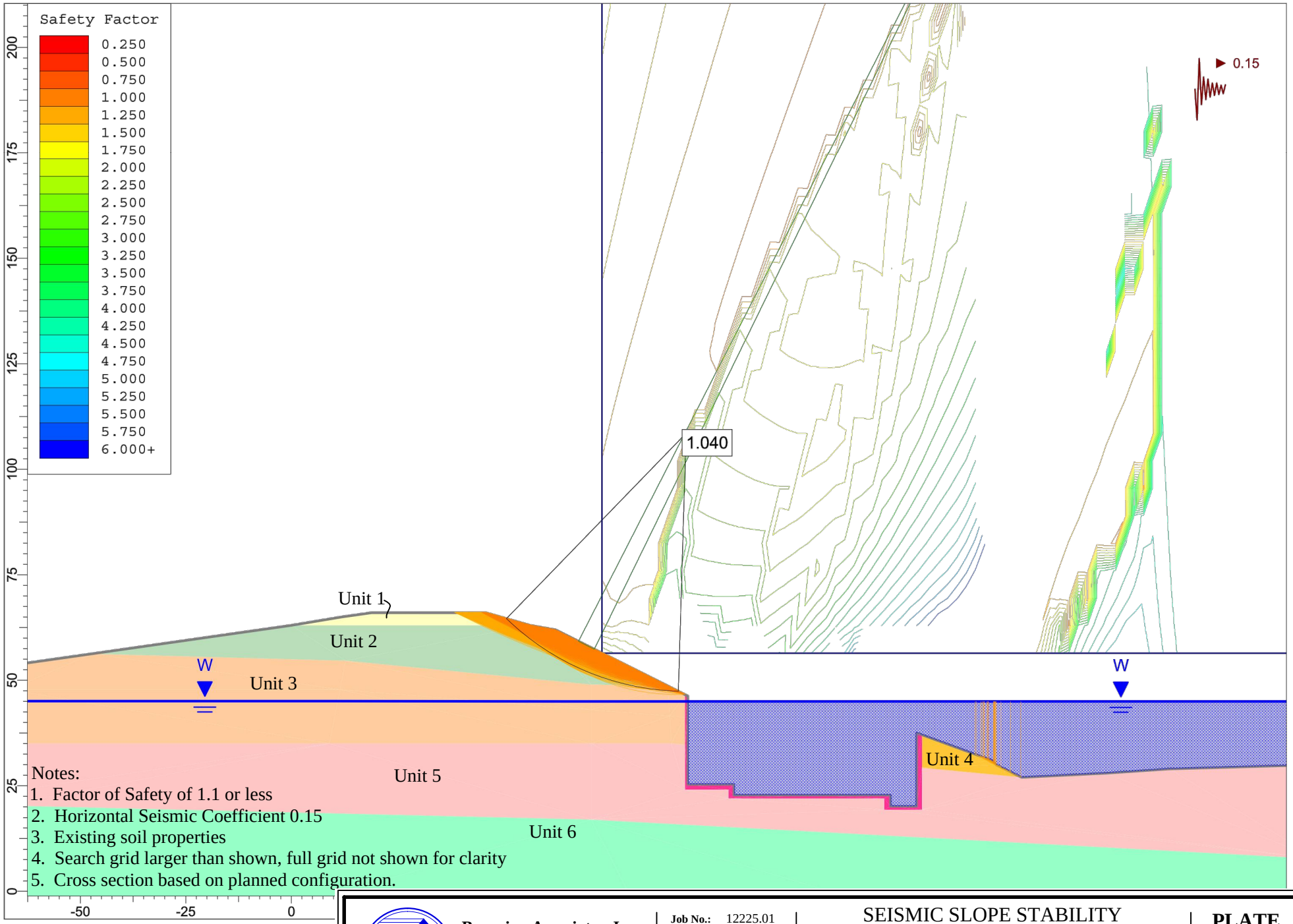

Notes:
1. Factor of Safety of 1.1 or less
2. Horizontal Seismic Coefficient 0.15
3. Existing soil properties
4. Search grid larger than shown, full grid not shown for clarity
5. Cross section based on planned configuration.

APPROXIMATE SCALE (FEET)

0 15 30 60

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Job No.: 12225.01
Appr.: KK
Date: 03/12/13

SEISMIC SLOPE STABILITY

SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
C2

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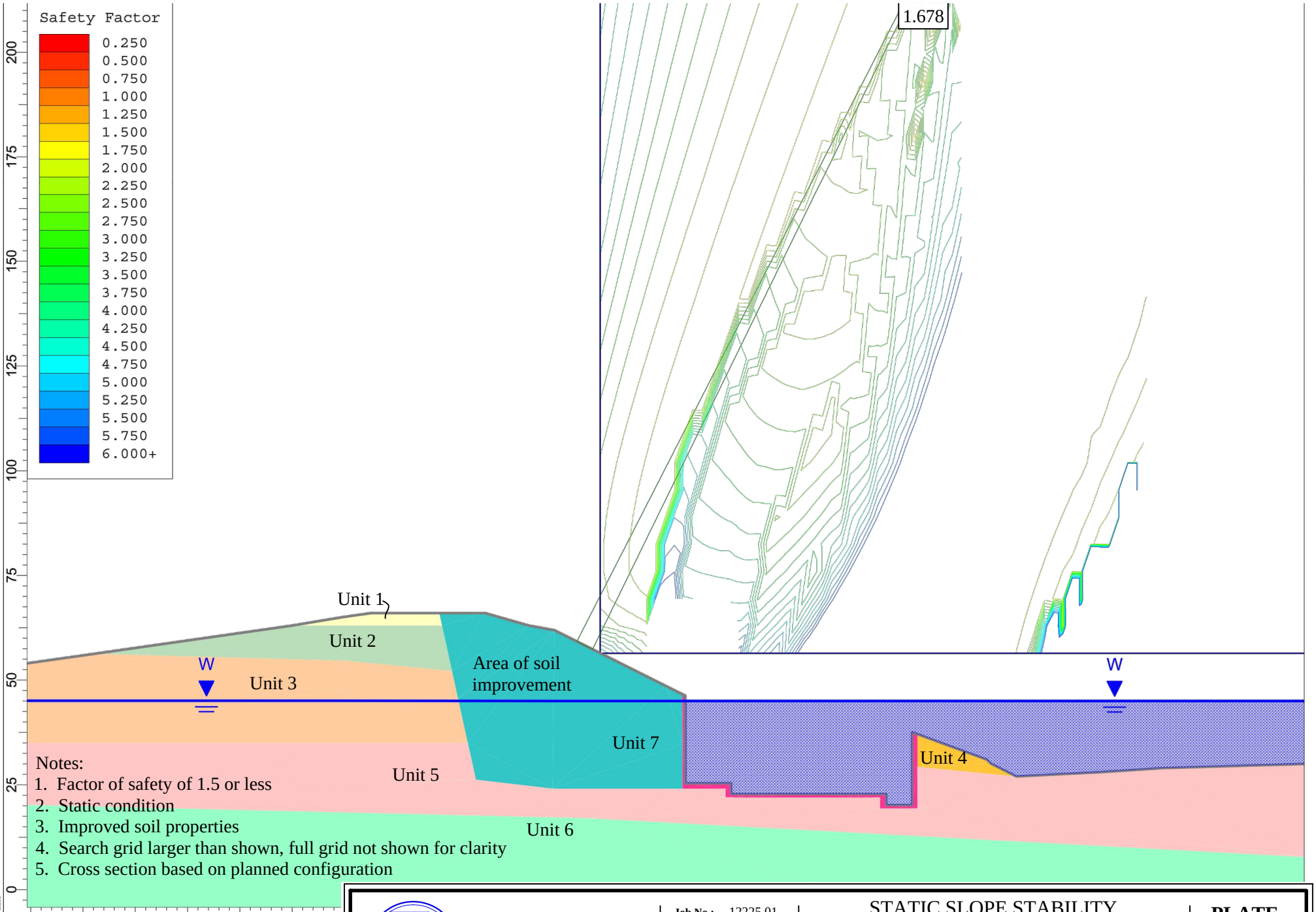

APPROXIMATE SCALE (FEET)

