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Nevada Environmental Response Trust
Henderson, Nevada

Prepared By:
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Date:
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Project Number:
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BARRIER WALL INTEGRITY EVALUATION REPORT, REVISION 1

NEVADA ENVIRONMENTAL RESPONSE TRUST SITE HENDERSON, NEVADA

RAMBOLL

Barrier Wall Integrity Evaluation Report, Revision 1

Nevada Environmental Response Trust Site
(Former Tronox LLC Site)
Henderson, Nevada

Nevada Environmental Response Trust (NERT) Representative Certification
I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of NERT. Based on my own involvement and/or my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Signature: Jay A Steinberg, not individually, but solely as President

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 11/19/19

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Responsible Certified Environmental Manager (CEM) for this project
I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

November 21, 2019

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Principal

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1. INTRODUCTION

Ramboll US Corporation (Ramboll) has prepared this Barrier Wall Integrity Evaluation Report to document the field evaluation of the integrity of the barrier wall located immediately downgradient of the Interceptor Well Field (IWF), the furthest upgradient line of groundwater extraction wells, part of the Groundwater Extraction and Treatment System (GWETS) at the Nevada Environmental Response Trust (NERT or the Trust) Site in Henderson, Nevada (the “Site”). The NERT Site is located approximately 13 miles southeast of the City of Las Vegas and is located in an area of unincorporated Clark County, Nevada, that is surrounded by the City of Henderson (Figure 1). This work was performed to address questions raised by the Nevada Division of Environmental Protection (NDEP) regarding the integrity of the barrier wall in their May 20, 2015 letter commenting on the 2014 Semi-Annual Remedial Performance Report (NDEP 2015).

This evaluation was outlined in the Barrier Wall Integrity Field Evaluation Work Plan, dated September 7, 2017 and approved by NDEP on October 3, 2017 (Ramboll Environ 2017a). The work was performed in accordance with the Work Plan, and as indicated in that document, the objective of this evaluation was to identify locations that may be providing preferential paths for groundwater flow through, around, or underneath the barrier wall and to evaluate these locations with technologies that can better characterize the extent and magnitude of zones of preferential flow at the barrier wall. The evaluation involved mapping the barrier wall with surface geophysics, verifying select wall locations using excavation, and then using the results of both investigations to identify specific areas for tracer testing and a Cone Penetration Test (CPT) investigation. The results of this evaluation will be used in conjunction with additional soil and groundwater sampling results from the NERT Site Remedial Investigation (RI) in progress to further characterize the mechanism(s) of perchlorate migration in groundwater downgradient of the barrier wall and discussed in the forthcoming NERT RI Report for Operable Units 1 and 2 (OU-1/OU-2). Together, these data collection efforts inform both the conceptual model for this area, which will be presented in the forthcoming OU-1/OU-2 RI and Feasibility Study (FS) reports.

2. BACKGROUND

Extensive environmental investigations and human health risk analyses have been performed at the Site for over 25 years with oversight from NDEP. NDEP and Kerr-McGee Chemical Corporation (KMCC), a former owner/operator of the Site, entered into a Consent Agreement in 1999 to mitigate the discharge of perchlorate from a surface water seep adjacent to the Las Vegas Wash. In October 2001, NDEP issued an Administrative Order of Consent (AOC) to be executed by KMCC (NDEP 2001). The AOC outlined the work to be performed and the schedule for completion of the remedial action, which was designed to reduce the amount of perchlorate in the groundwater ultimately discharging to the Las Vegas Wash. The AOC required the construction of a perchlorate treatment system capable of processing 825 gallons per minute. This included the construction of a low-permeability bentonite-slurry barrier wall in 2001, which was situated approximately 50 feet downgradient of the IWF to increase the capture of perchlorate-contaminated groundwater at this location. The barrier wall was to serve as a source control method, restricting the transport of contaminants from source areas to downgradient groundwater and off-site receptors. The AOC stipulated that the barrier wall be completed by October 31, 2001.

Prior to the installation of the barrier wall, 22 wells comprised the IWF, and at that time averaged an extraction rate of 24.7 gallons per minute (gpm). In March 2002 it was reported at a Risk Management Decision Team Meeting (KMCC 2002 Attachment 1 and KMCC 2001b) that pumping rates increased from 25 gpm prior to construction of the slurry wall to about 50 gpm following construction completion. As of 2016 there were 30 extraction wells (three of which have been unable to sustain their pumping rates since pumping at these wells began in 2013) comprising the IWF, with a combined discharge of 61.3 gpm.[1] Groundwater recharge trenches were installed downgradient (north) of the barrier wall and were used to inject stabilized Lake Mead water into the subsurface to replace water extracted by the IWF. Reinjection ceased in September 2010 as the recharge trenches were partially removed to accommodate soil excavation and remediation activities at the Site, and there is currently no plan to re-establish operation of the trenches.

Figure 2 shows the area of the IWF and the barrier wall.

The barrier wall was constructed in 2001 using a conventional slurry trench method. Wall specifications indicate the wall was designed to be 1,700 feet long, 60 feet deep, and three feet wide (KMCC 2001a); however, documents produced after construction (Northgate 2010a) indicate that the installed wall is approximately 1,600 feet long. Specifications also indicated that the soil-bentonite slurry wall was constructed to penetrate the alluvium, which consists of silty sand and gravel. The lower-most 25 feet of the wall were designed to tie into the Upper Muddy Creek formation (UMCf), which consists of sandy and clayey silt; however, documents produced after construction (Northgate 2010a) indicate that approximately 30 feet of the wall tied into the UMCf. The design criteria for the hydraulic conductivity of the barrier wall was 1×10^{-6} centimeters per second (cm/s) (Northgate 2010b).

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[1] Operations as reported in the NERT 2018 Annual Remedial Performance Report (Ramboll 2018).

In 2010, four samples of the barrier wall were collected for permeability testing by Northgate Environmental Management (Northgate) on behalf of KMCC (Northgate 2010b). The top of the wall was reportedly encountered during excavation between one and 4.9 feet below ground surface (bgs). Samples taken for permeability testing appear to have been collected within the vadose zone and not in areas where the wall is in contact with groundwater. Nevertheless, the average hydraulic conductivity measured for the four samples was 8.8×10^{-7} cm/s, meeting the design criteria. The four samples were found to have a hydraulic conductivity of 1.3×10^{-7}, 3.6×10^{-7}, 7.2×10^{-7}, and 2.3×10^{-6} cm/s. The study also analyzed water levels on either side of the wall. Overall, the study concluded that there were no significant leaks in the barrier wall in the four areas that were examined. There is no documentation of permeability testing at greater depths.

Although the permeability testing and hydraulic data suggest that the barrier wall is an effective barrier to groundwater flow, concentrations in downgradient wells have increased since the end of 2012, most notably in M-69, M-70, and M-71 (Figure 2). The increases in concentration in downgradient wells follow similar trends as those in the upgradient wells.

An initial evaluation of barrier wall effectiveness included in the 2013-2014 Annual Performance Report concluded that although the concentration data is consistent with leakage past the wall, the hydraulic data do not support this interpretation. For leakage to occur, it is expected that there first be a hydraulic response (an increase in head) in the upgradient wells followed by a similar hydraulic response in the downgradient wells. In fact, the data indicated the opposite—the hydraulic response is seen first in the downgradient wells (ENVIRON 2014a).

A subsequent evaluation of barrier wall performance examined historical water levels measured from 2006 to 2016 at well pairs upgradient and downgradient of the wall (Ramboll Environ 2016). Seven well pairs were analyzed over periods of time under varying hydraulic conditions, including the time period after shutdown of the groundwater recharge trenches downgradient of the interceptor well field and barrier wall. Based on the presence of significant groundwater elevation differences across the wall, the evaluation concluded that the wall provides an effective barrier to groundwater flow.

The present barrier wall integrity evaluation was performed to address questions raised by NDEP regarding the integrity of the barrier wall in their May 20, 2015 letter commenting on the 2014 Semi-Annual Remedial Performance Report (NDEP 2015). This work will also provide information that will be used to assess the utility of the barrier wall as a component of the long-term remedy that will be developed as part of the NERT Remedial Investigation and Feasibility Study (RI/FS) in progress. This barrier wall study was performed to further confirm the effectiveness of the barrier wall and to rule out leakage through the wall as a cause of the increasing perchlorate and hexavalent chromium concentrations observed in recent periods downgradient of the wall. The barrier wall orientation, extraction system layout, former recharge trenches and monitoring wells are shown on Figure 2.

3. GEOPHYSICAL SURVEYS

Consistent with the Work Plan, two geophysical surveys were conducted on February 6-10, 2018 and on February 20-21, 2018, each with different goals. The February 6-10, 2018 survey was a larger scale survey and used Willowstick™ Technologies LLC (Willowstick) geophysical method to evaluate the wall integrity by identifying preferential flow paths through, under, or around the wall if present. Willowstick is known for their development of new instrumentation and improved software algorithms for electromagnetic surveying, specifically optimized to identify preferential groundwater flow paths. The Willowstick geophysical survey consisted of a large-scale electromagnetic (EM) survey. The design of the field program for this survey was prepared in conjunction with personnel from Willowstick. The February 20-21, 2018 survey was a small-scale ground penetrating radar (GPR) and EM survey to locate the top of the barrier wall.

3.1 Barrier Wall Location

Prior to the performance of the geophysical surveys, Ramboll attempted to obtain site-specific information pertaining to the barrier wall. However, no as-built engineering drawings and no surveyed coordinates documenting the barrier wall location, width, depth or construction were available from EMD Acquisition LLC (EMD)[2]. A file review identified an environmental report (KMCC 2002) with a figure that included the wall location (earliest identified report with wall depicted). GIS analysis indicates it lines up with the same location as the currently used GIS files (within the resolution of the figure) but contains an extra section of the barrier wall at the western end, as shown with a dashed line in Figure 2. This wall section only appears in early figures depicting the wall and is not shown in later depictions of the wall (e.g. Northgate 2010b). The effects of a wall section in this location would have been seen in the measured heads near the wall during GWETS operation. There is no indication from the hydraulic heads that this section of wall was ever built. Attempts made to locate this extra section of the barrier wall and limitations due to interference from utilities and GWETS infrastructure are discussed throughout Section 3 of this report.

3.2 Willowstick Geophysics – February 6-10, 2018

The large scale electromagnetic geophysical measurements were collected using an EM method with proprietary algorithms and ultrasensitive equipment. The method involved energizing groundwater via a pair of monitoring wells on opposite sides of the barrier wall (see Table 1 for details). An electrode was placed below the water level surface in each well and the points created a distribution of electrical current in groundwater roughly 200 feet deep. Measurements of the electromagnetic field were then taken at a 16-foot grid spacing within the vicinity of the barrier wall to generate a map of the magnetic field lines. Lines found at a high density can be interpreted as related to preferential water flow paths in the subsurface.

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[2] In 2006, Tronox took ownership of the facility formerly operated by KMCC on the Site. In 2009, Tronox filed for Chapter 11 bankruptcy. The Trust took title to the Site on February 14, 2011, as a result of the settlement of Tronox's bankruptcy proceeding. Tronox, LLC (a subsidiary of Tronox), who performed operations on the site, was sold in 2018 to EMD. EMD currently has a long-term lease for approximately 114 acres of the Site, where it continues its manufacturing operations.

Implementation of the large-scale EM survey along the entire barrier wall required three survey areas and use of six monitoring wells. Willowstick placed electrodes in the following well pairs:

Table 1: Willowstick Survey February 6-10, 2018

Survey No.	South (Upgradient) Well	North (Downgradient) Well
Survey 1	M-22D	M-220
Survey 2	M-38	M-216
Survey 3	M-37	M-215

Electrodes were suspended below the water surface in two monitoring wells (one pairing) at a time for a data logging period of approximately 10 hours. During this period, access to the specific well pair was restricted. At the end of the data logging period, electrodes were removed from the wells and decontaminated before beginning the next data logging period at the subsequent well pair. The layout of wires, monitoring wells and geophysical survey areas is provided in Figure 3.

3.3 Summary of Willowstick Results

The Willowstick geophysical survey did not identify any preferential flow paths through the wall. The survey did not identify any preferential flow paths around the wall to the east or to the west. The survey was able to provide reliable results over the entire length of the wall except in the western-most third of Survey Area 3, near the Building D1 where subsurface and overhead utilities interfered with the signal and measurements. This region of interference also obscures the entire area where an extra section of the barrier wall, as described in Section 3.1, may be located at the western end of the wall. The utilities and GWETS infrastructure precluded determining the location of this potential wall section using geophysics.

The survey did identify three possible preferential groundwater flow paths beneath the subsurface barrier wall (Figure 4). Two of the flow paths are interpreted as primary groundwater flow paths (a-a’ and b-b’) and one as a secondary (c-c’) —meaning that the anomaly is a little weaker and less distinguishable from the background and from nearby utility influences, although representing a likely groundwater flow path. Additional minor flow paths, where the anomaly is very weak and difficult to distinguish from background and from nearby utility influences, are also indicated on Figure 4. Other than the two primary and one secondary preferential groundwater flow paths, no other areas along the wall indicated preferential flow. All three of these groundwater flow paths suggest that groundwater preferentially flows beneath the wall and not through, or around the wall. Evidence of preferential groundwater flow is indicated by Electric Current Distribution (ECD) model analysis.

Locations of the primary and secondary preferential groundwater flow paths beneath the wall are shown in plan-view in Figure 4, and Figure 5 shows the cross-section views (a-a’, b-b’, and c-c’) at those flow paths as three representative ECD slices. Figure 6 illustrates the location of the minor flow paths identified in the study area. Figure 7 shows the cross-section view of one of the minor flow paths and two cross-sections where no evidence of flow was detected as slices through the three-dimensional ECD model perpendicular to the wall. At section d-d’ (near the eastern tracer test), there is minor indication of a potential preferential flow path. At section e-e’ and f-f’ (near the western tracer test), there is no indication of preferential groundwater flow (as indicated in the figure. At these two locations, electrical current continues to flow but does not indicate there are preferential groundwater pathways. Based on the geophysical evidence, the barrier wall itself appears to function as designed and is devoid of any preferential seepage flow paths through the barrier wall. The geophysics report provided by Willowstick Technologies LLC is provided as Appendix A.

3.4 Surface Geophysics Pilot Testing - February 20-21, 2018

Following the Willowstick EM survey, and consistent with the Work Plan, small-scale GPR and EM surveys were conducted by National Ground Penetrating Radar Service, Inc. (NGPRS), of Los Angeles, California with the goal of locating the top of the barrier wall on February 20 and 21, 2018. The location of the barrier wall was not known with certainty due to the lack of as-built engineering drawings and surveyed coordinates from the time of construction. In addition, earliest versions of reports and past depictions of the wall included an extra section of the barrier wall at the western end (e.g., KMCC 2002); however, this depiction is absent from later reports and maps (e.g. Northgate 2010b). Finally, sampling for the laboratory hydraulic conductivity testing performed in 2010 indicated the depth to the top of the wall was 1.0 to 4.9 feet (Northgate 2010a).

3.4.1 EM Survey Results

A Geonics EM31 MK2 (EM) terrain conductivity meter was used by NGPRS to survey the barrier wall area. The barrier wall exploration was split into three test sections: east, west, and central, during the small-scale geophysical survey for maximum efficiency. The EM used a fixed intercoil spacing of 12.1 feet (3.7 meters) to provide an exploration depth of approximately 18 feet, with vertical dipoles (standard operating position). NGPRS collected data continuously along 10-foot spaced survey lines. The EM survey was conducted throughout the three test sections over an area totaling approximately 206,325 square feet surrounding the approximate barrier wall area with a maximum exploration depth of 18 feet bgs. Interference from fences, concrete walls and subsurface utilities was encountered during the EM survey. Interference prohibited collection of data in some areas, including the area where an extra section of the barrier wall may be located at the western end. Figure 8 shows the approximate areas covered by the EM Survey.

3.4.2 GPR Survey Results

NGPRS used a Geophysical Survey Systems, Inc. system (Model SIR3000) using an antenna with central frequency of 400 MHz to complete the GPR survey. Prior to the field survey, the GPR was estimated to be able to observe up to 8 feet bgs; however, based on the field conditions, including the presence of caliche, nearby fences and subsurface utilities, it was only able to reach approximately 4-6 feet bgs. The GPR was used to survey four areas at transects perpendicular to the wall orientation. The GPR operator was unable to identify the wall in any of the transects.

3.4.3 EM & GPR Survey Conclusions

The EM and GPR surveys were performed over an approximate 206,325 square-foot area surrounding the approximate barrier wall location. The EM survey was performed using 10-foot transects and was followed by a GPR survey using transect lines perpendicular to the barrier wall. Interference consisting of utilities, metallic debris and fencing, prohibited the collection of data in some areas, including the area where an extra section of the barrier wall may be located at the western end. The collected EM data were later processed by NGPRS and evaluated for conductivity responses generated. Based on the EM data, no indication of the presence of the barrier wall was identified. Further, the GPR signal was unable to penetrate to a depth that was sufficient to detect the top of the barrier wall, which was expected to be within 1 to 4 feet of the surface. Based on the geophysical results described above, exploration using CPT and Air knife was used to advance a series of shallow vertical holes to locate the top of the barrier wall, as discussed in Section 4. The GPR and EM survey report provided by NGPRS is provided in Appendix B.

4. WALL LOCATION ACTIVITIES

4.1 Exploratory Air Knife and CPT Event

The small-scale ground penetrating radar (GPR) and large-scale Willowstick electromagnetic (EM) surveys discussed above did not provide the precise location of the barrier wall. Consistent with the Work Plan, intrusive activities, specifically Air knife and Cone Penetrating Testing (CPT) probes, were subsequently utilized to identify the top of the barrier wall using information obtained from existing maps, GIS files, and the EM survey. Air knife activities were performed by Cascade Drilling L.P. of Las Vegas, Nevada (Cascade) and CPT testing was performed by Middle Earth of Orange, California. The air knife and CPT were utilized to explore five general areas of the barrier wall.

On June 4-7, 2018, Cascade used air knifing to clear 28 borings. The borings were extended down to approximately 10 feet bgs, except one boring which terminated at 4 ft due to the presence of a utility, and three other borings which terminated at depths ranging from 6-8 feet. The air knife was specifically used in locations that were in proximity to the NERT Site GWETS. The locations are recorded as A1 through A11, C1 through C7, M-78, I-X, B1, B1.1, B1.2, B1.3, B2, B3, BW1, BW0, and points are shown on Figure 9. The air knife is limited to a depth of ten feet, although the method was conducted over the suspected location of the wall the wall was not located using air knife. The wall may be deeper than 10 feet at these locations.

On June 5-7, 2018, Middle Earth used CPT to explore 4 transects perpendicular to the barrier wall focusing on areas that were less likely to have interference, on areas where large-scale EM data and older GIS data were relatively co-located, and on areas that were safely away from the GWETS. Thirty-one CPT borings were performed. The CPT borings were placed approximately one foot apart and extended to depths ranging from 11 to 27 feet bgs where refusal was encountered, except for one boring which was terminated at 9 feet (prior to refusal). The locations are identified as CPT-1, CPT-1A, CPT-1B, CPT-1C, CPT-1D, CPT-2.+5, CPT-2, CPT-2A through CPT-2H, CPT-3, CPT-3A, CPT-3A1, CPT-3A2, CPT-3B through CPT-3J, CPT-4, CPT-4A and CPT-4B and are shown on Figure 9. This CPT Investigation event probed locations that were directly over the anticipated wall location. However, none of the CPT soundings were able to locate the barrier wall despite the increase in depth compared to the air knife technique.

4.2 Excavation

Subsequent to the CPT investigation event, excavation was conducted along three transects that were expected to cross the wall. A track-mounted excavator (Bobcat E55) was used to perform test trenches to identify the top of the barrier wall. The excavation was performed by Earth Resource Group (ERG) of Las Vegas, Nevada.

On August 27-28, 2018, 3 exploratory trenches, identified as Trenches #1, 2, and 3, were excavated perpendicular (north-south) to the estimated location of the barrier wall to expose the top of the wall and survey its location. The trenches, one to the east, one to the west, and one in the middle of the wall, were up to 50 feet long, and up to 10 feet deep, and as wide as the bucket of the excavator (roughly 3 feet wide). The trench locations are shown on Figure 10. The characteristics of the trenches were as follows:

- Trench #1 was approximately 43 feet long. It was constrained to the south by a multitude of utilities associated with the GWETS, and the barrier wall was located before the excavation was constrained to the north by the closest electrical line. The trench was extended to a depth of approximately 7 feet bgs. Caliche was observed at a depth of approximately 4 feet bgs along the length of the excavation with an approximately 3 feet wide section of caliche missing at the placement of the observed bentonite-clay slurry wall.
- Trench #2 was approximately 50 feet long. It was constrained to the north by an electrical line and was constrained to the south by a concrete wall. The trench extended to 10 feet bgs in the northern most portion and to 5 feet bgs for the remainder of the excavation. The trench was not extended beyond 10 feet bgs due to the lack of shoring and the subsequent need for a larger excavator. The remainder of the trench was only extended to 5 feet bgs due a caliche layer which indicates that the barrier wall trenching had not been conducted in that location (the caliche would be missing anywhere the trenching for the wall had taken place). With these equipment limitations, the bentonite-clay slurry wall was not observed in Trench #2. Exploration in the central portion of the barrier wall had included 31 CPT locations with total depths ranging from 11 to 27 feet bgs and 11 air knifing locations with total depths of 10 feet bgs each. Given that numerous attempts to identify the wall in this area were unsuccessful and that migration pathways under the wall but not through the wall had been identified by geophysics, work was suspended in this area.
- Trench #3 was approximately 52 feet long. It was not constrained by any site features and extended to a depth of 7 feet bgs, at which depth the bentonite-clay slurry wall was located.

Ramboll applied stabilized Lake Mead water from the on-site water supply daily to the ground surface at each excavation location for five days prior to excavation. This served to control dust during the initial portions of the excavation and was intended to rehydrate bentonite of the soil slurry if encountered shallow enough during excavation. Ramboll worked directly with Envirogen Technologies, Inc. (ETI), the GWETS operator, to evaluate each location for potential subsurface utilities prior to trenching. Ramboll and Cascade also utilized air vacuum (air knife) technology, as needed, to “daylight” underground components of the GWETS system, shown on Figure 10, for an accurate utility locate.

The excavation program successfully located the barrier wall in two of the trenches. The barrier wall was identified at approximately 4 ft bgs in Trench #1 (near west end of the wall) and at approximately 7 ft bgs in Trench #3 (within the EMD Leasehold near the east end of the wall). The barrier wall was not, however, located in Trench #2 with a total depth of 10 feet bgs.

4.3 Survey

On August 29, 2018, Atkins Global, a Nevada-licensed surveyor, performed a survey of the barrier wall found within both Trench #1 and Trench #3. The wall locations and elevations were surveyed by a Nevada-licensed surveyor and tied to an established state or county benchmark. Horizontal coordinates were surveyed to a horizontal accuracy of at least 0.1 foot and referenced to the Nevada Coordinate System of 1983 (NAD83). The vertical elevations surveys are accurate to 0.01 foot relative to mean sea level datum (NAVD88).

The survey coordinates are provided in Table 2.

Table 2: Atkins Global Survey August 29, 2018

Atkins ID #	Northing	Easting	Elevation (feet above mean sea level)	Description
1808291001	26720002.55	828673.17	1738.73	Eastern portion of wall (Trench #3).
1808291002	26719849.04	827400.02	1746.31	Western portion of wall (Trench #1).

5. CPT INVESTIGATION

After locating the barrier wall, and consistent with the Work Plan, the primary CPT survey was completed to evaluate the in-situ engineering and hydraulic properties of the barrier wall. CPT soundings have been used extensively in subsurface media characterization and testing and have been shown to be an effective method of subsurface characterization, especially in media with discrete stratigraphic horizons and discontinuous lenses. CPT sensors produce a computerized log of tip and sleeve resistance, induced pore pressure just behind the cone tip, pore pressure ratio, and continuous lithological interpretations. The sleeve friction measures the average skin friction as the probe is advanced through the soil. The friction ratio is used to classify the soil, by its behavior or reaction to the cone being forced through the soil. Friction ratio is used to classify soil types, where high ratios generally indicate clayey materials while lower ratios are typical of sandy materials. Using these measurements, CPT classifies the material being penetrated into soil behavior types (SBT).

The barrier wall specifications called for a 50/50 mixture of bentonite and native soil as a slurry to be placed into an excavated trench. The friction ratio associated with the slurry of the barrier wall has a distinctly different value from the surrounding unconsolidated materials, allowing the slurry wall to be identified and mapped vertically. In addition, a Hydraulic Profiling Tool (HPT) was added to the CPT, which uses a sensitive, down-hole transducer to monitor the matrix back-pressure response to water injection (dissipation tests). This tool was used to approximate the hydraulic conductivity at selected locations in-situ.

5.1 Methodology

CPT soundings were performed by Middle Earth of Orange, California on November 6-8, 2018, starting from the expected centerline of the roughly three-foot-wide wall and pushed through the backfill down into the soil slurry of the barrier wall and continuing to the bottom of the soil slurry media comprising the barrier wall. Along the western transect, after completing the centerline sounding, the CPT then followed a modified step-off procedure. The CPT moved approximately one foot over and one foot forward to create a diagonal transect of the barrier wall which allowed for sufficient spacing to place three boreholes across the narrow wall. Following the soundings, each hole was grouted to the surface with a grout material that is lower than the hydraulic conductivity design criteria for the barrier wall (1×10^{-6} cm/sec) by two orders of magnitude. Two areas were explored with a total of 27 CPT soundings, identified as CPT-01 through CPT-27, and six dissipation tests. The locations of the CPT and dissipation tests are shown on Figure 11.

5.2 CPT Findings and Conclusions

Western Transect

The western transect consisted of three CPT soundings (CPT-1, 2, and 3) placed diagonally across the three-foot wall width to cover the wall width and still maintain the required spacing of 1 ft between penetrations. The soundings were conducted within the backfill in Trench #1 at the specific location where the wall was uncovered during the excavation. At the western transect, dissipation tests were conducted at two depth intervals (40 feet and 50 feet bgs, respectively) at each of two different sounding locations; CPT-1 and CPT-2.

All three soundings indicated that the wall was constructed of a uniform clayey material throughout. The top of the wall was encountered at approximately 4 feet bgs and terminated at approximately 55 feet bgs. The soundings were terminated around 57 feet bgs after the cone's friction ratio reported that it had moved from the clay SBT to a distinctly different and more variable SBT. The transect of three borings indicates that the wall is approximately 50 feet from top to bottom and does not deviate from vertical over its entire thickness at this location. Reports on each sounding including friction ratio and SBT are found in Appendix C.

Eastern Transect

The eastern transect consisted of 24 CPT soundings in three groups, and one additional standalone sounding to the west (Figure 11).[3] Each group was aligned perpendicular to the wall to maximize the chance of intersecting the top of the barrier wall. The first group of CPT soundings consisted of six soundings (CPT-4, 5, 7, 8, 9 and 10) that were placed approximately 12 feet from the surveyed wall location as determined from prior excavation. These soundings all terminated in alluvium due to refusal between 1 and 18 feet bgs.

The second group of CPT soundings consisted of seven soundings (CPT-21 through 27) that were placed approximately 2 feet from the original trench location. This location was selected since it is significantly closer to the original trench where excavation located the wall. Six of these soundings (all but CPT-27) terminated in the alluvium due to refusal at depths between 0.8 feet bgs and 21 feet bgs. CPT-27 was placed adjacent to the soundings where the penetration at the other six had been deepest. At this location the CPT pushed through silty sand (alluvium) until approximately 18 feet bgs, where it encountered a 3 ft layer of dense/stiff soil (possibly caliche), followed by interbedded clay and silty clay (UMCf) from approximately 21 feet bgs to the full depth of the sounding at a depth of approximately 67 ft bgs. Two dissipation tests were conducted in sounding CPT-27, one at 40 feet bgs and one at 50 feet bgs. Upon review of the data from the CPT sounding, the materials encountered below 21 feet bgs were determined to be from the UMCf and are not related to materials from the wall. The barrier wall has a similar friction ratio over some portions of the UMCf, but the UMCf is not uniform with depth.

The third group of CPT soundings consisted of 10 soundings (CPT-11 through CPT-20) that were placed approximately 13 feet from the original trenching location where access allowed exploration between the concrete barriers along the road. This location was selected in order to cover a larger extent of possible wall locations. These soundings all terminated in alluvium due to refusal between 1.6 and 24 feet bgs.

A single sounding (CPT-6) was also placed west of the other soundings. This sounding also terminated at refusal at a depth of 8 feet within the alluvium.

Initially, the CPT soundings were to be kept at a minimum distance of 10 feet away from all injection wells to not interfere with the injected dye testing (see Sections 7 and 8). Eventually, CPT soundings were placed closer than 10 feet from the injection wells in order

[3] As described in this section, more CPT soundings were performed in the Eastern Transect area as compared to the Western Transect area due to difficulties encountered with refusal of the CPT soundings and locating the wall in the Eastern Transect area. The first three CPT soundings made in the Western Transect area successfully encountered the barrier wall so no additional CPT soundings were needed in the Western Transect area.

to explore closer to the original trenching location where the wall was identified during excavation. CPT soundings were installed to refusal at each location. Despite having thoroughly investigated the area directly over the suspected wall and within two feet of the location identified through excavation, none of the CPT points penetrated the wall at the eastern transect.

Hydraulic Conductivity Testing

Pore dissipation testing conducted during the CPT soundings provide an estimate for small scale hydraulic conductivity near the tool, providing data about the range of hydraulic conductivities expected along an entire borehole. Our use for the tool is slightly different from typical. We wish to test the materials of the wall to ensure that they are of low hydraulic conductivity. Due to the limitations of this technique and the time available in the field, only rough estimates of hydraulic conductivity were obtained. Due to the time limitations associated with conducting complete dissipation tests in low conductivity materials (full version of each test can take many hours in a low conductivity material), each test was terminated before pressure had recovered to pre-test levels. These tests therefore require some extrapolation during analysis to estimate a hydraulic conductivity. The range of estimated hydraulic conductivity for the dissipation tests is 1.46×10^{-5} to 2.16×10^{-6} cm/sec as shown in Table 3. These values are not as low as expected, but this test only provides estimates, and is taken from truncated data. The conclusion that can be drawn from the pore dissipation testing is that CPT pressure dissipation testing indicated very low conductivity materials in every case.

The SBT at each dissipation test location is clay (except for those locations where the dissipation test was conducted in native materials, including CPT-27 @40 feet bgs and CPT-27 @50 feet bgs). The SBT categorization is based on readings from the tool during penetration. These estimated hydraulic conductivity ranges for each SBT category are available (Robertson 2010). The output of the tool indicates the tested locations fall into SBT zone 3 which has an associated hydraulic conductivity range of 1×10^{-7} to 1×10^{-8} cm/sec (SBT zone 3 is referred to as clay). The conclusion that can be drawn from the SBT values at each of the dissipation testing locations is that the material behaves like clay in every case and should have an expected hydraulic conductivity of between 1×10^{-7} to 1×10^{-8} cm/sec as shown in Table 3.

These results compare well with the Northgate laboratory testing of the wall materials (1.6×10^{-7} cm/sec to 2.3×10^{-6} cm/sec) (Northgate 2010), and the design standard for the wall of 1×10^{-6} cm/sec (Northgate 2010).

Table 3: Conductivity from CPT Dissipation Test Results and SBT Test Results

CPT Borehole Number	Depth (ft)	t_{50}(s) Dissipation Test⁺	K_h (cm/sec) Dissipation Testing⁺	SBT Zone Number	SBT	Hydraulic Conductivity (cm/sec)
CPT-01	40	566	Very low conductivity (1.46×10^{-5})	3	Clay	$1x10^{-8}$ – $1x10^{-7}$
CPT-01	50	453	Very low conductivity (1.47×10^{-5})	3	Clay	$1x10^{-8}$ – $1x10^{-7}$
CPT-02	40	665	Very low conductivity (1.25×10^{-5})	3	Clay	$1x10^{-8}$ – $1x10^{-7}$
CPT-02	50	663	Very low conductivity (2.16×10^{-6})	3	Clay	$1x10^{-8}$ – $1x10^{-7}$
*CPT-27	40	109	Very low conductivity (4.72×10^{-7})	4	Silt Mixture	$3x10^{-7}$ – $1X10^{-5}$
*CPT-27	50	181	Very low conductivity (2.11×10^{-7})	3	Clay	$1x10^{-8}$ – $1x10^{-7}$

Notes:

* CPT-27 tests were conducted in native materials of UMCf and do not appear to be in materials associated with the slurry wall construction.

⁺ Pore dissipation tests were not run through full pressure recovery due to time constraints and field objectives.

t_{50} is a factor that roughly represents the time for the soil to dissipate the induced pressure to one half the initial value.

K_h is the horizontal hydraulic conductivity as estimated from the dissipation tests.

6. INJECTION WELL INSTALLATION

On October 1-5, 2018, two clusters of three wells consisting of one injection and two monitoring wells were installed in close proximity to the barrier wall. As specified in the Work Plan, the wells were installed for the purpose of injecting and monitoring dye as part of the tracer tests (see Section 8). The specific locations of the wells (and thus the tracer tests) were selected based on the results of the excavations and Willowstick geophysical survey discussed in Section 4.3. The well clusters are referred to as the East Injection Well and West Injection Well clusters. Details regarding the well drilling are provided in the following sections.

Prior to well drilling activities, Affidavits were submitted to NDEP. Copies of the Notices of Intent approvals are included as Appendix D.

6.1 Methodology

For tracer tests at each selected location, a network of three wells was installed in a line perpendicular to and crossing the wall. At each location, an injection well was installed approximately five feet upgradient of the wall. Two additional wells were installed downgradient of the wall with one well located approximately five feet from the wall and the other approximately 10 feet further downgradient. The wells are identified as BWTR-1 through BWTR-6, where BWTR-1 and BWTR-4 are injection wells. Wells BWTR-1, BWTR-2 and BWTR-3 were installed as part of the west injection well cluster and wells BWTR-4, BWTR-5 and BWTR-6 were installed as part of the east injection well cluster (Figure 12).

All of the new wells were installed by a Cascade Drilling, LP (Cascade), a licensed contractor, using sonic drilling methods for five of six wells, and hollow stem auger methods for the remaining well, BWTR-3. The wells were constructed using four-inch diameter PVC, screened across the water table and reaching to within approximately 10 feet of the bottom of the wall.

6.2 Well Drilling

On October 1-5, 2018, a sonic drilling rig was utilized to advance wells BWTR-1, BWTR-2, BWTR-4, BWTR-5 and BWTR-6 to depths of approximately 46 to 47 feet bgs. Due to scheduling and unavailability of a sonic drilling rig to complete the set of wells, a drilling rig equipped with hollow stem auger was utilized to advance well BWTR-3 to a depth of approximately 47 feet bgs. All wells were constructed using 10 feet of four-inch diameter 0.020-slot Schedule 40 PVC screen and finished with Schedule 40 PVC riser. Annular space was filled with a sandpack that extended approximately 2 to 2.5 feet above the top of the screen, followed by a bentonite seal, followed by a cement seal to the surface. All wells were finished with well boxes with flush-mounted well box covers.

Soil types encountered during drilling consisted of poorly sorted silty sand from the ground surface to depths ranging from 20 feet below ground in wells installed in the Eastern Cluster (BWTR-4, 5, 6), and approximately 33 feet below ground in wells installed in the Western Cluster (BWTR-1, 2, 3). This lithology is representative of the Quaternary alluvium (Qal). Beneath the Qal, soils consisting of clayey silt extended to the termination depths of the well. The clayey silt became finer with depth at some drilling locations and was interbedded with caliche in wells located within the Eastern Cluster. This lithology is representative of the UMCf. Well logs documenting well construction details and lithology can be found in Appendix E. The locations of the wells are shown on Figures 12, 13 and 14.

6.3 Well Development

On October 8, 9 and 10, 2018, Cascade developed the six new wells using a submersible pump and surge block. Water quality parameters, flow rate, and water level information were recorded during development, using a YSI 556 and water quality meter. Volumes of water removed from the wells during development ranged from approximately 42 gallons (BWTR-2) to 105 gallons (BWTR-4). Well development logs for wells BWTR-1 through BWTR-6 are included in Appendix F.

6.4 Well Survey

On December 18, 2018, Atkins Global, a Nevada-licensed surveyor, performed a survey of new wells BWTR-1 through BWTR-6. Well locations and elevations were surveyed by a Nevada-licensed surveyor and tied to an established state or county benchmark. Horizontal coordinates were surveyed to a horizontal accuracy of at least 0.1 foot and referenced to the Nevada Coordinate System of 1983 (NAD83). The vertical elevations surveys are accurate to 0.01 foot relative to mean sea level datum (NAVD88).

The well locations are shown on Figure 12 and the well elevations are included in Table 4.

Table 4: Well Survey Data

Well/Boring ID	Northing	Easting	Elevation	Atkins ID
BWTR-1	26719839.57	827368.28	1748.08	1812181026
BWTR-2	26719850.60	827367.99	1747.15	1812181022
BWTR-3	26719859.56	827367.23	1746.05	1812181018
BWTR-4	26719998.60	828685.67	1739.51	1812181010
BWTR-5	26720009.82	828681.09	1739.06	1812181006
BWTR-6	26720019.46	828677.68	1738.73	1812181002

7. TRACER TESTS

A dye tracer test was utilized to identify locations that may be providing preferential paths, and to verify the findings of the geophysical tests and CPT tests for groundwater flow through the barrier wall. The dye tracer test was developed and implemented by Ramboll and Ozark Underground Laboratory (OUL) of Protem, Missouri. The test was designed by OUL in conjunction with Ramboll and the field introduction of dye tracer was conducted by OUL. All background and post-dye tracer introduction sampling was conducted by Ramboll.

7.1 Methodology

Fluorescent dye tracers were introduced into the groundwater on the upgradient side of the barrier wall via two newly-installed wells, BWTR-1 and BWTR-4 (referred to as West Injection Well and East Injection Well test locations), respectively (Figures 12, 13, and 14). At each dye tracer test location, monitoring for the fluorescent dye tracers took place in two wells installed at approximately 5 feet and 15 feet downgradient of the barrier wall, and in previously existing monitoring wells that were positioned within a reasonable potential flow path of the dye tracers. The East Injection Well dye tracer well network consisted of injection well BWTR-4, and monitoring wells BWTR-5, BWTR-6 and M-74 (Figure 13). The West Injection Well dye tracer well network consisted of injection well BWTR-1, monitoring wells BWTR-2, BWTR-3, and M-140 (Figure 14). In addition, influent from the IWF was sampled for dye tracers at both the East and the West Manifold feed lines (Figure 12). The IWF manifold monitoring was used to identify uptake of dye tracers via the extraction wells. Monitoring was conducted for a period of 17 weeks.

Prior to commencement of the dye tracer tests, all wells that were selected for monitoring were sampled and tested two times to determine background fluorescence. Sampling for background fluorescence was conducted using the same methods as monitoring for dye tracer breakthrough, described in Section 7.3.

7.2 Required Regulatory Permitting

The fluorescent dyes used as tracers were fluorescein and rhodamine WT. Each of these fluorescent dyes have been used extensively in groundwater and surface water tracer applications. The dyes are safe, non-toxic, and can be measured over a concentration range spanning up to six orders of magnitude, resulting in the ability to detect a very small fraction of the introduced concentration. Prior to implementation, UIC Form U240 (Chemical Use Request) was required by the NDEP Bureau of Water Pollution Control – Underground Injection Control Program, since it involved introduction of a chemical dye tracer into groundwater via injection wells. NDEP administers the Nevada UIC program and regulates injection wells under the authority of the Nevada Revised Statutes (NRS) 445A.300 - 445A.730 and the Nevada Administrative Code (NAC) NAC 445A.810 - 445A.925, inclusive. Typically, for short term field tests for purposes of remediation (less than six months), a Class V General Short-Term Remediation UIC permit is required. However, the introduction of dye tracers was not intended for remediation purposes and therefore a formal UIC Permit was not required. Based on communication with the NDEP Bureau of Water Pollution Control, the UIC Form U240: Chemical Use Request and an accompanying letter with supplemental information (purpose of dye tracer introduction, dye introduction locations, post-dye introduction monitoring locations, description of background and post-dye introduction monitoring, etc.) were all that was necessary to receive approval to conduct the dye tracer testing.

U240 Forms were submitted for each dye tracer (fluorescein and rhodamine WT) to the NDEP Bureau of Water Pollution Control for approval on October 3, 2018 and were accordingly approved on October 8, 2018. The approved U240 forms and safety data sheets for each dye tracer are included in Appendix G.

7.3 Background Sampling

Background sampling two weeks prior to dye tracer introduction was required in order to characterize any background fluorescence that could interfere with the dye tracer tests. Activated charcoal packets were deployed in the middle of the saturated screened interval of each monitoring well using string, plastic twist wire ties, and a weighted plastic bailer. The activated charcoal packets were retrieved and replaced at one-week intervals, though they were sometimes collected/replaced at shorter or longer periods when deemed necessary and appropriate. A grab groundwater sample was also collected with each activated charcoal sample. Once the samples were collected, they were packaged and shipped on ice to OUL.

Four rounds of background sampling were conducted between September 24 and October 16, 2018. The first two rounds were performed from September 24, 2018 to October 1, 2018 and October 1-8, 2018 (which occurred prior to the installation of the Eastern and Western Injection wells). These rounds included existing wells M-140 and M-74, which were the closest two existing monitoring wells to the Eastern and Western injection well test locations. The third round of background sampling, which occurred over the period of October 8-11, 2018, included the same wells as prior rounds and added the East and West manifolds of the IWF. The fourth baseline sampling event consisted of all of the previously mentioned monitoring and injection wells, in addition to the new wells installed to support the tracer test. The background fluorescence sampling results for each of the four rounds of sampling are presented in Table 5. During both the third and fourth round of background sampling fluorescein dye was detected in the samples from the Western Manifold of the IWF. This fluorescein dye appears to be associated with the dye tracer test performed as part of the AP Area Down and Up Flushing Treatability Study (Tetra Tech 2018) as it was detected prior to the introduction of dye tracers for the Barrier Wall Integrity Evaluation. The Tetra Tech treatability study included two dye tracer introduction events conducted between September 20, 2016 through August 8, 2017 using fluorescein and Rhodamine WT dye tracers upgradient of the western extraction wells of the IWF. Extracted groundwater from the western wells of the IWF are combined at the Western Manifold. The West Manifold exhibited evidence of fluorescein, but no other samples showed evidence of any fluorescent dye tracers.

Table 5: Background Fluorescence Sampling Results Summary

Well ID	9/24 – 10/1	10/1 – 10/8	10/8- 10/11	10/11 – 10/16
BWTR-1	--	--	--	ND
BWTR-2	--	--	--	ND
BWTR-3	--	--	--	ND
M-140	ND	ND	ND	ND
BWTR-4	--	--	--	ND
BWTR-5	--	--	--	ND
BWTR-6	--	--	--	ND
M-74	ND	ND	ND	ND
East Manifold - IWF	--	--	ND	ND
West Manifold - IWF	--	--	0.140 ppb*	0.123 ppb*

Notes:

ND = no fluorescent dyes detected

-- = not sampled

ppb = parts per billion

* Fluorescein detected in West Manifold

7.4 Tracer Test Dye Introduction

The fluorescein dye tracer was delivered in powder form and had to be mixed prior to introduction into the well. Approximately five-gallons of stabilized Lake Mead water was mixed with the powder fluorescein to create the tracer dye liquid. The fluorescein powder is very fine, so during the mixing process all efforts were made to prevent spillage or cross-contamination with other wells. All equipment used in the fluorescein dye preparation was either cleaned using bleach or discarded. The rhodamine WT tracer dye was delivered in liquid form and needed no preparation for introduction into the well.

On October 16, 2018, prior to the dye introduction, depths to groundwater were obtained from the injection and monitoring wells. The depths to groundwater were converted to groundwater elevations using well elevation survey data. The groundwater elevations are summarized in Table 6 and well locations are shown on Figure 12. Based on the groundwater data, the groundwater elevation difference across the wall at these locations was 6.9 feet at the eastern wall location and 3.6 feet at the western wall location. The groundwater elevation on the south side of the wall, proximate to the IWF extraction wells, is several feet lower than the groundwater elevation on the north side of the wall. The values indicate a substantial hydraulic barrier is present between the south extraction wells and the north monitoring wells, which are only about 13 feet apart.

Table 6: Groundwater Elevations Prior to Dye Introduction – October 16, 2018

Well	Groundwater Elevation (ft.)
BWTR-1	1720.55
BWTR-2	1712.72
BWTR-3	1713.69
MW-140	1712.83
BWTR-4	1721.41
BWTR-5	1717.36
BWTR-6	1716.63
MW-74	1716.85

On October 17, 2018 dye tracers were introduced by OUL at injection wells BWTR-1 and BWTR-4 which are located approximately five feet upgradient of the barrier wall. Locating the dye tracer introduction points in close proximity to the wall was intended to maximize the contact of the dye tracer with the wall and minimize the amount of dye tracer that would be captured by the interceptor extraction wells. Figures 12, 13, and 14 show the injection and monitoring wells used for the dye tracer test.

The dye tracer introduction consisted of the placement of rhodamine WT dye tracer into the western injection well BWTR-1 and fluorescein dye tracer into the eastern injection well BWTR-4. The dye tracer introductions were conducted using a different dye tracer in each injection well so that origin of the dye tracer could be distinguished in the post-dye introduction monitoring conducted at the wells downgradient.

The amount of dye tracer introduced into the wells consisted of five gallons of fluorescein in well BWTR-4 and 1.7 gallons of rhodamine WT in BWTR-1. Each dye tracer was gravity-fed into the well by OUL at a rate of approximately 3 gpm. Introduction of each dye tracer was followed by five well volumes (approximately 60 gallons) of stabilized Lake Mead water for flushing.

Post-dye tracer introduction monitoring was conducted at the two new monitoring wells at each testing location and at monitoring wells M-140 and M-74, thereby providing a well network of four monitoring wells for each tracer test. In addition to sampling at these four monitoring wells, the IWF was monitored at both the West Manifold and the East Manifold on the same schedule as wells M-140, M-74 and the newly installed monitoring wells. The post-dye tracer introduction monitoring is described in the section below.

7.5 Post-Dye Tracer Introduction Groundwater Monitoring

Monitoring was conducted by collecting grab samples of groundwater and by analyzing activated carbon samplers. The activated carbon samplers absorb the dye tracer continuously, which accumulates over time. Since the activated carbon samplers are removed on a weekly basis and replaced with fresh samplers, they are the best indication of timing of dye tracer arrival at a given sampling location. Grab groundwater samples provided a measure of dye tracer concentrations at fixed times at a given sampling location. Activated carbon samplers were deployed in each downgradient monitoring well prior to the dye tracer introduction in the upgradient wells. On a weekly basis, throughout the 17-week monitoring period, the activated carbon samplers were retrieved from the wells, grab groundwater samples were collected, and new activated carbon samplers were deployed. Both the activated carbon samplers and the grab groundwater samples were packaged and shipped to OUL for analysis. The procedures for the use of the activated carbon samplers and OUL analytical data are included in Appendix H. Grab groundwater samples were only analyzed if a dye tracer was detected during the analysis of the associated activated carbon sampler, or for manifold water samples (no activated carbon samplers were deployed at the manifold sample locations). If the dye tracer was not detected in the activated carbon sampler, then the grab groundwater sample was not analyzed. Table 7 presents a summary of the post-dye tracer introduction monitoring data.

Table 7: Post Dye Introduction Sampling Results Summary – Fluorescein

Well ID	10/16-10/25	10/25-10/31	10/31-11/07	11/07-11/14	11/14-11/20	11/20-11/28	11/28-12/05	12/05-12/13	12/13-12/20	12/20-1/02	1/02-1/09	1/09-1/16	1/16-1/23	1/23-1/30	1/30-2/08	2/08-2/13
BWTR-2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BWTR-3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M-140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BWTR-5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BWTR-6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M-74	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Additional Samples from Non-Well Locations																
East Manifold	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
+West Manifold	0.144 ppb	0.168 ppb	0.131 ppb	0.153 ppb	0.174 ppb	0.180 ppb	0.197 ppb	0.193 ppb	0.244 ppb	0.200 ppb	0.181 ppb	0.221 ppb	0.231 ppb *	0.193 ppb	0.309 ppb	0.245 ppb

Notes:

ND = not detected

ppb = parts per billion

+ Fluorescein was detected in all samples from the West Manifold

* Rhodamine WT was detected in a single sample, West Manifold sample 1/16-1/23, with a concentration of 0.046 ppb. The fluorescence peak is present but does not meet all the criteria for this dye. However, it has been calculated and reported as a positive dye result. Rhodamine WT was not detected for any other samples.

7.6 Findings

The results of the dye tracer testing indicate that the barrier wall serves its intended purpose of mitigating groundwater flow through the alluvium and improving groundwater extraction of the IWF.

During this study, a Rhodamine WT dye tracer was introduced into new well BWTR-1 approximately 5 feet south of the western end of the barrier wall and on the same side as the actively pumping IWF extraction wells. Analytical results from 17-weeks of post-dye tracer sampling of the wells north of the barrier wall did not identify detectable levels of the Rhodamine WT dye tracer (Table 7). A known prior injection of Fluorescein dye tracer was performed upgradient of the western test location as part of the AP Area Down and Up Flushing Treatability Study (Tetra Tech 2018). Fluorescein was detected in the water samples collected from the West Manifold of the IWF extraction system both before the dye tracer introduction at the western test location and throughout the post-dye tracer introduction monitoring period associated with this dye tracer test. Therefore, the presence of the fluorescein dye in the western manifold is not associated with the barrier wall integrity dye tracer test.

During this study, a Fluorescein dye tracer was introduced into new well BWTR-4 approximately 5 feet south of the eastern end of the barrier wall and on the same side as the actively pumping IWF extraction wells. Analytical results from 17-weeks of post-dye tracer sampling of the wells north of the barrier wall did not identify detectable levels of the Fluorescein dye tracer.

The lack of dye tracer test detections in downgradient wells at either of the testing locations provides sufficient evidence that the barrier wall serves its intended purpose of mitigating groundwater flow through the alluvium and improving groundwater extraction of the IWF. The tracer test results also corroborate the results of the Willowstick geophysics, which indicate that there are no preferential groundwater pathways through the wall.

8. CONCLUSIONS

The objective of this evaluation was to identify locations that may be providing preferential pathways for groundwater flow through, around, or underneath the barrier wall and to evaluate these locations with technologies that can better characterize the extent and magnitude of zones of preferential flow at the barrier wall. The evaluation mapped the barrier wall with geophysics, verified select wall locations using excavation, and then used CPT and tracer testing to explore the physical integrity of the wall.

KMCC was directed to install a "slurry wall downgradient of its chromium recovery line wells to increase the capture of perchlorate flux at this location" (NDEP 2001). The barrier wall was installed in 2001. Prior to the installation of the barrier wall, 22 wells comprised the IWF, and at that time averaged a combined discharge of 24.7 gpm (KMCC 2001b). In March 2002 it was reported that pumping rates increased from 25 gpm prior to construction of the slurry wall to about 50 gpm following construction completion (KMCC 2002 Attachment 1 and KMCC 2001b).

In 2010, Northgate gathered permeability samples from the wall indicating an average hydraulic conductivity of 8.8×10^{-7} cm/sec which established that the wall materials met the design criteria of 1×10^{-6} cm/sec. (Northgate 2010). Hydraulic data has continued to suggest that the barrier wall is an effective barrier to groundwater flow; however, concentrations of perchlorate in groundwater adjacent to wells M-69, M-70, and M-71 have increased since the end of 2012 prompting further investigation.

This investigation has employed additional techniques and come to similar conclusions regarding the effectiveness of the barrier wall with respect to both groundwater and solutes. Geophysics, physical testing using CPT, and tracer testing have been used to evaluate the barrier wall integrity.

The Willowstick geophysical survey did not identify any preferential flow paths through the wall. The survey did not identify any preferential flow paths around the wall to the east or to the west. The survey was able to provide reliable results over the entire length of the wall except in the western section near Building D1 where subsurface and overhead utilities interfered with the signal and measurements. This region of interference also obscures the entire area where an extra section of the barrier wall may be located at the western end. The utilities and GWETS infrastructure precluded determining the location of this wall section using geophysics. However, the Willowstick survey did identify three possible preferential groundwater flow paths beneath the subsurface barrier wall.

GPR and shallow EM surveys were unable to identify the location of the barrier wall. Intrusive activities, including Air knife, CPT transects, and excavation were subsequently used to identify the top of the barrier wall. The excavation program successfully located the barrier wall in two locations. The barrier wall was identified at approximately 4 ft bgs near the west end of the wall and at approximately 7 ft bgs near the east end of the wall. The wall was not identified at excavations in-between these areas despite trenching to 10 ft bgs. Additional subsurface exploration conducted in the center section included an air knife transect consisting of 11 air knife locations to 10 ft bgs, and two CPT transects consisting of

31 CPT locations, neither of which was able to identify the wall in the central portion of the investigation (Figure 9).

Two locations were further explored with a total of 27 CPT soundings, identified as CPT-01 through CPT-27, and 6 dissipation tests were performed. The western portion of the wall was penetrated by three CPT soundings and all three soundings indicated that the wall was constructed with uniformly clayey material throughout. The top of the wall was discovered at approximately 4 feet bgs and terminated at approximately 55 feet bgs. The soundings were terminated at refusal around 57 feet bgs after the cone's friction ratio reported that it had moved from the clay SBT to a distinctly different and more variable SBT. The transect of three soundings indicates that the wall is approximately 50 feet from top to bottom and does not deviate from vertical over its entire thickness at this location.

The eastern area was explored with 23 CPT soundings which did not successfully penetrate into the wall, but instead terminated in the alluvium.

Pore dissipation testing conducted during six of the CPT soundings provide an estimate for small scale hydraulic conductivity near the tool. Due to the time limitations associated with conducting complete dissipation tests in low conductivity materials, each test was terminated before pressure had recovered to pre-test levels. The range of roughly estimated hydraulic conductivity for these dissipation tests is 1.46×10^{-5} to 2.16×10^{-6} cm/sec. The CPT pressure dissipation testing indicated very low conductivity materials in every case.

SBT at the CPT soundings associated with the wall at each dissipation test location is SBT zone 3 (clay). The materials penetrated by the CPT where dissipation testing was conducted behave like clay in every case and has an estimated hydraulic conductivity of between 1×10^{-7} to 1×10^{-8} cm/sec.

Dye was injected into two wells BWTR-1 and BWTR-4, each approximately 5 feet south of the barrier wall on the same side as the actively pumping IWF. Monitoring at wells north of the wall did not find detectable levels of dye during the entire 17-week monitoring period indicating the wall serves its intended purpose of mitigating groundwater flow through the alluvium and improving groundwater extraction of the IWF.

Fluorescein was detected in water samples collected from the West Manifold both before the dye introduction at the western cluster wells, and throughout the monitoring period of this tracer test. As part of this dye study, Rhodamine WT (not Fluorescein) was injected at the west cluster of wells. Prior injection of Fluorescein was performed upgradient of the western cluster of wells as part of the AP Area Down and Up Flushing Treatability Study (Tetra Tech 2018). Therefore, the presence of the dye in the western manifold is not associated with the barrier wall integrity dye tracer test. No other wells exhibited the presence of dye in the grab samples.

The barrier wall integrity evaluation has provided additional geophysical, hydraulic, in-situ physical, and in-situ tracer test evidence that the wall is not compromised in the areas tested which indicate that the wall is functioning as designed. The tracer test results corroborate the results of the Willowstick geophysics, which indicate that there are no preferential groundwater pathways through the wall. This study corroborates the conclusions of annual remedial performance evaluations which also conclude that based on hydraulic evidence, the barrier wall is an effective barrier to groundwater flow (ENVIRON 2014a, Ramboll Environ 2015). Although some of the investigative techniques did not achieve their intended purpose, the collective findings of the Willowstick and tracer tests, in addition to the relative difference in groundwater elevations on both sides of the wall, demonstrate that the barrier wall is serving its intended purpose. However, given the location of the barrier wall and the fact that groundwater appears to migrate under the wall, additional containment options will be considered in the FS.

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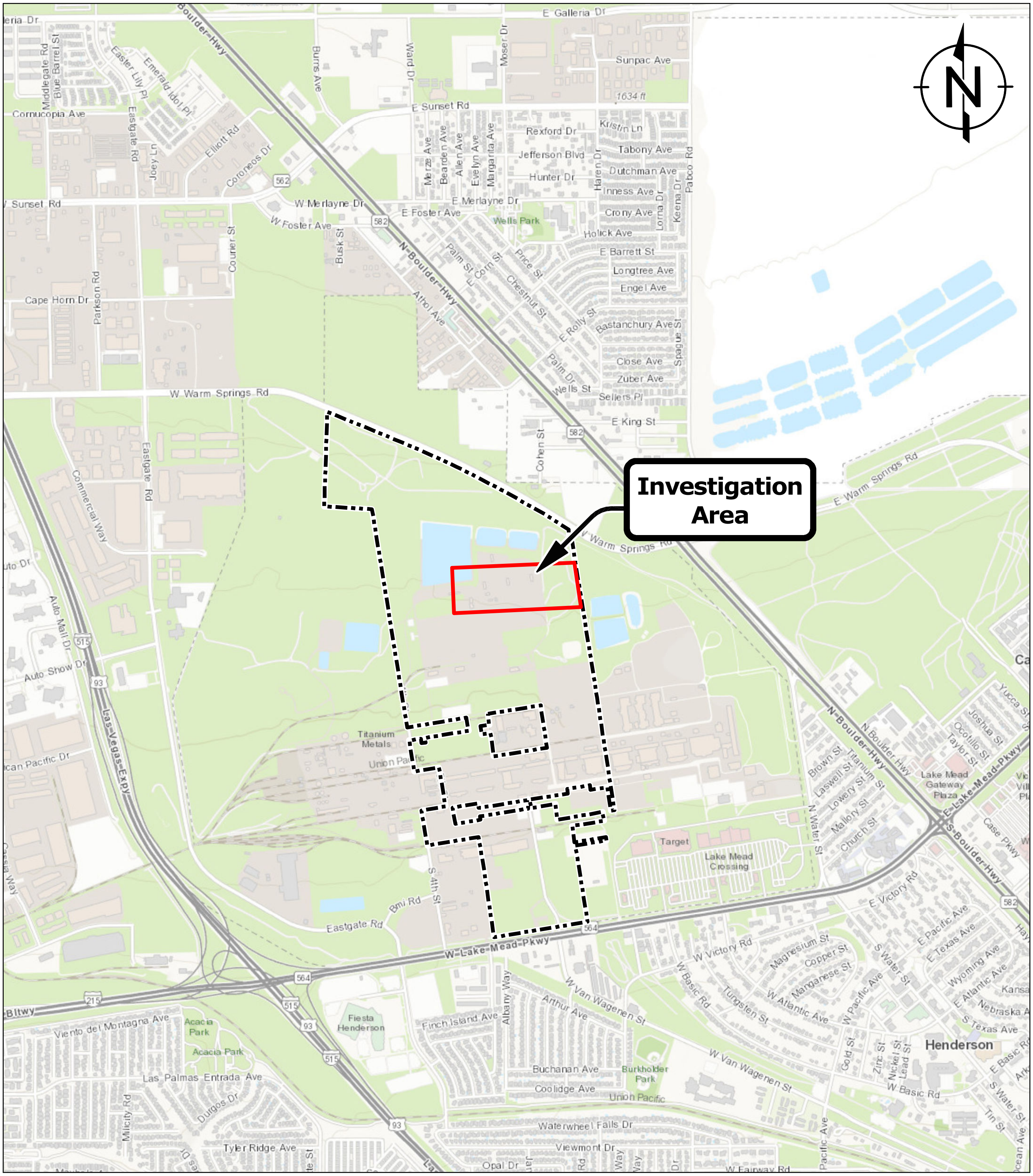
Tetra Tech, 2018. AP Area Down and Up Flushing Treatability Study; Nevada Environmental Response Trust Site; Henderson, Nevada. May 4.

FIGURES



Legend

Investigation Area

NERT Site Boundary

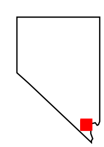
NOTES:
CONTOUR INTERVAL 20 FEET

SOURCE:
The National Map, 2018.

Map Scale: 1:24,000 Spatial Reference: NAD 1983 StatePlane Nevada East FIPS 2701 Feet; Map Center: 115°0'8"W 36°2'56"N

0 0.5 1
Scale in Miles

0 2,000 4,000
Scale in Feet



KEY MAP

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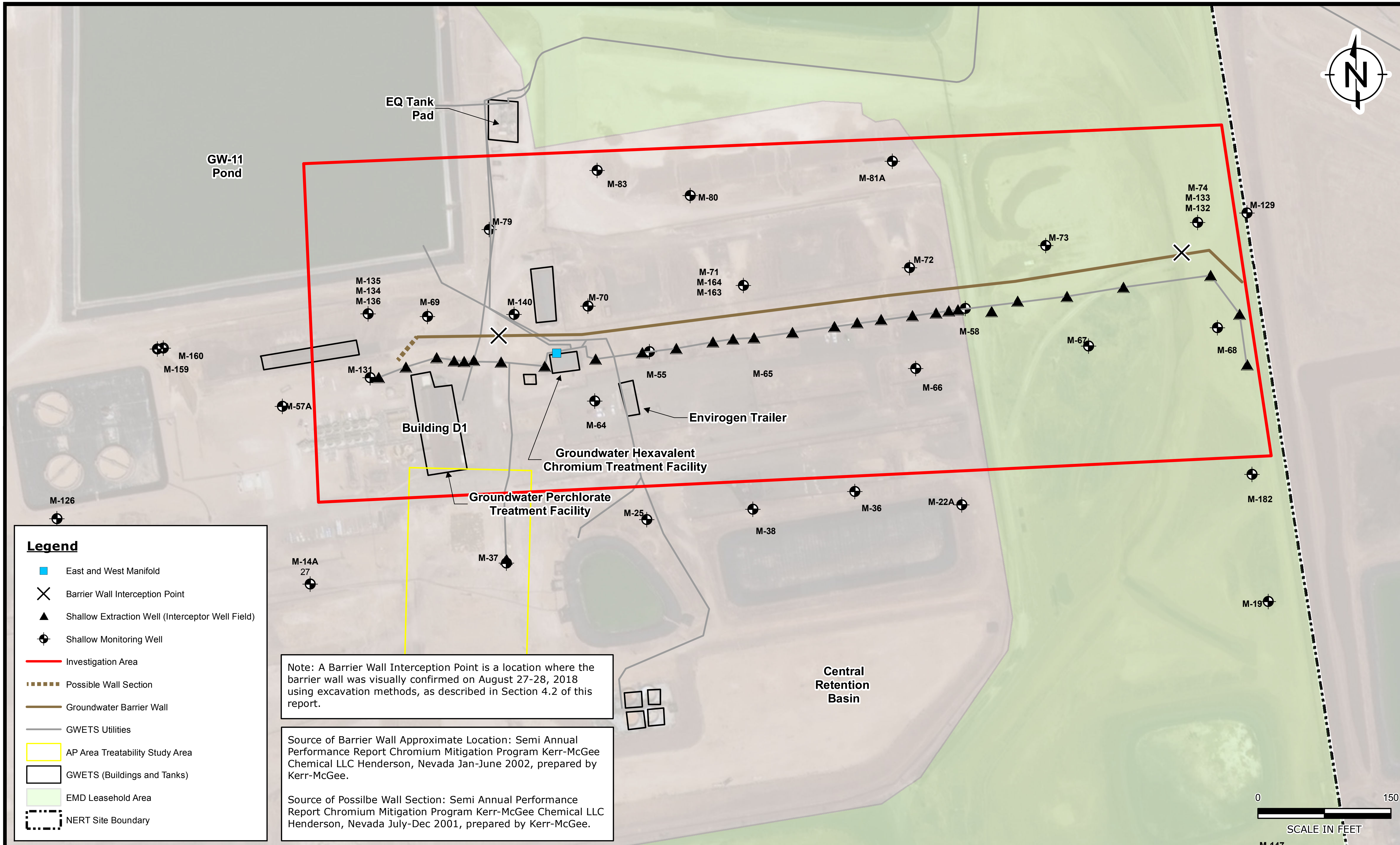
RAMBOLL

Investigation Area Location Map
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 1

Drafter: SKI | Date: 8/30/2019 | CN: 1690011200-048 | Approved by: | Revised:



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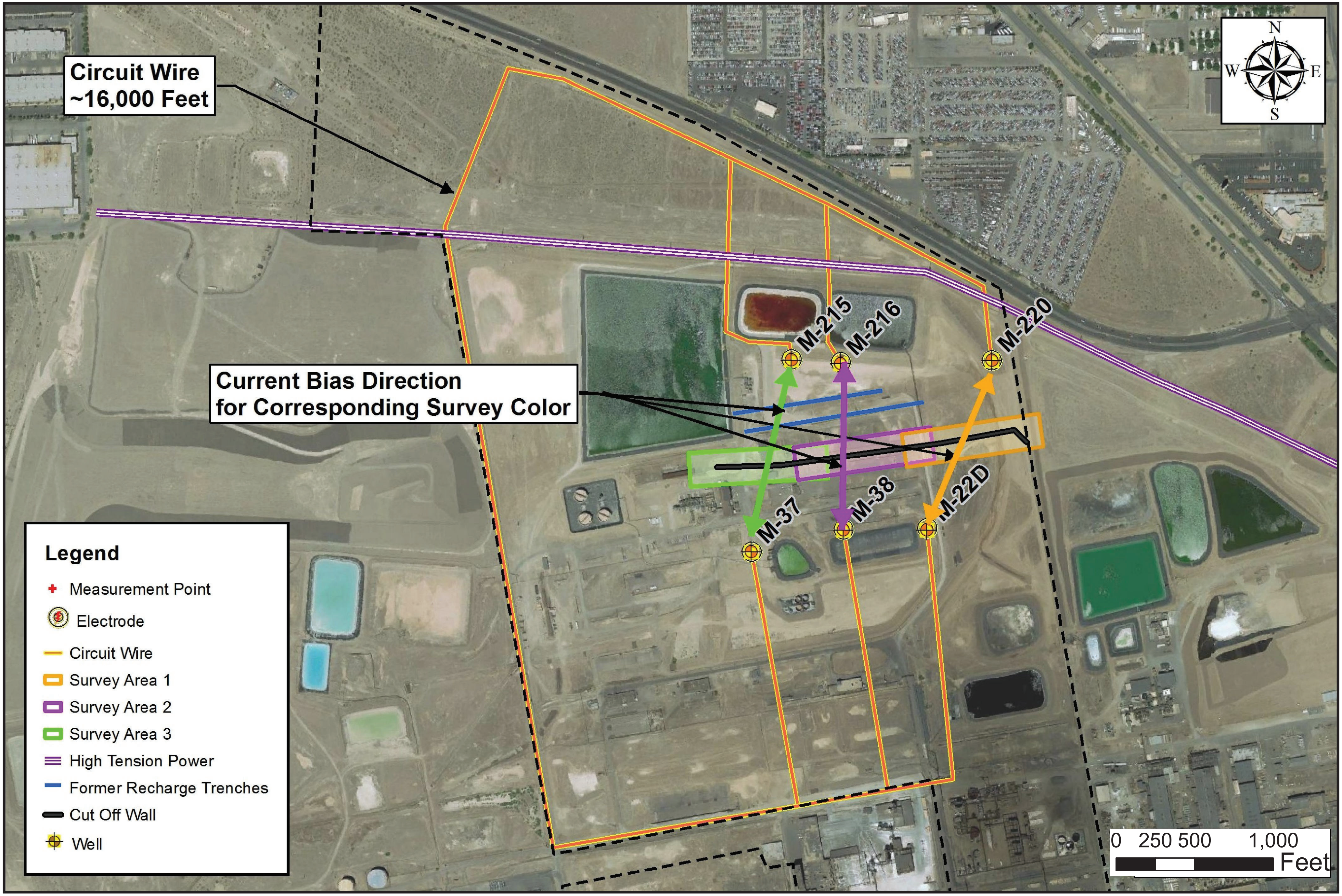
RAMBOLL

Interceptor Well Field and Barrier Wall
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
2

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:



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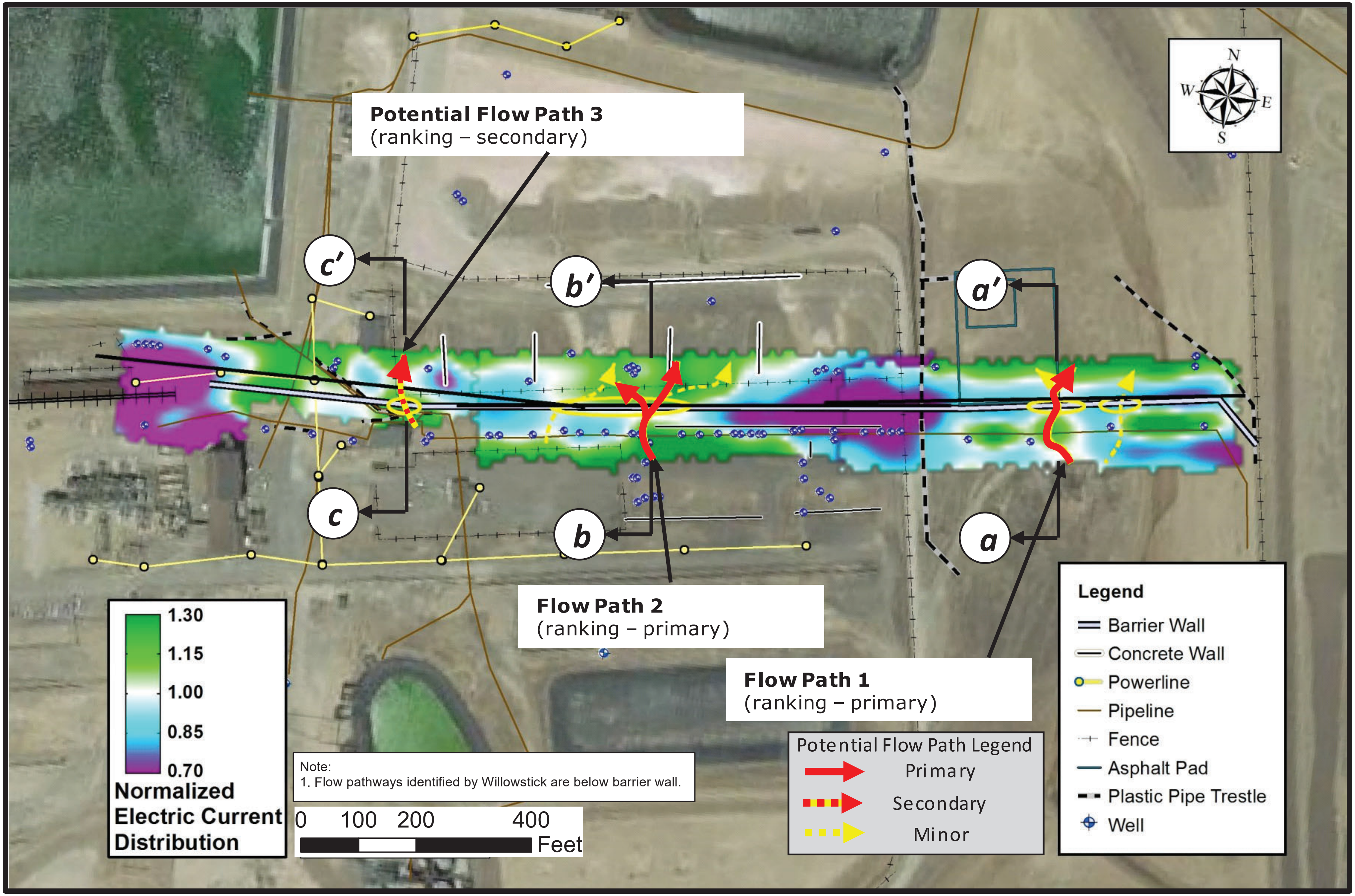
RAMBOLL

Willowstick Large Scale EM Survey and Circuit Wire Layout
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
3

Drafter: SKI	Date: 8/30/2019	Contract Number: 1690011200-048	Approved by:	Revised:



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RAMBOLL

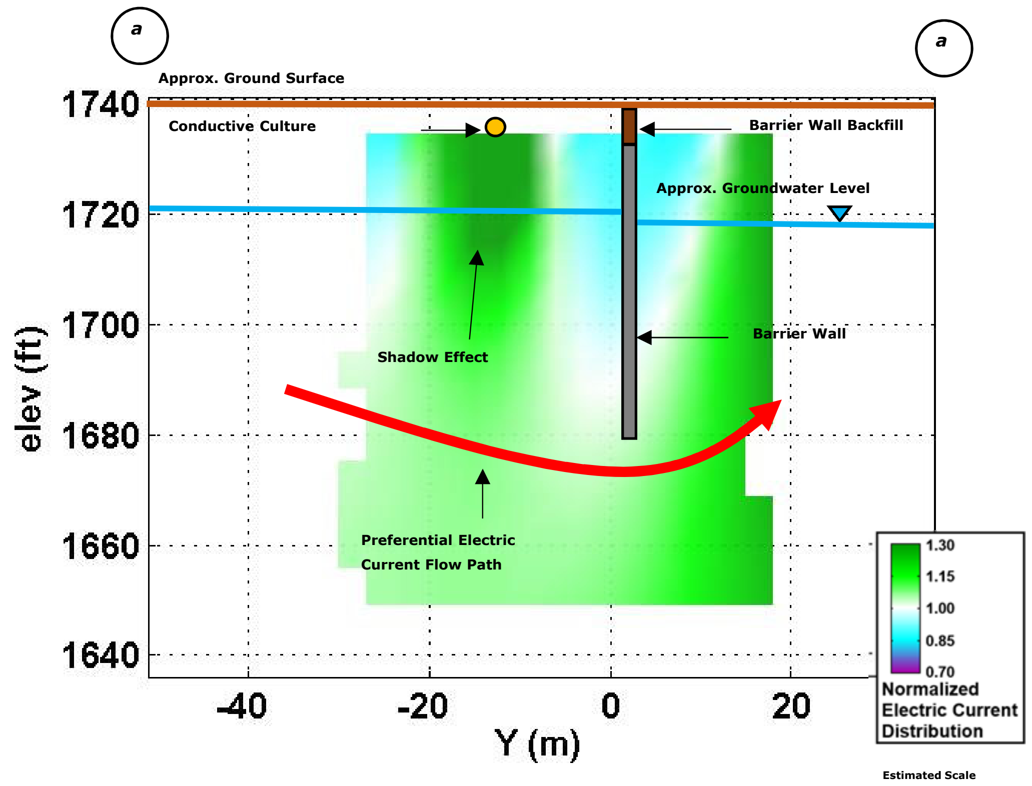
Location of Willowstick Cross-Sectional Slices at Potential Underflow Locations
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 4

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:

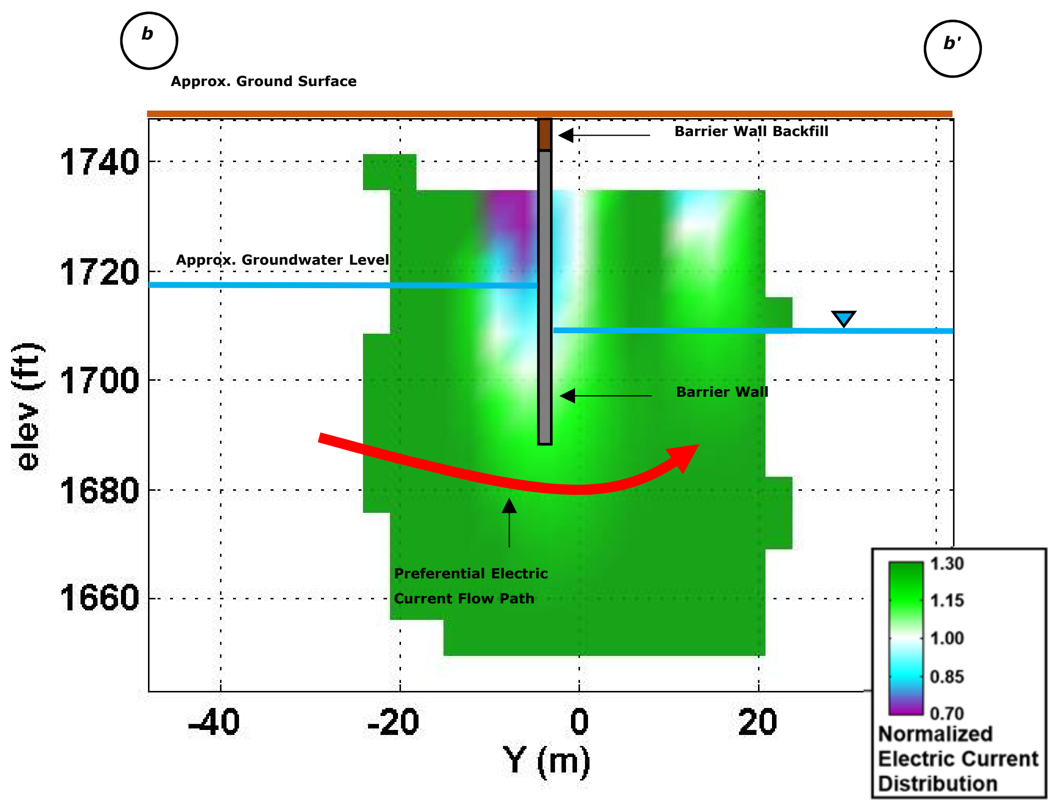
ECD Cross-Sectional Slice a-a'

This ECD cross-sectional slice shows that the preferential electric current is flowing below, not through the wall. This ECD slice also allows for the estimation of the barrier wall depth. a-a' location is a primary potential groundwater flow bath beneath the wall.



ECD Cross-Sectional Slice b-b'

This ECD cross-sectional slice shows that the preferential electric current is flowing below, not through the wall. This ECD slice also allows for the estimation of the barrier wall depth. b-b' location is a primary potential groundwater flow path beneath the wall.

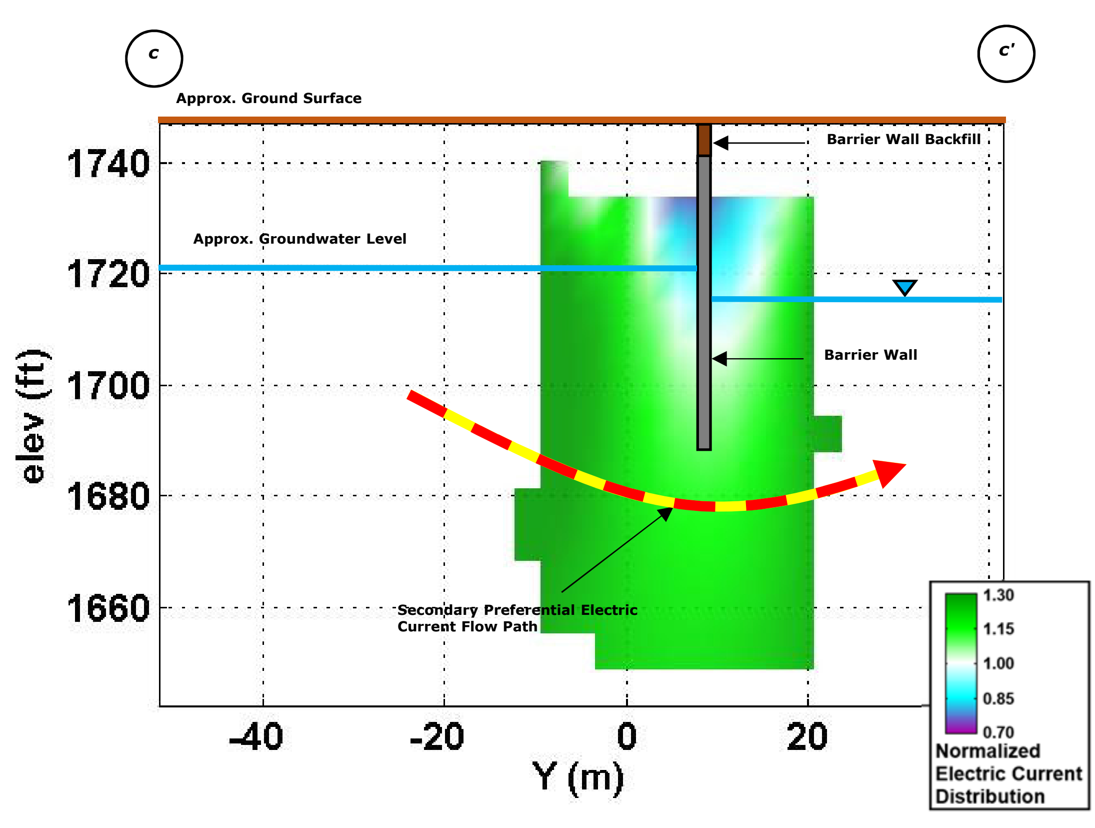


Surface elevation and groundwater level information obtained from M-65, M-172 and M-71 (December 2018).

Estimated Scale

ECD Cross-Sectional Slice c-c´

This ECD cross-sectional slice shows that the preferential electric current is flowing below, not through the wall. This ECD slice also allows for the estimation of the barrier wall depth. c-c' location is a secondary potential groundwater flow path beneath the wall.



