ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER SIPHON CROSSING

"Lifeline of the Hi-line"

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Montana DNRC
Water Resources Division

TD&H Engineering

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GEOTECHNICAL REPORT
ST. MARY RIVER SIPHON CROSSING
ST. MARY DIVERSION AND CONVEYANCE FACILITIES

1.0 INTRODUCTION

1.1 Purpose and Scope

This report presents the results of our geotechnical studies for the replacement of the St. Mary River Siphon crossing, part of the St. Mary Diversion Facilities located northeast of Babb, Montana. The purpose of the geotechnical studies was to determine the general surface and subsurface conditions at the siphon crossings and to develop geotechnical engineering recommendations to enhance long-term performance of the existing or any replacement structures. This report describes the fieldwork and laboratory analyses conducted for each of the field investigations performed since 2006, the surface and subsurface conditions encountered, and presents our recommendations for the existing siphon and future replacement siphon crossings. Any additional data which is collected after the time of this report may warrant modifications to the conclusions and recommendations contained herein. An exploration program for a proposed alignment of a replacement siphon was performed for the St. Mary River crossing and will be included as part of the discussion within this report. To our knowledge, a final design has not been initiated and the alignment investigated has not been approved as a final alignment for a replacement structure.

Our field work consisted of several separate investigations spanning from 2006 to present. Various investigations were performed to evaluate the existing siphon at the St. Mary River crossing as well as an investigation of the preliminary alignment for the proposed replacement siphon at the St. Mary River crossing. These investigations consisted of several borings, Cone Penetration Tests (CPT), the installation of various instruments, and long-term data collection and analysis. Each of the investigations performed will be discussed in greater detail in the following report. Samples were obtained from the various borings performed for each investigation and were returned to our Great Falls laboratory for testing. Laboratory testing was performed on select soil samples to determine engineering properties of the subsurface materials. The information obtained during our field investigations, laboratory analyses, and monitoring of field instrumentation was used to develop preliminary recommendations for the design of the replacement siphons.

1.2 Project Description

The St. Mary River siphon crossing is one of the most significant structures of the 29 miles of the St. Mary River Diversion Facilities. The inverted siphon consists of two riveted steel pipes ranging in diameter from 84 to 90 inches. The 90-inch pipe transitions to an 84-inch diameter as it crosses the St. Mary River Bridge and then back to 90 inches (see Photo 1). The overall siphon length from inlet to outlet is reported by the United States Bureau of Reclamation (USBR) to be 3,281 feet. The design discharge capacity of each pipe is 425 cfs for a combined capacity of 850 cfs. The maximum static head is 165 feet (71.5 psi) which is the elevation difference between the inlet water level and the center of the pipes at their lowest elevation (St. Mary River Bridge crossing). The siphon inlet and outlet consist of concrete transition structures.

Photo 1 View of the St. Mary River Bridge carrying the siphon, looking downstream (southeast). The old bridge shown was replaced up river with a new bridge constructed during the winter of 2008 and 2009 (06/04/04)

The left pipe, looking downstream, was constructed from 1912 to 1915, and the right pipe was constructed from 1925 to 1926. Most of the left, original pipe was placed underground with 3 to 5 feet of soil cover. The water diversion started in June of 1916 with just the left pipe. After nine years of operation, the left pipe underwent a major repair due to damages caused by corrosion, compression buckling, and development of major leaks. Because of this, it was decided that the right pipe should be constructed above ground on concrete saddles on 20-foot centers to support the new pipe. This also facilitated maintenance of the exterior protective coating. Additional expansion/contraction joints were also installed at this time to increase the internal joint movement distance from 10 inches to 24 inches. A typical expansion/contraction joint with a cathodic continuity cable is shown in Photo 2.

Photo 2 St. Mary River Siphon – Typical expansion/contraction joint, including cathodic protection continuity cable (10/26/04)

During the 1926 operation season, the recently constructed right pipe failed at the outlet transition. The pipe moved downslope such that approximately 100 lineal feet collapsed or was damaged. The repair was made by constructing an anchor just upstream of the outlet transition to stabilize the pipe and prevent it from moving downslope.

In the spring of 1937, the left pipe again underwent a major renovation which took place over a two-year period. The earth material was removed from the left pipe and concrete supports were constructed under the portions of the pipe that lay on the ground in the trench. Both pipes were recoated at that time.

In 1954, a section of the left pipe was replaced and steel plates were installed where corrosion had damaged the steel. Typical siphon repairs due to deflection and corrosion are shown in Photos 3 and 4. Also, there appeared to be seepage from the canal which moved along the siphon support foundation at both pipes. The left pipe was further unearthed and a perforated drain pipe installed, surrounded with well-graded gravel. One drain was installed on the north side of the left pipe, and one on the south side of the right pipe. A cathodic protection system was also installed on both pipes. This system remained in effect until 1997 when the pole support for the rectifier tipped over damaging the rectifier beyond repair.

Photo 3 Typical siphon repair due to deflection and/or corrosion (10/13/04)

Photo 4 Typical siphon repair due to deflection and/or corrosion (10/13/04)

The left siphon between Station 512+30 (location of the most downstream pipe anchor) and Station 518+21 (downstream end of steel pipe) historically has been a major problem area. Part of this section has moved up to 4.5 feet downslope since the pipe was constructed. The movement caused major compression buckling near Station 513+00. An inspection in the Fall of 1996 revealed complete closure of all the expansion joints in the left siphon, which resulted in compression buckling. This also caused the pipe supports to rotate downslope which created a point-load bearing condition. This resulted in up to 6-inch indentations in the pipe at the points of the concentrated load (Photo 5).

Photo 5 Photo shows ground movements right to left causing rotation of concrete support and point-loading of siphon which can lead to buckling (10/13/04)

The right pipe exhibits similar movement; however, the larger expansion joints used during construction allow the pipe to accommodate larger displacements. Inspections of the right pipe revealed that several of the larger expansion joints had also become entirely closed.

In June 1996, there was a significant amount of surface water which appeared to be coming from leaks in both pipes along the north slope. This resulted in erosion and loss of support for the left pipe at a vertical change in slope.

Repairs were carried out in February 1997. The work performed is listed as follows:

- Buckled section in left pipe was replaced.
- The expansion join near the buckled section was re-done.
- A 7-inch long extension was welded to the downstream end of the left pipe.
- The male ends in two expansion joints in the right siphon were cut and repaired to make them operable again.

In summary, the existing St. Mary River siphon, excluding the concrete transitions and bridge, exhibits the following deficiencies:

- The exposed concrete pipe supports are deteriorating.
- The left conduit continues to slide down the slope.
- Concrete supports under the conduit are rotating because of ground movements relative to the pipe. As the supports tip, they buckle the bottom of the pipe.
- Portions of the pipes continually need to be removed at the expansion/contraction joints to keep them functional. Additional lengths of pipe need to be added to replace displaced sections.
- Most of the expansion/contraction joints leak and tend to saturate the supporting soils and hillsides.

The St. Mary River siphon is in very poor condition and represents the most fragile component of the overall Diversion Facilities. Sudden failure could cause both economic and environmental catastrophes. Alternatives were considered by the Design Team for replacing the St. Mary River Siphon and include the various design parameters:

- One large replacement pipe versus two smaller pipes.
- Above ground supported siphon versus direct bury construction with integrated drainage. Combinations of direct bury and above ground supported may be ideal for this crossing.
- Pipe materials, i.e. cast-in-place concrete, steel, or other.
- Below river crossing or elevated above.
- New alignment and reduction of overall length.
- Level of corrosion protection necessary and which method is best suited for this site.
- Slope stability issues and level of stabilization corrective measures required.

2.0 SUMMARY OF FIELD AND LABORATORY STUDIES

2.1 Field Explorations

An initial exploration of the St. Mary River Crossing siphon was performed by the USBR in 1999 with a follow-up performed in 2001. In 1999, three soil borings were drilled on the south slope and completed as piezometers for future water level measurements. In 2001, three additional soil borings were drilled on the north slope and two borings were drilled at each end of the proposed replacement bridge. The three soil borings on the north slope were completed as piezomenters, although only two have survived. The locations of each of the borings are shown on Figure A1 and logs of the USBR soil borings are included near the end of Appendix A.

The first field investigation by TD&H was performed in September 2005. During this investigation six soil borings were drilled to depths ranging from 23.0 to 55.2 feet at the locations shown on Figure A1 to observe subsurface soil and ground water conditions. The borings were advanced through the subsurface soils using a truck-mounted, Mobile BK-81 drill rig equipped with 8-inch O.D. hollowstem augers. Rock coring was performed in one boring (SSI-3) and approximately 10 feet of HQ-size rock core (2.375-inch diameter) was obtained. The borings were logged by Mr. Erling A. Juel, P.E. of TD&H.

In-situ soil parameters were measured adjacent to the six soil boring locations using an electric cone penetrometer during the 2005 investigation. The cone penetration test with pore water measurements (CPTu) is described by ASTM D-5778. The CPTu probe measures cone tip resistance (q_c), sleeve friction (f_s), pore pressure behind the cone tip (u_2) generated during penetration, and the tilt angle of the probe during the push. A depth synchronization unit tracks the probe depth and penetration rate as the CPTu probe is systematically pushed into the subsurface soils using 1-meter long rods. A target penetration rate of 20 mm per second was utilized and data was electronically recorded every second.

In 2006 an investigation was performed to evaluate the subsurface conditions for design of the replacement St. Mary River bridge. The replacement structure is located just south (upstream) of the existing siphon crossing. This investigation consisted of five soil borings with depths ranging from 12.7 to 45.0 feet at the locations shown on Figures A1 and A2. Copies of these logs have been included at the end of Appendix A.

A follow-up phase of geotechnical exploration was performed in the summer of 2007. This work was warranted and scoped based on the results of the monitoring program implemented after the installation of the instrumentation in 2005. The 2007 field work included the following:

- Drilled two additional HSA soil borings on the south slope, PW-1 and PW-2, to depths of 48.0 and 43.0 feet, respectively (Figure A1).
- Each boring was completed as a ground water monitoring well with one well casing sized for pump testing.
- Ten feet of HQ-size rock core was obtained.
- Ground water pump testing was performed to characterize the aquifer parameters on the south slope.
- Preliminary slope stability modeling and analysis was completed to evaluate initial slope stability issues.

In the summer of 2008, several backhoe test pits were excavated adjacent to the left siphon barrel. This work helped characterize the nature of the trench backfill conditions, siphon leakage trapped in this zone and the nature of the subsurface drain reportedly installed in the 1950's. Although related to the overall project but not contracted by DNRC, TD&H drilled five soil borings for the Montana Department of Transportation (MDT) to facilitate design of the new Glacier Country bridge now located upstream of the siphon-bridge crossing.

PROPOSED REPLACEMENT ST. MARY RIVER SIPHON

An initial geotechnical investigation of the proposed replacement siphon alignment at the St. Mary River crossing was investigated during August and September 2009. The proposed replacement alignment was located on the north side of the existing siphon. As part of this investigation a total of 13 soil borings were drilled to depths ranging from 26.5 to 80.0 feet at the locations shown on Figure B1 to observe subsurface and ground water conditions. The borings were performed using a truck-mounted, Mobile BK-81 drill rig with 8-inch O.D. hollowstem augers. Rock coring was performed in nine of the borings (09PA-1 through 09PA-9) and approximately 144 feet of HQ-size rock core was obtained. The borings were logged by Mr. Craig Nadeau, E.I. of TD&H and copies of the boring logs are included in Appendix B.

As part of this study, many of the borings were completed as either slope inclinometers, ground water monitoring wells, or both. Slope inclinometers were installed in borings 09PA-1 through 09PA-4 and 09PA-7 through 09PA-10 by installing 2.75-inch, ABS plastic inclinometer casing. In addition to the dual-purpose slope inclinometers, a total of 12 ground water monitoring wells were installed (including nested wells in borings 09PA-5 and 09PA-6). The wells were constructed using PVC plastic pipe ranging in size from ¾-inch to 1¼-inch diameter. At borings 09PA-7 through 09PA-10, a second boring was fast-augered adjacent to the slope inclinometer to set the monitoring well and were installed using 1¼-inch PVC pipe. At borings 09PA-1 through 09PA-3, the ground water monitoring well was placed in the same boring as the slope inclinometer and completed using ¾-inch PVC pipe.

During each of the geotechnical investigations described above, samples of the subsurface materials were taken using 1⅜-inch I.D. split spoon samplers. The samplers were driven 18 inches, when possible, into the various strata using a 140-pound drop hammer falling 30 inches onto the drill rods. For each sample, the number of blows required to advance the sampler each successive six-inch increment was recorded, and the total number of blows required to advance the sampler the final 12 inches is termed the penetration resistance ("N-value"). This test is known as the Standard Penetration Test (SPT) described by ASTM D-1586. Penetration resistance values indicate the relative density of granular soils and the relative consistency of fine-grained soils. Samples were also obtained by hydraulically pushing 3-inch I.D., thin-walled Shelby tube samplers into the subsoils. Logs of all soil borings, which include soil descriptions, sample depths, and penetration resistance values are presented in the Appendix associated with each alignment.

Measurements to determine the presence and depth of ground water were based on observations made during the progression of drilling and by lowering an electronic water sounder through the open boring or auger shortly after the completion of drilling. The depths or elevations of the water levels measured, if encountered, and the date of measurement are shown on the boring logs.

2.2 Instrumentation

Many of the soil borings performed adjacent to the existing siphon and along the proposed alignment of the replacement system were completed as slope inclinometers and ground water monitoring wells. Slope inclinometers are geotechnical devices used for monitoring soil deformation normal to the casing axis. The casing serves as an alignment guide for a gravity-sensing transducer to pass. Casing inclination with respect to vertical is a measure of lateral soil movements. Inclinometers are used primarily for monitoring and assessing slope stability parameters.

Slope inclinometers were installed by placing a 2.75-inch diameter, ABS plastic inclinometer casing which extended from the bottom of the boring to a height ranging from approximately one foot to three feet above the ground surface into the open boring. The outside annulus was back-filled with cement-lime-bentonite grout slurry. Many of the slope inclinometers installed along the proposed alignment were constructed as dual purpose instruments by slotting the bottom ten feet of the casing and completing the inclinometer as a ground water monitoring well to this point. A bentonite plug was placed over the well sand to prevent contamination and plugging of the well section and the remainder of the outside annulus was back-filled with cement-lime-bentonite grout slurry as was used during previous installations. A protective steel monument which was set using pre-mixed concrete was installed at the ground surface to protect each of the pieces of instrumentation installed. Specifics regarding the method of installation used for each piece of instrumentation and the thickness of the various well components are shown on the borings logs in the appendices.

2.3 Laboratory Testing

Samples obtained during the field exploration were returned to our materials laboratory where they were observed and visually classified in general accordance with ASTM D-2487, which is based on the Unified Soil Classification System. Representative samples were selected for testing to determine the engineering and physical properties of the soils in general accordance with ASTM or other approved procedures.

Tests Conducted:	To determine:
Natural Moisture Content	Representative moisture content of soil at the time of sampling.
Grain-Size Distribution	Particle size distribution of soil constituents describing the percentages of clay/silt, sand, and gravel.
Atterberg Limits	A method of describing the effect of varying water content on the consistency and behavior of fine-grained soils.
Natural Dry Density	Dry unit weight of samples, representative of in-situ conditions.
UU Shear Strength (Field)	The undrained, unconfined shear strength (s_u) of cohesive soils as determined in the field by either a pocket penetrometer or a hand torvane.
Unconfined Compression	Undrained shear strength properties of cohesive soils determined in the laboratory by axial compression.
Rock Compressive Strength	Compressive strengths of rock cores determined in the laboratory by axial compression.

Sulfate Content	Indication of a soil's potential to deteriorate normal-strength concrete.
Resistivity and pH	The combination of these properties provides a measure of a soil's potential to corrode metal.

The laboratory testing for the various geotechnical phases of this project consisted of approximately 228 moisture-visual analyses, 32 sieve (grain-size distribution) analyses, and 34 Atterberg Limits analyses. In addition, 11 unconfined compression tests of soil, 11 unit weight (in-place dry density) tests, 2 unconfined compression tests of rock, and 6 corrosion/chemical determinations were performed. The results of all moisture-visual determinations are presented on the boring logs and the laboratory reports are shown within the appendix for the associated site being investigated. The results of the chemical analyses are included as well, and are discussed further within the report. Numerous unconfined compressive strengths (q_u) were determined in the field using a pocket penetrometer. The results are shown on the boring logs at the depths the samples were tested.

3.0 SITE CONDITIONS

3.1 Geology and Physiography

The site is geologically characterized as consisting of Quaternary-aged alluvial and glacial deposits of clay, sand, and gravel and is underlain by Cretaceous-aged sedimentary bedrock of the Virgelle Formation (K_{vi}). Glacial till/drift is the most predominant soil type which blankets the upper slopes of the project site. It is typically a clay soil with varying concentrations of sand and gravel. The glacial till/drift was deposited by past widespread alpine glaciation. Alluvial deposits of sand and gravel were encountered below the glacial drift on the north slope of the siphon crossing and at lower elevations near the St. Mary River. Alluvium is deposited by flowing water and most likely represents both stream or river deposits and glacial outwash deposits. Sedimentary bedrock was encountered at depth in many of the borings performed. The geologic cross-section for the siphon crossings (existing and proposed) were prepared based on the soil borings and are presented in the associated appendices.

The appropriate 2009 International Building Code (IBC) seismic design parameters for the site include site coefficients of 1.46 and 2.33 for F_a and F_v, respectively. The site class for the site is D, and the mapped spectral response accelerations at short periods (S_s) and at 1-second intervals (S_1) are 0.63g and 0.27g, respectively. For slope masses, embankments, and active landslides, risks from seismic activity include increased driving forces from lateral acceleration and a significant reduction of resisting shear strength forces. The likelihood of seismically-induced soil liquefaction or settlement for this project is not probable and does not warrant additional evaluation.

3.2 Surface Conditions

The siphon crossing currently consists of native grasses, brush, and bushes. Locally, areas in proximity to the existing siphon have been disturbed due to the initial construction and the subsequent repairs which were required. Maintenance access roads traverse each of the siphon slopes providing access to the required drilling areas. The proposed alignment, located north of the existing siphon at the St. Mary River crossing, had experienced very little disturbance prior to our investigation. To facilitate drilling, some minor earthwork to create drilling pads was performed at two drilling locations and vehicle paths were created by the daily access to the drilling sites. Since the completion of drilling the vehicle travel paths have overgrown and the signs of disturbance are limited to those areas which required earthwork.

Both sides of the river valley slope downward toward the St. Mary River. On the north side, slopes range from 16 to 25 percent and the topography is best described as strongly sloping to moderately steep and gently rolling. Slopes on the south side range from 14 to 26 percent and the terrain is best described as being slightly hummocky.

3.3 Subsurface Conditions

3.3.1 Soils.

Subsurface soil conditions between the existing siphon alignment and the proposed replacement siphon alignment appear to be relatively consistent based on the various explorations. On the north slope, approximately 6 to 22 feet of glacial till/drift consisting of fat and lean clay with varying sand and gravel concentrations was encountered extending from the existing site grades. The fine-grained till is underlain by interbedded deposits of alluvial and/or glacial outwash soils consisting predominantly of gravels with occasional sand layers. The coarse-grained alluvium ranges in thickness from 7 to 44 feet with the overall thickness of the alluvium increasing near the top of the north slope. Sedimentary bedrock including sandstone and shale was encountered in nearly all of the borings performed along the two alignments. Bedrock depths ranged from 8.0 to 66.0 feet. Bedrock depths during the investigation correspond to elevations of approximately 4,275.5 near the St. Mary River and elevations up to 4,408.9 near the proposed Spider Lake dam. The sedimentary bedrock continued to depths of at least 80.0 feet which was the maximum depth investigated.

On the south slope, subsurface conditions consist of a fine-grained glacial till/drift extending from the ground surface to depths ranging from 23 to 37 feet. The surficial fine-grained till/drift is underlain by either alluvial sands and gravels or sedimentary bedrock. The majority of the south slope contained alluvial sands and gravels ranging in thickness from 6 to 16 feet beneath the surficial till/drift. Two boring (SSI-1 and SSI-2) near the top of the slope along the existing siphon alignment contained no significant thickness of alluvium and the glacial till/drift is believed to directly overly bedrock at these locations. The pump well installed mid-slope between SSI-1 and SSI-2 in 2007 (PW-1) encountered approximately 10 feet of alluvial gravels which are believed to lie in a depressional zone within the bedrock and represent a pocket of alluvium. The underlying sedimentary bedrock primarily consists of shale; however, interbedded zones of sandstone were observed in the core samples. The sedimentary bedrock was encountered in each of the borings performed on the south slope and extends to a depth of at least 60.0 feet which was the maximum depth investigated on the south slope.

Two soil borings, 09PA-5 and 09PA-6, from the investigation for the proposed replacement siphon alignment were drilled in proximity to the St. Mary River. Subsurface soils near the river consist of 8.0 to 11.5 feet of coarse-grained alluvium underlain by sedimentary bedrock. In addition, three borings were performed during this investigation at the location of a proposed earthen dam upstream from Spider Lake. These borings include 09PA-11 through 09PA-13 which consisted of approximately 18.0 to 53.0 feet of glacial till/drift overlying sedimentary bedrock consisting of shale. A zone of poorly-graded sand was encountered in boring 09PA-12 between the glacial till and the sedimentary bedrock from 18.0 to 23.5 feet. The top 35.3 feet of glacial till observed in 09PA-11 was classified as fill due to the heterogeneity of the material. This fill is believed to have been placed at the time of the original canal construction.

Glacial Till/Drift

Glacial derived soil deposits are encountered at both siphon crossings. These soil deposits consist predominantly of lean clay with zones of fat clay. Clay deposits ranged in thickness from 6.5 feet to 53.0 feet and were noticeably thicker on the south slope of the St. Mary River siphon. The glacial deposits contain varying concentrations of sand, occasional seams of silt and/or sand, and occasional subrounded gravels. The clay soils are soft to hard as indicated by penetration resistance values that ranged from 3 to greater than 50 blows per foot (bpf) and averaged 19 bpf. Twenty-four samples of the material obtained from various borings contained between 0 and 22 percent gravel, between 1 and 49 percent sand, and between 51 and 99 percent fines (silt and clay). The glacial till/drift exhibited liquid limits ranging from 22 to 77 percent and plasticity indices ranging from 6 to 51 percent. The natural moisture contents measured varied from 8 to 37 percent and averaged 19 percent.

Ten samples of the fine-grained soils were tested to determine typical unconfined, undrained compressive strengths. The results are summarized in Table 1 and presented in the appendices. In addition, six samples were submitted for corrosivity testing. The results are summarized in Table 2 below and included in the appendix.

Table 1 Unconfined, Undrained Compression Test Results

Boring	Sample	Depth (ft)	Soil Type	Dry Unit Weight (pcf)	Undrained Shear Strength (psf)
09PA-1	A-2502	10.2 – 10.7	Fat CLAY	104	3949
09PA-8	A-2478	20.9 – 21.5	Sandy Lean CLAY	108	2760
09PA-10	A-2492	10.3 – 10.9	Fat CLAY	89	1085
NSI-1	S-4	10.0 – 12.0	Sandy Lean CLAY	101	1155
SSI-1	S-3	7.5 – 9.5	Sandy Lean CLAY	113	975
SSI-1	S-14	35.0 – 37.0	Fat CLAY with Sand	84	545
SSI-2	S-4	10.0 – 11.0	Gravelly Fat CLAY	89	265
SSI-2	S-8	20.0 – 21.0	Fat CLAY	100	140
SSI-3	S-3	7.5 – 9.5	Sandy Lean CLAY	109	510
SSI-3	S-9A	22.5 – 23.5	Lean CLAY	111	665

Table 2 Corrosivity Test Results

Boring	Sample	Depth (ft)	Soil Type	pH	Resistivity (ohm-cm)	Soluble Sulfates (%)
SSI-1	S-3	7.5 – 9.5	Sandy Lean CLAY	8.5	5555	< 0.01
SSI-2	S-5	12.5 – 14.0	Fat CLAY	8.3	1755	0.06
SSI-3	S-1	2.5 – 4.0	Lean CLAY	8.1	5885	< 0.01
NSI-1	S-3	7.5 – 9.0	Sandy Lean CLAY	8.7	2085	0.05
NSI-2	S-2	5.0 – 6.5	Lean CLAY	9.2	2380	0.02
NSI-3	S-2	5.5 – 7.0	Sandy Lean CLAY	8.0	4545	< 0.01

Granular Alluvium / Glacial Outwash

Granular alluvium and/or glacial outwash were encountered below the glacial till in many borings; however, the majority of the alluvium is concentrated on the north slope of the St. Mary River crossing. The predominant soil type is gravel with occasional occurrences of clayey and/or silty sand. The alluvium outwash is loose to very dense as indicated by penetration resistance values which ranged from 17 to greater than 50 bpf and averaged greater than 50 bpf. Nine samples of the material obtained from various borings contained between 10 and 55 percent gravel, between 25 and 62 percent sand, and between 12 and 48 percent fines (silt and clay). Four samples of the glacial outwash exhibited liquid limits ranging from 22 to 42 percent and plasticity indices ranging from 4 to 23 percent. Three additional samples contained fines which were determined to be granular and non-plastic. The natural moisture contents of samples above the water table (when encountered) varied from 1 to 18 percent and averaged 8 percent.

Sedimentary Bedrock

Sedimentary bedrock was encountered below the alluvium or glacial till in most of the borings performed during our investigations. The sedimentary bedrock is comprised primarily of shale with occasional zones of sandstone which vary in thickness. The shale and sandstone were observed to be relatively thinly interbedded at some locations. The bedrock is highly weathered at the upper contact and the degree of weathering appears to decrease with depth. Rock cores were obtained from borings in each of the various investigations. In general, recovery from the coring was good and ranged from 60 to 100 percent and averaged approximately 90 percent. RQDs (Rock Quality Designation) measured during coring ranged from 0.13 to 0.96 and averaged 0.59. The lower RQD values were obtained near the top contact with the bedrock in which the material is still fairly soft and fissile. The sedimentary bedrock is medium dense to very dense as indicated by penetration resistance values which ranged from 29 to greater than 50 bpf and averaged greater than 50 bpf. The natural moisture contents measured varied from 4 to 28 percent and averaged 13 percent.

3.3.2 Ground Water

Ground water was encountered within 18 of the 21 borings performed by TD&H along the existing and proposed alignments at the St. Mary River crossing. Ground water was encountered at depths ranging from 4.0 to 56.0 feet below the ground surface. The ground water depths measured at the time of the investigation correspond to ground water elevations ranging from 4,274 to 4,415. Water levels were measured at the time of drilling and the presence or absence of observed ground water may be directly related to the time of the subsurface investigation. Numerous factors contribute to seasonal ground water occurrences and fluctuations, and the evaluation of such factors is beyond the scope of this report.

The slope inclinometers installed on this project are not intended to serve as ground water monitoring wells (unless constructed as dual purpose instruments such as those installed during the 2009 investigation) due to the inherent nature of their construction and the annulus grout backfill. However, the USBR installed several piezomenters along the existing siphons and additional instrumentation intended for ground water monitoring has been installed by TD&H during the investigations described previously. As part of the regular slope inclinometer data collection performed by TD&H since the first installation in 2005, readings were obtained from the piezometers installed by both TD&H and the USBR. The following tables and exhibits summarize the ground water measurements made by TD&H.

TABLE 3 - Summary Of Ground Water Elevations
St. Mary River Siphon Crossing

	North Slope					South Slope							
	DH01-SMST	DH01-SMSM	NSI-1	NSI-2	NSI-3	DH99-1	DH99-2	DH99-3	SSI-1	SSI-2	SSI-3	PW-1	PW-2
Ground Elev.	4434.13	4390.90	4433.56	4388.37	4325.06	4423.25	4387.71	4303.98	4428.90	4387.29	4335.43	4407.29	4362.90
Top Elevation	4436.68	4393.40	4436.36	4390.92	4327.86	4426.00	4390.89	4306.88	4431.67	4390.09	4338.63	4410.28	4366.08
Bottom Elev.	4393.98	4367.20	4392.76	4348.22	4301.36	4375.10	4354.69	4275.58	4373.87	4352.49	4290.83	4359.51	4322.88
Casing Length	42.7	26.2	43.6	42.7	26.5	50.9	36.2	31.3	57.8	37.6	47.8	50.77	43.2
11/4/2005	NE	4368.06	NE	NE	NE	4400.63	4365.94	4282.38	NE	NE	NE		
11/28/2005	NE	4368.04	NE	NE	NE	4400.60	4363.04	4281.93	NE	NE	NE		
1/5/2006	NE	4368.04	NE	NE	NE	4400.48	4359.75	4281.70	NE	NE	NE		
2/7/2006	NE	4368.05	NE	NE	NE	4400.43	4359.16	4281.40	NE	NE	NE		
3/8/2006	NE	4368.05	NE	NE	NE	4400.34	4359.04	4281.56	NE	NE	NE		
4/5/2006	NE	4368.05	NE	NE	NE	4400.29	4362.87	4282.83	NE	NE	NE		
5/8/2006	NE	4368.08	NE	NE	NE	4400.32	4372.60	4282.83	NE	NE	NE		
6/6/2006	NE	4368.05	NE	NE	NE	4400.40	4374.23	4283.86	NE	NE	NE		
7/10/2006	NE	4368.05	NE	NE	NE	4400.52	4376.00	4285.12	NE	NE	NE		
8/5/2006	NE	4368.05	NE	NE	NE	4400.65	4376.58	4284.46	NE	NE	NE		
9/8/2006	NE	4368.05	NE	NE	NE	4400.82	4377.82	4283.88	NE	NE	NE		
9/25/2006	NE	4368.11	NE	NE	NE	4400.91	4377.00	4283.87	NE	NE	NE		
12/20/2006	NE	4368.05	NE	NE	NE	4401.06	4362.79	4282.00	NE	NE	NE		
2/12/2007	NE	4368.05	NE	NE	NE	4400.92	4359.35	4281.54	NE	NE	NE		
3/5/2007	NE	4368.05	NE	NE	NE	4400.81	4359.01	4281.46	NE	NE	NE		
4/11/2007	NE	4368.11	4393.02	NE	NE	4400.72	4364.70	4281.47	NE	NE	NE		
5/15/2007	NE	4368.09	4393.04	NE	NE	4400.74	4372.32	4282.85	NE	NE	4290.94		
6/7/2007	NE	4368.09	4393.04	NE	NE	4400.79	4373.86	4283.59	NE	NE	4290.93		
6/27/2007	NE	4368.10	4393.06	NE	NE	4400.82	4374.46	4283.85	NE	NE	4290.93		
7/16/2007	---	---	---	---	---	4400.91	4375.68	4283.86	NE	NE	---		
8/13/2007	NE	4368.15	4393.12	NE	NE	4400.46	4376.46	4283.78	NE	NE	4290.93	4389.98	4328.63

TABLE 3 Cont. - Summary Of Ground Water Elevations
St. Mary River Siphon Crossing

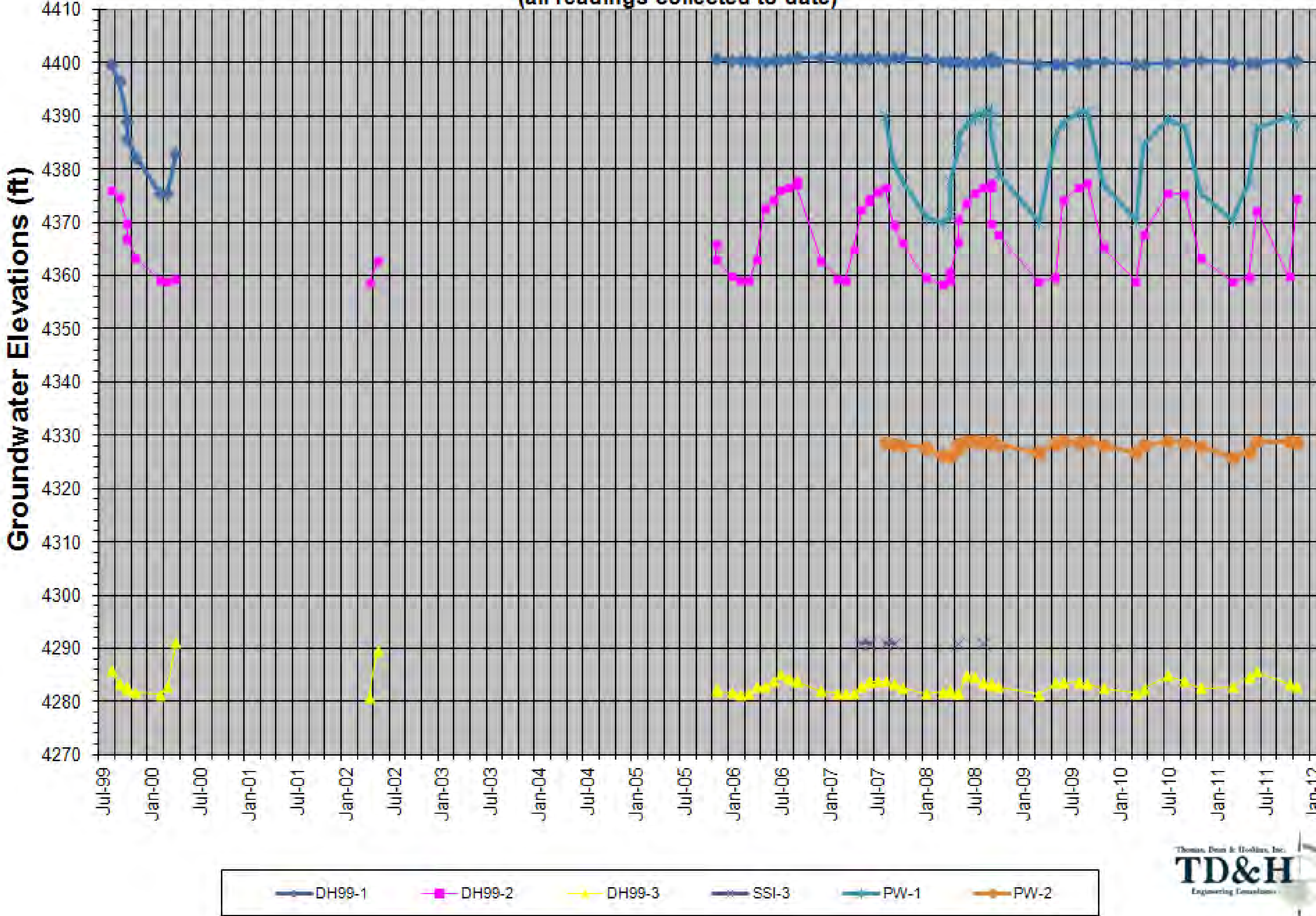
	North Slope					South Slope							
	DH01-SMST	DH01-SMSM	NSI-1	NSI-2	NSI-3	DH99-1	DH99-2	DH99-3	SSI-1	SSI-2	SSI-3	PW-1	PW-2
Ground Elev.	4434.13	4390.90	4433.56	4388.37	4325.06	4423.25	4387.71	4303.98	4428.90	4387.29	4335.43	4407.29	4362.90
Top Elevation	4436.68	4393.40	4436.36	4390.92	4327.86	4426.00	4390.89	4306.88	4431.67	4390.09	4338.63	4410.28	4366.08
Bottom Elev.	4393.98	4367.20	4392.76	4348.22	4301.36	4375.10	4354.69	4275.58	4373.87	4352.49	4290.83	4359.51	4322.88
Casing Length	42.7	26.2	43.6	42.7	26.5	50.9	36.2	31.3	57.8	37.6	47.8	50.77	43.2
9/24/2007	NE	4368.13	4393.17	NE	NE	4400.90	4369.44	4283.25	NE	NE	4290.92	4380.98	4328.41
10/15/2007	NE	4368.15	4393.18	NE	NE	4400.93	4366.20	4282.63	NE	NE	NE	4377.94	4328.16
1/4/2008	NE	4368.17	4393.24	NE	NE	4400.67	4359.59	4281.43	NE	NE	NE	4371.13	4327.69
3/21/2008	NE	4368.14	4393.25	NE	NE	4400.29	4358.41	4281.80	NE	NE	NE	4369.79	4326.20
4/7/2008	NE	4368.14	---	---	---	4400.18	4358.98	4281.99	---	---	---	4371.20	4325.99
4/11/2008	NE	4368.04	---	---	---	4400.16	4359.17	4281.91	---	---	---	4372.12	4325.96
4/18/2008	NE	4368.15	---	---	---	4400.15	4360.64	4282.10	---	---	---	4377.70	4326.18
5/5/2008	NE	4368.12	4393.25	NE	NE	4400.12	4366.47	4281.51	NE	NE	4290.93	4383.88	4327.68
5/16/2008	NE	4368.13	---	---	---	4400.19	4370.44	4281.41	---	---	---	4386.19	4328.50
6/2/2008	NE	4368.11	4393.24	NE	NE	4400.00	4373.61	4284.94	NE	NE	NE	4388.39	4329.00
7/3/2008	NE	4368.12	4393.27	NE	NE	4400.06	4375.35	4284.66	NE	NE	NE	4389.50	4329.01
7/18/2008									NE	NE	4338.63	4390.08	4328.89
8/4/2008	NE	4368.20	4393.32	NE	NE	4400.13	4376.40	4283.72	NE	NE	4290.88	4390.40	4328.74
9/2/2008	NE	4368.15	4393.32	NE	NE	4400.99	4377.35	4283.37	NE	NE	NE	4391.19	4328.78
9/17/2008	NE					4400.24	4376.50	4283.28	NE	NE	NE	4389.42	4328.84
9/22/2008	NE					4400.23	4369.79	4283.16	NE	NE	4338.63	4386.69	4328.64
10/14/2008	NE	4368.15	4393.47	NE	NE	4400.26	4367.58	4282.75	NE	NE	NE	4379.08	4328.20
3/10/2009	NE	4368.10	4393.52	NE	NE	4399.79	4358.71	4281.31	NE	NE	NE	4370.14	4326.76
5/11/2009	NE	4368.12	4393.55	NE	NE	4399.58	4359.69	4283.55	NE	NE	NE	4386.36	4328.62
6/12/2009	NE	4368.12	4393.57	NE	NE	4399.68	4374.11	4283.57	NE	NE	NE	4388.56	4328.98
8/11/2009	NE	4368.11	4393.62	NE	NE	4399.87	4376.58	4283.63	NE	NE	NE	4390.59	4328.73

TABLE 3 Cont. - Summary Of Ground Water Elevations
St. Mary River Siphon Crossing

	North Slope					South Slope							
	DH01-SMST	DH01-SMSM	NSI-1	NSI-2	NSI-3	DH99-1	DH99-2	DH99-3	SSI-1	SSI-2	SSI-3	PW-1	PW-2
Ground Elev.	4434.13	4390.90	4433.56	4388.37	4325.06	4423.25	4387.71	4303.98	4428.90	4387.29	4335.43	4407.29	4362.90
Top Elevation	4436.68	4393.40	4436.36	4390.92	4327.86	4426.00	4390.89	4306.88	4431.67	4390.09	4338.63	4410.28	4366.08
Bottom Elev.	4393.98	4367.20	4392.76	4348.22	4301.36	4375.10	4354.69	4275.58	4373.87	4352.49	4290.83	4359.51	4322.88
Casing Length	42.7	26.2	43.6	42.7	26.5	50.9	36.2	31.3	57.8	37.6	47.8	50.77	43.2
9/25/2009	NE	4368.11	4393.68	NE	NE	4400.05	4377.19	4283.27	NE	NE	NE	4390.64	4328.80
11/16/2009	NE	4368.15	4393.72	NE	NE	4400.11	4365.25	4282.53	NE	NE	NE	4377.18	4328.17
3/16/2010	NE	4368.15	4393.80	NE	NE	4399.75	4358.94	4281.60	NE	NE	NE	4370.36	4326.79
4/27/2010	NE	4368.15	4393.83	NE	NE	4399.69	4367.73	4282.43	NE	NE	NE	4384.48	4328.22
7/16/2010	NE	4368.10	4393.83	NE	NE	4399.90	4375.41	4284.88	NE	NE	NE	4389.36	4328.80
9/14/2010	4395.95	4368.00	4393.91	4350.36	NE	4400.26	4375.25	4283.79	NE	NE	NE	4387.76	4328.72
11/11/2010	4395.90	4368.11	4394.02	4354.44	NE	4400.39	4363.34	4282.51	NE	NE	NE	4375.65	4327.98
3/30/2011	4395.03	4368.05	4394.20	4360.99	NE	4400.04	4358.84	4282.76	NE	NE	NE	4370.36	4325.82
5/19/2011	4395.58	4368.15	4394.23	4383.15	NE	4399.90	4359.73	4284.71	NE	NE	NE	4377.48	4326.69
6/28/2011	4396.12	4368.10	4394.26	4384.03	NE	4399.96	4372.17	4285.69	NE	NE	NE	4387.61	4328.85
10/9/2011	NE	4368.12	4394.39	4380.43	NE	4400.27	4359.75	4283.26	NE	NE	NE	4390.02	4328.77
11/14/2011	NE	4368.15	4394.43	4378.28	NE	4400.46	4374.40	4282.80	NE	NE	NE	4388.31	4328.66

Note: DH01-SMSB, DH01-SMBW, and DH01-SMBE not completed as groundwater observation wells.
NE = Not Encountered
Starting 11/4/05 readings were obtained by TD&H. Prior to 11/4/05 readings were collected by USBR Staff

Exhibit 1 - Potentiometric Surface Elevations (PSE's)
St. Mary River Siphon - South Slope
(all readings collected to date)



TD&H Engineering Consultants

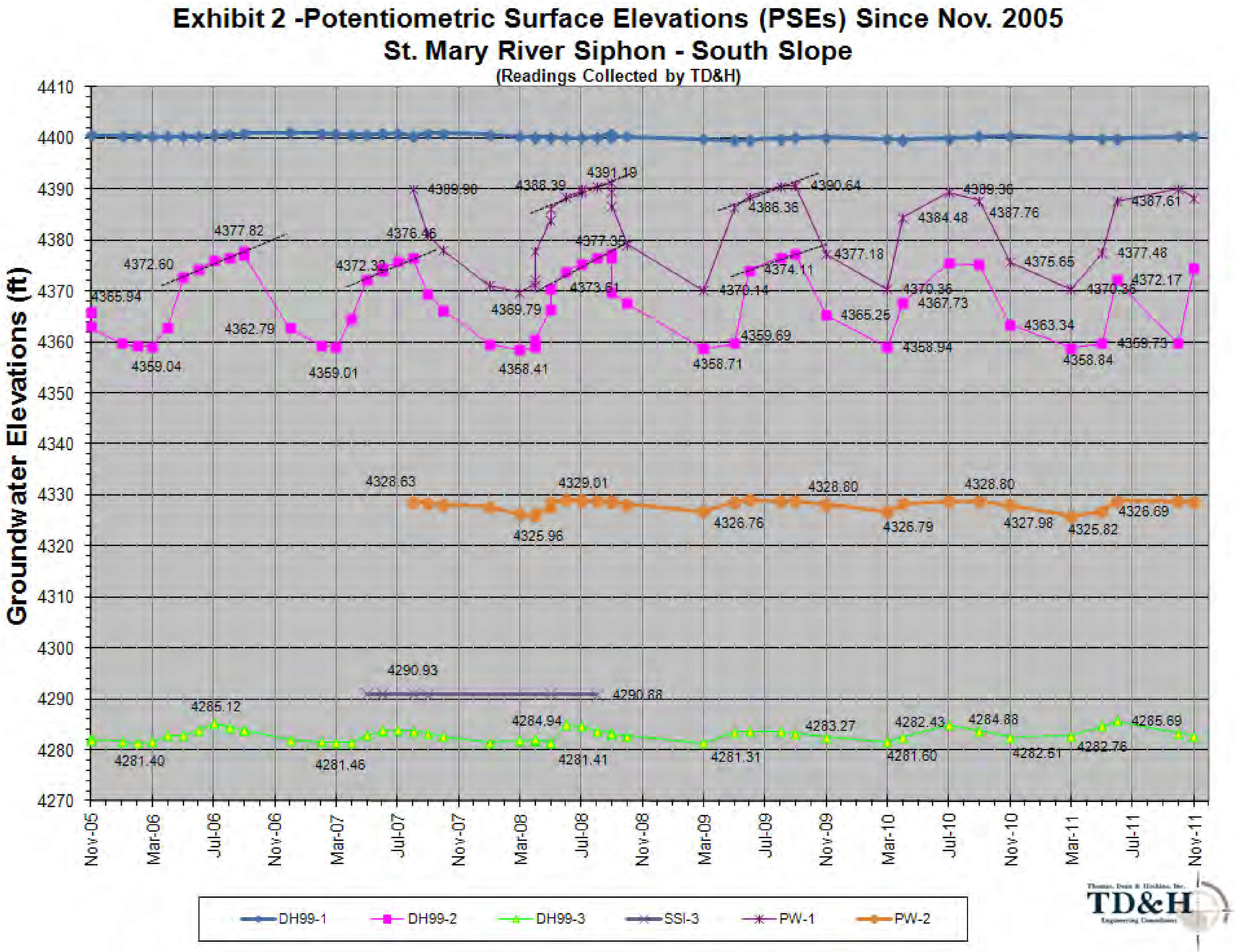


Exhibit 2 -Potentiometric Surface Elevations (PSEs) Since Nov. 2005
St. Mary River Siphon - South Slope
(Readings Collected by TD&H)
Groundwater Elevations (ft)
4410
4400
4390
4380
4370
4360
4350
4340
4330
4320
4310
4300
4290
4280
4270
Nov-05
Mar-06
Jul-06
Nov-06
Mar-07
Jul-07
Nov-07
Mar-08
Jul-08
Nov-08
Mar-09
Jul-09
Nov-09
Mar-10
Jul-10
Nov-10
Mar-11
Jul-11
Nov-11
4391.19
4389.90
4388.39
4390.64
4389.36
4386.36
4387.76
4387.61
4384.48
4377.82
4376.46
4377.35
4377.18
4377.48
4372.60
4372.32
4374.11
4375.65
4372.17
4365.94
4373.61
4370.14
4370.36
4370.36
4369.79
4367.73
4362.79
4365.25
4363.34
4359.69
4359.73
4359.04
4359.01
4358.41
4358.71
4358.94
4358.84
4328.63
4329.01
4328.80
4328.80
4326.76
4326.79
4327.98
4326.69
4325.96
4325.82
4290.93
4290.88
4285.12
4284.94
4283.27
4282.43
4284.88
4285.69
4281.40
4281.46
4281.41
4281.31
4281.60
4282.61
4282.76
DH99-1
DH99-2
DH99-3
SSI-3
PW-1
PW-2
TD&H

TABLE 4 - Summary Of Ground Water Elevations
St. Mary River Siphon Crossing - Proposed Alignment

	North Slope(Proposed Alignment)								South Slope (Proposed Alignment)											
	09PA-1SI	09PA-1MW	09PA-2SI	09PA-3SI	09PA-3MW	09PA-4SI	09PA-5A	09PA-5B	09PA-6A	09PA-6B	09PA-6C	09PA-7SI	09PA-7MW	09PA-8SI	09PA-8MW	09PA-9SI	09PA-9MW	09PA-10SI	09PA-10MW	09PA-12MW
Ground Elev.	4450.68	4450.68	4417.08	4370.76	4370.76	4308.30	4286.85	4286.85	4284.09	4284.09	4284.09	4324.52	4325.02	4362.37	4361.92	4396.49	4396.95	4416.42	4416.00	4410.75
Top Elevation	4452.02	4451.69	4419.00	4372.52	4371.78	4311.00	4288.68	4288.79	4285.80	4285.67	4285.74	4326.46	4326.58	4364.20	4363.14	4398.14	4398.75	4418.44	4418.22	4412.90
Bottom Elev.	4371.07	4387.64	4339.05	4339.86	4353.24	4273.33	4255.58	4275.47	4255.43	4268.78	4275.84	4271.88	4285.20	4303.29	4313.24	4341.34	4359.95	4371.47	4377.27	4390.93
Casing Length	80.95	64.05	79.95	32.66	18.54	37.67	33.10	13.32	30.37	16.89	9.90	54.58	41.38	60.91	49.90	56.80	38.80	46.97	40.95	21.97
9/25/2009	4394.80	4394.72	4383.86	4347.29	NE	4279.55	4275.99	4275.98	4277.63	4277.58	4277.69	4283.75	NE	4316.53	4315.19	4374.25	4375.46	4409.53	4409.36	4407.03
11/16/2009	4394.80	4394.65	4384.05	4346.85	4353.18	4279.59	4276.09	4276.11	4277.48	4277.40	4277.58	4283.46	NE	4315.97	4314.29	4368.41	4366.00	4397.36	4396.93	4406.91
3/16/2010	4394.04	4393.93	4383.89	4347.18	4354.17	4279.55	4275.86	4275.87	4276.74	4276.73	4276.76	4282.98	NE	4315.46	4313.90	4363.05	4361.30	4391.92	4392.25	4407.24
4/27/2010	4393.97	4393.92	4383.91	4347.73	NE	4278.57	4276.39	4276.40	4277.67	4277.65	4277.85	4283.10	NE	4315.61	4313.88	4366.96	4369.05	4407.47	4409.17	4408.12
7/16/2010	4395.73	4392.40	4384.13	4349.27	NE	4279.65	4277.57	4277.59	4280.10	4279.95	4280.11	4284.58	NE	4317.12	4315.26	4373.55	4374.52	4409.74	4409.33	4409.07
9/14/2010	4398.11	4398.13	4384.67	4350.94	NE	4279.60	4276.94	4276.95	4278.42	4278.35	4278.72	4283.87	NE	4317.03	4315.06	4374.55	4373.93	4408.93	4406.67	4408.70
11/11/2010	4397.80	4397.77	4384.74	4350.70	NE	4279.59	4276.54	4276.54	4277.59	4277.52	4277.83	4283.53	NE	4315.95	4314.01	4367.32	4364.64	4397.00	4395.87	4407.54
3/30/2011	4396.26	4396.18	4384.57	4350.18	4353.81	4279.59	4276.48	4276.48	4278.08	4278.04	4278.27	4283.29	NE	4315.35	4313.86	4362.98	4361.28	4392.26	4392.24	4407.62
5/19/2011	4397.40	4397.33	4384.79	4350.93	4353.90	4279.63	4277.94	4277.95	4280.05	4279.93	4280.13	4284.19	NE	4315.42	4313.76	4365.61	4364.84	4398.56	4404.85	4408.78
6/28/2011	4398.29	4398.26	4385.02	4352.67	4355.46	4279.68	4278.84	4278.85	4280.95	4280.77	4280.83	4284.81	NE	4316.52	4314.80	4372.19	4374.57	4409.02	4408.43	4409.28
10/9/2011	4398.14	4392.38	4385.27	4351.70	NE	4279.58	4276.79	4276.81	4278.12	4278.05	4278.26	4283.60	NE	4316.75	4314.92	4374.72	4374.63	4409.57	4409.22	4408.22
11/14/2011	4397.46	4397.38	4385.17	4350.47	NE	4279.56	4276.19	4276.22	4277.72	4277.63	4277.92	4283.73	NE	4316.74	4314.80	4374.49	4373.73	4408.30	4407.89	4408.17