0 15 30 60

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Job No.: 12225.01

Appr.: KKC

Date: 03/12/13

STATIC SLOPE STABILITY

SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE

C3

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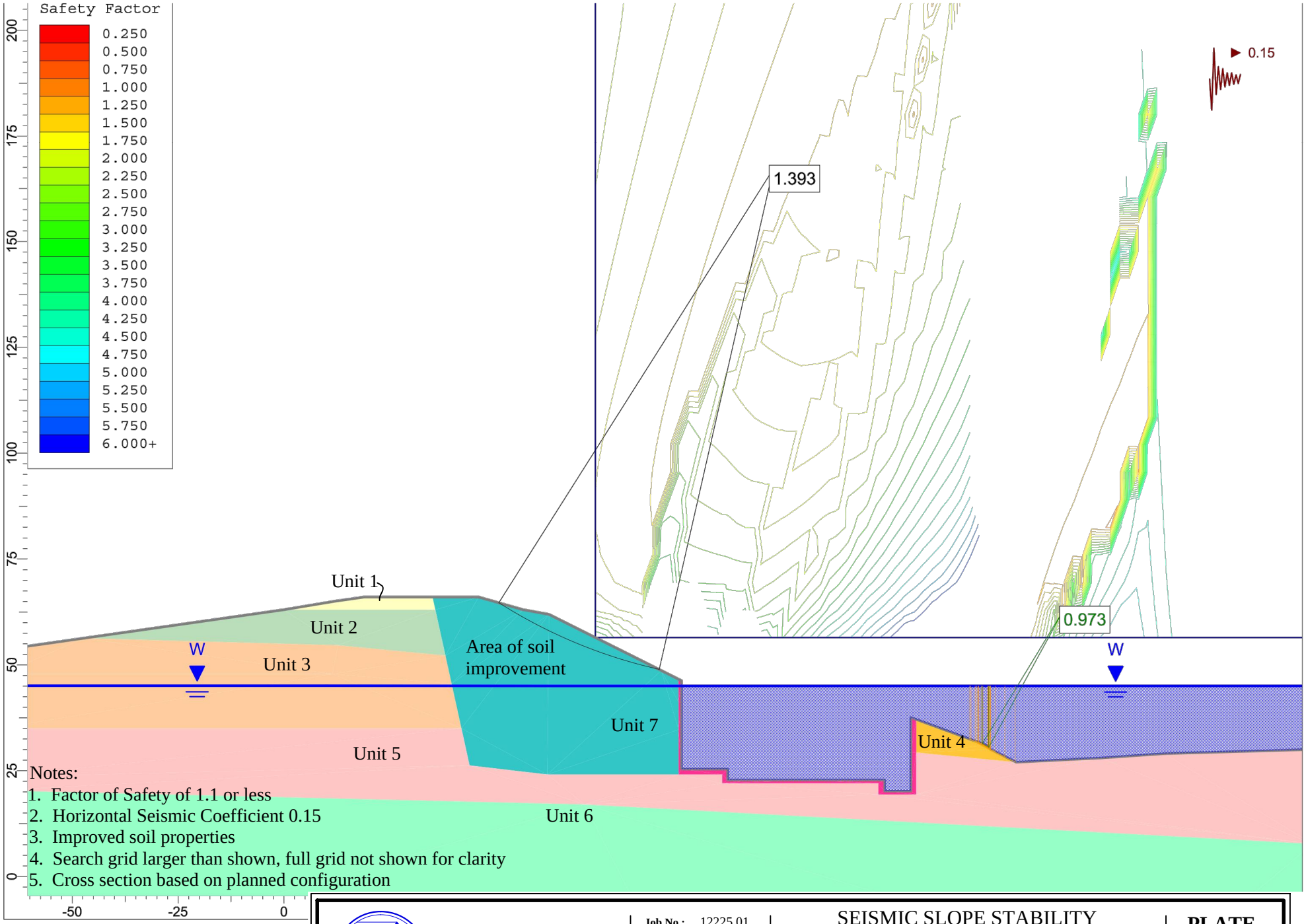

Notes:
1. Factor of Safety of 1.1 or less
2. Horizontal Seismic Coefficient 0.15
3. Improved soil properties
4. Search grid larger than shown, full grid not shown for clarity
5. Cross section based on planned configuration

APPROXIMATE SCALE (FEET)

0 15 30 60

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Santa Rosa, California 95403
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Job No.: 12225.01
Appr.: KK
Date: 03/12/13

SEISMIC SLOPE STABILITY
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER
REPLACEMENT PROJECT
Sonoma County, California

PLATE
C4

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APPENDIX D
Liquefaction Analysis Results

Boring M-1

Input Parameter:

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	0.0	(ft)	0.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	203.20	(in)	8
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	6	(ft)	20

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	σ_{vc}' (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	1.22	4.00	57	GM		1	25	75	1.25	1	0.75	1.00	61.5	26	14	1.69	103.56	5.1	108.63	1.00	0.482	1.05	1.10	2.000	2	2.00	1.22	0.000	-6.899	0.000	1.22	0.000	0.000	0.000	0.00
2	2.59	8.50	8	SM		1	29	75	1.25	1	0.85	1.00	9.8	55	30	1.69	16.49	5.3	21.81	0.98	0.476	1.05	1.10	0.230	0.27	0.56	2.59	0.129	0.419	0.129	1.37	0.178	0.021	0.009	0.35
3	3.35	11.00	13	SP		1	4	75	1.25	1	0.85	1.00	15.9	71	38	1.49	23.67	0.0	23.67	0.97	0.472	1.05	1.10	0.262	0.3	0.64	3.35	0.104	0.312	0.099	0.76	0.075	0.020	0.006	0.24
4	4.42	14.50	5	SP		1	4	75	1.25	1	0.85	1.00	6.1	94	50	1.47	8.98	0.0	8.98	0.96	0.466	1.05	1.06	0.111	0.12	0.27	4.42	0.500	0.932	0.500	1.07	0.533	0.040	0.037	1.46
5	5.49	18.00	2	SP		1	4	75	1.25	1	0.95	1.00	2.7	116	63	1.36	3.71	0.0	3.71	0.95	0.459	1.05	1.03	0.079	0.09	0.19	5.49	0.500	0.948	0.500	1.07	0.533	0.059	0.056	2.20
6	6.55	21.50	20	SP		1	3	75	1.25	1	0.95	1.00	27.3	139	75	1.11	30.45	0.0	30.45	0.93	0.452	1.05	1.06	0.514	0.58	1.28	6.55	0.044	-0.119	0.020	1.07	0.000	0.004	0.000	-0.02
7	7.32	24.00	18	GP		1	4	75	1.25	1	0.95	1.00	24.6	155	83	1.08	26.48	0.0	26.48	0.92	0.447	1.05	1.03	0.330	0.36	0.80	7.32	0.074	0.140	0.054	0.76	0.000	0.012	0.002	0.07
8	8.08	26.50	25	GP		1	3	75	1.25	1	0.95	1.00	34.1	171	92	1.03	35.19	0.0	35.19	0.91	0.441	1.05	1.02	1.154	1.25	2.00	8.08	0.021	-0.450	0.000	0.76	0.000	0.000	0.000	0.00
9	8.84	29.00	14	SP		1	3	75	1.25	1	1	1.00	20.1	187	101	1.00	20.15	0.0	20.15	0.90	0.436	1.05	1.00	0.208	0.22	0.50	8.84	0.156	0.510	0.156	0.76	0.000	0.023	0.012	0.46
10	9.45	31.00	24	SP		1	5	75	1.25	1	1	1.00	34.5	200	108	0.98	33.76	0.0	33.76	0.89	0.431	1.05	0.98	0.869	0.9	2.00	9.45	0.027	-0.348	0.000	0.61	0.000	0.000	0.000	0.00
11	10.06	33.00	24	GM		1	20	75	1.25	1	1	1.00	34.5	213	115	0.96	33.16	4.5	37.64	0.88	0.426	1.05	0.96	2.000	2	2.00	10.06	0.014	-0.628	0.000	0.61	0.000	0.000	0.000	0.00
12	10.67	35.00	40	SP		1	5	75	1.25	1	1	1.00	57.5	226	122	0.95	54.76	0.0	54.76	0.87	0.422	1.05	0.95	2.000	1.99	2.00	10.67	0.000	-1.981	0.000	0.61	0.000	0.000	0.000	0.00
13	11.28	37.00	38	SP		1	5	75	1.25	1	1	1.00	54.6	239	129	0.94	51.27	0.0	51.27	0.86	0.417	1.05	0.93	2.000	1.96	2.00	11.28	0.000	-1.692	0.000	0.61	0.000	0.000	0.000	0.00
14	11.73	38.50	38	GM		1	15	75	1.25	1	1	1.00	54.6	249	134	0.93	50.73	3.3	53.99	0.85	0.414	1.05	0.92	2.000	1.93	2.00	11.73	0.000	-1.917	0.000	0.46	0.000	0.000	0.000	0.00
15	13.11	43.00	41	SP-SM		1	10	75	1.25	1	1	1.00	58.9	278	149	0.90	53.17	1.1	54.32	0.83	0.403	1.05	0.88	2.000	1.87	2.00	13.11	0.000	-1.944	0.000	1.37	0.000	0.000	0.000	0.00
16	14.63	48	16	SP		1	5	75	1.25	1	1	1.00	23.0	310	167	0.80	18.30	0.0019	18.31	0.8076	0.39	1.05	0.94	0.187	0.18	0.47	14.6	0.192	0.604	0.192	1.52	0.000	0.025	0.015	0.59
17	15.70	51.5	61	SM		1	20	75	1.25	1	1	1.00	87.7	333	179	0.86	75.44	4.4779	79.92	0.7904	0.38	1.05	0.83	2.000	1.75	2.00	15.7	0.000	-4.189	0.000	1.07	0.000	0.000	0.000	0.00