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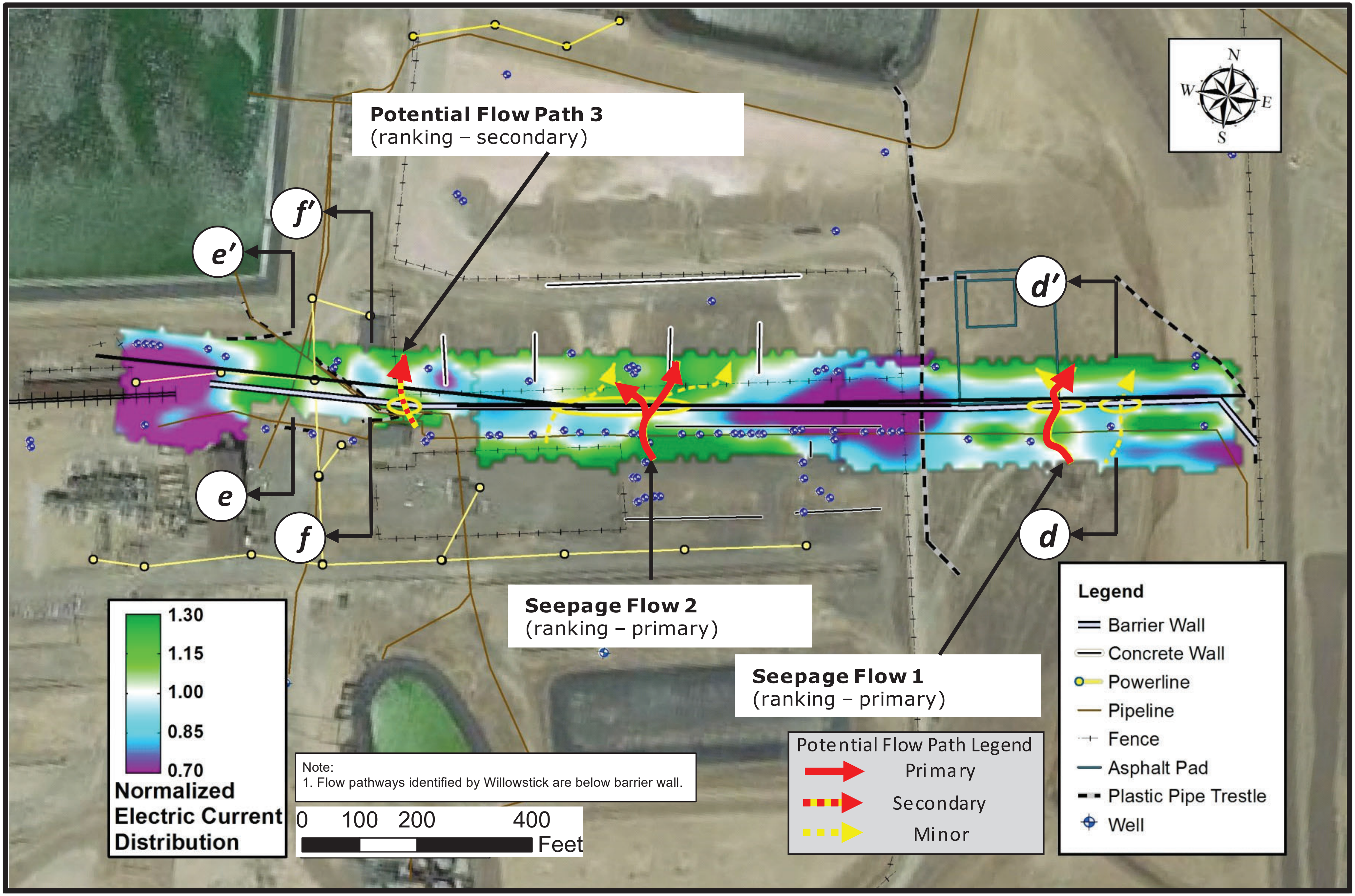
RAMBOLL

Willowstick ECD Cross-Sectional Slices at Locations of Potential Flow Under Wall
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
5

Drafter: MPI	Date: 8/30/2019	Contract Number: 1690011200-048	Approved by:	Revised:



RAMBOLL

Location of Willowstick Cross-Sectional Slices at Tracer Test Locations
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
6

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:

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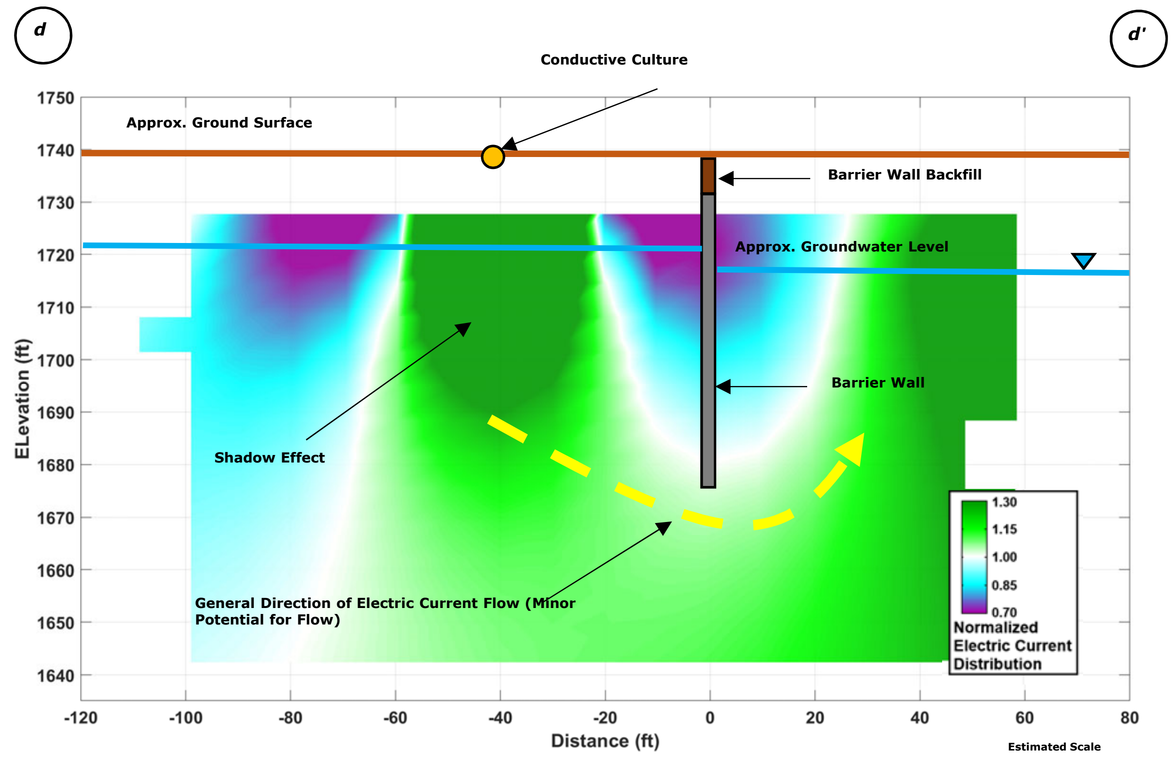
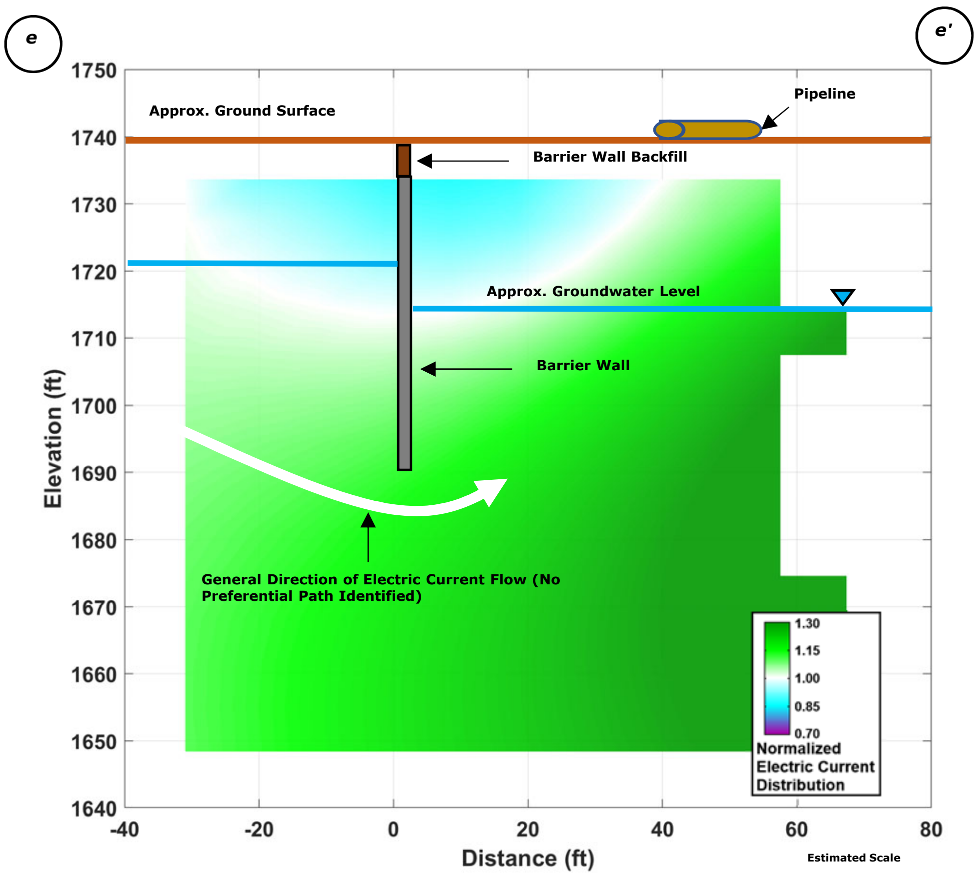
ECD Cross-Sectional Slice d-d′

This ECD cross-sectional slice shows that the preferential electric current is flowing below, not through the wall. This ECD slice also allows for the estimation of the barrier wall depth.



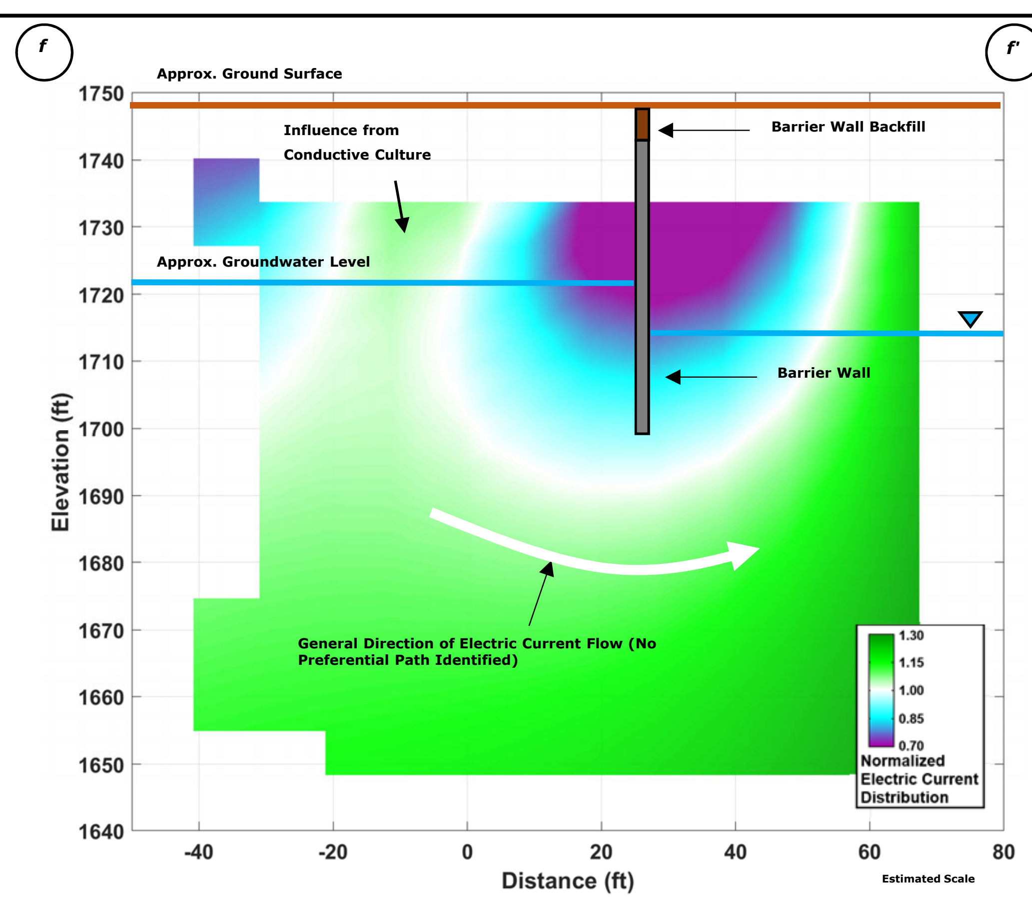
ECD Cross-Sectional Slice e-e′

This ECD slice is affected by conductive culture, including a powerline and pipeline. Due to these interferences, this slice is ineffective for showing the depth of the barrier wall.



ECD Cross-Sectional Slice f-f′

This ECD cross-sectional slice shows that the preferential electric current is flowing below, not through the wall. This ECD slice also allows for the estimation of the barrier wall depth.



RAMBOLL	**Willowstick ECD Cross-Sectional Slices at Locations of Tracer Testing** Nevada Environmental Response Trust Site Henderson, Nevada	Figure **7**

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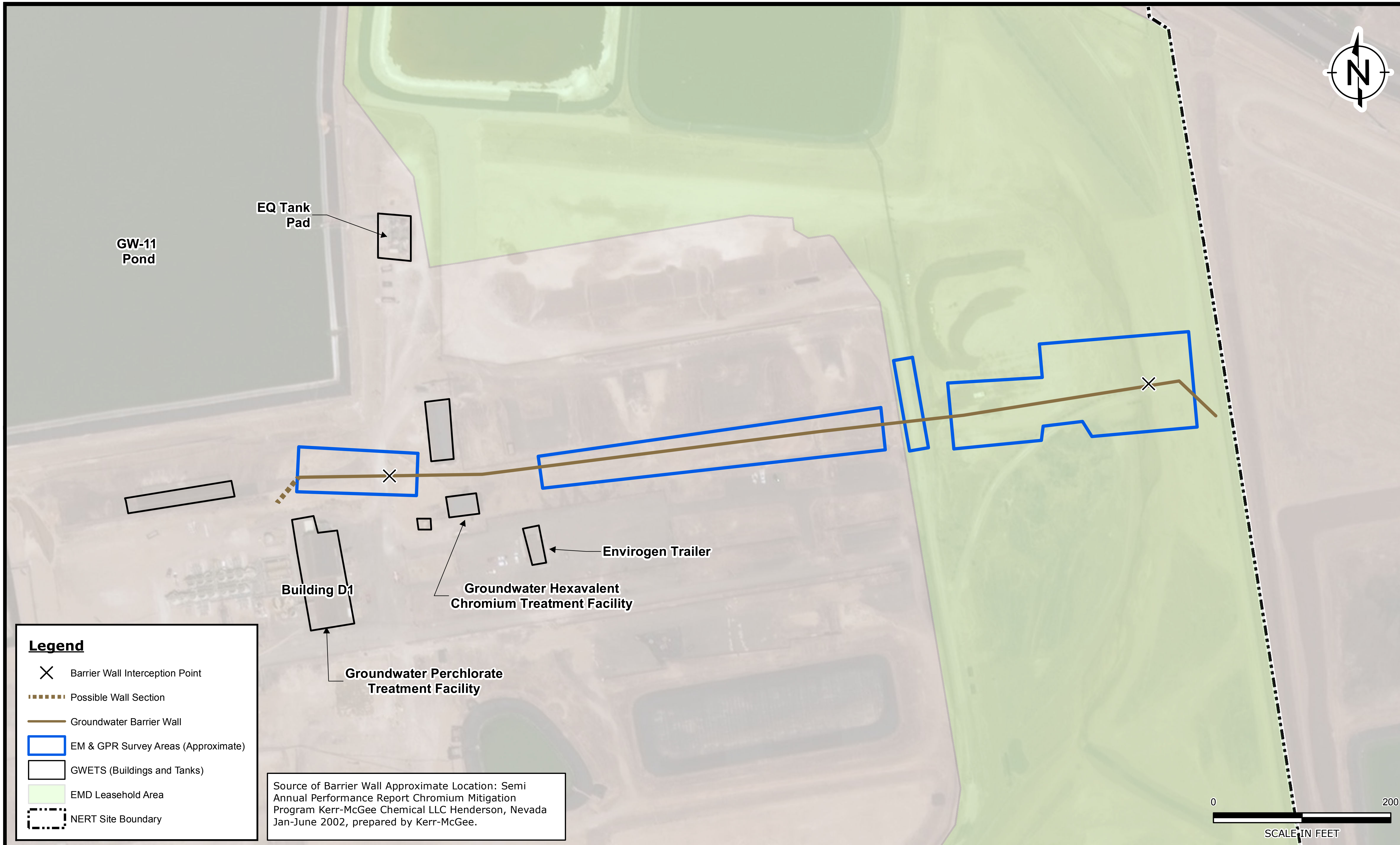

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RAMBOLL

Small Scale EM and GPR Survey Areas
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 8

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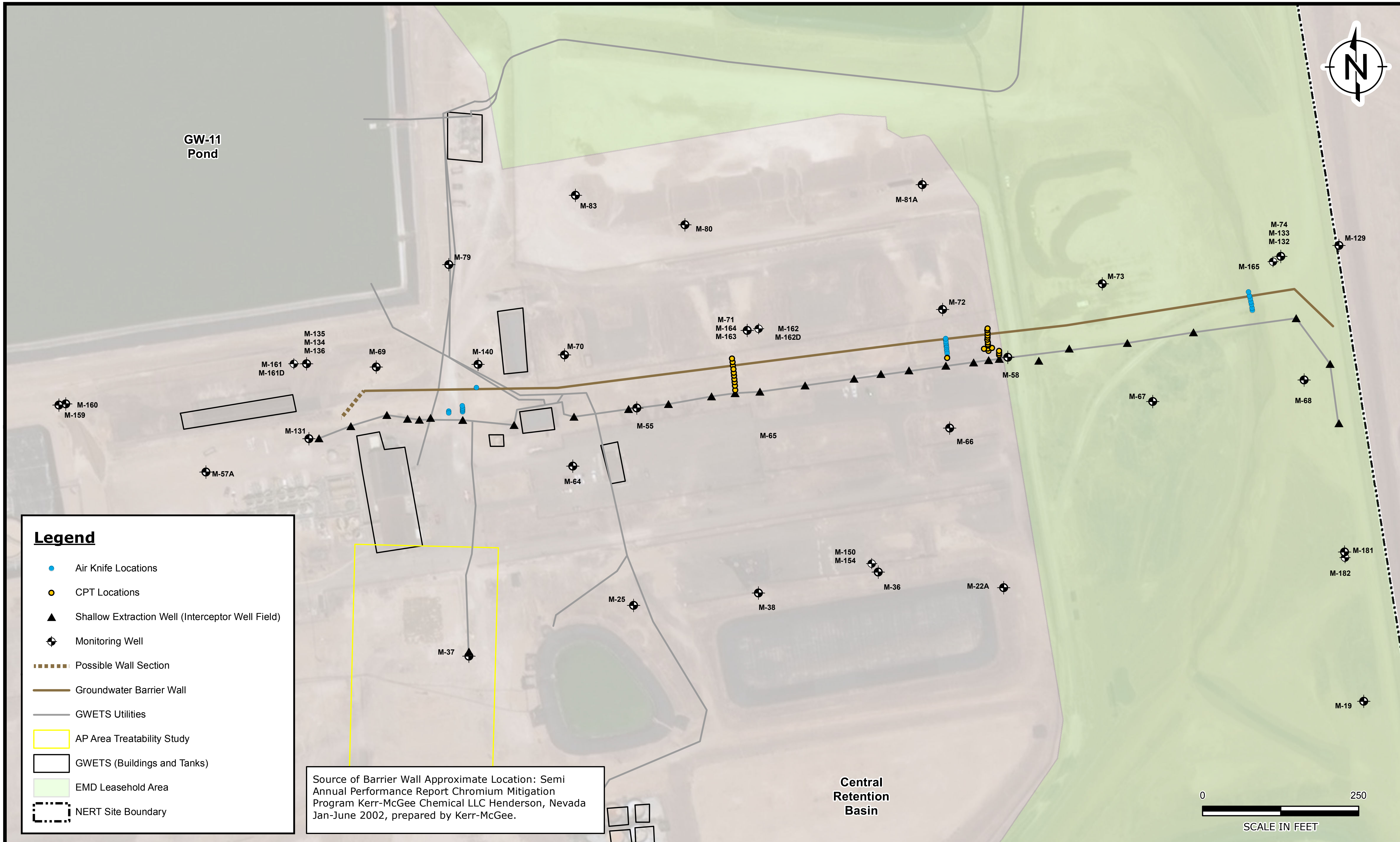

Legend

- Air Knife Locations
- CPT Locations
- Shallow Extraction Well (Interceptor Well Field)
- Monitoring Well
- Possible Wall Section
- Groundwater Barrier Wall
- GWETS Utilities
- AP Area Treatability Study
- GWETS (Buildings and Tanks)
- EMD Leasehold Area
- NERT Site Boundary

Source of Barrier Wall Approximate Location: Semi Annual Performance Report Chromium Mitigation Program Kerr-McGee Chemical LLC Henderson, Nevada Jan-June 2002, prepared by Kerr-McGee.

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RAMBOLL

Exploratory Air Knife and CPT Locations (June 4 - 7, 2018)
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
9

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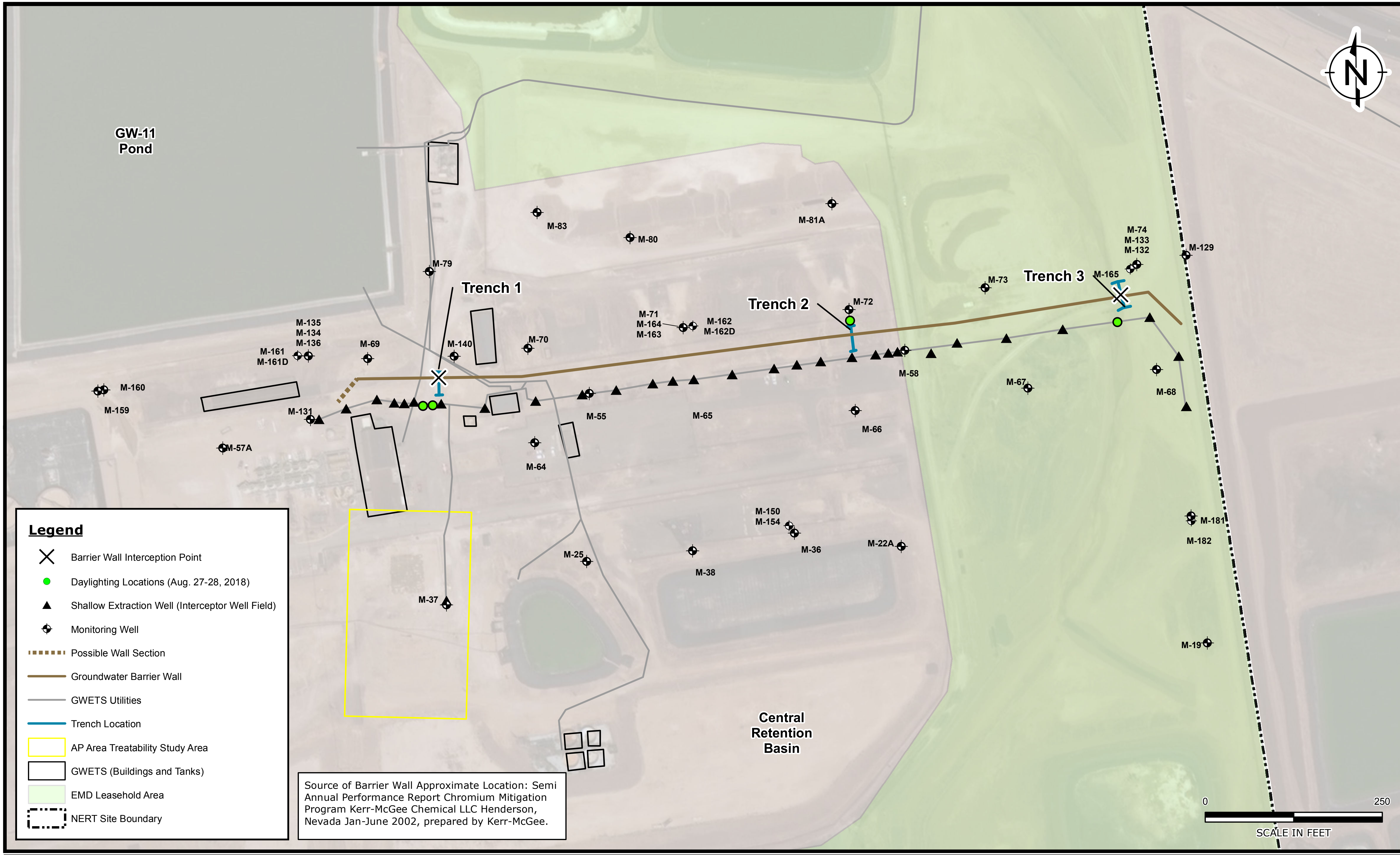

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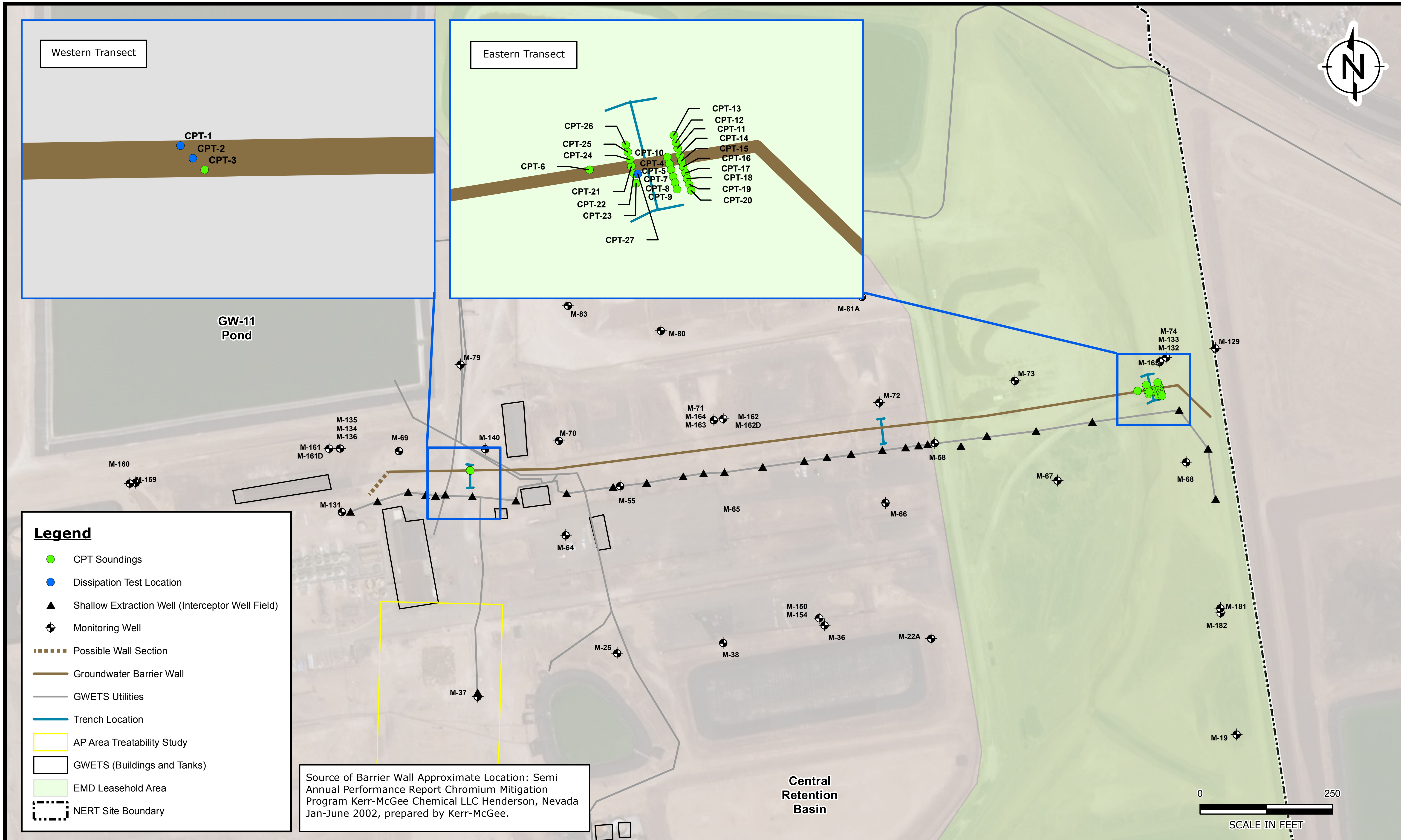
RAMBOLL

Exploratory Trenches and Barrier Wall Locations
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
10

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:



RAMBOLL

Locations of CPT and Dissipation Tests (November 6 - 8, 2018)
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 11

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:

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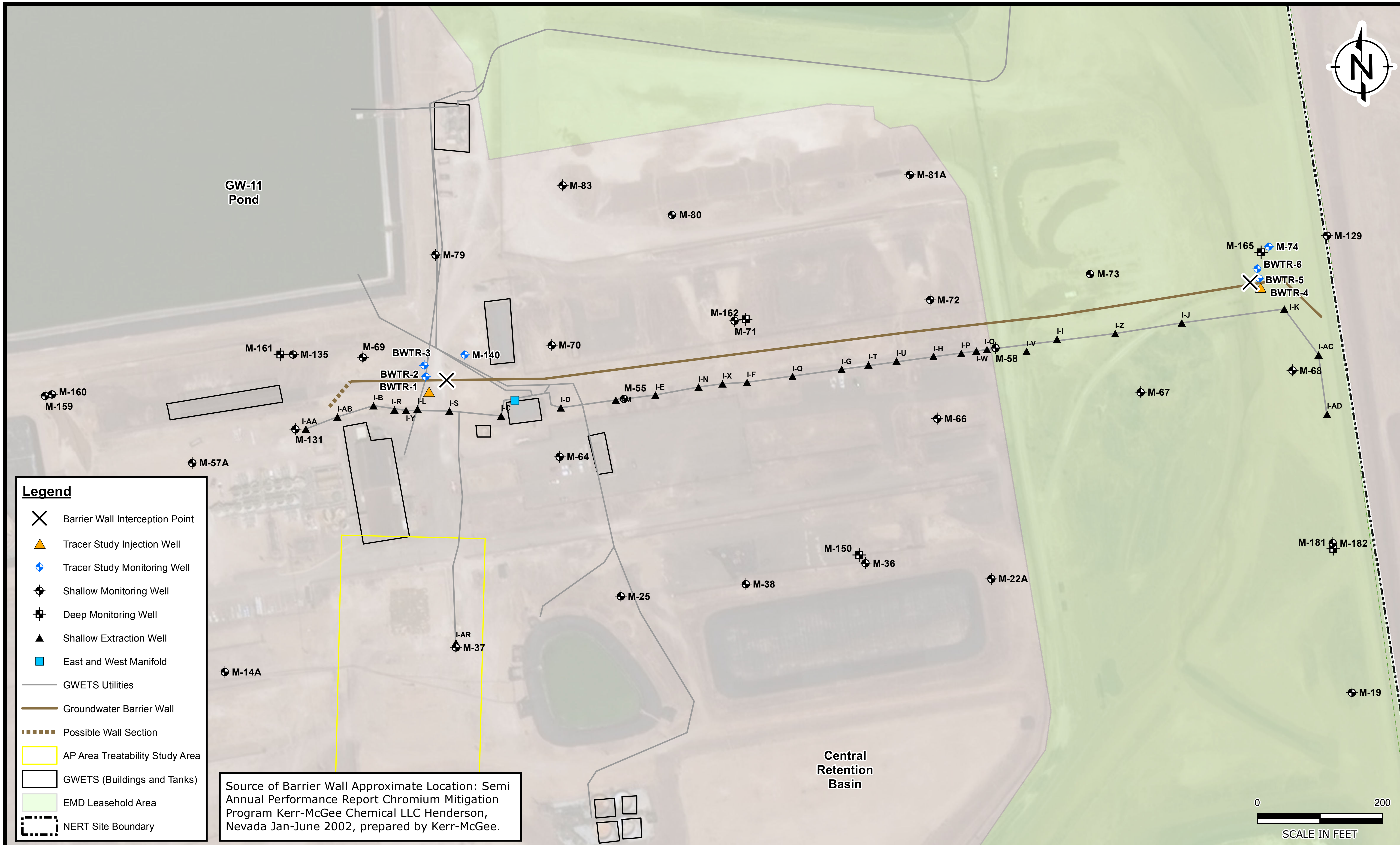

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RAMBOLL

Tracer Study Well Layout
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
12

Drafter: SKI | Date: 8/30/2019 | Contract Number: 1690011200-048 | Approved by: | Revised:

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RAMBOLL

Tracer Study - East Side Injection and Monitoring Locations
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **13**

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RAMBOLL

Tracer Study - West Side Injection and Monitoring Locations
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure
14

Drafter: SKI | Date: 8/30/2019 | CN: 1690011200-048 | Approved by: | Revised:

APPENDIX A
WILLOWSTICK GEOPHYSICAL REPORT

WILLOWSTICK INVESTIGATION

Of

Subsurface Barrier Wall

Nevada Environmental Response Trust (NERT)
Henderson, Clark County, Nevada

(Identify, map and model preferential seepage flow paths through, beneath and under subsurface barrier wall)

Prepared For:

Ramboll Environ
2200 Powell Street, Suite 700
Emeryville, California 94608

Prepared By:

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USA

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WST Project No. 18260

Final Report Date: March 12, 2018

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

1.1 Project Location and Purpose of Investigation

This report presents the results of a Willowstick® geophysical investigation to identify, map and model preferential groundwater flow paths bypassing the subsurface barrier wall constructed at the Nevada Environmental Response Trust (NERT) site in Henderson, Clark County, Nevada (see Figures 1 and 2).

Figure 1 – Location Map

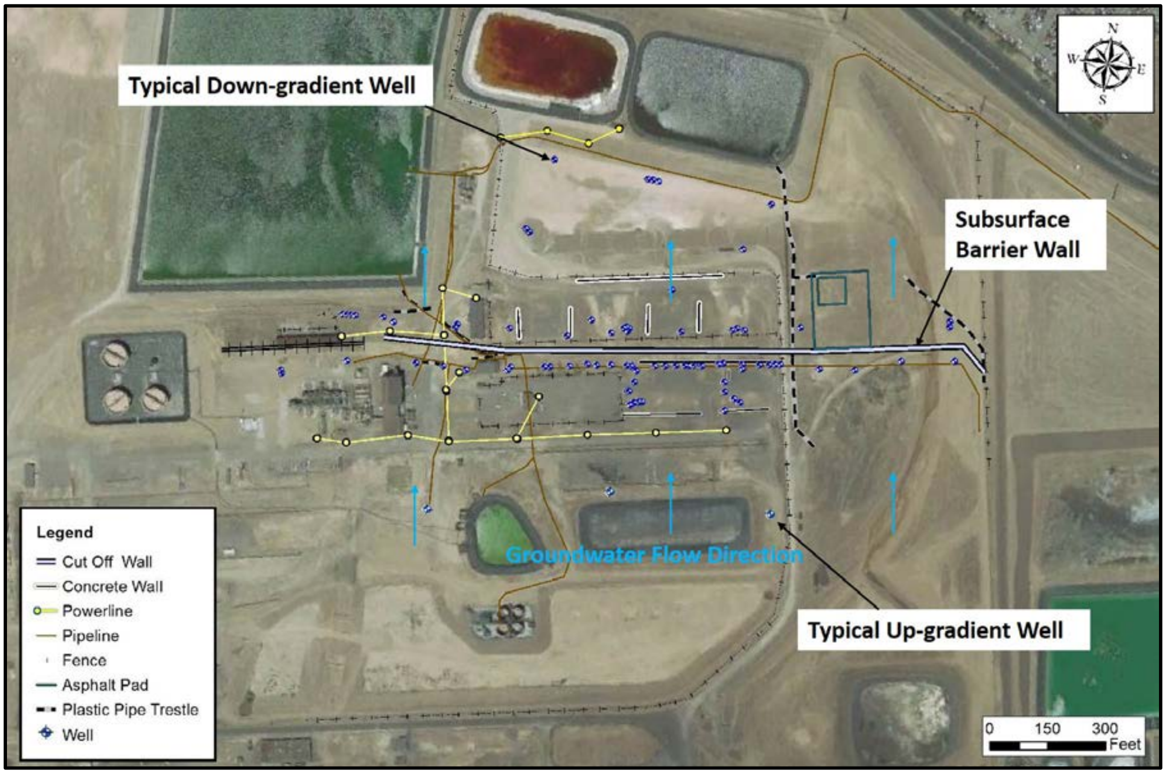


Figure 2 –Site Map

The subsurface barrier wall is reported to be 3 feet wide, 60 feet deep and 1600 feet long. The barrier wall was constructed by trenching the earth to a depth of roughly 60 feet (see Figures 3 and 4) and filling the trench to within 5 to 8 feet of the surface with a relatively impervious soil slurry material (having a hydraulic conductively of 1 x 10^{-6} cm/sec maximum). The top 5 to 8 feet was backfilled with native materials excavated from the trench. The top of the subsurface barrier wall extends approximately 12 feet above the water table (phreatic surface). The barrier wall also penetrates approximately 25 feet into the UMC formation (exhibiting a slightly tighter silty sandy lithology). The purpose of the barrier wall is to keep localized groundwater from flowing northward.

Figure 3 – Subsurface Barrier Wall Construction

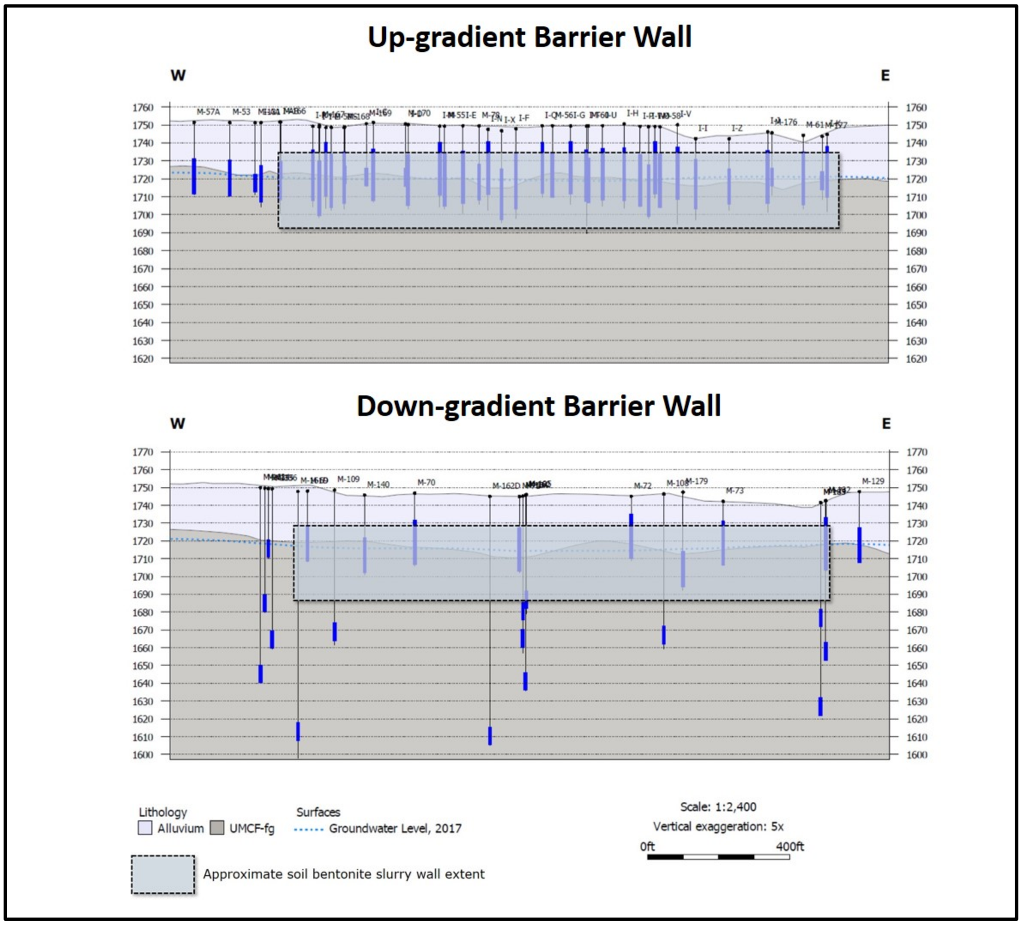


Figure 4 – Profile Views of Subsurface Barrier Wall

A significant number of monitoring wells have been constructed up-gradient and down-gradient of the barrier wall as evident in Figures 2 and 4. Despite efforts to minimize localized groundwater from flowing northward, monitoring well data indicates that groundwater bypasses the wall. The purpose of the Willowstick investigation is to identify where groundwater preferentially bypasses the barrier wall.

1.2 Approach to the Work

The application of the Willowstick technology, as applied to the subsurface barrier wall, is based on the principle that groundwater increases the conductivity of earthen materials through which it flows. As the signature electric current flows between strategically placed electrodes (located up-gradient and down-gradient of the barrier wall), it concentrates in the more conductive zones (i.e., in areas of highest transport porosity) where groundwater preferentially flows as it bypasses the wall. Our team measured and modeled the magnetic fields generated from the distribution of electric current through, beneath and around the barrier wall to identify preferential electric current flow paths and patterns. We then compared the measured magnetic field data to the expected magnetic field in a homogeneous environment to identify any variations from the homogeneous background model. Finally, we modeled and interpreted the concentration and distribution of electric current to identify where groundwater preferentially bypasses the barrier wall.

Three survey configurations were employed for the investigation (see Figures 5a and 5b).

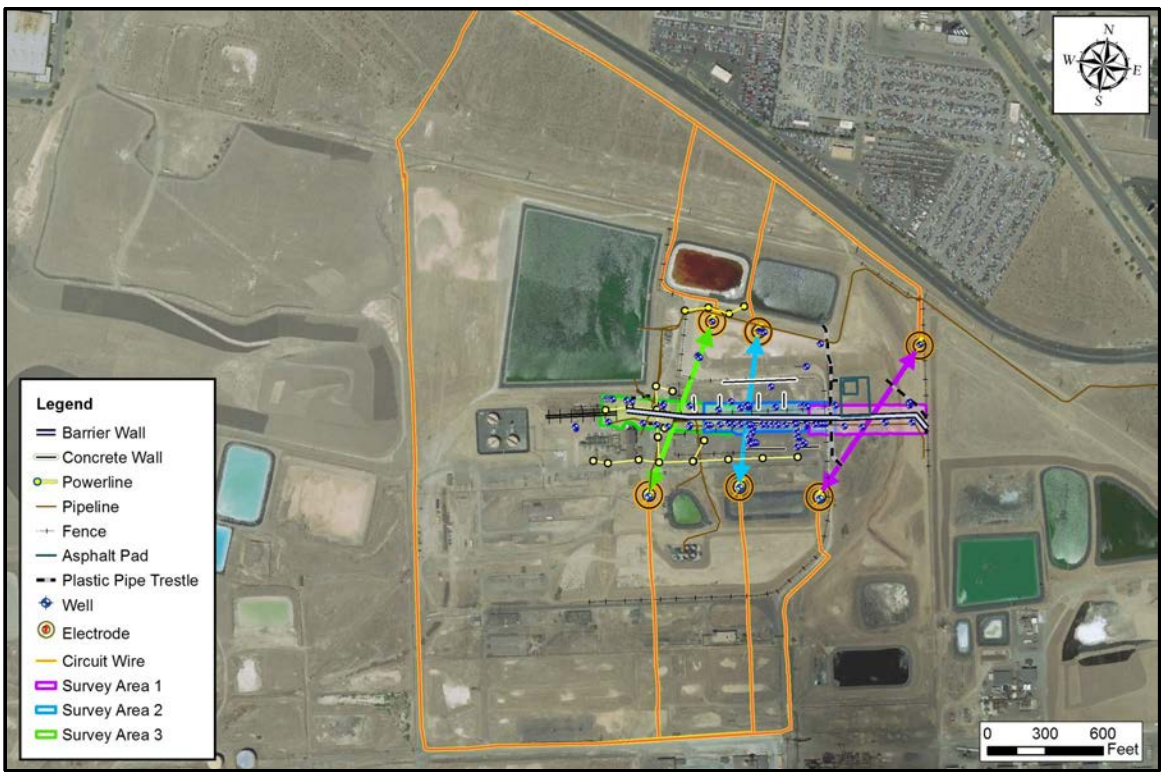


Figure 5a – Circuit Wire Layout

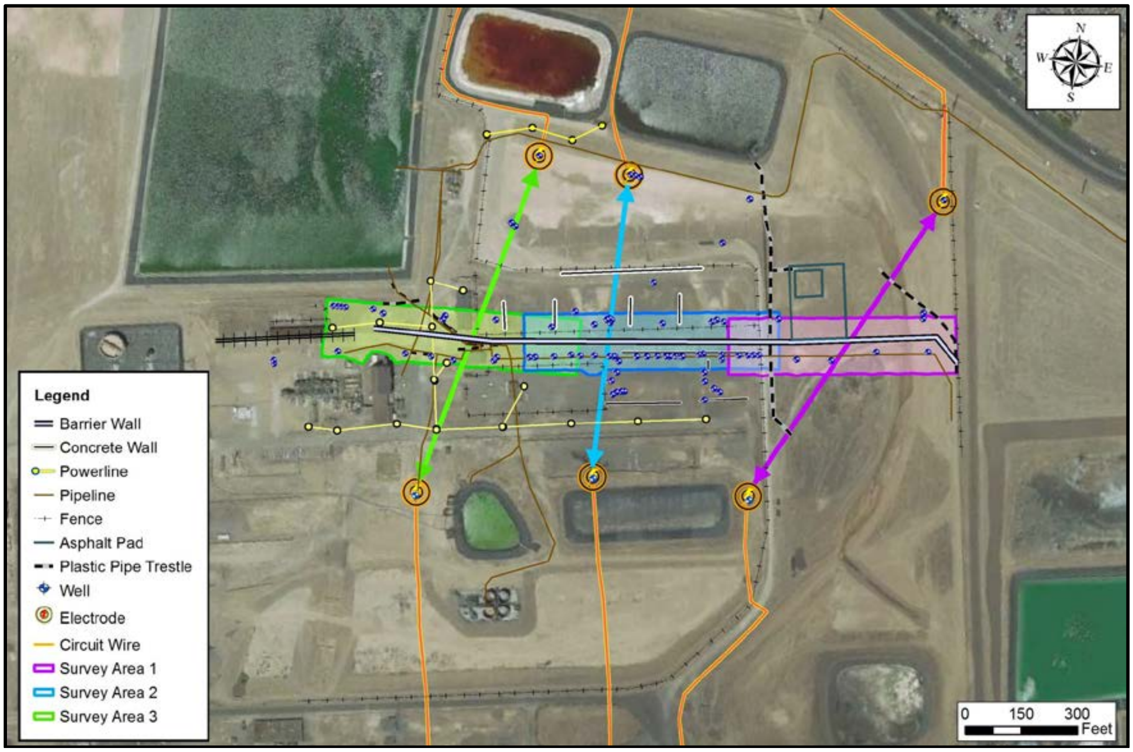


Figure 5b – Survey Coverage Areas

All three surveys utilized a horizontal dipole configuration. A schematic demonstrating the concept of the horizontal dipole configuration for this site is illustrated in Figure 6.

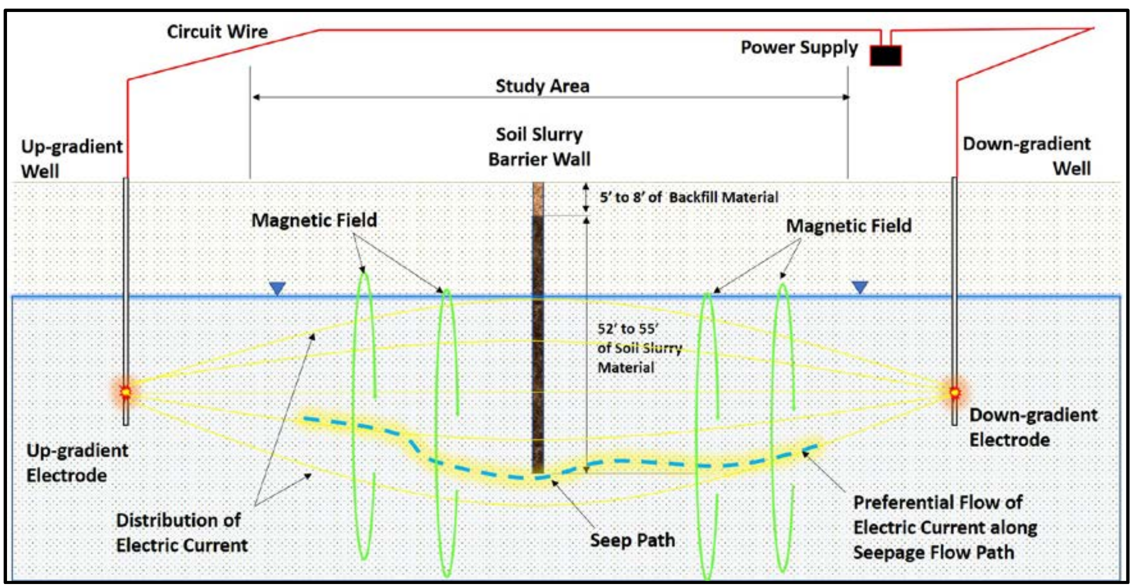


Figure 6 – Horizontal Dipole Configuration (schematic - not to scale)

As shown in Figure 6, the horizontal dipole configuration places an electrode up-gradient of the barrier wall in a monitoring well completed into the localized groundwater system. A second electrode is placed down-gradient of the barrier wall also in a monitoring well completed into the localized groundwater system. The overall approach involves injecting and driving AC electric current with a specific signature frequency (380 Hertz) between the strategically placed electrodes located on either side of the barrier wall. As electric current flowed between the paired electrodes, it generated a recognizable magnetic field that was measured from the earth's surface over the study area. The magnetic field was used to identify the distribution of electric current flow through, beneath and around the wall. By identifying the electrically conductive flow paths between the strategically placed electrodes, questions can be addressed regarding where seepage preferentially bypasses the subsurface barrier wall. The results of the surveys were carefully analyzed and modeled to identify preferential electric current flow paths that are interpreted as preferential groundwater flow paths.

1.3 Summary of Results and Discussion

The Willowstick investigation identified three preferential groundwater flow paths attributed to groundwater bypassing the subsurface barrier wall. Two of the flow paths are interpreted as primary groundwater flow paths and one as a secondary—meaning that the anomaly is a little weaker and less distinguishable from the background and from nearby conductive culture influences, although in our analysis it still represents a likely groundwater flow path. Other than the three-noted preferential groundwater flow paths, no other areas along the wall exhibited preferential flow. All three groundwater flow paths suggest that groundwater preferentially escapes beneath the wall and not through, over or around the wall. Evidence of preferential groundwater flow is indicated by Electric Current Distribution (ECD) model analysis. Figure 7 presents a collage of three ECD model slices—representative of each survey—which identifies where groundwater preferentially or potentially escapes beneath the barrier wall. All three elevation slices are taken near the bottom of the wall.

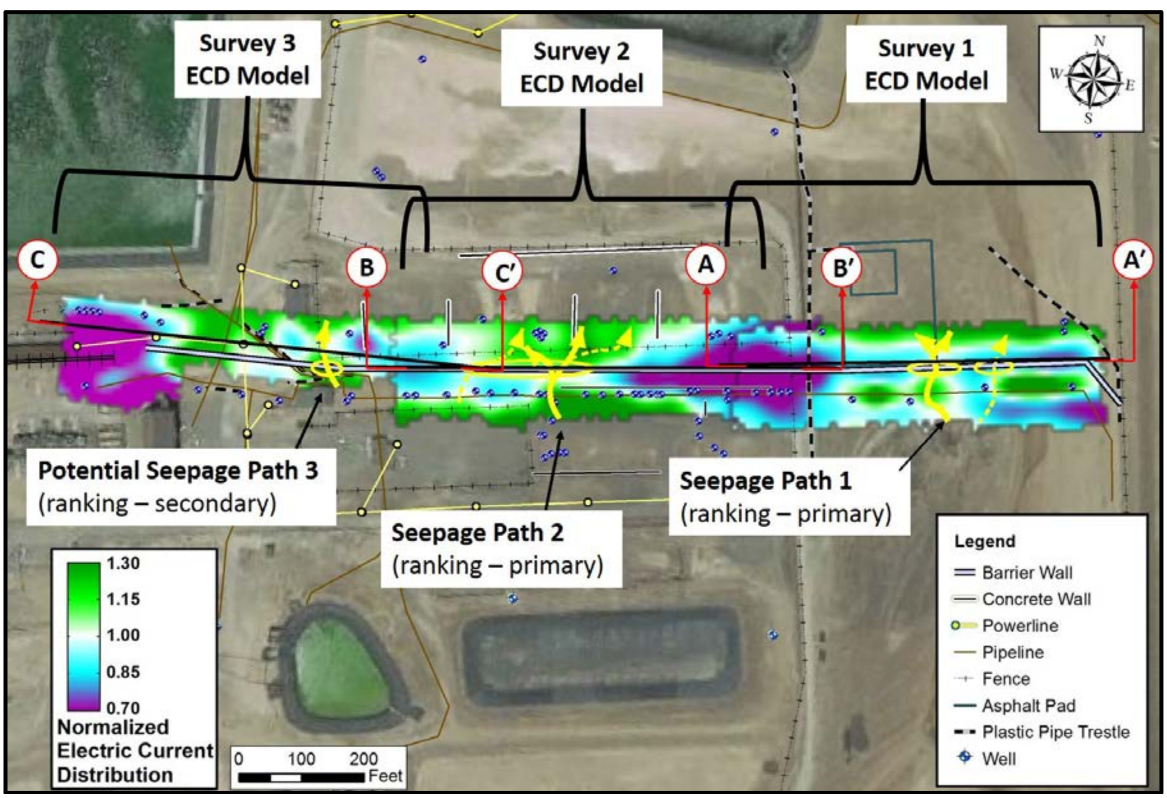


Figure 7 – Summary of Investigation

The ECD model slices indicate the relative intensity of the electric current flow, or where electric current flow is stronger (green) or weaker (purple) than expected. The yellow arrows highlight the center of the preferential flow paths. Some electric current follows along pipelines located in front of the wall and along a fence line located behind the wall. Due to the conductive nature of these features, this was expected and taken into account while interpreting the data. Some filtering is performed on the data, but the influence of conductive culture often cannot be filtered out entirely, so it must be considered during interpretation.

It should be noted that each of the three preferential flow paths align very closely with the direct line connecting the pair of electrodes (see Figure 5) for each survey. This is a coincidental occurrence, given that Willowstick has performed hundreds of similar surveys and detected hundreds of preferential flow paths at many other sites—but only occasionally do the flow paths lie directly on the centerline between the electrodes. Therefore, it can be safely concluded that the occurrence here in all three cases is purely coincidental.

To further describe preferential seepage flow beneath the barrier wall, Figures 8, 9 and 10 present ECD profile slices (longitudinal along the wall) of Survey 1 (Section A-A′), Survey 2 (Section B-B′) and Survey 3 (Section C-C′), respectively. The profile slices for Surveys 1 and 2 are taken at the barrier wall; whereas, the Survey 3 profile is taken 10 feet down-gradient of the wall to keep it slightly more away from some of the conductive culture in the Survey 3 area.

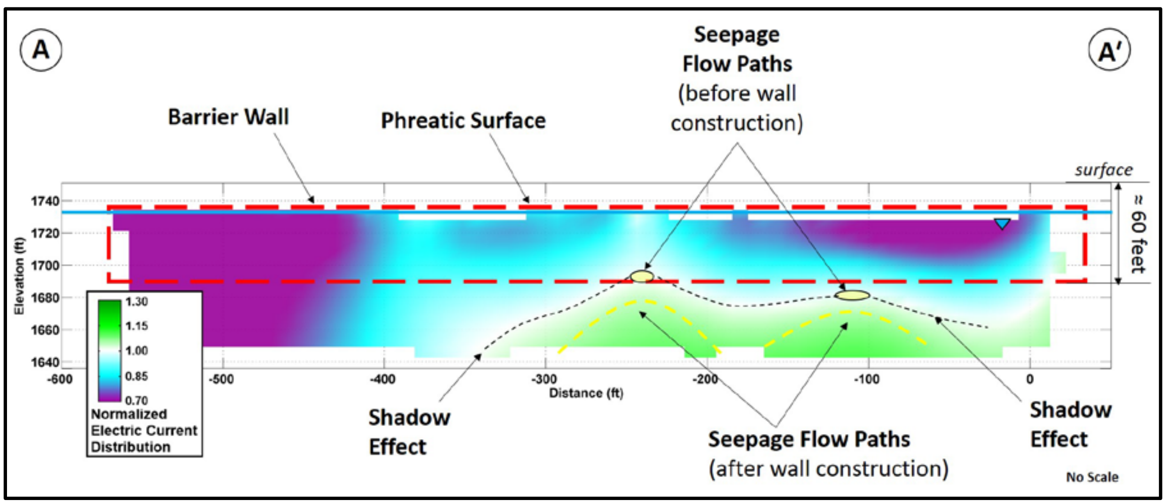


Figure 8 – Survey 1 Longitudinal Profile (Section A-A′)

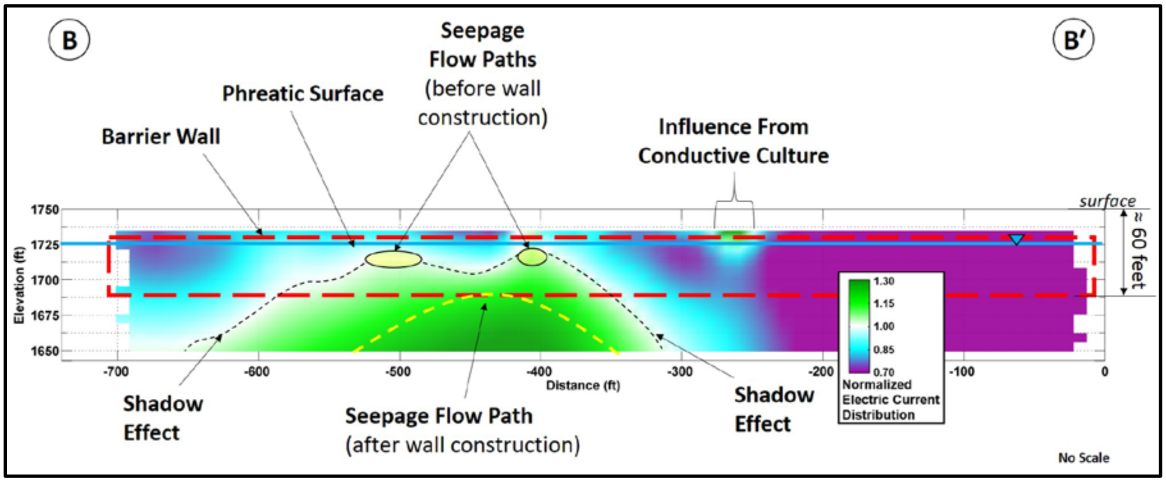


Figure 9 – Survey 2 Longitudinal Profile (Section B-B′)

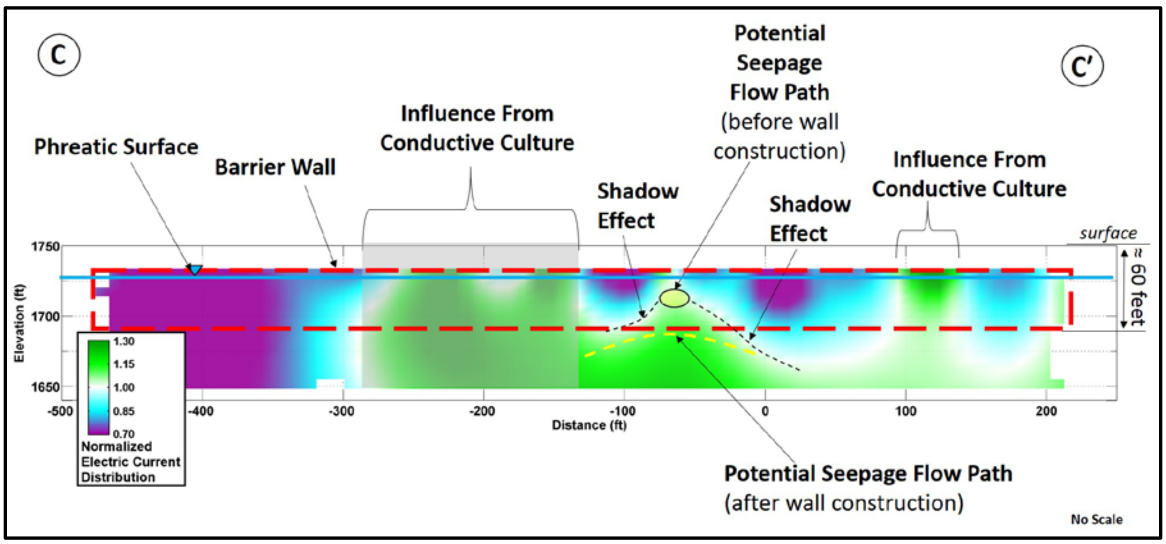
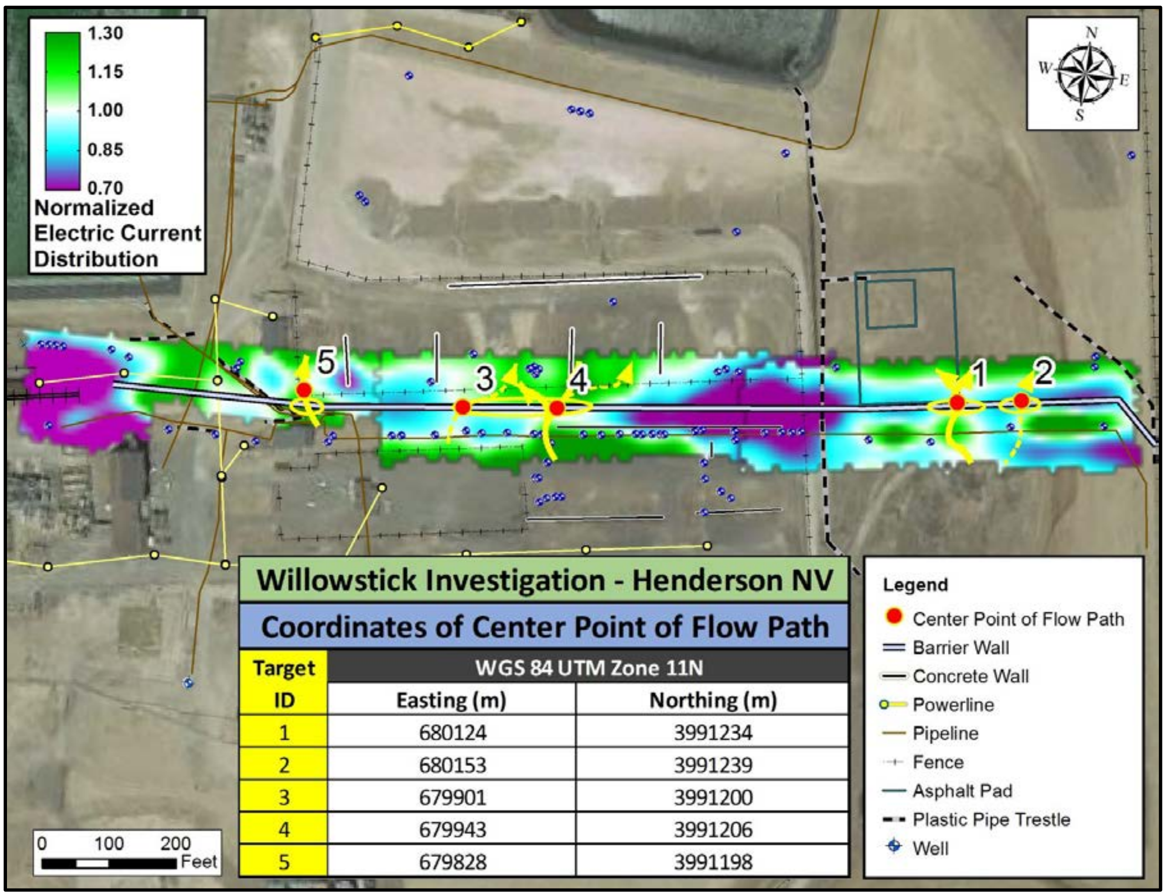


Figure 10 – Survey 3 Longitudinal Profile (Section C-C′)

As mentioned, the dark green shaded areas identify stronger-than-expected electric current flow, and certain of these have been interpreted as preferential groundwater flow paths, as shown in Figures 8-10. At first glance, it was thought that some of the peak anomalous green shaded areas (interpreted as preferential groundwater flow paths) occur through the barrier wall. However, after careful analysis of the ECD models, it is theorized that the dark green peaks positioned above the bottom of the wall (see yellow ovals) represent the depth of flow paths before the wall was constructed. These paths of higher interconnected porosity—or better described as paths of higher transport porosity—are observed both in front and in back of the wall in the ECD models. However, they appear "cut off" right at the wall, suggesting that groundwater along these pathways is forced *beneath* the wall, which is indicated by the yellow dashed lines in Figures 8-10.

In Figures 8-10, note also how the green shaded areas spread out downward beneath the noted groundwater flow paths. This is called the "shadow effect". A good analogy for explaining the shadow effect is to think of the survey data as shining a flashlight downward from above (because measurements can only be taken from above). If there is a solid object (or in this case a flow path or conductive pathway) the top will be illuminated but a shadow will be cast below the object, as noted in the figures.

Figure 11 provides coordinates of the noted flow paths where groundwater is most concentrated as it passes beneath the barrier wall. Since there is no formal stationing for the barrier wall, UTM coordinates are provided to help locate preferential flow paths. As mentioned, the flow paths occur beneath the wall and not through, over or around the wall. The widths of the flow paths are more difficult to define because they occur beneath the phreatic water surface in silty sandy soils that don’t exhibit sharp electrical contrasts or specific edges to the flow paths. Please note that approximate widths and depths (shown in the figures) were determined from model analysis and should be field verified before performing any remediation work.



Target ID	WGS 84 UTM Zone 11N Easting (m)	WGS 84 UTM Zone 11N Northing (m)
1	680124	3991234
2	680153	3991239
3	679901	3991200
4	679943	3991206
5	679828	3991198

Figure 11 – Coordinates of Groundwater Flow Paths

The Willowstick investigation has met the objectives of the investigation by identifying preferential groundwater flow paths beneath the barrier wall. No other parts of the wall, either through, beneath, over or around the wall exhibited a pattern of preferential groundwater flow. The barrier wall itself appears to work as designed and is void of any preferential seepage flow paths through the slurry wall. The information contained in this report can be used by Ramboll Environ in making informed, guided and cost-effective decisions concerning how to further characterize, monitor, and possibly remediate—if necessary—excessive groundwater from bypassing the barrier wall to the north.

2.0 SURVEY 1

2.1 General

For each of the three Willowstick surveys completed at the NERT site, we performed six basic steps or processes to complete and interpret the survey results. These are discussed in detail for Survey 1. Surveys 2 and 3 underwent the same general process of data collection, modeling and interpretation and will be presented more briefly to avoid repetitious discussion.

2.2 Step 1 – Survey Design and Layout

Figure 12 presents the layout for Survey 1. The map shows features that could be pertinent to the investigation, including possible conductive culture.

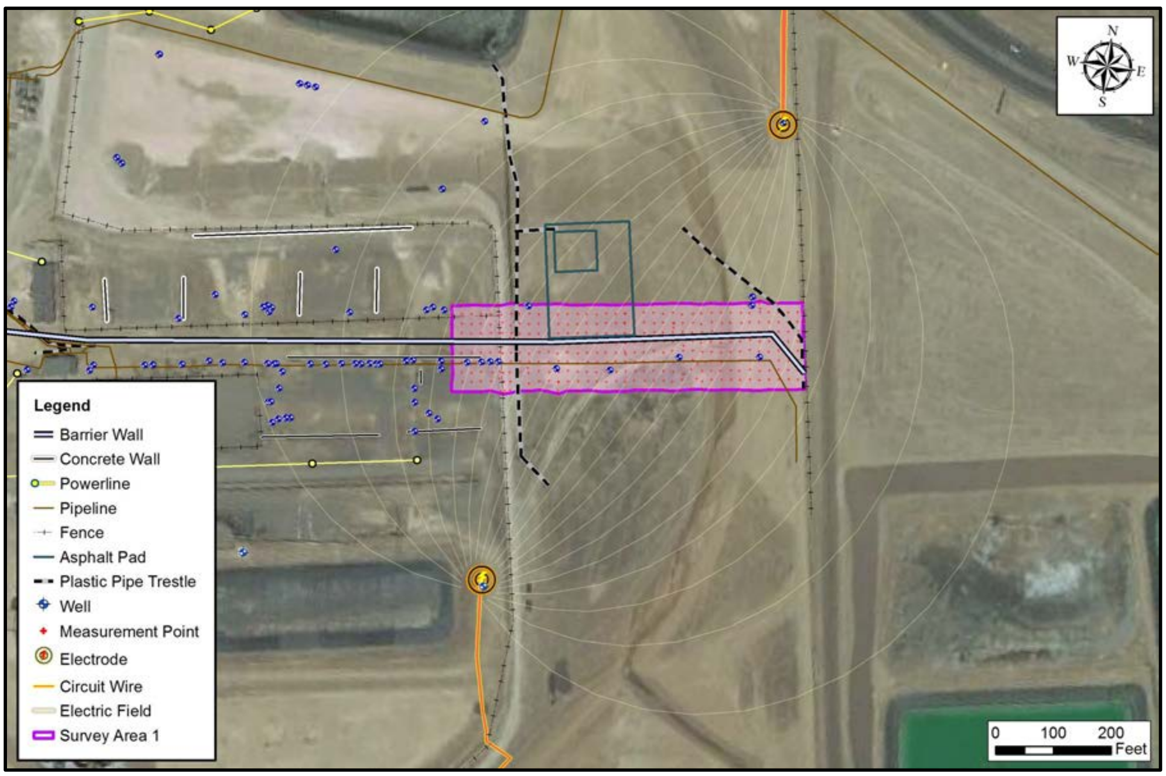


Figure 12 – Survey 1 Layout

In Figure 12, the coverage area for Survey 1 is outlined in purple. Numerous small red "+" symbols denote measurement stations, which were established on a 50-foot (15 m) grid. The field crew recorded the GPS position and elevation of each measurement station as part of the fieldwork, which is critical to quality control measures, data processing, modeling and interpretation. The grid spacing was adequate to obtain sufficient detail and resolution for identifying preferential electric current flow paths, while at the same time optimizing funds available for the investigation.

The red/orange circuit wire—connecting the strategically placed electrodes—was positioned in a large loop around the study area. The electrodes and circuit wire are located outside the study area as much as possible due to the strong magnetic field influence around them. Due to the fact that 100% of the electric current must pass through the circuit wire and electrodes, the magnetic field intensifies near these appurtenances. The spread of thin light-colored lines illustrates the general or approximate distribution of electric current through, beneath and around the barrier wall for this survey setup.

2.3 Step 2 – Predicted Magnetic Field Map

To identify areas of greater or lesser conductivity through the subsurface study area, a model was created for Survey 1's setup to calculate and predict the magnetic field response at each measurement station given the layout of electrodes, circuit wire and topography. This prediction is made based on a homogenous subsurface conductivity condition, and a fairly uniform-looking magnetic field is the result (see Figure 13).

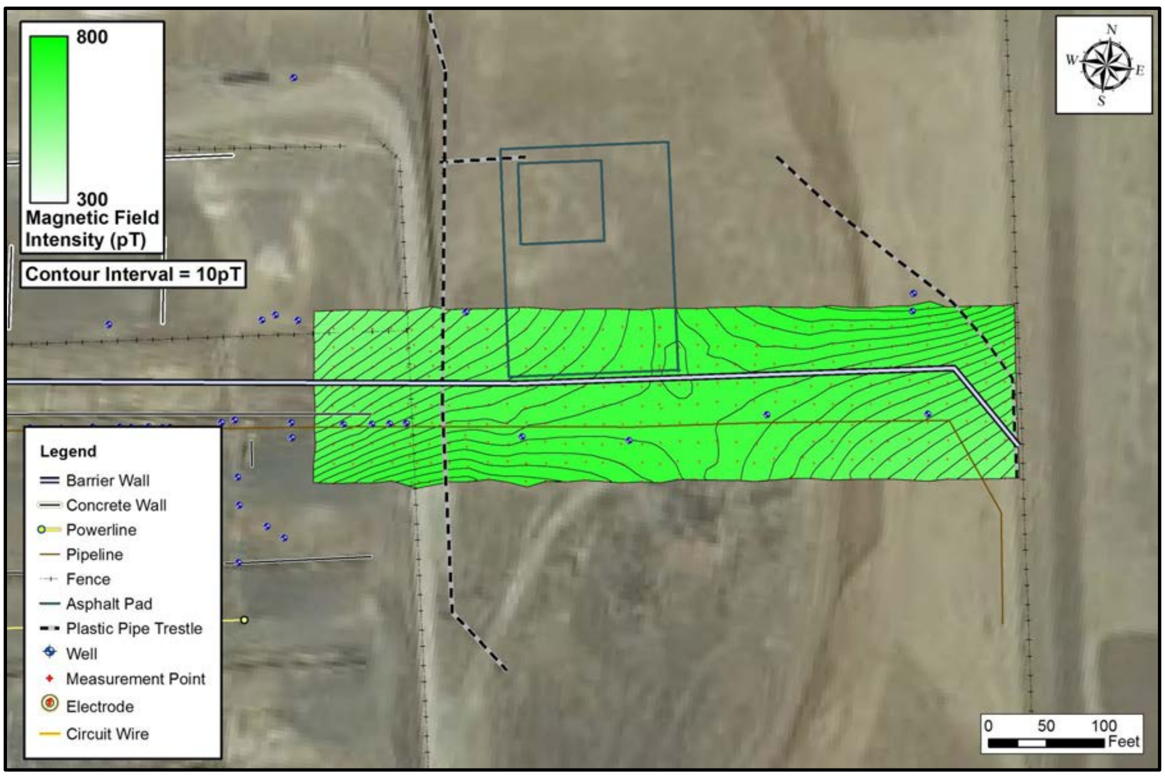


Figure 13 – Survey 1 Predicted Magnetic Field Map

It should be noted that among numerous Willowstick surveys performed worldwide, site conditions *never* match a perfectly homogeneous earth model—nor are they expected to—but it is highly useful to compare the data to the outcome of a homogeneous model.

Given a particular survey setup with specific electrode locations, circuit wire layout, and topography, the Willowstick tool determines the magnetic field intensity occurring at each given location *compared to what it would be if the subsurface were electrically homogeneous*—which can be calculated by proper application of known geophysical principles. A comparison of the “measured” to the level that was “expected” from a homogeneous earth is highly useful. For example, the electric current density may be 50% stronger at a particular location than it would be in the “homogeneous-earth” case. The comparison simply causes true heterogeneity (due to subsurface differences) to stand out or become more visible. Extreme care is taken in all survey configurations so that heterogeneity due to proximity, geometric relationship with electrodes, circuit wire, and topography are prevented from influencing the results of the survey. Fundamentally, the technology detects the preferred connective and conductive pathways between two selected points, and in order to do so, the signal emerging from preferred paths of electric current flow must be distinguishable from the diffuse or “background” flow pattern—which is always present and is often the dominant part of the signal. Fortunately, the background flow pattern can also be predicted with proper application of the laws of physics, enabling subtler preferential electric current flow paths to be detected than would otherwise be possible.

2.4 Step 3 – Observed or Measured Magnetic Field Map

Figure 14 presents the magnetic field observed (or measured) when the study area for Survey 1 was energized with the signature electric current.

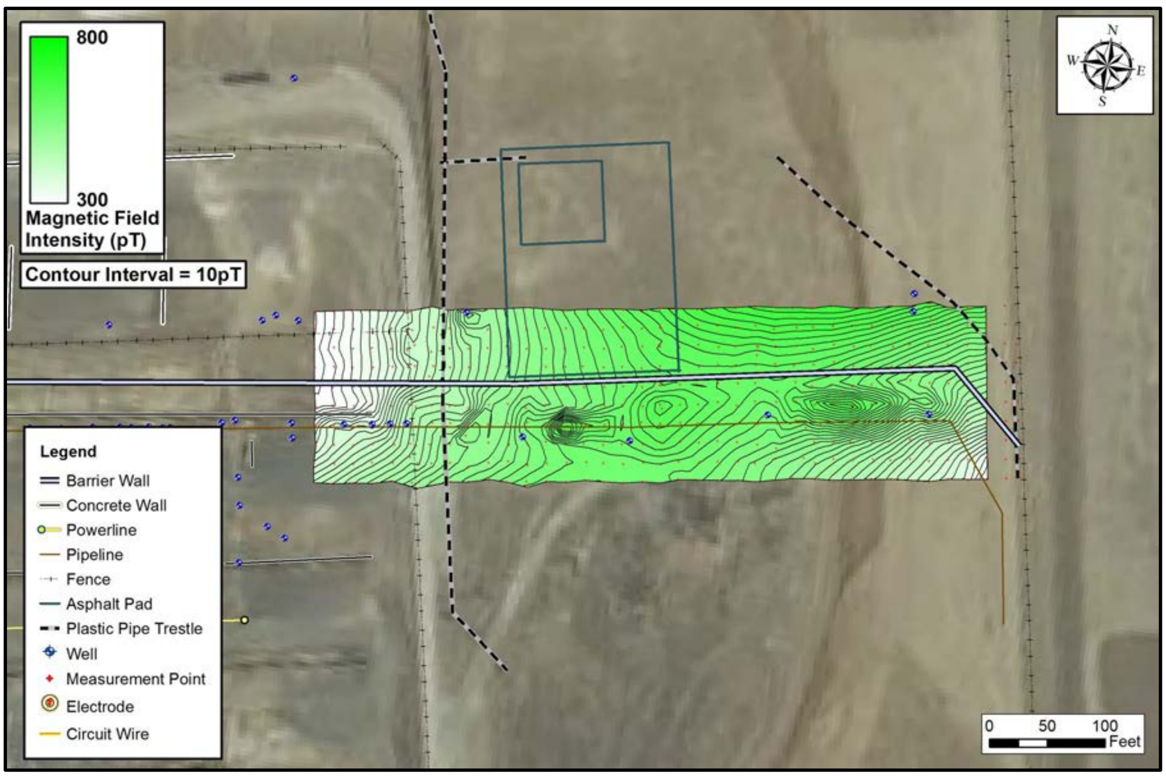


Figure 14 – Survey 1 Observed Magnetic Field Map

The measured or “observed” magnetic field map can be difficult to interpret without further analysis. Electric current can gather on conductive culture that may exist within the study area—such as pipelines and fences, etc. For this reason, filtering may be performed to reduce the effect of high-gradient interference to enable better interpretation of electric current flow through the subsurface study area.

The data was compared to the "homogeneous earth" magnetic field based on uniform flow in an electrically homogeneous earth. As mentioned, this causes the concentration of electric current due to heterogeneity, or changes in conductivity (such as potential seepage flow paths and patterns), to stand out.

2.5 Step 4 – Ratio Response Map

By filtering the observed magnetic field data and correcting it with the predicted magnetic field data, a ratio response map is created which removes electric current bias from the data set and shows areas of anomalous electric current flow—greater or lesser than the homogeneous model (see Figure 15).

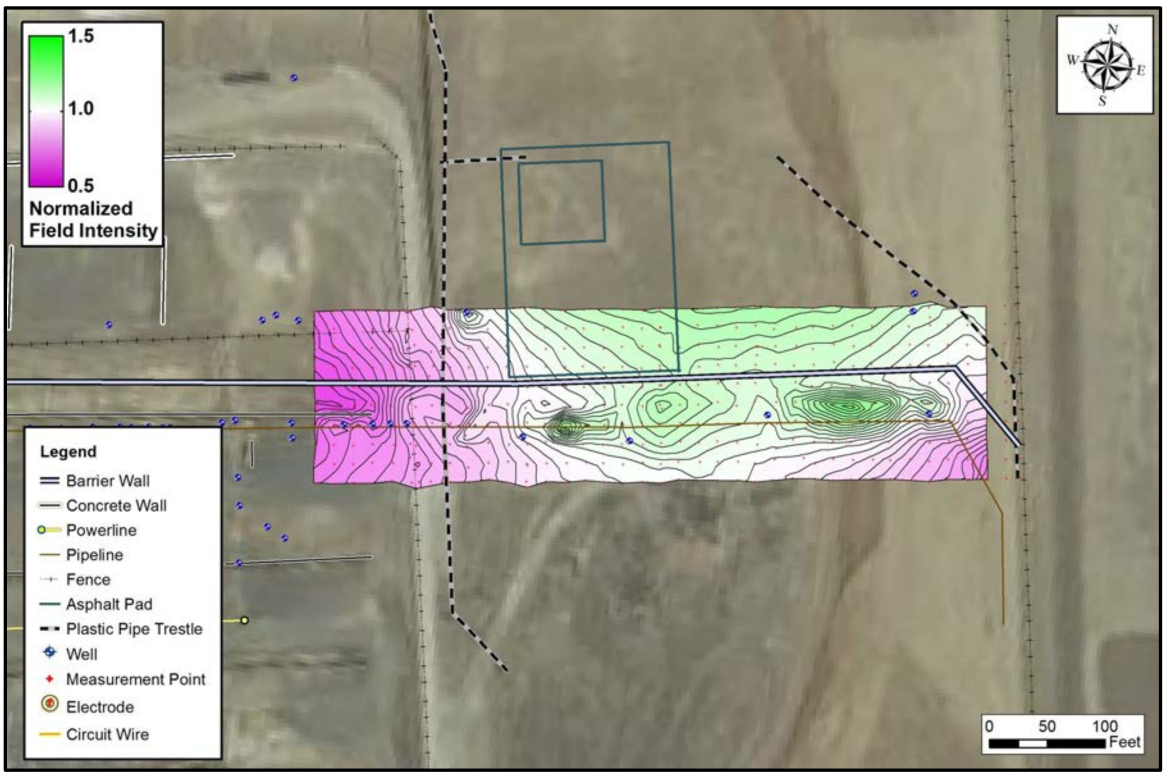


Figure 15 – Survey 1 Ratio Response Map

In the Ratio Response Map, the white shaded contours (where the ratio is approximately 1:1) show where the magnetic field intensity is equivalent to that expected by the homogeneous model. Areas shaded purple indicate magnetic field is less than expected, and areas shaded green indicate magnetic field is greater than expected. In summary, the ratio response map is simply a "*footprint*" map indicating the relative intensity of the magnetic field, or where electric current flow is stronger (green) or weaker (purple) than expected based on a homogeneous background model. It should also be noted that the green shaded area—pathway (where electric current is most concentrated) occurs along the centerline between the two electrodes. This is simply coincidental (as explained in Section 1.3). The ratio response map is effective at revealing where electric current is most concentrated as it flows through the subsurface study area. To further interpret the ratio response data and better characterize the position of preferential electric current flow, the data was subjected to an inversion algorithm designed to predict the distribution of electric current flow in three-dimensional space. The inversion model is referred to as an Electric Current Distribution (ECD) model.

2.6 Step 5 – ECD Model

At this point, the distribution of electric current flow beneath the study area—especially the depth of preferential flow paths—remains unknown until modeling is performed. The magnetic field is only measured from the ground surface (above a preferential flow path) and not below or beside the path, so modeling is required to identify a more accurate position (especially depth) of preferential electric current flow. To estimate depth, the ratio response data was processed by an inversion algorithm designed to predict the distribution of electric current flow in three-dimensional space within the subsurface study area. The inversion result is referred to as an Electric Current Distribution or ECD model. Figure 16 presents an example view demonstrating several different slices of the Willowstick ECD Model for Survey 1.

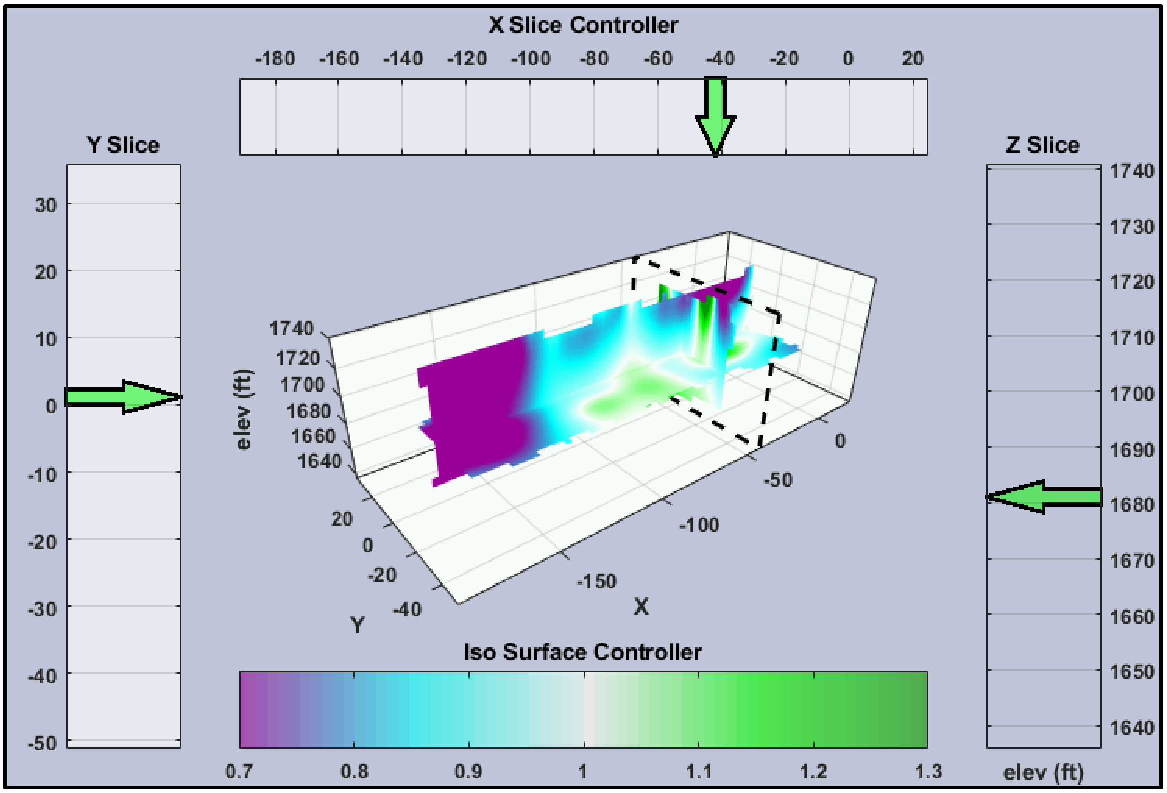


Figure 16 – Survey 1 ECD Model Viewer

As mentioned, in the model, the dark green shading identifies areas where electric current density is more concentrated than predicted. On the other end of the scale, the dark purple shading identifies areas where electric current is less concentrated. The model viewer can generate slices at any elevation or cross-section position within the volume as demonstrated in the example above.

2.7 Step 6 – Interpretation

Analyzing all the results obtained from Survey 1, including the Ratio Response Map and ECD inversion results, an interpretation was made considering all the information combined with relevant site features to produce the best interpretation possible. In Figures 17, 18 and 19 we present a combination of Survey 1's ECD model slices (plan, profile and cross-sectional views, respectively) that identify where seepage preferentially bypasses the wall beneath Survey 1's study area.

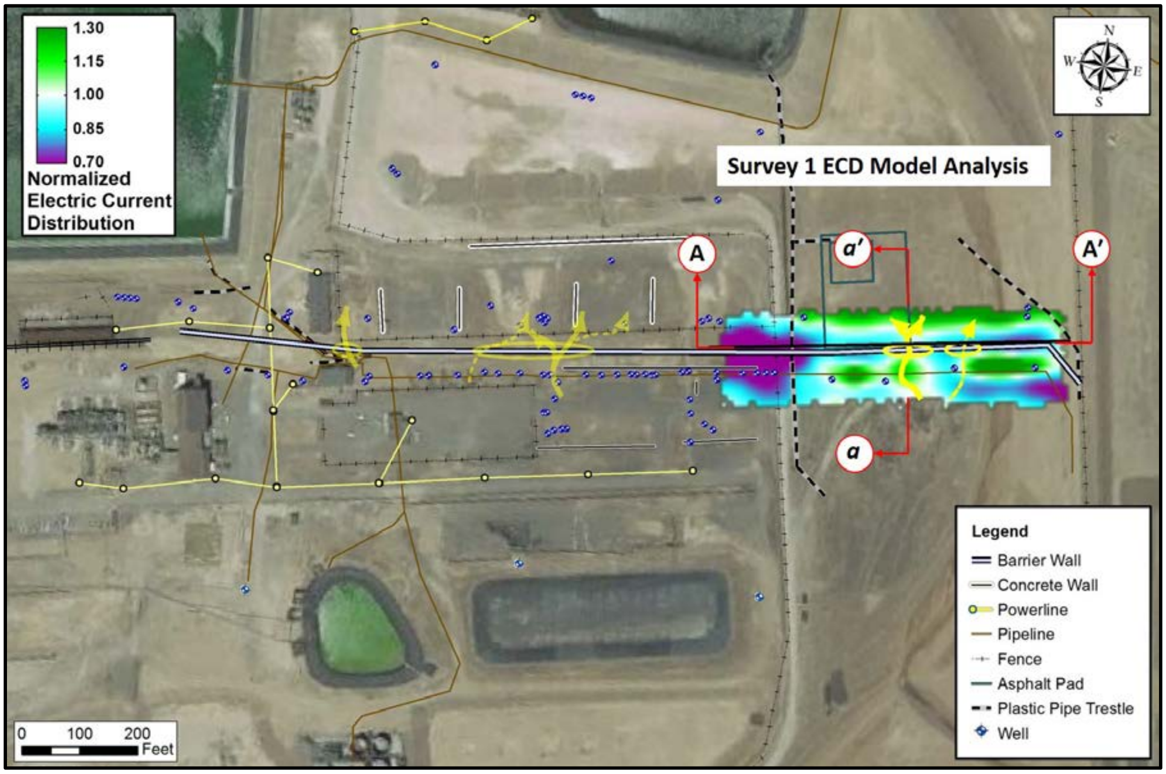


Figure 17 – Survey 1 ECD Model Slice (taken near bottom of barrier wall)

In Figure 17, the ECD model slice indicates the relative intensity of the electric current flow, or where electric current flow is stronger (green) or weaker (purple) than expected. The yellow arrows identify the center of the preferential groundwater flow paths. Some electric current follows along pipelines located in front of the wall and along a fence line located in back of the wall. Due to the conductive nature of these facilities, this was expected and taken into account while interpreting the data.