Note: NE = Not Encountered

Slope Inclinometers 09PA-1 through 09PA-12 completed as Dual Purpose Instruments

No instrumentation was installed at 09PA-11 and 09PA-13

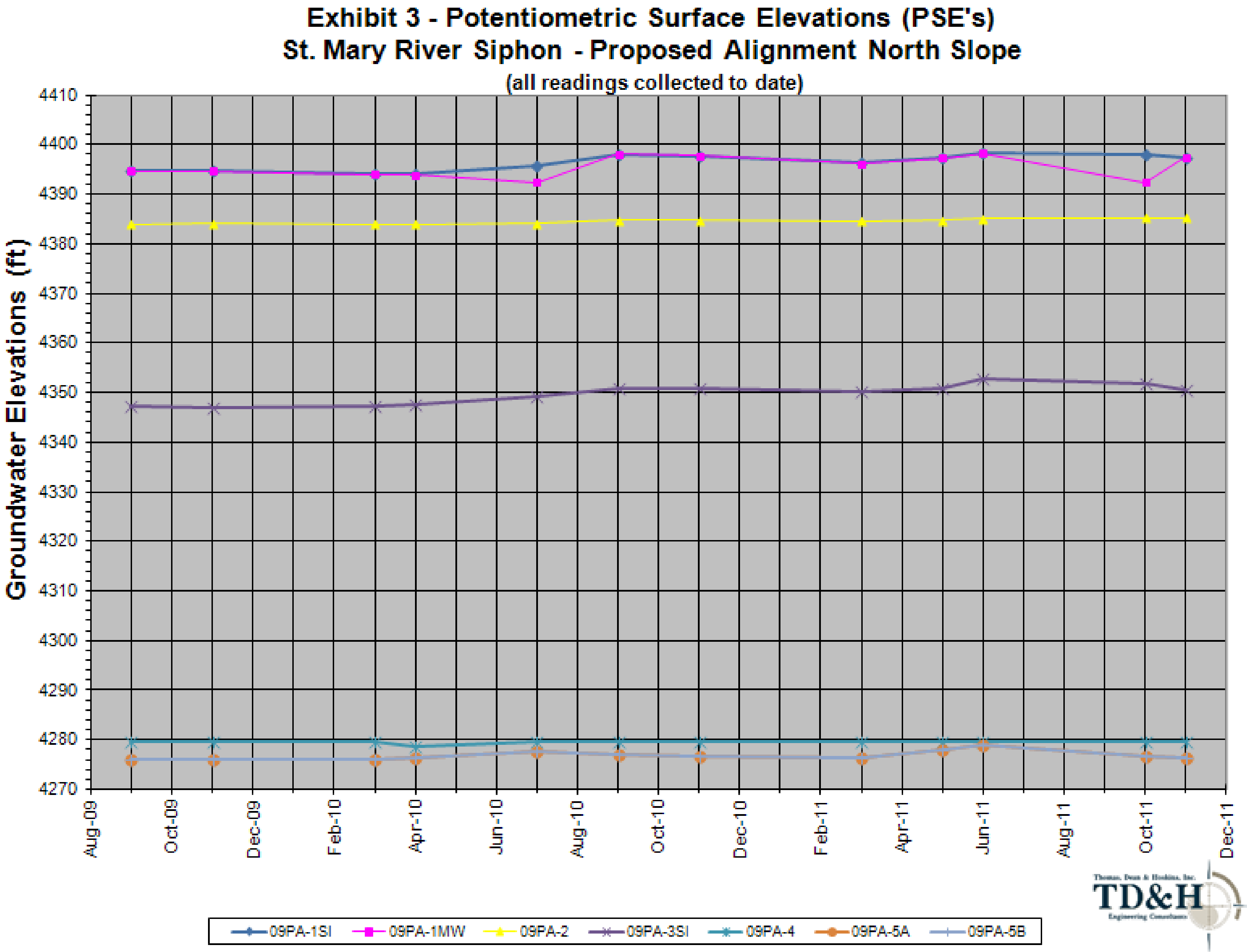


Exhibit 3 - Potentiometric Surface Elevations (PSE's)
St. Mary River Siphon - Proposed Alignment North Slope
(all readings collected to date)
Groundwater Elevations (ft)
4410
4400
4390
4380
4370
4360
4350
4340
4330
4320
4310
4300
4290
4280
4270
Aug-09
Oct-09
Dec-09
Feb-10
Apr-10
Jun-10
Aug-10
Oct-10
Dec-10
Feb-11
Apr-11
Jun-11
Aug-11
Oct-11
Dec-11
09PA-1SI
09PA-1MW
09PA-2
09PA-3SI
09PA-4
09PA-5A
09PA-5B
TD&H

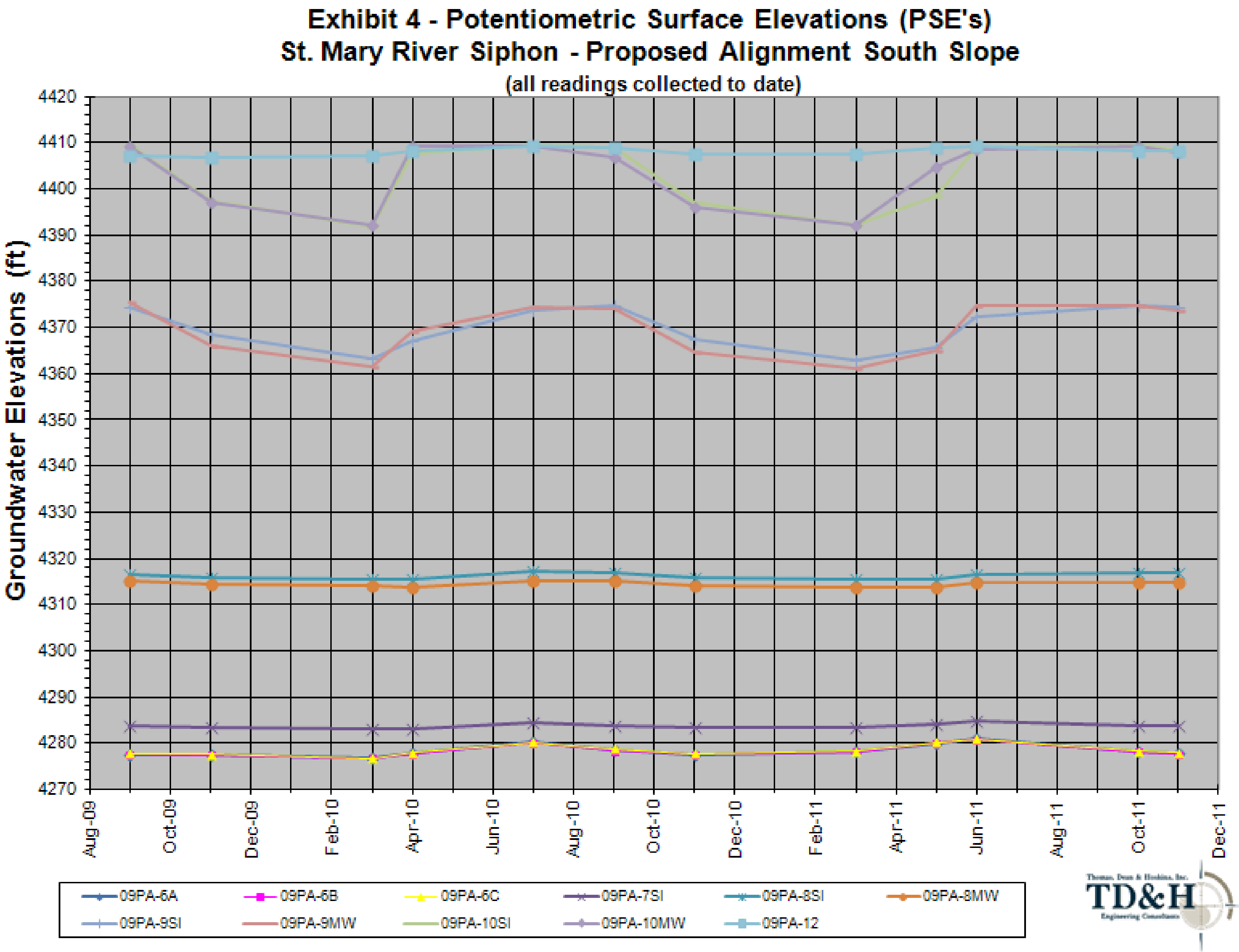


Exhibit 4 - Potentiometric Surface Elevations (PSE's)
St. Mary River Siphon - Proposed Alignment South Slope
(all readings collected to date)
Groundwater Elevations (ft)
4420
4410
4400
4390
4380
4370
4360
4350
4340
4330
4320
4310
4300
4290
4280
4270
Aug-09
Oct-09
Dec-09
Feb-10
Apr-10
Jun-10
Aug-10
Oct-10
Dec-10
Feb-11
Apr-11
Jun-11
Aug-11
Oct-11
Dec-11
09PA-6A
09PA-6B
09PA-6C
09PA-7SI
09PA-8SI
09PA-8MW
09PA-9SI
09PA-9MW
09PA-10SI
09PA-10MW
09PA-12
Thomas, Dean & Hoskins, Inc.
TD&H
Engineering Consultants

4.0 ENGINEERING ANALYSIS

4.1 Introduction

Both the north and south sides of the existing St. Mary River siphon have a history of slope movements which have impacted siphon performance and necessitated numerous repairs. Repairs consisting of installing replacement expansion/contraction joints have been performed on both siphons in the past as recently as 2006. Slope movements are on-going and can be characterized as follows:

- The older, buried siphon experiences more movement-related distress than the newer siphon which is supported above ground.
- The south slope exhibits more siphon movement than the north slope.
- Slope and siphon movements are seasonal and directly a function of ground water levels and/or operation of the diversion facilities

Translation and rotation of the concrete supports (Photo 5) tend to reduce the frictional drag from ground movements relative to the adjacent buried siphon. Also, leakage from the above ground supported siphon tends to promote runoff whereas leakage from the buried siphon tends to saturate the surficial and supporting soils. These two combined observations result in the older, buried pipe being more prone to displacements than the elevated pipe.

Continual downward slope movements create internal stresses within the siphon barrels that tend to resist movements. The siphon barrel eventually buckles when the cumulative drag forces imposed by the moving soil exceed the internal strength of the siphon material itself. Tendency for buckling is enhanced when driving and resisting forces become eccentric. The use of expansion/contraction joints allow siphon movements to occur and reduces the buildup of resisting forces until full travel of the joint is realized. On the other hand, expansion/contraction joints offer little resistance to siphon movements and thereby facilitate siphon movement.

Design of the replacement siphon structure must consider the current or potential slope stability issues in order to ensure acceptable long-term performance. The studies performed to date provide background information and recommendations to be considered during final design. The recommendations contained within this report should be reviewed and revised as appropriate once a final alignment and construction details of the replacement structure have been established.

4.2 Slope Inclinometers

Regular readings of the slope inclinometers installed at the existing St. Mary River crossing and along the preliminary replacement alignment have been obtained since completion of the various installations. The results of the slope inclinometers vary depending on location and will be addressed separately below.

EXISTING ST. MARY RIVER SIPHON

The slope inclinometers constructed along the existing alignment of the St. Mary River siphon include a total of six instruments. Regular data obtained from these instruments since their installation in 2005, indicate that both slopes of the existing alignment are experiencing sliding of varying magnitudes. On the north slope, the boring located at mid-slope (NSI-2) has undergone movement on the order of 1¾-inches since the beginning of monitoring in October 2005. The sliding appears to be occurring at a depth of approximately 11.0 feet which corresponds relatively closely with the contact between the glacial till and the underlying alluvium. The remaining inclinometers on the north slope have experienced much smaller movements on the order of approximately ¼-inch. The movements appear to be occurring within the glacial till and occur approximately four to six feet above the contact with the underlying alluvium. In the case of both NSI-1 and NSI-2, the slope movements are occurring at a depth which exhibited a spike in soil moisture and an overall softening of the clay during the original drilling exploration.

Two of the three instruments installed on the south slope indicate clearly defined slide planes. The slope inclinometer constructed at the top of the south slope (SSI-1) does not indicate any significant movements or trends. All movements measured at this instrument occur within the top 3 feet and appear to be surficial in nature. The remaining two inclinometers indicate movements on the order of 1½ to 2 inches. Readings were unable to be obtained from the mid-slope instrument (SSI-2) during the most recent data collection which occurred on November 14, 2011. Excessive slope movements had restricted the opening of the inclinometer casing beyond the required diameter to safely lower the instrument into the casing. The slide planes on the south slope are occurring at depths of 22 and 18 feet in SSI-2 and SSI-3, respectively. The slide plane measured in SSI-2 corresponds closely with the contact between the glacial till and the underlying sandstone bedrock, similar to what was seen on the north slope. At SSI-3, the slide plane has formed within the glacial till, approximately five feet above the contact with the underlying alluvium. As was observed on the north slope, this depth corresponds closely to a zone of increased moisture and decreased unconfined compressive strength measured in the field using a pocket penetrometer. All of the inclinometers indicate that the underlying granular alluvium and sedimentary bedrock is stable and minimal movements have been observed historically.

PROPOSED ST. MARY RIVER SIPHON ALIGNMENT

The slope inclinometers constructed along the proposed alignment of the replacement siphon at the St. Mary River crossing include a total of eight instruments. Data obtained from these instruments since their installation in 2009, indicate that slope movements have occurred on both slopes and are similar in nature to those observed adjacent to the existing siphon. Movements observed on the north slope are relatively small in magnitude and range from less than ¼-inch to as much as ½-inch. The depth of the sliding varies from 6 to as deep as 22 feet along this portion of the proposed alignment. The slide planes from all four instruments correspond relatively well with the elevation of the contact between the glacial till and the underlying alluvium.

A total of four instruments have been installed on the south slope of the proposed alignment. Three of these instruments are located on the main slope and have undergone movements of similar depth and magnitude as those observed on the existing siphon. Movements for these three instruments range from 1-inch to 1½-inch. The movements being observed in inclinometers 09PA-7 and 09PA-9 (bottom and top of slope) are occurring at a depth of approximately 25 feet. This depth corresponds closely with the transition from glacial till to the underlying alluvium in both cases. Inclinometer 09PA-8, installed at mid-slope, has undergone movements of approximately 1-inch which are occurring at a depth of approximately 30 feet. This zone is approximately eight to ten feet above the underlying alluvium; however, this zone did exhibit increased moisture and decreased strength as was observed on previous inclinometers. The final inclinometer (09PA-10), is located down station from the top of the south slope (See Figure B-1). This inclinometer indicates that minimal movements less than ¼-inch have occurred. The movements appear to be occurring above the alluvium within the glacial till. Minimal deviation in the inclinometer data is first observed approximately five feet above the alluvium. While minimal movements are observed at this depth, the majority of the movements appear to be concentrated around a depth of approximately 15 feet. The material encountered within this boring between 10 and 15 feet exhibited increased moisture and decreased undrained shear strengths measured using the pocket penetrometer. This similar phenomenon was seen at other inclinometers; however, the overall magnitude of the movements observed is likely reduced due to the rather shallow slope to the surface terrain at this location.

4.3 Slope Stability Issues

4.3.1 Introduction

The slope stability history of the siphon crossing prior to the original siphon construction in 1915 is not known. Hummocky terrain on the south slope of St. Mary River crossing suggests instability prior to siphon construction. In addition, the alignment of the proposed replacement siphon is a reasonable distance from the existing siphon and separated by sufficient surface contours to assume that leakage from the existing siphon would have minimal impact on the slope along the proposed alignment. The proposed alignment exhibits measurable slope movements at each of the inclinometers installed on the south side of the crossing. The terrain on the north side of the crossing does not support the theory of natural instability and the measurements made along the existing alignment agree. The existing alignment has undergone minimal movements during monitoring and all movements are occurring at relatively shallow depths.

4.3.2 Ground Water

Ground water levels have been measured by TD&H personnel since November 2005 and the amount of readings obtained expanded to include the additional instrumentation as it was installed over the years. Potential sources of ground water in vicinity to the siphon crossings include the following:

- Leakage from the unlined canal prism upstream and downstream of the siphon transition structures
- Leakage from the concrete to steel siphon interfaces at the transition structures
- Leakage from the siphon barrels and expansion/contraction joints
- Storm water infiltration due to surface irregularities on the slopes
- Natural occurring sources of ground water

In general, the glacial clay soils are relatively impervious; however, excavation and the construction of the buried siphon created a ready seepage path for upslope leakage to follow which increased shear strength softening directly below and adjacent to the buried siphon sections. Also, as movements of the siphon occur, whether above or below ground, leakage tends to increase which further exacerbates slope instability.

In general, the ground water monitoring wells located along the siphon exhibit ground water fluctuations that reach seasonal highs in September and lows in March. A similar phenomenon was observed in the ground water monitoring equipment installed along the proposed alignment; however, the magnitude of the variation in ground water levels was minor and appeared only on a small portion of the overall alignment. This corresponds to the natural fluctuation of ground water levels as well as the seasonal operation of the canal facilities. The range of ground water levels to date for each observation well is shown on the geologic cross-sections. To date, seasonal fluctuations within the monitoring wells installed along the St. Mary River crossing siphon (existing and proposed) range from less than one foot to greater than 20 feet. Larger fluctuations in the ground water levels are observed in monitoring wells located at the top of the slopes, which are closest to the canal and the transition structures. Along the proposed alignment, the only measurable fluctuations are observed in 09PA-1, 09PA-9, and 09PA-10 all of which are located at the top of the slopes and closest to the canal prism. Minimal fluctuations were observed within the other ground water monitoring instruments along this alignment. Overall fluctuations tend to decrease as you move down slope which supports the theory that ground water levels are strongly impacted by the loss of water in the canal prism and at the transition structures. Fluctuations observed down slope are likely due to leaking of the existing siphon which impact soils in close proximity to the siphon.

Along the south slope of the St. Mary siphon, ground water was observed to be in a confined condition within the fractured sandstone in borings SSI-1 and SSI-2. A similar phenomenon was observed in boring PW-1 within a pocket of isolated alluvium. The overlying impervious clay provides an “impermeable” layer through which water flow is very limited. During drilling, penetration into the sandstone allowed the ground water to rise up into the soil boring. The confining hydrostatic pressures acting on the base of the clay confining layer are on the order of 610 psf (9.75 ft) in SSI-1 and 500 psf (8 ft) in SSI-2. The alluvium encountered between the glacial till and the bedrock along the proposed alignment reduces the potential for the accumulation of significant hydrostatic pressures; however, a relatively thin alluvium section encountered at 09PA-9 and 09PA-10 along with increased ground water level created a similar confined flow situation with hydrostatic pressures on the order of 220 psf (3.5 feet) and 840 psf (13.5 ft), respectively. These pore water pressures and hydrostatic forces are most likely a primary contributing factor to a deep seated failure plane along the south slope and is likely the sole cause of slope movements on the relatively flat slope near 09PA-10.

4.3.3 Soil Shear Strengths

Our experience with similar till soils indicates that the residual drained shear strength angle (ϕ) is commonly between 8 and 18 degrees. Residual shear strength in the clay would tend to develop with increasing displacements along a developed slide plane. The existing slopes vary from 14 to 26 percent (8 to 15 degrees) along the St. Mary River siphon. Increased moisture within the clay mass would tend to reduce the overall shear strength of the soil in localized areas. Seepage paths through the clay would tend to be softer, weaker, and more susceptible to sliding.

4.3.4 Slope Stability Modeling

Based on the location of known slides obtained from the inclinometer data, the soil properties of the various layers were back calculated using Slope-W, a slope stability modeling software which is part of the GeoStudio package. Inclinometer data indicate that the underlying alluvium and bedrock are stable and only minimal movements have been recorded near the very surface of the alluvial deposits.

The primary causes of the slope movements appear to be related to seasonal high water levels and impacts of soil softening due to leaking of the existing siphon system. The south slope appears to suffer from inherent instabilities due to the slope topography, geology, and the seasonal high ground water elevations. The impacts of the existing system are extremely difficult to model due to the complexity of the situation. Thus, the proposed replacement alignment on the south slope was used to back calculate properties of the glacial till. Impacts of the existing system are likely to affect the results of the inclinometer data along the existing alignment which may result in slightly erroneous soil properties. The proposed alignment is sufficient distance away from the existing system and separating by enough grade change that potential impacts to this portion of the slope are reduced. The soil properties, shown in the table below, were back calculated for the glacial till to provide failure conditions (safety factor equal to 1.0) under high ground water conditions.

Soil Type	Unit Weight, γ (pcf)	Friction Angle, ϕ (deg)	Cohesion, c (psf)
Glacial Till	130	5.0	170
Alluvium	140	44.0	0
Sandstone Bedrock	Impenetrable		

The soil properties shown above are assumed constant within each distinct soil type and exhibit no variation with depth or location on the slope. This assumption is likely unrealistic as soil strength properties commonly vary with both depth and moisture, as can be seen when looking at the pocket penetrometer results shown on the boring logs. The values shown above are considered average values within the profile and values both higher and lower than those shown are likely present.

Using the soil properties shown above, the majority of the known slides were able to be replicated with factors of safety of approximately one, which indicates failure conditions. Some slide locations were not able to be replicated or did not achieve safety factors indicating failure, especially on the north slope. This is partially due to the limits of the model developed; however, instabilities observed in field instrumentation are believed to be the result of leaking from the existing siphon system, which could not be accurately incorporated into the model. The model was used to evaluate the effectiveness of slope drainage and seismic activity on overall slope stability.

In those zones which experience high hydrostatic uplift forces due to the confined flow of the ground water, such as the top of the south slope, a slope drainage system would help to improve the overall stability of the crossing. However, portions of the slope experience no hydrostatic uplift and still exhibit relatively deep seated movements which are likely due to the steep terrain and geologic conditions.

For the seismic analysis, peak horizontal ground accelerations of 0.005g and 0.035g were analyzed. These values represent the peak horizontal ground accelerations for a 10-year and 100-year return interval, respectively. During seismic events of these magnitudes, safety factors were reduced by approximately 2.5 percent and 19 percent, respectively.

Based on the field data collected and the long term performance of the existing structure, it is apparent that the slopes are not stable. This modeling demonstrated that methods to reduce the hydrostatic pore pressures within the slope, such as a horizontal drain system, are valid approaches and will help improve the stability of portions of the slope. Ground water and seepage from the existing siphon appear to be a significant driving force in the overall instability; however, the natural geology and grade of both slopes create inherent instabilities. These instabilities are increased by the addition of water or potential seismic activity in the area.

4.4 Replacement Siphons

To reduce seepage and increases in soil-moisture on the slopes, considerations should be given for lining portions of the canal prism both upstream and downstream of the siphon transition structures. In addition, attention should be given to the interface between the transition structure and the siphon to further reduce leakage and seepage.

In our opinion, slope movements on the south slope of the St. Mary River crossing are a combination of shallow and deep-seated failures. The shallow movements are likely related to siphon operations while the deep-seated movements are most likely naturally occurring. These deep-seated movements are a product of the subsurface soil and ground water conditions present on the slope. However, leakage from the canal prism downstream of the outlet may be contributing to ground water flows exiting the natural drainage swale in the vicinity of the south slope. The proposed alignment, which should see minimal impacts from the operation of the existing canal system, exhibited significant slope movements during the two-year period of monitoring. Based on the overall instability of the south slope, we feel it is prudent to either support the replacement siphons above ground or utilize a deep excavation and replacement backfill prism incorporating ground stabilization. To increase the cost effectiveness of a deep excavation alternative, a single large diameter siphon barrel would be required. Incorporation of a horizontal drain system in the south slope would also help to significantly reduce the magnitude of potential movements.

Based on the findings from the investigations and monitoring performed, it is our opinion that the replacement siphon on the north slope of the St. Mary River crossing can either be buried or supported above ground depending on the configuration chosen for the replacement structure. The slope is generally more stable than the south slope at this crossing; however, minor movements are already occurring along the proposed alignment. The movements are occurring at the contact between the surficial till and the underlying alluvium encountered at depths ranging from 7 to 22 feet below current site grade. A buried siphon installation using a single barrel would likely extend to depths on the order of 15 to 20 feet. With this alternative the excavation could cost effectively be continued deeper at specific locations to remove the remaining till. The overexcavation would subsequently be filled with compacted granular backfill which would increase the strength and drainage around the siphon and improve overall stability of the slope.

Lining of the canal prism (both upstream and downstream) as well as improvements to the transition structures to minimize leakage will be important in reducing the potential for additional sliding and improve the long term performance of this replacement structure. Design of the any above ground support structures must include provisions for siphon adjustment in the event the supports should move. The foundations for these supports would likely include driven piling or drilled shafts extending down into bedrock or to sufficient depth within the alluvium to resist potential sliding. A conceptual detail for an elevated siphon installation is shown in Figure C1. Alternatively, a buried installation should consider the use of a single, large diameter siphon barrel to increase the depth of the excavation which will cut off many of the existing slide planes. This design should also incorporate a drainage system integral to the backfill zone to intercept and convey leakage, seepage, and infiltration away from the foundation soils. A conceptual detail of a buried installation utilizing a single replacement pipe is shown in Figure C2. The ground surface should be revegetated and sloped to drain away from the buried siphon to reduce infiltration. Also, siphon anchorage, tied into the underlying bedrock, should also be included in the final design to provided additional resistance against potential sliding.

4.5 Slope Stability Enhancements

The slope instabilities and ground movements impacting the St. Mary River siphon are a combination of relatively shallow and deep seated slope movements. The shallow movements appear to be limited to the local area surrounding the siphon structure; however, deep-seated movements are documented to be occurring on both alignments. Deep-seated movements appear to be mainly occurring on the south slope of the river crossing; however, instabilities were commonly noted on the north slope at the contact with the glacial till and the underlying alluvium. The shallower movements appear to be primarily due to increases in infiltration and soil moisture in proximity to the existing siphons. These increases in moisture lead to softening of the supporting soil and an overall loss of strength. Methods to improve the drainage around the existing siphon structure would tend to reduce pore pressures within the soil mass. The reduction in pore pressures would simultaneously increase the shear strength of the soil and decrease the total driving forces acting on the slope.

The main sources of the additional moisture are due to natural annual precipitation and the additional loss of water from the siphon structure. Of these two factors, only the loss of water by the system is within our control; however, improved drainage surrounding the structure will help with the management of the naturally occurring precipitation. The monitoring wells along the slope show a strong correlation between ground water elevations and the length of canal operation. At the time of the seasonal canal start-up, the ground water levels are near the lowest elevation. The ground water levels gradually rise and reach their peak near the end of the operation season for the system. Once the canal is shut-down for the season, the ground water levels gradually return to the base values. This trend is readily seen on Exhibits 1 and 2 and the trend is better defined in years prior to 2009 in which more frequent data collection was performed.

As discussed previously, the main sources of water infiltration from the siphon system are due to leaks from the pipes themselves and infiltration through the unlined canal prism upstream and downstream of the siphon. Reduction in these two factors should have a beneficial influence on the overall stability of the slopes. This approach would include prompt repair and maintenance of the existing siphons to repair leaks and minimize water losses and potential lining of the upstream and downstream canal prism. Additional improvements in the overall stability of the slopes may be realized by implementing a horizontal drain system as described in our previous design report dated April 2008. This horizontal drain system is designed to help alleviate the hydrostatic pressure acting at the base of the glacial till which is a major driving force in the overall instability on the south slope. Large hydrostatic forces are not seen on the north slope due to the thickness of the alluvium; thus, installation of a horizontal drain system would not necessarily provide substantial improvements to the stability of the north slope.

These potential improvements are considered relatively short-term in nature, as the existing siphon structure is in poor condition. These options will help to reduce the seepage volumes and minimize the potential for slope movements until a replacement siphon system can be designed, constructed, and placed into operation. These alternatives will require seasonal maintenance and/or repair which can be quite costly if implemented for a long-term fix of this system. The horizontal drain system should be installed and stay in use after the construction of the new siphon system. The horizontal drains will help reduce the magnitude of hydrostatic pressures which develop at the base of the glacial till and minimize the risk of slope movements which may impact the recommended above ground siphon supports. Continued monitoring of slope movements and ground water elevations prior to and after the implementation of any improvements or replacement structure will help in gauging their effectiveness and functionality.

5.0 RECOMMENDATIONS

5.1 General

1. Periodic or annual inclinometer and piezometer monitoring should be continued until final design of the replacement siphons has been completed. It is important to obtain and review this additional data to confirm or modify the recommendations provided in this report. In addition, collection of seasonal data will provide a baseline for evaluating the effectiveness of future improvements and/or replacement systems.

5.2 Replacement Siphons

2. Considerations should be made for lining portions of the canal prism both upstream and downstream of the siphon transition structures to help reduce seepage and the introduction of additional moisture to the siphon slopes. These improvements will help minimize the addition of ground water and provide some improvement to the overall stability of the slopes.

3. The corrosivity analyses on similar soils indicate that the soils are corrosive to bare metal and aggressive to normal concrete. Based on our past experience and laboratory testing and field observations, moderate concentrations of water-soluble sulfates are common in the local clay soils. The concentration of sulfates is considered detrimental causing deterioration of concrete. Sulfate resistant cement (Type V) or Type II cement with a maximum of 8 percent C_3A (tricalcium aluminate) content should be used in all concrete exposed to the native clay soils. Likewise, the native clay soils have a known propensity for moderate to severe corrosion activity towards unprotected, bare metal surfaces. Corrosion protection schemes should be incorporated into the designs where applicable.

4. The slope movements occurring on the slopes require either an above ground supported system similar to that shown on Figure C1 or a deep excavation and backfill system similar to that shown on Figure C2. The buried alternative is best suited for a single, large diameter replacement siphon which will maximum the excavation depth and effectively cut off many of the existing slide planes. The above ground supported system is best suited for a replacement siphon utilizing two or more, smaller diameter barrels. In order to maintain continuity between the two sides of the crossing we recommend that the same configuration be used for both slopes.

5.3 Slope Stability Enhancements

5. Installation of a horizontal drain system on the south slope will help alleviate the high hydrostatic pressures which act as a driving force for the instability of the slope. Reductions in the hydrostatic forces will provide an increase in the overall stability for both alignments if constructed to span the hillside.

6. Improvements discussed above (Item 2) to reduce potential infiltration should be considered for the existing system if a substantial amount of time is anticipated prior to construction of a replacement system. Any reduction in the volume of the seepage which enters the slope will help reduce the potential for sliding and help control potential maintenance costs.

5.4 Continuing Services

7. Consultation between the geotechnical engineer and the design professionals during the design phases is highly recommended. This is important to ensure that the intentions of our recommendations are incorporated into the design, and that any changes in the design concept consider the geotechnical limitations dictated by the on-site subsurface soil and ground water conditions.

6.0 LIMITATIONS

This report has been prepared in accordance with generally accepted geotechnical engineering practices in this area for use by the client for design purposes. The findings, analyses, and recommendations contained in this report are based on site conditions encountered and further assume that the results of the exploratory borings are representative of the subsurface conditions throughout the site, that is, that the subsurface conditions everywhere are not significantly different from those disclosed by the subsurface study. If during construction, subsurface conditions appear different from those encountered during our study, this office should be advised at once so we can review these conditions and reconsider our recommendations, when necessary.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by a limited number of soil borings and laboratory analyses. Such unexpected conditions frequently require that additional expenditures be made to obtain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

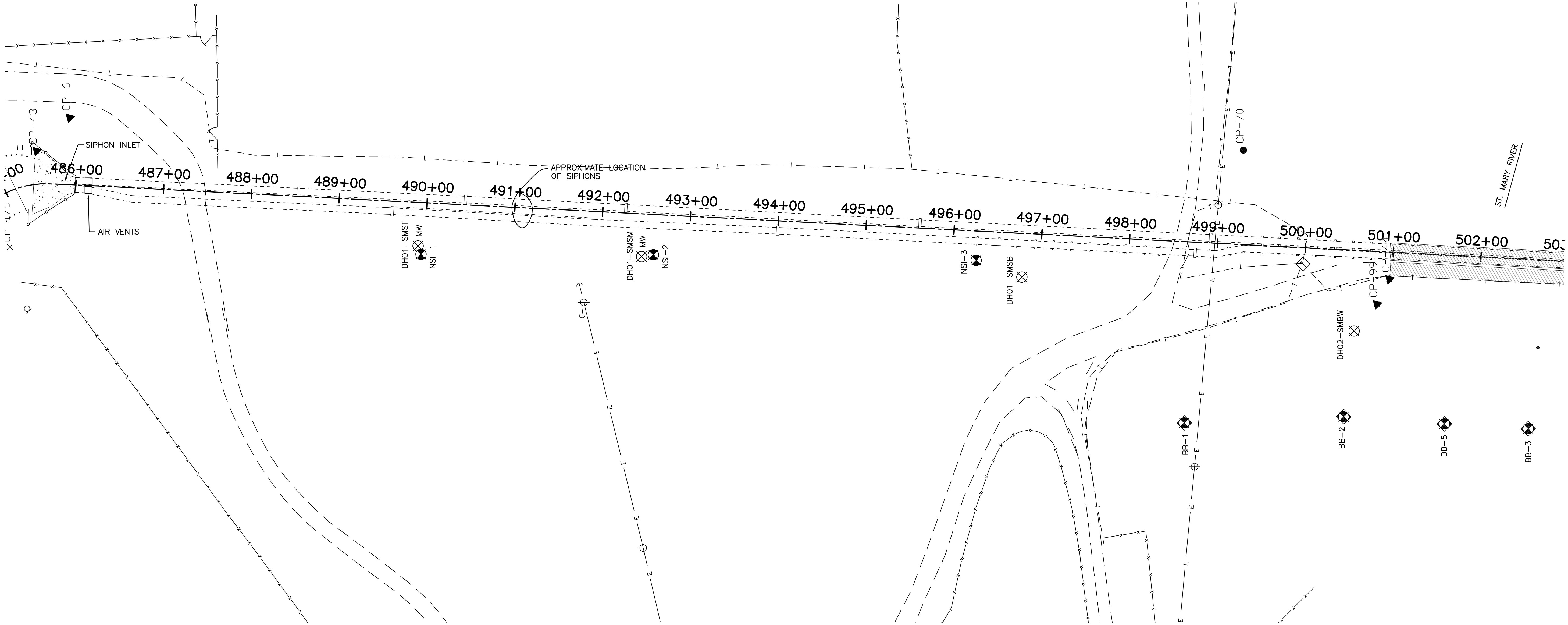
If substantial time has elapsed between the submission of this report and the start of work at the site, or if conditions have changed because of natural causes or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations considering the time lapse or changed conditions.

If you desire, we will review those portions of the plans and specifications which pertain to earthwork and foundations to determine if they are consistent with our recommendations. In addition, we are available to observe construction, particularly the placement and compaction of all fill, preparation of all foundations and quality control testing of Portland cement concrete.

This report was prepared for the exclusive use of the owner and architect and/or engineer in the design of the subject facility. It should be made available to prospective contractors and/or the contractor for information on factual data only and not as a warranty of subsurface conditions such as those interpreted from the boring logs and presented in discussions of subsurface conditions included in this report.

Prepared by: Craig R. Nadeau Craig R. Nadeau, P.E. Geotechnical Engineer	Reviewed by: Erling A. Juel Erling A. Juel, P.E. President

APPENDIX A



NORTH SLOPE

INSTALLATION	TOP OF CASING	GROUND SURFACE
NSI-1	4436.36	4433.56
NSI-2	4390.92	4388.37
NSI-3	4327.86	4325.06
DH01-SMST	4436.68	4434.13
DH01-SMSM	4393.40	4390.90

INSTALLATION	TOP OF CASING	GROUND SURFACE
DH01-SMSB	–	(1) 4317.50
DH02-SMBW	–	(1) 4287.50
BB-1	–	4307.00
BB-2	–	4289.80
BB-5	–	4279.72

BASED ON TD&H SURVEYS
(1) – NOT FOUND IN FIELD, APPROXIMATED BASED ON USBR LOGS

0 60' 120' 180'
SCALE

LEGEND

- 3415 — CONTOUR
- CONTROL POINT (CP OR CP)
- EDGE OF GRAVEL
- FENCE – CHAIN LINK
- FENCE – WIRE
- GUY WIRE
- BRIDGE BORING BY TD&H
- OVERHEAD ELECTRIC
- POWER POLE
- PROPERTY/ALLOTMENT PIN
- WELL/INCLINOMETER BY TD&H
- TELEPHONE RISER
- TRAFFIC SIGN
- SIPHON
- MONITORING WELL/BORING BY USBR

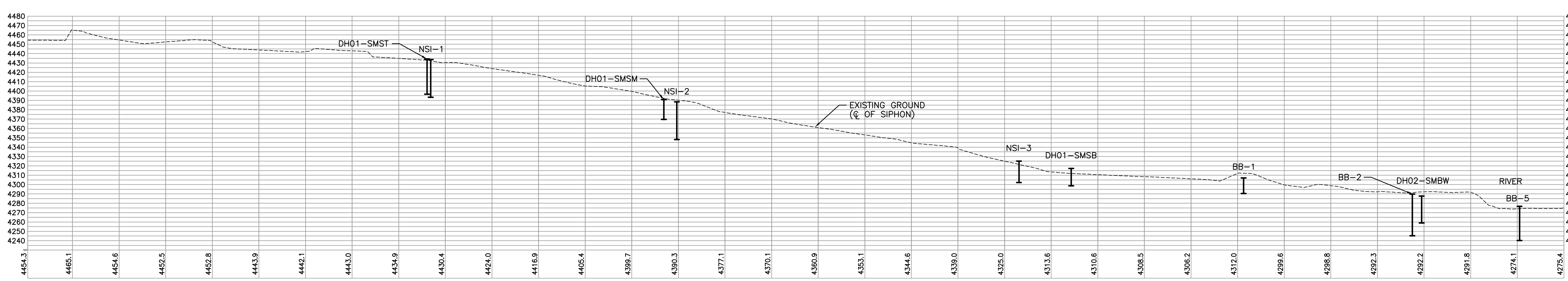


FIGURE A1

MONTANA REGISTERED PROFESSIONAL ENGINEER — ERLING A. JUEL 10740PE

REVISIONS
BY ___ DATE ___ DESCR ___
BY ___ DATE ___ DESCR ___
BY ___ DATE ___ DESCR ___

TD&H

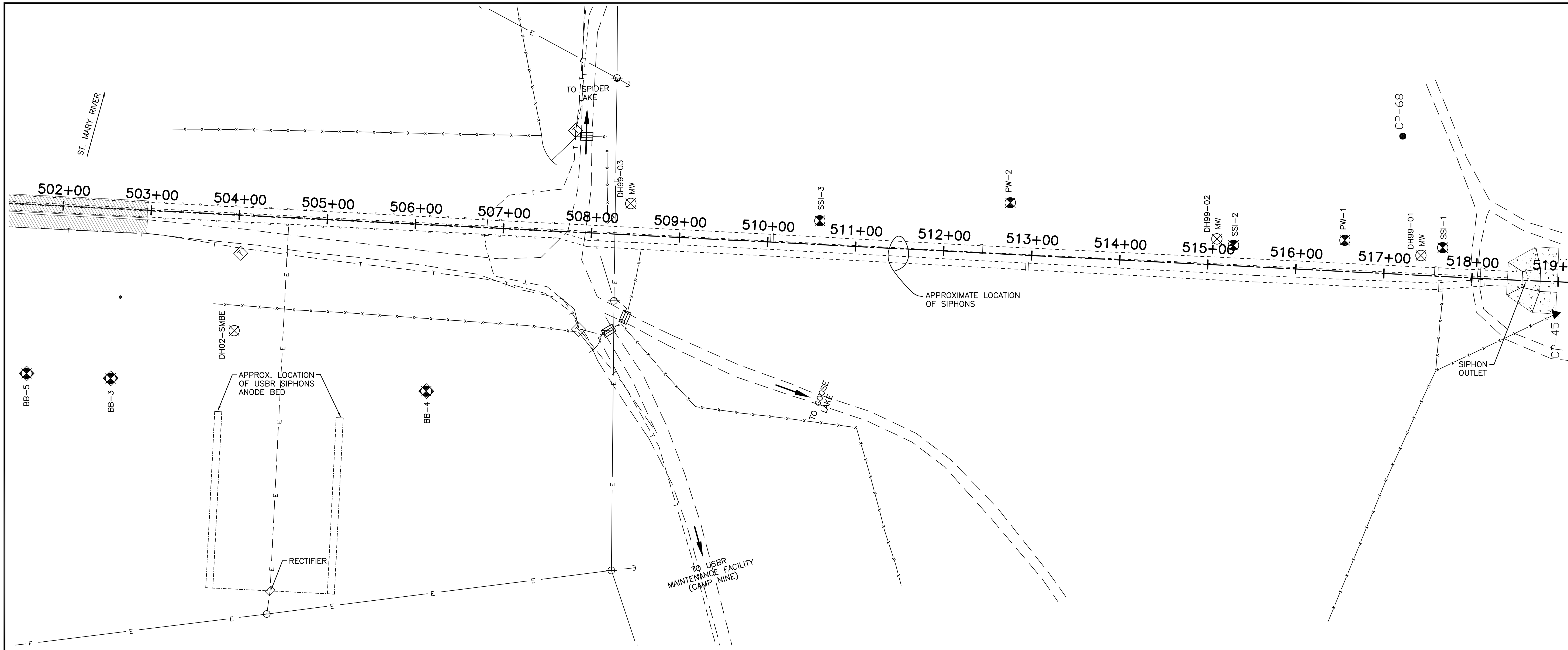
THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA
SPOKANE
LEWISTON
MONTANA
WASHINGTON
IDAHO

DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	09.10.07
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER SIPHON CROSSING NORTH SLOPE PLAN & PROFILE

CAD NO. 04167figA1 .DWG



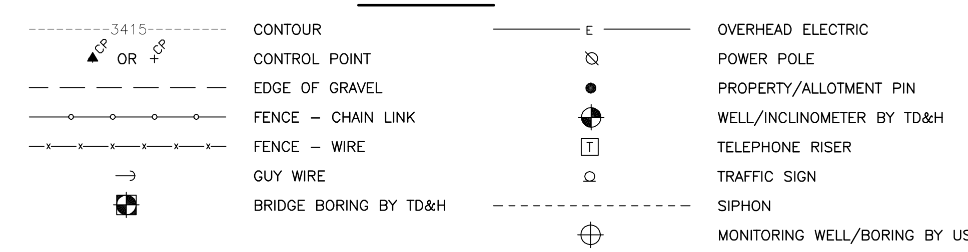
SOUTH SLOPE

INSTALLATION	TOP OF CASING	GROUND SURFACE
SSI-1	4431.67	4428.90
SSI-2	4390.09	4387.29
SSI-3	4338.63	4335.43
DH99-1	4426.00	4423.25
DH99-2	4390.89	4387.71
DH99-3	4306.88	4303.98

INSTALLATION	TOP OF CASING	GROUND SURFACE
DH02-SMBE	–	(1) 4286.50
BB-3	–	4285.80
BB-4	–	4290.30
PW-1	4410.28	4407.29
PW-2	4366.08	4362.90

BASED ON TD&H SURVEYS
(1) – NOT FOUND IN FIELD, APPROXIMATED BASED ON USBR LOGS

LEGEND



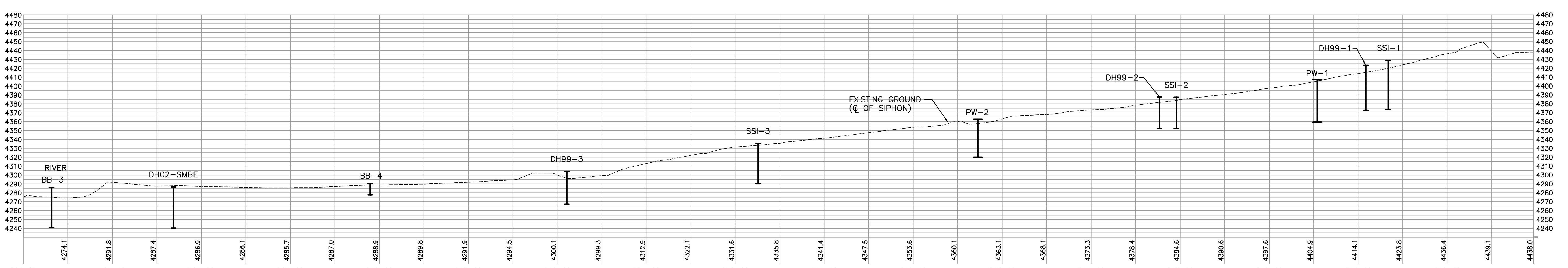


FIGURE A1

MONTANA ERLING A. JUEL 10740PE REGISTERED PROFESSIONAL ENGINEER

REVISIONS
BY ____ DATE ____ DESCR ____
BY ____ DATE ____ DESCR ____
BY ____ DATE ____ DESCR ____

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA
SPOKANE
LEWISTON
MONTANA
WASHINGTON
IDAHO

TD&H

DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	09.10.07
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER SIPHON CROSSING
SOUTH SLOPE PLAN & PROFILE

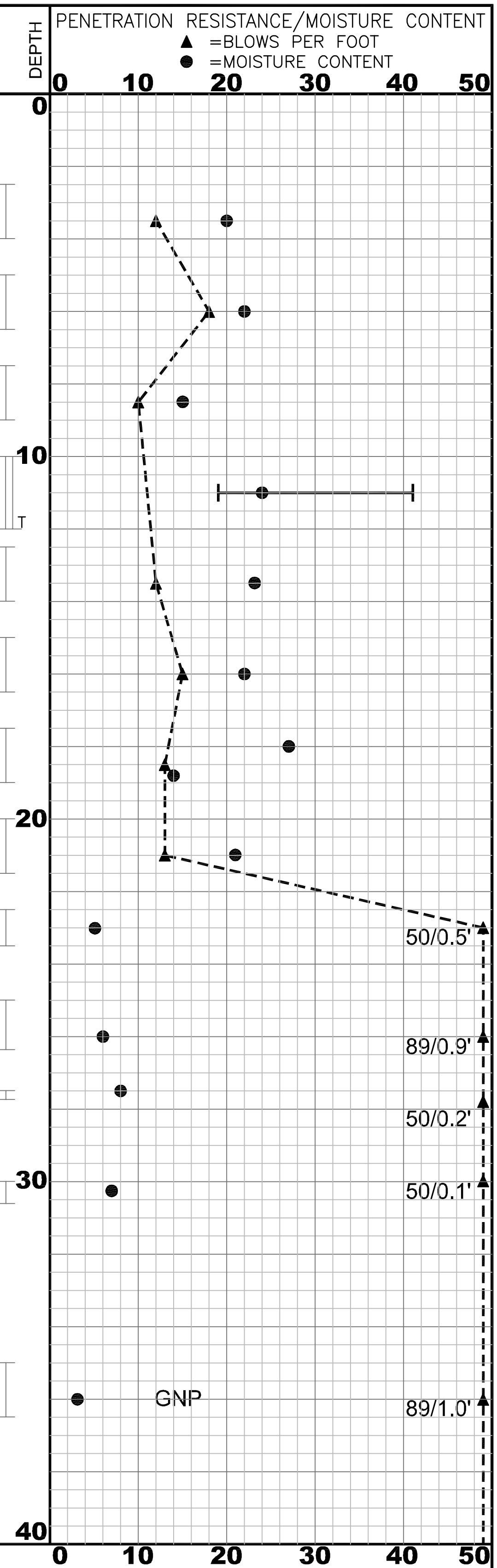
CAD NO. 04167figA1 .DWG
SHEET 2 OF 2

SURFACE: Native Grasses and Vegetation
SURFACE ELEVATION: 4433.6

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	TOPSOIL AND ORGANIC MATERIAL	0.5		
	Sandy **LEAN CLAY**, stiff to very stiff, occasional subangular to subrounded gravel, occasional mottled, occasional salt crystals, moist, brown to grayish brown		Groundwater Not Encountered During Drilling	S–1
	–q_u =3.0 to 4.0 tsf			S–2
	–q_u =4.0 to 4.5 tsf			S–3
	–21" of Recovery			S–4 (T)
	–q_u =2.5 to 3.0 tsf			S–5
	–q_u =1.5 to 2.0 tsf			S–6
	–q_u =1.5 to 2.0 tsf, rough drilling 18.5' to 19.5'			S–7
	–q_u =1.5 to 2.5 tsf	22.0		S–8
	Silty **SAND** with Gravel, very dense, generally subrounded to subangular, slightly moist to moist, reddish brown			S–9
	–brown, subangular	27.0		S–10
	Silty **GRAVEL** with Sand, very dense, subrounded to subangular, moist to slightly moist, grayish brown	33.0		S–11, S–12
	Poorly–Graded **GRAVEL** with Silt and Sand, very dense, subangular to subrounded, slightly moist, grayish brown	37.5		S–13
	Silty **GRAVEL** with Sand, very dense, subangular, moist, brown			

Logged by: Erling A. Juel, P.E. (09/12/05)
Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

(Continued on Following Sheet)



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring NSI-1

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 — 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. A2
Sheet 1 of 2

GRAPHIC LOG	SURFACE: Native Grasses and Vegetation SURFACE ELEVATION: 4433.6 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT
	(Continued from Previous Sheet)	40.3		S-14	40	50/0.3
	Practical Auger Refusal at 40.3 feet					
	Installed Slope Inclinometer Casing - Top of Casing Elevation: 4436.36 - Overall Length: 43.6 feet Construction: 2.75-inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument		**Groundwater Not Encountered During Drilling**		50	
					60	
					70	
	Logged by: Erling A. Juel, P.E. (09/12/05) Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.				80	

Penetration resistance/moisture content scale: 0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit

In Situ Water Content

Liquid Limit

Plastic Index

GNP = Granular and Nonplastic

H = Sample Heave

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring NSI-1 (cont.)