Liquefaction Potential

LDI= 1.32 (m) 51.9 (in) S= 0.109 (m) 4.30 (in)

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3/12/2013 6:48:14 PM plot date

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Tel: (707) 838-3027

Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LIQUEFACATION ANALYSIS M-1
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D1
SHEET 1 of 2

Boring M-1

Input Parameter:

Peak Ground Accel (g) =	0.400			
Earthquake Magnitude, M =	7.3			
Water Table Depth (m) =	0.0		(ft)	0.00
Average γ Above Water Table (kN/m^3) =		19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =		21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	203.20		(in)	8
Requires Correction for Sample Liners (YES/NO):			no	
Rod Lengths Assumed Equal to the Depth Plus		1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)		9.81		
Height of Exposed Face (m)		6	(ft)	20

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Measured Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	$\sigma_{vc'}$ (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}es}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	1.22	4.00	57	GM		1	25	75	1.25	1	0.75	1.00	61.5	26	14	1.69	103.56	5.1	108.63	1.00	0.482	1.05	1.10	2.000	2	2.00	1.22	0.000	-6.899	0.000	1.22	0.000	0.000	0.000	0.00
2	2.59	8.50	16	SM		1	29	75	1.25	1	0.85	1.00	19.6	55	30	1.50	29.39	5.3	34.71	0.98	0.476	1.05	1.10	1.044	1.21	2.00	2.59	0.023	-0.415	0.000	1.37	0.000	0.000	0.000	0.00
3	3.35	11.00	20	SP		1	4	75	1.25	1	0.85	1.00	24.4	71	38	1.39	33.90	0.0	33.90	0.97	0.472	1.05	1.10	0.892	1.03	2.00	3.35	0.026	-0.358	0.000	0.76	0.000	0.000	0.000	0.00
4	4.42	14.50	22	SP		1	4	75	1.25	1	0.85	1.00	26.9	94	50	1.26	33.97	0.0	33.97	0.96	0.466	1.05	1.10	0.903	1.05	2.00	4.42	0.026	-0.362	0.000	1.07	0.000	0.000	0.000	0.00
5	5.49	18.00	21	SP		1	4	75	1.25	1	0.95	1.00	28.7	116	63	1.18	33.72	0.0	33.72	0.95	0.459	1.05	1.10	0.863	1	2.00	5.49	0.027	-0.345	0.000	1.07	0.000	0.000	0.000	0.00
6	6.55	21.50	22	SP		1	3	75	1.25	1	0.95	1.00	30.0	139	75	1.11	33.30	0.0	33.30	0.93	0.452	1.05	1.07	0.799	0.9	2.00	6.55	0.029	-0.315	0.000	1.07	0.000	0.000	0.000	0.00
7	7.32	24.00	23	GP		1	4	75	1.25	1	0.95	1.00	31.4	155	83	1.07	33.52	0.0	33.52	0.92	0.447	1.05	1.05	0.832	0.92	2.00	7.32	0.028	-0.331	0.000	0.76	0.000	0.000	0.000	0.00
8	8.08	26.50	25	GP		1	3	75	1.25	1	0.95	1.00	34.1	171	92	1.03	35.19	0.0	35.19	0.91	0.441	1.05	1.02	1.154	1.25	2.00	8.08	0.021	-0.450	0.000	0.76	0.000	0.000	0.000	0.00
9	8.84	29.00	24	SP		1	3	75	1.25	1	1	1.00	34.5	187	101	1.00	34.53	0.0	34.53	0.90	0.436	1.05	1.00	1.007	1.06	2.00	8.84	0.024	-0.402	0.000	0.76	0.000	0.000	0.000	0.00
10	9.45	31.00	24	SP		1	5	75	1.25	1	1	1.00	34.5	200	108	0.98	33.76	0.0	33.76	0.89	0.431	1.05	0.98	0.869	0.9	2.00	9.45	0.027	-0.348	0.000	0.61	0.000	0.000	0.000	0.00
11	10.06	33.00	24	GM		1	20	75	1.25	1	1	1.00	34.5	213	115	0.96	33.16	4.5	37.64	0.88	0.426	1.05	0.96	2.000	2	2.00	10.06	0.014	-0.628	0.000	0.61	0.000	0.000	0.000	0.00
12	10.67	35.00	40	SP		1	5	75	1.25	1	1	1.00	57.5	226	122	0.95	54.76	0.0	54.76	0.87	0.422	1.05	0.95	2.000	1.99	2.00	10.67	0.000	-1.981	0.000	0.61	0.000	0.000	0.000	0.00
13	11.28	37.00	38	SP		1	5	75	1.25	1	1	1.00	54.6	239	129	0.94	51.27	0.0	51.27	0.86	0.417	1.05	0.93	2.000	1.96	2.00	11.28	0.000	-1.692	0.000	0.61	0.000	0.000	0.000	0.00
14	11.73	38.50	38	GM		1	15	75	1.25	1	1	1.00	54.6	249	134	0.93	50.73	3.3	53.99	0.85	0.414	1.05	0.92	2.000	1.93	2.00	11.73	0.000	-1.917	0.000	0.46	0.000	0.000	0.000	0.00
15	13.11	43.00	41	SP-SM		1	10	75	1.25	1	1	1.00	58.9	278	149	0.90	53.17	1.1	54.32	0.83	0.403	1.05	0.88	2.000	1.87	2.00	13.11	0.000	-1.944	0.000	1.37	0.000	0.000	0.000	0.00
16	14.63	48	28	SP		1	5	75	1.25	1	1	1.00	40.3	310	167	0.84	34.01	0.0019	34.01	0.8076	0.39	1.05	0.88	0.910	0.84	2.00	14.6	0.026	-0.365	0.000	1.52	0.000	0.000	0.000	0.00
17	15.70	51.5	61	SM		1	20	75	1.25	1	1	1.00	87.7	333	179	0.86	75.44	4.4779	79.92	0.7904	0.38	1.05	0.83	2.000	1.75	2.00	15.7	0.000	-4.189	0.000	1.07	0.000	0.000	0.000	0.00

Layer of liquefaction potential without soil improvement

LDI= 0.00 (m) 0 (in) S= 0.000 (m) 0.00 (in)

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Notes:
Liquefaction analysis to evaluate required minimum blow count with modified soil improvements to prevent liquefaction

Brunsing Associates, Inc.
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Tel: (707) 838-3027

Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LIQUEFACATION ANALYSIS M-1
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D1
SHEET 2 of 2

Boring M-2

Input Parameters

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	0.0	(ft)	0.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	203.20	(in)	8
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	6	(ft)	20

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	$\sigma_{vc'}$ (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	3.20	10.50	40	GM		1	40	75	1.25	1	0.85	1.00	48.9	68	36	1.31	63.89	5.6	69.47	0.98	0.472	1.05	1.10	2.000	2	2.00	3.20	0.000	-3.248	0.000	3.20	0.000	0.000	0.000	0.00
2	4.42	14.50	12	SM		1	38	75	1.25	1	0.85	1.00	14.7	94	50	1.32	19.37	5.6	24.93	0.96	0.466	1.05	1.10	0.288	0.33	0.72	4.42	0.090	0.236	0.071	1.22	0.087	0.017	0.004	0.16
3	5.64	18.50	21	SP		1	5	75	1.25	1	0.95	1.00	28.7	120	64	1.17	33.44	0.0	33.44	0.95	0.458	1.05	1.10	0.820	0.95	2.00	5.64	0.028	-0.325	0.000	1.22	0.000	0.000	0.000	0.00
4	7.16	23.50	20	SP		1	4	75	1.25	1	0.95	1.00	27.3	152	82	1.08	29.53	0.0	29.53	0.93	0.448	1.05	1.04	0.457	0.5	1.12	7.16	0.050	-0.057	0.028	1.52	0.000	0.006	0.000	-0.01
5	8.84	29.00	26	SP		1	3	75	1.25	1	1	1.00	37.4	187	101	1.00	37.40	0.0	37.40	0.90	0.436	1.05	1.00	1.939	2	2.00	8.84	0.014	-0.611	0.000	1.68	0.000	0.000	0.000	0.00
6	10.36	34.00	10	SP		1	2	75	1.25	1	1	1.00	14.4	220	118	0.92	13.28	0.0	13.28	0.88	0.424	1.05	0.98	0.142	0.15	0.35	10.36	0.331	0.820	0.331	1.52	0.000	0.031	0.026	1.01
7	12.50	41.00	38	SP		1	3	75	1.25	1	1	1.00	54.6	265	142	0.91	49.90	0.0	49.90	0.84	0.408	1.05	0.90	2.000	1.89	2.00	12.50	0.000	-1.581	0.000	2.13	0.000	0.000	0.000	0.00
8	12.80	42.00	67	GP		1	3	75	1.25	1	1	1.00	96.3	272	146	0.91	87.43	0.0	87.43	0.84	0.405	1.05	0.89	2.000	1.88	2.00	12.80	0.000	-4.882	0.000	0.30	0.000	0.000	0.000	0.00