Figure 18 presents an ECD model profile slice of Survey 1 (Section A-A′) taken at the wall.

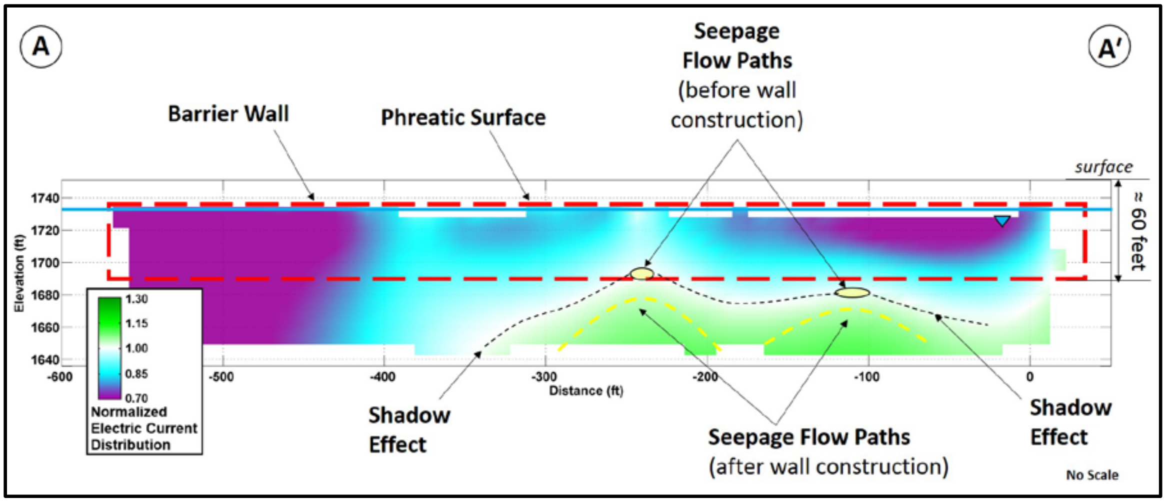


Figure 18 – Survey 1 Section A-A′

Please note that there appears to be two groundwater flow paths beneath the wall—most apparent in Figure 18. Figure 19 presents a cross-sectional view (Section a-a′)—taken through the center of the seepage flow path.

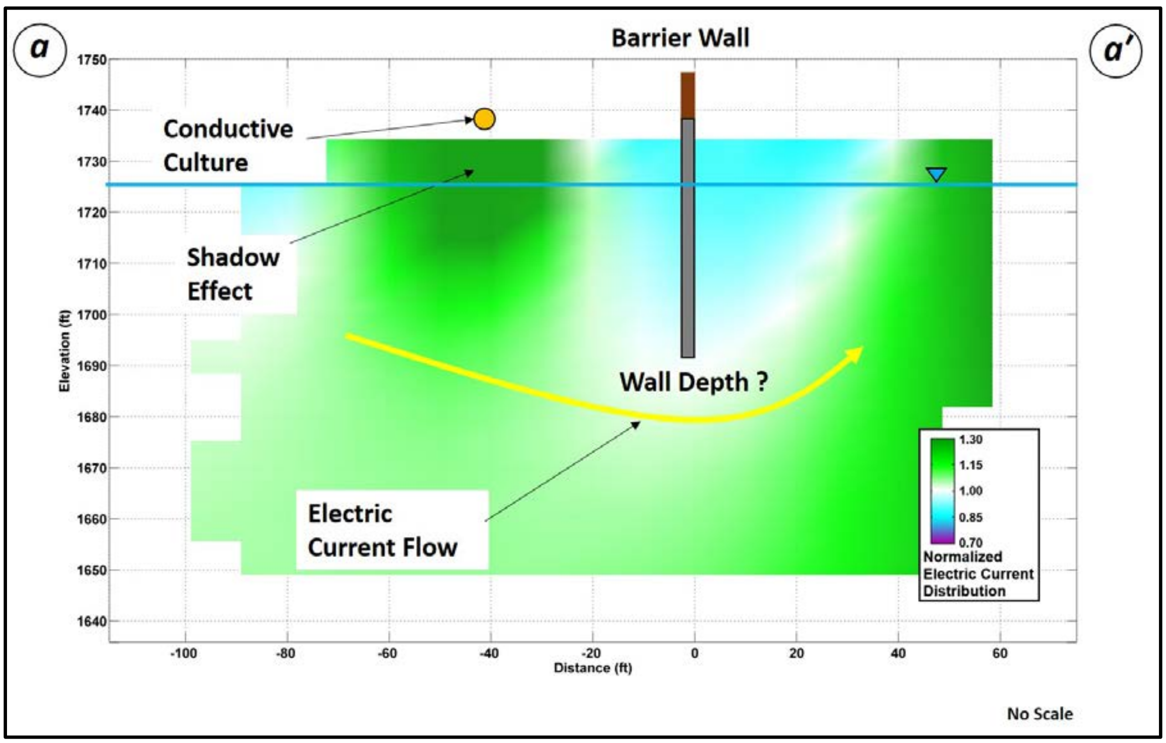


Figure 19 – Survey 1 Section a-a′

As noted in Figures 18 and 19, electric current preferentially flows beneath the wall and not through or around the wall as evident by the blue or purple shading surrounding the wall. The yellow arrows and dashed lines in the figures identify the center position of preferential electric current flow—interpreted as the center of the preferential groundwater flow paths. Also, note how the green shaded areas in Figure 18 spreads out downward beneath the noted groundwater flow paths. This is called the "shadow effect". A good analogy for explaining the shadow effect is to think of the survey data as shining a flashlight downward from above (because measurements can only be taken from above). If there is a solid object (a flow path or some conductive pathway) the top will be illuminated but a shadow will be cast below the object, as noted in the figures. Also, due to edge effects from the ECD model—most notable in Figure 19—care must be taken when interpreting features near edges of the model. Regardless, it is quite apparent that groundwater flows beneath the barrier wall and not through or around the wall.

Based on ECD model analysis, a search window is given to narrow potential drilling targets to field-verify, intercept, and further characterize the noted seepage flow paths beneath the barrier wall for monitoring and/or remediation purposes (see Figure 20). Each of the target coordinates given in the figures is summarized in a table at the end of this report.

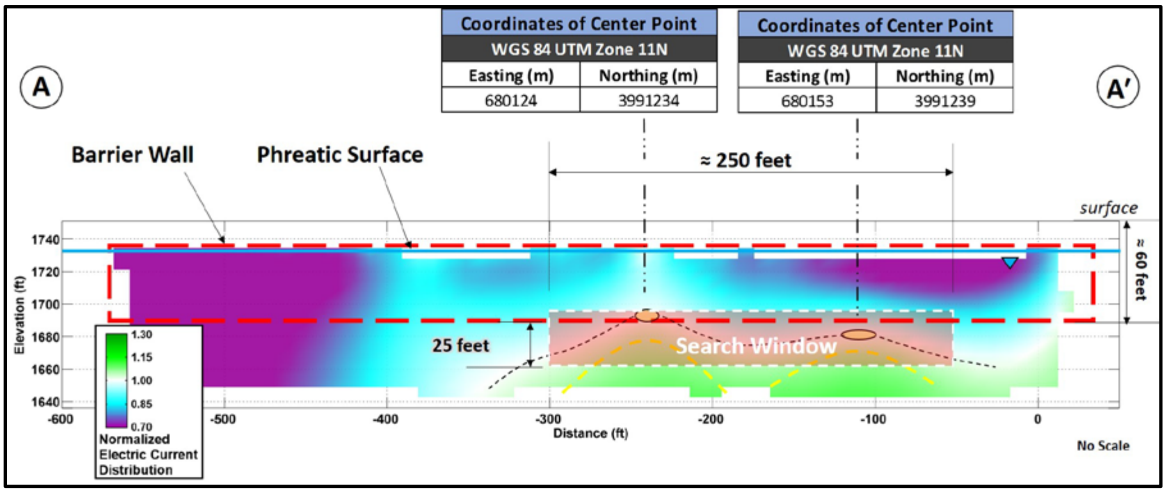


Figure 20 – Survey 1 Search Window

The red shaded window indicates where electric current is most concentrated and approximates the seepage flow path's maximum depth and width. Hence the maximum depth below the bottom of the barrier wall is estimated to be roughly 25 feet (beyond the wall). The width of the flow path is a little harder to estimate due to the fact that the flow path resides below the phreatic water surface and are located in silty sandy materials that don't exhibit a sharp electrical contrast or specific edge to the flow paths. The search window also extends a few feet above the wall—where reinforcement may be needed. Since there is no formal stationing for the barrier wall, UTM coordinates are provided to help locate the center of the preferential flow paths. Please note that the locations and depths were determined from model analysis and should be field verified before performing any remediation work.

3.0 SURVEY 2

3.1 Survey Design and Layout

Survey 2 utilized a similar electrode configuration as did Survey 1, but Survey 2's study area is shifted to the west—targeting electric current to flow through the center portion of the barrier wall (see Figure 21).

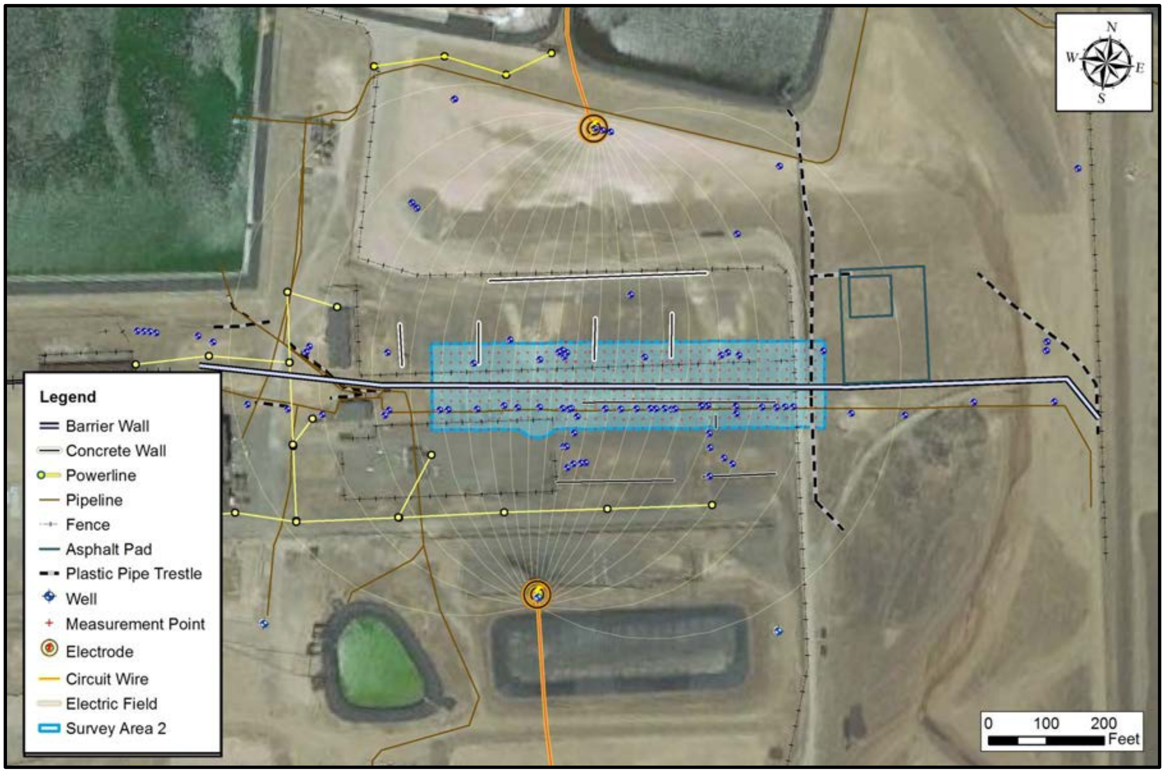


Figure 21 – Survey 2 Layout

3.2 Results and Interpretation

Survey 2 uses the same data reduction and modeling procedures as described for Survey 1; therefore, Survey 2 will be presented in an abbreviated format. To summarize the results of Survey 2, Figures 22, 23 and 24 present ECD model slices (elevation, longitudinal profile and cross-sectional slices, respectively) revealing the findings of Survey 2's investigation.

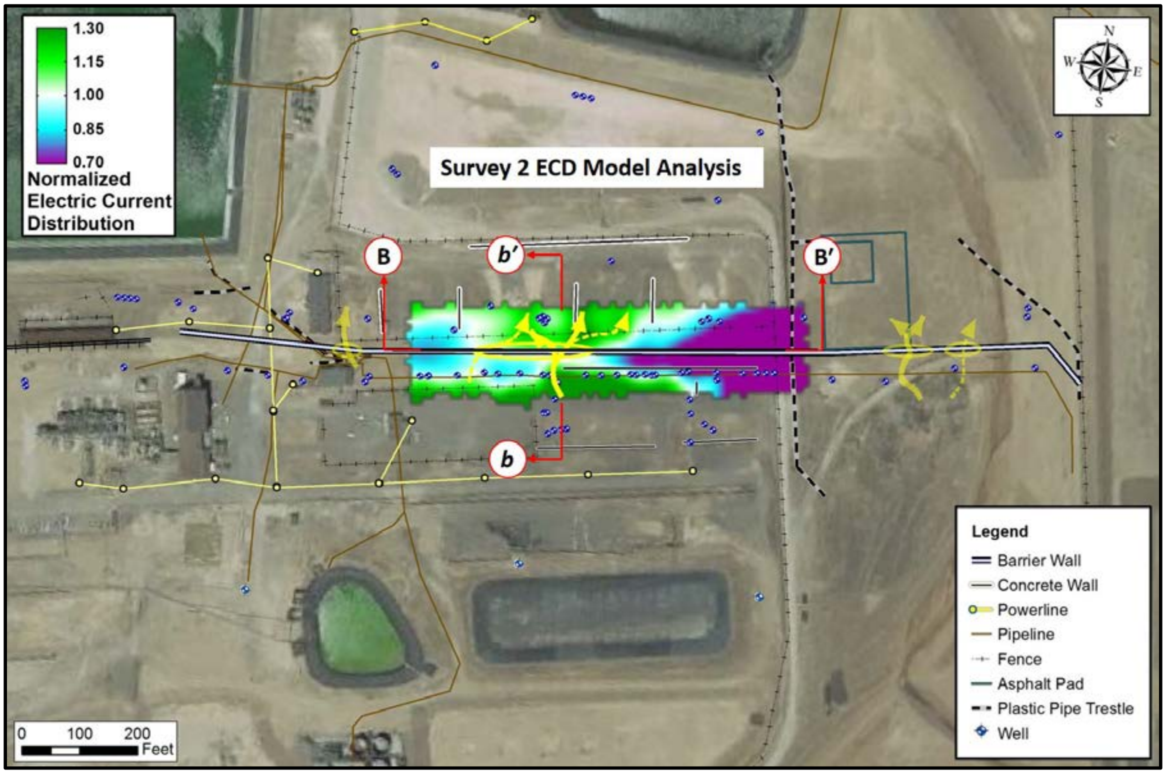


Figure 22 – Survey 2 ECD Model Slice (taken near bottom of barrier wall)

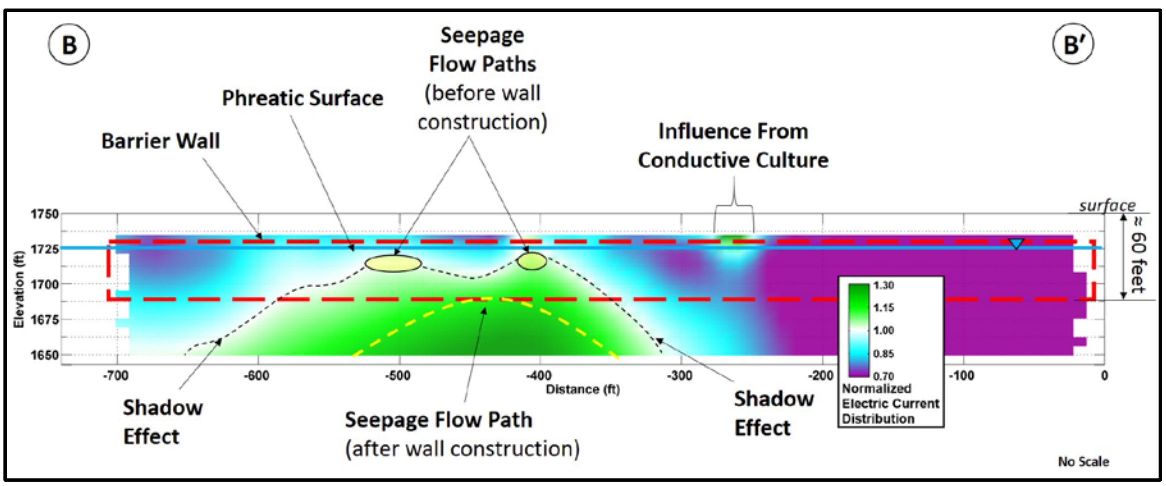


Figure 23 – Survey 2 Section B-B′

At first glance, when interpreting the flow paths observed in Survey 2, it was thought that some of the anomalous green shaded peaks (interpreted as preferential groundwater flow paths) occur *through* the barrier wall. However, after careful analysis of the ECD models, it is theorized the dark green anomalous peak areas positioned above the bottom of the wall represent the depth of flow paths before the wall was constructed (see yellow ovals). These paths of higher interconnected porosity—or better described as paths of higher transport porosity—can be observed in front and in back of the wall in the ECD model. However, at the wall the flow paths are cut off. Due to construction of the wall, groundwater following along these pathways changes direction and flows beneath the wall as suggested by the yellow dashed "*arched*" line. After the wall was constructed, the two noted groundwater flow paths appear to have merged beneath the wall as one flow path. This is most apparent in Figure 24 as evident by the blue and purple shading surrounding the barrier wall.

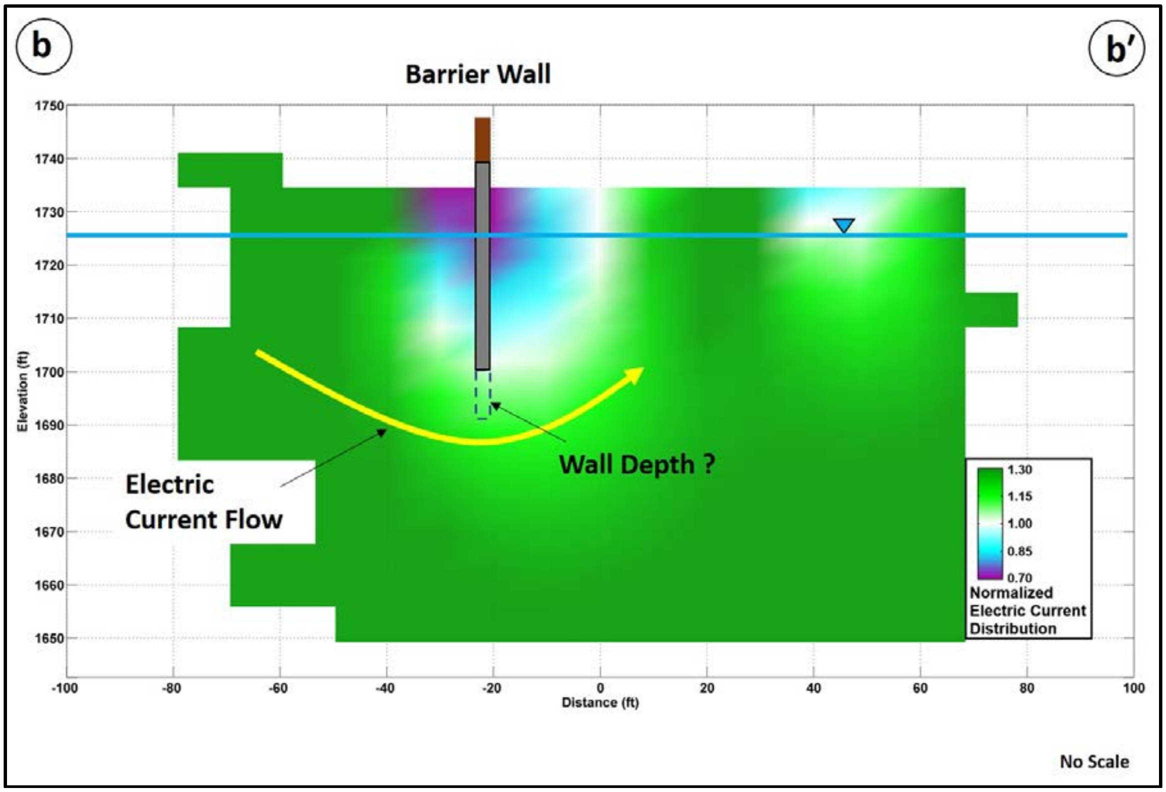


Figure 24 – Survey 2 Section b-b′

Also, of importance is the observation that the barrier wall may not extend as deep as the reported 60 feet in all places along the wall. This may be due to topographic relief or from drift of the cutter blade while constructing the wall. In either case, the results of the survey suggest that the bottom of the wall may not extend to the same elevation for its entire length.

Based on ECD model analysis of Survey 2, a search window is given to narrow potential drilling targets to field-verify, intercept, and further characterize the noted seepage flow paths beneath the barrier wall for monitoring and/or remediation purposes (See Figure 25).

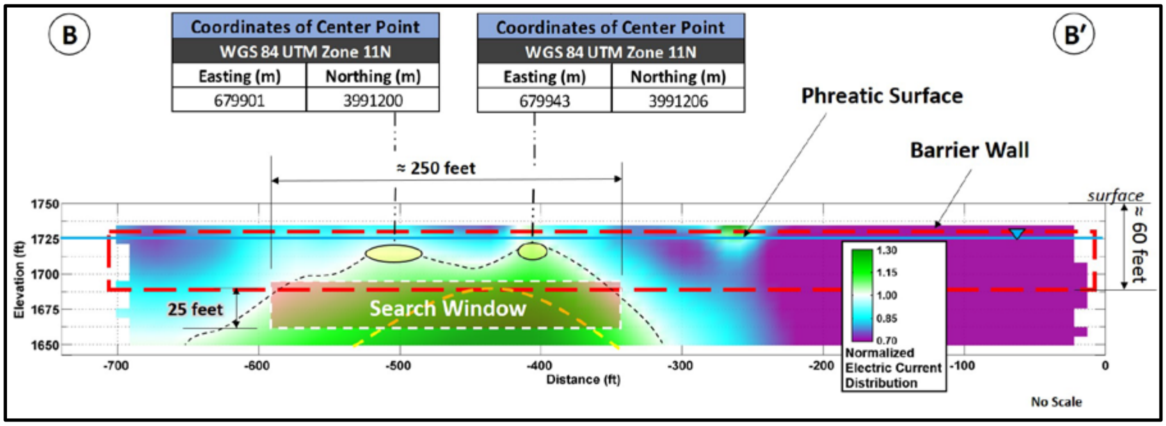


Figure 25 – Survey 2 Search Window

4.0 SURVEY 3

4.1 Survey Design and Layout

Survey 3 utilized an electrode configuration similar to Surveys 1 and 2, but Survey 3's study area is shifted to the west end of the barrier wall (see Figure 26).

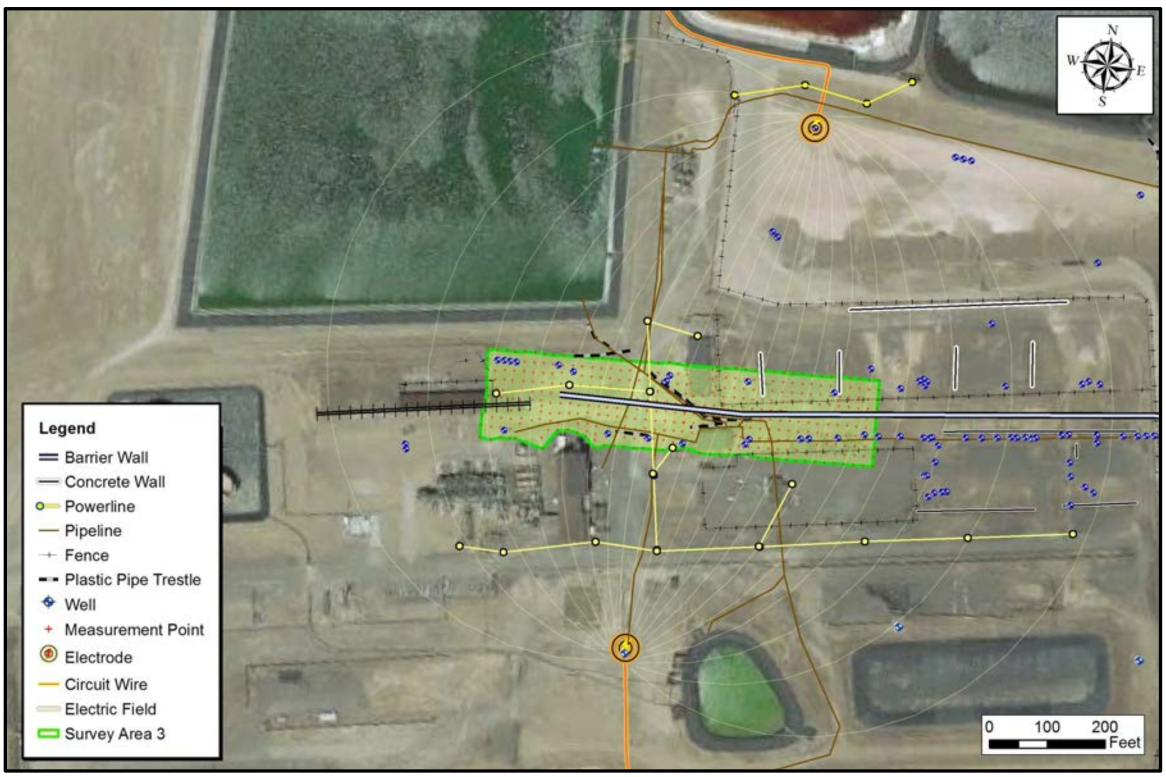


Figure 26 – Survey 3 Layout

4.2 Results and Interpretation

Survey 3 uses the same data reduction and modeling procedures as described for Surveys 1 and 2. Figures 27, 28 and 29 present ECD model slices (elevation, longitudinal profile and cross-sectional slices, respectively) that summarize the findings of Survey 3.

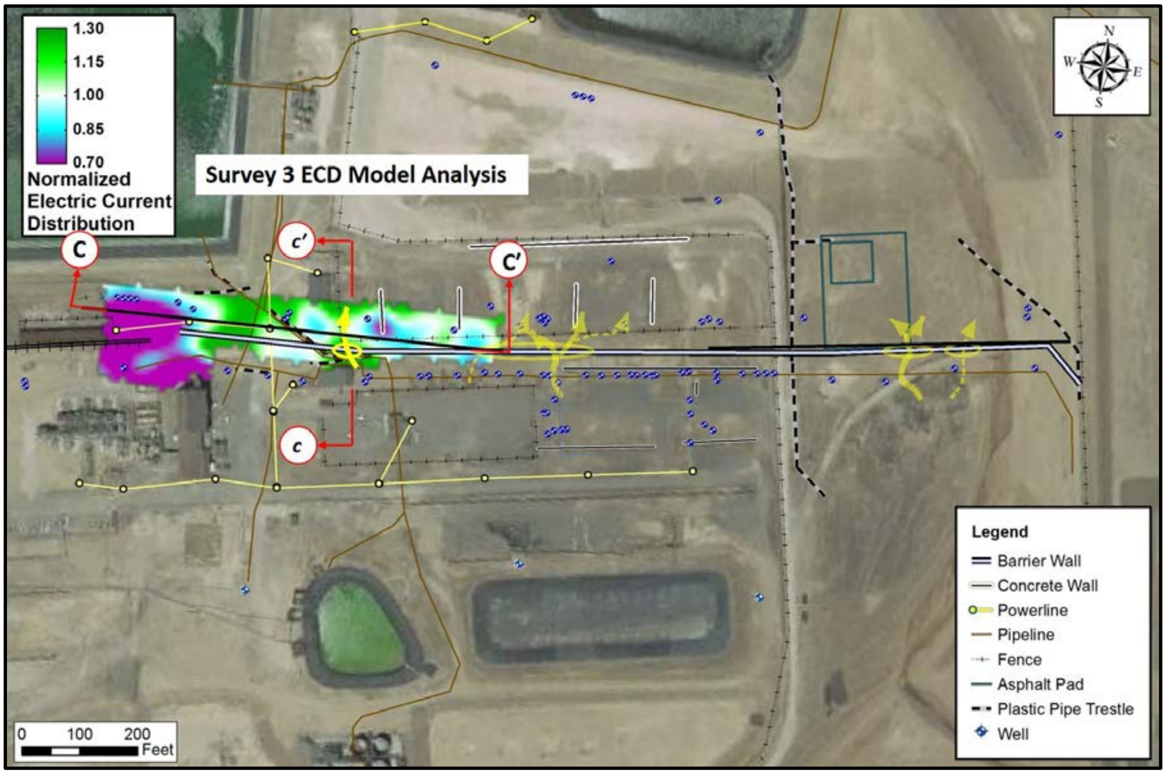


Figure 27 – Survey 3 ECD Model Slice (taken near bottom of barrier wall)

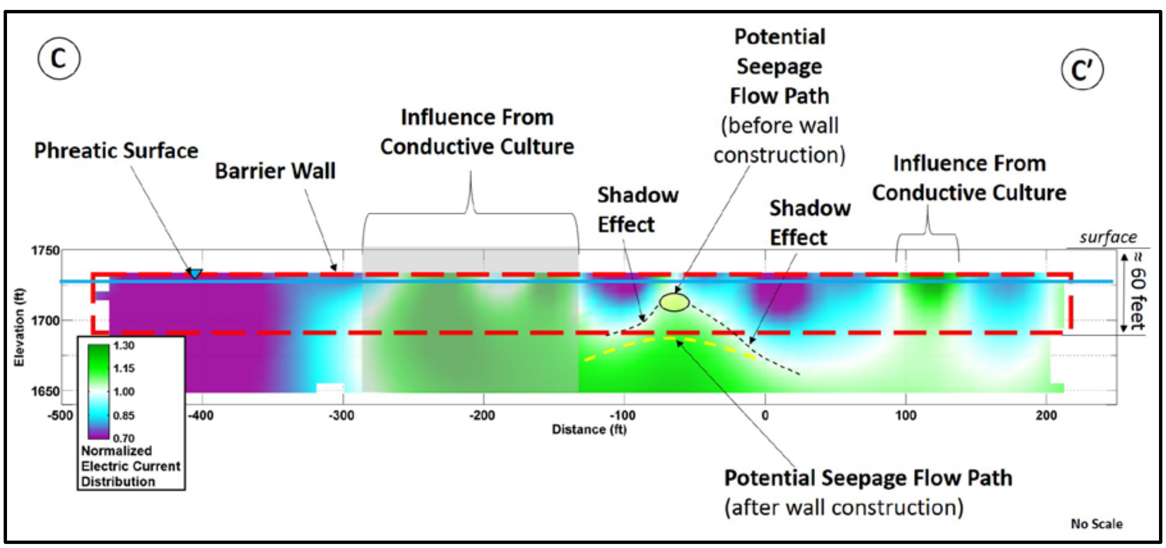


Figure 28 – Survey 3 Section C-C′

Unlike Surveys 1 and 2, Survey 3's longitudinal profile is taken 10 feet down-gradient of the barrier wall because conductive culture is located directly up-gradient of the potential groundwater flow path. The groundwater flow path is referred to as a "*potential*" flow path because of the close proximity to conductive culture that crosses through the wall in this area. The area of influence from culture has been clouded in Figures 28 and 30 with a gray transparent rectangle for ease of interpretation. Nevertheless, the anomaly observed just downstream of the wall (labeled as Potential Seepage Flow Path) exhibits all the characteristics of a potential groundwater flow path.

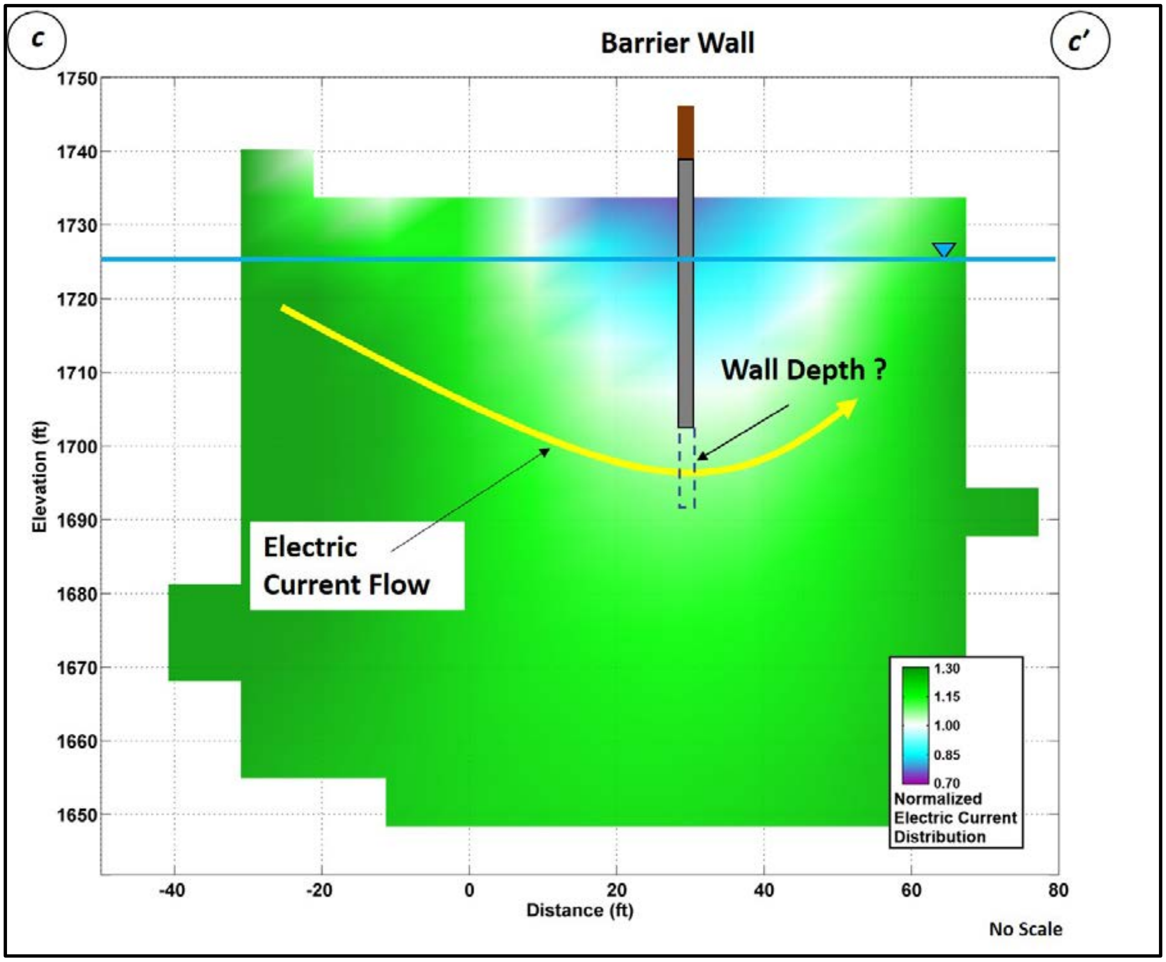


Figure 29 – Survey 3 Section *c-c′*

As noted in Survey 2, the bottom of the barrier wall may not extend as deep as reported. Again, this may due to topographic relief or from drift of the cutter blade while constructing the wall. In either case, the bottom of the wall may not extend to the same elevation for its entire length.

Based on ECD model analysis of Survey 3, a search window is given to narrow potential drilling targets to field-verify, intercept, and further characterize the noted seepage flow path beneath the barrier wall for monitoring and/or remediation purposes (See Figure 30).

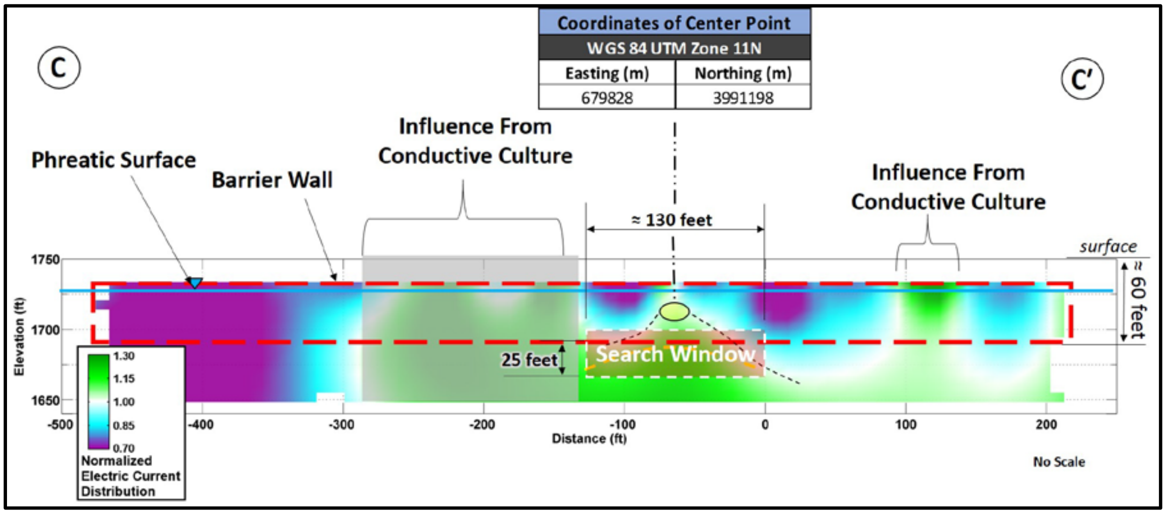


Figure 30 – Survey 3 Search Window

5.0 CONCLUSION

5.1 Objectives Met

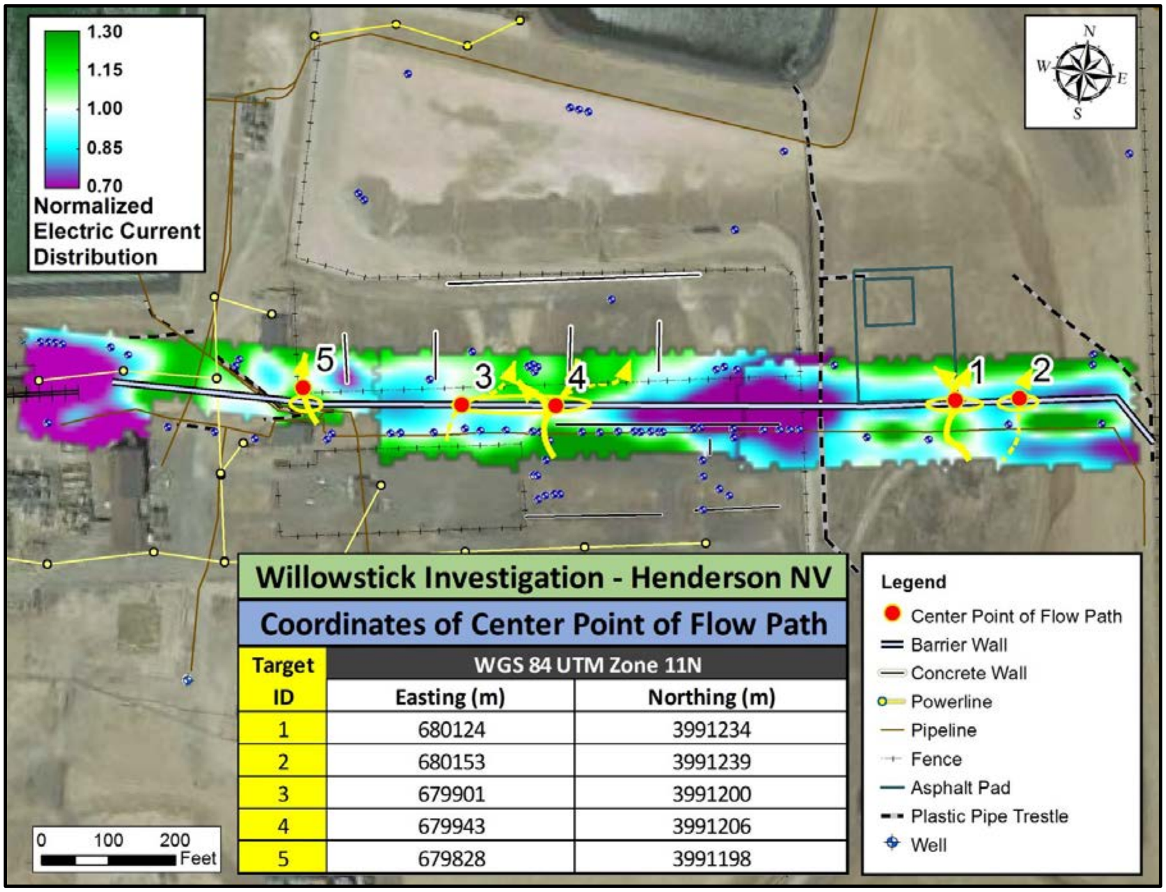
The Willowstick investigation has met the objective by identifying preferential groundwater flow paths bypassing the barrier wall. Three survey configurations were employed for the investigation—biasing electric current to flow through, beneath, over and around the barrier wall. As the signature electric current flowed between strategically placed electrodes (located up-gradient and down-gradient of the barrier wall, it concentrated in the more conductive zones. (i.e., in areas of highest transport porosity) where groundwater preferentially concentrates as it finds its way around, beneath and over the wall.

The flow and distribution of electric current was carefully evaluated and three specific flow paths were identified. All three flow paths where identified as flowing <u>beneath</u> the wall and none were found flowing through, around or over the wall.

Two of the flow paths are interpreted as primary groundwater flow paths, and one is considered a secondary groundwater flow path—meaning that the anomaly is a little weaker and less distinguishable from the background and from nearby conductive culture influences, although in our analysis it still represents a likely groundwater flow path. Other than the three-noted preferential groundwater flow paths, no other areas of the wall exhibited preferential flow. Please note that the locations and depths of the three flow paths were determined from model analysis and should be field-verified before performing any remediation work.

5.2 Summary of Target Coordinates

Figure 31 summarizes the findings of the investigation and provides locations (coordinates) where preferential groundwater flow paths can be intercepted, ground proofed and further delineated.



Target	WGS 84 UTM Zone 11N	
ID	Easting (m)	Northing (m)
1	680124	3991234
2	680153	3991239
3	679901	3991200
4	679943	3991206
5	679828	3991198

Figure 31 – Groundwater Flow Path Coordinates

The information contained in this report can be used by Ramboll Environ in making informed, guided and cost-effective decisions concerning how to further characterize, monitor and possibly remediate groundwater from preferentially bypassing the barrier wall.

6.0 DISCLAIMER

6.1 Disclaimer

The Willowstick geophysical survey methodology is a new and emerging technology. The data, interpretations and recommendations obtained from the survey and modeling methodology is based upon sound applied physics and Willowstick's experience in working with and developing the technology. By definition, the evaluation of geologic, hydro-geologic and/or geophysical conditions is a difficult and an inexact science. However, Willowstick feels strongly that the technology has yielded information that can greatly help in determining the current conditions of groundwater flow at the NERT subsurface barrier wall site.

APPENDIX B
NATIONAL GPRS GEOPHYSICAL SURVEY REPORT

March 26, 2018

Ramboll
101 Carnegie Center
Princeton, NJ 08540

Attn: Jonathan Johnson / jcjohnson@ramboll.com

Subject: Pilot Geophysical Exploration Report
Ground Penetrating Radar, Electro Magnetic Induction, and Global Positioning Survey Results
Bentonite Cut-Off Wall - Bruce Woodbury Beltway & 8th Street., Henderson, Nevada

To: Jonathan Johnson

In accordance with your request and authorization, National Ground Penetrating Radar Service, Inc. (NGPRS) conducted a Geophysical Survey at the above referenced location. Our services included a subsurface survey, and report.

Report data obtained at the site will be held for 3 years at which time data will be discarded. Please advise us in writing if you wish to have us retain them for a longer period.

We appreciate the opportunity to have been of service on this project. If there are any questions regarding our review, please contact me Toll Free at (877) 556-4777.

Sincerely,

NATIONAL GROUND PENETRATING RADAR SERVICE, INC.

Ray Wagner
Professional Geologist

Stan Liszka
Certified Professional Geologist

PILOT GEOPHYSICAL EXPLORATION REPORT

Project Location:

Bentonite Cut-Off Wall
Bruce Woodbury Beltway & 8th Street.
Henderson, Nevada

Prepared for:

Ramboll
101 Carnegie Center
Princeton, NJ 08540

Prepared by:

National Ground Penetrating Radar Service, Inc.

Western Division Headquarters
818 West 7th Street, Suite 930
Los Angeles, California 90017

(818) 839-9971

Project No. 178951

Report Date:

March 26, 2018

Executive Summary

National Ground Penetrating Radar Service, Inc. (NGPRS) was retained by Ramboll (RAM) to perform a Ground Penetrating Radar (GPR), Electro Magnetics (EM), and Global Positioning System (GPS) survey at Bruce Woodbury Beltway & 8th Street. in Henderson, Nevada. The site is currently used for commercial industrial plant purposes, and the pilot geophysical survey was conducted over a covered surface in an exterior area consisting of approximately 4-acres. The purpose of the survey was to elevate the suitability of EM and GPR to locate the position of a bentonite cut-off wall installed to control ground water flow at a portion of the site.

Jeremy Mitchell and Sam Kirmis (NGPRS) performed the field work on February 22 and 23, 2018.

The exact location of the bentonite wall was not identified using GPR or EM during this exploration due to the following:

- The GPR signal was not able to penetrate deep enough to image the bentonite wall. Also, access limitations within the survey area due to fencing and concrete wall adjacent to the suspected location of the bentonite wall were also encountered during the GPR survey.
- Interference from subsurface piping and surface features (fencing and concrete wall) or structures limited the ability of the EM to determine the position of the bentonite wall.

Based on the information presented in this report, we require the following:

• It is required to use manual hand digging and/or soft-digging techniques with air vacuums if excavating within three (3) feet of any underground utility or anomaly.

TABLE OF CONTENTS

TABLE OF ATTACHMENTS

1.0 INTRODUCTION

Tronox, LLC (TRONOX) owns and operates a commercial industrial plant located at Bruce Woodbury Beltway & 8th Street. in Henderson, Nevada (Figure 1). TRONOX is planning to install groundwater monitoring wells along an existing bentonite wall, and the bentonite wall needs to be located prior to monitoring well installation. Ramboll (RAM) was contracted byTRONOX to act as the Prime Contractor for the project.

National Ground Penetrating Radar Service, Inc. (NGPRS) was contracted by Jonathan Johnson representing RAM to conduct a Ground Penetrating Radar (GPR), Electro Magnetics (EM), and Global Positioning System (GPS) pilot geophysical survey to meet project requirements in accordance with NGPRS proposal No. 162656 and 162568 dated August 31, 2017.

1.1 Project Description

The purpose of the pilot geophysical survey was to locate, mark and map the location of a bentonite slurry groundwater cut-off wall (bentonite wall) to allow placement of groundwater monitoring wells on each side or the bentonite wall.

1.2 Scope of Work

Our Scope of Work (SOW) was to perform a Pilot Test to map changes in ground conductivity to and GPR survey of the following:

1. Perform a pilot geophysical exploration of an exterior, approximately 4-acre area.
2. Use Ground Penetrating Radar (GPR) to determine the effectiveness to locate and mark reflections representative of the bentonite wall.
3. Use Electro Magnetics (EM) to survey the property to locate conductive anomalies to correlate results with the bentonite wall location.
4. Use a Global Positioning System (GPS) to map the bentonite wall location.
5. Submit a written report of findings.

1.3 Project Location

A Survey Area Site Map is shown in Figure 2. The site is located north of the Bruce Woodbury Beltway at 8th Street in Henderson, Nevada. The survey area encompassed approximately 4-acres, and is outlined in white in Figure 2.

1.3.1 Surface Conditions

The survey was conducted in an exterior area over soil covered surfaces. Some physical limitations to access were encountered in the performance of this survey, which included site features (e.g., fencing and facility structures).

1.3.2 Subsurface Conditions

The United States Department of Agriculture GPR Soil Suitability map for Clark County, Nevada is shown in Appendix A. The map indicates a GPR survey should produce Moderate results in native soils. Taking into consideration engineered soil conditions, we anticipated the maximum GPR survey depth to be approximately four to six (4 - 6) feet, with a 400 megahertz (MHz) antenna.

2.0 SURVEY PROCEDURES

2.1 Equipment

2.1.1 Ground Penetrating Radar (GPR)

The GPR survey was conducted using a Geophysical Survey Systems, Inc. system (Model SIR3000) using an antenna with central frequency of 400 MHz and a 100 ns time window. The system includes a survey wheel that triggers the recording of the data at fixed intervals, thereby increasing the accuracy of the locations of features detected along the survey lines.

GPR uses a high-frequency electromagnetic pulse (referred to herein as "radar signal") transmitted from a radar antenna to probe the subsurface. The transmitted radar signals are reflected from subsurface interfaces of materials with contrasting electrical properties. The travel times of the radar signal can be converted to approximate depth below the surface by correlation with targets of known depths, including stratigraphic horizons, caskets, underground utilities, or by using handbook values of velocities for the materials in the subsurface. The acquisition of GPR data was monitored in the field on a graphic recorder and the real time images were immediately available for field use. The GPR data were also recorded digitally for subsequent processing. Interpretation of the records is based on the nature and intensity of the reflected signals and on the resulting patterns.

Equipment and settings are shown in Appendix B.

2.1.2 Electro Magnetics (EM)

A Geonics EM31 MK2 (EM) terrain conductivity meter was used to explore the property to determine if the EM could locate the bentonite wall based on elevated conductivity readings.

Prior to beginning the survey, the operation and calibration of the instrument was checked in a background area away from physical interferences (e.g., power lines, and fences). Operational instrument checks included the EM31's battery level and meter nulling (zeroing). EM31 calibration consisted of adjusting the in phase setting and the instrument's phasing and sensitivity. All instrument adjustments were made in accordance with the manufacturer's operation manual (Geonics, 1994).

The EM survey data was collected using the vertical dipole orientation with both quadrature (apparent conductivity) and inphase (metal sensitivity) modes. The EM31 uses a fixed intercoil spacing of 3.7 meters (12.1 feet) to provide an exploration depth of approximately 18 feet, with vertical dipoles (standard operating position). NGPRS collected data continuously along each survey line, which were spaced at 10-foot intervals. Transmitter and Receiver orientation were kept parallel to the survey line direction (approximately north-south) during data collection. All data was recorded into an Archer data logger during the survey, along with GPS coordinates for survey line location, and EM31 operational information.

Equipment information and settings are shown in Appendix C.

2.1.3 Global Positioning System (GPS)

The GPS survey was conducted using a Trimble (c) GPS (Model R1) antenna system. The GNSS Bluetooth antenna is designed for mobile devices with WAAS correction. The peripheral GNSS receiver pairs with mobile devices such as smart phones, tablets, and other devices. Survey points were recorded using the WGS1984 latitude/longitude coordinate system with sub-meter accuracy.

Equipment and settings are shown in Appendix D.

2.1.4 Software

Post processing of any saved GPR data was completed using Geophysical Survey Systems, Inc. RAdar Data ANalyzer (RADAN) software (Version 7.3). EM data was processed using Geonics DAT31W software and Golden Surfer 14 contour and surface mapping software.

GPS data was processed using a Trimble© Insphere cloud platform.

2.2 Field Approach

Jeremy Mitchell and Sam Kirmis (NGPRS) performed the field work on February 22 and 23, 2018. Multiple single direction EM transects were completed in selected areas identified by the client, based on knowledge of the using a line spacing of approximately ten (10) feet with data collected continuously along each EM line. GPR transects were taken in four accessible areas using an interval spacing determined by the site conditions and access.

3.0 RESULTS

3.1 Ground Penetrating Radar (GPR)

A maximum allowable GPR signal penetration depth of six (6) feet was achieved at this site using the 400 MHz antenna.

GPR was performed at four (4) locations with clear access for data collection. The GPR signal was not able to penetrate deep enough to image the bentonite wall. Underground piping and unknown utilities were observed at several locations consistent with targets located with the EM equipment.

Access limitations within the survey area due to fencing and concrete wall adjacent to the suspected location of the bentonite wall were also encountered during the GPR survey.

3.2 Electro Magnetics (EM)

EM data was collected from the site was initially checked against targets of interest (e.g., metal debris, surface features and identified utilities) to evaluate the instrument response and determine if the bentonite wall could be identified from other targets (e.g., target interference).

Due to interference from subsurface piping and surface features (fencing and concrete wall) or structures the EM was not able to determine the position of the bentonite wall. The collected EM data was processed, contoured and evaluated for conductivity responses.

The EM response contour map with the interpreted approximate location of the bentonite wall shown in red are shown in Figure 3. Figure 3A provides the June 2003 Imagery (post installation) with the approximate location of the bentonite wall based on the EM response.

4.0 RECOMMENDATIONS & REQUIREMENTS

We recommend RAM retain NGPRS to clear any additional areas if excavation is to occur outside of the identified survey area.

Based on the information presented in this report, we require the following:

- It is required to use manual hand digging and/or soft-digging techniques with air vacuums if excavating within three (3) feet of any underground utility or anomaly.

5.0 LIMITATIONS

NATIONAL GROUND PENETRATING RADAR SERVICE, INC. (NGPRS) MAKES NO GUARANTEE THAT ALL SUBSURFACE TARGETS OF INTEREST WERE DETECTED IN THIS SURVEY. NGPRS IS NOT RESPONSIBLE FOR DETECTING SUBSURFACE TARGETS THAT NORMALLY CANNOT BE DETECTED BY THE METHODS EMPLOYED OR THAT CANNOT BE DETECTED BECAUSE OF SITE CONDITIONS. GPR SIGNAL PENETRATION MAY NOT BE DEEP ENOUGH TO DETECT SOME TARGETS. NGPRS IS NOT RESPONSIBLE FOR MAINTAINING FIELD MARKOUTS AFTER LEAVING THE WORK AREA. RAMUNDERSTANDS THAT MARK-OUTS MADE DURING INCLEMENT WEATHER OR IN AREAS OF HIGH PEDESTRIAN OR VEHICULAR TRAFFIC MAY NOT LAST.

Field mark-outs. Utilities detected by the EMLL method at the time of the survey are marked in the field, and the operator makes every attempt, field conditions permitting, to detect and mark as many utilities as possible at the time of survey. Adverse weather and site conditions (e.g., rain, snow, snow and soil piles, uneven surfaces, high traffic, etc.) can hamper in-field interpretation. Utility mark-outs made on wet pavement, snow, snow piles, gravel surfaces, or in active construction zones may not last. NGPRS is not responsible for maintaining utility mark-outs after leaving the work area.

5.1 Ground Penetrating Radar (GPR)

There are limitations of the GPR technique as used to detect and/or locate targets such as those of the objectives of this survey: (1) surface conditions, (2) electrical conductivity of the ground, (3) contrast of the electrical properties of the target and the surrounding soil, and (4) spacing of the traverses. Of these restrictions, only the last is controllable by us.

The condition of the ground surface can affect the quality of the GPR data and the depth of penetration of the GPR signal. Sites covered with snow piles, high grass, bushes, landscape structures, debris, obstacles, soil mounds, etc. limit the survey access and the coupling of the GPR antenna with the ground. In many cases, the GPR signal will not penetrate below concrete pavement, especially inside buildings, and a target may not be detectable.

The electrical conductivity of the ground determines the attenuation of the GPR signals, and thereby limits the maximum depth of exploration. For example, the GPR signal does not penetrate clay-rich soils, and targets buried in clay might not be detected. A definite contrast in the electrical conductivities of the surrounding ground and the target material is required to obtain a reflection of the GPR signal. If the contrast is too small, possibly due to construction details or deeply corroded metal in the target, then the reflection may be too weak to recognize and the target can be missed. In many cases, plastic, clay, asbestos concrete (transite), brick-lined, stone-lined, and other non-metallic utilities are extremely difficult to detect.

Spacing of the transects is limited by access at many sites, but where flexibility of transect spacing is possible, the spacing is adjusted to the size of the target. The GPR operator controls the spacing between lines, and the design of the survey is based on the dimensions of the smallest feature of interest, and budgetary controls. GPR surveys typically require one (1) inch diameter of target for every one (1) inch of survey depth to be detectable.

5.2 Electro Magnetics (EM)

There are limitations of the EM survey method to detect and/or locate changes in apparent ground conductivity including: (1) interference from surface and subsurface metallic objects or structures, (2) interference from over-head power lines; (3) highly conductive soil or groundwater (saline or brine); (4) exploration depth based on the fixed transmitter-receiver coil spacing.

Additionally, data collection frequency and transect line spacing affect the ability to detect and delineate subsurface targets using changes in conductivity. Spacing of the transect lines may be limited due to site features, landscape structures, and vegetation.

5.3 Global Positioning System (GPS)

Information regarding GPS limitations is provided on the National Oceanic and Atmospheric Administration website at http://www.gps.gov/systems/gps/performance/accuracy/.

6.0 QUALIFICATIONS & DECLARATIONS

6.1 Declaration

The conclusions in the report are predicated on observation and testing of the earthwork and/or construction of the foundation under the direction of the Certified Individual of record. Opinions are based on data assumed representative of the site. We do not warranty conditions below the depth of equipment readings. Recommendations represented in this report should be verified and approved by a designated engineer of record.

We declare that, to the best of our professional knowledge and belief, we have performed the GPR survey in accordance with American Society of Testing and Material (ASTM) D-6432-99 "Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation", and the GPR & EMLL survey in accordance with American Society of Civil Engineers (ASCE) 38-02 "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data" Quality Level "B" results, and we have the specific qualifications based on education, training, and experience to perform a project of the nature, history, and setting of the Site.

6.2 Qualifications of the Professional(s)

The site survey was conducted by Jeremy Mitchell and Sam Kirmis who is a certified GPR operator. Ray Wagner assisted in the preparation of this report, and Stan Liszka reviewed the contents of this report. Staff certification qualifications are shown in attached Appendix E.

7.0 RECORD SOURCES

Imagery displayed on the "Figures" was obtained through ©2018 Google Earth a computer application that renders a 3D representation of Earth based on satellite imagery. All imagery and/or maps used by NGPRS used in this report conforms with the attribution guidelines for Google Maps and Google Earth explained at the following website https://www.google.com/permissions/geoguidelines/attr-guide.html.

Figure 1 - Vicinity Location Map

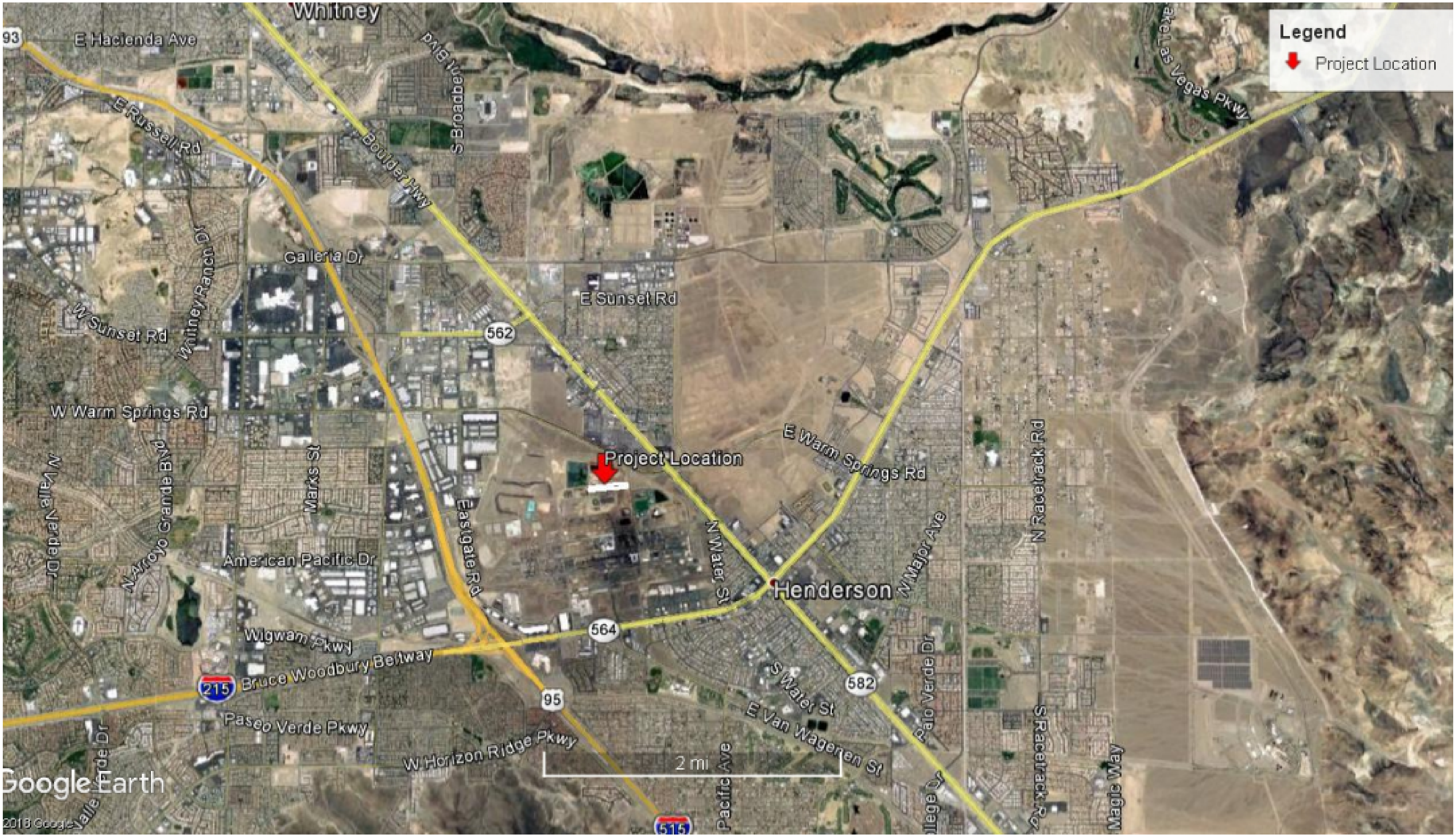


Figure 1 - Project Location Vicinity Map
Client: Ramboll, Henderson, Nevada
Project No. 178951, March 2018

Figure 2 - Survey Area Site Map

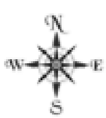


Figure 2 - Survey Area Location Map
Client: Ramboll, Henderson, Nevada
Project No. 178951, March 2018

Figures 3 - EM Response Contour Map

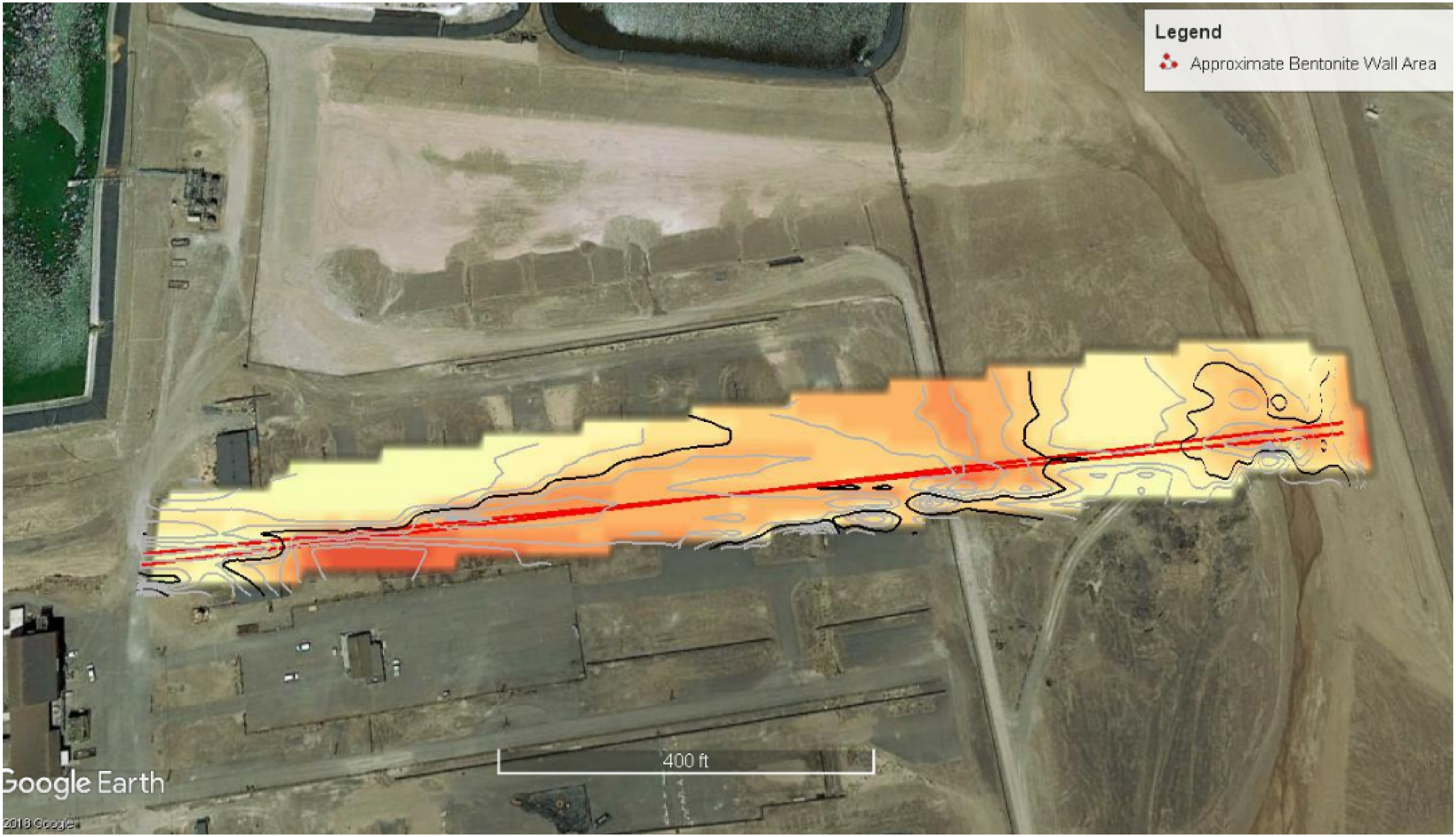
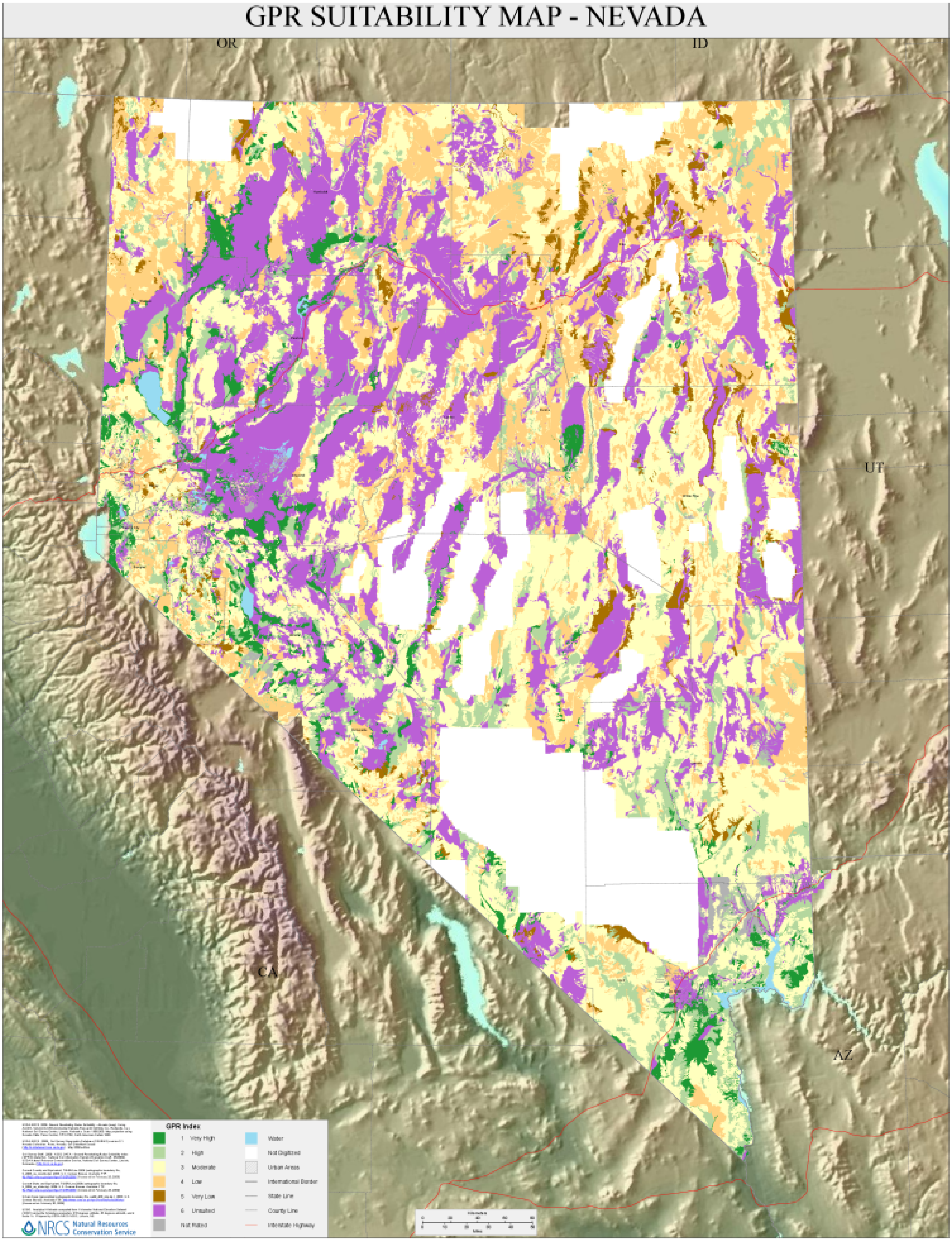


Figure 3 - EM Response Contour Map
Client: Ramboll, Henderson, Nevada
Project No. 178951, March 2018

Figure 3A - 2003 Site Imagery of Bentonite Wall Area
Client: Ramboll, Henderson, Nevada
Project No. 178951, March 2018

Appendix A - United States Department of Agriculture - GPR Soil Suitability Map



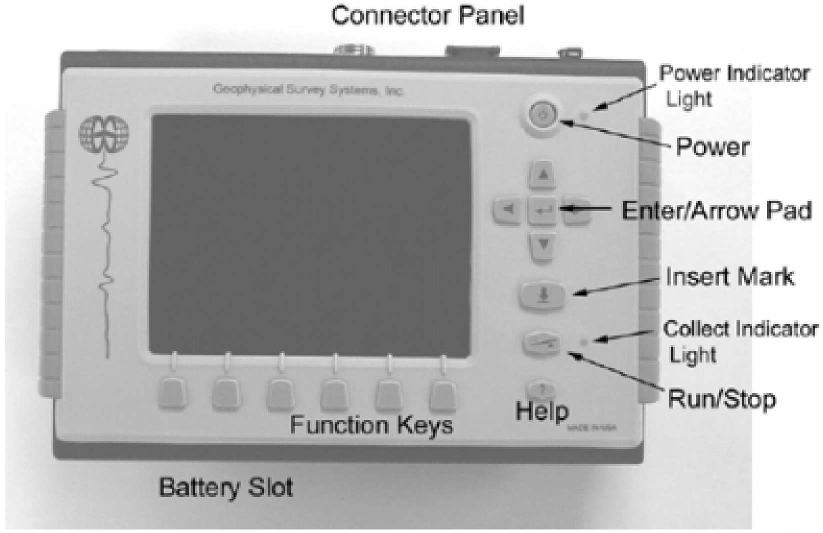
GPR Suitability Map – Nevada

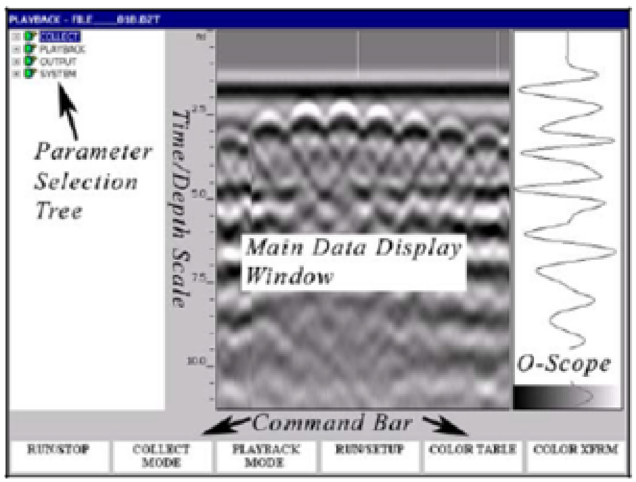
Appendix B - Ground Penetrating Radar (GPR) Equipment Settings

Equipment Settings

```
⊟ COLLECT
  ⊟ RADAR
      400 MHZ
      T_RATE
      MODE Distance
      GPS None
  ⊟ SCAN
      SAMPLES 512
      FORMAT(bits) 16
      RANGE(nS) 60
      DIEL 10.00
      RATE 100
      SCN/UNIT 18.00
  ⊟ GAIN
      AUTO
      POINTS 3
      GP1(dB) -10
      GP2(dB) 15
      GP3(dB) 25


  ⊟ POSITION
      AUTO
      OFFSET 25.00
      SURFACE(%)7.00
  ⊟ FILTERS
      LP_IIR 800
      HP_IIR 100
      LP_FIR 0
      HP_FIR 0
      STACKING 3
      BGR_RMVL 0
```





Data Display Window

Ground Penetrating Radar

3-Wheel Cart - *In Action*

Appendix C - Electro Magnetics (EM) Equipment Settings

Geonics EM31-MK2

The Geonics EM31-MK2 maps geologic variations, groundwater contaminants, or any subsurface feature associated with changes in ground conductivity (in mS/m). It uses an electromagnetic inductive technique that allows measurements without electrodes or ground contact. This inductive method allows surveys to be carried out under most geologic conditions including those of high surface resistivity such as sand, gravel, and asphalt.

Archer 2™ Rugged Handheld

The Archer is used for data logging processes in the field.

Geonics EM31 Conductivity Survey (Henderson, NV)

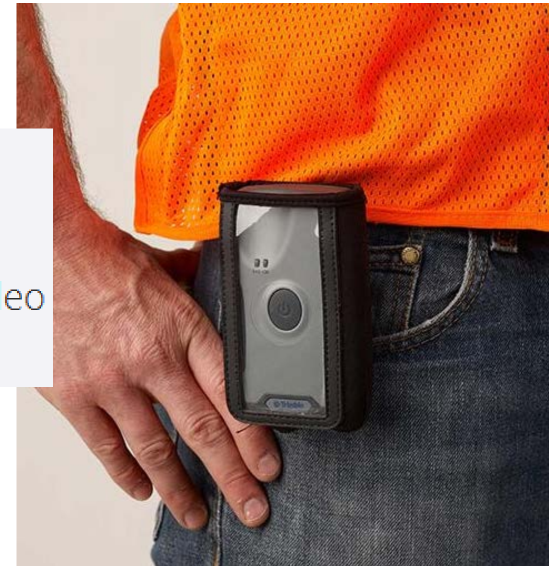
The *Geonics EM31-MK2* is calibrated in accordance with industry and manufacturer specs prior to every electromagnetic survey. This system has an intercoil spacing of 3.7 meters which results in an exploration depth of approx. 6 meters in the vertical dipole mode and 3 meters in the horizontal dipole mode. Data is logged and subsequently processed using *Surfer* software to produce a contour map for the client.

Appendix D - Global Positioning System (GPS) Equipment Settings

1. External antenna connector
2. LED: Bluetooth and GNSS
3. Power LED
4. Power button / Bluetooth pairing button
5. Mini USB / charger connection (rear of device)

50 cm	44	Integrated
Precision	Channels	Antenna

GPS, GLONASS, SBAS, BeiDou, Galileo
Satellites



Trimble R1 Antenna

The R1 GNSS (Global Navigation Satellite System) is a high-performance GNSS receiver with an integrated antenna, and Bluetooth® wireless technology for connectivity with smartphones or laptops.

Supported devices

The R1 GNSS receiver is compatible with devices powered by the following operating systems:

- Android versions 4.1x and later
- iOS
- Windows® 7 and Windows 8.x
- Windows Embedded Handheld 6.5

Supported constellations

The R1 GNSS receiver supports the following L1 constellations:

- GPS L1 C/A
- GLONASS L1 C/A (G1)
- Galileo E1
- BeiDou B1
- QZSS L1 C/A

Supported correction sources

The R1 GNSS receiver supports the following correction signals:

- SBAS (WAAAS / EGNOS / MSAS / GAGAN, SDCM)
- CMR, CMR+, CMRx
- RTCM 2.0 to 2.3 (DGPS and RTK), RTCM 3.0 and 3.1
- QZSS L1 SAIF
- RTX ViewPoint™ (via Internet and L-Band satellite)

Appendix E - Certification of Professional(s)

GSSI

Certifies that:

Jeremy Mitchell

Completed a Training Course in the Theory and Practice of Applying Subsurface Interface Radar in Engineering and Geophysical Investigations.

StructureScan™ Pro SIR 4000

Christopher Hawekotte
President

Dan Welch
Training Manager

February 5 – 6, 2018

Geophysical Survey Systems, Inc.
40 Simon Street • Nashua, NH 03060-3075
www.geophysical.com

Certificate of Locating Competency

Staking University

Sam Kirmis

Has attended training and passed a practical examination
indicating a thorough knowledge of electro-magnetic locating instruments

Attendance Date: November 27th- December 1st
Certification #P3733
(Valid for two years from the certification date)

Approved by: ______________________
Staking University Records Administrator

MINNESOTA STATE BOARD OF ARCHITECTURE, ENGINEERING,
LAND SURVEYING, LANDSCAPE ARCHITECTURE, GEOSCIENCE
AND INTERIOR DESIGN

THIS IS TO CERTIFY THAT

Raymond A Wagner

is a licensed

Professional Geologist

License Number	Effective Date	Expiration Date
30532	06/01/2016	06/30/2018

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
NATIONAL HEADQUARTERS
12000 Washington Street, Suite 285, Thornton, CO 80241
(303) 412-6205 · FAX (303) 253-9220 · e-mail: aipg@aipg.org · www.aipg.org

TO WHOM IT MAY CONCERN:

This is to attest that **Stanley W. Liszka, III** is currently a Member in good standing and Certified by the American Institute of Professional Geologists.