St. Mary River Siphon Crossing

St. Mary Rehabilitation Project

North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS-BOZEMAN-KALISPELL-HELENA MONTANA SPOKANE WASHINGTON LEWISTON IDAHO

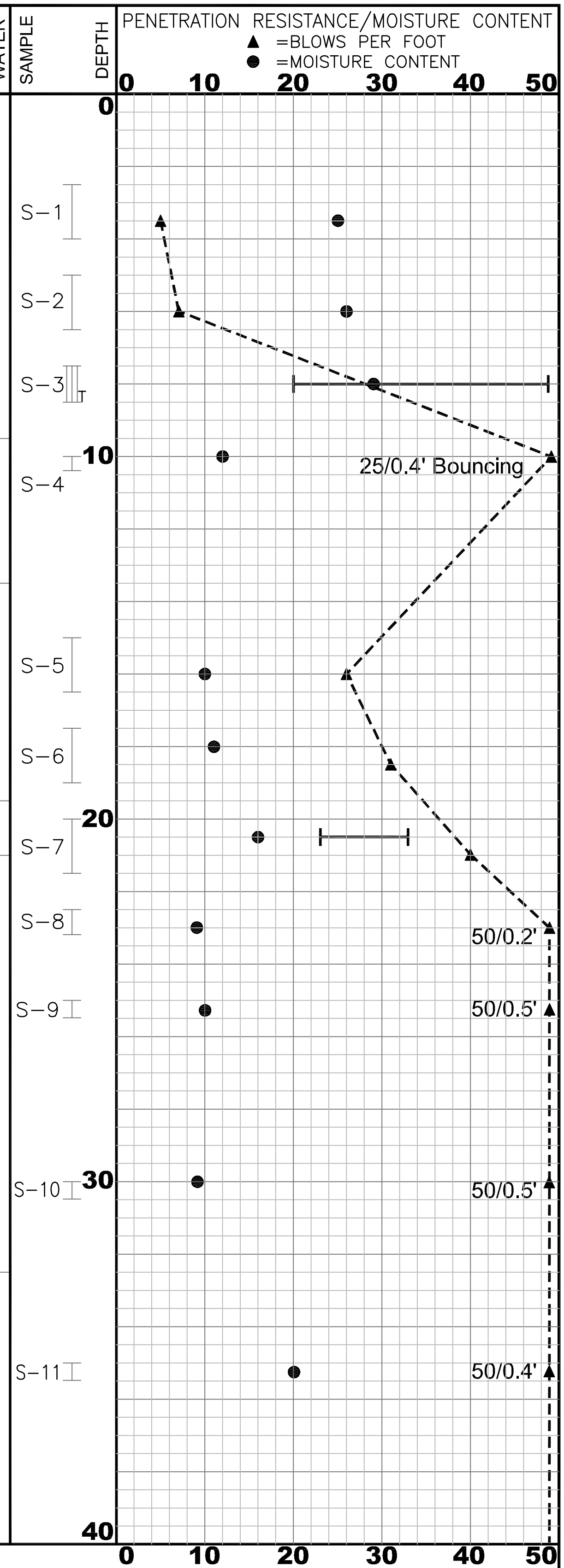
Figure No. A2

SURFACE: Barren Soil – Cleared Pad
SURFACE ELEVATION: 4388.4

Depth (ft)	Soil Description	Ground Water	Sample
0–9.5	**LEAN CLAY** with Sand, firm, trace angular to subrounded gravel, trace organics, slightly varved, moist to very moist, grayish brown –q_u =1.0 tsf –q_u =1.5 to 2.0 tsf –q_u =1.0 to 1.5 tsf		S–1, S–2, S–3 (T)
9.5–13.5	Clayey **GRAVEL** with Sand, very dense, subangular to subrounded, occasional cobbles, slightly moist to moist, grayish brown –rough drilling from 10' to 14'		S–4
13.5–19.5	Silty **SAND**, medium dense to dense, occasional sandstone fragments, moist		S–5, S–6
19.5–21.0	Sandy **LEAN CLAY**, very stiff, moist, light grayish brown		S–7
21.0–32.5	**SANDSTONE**, very dense, highly weathered and decomposed, fine to medium–grained, friable, no structure, massive, noncalcareous, moist, olive brown to light gray	Groundwater Not Encountered During Drilling	S–8, S–9, S–10
32.5–	**SHALE**, very dense/hard, highly weathered, friable, noncalcareous, occasional sandy layers, moist to very moist, medium gray		S–11

Logged by: Erling A. Juel, P.E. (09/16/05 to 09/17/05)
Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

(Continued on Following Sheet)



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring NSI-2

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA; SPOKANE WASHINGTON; LEWISTON IDAHO

Figure No. A3
Sheet 1 of 2

GRAPHIC LOG	SURFACE: Barren Soil – Cleared Pad SURFACE ELEVATION: 4388.4 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
	(Continued from Previous Sheet)	40.3		S–12	40	50/0.3'
	Practical Auger Refusal at 40.3 feet					
	Installed Slope Inclinometer Casing – Top of Casing Elevation: 4390.92 – Overall Length: 42.7 feet Construction: 2.75–inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument		Groundwater Not Encountered During Drilling		50	
					60	
					70	
	Logged by: Erling A. Juel, P.E. (09/16/05 to 09/17/05) Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.				80	

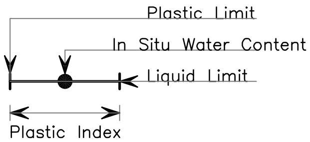
0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

▲ SPT blows per foot
● Field Moisture content
▼ Groundwater Level
G Grab/composite sample
1–3/8–inch I.D. split spoon
2–1/2–inch I.D. split spoon
R 2–1/2–inch I.D. ring sampler
T 3–inch I.D. thin–walled sampler
* No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring NSI-2 (cont.)

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA SPOKANE WASHINGTON LEWISTON IDAHO

Figure No. A3

SURFACE: Native Grasses and Brush
SURFACE ELEVATION: 4325.1

Depth (ft)	Soil Description	Sample
0–1.0	**TOPSOIL AND ORGANIC MATTERIAL**	
1.0–5.0	Sandy **LEAN CLAY**, stiff, moist, dark brown	S-1
5.0–7.5	Sandy **SILTY CLAY**, stiff, slightly moist, dark brown to black	S-2
7.5–14.0	Sandy **LEAN CLAY**, soft to stiff, moist, black to dark brown —less sand, more clay fines	S-3, S-4, S-5
14.0–23.0	Well-Graded **GRAVEL** with Silt and Sand, dense to very dense, subangular to subrounded, occasional cobbles, slightly moist to moist, brown to grayish brown	S-6 *, S-7, S-8

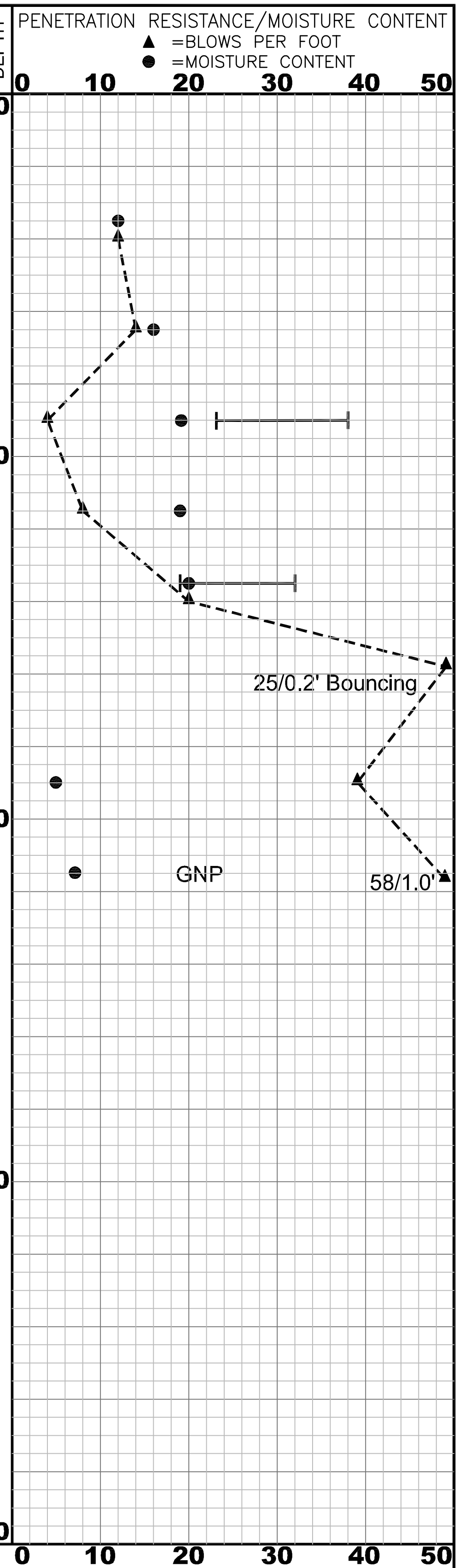
Practical Auger Refusal at 23.0 feet

Installed Slope Inclinometer Casing
- Top of Casing Elevation: 4327.86
- Overall Length: 26.5 feet

Construction: 2.75-inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument

Groundwater Not Encountered During Drilling

Logged by: Erling A. Juel, P.E. (09/16/05)
Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit, In Situ Water Content, Liquid Limit, Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring NSI-3
St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 | 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

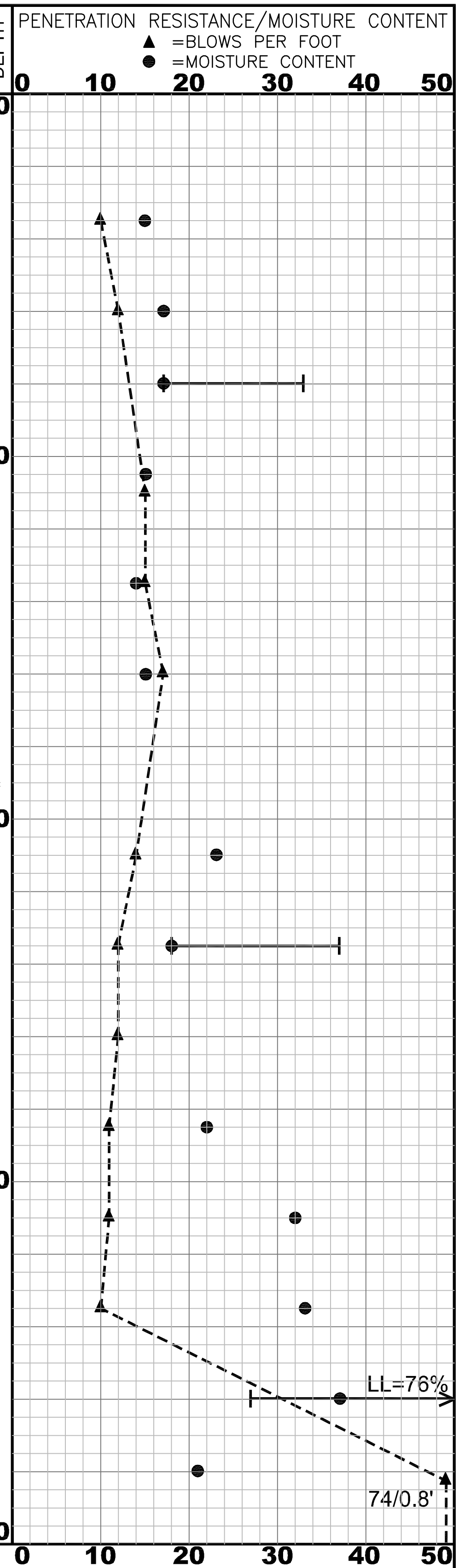
Figure No. A4

GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4428.9 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	TOPSOIL AND ORGANIC MATERIAL	0.5			0
	Sandy **LEAN CLAY**, stiff to very stiff, occasional subrounded to subangular gravel, moist, brown to grayish brown –qu =4.0 to 4.5 tsf			S–1	
	–qu =3.0 to 3.75 tsf			S–2	
				S–3 T	
					10
	–more gravel, qu =2.5 to 3.0 tsf			S–4	
				S–5	
	–qu =2.5 to 3.0 tsf			S–6	
	–crushed shelby tube, no sample recovery		Groundwater Encountered During Drilling	S–7 T*	
					20
	–more plastic fines, less gravel, wet at 21.5 feet			S–8	
	–qu =1.0 tsf			S–9	
				S–10 *	
		▼27.5			
	–more plastic fines, qu =1.5 to 2.0 tsf	29.5		S–11	
	FAT CLAY, stiff, mottled, slightly moist, brown to grayish brown				30
				S–12	
				S–13	
				S–14 T	
		37.25			
	SANDSTONE, very dense, intensely weathered to 42 feet, less weathered with depth, fine to medium grained, mostly friable, weakly to moderately calcareous, medium gray			S–15	
					40

Logged by: Erling A. Juel, P.E. (09/13/05)

Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

(Cont. on Following Sheet)



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

H = Sample Heave

Log of Soil Boring SSI-1

St. Mary River Siphon Crossing

St. Mary Rehabilitation Project

North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL–HELENA SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

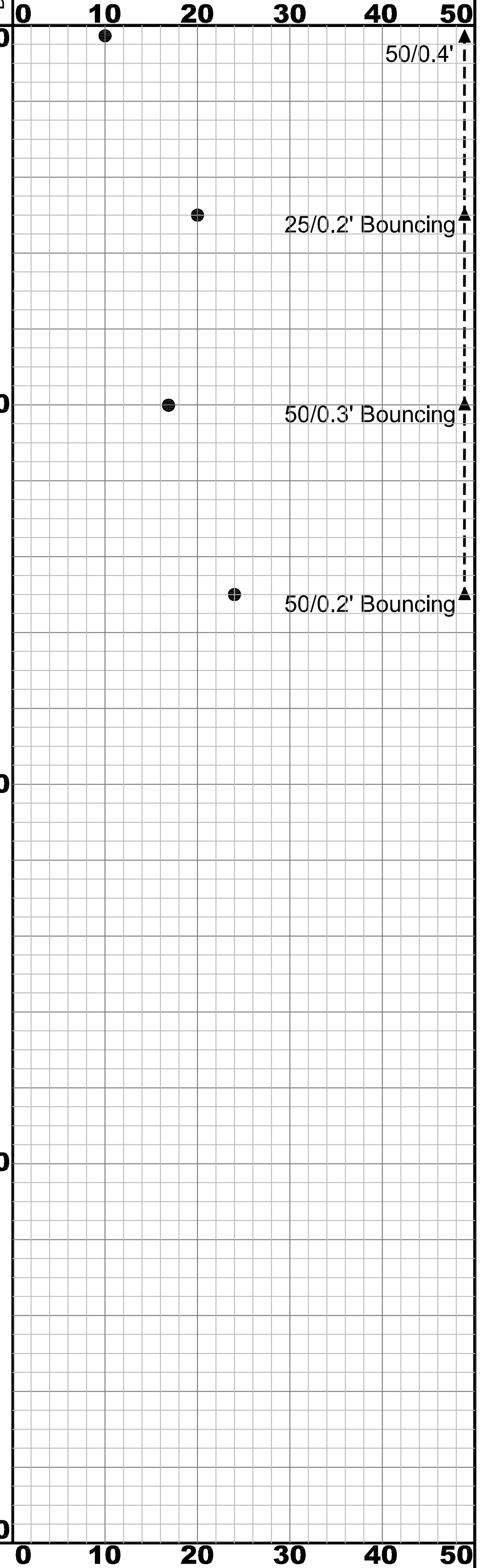
Figure No. A5

GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4428.9 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	(Continued from Previous Sheet)			S-16	40
				S-17	
				S-18	50
	–Clay shale fines	55.2		S-19	
	Bottom of Boring at 55.2'				
	Installed Slope Inclinometer Casing – Top of Casing Elevation: 4431.67 – Overall Length: 57.8 feet Construction: 2.75–inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument		**Groundwater Encountered During Drilling**		60
					70
					80

Logged by: Erling A. Juel, P.E. (09/13/05)

Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring SSI-1 (cont.)

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

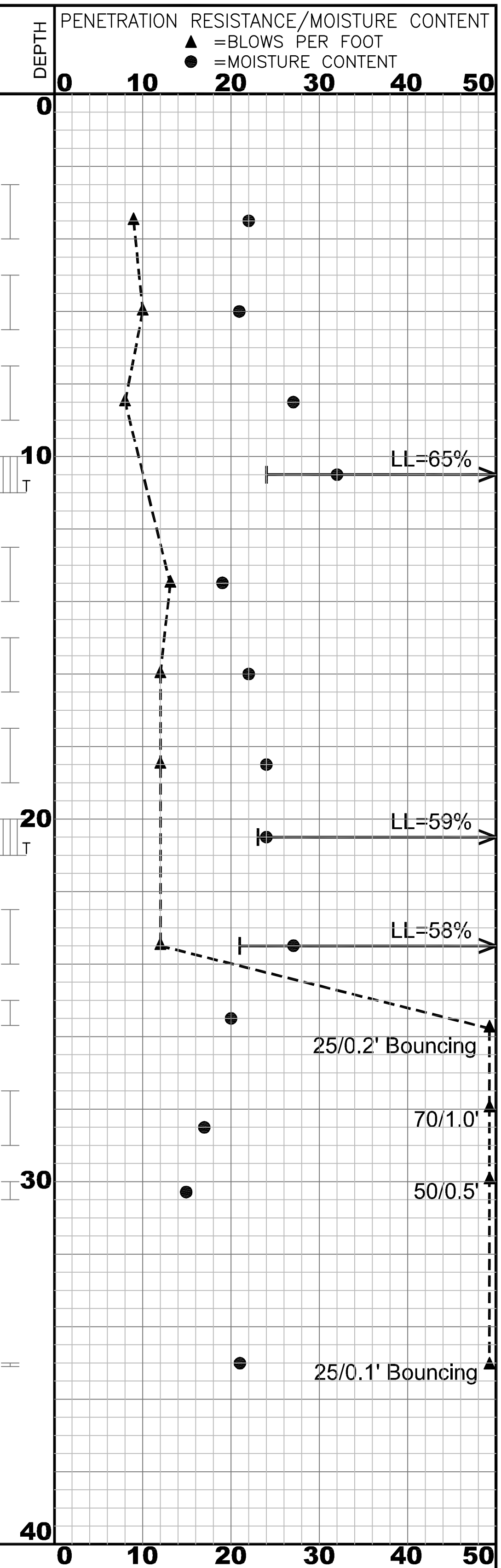
Figure No. A5
Sheet 2 of 2

SURFACE: Native Grasses
SURFACE ELEVATION: 4387.3

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	TOPSOIL AND ORGANIC MATERIAL	0.5		
	Sandy **LEAN CLAY**, stiff to firm, trace subrounded gravel, trace organics, moist, grayish brown −qu =2.0 to 2.5 tsf −qu =1.5 tsf −less sand and gravel, qu =1.0 tsf	9.5		S−1, S−2, S−3
	FAT CLAY, stiff, occasional trace coarse sand, slightly layered to slightly varved, moist, medium gray −more sand and gravel −qu =1.5 to 2.0 tsf 12.5' to 14.0' and 15.0' to 16.5' −qu =1.0 to 1.5 tsf	24.5	▼16.5 Groundwater Encountered During Drilling	S−4 (T), S−5, S−6, S−7, S−8 (T), S−9
	SANDSTONE, very dense, serverely weathered, mostly friable, harder with depth, medium to fine−grained, lack of structure/ no bedding, weakly to noncalcareous, olive brown to grayish brown Installed Slope Inclinometer Casing − Top of Casing Elevation: 4390.09 − Overall Length: 37.6 feet Construction: 2.75−inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument	35.1		S−10, S−11, S−12, S−13

Practical Auger Refusal at 35.1'

Logged by:	Erling A. Juel, P.E. (09/15/05)
Drilled by:	Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

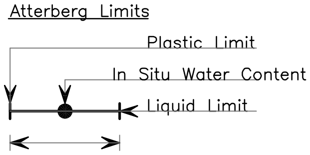


Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1−3/8−inch I.D. split spoon
- 2−1/2−inch I.D. split spoon
- R 2−1/2−inch I.D. ring sampler
- T 3−inch I.D. thin−walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring SSI-2

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS−BOZEMAN−KALISPELL−HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

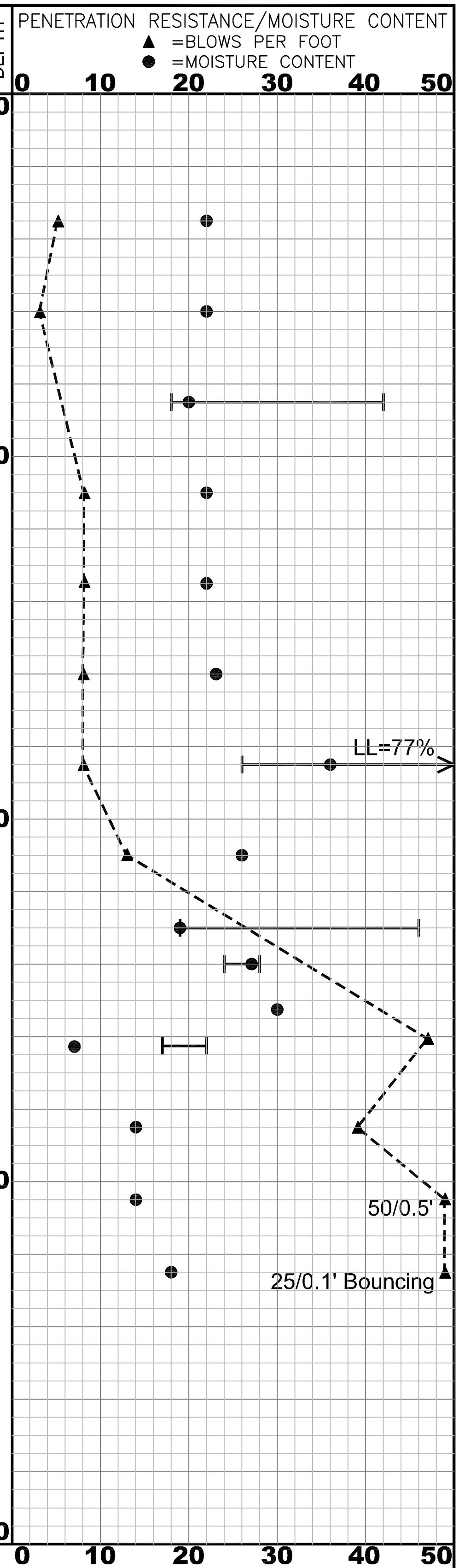
Figure No. A6
Sheet 1 of 1

GRAPHIC LOG	SURFACE: Barren Soil – Cleared Pad SURFACE ELEVATION: 4335.4 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FILL; **LEAN CLAY**, moist, grayish brown	2.0			0
	LEAN CLAY with Sand, soft to firm, subrounded gravel, abundant organics, moist, grayish brown	7.0		S–1 S–2	
	Sandy **LEAN CLAY**, firm, mottled, trace fine subrounded gravel, scattered salts, moist, grayish brown –q_u =1.0 to 2.0 tsf –q_u =1.5 to 2.0 tsf, more gravel, less moisture –q_u =1.5 to 2.0 tsf, high plasticity fines, slight layering	17.0	Groundwater Encountered During Drilling	S–3 (T) S–4 S–5 S–6	10
	FAT CLAY, firm to stiff, slightly varved, occasional coarse sand, occasional saturated 1–inch thick silt seams, moist to wet, brown to medium gray –q_u =1.0 to 1.5 tsf –q_u =1.5 to 2.5 tsf	23.5		S–7 S–8	20
	SILT, relatively loose, very moist, grayish brown	25.5		S–9 (T)	
	Silty, Clayey **GRAVEL** with Sand, dense to very dense, subangular, wet zones, generally moist to saturated, grayish brown	31.5	▼26.0	S–10 S–11 S–12	30
	SANDSTONE, very dense, highly weathered at upper contact, less weathered with depth, moderately to intensely fractured, thinly bedded, weakly to moderately calcareous, olive brown to grayish brown			S–13 C–1	40

Logged by: Erling A. Juel, P.E. (09/14/05)

Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.

(Continued on Following Sheet)



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring SSI-3

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA SPOKANE WASHINGTON LEWISTON IDAHO

Figure No. A7

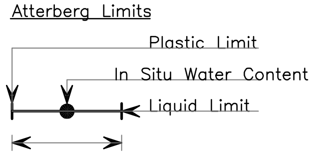
GRAPHIC LOG	SURFACE: Barren Soil — Cleared Pad SURFACE ELEVATION: 4335.4 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
	(Continued from Previous Sheet)			C-2	40	
	Rock Core Run #1 (See Sheet 3) Depth: 35.0' to 40.0' Coring Rate: 2.30 min/ft. Recovery: 94% **RQD**: 0.73	45.0				
	Rock Core Run #2 (See Sheet 4) Depth: 40.0' to 45.0' Coring Rate: 1.70 min/ft. Recovery: 100% **RQD**: 0.96		**Groundwater Encountered During Drilling**			
	Bottom of Boring at 45.0'				50	
	Logged by: Erling A. Juel, P.E. (09/14/05) Drilled by: Haztech Drilling using a BK-80 drill rig with 8-inch HSA.					
	Installed Slope Inclinometer Casing — Top of Casing Elevation: 4338.63 — Overall Length: 47.8 feet Construction: 2.75—inch I.D., ABS plastic inclinometer casing; cement/lime/bentonite annulus grout; steel, protective casing monument				60	
					70	
					80	0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1—3/8—inch I.D. split spoon
- 2—1/2—inch I.D. split spoon
- R 2—1/2—inch I.D. ring sampler
- T 3—inch I.D. thin—walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring SSI-3 (cont.)

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

September 2005 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS—BOZEMAN—KALISPELL—HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. A7
Sheet 2 of 4

BORING SSI–3, ELEVATION 4335.4 FT, ROCK CORE RUN 1
CORE RUN 1: DEPTH=35.0' TO 40.0', RQD=73%, RECOVERY=94%

FIGURE A7

ST. MARY RIVER SIPHON CROSSING NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING SSI-3 CORE RUN 1	DRAWN BY: WAB DESIGNED BY: HMM QUALITY CHECK:	DATE: SEPTEMBER 2005 JOB NO. 04-167 CAD NO. 04167-SSI-33 .DWG	SHEET 3 of 4

BORING SSI–3, ELEVATION 4335.4 FT, ROCK CORE RUN 2
CORE RUN 2: DEPTH=40.0' TO 45.0', RQD=96%, RECOVERY=100%

FIGURE A7

ST. MARY RIVER SIPHON CROSSING NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO
PHOTO OF SOIL BORING SSI-3 CORE RUN 2	DRAWN BY: WAB DESIGNED BY: HMM QUALITY CHECK:	DATE: SEPTEMBER 2005 JOB NO. 04-167 CAD NO. 04167-SSI-34 .DWG SHEET 4 of 4

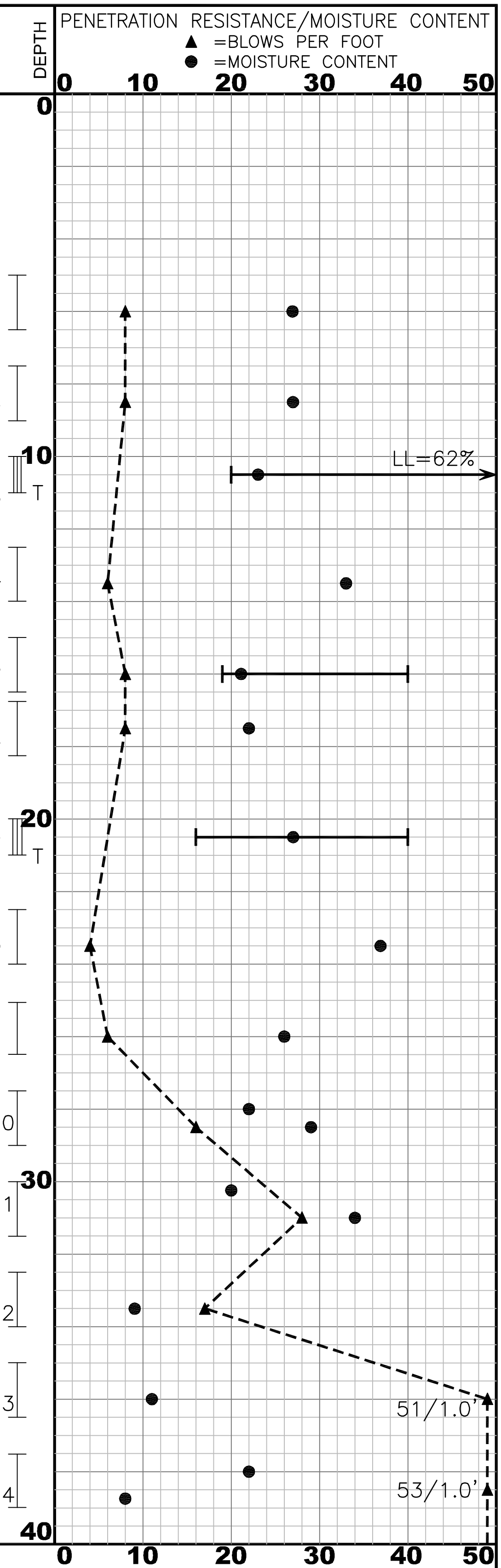
SURFACE: Native Grasses and Weeds
SURFACE ELEVATION: 4407.3

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	TOPSOIL	0.2		
	LEAN CLAY with Sand, firm, trace rounded fine gravel, moist, grayish brown			
	–qu =2.0 to 3.5 tsf			S–1
	–qu =2.0 to 2.5 tsf	9.5		S–2
	FAT CLAY, soft to firm, occasional salt crystals, coarse sandy zones, slightly layered to slightly varved, occasionally interbedded silt layers, moist to very moist, medium gray		Groundwater Encountered During Drilling	S–3 T
	–qu =1.5 to 2.0 tsf between 10' and 18.3'			S–4
	–cobble at 16.8'			S–5
				S–6
		18.88	▼	
				S–7 T
	–qu =0.5 to 1.5 tsf			S–8
	–qu =1.5 to 2.0 tsf			S–9
		28.3		S–10
	LEAN CLAY, stiff, high plasticity, very moist, yellowish brown	28.9		
	Clayey **GRAVEL** with Sand, medium dense to very dense, subrounded to subangular, frequent cobbles, moist to wet, grayish brown			S–11
				S–12
				S–13
	SANDSTONE, very dense, moderately weathered at upper contact, moderately fractured, thinly bedded, slightly calcareous, olive brown to grayish brown	38.7		S–14

Logged by: Erling A. Juel, P.E. (7/16-17/07)

Drilled by: Boland Drilling using a Mobile B-59 drill rig with 10-inch HSA.

(Continued on Following Sheet)



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring PW-1

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

July 2007 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. A8

GRAPHIC LOG	SURFACE: Native Grasses and Weeds SURFACE ELEVATION: 4407.3 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT

(Continued from Previous Sheet)

Rock Core Run #1
Depth = 40.0' to 43.5'
Recovery = 54.8%
RQD = 0.35

Run #2
Depth = 43.5' to 44.6'
Rate = 2.72 min/ft.
Recovery = 54.5%
RQD = 0.00

Run #3
Depth = 44.6' to 46.9'
Rate = 6.1 min/ft.
Recovery = 95.7%
RQD = 0.87

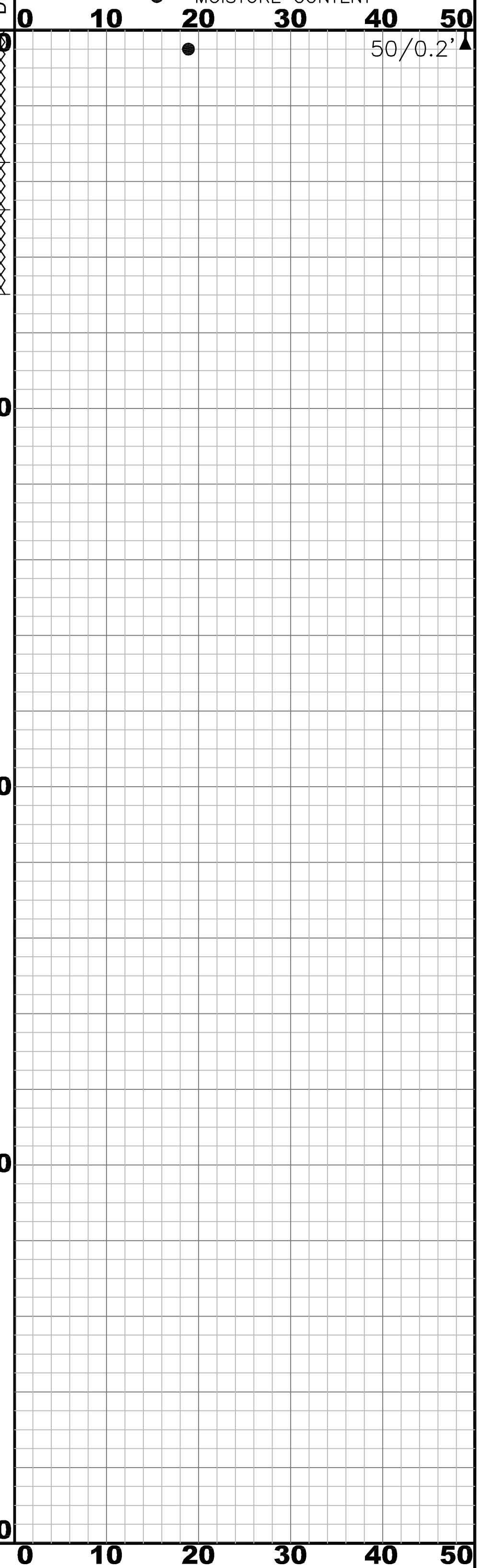
48.0

Reamed core holes with augers

Bottom of Boring at 48.0'

Groundwater Encountered During Drilling

Samples: S-15, C-1, C-2, C-3



Logged by: Erling A. Juel, P.E. (7/16-17/07)

Drilled by: Boland Drilling using a Mobile B-59 drill rig with 10-inch HSA.

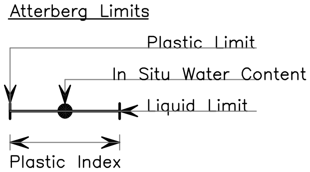
Installed Groundwater Monitoring Well
- Top of Casing Elevation: 4410.28
- Overall Length: 50.77'
- Construction: 4.0-inch, PVC plastic casing;
- Steel protective casing monument
- Screened PVC 20-slot (0.020" openings)
- Screened Interval 47.15' to 37.65' BGS
- 10-20 Sand Pack 48.00' to 24.00' BGS
- Bentonite Seal 24.00' to 19.25' BGS
- Auger Cuttings 19.25' to 1.00' BGS

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring PW-1 (cont.)

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

July 2007 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. A8

BORING PW–1, SURFACE ELEVATION 4407.3 FT
CORE RUN 1: DEPTH=40.0' TO 43.5', RQD=35%, RECOVERY=55%
CORE RUN 2: DEPTH=43.5' TO 44.6', RQD= 0%, RECOVERY=55%
CORE RUN 3: DEPTH=44.6' TO 46.9', RQD=87%, RECOVERY=96%

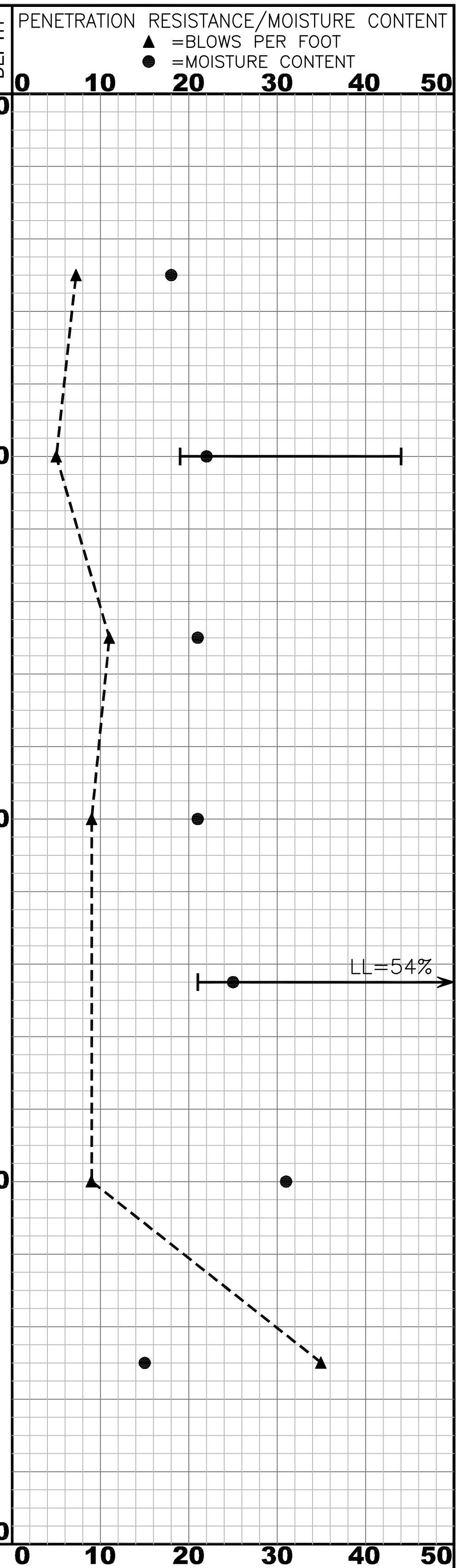
FIGURE A8

ST. MARY RIVER SIPHON CROSSING **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING PW-1 **CORE RUNS 1, 2 & 3**	DRAWN BY: MWC DESIGNED BY: EAJ QUALITY CHECK:	DATE: 09.11.07 JOB NO. 04-167 CAD NO. 04167-PW-13 .DWG	SHEET 3 of 3

GRAPHIC LOG	SURFACE: Native Grasses and Weeds SURFACE ELEVATION: 4362.9 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	TOPSOIL	0.3			0
	LEAN CLAY with Sand, firm, subrounded fine gravel, moist, grayish brown			S–1	
	–qu =1.5 to 2.0 tsf between 4.0' and 10.5'			S–2	10
	FAT CLAY, firm to stiff, thinly bedded to slightly varved with fine sand and silt, scattered subrounded fine gravel, moist, medium gray	12.0			
	–qu =1.5 to 2.0 tsf			S–3	
	–qu =1.0 to 1.5 tsf		Groundwater Encountered During Drilling	S–4	20
				S–5 (T)	
	–qu =1.5 to 2.5 tsf			S–6	30
	Clayey **GRAVEL** with Sand, dense, rounded to subrounded, moist to wet, brown	32.0			
		34.27	▼	S–7	
	SANDSTONE, very dense, moderately weathered at upper contact, moderately fractured, thinly bedded, slightly calcareous, olive brown to grayish brown	38.0			
	(Continued on Following Sheet)			C–1	40

Logged by: Erling A. Juel, P.E. (7/17-18/07)

Drilled by: Boland Drilling using a Mobile B-59 drill rig with 10-inch HSA.



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

H = Sample Heave

Log of Soil Boring PW-2

St. Mary River Siphon Crossing

St. Mary Rehabilitation Project

North of Babb, Montana

July 2007 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA SPOKANE WASHINGTON LEWISTON IDAHO

Figure No. A9

GRAPHIC LOG	SURFACE: Native Grasses and Weeds SURFACE ELEVATION: 4362.9 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT
	(Continued from Previous Sheet)	42.9		C−1 cont.	40	
	Bottom of Boring at 42.9'		Groundwater Encountered During Drilling		50	
					60	
					70	
					80	

Bottom of Boring at 42.9'

Rock Core Run #1
Depth = 38.0' to 42.9' BGS
Coring Rate = 1.84 min/ft.
Recovery = 86.2%
RQD = 0.43

Logged by: Erling A. Juel, P.E. (7/17-18/07)

Drilled by: Boland Drilling using a Mobile B-59 drill rig with 10-inch HSA.

Installed Groundwater Monitoring Well
- Top of Casing Elevation: 4366.08
- Overall Length: 43.2'
- Construction: 1.0−inch, PVC plastic casing;
- Steel protective casing monument
- Saw−Cut Interval 39.67' to 36.67' BGS
- Sand Pack 39.80' to 30.00' BGS
- Bentonite Seal 30.00' to 26.50' BGS
- Auger Cuttings 26.50' to 1.00' BGS

Groundwater Encountered During Drilling

0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

Symbol	Description
▲	SPT blows per foot
●	Field Moisture content
▼	Groundwater Level
G	Grab/composite sample
	1−3/8−inch I.D. split spoon
	2−1/2−inch I.D. split spoon
R	2−1/2−inch I.D. ring sampler
T	3−inch I.D. thin−walled sampler
*	No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic
H = Sample Heave

Log of Soil Boring PW-2 (cont.)

St. Mary River Siphon Crossing
St. Mary Rehabilitation Project
North of Babb, Montana

July 2007 04-167

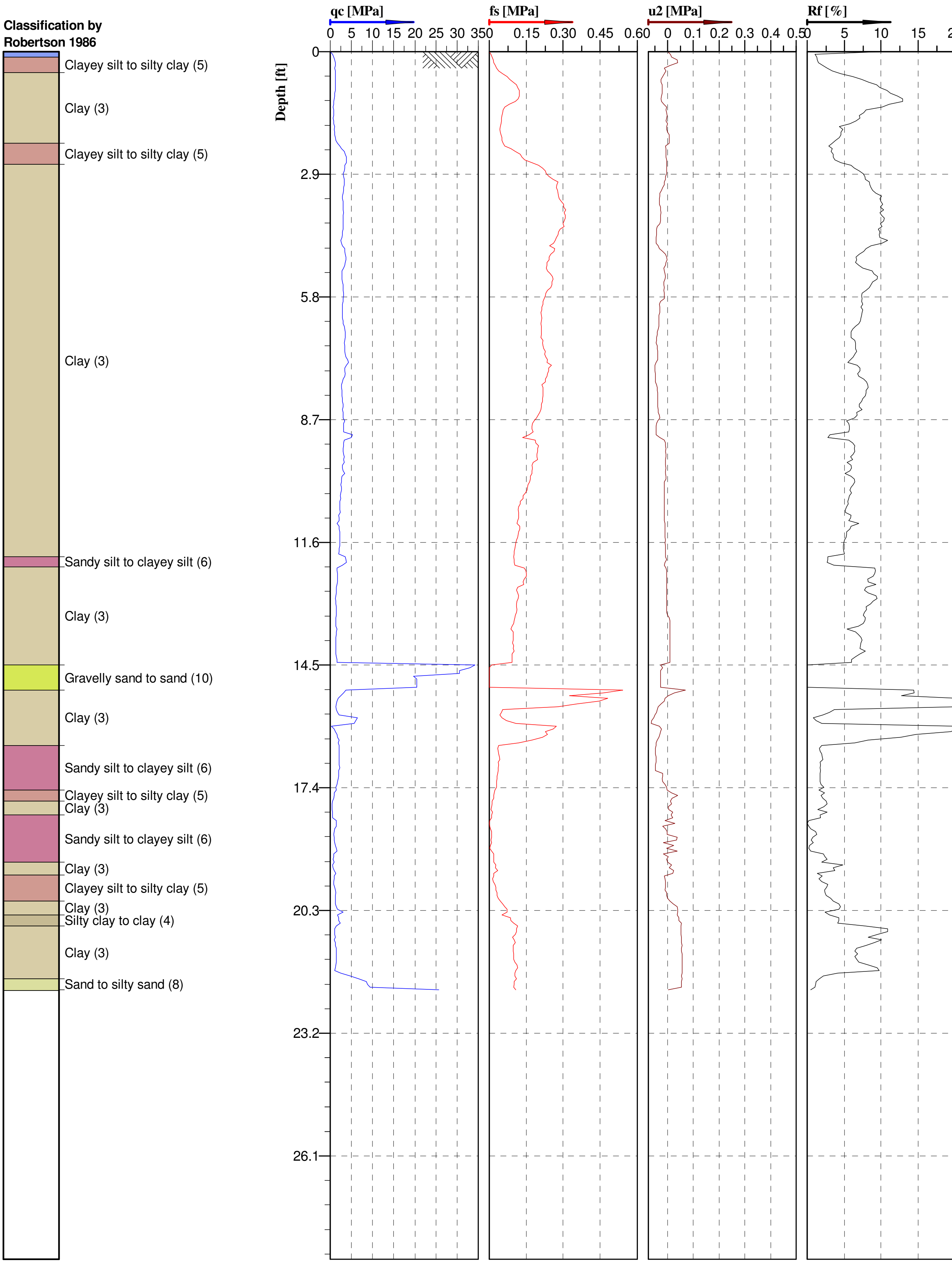
TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. A9

BORING PW-2, SURFACE ELEVATION 4362.9 FT
CORE RUN 1: DEPTH=38.0' TO 42.85', RQD=43%, RECOVERY=86%

FIGURE A9

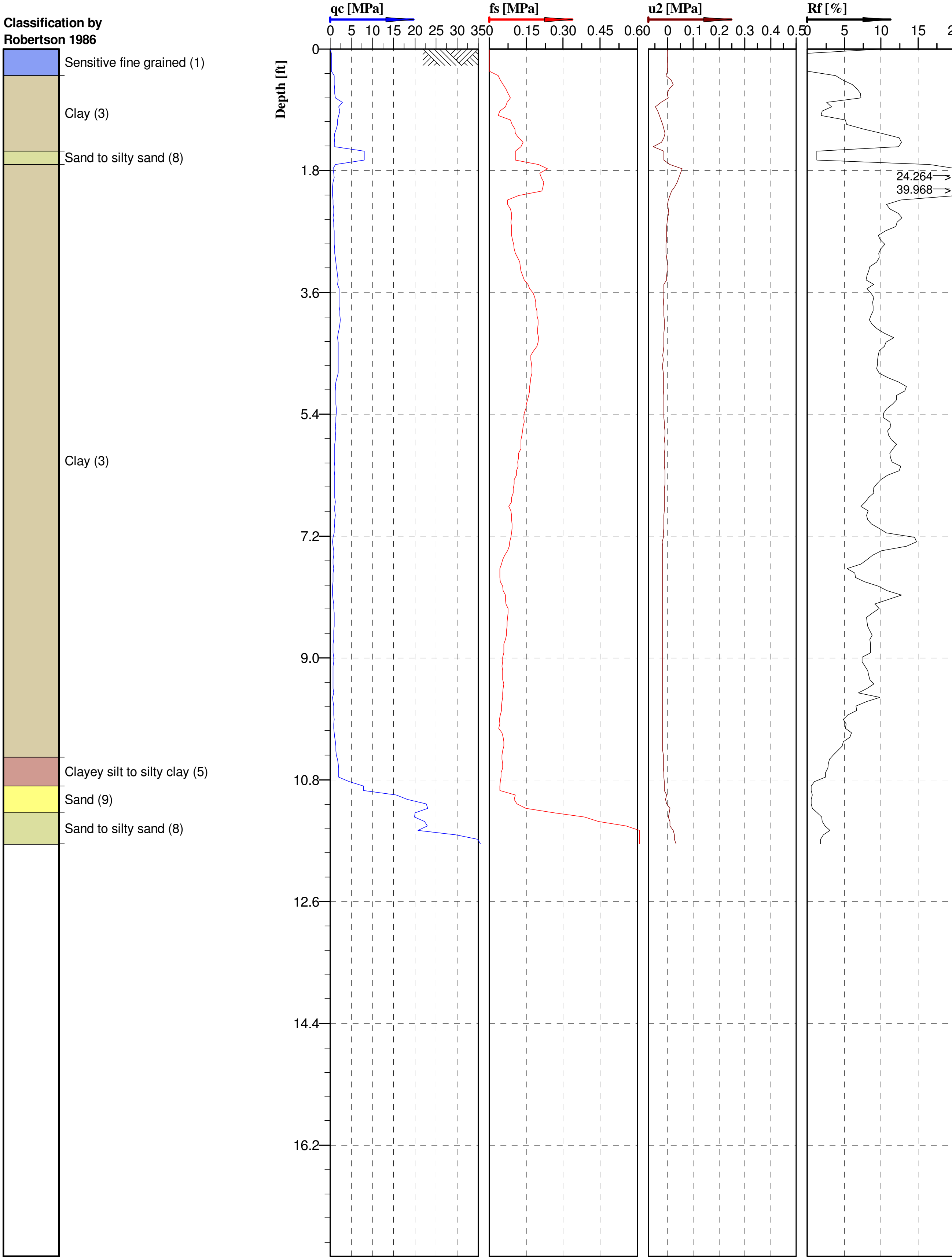
ST. MARY RIVER SIPHON CROSSING NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS-BOZEMAN-KALISPELL, SPOKANE, LEWISTON — MONTANA, WASHINGTON, IDAHO	
PHOTO OF SOIL BORING PW-2 CORE RUN 1	DRAWN BY: MWC	DATE: 09.11.07	SHEET 3 of 3
	DESIGNED BY: EAJ	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-PW-23 .DWG	

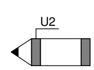


U2

Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

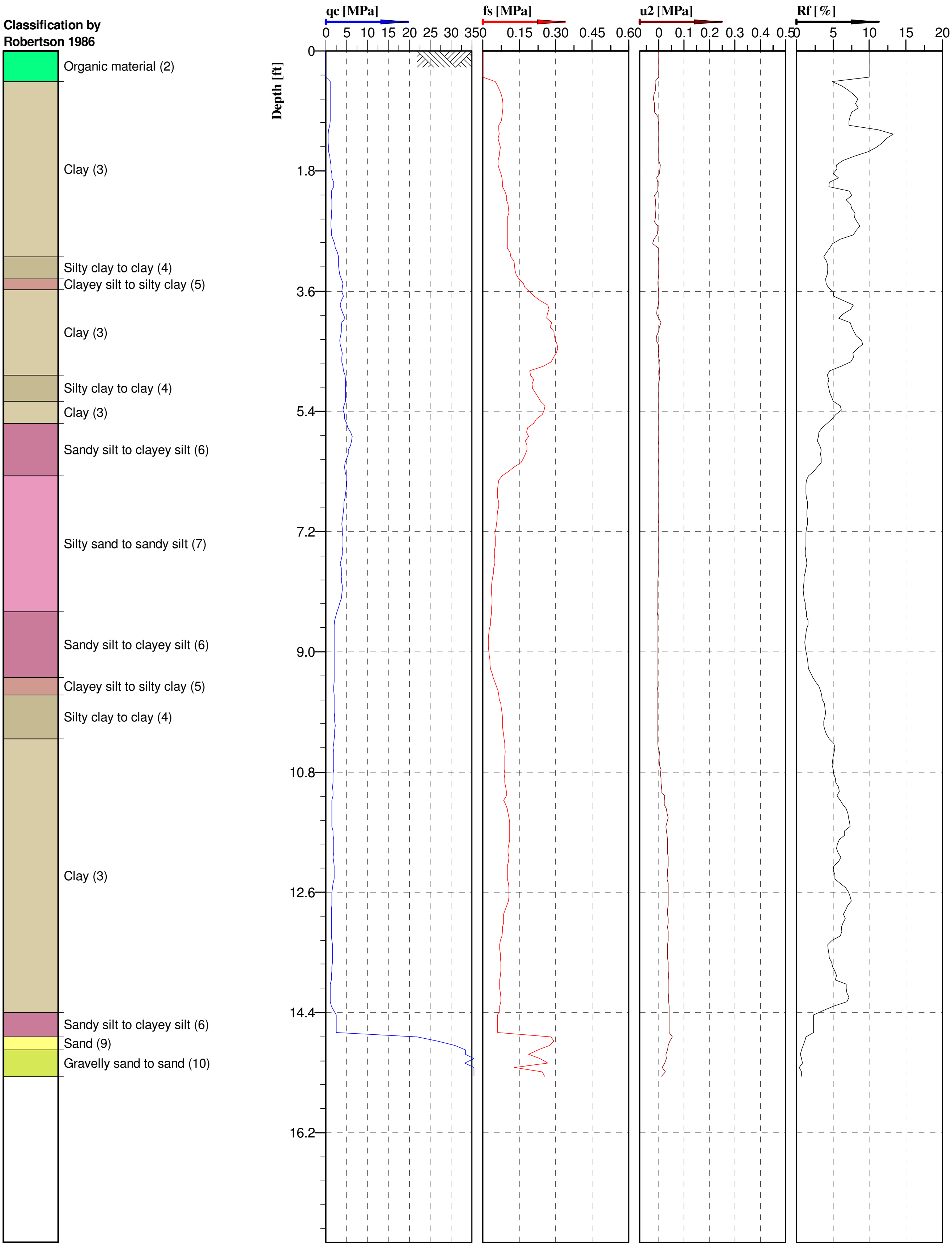
Location: NSI-1, North Side	Position:	Ground level: 4433.6	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/12/2005	Scale: 1 : 40
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A10
		File: NSI-1.cpd	





Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

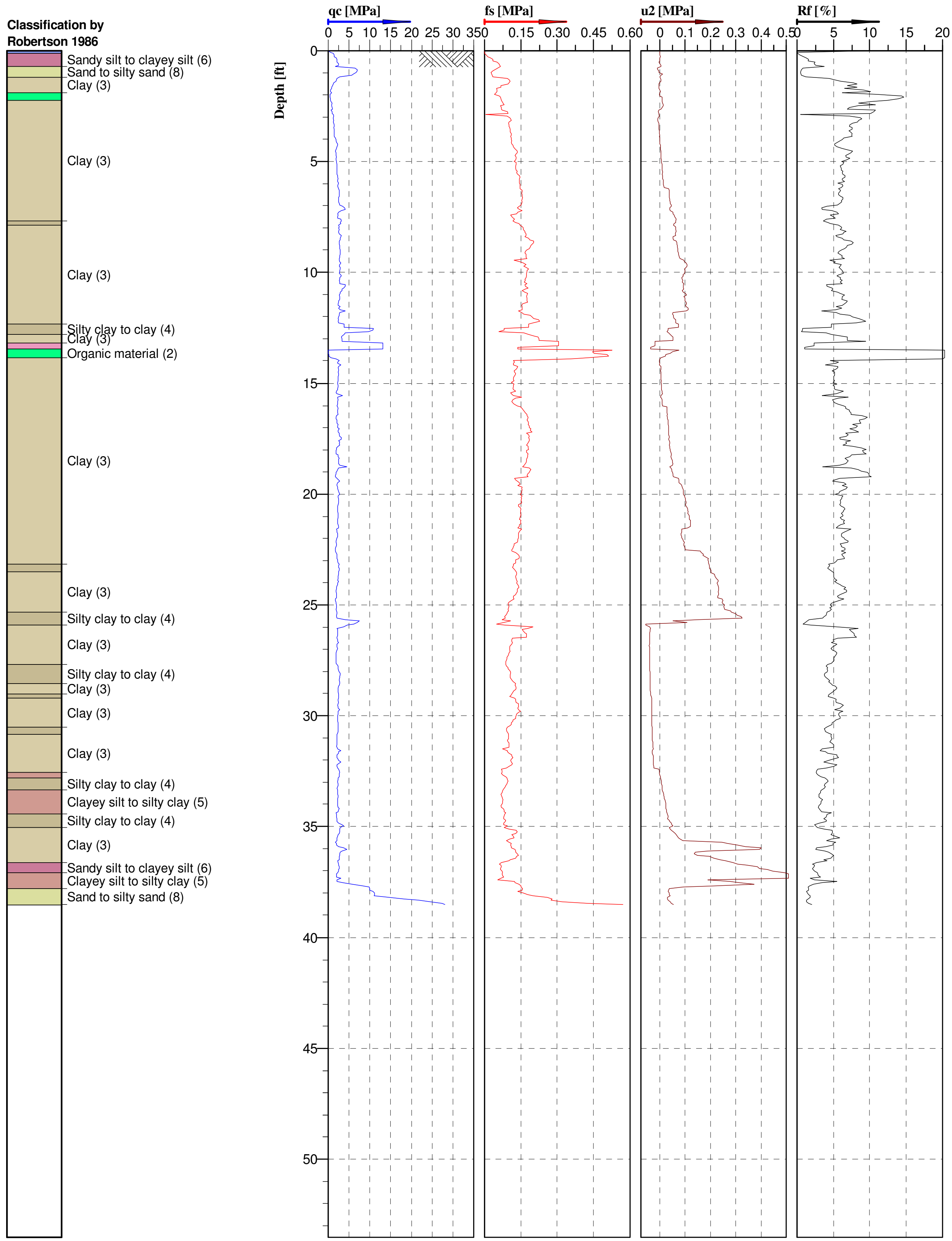
Location: NSI-2, North Side	Position:	Ground level: 4388.4	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/17/2005	Scale: 1 : 25
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A11
		File: NSI-2.cpd	



U2

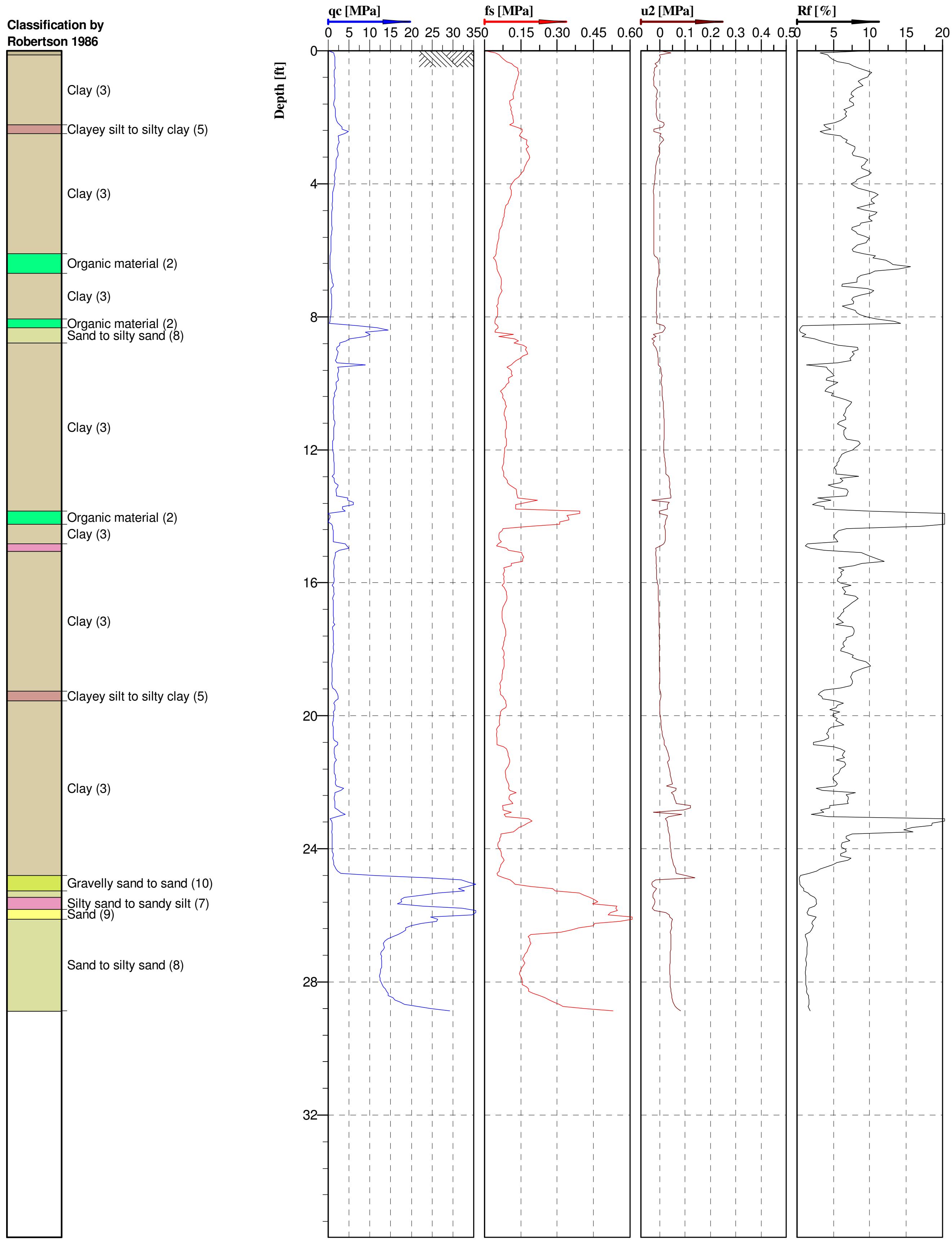
Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: NSI-3, North Side	Position:	Ground level: 4325.1	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/16/2005	Scale: 1 : 25
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A12
		File: NSI-3.cpd	



Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: SSI-1, South Side	Position:	Ground level: 4428.9	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/14/2005	Scale: 1 : 75
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A13
		File: SSI-1.cpd	

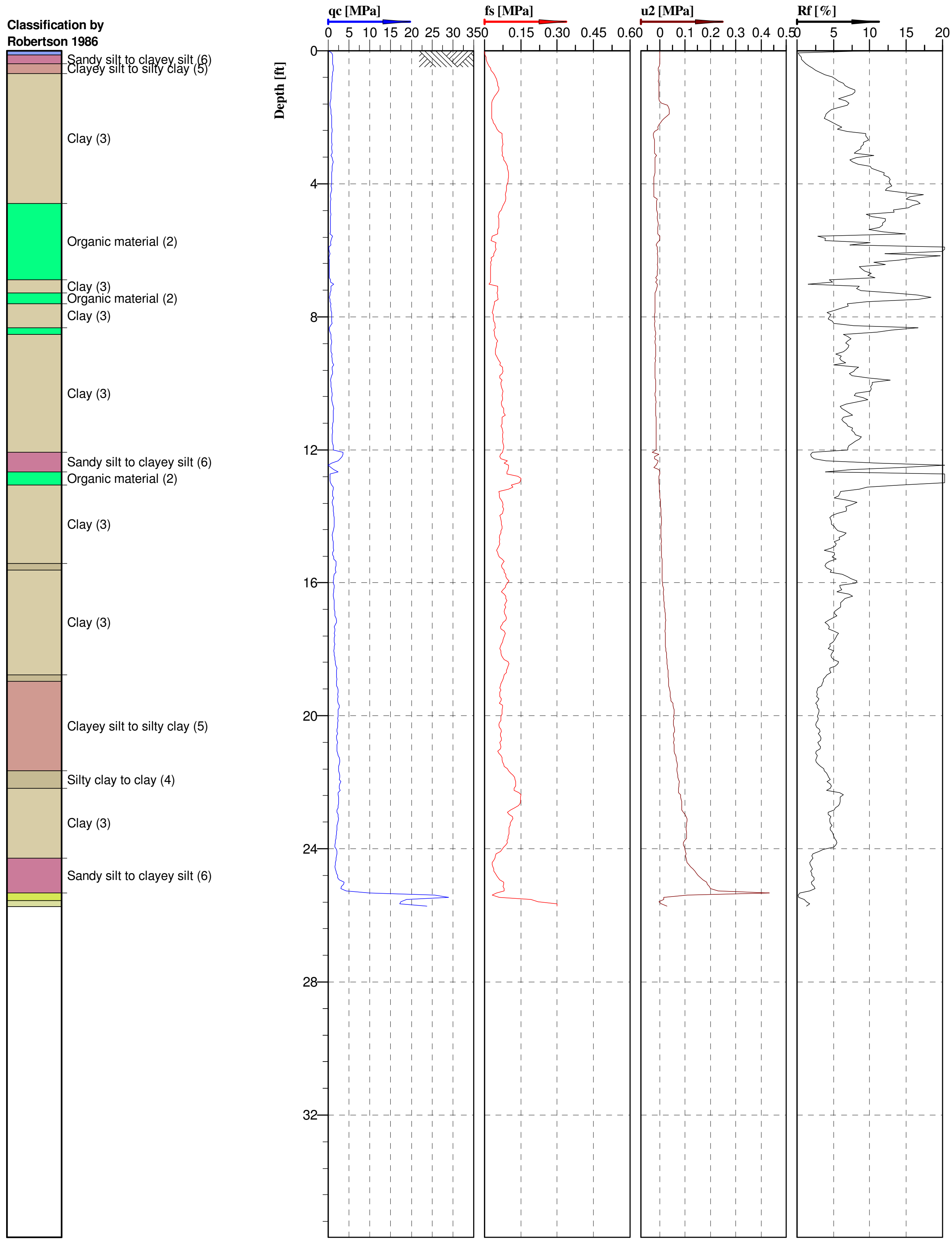


TD&H Thomas, Dean & Hoskins, Inc. Engineering Consultants

U2

Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

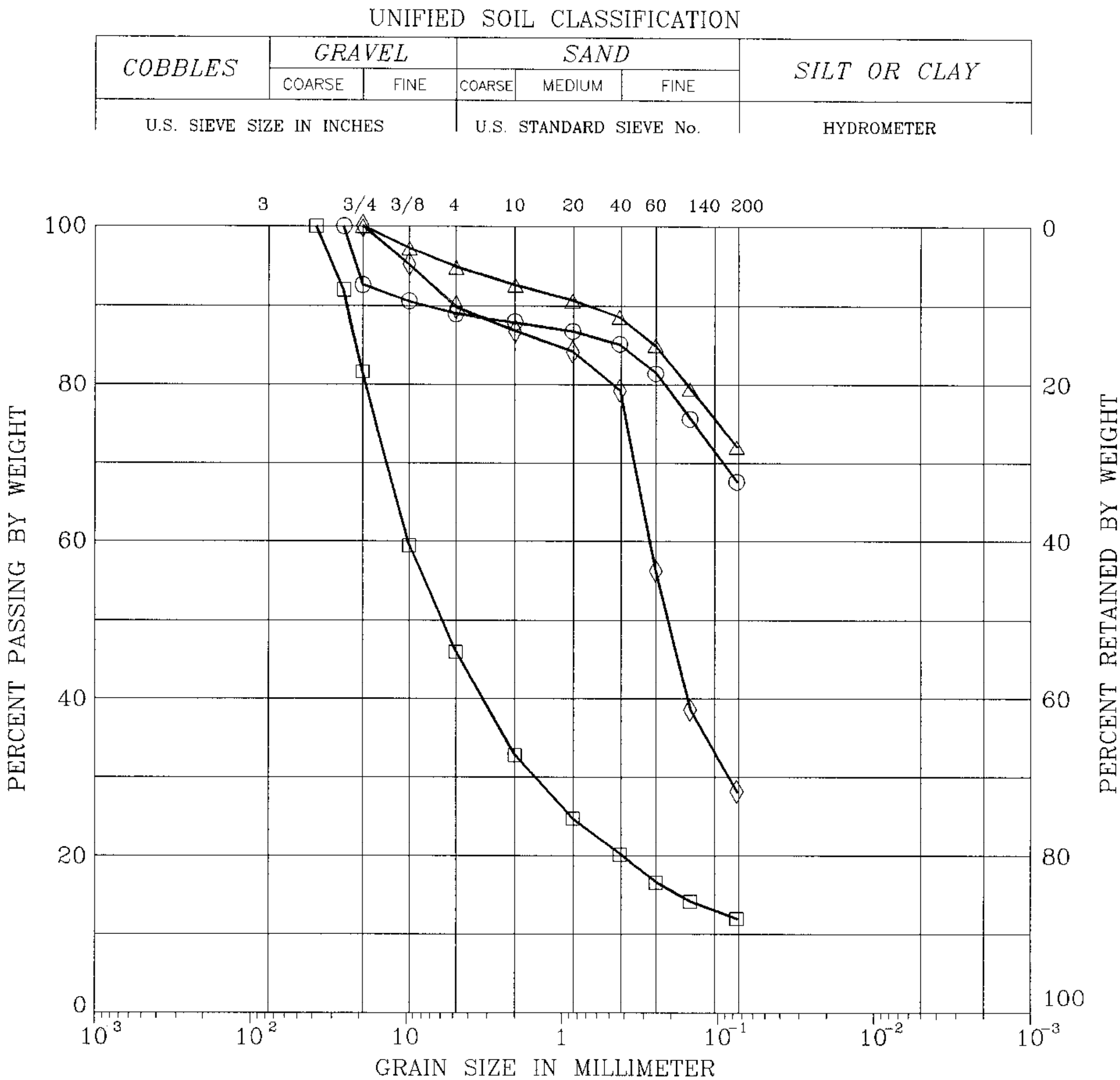
Location: SSI-2, South Side	Position:	Ground level: 4387.3	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/15/2005	Scale: 1 : 50
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A14
		File: SSI-2.cpd	



U2

Cone No: 0
Tip area [cm2]: 10
Sleeve area [cm2]: 150

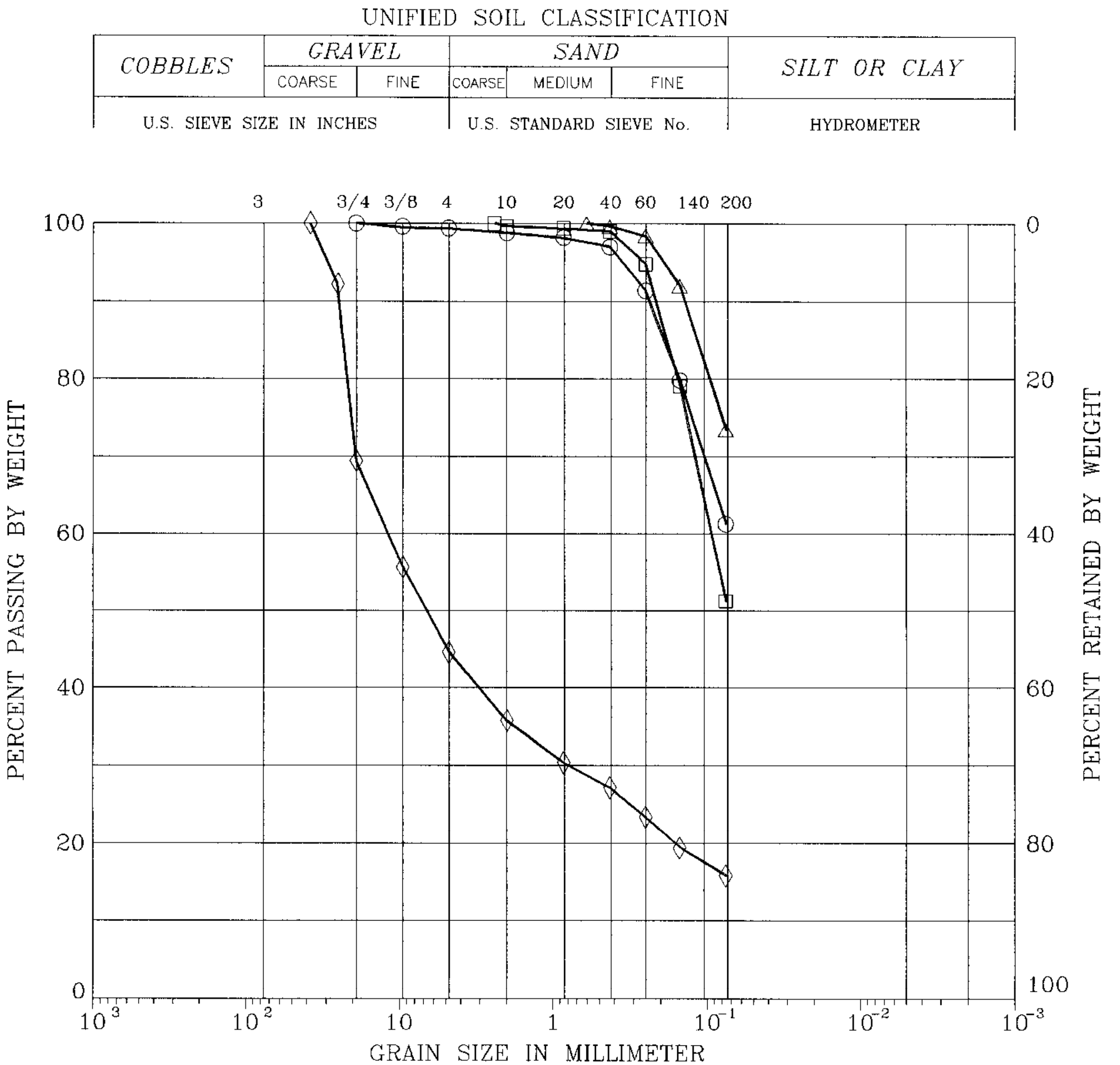
Location: SSI-3, South Side	Position:	Ground level: 4335.4	Test no: 1
Project ID: 04-167-002	Client: DNRC - CARDD	Date: 9/15/2005	Scale: 1 : 50
Project: St. Mary River Siphon Crossing		Page: 1/1	Fig: A15
		File: SSI-3.cpd	



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	NSI1,S4	10–12	41	22	SANDY, LEAN CLAY (CL)
□	NSI1,S13	35–36.5	***	***	POORLY-GRADED GRAVEL WITH SAND AND SILT (GP-GM)
△	NSI2,S3	7.5–8.5	49	29	LEAN CLAY WITH SAND (CL)
◇	NSI2,S5	15–16.5	***	***	SILTY SAND (SM)

Remark : *** Granular – Nonplastic

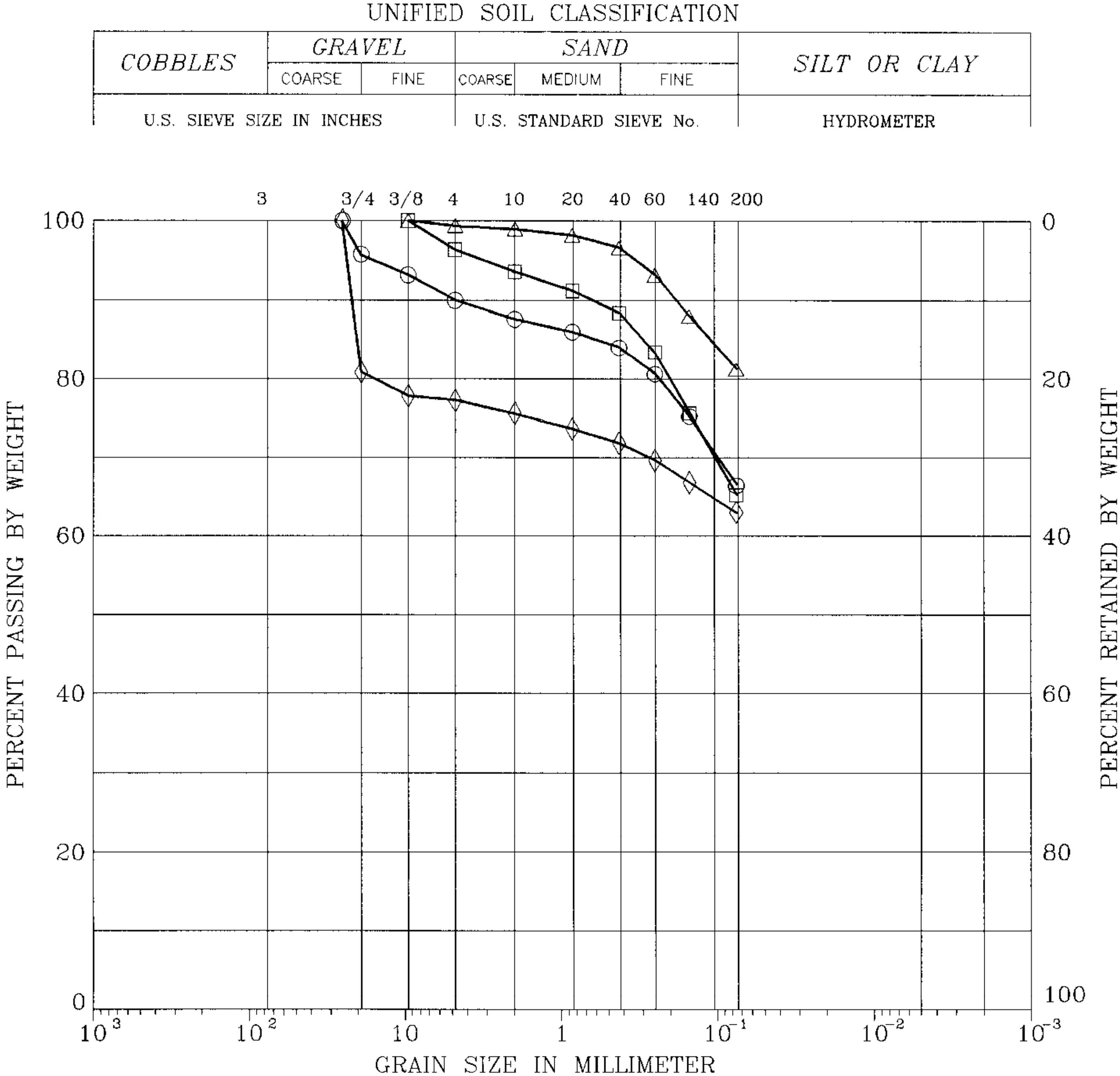
Project No.04–167	St. Mary River Siphons
THOMAS, DEAN & HOSKINS Engineering Consultants	GRAIN SIZE DISTRIBUTION Figure No. A16



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	NSI2,S7	20–21.5	33	10	SANDY, LEAN CLAY (CL)
□	NSI3,S3	8.0–9.5	38	15	SANDY, LEAN CLAY (CL)
△	NSI3,S5	13–14.5	32	13	LEAN CLAY WITH SAND (CL)
◇	NSI3,S8	20.5–22	***	***	SILTY GRAVEL WITH SAND (GM)

Remark : *** Granular – Nonplastic

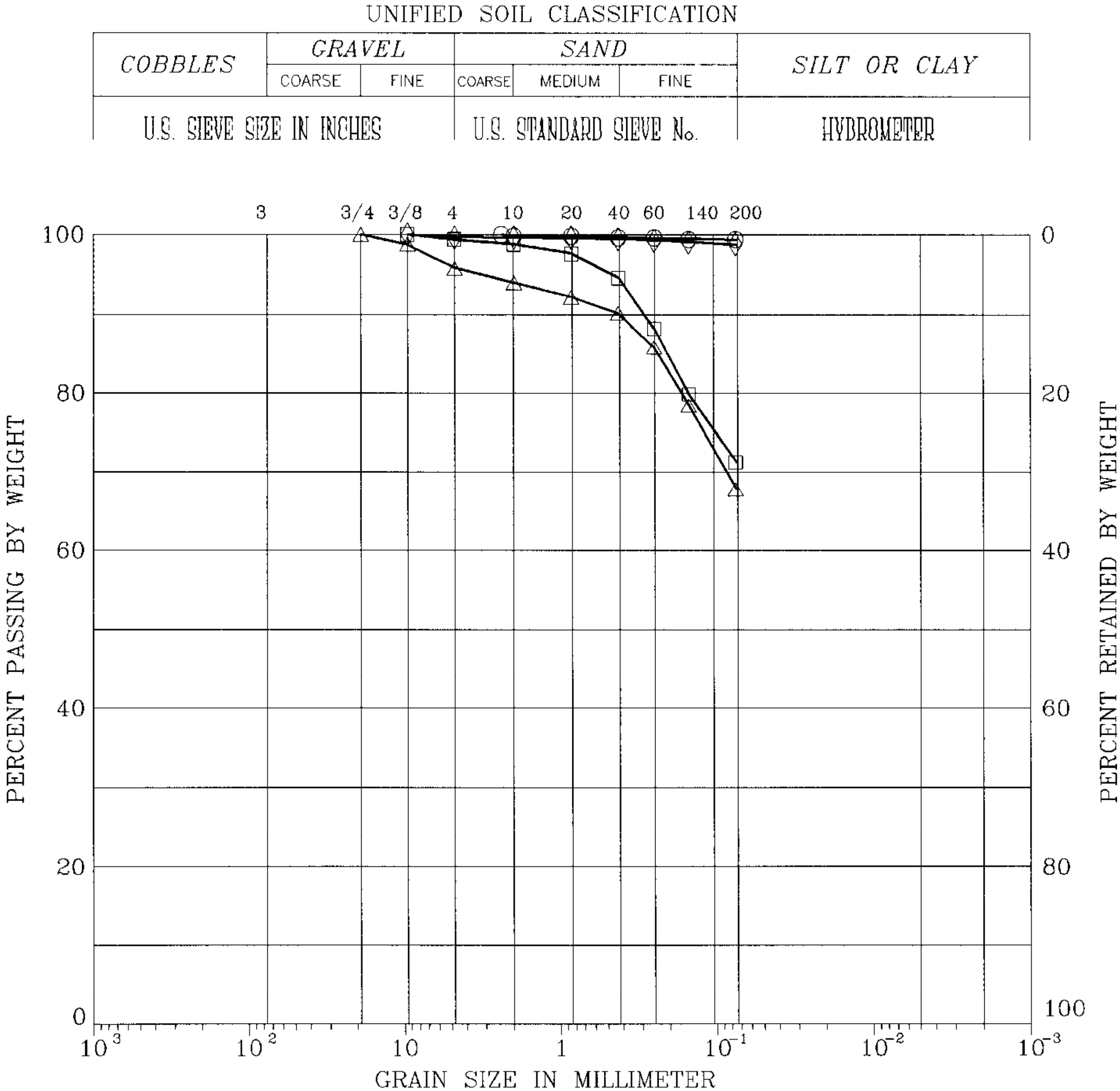
Project No.04-167	St. Mary River Siphons
THOMAS, DEAN & HOSKINS Engineering Consultants	GRAIN SIZE DISTRIBUTION Figure No. A17



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	SSI1,S3	7.5–9.5	33	16	SANDY, LEAN CLAY (CL)
□	SSI1,S9	22.5–24	37	19	SANDY, LEAN CLAY (CL)
△	SSI1,S14	35–37	76	49	FAT CLAY WITH SAND (CH)
◇	SSI2,S4	10–11	65	41	GRAVELLY, FAT CLAY (CH)

Remark : *** Granular – Nonplastic

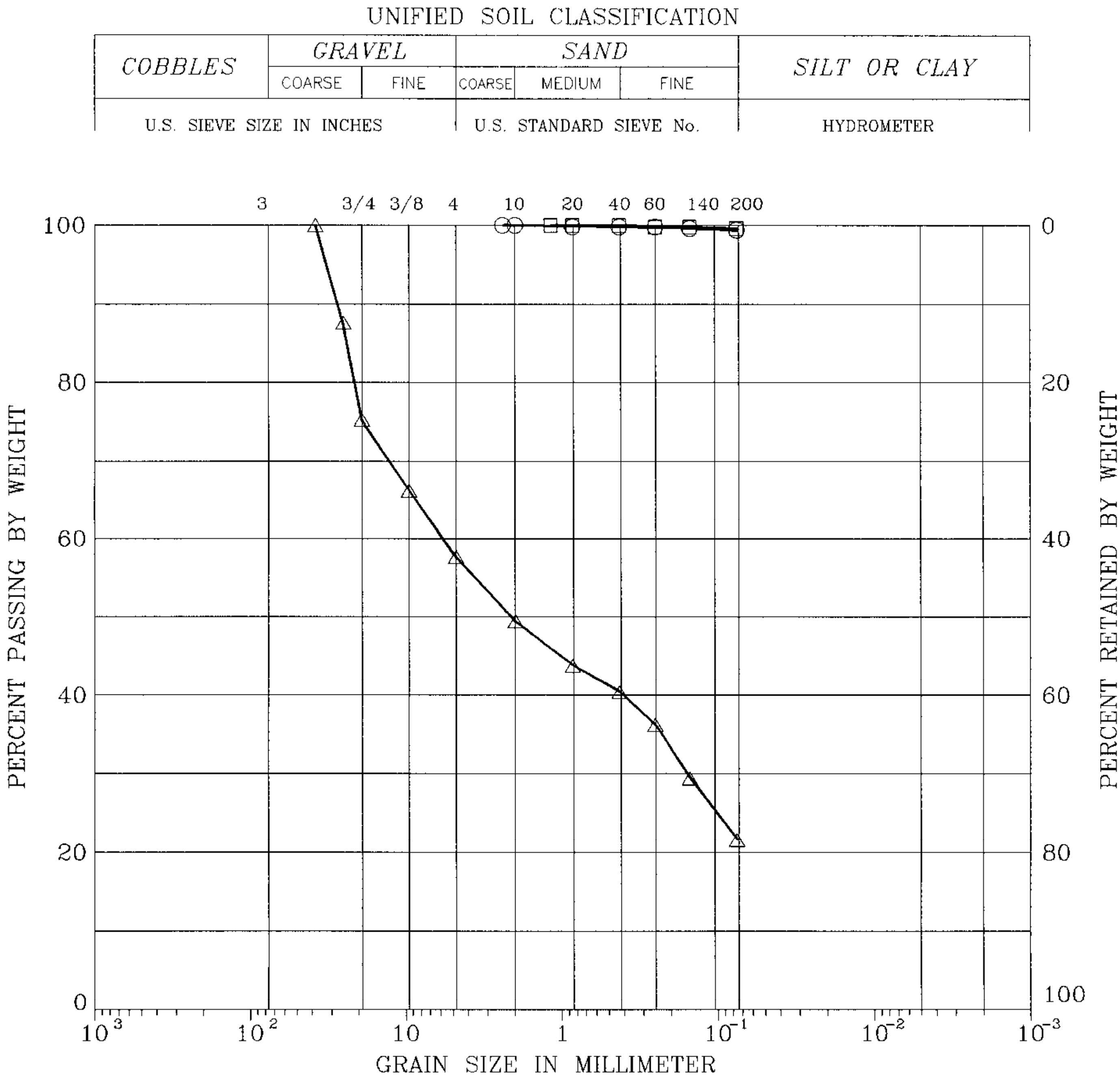
Project No.04–167	St. Mary River Siphons
THOMAS, DEAN & HOSKINS Engineering Consultants	GRAIN SIZE DISTRIBUTION Figure No. A18



SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	SSI2,S8	20–21	59	36	FAT CLAY (CH)
□	SSI2,S9	22.5–24	58	37	FAT CLAY WITH SAND (CH)
△	SSI3,S3	7.5–9.5	42	24	SANDY, LEAN CLAY (CL)
◇	SSI3,S7	17.5–19	77	50	FAT CLAY (CH)

Remark : *** Granular – Nonplastic

Project No.04–167	St. Mary River Siphons
THOMAS, DEAN & HOSKINS Engineering Consultants	GRAIN SIZE DISTRIBUTION Figure No. A19

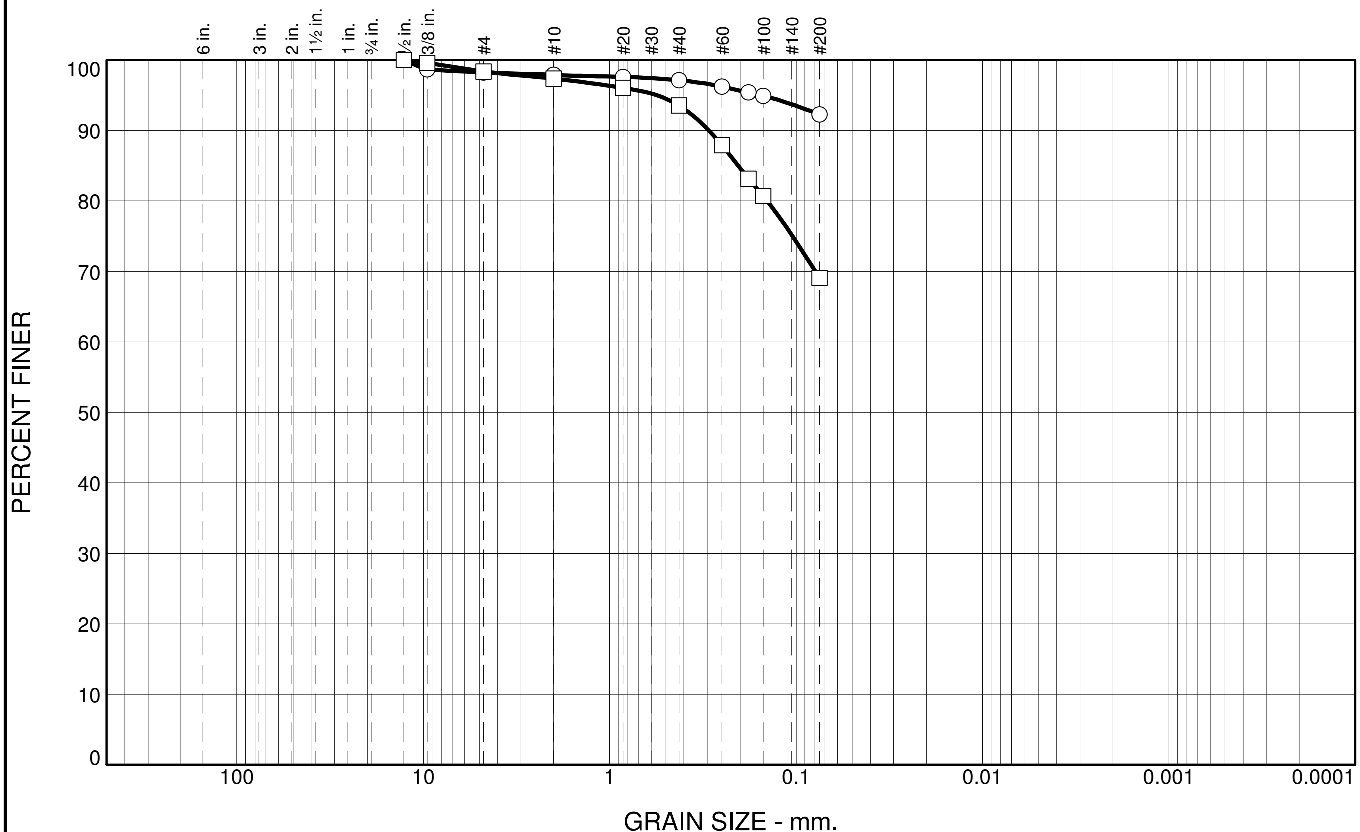


SYMBOL	BORING	DEPTH (ft)	LL (%)	PI (%)	DESCRIPTION
○	SSI3,S9A	22.5–24	46	27	LEAN CLAY (CL)
□	SSI3,S9B	23.5–24	28	4	SILT (ML)
△	SS13,S10	25.5–30	22	5	SILTY, CLAYEY GRAVEL WITH SAND (CC–GM)

Remark : *** Granular – Nonplastic

Project No.04–167	St. Mary River Siphons
THOMAS, DEAN & HOSKINS Engineering Consultants	GRAIN SIZE DISTRIBUTION Figure No. A20

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	1.8	5.9	92.3		CH	62	20	42
□	0.0	1.6	29.3	69.1		CL	40	19	21

SIEVE inches size	PERCENT FINER ○	□	
1/2	100.0	100.0	
3/8	98.7	99.6	
	GRAIN SIZE		
D_{60}			
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	
#4	98.2	98.4	
#10	97.9	97.4	
#20	97.6	96.0	
#40	97.1	93.6	
#60	96.2	87.9	
#80	95.4	83.2	
#100	94.9	80.7	
#200	92.3	69.1	

Material Description

○ Fat CLAY

□ Sandy Lean CLAY

REMARKS:

○ Report No. A-799-206

□ Report No. A-801-206

○ Location: PW-1 Depth: 10.0 - 11.0 ft Sample Number: A-799

□ Location: PW-1 Depth: 15.0 - 16.5 ft Sample Number: A-801

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS - BOZEMAN - KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

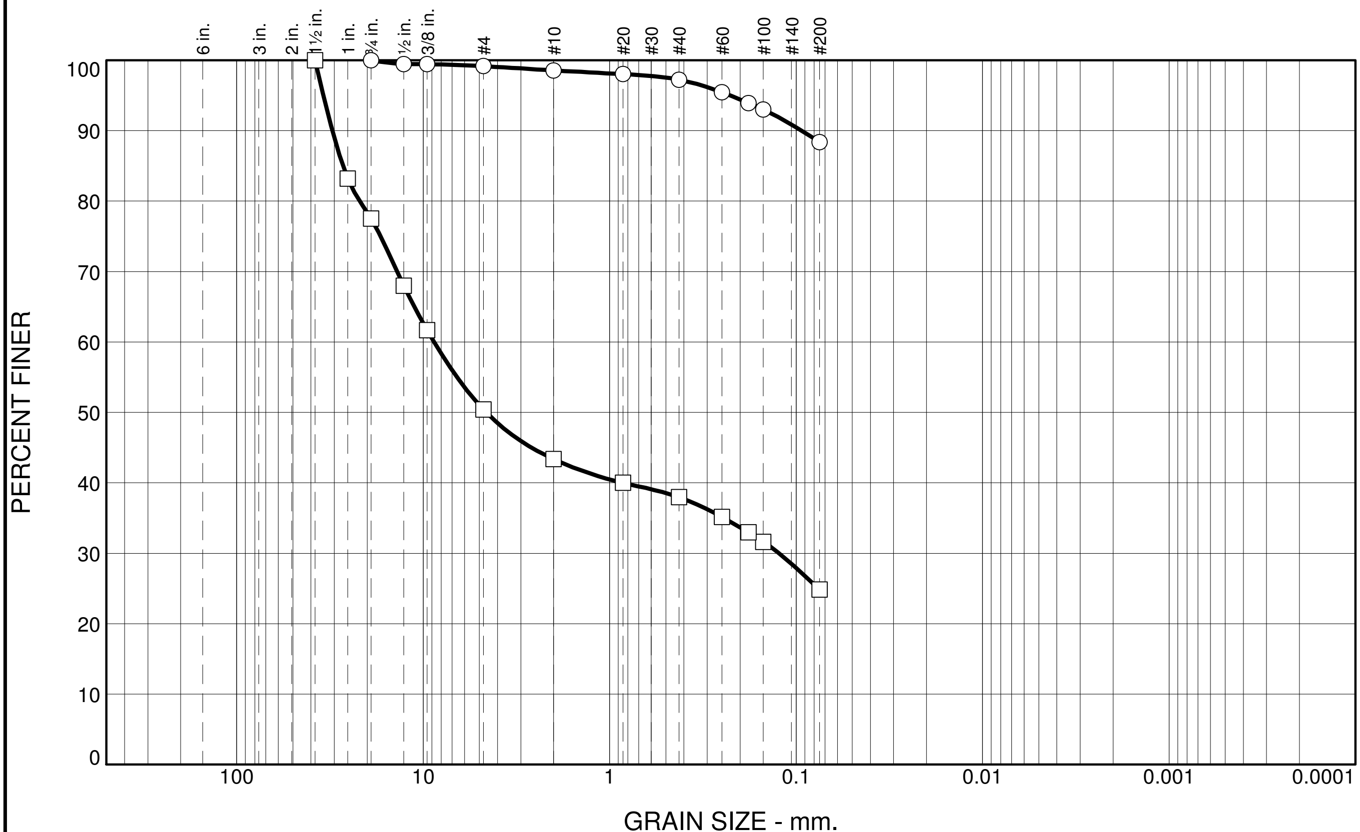
Client: Department of Natural Resources and Conservation

Project: St. Mary River Siphon

Project No.: 04-167 Figure A21

Tested By: CRN **Checked By:** Craig R Nadeau

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	0.8	10.8	88.4		CL	40	16	24
□	0.0	49.6	25.6	24.8		GC	25	16	9

SIEVE inches size	PERCENT FINER ○	PERCENT FINER □	PERCENT FINER
1.5		100.0	
1.0		83.2	
3/4	100.0	77.5	
1/2	99.5	68.0	
3/8	99.5	61.7	

	GRAIN SIZE		
D_{60}		8.7384	
D_{30}		0.1240	
D_{10}			

	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	PERCENT FINER □	PERCENT FINER
#4	99.2	50.4	
#10	98.6	43.4	
#20	98.0	40.0	
#40	97.2	38.0	
#60	95.5	35.1	
#80	93.9	33.0	
#100	93.0	31.6	
#200	88.4	24.8	

Material Description

○ Lean CLAY

□ Clayey GRAVEL with Sand

REMARKS:

○ Report No. A-803-206

□ Report No. A-809/810/820-206
Composite Samples

○ Location: PW-1 Depth: 20.0 - 21.0 ft Sample Number: A-803

□ Location: PW-1 Depth: 30.5 - 31.5 ft Sample Number: A-809/810/820 Comp

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS - BOZEMAN - KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

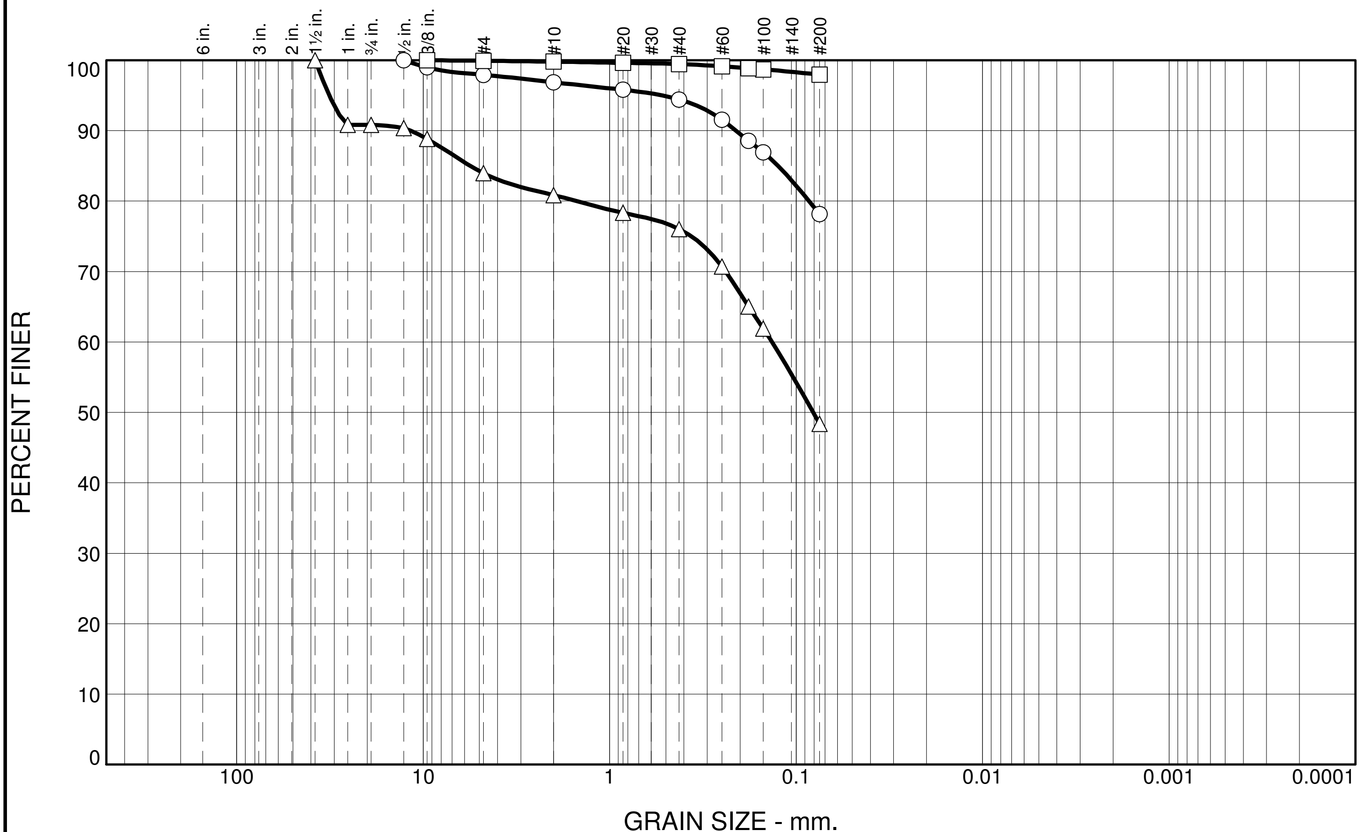
Client: Department of Natural Resources and Conservation

Project: St. Mary River Siphon

Project No.: 04-167 Figure A22

Tested By: ● CRN ■ DSM **Checked By:** Craig R Madison

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	2.1	19.7	78.2		CL	43	19	24
□	0.0	0.1	1.9	98.0		CH	54	21	33
△	0.0	16.0	35.6	48.4		SC			

SIEVE inches size	PERCENT FINER ○	□	△
1.5			100.0
1.0			90.8
3/4			90.8
1/2	100.0		90.4
3/8	99.0	100.0	88.8
GRAIN SIZE			
D_{60}			0.1349
D_{30}			
D_{10}			
COEFFICIENTS			
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	97.9	99.9	84.0
#10	96.9	99.8	80.9
#20	95.8	99.6	78.3
#40	94.4	99.5	76.0
#60	91.6	99.1	70.7
#80	88.6	98.9	65.1
#100	86.9	98.7	61.9
#200	78.2	98.0	48.4

Material Description

○ Lean CLAY with Sand

□ Fat CLAY

△ Clayey SAND with Gravel

REMARKS:

○ Report No. A-814-206

□ Report No. A-817-206

△ Report No. A-819-206

○ Location: PW-2 Depth: 9.0 - 10.5 ft Sample Number: A-814
□ Location: PW-2 Depth: 24.0 - 25.0 ft Sample Number: A-817
△ Location: PW-2 Depth: 34.0 - 35.0 ft Sample Number: A-819