Liquefaction Potential

LDI= 0.09 (m) 3.4 (in)

S= 0.03 (m) 1.2 (in)

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Tel: (707) 838-3027

Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LIQUEFACATION ANALYSIS M-2
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D2
SHEET 1 of 2

Boring M-2

Input Parameters

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	0.0	(ft)	0.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	203.20	(in)	8
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	6	(ft)	20

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Measured Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	$\sigma_{vc'}$ (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & $\sigma_{vc'}$=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	3.20	10.50	40	GM		1	40	75	1.25	1	0.85	1.00	48.9	68	36	1.31	63.89	5.6	69.47	0.98	0.472	1.05	1.10	2.000	2	2.00	3.20	0.000	-3.248	0.000	3.20	0.000	0.000	0.000	0.00
2	4.42	14.50	18	SM		1	38	75	1.25	1	0.85	1.00	22.0	94	50	1.27	27.86	5.6	33.42	0.96	0.466	1.05	1.10	0.817	0.95	2.00	4.42	0.028	-0.323	0.000	1.22	0.000	0.000	0.000	0.00
3	5.64	18.50	21	SP		1	5	75	1.25	1	0.95	1.00	28.7	120	64	1.17	33.44	0.0	33.44	0.95	0.458	1.05	1.10	0.820	0.95	2.00	5.64	0.028	-0.325	0.000	1.22	0.000	0.000	0.000	0.00
4	7.16	23.50	23	SP		1	4	75	1.25	1	0.95	1.00	31.4	152	82	1.07	33.75	0.0	33.75	0.93	0.448	1.05	1.05	0.867	0.96	2.00	7.16	0.027	-0.347	0.000	1.52	0.000	0.000	0.000	0.00
5	8.84	29.00	26	SP		1	3	75	1.25	1	1	1.00	37.4	187	101	1.00	37.40	0.0	37.40	0.90	0.436	1.05	1.00	1.939	2	2.00	8.84	0.014	-0.611	0.000	1.68	0.000	0.000	0.000	0.00
6	10.36	34.00	25	SP		1	2	75	1.25	1	1	1.00	35.9	220	118	0.95	34.10	0.0	34.10	0.88	0.424	1.05	0.96	0.926	0.94	2.00	10.36	0.025	-0.372	0.000	1.52	0.000	0.000	0.000	0.00
7	12.50	41.00	38	SP		1	3	75	1.25	1	1	1.00	54.6	265	142	0.91	49.90	0.0	49.90	0.84	0.408	1.05	0.90	2.000	1.89	2.00	12.50	0.000	-1.581	0.000	2.13	0.000	0.000	0.000	0.00
8	12.80	42.00	67	GP		1	3	75	1.25	1	1	1.00	96.3	272	146	0.91	87.43	0.0	87.43	0.84	0.405	1.05	0.89	2.000	1.88	2.00	12.80	0.000	-4.882	0.000	0.30	0.000	0.000	0.000	0.00

Layer of liquefaction potential without soil improvement

LDI= 0.00 (m) 0.0 (in) S= 0.00 (m) 0.0 (in)

Notes:
Liquefaction analysis to evaluate required minimum blow count with modified soil improvements to prevent liquefaction

Brunsing Associates, Inc.
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Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LIQUEFACATION ANALYSIS M-2
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D2
SHEET 2 of 2

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Boring M-3

Input Parameter

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	5.2	(ft)	17.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	177.80	(in)	7
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	5	(ft)	15

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	$\sigma_{vc'}$ (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60-cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	1.52	5.00	30	SM		0	30	75	1.25	1	0.8	1.00	34.5	29	29	1.39	47.82	5.4	53.18	0.99	0.258	1.05	1.10	2.000	N.A.	N.A.	1.52	0.000	-1.850	0.000	1.52	0.000	0.000	0.000	0.00
2	2.44	8.00	23	SP-SM		0	10	75	1.25	1	0.8	1.00	26.5	47	47	1.29	34.06	1.1	35.21	0.98	0.256	1.05	1.10	1.159	N.A.	N.A.	2.44	0.021	-0.451	0.000	0.91	0.000	0.000	0.000	0.00
3	3.96	13.00	7	SP-SM		0	10	75	1.25	1	0.85	1.00	8.6	76	76	1.16	9.94	1.1	11.09	0.97	0.252	1.05	1.03	0.126	N.A.	N.A.	3.96	0.420	0.888	0.000	1.52	0.000	0.000	0.000	0.00
4	5.49	18.00	5	SP		1	2	75	1.25	1	0.95	1.00	6.8	106	103	0.99	6.76	0.0	6.76	0.95	0.254	1.05	1.00	0.097	0.1	0.40	5.49	0.500	0.948	0.500	1.52	0.000	0.046	0.044	1.72
5	7.01	23.00	6	SP-SM		1	10	75	1.25	1	0.95	1.00	8.2	138	120	0.91	7.44	1.1	8.58	0.93	0.277	1.05	0.98	0.108	0.11	0.41	7.01	0.500	0.938	0.500	1.52	0.000	0.041	0.038	1.50
6	8.53	28.00	10	SP		1	2	75	1.25	1	1	1.00	14.4	170	138	0.85	12.26	0.0	12.26	0.91	0.292	1.05	0.97	0.134	0.14	0.47	8.53	0.370	0.854	0.370	1.52	0.000	0.033	0.028	1.11
7	10.06	33.00	25	SP		1	2	75	1.25	1	1	1.00	35.9	203	155	0.86	30.84	0.0	30.84	0.88	0.300	1.05	0.91	0.543	0.52	1.74	10.06	0.041	-0.146	0.006	1.52	0.000	0.001	0.000	-0.01
8	11.58	38.00	21	SP		1	2	75	1.25	1	1	1.00	30.2	235	172	0.81	24.31	0.0	24.31	0.86	0.304	1.05	0.92	0.275	0.27	0.87	11.58	0.096	0.274	0.048	1.52	0.000	0.012	0.003	0.13
9	13.11	43.00	31	SM		1	20	75	1.25	1	1	1.00	44.6	267	190	0.83	37.16	4.5	41.64	0.83	0.305	1.05	0.81	2.000	1.72	2.00	13.11	0.006	-0.928	0.000	1.52	0.000	0.000	0.000	0.00
10	14.63	48.00	40	SP		1	2	75	1.25	1	1	1.00	57.5	300	207	0.83	47.61	0.0	47.61	0.81	0.304	1.05	0.79	2.000	1.66	2.00	14.63	0.001	-1.396	0.000	1.52	0.000	0.000	0.000	0.00
11	15.54	51.00	46	SP		1	2	75	1.25	1	1	1.00	66.1	319	217	0.82	54.04	0.0	54.04	0.79	0.303	1.05	0.77	2.000	1.63	2.00	15.54	0.000	-1.921	0.000	0.91	0.000	0.000	0.000	0.00

Liquefaction Potential

LDI= 0.00 (m) 0.0 (in) S= 0.113 (m) 4.45 (in)

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Brunsing Associates, Inc.
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Job No.: 12225.01
Appr.: KK
Date: 03/12/13

LIQUEFACATION ANALYSIS M-3
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D3
SHEET 1 of 2

Boring M-3

Input Parameter:

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	5.2	(ft)	17.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	177.80	(in)	7
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	5	(ft)	15

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Measured Soil Type (USCS)	Measured Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{ve} (kPa)	σ_{ve}' (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}es}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{ve}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	1.52	5.00	30	SM		0	30	75	1.25	1	0.8	1.00	34.5	29	29	1.39	47.82	5.4	53.18	0.99	0.258	1.05	1.10	2.000	N.A.	N.A.	1.52	0.000	-1.850	0.000	1.52	0.000	0.000	0.000	0.00
2	2.44	8.00	23	SP-SM		0	10	75	1.25	1	0.8	1.00	26.5	47	47	1.29	34.06	1.1	35.21	0.98	0.256	1.05	1.10	1.159	N.A.	N.A.	2.44	0.021	-0.451	0.000	0.91	0.000	0.000	0.000	0.00
3	3.96	13.00	7	SP-SM		0	10	75	1.25	1	0.85	1.00	8.6	76	76	1.16	9.94	1.1	11.09	0.97	0.252	1.05	1.03	0.126	N.A.	N.A.	3.96	0.420	0.888	0.000	1.52	0.000	0.000	0.000	0.00
4	5.49	18.00	22	SP		1	2	75	1.25	1	0.95	1.00	30.0	106	103	0.99	29.85	0.0	29.85	0.95	0.254	1.05	1.00	0.476	0.5	1.97	5.49	0.047	-0.079	0.001	1.52	0.000	0.000	0.000	0.00
5	7.01	23.00	23	SP-SM		1	10	75	1.25	1	0.95	1.00	31.4	138	120	0.94	29.51	1.1	30.66	0.93	0.277	1.05	0.96	0.529	0.54	1.94	7.01	0.042	-0.133	0.001	1.52	0.000	0.000	0.000	0.00
6	8.53	28.00	24	SP		1	2	75	1.25	1	1	1.00	34.5	170	138	0.90	30.90	0.0	30.90	0.91	0.292	1.05	0.93	0.547	0.54	1.85	8.53	0.041	-0.149	0.003	1.52	0.000	0.001	0.000	0.00
7	10.06	33.00	26	SP		1	2	75	1.25	1	1	1.00	37.4	203	155	0.86	32.20	0.0	32.20	0.88	0.300	1.05	0.90	0.665	0.63	2.00	10.06	0.034	-0.239	0.000	1.52	0.000	0.000	0.000	0.00
8	11.58	38.00	27	SP		1	2	75	1.25	1	1	1.00	38.8	235	172	0.83	32.23	0.0	32.23	0.86	0.304	1.05	0.88	0.668	0.62	2.00	11.58	0.034	-0.241	0.000	1.52	0.000	0.000	0.000	0.00
9	13.11	43.00	31	SM		1	20	75	1.25	1	1	1.00	44.6	267	190	0.83	37.16	4.5	41.64	0.83	0.305	1.05	0.81	2.000	1.72	2.00	13.11	0.006	-0.928	0.000	1.52	0.000	0.000	0.000	0.00
10	14.63	48.00	40	SP		1	2	75	1.25	1	1	1.00	57.5	300	207	0.83	47.61	0.0	47.61	0.81	0.304	1.05	0.79	2.000	1.66	2.00	14.63	0.001	-1.396	0.000	1.52	0.000	0.000	0.000	0.00
11	15.54	51.00	46	SP		1	2	75	1.25	1	1	1.00	66.1	319	217	0.82	54.04	0.0	54.04	0.79	0.303	1.05	0.77	2.000	1.63	2.00	15.54	0.000	-1.921	0.000	0.91	0.000	0.000	0.000	0.00