Date of AIPG Certification	**April 6, 2016**
AIPG Certified Professional Geologist number	**CPG-11833**
Certification good through	**December 31, 2018**

For the American Institute of Professional Geologists,

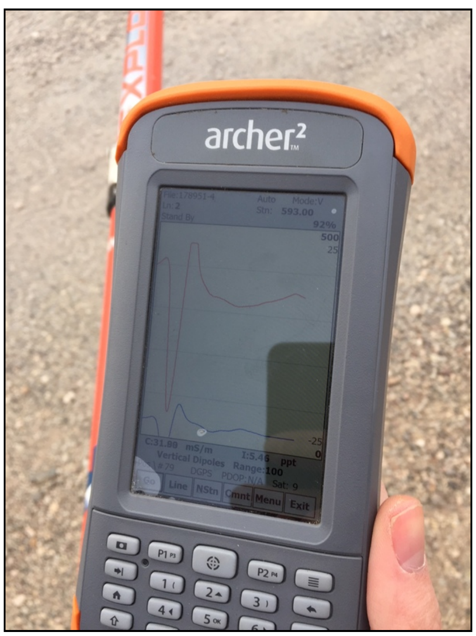
Aaron W. Johnson
Executive Director

Date: October 24, 2017

Appendix F - Photographs

1 : Pilot Test Survey Area

2 : Pilot Test Survey Area



3 : EM Data Logger

4 : EM31 Terrain Conductivity Meter with GPS

APPENDIX C
CPT LITHOLOGY AND DISSIPATION TEST REPORTS

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

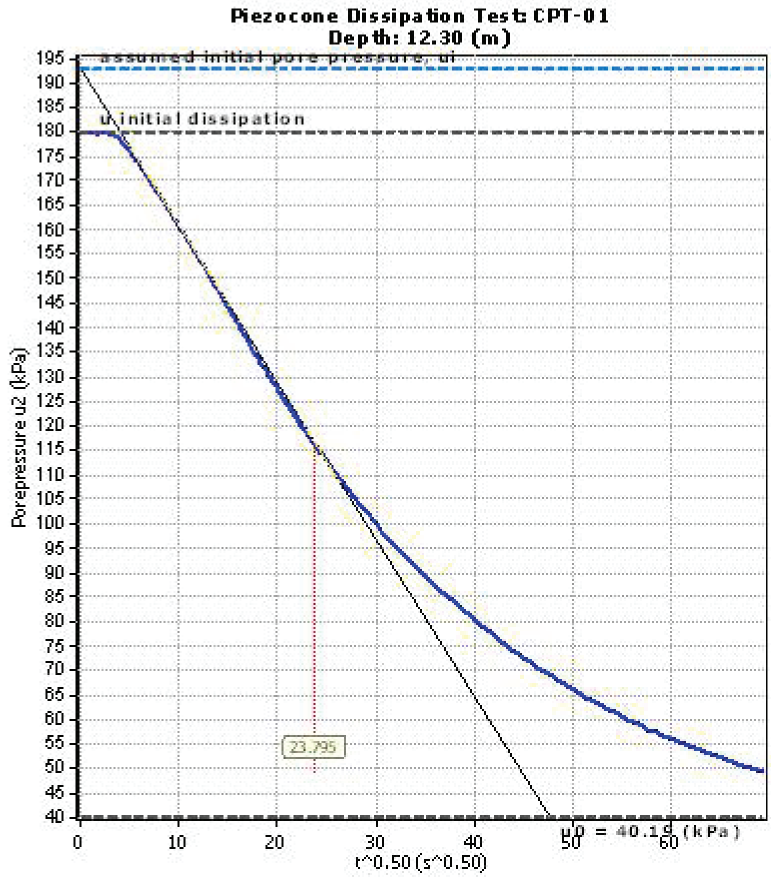
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

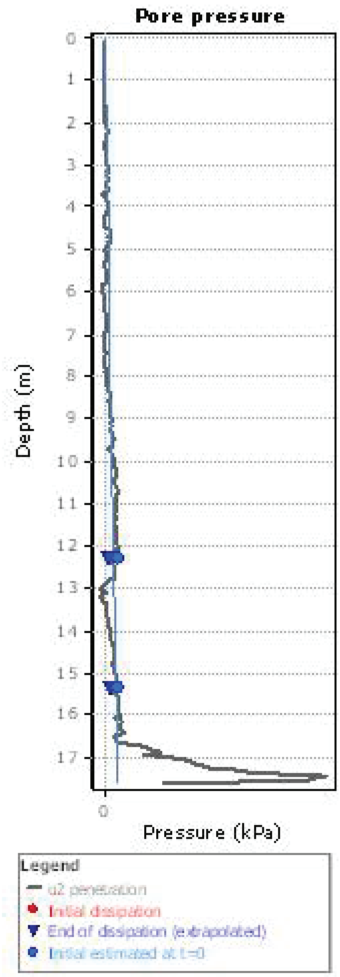
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
CPT-01	12.30	23.8	566	1.80E-005	2154.20	6.73E-006	212	0.45	1.46E-007


Piezocone Dissipation Test: CPT-01
Depth: 12.30 (m)
assumed initial pore pressure, ui
u initial dissipation
23.795
u0 = 40.19 (kPa)
Porepressure u2 (kPa)
t^0.50 (s^0.50)


Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

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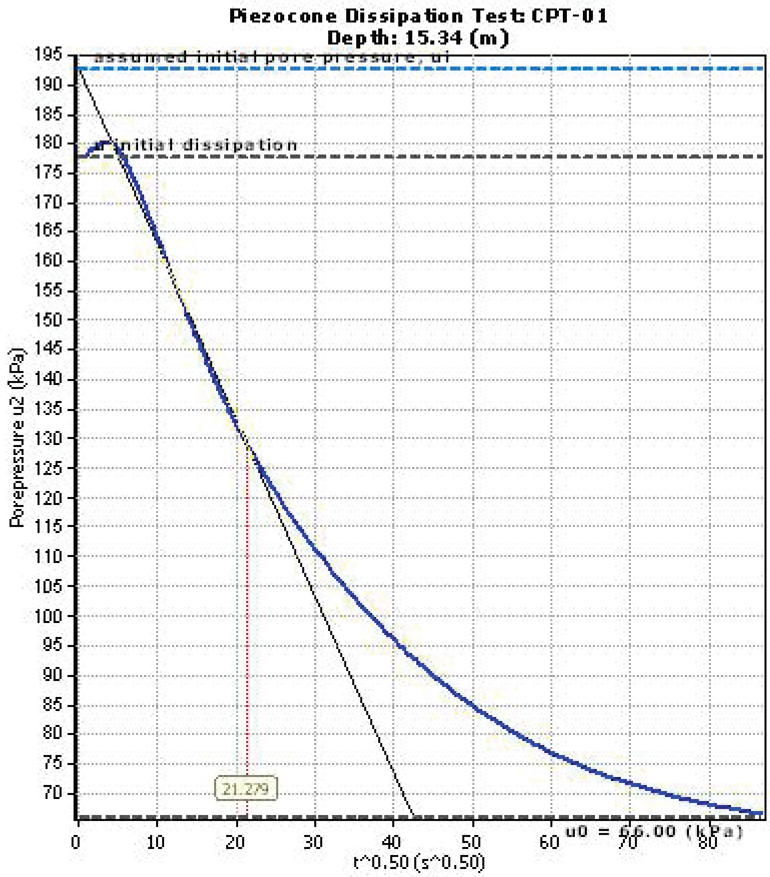
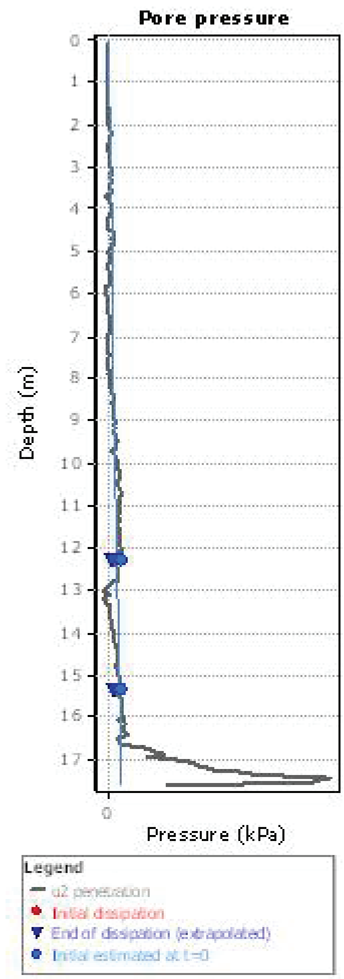
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
CPT-01	15.34	21.3	453	1.44E-005	2154.20	8.41E-006	265	0.56	1.47E-007


Piezocone Dissipation Test: CPT-01
Depth: 15.34 (m)
assumed initial pore pressure, ui
initial dissipation
21.279
u0 = 66.00 (kPa)
Porepressure u2 (kPa)
t^0.50 (s^0.50)


Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

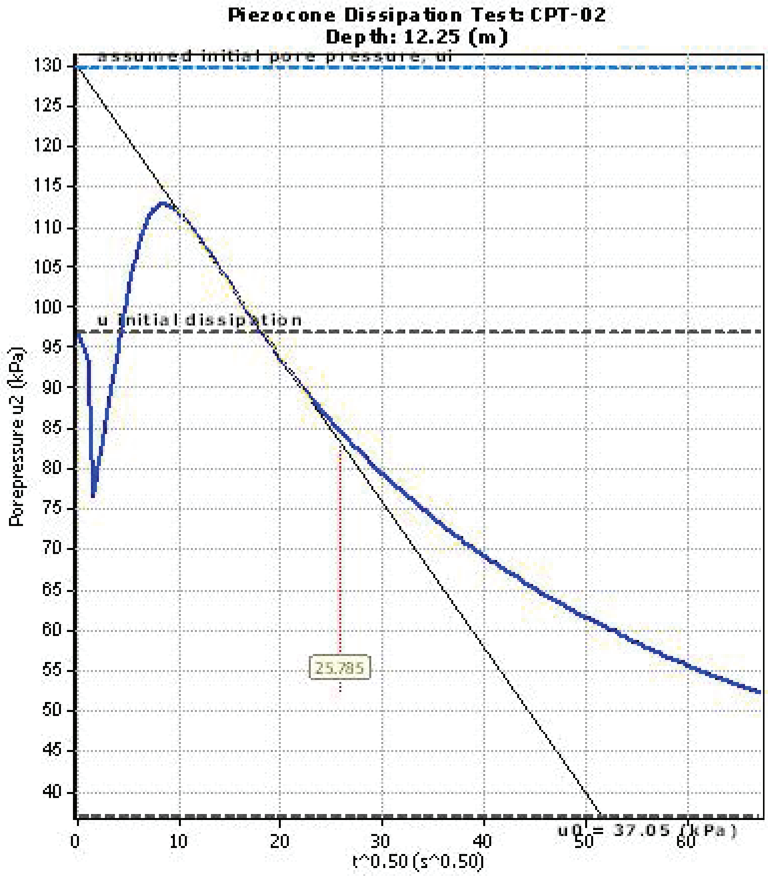
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

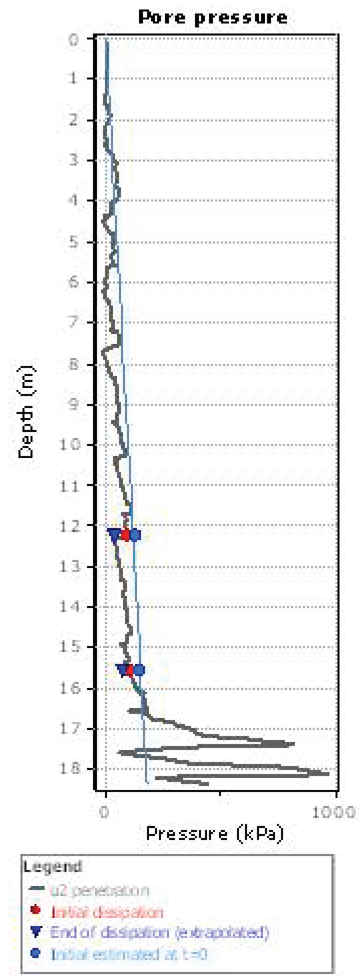
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h ($m^2/year$)	M (MPa)	k_h (m/s)
CPT-02	12.25	25.8	665	2.11E-005	2154.20	5.73E-006	181	0.45	1.25E-007


Piezocone Dissipation Test: CPT-02
Depth: 12.25 (m)
assumed initial pore pressure, ui
u initial dissipation
25.785
u0 = 37.05 (kPa)
Porepressure u2 (kPa)
t^0.50 (s^0.50)


Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

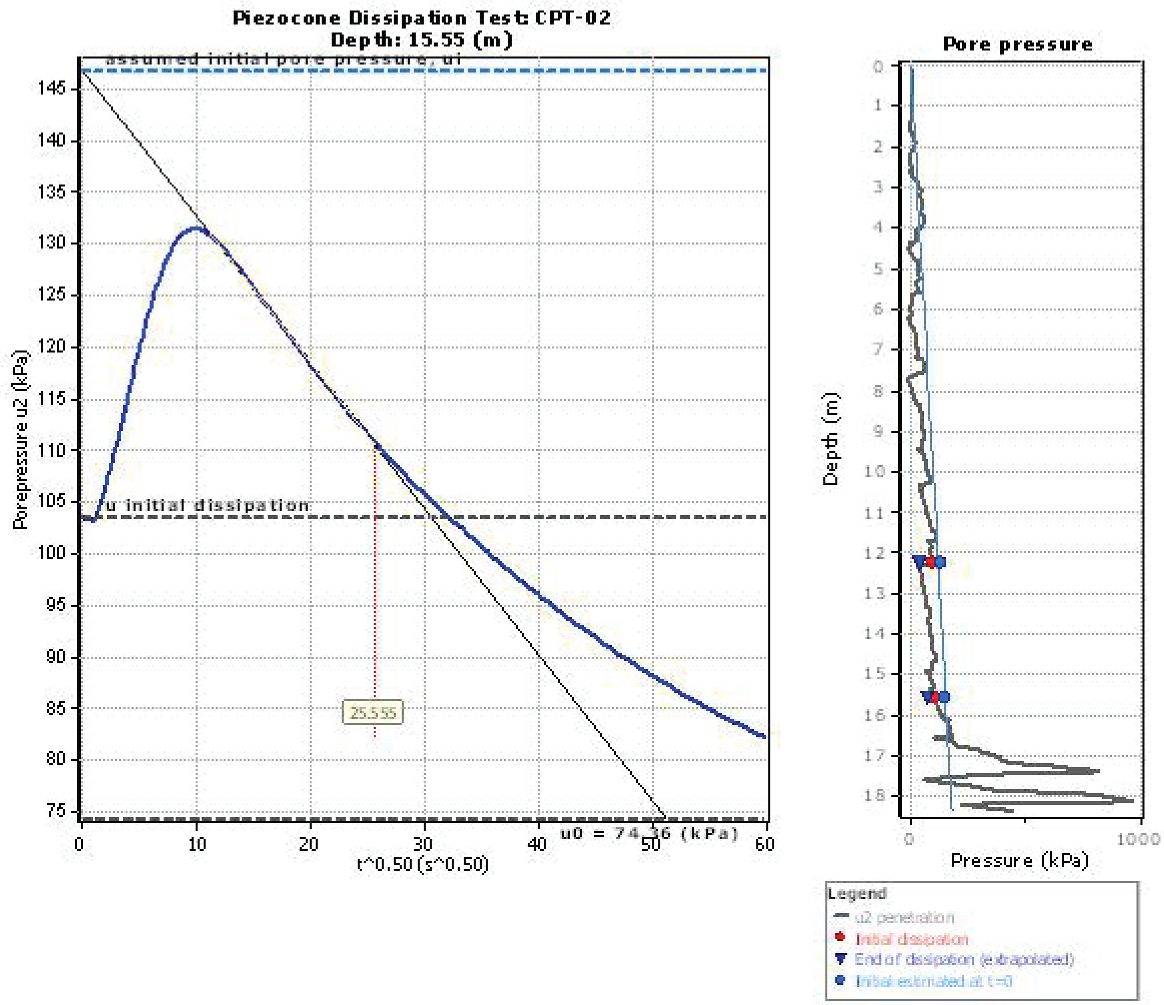
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m²/s)	c_h (m²/year)	M (MPa)	k_h (m/s)
CPT-02	15.55	25.6	653	2.07E-005	100.00	1.26E-006	40	0.57	2.16E-008


Piezocone Dissipation Test: CPT-02
Depth: 15.55 (m)
assumed initial pore pressure, ui
u initial dissipation
u0 = 74.36 (kPa)
25.555
Porepressure u2 (kPa)
t^0.50 (s^0.50)
Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

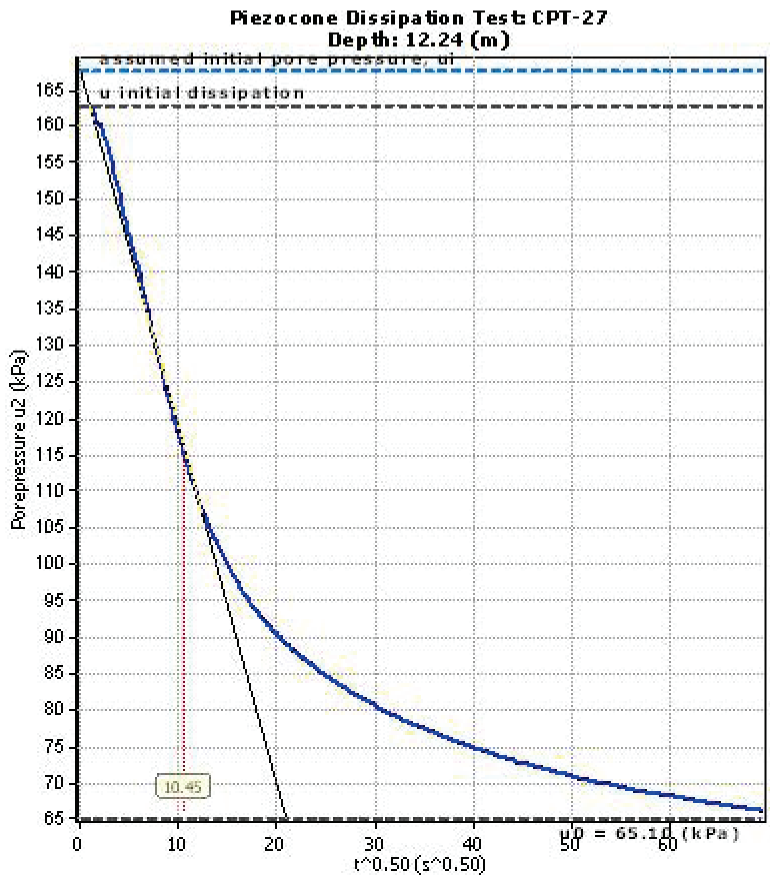
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

$$k_h = c_h \times \gamma_w / M$$

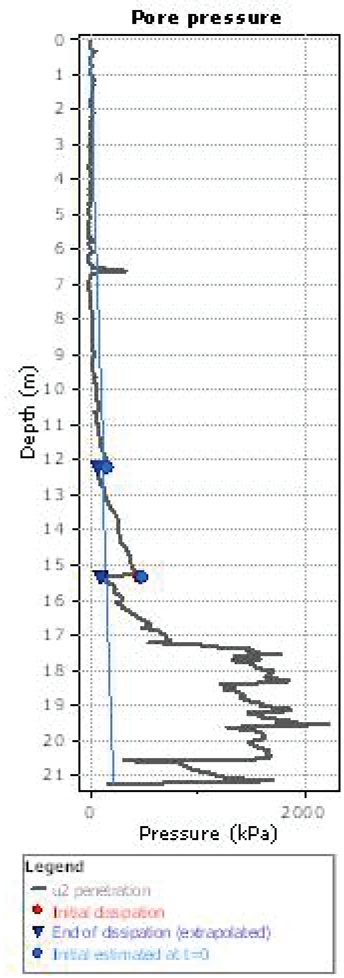
where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
CPT-27	12.24	10.4	109	3.46E-006	479.07	1.64E-005	519	34.15	4.72E-009



Piezocone Dissipation Test: CPT-27
Depth: 12.24 (m)
assumed initial pore pressure, ui
u initial dissipation
Porepressure u2 (kPa)
t^0.50 (s^0.50)
10.45
u0 = 65.10 (kPa)



Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

Dissipation Tests Results

Dissipation tests

Dissipation tests consists of stopping the piezocone penetration and observing porepressures (u) with elapsed time (t). The data are automatic recorded by the field computer and should take place until a minimum of 50% dissipation.

The porepressures are plotted as a function of square root of (t). The graphical technique suggested by Robertson and Campanella (1989), yields a value for t_{50}, which corresponds to the time for 50% consolidation.

The value of the coefficient of consolidation in the radial or horizontal direction c_h was then calculated by Houlsby and Teh's (1988) theory using the following equation:

$$c_h = \frac{T \times r^2 \times I_r^{0.5}}{t_{50}}$$

where:

T: time factor given by Houlsby and Teh's (1988) theory corresponding to the porepressure position
r: piezocone radius
I_r: stiffness index, equal to shear modulus G divided by the undrained strength of clay (S_u).
t_{50}: time corresponding to 50% consolidation

Permeability estimates based on dissipation test

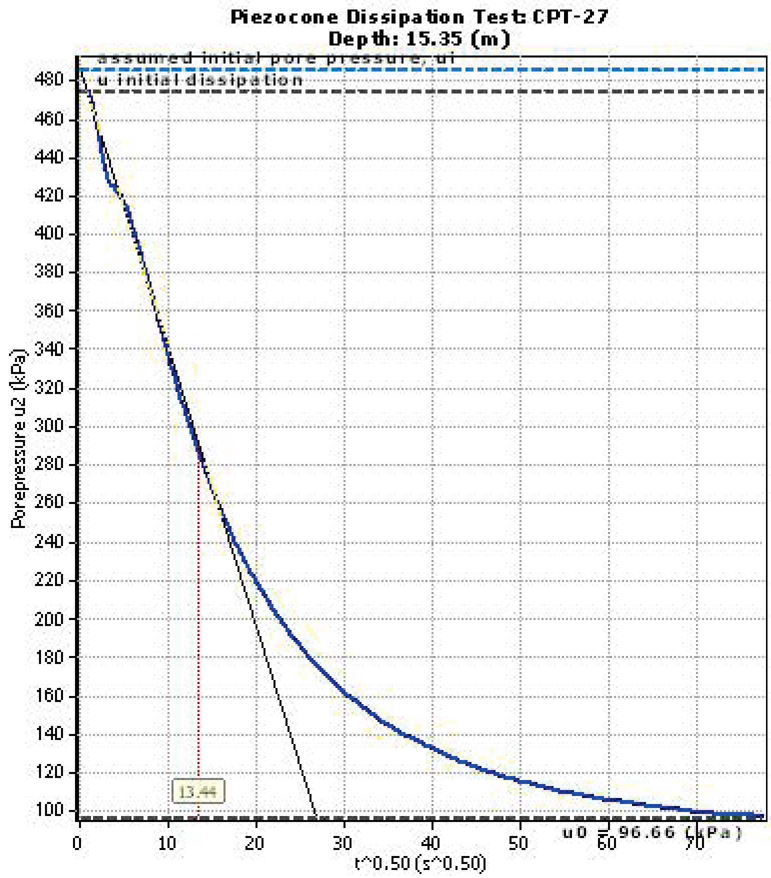
The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction (c_h) which is influenced by a combination of the soil permeability (k_h) and compressibility (M), as defined by the following:

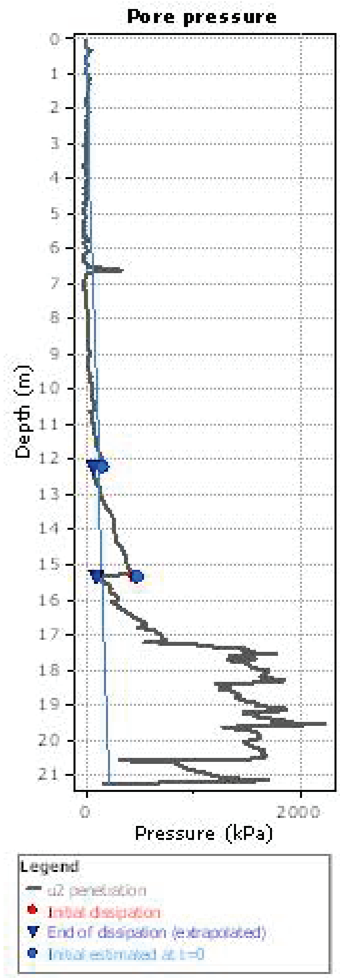
$$k_h = c_h \times \gamma_w / M$$

where: M is the 1-D constrained modulus and γ_w is the unit weight of water, in compatible units.

Tabular results

CPTU Borehole	Depth (m)	$(t_{50})^{0.50}$	t_{50} (s)	t_{50} (years)	G/S_u	c_h (m^2/s)	c_h (m^2/year)	M (MPa)	k_h (m/s)
CPT-27	15.35	13.4	181	5.73E-006	463.31	9.78E-006	308	45.39	2.11E-009


Piezocone Dissipation Test: CPT-27
Depth: 15.35 (m)
assumed initial pore pressure, ui
u initial dissipation
Porepressure u2 (kPa)
t^0.50 (s^0.50)
13.44
u0 = 96.66 (kPa)


Pore pressure
Depth (m)
Pressure (kPa)
Legend
u2 penetration
Initial dissipation
End of dissipation (extrapolated)
Initial estimated at t=0

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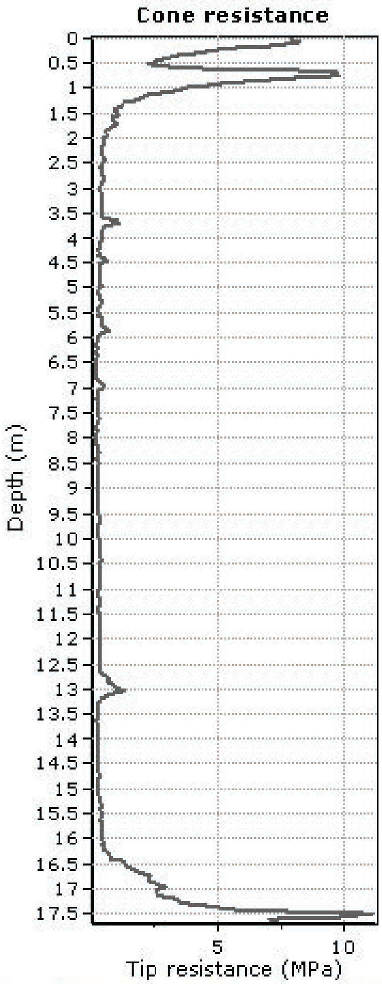
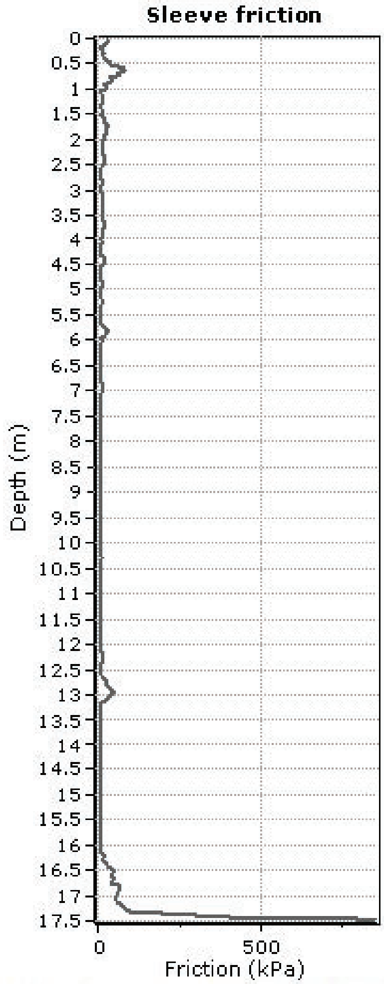
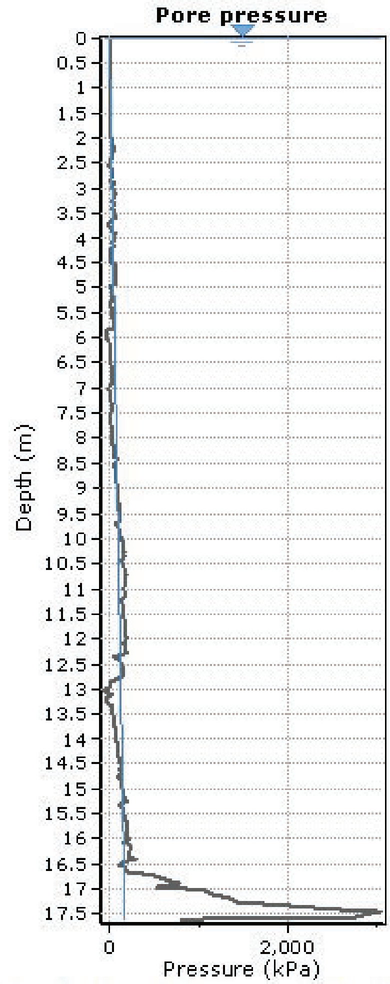
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

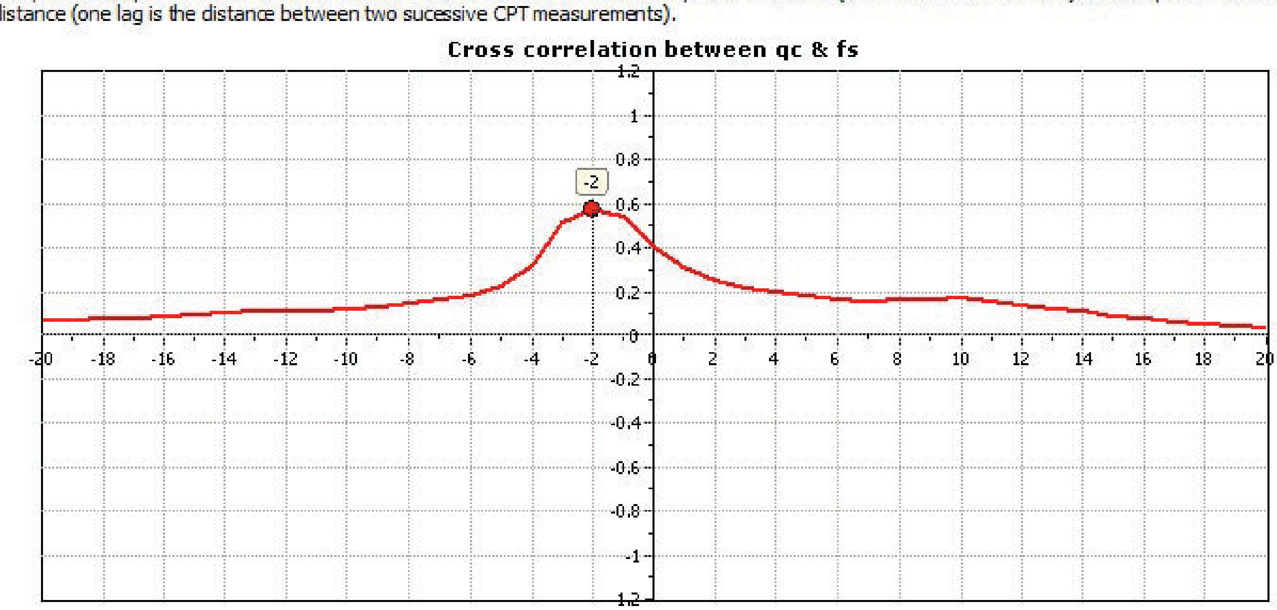
Project:
Location:







The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



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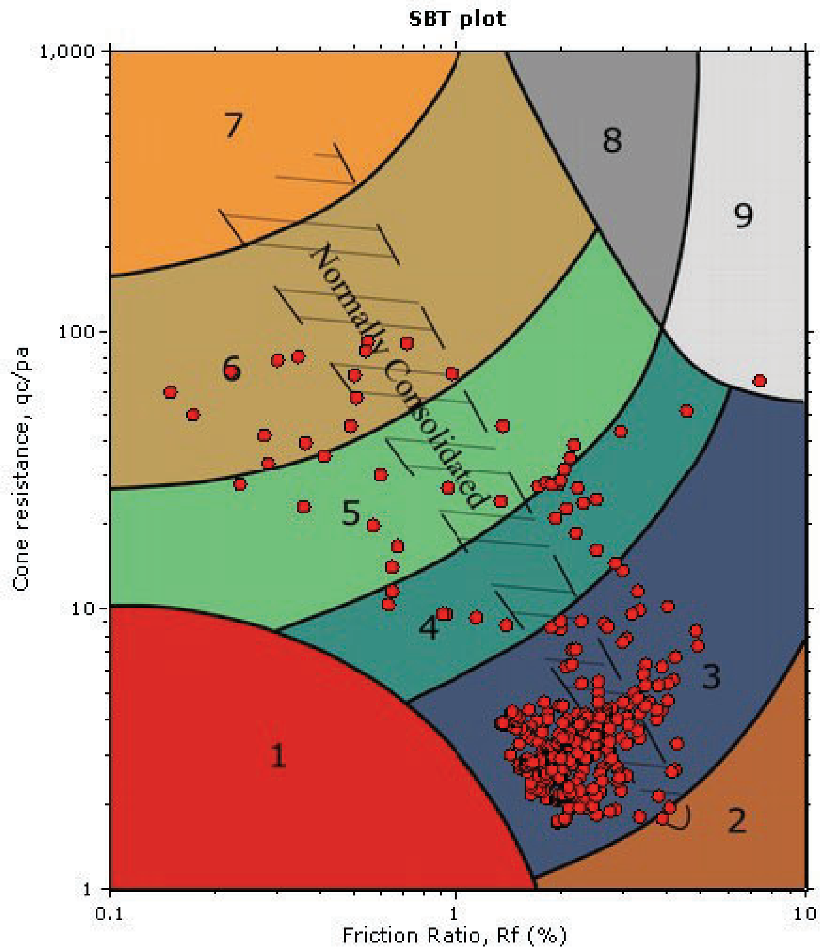
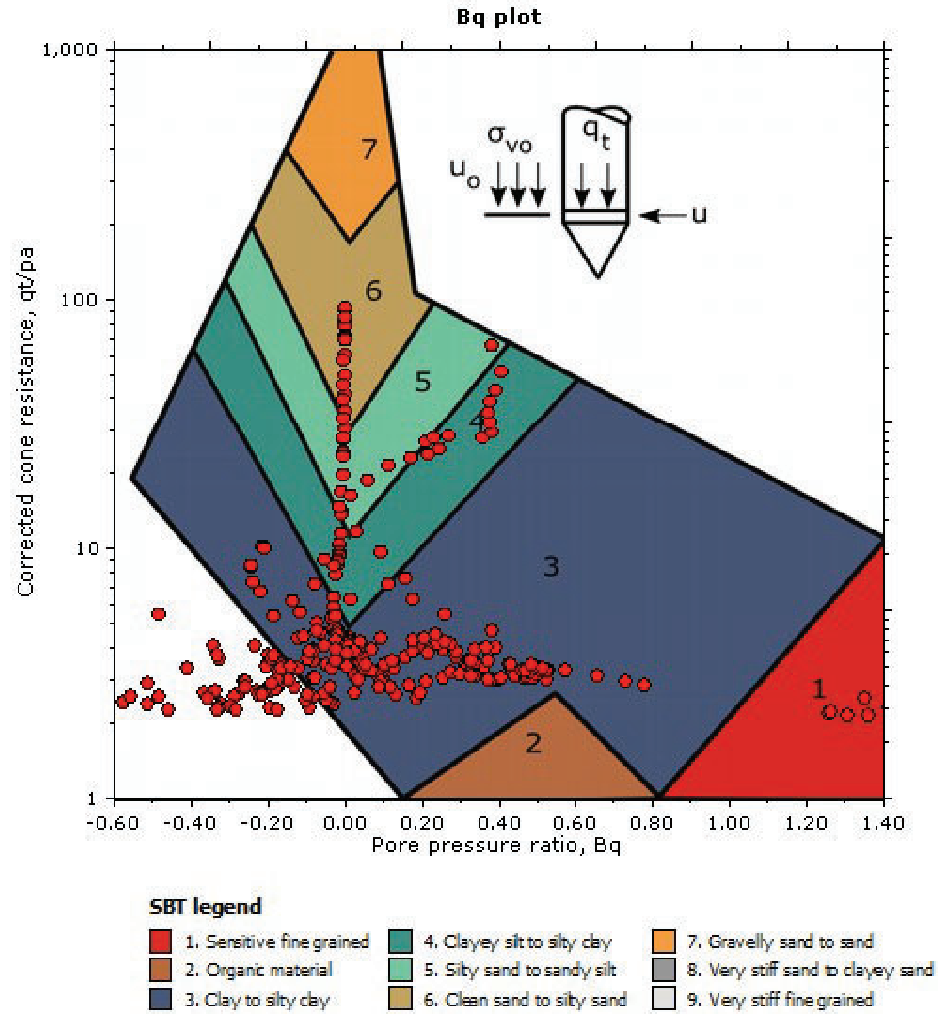
Project:
Location:

CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

SBT - Bq plots





Ramboll
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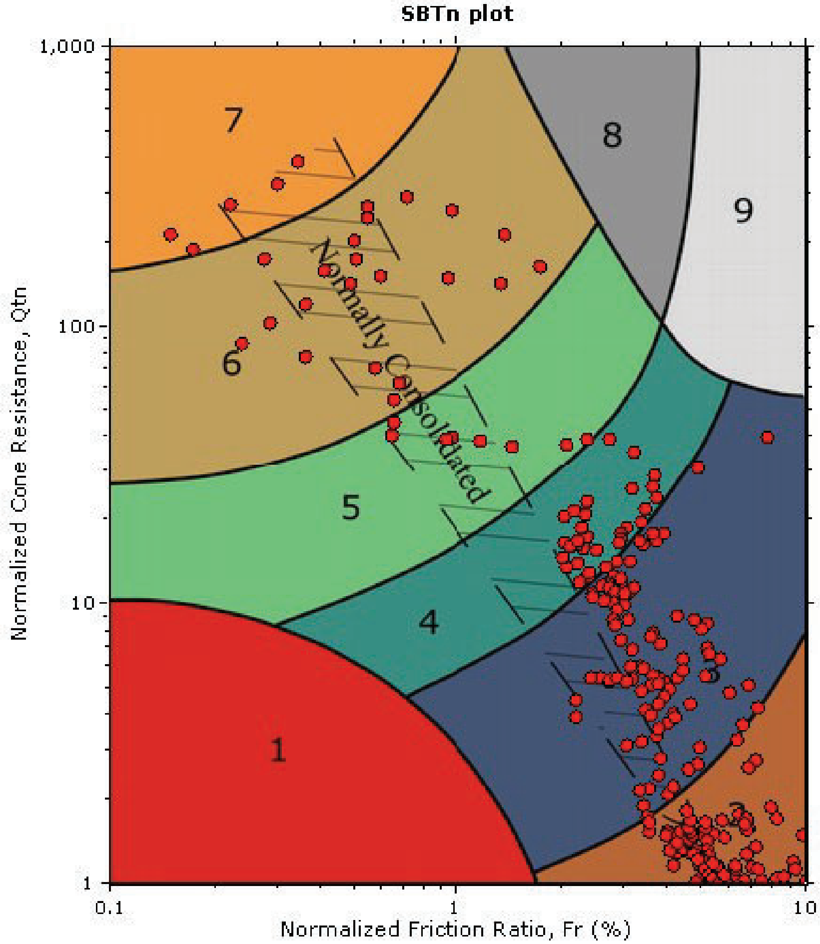
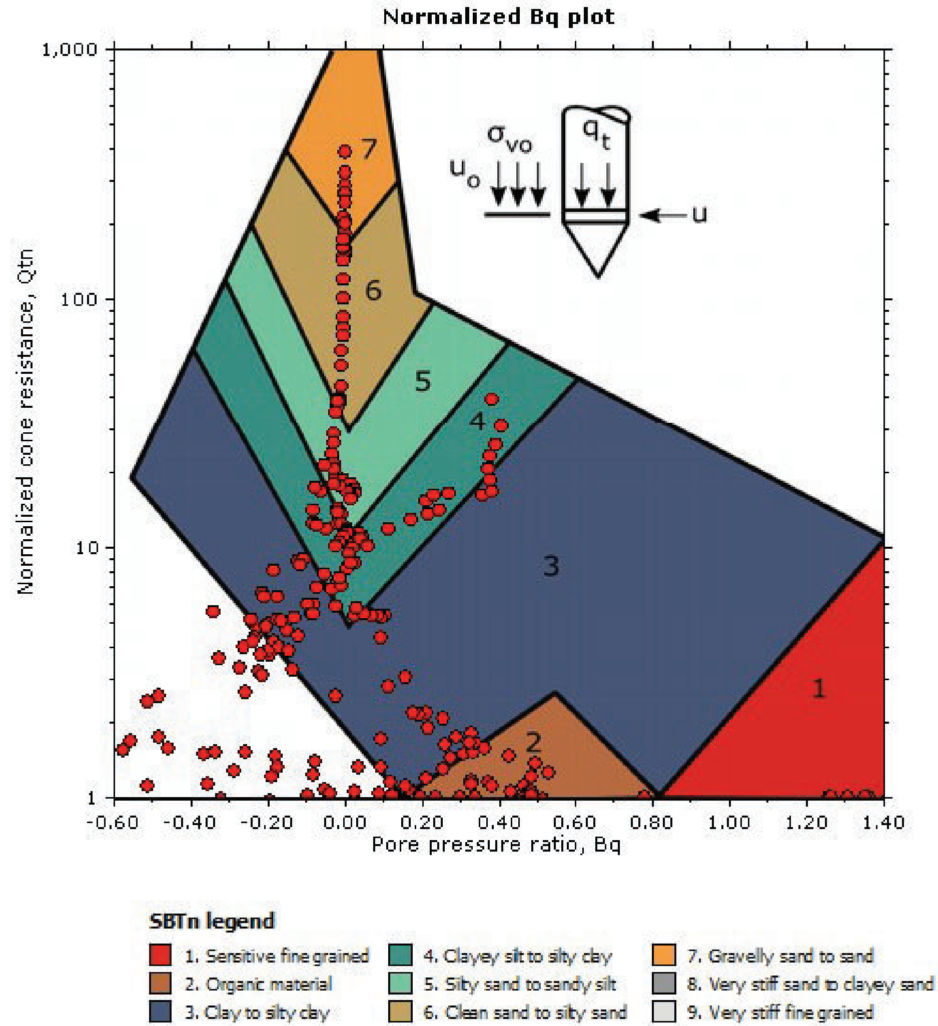
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

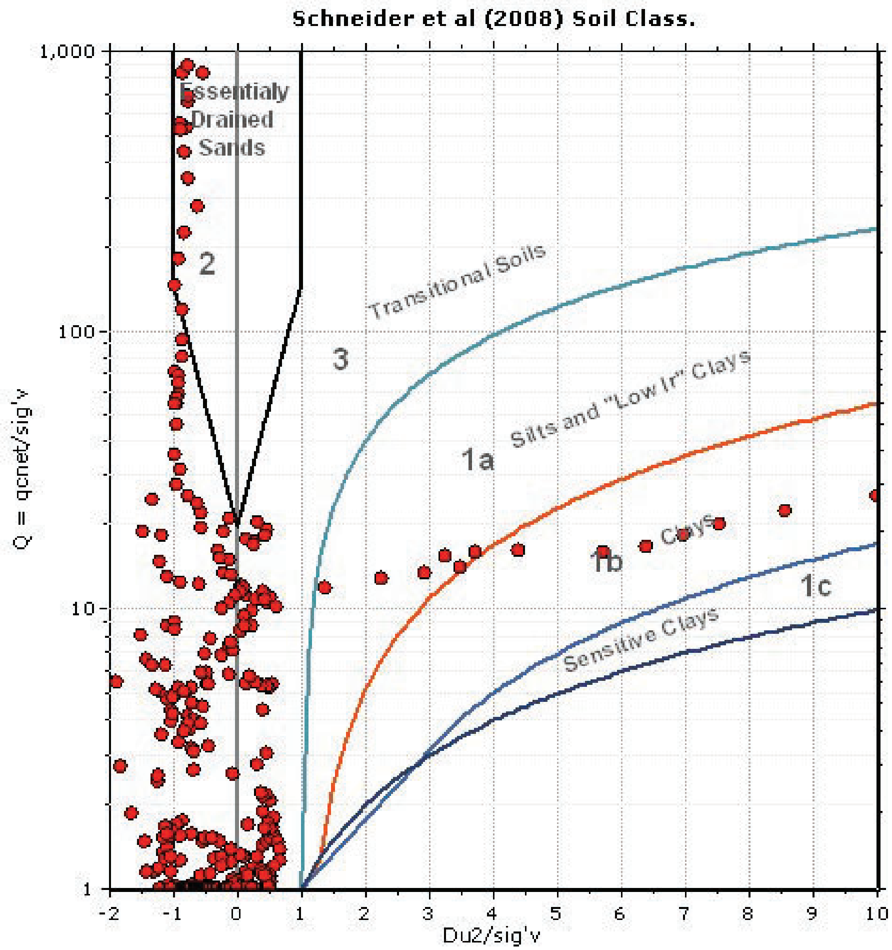
Project:
Location:

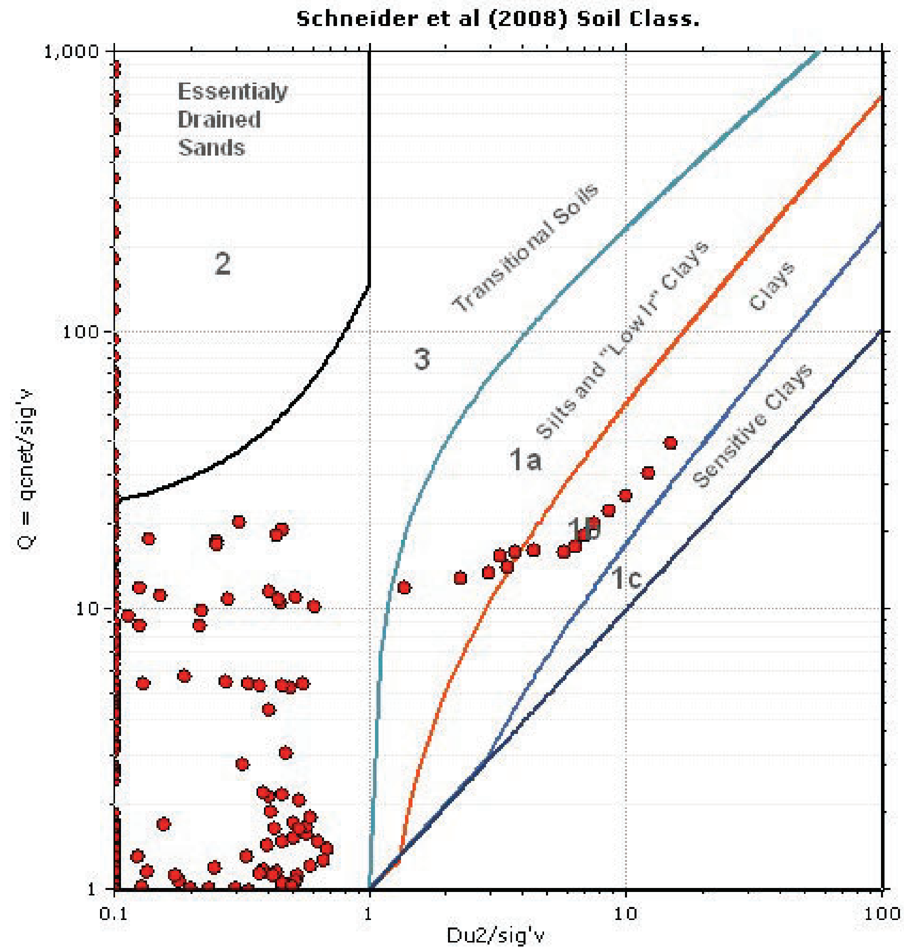
SBT - Bq plots (normalized)

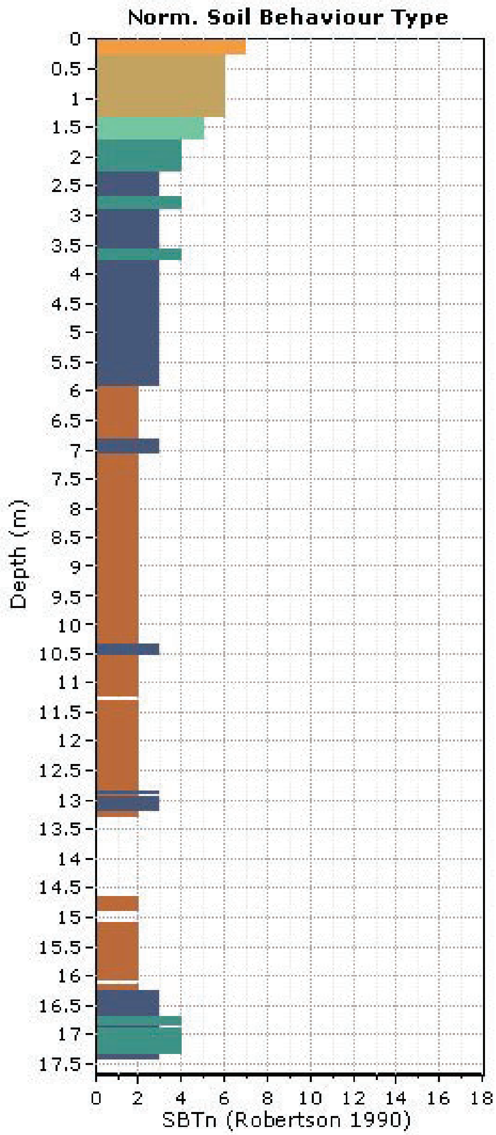


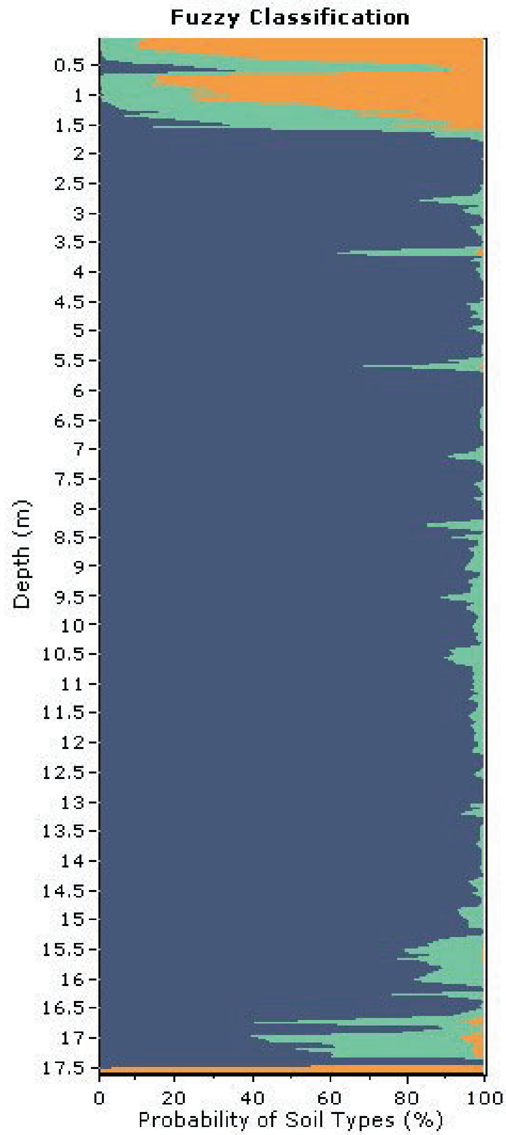


Bq plots (Schneider)






Norm. Soil Behaviour Type
Depth (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
0 2 4 6 8 10 12 14 16 18
SBTn (Robertson 1990)


Fuzzy Classification
Depth (m)
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
0 20 40 60 80 100
Probability of Soil Types (%)

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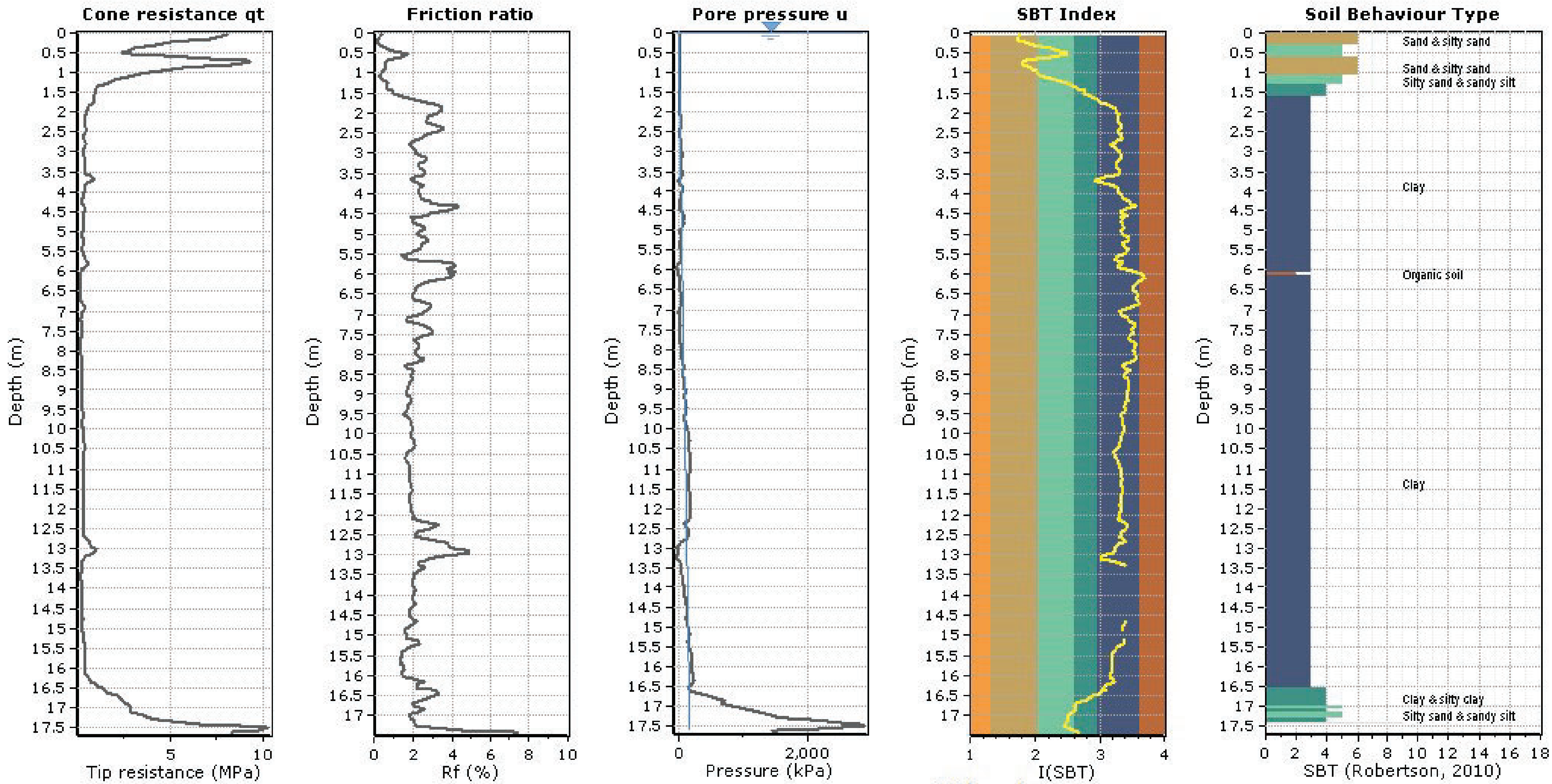
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

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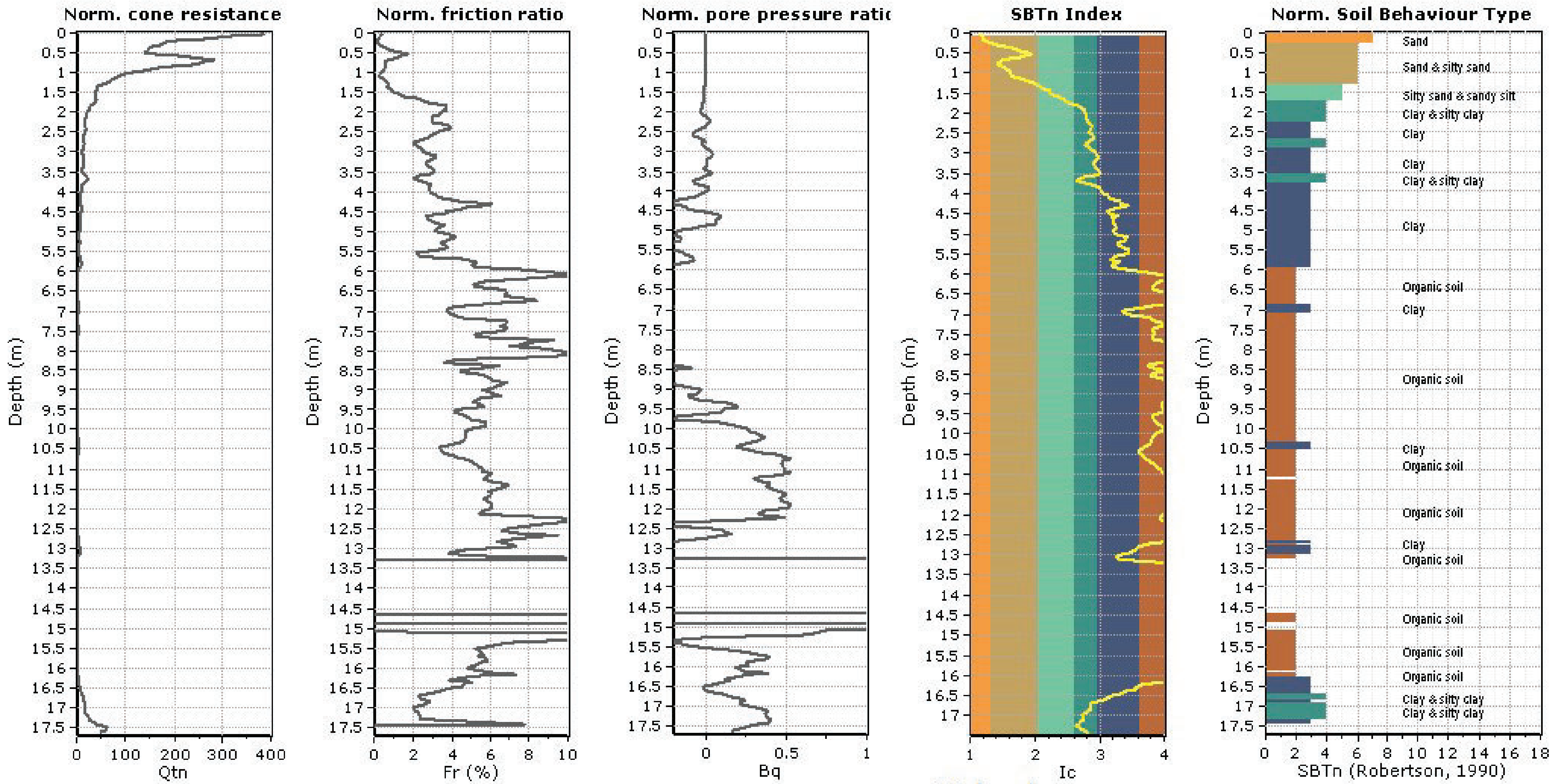
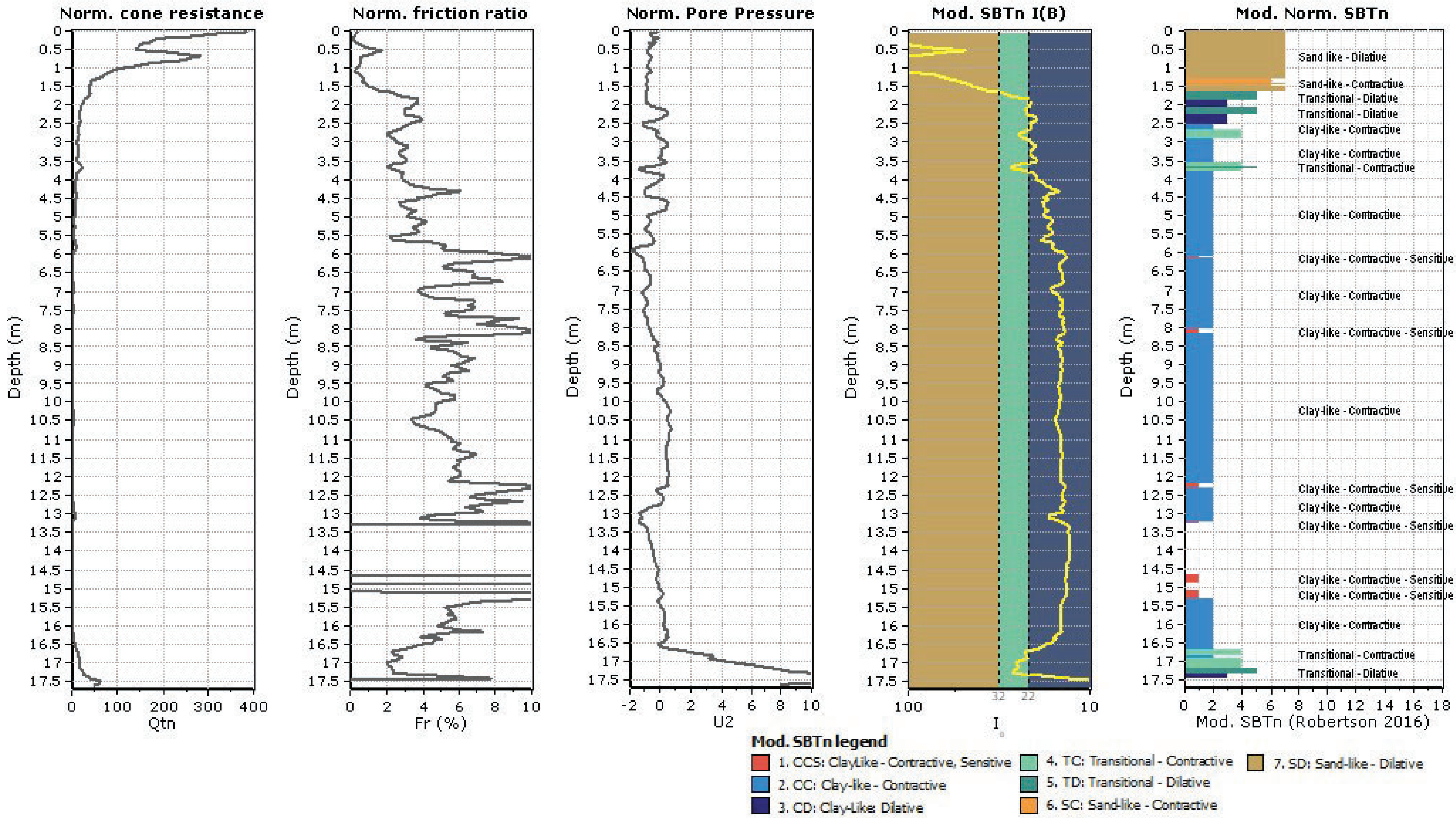
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained


Norm. cone resistance
Depth (m)
Qtn
Norm. friction ratio
Fr (%)
Norm. Pore Pressure
U2
Mod. SBTn I(B)
Mod. Norm. SBTn
Sand like - Dilative
Sand-like - Contractive
Transitional - Dilative
Clay-like - Contractive
Transitional - Contractive
Clay-like - Contractive - Sensitive
Mod. SBTn (Robertson 2016)
Mod. SBTn legend
1. CCS: Clay-Like - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

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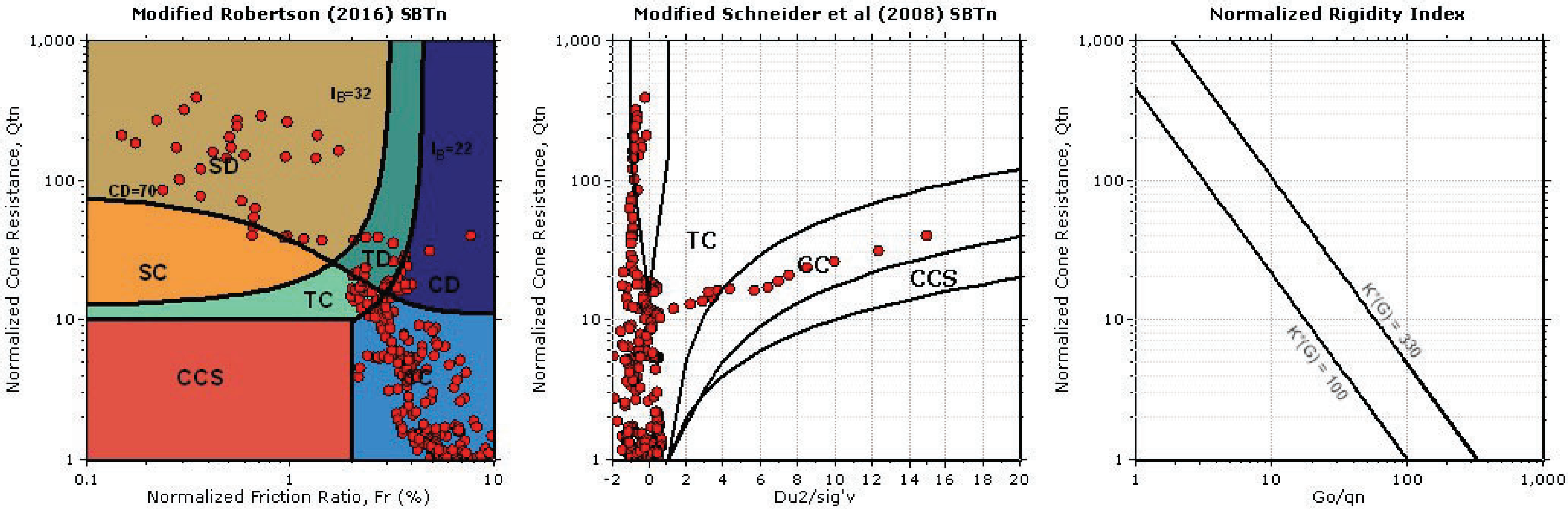
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

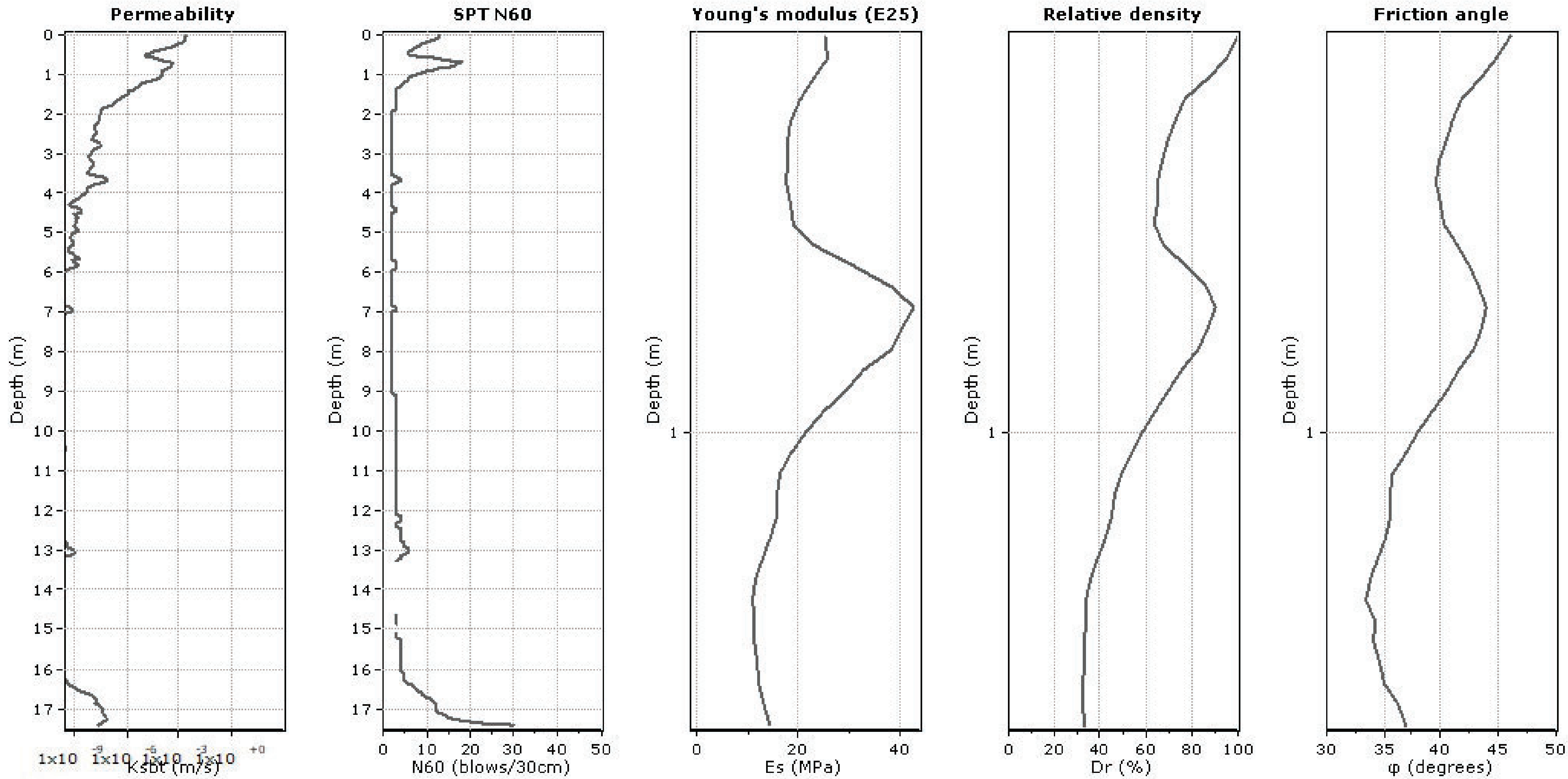
Project:
Location:

Updated SBTn plots

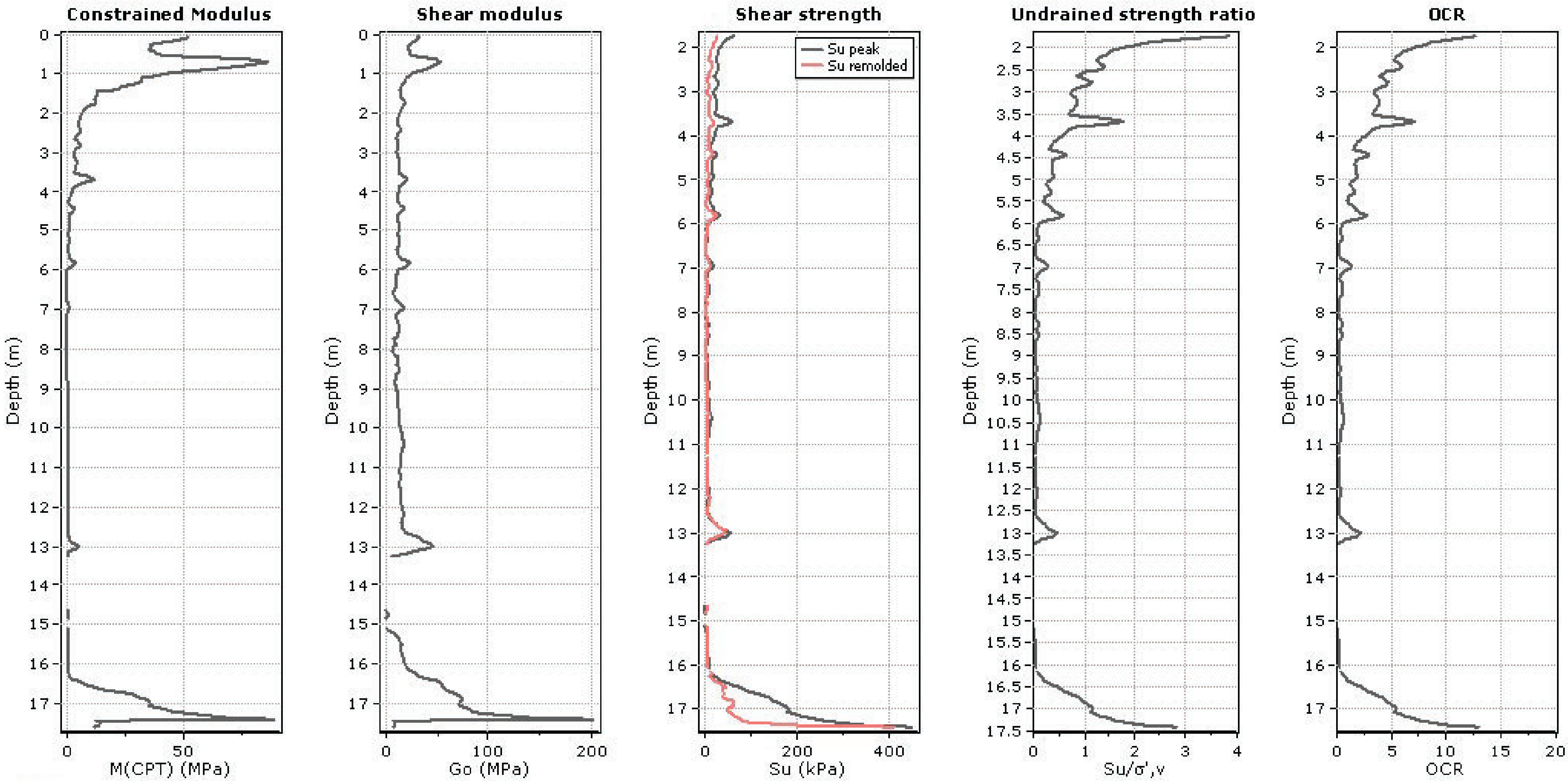


CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
TC: Transitional - Contractive
TD: Transitional - Dilative
SC: Sand-like - Contractive
SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data



Calculation parameters

Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data

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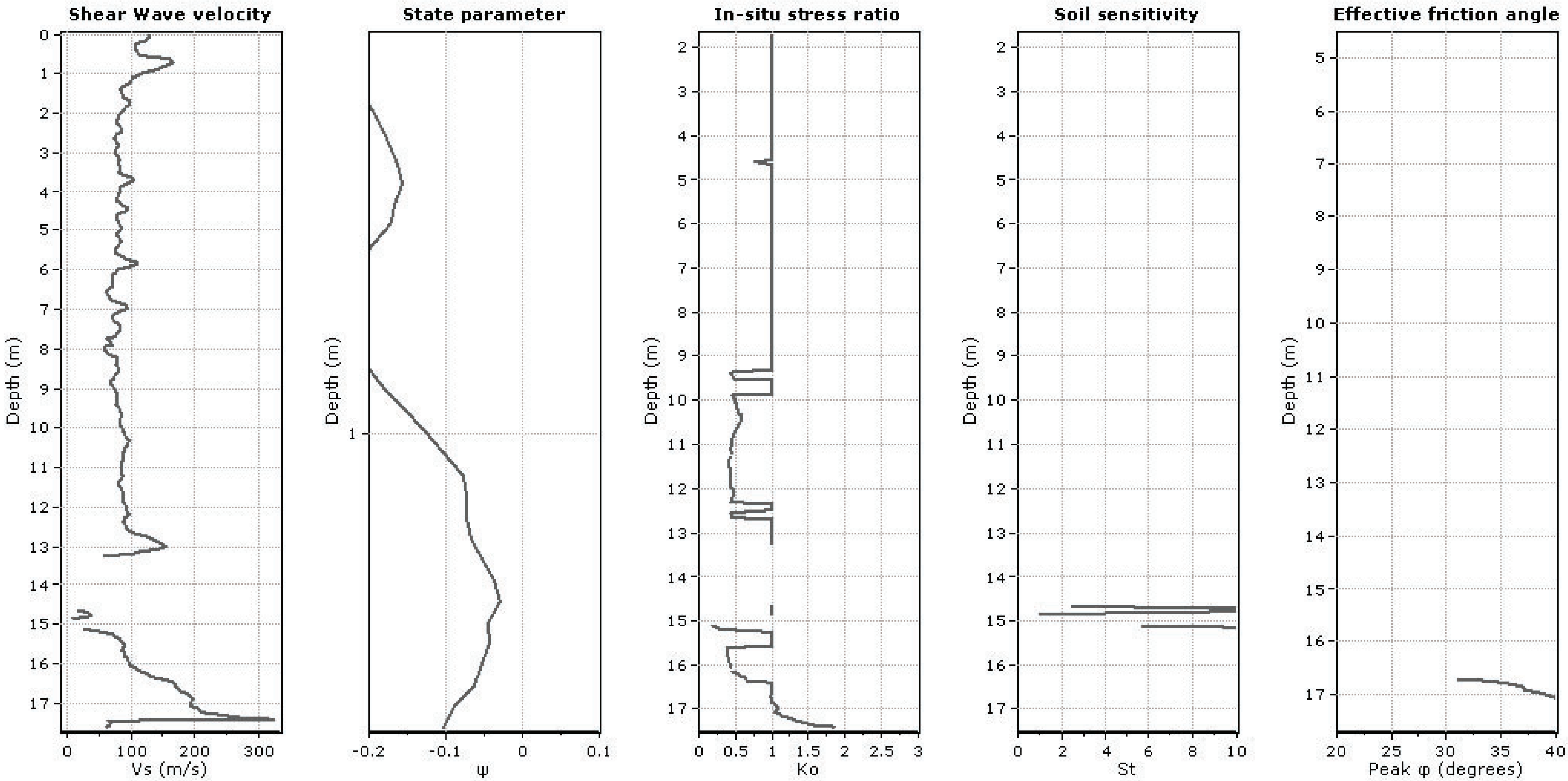
CPT: CPT-01
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

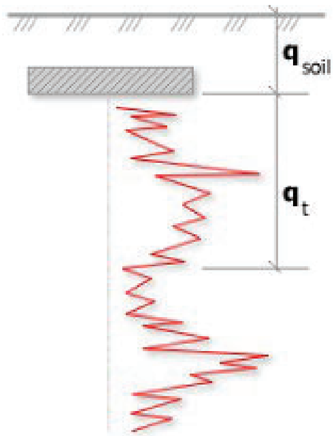
Project:
Location:



Calculation parameters

Soil Sensitivity factor, N_S: 350.00

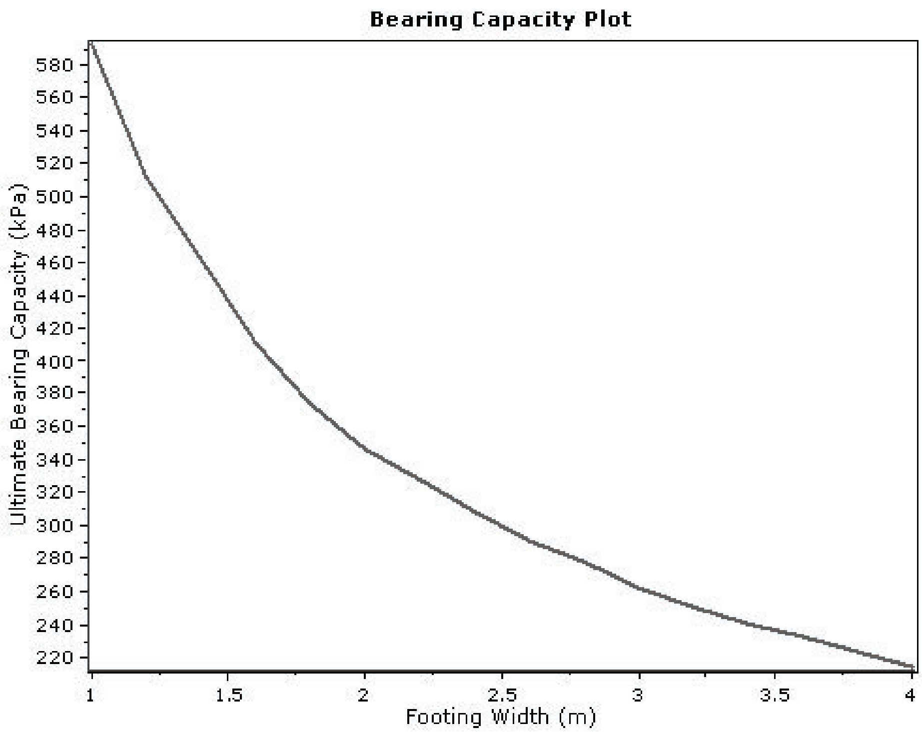
User defined estimation data



Bearing Capacity calculation is perfromed based on the formula:

$$Q_{ult} = R_k \times q_t + q_{soil}$$

where:
R_k: Bearing capacity factor
q_t: Average corrected cone resistance over calculation depth
q_{soil}: Pressure applied by soil above footing



:: Tabular results ::

No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	2.91	0.20	9.50	592.18
2	1.20	0.50	2.30	2.51	0.20	9.50	511.83
3	1.40	0.50	2.60	2.27	0.20	9.50	462.72
4	1.60	0.50	2.90	2.00	0.20	9.50	409.65
5	1.80	0.50	3.20	1.82	0.20	9.50	374.20
6	2.00	0.50	3.50	1.68	0.20	9.50	346.42
7	2.20	0.50	3.80	1.59	0.20	9.50	328.39
8	2.40	0.50	4.10	1.49	0.20	9.50	308.49
9	2.60	0.50	4.40	1.41	0.20	9.50	290.62
10	2.80	0.50	4.70	1.34	0.20	9.50	278.17
11	3.00	0.50	5.00	1.27	0.20	9.50	262.70
12	3.20	0.50	5.30	1.21	0.20	9.50	250.87
13	3.40	0.50	5.60	1.15	0.20	9.50	240.16
14	3.60	0.50	5.90	1.12	0.20	9.50	232.56
15	3.80	0.50	6.20	1.07	0.20	9.50	223.07
16	4.00	0.50	6.50	1.02	0.20	9.50	214.44

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 I_c + 1.68}$$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$$

:: Drained Friction Angle, φ (°) ::

$$\varphi = \varphi'_{cv} + 15.94 \cdot \log(Q_{tn,cs}) - 26.88$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$a = 14$ for $Q_{tn} > 14$
$a = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = a \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

$$M_{CPT} = 0.03 \cdot (q_t - \sigma_v) \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$$OCR = k_{OCR} \cdot Q_{tn}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

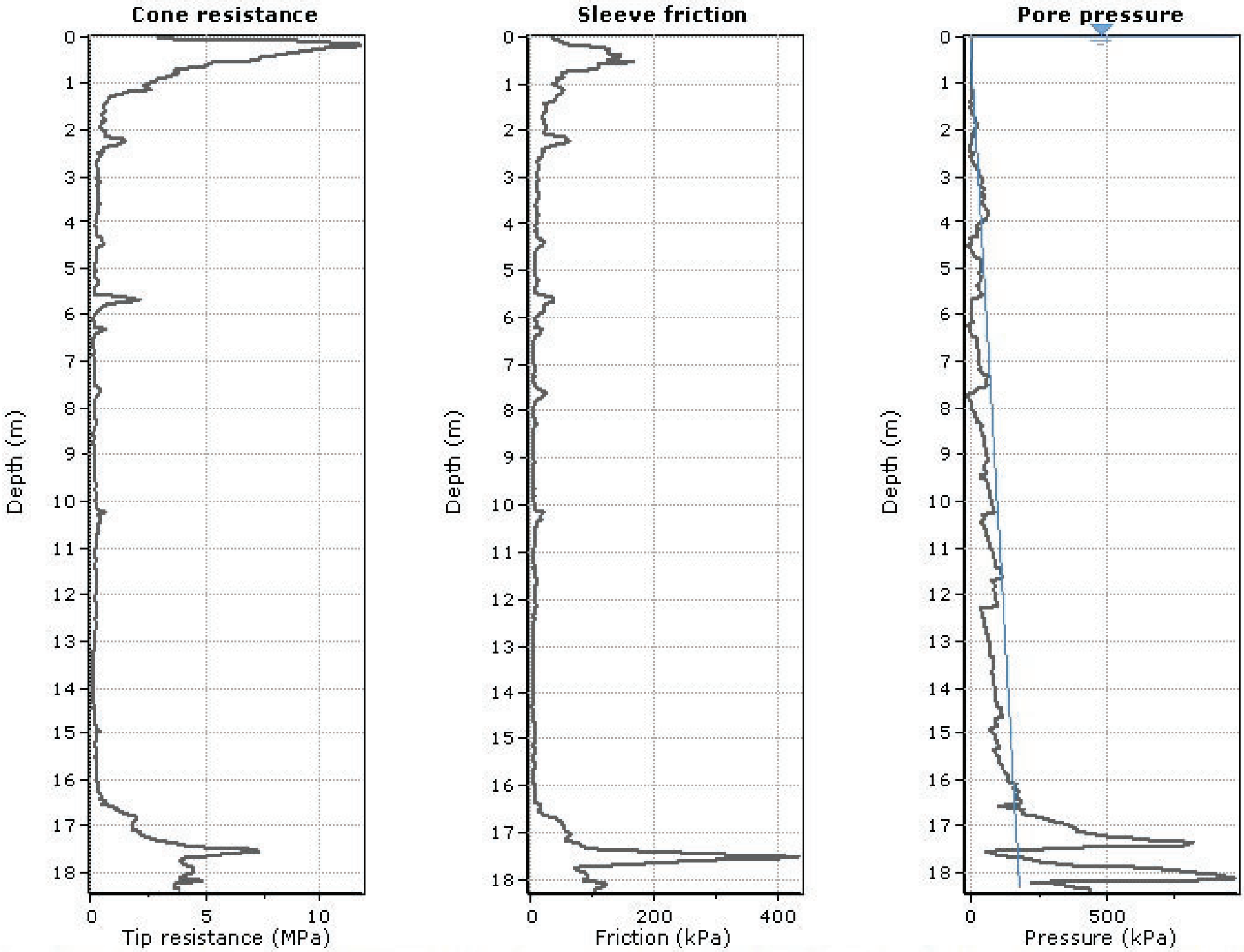
$$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$$

(applicable for $0.10 < B_q < 1.00$)

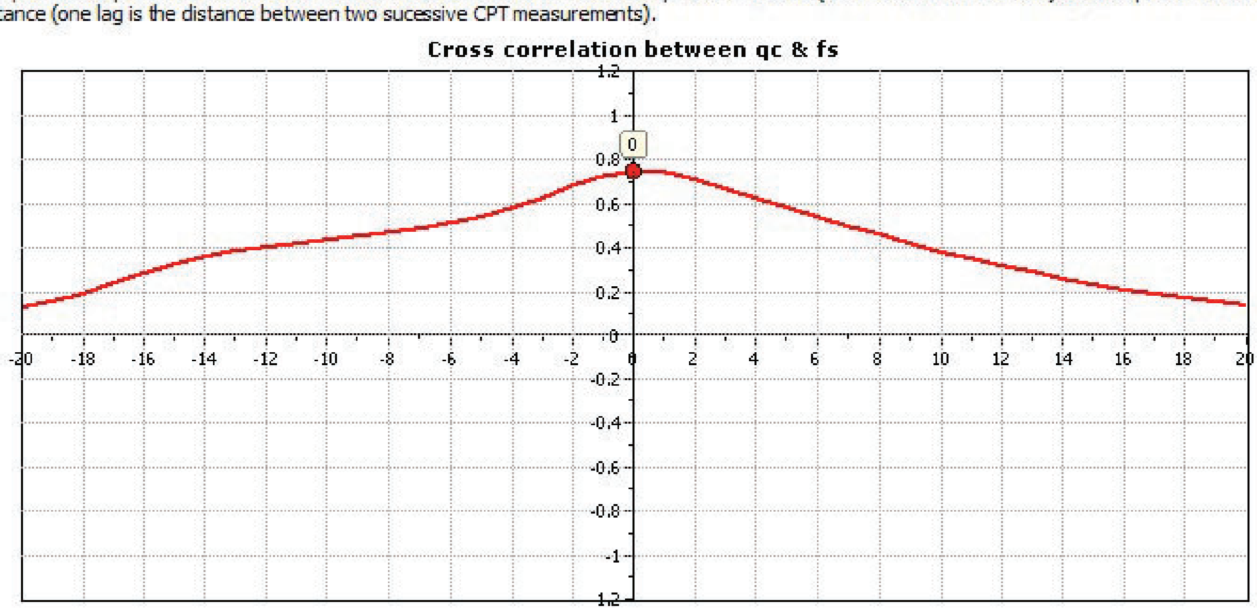
References

• Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012

• Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



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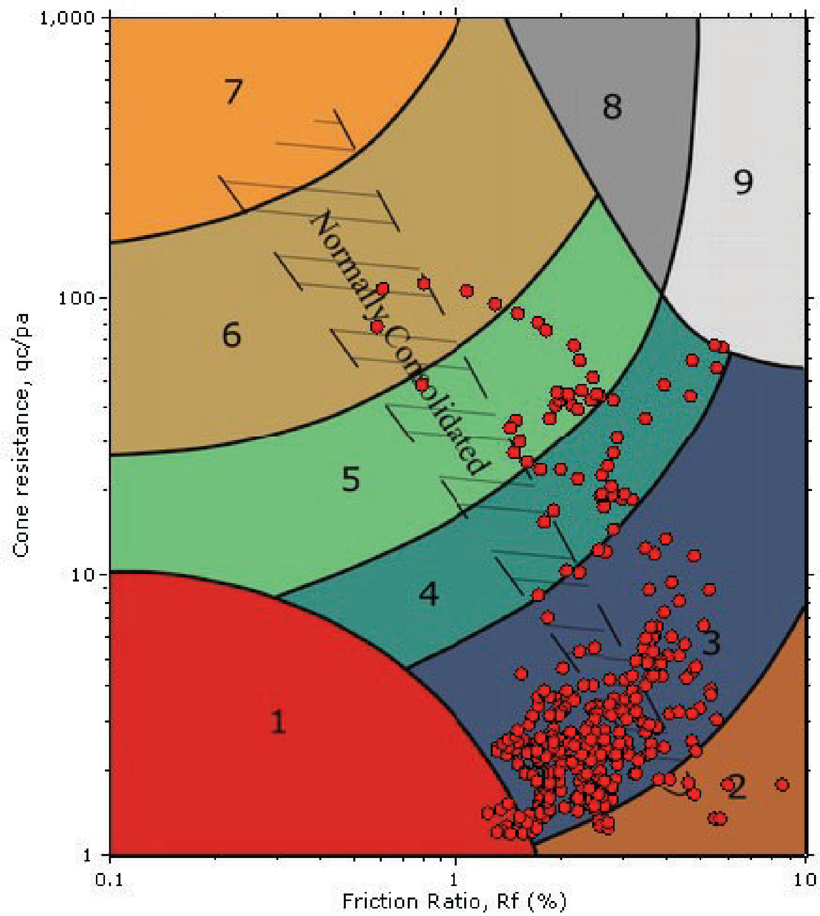
CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