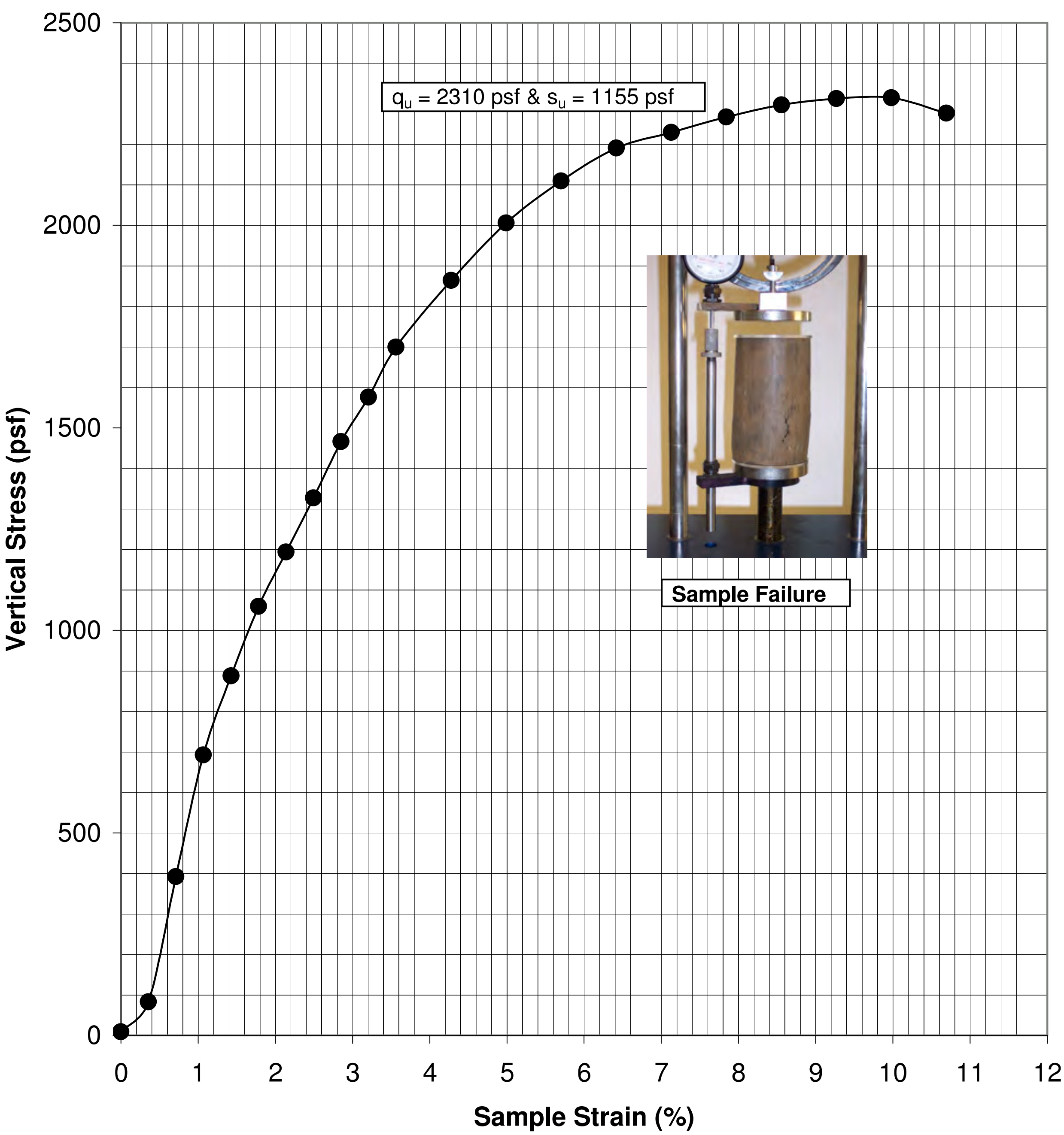
TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS - BOZEMAN - KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Client: Department of Natural Resources and Conservation
Project: St. Mary River Siphon
Project No.: 04-167 Figure A23

Tested By: CRN **Checked By:** Craig R Madsen

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification: Sandy, **LEAN CLAY** (CL)
Sample Location: NSI-1, S-4
Sample Depth: 10.0 - 12.0 ft.
Field Moisture: 24%
Dry Unit Weight: 101 pcf

Atterberg Limits
LL= 41
PI = 22

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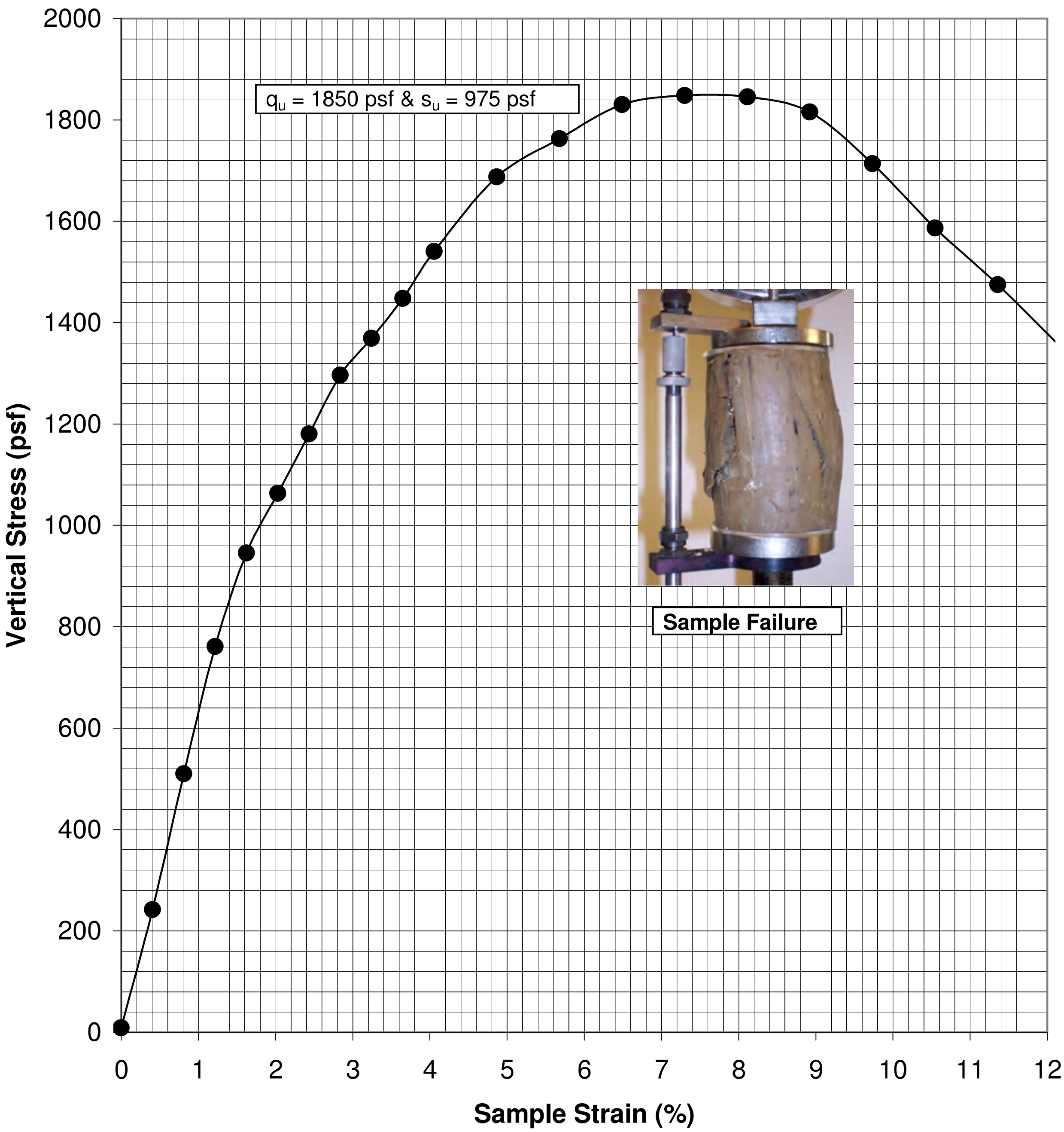
Figure A24

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification: Sandy, **LEAN CLAY** (CL)
Sample Location: SSI-1, S-3
Sample Depth: 7.5 - 9.5 ft.
Field Moisture: 17%
Dry Unit Weight: 113 pcf

Atterberg Limits
LL= 33
PI = 16

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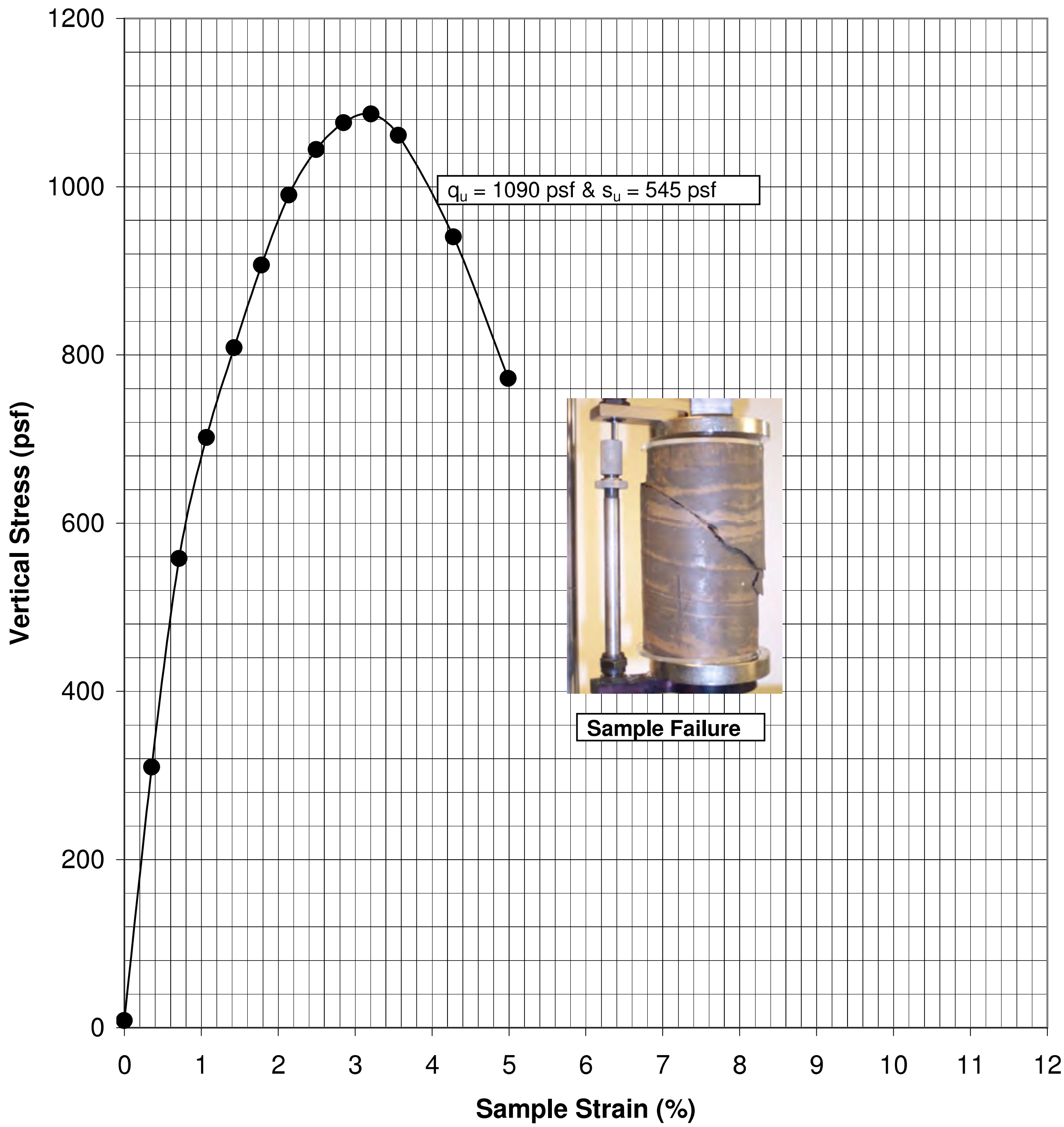
Figure A25

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification: **FAT CLAY** with sand (CH)
Sample Location: SSI-1, S-14
Sample Depth: 35.0 - 37.0 ft.
Field Moisture: 37%
Dry Unit Weight: 84 pcf

Atterberg Limits
LL= 76
PI = 49

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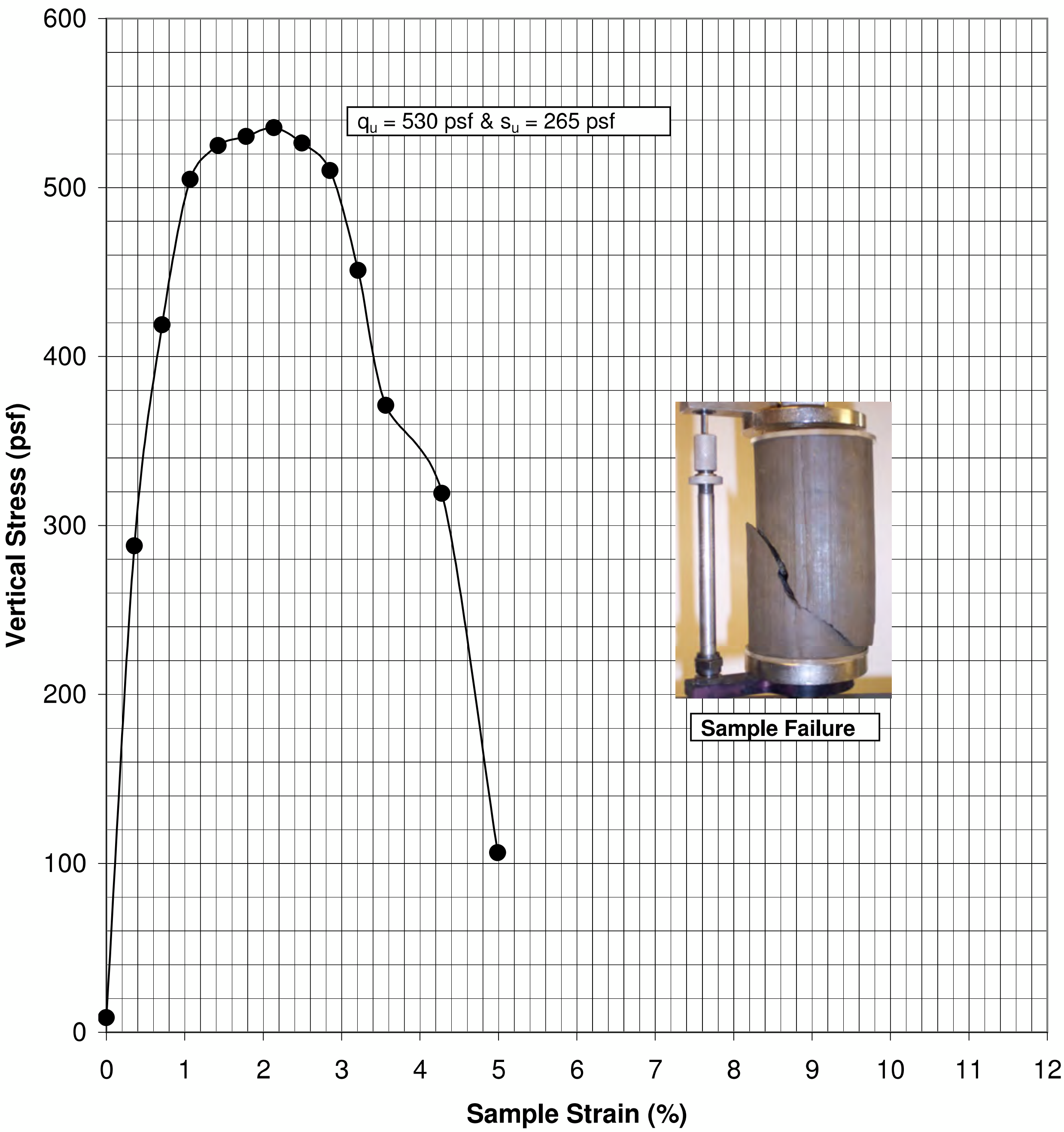
Figure A26

St. Mary River Siphons

TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification: Gravelly, **FAT CLAY** (CH)
Sample Location: SSI-2, S-4
Sample Depth: 10.0 - 11.0 ft.
Field Moisture: 32%
Dry Unit Weight: 89 pcf

Atterberg Limits
LL= 65
PI = 41

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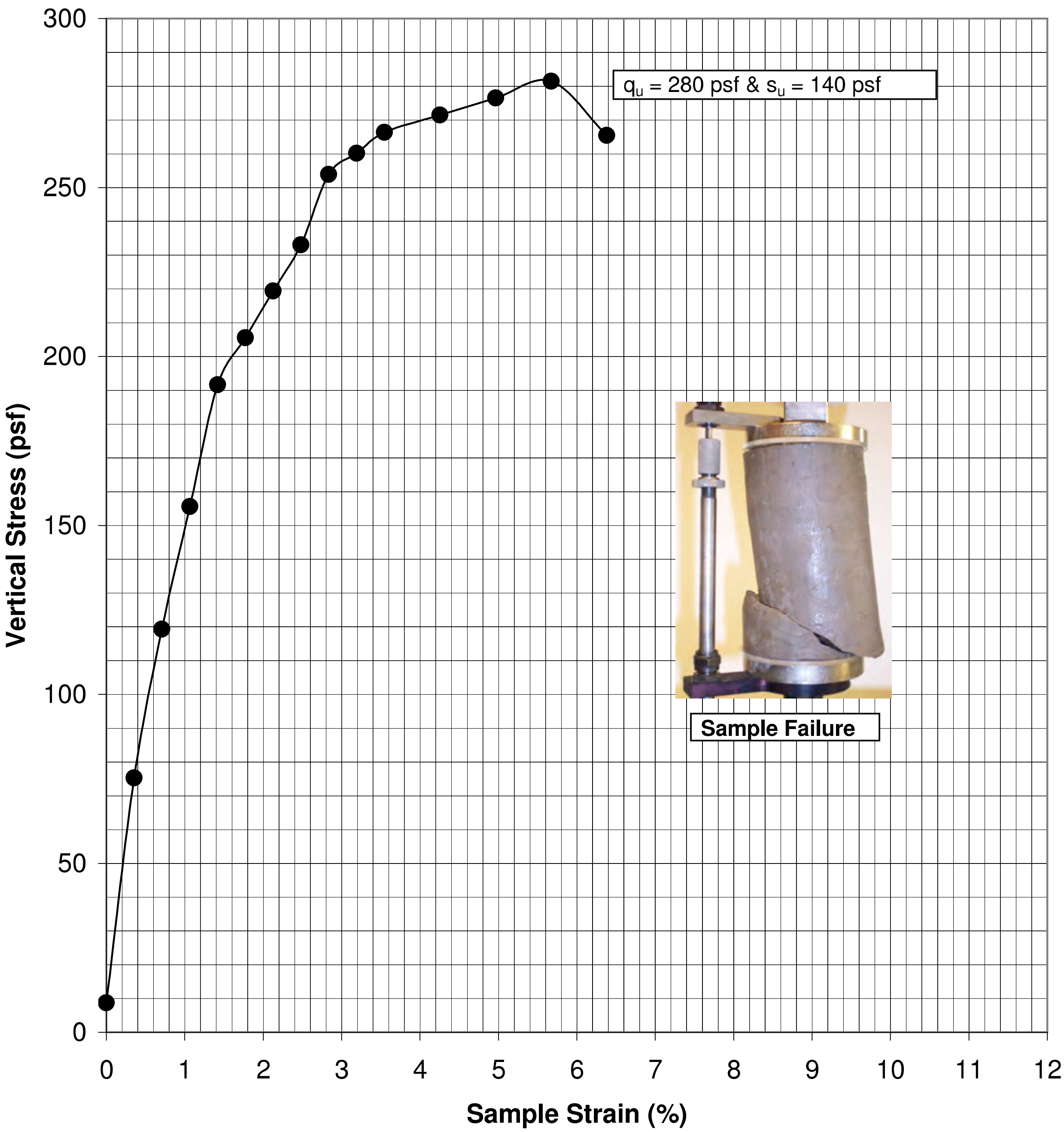
Figure A27

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification:	**FAT CLAY** (CH)	
Sample Location:	SSI-2, S-8	
Sample Depth:	20.0 - 21.0 ft.	Atterberg Limits
Field Moisture:	25%	**LL= 59**
Dry Unit Weight:	100 pcf	**PI = 36**

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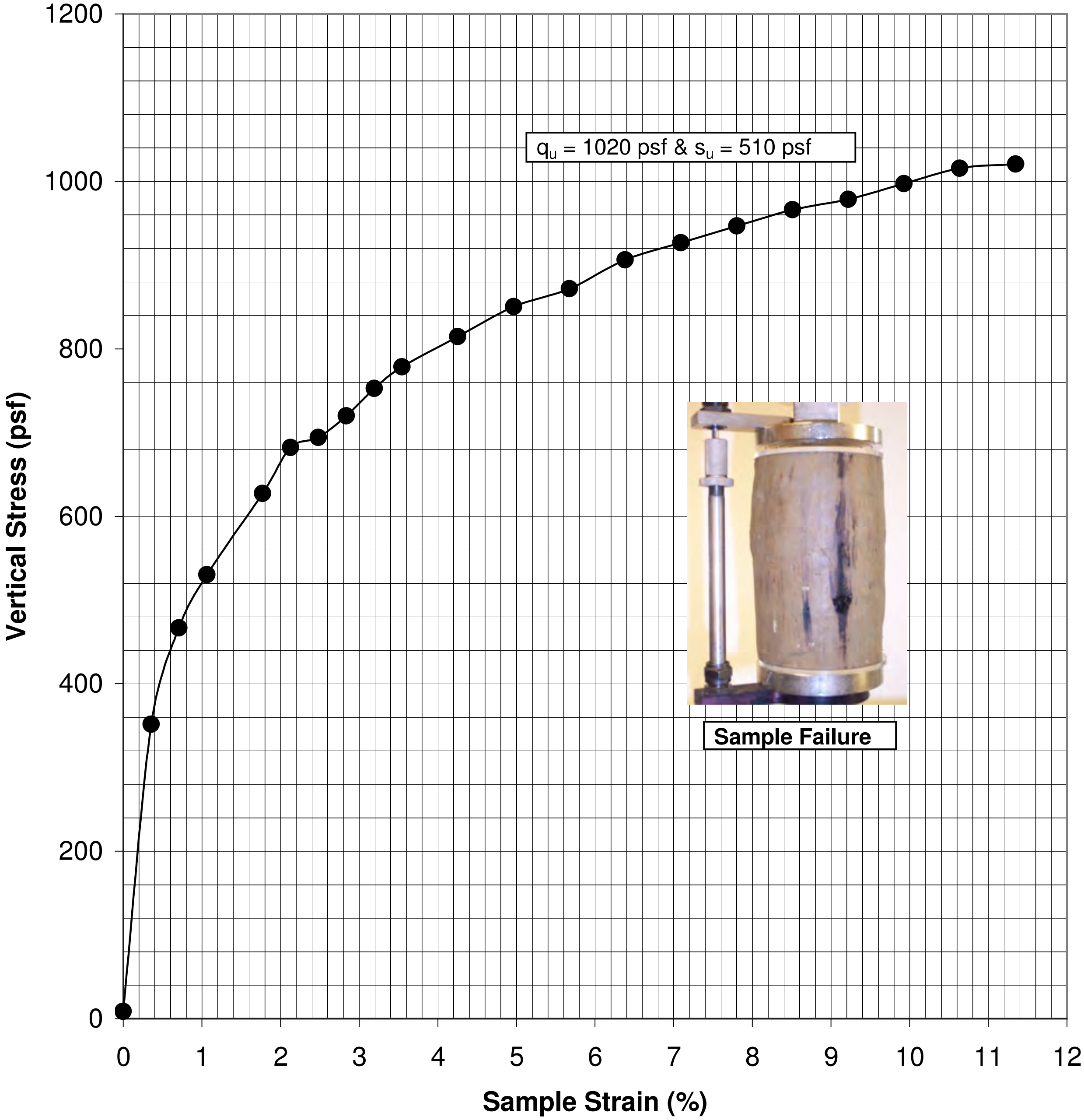
Figure A28

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification:	Sandy, **LEAN CLAY** (CL)	
Sample Location:	SSI-3, S-3	
Sample Depth:	7.5 - 9.5 ft.	Atterberg Limits
Field Moisture:	20%	**LL= 42**
Dry Unit Weight:	109 pcf	**PI = 24**

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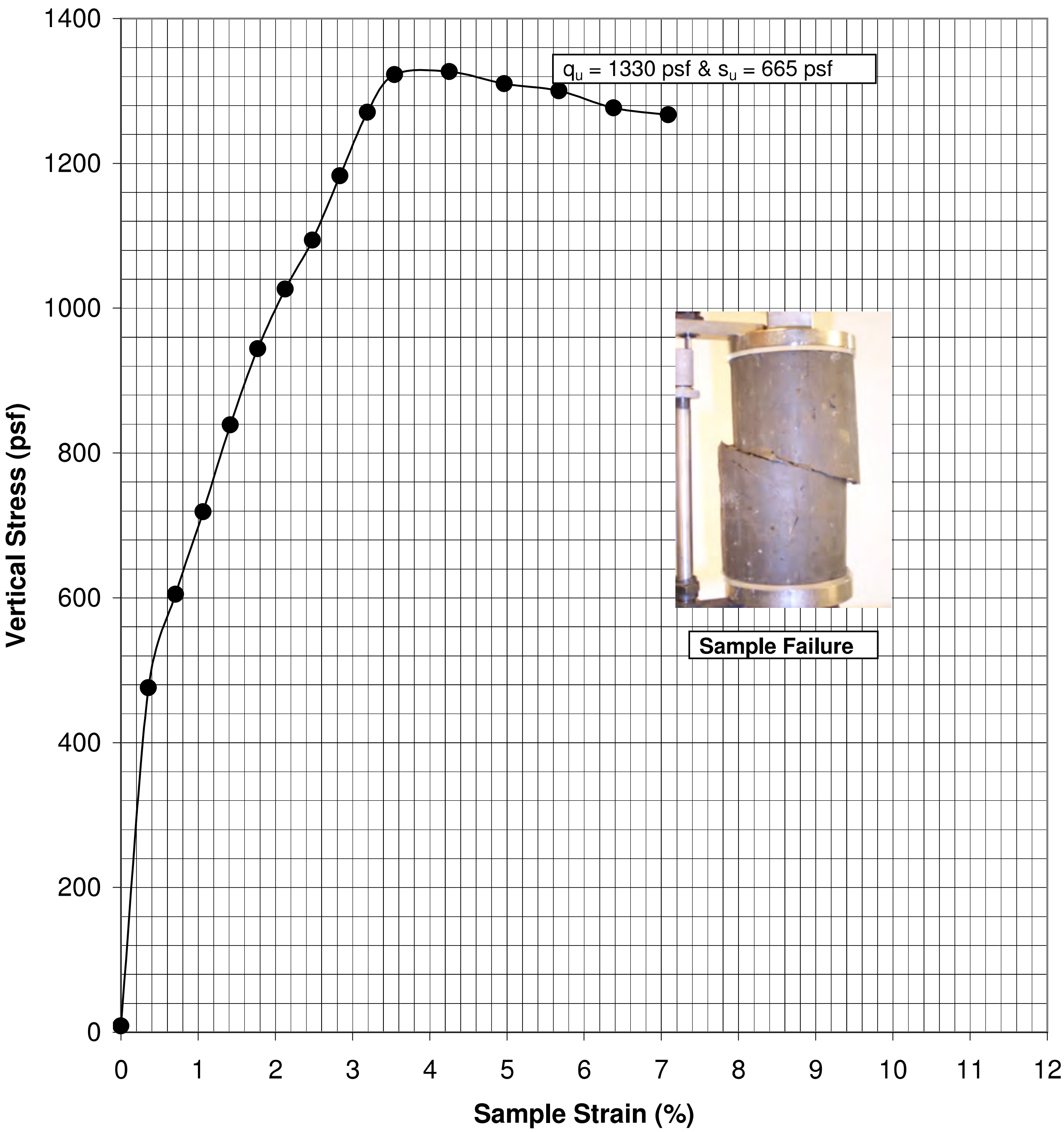
Figure A29

UNCONFINED COMPRESSION TEST



Sample Failure

Soil Classification: **LEAN CLAY** (CL)
Sample Location: SSI-3, S-9A
Sample Depth: 22.5 - 23.5 ft.
Field Moisture: 19%
Dry Unit Weight: 111 pcf

Atterberg Limits
LL= 46
PI = 27

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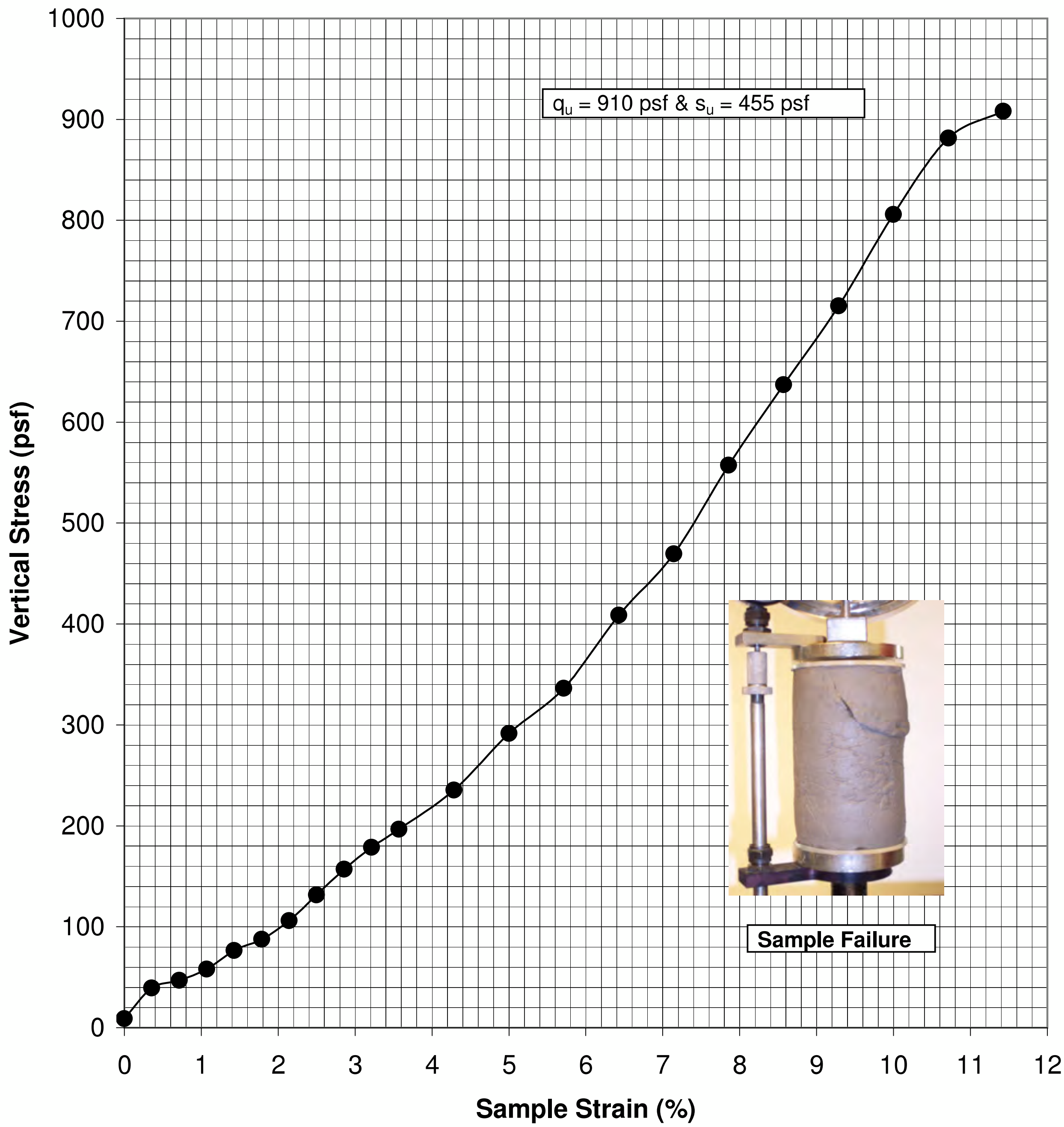
Figure A30

St. Mary River Siphons	TD&H Project #: 04-167

UNCONFINED COMPRESSION TEST



Soil Classification:	**SILT** (ML)	
Sample Location:	SSI-3, S-9B	
Sample Depth:	23.5 - 24.0 ft.	Atterberg Limits
Field Moisture:	27%	**LL= 28**
Dry Unit Weight:	98 pcf	**PI = 4**

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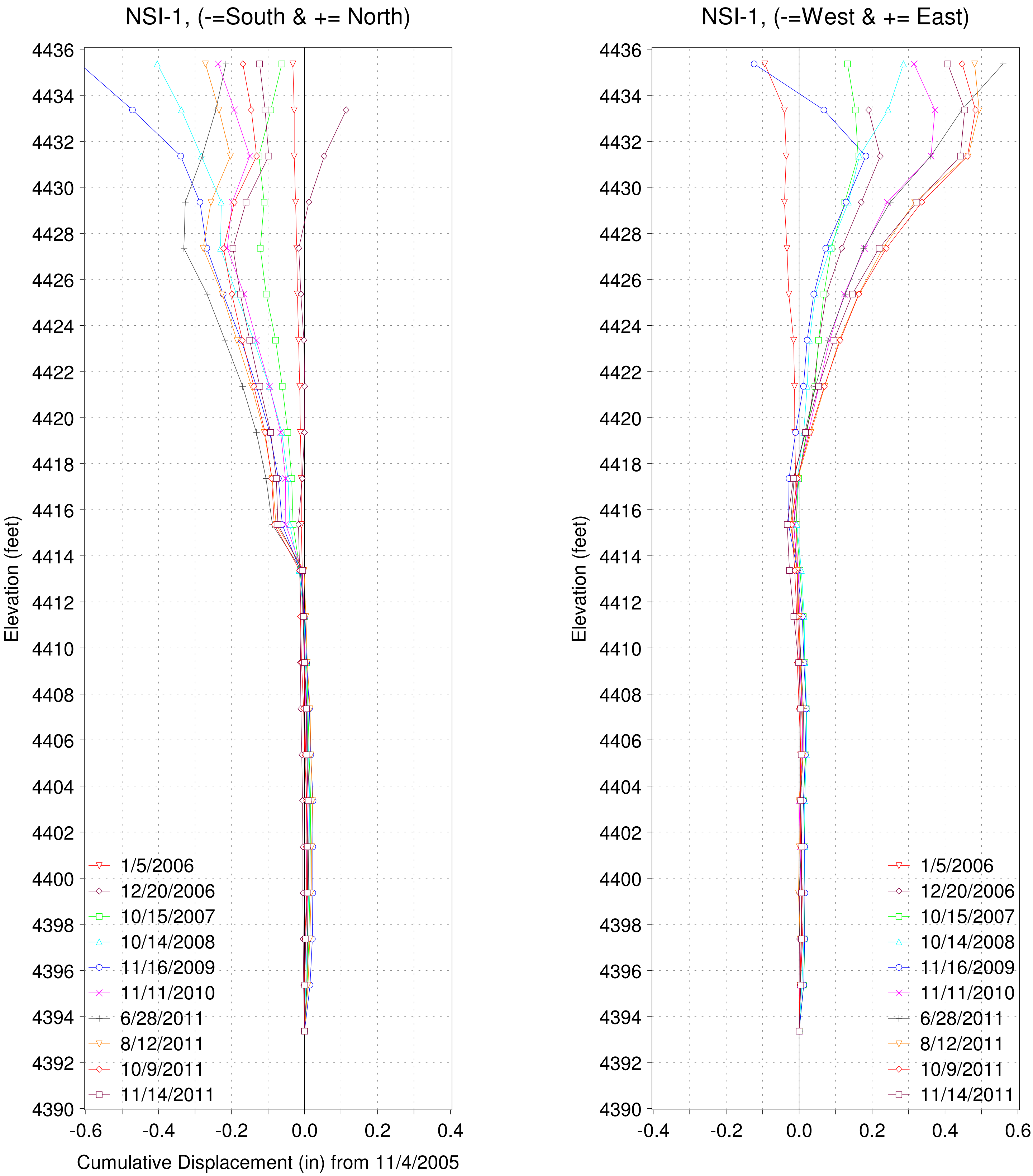
Figure A31



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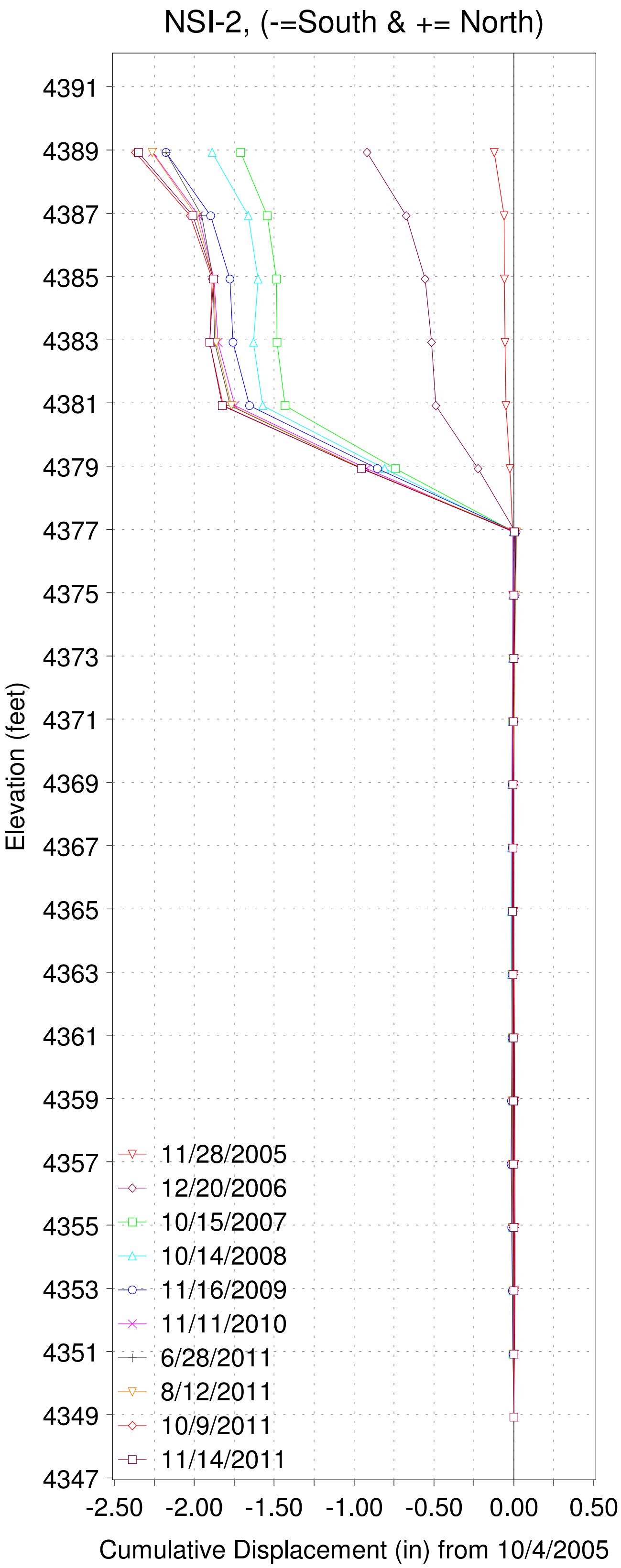
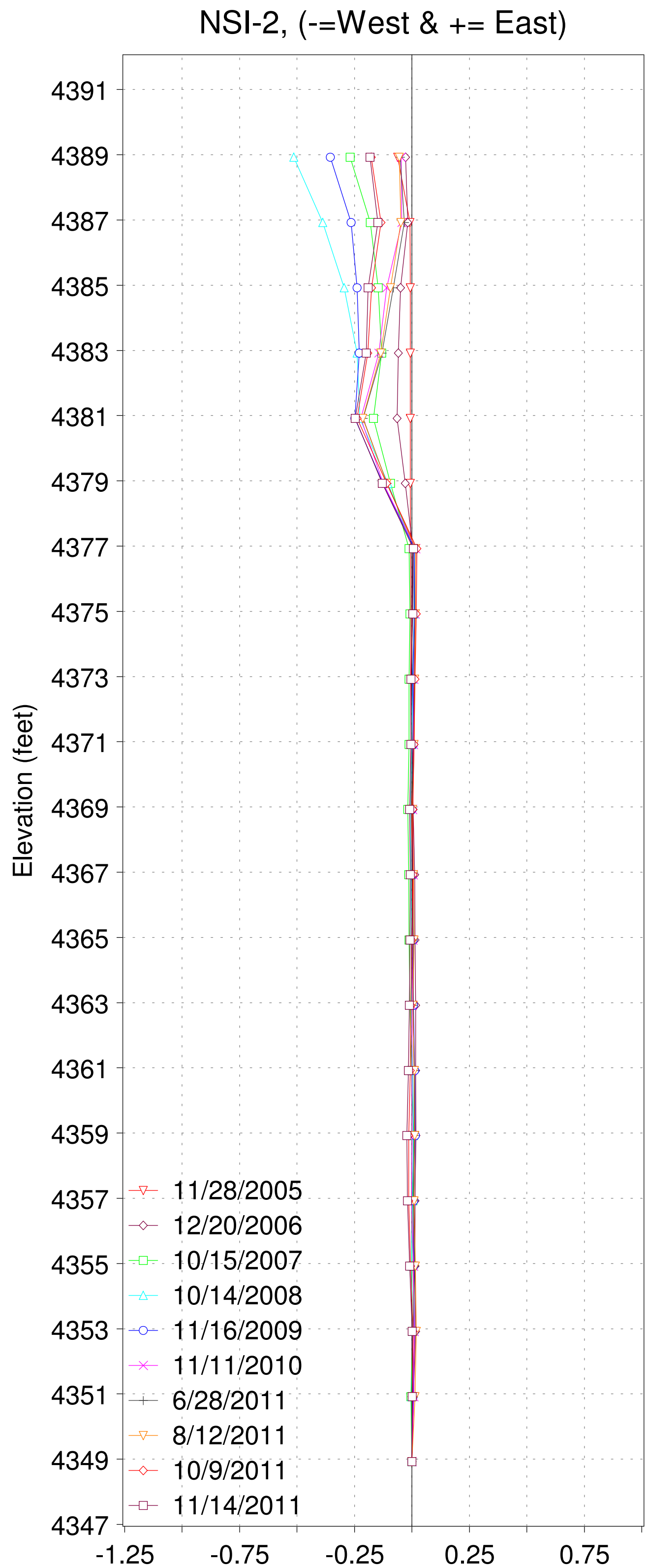
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, North Slope

Ground Elevation= 4433.4

Figure A32





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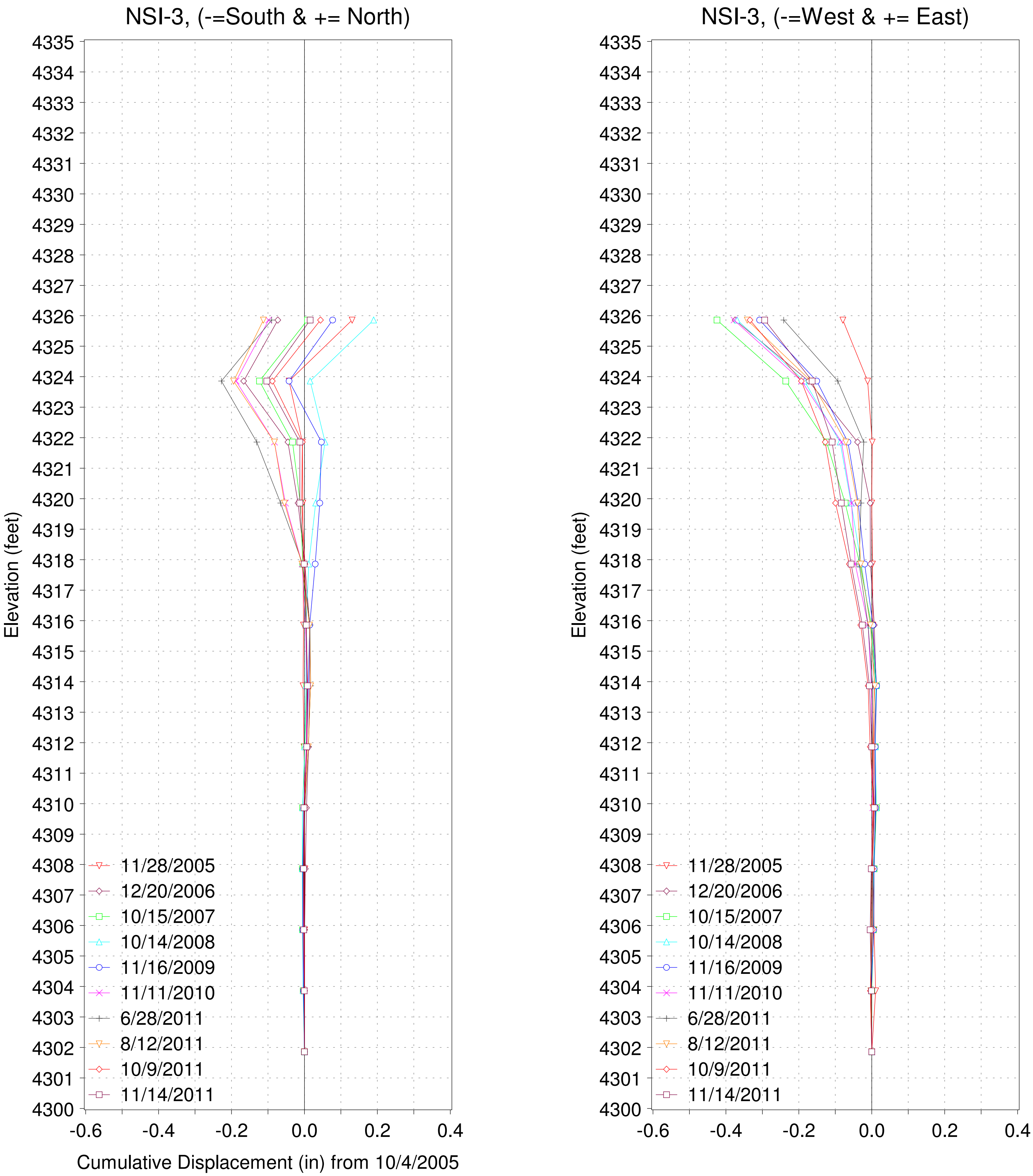
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, North Slope

Ground Elevation=4388.4

Figure A33



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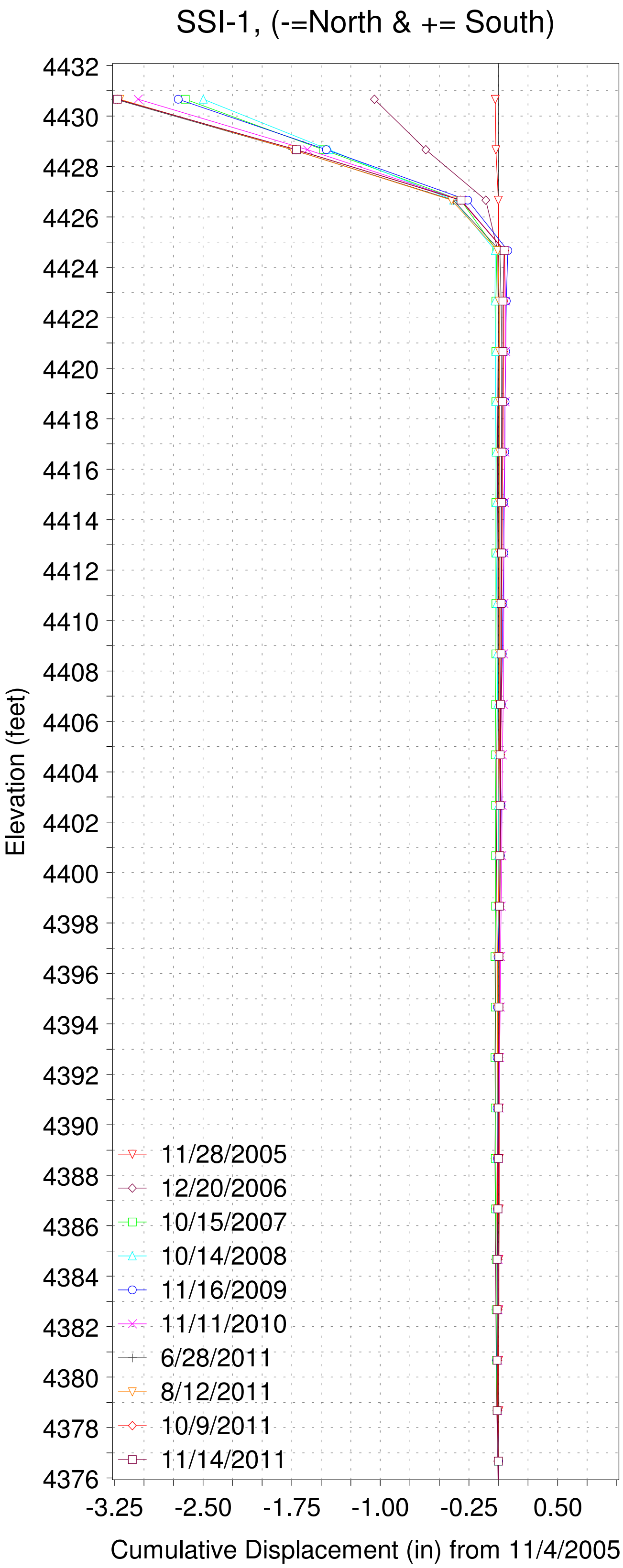
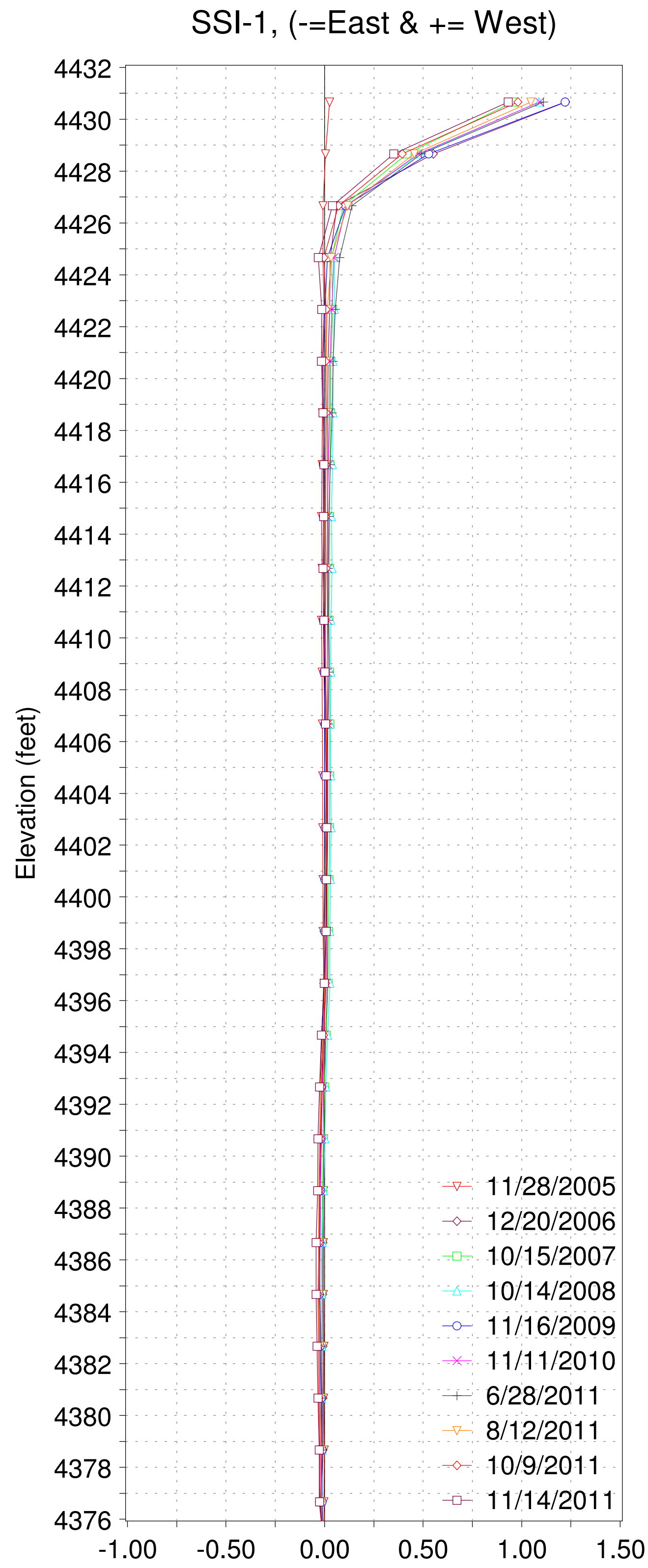
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, North Slope