Layer of liquefaction potential without soil improvement

LDI= 0.00 (m) 0.0 (in) S= 0.000 (m) 0.00 (in)

Notes:
Liquefaction analysis to evaluate required minimum blow count with modified soil improvements to prevent liquefaction

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LIQUEFACATION ANALYSIS M-3
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D3
SHEET 2 of 2

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Boring M-4

Input Parameters

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	1.2	(ft)	4.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	177.80	(in)	7
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	9	(ft)	30

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Measured Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	σ_{vc}' (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	0.61	2.00	30	GM		0	30	75	1.25	1	0.75	1.00	32.3	12	12	1.70	54.98	5.4	60.35	1.00	0.260	1.05	1.10	2.000	N.A.	N.A.	0.61	0.000	-2.453	0.000	0.61	0.000	0.000	0.000	0.00
2	3.05	10.00	25	SM		1	15	75	1.25	1	0.85	1.00	30.5	62	44	1.27	38.70	3.3	41.96	0.98	0.358	1.05	1.10	2.000	2	2.00	3.05	0.006	-0.954	0.000	2.44	0.000	0.000	0.000	0.00
3	4.57	15.00	13	SP		1	12	75	1.25	1	0.95	1.00	17.8	94	62	1.22	21.74	2.1	23.81	0.96	0.383	1.05	1.08	0.264	0.3	0.78	4.57	0.102	0.304	0.062	1.52	0.094	0.015	0.005	0.18
4	6.10	20.00	15	GP-GM		1	12	75	1.25	1	0.95	1.00	20.5	127	79	1.10	22.62	2.1	24.69	0.94	0.393	1.05	1.04	0.283	0.31	0.79	6.10	0.092	0.251	0.059	1.52	0.090	0.014	0.004	0.14
5	7.62	25.00	13	SP		1	3	75	1.25	1	0.95	1.00	17.8	159	96	1.02	18.14	0.0	18.14	0.92	0.395	1.05	1.01	0.185	0.2	0.50	7.62	0.195	0.613	0.195	1.52	0.298	0.025	0.015	0.60
6	9.14	30.00	24	GM		1	15	75	1.25	1	1	1.00	34.5	191	114	0.96	33.22	3.3	36.48	0.90	0.392	1.05	0.97	1.540	1.57	2.00	9.14	0.017	-0.543	0.000	1.52	0.000	0.000	0.000	0.00
7	10.67	35.00	34	SP		1	2	75	1.25	1	1	1.00	48.9	224	131	0.93	45.61	0.0	45.61	0.87	0.387	1.05	0.92	2.000	1.95	2.00	10.67	0.002	-1.237	0.000	1.52	0.000	0.000	0.000	0.00

Liquefaction Potential

LDI= 0.48 (m) 19.0 (in)

S= 0.023 (m) 0.92 (in)

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LIQUEFACATION ANALYSIS M-4
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D4
SHEET 1 of 2

Boring M-4

Input Parameter

Peak Ground Accel (g) =	0.400		
Earthquake Magnitude, M =	7.3		
Water Table Depth (m) =	1.2	(ft)	4.00
Average γ Above Water Table (kN/m^3) =	19.2	(lb/ft^3)	122
Average γ Below Water Table (kN/m^3) =	21.2	(lb/ft^3)	135
Borehole Diameter (mm) =	177.80	(in)	7
Requires Correction for Sample Liners (YES/NO):		no	
Rod Lengths Assumed Equal to the Depth Plus	1.5	m (for the above ground extension)	
Gravilty Acceleration (m/sec^2)	9.81		
Height of Exposed Face (m)	9	(ft)	30

SPT Sample Number	Depth (m)	Measured Depth (ft)	Measured N	Measured Soil Type (USCS)	Flag "Clay"	Sat/Unsat	Fines Content (%)	Energy Ratio, ER (%)	C_E	C_B	C_R	C_S	N_{60}	σ_{vc} (kPa)	$\sigma_{vc'}$ (kPa)	C_N	$(N_1)_{60}$	ΔN for Fines Content	$(N_1)_{60\text{-}cs}$	Stress Reduct, Coeff, r_d	CSR	MSF for Sand	K_σ for Sand	CRR for M=7.5 & σ_{vc}'=1atm	CRR	Factor of Safety	Depth (m)	Limiting Shear Strain γ_{lim}	Parameter F_α	Maximum Shear Strain γ_{max}	ΔH_i (m)	ΔLDI_i (m)	Vertical Reconsol. Strain ε_v	ΔS_i (m)	ΔS_i (in)
1	0.61	2.00	30	GM		0	30	75	1.25	1	0.75	1.00	32.3	12	12	1.70	54.98	5.4	60.35	1.00	0.260	1.05	1.10	2.000	N.A.	N.A.	0.61	0.000	-2.453	0.000	0.61	0.000	0.000	0.000	0.00
2	3.05	10.00	25	SM		1	15	75	1.25	1	0.85	1.00	30.5	62	44	1.27	38.70	3.3	41.96	0.98	0.358	1.05	1.10	2.000	2	2.00	3.05	0.006	-0.954	0.000	2.44	0.000	0.000	0.000	0.00
3	4.57	15.00	19	SP		1	12	75	1.25	1	0.95	1.00	25.9	94	62	1.19	30.76	2.1	32.83	0.96	0.383	1.05	1.10	0.738	0.86	2.00	4.57	0.031	-0.283	0.000	1.52	0.000	0.000	0.000	0.00
4	6.10	20.00	21	GP-GM		1	12	75	1.25	1	0.95	1.00	28.7	127	79	1.09	31.19	2.1	33.26	0.94	0.393	1.05	1.06	0.795	0.89	2.00	6.10	0.029	-0.313	0.000	1.52	0.000	0.000	0.000	0.00
5	7.62	25.00	24	SP		1	3	75	1.25	1	0.95	1.00	32.8	159	96	1.02	33.31	0.0	33.31	0.92	0.395	1.05	1.01	0.801	0.85	2.00	7.62	0.029	-0.316	0.000	1.52	0.000	0.000	0.000	0.00
6	9.14	30.00	24	GM		1	15	75	1.25	1	1	1.00	34.5	191	114	0.96	33.22	3.3	36.48	0.90	0.392	1.05	0.97	1.540	1.57	2.00	9.14	0.017	-0.543	0.000	1.52	0.000	0.000	0.000	0.00
7	10.67	35.00	34	SP		1	2	75	1.25	1	1	1.00	48.9	224	131	0.93	45.61	0.0	45.61	0.87	0.387	1.05	0.92	2.000	1.95	2.00	10.67	0.002	-1.237	0.000	1.52	0.000	0.000	0.000	0.00

Layer of liquefaction potential without soil improvement

LDI= 0.00 (m) 0.0 (in)

S= 0.000 (m) 0.00 (in)

Notes:
Liquefaction analysis to evaluate required minimum blow count with modified soil improvements to prevent liquefaction

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LIQUEFACATION ANALYSIS M-4
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D4
SHEET 2 of 2