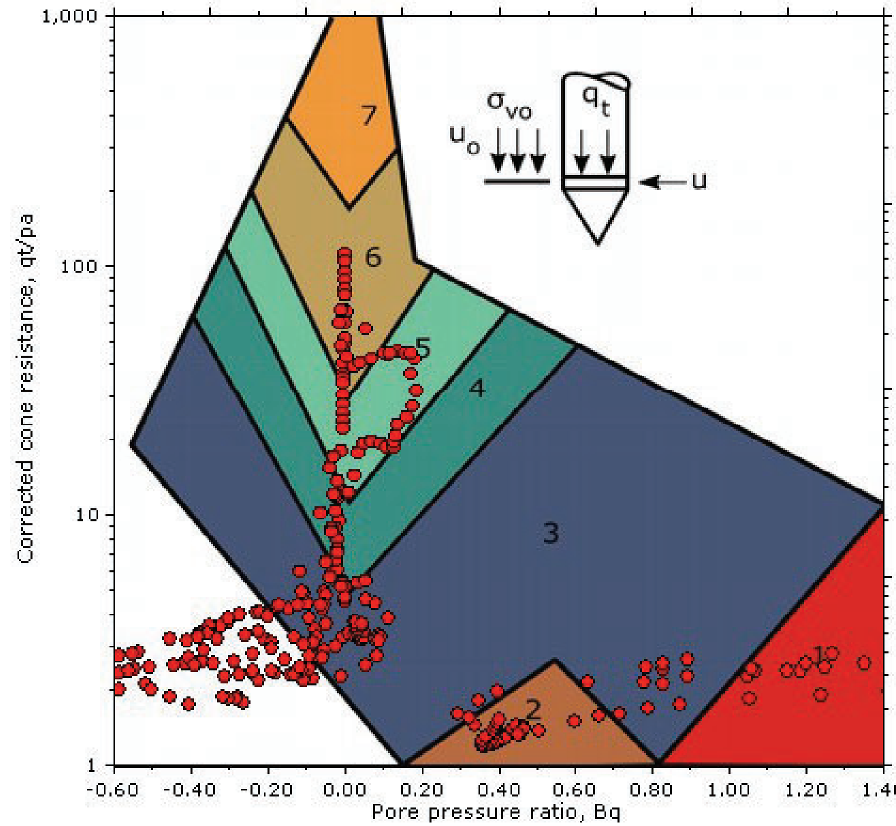
Project:
Location:

SBT - Bq plots

SBT plot



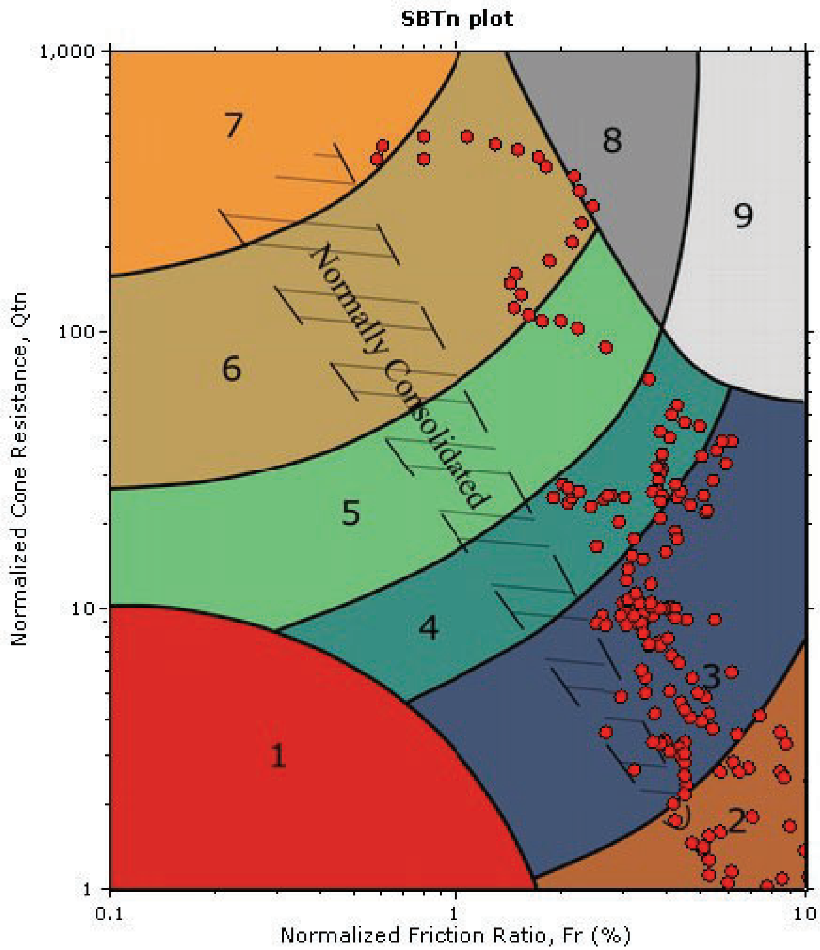
Bq plot

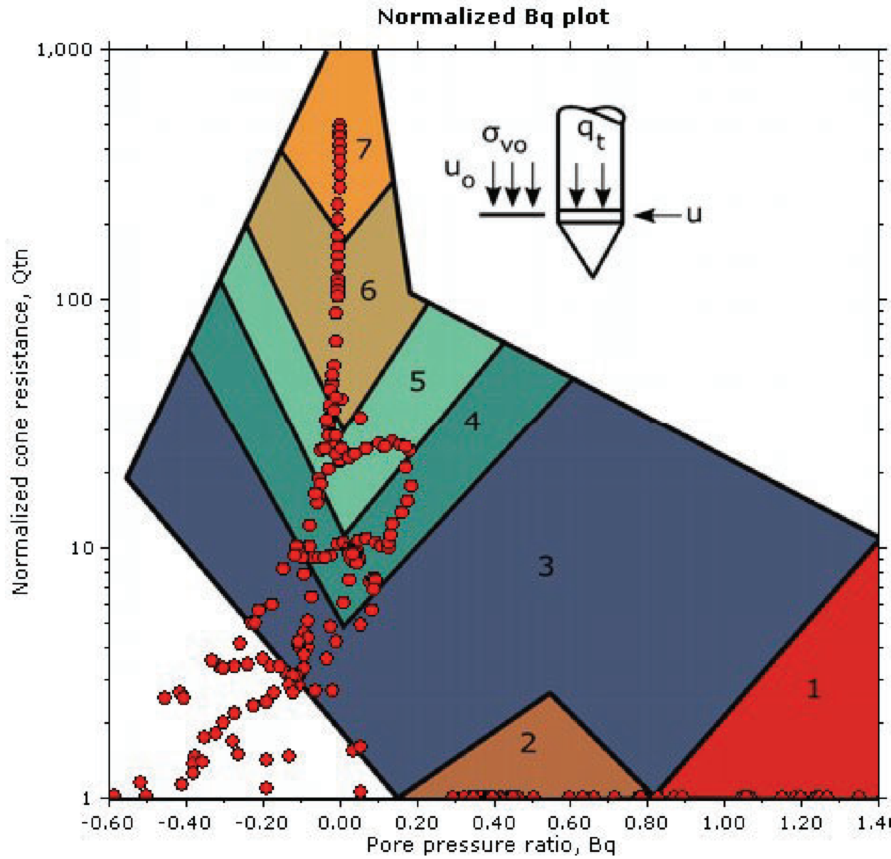


SBT legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravelly sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

SBT - Bq plots (normalized)





SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
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- 6. Clean sand to silty sand
- 7. Gravelly sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

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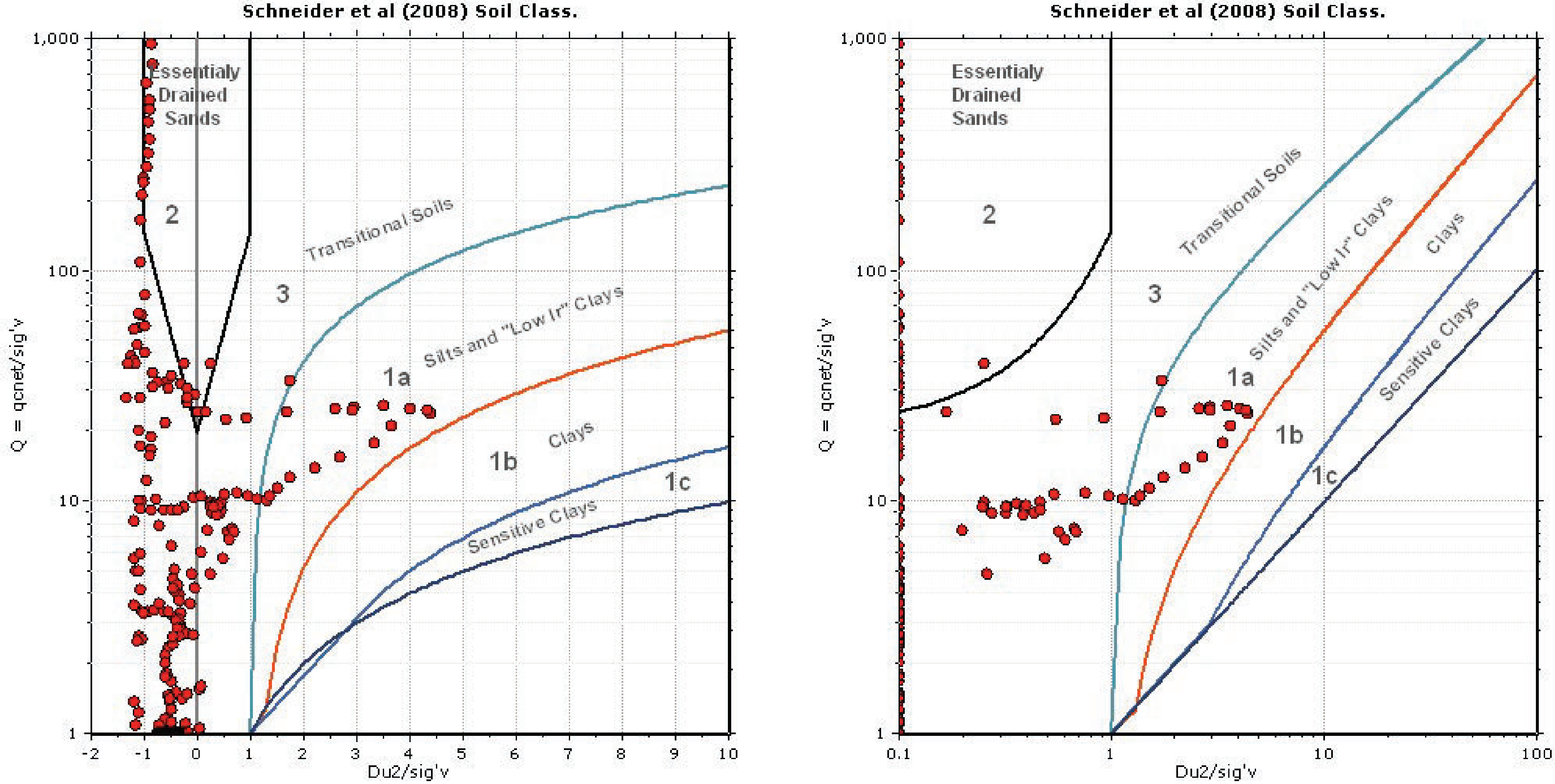
Project:
Location:

CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Bq plots (Schneider)



Ramboll
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CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
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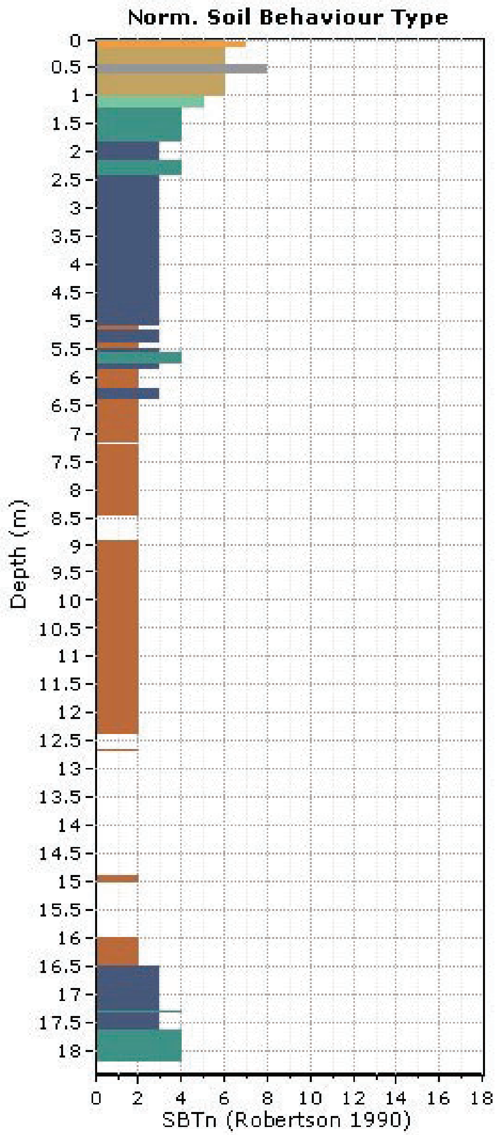
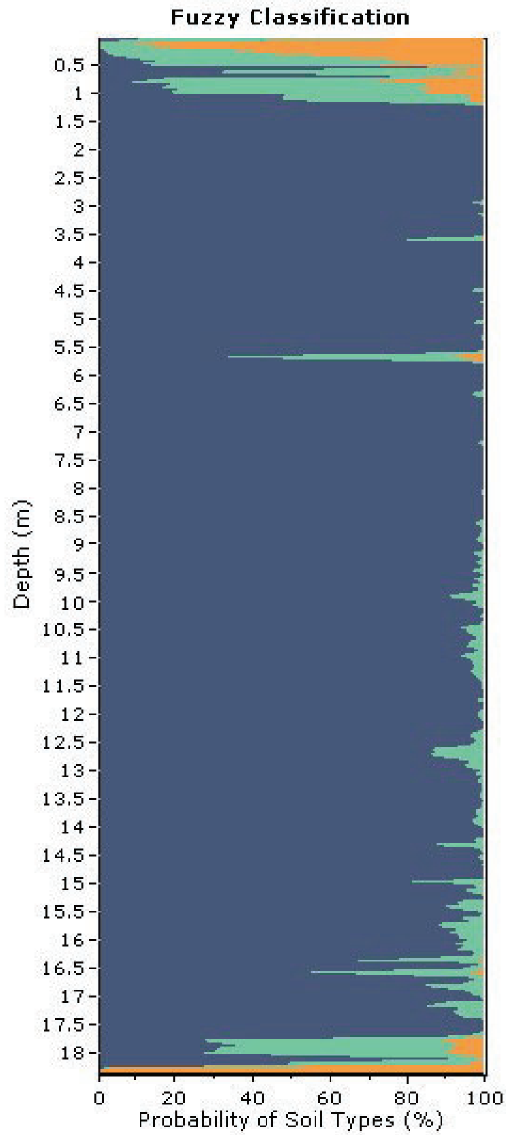
Cone Operator:

Project:
Location:





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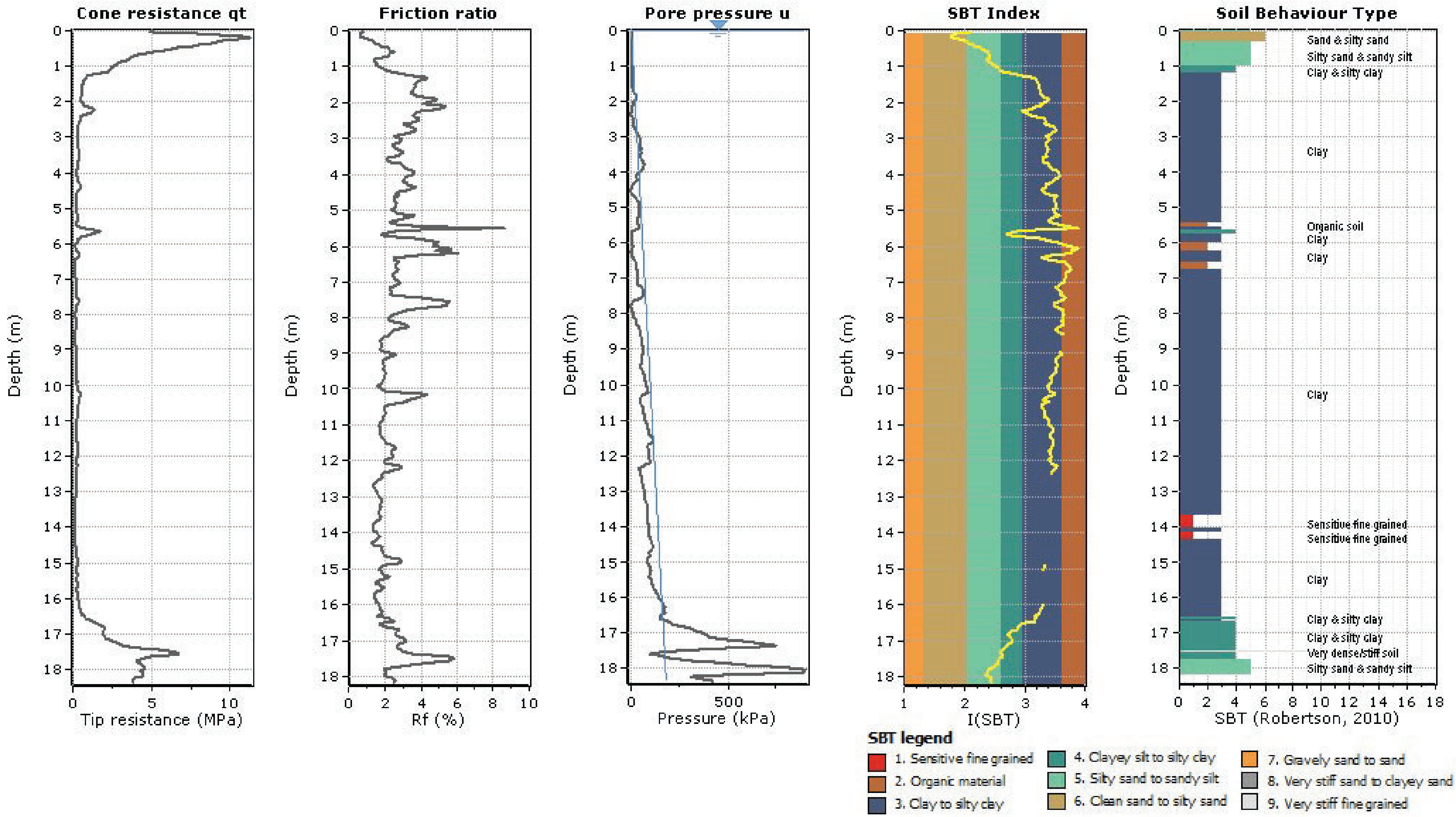
CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



Ramboll
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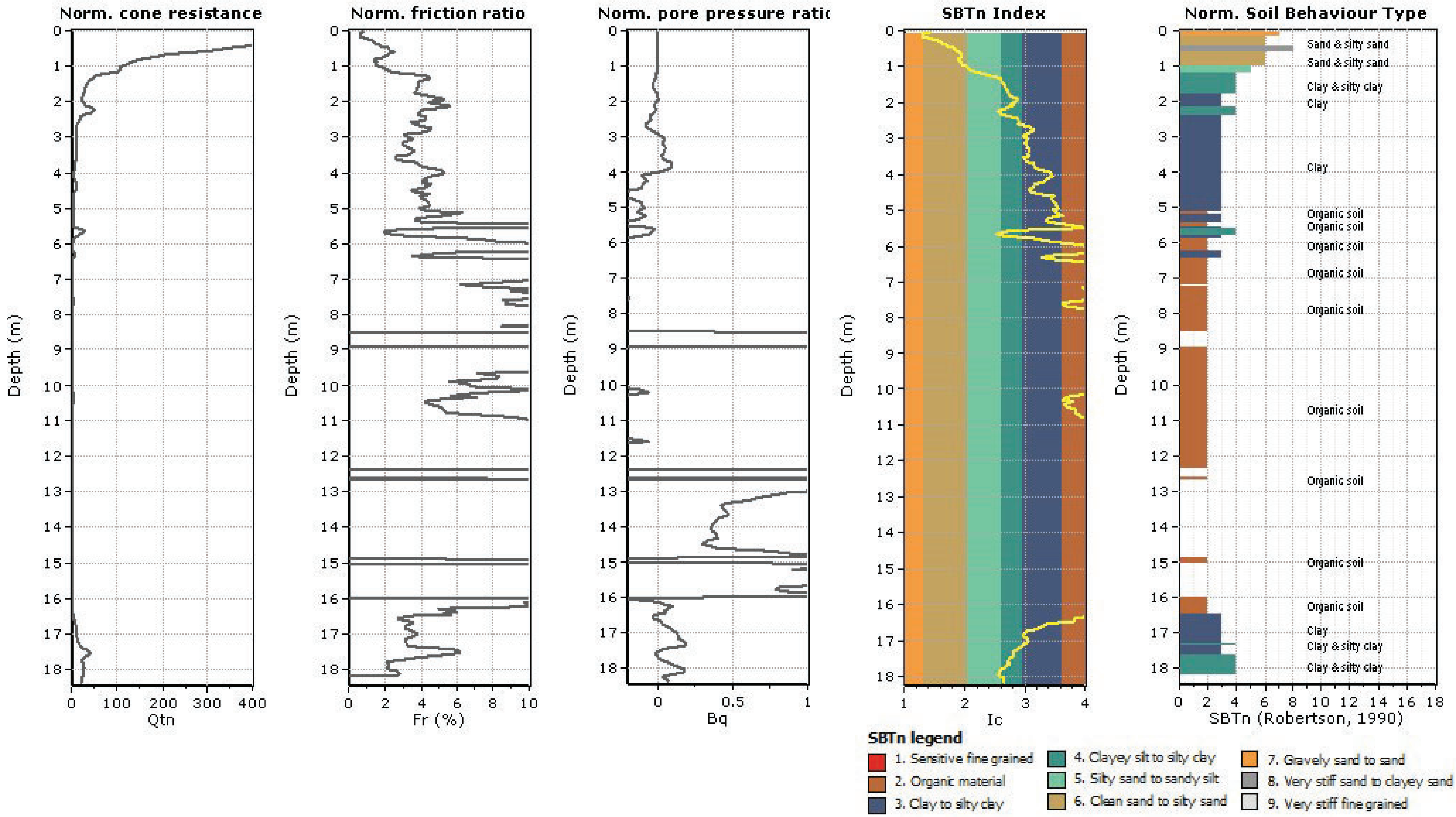
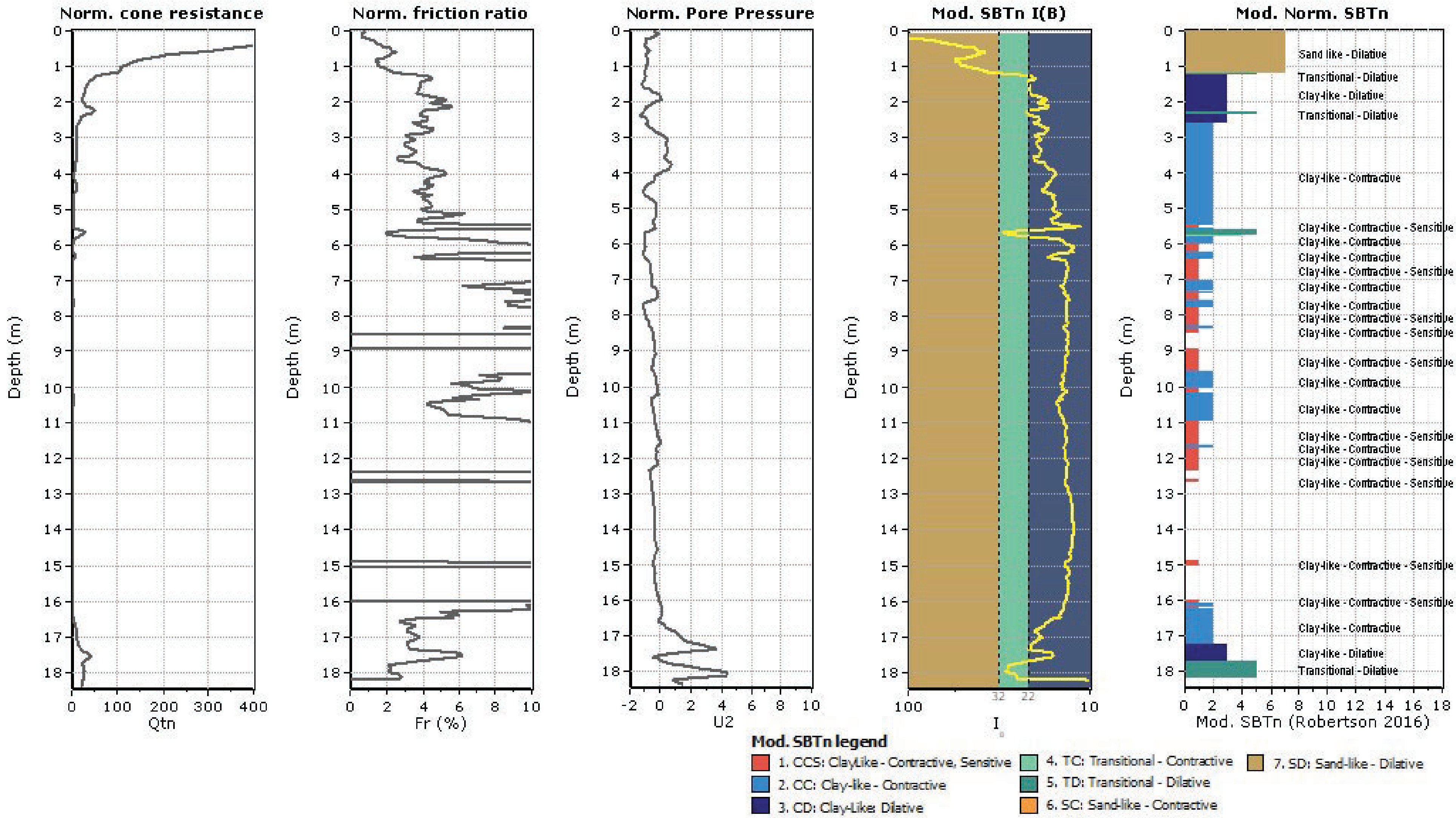
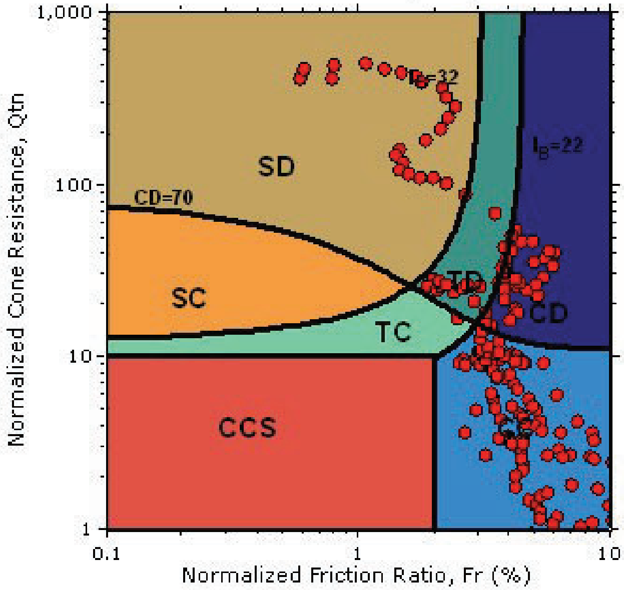
CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

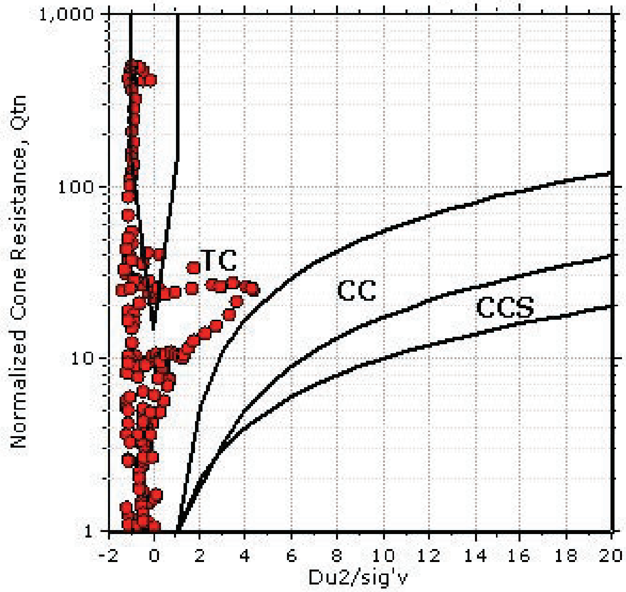
Project:
Location:

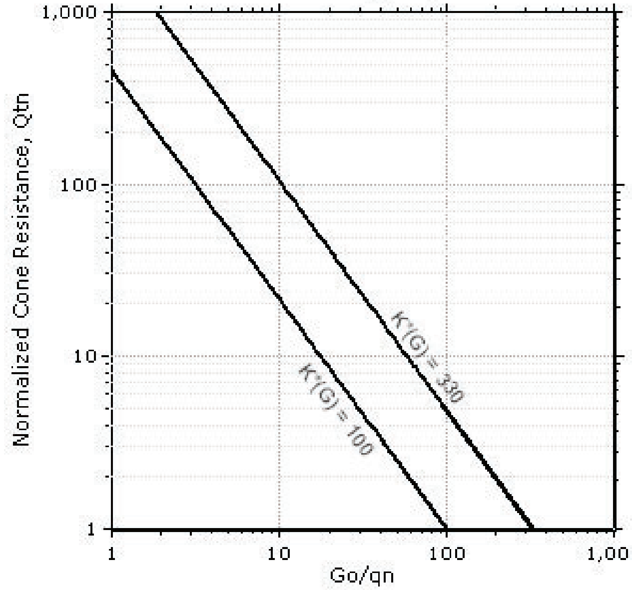



Norm. cone resistance
Depth (m)
Qtn
Norm. friction ratio
Fr (%)
Norm. Pore Pressure
U2
Mod. SBTn I(B)
I
Mod. Norm. SBTn
Sand like - Dilative
Transitional - Dilative
Clay-like - Dilative
Transitional - Dilative
Clay-like - Contractive
Clay-like - Contractive - Sensitive
Mod. SBTn (Robertson 2016)
Mod. SBTn legend
1. CCS: Clay-like - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

Updated SBTn plots

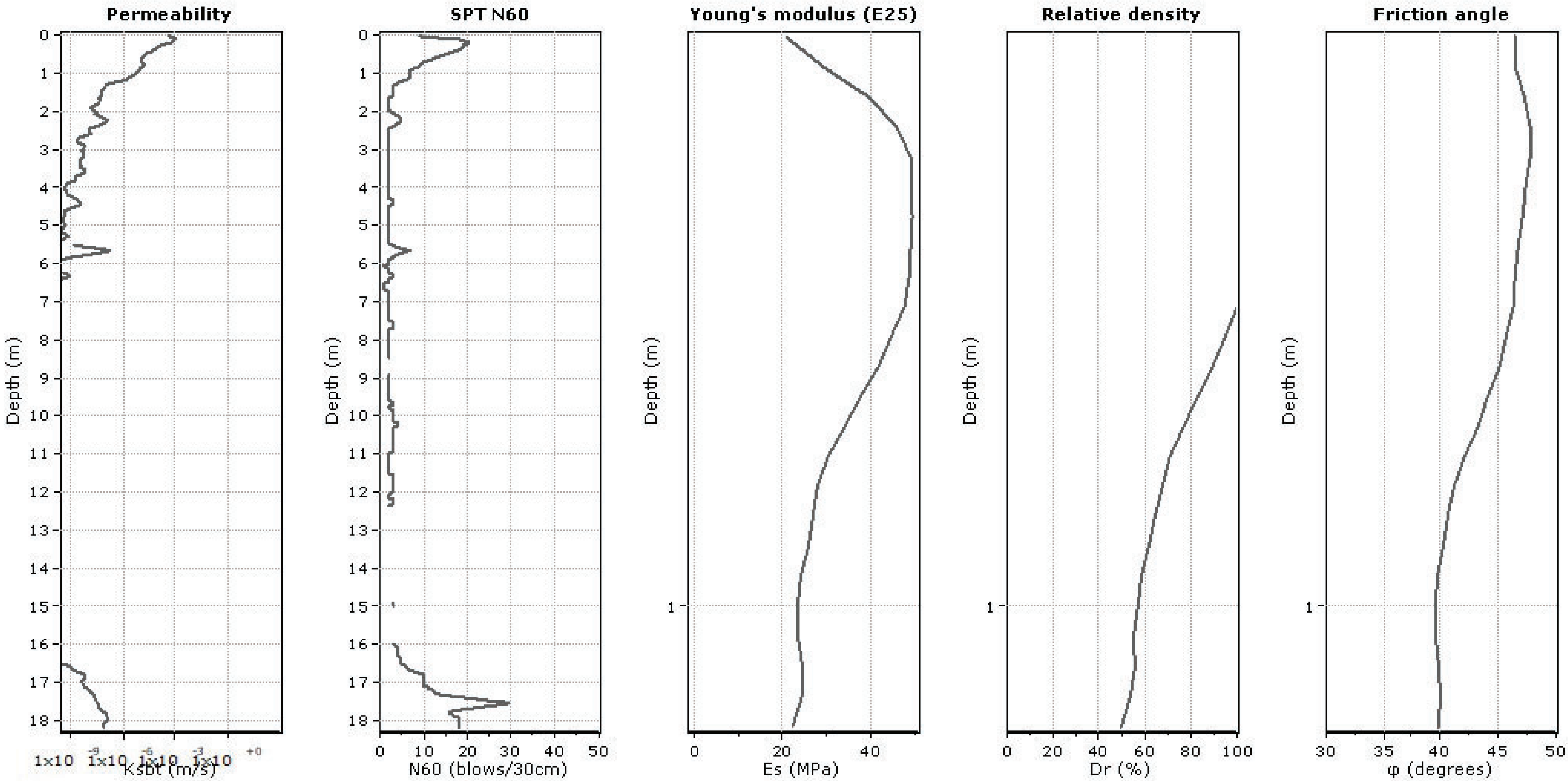






CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
TC: Transitional - Contractive
TD: Transitional - Dilative
SC: Sand-like - Contractive
SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

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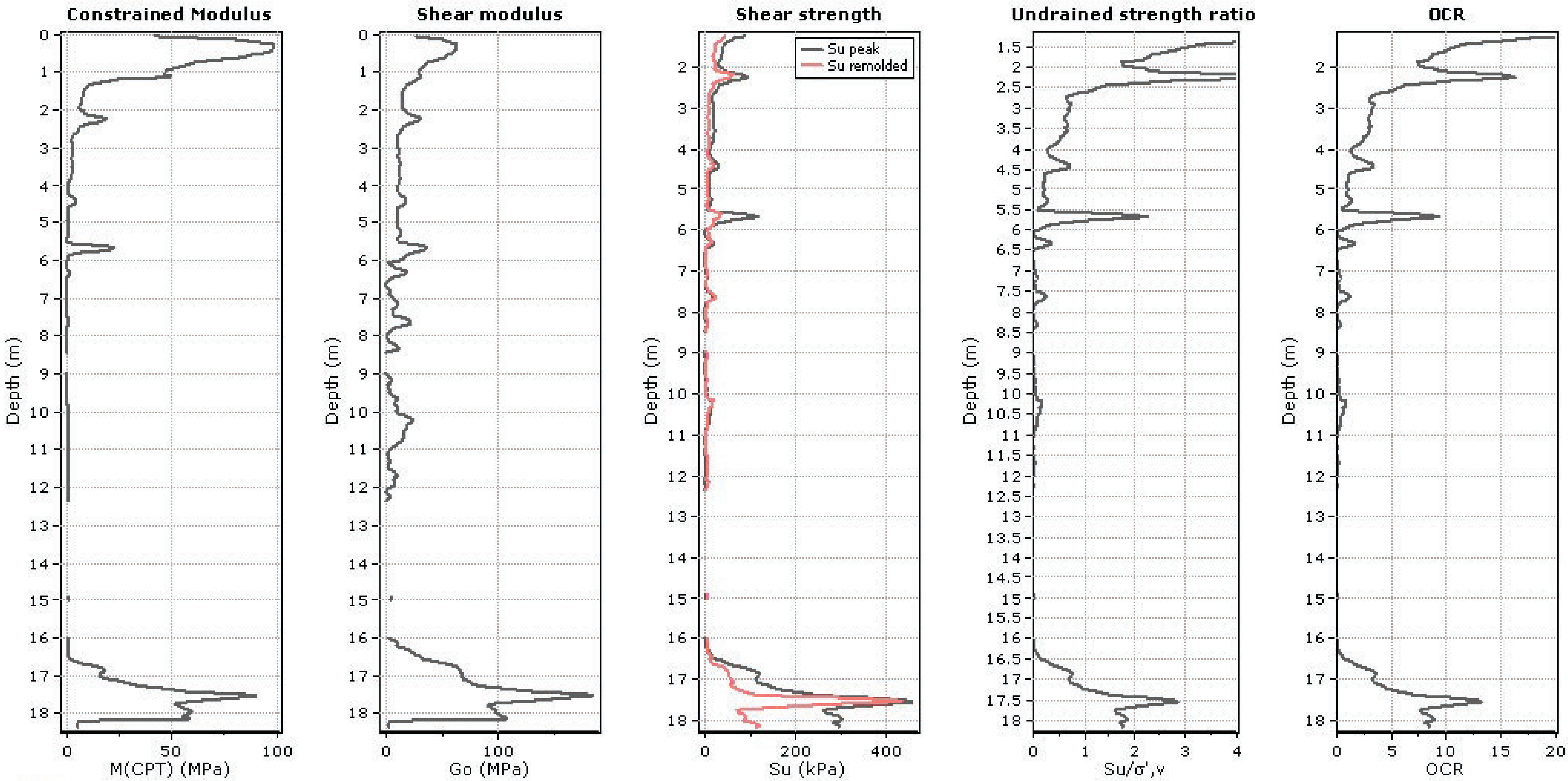
CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



Calculation parameters
Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data

Ramboll
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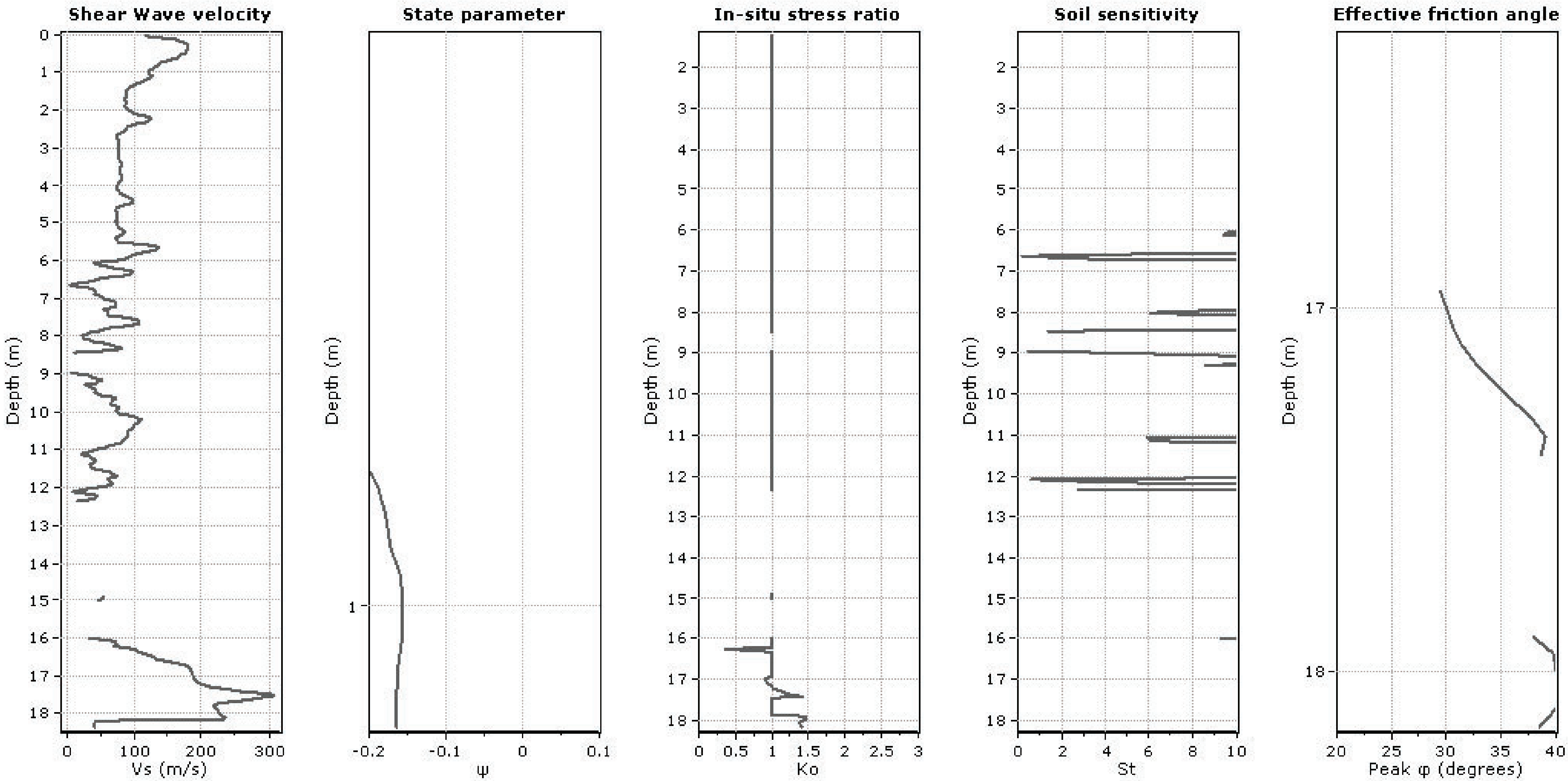
CPT: CPT-02
Total depth: 18.35 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

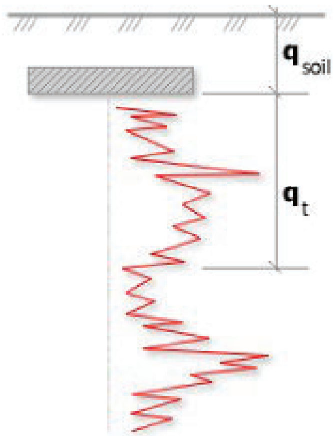
Project:
Location:



Calculation parameters

Soil Sensitivity factor, N_S: 350.00

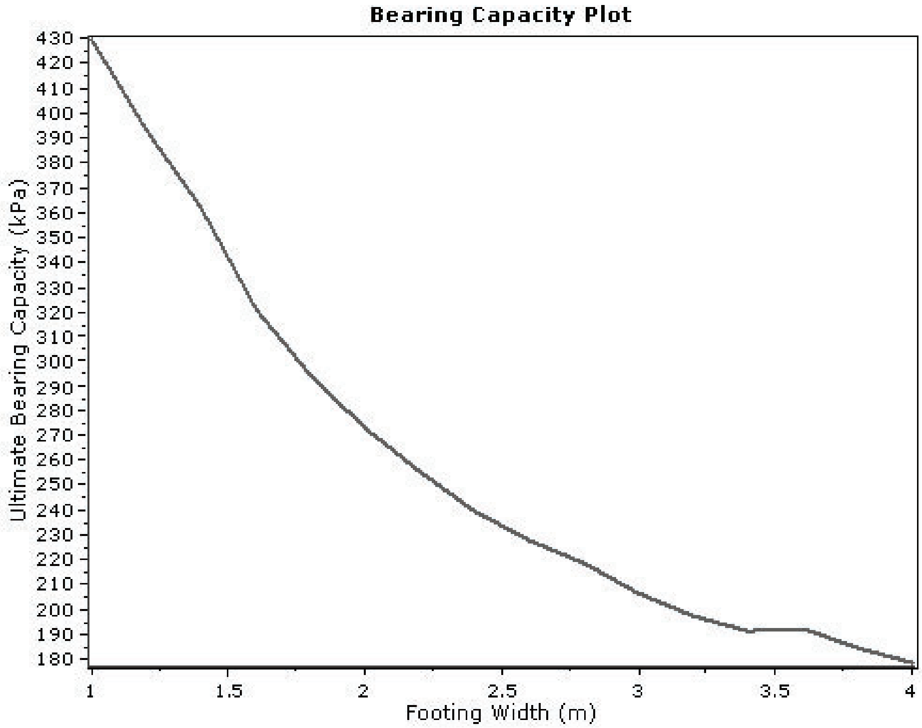
User defined estimation data



Bearing Capacity calculation is perfromed based on the formula:

$$Q_{ult} = R_k \times q_t + q_{soil}$$

where:
R_k: Bearing capacity factor
q_t: Average corrected cone resistance over calculation depth
q_{soil}: Pressure applied by soil above footing



:: Tabular results ::

No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	2.10	0.20	9.50	429.42
2	1.20	0.50	2.30	1.92	0.20	9.50	393.46
3	1.40	0.50	2.60	1.76	0.20	9.50	361.96
4	1.60	0.50	2.90	1.56	0.20	9.50	320.94
5	1.80	0.50	3.20	1.42	0.20	9.50	294.31
6	2.00	0.50	3.50	1.32	0.20	9.50	273.11
7	2.20	0.50	3.80	1.23	0.20	9.50	255.74
8	2.40	0.50	4.10	1.15	0.20	9.50	239.70
9	2.60	0.50	4.40	1.09	0.20	9.50	227.77
10	2.80	0.50	4.70	1.05	0.20	9.50	218.84
11	3.00	0.50	5.00	0.98	0.20	9.50	206.32
12	3.20	0.50	5.30	0.94	0.20	9.50	197.46
13	3.40	0.50	5.60	0.91	0.20	9.50	191.65
14	3.60	0.50	5.90	0.91	0.20	9.50	192.08
15	3.80	0.50	6.20	0.87	0.20	9.50	184.39
16	4.00	0.50	6.50	0.85	0.20	9.50	178.57

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 I_c + 1.68}$$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$$

:: Drained Friction Angle, φ (°) ::

$$\varphi = \varphi'_{cv} + 15.94 \cdot \log(Q_{tn,cs}) - 26.88$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$\alpha = 14$ for $Q_{tn} > 14$
$\alpha = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = \alpha \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

$$M_{CPT} = 0.03 \cdot (q_t - \sigma_v) \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$$OCR = k_{OCR} \cdot Q_{tn}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

$$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$$

(applicable for $0.10 < B_q < 1.00$)

References

• Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012

• Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

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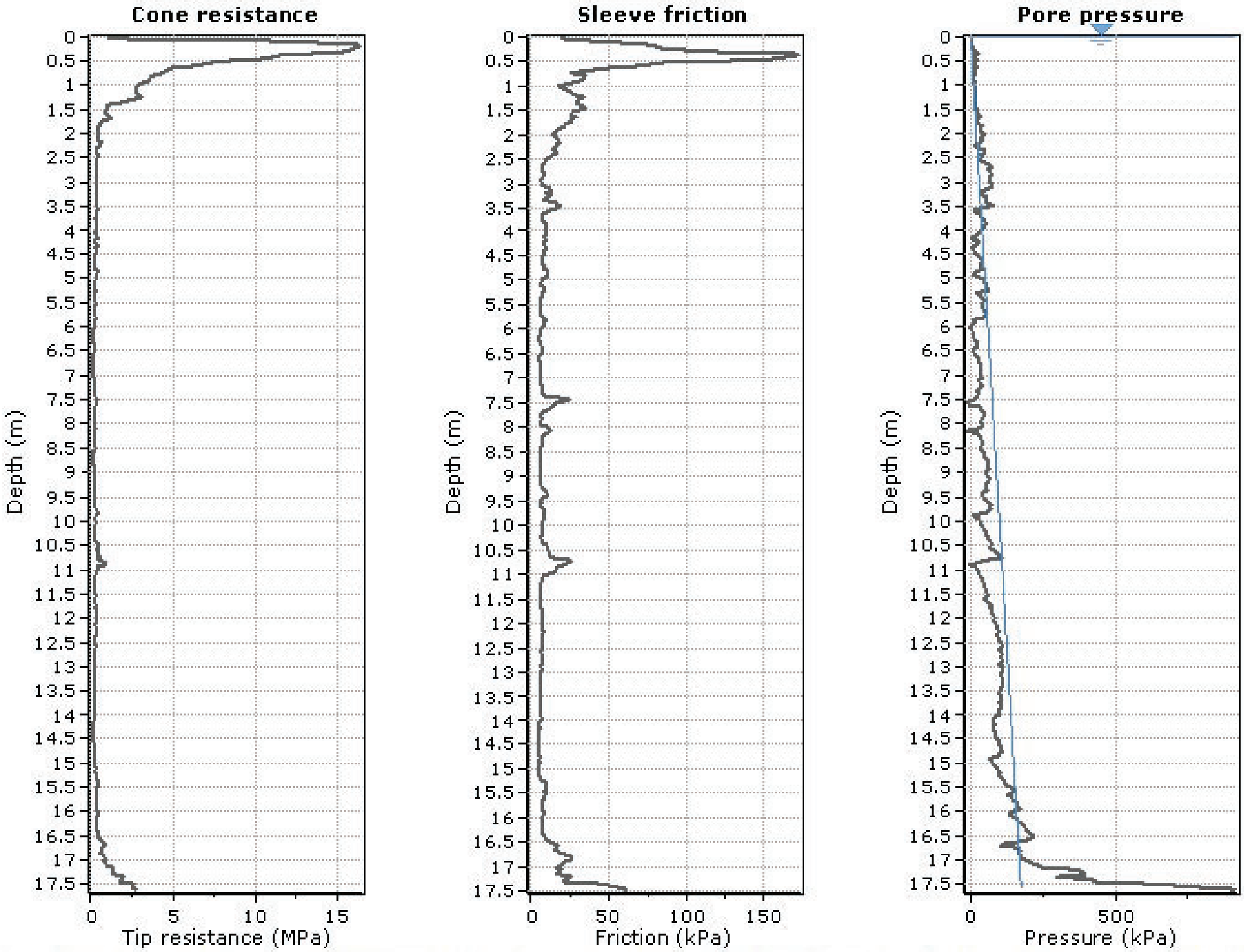
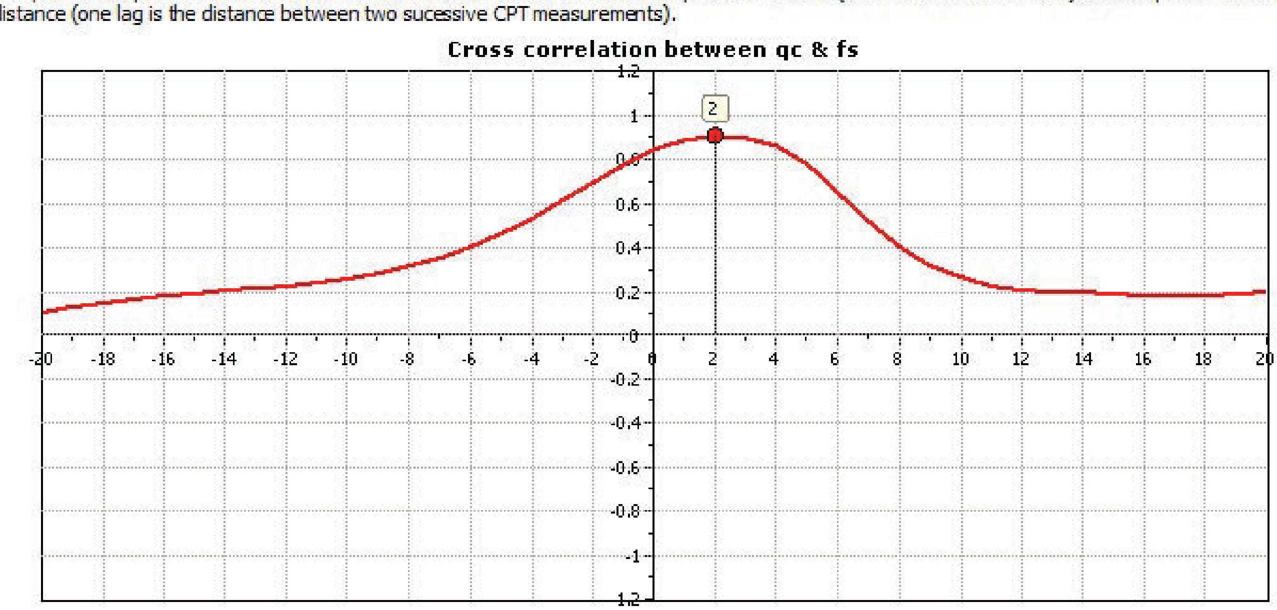
CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



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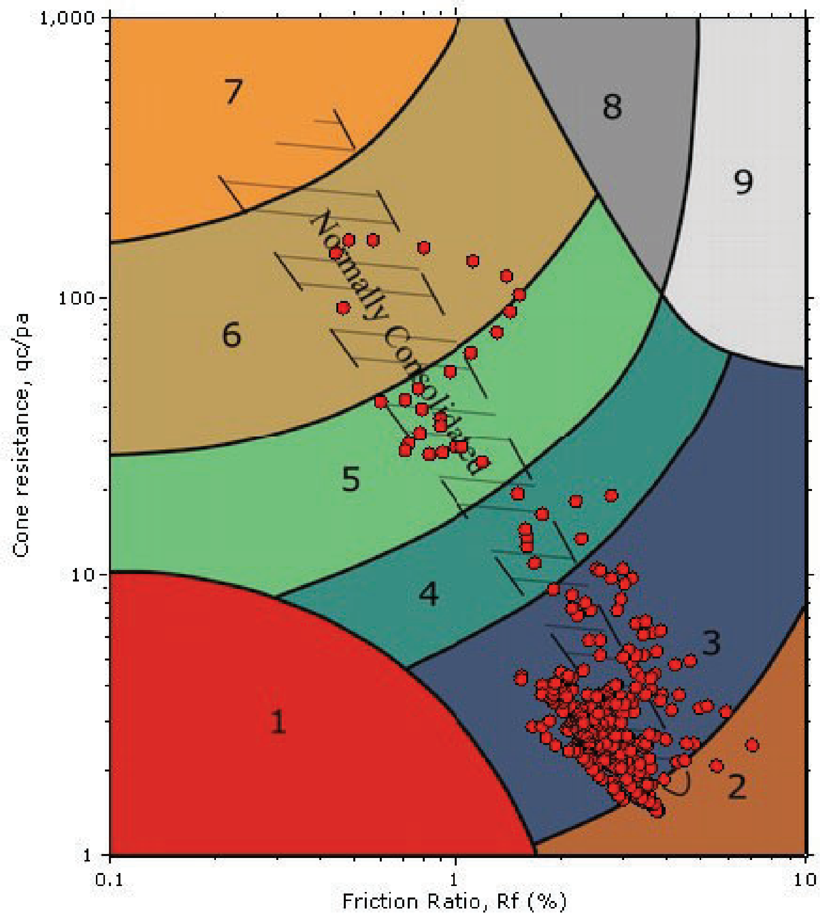
Project:
Location:

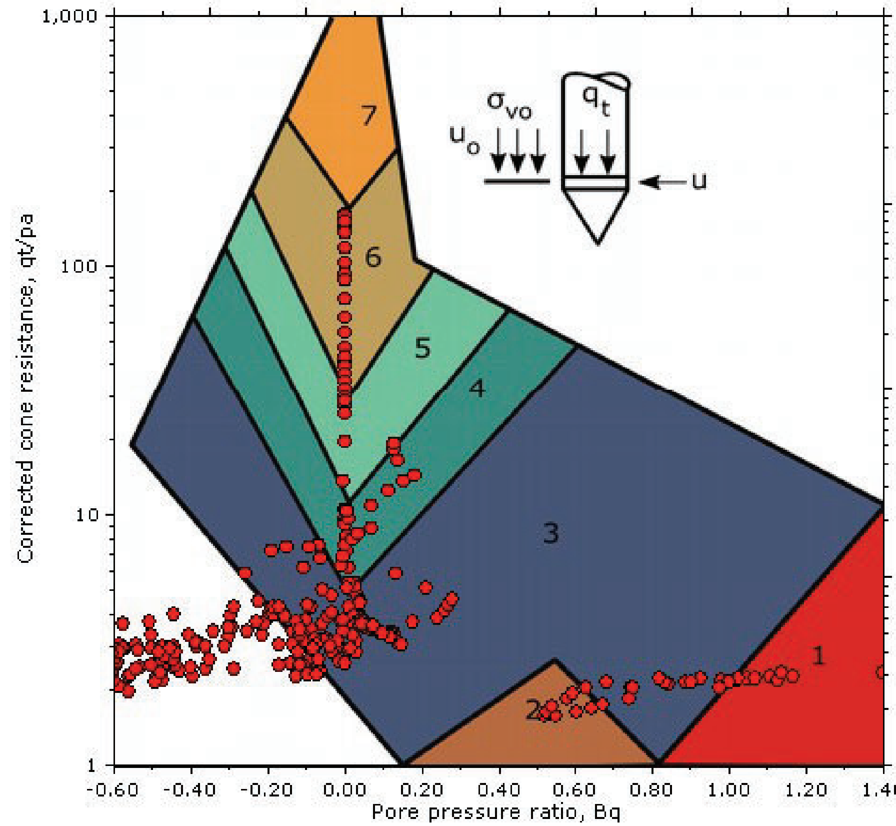
CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

SBT - Bq plots

SBT plot



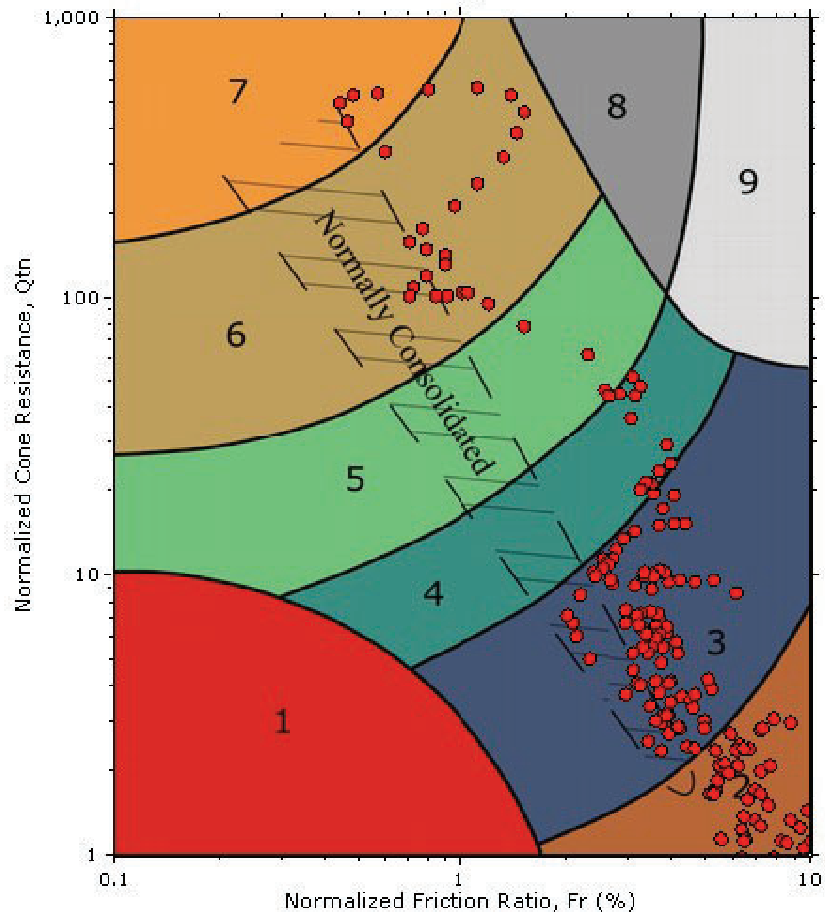
Bq plot

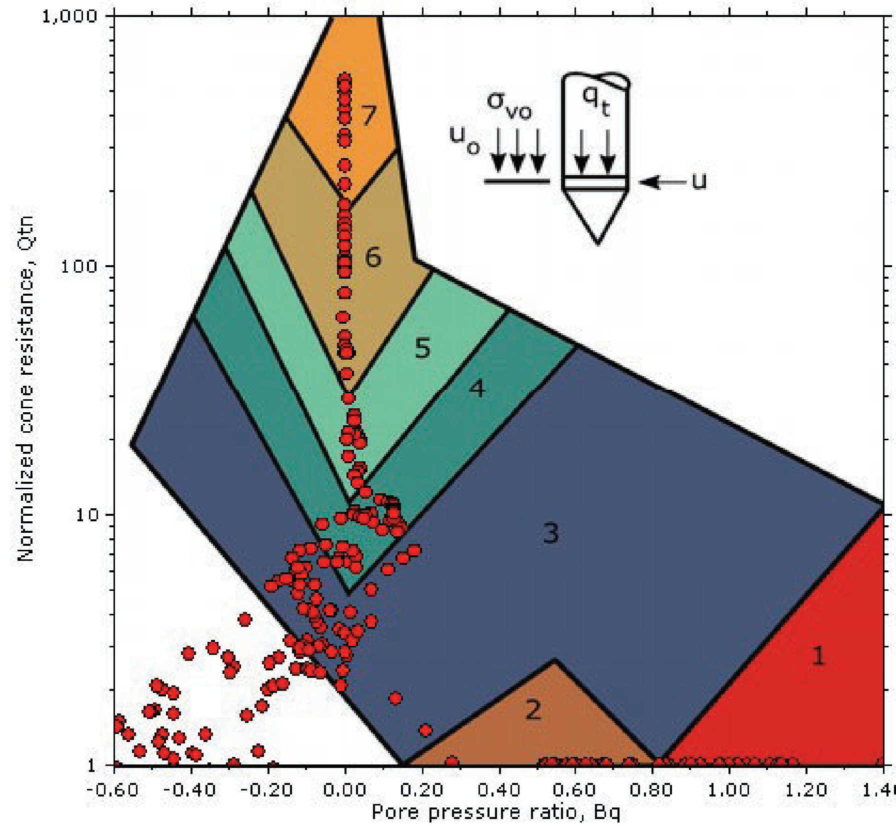


SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

SBT - Bq plots (normalized)

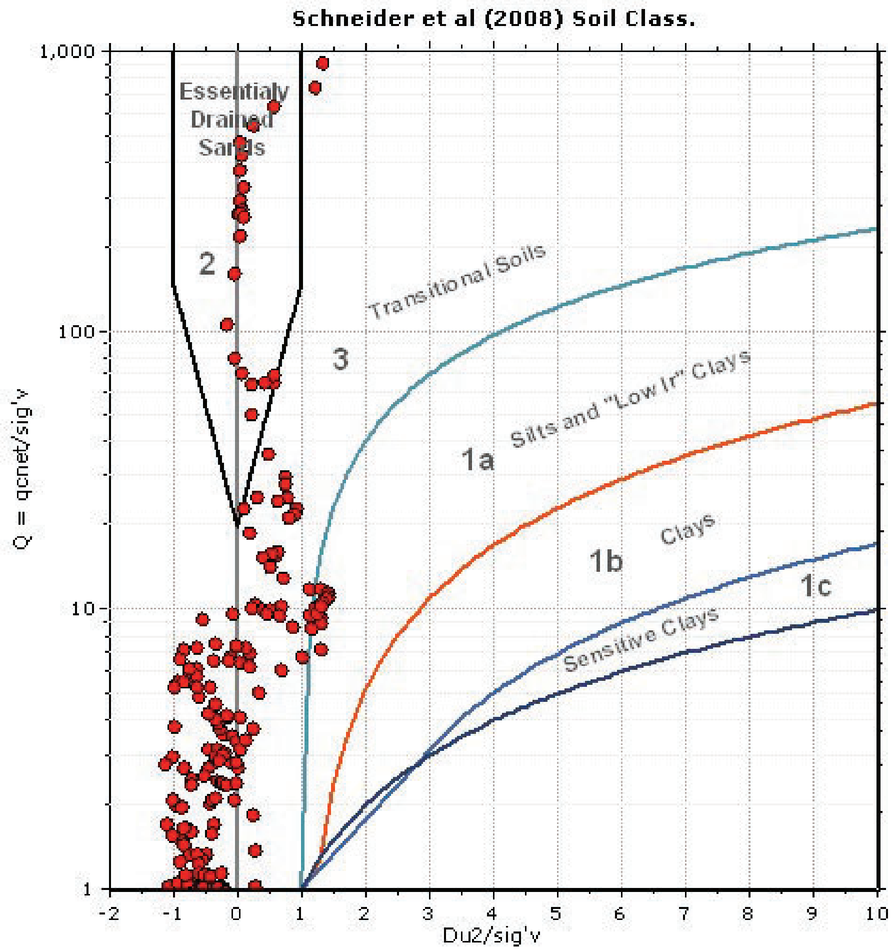


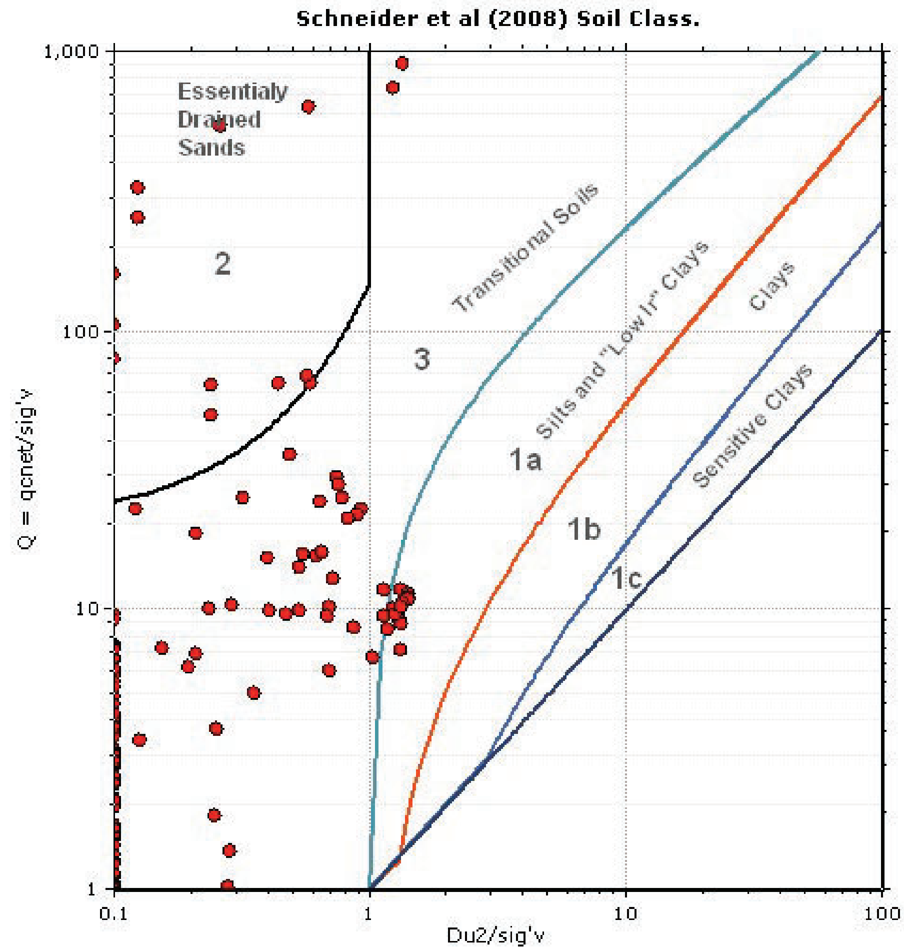


SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

Bq plots (Schneider)





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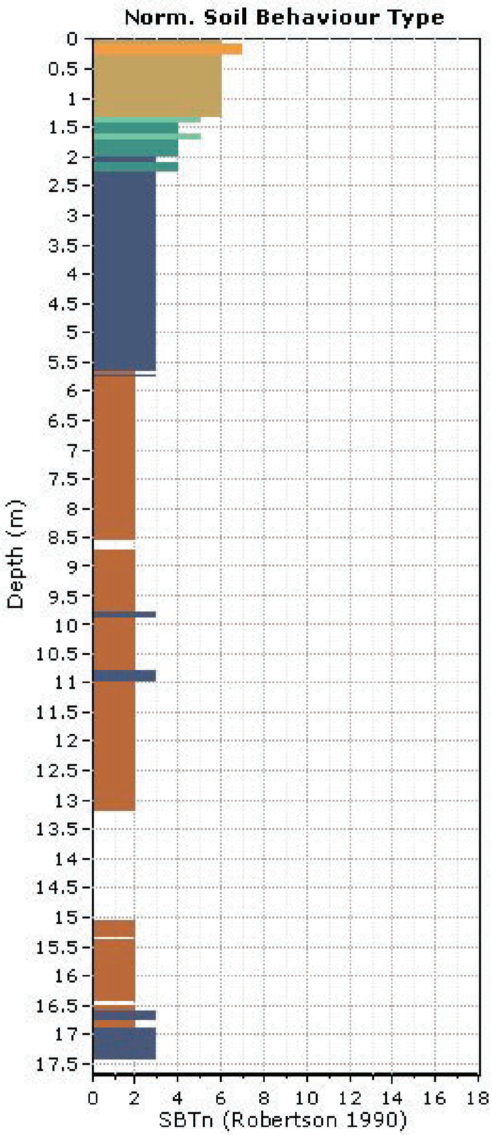
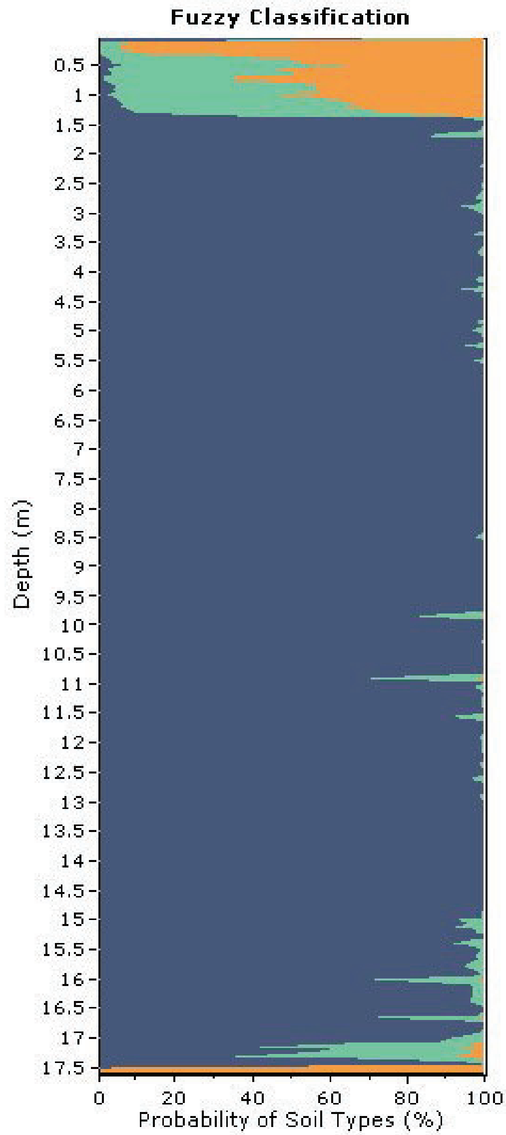
CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:





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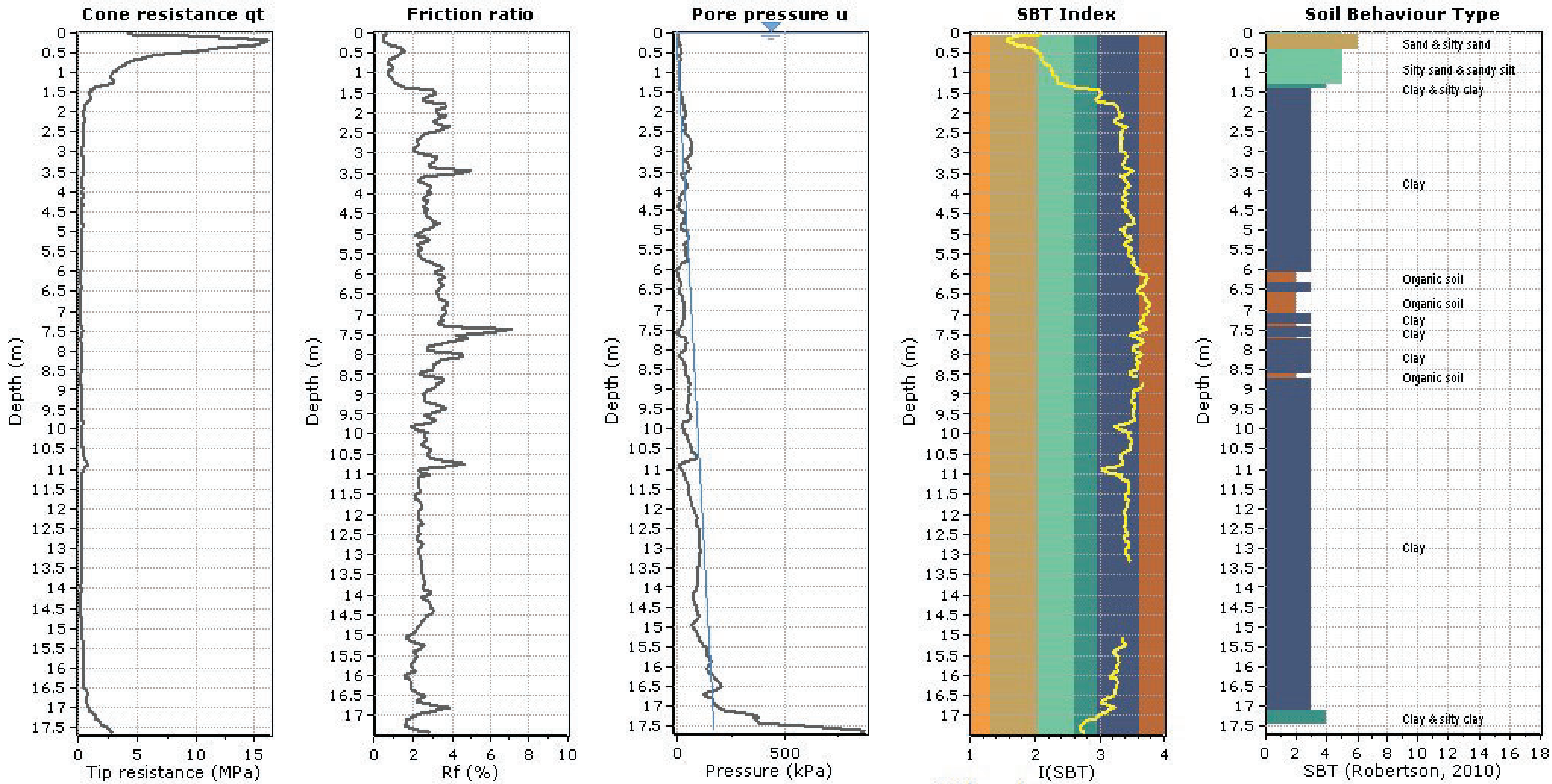
Project:
Location:

CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



SBT legend

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6. Clean sand to silty sand
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8. Very stiff sand to clayey sand
9. Very stiff fine grained

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CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
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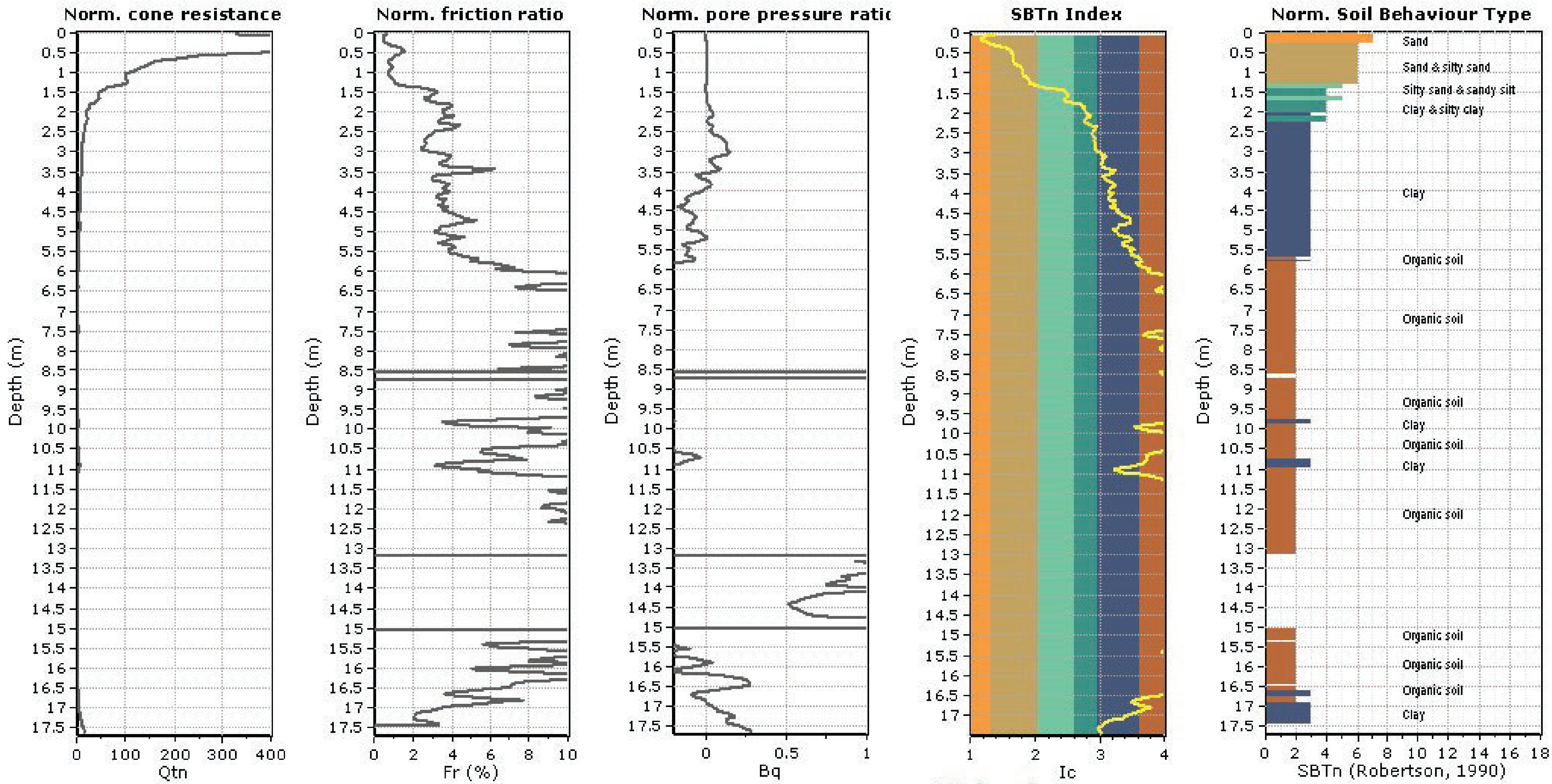

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CPT: CPT-03
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Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
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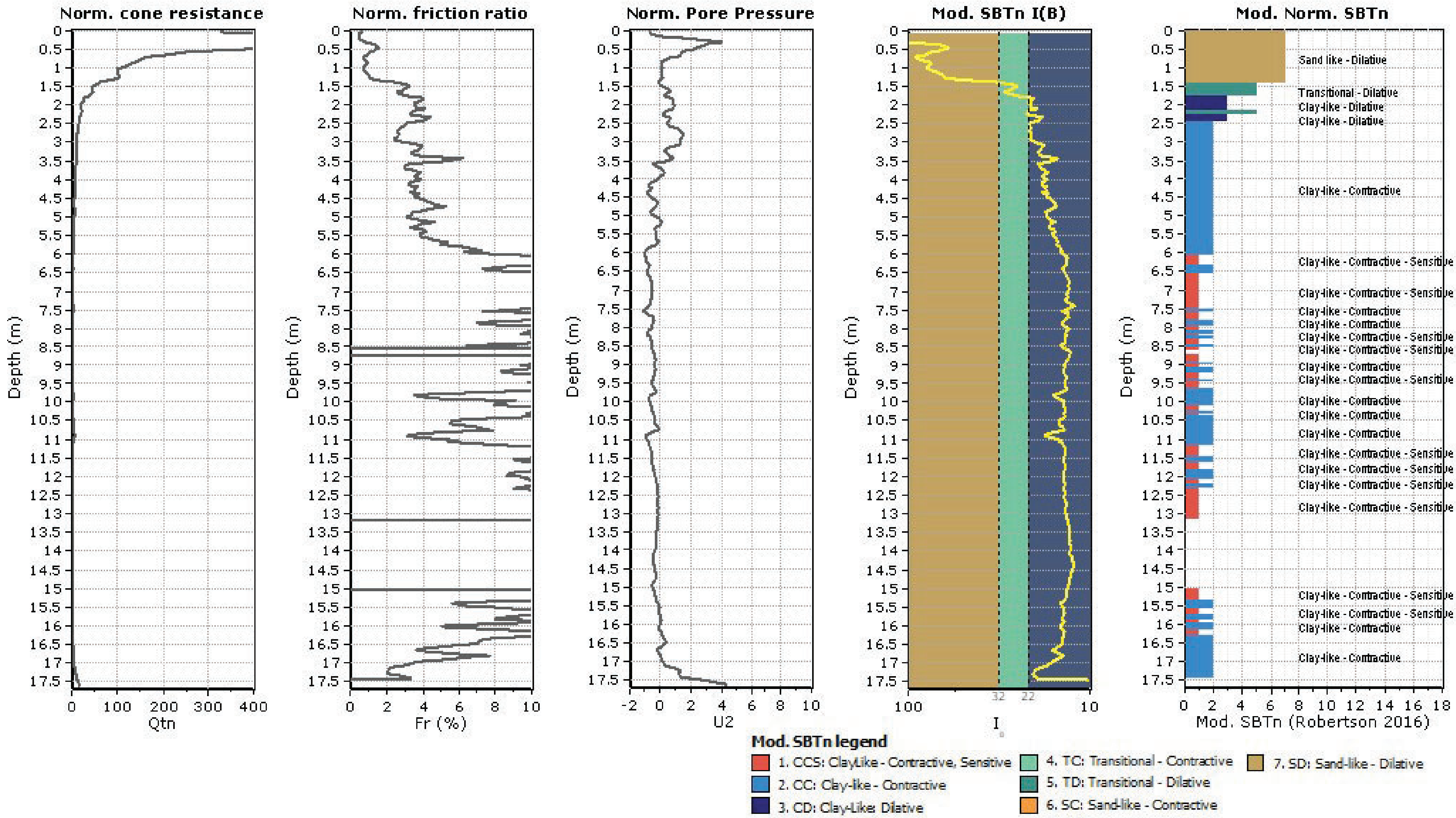
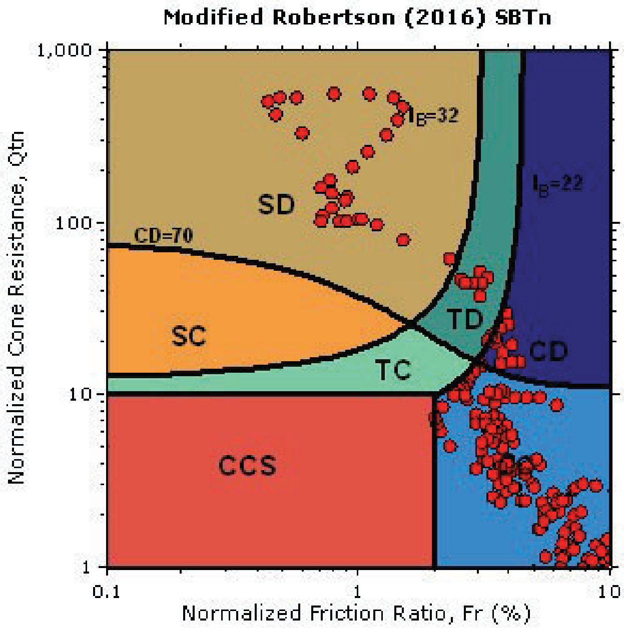
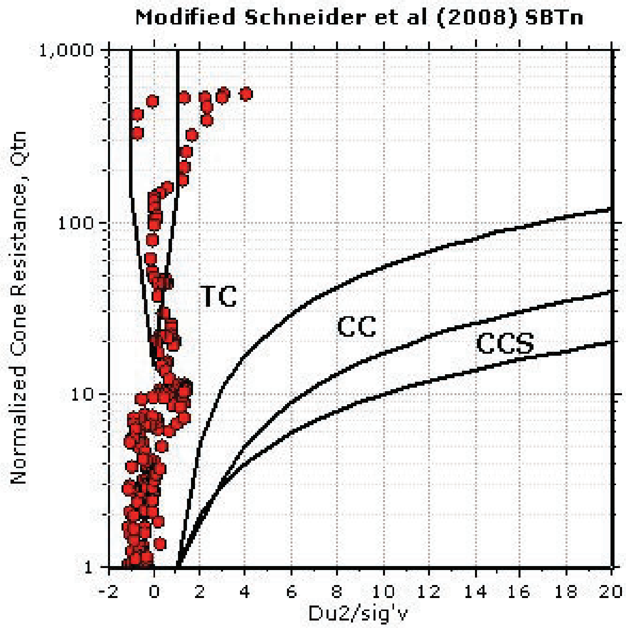
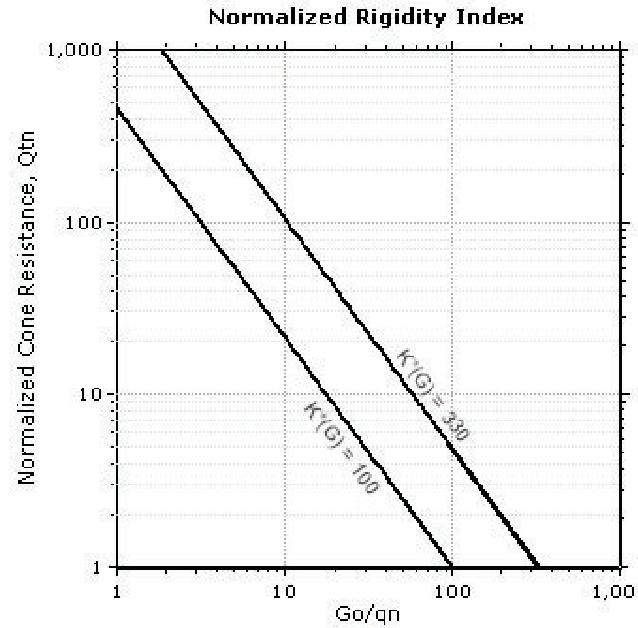