Ground Elevation= 4325.1

Figure A34





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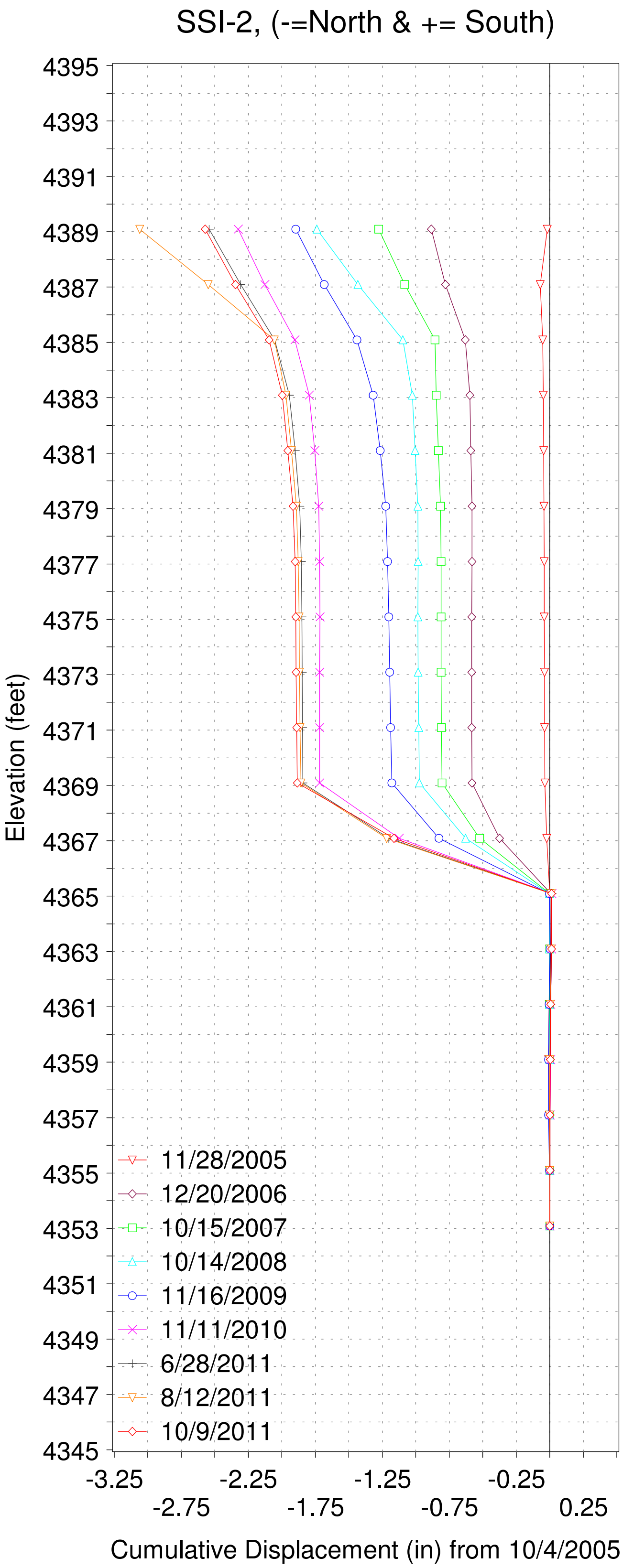
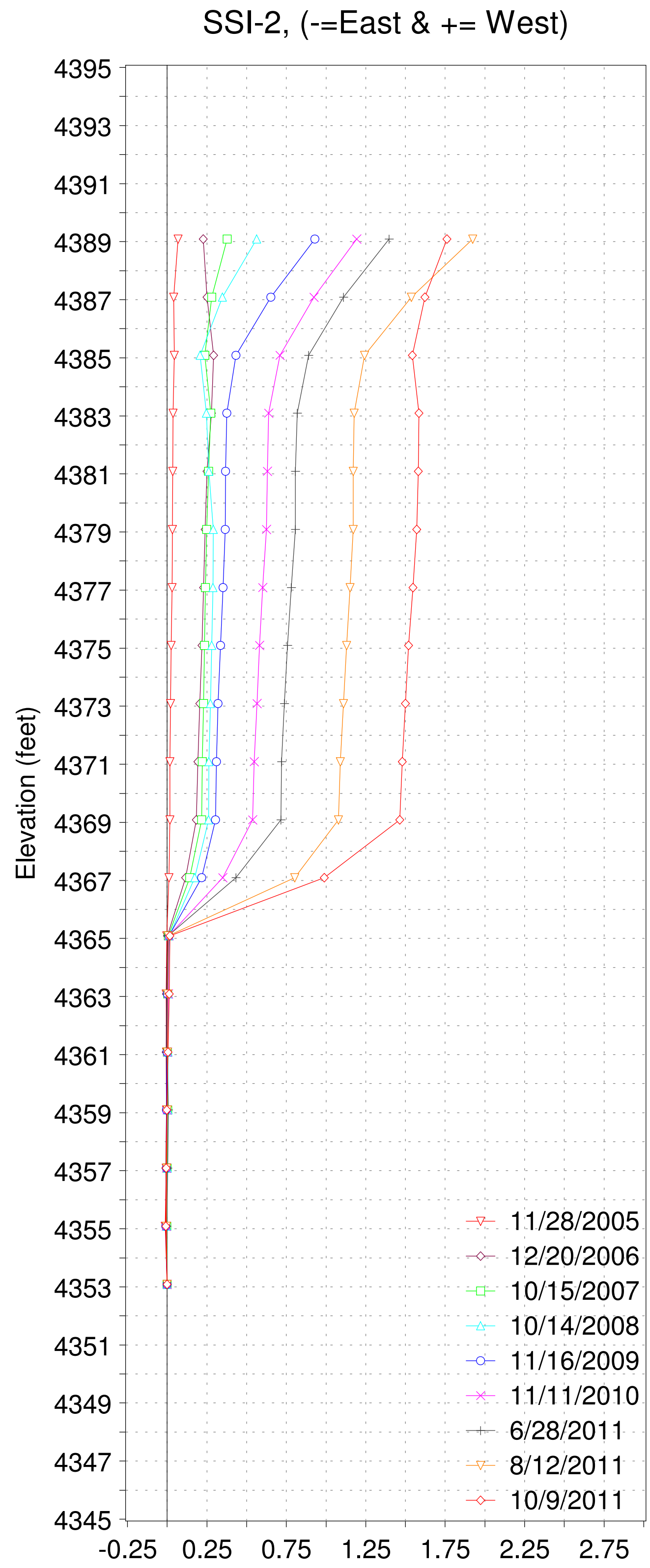
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, South Slope

Ground Elevation= 4428.9

Figure A35





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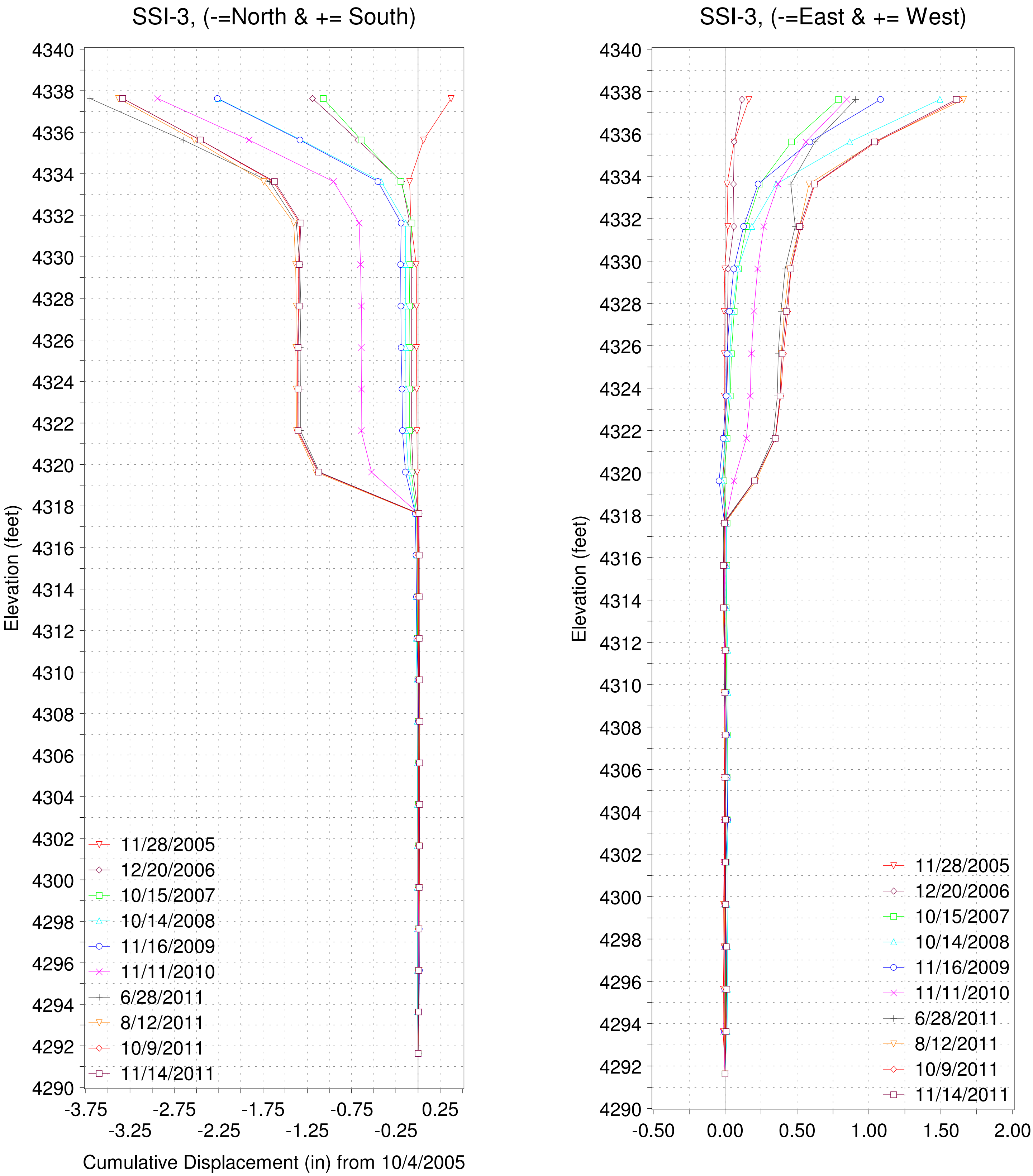
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, South Slope

Ground Elevation=4387.3

Figure A36



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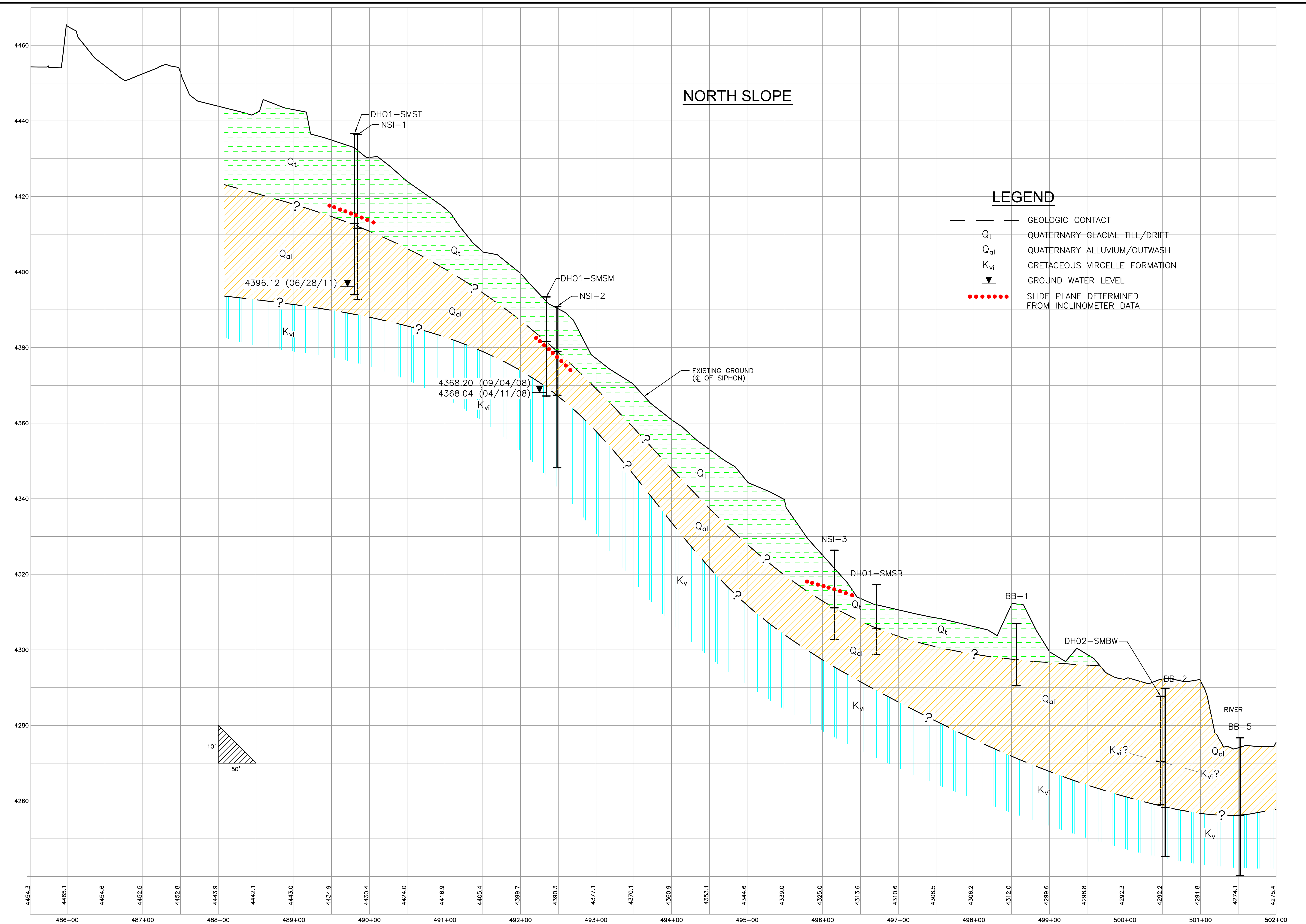
Engineering Consultants

St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, South Slope

Ground Elevation= 4335.4

Figure A37



REVISIONS
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BY ___ DATE ___ DESCR ___
BY ___ DATE ___ DESCR ___

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SPOKANE
LEWISTON
MONTANA
WASHINGTON
IDAHO
TD&H

DRAWN BY: MWC
DESIGNED BY: EAJ
QUALITY CHECK:
DATE: 01.20.12
JOB NO. 04-167
FIELDBOOK

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES
FOR THE ST. MARY RIVER SIPHON CROSSING
GEOLOGIC CROSS SECTION - NORTH SLOPE

CAD NO. 04167figA38 .DWG
SHEET 1 OF 2

FIGURE A38

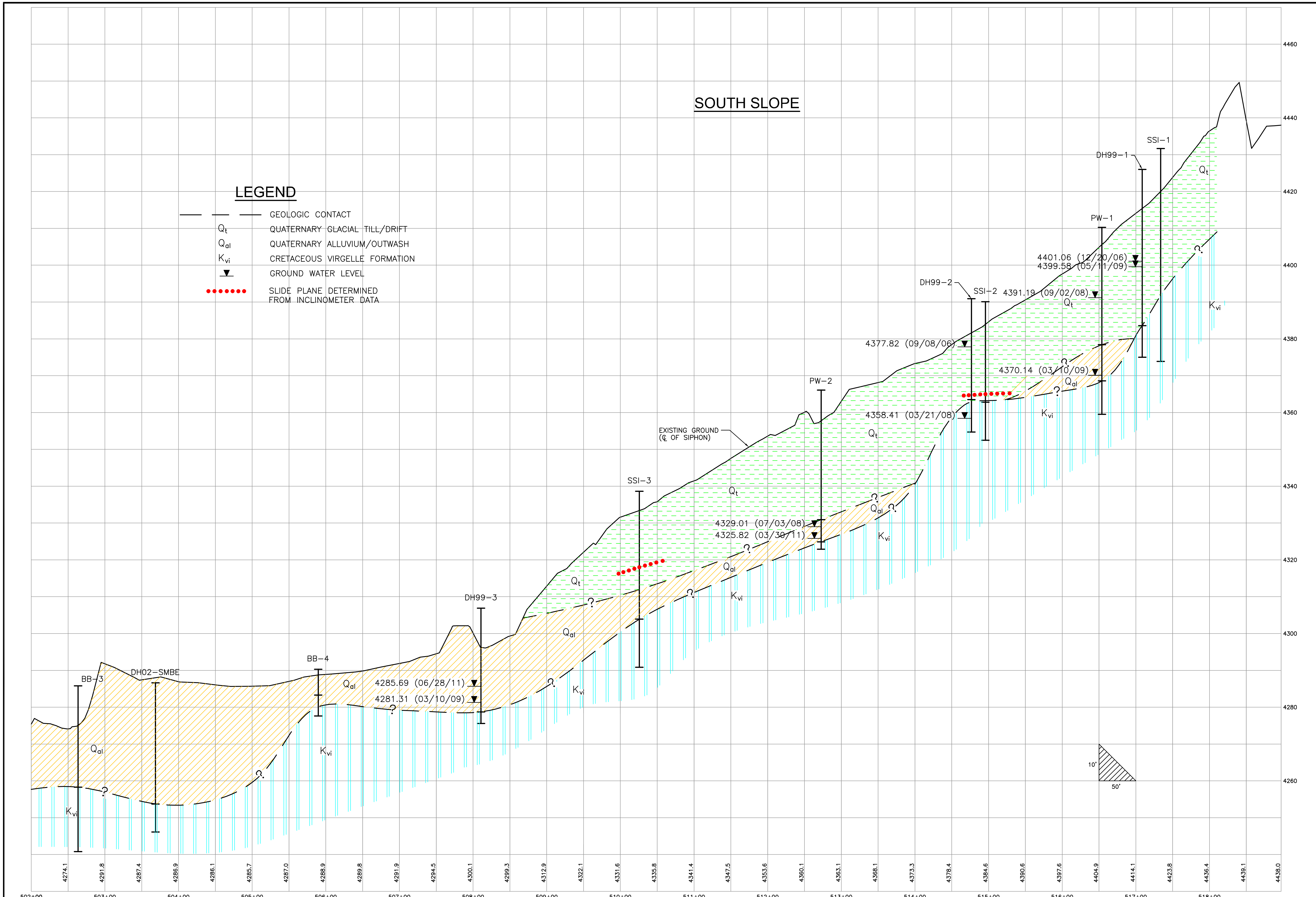

FIGURE A38

REVISIONS

BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR

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WASHINGTON
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DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	09.10.07
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER SIPHON CROSSING
GEOLOGIC CROSS SECTION - SOUTH SLOPE

CAD NO. 04167fig33 .DWG
SHEET 2 OF 2

FIGURE A39
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
GEOMETRY, MATERIAL PROPERTIES, AND ELEVATED GROUND WATER LEVEL

TD&H Engineering

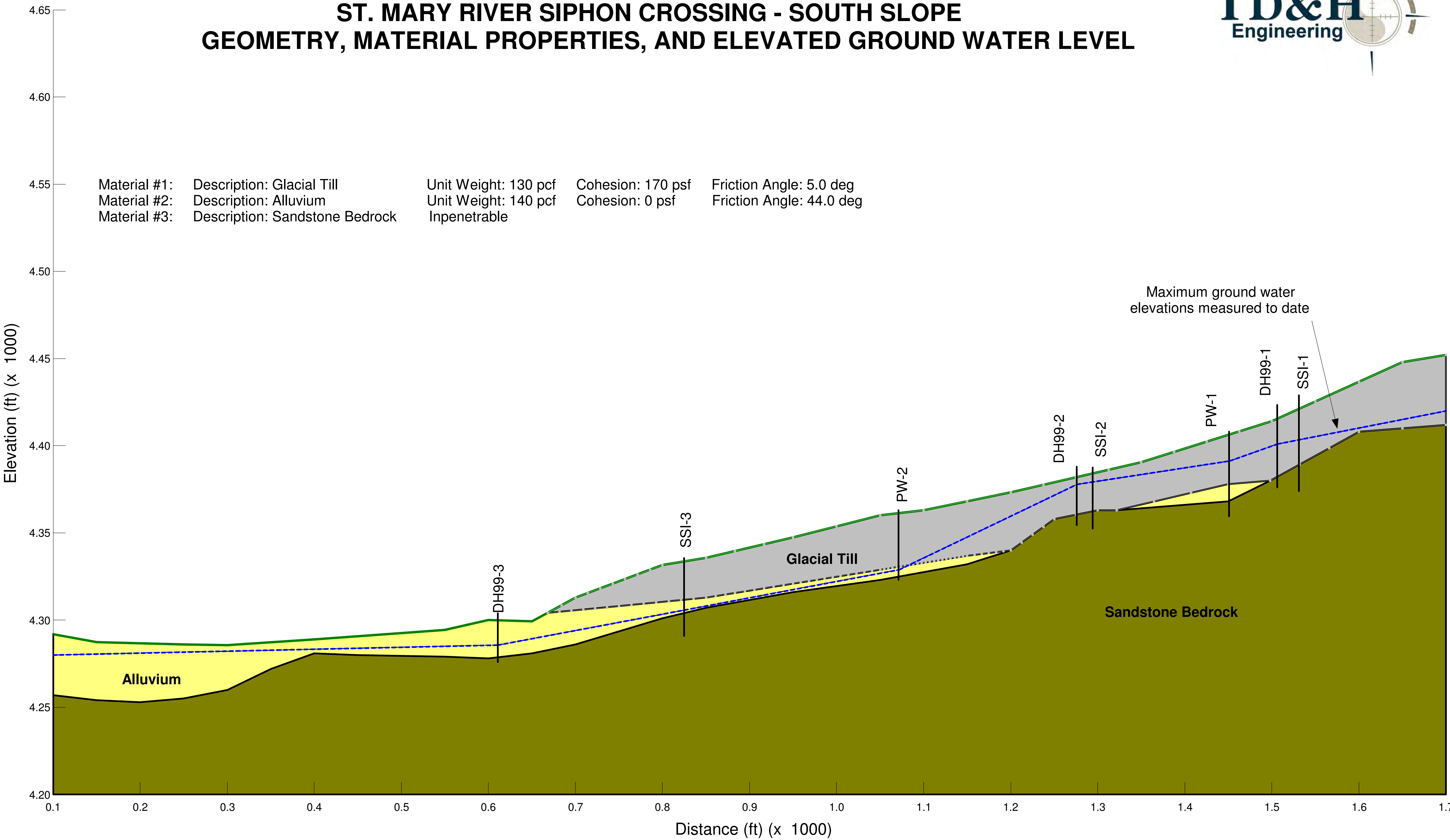


FIGURE A40
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, ELEVATED GROUNDWATER LEVELS, NONSEISMIC

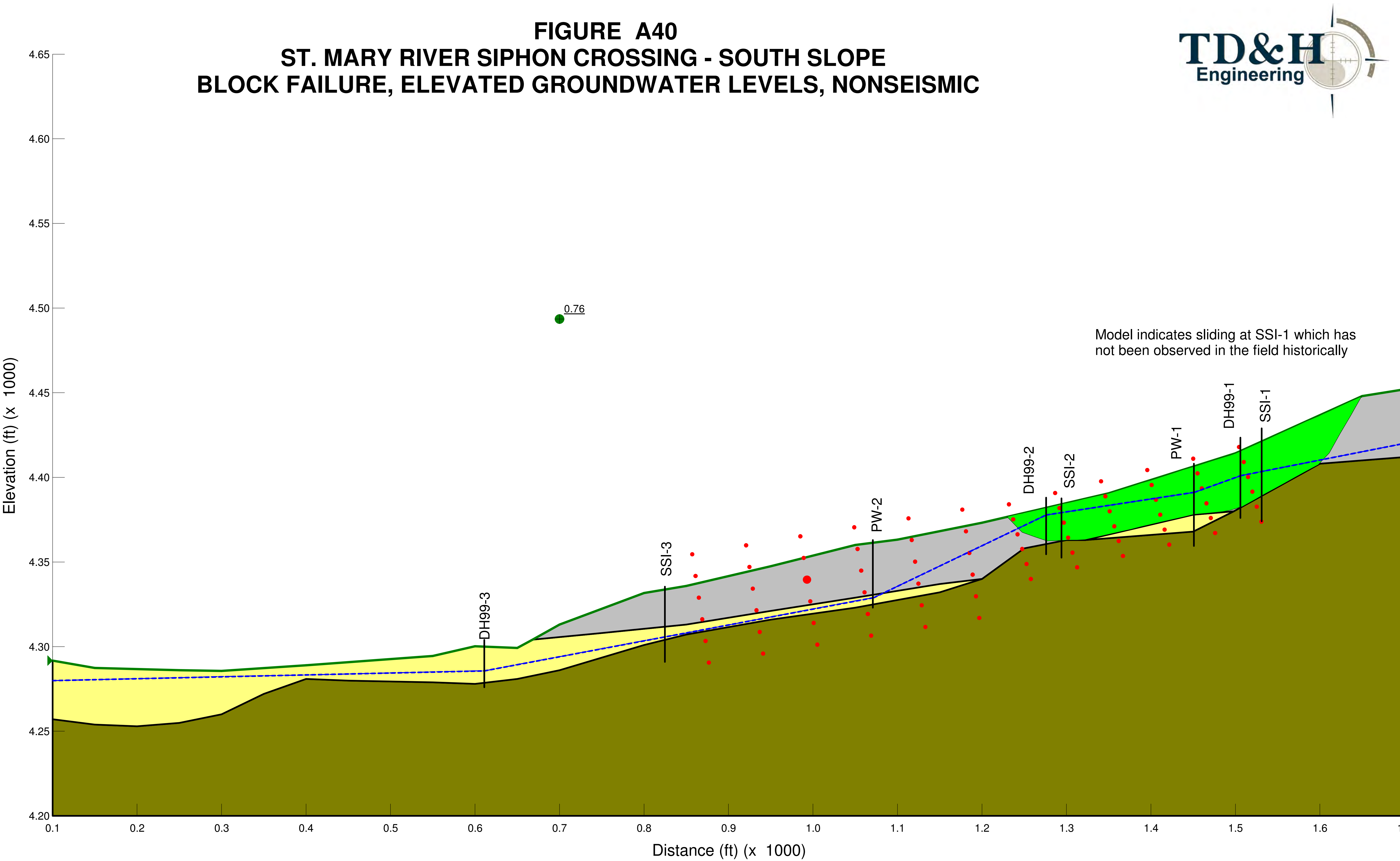


FIGURE A41
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, REDUCED GROUNDWATER LEVELS, NONSEISMIC

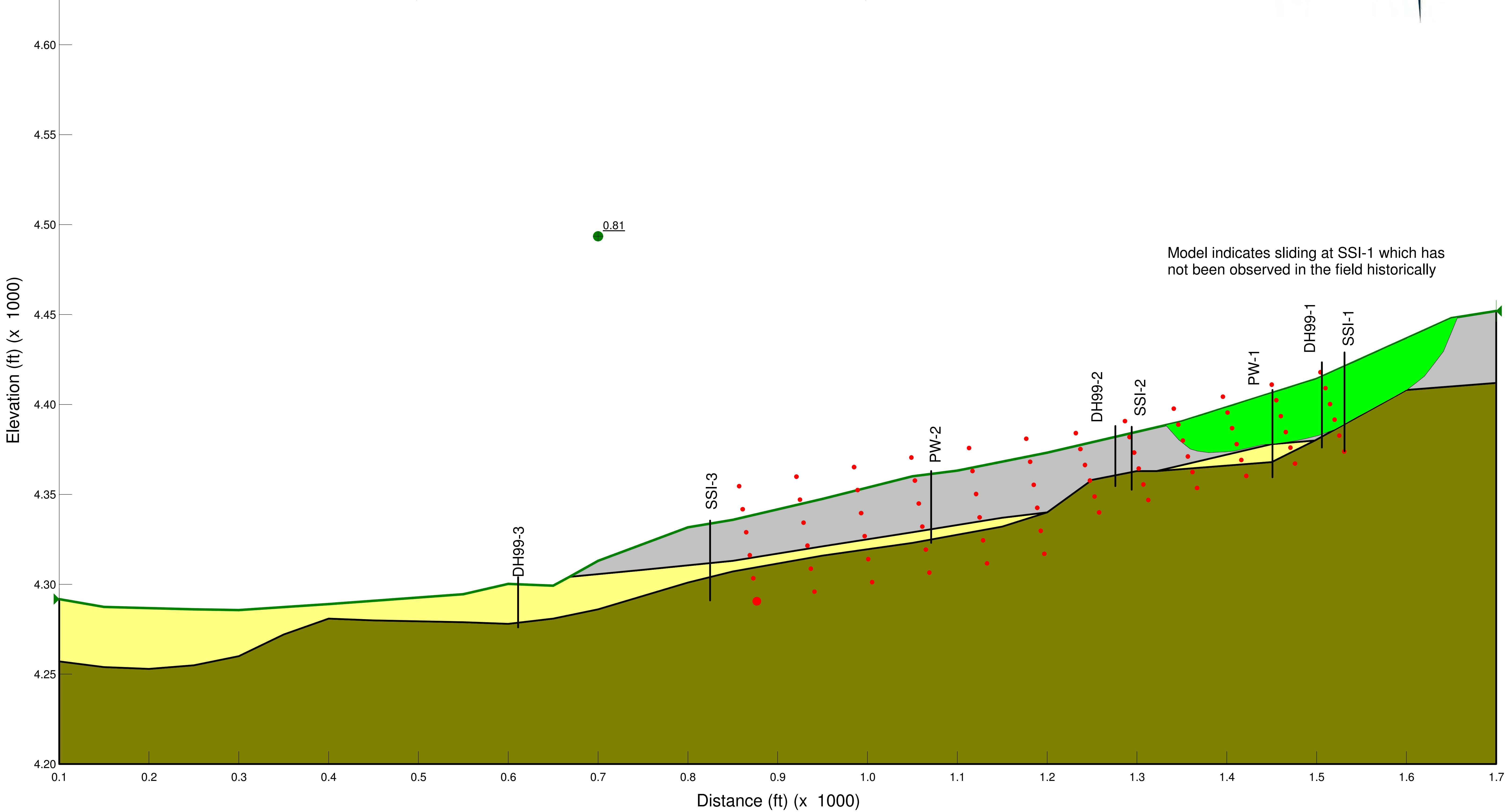


FIGURE A42
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, ELEVATED GROUNDWATER LEVELS, SEISMIC Kh = 0.005g

TD&H Engineering

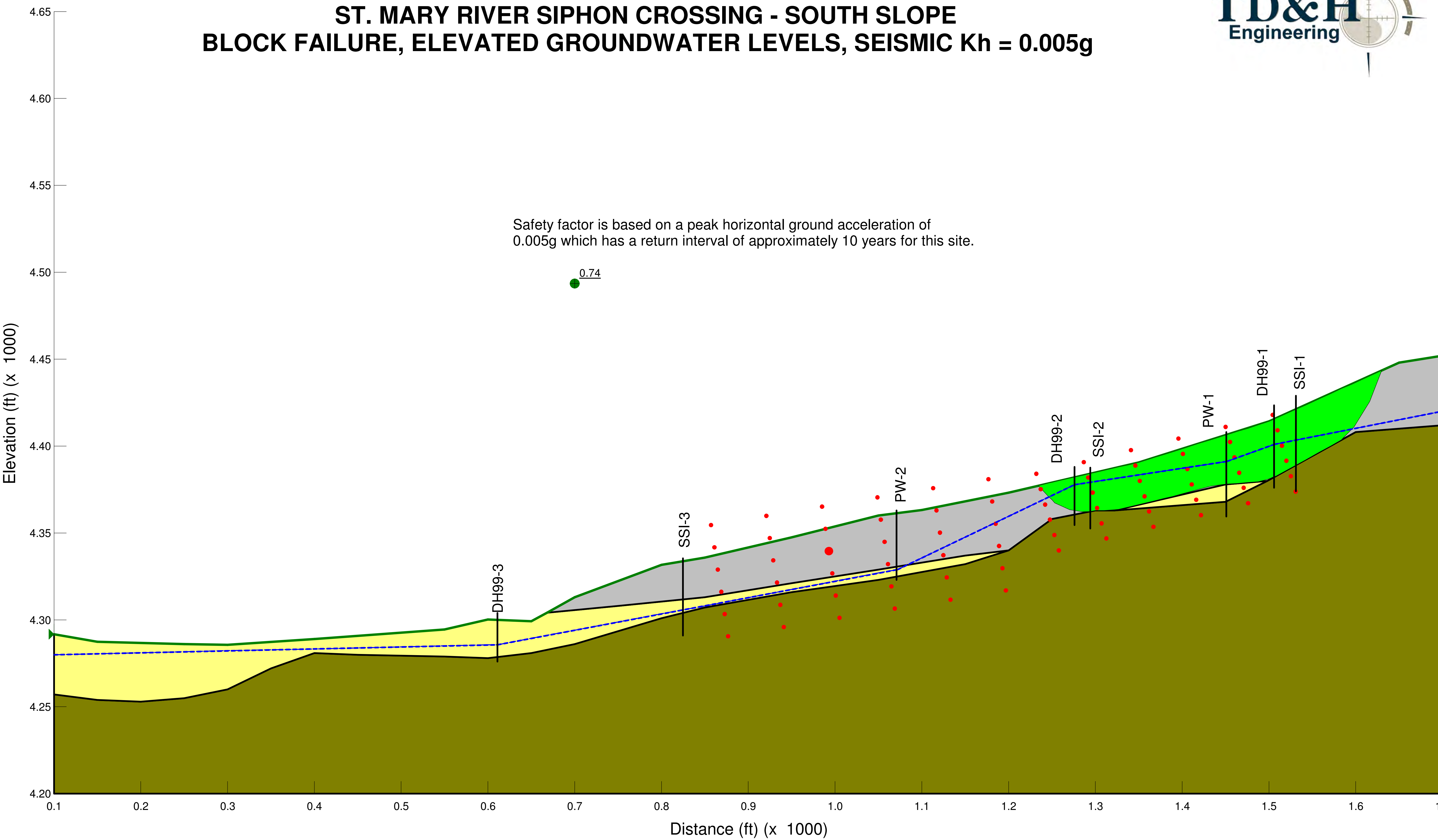


FIGURE A43
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, ELEVATED GROUNDWATER LEVELS, SEISMIC Kh = 0.035g

TD&H Engineering

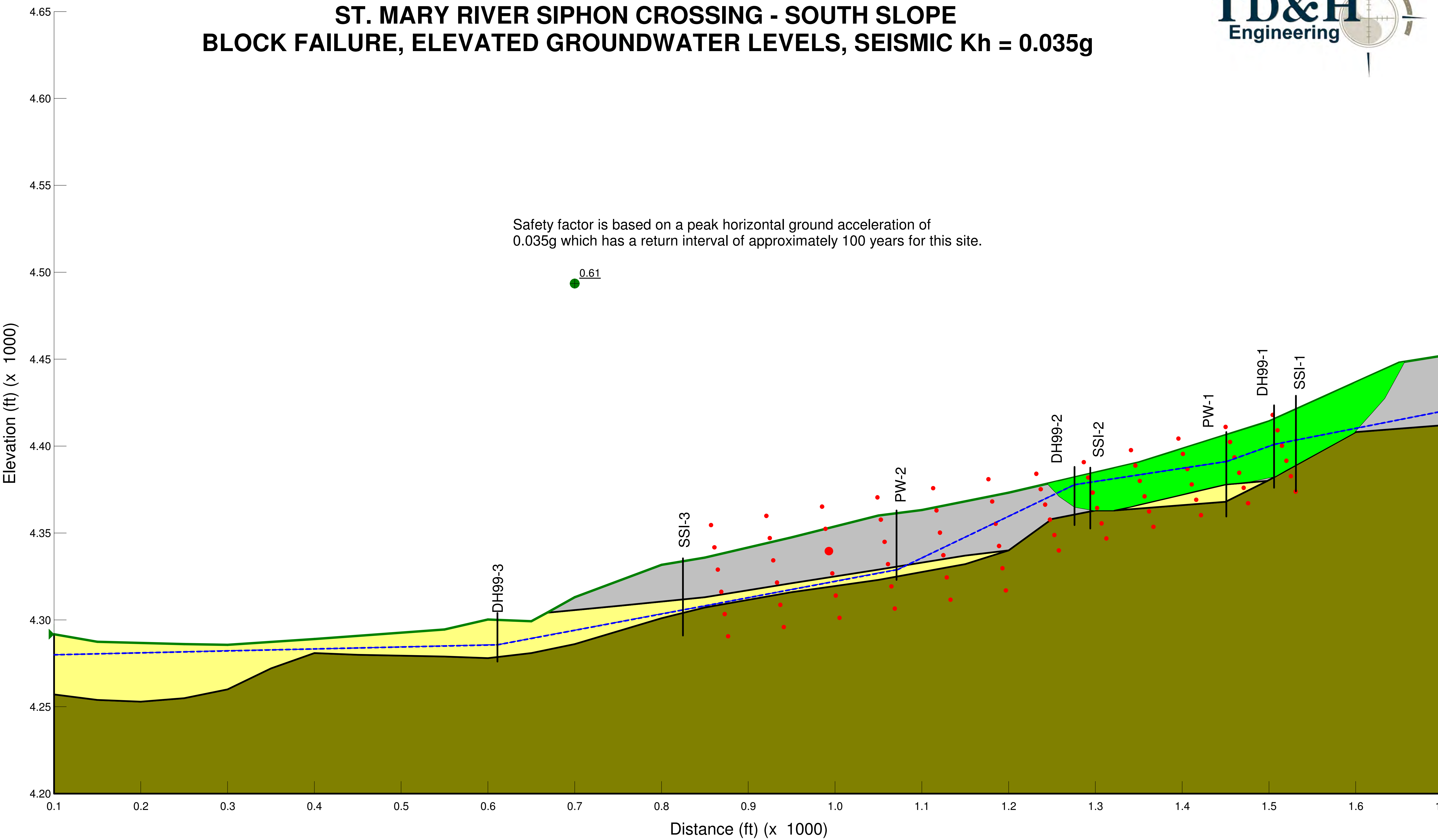


FIGURE A44
ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, ELEVATED GROUNDWATER LEVELS, NONSEISMIC

TD&H Engineering

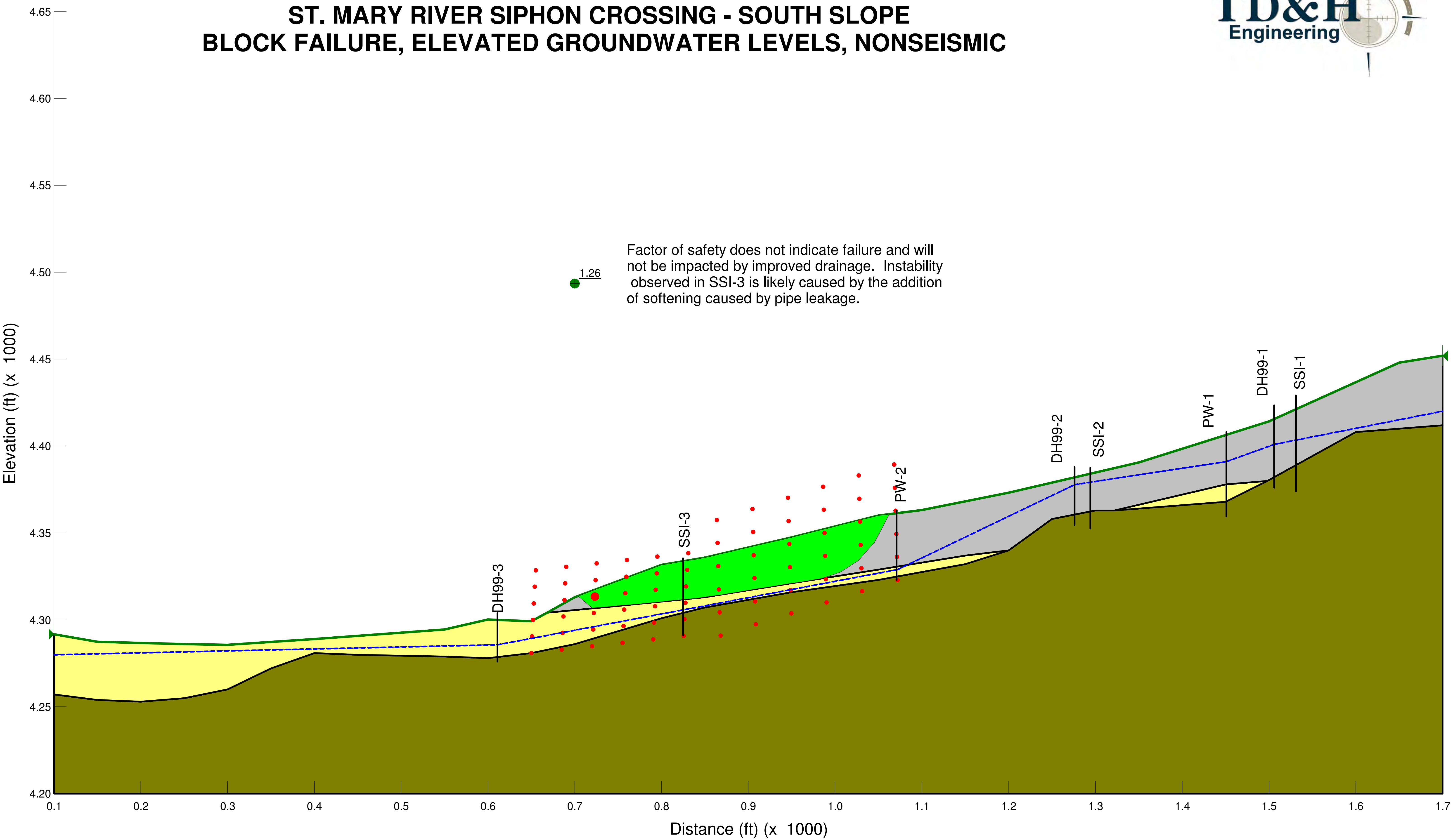


FIGURE A45
ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
GEOMETRY, MATERIAL PROPERTIES, AND ELEVATED GROUND WATER LEVEL

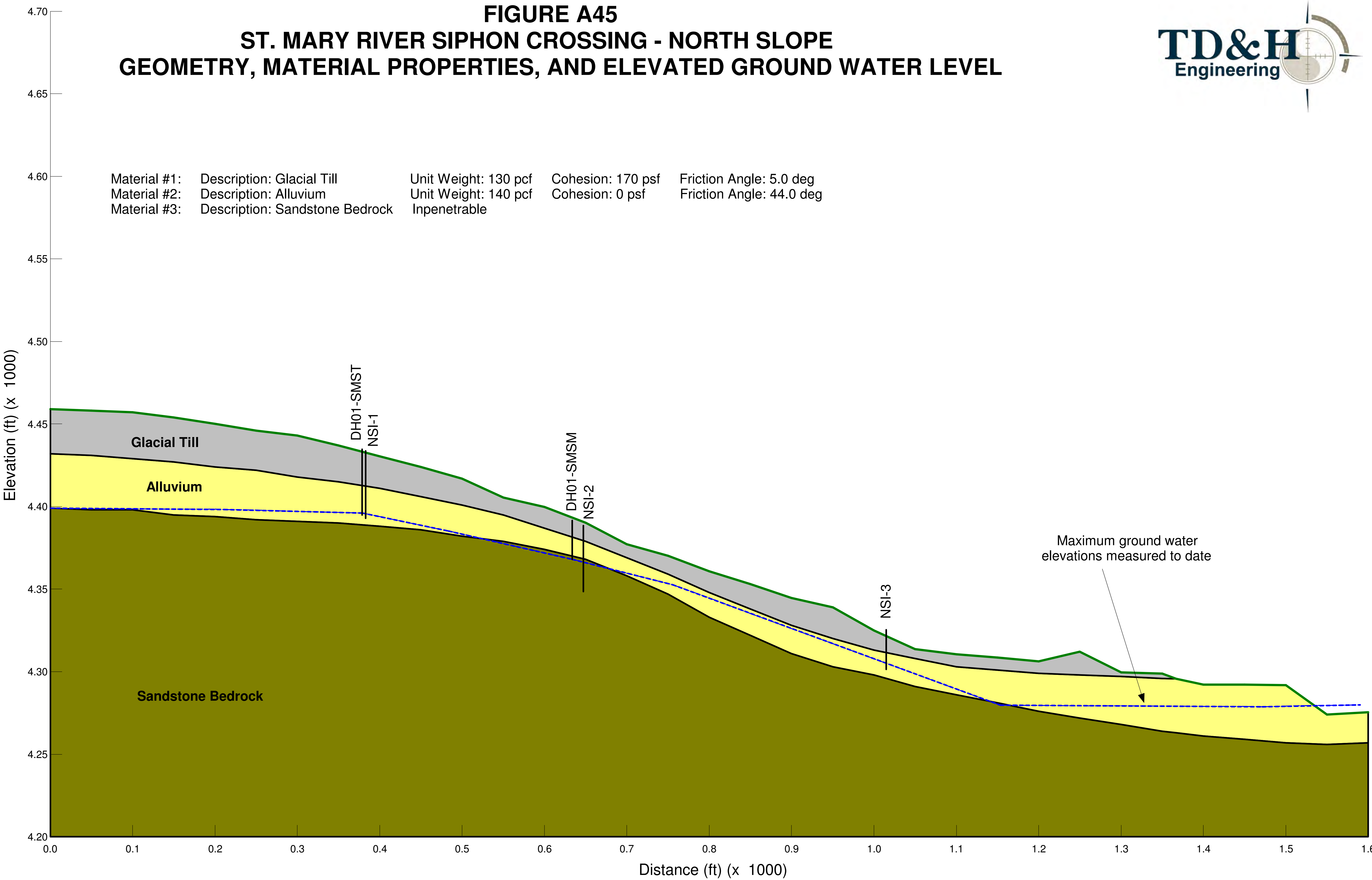


FIGURE A46
ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, NONSEISMIC

TD&H Engineering

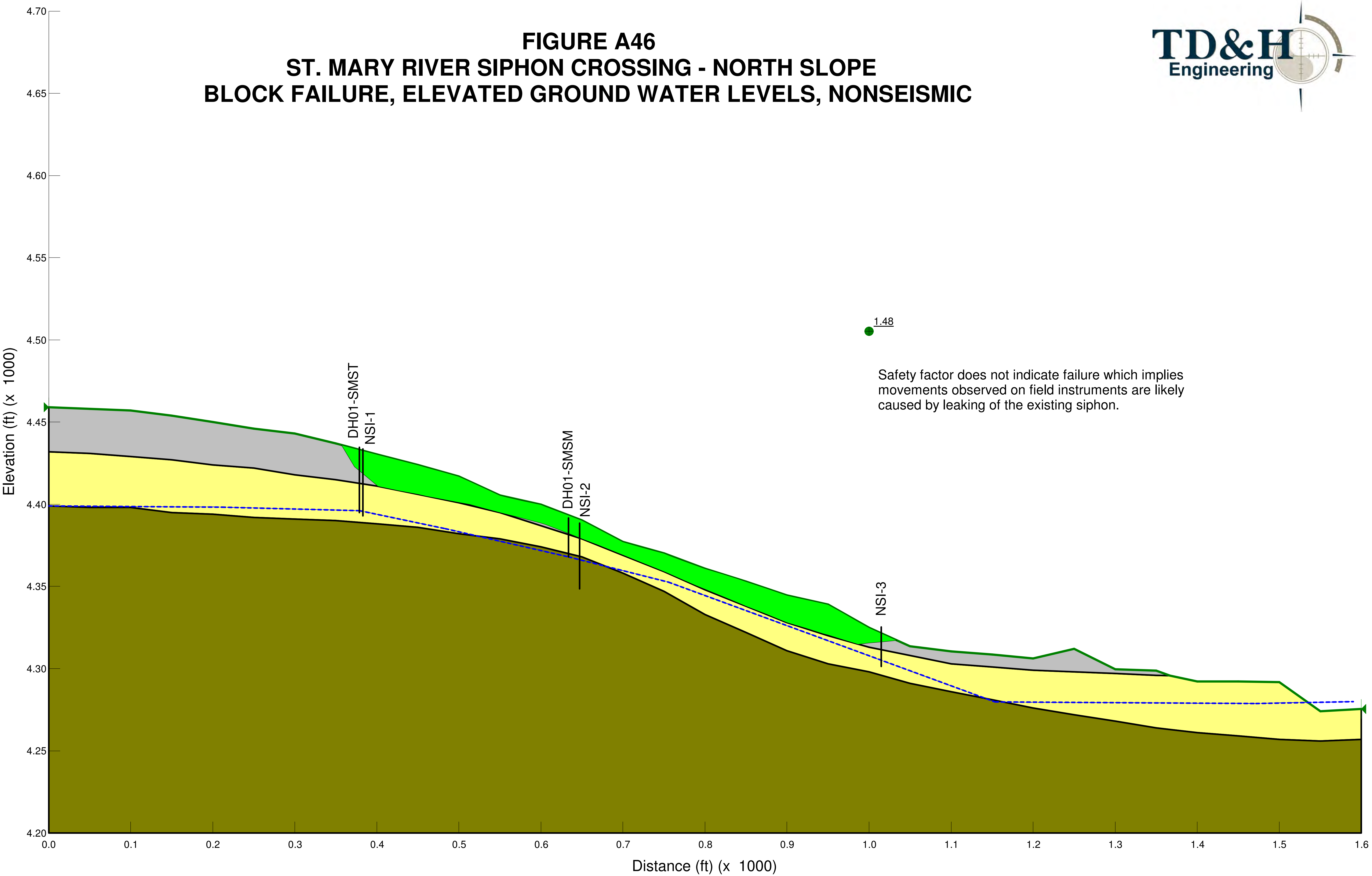


FIGURE A47
ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, SEISMIC Kh = 0.005g