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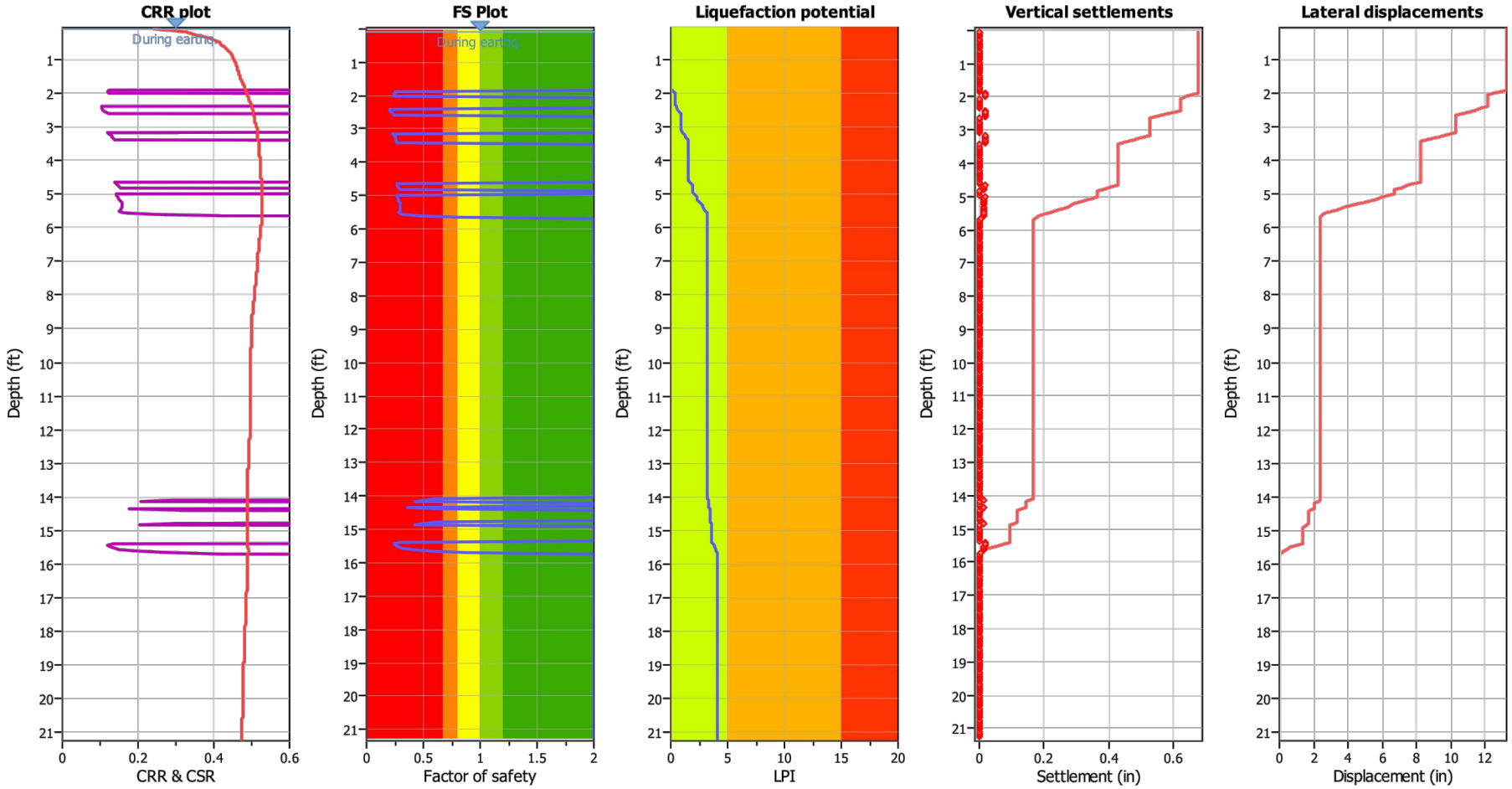
Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	0.10 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.30	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.40	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.10 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liquefaction are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

CLiq v.1.7.1.14 - CPT Liquefaction Assessment Software - Report created on: 3/8/2013, 1:18:24 PM

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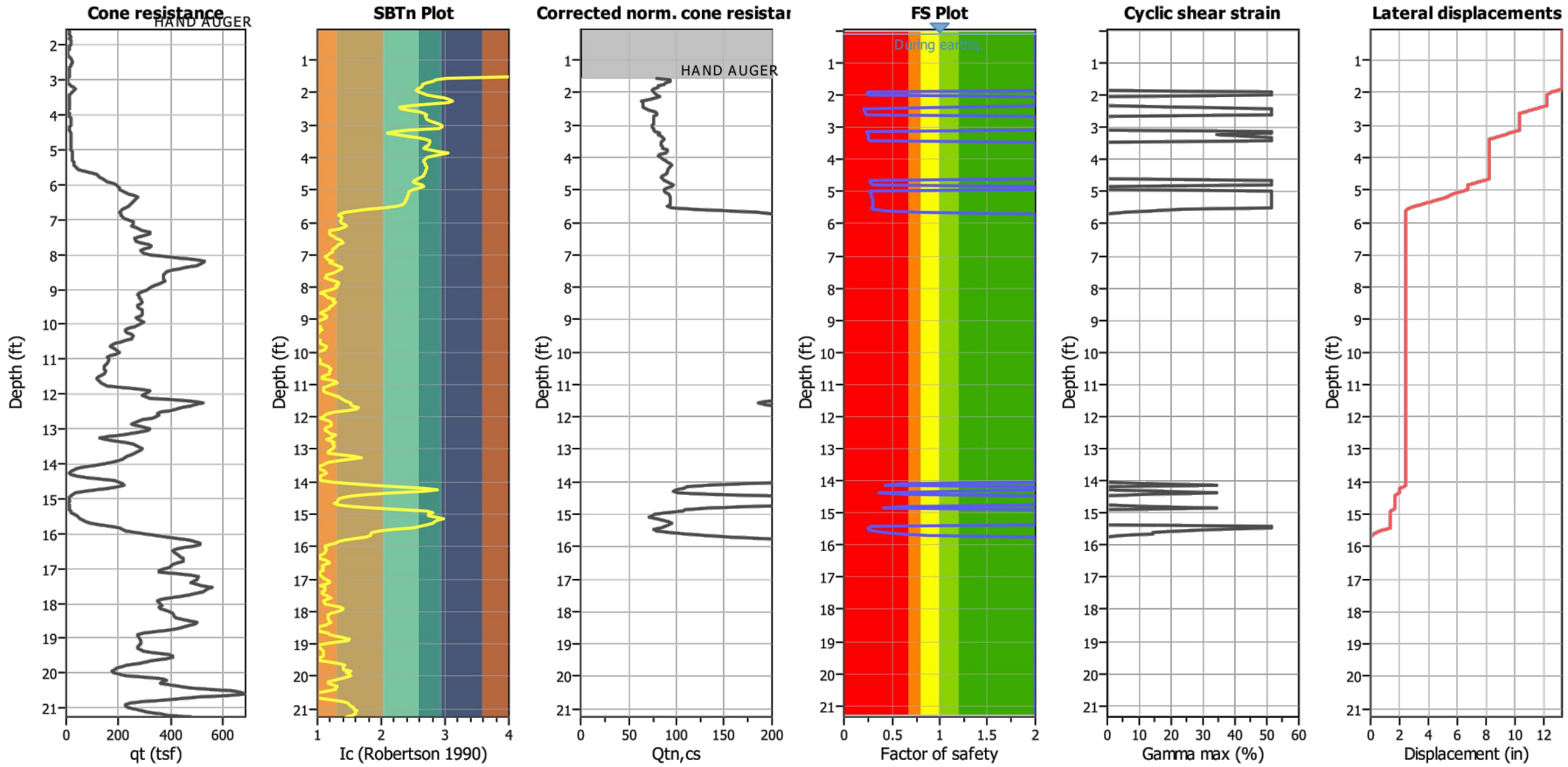
LIQUEFACATION ANALYSIS CPT-07
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D5
SHEET 1 of 2

Estimation of post-earthquake lateral Displacements

Geometric parameters: Gently sloping ground without free face (Slope 1.00 %)



Abbreviations

q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$Q_{tn,cs}$: Equivalent clean sand normalized CPT total cone resistance