Updated SBTn plots







CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
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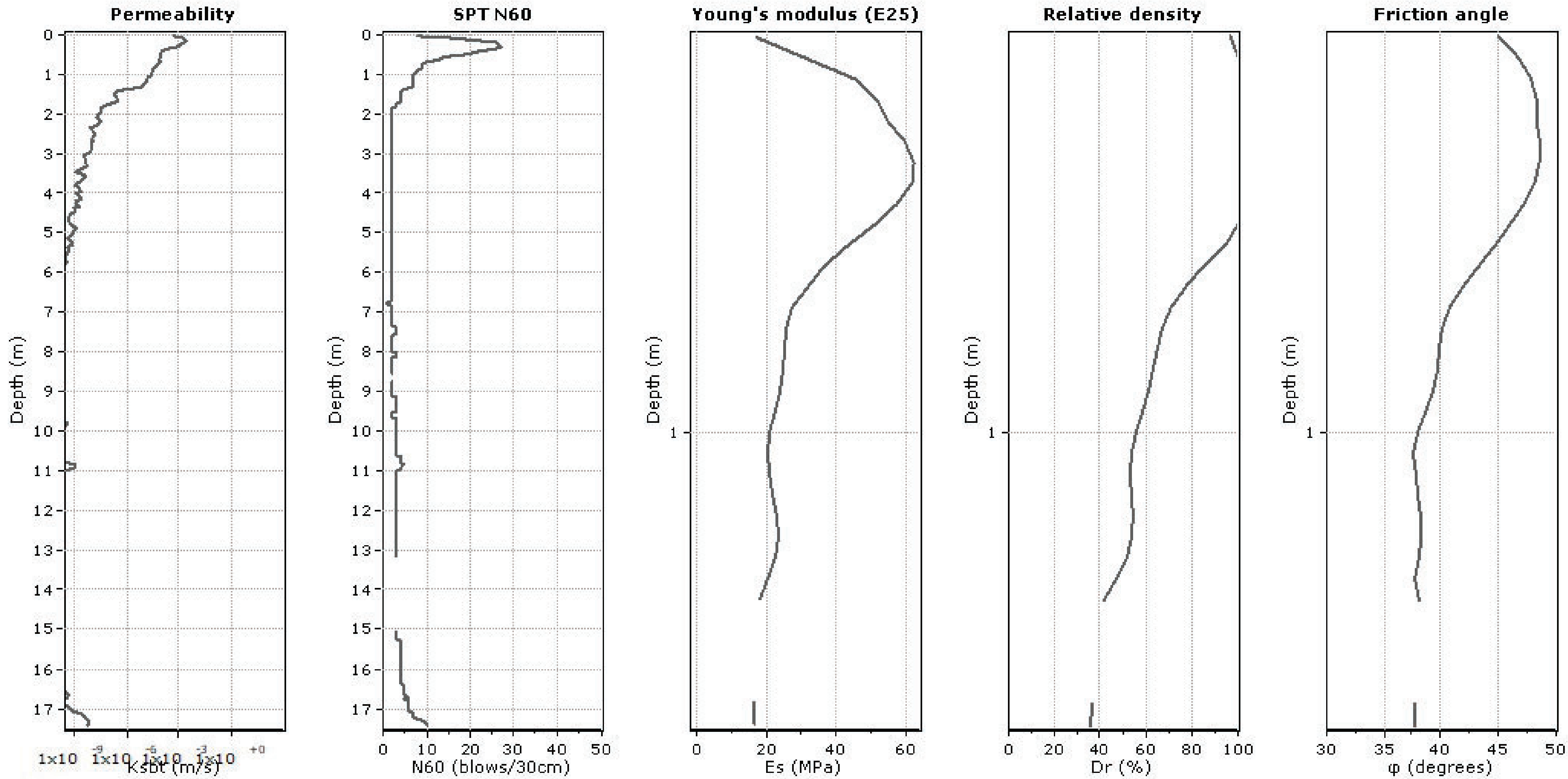
K(G) > 330: Soils with significant microstructure (e.g. age/cementation)



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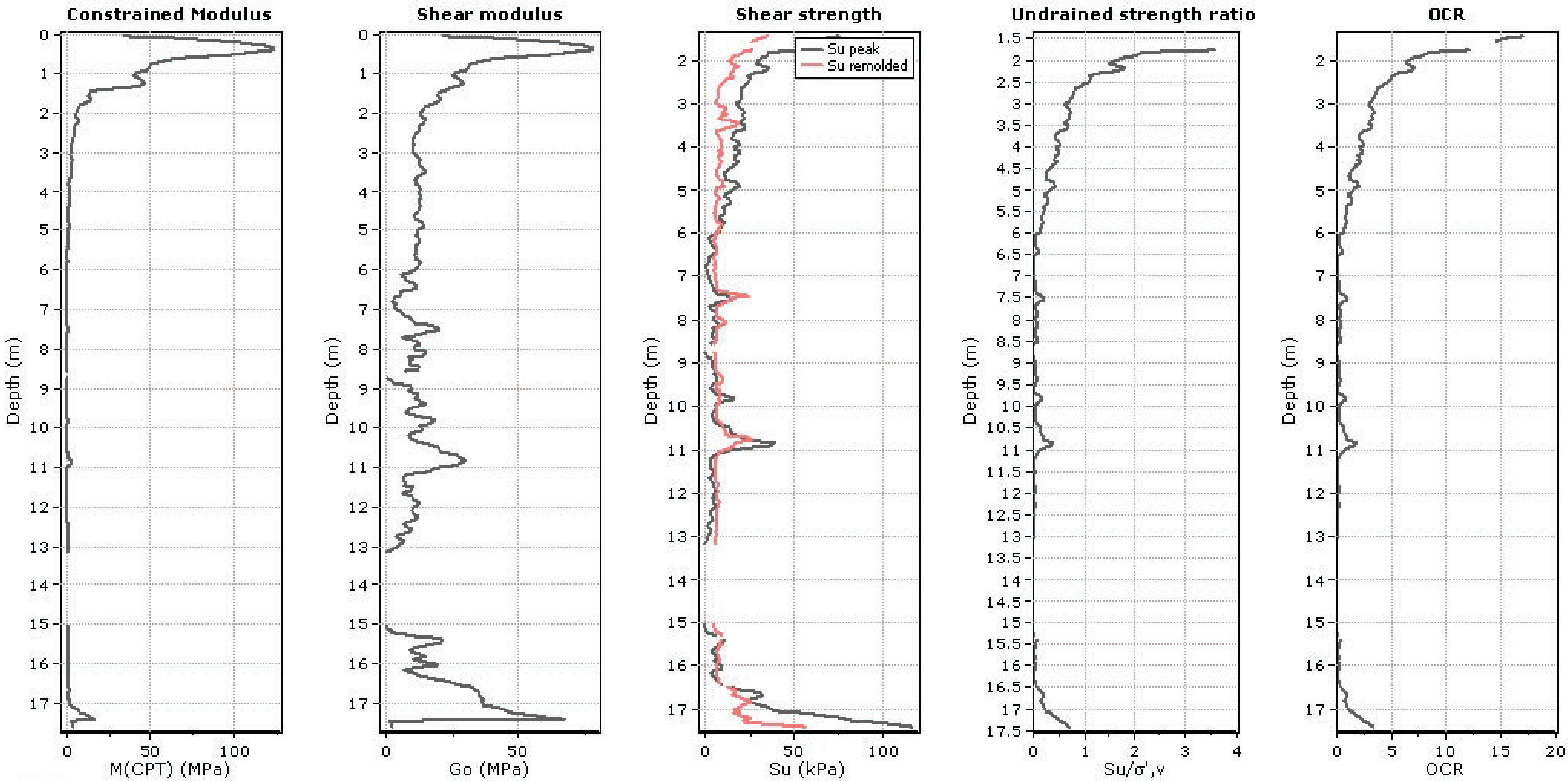
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

Project:
Location:



Calculation parameters
Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14

OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data

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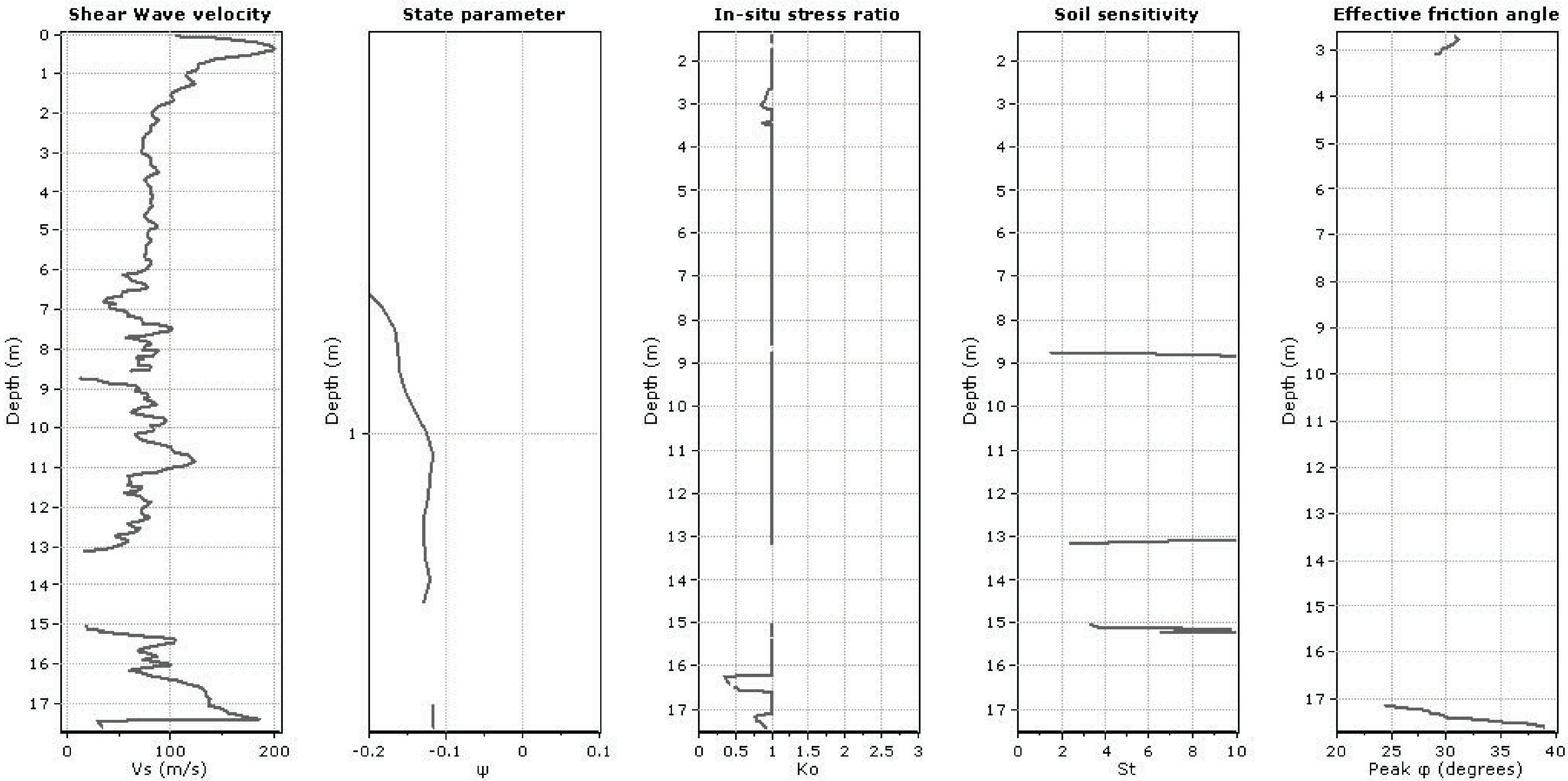
Project:
Location:

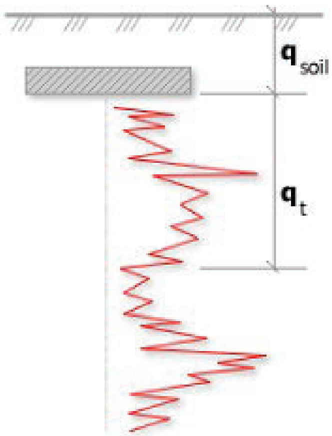
CPT: CPT-03
Total depth: 17.60 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



Calculation parameters

Soil Sensitivity factor, N_S: 350.00

User defined estimation data



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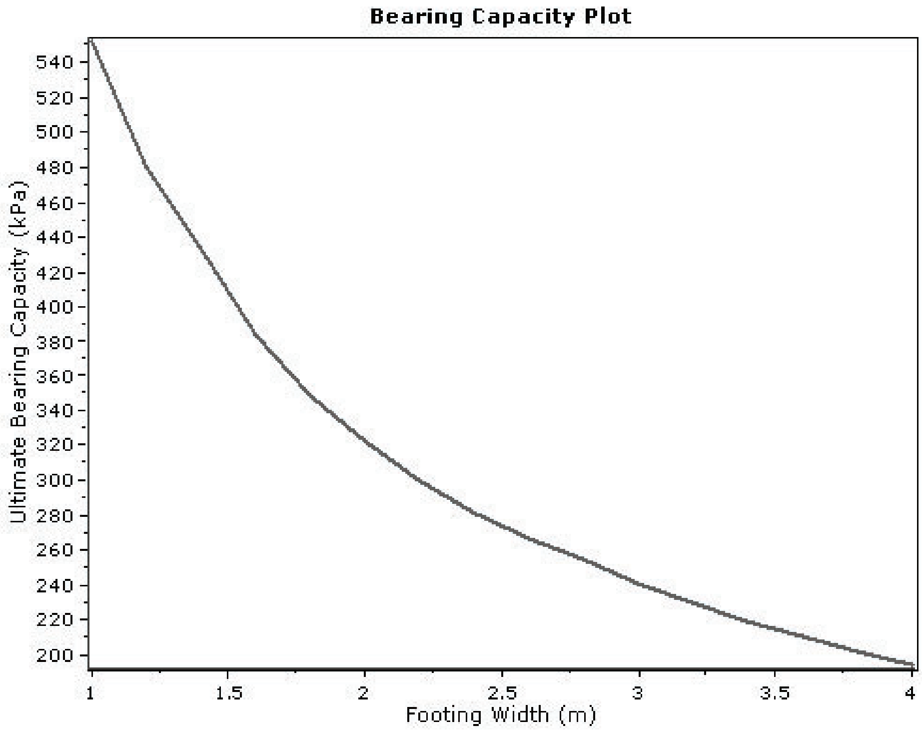
$$Q_{ult} = R_k \times q_t + q_{soil}$$

where:
R_k: Bearing capacity factor
q_t: Average corrected cone resistance over calculation depth
q_{soil}: Pressure applied by soil above footing



:: Tabular results ::

No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	2.71	0.20	9.50	552.27
2	1.20	0.50	2.30	2.35	0.20	9.50	480.02
3	1.40	0.50	2.60	2.12	0.20	9.50	433.31
4	1.60	0.50	2.90	1.87	0.20	9.50	382.52
5	1.80	0.50	3.20	1.70	0.20	9.50	349.08
6	2.00	0.50	3.50	1.57	0.20	9.50	322.79
7	2.20	0.50	3.80	1.46	0.20	9.50	300.58
8	2.40	0.50	4.10	1.36	0.20	9.50	282.09
9	2.60	0.50	4.40	1.28	0.20	9.50	266.35
10	2.80	0.50	4.70	1.22	0.20	9.50	254.24
11	3.00	0.50	5.00	1.15	0.20	9.50	240.23
12	3.20	0.50	5.30	1.10	0.20	9.50	229.45
13	3.40	0.50	5.60	1.05	0.20	9.50	219.56
14	3.60	0.50	5.90	1.01	0.20	9.50	210.65
15	3.80	0.50	6.20	0.96	0.20	9.50	202.04
16	4.00	0.50	6.50	0.92	0.20	9.50	194.41

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 I_c + 1.68}$$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$$

:: Drained Friction Angle, φ (°) ::

$$\varphi = \varphi'_{cv} + 15.94 \cdot \log(Q_{tn,cs}) - 26.88$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$a = 14$ for $Q_{tn} > 14$
$a = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = a \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

$$M_{CPT} = 0.03 \cdot (q_t - \sigma_v) \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$$OCR = k_{OCR} \cdot Q_{tn}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

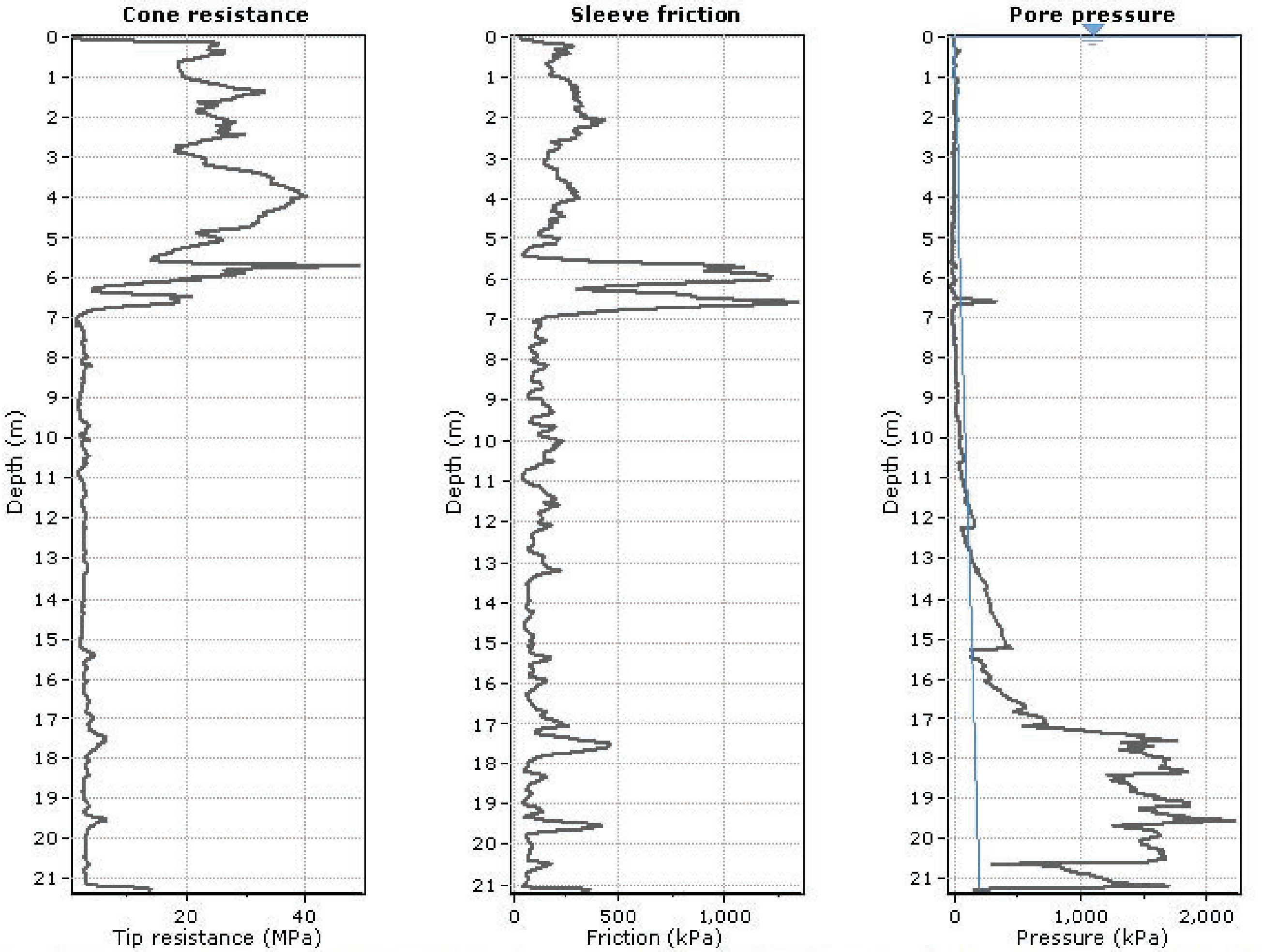
$$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$$

(applicable for $0.10 < B_q < 1.00$)

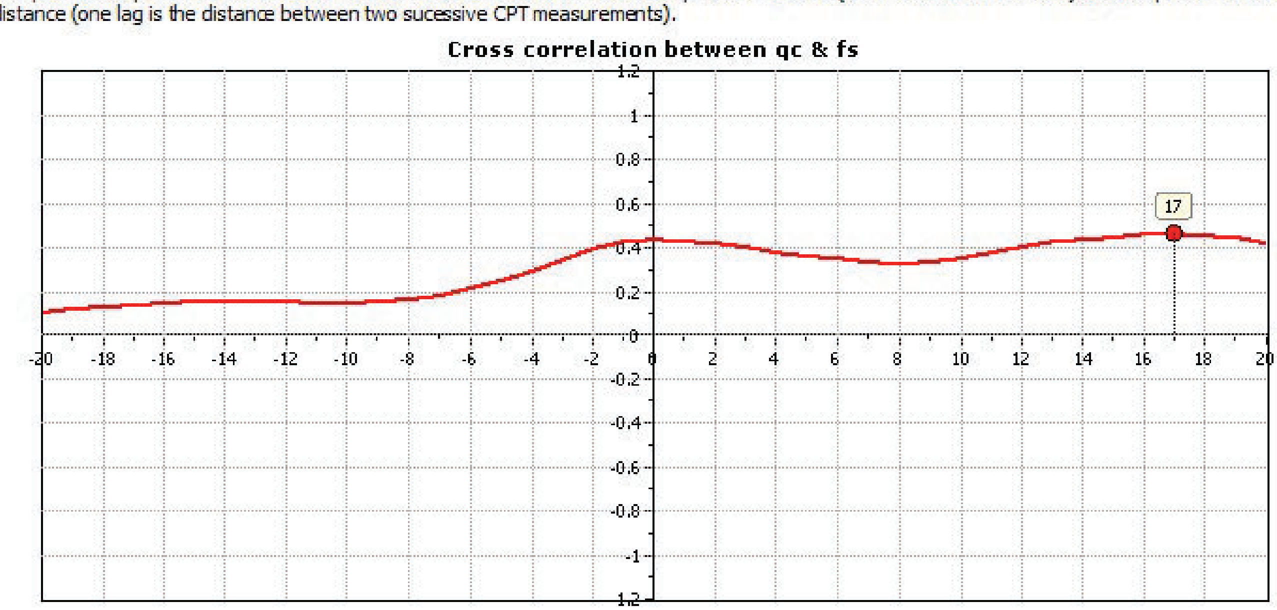
References

• Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012

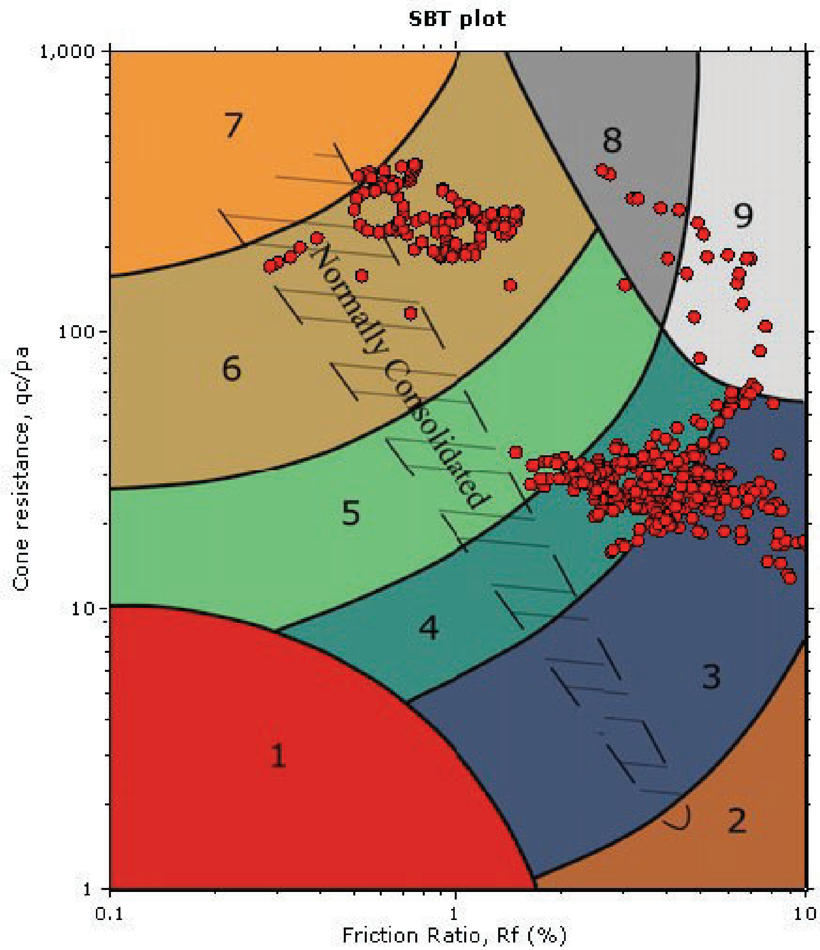
• Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

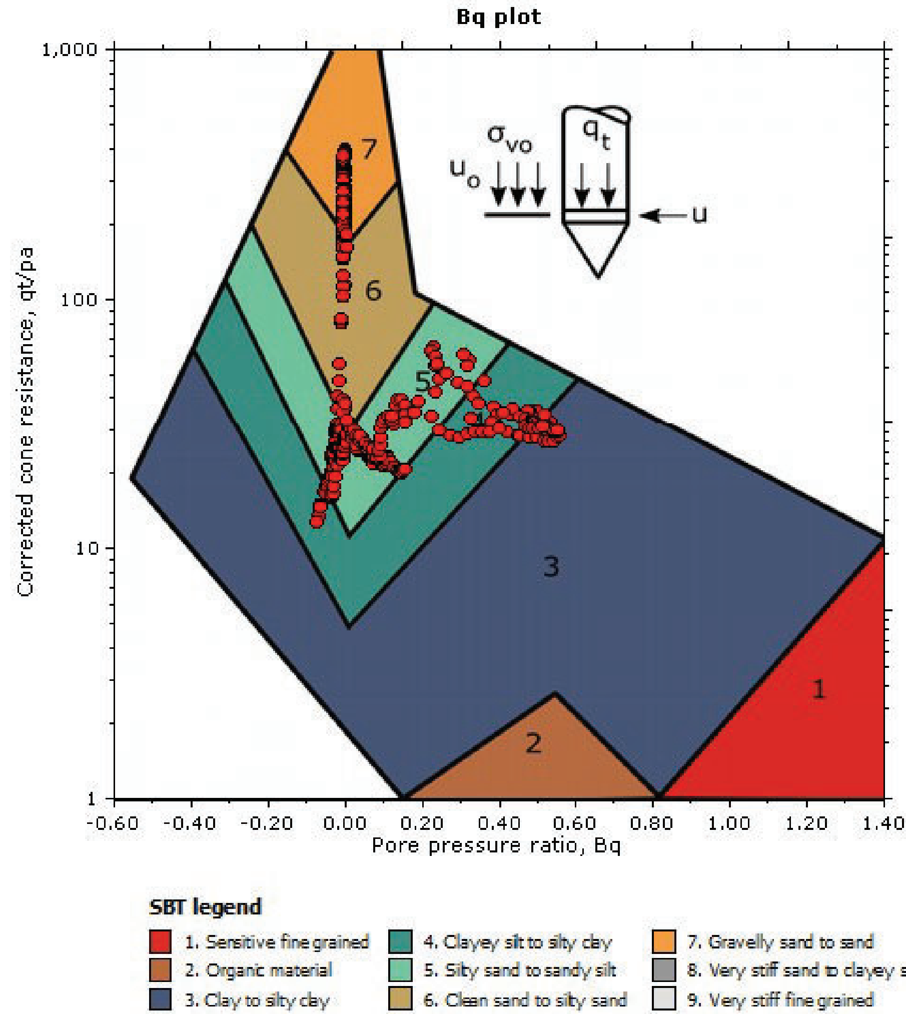


The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).

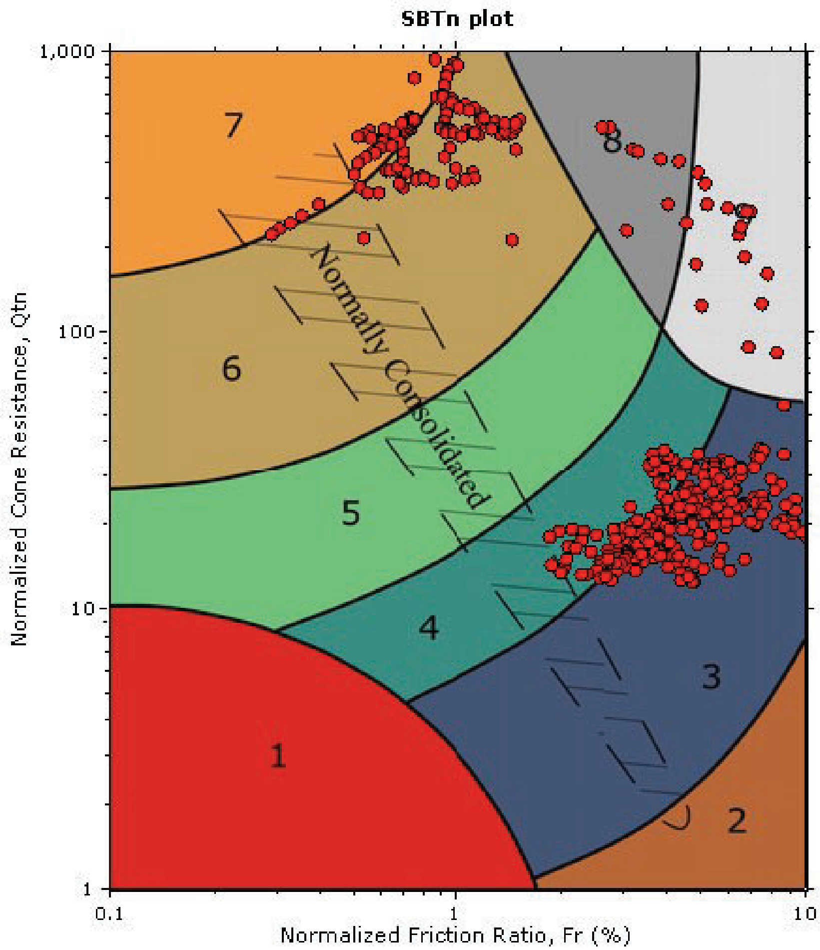


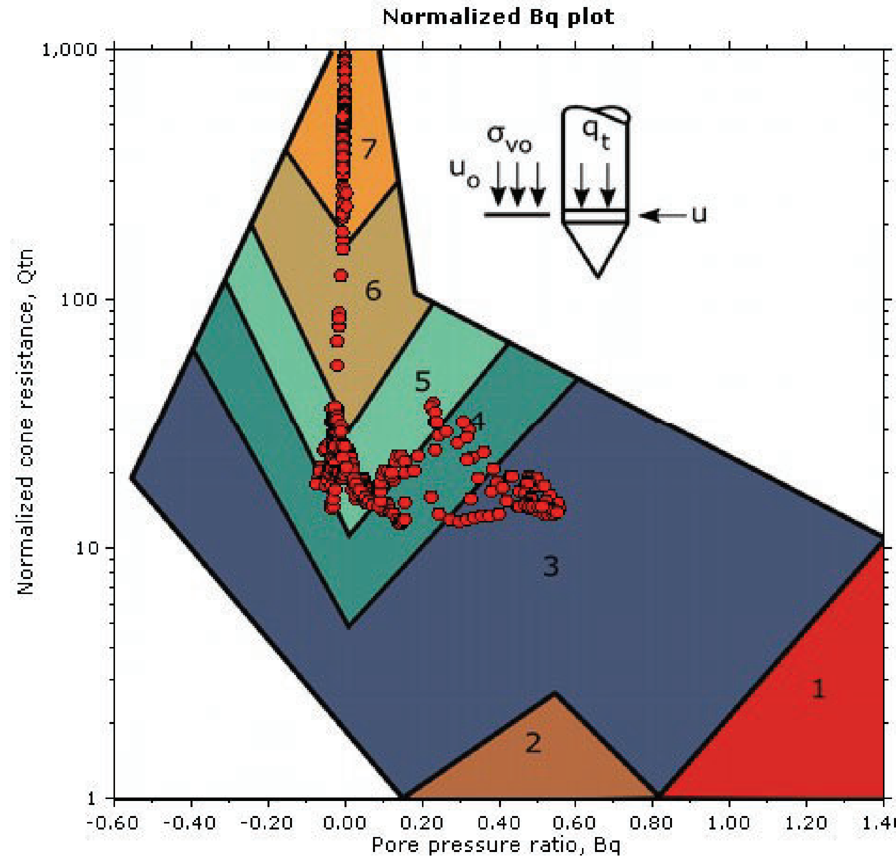
SBT - Bq plots


SBT plot
Cone resistance, qc/pa
Friction Ratio, Rf (%)
Normally Consolidated
1,000
100
10
1
0.1
1
10
1
2
3
4
5
6
7
8
9


Bq plot
Corrected cone resistance, qt/pa
Pore pressure ratio, Bq
1,000
100
10
1
-0.60
-0.40
-0.20
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1
2
3
5
6
7
u
SBT legend
1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

SBT - Bq plots (normalized)

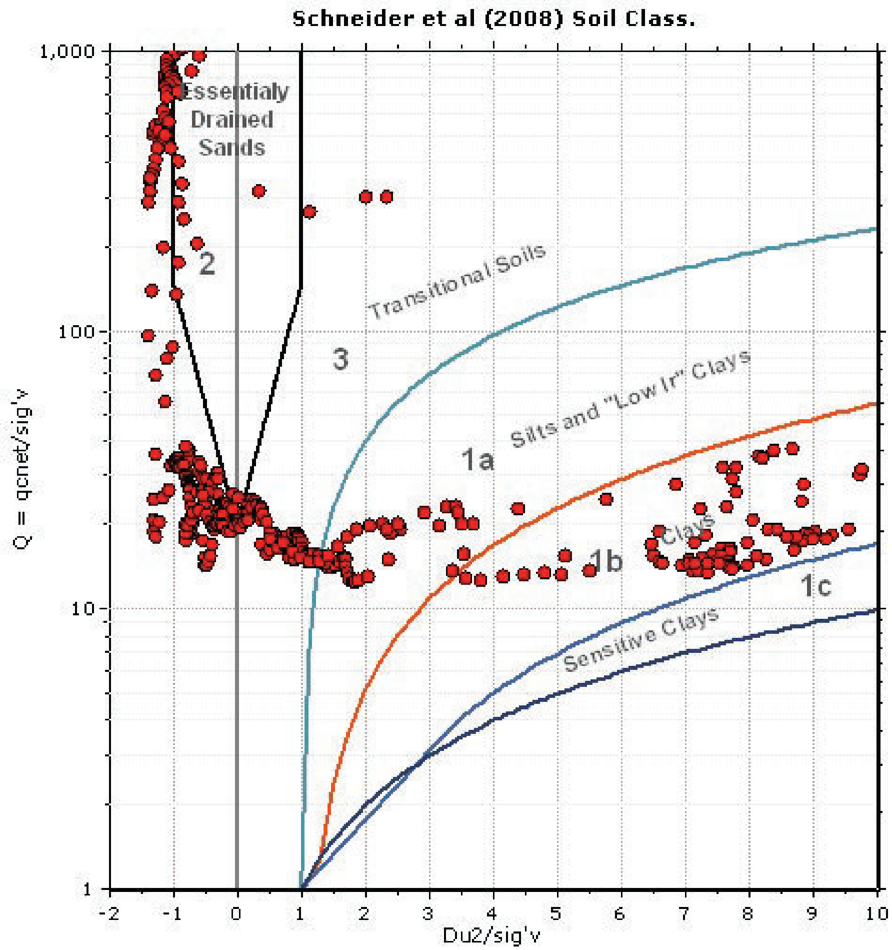


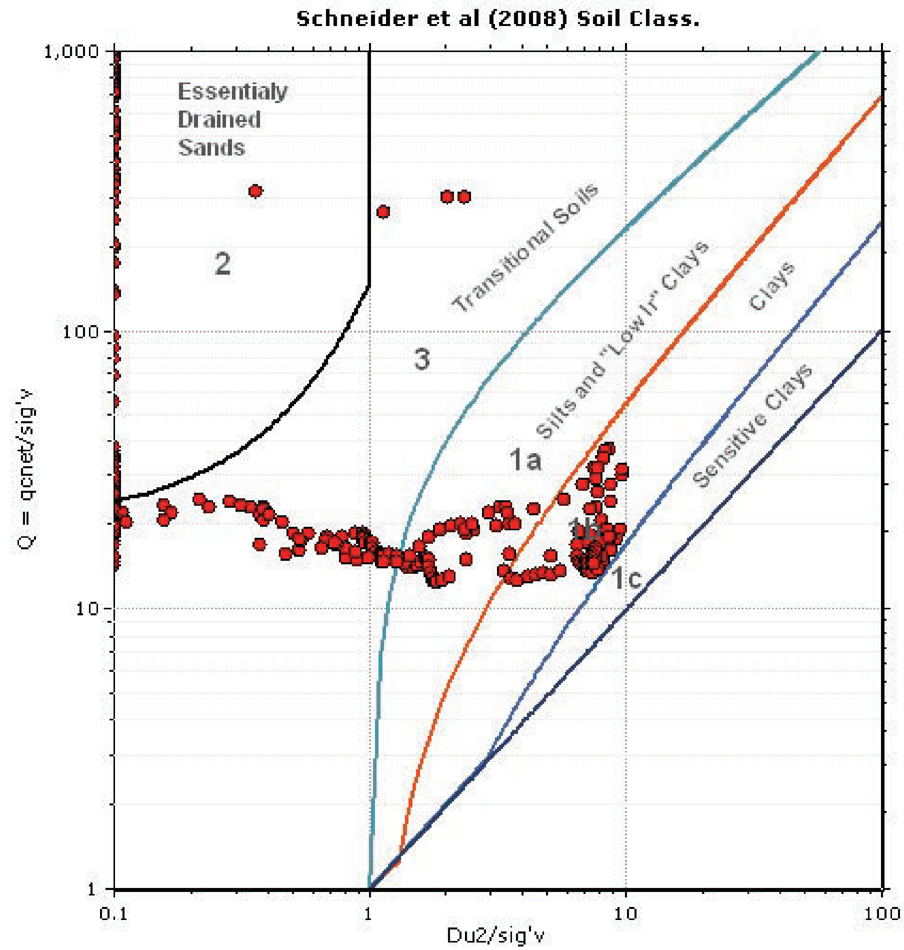


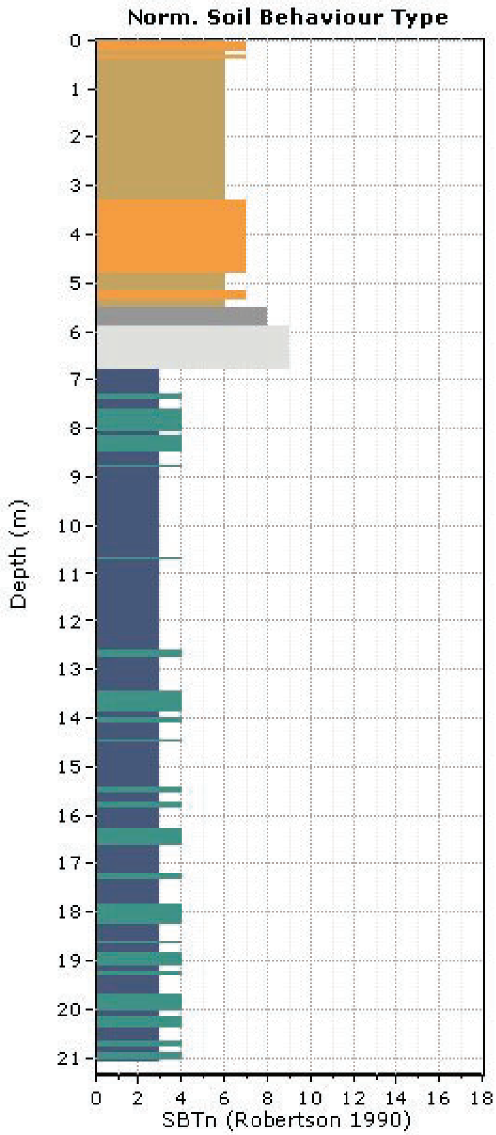
SBTn legend

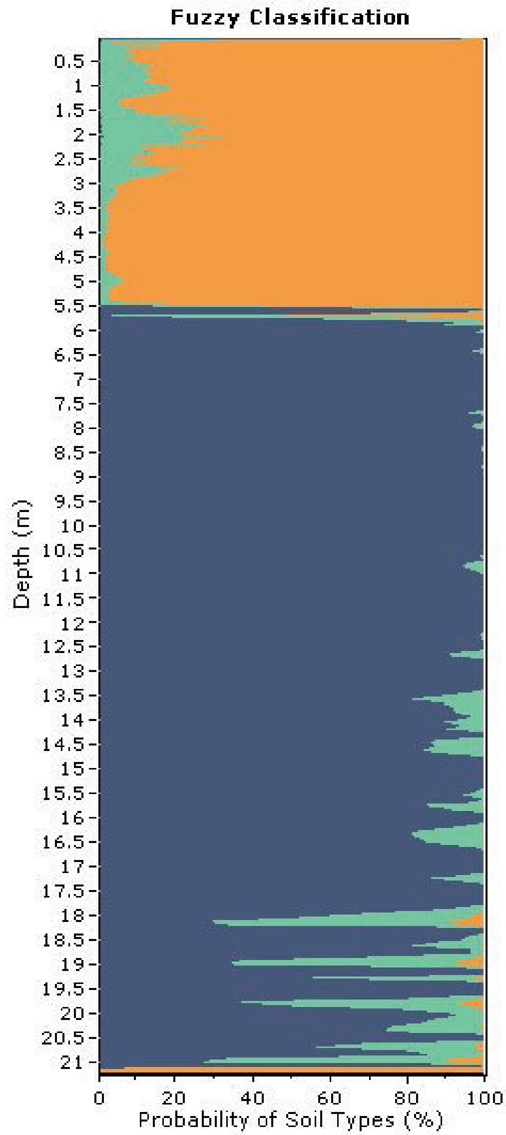
1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravelly sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

Bq plots (Schneider)





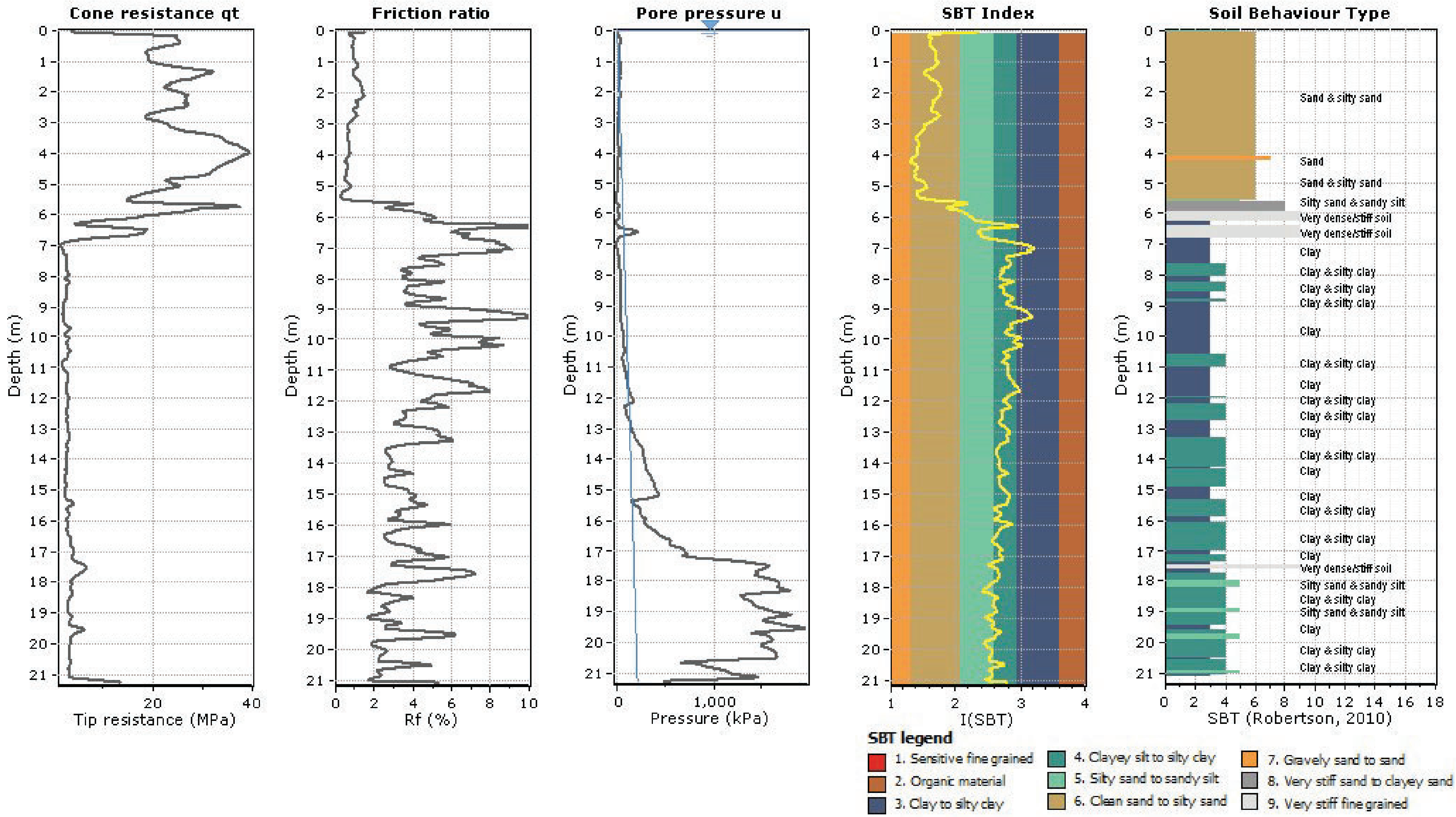

Norm. Soil Behaviour Type
Depth (m)
SBTn (Robertson 1990)


Fuzzy Classification
Depth (m)
Probability of Soil Types (%)

Ramboll
101 Carnegie Center Dr., Princeton NJ
http://www.ramboll.com

CPT: CPT-27
Total depth: 21.25 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

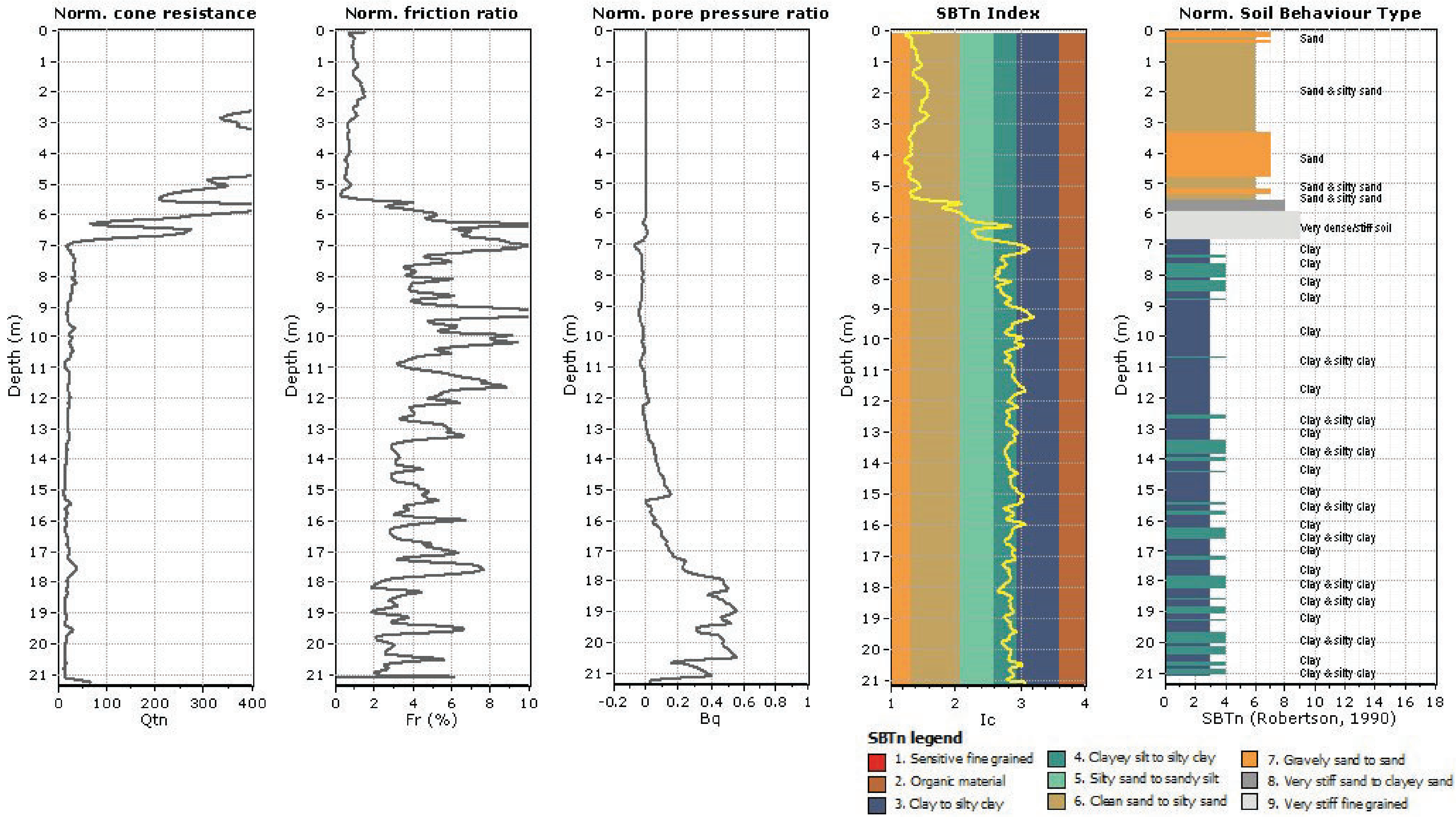
Project:
Location:



Ramboll
101 Carnegie Center Dr., Princeton NJ
http://www.ramboll.com

Project:
Location:

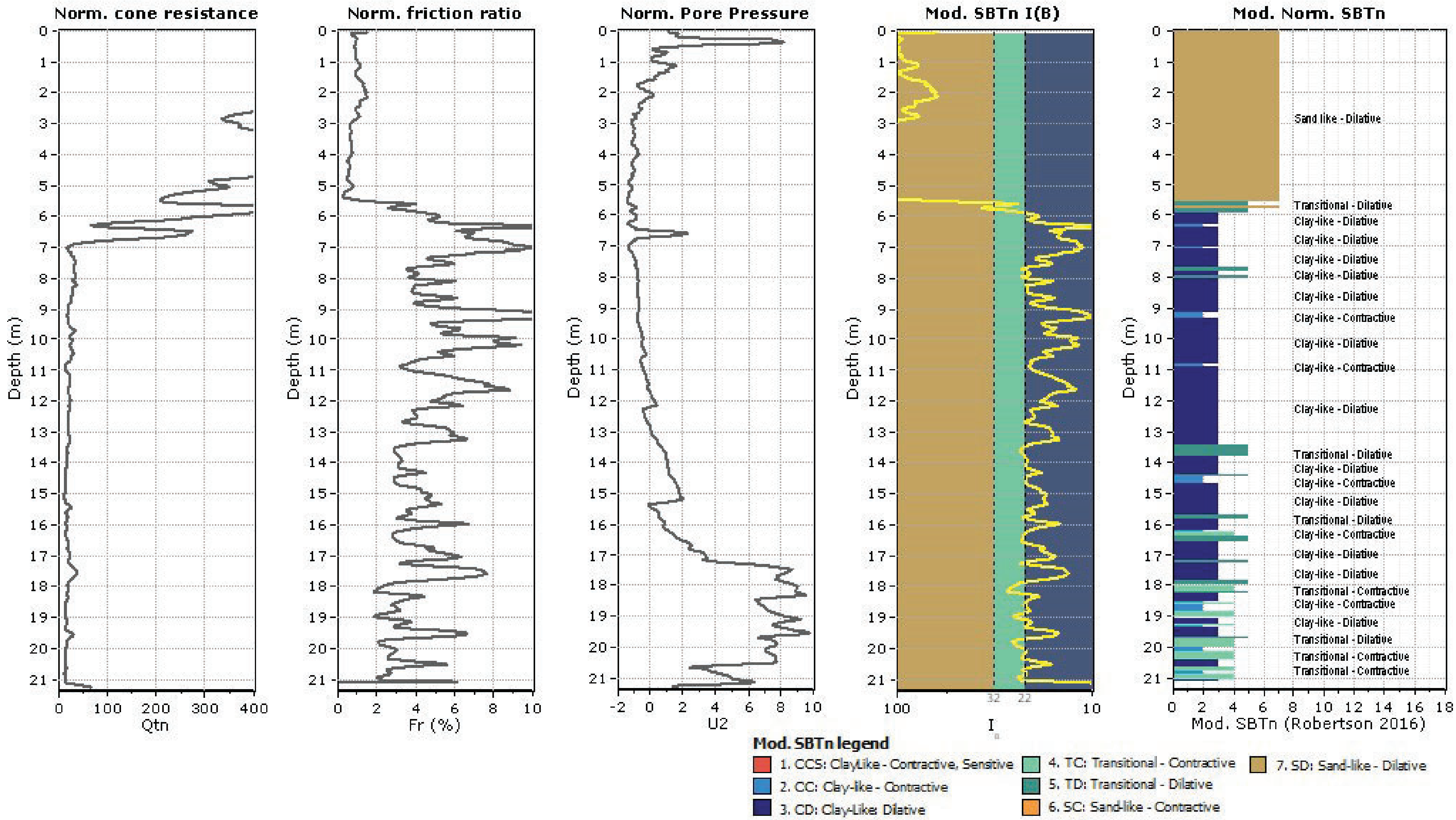
CPT: CPT-27
Total depth: 21.25 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:



Ramboll
101 Carnegie Center Dr., Princeton NJ
http://www.ramboll.com

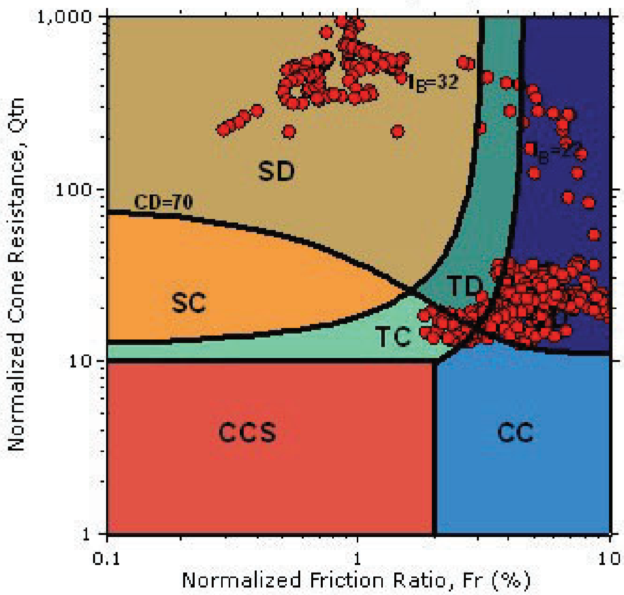
Project:
Location:

CPT: CPT-27
Total depth: 21.25 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

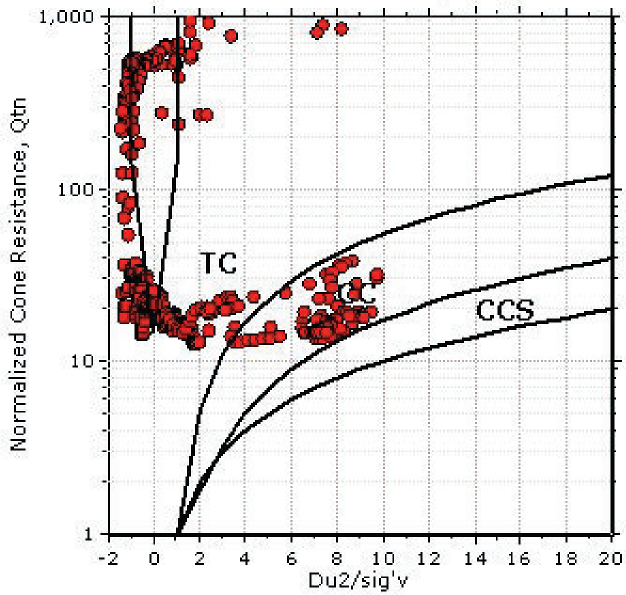


Updated SBTn plots

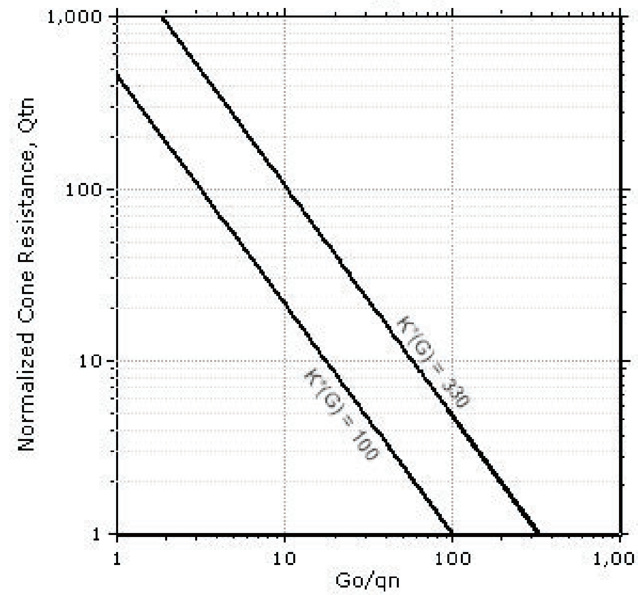
Modified Robertson (2016) SBTn



Modified Schneider et al (2008) SBTn



Normalized Rigidity Index



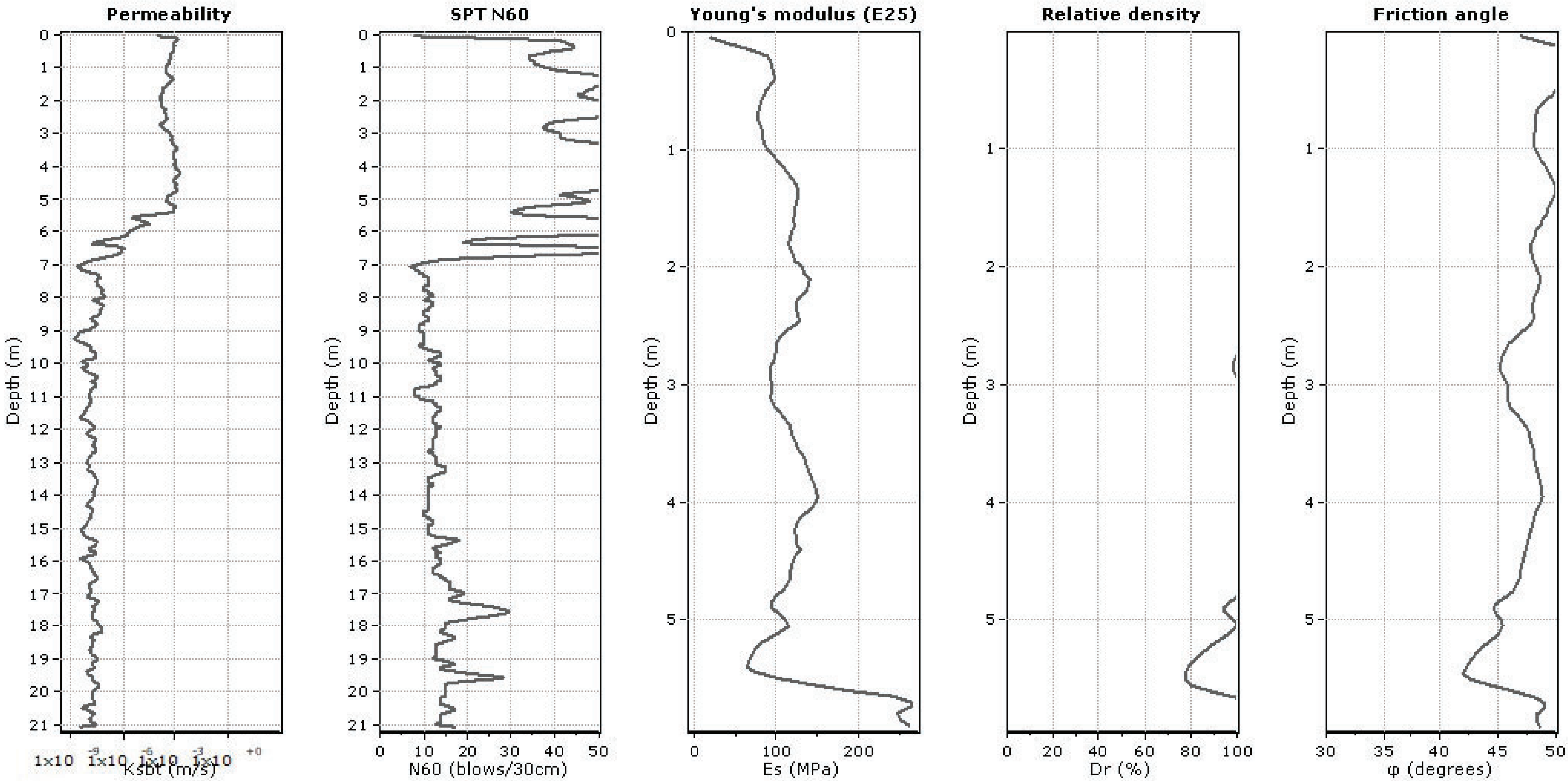
CCS: Clay-like - Contractive - Sensitive
CC: Clay-like - Contractive
CD: Clay-like - Dilative
TC: Transitional - Contractive
TD: Transitional - Dilative
SC: Sand-like - Contractive
SD: Sand-like - Dilative

K(G) > 330: Soils with significant microstructure (e.g. age/cementation)

Ramboll
101 Carnegie Center Dr., Princeton NJ
http://www.ramboll.com

CPT: CPT-27
Total depth: 21.25 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

Project:
Location:

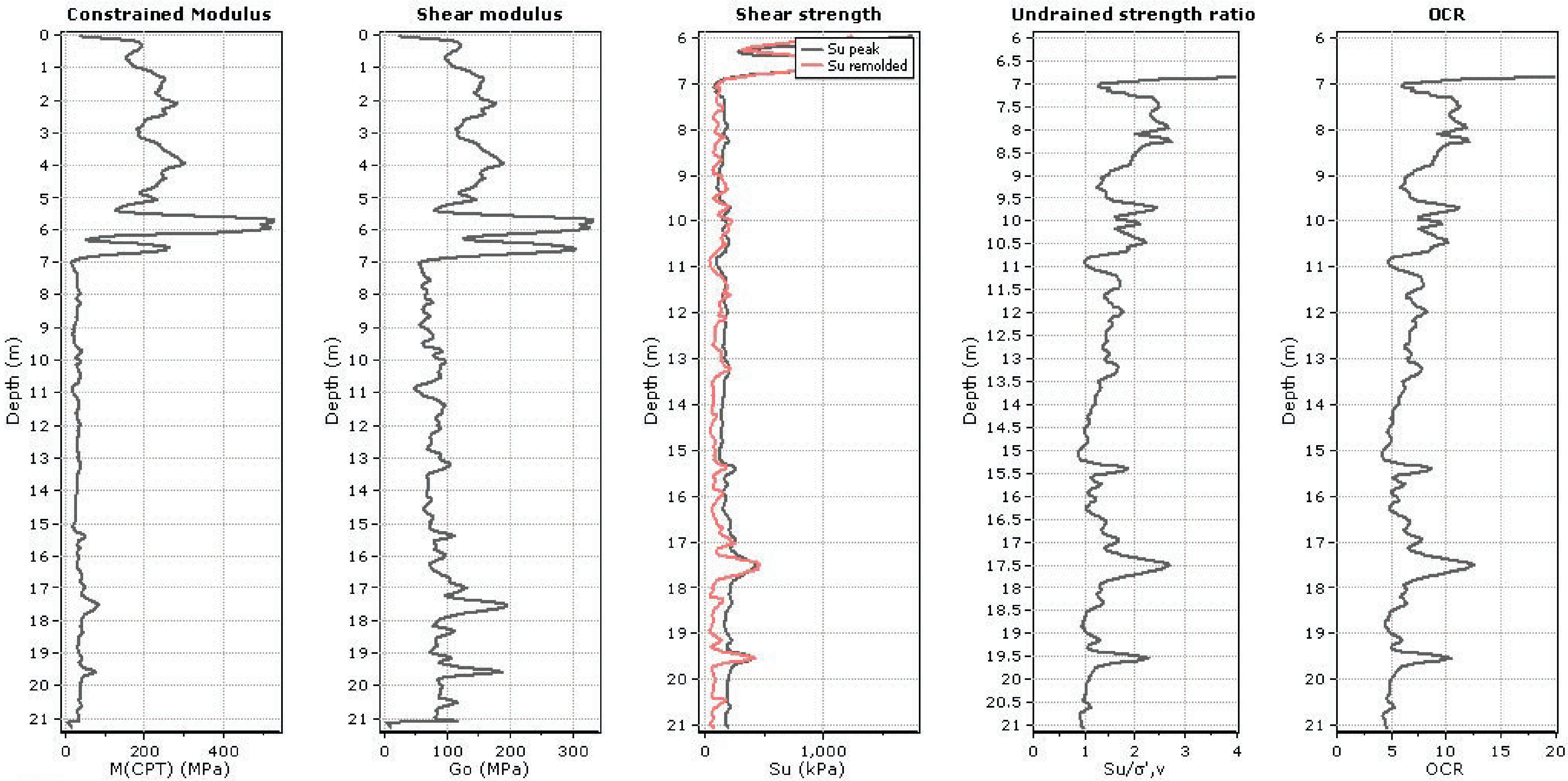


Calculation parameters
Permeability: Based on SBT_n
SPT N_{60}: Based on I_c and q_t
Young's modulus: Based on variable alpha using I_c (Robertson, 2009)
Relative density constant, C_{Dr}: 350.0
Phi: Based on Kulhawy & Mayne (1990)
User defined estimation data

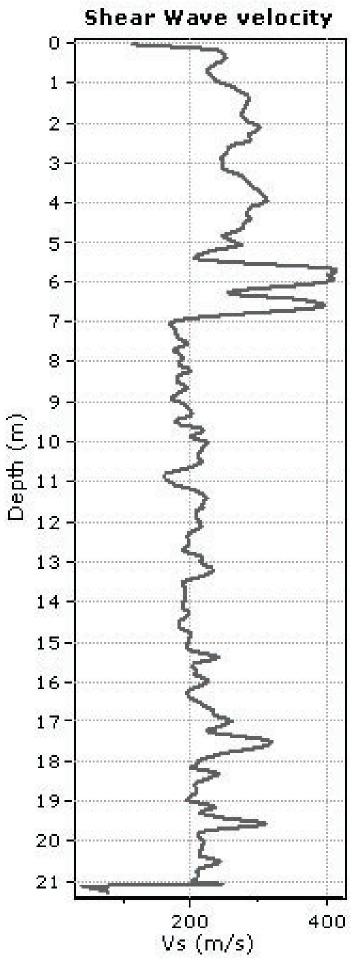
Ramboll
101 Carnegie Center Dr., Princeton NJ
http://www.ramboll.com

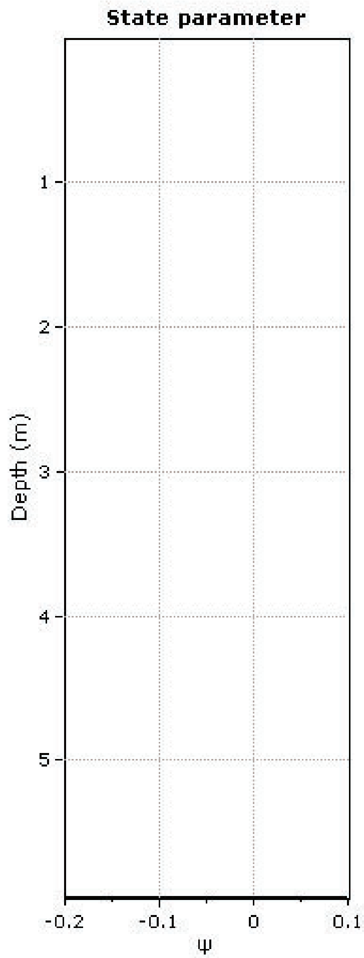
Project:
Location:

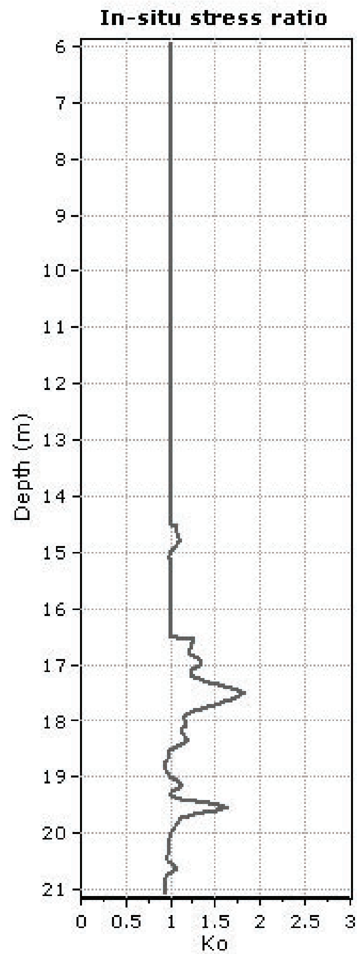
CPT: CPT-27
Total depth: 21.25 m, Date: 3/15/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type:
Cone Operator:

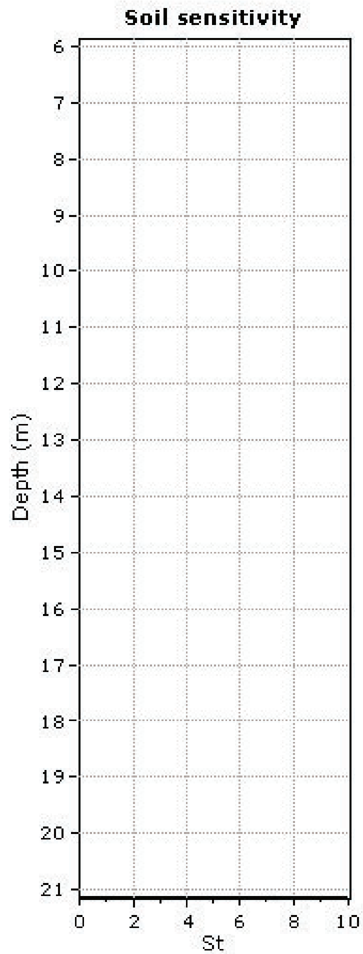


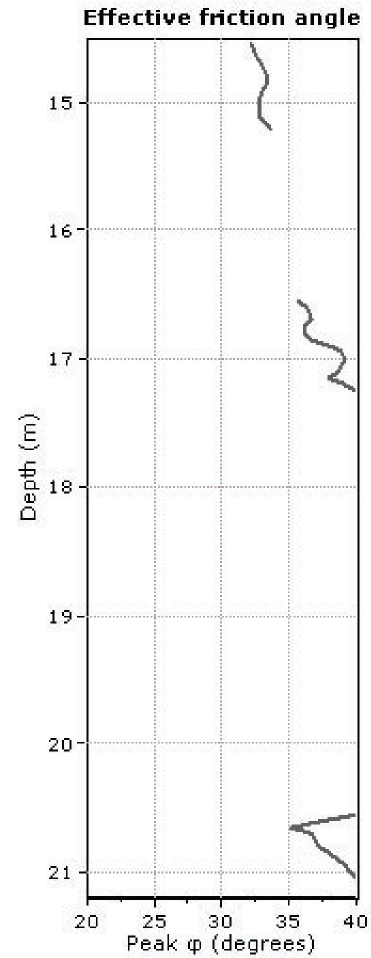
Calculation parameters
Constrained modulus: Based on variable *alpha* using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable *alpha* using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 14
OCR factor for clays, N_{kt}: 0.33
User defined estimation data
Flat Dilatometer Test data







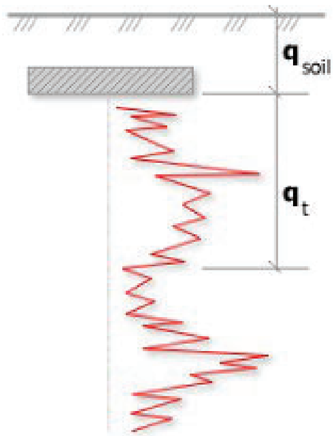




Calculation parameters

Soil Sensitivity factor, N_S: 350.00

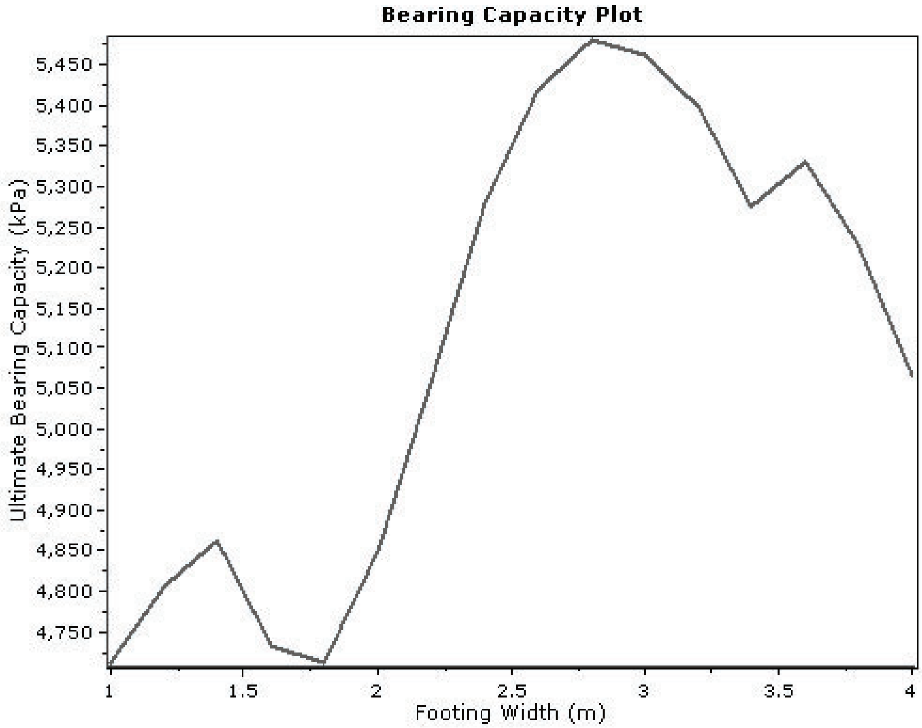
User defined estimation data



Bearing Capacity calculation is perfromed based on the formula:

$$Q_{ult} = R_k \times q_t + q_{soil}$$

where:
R_k: Bearing capacity factor
q_t: Average corrected cone resistance over calculation depth
q_{soil}: Pressure applied by soil above footing



:: Tabular results ::

No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	23.51	0.20	9.50	4712.17
2	1.20	0.50	2.30	23.99	0.20	9.50	4808.06
3	1.40	0.50	2.60	24.26	0.20	9.50	4862.24
4	1.60	0.50	2.90	23.62	0.20	9.50	4732.97
5	1.80	0.50	3.20	23.52	0.20	9.50	4712.90
6	2.00	0.50	3.50	24.21	0.20	9.50	4851.72
7	2.20	0.50	3.80	25.24	0.20	9.50	5058.03
8	2.40	0.50	4.10	26.35	0.20	9.50	5279.58
9	2.60	0.50	4.40	27.04	0.20	9.50	5418.38
10	2.80	0.50	4.70	27.35	0.20	9.50	5480.48
11	3.00	0.50	5.00	27.26	0.20	9.50	5460.90
12	3.20	0.50	5.30	26.94	0.20	9.50	5397.88
13	3.40	0.50	5.60	26.32	0.20	9.50	5273.96
14	3.60	0.50	5.90	26.61	0.20	9.50	5330.94
15	3.80	0.50	6.20	26.09	0.20	9.50	5227.99
16	4.00	0.50	6.50	25.28	0.20	9.50	5065.76

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 I_c + 1.68}$$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$$

:: Drained Friction Angle, φ (°) ::

$$\varphi = \varphi'_{cv} + 15.94 \cdot \log(Q_{tn,cs}) - 26.88$$

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$a = 14$ for $Q_{tn} > 14$
$a = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = a \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

$$M_{CPT} = 0.03 \cdot (q_t - \sigma_v) \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Small strain shear Modulus, Go (MPa) ::

$$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$$OCR = k_{OCR} \cdot Q_{tn}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$$K_O = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

$$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$$

(applicable for $0.10 < B_q < 1.00$)

References

- Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012
- Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

APPENDIX D
NOTICES OF INTENT

BRIAN SANDOVAL
GOVERNOR

STATE OF NEVADA

BRADLEY CROWELL
Director

JASON KING, P.E.
State Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
400 Shadow Lane, Suite 201
Las Vegas, Nevada 89106
(702) 486-2770 · Fax (702) 486-2781
http://water.nv.gov

NOTICE OF INTENT CARD
REVIEW FORM

To: Neil Hale   Date: October 11, 2018

Facsimile No.: ____________ or E-mail Address: nhale@cascade-env.com

This document was: ☑ E-mailed ☐ Faxed

NOI Card Number: S2018-14 ☑ **Approved** ☐ **Rejected** (See reasons below)

Work performed	missing	☐	invalid	☐
Proposed use of well	missing	☐	invalid	☐
Intended start date	missing	☐	invalid	☐
Waiver/Permit number if applicable	missing	☐	invalid	☐
Well location (legal description, GPS coordinates)	missing	☐	invalid	☐
Parcel number	missing	☐	invalid	☐
Address at well location	missing	☐	invalid	☐
Permit number	missing	☐	invalid	☐
Waiver number or NDEP Facility ID Number	missing	☐	invalid	☐
Address of Client	missing	☐	invalid	☐
Name of client/owner	missing	☐	invalid	☐
Contractor's license number	missing	☐	invalid	☐
Onsite well driller's license number	missing	☐	invalid	☐
Drilling company name/address	missing	☐	invalid	☐
Driller's signature	missing	☐	invalid	☐
Replacement well	Yes	☐	No	☑

If yes, existing well must be plugged at time the replacement well is drilled, pursuant to NAC 534.300 Replacement Well.

Instructions: Please note that you must provide a copy of the well driller's report for the installation of three (3) monitor wells within 30 days of completion. If you have any questions, please do not hesitate to give our office a call.

JS

Person reviewing NOI Card: Christi Cooper, waiver issued by Tracy Geter

Date reviewed: October 11, 2018

BRIAN SANDOVAL
Governor

BRADLEY CROWELL
Director

STATE OF NEVADA

JASON KING, P.E.
State Engineer

JOHN GUILLORY, P.E.
Supervising Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
SOUTHERN NEVADA BRANCH OFFICE
400 Shadow Lane, Suite 201
Las Vegas, Nevada 89106
(702) 486-2770 • Fax (702) 486-2781
http://water.nv.gov

October 11, 2018

MO-3559

Neil Hale
Field Supervisor
Cascade Drilling, LP
4221 West Oquendo Road
Las Vegas, Nevada 89118

RE: Request for waiver to install three (3) temporary monitor wells to collect groundwater samples and analyze the samples as requested by Nevada Division of Environmental Protection (NDEP) Order Number H-000539, located on vacant land, just east of 510 South 4th Street Road, Clark County, Nevada and within the Las Vegas Valley Basin (212).

Dear Mr. Hale:

As provided in Nevada Administrative Code (NAC) § 534.450 of the Regulation for Water Well and Related Drilling, permission is herewith **granted** to install three (3) temporary monitor wells to assess water conditions as described in your request received September 27, 2018. Your statement ensuring Nevada Environmental Response Trust responsibility for abandonment of the well upon project completion was received in this office on September 27, 2018.

The three (3) proposed monitor wells referenced in your letter are listed below:

Well Name	Legal Description	GPS Coordinates (NAD 83/ WGS 84)
BWTR-1	NE¼, SW¼ Section 12, T.22S, R62E	36° 02' 55.070" N, -115° 00' 15.020" W
BWTR-2	NE¼, SW¼ Section 12, T.22S, R62E	36° 02' 55.310" N, -115° 00' 15.080" W
BWTR-3	NE¼, SW¼ Section 12, T.22S, R62E	36° 02' 55.490" N, -115° 00' 15.110" W

This office also waives the following regulations:

1) NAC § 534.4351. The purpose of this well is to collect groundwater samples and analyze the samples as requested by NDEP Order Number H-000539, located on vacant land, just east of 510 South 4th Street Road, Clark County, Nevada. The wellhead shall be protected from damage due to vandalism or sunlight. If polyvinyl chloride (PVC) casing is used, then the well must be completed with ASTM F-480 (Sch. 40 or heavier) well casing as provided in NAC § 534.362.

2) NAC 534.4357(1c) - "If water or vapors which are being monitored in a monitoring well are not encountered within 5 feet below the surface of the ground, the well driller shall place in the annual space of the well: From the seal placed pursuant to paragraph (b) to the surface, a seal, with a minimum thickness of 20 feet below the surface, consisting of cement grout, neat cement or concrete grout." Due to the shallow depth and large screen intervals of the proposed monitor well, you are allowed to install the sanitary seal as shown in your waiver request.

Glued casing joint connections will not be allowed. Full compliance with the remainder of the statute and regulation is required.

A plot map showing the actual location of the completed wells must be submitted upon completion of the drilling operations. Please include an accurate description of the location of the monitor well on the completion reports (GPS coordinates are required).

The well driller's reports shall bear this waiver number: MO-3559.

Authorization to drill under this waiver expires one (1) year from the date of this letter.

The well driller must have a copy of this waiver in possession at all times during drilling activities pertaining to this project. This well may only be pumped when necessary to obtain samples.

Please note that you must notify the Nevada Division of Environmental Protection (NDEP) for possible permitting requirements for groundwater or temporary surface discharge permits, which may include Underground Injection Control (UIC) or National Pollution Discharge Elimination System (NPDES) Permit Numbers. For more information regarding the permitting process with NDEP, please contact NDEP Water Pollution Control Department at (775) 687-4670.

The wells shall be plugged and abandoned, as provided by regulation, upon project completion. The current owner of Assessor's Parcel Number 178-12-301-005 is shown as Nevada Environmental Response Trust by the records of the Clark County Assessor's office. This waiver does not imply or grant any land use agreements between Nevada Environmental Response Trust and any land owners. It is expressly understood that this authorization does not relieve the operator of the requirements of any other state, federal or local agencies.

If you have any questions, please contact this office at 702-486-2770.

Sincerely,

Tracy Geter
Drilling Supervisor

cc: File
Carson City Office
Christi Cooper, SNBO Office
Jay A. Steinberg, President, Nevada Environmental Response Trust, Chicago, IL

BRIAN SANDOVAL
GOVERNOR

STATE OF NEVADA

BRADLEY CROWELL
Director

JASON KING, P.E.
State Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
400 Shadow Lane, Suite 201
Las Vegas, Nevada 89106
(702) 486-2770 · Fax (702) 486-2781
http://water.nv.gov

NOTICE OF INTENT CARD
REVIEW FORM

To: Neil Hale

Date: October 10, 2018

Facsimile No.: ______ or E-mail Address: nhale@cascade-env.com

This document was: ☑ E-mailed ☐ Faxed

NOI Card Number: S2018-13 ☑ **Approved** ☐ **Rejected** (See reasons below)

Work performed	missing	☐	invalid	☐
Proposed use of well	missing	☐	invalid	☐
Intended start date	missing	☐	invalid	☐
Waiver/Permit number if applicable	missing	☐	invalid	☐
Well location (legal description, GPS coordinates)	missing	☐	invalid	☐
Parcel number	missing	☐	invalid	☐
Address at well location	missing	☐	invalid	☐
Permit number	missing	☐	invalid	☐
Waiver number or NDEP Facility ID Number	missing	☐	invalid	☐
Address of Client	missing	☐	invalid	☐
Name of client/owner	missing	☐	invalid	☐
Contractor's license number	missing	☐	invalid	☐
Onsite well driller's license number	missing	☐	invalid	☐
Drilling company name/address	missing	☐	invalid	☐
Driller's signature	missing	☐	invalid	☐
Replacement well	Yes	☐	No	☑

If yes, existing well must be plugged at time the replacement well is drilled, pursuant to NAC 534.300 Replacement Well.

Instructions: Please note that you must provide a copy of the well driller's report for the installation of three (3) monitor wells within 30 days of completion. If you have any questions, please do not hesitate to give our office a call.

JB

Person reviewing NOI Card: Christi Cooper, waiver issued by Tracy Geter

Date reviewed: October 10, 2018

BRIAN SANDOVAL
Governor

BRADLEY CROWELL
Director

STATE OF NEVADA

JASON KING, P.E.
State Engineer

JOHN GUILLORY, P.E.
Supervising Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

SOUTHERN NEVADA BRANCH OFFICE

400 Shadow Lane, Suite 201
Las Vegas, Nevada 89106
(702) 486-2770 • Fax (702) 486-2781
http://water.nv.gov

October 10, 2018

MO-3557

Neil Hale
Field Supervisor
Cascade Drilling, LP
4221 West Oquendo Road
Las Vegas, Nevada 89118

RE: Request for waiver to install three (3) temporary monitor wells to collect groundwater samples and analyze the samples as requested by Nevada Division of Environmental Protection (NDEP) Order Number H-000539, located at 560 West Lake Mead Parkway, Clark County, Nevada and within the Las Vegas Valley Basin (212).