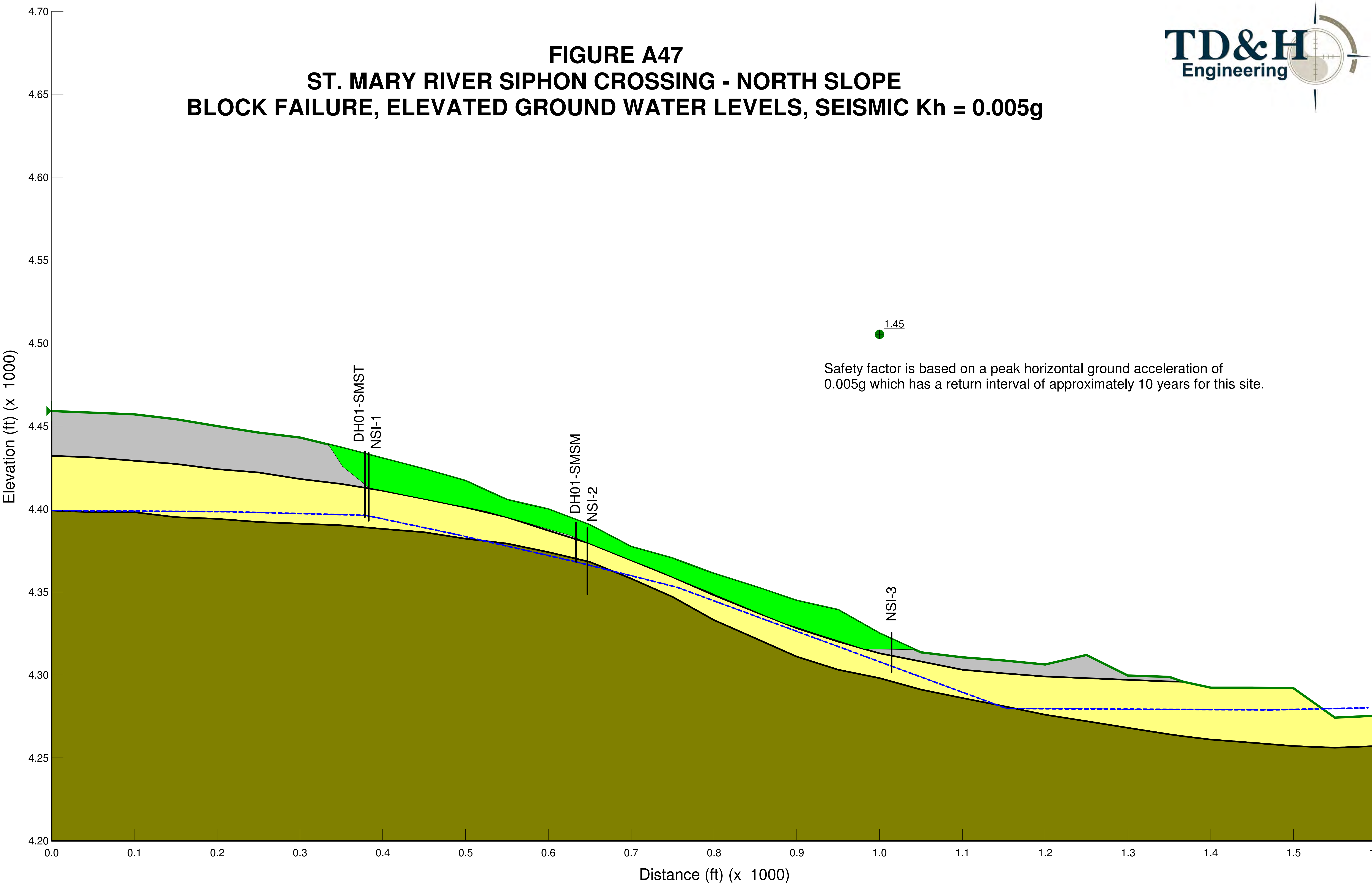
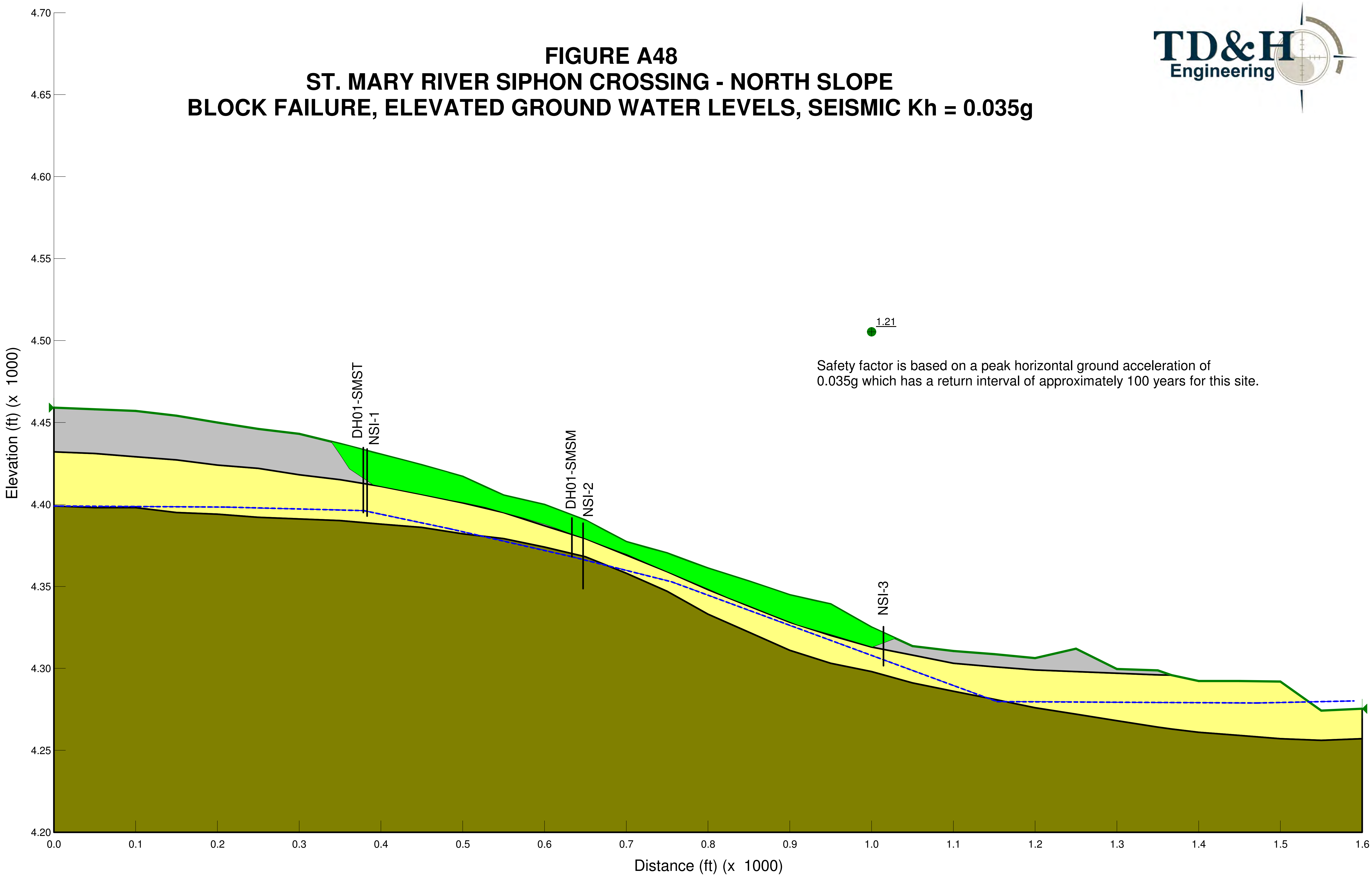


FIGURE A48
ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, SEISMIC Kh = 0.035g



NORTHERN
Analytical Laboratories, Inc.

602 South 25th Street
P O Box 30315
Billings, MT 59107
Telephone: (406) 254-7226
Fax: (406) 254-1389

REPORT TO: ATTN: HARTWIG MOELLER
THOMAS, DEAN & HOSKINS
ENGINEERING CONSULTANTS
1200 25[TH] STREET SOUTH
GREAT FALLS, MT 59405

DATE: December 12, 2005
JOB NUMBER: 67-250
PAGE: 1 of 10
INVOICE NO.: 5110172

REPORT OF: Soil Analysis – Project #04-167

CASE NARRATIVE:

On November 16, 2005, these soil samples (laboratory numbers 2005110172-1 through -6) were received in our laboratory for analysis. Tests were conducted in accordance with American Association of State Highway and Transportation Officials (AASHTO) and a method specified by the Montana Department of Transportation.

The results of the analysis are shown on the following pages. A < sign indicates the value reported was the practical quantitation limit (PQL) for this sample using the method described. Concentrations of analyte, if present, below this were not quantifiable. Sample results are not corrected for analyte blank concentrations. Values in brackets are the quality control limits for the associated quality control test.

The condition of the samples upon receipt at the laboratory is noted on the attached sample receipt checklist. A letter of transmittal is enclosed.

Reviewed by ____________________
Kathleen A. Smit - Laboratory Manager

Attachments: Letter of Transmittal
Sample Receipt Checklist

nct

As a mutual protection to clients, the public and ourselves, all reports are submitted as the confidential property of our clients and authorization for publication of statements, conclusions or extracts from or regarding our reports is reserved pending our written approval. Test results apply specifically to the samples tested only. The entire report shall not be reproduced, except in full, without the written approval of the laboratory. Samples will be disposed of after testing is completed unless other arrangements are agreed to in writing.

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-1 **Description:** SSI-1, S3 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	<0.01	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.5	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.18	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-2 **Description:** SSI-2, S5 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	0.06	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.3	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.57	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-3 **Description:** SSI-3, S1 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	<0.01	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.1	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.17	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-4 **Description:** NSI-1, S3 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	0.05	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.7	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.48	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-5 **Description:** NSI-2, S2 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	0.02	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	9.2	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.42	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-6 **Description:** NSI-3, S2 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	<0.01	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.0	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.22	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-7 **Description:** DUPLICATE OF 2005110172-4 **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** NONE GIVEN

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	0.04	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	8.7	-----	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	0.48	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-8 **Description:** METHOD BLANK **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** PREPARED BY LAB

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	<0.01	%	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	NA	-----	-----	-----
Electrical Conductivity, Soil in Water 1:2	<0.01	mmhos/cm	MDT	12/02/2005

Northern Analytical Laboratories, Inc.

Client Name: THOMAS, DEAN & HOSKINS ENG. CONSULTANTS

Project No.: NONE GIVEN

Project Name: 04-167

Sample No.: 2005110172-9 **Description:** LABORATORY CONTROL SAMPLE **Matrix:** SOIL

Date Received: 11/16/2005

Date Collected: ----- **Collected by:** PREPARED BY LAB

Laboratory Test	Measured Value	Test Units	Test Method	Date of Analysis
ANIONS				
Sulfate Water Soluble Dry Basis	115	% [84-122]	T290-95 MOD	11/25/2005
INORGANICS				
pH, Soil in Water	102	% [97-103]	T 289-91	12/02/2005
Electrical Conductivity, Soil in Water 1:2	100	% [83-117]	MDT	12/02/2005

THOMAS, DEAN & HOSKINS, INC.

1200 Twenty-Fifth Street South
Great Falls, MT 59405

LETTER OF TRANSMITTAL

TO: NORTHERN Analytical Laboratories, Inc.
Attn.: Kathleen A. Smit, CIH
602 South 25th Street
Billings, MT 59101
FAX: (406) 254-1389
Tel.: (406) 254-7226

DATE: November 15, 2005

JOB: # 04-167

WE ARE SENDING YOU [ ] Attached [X] Under separate cover via UPS the following items:

[ ] Shop Drawings [ ] Prints [_] Plans [X] Samples

[_] Copy of letter [_] Change Order [_] Specifications [ ] Submittals

COPIES	DATE	NO.	DESCRIPTION
2005	10172		The following six (6) to be tested for 1) Soil Resistivity, 2) Soluble Sulfates, 3) pH -1 SSI-1, S-3; -2 SSI-2, S-5; -3 SSI-3, S-1; -4 NSI-1, S-3; -5 NSI-2, S-2; -6 NSI-3, S-2
			Dup #4 7
			MB 8
			LCS 9

THESE ARE TRANSMITTED as checked below:

[_] For approval [ ] No exception taken [_] Resubmit _ copies for approval

[ ] For your use [ ] Make corrections noted [_] Submit _ copies for distribution

[X] As requested [_] For review and comment [_] Return _ corrected prints

CC: E. Juel

THOMAS, DEAN & HOSKINS, INC.

Rec 11/16/05 @ 1015 from UPS by [illegible]

Hartwig Moeller

Geotech. Lab. Supervisor

NORTHERN
Analytical Laboratories, Inc.

SAMPLE RECEIPT CHECKLIST

Dear Valued Client: This checklist documents the condition of your sample(s) as it (they) arrived at our lab. Please review it and familiarize yourself with its contents. Should you have any questions or comments, please contact us. Thank you for your use of our services.

Client Name: TD & H, Inc.
Project: 04-167 & 03-086
Laboratory Number(s): 110172 & 173
Checklist Completed by (Initials / Date): MW 11/16/05
Date/Time Received (Date / Time): 11/16/05 1015
Received by: MW
Carrier Name: UPS
Sample Type: Soil

	YES	NO
1. Shipping container in good condition?	✓	
2. Custody seals present on shipping container? Condition: Intact ____ Broken ____		✓
3. Chain of custody present?	✓	
4. Chain of custody signed when relinquished and received?	✓	
(5.) Chain of custody agrees with sample labels?	✓	✓
6. Custody seals on sample bottles? Condition: Intact ____ Broken ____		✓
7. Samples in proper container/bottle?*	✓	
8. Sample containers intact?*	✓	
9. Sufficient sample volume for indicated test?*	✓	
10. Ice/Frozen Blue Ice present in shipping container? (circle one)		✓
container temperature 1. 15.8° 2. ______ 3. ______ * (if <0 or>10)		
11. All samples rec'd within holding time?*	✓	
12. VOA vials have zero headspace? * (if contains >5mm headspace)	NA	
13. Trip Blank received?	(lined through)	

	YES	NO
14. pH check performed by: ____________		
15. Metals bottle(s) pH <2?	NA	
16. Nutrient bottle(s) pH <2?	(lined through)	
17. Cyanide bottle(s) pH >12?		
18. Sulfide bottle(s) pH >9?		
19. TOC bottle(s) pH <2?		
20. Phenolics bottle(s) pH <2?		
21. Oil & grease bottle(s) pH <2? (checked by analyst)		
22. EPH/DRO bottle(s) pH <2? (checked by analyst)		
23. Volatiles (VOA) pH <2? (checked by analyst)		
24. Semivolatiles (525) pH <2? (checked by analyst)		
25. Other test types		
26. Client contacted?		
27. Person contacted		
28. Date contacted		

NOTES: **Samples may be affected when not transported at the temperature recommended by the EPA for the test you've selected. Please contact the lab if you have concerns about the temperature of your samples.**

*** Critical item - if marked "NO" contact lab manager.**

COMMENTS: #5- did not rec sample B-9;S1

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GEOLOGIC LOG OF DRILL HOLE: DH01-SMST

FEATURE: No. Central Montana Regional Feasibility Study PROJECT: Milk River Project
STATE: Montana
LOCATION: St. Mary Siphon
COORDINATES: N 1,735,143.8 E 1,037,857.8
GROUND ELEVATION: 4436.7
BEGUN: 6/24/01 FINISHED: 6/25/01
TOTAL DEPTH: 40.0
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: N.R.
DEPTH TO BEDROCK: N.R.
HOLE LOGGED BY: C. Clark
REVIEWED BY: L. Crutchfield

NOTES

NOTES: All measurements are given in feet and taken from the ground surface unless otherwise noted.
N.M. = Not Measured
N.R. = Not Reached

LOCATION: Approximately 25' West of St. Mary siphon, 150' downstream from siphon intake. St. Mary Canal, Montana. Near station 487+00.

PURPOSE OF HOLE: Investigate the foundation conditions for a proposed siphon replacement across the St. Mary River, St. Mary Canal.

DRILLING EQUIPMENT: Truck mounted CME-85 drill; 4-1/4" Hollow Stem Augers (HSA) with split inner barrel; CME automatic hammer with 2' long Standard Penetration Test (SPT) barrel on NWJ rods.

DRILLING METHODS: HSA with split sample barrel from 0.0' to 5.0' and cleanout intervals; continuous SPT's at 2.5' intervals from 5.0' to 40.0'.

DRILLER: Mike Kocian - USBR

DRILLING CONDITIONS AND COMMENTS: Lost lead auger and bit in the hole at 40.0'

WATER LEVEL: N.R.

HOLE COMPLETION: Set porous tube piezometer from 40.0' to 38.0' with 1" PVC riser pipe to 2.7' above ground surface; augers were pulled and hole caved to 30.0'; placed 3/8" bentonite chip hole plug from 30.0' to 1.5'; set 5' long 4" steel protective standpipe with locking cap from 1.5' to 3.0' above ground surface in neat cement grout.

DEPTH / FLD. CLASS/LITH. / % CORE RECOVERY / GEOL. UNIT SYM. / SPT (BLOWS/FT) (0–50)

Depth interval	FLD. CLASS/LITH.	GEOL. UNIT SYM.
0.0–9.0	CL	Qgt
9.0–17.5	CL	Qgt
17.5–23.8	CL	Qgt
23.8–30.0	SM	Qow
30.0–31.5	GM	Qow
31.5–32.5	SM	Qow
32.5–34.0	GW	Qow
34.0–40.0	SM	Qow

% CORE RECOVERY (top to bottom): 50, 33, 100, 80, 100, 80, 100, 53, 100, 100, 100, 100, 100, 40, 100, 67, 100, 50, 100, 60, 100, 63, 80, 87, 100, 100, 100, 73

SPT (BLOWS/FT) (top to bottom): 11, 8, 10, 9, 19, 7, 7, 27, 50/50, 50/50, 46, 40, 50/50, 50/50

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 23.8' - QUATERNARY GLACIAL TILL (Qgt):

0.0' to 9.0' - SANDY LEAN CLAY (CL): About 70% medium plasticity fines; about 30% fine sand; trace of fine to coarse, hard gravel; maximum size recovered, 1"; moist; firm, strong reaction with HCl.

9.0' to 17.5' - LEAN CLAY WITH SAND (CL): About 75% medium plasticity fines; about 25% fine sand; trace of fine to coarse, hard gravel; maximum size recovered, 3"; light brown to medium brown; moist; firm; iron staining; strong reaction with HCl.

17.5' to 23.8' - LEAN CLAY WITH SAND (CL): About 85 to 95% medium plasticity fines; about 5 to 15% fine sand; maximum size recovered, fine sand; light brown to red-brown; moist; firm; no reaction with HCl.

23.8' to 40.0' - QUATERNARY GLACIAL OUTWASH (Qow):

23.8' to 30.0' - SILTY SAND WITH GRAVEL (SM): About 50 to 60% fine to coarse, predominately fine, sand; about 20 to 30% nonplastic fines; about 20% fine to coarse, hard, subangular gravel; maximum size recovered, 3"; light brown; slightly moist; firm; strong reaction with HCl.

30.0' to 31.5' - SILTY GRAVEL WITH SAND (GM): About 65 to 70% fine to coarse, hard, angular gravel; about 15% fine to coarse sand; about 15 to 20% low plasticity fines; maximum size recovered, 2"; white to light brown; moist; firm; strong reaction with HCl.

31.5' to 32.5' - SILTY SAND (SM): About 70% fine to coarse sand; about 20% nonplastic fines; about 10% fine to coarse, hard, subangular gravel; maximum size recovered, 2-1/2"; light brown; firm; strong reaciton with HCl.

32.5' to 34.0' - WELL GRADED GRAVEL (GW): About 65% coarse, subrounded to angular, gravel; about 35% fine to coarse sand; trace of nonplastic fines; maximum size recovered, 1-1/2"; brown, moist, firm; strong reaction with HCl

COMMENTS:

Continued next page

a

GEOLOGIC LOG OF DRILL HOLE: DH01-SMST

FEATURE: No. Central Montana Regional Feasibility Study
LOCATION: St. Mary Siphon
BEGUN: 6/24/01 FINISHED: 6/25/01
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: N.R.

PROJECT: Milk River Project
COORDINATES: N 1,735,143.8 E 1,037,857.8
TOTAL DEPTH: 40.0
DEPTH TO BEDROCK: N.R.

STATE: Montana
GROUND ELEVATION: 4436.7
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
HOLE LOGGED BY: C. Clark
REVIEWED BY: L. Crutchfield

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0 50	CLASSIFICATION AND PHYSICAL CONDITION
						32.8' - Heavily oxidized coarse sand lense 34.0' to 40.0' - SILTY SAND WITH GRAVEL (SM): About 50 to 55% fine to coarse sand; about 30 to 35% fine to coarse, hard, subrounded to subangular gravel; 15% low to nonplastic fines; maximum size recovered, 3"; brown; soft; moist; strong reaction with HCl.

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GEOLOGIC LOG OF DRILL HOLE: DH01-SMSM

SHEET 1 OF 1

FEATURE: No. Central Montana Regional Feasibility Study
LOCATION: St. Mary Siphon
BEGUN: 6/25/01 **FINISHED:** 6/25/01
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: N.R.

PROJECT: Milk River Project
COORDINATES: N 1,734,956.6 E 1,038,028.9
TOTAL DEPTH: 23.8
DEPTH TO BEDROCK: N.R.

STATE: Montana
GROUND ELEVATION: 4393.4
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:** 0
HOLE LOGGED BY: C. Clark
REVIEWED BY: L. Crutchfield

NOTES

NOTES All measurements are given in feet and taken from the ground surface unless otherwise noted.
N.M. = Not Measured
N.R. = Not Reached

LOCATION: Approximately 25' West of St. Mary siphon, about halfway down hill on Northeast side of St. Mary Canal, Montana. Near station 498+70.

PURPOSE OF HOLE: To determine the foundation conditions for a proposed siphon replacement across the St. Mary River, St. Mary Canal.

DRILLING EQUIPMENT: Truck mounted CME-85 drill; 4-1/4" Hollow Stem Augers (HSA) with split inner barrel; CME automatic hammer with 2' long Standard Penetration Test (SPT) barrel on NWJ rods.

DRILLING METHODS: HSA with split sample barrel from 0.0' to 4.3' and cleanout intervals; continuous SPT's at 2.5' intervals from 4.3' to 23.8'.

DRILLER: Mike Kocian - USBR

WATER LEVEL: N.R.

HOLE COMPLETION: Set porous tube piezometer from 23.0' to 21.0' with 1" pvc riser pipe to 3.2' above ground surface; placed 8/12 graded sand from 23.8' to 16.0'; placed 3/8" bentonite chip hole plug from 16.0' to 1.5'; set 5' long 4" steel protective standpipe with locking cap from 1.5' to 3.5' above ground surface in neat cement grout.

LOG

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0–50
0–9.3	CL	0, 13, 100, 80, 0	Qgt	8, 8
9.3–11.8	CL	94, 80	Qgt	4
11.8–16.8	CL	87, 40, 20, 0	Qow	24, 50
16.8–23.8	SM	69, 0, 93, 0, 100, 100	Qow	25, 26, 50

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

0.0' to 11.8' - QUATERNARY GLACIAL TILL (Qgt):

0.0' to 9.3' - LEAN CLAY WITH SAND (CL): About 75% medium plasticity fines; about 25% fine to coarse sand, predominately fine sand; trace of fine gravel; maximum size recovered, 3/4" dark brown to black; moist; soft; weak reaction with HCl.

9.3' to 11.8' - LEAN CLAY WITH SAND (CL): About 90% medium plasticity fines; about 10% fine to coarse sand, predominately fine sand; trace of fine, hard, subrounded gravel; maximum size recovered, 3/4"; brown, moist to wet; soft; weak reaction with HCl.

11.8' to 23.8' - QUATERNARY GLACIAL OUTWASH (Qow):

11.8' to 16.8' - CLAYEY SAND WITH GRAVEL (SM): About 50 to 60% fine to coarse sand, predominately fine sand; about 15% to 25% medium plasticity fines; about 25% subrounded, fine to coarse gravel; maximum size recovered, 2-3/4"; light brown; soft; moist; no reaction with HCl.

16.8' to 23.8' - SILTY SAND (SM): About 75% fine to coarse sand; about 20% nonplastic fines; about 5% subangular, fine to coarse gravel; maximum size recovered, 2"; light brown; soft; moist; weak reaction with HCl.

19.7' to 20.8' - 60% fine to medium sand; about 40% low plasticity fines; some iron oxidation; light brown to gray; no reaction with HCl.

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE: DH01-SMSB

FEATURE: No. Central Montana Regional Feasibility Study
LOCATION: St. Mary Siphon
BEGUN: 6/26/01 FINISHED: 6/26/01
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: N.R.

PROJECT: Milk River Project
COORDINATES: N 1,734,632.6 E 1,038,318.1
TOTAL DEPTH: 18.6
DEPTH TO BEDROCK: N.R.

STATE: Montana
GROUND ELEVATION: 4317.3
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
HOLE LOGGED BY: C. Clark
REVIEWED BY: L. Crutchfield

NOTES

NOTES All measurements are given in feet and taken from the ground surface unless otherwise noted.
N.M. = Not Measured
N.R. = Not Reached

LOCATION: Near bottom of slope on the west side of St. Mary Siphon, approximately 25' south of south siphon barrel, St. Mary Canal, Montana. Near station 505+30.

PURPOSE OF HOLE: Investigate the foundation conditions for a proposed siphon replacement across the St. Mary River, St. Mary Canal.

DRILLING EQUIPMENT: Truck mounted CME-85 drill; 4-1/4" Hollow Stem Augers (HSA) with split sample barrel; CME automatic hammer with 2' long Standard Penetration Test (SPT) barrel on NWJ rods.

DRILLING METHODS: HSA with split sample barrel from 0.0' to 5.1' and cleanout intervals; continuous SPT's at 2.5' intervals from 5.1' to 18.3'.

DRILLER: M. Kocian - USBR

DRILLING CONDITIONS AND COMMENTS: Could not advance past 18.6' due to boulders.

WATER LEVEL: N.R.

HOLE COMPLETION: Pulled augers. Backfilled hole with cuttings and marked with a T-post.

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0–50
0–5	CL	25	Qal	
5	SC	80		0
		90		
	CL	80		3
10	SC	60		
		80		25
	GW-GM	100		
		67		33
15	SW	100		
		63		50
	SW	0		50
	SP	80		38

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

0.0' to 18.6' - QUATERNARY ALLUVIUM (Qal):

0.0' to 5.1' - SANDY LEAN CLAY (CL): About 60% medium plasticity fines; about 40% fine to coarse, predominately fine, sand; trace of fine to coarse, hard gravel; maximum size recovered, 1-1/4"; light brown to black; soft; moist; tan sand lens up to 1/8" throughout; roots throughout; no reaction with HCl.

5.1' to 7.6' - CLAYEY SAND (SC): About 70% fine to coarse, predominately fine, sand; about 30% medium plasticity fines; trace of fine, hard gravel; maximum size recovered, 3/4"; dark brown to black; moist; soft; no reaction with HCl.

7.6' to 9.1' - SANDY LEAN CLAY (CL): About 60% medium plasticity fines; about 40% fine to coarse, predominately fine, sand; trace of fine to coarse, hard gravel; maximum size recovered, 1-1/4"; light brown to black; moist; no reaction with HCl.

9.1' to 11.6' - CLAYEY SAND WITH GRAVEL (SC): About 70% fine sand; about 30% medium plasticity fines; maximum size recovered, 3"; dark brown to black; wet; weak reaction with HCl.

11.6' to 14.1' - WELL GRADED GRAVEL WITH SILT AND SAND (GW-GM): About 70% fine to coarse, hard, subrounded gravel; about 20% fine to coarse sand; about 10% low plasticity fines; maximum size recovered, 3"; wet, soft; weak reaction with HCl.

12.6' to 13.0' - CLAYEY SAND (SC)

14.1' to 15.9' - WELL GRADED SAND WITH GRAVEL AND COBBLES (SW):

COMMENTS:

Continued next page

GEOLOGIC LOG OF DRILL HOLE: DH01-SMSB

FEATURE: No. Central Montana Regional Feasibility Study PROJECT: Milk River Project STATE: Montana
LOCATION: St. Mary Siphon COORDINATES: N 1,734,632.6 E 1,038,318.1 GROUND ELEVATION: 4317.3
BEGUN: 6/26/01 FINISHED: 6/26/01 TOTAL DEPTH: 18.6 ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: N.R. DEPTH TO BEDROCK: N.R. HOLE LOGGED BY: C. Clark
REVIEWED BY: L. Crutchfield

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0 50	CLASSIFICATION AND PHYSICAL CONDITION
						About 70% fine to coarse sand; about 25% fine to coarse, hard, subrounded gravel; about 5% low plasticity fines; trace of cobbles; maximum size recovered, capacity of sampler; moist; firm; no reaction with HCl. 15.9' to 17.1' - WELL GRADED SAND WITH GRAVELL (SW): About 55% to 60% fine to coarse sand; about 40% to 45% fine to coarse gravel; trace of medium plasticity fines; maximum size recovered, 2-1/2"; light brown; moist; firm; no reaction with HCl. 17.1' to 18.6' Poorly Graded Sand with Gravel (SP): About 75% fine to coarse sand; about 20% fine to coarse gravel; about 5% low plasticity fines; maximum size recovered, 1-1/2"; medium brown; moist; firm; no reaction with HCl.

GEOLOGIC LOG OF DRILL HOLE: DHO2-SMBW

FEATURE: No. Central Montana Regional Feasibility Study
PROJECT: Milk River Project
STATE: Montana
LOCATION: St. Mary Bridge, East Abutment
COORDINATES: N 1,734,322 E 1,038,542
GROUND ELEVATION: 4287.7
BEGUN: 3/30/02 FINISHED: 3/30/02
TOTAL DEPTH: 28.7
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: -14.3 (4273.4) 03/30/02
DEPTH TO BEDROCK: 17.3
HOLE LOGGED BY: P. Atherton
REVIEWED BY: L. Crutchfield

NOTES

Notes:
All measurements are in feet, from ground surface, unless otherwise noted.
N.M. = Not Measured
N.R. = Not Reached or not encountered.

LOCATION:
150 feet southwest of the west abutment of St. Mary River Bridge, adjacent to the St. Mary Siphon, St. Mary Canal, Montana.

PURPOSE OF HOLE:
Investigate foundation conditions for replacing the bridge over St. Mary River to Camp 9.

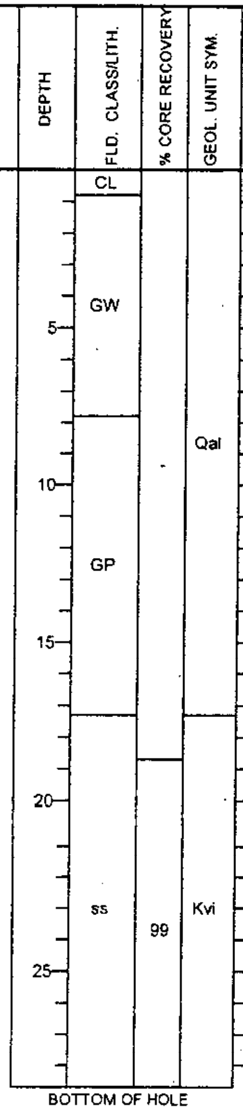
DRILL EQUIPMENT:
Truck mounted SIMCO AV5000, 0.0 to 18.7': 3-1/2" O.D. rods, 5-7/8" tricone roller rockbit, 6" Aardvark casing; 18.7' to 28.7': HQ wireline rods and 10' HQD3 core barrel.

DRILLING METHODS:
Rockbit and advance casing 0.0' to 18.7' with air as drilling medium; HQ core with clear water as drilling medium from 18.7' to 28.7'.

DRILLER
J. McLaughlan - USBR

WATER LEVEL:
14.3' on 03/30/02, during drilling

HOLE COMPLETION:
Pulled Casing. Backfilled hole with 3/8" bentonite chips, then set fence post marker.



CLASSIFICATION AND PHYSICAL CONDITION

No intact sample recovered, interval from 0 to 18.7' drilled with tricone roller rockbit, the estimates are based upon observation of cuttings and drilling conditions. Generally, recovered angular, fine hard gravel with varying amounts of angular to rounded fine to coarse sand with varying amounts of fines; predominantly flat fragments of volcanic, metamorphic, and sedimentary rock; moderate reddish brown to tan; moist to wet; maximum size, 1".

0.0' to 17.3' - QUATERNARY ALLUVIUM (Qal):

0.0' to 0.8' - SANDY LEAN CLAY (CL): About 60% low plasticity fines; 40% fine to coarse, predominantly fine, sand; maximum size, 1/4"; dark brown to black; moist; firm; weak reaction with HCl.
0.0' to 0.8' - Roots

0.8' to 8.4' - WELL GRADED GRAVEL WITH SAND AND COBBLES (GW): About 60% subrounded to rounded, fine to coarse, hard gravel; about 35% fine to coarse sand; about 5% fines of undetermined plasticity; moderate reddish brown; moist; firm to hard; weak to moderate reaction with HCl.
0.8' to 6.8' - Roots

Total Sample (by volume): About 5% 3-5" cobbles, 5% 5-12" cobbles; maximum size, 9".

8.4' to 17.3' - POORLY GRADED GRAVEL WITH SAND, COBBLES, AND BOULDERS (GP): About 70% subrounded to rounded, fine to coarse, predominantly coarse, hard gravel; about 25% fine to coarse, predominantly fine, sand; about 5% fines of undetermined plasticity; greenish gray to pale yellowish brown; wet; firm to hard; weak to moderate reaction with HCl

Total Sample (by volume): About 15% 3-5" cobbles, 5% 5-12" cobbles, and 5% boulders; maximum size, 14".

17.3' to 28.7' - CRETACEOUS VIRGELLE FORMATION (Kvi):

17.3' to 18.7' SANDSTONE - No sample retained, rockbitted to confirm not on a boulder, tan sand returned in air medium.

18.7' to 28.7' SANDSTONE - Fine to medium grained; pale gray to bluish gray; slightly fractured; soft to moderately soft; bedding is indistinct to thin; interval displays a few randomly spaced very thin mudstone beds less than 1/4" thick; slightly fractured; decomposed to moderately weathered; moderate to strong reaction with HCl.

GEOLOGIC LOG OF DRILL HOLE: DH02-SMBE

FEATURE: No. Central Montana Regional Feasibility Study
PROJECT: Milk River Project
STATE: Montana
LOCATION: St. Mary Bridge, West Abutment
COORDINATES: N 1,734,042.7 E 1,038,740.7
GROUND ELEVATION: 4286.6
BEGUN: 4/11/02 FINISHED: 4/15/02
TOTAL DEPTH: 40.5
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: 6.8 (4279.80) 04/15/02
DEPTH TO BEDROCK: 32.9
HOLE LOGGED BY: P. Atherton
REVIEWED BY: L. Crutchfield

NOTES

LOCATION:
100 feet southeast of the east abutment of St. Mary River Bridge, adjacent to St. Mary Siphon, St. Mary Canal, Montana.

PURPOSE OF HOLE:
Investigate foundation conditions for replacing the St. Mary River Bridge for St. Mary Canal.

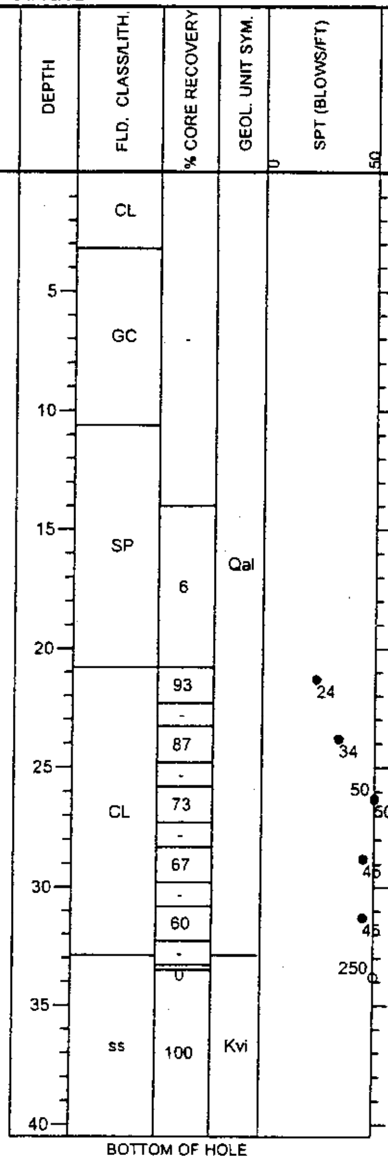
DRILL EQUIPMENT:
Truck mounted SIMCO AV5000, 3-1/2" O.D. rods, 5-7/8" tricone roller rockbit, 6" Aardvark casing; Cored intervals with HQ wireline rods and 10' HQD3 core barrel; Standard Penetration Tests (SPT's) with 2' long SPT barrel on NWJ rods, cathead driven manual hammer.

DRILLING METHODS:
0.0 to 14.0' and cleanout intervals between SPT's: Rockbit and advance 6" Aardvark casing.
14.0' to 20.8': HQ3 wireline.
20.8' to 33.5': continuous SPT's (2.5' intervals).
33.5' to 40.5': HQ3 wireline.

DRILLER
J. McLaughlan - USBR

WATER LEVEL:
6.8' on 4/16/02

HOLE COMPLETION:
Pulled Casing. Backfilled hole with cuttings from 40.5' back to 14', 3/8" bentonite chips from 14' back to ground surface, then set fence post marker.



CLASSIFICATION AND PHYSICAL CONDITION

0.0' to 32.9' - QUATERNARY ALLUVIUM (Qal):

No intact sample recovered (0.0 to 14.0' and cleanout intervals between SPT's drilled with tricone roller rockbit), these intervals are estimates based upon observation of cuttings and drilling conditions. Generally, recovered angular, fine hard gravel with varying amounts of angular to rounded fine to coarse sand with varying amounts of fines; predominantly flat fragments of volcanic, metamorphic, and sedimentary rock; moderate reddish brown to tan; moist to wet; maximum size, 1".

0.0' to 3.2' -SANDY LEAN CLAY (CL): About 60% low plasticity fines; about 35% fine to coarse, predominantly fine, subrounded sand; about 5% fine, hard, subrounded gravel; maximum size, 1/2"; moderate to dark brown; dry; firm.
0.0' to 3.0' - Roots

3.2' to 10.6' - CLAYEY GRAVEL WITH SAND AND COBBLES (GC): About 55% fine to coarse subrounded, hard gravel; about 30% fine to coarse sand; about 15% low plasticity fines; a trace of cobbles, maximum size, 6".

10.6' to 20.8' - POORLY GRADED SAND WITH GRAVEL, COBBLES, AND BOULDERS (SP): About 60% subrounded, fine to coarse, predominantly fine, sand; about 35% fine to coarse, subrounded gravel; 5% fines of undetermined plasticity.

Total sample (by volume): About 5% 3 - 5" cobbles, a trace of 5 - 12" cobbles and boulders, maximum size, 14"

20.8' to 32.9' - SANDY LEAN CLAY WITH COBBLES (CL): About 65% low to medium plasticity fines, about 30% fine to coarse, subrounded sand, about 5% fine to coarse, predominantly fine, hard gravel; moist, firm, tan to brown; a trace of cobbles,

COMMENTS:

Note: All measurements in feet and from ground surface.
N. R. = Not Reached
N. M. = Not Measured

Continued next page

15

GEOLOGIC LOG OF DRILL HOLE: DHO2-SMBE

FEATURE: No. Central Montana Regional Feasibility Study
LOCATION: St. Mary Bridge, West Abutment
BEGUN: 4/11/02 FINISHED: 4/15/02
DEPTH AND ELEV OF WATER
LEVEL AND DATE MEASURED: -6.8 (4279.80) 04/15/02

PROJECT: Milk River Project
COORDINATES: N 1,734,042.7 E 1,038,740.7
TOTAL DEPTH: 40.5
DEPTH TO BEDROCK: 32.9

STATE: Montana
GROUND ELEVATION: 4286.6
ANGLE FROM HORIZONTAL: -90 AZIMUTH: 0
HOLE LOGGED BY: P. Atherton
REVIEWED BY: L. Crutchfield

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0 50	CLASSIFICATION AND PHYSICAL CONDITION

maximum size, 5".

32.9' to 40.5' - CRETACEOUS VIRGELLE SANDSTONE (Kvi):

32.9' to 33.5' SANDSTONE - No sample retained, rockbitted to confirm not on a boulder, tan sand returned during drilling.

33.5' to 40.5' SANDSTONE - Fine to medium grained; pale yellowish brown to gray; slightly fractured (except 25.9' to 28.5' displays numerous, closely spaced, sub-parallel fractures which dip 40 to 50 degrees, are open 1/10" to 1/4", are clean and slightly rough); soft to moderately soft (moderately hard from 21' to 28.7'); displays some cross bedding, bedding is thin, dips about 10 degrees; interval displays a few randomly spaced very thin shale or siltstone beds less than 1/4" thick; moderate to strong reaction with HCl.

GEOLOGIC LOG OF DRILL HOLE: DH99-1

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/13/99 **FINISHED:** 5/14/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: 29.5 (4439.40) 5/14/99

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 50.4
DEPTH TO BEDROCK: 39.7

STATE: Montana
GROUND ELEVATION: 4409.9
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0–50	CLASSIFICATION AND PHYSICAL CONDITION

NOTES

NOTES
All measurements are from ground surface and in feet unless otherwise noted.

Hole drilled from pad dozed into slope.

PURPOSE OF HOLE
To determine subsurface condition of siphon foundation and to install piezometers in foundation.

DRILLER
M. Kocian - BOR

DRILL RIG
Truck-mounted CME 85 auger.

DRILLING METHOD
0.0-21.2' Cored hole with 4-1/4" hollow stem augers while performing continuous Standard Penetration Testing. No fluid added while performing penetration testing.

21.2-50.4' Cored hole with 4-1/4" hollow stem augers while performing Standard Penetration Testing at approximate 5' intervals. No fluid added while performing penetration testing.

DRILLING CONDITIONS AND DRILLER'S

LOG COLUMNS

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

Fld. Class/Lith. (top to bottom): CL, SM, CL, ML, CL, ss

% Core Recovery (top to bottom): 100, 53, 100, 0, 100, 0, 100, 0, 100, 100, 100, 100, 100, 100, 100, 73, 100, 80, 20, 87, 29, 0, 71, 53, 71, 43

SPT (blows/ft) (top to bottom): 10, 5, 9, 8, 8, 8, 5, 4, 2, 2, 2, 10, 50

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 39.7' GLACIAL DRIFT - QUATERNARY (Qg):

0.0 to 6.6' LEAN CLAY WITH SAND (CL). About 85% low plasticity fines; about 15% fine to coarse sand; trace of fine to coarse, hard subangular gravel; maximum size recovered, 2-1/2"; moist; firm; dark gray brown; grass roots to 1.7'; strong reaction with HCl.

6.6 to 7.3' SILTY SAND WITH GRAVEL (SM). About 65% fine to coarse sand; about 25% fine to coarse, hard, subangular gravel; about 15% fines with no plasticity; maximum size recovered, 2-1/4"; moist; soft; dark gray brown; strong reaction with HCl.

7.3 to 18.4' LEAN CLAY WITH SAND (CL). About 80% low plasticity fines; about 15% fine to coarse sand; about 5% fine to coarse, hard, subangular gravel; maximum size recovered, 2-3/4"; moist; firm; dark gray brown; weak to moderate reaction with HCl.

18.4 to 19.3' SANDY SILT (ML). About 85% fines with to plasticity; about 15% fine to coarse, predominately fine to medium, sand; trace of fine to coarse, hard, subangular gravel; maximum size recovered, 1-3/4"; moist; soft; brown; strong reaction with HCl.

19.3 to 39.7' LEAN CLAY WITH SAND (CL). About 85% medium plasticity fines; about 15% fine to coarse, predominatelt fine, sand; trace of fine to coarse, hard subangular gravel; maximum size recovered, 2-1/2"; moist; firm; dark gray brown; no to weak reaction with HCl.

39.7 to 50.4' VIRGELLE FORMATION - CRETACEOUS (Kvt):39.7 to 50.4' Sandstone (ss). Brown to gray brown; fine to medium grained; decomposed (W9) 39.7-49.6' and intensely weathered (W7) 49.6-50.4'; very soft (H7) to moderately soft (H5); very intensely fractured (FD9) where discernible; moderate to strong reaction with HCl.

COMMENTS:

Continued next page

GEOLOGIC LOG OF DRILL HOLE: DH99-1

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/13/99 **FINISHED:** 5/14/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: 29.5 (4439.40) 5/14/99

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 50.4
DEPTH TO BEDROCK: 39.7

STATE: Montana
GROUND ELEVATION: 4409.9
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	0 SPT (BLOWS/FT) 50	CLASSIFICATION AND PHYSICAL CONDITION

COMMENTS

4.7-6.2' Penetrated 0.2' with weight of rods and hammer.

7.2-8.7' Penetrated 0.7' with weight of rods and hammer.

9.7-11.2' Penetrated 0.3' with weight of rods and hammer.

14.7-16.2' Penetrated 0.5' with weight of rods and hammer.

17.2-18.7' Penetrated 0.2' with weight of rods and hammer.

19.7-21.2' Penetrated 0.8' with weight of rods and hammer.

24.7-26.2' Penetrated 0.9' with weight of rods and hammer.

29.7-31.2' Penetrated 1.0' with weight of rods and hammer.

34.7-36.2' Penetrated 1.0' with weight of rods and hammer.

36.2-39.7' Core loss due to large rock stuck in shoe.

39.7-41.2' Penetrated 0.8' with weight of rods and hammer.

44.7-46.2' Core loss due to large rock stuck in shoe.

Water Levels

Date	Depth
5/14/99	29.5

DRILL FLUID

Augered dry. No fluid added while performing penetration testing.

HOLE COMPLETION

Set porous tube piezometer 48.5-46.5' with 3/4" PVC to 2.4' above ground surface. Sand-packed hole 50.4-34.4' with .010/.020 sand. Backfilled hole with bentonite chips and cuttings 34.4' to 3.0'. Cemented in steel stand pipe with lockable lid.

GEOLOGIC LOG OF DRILL HOLE: DH99-2

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/15/99 **FINISHED:** 5/15/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: 13.2 (4387.80) 5/16/99

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 35.3
DEPTH TO BEDROCK: 24.2

STATE: Montana
GROUND ELEVATION: 4374.6
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0–50	CLASSIFICATION AND PHYSICAL CONDITION
		CL	100, 100, 100, 87, 100, 0, 67, 100, 100, 0, 100, 100, 0, 100, 43				Qg	6, 8, 2, 3, 4, 9, 8	
	24.2–35.3	ss	14, 38, 100				Kvt		

BOTTOM OF HOLE

NOTES
All measurements are from ground surface and in feet unless otherwise noted.

Hole drilled from pad dozed into slope.

PURPOSE OF HOLE
To determine subsurface condition of siphon foundation and to install piezometers in foundation.

DRILLER
M. Kocian - BOR

DRILL RIG
Truck-mounted CME 85 auger.

DRILLING METHOD
0.0-20.6' Cored hole with 4-1/4" hollow stem augers while performing continuous Standard Penetration Testing. No fluid added while performing penetration testing.

20.6-35.3' Cored hole with 4-1/4" hollow stem augers.

DRILLING CONDITIONS AND DRILLER'S COMMENTS
6.6-8.1' Penetrated 0.1' with weight of rods and hammer.

9.1-10.6' Penetrated 1.3' with

0.0 to 24.2' GLACIAL DRIFT - QUATERNARY (Qg):

0.0 to 24.2' LEAN CLAY WITH SAND (CL). About 80% low to medium plasticity fines; about 20% fine to coarse sand; trace of fine, hard, subangular gravel; maximum size recovered, 1/2"; moist; firm, low density (disturbed?) to 8.7'; dark gray brown; weak to moderate reaction with HCl.

24.2 to 35.3' VIRGELLE FORMATION - CRETACEOUS (Kvt):

24.2. to 35.3' Sandstone (ss). Brown to gray brown; fine to medium grained; decomposed to intensely weathered (W9-W7); very soft to soft (H7-H6), hardens with depth; massive bedding; no to weak reaction with HCl.

28.8 to 29.1' Limestone interbed.

COMMENTS:

Continued next page

3.2.GDT 8/5/99
G.4 STMARY

GEOLOGIC LOG OF DRILL HOLE: DH99-2

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/15/99 **FINISHED:** 5/15/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED: 13.2 (4387.80) 5/16/99

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 35.3
DEPTH TO BEDROCK: 24.2

STATE: Montana
GROUND ELEVATION: 4374.6
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	0 SPT (BLOWS/FT) 50	CLASSIFICATION AND PHYSICAL CONDITION

weight of rods and hammer.

12.1-13.1' Penetrated 0.6' with weight of rods and hammer.

Water Levels
Date Depth
5/16/99 13.2

DRILL FLUID
Augered dry. No fluid added while performing penetration testing.

HOLE COMPLETION
Set porous tube piezometer 33.1-31.3' with 3/4" PVC riser pipe to 3.1' above ground surface. Sand-packed hole 35.3-20.8' with .010/.020 sand. Backfilled hole with bentonite chips and cuttings 20.8' to 3.0'. Cemented in steel stand pipe with lockable lid.

GEOLOGIC LOG OF DRILL HOLE: DH99-3

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/17/99 **FINISHED:** 5/18/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED:

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 36.8
DEPTH TO BEDROCK: 25.3

STATE: Montana
GROUND ELEVATION: 4290.8
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	SPT (BLOWS/FT) 0–50
0.0–1.2	CL	62				Qcol	
1.2–10.3	GP	60, 89, 100				Qal	12 (at 5); 12 (at 10)
10.3–14.9	ML	100				Qal	
14.9–25.3	GP	27, 34, 36				Qal	39 (at 15)
25.3–36.8	ss	100, 100, 100				Kvt	

BOTTOM OF HOLE

NOTES

NOTES
All measurements are from ground surface and in feet unless otherwise noted.

Hole drilled from pad dozed into slope.

PURPOSE OF HOLE
To determine subsurface condition of siphon foundation and to install piezometers in foundation.