F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

Surface condition

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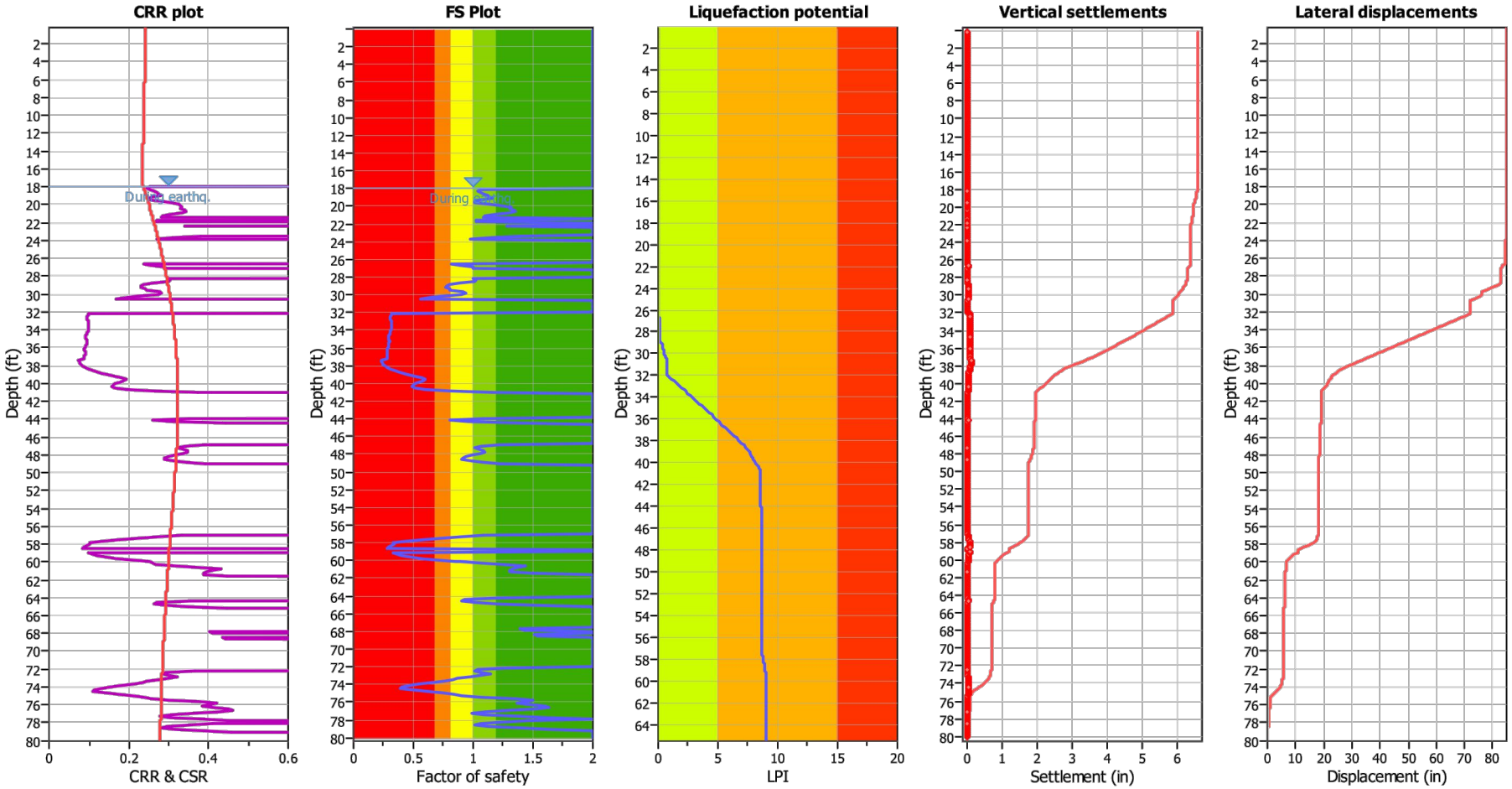
LIQUEFACATION ANALYSIS CPT-07
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D5
SHEET 2 of 2

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	18.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.30	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.40	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	21.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liquefaction are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme
- Very high risk
- High risk
- Low risk

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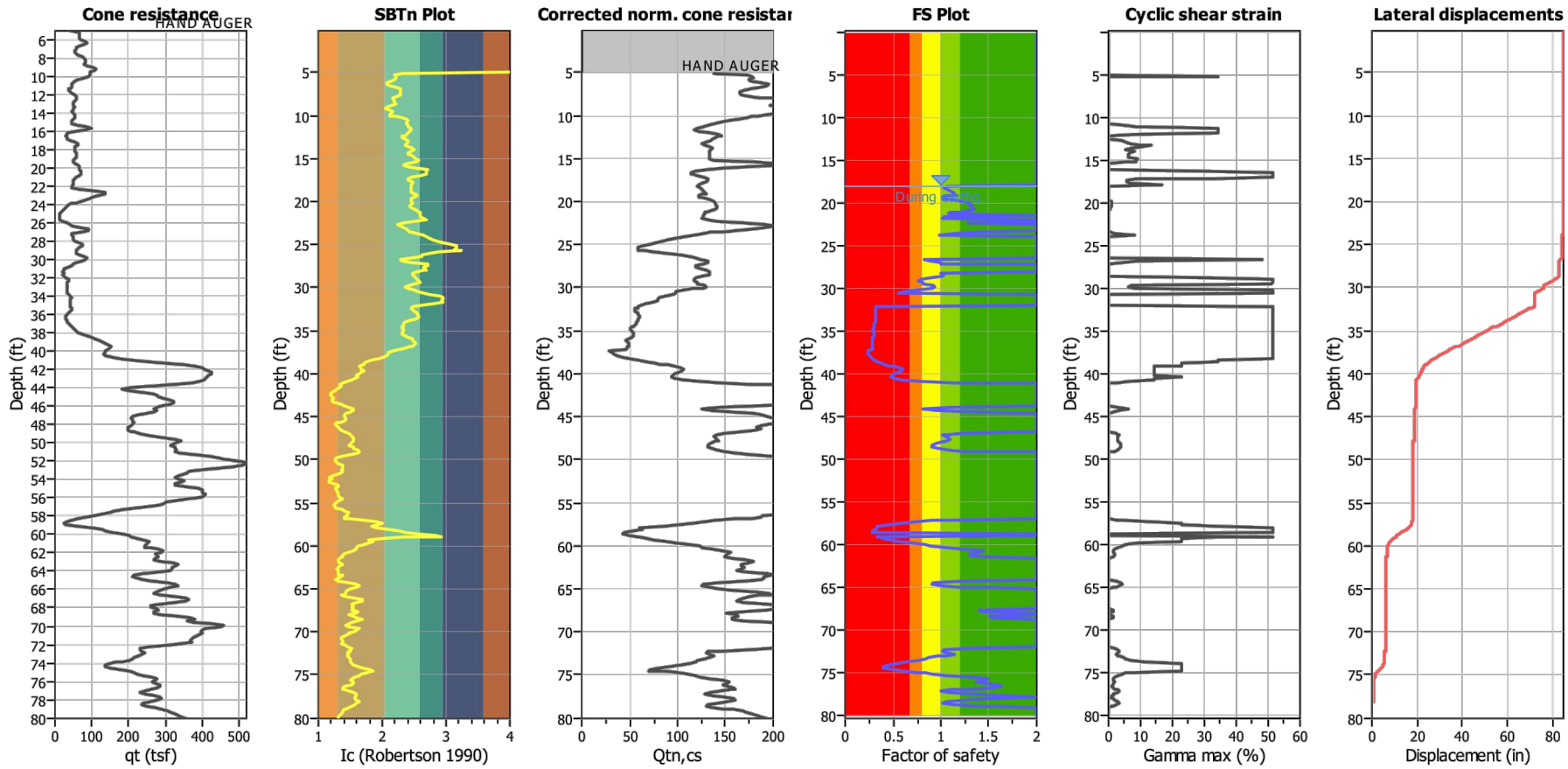
LIQUEFACATION ANALYSIS CPT-08
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D6
SHEET 1 of 2

Estimation of post-earthquake lateral Displacements

Geometric parameters: Gently sloping ground without free face (Slope 1.00 %)



Abbreviations

q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$Q_{tn,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