Dear Mr. Hale:

As provided in Nevada Administrative Code (NAC) § 534.450 of the Regulation for Water Well and Related Drilling, permission is herewith **granted** to install three (3) temporary monitor wells to assess water conditions as described in your request received September 27, 2018. Your statement ensuring Nevada Environmental Response Trust responsibility for abandonment of the well upon project completion was received in this office on September 27, 2018.

The three (3) proposed monitor wells referenced in your letter are listed below:

Well Name	Legal Description	GPS Coordinates (NAD 83/ WGS 84)
BWTR-4	NW¼, SE¼ Section 12, T.22S, R62E	36° 02' 56.510" N, -114° 59' 59.170" W
BWTR-5	NW¼, SE¼ Section 12, T.22S, R62E	36° 02' 56.660" N, -114° 59' 59.200" W
BWTR-6	NW¼, SE¼ Section 12, T.22S, R62E	36° 02' 56.810" N, -114° 59' 59.230" W

This office also waives the following regulations:

1) NAC § 534.4351. The purpose of this well is to collect groundwater samples and analyze the samples as requested by NDEP Order Number H-000539, located at 560 West Lake Mead Parkway, Clark County, Nevada. The wellhead shall be protected from damage due to vandalism or sunlight. If polyvinyl chloride (PVC) casing is used, then the well must be completed with ASTM F-480 (Sch. 40 or heavier) well casing as provided in NAC § 534.362.

2) NAC 534.4357(1c) - "If water or vapors which are being monitored in a monitoring well are not encountered within 5 feet below the surface of the ground, the well driller shall place in the annual space of the well: From the seal placed pursuant to paragraph (b) to the surface, a seal, with a minimum thickness of 20 feet below the surface, consisting of cement grout, neat cement or concrete grout." Due to the shallow depth and large screen intervals of the proposed monitor well, you are allowed to install the sanitary seal as shown in your waiver request.

Glued casing joint connections will not be allowed. Full compliance with the remainder of the statute and regulation is required.

A plot map showing the actual location of the completed wells must be submitted upon completion of the drilling operations. Please include an accurate description of the location of the monitor well on the completion reports (GPS coordinates are required).

The well driller's reports shall bear this waiver number: MO-3557.

Authorization to drill under this waiver expires one (1) year from the date of this letter.

The well driller must have a copy of this waiver in possession at all times during drilling activities pertaining to this project. This well may only be pumped when necessary to obtain samples.

Please note that you must notify the Nevada Division of Environmental Protection (NDEP) for possible permitting requirements for groundwater or temporary surface discharge permits, which may include Underground Injection Control (UIC) or National Pollution Discharge Elimination System (NPDES) Permit Numbers. For more information regarding the permitting process with NDEP, please contact NDEP Water Pollution Control Department at (775) 687-4670.

NOI No. S5012-13
APN: 178-12-801-008
NDEP Order No. H-000539
For three, 4-inch monitor wells

The wells shall be plugged and abandoned, as provided by regulation, upon project completion. The current owner of Assessor's Parcel Number 178-12-801-008 is shown as Nevada Environmental Response Trust by the records of the Clark County Assessor's office. This waiver does not imply or grant any land use agreements between Nevada Environmental Response Trust and any land owners. It is expressly understood that this authorization does not relieve the operator of the requirements of any other state, federal or local agencies.

If you have any questions, please contact this office at 702-486-2770.

Sincerely,

Tracy Geter
Drilling Supervisor

cc: File
Carson City Office
Christi Cooper, SNBO Office
Jay A. Steinberg, President, Nevada Environmental Response Trust, Chicago, IL

APPENDIX E
WELL CONSTRUCTION LOGS

MONITORING WELL LOG: BWTR-1

DRILLING CONTRACTOR: Cascade	PROJECT NAME: NERT: Barrier Wall Evaluation
DRILLER: J. Lary III	PROJECT NUMBER: 1690006943-033
RIG: DR-24HD	LOCATION: Henderson, Nevada
DRILLING METHOD: Sonic	LOGGED BY: B. Keegans
BOREHOLE DIAMETER: 10 in WELL DIAMETER: 4 in	START TIME: 10:45 STOP TIME: 16:00
TOTAL DEPTH: 47.0 ft	DATE(S): 10/01/2018
DEPTH TO WATER: 27.5 ft	

COMMENTS:

LEGEND:
SNC - Sonic Core
"-" - Not screened

WELL CONSTRUCTION KEY:
- Concrete
- Grout
- Bentonite
- Lapus Lustre #2/12 sand
- PVC riser pipe
- Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION	WELL CONSTRUCTION	WATER LEVEL
0–17.0		SNC	- (5), - (10), - (15)		SW-SM	0 - 17.0	Brown-tan silty fine to medium SAND with sub-angular fine gravel (poorly sorted), damp		
17.0–27.0		SNC	- (20), - (25)		ML	17.0 - 27.0	Brown-tan sandy SILT, trace clay, moist		
27.0–30.0		SNC			SW-SC	27.0 - 30.0	Brown clayey fine to medium SAND (poorly sorted), moist		▼ (27.5)
30.0–33.0		SNC	- (30)		GP-GC	30.0 - 33.0	Brown-gray sandy GRAVEL (poorly sorted), some clay, wet		
33.0–41.5		SNC	- (35), - (40)		MH	33.0 - 41.5	Red-brown clayey SILT (moderately sorted), trace fine gravel, wet		
41.5–47.0		SNC	- (45)		MH	41.5 - 47.0	Orange-brown clayey SILT, wet		
							EOB at 47.0 ft		

MONITORING WELL LOG: BWTR-2

DRILLING CONTRACTOR: Cascade
DRILLER: J. Lary III
RIG: DR-24HD
DRILLING METHOD: Sonic
BOREHOLE DIAMETER: 10 in WELL DIAMETER: 4 in
TOTAL DEPTH: 46.0 ft
DEPTH TO WATER: 34.4 ft

PROJECT NAME: NERT: Barrier Wall Evaluation
PROJECT NUMBER: 1690006943-033
LOCATION: Henderson, Nevada
LOGGED BY: B. Keegans
START TIME: 10:50 STOP TIME: 16:00
DATE(S): 10/02/2018

COMMENTS:

LEGEND:
SNC - Sonic Core
"-" - Not screened

WELL CONSTRUCTION KEY:
- Concrete
- Grout
- Bentonite
- Lapus Lustre #2/12 sand
- PVC riser pipe
- Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION	WELL CONSTRUCTION	WATER LEVEL
0–17.6		SNC	- (5), - (10), - (15)		SW-SM	0 - 17.6	Brown-tan silty SAND with fine sub-angular gravel (poorly sorted), some cobbles, damp @ 17.5 ft encountered layer of very hard caliche		
17.6–20		SNC	- (20)		SP	17.6 - 20.0	Brown fine SAND, trace fine sub-angular gravel (well sorted), damp		
20–32		SNC	- (25), - (30)		SP-SM	20.0 - 32.0	Brown-tan silty SAND with fine sub-angular gravel (poorly sorted), some clay, some cobbles, moist		
32–46		SNC	- (35), - (40), - (45)		MH	32.0 - 46.0	Red-brown clayey SILT (moderately sorted), trace fine gravel, wet		▼ (34.4 ft)
46–50							EOB at 46.0 ft		

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

MONITORING WELL LOG: BWTR-3

DRILLING CONTRACTOR:	Cascade	PROJECT NAME:	NERT: Barrier Wall Evaluation
DRILLER:	Neal T.	PROJECT NUMBER:	1690006943-033
RIG:	KE-4P45	LOCATION:	Henderson, Nevada
DRILLING METHOD:	Hollow-stem auger	LOGGED BY:	C. Wu
BOREHOLE DIAMETER:	10 in; WELL DIAMETER: 4 in	START TIME:	14:30; STOP TIME: 16:25
TOTAL DEPTH:	47.0 ft	DATE(S):	10/05/2018
DEPTH TO WATER:	32.4 ft		

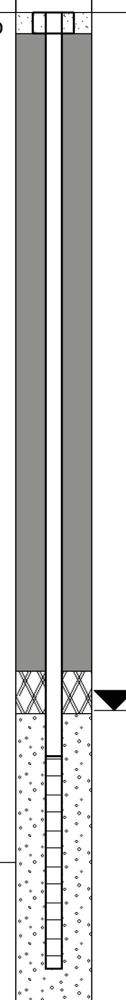
COMMENTS:
Cascade used Airknife to drill to 10.0 ft on 10/4/2018.

LEGEND:
"-" - Not screened

WELL CONSTRUCTION KEY:
- Concrete
- Grout
- Bentonite
- Lapus Lustre #2/12 sand
- PVC riser pipe
- Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION
0					SP	0 - 40.0	Brown fine SAND (well sorted), trace fine sub-angular gravel, damp
5			-				
10			-				
15			-				@ 15.0 ft becomes moist
20			-				
25			-				
30			-				
35			-				
40			-		MH	40.0 - 47.0	Red-brown clayey SILT (moderately sorted), trace fine gravel, moist
45			-				
47							EOB at 47.0 ft
50							

WELL CONSTRUCTION



WATER LEVEL

RAMBOLL

MONITORING WELL LOG: BWTR-4

DRILLING CONTRACTOR: Cascade
DRILLER: J. Larry III
RIG: DR-24HD
DRILLING METHOD: Sonic
BOREHOLE DIAMETER: 10 in WELL DIAMETER: 4 in
TOTAL DEPTH: 46.0 ft
DEPTH TO WATER: 18.1 ft

PROJECT NAME: NERT: Barrier Wall Evaluation
PROJECT NUMBER: 1690006943-033
LOCATION: Henderson, Nevada
LOGGED BY: B. Keegans
START TIME: 09:30 STOP TIME: 13:30
DATE(S): 10/03/2018

COMMENTS:

LEGEND:
SNC - Sonic Core
"-" - Not screened

WELL CONSTRUCTION KEY:
- Concrete
- Grout
- Bentonite
- Lapus Lustre #2/12 sand
- PVC riser pipe
- Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION	WELL CONSTRUCTION	WATER LEVEL
0 - 17.5		SNC	- (5), - (10), - (15)		SP-SM	0 - 17.5	Gray-tan-brown silty SAND with fine sub-angular gravel (poorly sorted), some cobbles, damp @ 10.0 ft becomes moist		
17.5 - 20.0		SNC			SW	17.5 - 20.0	Brown-tan fine to medium SAND, trace clay, moist		▼ (18.1 ft)
20.0 - 46.0		SNC	- (20), - (25), - (30), - (35), - (40), - (45)		MH	20.0 - 46.0	Red-brown clayey SILT (moderately sorted), trace fine gravel, wet		
46.0							EOB at 46.0 ft		

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

MONITORING WELL LOG: BWTR-5

DRILLING CONTRACTOR: Cascade

DRILLER: J. Lary III

RIG: DR-24HD

DRILLING METHOD: Sonic

BOREHOLE DIAMETER: 10 in WELL DIAMETER: 4 in

TOTAL DEPTH: 46.0 ft

DEPTH TO WATER: 21.7 ft

PROJECT NAME: NERT: Barrier Wall Evaluation

PROJECT NUMBER: 1690006943-033

LOCATION: Henderson, Nevada

LOGGED BY: B. Keegans

START TIME: 14:00 STOP TIME: 16:30

DATE(S): 10/03/2018

COMMENTS:

LEGEND:
SNC - Sonic Core
"-" - Not screened

WELL CONSTRUCTION KEY:
- ░ Concrete
- ▓ Grout
- ▨ Bentonite
- ░ Lapus Lustre #2/12 sand
- □ PVC riser pipe
- ☰ Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION	WELL CONSTRUCTION	WATER LEVEL
0–20		SNC	- (5), - (10), - (15), - (20)		SW-SM	0 - 20.0	Gray-tan-brown silty fine to medium SAND with fine sub-angular gravel, some cobbles, damp @ 11.0 ft becomes moist		
20–46		SNC	- (25), - (30), - (35), - (40), - (45)		MH	20.0 - 46.0	Red-brown clayey SILT, trace fine gravel, wet @ 25-32.5 ft contains caliche		▼
							EOB at 46.0 ft		

Depth scale: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

MONITORING WELL LOG: BWTR-6

DRILLING CONTRACTOR: Cascade
DRILLER: J. Lary III
RIG: DR-24HD
DRILLING METHOD: Sonic
BOREHOLE DIAMETER: 10 in WELL DIAMETER: 4 in
TOTAL DEPTH: 47.0 ft
DEPTH TO WATER: 22.1 ft

PROJECT NAME: NERT: Barrier Wall Evaluation
PROJECT NUMBER: 1690006943-033
LOCATION: Henderson, Nevada
LOGGED BY: B. Keegans
START TIME: 07:40 STOP TIME: 11:30
DATE(S): 10/04/2018

COMMENTS:

LEGEND:
SNC - Sonic Core
"-" - Not screened

WELL CONSTRUCTION KEY:
- Concrete
- Grout
- Bentonite
- Lapus Lustre #2/12 sand
- PVC riser pipe
- Well Screen (0.020 inch slot)

DEPTH (ft)	RECOVERY (ft/ft)	SAMPLER TYPE	PID (ppm)	GRAPHIC LOG	USCS CODE	DEPTH INTERVAL (ft)	MATERIAL DESCRIPTION	WELL CONSTRUCTION	WATER LEVEL
0–17.5 (5, 10, 15)		SNC	-, -, -		SM	0 - 17.5	Gray-tan-brown silty fine to medium SAND (poorly sorted) with fine sub-angular gravel, some cobbles, damp		
17.5–22.0 (20)		SNC	-		SW	17.5 - 22.0	Tan-brown fine to medium SAND, moist		
22.0–37.5 (25, 30, 35)		SNC	-, -, -		CL	22.0 - 37.5	Red-brown silty CLAY, trace fine gravel interbedded with calcium carbonate, wet		▼ 22.1
37.5–47.0 (40, 45)		SNC	-, -		MH	37.5 - 47.0	Orange-brown clayey SILT, wet		
47.0–50							EOB at 47.0 ft		

APPENDIX F
WELL DEVELOPMENT LOGS

RAMBOLL
2200 Powell Street, Suite 700
Emeryville, California 94608
(510) 655-7400
Fax (510) 655-9517

WELL DEVELOPMENT

PRELIMINARY FIELD DRAFT
REVIEW PENDING

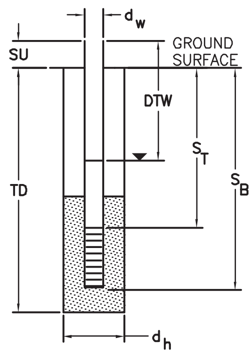
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT: NERT- Barrier Wall Evaluation		WELL NO.: BWTR-1
JOB NO.: 1690006943-033	SITE: Tronox	PREPARED BY: CJ Wu

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 27.05' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 47' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi\left(\frac{d_w}{2}\right)^2 (TD-H) = 12.2 \text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°C)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:

DATE	TIME BEGIN	TIME FINISH	METHOD	WATER REMOVED (gal)	CUMULATIVE TOTAL REMOVED GAL.	CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	COMMENTS (Prior to bailing DTB: 39.62' BTOC)
10/8	14:59	15:10	Bail	9	9	74%	-	-	-	-	36.15	44.93	Brown, Turbid
10/8	15:17	15:20	Surge	0	9	74%	-	-	-	-	28.90	44.95	35-38' BTOC
10/8	15:25	15:28	Surge	0	9	74%	-	-	-	-	27.78	44.95	38-41' BTOC
10/8	15:33	15:36	Surge	0	9	74%	-	-	-	-	27.85	44.95	41-44' BTOC
10/8	15:41	15:44	Surge	0	9	74%	-	-	-	-	27.92	44.95	42-44.95' BTOC
10/8	15:46	15:56	Bail	19	28	230%	-	-	-	-	43.18	44.95	Brown, Turbid
10/10	09:05	09:15	Surge	0	28	230%	-	-	-	-	27.80	44.95	35-44.95' BTOC
10/10	09:20	09:28	Bail	21	49	402%	-	-	-	-	43.99	44.95	0.17 gal/min
10/11	10:05	10:10	Pump	0.85	49.85	409%	7.59	6.906	78.18	571	27.13	44.95	0.17 gal/min
10/11	10:10	10:15	Pump	0.85	50.70	416%	7.49	6.838	77.89	204	28.30	44.95	0.17 gal/min
10/11	10:15	10:20	Pump	0.85	51.55	423%	7.45	6.831	77.96	56.0	28.32	44.95	0.17 gal/min
10/11	10:20	10:25	Pump	0.85	52.40	430%	7.54	6.887	78.49	26.3	28.17	44.95	0.17 gal/min
10/11	10:25	10:30	Pump	0.85	53.75	441%	7.50	6.907	78.62	10.62	28.20	44.95	0.17 gal/min
10/11	10:30	10:35	Pump	0.85	54.10	443%	7.64	6.954	78.79	6.22	28.39	44.95	0.17 gal/min
10/11	10:35	10:40	Pump	0.85	54.95	450%	7.49	6.886	78.61	8.63	28.42	44.95	0.17 gal/min
10/11	10:40	10:41	Pump	0.17	55.12	451%	7.53	6.946	78.61	5.79	28.38	44.95	0.17 gal/min

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WELL DEVELOPMENT
PRELIMINARY FIELD DRAFT
REVIEW PENDING

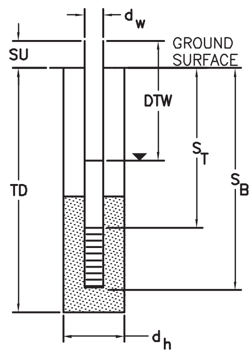
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT	NERT- Barrier Wall Evaluation	WELL NO.	BWTR-2
JOB NO.	1690006943-033	SITE	Tronox
PREPARED BY	CJ Wu		

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 33.42' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 46' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi\left(\frac{d_w}{2}\right)^2 (TD-H) = 7.9\text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°c)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:

DATE	TIME BEGIN	TIME FINISH	METHOD	WATER REMOVED (gal)	CUMULATIVE TOTAL REMOVED GAL.	CUMULATIVE TOTAL REMOVED CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	COMMENTS Prior to bailing DTB: 45.10' BTOC
10/9	08:00	08:03	Surge	0	0	0%	-	-	-	-	32.73	45.10	35-38' BTOC
10/9	08:07	08:10	Surge	0	0	0%	-	-	-	-	32.60	45.10	38-41' BTOC
10/9	08:14	08:17	Surge	0	0	0%	-	-	-	-	31.89	45.10	41-44' BTOC
10/9	08:21	08:24	Surge	0	0	0%	-	-	-	-	33.06	45.10	42-45' BTOC
10/9	08:28	08:40	Bail	17	17	215%	-	-	-	-	43.60	45.10	Brown, Turbid
10/10	08:28	08:38	Surge	0	17	215%	-	-	-	-	33.65	45.10	25-45' BTOC
10/10	08:44	08:51	Bail	15	32	405%	-	-	-	-	43.65	45.10	Brown, Turbid
10/11	09:09	09:14	Pump	3.5	35.5	411%	7.50	7.252	77.01	147	34.19	45.10	0.7 gal/min
10/11	09:14	09:17	Pump	0.75	36.35	460%	7.51	7.622	76.74	132	34.19	45.10	0.25 gal/min
10/11	09:17	09:22	Pump	1.25	37.5	475%	7.56	7.631	76.86	129	34.42	45.10	0.25 gal/min
10/11	09:22	09:27	Pump	1.25	38.75	491%	7.54	7.655	77.27	33.4	34.64	45.10	0.25 gal/min
10/11	09:27	09:32	Pump	1.25	40	506%	7.62	7.617	76.89	13.30	34.78	45.10	0.25 gal/min
10/11	09:32	09:35	Pump	0.75	40.75	516%	7.55	7.600	77.27	9.39	34.92	45.10	0.25 gal/min
10/11	09:35	09:38	Pump	0.75	41.5	525%	7.53	7.601	77.32	8.00	35.20	45.10	0.25 gal/min
10/11	09:38	09:41	Pump	0.75	42.25	535%	7.56	7.615	77.34	5.82	35.24	45.10	0.25 gal/min
10/11	09:41	09:42	Pump	0.25	42.5	538%	7.56	7.608	77.41	4.64	35.25	45.10	0.25 gal/min

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WELL DEVELOPMENT

PRELIMINARY FIELD DRAFT
REVIEW PENDING

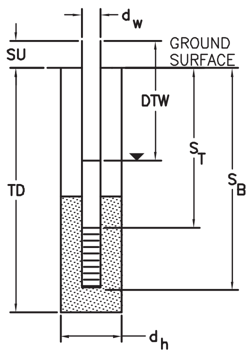
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT		WELL NO.
NERT- Barrier Wall Evaluation		BWTR-3
JOB NO.	SITE	PREPARED BY
1690006943-033	Tronox	CJ Wu

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 32.60' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 47' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi \left(\frac{d_w}{2}\right)^2 (TD-H) = 8.6 \text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°c)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:

DATE	TIME BEGIN	TIME FINISH	METHOD	WATER REMOVED (gal)	CUMULATIVE TOTAL REMOVED GAL.	CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	COMMENTS Prior to bailing DTB: 45.25' BTOC
10/9	09:05	09:08	Surge	0	0	0%	-	-	-	-	31.97	45.25	35-38' BTOC
10/9	09:11	09:14	Surge	0	0	0%	-	-	-	-	31.93	45.25	38-41' BTOC
10/9	09:18	09:21	Surge	0	0	0%	-	-	-	-	31.87	45.25	41-44' BTOC
10/9	09:25	09:28	Surge	0	0	0%	-	-	-	-	31.87	45.25	42-45' BTOC
10/9	09:32	09:43	Bail	22	22	256%	-	-	-	-	42.85	45.25	Brown, Turbid
10/10	07:40	07:50	Surge	0	22	256%	-	-	-	-	30.80	45.25	35-45' BTOC
10/10	07:55	08:12	Bail	26	48	558%	-	-	-	-	42.95	45.25	Brown, Turbid
10/11	07:54	08:02	Pump	2	50	581%	7.29	7.320	76.52	554	32.34	45.25	0.25 gal/min
10/11	08:02	08:04	Pump	0.5	50.5	587%	7.48	7.593	76.92	434	33.80	45.25	0.25 gal/min
10/11	08:04	08:09	Pump	1.25	51.25	596%	7.45	7.550	76.33	244	33.95	45.25	0.25 gal/min
10/11	08:09	08:14	Pump	1.25	53	616%	7.54	7.534	76.02	90.9	34.08	45.25	0.25 gal/min
10/11	08:14	08:20	Pump	1.5	54.5	634%	7.58	7.505	75.78	40.6	34.14	45.25	0.25 gal/min
10/11	08:20	08:25	Pump	1.25	55.75	648%	7.58	7.548	76.15	21.0	34.25	45.25	0.25 gal/min
10/11	08:25	08:30	Pump	1.25	57	663%	7.53	7.521	75.88	14.48	34.42	45.25	0.25 gal/min
10/11	08:30	08:35	Pump	1.25	58.25	677%	7.55	7.458	75.58	10.83	34.42	45.25	0.25 gal/min
10/11	08:35	08:40	Pump	1.25	59.5	692%	7.58	7.463	75.70	7.93	34.42	45.25	0.25 gal/min
10/11	08:40	08:45	Pump	1.25	60.75	706%	7.53	7.432	75.30	9.53	34.42	45.25	0.25 gal/min
10/11	08:45	08:46	Pump	1.25	61	709%	7.49	7.469	75.38	9.13	34.52	45.25	0.25 gal/min

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WELL DEVELOPMENT
PRELIMINARY FIELD DRAFT
REVIEW PENDING

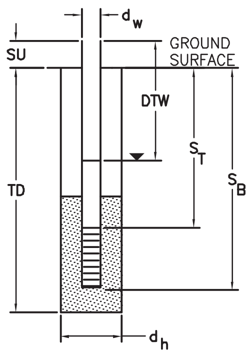
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT		WELL NO.
NERT- Barrier Wall Evaluation		BWTR-4
JOB NO. 1690006943-033	SITE Tronox	PREPARED BY CJ Wu

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 17.69' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 46' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi\left(\frac{d_w}{2}\right)^2 (TD-H) = 19.0 \text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°c)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:

DATE	TIME BEGIN	TIME FINISH	METHOD	WATER REMOVED (gal)	CUMULATIVE TOTAL REMOVED GAL.	CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	COMMENTS Prior to bailing DTB: 41.07' BTOC
10/8	12:31	12:34	Bail	6	6	31.6%	-	-	-	-	24.85	45.67	Brown, Turbid
10/8	12:38	12:41	Surge	0	6	31.6%	-	-	-	-	18.95	45.67	35-38' BTOC
10/8	12:49	12:52	Surge	0	6	31.6%	-	-	-	-	18.68	45.67	38-41' BTOC
10/8	12:55	12:58	Surge	0	6	31.6%	-	-	-	-	18.42	45.67	41-44' BTOC
10/8	13:02	13:05	Surge	0	6	31.6%	-	-	-	-	18.38	45.67	42-45' BTOC
10/8	13:08	13:22	Bail	26	32	168%	-	-	-	-	43.91	45.67	Brown, Turbid
10/9	14:08	14:18	Surge	0	32	168%	-	-	-	-	17.52	45.67	35-45' BTOC
10/9	14:20	14:33	Bail	27	59	311%	-	-	-	-	44.33	45.67	Brown, Turbid
10/10	13:35	13:45	Surge	0	59	311%	-	-	-	-	17.05	45.67	35-45' BTOC
10/10	13:46	14:01	Bail	27	86	453%	-	-	-	-	44.90	45.67	Brown, Turbid
10/11	13:43	13:48	Pump	3.75	87.75	462%	7.74	8.134	77.99	11.05	17.82	45.67	0.75 gal/min
10/11	13:48	13:53	Pump	3.75	93.50	492%	7.67	8.077	77.37	13.26	22.88	45.67	0.75 gal/min
10/11	13:53	13:58	Pump	3.75	97.25	512%	7.61	8.050	77.24	11.06	23.89	45.67	0.75 gal/min
10/11	13:58	14:03	Pump	3.75	101	532%	7.82	8.091	77.49	6.01	24.92	45.67	0.75 gal/min
10/11	14:03	14:08	Pump	3.75	104.75	551%	7.65	8.112	77.68	5.34	26.03	45.67	0.75 gal/min
10/11	14:08	14:09	Pump	0.75	105.5	555%	7.68	8.103	77.63	5.82	26.52	45.67	0.75 gal/min

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WELL DEVELOPMENT
PRELIMINARY FIELD DRAFT
REVIEW PENDING

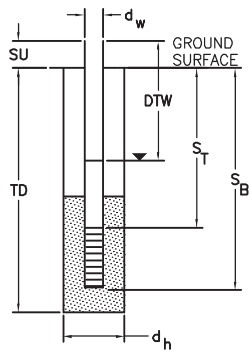
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT		WELL NO.
NERT- Barrier Wall Evaluation		BWTR-5
JOB NO.	**SITE**	**PREPARED BY**
1690006943-033	Tronox	CJ Wu

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 22.09' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 46' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi\left(\frac{d_w}{2}\right)^2 (TD-H) = 15.8 \text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°c)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:					CUMULATIVE TOTAL REMOVED		WATER CHARACTER CRITERIA						COMMENTS Prior to bailing DTB: 45.21' BTOC
DATE	TIME BEGIN	TIME FINISH	METHOD	WATER REMOVED (gal)	GAL.	CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	
10/8	11:26	11:30	Bail	6	6	38.0%	-	-	-	-	29.76	45.41	Brown, Turbid
10/8	11:36	11:39	Surge	0	6	38.0%	-	-	-	-	28.85	45.41	35-38' BTOC
10/8	11:44	11:47	Surge	0	6	38.0%	-	-	-	-	28.39	45.41	38-41' BTOC
10/8	11:52	11:55	Surge	0	6	38.0%	-	-	-	-	28.00	45.41	41-44' BTOC
10/8	11:57	12:00	Surge	0	6	38.0%	-	-	-	-	29.64	45.41	42-45' BTOC
10/8	12:05	12:10	Bail	16	22	139%	-	-	-	-	43.70	45.41	Brown, Turbid
10/9	12:30	12:40	Surge	0	22	139%	-	-	-	-	22.70	45.41	35-45' BTOC
10/9	12:42	12:51	Bail	21	43	272%	-	-	-	-	44.21	45.41	Brown, Turbid
10/10	13:00	13:10	Surge	0	43	272%	-	-	-	-	22.24	45.41	35-45' BTOC
10/10	13:11	13:25	Bail	21	64	405%	-	-	-	-	44.45	45.41	Brown, Turbid
10/11	12:50	12:55	Pump	1.5	65.5	415%	7.57	7.294	78.33	85.9	22.30	45.41	0.3 gal/min
10/11	12:55	13:00	Pump	1.5	67	424%	7.59	7.366	77.37	31.4	25.10	45.41	0.3 gal/min
10/11	13:00	13:05	Pump	1.5	68.5	434%	7.66	7.234	75.45	14.80	26.70	45.41	0.3 gal/min
10/11	13:05	13:10	Pump	1.5	70	443%	7.66	7.258	76.63	18.65	28.21	45.41	0.3 gal/min
10/11	13:10	13:15	Pump	1.5	71.5	453%	7.73	7.267	76.84	11.22	29.55	45.41	0.3 gal/min
10/11	13:15	13:20	Pump	1.5	73	462%	7.69	7.261	77.35	8.25	30.42	45.41	0.3 gal/min
10/11	13:20	13:25	Pump	1.5	74.5	472%	7.79	7.251	77.12	5.76	30.67	45.41	0.3 gal/min
10/11	13:25	13:26	Pump	0.3	74.8	473%	7.75	7.221	77.49	4.95	30.70	45.41	0.3 gal/min

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WELL DEVELOPMENT
PRELIMINARY FIELD DRAFT
REVIEW PENDING

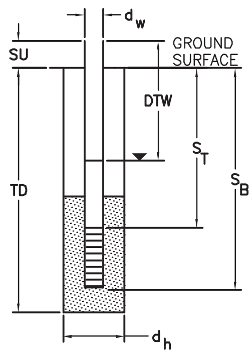
METHOD(S)	PUMP	BAILER	SURGE BLOCK
TYPE	Monsoon (#001044)		
MATERIAL	Plastic	Aluminium	Steel
DIMENSION	2" dia.	6' long 4"dia.	6' long
OTHER	Lifts up to 120" DTW		

PROJECT		WELL NO.
NERT- Barrier Wall Evaluation		BWTR-6
JOB NO.	SITE	PREPARED BY
1690006943-033	Tronox	CJ Wu

DEVELOPMENT CRITERIA
5 Well Volumes

DECONTAMINATION METHOD
Aloconox and DI Water

HOLE DIAMETER d_h = 10"
WELL CASING
INSIDE DIAMETER d_w = 4"
CASING STICKUP SU= 0'
DEPTH TO:
WELL LEVEL DTW= 21.92' BTOC
TOP SCREEN $SU+S_T$ = 35' BTOC
BASE SCREEN $SU+S_g$ = 45' BTOC
BOTTOM WELL SU+TD= 47' BTOC



CASING VOLUME CALCULATION (USE CONSISTENT UNITS)

$$\text{CASING VOLUME} = V_C = \pi\left(\frac{d_w}{2}\right)^2 (TD-H) = 15.4 \text{ gal.}$$

FIELD EQUIPMENT CALIBRATIONS

EQUIPMENT MODEL/TYPE	YSI 556	Oakton T-60	
SERIAL NO.	09E100417	2126461	
DATE CALIBRATED	10/5/2018	10/10/18	
TEMP (°C)	refer to cal.		
STANDARD/ACTUAL	certificate		

DEVELOPMENT LOG:					CUMULATIVE TOTAL REMOVED		WATER CHARACTER CRITERIA						COMMENTS
DATE	TIME		METHOD	WATER REMOVED (gal)									Prior to bailing DTB: 43.24' BTOC
	BEGIN	FINISH			GAL.	CASING VOLUMES	pH	CONDUCTIVITY (mS/cm)	TEMP.(F°)	TURBIDITY	DTW (BTOC)	DTB (BTOC)	
10/8	09:00	09:05	Bail	3.0	3	19.5%	-	-	-	-	-	-	Brown, Turbid
10/8	09:05	09:06	Bail	3.0	6	39.0%	-	-	-	-	29.55	44.63	Brown, Turbid
10/8	09:15	09:28	Surge	0	6	39.0%	-	-	-	-	-	-	35-38' BTOC
10/8	09:28	09:31	Surge	0	6	39.0%	-	-	-	-	28.63	44.63	34.65-39.65' BTOC
10/8	09:36	09:39	Surge	0	6	39.0%	-	-	-	-	28.41	44.63	37.63-40.63' BTOC
10/8	09:44	09:47	Surge	0	6	39.0%	-	-	-	-	28.16	44.63	40.63-43.63' BTOC
10/8	09:55	09:58	Surge	0	6	39.0%	-	-	-	-	27.86	44.63	41.63-44.63' BTOC
10/8	10:05	10:14	Bail	21	27	175%	-	-	-	-	43.69	44.63	Brown, Turbid
10/9	11:39	11:42	Surge	0	27	175%	-	-	-	-	23.95	44.63	35-38' BTOC
10/9	11:48	11:58	Surge	0	27	175%	-	-	-	-	24.19	44.63	35-44.6' BTOC
10/9	12:00	12:12	Bail	24	51	331%	-	-	-	-	43.54	44.63	Light brown, Turbid
10/10	11:37	11:47	Surge	0	51	331%	-	-	-	-	24.30	44.63	35-44.63' BTOC
10/10	11:50	12:03	Bail	26	77	500%	-	-	-	-	43.60	44.63	Brown, Turbid
10/10	14:07	14:21	Pump	3.0	80	519%	7.32	4.874	78.29	344	35.02	44.63	3-4 gal/min
10/10	14:21	14:28	Pump	1.05	81.05	526%	7.49	4.263	77.88	59.7	37.30	44.63	0.15 gal/min
10/10	14:28	14:33	Pump	0.75	81.8	531%	7.61	4.282	77.61	57.7	37.87	44.63	0.15 gal/min
10/10	14:33	14:38	Pump	0.75	82.55	536%	7.64	4.370	77.80	61.9	38.45	44.63	0.15 gal/min
10/10	14:38	14:42	Pump	0.60	83.15	540%	7.70	4.352	77.68	80.2	39.19	44.63	0.15 gal/min
10/10	14:42	14:45	Pump	0.45	83.60	543%	7.69	4.356	78.07	76.2	39.54	44.63	0.15 gal/min
10/10	14:45	14:49	Pump	0.60	84.2	547%	7.74	4.347	89.2	89.2	39.63	44.63	0.15 gal/min
10/10	14:49	14:50	Pump	0.15	84.35	548%	7.68	4.370	83.6	83.6	39.99	44.63	0.15 gal/min

APPENDIX G
U240 FORM AND SAFETY DATA SHEETS

Nevada Division of Environmental Protection
Bureau of Water Pollution Control - Underground Injection Control Program
901 S. Stewart St Ste 4001 Carson City Nevada 89701

UIC Form U240 – Chemical Use Request

The Nevada Division of Environmental Protection is requiring the following information for any entity seeking approval for chemical use, including chemicals for scale inhibitors, corrosion inhibitors, well rehab or cleaning, cooling towers, water well treatment, etc. (Note: for standard operating procedures using standard industry chemicals approved by Division of Minerals on Class 2 and geothermal wells, this form is not required, however NDEP reserves the right to require for certain situations/chemicals)

1. This form will be returned if all blanks are not completed.
2. Fill out a separate form for each chemical. Attach separate sheets if needed to answer questions.
3. A copy of the approved request shall be maintained in UIC O&M manual or UIC records for as long as the chemical is used.
4. NDEP approval below is only for the action stated on the approved form. Any changes in chemical use, location or amounts must be approved with a new request.

FACILITY AND PERMIT INFORMATION

1) UIC Permit No.: N/A	3) City/Valley: Henderson
2) Project/Facility Name: Nevada Environmental Response Trust Site	4) County: Clark

5) The water this chemical will come in contact with is: ☐ Cooling tower water ☒ Well water ☐ other: ____________

6) Discuss where the water (in Item #5) will be discharged: Well water (injection well) will discharge into the water table.

7) List other chemicals used in this water: None

CHEMICAL INFORMATION – Note: Chemical information shall be submitted to the Division that clearly states the chemical composition (what's in it and at what concentration/mass). If the information is not provided, the Division will not approve this chemical. Proprietary information may be submitted confidentially.

8) Chemical Name: Rhodamine WT

9) Chemical formula: C29H29N2O5Cl2Na or C29H29ClN2Na2O5	10) CAS No.: 65392-81-6, 75701-30-3, 528-44-9

11) Manufacturer's name, phone and address: Sensient Colors LLC, 2515 N. Jefferson, 63106 St. Louis, MO Phone: 1 800-325-8110

12) Is the chemical radioactive? ☐ YES ☒ NO Describe:

13) Is a MSDS sheet available for this chemical? ☒ YES ☐ NO If YES, attach Is an Environmental Data Sheet (EDS) available? ☐ YES ☒ NO If YES, attach

14) At working concentration[1], is the chemical hazardous or toxic to humans, livestock, fish, wildlife? If Yes, what entity and at what concentrations?:	☐ YES ☒ NO
15) If water is discharged to surface at any time, has the NV Division of Wildlife been consulted?	☐ YES ☐ NO NA No surface discharge

CHEMICAL FEED INFORMATION

16) Estimated use start date: October 15, 2018

17) Describe where the chemical is applied to the water: Dye will be placed in injection wells BWTR-1 and BWTR-4 on the southern side of the barrier wall.

18) Describe how the chemical is applied: Rhodamine WT liquid mixture will be placed via gravity feed into the wells.

19) Purpose of chemical: ☐ scale inhibitor ☐ corrosions inhibitor ☐ biocide ☐ algaecide ☐ dispersant ☐ surfactant ☒ Other: Dye tracer testing.

20) Describe the frequency of application: Once

21) What is the feed rate of the chemical as it is fed into the water: Approximately 3 gallons per minute (Gravity feed), total of approx. 1.7 gallons of dye. Approximately 5 well volumes of clean chase water will follow the initial dye introduction, totaling approx. 60 gallons.
Estimated use per month: Once

22) What is the final, effective concentration of chemical mixture immediately prior to application: 220,000 mg/L

23) What is the "working" concentration of chemical after mixing with the water in the cooling tower/well/etc.: 220,000 mg/L and will decrease over time.

24) Is the bulk storage container properly marked with the chemical name and information? ☒ YES ☐ NO

25) Describe the chemical monitoring before and after application: Background samples of groundwater will be collected to evaluate for the presence of the dye prior to the dye introduction. Sampling of two wells downgradient of the injection well will be performed for approximately 17 weeks after the dye introduction.

26) Discuss the interaction between the proposed chemicals/additives and chemicals already in use, and the by-products of their interaction:
The dye is not reactive with other substances.

FORM COMPLETION

Print Name of Person Completing Form: Jon Johnson/Ramboll US Corp.

Signature: [signature]	Date: 10/3/2018

1. Working concentration is the chemical concentration within the final water system (e.g. cooling tower system), found under Item 23 above.

NDEP Approval [signature] Staff 2 DO NOT WRITE IN THIS SPACE 10/8/18

Name Title Date

Nevada Division of Environmental Protection
Bureau of Water Pollution Control - Underground Injection Control Program
901 S. Stewart St Ste 4001 Carson City Nevada 89701

NDEP

UIC Form U240 – Chemical Use Request

The Nevada Division of Environmental Protection is requiring the following information for any entity seeking approval for chemical use, including chemicals for scale inhibitors, corrosion inhibitors, well rehab or cleaning, cooling towers, water well treatment, etc. (Note: for standard operating procedures using standard industry chemicals approved by Division of Minerals on Class 2 and geothermal wells, this form is not required, however NDEP reserves the right to require for certain situations/chemicals)

1. This form will be returned if all blanks are not completed.
2. Fill out a separate form for each chemical. Attach separate sheets if needed to answer questions.
3. A copy of the approved request shall be maintained in UIC O&M manual or UIC records for as long as the chemical is used.
4. NDEP approval below is only for the action stated on the approved form. Any changes in chemical use, location or amounts must be approved with a new request.

FACILITY AND PERMIT INFORMATION

1) UIC Permit No.: NA	3) City/Valley: Henderson
2) Project/Facility Name: Nevada Environmental Response Trust Site	4) County: Clark

5) The water this chemical will come in contact with is: ☐ Cooling tower water ☒ Well water ☐ other: ______

6) Discuss where the water (in Item #5) will be discharged: Well water (injection well) will discharge into water table.

7) List other chemicals used in this water: None

CHEMICAL INFORMATION – Note: Chemical information shall be submitted to the Division that clearly states the chemical composition (what's in it and at what concentration/mass). If the information is not provided, the Division will not approve this chemical. Proprietary information may be submitted confidentially.

8) Chemical Name: Fluorescein

9) Chemical formula: $C_{20}H_{12}O_5$	10) CAS No.: 2321-07-5

11) Manufacturer's name, phone and address: Hue Corporation, P.O. Box 509, Tustin, CA 92781 phone: 714-389-3130

12) Is the chemical radioactive? ☐ YES ☒ NO Describe:

13) Is a MSDS sheet available for this chemical? ☒ YES ☐ NO If YES, attach   Is an Environmental Data Sheet (EDS) available? ☐ YES ☒ NO If YES, attach

14) At working concentration[1], is the chemical hazardous or toxic to humans, livestock, fish, wildlife? If Yes, what entity and at what concentrations?:	☐ YES ☒ NO
15) If water is discharged to surface at any time, has the NV Division of Wildlife been consulted?	☐ YES ☐ NO NA No surface discharge

CHEMICAL FEED INFORMATION

16) Estimated use start date: October 15, 2018

17) Describe where the chemical is applied to the water: Dye will be placed in injection wells BWTR-1 and BWTR-4 on the southern side of the barrier wall.

18) Describe how the chemical is applied: Fluorescein in powder form will be mixed with 5 gal of water and placed via gravity feed in the wells.

19) Purpose of chemical: ☐ scale inhibitor ☐ corrosions inhibitor ☐ biocide ☐ algaecide ☐ dispersant ☐ surfactant ☒ Other: Dye tracer testing

20) Describe the frequency of application: Once

21) What is the feed rate of the chemical as it is fed into the water: Approximately 3 gallons per minute (Gravity feed), total of 5 gallons. Approximately 5 well volumes of clean chase water will follow the initial dye introduction, totaling approx. 60 gallons.
Estimated use per month: Once

22) What is the final, effective concentration of chemical mixture immediately prior to application: 72,000 mg/L

23) What is the "working" concentration of chemical after mixing with the water in the cooling tower/well/etc.: 72,000 mg/L and will decrease over time.

24) Is the bulk storage container properly marked with the chemical name and information? ☒ YES ☐ NO

25) Describe the chemical monitoring before and after application: Background samples of groundwater will be collected to evaluate for the presence of the dye prior to the dye introduction. Sampling of two wells downgradient of the injection well will be performed for approximately 17 weeks after the dye introduction.

26) Discuss the interaction between the proposed chemicals/additives and chemicals already in use, and the by-products of their interaction:
The dye is not reactive with other substances but may degrade into CO or CO_2.

FORM COMPLETION

Print Name of Person Completing Form: Jon Johnson/Ramboll US Corp

Signature: [signature]	Date: 10/3/2018

1. Working concentration is the chemical concentration within the final water system (e.g. cooling tower system), found under Item 23 above.

NDEP Approval: [signature]   Staff 2   10/8/18

Name   Title   Date

PLATE

Proposed Dye Tracer Testing Area (also see Inset A)
Former AMPAC/Endeavour Re-injection System
Seep Well Field
AMPAC/Endeavour Athens Pen Extraction Wells
AMPAC/Endeavour Athens Road Extraction Wells
Athens Road Well Field
OSSM Well Field and Injection Trenches
NERT Barrier Wall and Interceptor Well Field
TIMET Barrier Wall
TIMET Well Field
AMPAC/Endeavour Auto Mall Extraction Wells (Deeper Water Bearing Zone)
Former PEPCON Site
Las Vegas Wash
City of Henderson Bird Viewing Preserve
E RUSSELL RD
E SUNSET RD
W WARM SPRINGS RD
W LAKE MEAD DR
N BOULDER HWY
N US 95
PABCO RD
E LAKE MEAD PKWY
Inset A
Inset B
Inset C
Former Recharge Trenches
NERT Barrier Wall
1 inch = 1,200 feet
1:14,400
0 1,200 2,400 3,600
Feet
NERT Remedial Investigation Study Areas
Downgradient Study Area
Eastside Study Area
NERT Off-Site Study Area
NERT Site
Other Features
Site Features (Buildings and Tanks)
Muddy Creek Topographic High/Unsaturated Alluvium
Approximate Location of Paleochannel Centerline
1700 Potentiometric Surface Contour (feet above mean sea level)
1,700 Groundwater Elevation (feet above mean sea level)
(M-121 - Potentiometric Surface in the Upper Muddy Creek Formation)
NA Not Available during second quarter 2017 as part of the Groundwater Monitoring Program
DRY Well Dry during second quarter 2017
Shallow Monitoring Wells (Shown by owner; used in contouring)
Owner Unknown
AMPAC/Endeavour
BRC
Chimera Golf Club
City of Henderson
OSSM
NERT
SNWA
TIMET
Deep Monitoring Wells (Shown by owner; not used in contouring)
OSSM
City of Henderson
BRC
AMPAC/Endeavour
NERT
Extraction Wells
Shallow (pumping rate used in contouring)
Deep (not used in contouring)
Notes:
Results shown may have been rounded for clarity. Some wells in the area of the OSSM and TIMET well fields have been removed for clarity. See Table A-1 and A-4 for all results reported to full precision.
Plate 1
POTENTIOMETRIC SURFACE MAP
SHALLOW WATER-BEARING ZONE
SECOND QUARTER 2017
Annual Performance Report
Nevada Environmental Response Trust (NERT)
Henderson, Nevada
RAMBOLL ENVIRON
Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet
Projection: Transverse Mercator
Datum: North American 1983
PROJECT: 21-41400A
BY: KL/MMV
DATE: 12/8/2017

FIGURES

H:\LePetomane\NERT\RI_Barrier Wall Integrity Evaluation\GIS\Figure1a_WestInjectPoints_2018-09-18_10.4.mxd

RAMBOLL

Barrier Wall Tracer Study - West Side Injection and Monitoring Locations

Nevada Environmental Response Trust

Henderson, Nevada

FIGURE **1a**

DRAFTED BY: J. KING | DATE: 9/18/2018 | PROJECT: 1690006943-033

H:\LePetomane\NERT\RI_Barrier Wall Integrity Evaluation\GIS\Figure1b_EastInjectPoints_2018-09-18_10.4.mxd

RAMBOLL

Barrier Wall Tracer Study - East Side Injection and Monitoring Locations

Nevada Environmental Response Trust

Henderson, Nevada

FIGURE **1b**

DRAFTED BY: J. KING | DATE: 9/18/2018 | PROJECT: 1690006943-033

ATTACHMENT 1
SAFETY DATA SHEETS

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ……………………… **HUE URANINE CONC** (Also known as Fluorescein)
PRODUCT NUMBER ………………… 1-C8-073PC
COLOR INDEX NAME ………………… ACID YELLOW 073
COLOR INDEX NO …………………… 45350
C. A. S. # ……………………………… 518-47-8
CHEMICAL FAMILY…………………… XANTHENE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US): NO SYMBOL

SIGNAL WORD WARNING

HAZARD STATEMENT(S)
H333 - MAY BE HARMFUL IF INHALED
H320 - CAUSES EYE IRRITATION
H316 - CAUSES MILD SKIN IRRITATION

PRECAUTIONARY STATEMENTS P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS:
GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL

OTHER HAZARDS	NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY	NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION: REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

SKIN: WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.

EYES: FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.

INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL.
IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL GREATER THAN 7,000 MG/KG - RAT
DERMAL (ANIMAL) NA
EFFECTS TO EYES (ANIMAL) EYES - RABBIT, NOT IRRITATING
SKIN IRRITATION (ANIMAL) SKIN - RABBIT, SLIGHT IRRITANT

SKIN CORROSION/IRRITATION NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION CAUSES EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED
GERM CELL MUTAGENICITY NOT CLASSIFIED
CARCINOGENICITY NOT CLASSIFIED
REPRODUCTIVE TOXICITY NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD NOT CLASSIFIED
INHALATION MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT CAUSES SERIOUS EYE IRRITATION.
INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY NA
PERSISTENCE AND DEGRADABILITY NA
BIOACCUMULATIVE POTENTIAL NA
MOBILITY IN SOIL LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL CATFISH - 2,267,000 UG/LITER RAINBOW TROUT - 1,372,000 UG/LITER BLUEGILL - 3,433,000 UG/LITER
OTHER ADVERSE EFFECTS NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL.
PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING.
OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER NONE
UN PROPER SHIPPING NAME NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT) NA
DOT SPECIAL PROVISIONS NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT NONE
TRANSPORT BY SEA NONE
AIR TRANSPORT NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

518-47-8	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

Safety Data Sheet

INTRACID RHODAMINE WT LIQUID

Safety Data Sheet dated: 5/13/2015 - version 1

Date of first edition: 5/13/2015

1. IDENTIFICATION

Product identifier

Mixture identification:

Trade name: INTRACID RHODAMINE WT LIQUID

Other means of identification:

Trade code: A45171566

Recommended use of the chemical and restrictions on use

Recommended use: Industrial color additive

Restrictions on use: Not Determined

Name, address, and telephone number of the chemical manufacturer, importer, or other responsible party

Sensient Colors LLC
2515 N. Jefferson
63106 St. Louis, MO (USA)
Phone: 1 800-325-8110
Emergency Number(CHEMTREC): 1-800-424-9300

2. HAZARD(S) IDENTIFICATION

The identity of the individual components of this product is proprietary information and is considered a trade secret pursuant to 29 CFR 1910.1200

Hazardous components as defined in the OSHA Hazard Communication Standard: components with a HEALTH hazard (carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, etc..) and/or a PHYSICAL hazard (a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive, etc.)

Classification of the chemical

Skin Irrit. 2	Causes skin irritation.
Eye Irrit. 2B	Causes eye irritation

Label elements

Symbols:

Warning

Code	Description
H315	Causes skin irritation.
H320	Causes eye irritation

Code	Description
P264	Wash ... Thoroughly after handling.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352	IF ON SKIN: Wash with plenty of water/…
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P321	Specific treatment (see ... On this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.

P362+P364 Take off contaminated clothing and wash it before reuse.

Ingredient(s) with unknown acute toxicity:

None

Hazards not otherwise classified identified during the classification process:

None

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances

Not Determined

Mixtures

Hazardous components within the meaning of 29 CFR 1910.1200 and related classification:

List of components

Qty	Name	Ident. Numb.	Classification	Registration Number
10-12.5 %	RHODAMINE LIQUID	CAS:65392-81-6 EC:265-730-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
10-12.5 %	RHODAMINE LIQUID	CAS:75701-30-3 EC:278-292-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
1-3 %	TRIMELLITIC ACID	CAS:528-44-9 EC:208-432-3	Skin Irrit. 2, H315; Eye Irrit. 2A, H319; STOT SE 3, H335	

4. FIRST AID MEASURES

Description of first aid measures

In case of skin contact:

Immediately take off all contaminated clothing and shoes.

Immediately remove any contaminated clothing, shoes or stockings.

After contact with skin, wash immediately with soap and plenty of water.

In case of eye contact:

Wash immediately and thoroughly with running water, keeping eyelids regularly raised, for at least 15 minutes. Cold water may be used. Check for and remove any contact lenses at once. OBTAIN A MEDICAL EXAMINATION.

Protect the eyes with a sterile gauze or a clean, dry handkerchief.

In case of ingestion:

Do not induce vomiting, get medical attention showing the MSDS and label hazardous.

In case of inhalation:

Remove casualty to fresh air and keep warm and at rest.

Most important symptoms/effects, acute and delayed

Eye irritation

Eye damages

Skin Irritation

Erythema

Indication of any immediate medical attention and special treatment needed

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

5. FIRE-FIGHTING MEASURES

Extinguishing media

Suitable extinguishing media:

Water, CO_2, foam, chemical powders, according to the materials involved in the fire.

In case of fire, use foam, dry chemical, CO_2.

Unsuitable extinguishing media:

None in particular.

Specific hazards arising from the chemical

Do not inhale explosion and combustion gases.

Burning produces heavy smoke.

Hazardous combustion products: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Special protective equipment and precautions for fire-fighters

Use suitable breathing apparatus .

Collect contaminated fire extinguishing water separately. This must not be discharged into drains.

Move undamaged containers from immediate hazard area if it can be done safely.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Wear personal protection equipment.

Remove persons to safety.

See protective measures under point 7 and 8.

Methods and material for containment and cleaning up

Suitable material for taking up: dry and inert absorbing material (e.g. vermiculite, sand, earth).

Wash with plenty of water.

7. HANDLING AND STORAGE

Precautions for safe handling

Avoid contact with skin and eyes, inhalation of vapours and mists.

Don't use empty container before they have been cleaned.

Before making transfer operations, assure that there aren't any incompatible material residuals in the containers.

Contamined clothing should be changed before entering eating areas.

Do not eat or drink while working.

See also section 8 for recommended protective equipment.

Conditions for safe storage, including any incompatibilities

Storage temperature: Not Determined

Incompatible materials:

None in particular.

Instructions as regards storage premises:

Adequately ventilated premises.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

No Data Available

Appropriate engineering controls: Not Determined

Individual protection measures

Eye/face protection:

Use close fitting safety goggles, don't use eye lens.

Skin protection:

Use clothing that provides comprehensive protection to the skin, e.g. cotton, rubber, PVC or viton.

Hand protection:

Use protective gloves that provide comprehensive protection, e.g. P.V.C., neoprene or rubber.

Respiratory protection:

Not Determined

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical State Liquid

Appearance: Liquid,

Odour: Not Determined

Odour threshold: Not Determined

pH: 10.50

Melting point/ range: Not Determined

Boiling point/ range: Not Determined

Flash point: > 100°C / 212°F

Evaporation rate: Not Determined

Upper/lower flammability or explosive limits: Not Determined

Vapour density: Not Determined

Vapour pressure: Not Determined

Density: Not Determined

Water solubility: Not Determined

Lipid solubility: Not Determined

Partition coefficient (n-octanol/water): Not Determined

Auto-ignition temperature: Not Determined

Decomposition temperature: Not Determined

Viscosity: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Flammability (Solid, Gas): Not Determined

Other information

Substance group relevant properties: Not Determined
Miscibility: Not Determined
Fat Solubility: Not Determined
Conductivity: Not Determined

10. STABILITY AND REACTIVITY

Reactivity

Stable under normal conditions.

Chemical stability

Data not Available.

Possibility of hazardous reactions

Burning produces carbon monoxide and/or carbon dioxide.

Conditions to avoid

Stable under normal conditions of temperature and pressure.

Incompatible materials

Avoid strong oxidizing agents, peroxides, acids, alkali metals.

Hazardous decomposition products

Burning produces carbon monoxide and/or carbon dioxide.

11. TOXICOLOGICAL INFORMATION

Information on toxicological effects

Toxicological information of the product: No Data Available

Substance(s) listed on the IARC Monographs:

None

Substance(s) listed as OSHA Carcinogen(s):

None

Substance(s) listed as NIOSH Carcinogen(s):

None

Substance(s) listed on the NTP report on Carcinogens:

None

12. ECOLOGICAL INFORMATION

Toxicity

Adopt good working practices, so that the product is not released into the environment.
Eco-toxicity:

List of Eco-Toxicological properties of the product

No Data Available

Persistence and degradability

Not Determined

Bioaccumulative potential

Not Determined

Mobility in soil

Not Determined

Other adverse effects

Not Determined

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Recover if possible. In so doing, comply with the local and national regulations currently in force.

14. TRANSPORT INFORMATION

UN number

ADR-UN number: N/A
DOT-UN Number: N/A
IATA-Un number: N/A
IMDG-Un number: N/A

UN proper shipping name

ADR-Shipping Name: N/A
DOT Proper Shipping Name: N/A
IATA-Technical name: N/A
IMDG-Technical name: N/A

Transport hazard class(es)

ADR-Class: N/A
DOT Hazard Class: N/A
IATA-Class: N/A
IMDG-Class: N/A

Packing group

ADR-Packing Group: N/A
Exempted for ADR: N/A
IATA-Packing group: N/A
IMDG-Packing group: N/A

Environmental hazards

Marine pollutant: No
Environmental Pollutant: Not Determined

Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code

Not Determined

Special precautions

Department of Transportation (DOT):

DOT-Special Provision(s): N/A
DOT Label(s): N/A
DOT Symbol: N/A
DOT Cargo Aircraft: N/A
DOT Passenger Aircraft: N/A
DOT/TDG Bulk: N/A
DOT Non-Bulk: N/A

Road and Rail (ADR-RID):

ADR-Label: N/A
ADR-Upper number: N/A
ADR Tunnel Restriction Code: N/A

Air (IATA):

IATA-Passenger Aircraft: N/A
IATA-Cargo Aircraft: N/A
IATA-Label: N/A
IATA-Sub Risk: N/A
IATA-Erg: N/A
IATA-Special Provisioning: N/A

Sea (IMDG):

IMDG-Stowage Code: N/A
IMDG-Stowage Note: N/A
IMDG-Sub Risk: N/A
IMDG-Special Provisioning: N/A
IMDG-Page: N/A
IMDG-Label: N/A
IMDG-EMS: N/A
IMDG-MFAG: N/A

15. REGULATORY INFORMATION

USA - Federal regulations

TSCA - Toxic Substances Control Act

TSCA inventory:

All the components are listed on the TSCA inventory

TSCA listed substances:

RHODAMINE LIQUID	is listed in TSCA	Section 8b
RHODAMINE LIQUID	is listed in TSCA	Section 8b
TRIMELLITIC ACID	is listed in TSCA	Section 8b, Section 5

SARA - Superfund Amendments and Reauthorization Act

Section 302 - Extremely Hazardous Substances:

no substances listed

Section 304 - Hazardous substances:

no substances listed

Section 313 - Toxic chemical list:

no substances listed

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

Substance(s) listed under CERCLA:

no substances listed

CAA - Clean Air Act

CAA listed substances:

no substances listed

CWA - Clean Water Act

CWA listed substances:

no substances listed

USA - State specific regulations

California Proposition 65

Substance(s) listed under California Proposition 65:

no substances listed

Massachusetts Right to know

Substance(s) listed under Massachusetts Right to know:

no substances listed

Pennsylvania Right to know

Substance(s) listed under Pennsylvania Right to know:

no substances listed

New Jersey Right to know

Substance(s) listed under New Jersey Right to know:

no substances listed

16. OTHER INFORMATION

Code	Description
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H320	Causes eye irritation
H335	May cause respiratory irritation.

Safety Data Sheet dated: 5/13/2015 - version 1

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality. The information relates only to the specific material and may not be valid for such material used in combination with any other material or in any process.

This document was prepared by a competent person who has received appropriate training.

It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended.

This MSDS cancels and replaces any preceding release.

Legend to abbreviations and acronyms used in the safety data sheet:

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID: Regulation Concerning the International Transport of Dangerous Goods by Rail

IMDG: International Maritime Code for Dangerous Goods

IATA: International Air Transport Association

IATA-DGR: Dangerous Goods Regulation by the "International Air Transport Association" (IATA)

ICAO: International Civil Aviation Organization

ICAO-TI: Technical Instructions by the "International Civil Aviation Organization" (ICAO)

GHS: Globally Harmonized System of Classification and Labeling of Chemicals
CLP: Classification, Labeling, Packaging
EINECS: European Inventory of Existing Commercial Chemical Substances
INCI: International Nomenclature of Cosmetic Ingredients
CAS: Chemical Abstracts Service (division of the American Chemical Society)
GefStoffVO: Ordnance on Hazardous Substances, Germany
LC50: Lethal concentration, for 50 percent of test population
LD50: Lethal dose, for 50 percent of test population
DNEL: Derived No Effect Level
PNEC: Predicted No Effect Concentration
TLV: Threshold Limiting Value
TWATLV: Threshold Limiting Value for the Time Weighted Average 8 hour day.(ACGIH Standard)
STEL: Short Term Exposure limit
STOT: Specific Target Organ Toxicity
WGK: German Water Hazard Class
KSt: Explosion coefficient
y for the damage.

APPENDIX H
OZARK UNDERGROUND LAB TRACER TEST DATA REPORT

Ozark UNDERGROUND LABORATORY 1572 Aley Lane • Protem, MO 65733 • (417) 785-4289 • fax (417) 785-4290 • contact@ozarkundergroundlab.com

NERT SITE BARRIER WALL GROUNDWATER TRACING INVESTIGATION SUMMARY REPORT HENDERSON, NEVADA

Revised
March 2019

Shiloh L. Beeman, RG
Senior Hydrogeologist
Ozark Underground Laboratory, Inc.

A summary report prepared for Jonathan Johnson, Ph.D., Senior Manager, of Ramboll, Princeton, New Jersey.

TABLE OF CONTENTS

List of Tables

1 INTRODUCTION

This report has been prepared to describe a groundwater dye tracing investigation conducted at the Nevada Environmental Response Trust (NERT) site in Henderson, Nevada. The groundwater tracing investigation was focused on detecting possible leakage zones at the subsurface groundwater barrier wall. The Ozark Underground Laboratory (OUL) performed the dye tracing investigation in cooperation with Ramboll from October 2018 through mid-February 2019.

1.1 Purpose and Scope of Investigation

The purpose of this investigation was to test the integrity of an existing onsite subsurface groundwater barrier wall. The dye tracing was focused on two locations that represented possible areas of subsurface leakage previously identified by surface geophysical methods.

The scope of the investigation involved the concurrent introduction of two different tracer dyes in two monitoring wells located at different locations immediately upgradient of the barrier wall. Sampling stations consisted of site monitoring wells (three primary monitoring locations downgradient of the barrier wall near each dye introduction) and groundwater extraction control points.

1.2 Site Background

The NERT site is located in Henderson, Nevada. NERT owns, and is responsible for, the remediation of a large area of historical chemical manufacturing dating back to the early 1940s before the city of Henderson grew into the area. Since the early manganese manufacturing to support the World War II effort, chemical manufacturing has continued in the area under various companies and operations. Groundwater characterization and treatment began in the area in the 1980s for hexavalent chromium. Groundwater impact has been detected as far away as the Las Vegas Wash, leading to the initiation of groundwater treatment for perchlorate in 1999. NERT was established in 2011 to remediate the historical legacy contamination.

Although much of the immediate area is dedicated to ongoing site remediation, manufacturing operations are ongoing in the eastern portion of the site by Tronox/EMD.

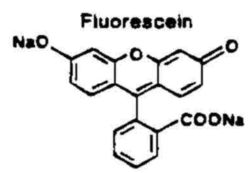
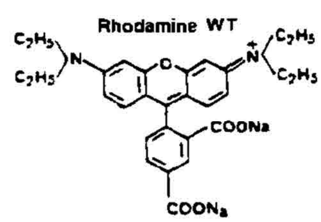
2 METHODOLOGY

This section summarizes details regarding the tracer dyes selected for use in this study, the dye introduction locations, sampling for tracer dyes, and laboratory analysis. More detailed information is included in the OUL's Procedures and Criteria document found in Appendix A. The work plan for this dye investigation was prepared by Ramboll with input from the OUL.

2.1 Dye Introductions

Two different dyes were used for two separate traces during this study. These dyes were fluorescein and rhodamine WT. Both of these dyes are environmentally safe (Smart, 1984; Field et al., 1995) and pose no risk to groundwater quality degradation in the concentrations used in professionally directed groundwater tracing work. Table 1 illustrates the chemical structures of these dyes and summarizes some of their more important properties. These dyes are among the most detectable of the commonly used fluorescent tracer dyes. They can be adsorbed onto activated carbon samplers for cumulative sampling and can also be detected in water samples.

Table 1. Properties of Tracer Dyes Used in this Study.

Fluorescein Dye • Also known as Acid Yellow 73 • Color Index Constitution Number 45350 • Brilliant fluorescent yellow-green dye • Most commonly used fluorescent tracer dye • Most easily detectable dye • Approximately 75% dye equivalent	
Rhodamine WT Dye • Also known as Acid Red 388 • Color Index Constitution Number not assigned • Reddish orange-colored dye • Less resistant to adsorption onto aquifer materials • Formulated specifically for groundwater tracing • Liquid dye, 20% dye equivalent, 80% diluent	

Dyes were introduced into monitoring wells specifically constructed for the dye introductions. The following summarizes the locations of the dye introduction wells.

- Monitoring Well BWTR-4 was constructed on the eastern portion of the site in an area controlled by the Tronox facility.

- Monitoring Well BWTR-1 was constructed on the western portion of the site near the groundwater extraction system.

A clean water test was performed at each location following well construction to verify acceptance of water at a rate that would facilitate the dye introductions. Both monitoring wells took water at acceptable rates for the dye introductions. Table 2 summarizes the dye introduction locations and the amount and type of dye used for each trace.

Table 2. Dye Introduction Locations.

Trace Name	Monitoring Well	Dye Type & Quantity
Trace 18-01: Eastern Barrier Wall / Tronox Site	BWTR-4	Fluorescein 4 pounds
Trace 18-02: Western Barrier Wall / Extraction System	BWTR-1	Rhodamine WT 16 pounds

Section 3 of this report contains additional details of the individual dye introductions and the results of each trace.

2.2 Sampling for Tracer Dyes

This section describes the types of tracer dye sampling performed during this study. All samples were collected by Ramboll staff and analyzed by staff of the OUL in Protem, Missouri.

2.2.1 Types of Samples

Two kinds of samples were collected during the project: activated carbon samplers and grab water samples. Primary reliance was placed upon the activated carbon samplers for the analysis of tracer dyes. All sample collection procedures followed the protocols found in OUL's Procedures and Criteria document found in Appendix A (Aley and Beeman, 2015).

The activated carbon samplers consisted of screen wire packets filled with 4.25 grams of laboratory-grade activated coconut shell carbon. These samplers adsorb, retain, and accumulate the tracer dyes. When eluted in the laboratory, samples routinely yield dye concentrations one to two orders of magnitude greater than the mean dye concentrations in the water (Aley, 2017). Activated carbon samplers are continuous and accumulating samplers.

Grab samples of water provide dye concentrations at a particular point in time. Water samples are routinely collected at all sampling stations where practical and are archived. The water samples were analyzed if any of the dyes were detected in the associated activated carbon sampler, if an activated carbon sampler was lost or was not collected, if fluorescence peaks in the associated carbon sampler suggest that the water sample should be analyzed, or if the data would be useful for the study. Water samples are also analyzed for locations where access is limited and activated carbon samplers cannot be feasibly used. Water samples were collected into 50-milliliter plastic sample vials.

2.2.2 Sampling Locations

A total of 20 sampling stations were utilized for this investigation. Primary sampling stations consisted of three monitoring wells at each of the two dye introduction wells and two groundwater extraction system control points. Background sampling was also performed at four additional locations to assist with interpretation of the overall fluorescence data set.

Table 3. Sampling Station Summary.

Station Name	Location Type	Types of Samples Collected
BWTR-1	Dye introduction – background only	activated carbon & water
BWTR-2	Monitoring well	activated carbon & water
BWTR-3	Monitoring well	activated carbon & water
BWTR-4	Dye introduction – background only	activated carbon & water
BWTR-5	Monitoring well	activated carbon & water
BWTR-6	Monitoring well	activated carbon & water
MW-140	Monitoring well	activated carbon & water
MW-220	Monitoring well	activated carbon & water
MW-74	Monitoring well	activated carbon & water
East Manifold	Extraction well control point	Water sample only
West Manifold	Extraction well control point	Water sample only
Extraction Well AA	Background only	Water sample only
Extraction Well AB	Background only	Water sample only
Extraction Well B	Background only	Water sample only
Extraction Well C	Background only	Water sample only
Extraction Well L	Background only	Water sample only
Extraction Well R	Background only	Water sample only
Extraction Well S	Background only	Water sample only
Extraction Well Y	Background only	Water sample only
Flush Water	Control station	Water sample only

2.2.3 Sampling Events

Background sampling was performed to verify that the dyes and dye quantities tentatively selected during project planning were the most suitable for the individual sites. Background sampling was performed to detect and quantify the presence of tracer dyes or fluorescent compounds with characteristics similar to tracer dyes at any of the sampling stations. During field events, activated carbon samplers were collected and replaced prior to dye introductions. Background sampling was performed from September 24 through October 16, 2018.

Sampling for tracer dyes was performed following dye introductions. The date of dye introductions was October 17, 2018. At sampling stations identified in the work plan, sampling events were performed on approximately weekly intervals for 16 weeks. Sampling events following dye introductions occurred from October 25, 2018 through February 13, 2019.

2.2.4 Sample Collection Procedures

Activated carbon samplers were placed in designated monitoring wells. One sampler was placed within the lower portion of the saturated screened interval of each monitoring well being sampled. Grab samples of water were collected following the collection of each activated carbon sampler.

When cumulative samplers were collected, new samplers were replaced. Collected samplers were placed in sterile plastic bags. The bags were labeled on the outside with the station name and the date and time of collection. Grab water samples were also collected at the same time as the activated carbon samplers.

Samples collected in the field were maintained under refrigeration until delivery to the laboratory. Upon arrival at OUL, samplers were refrigerated at 4°C until analysis. All sampler placement and collection was performed by Ramboll field staff. All analysis work was conducted by OUL personnel and conformed OUL’s standard protocols included in Appendix A (Aley and Beeman, 2015).

2.3 Laboratory Analysis for Fluorescence

Laboratory analysis for fluorescence was performed at the OUL in Protem, Missouri. This section provides an overview of laboratory analysis for fluorescence.

Standard tracer dyes used in this project include fluorescein and rhodamine WT dyes. Samples of these dyes are collected on activated carbon samplers and in grab water samples. Activated carbon samples were rinsed under a relatively strong jet of water and eluted in a standard eluting solution. Water samples were pH adjusted to raise the pH of the water to 9.5 or higher. Elutant and pH adjusted water samples were analyzed on a Shimadzu RF-5301 spectrofluorophotometer under a synchronous scanning protocol. All dye concentrations were based on the as-sold mixtures of the dyes.

Little or no detectable fluorescence background in or near the range of rhodamine WT is generally encountered in most groundwater tracing studies. It is not uncommon to encounter some fluorescence background in the range of fluorescein dye in groundwater tracing studies in urban areas. Background sampling prior to the introduction of any tracer dyes is routinely performed to characterize this background fluorescence and to identify the existence of any tracer dyes that may be present in the area. The results of the background sampling for this study are described in Section 3.1.

The OUL has established normal emission fluorescence wavelength ranges for each of the dyes used in this project (fluorescein and rhodamine WT). The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 4 provides normal emission wavelength ranges and detection limits for the primary two dyes used in this study when analyzed on the OUL's RF-5301 spectrofluorophotometer. Detailed procedures and criteria used during the tracer study are found in the OUL's Procedures and Criteria document found in Appendix A (Aley and Beeman, 2015).

Table 4. RF-5301 Spectrofluorophotometer: Normal Emission Wavelength Ranges and Detection Limits for Fluorescein and Rhodamine WT Dyes in Water and Elutant samples

Dye and Matrix	Normal Acceptable Emission Wavelength Range (nm)	Detection Limit (ppb)
Fluorescein in Elutant	514.5 to 519.6	0.025
Fluorescein in Water	506.8 to 510.6	0.002
Rhodamine WT in Elutant	564.6 to 571.2	0.170
Rhodamine WT in Water	571.9 to 577.2	0.015

Note: Detection limits are based upon the as-sold weight of the dye mixtures used by the OUL.

The following four criteria are used by the OUL as normal criteria for determining positive dye recoveries in elutant from activated carbon samplers:

Elutant Criterion 1. At least one fluorescence peak must be present at the station in the normal range for the dye for samples analyzed by the RF-5301 (see Table 4).

Elutant Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit.

Elutant Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Elutant Criterion 4. The shape of the fluorescence peak must be typical of the dye for which the analysis is run. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescent tracer dyes. In addition, there must be no other factors that suggest that the fluorescence peak may not be the dye from the groundwater tracing work.

The following three criteria are used by the OUL as normal criteria for determining positive dye recoveries in water samples.

Water Criterion 1. The associated charcoal samplers for the station should contain a positive dye detection in accordance with the elutant criteria listed above. These criteria may be waived if no charcoal sampler exists.

Water Criterion 2. No factors must exist that suggest that the fluorescence peak may not be fluorescent dye from the groundwater tracing work in question. The fluorescence peak should generally be in the typical range listed in Table 4.

Water Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit.

Water Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

3 DYE TRACING RESULTS

This section summarizes findings from dye tracing work performed from October 2018 through mid-February 2019. Results are summarized under the following sub-headings:

1) Background Fluorescence Study;
2) Groundwater Tracing Results;
3) Discussion.

Sampling results are tabulated in Appendix B. Tables include dye analysis results for all sampling stations from groundwater traces conducted as part of this investigation. The results are reported in parts per billion (ppb). Within the tables, the following abbreviations are routinely encountered: "ND" means that no dye was detected, and "nm" is an abbreviation for nanometers.

3.1 Background Fluorescence Study

Background sampling was performed over the period from September 24 through October 16, 2018. Due to the installation of many of the monitoring wells used as sampling points during the background period, background sampling was not performed uniformly during the background period. However, background samples were collected at all sampling stations prior to the introduction of tracer dyes. The background sampling performed was adequate to characterize background conditions for this tracer investigation.

In addition to background samples collected at monitoring wells used as the primary sampling stations following the introduction of tracer dyes, background samples were also collected from the dye introduction wells for further background characterization prior to the dye introductions.

Fluorescence peaks within or near the range of fluorescein dye were detected in water samples collected at the groundwater extraction "West Manifold." This location contains water collected from a number of groundwater extraction wells on the western side of the extraction system. Additional background water samples were collected from the individual extraction wells on October 16, 2018, in order to assist with determining a more precise source area of this background fluorescence. However, the results of water samples collected at these individual extraction wells were all non-detect. The fluorescence background at this location continued throughout the sampling period and was attributed to a tracer study performed upgradient by a separate groundwater characterization and remediation contractor.

To mitigate the low concentrations of fluorescence in the range of fluorescein dye in the area of the western portion of the barrier wall, rhodamine WT dye was used instead of fluorescein in this area. Fluorescein dye was used on the eastern portion of the barrier wall, away from this fluorescence background.

No other fluorescence at or near the range of fluorescein dye was detected in the background period.

No fluorescence at or near the range of rhodamine WT was detected in any of the samples collected during the background period.

A control sample of the flush water was collected for background characterization. No background fluorescence was detected in the flush water control sample.

3.2 Groundwater Tracing Results

Two groundwater traces were conducted during this investigation. The results of these traces are described in this section.

3.2.1 Well BWTR-4 Trace: Eastern Barrier Wall / Tronox Site

Four pounds of fluorescein dye mixture containing approximately 75% dye equivalent and 25% diluent was introduced in Monitoring Well BWTR-4 on October 17, 2018. The powdered dye mixture was mixed into 20 L of water prior to dye introduction. The initial dye concentration was 68,000,000 ppb (6.8% solution). Approximately five well volumes of clean water were slowly introduced into the monitoring well following the dye to flush the dye from the monitoring well following the dye introduction. This flush water provided immediate dilution in the monitoring well and surrounding aquifer.

Primary sampling locations for this trace included monitoring wells BWTR-5, BWTR-6, and M-74. Monitoring well M-220 was also sampled during the background period.

As detailed in Appendix B, fluorescein dye was not detected in any of the samples collected following the dye introduction.

3.2.2 Well BWTR-1 Trace: Western Barrier Wall / Extraction System

Sixteen pounds of liquid rhodamine WT dye mixture containing approximately 20% dye equivalent and 80% diluent was introduced into Monitoring Well BWTR-1 on the afternoon of October 17, 2018. The dye was not diluted prior to introduction, resulting in an initial dye concentration of 200,000,000 ppb (20% solution). Approximately five well volumes of clean water were slowly introduced into the monitoring well following the dye introduction. This flush water provided immediate dilution in the monitoring well and surrounding aquifer.

Primary sampling locations for this trace included monitoring wells BWTR-2, BWTR-3, and M-140. The extraction system east manifold and west manifold were also sampled.

Rhodamine WT was detected not detected in any activated carbon samplers collected at the site following the dye introduction. However, RWT was detected in a single sample collected from the West Manifold on 1/23/19 at 1505 hours. The concentration of RWT in this sample was very low at 0.046 ppb and was footnoted as not meeting all the criteria for a positive dye detection. No dye was detected in the two samples at this location following the sample on 1/23/19. If this were dye breakthrough at this location, more than one detection of this dye typically would be anticipated at this location. As such, this single fluorescence detection does not provide conclusive dye breakthrough at this location.

3.3 Discussion

Due to the very low detection limits of tracer dyes, extreme care was used to prevent possible cross contamination of the tracer dyes during the dye introductions and subsequent sampling events.

- Dye containers were not handled by sampling personnel at any time.
- Adsorbent materials were used to collect all small drips and small splashes of dye during the dye introductions to prevent any extraneous dye from being spilled near the dye introduction wells.
- Samples were not collected by OUL personnel that handled dye containers and introduced the tracer dyes.
- Water level indicators were thoroughly decontaminated prior to use at each well location.
- All grab samples of water collected from monitoring wells were collected from dedicated sample bailers.
- Nitrile gloves were changed frequently by all dye handling and sample collection personnel, with strict glove donning and doffing procedures used to prevent possible contamination of bare hands.

Although background fluorescence was detected at or near the range of fluorescein dye in water samples collected from the West Manifold of the groundwater extraction system, this fluorescence did not interfere with the execution of the tracer investigation or interpretation of the results. Due to the water from numerous wells being piped through the West Manifold location, additional sampling was undertaken to elicit a more precise source of the background fluorescence. Although the results of the additional extraction well sampling did not result in additional detections of this background fluorescence, the background concentrations of fluorescein persisted in the West Manifold sampling location throughout the study period. This background fluorescence was likely attributable to a previous tracer study upgradient of the barrier wall and groundwater extraction system by other groundwater remediation contractors.

The results of this dye tracing investigation indicate no groundwater leakage through the barrier wall at or near the dye introduction locations. Based upon the design of the monitoring wells, flow under the barrier wall could not be discerned in this test.

4 SUMMARY

A dye tracing investigation was conducted at the NERT site in Henderson, Nevada in order to determine the integrity of the existing groundwater barrier wall in two locations of questionable integrity based upon the results of a surface geophysical assessment. Two groundwater dye traces were performed as part of this investigation, as summarized below:

- **Well BWTR-4 Trace: Eastern Barrier Wall / Tronox Site.** Four pounds of fluorescein dye mixture was introduced in Monitoring Well BWTR-4 on October 17, 2018. Primary sampling locations for this trace included monitoring wells BWTR-5, BWTR-6, and M-74. Fluorescein dye attributable to this dye introduction was not detected in any of the samples collected following the dye introduction.

- **Well BWTR-1 Trace: Western Barrier Wall / Extraction System**. Sixteen pounds of rhodamine WT dye mixture was introduced into Monitoring Well BWTR-1 on October 17, 2018. Primary sampling locations for this trace included monitoring wells BWTR-2, BWTR-3, and M-140.

The extraction system East Manifold and West Manifold were sampled in addition to monitoring wells across the barrier wall from each dye introduction location. No dye was detected in samples collected from the East Manifold. At the West Manifold, there was one potential RWT dye detection in one water sample collected on 1/23/19.

Based upon the results of this dye tracing investigation, no groundwater leakage through the barrier wall is occurring at or near the dye introduction locations. Based upon the design of the monitoring wells, flow under the barrier wall could not be discerned in this test.

5 REFERENCES

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APPENDIX A

Ozark Underground Laboratory's
Procedures and Criteria Document

PROCEDURES AND CRITERIA
ANALYSIS OF FLUORESCENT DYES
IN WATER AND CHARCOAL SAMPLERS:

FLUORESCEIN, EOSINE, RHODAMINE WT, AND SULFORHODAMINE B DYES

Revision Date:
March 3, 2015

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INTRODUCTION

This document describes standard procedures and criteria currently in use at the Ozark Underground Laboratory (OUL) as of the date shown on the title page. Some samples may be subjected to different procedures and criteria because of unique conditions; such non-standard procedures and criteria are identified in reports for those samples. Standard procedures and criteria change as knowledge and experience increases and as equipment is improved or up-graded. The OUL maintains a summary of changes in standard procedures and criteria.

TRACER DYES AND SAMPLE TYPES

Dye Nomenclature

Dye manufacturers and retailers use a myriad of names for the dyes. This causes confusion among dye users and report readers. The primary dyes used at the OUL and described in this document are included in Table 1 below.

Table 1. Primary OUL Dye Nomenclature.

OUL Common Name	Color Index Number	Color Index Name	Other Names
Fluorescein	45350	Acid Yellow 73	uranine, uranine C, sodium fluorescein, fluorescein LT and fluorescent yellow/green
Eosine	45380	Acid Red 87	eosin, eosine OJ, and D&C Red 22
Rhodamine WT	None assigned	Acid Red 388	fluorescent red (but not the same as rhodamine B)
Sulforhodamine B	45100	Acid Red 52	pontacyl brilliant pink B, lissamine red 4B, and fluoro brilliant pink

The OUL routinely provides dye for tracing projects. Dyes purchased for groundwater tracing are always mixtures that contain both dye and an associated diluent. Diluents enable the manufacturer to standardize the dye mixture so that there are minimal differences among batches. Additionally, diluents are often designed to make it easier to dissolve the dye mixture in water, or to produce a product which meets a particular market need (groundwater tracing is only a tiny fraction of the dye market). The percent of dye in "as-sold" dye mixtures often varies dramatically among manufacturers and retailers, and retailers are sometimes incorrect about the percent of dye in their products. The OUL subjects all of its dyes to strict quality control (QC) testing. Table 2 summarizes the as-sold dye mixtures used by the OUL.

Table 2. As-Sold Dye Mixtures at the OUL.

OUL Common Name	Form	Dye Equivalent
Fluorescein	Powder	75% dye equivalent, 25% diluent
Eosine	Powder	75% dye equivalent, 25% diluent
Rhodamine WT	Liquid	20% dye equivalent, 80% diluent
Sulforhodamine B	Powder	75% dye equivalent, 25% diluent

Analytical results are based on the as-sold weights of the dyes provided by the OUL. The use of dyes from other sources is discouraged due to the wide variability of dye equivalents within the market. However, if alternate source dyes are used, a sample should be provided to the OUL for quality control and to determine if a correction factor is necessary for the analytical results.

Types of Samples

Typical samples that are collected for fluorescent tracer dye analysis include charcoal samplers (also called activated carbon or charcoal packets) and water samples.

The charcoal samplers are packets of fiberglass screening partially filled with 4.25 grams of activated coconut charcoal. The charcoal used by the OUL is Calgon 207C coconut shell carbon, 6 to 12 mesh, or equivalent. The most commonly used charcoal samplers are about 4 inches long by 2 inches wide. A cigar-shaped sampler is made for use in very small diameter wells (such as 1-inch diameter piezometers); this is a special order item and should be specifically requested in advance when needed. All of the samplers are closed by heat sealing.

In specialized projects, soil samples have been collected from soil cores and analyzed for fluorescent tracer dyes. Project-specific procedures have been developed for projects such as these. For additional information, please contact the OUL.

FIELD PROCEDURES

Field procedures included in this section are intended as guidance, and not firm requirements. Placement of samplers and other field procedures require adjustment to field conditions. Personnel at the OUL are available to provide additional assistance for implementation of field procedures specific to specialized field conditions.

Placement of Samplers

Charcoal samplers are placed so as to be exposed to as much water as possible. Water should flow through the packet. In springs and streams they are typically attached to a rock or other anchor in a riffle area. Attachment of the packets often uses plastic tie wires. In swifter water galvanized wire (such as electric fence wire) is often used. Other types of anchoring wire can be used. Electrical wire with plastic insulation is also good. Packets are attached so that they extend outward from the anchor rather than laying flat against it. Two or more separately anchored packets are typically used for sampling springs and streams. The placement of multiple packets is recommended in order to minimize the chance of loss during the sampling period. The use of fewer packets is discouraged except when the spring or stream is so small that there is not appropriate space for placing multiple packets.

When pumping wells are being sampled, the samplers are typically placed in sample holders made of plastic pipe fittings. Brass hose fittings can be at the end of the sample holders so that the sample holders can be installed on outside hose bibs and water which has run through the samplers can be directed to waste through a connected garden hose. The samplers can be unscrewed in the middle so that charcoal packets can be changed. The middle portions of the samplers consist of 1.5 inch diameter pipe and pipe fitting.

Charcoal packets can be lowered into monitoring wells for sampling purposes. In general, if the well is screened, samplers should be placed approximately in the middle of the screened interval. Due to the typically lower volume of water that flows through a well, only one charcoal sampler should be used per well. However, multiple packets can be placed in a single well at depths to test different depth horizons when desirable. A weight should be added near the charcoal packet to ensure that it will not float. The weight should be of such a nature that it will not affect water quality. One common approach is to anchor the packets with a white or uncolored plastic cable tie to the top of a dedicated weighted disposable bailer. We typically run nylon cord from the top of the well to the charcoal packet and its weight. ***Do not use colored cord*** since some of them are colored with fluorescent dyes. Nylon fishing line should not be used since it can be readily cut by a sharp projection in the well.

In some cases, especially with small diameter wells and appreciable well depths, the weighted disposable bailers sink very slowly or may even fail to sink because of friction and floating of the anchoring cord. In such cases a weight may be added to the top of the disposable bailer. Stainless steel weights are ideal, but are not needed in all cases. All weights should be cleaned prior to use; the cleaning approach should comply with decontamination procedures in use at the project site.