Surface condition

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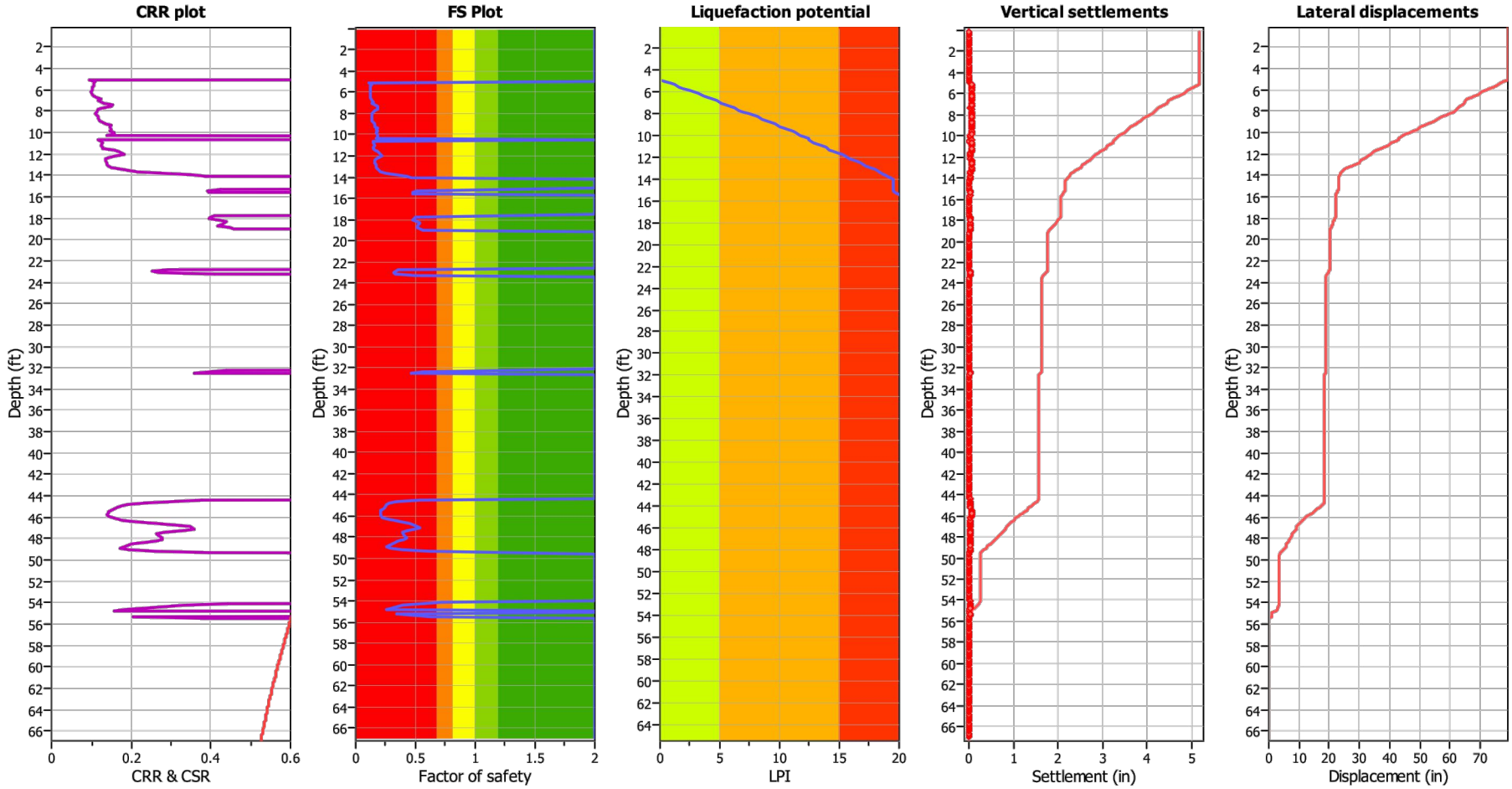
LIQUEFACATION ANALYSIS CPT-08
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D6
SHEET 2 of 2

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	-4.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.30	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.40	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	0.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liquefaction are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

CLiq v.1.7.1.14 - CPT Liquefaction Assessment Software - Report created on: 3/8/2013, 1:20:06 PM

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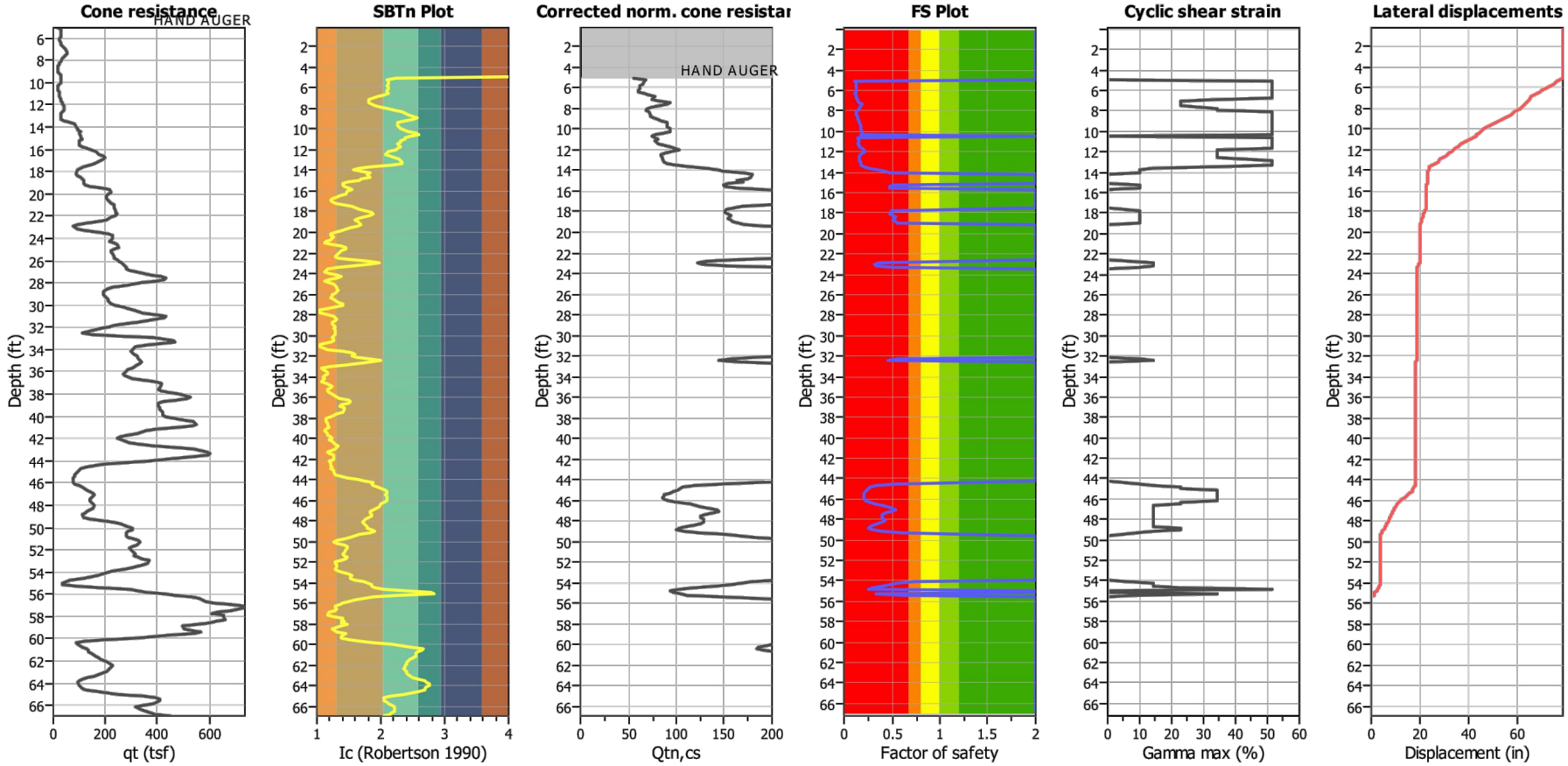
LIQUEFACATION ANALYSIS CPT-12
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D7
SHEET 1 of 2

Estimation of post-earthquake lateral Displacements

Geometric parameters: Gently sloping ground without free face (Slope 1.00 %)



Abbreviations

q_t: Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c: Soil Behaviour Type Index
$Q_{tn,cs}$: Equivalent clean sand normalized CPT total cone resistance
F.S.: Factor of safety
γ_{max}: Maximum cyclic shear strain
LDI: Lateral displacement index

Surface condition

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LIQUEFACATION ANALYSIS CPT-12
SONOMA COUNTY WATER AGENCY
MIRABEL FISH SCREEN AND LADDER REPLACEMENT PROJECT
Sonoma County, California

PLATE
D7
SHEET 2 of 2

APPENDIX E
Slug Test Recovery Tables

Table 1, below, shows transducer data for well M-4 during the slug test.

Table 1. M-4 Slug Test Transducer Data

Date and Time	Water Elevation	Notes
11/27/12 13:00	28.063	
11/27/12 13:01	28.122	Slug Inserted
11/27/12 13:02	28.107	
11/27/12 13:03	28.088	
11/27/12 13:04	28.078	
11/27/12 13:05	25.696	Slug Pulled
11/27/12 13:06	28.176	
11/27/12 13:07	28.156	
11/27/12 13:08	28.181	
11/27/12 13:09	28.161	End of Test

As shown in Table 1, the slug test shows no appreciable response during insertion of the slug (rising head condition), but it does show a momentary drop in the groundwater elevation in response to removal of the slug (falling head condition). Table 2, below, shows transducer data from well M-3 during the slug test.

Table 2. M-3 Sslug Test Transducer Data

Date and Time	Water Elevation	Notes
11/27/12 11:30	14.232	
11/27/12 11:31	14.247	
11/27/12 11:32	14.242	
11/27/12 11:33	14.296	Slug Inserted
11/27/12 11:34	14.232	
11/27/12 11:35	14.218	
11/27/12 11:36	14.218	
11/27/12 11:37	12.663	Slug Pulled
11/27/12 11:38	14.547	
11/27/12 11:39	14.538	
11/27/12 11:40	14.528	
11/27/12 11:41	14.518	
11/27/12 11:42	14.513	
11/27/12 11:43	14.503	
11/27/12 11:44	14.543	
11/27/12 11:45	14.523	
11/27/12 11:46	14.518	
11/27/12 11:47	14.508	

As shown in Table 2, the water table response during slug testing in M-3 was comparable to that in M-4. It is difficult to discern the response under rising head conditions but easier to observe the momentary drop in elevation during falling head conditions. In both cases, however, the groundwater elevation recovered in less than one minute.

DISTRIBUTION

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Quality Control Reviewer

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