Optional Preparation of Charcoal Samplers

Charcoal packets routinely contain some fine powder that washes off rapidly when they are placed in water. While not usually necessary, the following optional preparation step is suggested if the fine charcoal powder is problematic.

Charcoal packets can be triple rinsed with distilled, demineralized, or reagent water known to be free of tracer dyes. This rinsing is typically done by soaking. With this approach, approximately 25 packets are placed in one gallon of water and soaked for at least 10 minutes. The packets are then removed from the water and excess water is shaken off the packets. The packets are then placed in a second gallon of water and again soaked for at least 10 minutes. After this soaking they are removed from the water and excess water is shaken off the packets. The packets are then placed in a third gallon of water and the procedure is again repeated. Rinsed packets are placed in plastic bags and are placed at sampling stations within three days. Packets can also be rinsed in jets of water for about one minute; this requires more water and is typically difficult to do in the field with water known to be free of tracer dyes.

Collection and Replacement of Samplers

Samplers are routinely collected and replaced at each of the sampling stations. The frequency of sampler collection and replacement is determined by the nature of the study. Collections at one week intervals are common, but shorter or longer collection frequencies are acceptable and sometimes more appropriate. Shorter sampling frequencies are often used in the early phases of a study to better characterize time of travel. As an illustration, we often collect and change charcoal packets 1, 2, 4, and 7 days after dye injection. Subsequent sampling is then weekly.

The sampling interval in wells at hazardous wastes sites should generally be no longer than about a week. Contaminants in the water can sometimes use up sorption sites on the charcoal that would otherwise adsorb the dye. This is especially important if the dye might pass in a relatively short duration pulse.

Where convenient, the collected samplers should be briefly rinsed in the water being sampled to remove dirt and accumulated organic material. This is not necessary with well samples. The packets are shaken to remove excess water. Next, the packet (or packets) are placed in a plastic bag (Whirl-Pak® bags are ideal). The bag is labeled on the outside with a black permanent type felt marker pen, such as a Sharpie®. ***Use only pens that have black ink***; colored inks may contain fluorescent dyes. The notations include station name or number and the date and time of collection. Labels must not be inserted inside the sample bags.

Collected samplers are kept in the dark to minimize algal growth on the charcoal prior to analysis work. New charcoal samplers are routinely placed when used charcoal packets are collected. The last set of samplers placed at a stream or spring is commonly not collected.

Water Samples

Water samples are often collected. They should be collected in either glass or plastic; the OUL routinely uses 50 milliliter (mL) research-grade polypropylene copolymer Perfector Scientific vials (Catalog Number 2650) for such water samples. No more than 30 mL of water is required for analysis. The sides of the vials should be labeled with the project name, sample ID, sample date and time with a black permanent felt tip pen. ***Do not label the lid only***. The vials should be placed in the dark and refrigerated immediately after collection, and maintained under refrigeration until shipment. The OUL supplies vials for the collection of water samples.

Sample Shipment

When water or charcoal samplers are collected for shipment to the OUL they should be shipped promptly. We prefer (and in some studies require) that samples be refrigerated with frozen re-usable ice packs upon collection and that they be shipped refrigerated with frozen ice packs by overnight express. ***Do not ship samplers packed in wet ice*** since this can create a potential for cross contamination when the ice melts. Our experience indicates that it is not essential for samplers to be maintained under refrigeration; yet maintaining them under refrigeration clearly minimizes some potential problems. A product known as "green ice" should not be used for maintaining the samples in a refrigerated condition since this product contains a dye which could contaminate samples if the "green ice" container were to break or leak.

We receive good overnight and second day air service from both UPS and FedEx. The U.S. Postal Service does not typically provide next day service to us. DHL does not provide overnight service to us. FedEx is recommended for international shipments. The OUL does not receive Saturday delivery.

Each shipment of charcoal samplers or water samples ***must be accompanied by a sample custody document***. The OUL provides a sheet (which bears the title "Samples for Fluorescence Analysis") that can be used if desired. These sheets can be augmented by a client's chain-of-custody forms or any other relevant documentation. OUL's custody document works well for charcoal samplers because it allows for both the placement date and time as well as the collection date and time. Many other standard chain-of-custody documents do not allow for these types of samples. Attachment 1 includes a copy of OUL's Sample Collection Data Sheet.

Please write legibly on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Supplies Provided by the OUL

The OUL provides supplies for the collection of fluorescent tracer dyes. Supplies provided upon request are charcoal packets, Whirl-Pak® bags (to contain the charcoal packets after collection for shipment to the laboratory), and water vials. These supplies are subjected to strict QA/QC procedures to ensure the materials are free of any potential tracer dye contaminants. The charge for these materials is included in the cost of sample analysis. Upon request, coolers and re-freezable ice packs are also provided for return shipment of samples.

The OUL also has tracer dyes available for purchase. These dyes are subject to strict QA/QC testing. All analytical work is based upon the OUL as-sold weight of the dyes.

LABORATORY PROCEDURES

The following procedures are followed upon receipt of samples at the laboratory.

Receipt of Samples

Samplers shipped to the OUL are logged in and refrigerated upon receipt. Prior to cleaning and analysis, samplers are assigned a laboratory identification number.

It sometimes occurs that there are discrepancies between the sample collection data sheet and the actual samples received. When this occurs, a "Discrepancy Sheet" form is completed and sent to the shipper of the sample for resolution. The purpose of the form is to help resolve discrepancies, even when they may be minor. Many discrepancies arise from illegible custody documents. ***Please write legibly*** on the custody documents and ***use black ink***. Check the accuracy of the sample sheet against the samples prior to shipment to identify and correct errors that may delay the analysis of your samples following receipt at the laboratory.

Cleaning of Charcoal Samplers

Samplers are cleaned by spraying them with jets of clean water from a laboratory well in a carbonate aquifer. OUL uses non-chlorinated water for the cleansing to minimize dye deterioration. We do not wash samplers in public water supplies. Effective cleansing cannot generally be accomplished simply by washing in a conventional laboratory sink even if the sink is equipped with a spray unit.

The duration of packet washing depends upon the condition of the sampler. Very clean samplers may require less than a minute of washing; dirtier samplers may require several minutes of washing.

Elution of the Charcoal

There are various eluting solutions that can be used for the recovery of tracer dyes. The solutions typically include an alcohol, water, and a strong basic solution such as aqueous ammonia and /or potassium hydroxide.

The standard elution solution used at the OUL is a mixture of 5% aqua ammonia and 95% isopropyl alcohol solution and sufficient potassium hydroxide pellets to saturate the solution. The isopropyl alcohol solution is 70% alcohol and 30% water. The aqua ammonia solution is 29% ammonia. The potassium hydroxide is added until a super-saturated layer is visible in the bottom of the container. This super-saturated layer is not used for elution. Preparation of eluting solutions uses dedicated glassware which is never used in contact with dyes or dye solutions.

The eluting solution will elute fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes. It is also suitable for separating fluorescein peaks from peaks of some naturally present materials found in may be found in samplers.

Fifteen mL of the eluting solution is poured over the washed charcoal in a disposable sample beaker. The sample beaker is capped. The sample is allowed to stand for 60 minutes. After this time, the liquid is carefully poured off the charcoal into a new disposable beaker which has been appropriately labeled with the laboratory identification number. A few grains of charcoal may inadvertently pass into the second beaker; no attempt is made to remove these from the second sample beaker. After the pouring, a small amount of the elutant will remain in the initial sample beaker. After the transfer of the elutant to the second sample beaker, the contents of the first sample beaker (the eluted charcoal) are discarded. Samples are kept refrigerated until analyzed.

pH Adjustment of Water Samples

The fluorescence intensity of several of the commonly used fluorescent tracer dyes is pH dependent. The pH of samples analyzed for fluorescein, eosine, and sulforhodamine B dyes are adjust to a target pH of greater than 9.5 in order to obtain maximum fluorescence intensities.

Adjustment of pH is achieved by placing samples in a high ammonia atmosphere for at least two hours in order to increase the pH of the sample. Reagent water standards are placed in the same atmosphere as the samples. If dye concentrations in a sample are off-scale and require dilution for quantification of the dye concentration, the diluting water used is OUL reagent water that has been pH adjusted in a high ammonia atmosphere. Samples that are only analyzed for rhodamine WT or sulforhodamine B are not required to be pH adjusted.

Analysis on the Shimadzu RF-5301

The OUL uses a Shimadzu spectrofluorophotometer model RF-5301. This instrument is capable of synchronous scanning. The OUL also owns a Shimadzu RF-540 spectrofluorometers that is occasionally used for special purposes.

A sample of the elutant or water is withdrawn from the sample container using a disposable polyethylene pipette. Approximately 3 mL of the sample is then placed in disposable rectangular polystyrene cuvette. The cuvette has a maximum capacity of 3.5 mL. The cuvette is designed for fluorometric analysis; all four sides and the bottom are clear. The acceptable spectral range of these cuvettes is 340 to 800 nm. The pipettes and cuvettes are discarded after one use.

The cuvette is then placed in the RF-5301. This instrument is controlled by a programmable computer and operated by proprietary software developed for dye tracing applications.

Our instruments are operated and maintained in accordance with the manufacturer's recommendations. On-site installation of our first instrument and a training session on its use was provided by the instrument supplier. Repairs are made by a Shimadzu-authorized repairman.

Our typical analysis of an elutant sample where fluorescein, eosine, rhodamine WT, or sulforhodamine B dyes may be present includes synchronous scanning of excitation and emission spectra with a 17 nm separation between excitation and emission wavelengths. For these dyes, the excitation scan is from 443 to 613 nm; the emission scan is from 460 to 630 nm. The emission fluorescence from the scan is plotted on a graph. The typical scan speed setting is “fast” on the RF-5301. The typical sensitivity setting used is "high."

Table 3. Excitation and emission slit width settings routinely used for dye analysis.

Parameter	**Excitation Slit (nm)**	**Emission Slit (nm)**
ES, FL, RWT, and SRB in elutant	3	1.5
ES, FL, RWT, and SRB in water	5	3

Note: ES = Eosine. FL = Fluorescein. RWT = Rhodamine WT. SRB = Sulforhodamine B.

The instrument produces a plot of the synchronous scan for each sample; the plot shows emission fluorescence only. The synchronous scans are subjected to computer peak picks using proprietary software; peaks are picked to the nearest 0.1 nm. Instrument operators have the ability to manually adjust peaks as necessary based upon computer-picked peaks and experience. All samples run on the RF-5301 are stored electronically with sample information. All samples analyzed are recorded in a bound journal.

Quantification

We calculate the magnitude of fluorescence peaks for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in both elutant and water samples. Dye quantities are expressed in microgram per liter (parts per billion; ppb). The dye concentrations are calculated by separating fluorescence peaks due to dyes from background fluorescence on the charts, and then calculating the area within the fluorescence peak. This area is proportional to areas obtained from standard solutions.

We run dye concentration standards each day the RF-5301 is used. Six standards are used; the standard or standards appropriate for the analysis work being conducted are selected. All standards are based upon the as-sold weights of the dyes. The standards are as follows:

1) 10 ppb fluorescein and 100 ppb rhodamine WT in well water from the Jefferson City-Cotter Formation
2) 10 ppb eosine in well water from the Jefferson City-Cotter Formation
3) 100 ppb sulforhodamine B in well water from the Jefferson City-Cotter Formation.
4) 10 ppb fluorescein and 100 ppb rhodamine WT in elutant.
5) 10 ppb eosine in elutant.
6) 100 ppb sulforhodamine B in elutant.

Preparation of Standards

Dye standards are prepared as follows:

Step 1. A small sample of the as-sold dye is placed in a pre-weighed sample vial and the vial is again weighed to determine the weight of the dye. We attempt to use a sample weighing between 1 and 5 grams. This sample is then diluted with well water to make a 1% dye solution by weight (based upon the as-sold weight of the dye). The resulting dye solution is allowed to sit for at least four hours to ensure that all dye is fully dissolved.

Step 2. One part of each dye solution from Step 1 is placed in a mixing container with 99 parts of well water. Separate mixtures are made for fluorescein, rhodamine WT, eosine, and sulforhodamine B. The resulting solutions contain 100 mg/L dye (100 parts per million dye mixture). The typical prepared volume of this mixture is appropriate for the sample bottles being used; we commonly prepare about 50 mL of the Step 2 solutions. The dye solution from Step 1 that is used in making the Step 2 solution is withdrawn with a digital Finnpipette which is capable of measuring volumes between 0.200 and 1.000 mL at intervals of 0.005 mL. The calibration certificate with this instrument indicates that the accuracy (in percent) is as follows:

At 0.200 mL, 0.90%

At 0.300 mL, 0.28%

At 1.000 mL, 0.30%

The Step 2 solution is called the long term standard. OUL experience indicates that Step 2 solutions, if kept refrigerated, will not deteriorate appreciably over periods of less than a year. Furthermore, these Step 2 solutions may last substantially longer than one year.

Step 3. A series of intermediate-term dye solutions are made. Approximately 45 mL. of each intermediate-term dye solution is made. All volume measurements of less than 5 mL are made with a digital Finnpipette. (see description in Step 2). All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value. The following solutions are made; all concentrations are based on the as-sold weight of the dyes:

1) 1 ppm fluorescein dye and 10 ppm rhodamine WT dye.
2) 1 ppm eosine.
3) 10 ppm sulforhodamine B dye.

Step 4. A series of six short-term dye standards are made from solutions in Step 3. These standards were identified earlier in this section. In the experience of the OUL these standards have a useful shelf life in excess of one week. However, in practice, Step 4 elutant standards are made weekly, and Step 4 water standards are made daily.

Dilution of Samples

Samples with peaks that have arbitrary fluorescence unit values of 500 or more are diluted a hundred fold to ensure accurate quantification.

Some water samples have high turbidity or color which interferes with accurate detection and measurement of dye concentrations. It is often possible to dilute these samples and then measure the dye concentration in the diluted sample.

The typical dilutions are either 10 fold (1:10) or 100 fold (1:100). A 1:10 dilution involves combining one part of the test sample with 9 parts of water (if the sample is water) or elutant (if the sample is elutant). A 1:100 dilution involves combining one part of the test sample is combined with 99 parts of water or elutant, based upon the sample media. Typically, 0.300 mL of the test solution is combined with 29.700 mL of water (or elutant as appropriate) to yield a new test solution.

All volume measurements of less than 5 mL are made with a digital Finnpipette. All other volume measurements are made with Rheinland Kohn Geprufte Sicherheit 50 mL capacity pump dispenser which will pump within plus or minus 1% of the set value.

The water used for dilution is from a carbonate aquifer. All dilution water is pH adjusted to greater than pH 9.5 by holding it in open containers in a high ammonia concentration chamber. This adjustment takes a minimum of two hours.

Quality Control

Laboratory blanks are run for every sample where the last two digits of the laboratory numbers are 00, 20, 40, 60, or 80. A charcoal packet is placed in a pumping well sampler and at least 25 gallons of unchlorinated water is passed through the sampler at a rate of about 2.5 gallons per minute. The sampler is then subjected to the same analytical protocol as all other samplers.

System functioning tests of the analytical instruments are conducted in accordance with the manufacturer's recommendations. Spiked samples are also analyzed when appropriate for quality control purposes.

All materials used in sampling and analysis work are routinely analyzed for the presence of any compounds that might create fluorescence peaks in or near the acceptable wavelength ranges for any of the tracer dyes. This testing includes approximately 1% of materials used.

Project specific QA/QC samples may include sample replicates and sample duplicates. A replicate sample is when a single sample is analyzed twice. A sample duplicate is where two samples are collected in a single location and both are analyzed. Sampe replicates and duplicates are run for QA/QC purposes upon request of the client. These results are reported in the Certificate of Analysis.

Reports

Sample analysis results are typically reported in a Certificate of Analysis. However, specialized reports are provided in accordance with the needs of the client. Certificates of Analysis typically provide a listing of station number, sample ID, and dye concentrations if detected. Standard data format includes deliverables in MS Excel and Adobe Acrobat (.pdf) format. Hard copy of the data package, and copies of the analytical charts are available upon request.

Work at the OUL is directed by Mr. Thomas Aley. Mr. Aley has 45 years of professional experience in hydrology and hydrogeology. He is certified as a Professional Hydrogeologist (Certificate #179) by the American Institute of Hydrology and licensed as a Professional Geologist in Arkansas, Arkansas, Kentucky, and Alabama. Additional details regarding laboratory qualifications are available upon request.

Waste Disposal

All laboratory wastes are disposed of according to applicable state and federal regulations. Waste elutant and water samples are collected in 15 gallon poly drums and disposed with a certified waste disposal facilityas non-hazardous waste.

In special cases, wastes for a particular project may be segregated and returned to the client upon completion of the project. These projects may have samples that contain contaminants that the client must account for all materials generated and disposed. These situations are managed on a case-by-case basis.

CRITERIA FOR DETERMINATION OF POSITIVE DYE RECOVERIES

Normal Emission Ranges and Detection Limits

The OUL has established normal emission fluorescence wavelength ranges for each of the four dyes described in this document. The normal acceptable range equals mean values plus and minus two standard deviations. These values are derived from actual groundwater tracing studies conducted by the OUL.

The detection limits are based upon concentrations of dye necessary to produce emission fluorescence peaks where the signal to noise ratio is 3. The detection limits are realistic for most field studies since they are based upon results from actual field samples rather than being based upon values from spiked samples in a matrix of reagent water or the elutants from unused activated carbon samplers. In some cases detection limits may be smaller than reported if the water being sampled has very little fluorescent material in it. In some cases detection limits may be greater than reported; this most commonly occurs if the sample is turbid due to suspended material or a coloring agent such as tannic compounds. Turbid samples are typically allowed to settle, centrifuged, or, if these steps are not effective, diluted prior to analysis.

Table 4 provides normal emission wavelength ranges and detection limits for the four dyes when analyzed on the OUL's RF-5301.

Table 4. RF-5301 Spectrofluorophotometer. Normal emission wavelength ranges and detection limits for fluorescein, eosine, rhodamine WT, and sulforhodamine B dyes in water and elutant samples.

Fluorescent Dye	**Normal Acceptable Emission Wavelength Range (nm)**		**Detection Limit (ppb)**	
	Elutant	**Water**	**Elutant**	**Water**
Eosine	539.3 to 545.1	532.5 to 537.0	0.050	0.015
Fluorescein	514.1 to 519.2	505.9 to 509.7	0.025	0.002
Rhodamine WT	564.6 to 571.2	571.9 to 577.2	0.170	0.015
Sulforhodamine B	575.2 to 582.0	580.1 to 583.7	0.080	0.008

Note: Detection limits are based upon the as-sold weight of the dye mixtures normally used by the OUL.
Fluorescein and eosine detection limits in water are based on samples pH adjusted to greater than 9.5.

It is important to note that the normal acceptable emission wavelength ranges are subject to change based on instrument maintenance, a change in instrumentation, or slight changes in dye formulation. Significant changes in normal acceptable emission wavelength ranges will be updated in this document as they occur.

Fluorescence Background

Due to the nature of fluorescence analysis, it is important to identify and characterize any potential background fluorescence at dye introduction and monitoring locations prior to the introduction of any tracer dyes.

There is generally little or no detectable fluorescence background in or near the general range of eosine, rhodamine WT, and sulforhodamine B dyes encountered in most groundwater tracing studies. There is often some fluorescence background in or near the range of fluorescein dye present at some of the stations used in groundwater tracing studies.

Criteria for Determining Dye Recoveries

The following sections identify normal criteria used by the OUL for determining dye recoveries. The primary instrument in use is a Shimadzu RF-5301.

EOSINE

Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 539.3 to 545.1 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The eosine detection limit in elutant samples is 0.050 ppb, thus this dye concentration limit equals 0.150 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of eosine. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of eosine. In addition, there must be no other factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining Eosine Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain eosine dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be eosine dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 532.5 to 537.0 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our eosine detection limit in water samples is 0.015 ppb, thus this dye concentration limit equals 0.045 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

FLUORESCEIN

Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the range of 514.1 to 519.2 nm in the sample.

Criterion 2. The dye concentration associated with the fluorescence peak must be at least 3 times the detection limit. The fluorescein detection limit in elutant samples is 0.025 ppb, thus this dye concentration limit equals 0.075 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of fluorescein. Much background fluorescence yields low, broad, and asymmetrical fluorescence peaks rather than the more narrow and symmetrical fluorescence peaks typical of fluorescein. In addition, there must be no other factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work.

Normal Criteria Used by the OUL for Determining Fluorescein Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain fluorescein dye in accordance with the criteria listed above. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be fluorescein dye from our groundwater tracing work. The fluorescence peak should generally be in the range of 505.9 to 509.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our fluorescein detection limit in water samples is 0.002 ppb, thus this dye concentration limit equals 0.006 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

RHODAMINE WT

Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 564.6 to 571.2 nm.

Criterion 2. The dye concentration associated with the rhodamine WT peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.170 ppb, thus this dye concentration limit equals 0.510 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of rhodamine WT. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining Rhodamine WT Dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain rhodamine WT dye in accordance with the criteria listed above. These criteria may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be rhodamine WT dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 571.9 to 577.2 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. Our rhodamine WT detection limit in water samples is 0.015 ppb, thus this dye concentration limit is 0.045 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

SULFORHODAMINE B

Normal Criteria Used by the OUL for Determining Sulforhodamine B Dye Recoveries in Elutants from Charcoal Samplers

Criterion 1. There must be at least one fluorescence peak in the sample in the range of 575.2 to 582.0 nm.

Criterion 2. The dye concentration associated with the sulforhodamine B peak must be at least 3 times the detection limit. The detection limit in elutant samples is 0.080 ppb, thus this dye concentration limit equals 0.240 ppb.

Criterion 3. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Criterion 4. The shape of the fluorescence peak must be typical of sulforhodamine B. In addition, there must be no other factors which suggest that the fluorescence peak may not be dye from the groundwater tracing work under investigation.

Normal Criteria Used by the OUL for Determining Sulforhodamine B dye Recoveries in Water Samples

Criterion 1. In most cases, the associated charcoal samplers for the station should also contain sulforhodamine B dye in accordance with the criteria listed earlier. This criterion may be waived if no charcoal sampler exists.

Criterion 2. There must be no factors which suggest that the fluorescence peak may not be sulforhodamine B dye from the tracing work under investigation. The fluorescence peak should generally be in the range of 580.1 to 583.7 nm.

Criterion 3. The dye concentration associated with the fluorescence peak must be at least three times the detection limit. The detection limit in water is 0.008 ppb, thus this dye concentration limit equals 0.024 ppb.

Criterion 4. The dye concentration must be at least 10 times greater than any other concentration reflective of background at the sampling station in question.

Standard Footnotes

Sometimes not all the criteria are met for a straight forward determination of tracer dye in a sample. For these reasons, the emission graph is scrutinized carefully by the analytical technician and again during the QA/QC process. Sometimes the emission graphs require interpretation as to whether or not a fluorescence peak represents the tracer dye or not. Background samples from each of the sampling stations aid in the interpretation of the emission fluorescence graphs. When the results do not meet all the criteria for a positive dye detection, often the fluorescence peak is quantified and flagged with a footnote to the result as not meeting all the criteria for a positive dye detection. Standard footnotes are as follows:

Single asterisk (*): A fluorescence peak is present that does not meet all the criteria for a positive dye recovery. However, it has been calculated as though it were the tracer dye.

Double asterisk (**): A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye recovery.

Other footnotes specific to the fluorescence signature are sometimes also used. These footnotes are often developed for a specific project.

The quantification of fluorescence peaks that do not meet all the criteria for a positive dye detection can be important for interpretation of the dataset as a whole.

ATTACHMENT 1
Sample Collection Data Sheet

OZARK UNDERGROUND LABORATORY, INC.

1572 Aley Lane Protem, MO 65733 (417) 785-4289 fax (417) 785-4290 email: contact@ozarkundergroundlab.com

SAMPLE COLLECTION DATA SHEET for FLUORESCENCE ANALYSIS

Project ______________________ **Week No:** ___ **Samples Collected By:** ______________________

Samples Shipped By: ______________________ **Samples Received By:** ______________________

Date Samples Shipped: __________ **Date Samples Received:** __________ **Time Samples Received:** __________ **Return Cooler? Yes** ☐ **No** ☐

Bill to: ______________________ **Send Results to:** ______________________

Analyze for: ☐ **Fluorescein** ☐ **Eosine** ☐ **Rhodamine WT** ☐ **Other** __________ **Ship cooler to:** ______________________

OUL use only		***Please indicate stations where dye was visible in the field*** *for field technician use - use black ink only*						*OUL use only*
# CHAR REC'D	**LAB NUMBER**	**STATION NUMBER 1-4 Numbers**	**STATION NAME**	**PLACED DATE**	**PLACED TIME**	**COLLECTED DATE**	**COLLECTED TIME**	**# WATER REC'D**

COMMENTS ____

This sheet filled out by OUL staff? Yes ☐ **No** ☐ **Charts for samples on this page proofed by OUL:** ______________________

OUL Project No. _______ **Date Analyzed:** ______________ **Analyzed By:** ______________________

Page ___ of ____

APPENDIX B

Dye Tracing Analytical Results Tables

Table B-1. Results for charcoal samplers analyzed for the presence of fluorescein and rhodamine WT (RWT) dyes.

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

OUL Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		RWT	
				Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
D2619	**BWTR-1**	**NDT**	**10/16/18 1525**	**ND**		**ND**	
D2621	**BWTR-2**	**NDT**	**10/16/18 1517**	**ND**		**ND**	
D2817	BWTR-2	10/16/18 1517	10/25/18 1027	ND		ND	
D2939	BWTR-2	10/25/18 1027	10/31/18 0800	ND		ND	
D3043	BWTR-2	10/31/18 0800	11/7/18 1308	ND		ND	
D3230	BWTR-2	11/7/18 1308	11/14/18 1410	ND		ND	
D3286	BWTR-2	11/14/18 1410	11/20/18 1120	ND		ND	
D3604	BWTR-2	11/20/18 1120	11/28/18 0855	ND		ND	
D3673	BWTR-2	11/28/18 0855	12/5/18 1257	ND		ND	
D3883	BWTR-2	12/5/18 1259	12/13/18 0907	ND		ND	
D4094	BWTR-2	12/13/18 0907	12/20/18 0841	ND		ND	
D4163	BWTR-2	12/20/18 0841	1/2/19 1416	ND		ND	
D4317	BWTR-2	1/2/19 1416	1/9/19 1249	ND		ND	
D4419	BWTR-2	1/9/19 1249	1/16/19 1540	ND		ND	
D4571	BWTR-2	1/16/19 1540	1/23/19 1410	ND		ND	
D4641	BWTR-2	1/23/19 1410	1/30/19 1454	ND		ND	
D4787	BWTR-2	1/30/19 1454	2/8/19 0845	ND		ND	
D4808	BWTR-2	2/8/19 0845	2/13/19 1400	ND		ND	
D2622	**BWTR-3**	**NDT**	**10/16/18 1509**	**ND**		**ND**	
D2818	BWTR-3	10/16/18 1509	10/25/18 1043	ND		ND	
D2941	BWTR-3	10/25/18 1043	10/31/18 0810	ND		ND	
D3044	BWTR-3	10/31/18 0810	11/7/18 1320	ND		ND	
D3231	BWTR-3	11/7/18 1320	11/14/18 1414	ND		ND	
D3287	BWTR-3	11/14/18 1414	11/20/18 1124	ND		ND	
D3605	BWTR-3	11/20/18 1124	11/28/18 0915	ND		ND	
D3674	BWTR-3	11/28/18 0915	12/5/18 1252	ND		ND	
D3884	BWTR-3	12/5/18 1253	12/13/18 0902	ND		ND	
D4095	BWTR-3	12/13/18 0902	12/20/18 0846	ND		ND	
D4164	BWTR-3	12/20/18 0846	1/2/19 1422	ND		ND	
D4318	BWTR-3	1/2/19 1422	1/9/19 1253	ND		ND	
D4421	BWTR-3	1/9/19 1253	1/16/19 1551	ND		ND	
D4572	BWTR-3	1/16/19 1551	1/23/19 1420	ND		ND	
D4642	BWTR-3	1/23/19 1420	1/30/19 1505	ND		ND	
D4788	BWTR-3	1/30/19 1505	2/8/19 0855	ND		ND	
D4809	BWTR-3	2/8/19 0855	2/13/19 1408	ND		ND	
D2623	**BWTR-4**	**NDT**	**10/16/18 1405**	**ND**		**ND**	
D2624	**BWTR-5**	**NDT**	**10/16/18 1344**	**ND**		**ND**	
D2819	BWTR-5	10/16/18 1344	10/25/18 0834	ND		ND	

OUL Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		RWT	
				Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
D2942	BWTR-5	10/25/18 0834	10/31/18 0850	ND		ND	
D3045	BWTR-5	10/31/18 0850	11/7/18 1448	ND		ND	
D3232	BWTR-5	11/7/18 1448	11/14/18 1515	ND		ND	
D3288	BWTR-5	11/14/18 1515	11/20/18 1230	ND		ND	
D3606	BWTR-5	11/20/18 1230	11/28/18 1015	ND		ND	
D3675	BWTR-5	11/28/18 1015	12/5/18 1334	ND		ND	
D3885	BWTR-5	12/5/18 1336	12/13/18 1200	ND		ND	
D4096	BWTR-5	12/13/18 1200	12/20/18 1022	ND		ND	
D4165	BWTR-5	12/20/18 1022	1/2/19 1510	ND		ND	
D4319	BWTR-5	1/2/19 1510	1/9/19 1330	ND		ND	
D4422	BWTR-5	1/9/19 1330	1/16/19 1410	ND		ND	
D4573	BWTR-5	1/16/19 1410	1/23/19 1305	ND		ND	
D4643	BWTR-5	1/23/19 1305	1/31/19 1355	ND		ND	
D4789	BWTR-5	1/31/19 1355	2/8/19 0930	ND		ND	
D4810	BWTR-5	2/8/19 0930	2/13/19 1450	ND		ND	
D2625	**BWTR-6**	**NDT**	**10/16/18 1345**	**ND**		**ND**	
D2821	BWTR-6	10/16/18 1345	10/25/18 0856	ND		ND	
D2943	BWTR-6	10/25/18 0856	10/31/18 0900	ND		ND	
D3046	BWTR-6	10/31/18 0900	11/7/18 1453	ND		ND	
D3233	BWTR-6	11/7/18 1453	11/14/18 1523	ND		ND	
D3289	BWTR-6	11/14/18 1523	11/20/18 1237	ND		ND	
D3607	BWTR-6	11/20/18 1237	11/28/18 1025	ND		ND	
D3676	BWTR-6	11/28/18 1025	12/5/18 1330	ND		ND	
D3886	BWTR-6	12/5/18 1332	12/13/18 1154	ND		ND	
D4097	BWTR-6	12/13/18 1154	12/20/18 1031	ND		ND	
D4166	BWTR-6	12/20/18 1031	1/2/19 1514	ND		ND	
D4321	BWTR-6	1/2/19 1514	1/9/19 1334	ND		ND	
D4423	BWTR-6	1/9/19 1334	1/16/19 1416	ND		ND	
D4574	BWTR-6	1/16/19 1416	1/23/19 1245	ND		ND	
D4644	BWTR-6	1/23/19 1245	1/31/19 1400	ND		ND	
D4790	BWTR-6	1/31/19 1400	2/8/19 0940	ND		ND	
D4811	BWTR-6	2/8/19 0940	2/13/19 1502	ND		ND	
D2297	**M-140-181001**	**9/24/18 1436**	**10/1/18 1320**	**ND**		**ND**	
D2415	M-140	10/1/18 1320	10/8/18 1510	ND		ND	
D2627	M-140	NDT	10/16/18 1531	ND		ND	
D2822	M-140	10/16/18 1531	10/25/18 1110	ND		ND	
D2944	M-140	10/25/18 1110	10/31/18 0815	ND		ND	
D3047	M-140	10/31/18 0815	11/7/18 1333	ND		ND	
D3234	M-140	11/7/18 1333	11/14/18 1432	ND		ND	
D3290	M-140	11/14/18 1432	11/20/18 1138	ND		ND	

OUL Number	Station Name	Date/Time Placed	Date/Time Collected	Fluorescein		RWT	
				Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
D3608	M-140	11/20/18 1138	11/28/18 0930	ND		ND	
D3677	M-140	11/28/18 0930	12/5/18 1246	ND		ND	
D3887	M-140	12/5/18 1247	12/13/18 0857	ND		ND	
D4098	M-140	12/13/18 0857	12/20/18 0858	ND		ND	
D4167	M-140	12/20/18 0858	1/2/19 1430	ND		ND	
D4322	M-140	1/2/19 1430	1/9/19 1307	ND		ND	
D4424	M-140	1/9/19 1307	1/16/19 1532	ND		ND	
D4575	M-140	1/16/19 1532	1/23/19 1430	ND		ND	
D4645	M-140	1/23/19 1430	1/30/19 1517	ND		ND	
D4791	M-140	1/30/19 1517	2/8/19 0905	ND		ND	
D4812	M-140	2/8/19 0905	2/13/19 1418	ND		ND	
D2416	**M-220**	**10/1/18 1540**	**10/8/18 1345**	**ND**		**ND**	
D2626	M-220	NDT	10/16/18 1330	ND		ND	
D2298	**M-74-181001**	**9/24/18 1545**	**10/1/18 1540**	**ND**		**ND**	
D2823	M-74	10/17/18 1330	10/25/18 0922	ND		ND	
D2945	M-74	10/25/18 0922	10/31/18 0905	ND		ND	
D3048	M-74	10/31/18 0905	11/7/18 1436	ND		ND	
D3235	M-74	11/7/18 1436	11/14/18 1505	ND		ND	
D3291	M-74	11/14/18 1505	11/20/18 1217	ND		ND	
D3609	M-74	11/20/18 1217	11/28/18 1040	ND		ND	
D3678	M-74	11/28/18 1040	12/5/18 1325	ND		ND	
D3888	M-74	12/5/18 1327	12/13/18 1147	ND		ND	
D4099	M-74	12/13/18 1147	12/20/18 1052	ND		ND	
D4168	M-74	12/20/18 1052	1/2/19 1536	ND		ND	
D4323	M-74	1/2/19 1536	1/9/19 1342	ND		ND	
D4425	M-74	1/9/19 1342	1/16/19 1435	ND		ND	
D4576	M-74	1/16/19 1435	1/23/19 1325	ND		ND	
D4646	M-74	1/23/19 1325	1/31/19 1410	ND		ND	
D4792	M-74	1/31/19 1410	2/8/19 0955	ND		ND	
D4813	M-74	2/8/19 0955	2/13/19 1514	ND		ND	

Footnotes:

ND = No dye detected

NDT = No sample date or time provided

Table B-2. Results for water samples analyzed for the presence of fluorescein and rhodamine WT (RWT) dyes.

Peak wavelengths are reported in nanometers (nm); dye concentrations are reported in parts per billion (ppb).

OUL	Station Name	Date/Time	Fluorescein		RWT	
Number		Collected	Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
D2452	**BWTR-1**	**10/11/18 1045**	**ND**		**ND**	
D2453	**BWTR-4**	**10/11/18 1415**	**ND**		**ND**	
D2658	**Extraction Well AA**	**10/16/18 1507**	**ND**		**ND**	
D2657	**Extraction Well AB**	**10/16/18 1505**	**ND**		**ND**	
D2656	**Extraction Well B**	**10/16/18 1500**	**ND**		**ND**	
D2651	**Extraction Well C**	**10/16/18 1450**	**ND**		**ND**	
D2653	**Extraction Well L**	**10/16/18 1454**	**ND**		**ND**	
D2655	**Extraction Well R**	**10/16/18 1458**	**ND**		**ND**	
D2652	**Extraction Well S**	**10/16/18 1452**	**ND**		**ND**	
D2654	**Extraction Well Y**	**10/16/18 1500**	**ND**		**ND**	
D2659	**Flush Water**	**10/17/18 1120**	**ND**		**ND**	
D2649	**M-74**	**10/17/18 1330**	**ND**		**ND**	
D2454	**East Manifold for GW extraction system**	**10/11/18 1115**	**ND**		**ND**	
D2650	East Manifold	10/16/18 1445	ND		ND	
D2894	East Manifold	10/25/18 1003	ND		ND	
D2995	East Manifold	10/31/18 0750	ND		ND	
D3074	East Manifold	11/7/18 1255	ND		ND	
D3275	East Manifold	11/14/18 1357	ND		ND	
D3317	East Manifold	11/20/18 1110	ND		ND	
D3686	East Manifold	11/28/18 0840	ND		ND	
D3735	East Manifold	12/5/18 1240	ND		ND	
D3986	East Manifold	12/13/18 0849	ND		ND	
D4135	East Manifold	12/20/18 0832	ND		ND	
D4184	East Manifold	1/2/19 1405	ND		ND	
D4409	East Manifold	1/9/19 1244	ND		ND	
D4442	East Manifold	1/16/19 1525	ND		ND	
D4577	East Manifold	1/23/19 1455	ND		ND	
D4663	East Manifold	1/30/19 1443	ND		ND	
D4793	East Manifold	2/8/19 0830	ND		ND	
D4830	East Manifold	2/13/19 1345	ND		ND	
D2455	**West Manifold for GW extraction system**	**10/11/18 1115**	**507.7**	**0.140**	**ND**	
D2767	West Manifold	10/16/18 1448	507.1	0.123	ND	
D2895	West Manifold	10/25/18 1008	508.4	0.144	ND	
D2996	West Manifold	10/31/18 0755	508.2	0.168	ND	
D3075	West Manifold	11/7/18 1256	508.2	0.131	ND	
D3276	West Manifold	11/14/18 1400	508.0	0.153	ND	
D3318	West Manifold	11/20/18 1112	507.5	0.174	ND	
D3687	West Manifold	11/28/18 0845	507.0	0.180	ND	
D3736	West Manifold	12/5/18 1241	507.3	0.197	ND	
D3987	West Manifold	12/13/18 0850	507.2	0.193	ND	
D4136	West Manifold	12/20/18 0835	507.2	0.244	ND	
D4185	West Manifold	1/2/19 1407	507.8	0.200	ND	

OUL Number	Station Name	Date/Time Collected	Fluorescein		RWT	
			Peak (nm)	Conc. (ppb)	Peak (nm)	Conc. (ppb)
D4410	West Manifold	1/9/19 1246	507.6	0.181	ND	
D4443	West Manifold	1/16/19 1528	507.4	0.221	ND	
D4578	West Manifold	1/23/19 1505	507.6	0.231	574.0 **	0.046
D4664	West Manifold	1/30/19 1445	508.1	0.193	ND	
D4794	West Manifold	2/8/19 0832	508.4	0.309	ND	
D4831	West Manifold	2/13/19 1349	508.0	0.245	ND	

Footnotes:

ND = No dye detected

NDT = No sample date or time provided

** = A fluorescence peak is present that does not meet all the criteria for this dye. However, it has been calculated as a positive dye result.

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ……………………..… **HUE EOSINE EX CONC**
PRODUCT NUMBER ……………….… 1-C6-087-XPC
COLOR INDEX NAME ………………… ACID RED 087
COLOR INDEX NO ……………………. 45380
C. A. S. # ………………………………. 17372-87-1
CHEMICAL FAMILY……………………. XANTHENE DYE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US):	NO SYMBOL
SIGNAL WORD	WARNING
HAZARD STATEMENT(S)	H333 - MAY BE HARMFUL IF INHALED H320 - CAUSES EYE IRRITATION H316 - CAUSES MILD SKIN IRRITATION
PRECAUTIONARY STATEMENTS	P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR

SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS: GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL
P501 - DISPOSE OF CONTENTS/ CONTAINER IN ACCORDANCE WITH LOCAL/ REGIONAL/ NATIONAL INTERNATIONAL REGULATIONS.

OTHER HAZARDS NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID RED 087	17372-87-1	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION: REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

SKIN: WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.

EYES: FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.

INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL. IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	POWDER, NO ODOR
pH	7.0 - 8.5
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NOT APPLICABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA

SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA
AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL GREATER THAN 2000 MG/KG - RAT
DERMAL (ANIMAL) NO DATA AVAILABLE
EFFECTS TO EYES (ANIMAL) NO DATA AVAILABLE
SKIN IRRITATION (ANIMAL) NO DATA AVAILABLE

SKIN CORROSION/IRRITATION NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION CAUSES SERIOUS EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED
GERM CELL MUTAGENICITY NOT CLASSIFIED
CARCINOGENICITY NOT CLASSIFIED
REPRODUCTIVE TOXICITY NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD NOT CLASSIFIED
INHALATION MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT CAUSES SERIOUS EYE IRRITATION.
INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY NA
PERSISTENCE AND DEGRADABILITY NA
BIOACCUMULATIVE POTENTIAL NA
MOBILITY IN SOIL NA
OTHER ADVERSE EFFECTS NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL.
PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING.
OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER NONE
UN PROPER SHIPPING NAME NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT) NA
DOT SPECIAL PROVISIONS NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT NONE
TRANSPORT BY SEA NONE
AIR TRANSPORT NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THIS SUBSTANCE IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

17372-87-1	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	CONTAINS: <11PPM BENZENE, (CAS#71-43-2) <11PPM TOLUENE, (CAS#108-88-3) <11PPM XYLENES, (CAS#1330-20-7)

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ……………………..... **HUE URANINE CONC** (Also known as Fluorescein)
PRODUCT NUMBER ………………… 1-C8-073PC
COLOR INDEX NAME ……………….. ACID YELLOW 073
COLOR INDEX NO ……..…………….. 45350
C. A. S. # …………………………..…. 518-47-8
CHEMICAL FAMILY……………………. XANTHENE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US): NO SYMBOL

SIGNAL WORD WARNING

HAZARD STATEMENT(S)
H333 - MAY BE HARMFUL IF INHALED
H320 - CAUSES EYE IRRITATION
H316 - CAUSES MILD SKIN IRRITATION

PRECAUTIONARY STATEMENTS
P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS:
GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL

OTHER HAZARDS NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION: REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

SKIN: WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.

EYES: FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.

INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL.
IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL GREATER THAN 7,000 MG/KG - RAT
DERMAL (ANIMAL) NA
EFFECTS TO EYES (ANIMAL) EYES - RABBIT, NOT IRRITATING
SKIN IRRITATION (ANIMAL) SKIN - RABBIT, SLIGHT IRRITANT

SKIN CORROSION/IRRITATION NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION CAUSES EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED
GERM CELL MUTAGENICITY NOT CLASSIFIED
CARCINOGENICITY NOT CLASSIFIED
REPRODUCTIVE TOXICITY NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD NOT CLASSIFIED
INHALATION MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT CAUSES SERIOUS EYE IRRITATION.
INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY NA
PERSISTENCE AND DEGRADABILITY NA
BIOACCUMULATIVE POTENTIAL NA
MOBILITY IN SOIL LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL CATFISH - 2,267,000 UG/LITER RAINBOW TROUT - 1,372,000 UG/LITER BLUEGILL - 3,433,000 UG/LITER
OTHER ADVERSE EFFECTS NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL. PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING. OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER NONE
UN PROPER SHIPPING NAME NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT) NA
DOT SPECIAL PROVISIONS NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT NONE
TRANSPORT BY SEA NONE
AIR TRANSPORT NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

518-47-8	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

ALL INFORMATION AND DATA APPEARING ON THIS SDS ARE BELIEVED TO BE RELIABLE AND ACCURATE. HOWEVER, IT IS THE USER' S RESPONSIBILITY TO DETERMINE THE SAFETY, TOXICITY, AND SUITABILITY FOR USE OF THE PRODUCT DESCRIBED. SINCE THE ACTUAL USE BY OTHERS IS BEYOND OUR CONTROL, NO GUARANTEE, EXPRESSED OR IMPLIED, IS MADE BY HUE CORPORATION.
USER ASSUMES ALL RISK AND RESPONSIBILITY.

Safety Data Sheet

INTRACID RHODAMINE WT LIQUID

Safety Data Sheet dated: 5/13/2015 - version 1

Date of first edition: 5/13/2015

1. IDENTIFICATION

Product identifier

Mixture identification:

Trade name: INTRACID RHODAMINE WT LIQUID

Other means of identification:

Trade code: A45171566

Recommended use of the chemical and restrictions on use

Recommended use: Industrial color additive

Restrictions on use: Not Determined

Name, address, and telephone number of the chemical manufacturer, importer, or other responsible party

Sensient Colors LLC

2515 N. Jefferson

63106 St. Louis, MO (USA)

Phone: 1 800-325-8110

Emergency Number(CHEMTREC): 1-800-424-9300

2. HAZARD(S) IDENTIFICATION

The identity of the individual components of this product is proprietary information and is considered a trade secret pursuant to 29 CFR 1910.1200

Hazardous components as defined in the OSHA Hazard Communication Standard: components with a HEALTH hazard (carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, etc..) and/or a PHYSICAL hazard (a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive, etc.)

Classification of the chemical

Skin Irrit. 2	Causes skin irritation.
Eye Irrit. 2B	Causes eye irritation

Label elements

Symbols:

Warning

Code	Description
H315	Causes skin irritation.
H320	Causes eye irritation

Code	Description
P264	Wash ... Thoroughly after handling.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352	IF ON SKIN: Wash with plenty of water/...
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P321	Specific treatment (see ... On this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.

P362+P364 Take off contaminated clothing and wash it before reuse.

Ingredient(s) with unknown acute toxicity:

None

Hazards not otherwise classified identified during the classification process:

None

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances

Not Determined

Mixtures

Hazardous components within the meaning of 29 CFR 1910.1200 and related classification:

List of components

Qty	Name	Ident. Numb.	Classification	Registration Number
10-12.5 %	RHODAMINE LIQUID	CAS:65392-81-6 EC:265-730-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
10-12.5 %	RHODAMINE LIQUID	CAS:75701-30-3 EC:278-292-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
1-3 %	TRIMELLITIC ACID	CAS:528-44-9 EC:208-432-3	Skin Irrit. 2, H315; Eye Irrit. 2A, H319; STOT SE 3, H335	

4. FIRST AID MEASURES

Description of first aid measures

In case of skin contact:

Immediately take off all contaminated clothing and shoes.

Immediately remove any contaminated clothing, shoes or stockings.

After contact with skin, wash immediately with soap and plenty of water.

In case of eye contact:

Wash immediately and thoroughly with running water, keeping eyelids regularly raised, for at least 15 minutes. Cold water may be used. Check for and remove any contact lenses at once. OBTAIN A MEDICAL EXAMINATION.

Protect the eyes with a sterile gauze or a clean, dry handkerchief.

In case of ingestion:

Do not induce vomiting, get medical attention showing the MSDS and label hazardous.

In case of inhalation:

Remove casualty to fresh air and keep warm and at rest.

Most important symptoms/effects, acute and delayed

Eye irritation

Eye damages

Skin Irritation

Erythema

Indication of any immediate medical attention and special treatment needed

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

5. FIRE-FIGHTING MEASURES

Extinguishing media

Suitable extinguishing media:

Water, CO2, foam, chemical powders, according to the materials involved in the fire.

In case of fire, use foam, dry chemical, CO2.

Unsuitable extinguishing media:

None in particular.

Specific hazards arising from the chemical

Do not inhale explosion and combustion gases.

Burning produces heavy smoke.

Hazardous combustion products: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Special protective equipment and precautions for fire-fighters

Use suitable breathing apparatus .

Collect contaminated fire extinguishing water separately. This must not be discharged into drains.

Move undamaged containers from immediate hazard area if it can be done safely.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Wear personal protection equipment.

Remove persons to safety.

See protective measures under point 7 and 8.

Methods and material for containment and cleaning up

Suitable material for taking up: dry and inert absorbing material (e.g. vermiculite, sand, earth).

Wash with plenty of water.

7. HANDLING AND STORAGE

Precautions for safe handling

Avoid contact with skin and eyes, inhalation of vapours and mists.

Don't use empty container before they have been cleaned.

Before making transfer operations, assure that there aren't any incompatible material residuals in the containers.

Contamined clothing should be changed before entering eating areas.

Do not eat or drink while working.

See also section 8 for recommended protective equipment.

Conditions for safe storage, including any incompatibilities

Storage temperature: Not Determined

Incompatible materials:

None in particular.

Instructions as regards storage premises:

Adequately ventilated premises.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

No Data Available

Appropriate engineering controls: Not Determined

Individual protection measures

Eye/face protection:

Use close fitting safety goggles, don't use eye lens.

Skin protection:

Use clothing that provides comprehensive protection to the skin, e.g. cotton, rubber, PVC or viton.

Hand protection:

Use protective gloves that provide comprehensive protection, e.g. P.V.C., neoprene or rubber.

Respiratory protection:

Not Determined

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical State Liquid

Appearance: Liquid,

Odour: Not Determined

Odour threshold: Not Determined

pH: 10.50

Melting point/ range: Not Determined

Boiling point/ range: Not Determined

Flash point: > 100°C / 212°F

Evaporation rate: Not Determined

Upper/lower flammability or explosive limits: Not Determined

Vapour density: Not Determined

Vapour pressure: Not Determined

Density: Not Determined

Water solubility: Not Determined

Lipid solubility: Not Determined

Partition coefficient (n-octanol/water): Not Determined

Auto-ignition temperature: Not Determined

Decomposition temperature: Not Determined

Viscosity: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Flammability (Solid, Gas): Not Determined

Other information

Substance group relevant properties: Not Determined

Miscibility: Not Determined

Fat Solubility: Not Determined

Conductivity: Not Determined

10. STABILITY AND REACTIVITY

Reactivity

Stable under normal conditions.

Chemical stability

Data not Available.

Possibility of hazardous reactions

Burning produces carbon monoxide and/or carbon dioxide.

Conditions to avoid

Stable under normal conditions of temperature and pressure.

Incompatible materials

Avoid strong oxidizing agents, peroxides, acids, alkali metals.

Hazardous decomposition products

Burning produces carbon monoxide and/or carbon dioxide.

11. TOXICOLOGICAL INFORMATION

Information on toxicological effects

Toxicological information of the product: No Data Available

Substance(s) listed on the IARC Monographs:

None

Substance(s) listed as OSHA Carcinogen(s):

None

Substance(s) listed as NIOSH Carcinogen(s):

None

Substance(s) listed on the NTP report on Carcinogens:

None

12. ECOLOGICAL INFORMATION

Toxicity

Adopt good working practices, so that the product is not released into the environment.

Eco-toxicity:

List of Eco-Toxicological properties of the product

No Data Available

Persistence and degradability

Not Determined

Bioaccumulative potential

Not Determined

Mobility in soil

Not Determined

Other adverse effects

Not Determined

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Recover if possible. In so doing, comply with the local and national regulations currently in force.

14. TRANSPORT INFORMATION

UN number

ADR-UN number: N/A

DOT-UN Number: N/A

IATA-Un number: N/A

IMDG-Un number: N/A

UN proper shipping name

ADR-Shipping Name: N/A
DOT Proper Shipping Name: N/A
IATA-Technical name: N/A
IMDG-Technical name: N/A

Transport hazard class(es)

ADR-Class: N/A
DOT Hazard Class: N/A
IATA-Class: N/A
IMDG-Class: N/A

Packing group

ADR-Packing Group: N/A
Exempted for ADR: N/A
IATA-Packing group: N/A
IMDG-Packing group: N/A

Environmental hazards

Marine pollutant: No
Environmental Pollutant: Not Determined

Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code

Not Determined

Special precautions

Department of Transportation (DOT):

DOT-Special Provision(s): N/A
DOT Label(s): N/A
DOT Symbol: N/A
DOT Cargo Aircraft: N/A
DOT Passenger Aircraft: N/A
DOT/TDG Bulk: N/A
DOT Non-Bulk: N/A

Road and Rail (ADR-RID):

ADR-Label: N/A
ADR-Upper number: N/A
ADR Tunnel Restriction Code: N/A

Air (IATA):

IATA-Passenger Aircraft: N/A
IATA-Cargo Aircraft: N/A
IATA-Label: N/A
IATA-Sub Risk: N/A
IATA-Erg: N/A
IATA-Special Provisioning: N/A

Sea (IMDG):

IMDG-Stowage Code: N/A
IMDG-Stowage Note: N/A
IMDG-Sub Risk: N/A
IMDG-Special Provisioning: N/A
IMDG-Page: N/A
IMDG-Label: N/A
IMDG-EMS: N/A
IMDG-MFAG: N/A

15. REGULATORY INFORMATION

USA - Federal regulations

TSCA - Toxic Substances Control Act

TSCA inventory:

All the components are listed on the TSCA inventory

TSCA listed substances:

RHODAMINE LIQUID	is listed in TSCA	Section 8b
RHODAMINE LIQUID	is listed in TSCA	Section 8b
TRIMELLITIC ACID	is listed in TSCA	Section 8b, Section 5

SARA - Superfund Amendments and Reauthorization Act

Section 302 - Extremely Hazardous Substances:

no substances listed

Section 304 - Hazardous substances:

no substances listed

Section 313 - Toxic chemical list:

no substances listed

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

Substance(s) listed under CERCLA:

no substances listed

CAA - Clean Air Act

CAA listed substances:

no substances listed

CWA - Clean Water Act

CWA listed substances:

no substances listed

USA - State specific regulations

California Proposition 65

Substance(s) listed under California Proposition 65:

no substances listed

Massachusetts Right to know

Substance(s) listed under Massachusetts Right to know:

no substances listed

Pennsylvania Right to know

Substance(s) listed under Pennsylvania Right to know:

no substances listed

New Jersey Right to know

Substance(s) listed under New Jersey Right to know:

no substances listed

16. OTHER INFORMATION

Code	Description
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H320	Causes eye irritation
H335	May cause respiratory irritation.

Safety Data Sheet dated: 5/13/2015 - version 1

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality. The information relates only to the specific material and may not be valid for such material used in combination with any other material or in any process.

This document was prepared by a competent person who has received appropriate training.

It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended.

This MSDS cancels and replaces any preceding release.

Legend to abbreviations and acronyms used in the safety data sheet:

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID: Regulation Concerning the International Transport of Dangerous Goods by Rail

IMDG: International Maritime Code for Dangerous Goods

IATA: International Air Transport Association

IATA-DGR: Dangerous Goods Regulation by the "International Air Transport Association" (IATA)

ICAO: International Civil Aviation Organization

ICAO-TI: Technical Instructions by the "International Civil Aviation Organization" (ICAO)

GHS: Globally Harmonized System of Classification and Labeling of Chemicals
CLP: Classification, Labeling, Packaging
EINECS: European Inventory of Existing Commercial Chemical Substances
INCI: International Nomenclature of Cosmetic Ingredients
CAS: Chemical Abstracts Service (division of the American Chemical Society)
GefStoffVO: Ordnance on Hazardous Substances, Germany
LC50: Lethal concentration, for 50 percent of test population
LD50: Lethal dose, for 50 percent of test population
DNEL: Derived No Effect Level
PNEC: Predicted No Effect Concentration
TLV: Threshold Limiting Value
TWATLV: Threshold Limiting Value for the Time Weighted Average 8 hour day.(ACGIH Standard)
STEL: Short Term Exposure limit
STOT: Specific Target Organ Toxicity
WGK: German Water Hazard Class
KSt: Explosion coefficient
y for the damage.

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME ……………………..... **HUE EOSINE EX CONC**
PRODUCT NUMBER ….................. 1-C6-087-XPC
COLOR INDEX NAME …................. ACID RED 087
COLOR INDEX NO …….................. 45380
C. A. S. # ……………………………..…. 17372-87-1
CHEMICAL FAMILY…………………….. XANTHENE DYE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US): NO SYMBOL

SIGNAL WORD WARNING

HAZARD STATEMENT(S)
H333 - MAY BE HARMFUL IF INHALED
H320 - CAUSES EYE IRRITATION
H316 - CAUSES MILD SKIN IRRITATION

PRECAUTIONARY STATEMENTS P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR

SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS: GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL
P501 - DISPOSE OF CONTENTS/ CONTAINER IN ACCORDANCE WITH LOCAL/ REGIONAL/ NATIONAL INTERNATIONAL REGULATIONS.

OTHER HAZARDS NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID RED 087	17372-87-1	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION: REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

SKIN: WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.

EYES: FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.

INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL. IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND SPECIALTY INKS, PRINTING ON NYLON, SILK AND WOOL.

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	POWDER, NO ODOR
pH	7.0 - 8.5
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NOT APPLICABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA

SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA
AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL	GREATER THAN 2000 MG/KG - RAT
DERMAL (ANIMAL)	NO DATA AVAILABLE
EFFECTS TO EYES (ANIMAL)	NO DATA AVAILABLE
SKIN IRRITATION (ANIMAL)	NO DATA AVAILABLE

SKIN CORROSION/IRRITATION	NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION	CAUSES SERIOUS EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION	NOT CLASSIFIED
GERM CELL MUTAGENICITY	NOT CLASSIFIED
CARCINOGENICITY	NOT CLASSIFIED
REPRODUCTIVE TOXICITY	NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE)	MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD	NOT CLASSIFIED
INHALATION	MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT	CAUSES SERIOUS EYE IRRITATION.
INGESTION	INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY	NA
PERSISTENCE AND DEGRADABILITY	NA
BIOACCUMULATIVE POTENTIAL	NA
MOBILITY IN SOIL	NA
OTHER ADVERSE EFFECTS	NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL.
PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING.
OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER	NONE
UN PROPER SHIPPING NAME	NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT)	NA
DOT SPECIAL PROVISIONS	NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT	NONE
TRANSPORT BY SEA	NONE
AIR TRANSPORT	NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT	NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT	NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THIS SUBSTANCE IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

17372-87-1	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	CONTAINS: <11PPM BENZENE, (CAS#71-43-2) <11PPM TOLUENE, (CAS#108-88-3) <11PPM XYLENES, (CAS#1330-20-7)

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

HUE CORPORATION

Color your everything, may your Hue come true

SECTION I. IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY/UNDERTAKING

PRODUCT IDENTIFIER:

PRODUCT NAME .... **HUE URANINE CONC** (Also known as Fluorescein)
PRODUCT NUMBER 1-C8-073PC
COLOR INDEX NAME .... ACID YELLOW 073
COLOR INDEX NO 45350
C. A. S. # 518-47-8
CHEMICAL FAMILY......................... XANTHENE

INTENDED USE OF THE PRODUCT:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

NAME, ADDRESS AND TELEPHONE OF RESPONSIBLE PARTY:

HUE CORPORATION	TELEPHONE	714-389-3130
P.O. BOX 509	FAX	714-389-9731
TUSTIN, CA 92781	EMAIL	SUPPORT@HUECORPORATION.COM

EMERGENCY TELEPHONE NUMBER:

CHEMTREC (USA)	1-800-424-9300
CHEMTREC (OUTSIDE USA)	1-703-527-3887

SECTION 2. HAZARD(S) IDENTIFICATION

CLASSIFICATION OF THE SUBSTANCE OR MIXTURE:

GHS-US
ACUTE TOX. - INHALATION (CATEGORY 5)
EYE DAM./IRRITATION (CATEGORY 2B)
SKIN CORR./IRRITATION (CATEGORY 3)

GHS LABELING:

HAZARD PICTOGRAMS (GHS-US):	NO SYMBOL
SIGNAL WORD	WARNING
HAZARD STATEMENT(S)	H333 - MAY BE HARMFUL IF INHALED H320 - CAUSES EYE IRRITATION H316 - CAUSES MILD SKIN IRRITATION
PRECAUTIONARY STATEMENTS	P305 + 351 + P338 - IF IN EYES: RINSE CAUTIOUSLY WITH WATER FOR SEVERAL MINUTES. REMOVE CONTACT LENSES IF PRESENT AND EASY

TO DO. CONTINUE RINSING.
P337 + P313 - IF EYE IRRITATION OCCURS/PERSISTS:
GET MEDICAL ADVICE AND ATTENTION.
P261 - AVOID BREATHING DUST/FUMES/GAS/MIST/VAPORS/SPRAY
P264 - WASH FACE THOROUGHLY AFTER HANDLING.
P322 + P313 - IF SKIN IRRITATION OCCURS: GET MEDICAL ADVICE/ ATTENTION.
P304 + 312 - IF INHALED: CALL A POISON CENTER/DOCTOR/PHYSICIAN IF YOU FEEL UNWELL

OTHER HAZARDS — NO DATA AVAILABLE
UNKNOWN ACUTE TOXICITY — NO DATA AVAILABLE

SECTION 3. COMPOSITION / INFORMATION ON INGREDIENTS

DESCRIPTION OF MIXTURE: PROPRIETARY MIXTURE OF DYES.

SUBSTANCE:

NAME	C.A.S.#	WEIGHT 100%	GHS-US CLASSIFICATION
ACID YELLOW 073	518-47-8	100%	ACUTE TOX. - INHALATION (CATEGORY 5) EYE DAM./IRRITATION (CATEGORY 2B) SKIN CORR./IRRITATION (CATEGORY 3)

SECTION 4. FIRST AID MEASURES

FIRST AID MEASURES GENERAL:

INHALATION: REMOVE TO FRESH AIR. IF BREATHING IS DIFFICULT, GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.

SKIN: WASH WITH MILD SOAP AND WATER. IF IRRITATION OCCURS GET MEDICAL ATTENTION. IF CLOTHING IS CONTAMINATED, RE-MOVE AND WASH BEFORE REUSE.

EYES: FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES, HOLDING EYELIDS APART FOR THOROUGH IRRIGATION. GET IMMEDIATE MEDICAL ATTENTION.

INGESTION: INDUCE VOMITING - SEEK IMMEDIATE MEDICAL ATTENTION.

MOST IMPORTANT SYMPTOMS AND EFFECTS, ACUTE AND DELAYED:

THIS PRODUCT IS NOT HAZARDOUS AS DEFINED BY HAZARDOUS COMMUNICATION STANDARD. HOWEVER, AS WITH ALL CHEMICAL; HANDLE WITH CARE, AVOID EYE AND SKIN CONTACT, AVOID INHALATION OF DUSTS OR VAPORS. WASH THOROUGHLY AFTER HANDLING. KEEP CONTAINERS CLOSED.

SECTION 5. FIRE-FIGHTING MEASURES

EXTINGUISHING MEDIA:

WATER, DRY CHEMICAL, CARBON DIOXIDE, FOAM.

SPECIAL HAZARDS ARISING FROM SUBSTANCE OR MEDIA:

FIREFIGHTERS SHOULD BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS TO GUARD AGAINST POTENTIALLY TOXIC AND IRRITATING FUMES. AVOID DUSTING. DUST CAN FORM EXPLOSIVE MIXTURES WITH AIR.

PROTECTION/ADVICE FOR FIREFIGHTER(S):

BE EQUIPPED WITH SELF-CONTAINED BREATHING APPARATUS AND PROTECTIVE CLOTHING.

SECTION 6. ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS:

REMOVE PERSONS FROM DANGER AREA.

ENVIROMENTAL PRECAUTIONS:

AVOID ANY UNCONTROLLED RELEASE OF MATERIAL. DO NOT EMPTY INTO DRAINS OR THE AQUATIC ENVIRONMENT.

EMERGENCY PROCEDURES:

NO ADDITIONAL INFORMATION

METHODS AND MATERIALS FOR CONTAMINENT AND CLEANING UP:

WHERE SPILLS ARE POSSIBLE, A COMPREHENSIVE SPILL RESPONSE PLAN SHOULD BE DEVELOPED AND IMPLEMENTED. AVOID ANY UNCONTROLLED RELEASE OF MATERIAL.

UTILIZE RECOMMENDED PROTECTIVE CLOTHING AND EQUIPMENT (SEE SECTION 8).
SPILLS SHOULD BE SWEPT UP USING AN ABSORBENT DUST CONTROL PRODUCT AND PLACED IN CONTAINERS. SPILL AREA CAN BE WASHED WITH WATER. COLLECT WATER FOR APPROVED DISPOSAL. IN THE EVENT OF UNCONTROLLED RELEASE OF THIS MATERIAL, THE USER SHOULD DETERMINE IF THE RELEASE IS REPORTABLE UNDER APPLICABLE LAWS AND REGULATIONS.

SECTION 7. HANDLING AND STORAGE

PRECAUTIONS FOR SAFE HANDLING:

HANDLE WITH CARE. AVOID OVER EXPOSURE. USE NIOSH/OSHA APPROVED RESPIRATOR, WORK GLOVES, AND CLOTHING. WASH AFTER HANDLING. SENSITIVE INDIVIDUALS MAY EXPERIENCE RESPIRATORY ALLERGIES. MAY CAUSE SKIN IRRITATION. USE WITH LOCAL VENTILATION.

CONDITIONS FOR SAFE STORAGE, INCLUDING ANY INCOMPATIBILITIES:

USE PROCESS ENCLOSURES, LOCAL EXHAUST VENTILATION OR OTHER ENGINEERING CONTROLS TO KEEP AIRBORNE LEVELS BELOW RECOMMENDED EXPOSURE LIMITS.

KEEP AWAY FROM HEAT. KEEP AWAY FROM SOURCES OF IGNITION.

KEEP AWAY FROM STRONG OXIDIZING AND REDUSING AGENTS.

SPECIFIC END USES:

FELT TIP, MARKER INKS, WATER BASED COATINGS AND LEAK DETECTION

SECTION 8. EXPOSURE CONTROLS /PERSONAL PROTECTION

CONTROL PARAMETERS:

INGREDIENTS WITH LIMIT VALUES THAT REQUIRE MONITORING AT THE WORKPLACE - NOT REQUIRED

EXPOSURE CONTROLS:

APPROPRIATE ENGINEERING CONTROLS - THE USUAL PRECAUTIONARY MEASURES ARE TO BE ADHERED TO WHEN HANDLING CHEMICALS.

PERSONAL PROTECTIVE EQUIPMENT:

HAND PROTECTION	WEAR IMPERMEABLE RUBBER OR PLASTIC GLOVES
EYE PROTECTION	TIGHTLY SEALED SAFETY GOGGLES OR FULL FACE SIDE SHIELDS.
SKIN AND BODY	APRON, COVERALLS AND NON-LEATHER SOLED WORK SHOES. WASH DYE CONTAMINATED CLOTHES AND SKIN WITH MILD SOAP AND DETERGENTS.
RESPIRATORY	WEAR OSHA/NIOSH APPROVED DUST MASK/RESPIRATOR
HYGIENE MEASURES	HANDLE IN ACCORDANCE WITH GOOD INDUSTRIAL HYGIENE AND SAFETY PRACTICES. WASH HANDS AFTER HANDLING MATERIAL.
OTHER PROTECTION	DELUGE SAFETY SHOWER AND EYE WASH STATION SHOULD BE LOCATED NEAR WORK AREA.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

INFORMATION ON BASIC PHYSICAL AND CHEMICAL PROPERTIES :

APPEARANCE, COLOR, ODOR	YELLOW POWDER, NO ODOR
pH	8.0 - 9.0
MELTING POINT/FREEZING POINT	ND
INITIAL BOILING POINT/BOILING RANGE	0.00
FLASHPOINT	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
EVAPORATION RATE	NO DATA
FLAMMABILITY (SOLID,GAS)	NORMALLY STABLE, NOT COMBUSTIBLE NOR FLAMMABLE
UPPER EXPLOSIVE LIMITS	NA
LOWER EXPLOSIVE LIMITS	NA
VAPOR PRESSURE	NA
VAPOR DENSITY	NA
RELATIVE DENSITY	NA
SOLUBILITY IN WATER	SOLUBLE
PARTITION COEFFICIENT N-OCTANOL/WATER	NO DATA

AUTO-IGNITION TEMPERATURE	NO DATA
DECOMPOSITION TEMPERATURE	NO DATA
VISCOSITY, DYNAMIC	NO DATA
VISCOSITY, CINEMATIC	NO DATA
EXPLOSIVE PROPERTIES	N/A
OXIDIZING PROPERTIES	NA
OTHER INFORMATION	NA

SECTION 10. STABILITY AND REACTIVITY

CHEMICAL STABILITY STABLE UNDER NORMAL STORAGE AND HANDLING CONDITIONS.
CONDITIONS TO AVOID OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
INCOMPATIBLE MATERIALS OXIDIZING & REDUCING AGENTS MAY DESTROY COLOR.
HAZARDOUS DECOMPOSITION PRODUCTS - CO, CO2, OXIDES OF NITROGEN AND OTHER POTENTIALLY TOXIC FUMES.

SECTION 11. TOXICOLOGICAL INFORMATION

TOXICOLOGICAL EFFECTS :

ORAL (ANIMAL GREATER THAN 7,000 MG/KG - RAT
DERMAL (ANIMAL) NA
EFFECTS TO EYES (ANIMAL) EYES - RABBIT, NOT IRRITATING
SKIN IRRITATION (ANIMAL) SKIN - RABBIT, SLIGHT IRRITANT

SKIN CORROSION/IRRITATION NOT CLASSIFIED
SERIOUS EYE DAMAGE/IRRITATION CAUSES EYE IRRITATION
RESPIRATORY OR SKIN SENSITIZATION NOT CLASSIFIED
GERM CELL MUTAGENICITY NOT CLASSIFIED
CARCINOGENICITY NOT CLASSIFIED
REPRODUCTIVE TOXICITY NOT CLASSIFIED
SPECIFIC TARGET ORGAN TOXICITY (SINGLE EXPOSURE) MAY CAUSE DROWSINESS OR DIZZINESS.
ASPIRATION HAZARD NOT CLASSIFIED
INHALATION MAY CAUSE DROWSINESS OR DIZZINESS.
EYE CONTACT CAUSES SERIOUS EYE IRRITATION.
INGESTION INGESTION MAY CAUSE NAUSEA, VOMITING AND DIARRHEA

SECTION 12. ECOLOGICAL INFORMATION

TOXICITY NA
PERSISTENCE AND DEGRADABILITY NA
BIOACCUMULATIVE POTENTIAL NA
MOBILITY IN SOIL LC-50 (LETHAL CONCENTRATION) UG = MICROGRAMS/LITER CHANNEL CATFISH - 2,267,000 UG/LITER RAINBOW TROUT - 1,372,000 UG/LITER BLUEGILL - 3,433,000 UG/LITER
OTHER ADVERSE EFFECTS NA

SECTION 13. DISPOSAL CONSIDERATION

WASTE DISPOSAL RECOMMENDATION :

EMPTY BAGS THOROUGHLY. CARRY OUT THE PROPER RECYLING, REUSAGE OR DISPOSAL.
PLEASE REFER TO THE RELEVANT EU REGULATIONS, IN PARTICULAR THE GUIDELINES/DECISIONS OF THE COUNCIL REGARDING HANDLING OF WASTES (E.G. 75/442/EEC, 91/689/EEC, 94/67/EC, 94/904/EC) AS IMPLEMENTED IN NATIONAL REGULATIONS.

REGIONAL RECOMMENDATION :

BURY OR INCINERATE ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.

CONTAINERS SHOULD NOT BE REUSED WITHOUT PROFESSIONAL CLEANING AND RECONDITIONING.
OBSERVE ALL LABELED SAFEGUARDS UNTIL CLEANED, RECONDITIONED OR DESTROYED.

PLEASE REFER TO SECTION 8 (EXPOSURE CONTROLS /PERSONAL PROTECTION) OF THIS SDS.

SECTION 14. TRANSPORTATION INFORMATION

UN NUMBER NONE
UN PROPER SHIPPING NAME NONE

DEPARTMENT OF TRANSPORTATION (DOT) : NOT HAZARDOUS FOR TRANSPORTATION

TRANSPORT HAZARD CLASS(ES)

HAZARD LABLES (DOT) :

PACKING GROUP (DOT) NA
DOT SPECIAL PROVISIONS NA

ADDITIONAL INFORMATION:

OVERLAND TRANSPORT NONE
TRANSPORT BY SEA NONE
AIR TRANSPORT NONE
DOT QUANTITY LIMITATIONS PASSENGER AIRCRAFT NA
DOT QUANTITY LIMITATIONS CARGO AIRCRAFT NA

SECTION 15. REGULATORY INFORMATION

US FEDERAL REGULATIONS:

THE SUBSTANCES IS LISTED ON UNITED STATES TSCA (TOXIC SUBSTANCE CONTROL ACT) INVENTORY.

US STATE REGULATIONS:

NONE

CHEMICAL IDENTITY:

518-47-8	TSCA	DSL	NDSL	EINECS	ELINCS	ENCS	CHINA	KECL	PICCS	AICS
	X	-	-	-	-	-	-	-	-	-

TSCA STATUS	IN COMPLIANCE
E C CLASSIFICATION	(67/548/EEC - 88/379/EEC) N/A
EINECS NUMBER	
REACH CLASSIFICATION	
R PHRASES	
ADDITIONAL REGULATORY INFORMATION	

SECTION 16. OTHER INFORMATION

INDICATION OF CHANGES:

NA

OTHER INFORMATION:

NA

GHS FULL TEXT PHRASES:

MAY BE HARMFUL IF INHALED	H333
CAUSES EYE IRRITATION	H320
CASUES MILD SKIN IRRITATION	H316

	HEALTH	FLAMMABILITY	REACTIVITY	PERSONAL PROT
H. M. I. S. CLASSIFICATION:	1	0	0	D

HMIS CODE: **4** - SEVERE HAZARD, **3** - SERIOUS HAZARD, **2** - MODERATE HAZARD, **1** - SLIGHT HAZARD, **0** - MINIMAL HAZARD

SAFETY DATA SHEET (SDS)
REVISION DATE: 03/03/2016

Safety Data Sheet

INTRACID RHODAMINE WT LIQUID

Safety Data Sheet dated: 5/13/2015 - version 1

Date of first edition: 5/13/2015

1. IDENTIFICATION

Product identifier

Mixture identification:

Trade name: INTRACID RHODAMINE WT LIQUID

Other means of identification:

Trade code: A45171566

Recommended use of the chemical and restrictions on use

Recommended use: Industrial color additive

Restrictions on use: Not Determined

Name, address, and telephone number of the chemical manufacturer, importer, or other responsible party

Sensient Colors LLC

2515 N. Jefferson

63106 St. Louis, MO (USA)

Phone: 1 800-325-8110

Emergency Number(CHEMTREC): 1-800-424-9300

2. HAZARD(S) IDENTIFICATION

The identity of the individual components of this product is proprietary information and is considered a trade secret pursuant to 29 CFR 1910.1200

Hazardous components as defined in the OSHA Hazard Communication Standard: components with a HEALTH hazard (carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, etc..) and/or a PHYSICAL hazard (a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive, etc.)

Classification of the chemical

Skin Irrit. 2	Causes skin irritation.
Eye Irrit. 2B	Causes eye irritation

Label elements

Symbols:

Warning

Code	Description
H315	Causes skin irritation.
H320	Causes eye irritation

Code	Description
P264	Wash ... Thoroughly after handling.
P280	Wear protective gloves/protective clothing/eye protection/face protection.
P302+P352	IF ON SKIN: Wash with plenty of water/…
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P321	Specific treatment (see ... On this label).
P332+P313	If skin irritation occurs: Get medical advice/attention.
P337+P313	If eye irritation persists: Get medical advice/attention.

P362+P364 Take off contaminated clothing and wash it before reuse.

Ingredient(s) with unknown acute toxicity:

None

Hazards not otherwise classified identified during the classification process:

None

3. COMPOSITION/INFORMATION ON INGREDIENTS

Substances

Not Determined

Mixtures

Hazardous components within the meaning of 29 CFR 1910.1200 and related classification:

List of components

Qty	Name	Ident. Numb.	Classification	Registration Number
10-12.5 %	RHODAMINE LIQUID	CAS:65392-81-6 EC:265-730-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
10-12.5 %	RHODAMINE LIQUID	CAS:75701-30-3 EC:278-292-6	Skin Irrit. 2, H315; Eye Irrit. 2B, H320	
1-3 %	TRIMELLITIC ACID	CAS:528-44-9 EC:208-432-3	Skin Irrit. 2, H315; Eye Irrit. 2A, H319; STOT SE 3, H335	

4. FIRST AID MEASURES

Description of first aid measures

In case of skin contact:

Immediately take off all contaminated clothing and shoes.

Immediately remove any contaminated clothing, shoes or stockings.

After contact with skin, wash immediately with soap and plenty of water.

In case of eye contact:

Wash immediately and thoroughly with running water, keeping eyelids regularly raised, for at least 15 minutes. Cold water may be used. Check for and remove any contact lenses at once. OBTAIN A MEDICAL EXAMINATION.

Protect the eyes with a sterile gauze or a clean, dry handkerchief.

In case of ingestion:

Do not induce vomiting, get medical attention showing the MSDS and label hazardous.

In case of inhalation:

Remove casualty to fresh air and keep warm and at rest.

Most important symptoms/effects, acute and delayed

Eye irritation

Eye damages

Skin Irritation

Erythema

Indication of any immediate medical attention and special treatment needed

In case of accident or unwellness, seek medical advice immediately (show directions for use or safety data sheet if possible).

5. FIRE-FIGHTING MEASURES

Extinguishing media

Suitable extinguishing media:

Water, CO2, foam, chemical powders, according to the materials involved in the fire.

In case of fire, use foam, dry chemical, CO2.

Unsuitable extinguishing media:

None in particular.

Specific hazards arising from the chemical

Do not inhale explosion and combustion gases.

Burning produces heavy smoke.

Hazardous combustion products: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Special protective equipment and precautions for fire-fighters

Use suitable breathing apparatus .

Collect contaminated fire extinguishing water separately. This must not be discharged into drains.

Move undamaged containers from immediate hazard area if it can be done safely.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions, protective equipment and emergency procedures

Wear personal protection equipment.

Remove persons to safety.

See protective measures under point 7 and 8.

Methods and material for containment and cleaning up

Suitable material for taking up: dry and inert absorbing material (e.g. vermiculite, sand, earth).

Wash with plenty of water.

7. HANDLING AND STORAGE

Precautions for safe handling

Avoid contact with skin and eyes, inhalation of vapours and mists.

Don't use empty container before they have been cleaned.

Before making transfer operations, assure that there aren't any incompatible material residuals in the containers.

Contamined clothing should be changed before entering eating areas.

Do not eat or drink while working.

See also section 8 for recommended protective equipment.

Conditions for safe storage, including any incompatibilities

Storage temperature: Not Determined

Incompatible materials:

None in particular.

Instructions as regards storage premises:

Adequately ventilated premises.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Control parameters

No Data Available

Appropriate engineering controls: Not Determined

Individual protection measures

Eye/face protection:

Use close fitting safety goggles, don't use eye lens.

Skin protection:

Use clothing that provides comprehensive protection to the skin, e.g. cotton, rubber, PVC or viton.

Hand protection:

Use protective gloves that provide comprehensive protection, e.g. P.V.C., neoprene or rubber.

Respiratory protection:

Not Determined

9. PHYSICAL AND CHEMICAL PROPERTIES

Information on basic physical and chemical properties

Physical State Liquid

Appearance: Liquid,

Odour: Not Determined

Odour threshold: Not Determined

pH: 10.50

Melting point/ range: Not Determined

Boiling point/ range: Not Determined

Flash point: > 100°C / 212°F

Evaporation rate: Not Determined

Upper/lower flammability or explosive limits: Not Determined

Vapour density: Not Determined

Vapour pressure: Not Determined

Density: Not Determined

Water solubility: Not Determined

Lipid solubility: Not Determined

Partition coefficient (n-octanol/water): Not Determined

Auto-ignition temperature: Not Determined

Decomposition temperature: Not Determined

Viscosity: Not Determined

Explosive properties: Not Determined

Oxidising properties: Not Determined

Flammability (Solid, Gas): Not Determined

Other information

Substance group relevant properties: Not Determined
Miscibility: Not Determined
Fat Solubility: Not Determined
Conductivity: Not Determined

10. STABILITY AND REACTIVITY

Reactivity

Stable under normal conditions.

Chemical stability

Data not Available.

Possibility of hazardous reactions

Burning produces carbon monoxide and/or carbon dioxide.

Conditions to avoid

Stable under normal conditions of temperature and pressure.

Incompatible materials

Avoid strong oxidizing agents, peroxides, acids, alkali metals.

Hazardous decomposition products

Burning produces carbon monoxide and/or carbon dioxide.

11. TOXICOLOGICAL INFORMATION

Information on toxicological effects

Toxicological information of the product: No Data Available

Substance(s) listed on the IARC Monographs:

None

Substance(s) listed as OSHA Carcinogen(s):

None

Substance(s) listed as NIOSH Carcinogen(s):

None

Substance(s) listed on the NTP report on Carcinogens:

None

12. ECOLOGICAL INFORMATION

Toxicity

Adopt good working practices, so that the product is not released into the environment.
Eco-toxicity:

List of Eco-Toxicological properties of the product

No Data Available

Persistence and degradability

Not Determined

Bioaccumulative potential

Not Determined

Mobility in soil

Not Determined

Other adverse effects

Not Determined

13. DISPOSAL CONSIDERATIONS

Waste treatment methods

Recover if possible. In so doing, comply with the local and national regulations currently in force.

14. TRANSPORT INFORMATION

UN number

ADR-UN number: N/A
DOT-UN Number: N/A
IATA-Un number: N/A
IMDG-Un number: N/A

UN proper shipping name

ADR-Shipping Name: N/A
DOT Proper Shipping Name: N/A
IATA-Technical name: N/A
IMDG-Technical name: N/A

Transport hazard class(es)

ADR-Class: N/A
DOT Hazard Class: N/A
IATA-Class: N/A
IMDG-Class: N/A

Packing group

ADR-Packing Group: N/A
Exempted for ADR: N/A
IATA-Packing group: N/A
IMDG-Packing group: N/A

Environmental hazards

Marine pollutant: No
Environmental Pollutant: Not Determined

Transport in bulk according to Annex II of MARPOL73/78 and the IBC Code

Not Determined

Special precautions

Department of Transportation (DOT):

DOT-Special Provision(s): N/A
DOT Label(s): N/A
DOT Symbol: N/A
DOT Cargo Aircraft: N/A
DOT Passenger Aircraft: N/A
DOT/TDG Bulk: N/A
DOT Non-Bulk: N/A

Road and Rail (ADR-RID):

ADR-Label: N/A
ADR-Upper number: N/A
ADR Tunnel Restriction Code: N/A

Air (IATA):

IATA-Passenger Aircraft: N/A
IATA-Cargo Aircraft: N/A
IATA-Label: N/A
IATA-Sub Risk: N/A
IATA-Erg: N/A
IATA-Special Provisioning: N/A

Sea (IMDG):

IMDG-Stowage Code: N/A
IMDG-Stowage Note: N/A
IMDG-Sub Risk: N/A
IMDG-Special Provisioning: N/A
IMDG-Page: N/A
IMDG-Label: N/A
IMDG-EMS: N/A
IMDG-MFAG: N/A

15. REGULATORY INFORMATION

USA - Federal regulations

TSCA - Toxic Substances Control Act

TSCA inventory:

All the components are listed on the TSCA inventory

TSCA listed substances:

RHODAMINE LIQUID	is listed in TSCA	Section 8b
RHODAMINE LIQUID	is listed in TSCA	Section 8b
TRIMELLITIC ACID	is listed in TSCA	Section 8b, Section 5

SARA - Superfund Amendments and Reauthorization Act

Section 302 - Extremely Hazardous Substances:

no substances listed

Section 304 - Hazardous substances:

no substances listed

Section 313 - Toxic chemical list:

no substances listed

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act

Substance(s) listed under CERCLA:

no substances listed

CAA - Clean Air Act

CAA listed substances:

no substances listed

CWA - Clean Water Act

CWA listed substances:

no substances listed

USA - State specific regulations

California Proposition 65

Substance(s) listed under California Proposition 65:

no substances listed

Massachusetts Right to know

Substance(s) listed under Massachusetts Right to know:

no substances listed

Pennsylvania Right to know

Substance(s) listed under Pennsylvania Right to know:

no substances listed

New Jersey Right to know

Substance(s) listed under New Jersey Right to know:

no substances listed

16. OTHER INFORMATION

Code	Description
H315	Causes skin irritation.
H319	Causes serious eye irritation.
H320	Causes eye irritation
H335	May cause respiratory irritation.

Safety Data Sheet dated: 5/13/2015 - version 1

The information contained herein is based on our state of knowledge at the above-specified date. It refers solely to the product indicated and constitutes no guarantee of particular quality. The information relates only to the specific material and may not be valid for such material used in combination with any other material or in any process.

This document was prepared by a competent person who has received appropriate training.

It is the duty of the user to ensure that this information is appropriate and complete with respect to the specific use intended.

This MSDS cancels and replaces any preceding release.

Legend to abbreviations and acronyms used in the safety data sheet:

ADR: European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID: Regulation Concerning the International Transport of Dangerous Goods by Rail

IMDG: International Maritime Code for Dangerous Goods

IATA: International Air Transport Association

IATA-DGR: Dangerous Goods Regulation by the "International Air Transport Association" (IATA)

ICAO: International Civil Aviation Organization

ICAO-TI: Technical Instructions by the "International Civil Aviation Organization" (ICAO)

GHS: Globally Harmonized System of Classification and Labeling of Chemicals
CLP: Classification, Labeling, Packaging
EINECS: European Inventory of Existing Commercial Chemical Substances
INCI: International Nomenclature of Cosmetic Ingredients
CAS: Chemical Abstracts Service (division of the American Chemical Society)
GefStoffVO: Ordnance on Hazardous Substances, Germany
LC50: Lethal concentration, for 50 percent of test population
LD50: Lethal dose, for 50 percent of test population
DNEL: Derived No Effect Level
PNEC: Predicted No Effect Concentration
TLV: Threshold Limiting Value
TWATLV: Threshold Limiting Value for the Time Weighted Average 8 hour day.(ACGIH Standard)
STEL: Short Term Exposure limit
STOT: Specific Target Organ Toxicity
WGK: German Water Hazard Class
KSt: Explosion coefficient
y for the damage.