DRILLER
M. Kocian - BOR

DRILL RIG
Truck-mounted CME 85 auger.

DRILLING METHOD
0.0-16.2' Cored hole with 4-1/4" hollow stem augers while performing continuous Standard Penetration Testing at 5' intervals. No fluid added while performing penetration testing.

16.2-30.2' Continuously cored with 4-1/4" ID hollow stem augers.

30.2-36.8' Continuously cored with HQ wireline core barrel and rods.

DRILLING CONDITIONS AND DRILLER'S COMMENTS
16.2' Stopped Standard Penetration Testing due to coarse material in alluvium.

19.7-30.2' Used a basket core catcher with augers due to low

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.2' COLLUVIUM - QUATERNARY (Qcol):

0.0 to 1.2' SANDY LEAN CLAY (CL). About 65% medium plasticity fines; about 35% fine to medium sand; maximum size recovered, medium sand; moist; firm; dark brown; grass roots to 1.2'; moderate to strong reaction with HCl.

1.2 to 25.3' ALLUVIUM - QUATERNARY (QAL):

1.2 to 10.3' POORLY GRADED GRAVEL WITH SAND (GP). About 75% fine to coarse, hard, subrounded gravel; about 25% fine to coarse sand; trace of fines with no plasticity; TOTAL SAMPLE (BY VOLUME), about 15% 3- to 5-inch subrounded cobbles; remainder minus 3-inch; maximum size recovered, 4-1/4"; wet; soft, loose; dark gray brown; moderate to strong reaction with HCl.

10.3 to 14.9' SILT WITH SAND (ML). About 85% fines with no plasticity; about 15% fine sand; maximum size recovered, fine sand; wet to moist; soft; brown; weak to moderate reaction with HCl.

14.9 to 25.3' POORLY GRADED GRAVEL WITH SAND (GP). About 50% fine to coarse, hard, subrounded gravel; about 45% fine to coarse sand; about 5% fines with no plasticity; TOTAL SAMPLE (BY VOLUME), about 10% 3- to 5-inch subrounded cobbles; remainder minus 3-inch; maximum size recovered, 3-3/4"; wet; soft, loose; gray brown; strong reaction with HCl.

25.3 to 36.8' VIRGELLE FORMATION - CRETACEOUS (Kvt):

25.3 to 36.8' Sandstone (ss). Gray to gray brown; fine to medium grained; very intensely to intensely weathered (W8-W7) 25.3-30.2' and moderately to slightly weathered (W4) 30.2-36.8'; very soft (H7) to moderately hard (H4), dependant on weathering; very intensely fractured (FD9) to moderately fractured (FD5) dependant on weathering; no to weak reaction with HCl.

COMMENTS:

Continued next page

GEOLOGIC LOG OF DRILL HOLE: DH99-3

FEATURE: St. Mary Siphon
LOCATION: Left of Siphon on Outlet Side
BEGUN: 5/17/99 **FINISHED:** 5/18/99
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED:

PROJECT: Milk River Project
COORDINATES:
TOTAL DEPTH: 36.8
DEPTH TO BEDROCK: 25.3

STATE: Montana
GROUND ELEVATION: 4290.8
ANGLE FROM HORIZONTAL: -90 **AZIMUTH:**
HOLE LOGGED BY: L. Crutchfield
REVIEWED BY:

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	% FINES BY WT.	% SAND BY WT.	% MOIST CONTENT	GEOL. UNIT SYM.	0 SPT (BLOWS/FT) 50	CLASSIFICATION AND PHYSICAL CONDITION

cohesion of material.

DRILL FLUID
0.0-30.2' Augered dry. No fluid added while performing penetration testing.

30.2-36.8' Cored with clear water collected from siphon seepage.

HOLE COMPLETION
Set porous tube piezometer 28.4-26.4' with 3/4" PVC to 2.9' above ground surface. Sandpacked hole 36.8-18.7' with .010/.020 sand. Backfilled hole with bentonite chips and cuttings 18.7' to 3.0'. Cemented in steel stand pipe with lockable lid.

SURFACE: Native Grasses
STATION/OFFSET: 108+51.96, 13.95' RT
SURFACE ELEVATION: 4307.0

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	TOPSOIL AND ORGANIC MATERIAL	1.0		
	Sandy, **LEAN CLAY, A-7-6(11)**, relatively stiff, abundant organics, slightly moist, dark brown	5.0		S-1 G
	Well-graded **GRAVEL** with silt and sand, medium dense, occasional cobbles, subangular to subrounded, moist, grayish brown	9.5		S-2
	Sandy, **LEAN CLAY, A-6(8)**, stiff, interbedded with silty clay and silty sand, very moist, grayish brown	12.0		S-3
	Well-graded **GRAVEL** with silt and sand, medium dense, occasional cobbles, subangular to subrounded, moist, greenish gray	16.5		S-4

Bottom of Boring : 16.5 feet

Groundwater Not Encountered During Drilling

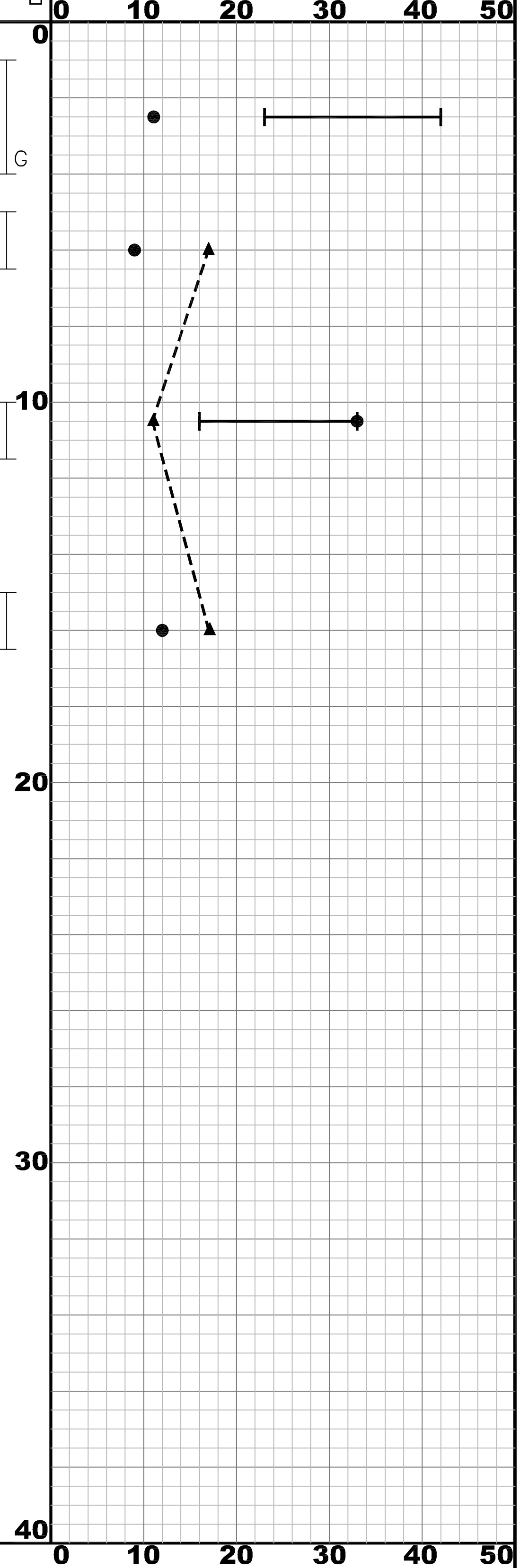
Logged by: Erling A. Juel, P.E. (09/28/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

PENETRATION RESISTANCE/MOISTURE CONTENT

▲ =BLOWS PER FOOT

● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-1

St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 06-093

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. 4
Sheet 1 of 1

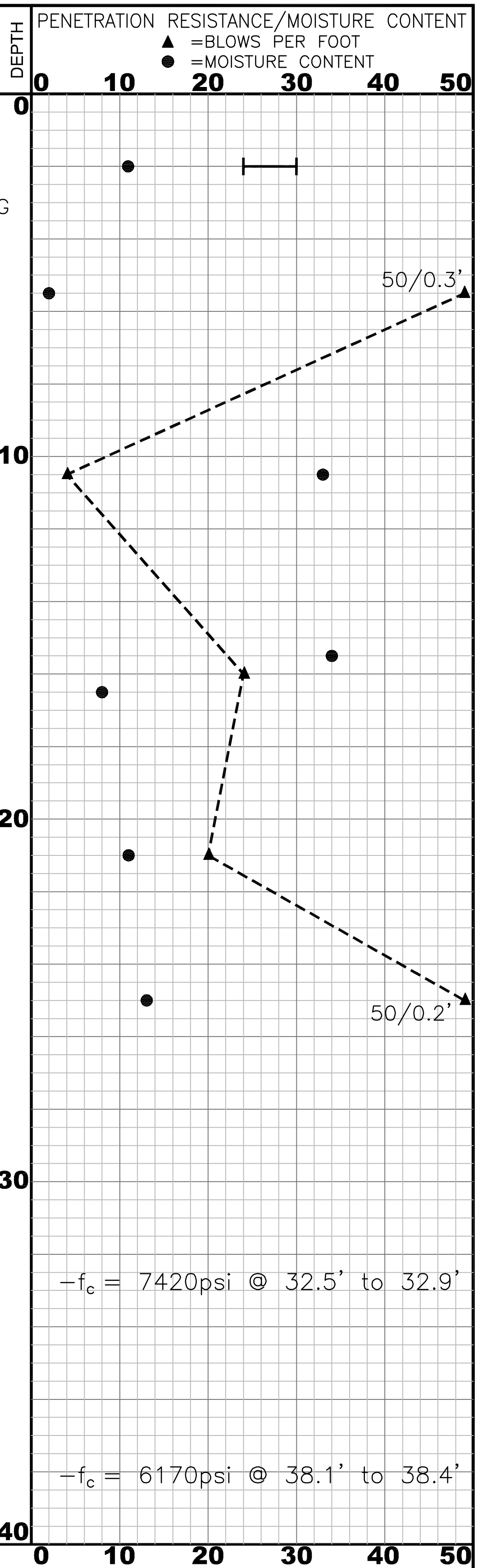
SURFACE: Native Grasses STATION/OFFSET: 110+34.21, 0.11' LT

SURFACE ELEVATION: 4289.8

SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
TOPSOIL AND ORGANIC MATERIAL	0.5		
Sandy **SILT, A-4(1)**, relatively dense, abundant organics, moist, dark brown	3.5		S-1 G
Poorly-graded **GRAVEL** with silt and sand, very dense, numerous cobbles and boulders, subangular to subrounded, slightly moist to saturated, grayish brown	8.91 ▼ / 9.5		S-2
LEAN CLAY with sand, soft, saturated, gray	15.5		S-3
Clayey **GRAVEL** with sand, medium dense, subangular to subrounded, cobbles and boulders, saturated, grayish brown -sandstone boulder 25-27 feet -sandstone boulder 30-30.8 feet	31.5	Groundwater Encountered During Drilling	S-4, S-5, S-6, C-1
SHALE, moderately hard, moderately weathered, massive to very thickly bedded, blocky to conchoidal-type breaks, occassional slickensides, noncalcareous, dark gray -intensely fractured 36.75 to 37.25 feet	37.8		C-2
SANDSTONE, moderately soft, moderately weathered, shaly partings, joints at 60°, secondary mineralization of joints, thinly bedded, medium gray, salt and pepper	39.4		C-3
SHALE (See Description on Following Sheet)			

Logged by: Erling A. Juel, P.E. (09/27/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit, In Situ Water Content, Liquid Limit, Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-2

St. Mary River Bridge Replacement

MT 18(35) UPN 6001

North of Babb, Montana

November 2006 06-093

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS-BOZEMAN-KALISPELL-HELENA MONTANA SPOKANE WASHINGTON LEWISTON IDAHO

Figure No. 5

Sheet 1 of 6

GRAPHIC LOG | SURFACE: Native Grasses | STATION/OFFSET: 110+34.21, 0.11' LT
SURFACE ELEVATION: 4289.8

SOIL DESCRIPTION | DEPTH | GROUND WATER | SAMPLE | DEPTH | PENETRATION RESISTANCE/MOISTURE CONTENT

▲ =BLOWS PER FOOT
● =MOISTURE CONTENT

0 10 20 30 40 50

(Continued from Previous Sheet)

SHALE, moderately hard to hard, moderately weathered, highly fractured, massive to thickly bedded, blocky to conchoidal-type breaks, non calcareous, dark gray

C-4

44.5

Bottom of Boring/Coring: 44.5 feet

Rock Core Run #1 (See Sheet 3)
Depth: 25.0' to 30.0'
Coring Rate: 1.25 min/ft.
Recovery: 57%
RQD: 0%

Rock Core Run #2 (See Sheet 4)
Depth: 30.0' to 34.5'
Coring Rate: 1.25 min/ft.
Recovery: 78%
RQD: 48%

Rock Core Run #3 (See Sheet 5)
Depth: 34.5' to 39.5'
Coring Rate: Not Recorded
Recovery: 78%
RQD: 35%

Rock Core Run #4 (See Sheet 6)
Depth: 39.5' to 44.5'
Coring Rate: 0.60 min/ft.
Recovery: 100%
RQD: 65%

Groundwater Encountered During Drilling

Depth scale: 40, 50, 60, 70, 80

Logged by: Erling A. Juel, P.E. (09/27/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-2 (cont.)

St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 | 06-093

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

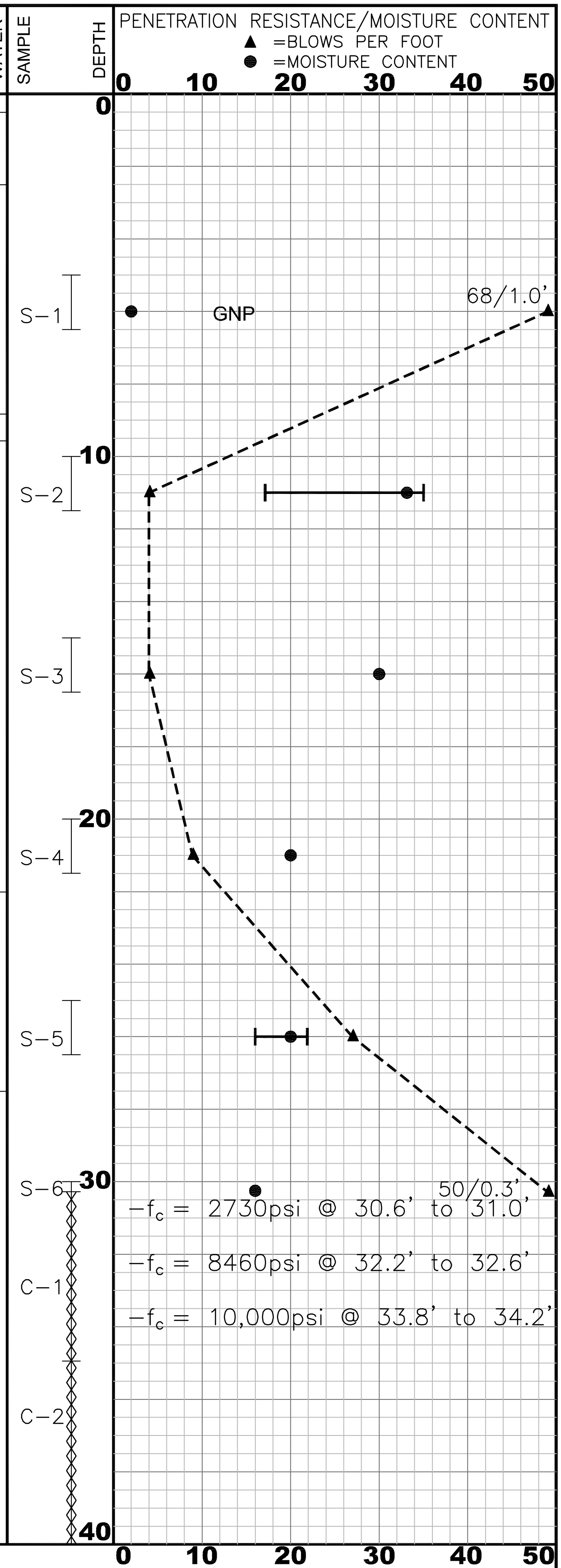
Figure No. 5

SURFACE: Brush and Decidious Trees
SURFACE ELEVATION: 4285.8 STATION/OFFSET: 112+44.46, 3.29' RT

Soil Description	Depth
TOPSOIL AND ORGANIC MATERIAL	0.5
Sandy **SILT,** relatively dense, fiberous organics, moist, dark brown	2.5
Well-graded **GRAVEL** with silt and sand, **A-1-a(0)**, very dense, frequent cobbles, subrounded to subangular, slightly moist, greenish gray	8.86 (groundwater), 9.5
LEAN CLAY, A-6(15), soft, varved with silt, occasional silty, fine sand, saturated, gray – more silt and silt with sand – sandy seams	22.0
Silty, clayey **SAND** with gravel, **A-1-b(0)**, medium dense, medium dense, subangular, saturated, grayish brown	27.5
SANDSTONE, hard to very hard, slightly weathered to fresh, slightly to moderately calcareous (varies), slightly fractured, occasional joints at 60°, mostly horizontal mechanical breaks and bedding joints, occasional cross-bedding, near horzontal bedding, abundant quartz, medium-grained, meduim gray, salt and pepper	

Logged by: Erling A. Juel, P.E. (09/26-27/06)
Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

Groundwater Encountered During Drilling



(Continued on Following Sheet)

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

▲ SPT blows per foot
● Field Moisture content
▼ Groundwater Level
Grab/composite sample
1-3/8-inch I.D. split spoon
2-1/2-inch I.D. split spoon
2-1/2-inch I.D. ring sampler
3-inch I.D. thin-walled sampler
* No sample recovery

Atterberg Limits: Plastic Limit, In Situ Water Content, Liquid Limit, Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-3

St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 06-093

THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA, SPOKANE WASHINGTON, LEWISTON IDAHO

Figure No. 6

GRAPHIC LOG	SURFACE: Brush and Decidious Trees SURFACE ELEVATION: 4285.8 STATION/OFFSET: 112+44.46, 3.29' RT SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
	(Continued from Previous Sheet)				40	
	SHALE, moderately hard to moderately soft, slightly weathered, very thinly bedded, fissile, noncalcareous, blocky, dark gray	44.3 45.0		C-3		
	Bottom of Boring/Coring: 45.0 feet		Groundwater Encountered During Drilling		50 60 70 80	

Rock Core Run #1 (See Sheet 3)
Depth: 30.0' to 35.0'
Coring Rate: 1.00 min/ft.
Recovery: 100%
RQD: 90%

Rock Core Run #2 (See Sheet 4)
Depth: 35.0' to 40.0'
Coring Rate: 1.00 min/ft.
Recovery: 100%
RQD: 80%

Rock Core Run #3 (See Sheet 5)
Depth: 40.0' to 45.0'
Coring Rate: 1.60 min/ft.
Recovery: 93%
RQD: 56%

Logged by: Erling A. Juel, P.E. (09/26-27/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

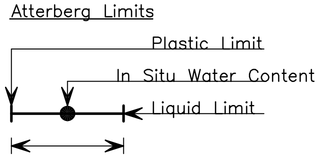
0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- I_G Grab/composite sample
- I 1-3/8-inch I.D. split spoon
- II 2-1/2-inch I.D. split spoon
- III_R 2-1/2-inch I.D. ring sampler
- III_T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Log of Soil Boring BB-3 (cont.)

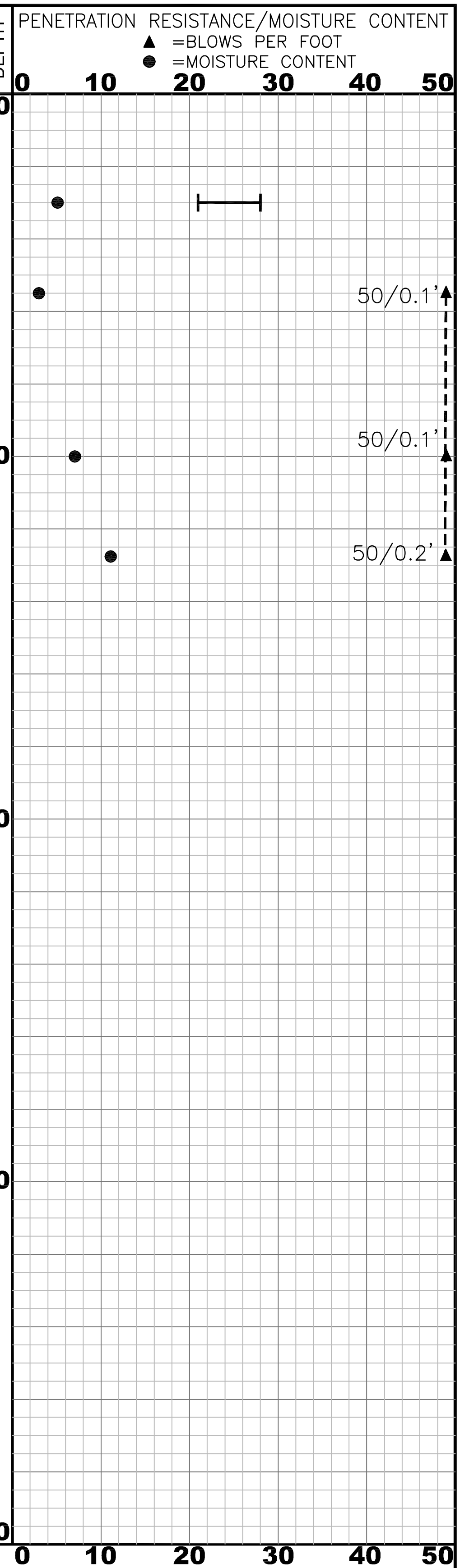
St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 06-093

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. 6
Sheet 2 of 5

GRAPHIC LOG	SURFACE: Native Grasses and Brush SURFACE ELEVATION: 4290.3 STATION/OFFSET: 116+00.32, 12.14' RT SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	TOPSOIL AND ORGANIC MATERIAL	0.5			0
	Silty **SAND,** relatively dense, slightly moist, dark brown	1.5			
	Poorly-graded **GRAVEL** with clay and sand, **A-1-a(0)**, very dense, subrounded to subangular, slightly moist, grayish brown	7.0		S-1 G S-2	
	SANDSTONE, very dense, mostly friable, slightly to strongly calcareous, slightly moist, grayish brown	12.7		S-3 S-4	10
	Bottom of Boring: 12.7 feet		**Groundwater Not Encountered During Drilling**		20 30 40



Logged by: Erling A. Juel, P.E. (09/27/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit, In Situ Water Content, Liquid Limit, Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-4

St. Mary River Bridge Replacement

MT 18(35) UPN 6001

North of Babb, Montana

November 2006 06-093

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS-BOZEMAN-KALISPELL-HELENA SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

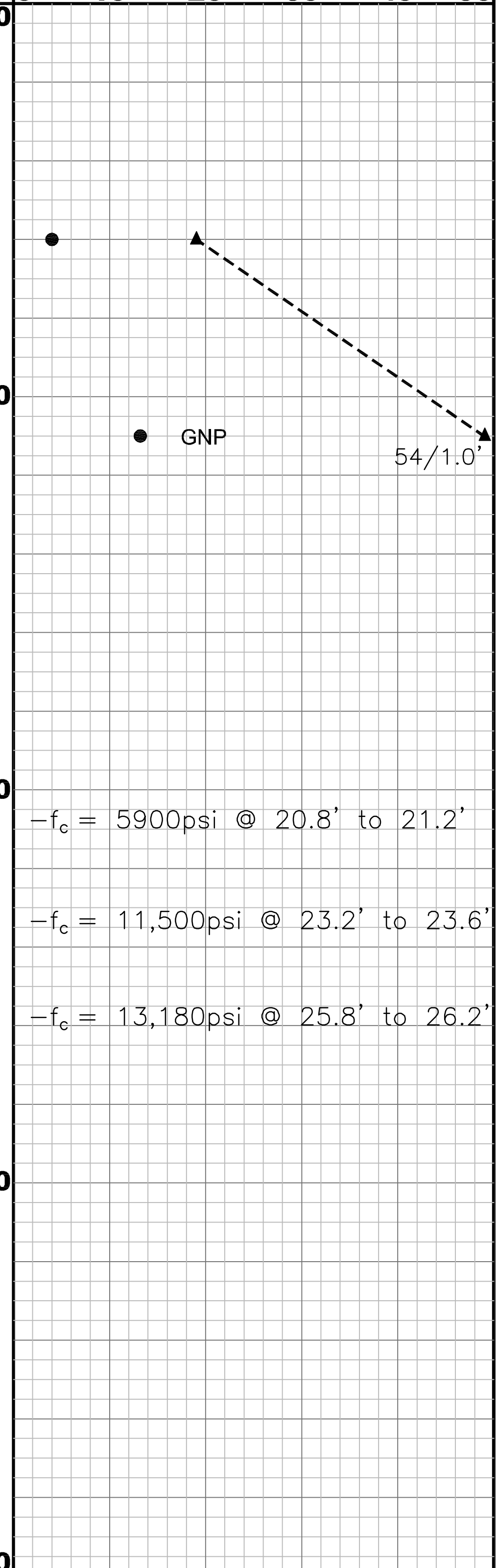
Figure No. 7
Sheet 1 of 1

SURFACE: 18" inches of water STATION/OFFSET: 111+48.93, 2.42' RT
SURFACE ELEVATION: 4276.7 (River Bottom)

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	COBBLES AND BOULDERS, relatively loose, silty sand with gravel matrix, subrounded to subangular, saturated, variegated, reddish, greenish, grayish brown —Silty **SAND** with gravel matrix, **A-2-4** Core Runs C—1 and C—2 contained subrounded gravel alluvium, mostly limestone cobbles and boulders	15.5		S—1, S—2, C—1, C—2
	LEAN CLAY with sand, comprised chiefly of highly weathered, reworked shale with sandstone, siltstone and limestone fragments, hard, medium gray	20.5		C—3, C—4
	SANDSTONE, very hard, slightly weathered to fresh, slightly to moderately calcareous(varies), slightly fractured, joints at 60°, occasional cross—bedding, bedding approximately horizontal, mechanical breaks and bedding joints at horizontal, abundant quartz, medium—grained, medium gray, salt and pepper	36.5	Groundwater Encountered During Drilling	C—5, C—5, C—6
	Bottom of Boring/Coring: 36.5 feet (See Following Sheet For Core Run Data)			

Logged by: Erling A. Juel, P.E. (09/26/06)

Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1—3/8—inch I.D. split spoon
- 2—1/2—inch I.D. split spoon
- 2—1/2—inch I.D. ring sampler
- 3—inch I.D. thin—walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring BB-5

St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 06-093

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS—BOZEMAN—KALISPELL—HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. 8
Sheet 1 of 7

GRAPHIC LOG	SURFACE: 18" inches of Water STATION/OFFSET: 111+48.93, 2.42' RT SURFACE ELEVATION: 4276.7 (River Bottom) SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50

Rock Core Run #1
Depth: 10.0' to 12.5'
Coring Rate: 1.80 min/ft.
Recovery: N/A
RQD: N/A

Rock Core Run #2
Depth: 12.0' to 14.5'
Coring Rate: 3.25 min/ft.
Recovery: N/A
RQD: N/A

Rock Core Run #3 (See Sheet 3)
Depth: 14.5' to 16.5'
Coring Rate: 3.38 min/ft.
Recovery: 90%
RQD: N/A

Rock Core Run #4 (See Sheet 4)
Depth: 16.5' to 21.5'
Coring Rate: 2.80 min/ft.
Recovery: 100%
RQD: 36%

Rock Core Run #5 (See Sheet 5)
Depth: 21.5' to 26.5'
Coring Rate: 1.15 min/ft.
Recovery: 100%
RQD: 100%

Rock Core Run #6 (See Sheet 6)
Depth: 26.5' to 31.5'
Coring Rate: 1.20 min/ft.
Recovery: 100%
RQD: 100%

Rock Core Run #7 (See Sheet 7)
Depth: 31.5' to 36.5'
Coring Rate: 1.40 min/ft.
Recovery: 100%
RQD: 100%

Groundwater Encountered During Drilling

Depth: 40, 50, 60, 70, 80

Logged by: Erling A. Juel, P.E. (09/26/06)
Drilled by: Haztech Drilling using a track-mounted CME-850 drill rig with 8-inch HSA.

0 10 20 30 40 50

LEGEND

▲ SPT blows per foot
● Field Moisture content
▼ Groundwater Level
Grab/composite sample
1-3/8-inch I.D. split spoon
2-1/2-inch I.D. split spoon
2-1/2-inch I.D. ring sampler
3-inch I.D. thin-walled sampler
* No sample recovery

Atterberg Limits
Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring BB-5 (cont.)
St. Mary River Bridge Replacement
MT 18(35) UPN 6001
North of Babb, Montana

November 2006 06-093

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

APPENDIX B

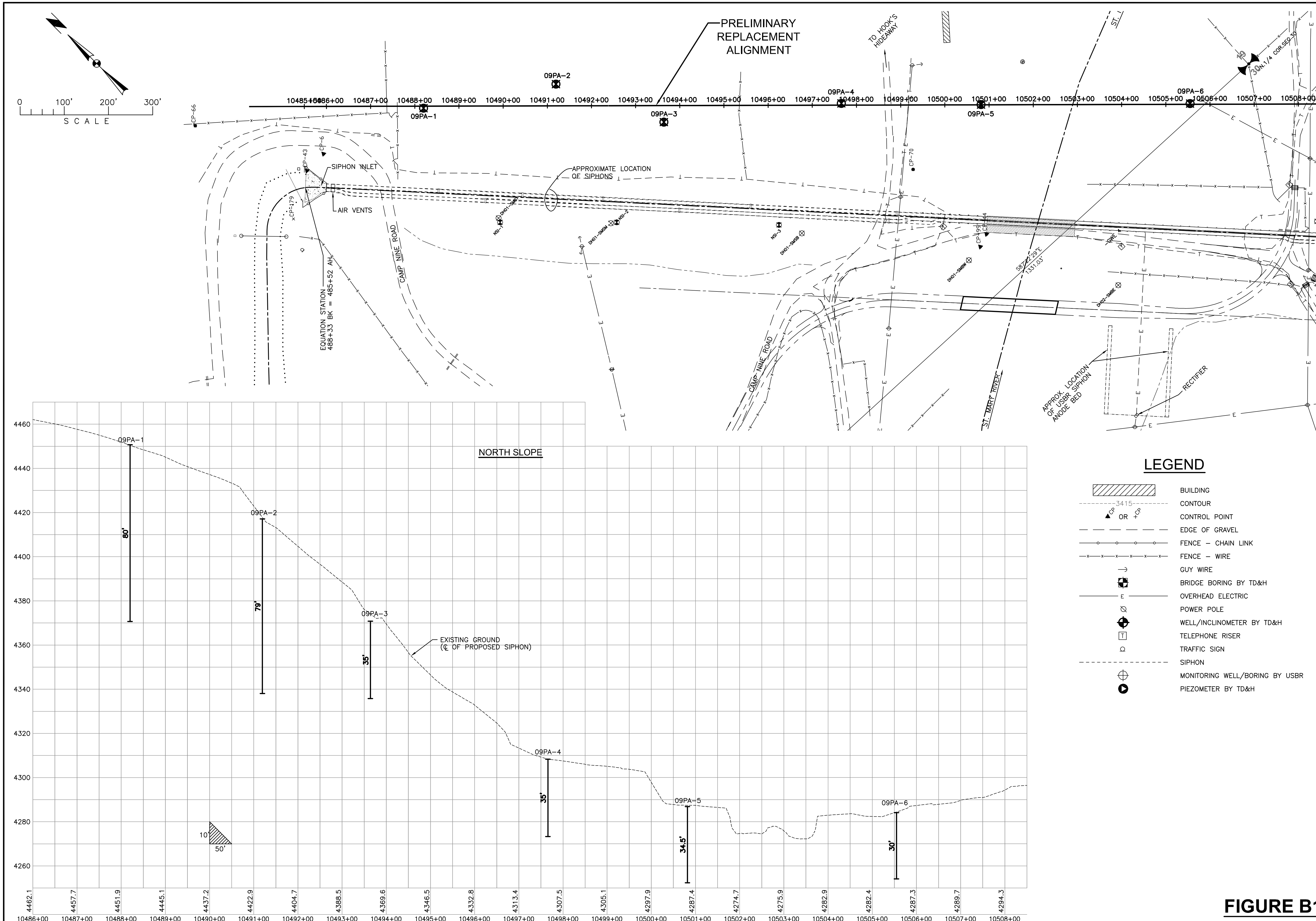


FIGURE B1

REVISIONS

BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA — MONTANA
SPOKANE — WASHINGTON
LEWISTON — IDAHO

TD&H

DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	09.10.07
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER PROPOSED SIPHON CROSSING NORTH REPLACEMENT ALIGNMENT & 2009 SOIL BORINGS

CAD NO. 04167figB1.DWG

SHEET 1 OF 2

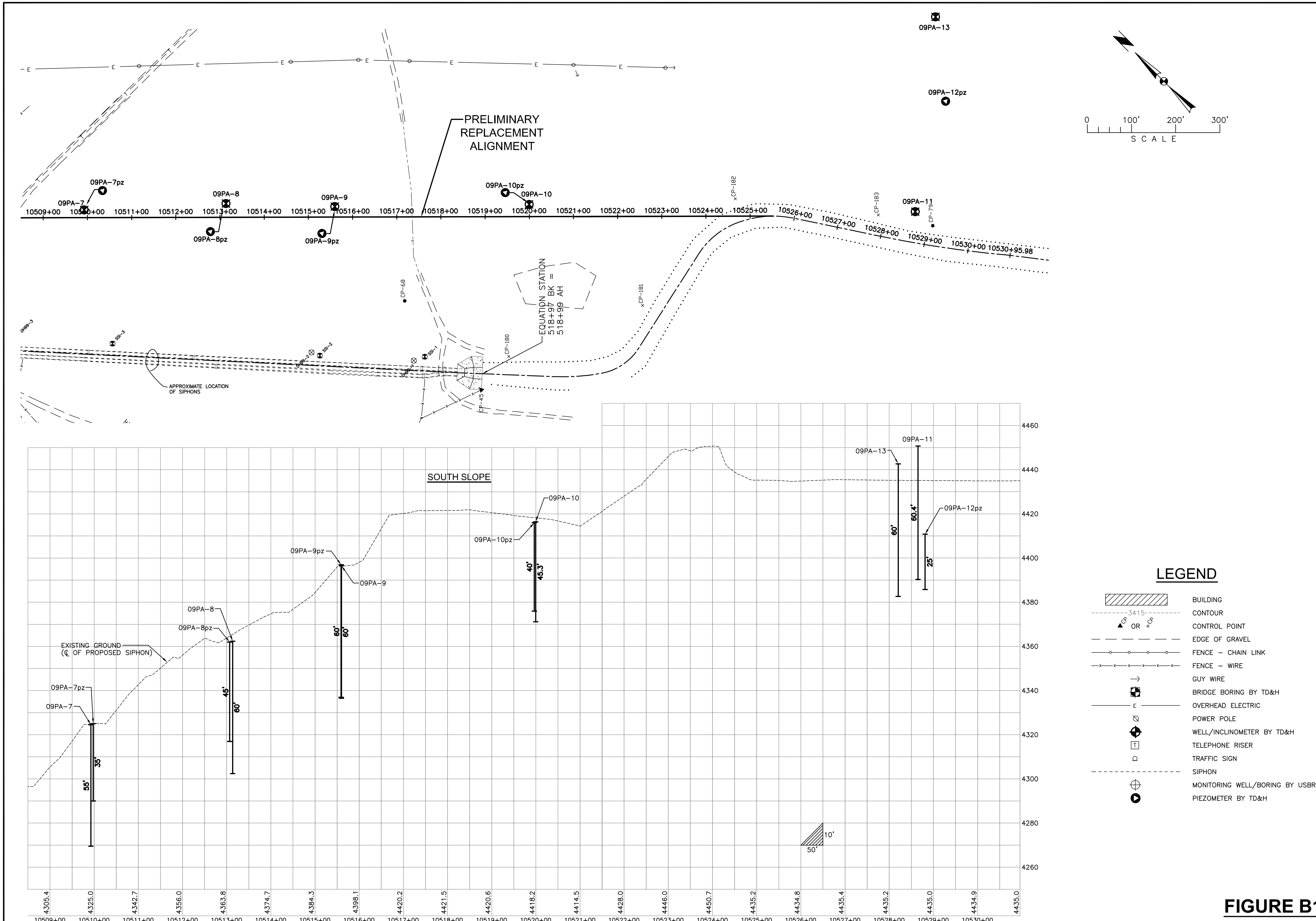


FIGURE B1

REVISIONS

BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL–HELENA
SPOKANE
LEWISTON
MONTANA
WASHINGTON
IDAHO

TD&H

DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	09.10.07
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER PROPOSED SIPHON CROSSING SOUTH REPLACEMENT ALIGNMENT & 2009 SOIL BORINGS

CAD NO. 04167figB1 .DWG
SHEET 2 OF 2

SURFACE: Native Grasses and Weeds
SURFACE ELEVATION: 4450.68

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff, brown, slightly moist, trace gravel, mottled.				0
	q_u = 3.0 to 3.5 tsf.				10
	q_u = 3.0 to 3.5 tsf.				
		22.0			20
	Clayey **GRAVEL** with Sand, very dense to hard, brown, slightly moist.				
					30
	—core boulder @37.0'				40

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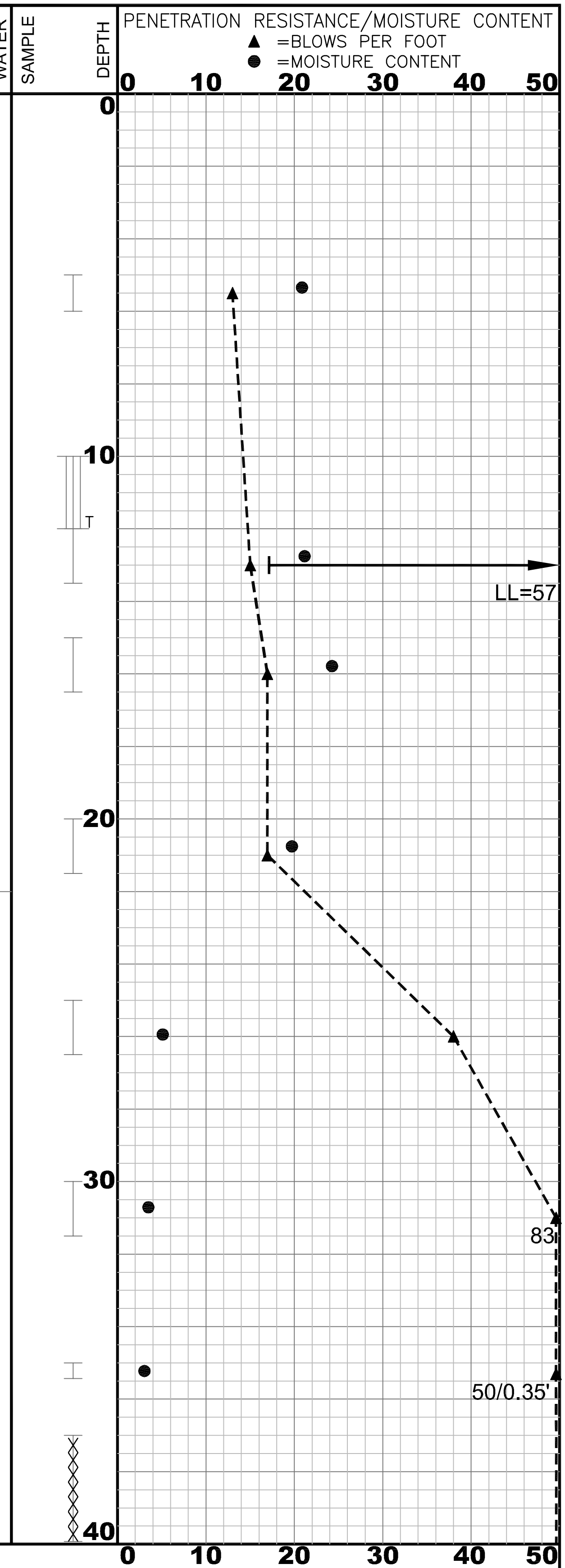
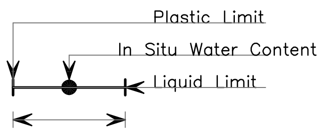


Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Log of Soil Boring 09PA-1

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

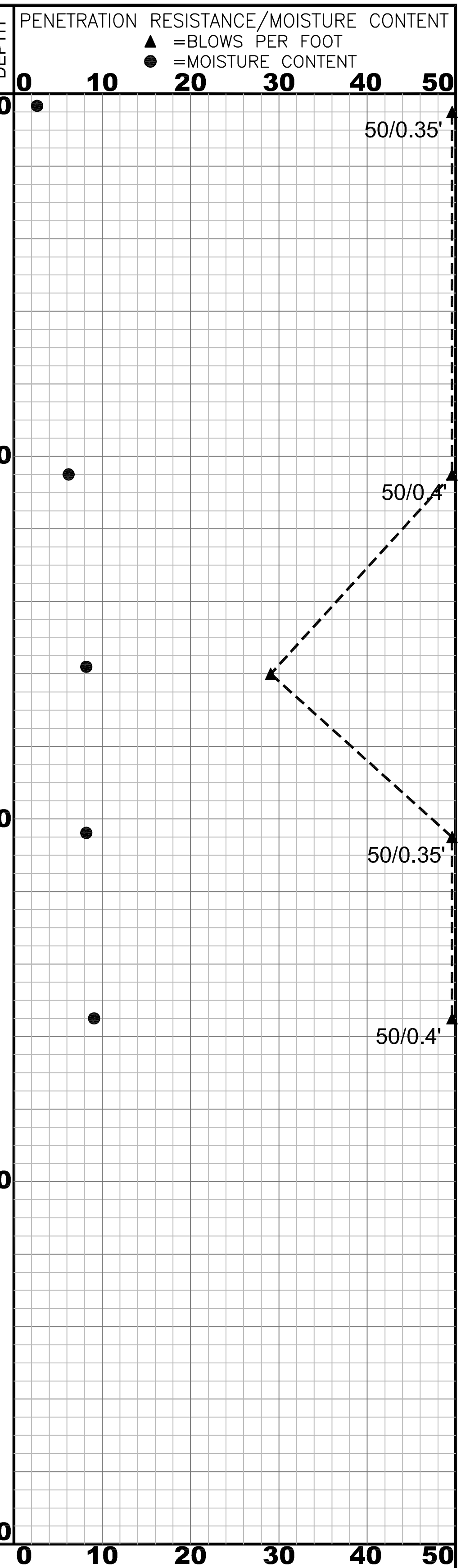
September 2009 — 04-167

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL, SPOKANE, LEWISTON — MONTANA, WASHINGTON, IDAHO

Figure No. B2

GRAPHIC LOG	SURFACE: Native Grasses and Weeds SURFACE ELEVATION: 4450.68 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	—core boulders from 43.7' to 50.'				40
					50
	—Medium dense sandy zone near 55.0'.	55.9	▼		
	—core boulder @58.9'				60
	SANDSTONE, hard, gray, slightly moist, weathered (decreases with depth).	66.0			
	Rock Core Run #1 Depth: 70.0' to 75.0' Coring Rate: 1.82 min/ft. Recovery: 98% **RQD**: 0.73				70
	Rock Core Run #2 Depth: 75.0' to 80.0' Coring Rate: 2.24 min/ft. Recovery: 100% **RQD**: 0.59				
	SHALE, hard, gray, slightly moist, weathered zones	79.0			80

Continued to Next Page



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits
- Plastic Limit
- In Situ Water Content
- Liquid Limit
- Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-1

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

September 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B2

GRAPHIC LOG	SURFACE: Native Grasses and Weeds SURFACE ELEVATION: 4450.68 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
	Bottom of Soil Boring : 80.0 feet				80	
					90	
					100	
					110	
					120	0 10 20 30 40 50

Logged by: Craig R. Nadeau, E.I. (09/01-03/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Dual Purpose Slope Inclinometer / Monitoring Well
- Top of Casing Elevation: 4452.02
- Overall length: 81.0 feet

Construction:
2.75–inch I.D., ABS plastic inclinometer casing (Bottom 8.0 feet slotted) + 3/4–inch O.D. PVC plastic pipe
- Screened interval: 80.0' to 82.0' BGS
- 10–20 Sand Pack 20.0' to 70.0' BGS
- Bentonite Seal 70.0' to 68.0' BGS
- Screened interval (3/4–inch PVC) 79.8' to 69.8' BGS
- 10–20 Sand Pack 70.0' to 53.0' BGS
- Bentonite Seal 53.0' to 51.0' BGS
- Cement/lime/bentonite grout 51.0' to 1.0' BGS
- Steel protective casing monument set in concrete

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-1

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

September 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B2

BORING 09PA-1, ELEVATION 4450.7 FT, ROCK CORE RUN 1
CORE MISC. BOULDERS 37.0' TO 50.0'
CORE RUN 1: DEPTH=70.0' TO 75.0', RQD=0.73, RECOVERY=98%

FIGURE B2

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-1 **CORE RUN 1**	DRAWN BY: RLR	DATE: SEPTEMBER 2009	**SHEET 4 of 5**
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B01-4.DWG	

BORING 09PA–1, ELEVATION 4450.7 FT, ROCK CORE RUN 2
CORE RUN 2: DEPTH=75.0' TO 80.0', RQD=0.59, RECOVERY=100%

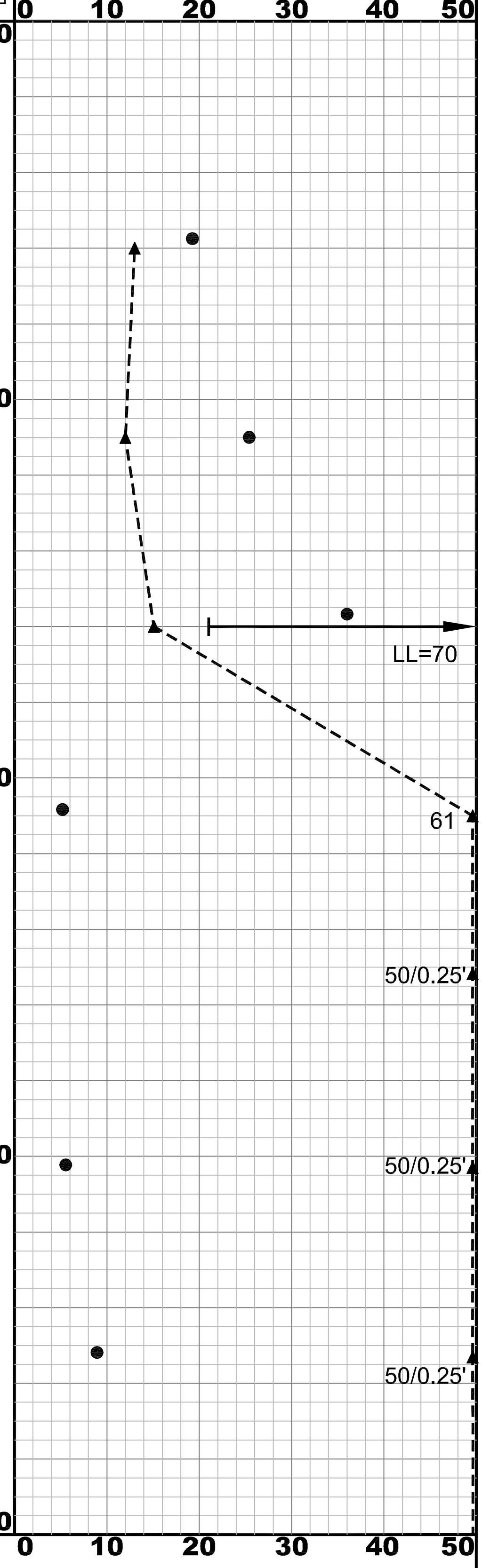
FIGURE B2

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-1 CORE RUN 2	DRAWN BY: RLR	DATE: SEPTEMBER 2009	SHEET 5 of 5
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B01-5.DWG	

SURFACE: Native Grasses and Shrubs
SURFACE ELEVATION: 4417.08

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff to very stiff, brown, slightly moist, occasional gravel.				0
	q_u = 3.0 to 3.5 tsf.				
	q_u = 3.0 to 3.5 tsf.				10
		16.5			
	Clayey **GRAVEL** with Sand, very dense to hard, light brown, slightly moist.				20
				*	
	–core boulder @27.5'				
					30
		33.2	▼		
		36.0			
	SHALE, hard, gray, slightly moist, weathered and fractured in zones.				
	Continued to Next Page				40

PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-2

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B3
Sheet 1 of 8

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4417.08 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT
	Rock Core Run #1 Depth: 40.0' to 45.0' Coring Rate: 1.71 min/ft. Recovery: 90% **RQD**: 0.37 **Rock Core Run #2** Depth: 45.0' to 50.0' Coring Rate: 2.54 min/ft. Recovery: 100% **RQD**: 0.63 **Rock Core Run #3** Depth: 50.0' to 55.0' Coring Rate: 2.09 min/ft. Recovery: 100% **RQD**: 0.35	55.0			40 50	50/0.5'
	SANDSTONE, hard, gray, slightly moist, fractured with salts in joints **Rock Core Run #4** Depth: 55.0' to 60.0' Coring Rate: 1.75 min/ft. Recovery: 100% **RQD**: 0.64 **Rock Core Run #5** Depth: 60.0' to 65.0' Coring Rate: 1.52 min/ft. Recovery: 100% **RQD**: 0.67	67.9			60	
	SHALE, hard, dark gray, slightly moist, fractured **Rock Core Run #6** Depth: 65.0' to 70.0' Coring Rate: 1.79 min/ft. Recovery: 100% **RQD**: 0.68 **Rock Core Run #7** Depth: 70.0' to 75.0' Coring Rate: 1.81 min/ft. Recovery: 100% **RQD**: 0.48 **Rock Core Run #8** Depth: 75.0' to 79.0' Coring Rate: 1.58 min/ft. Recovery: 100% **RQD**: 0.77	79.0			70 80	
	Bottom of Soil Boring: 79.0 feet					

0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-2

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B3
Sheet 2 of 8

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4417.08 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
					80	
	Logged by: Craig R. Nadeau, E.I. (08/31/09) Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.					
					90	
	Installed Dual Purpose Slope Inclinometer – Top of Casing Elevation: 4419.00 – Overall length: 80.0 feet					
	Construction: –2.75–inch I.D., ABS plastic inclinometer casing Bottom 10.0 feet slotted as well –Screened interval: 79.0' to 69.0' BGS –10–20 Sand Pack 79.0' to 39.0' BGS –Bentonite Seal 39.0' to 37.5' BGS –Cement/lime/bentonite grout 37.5' to 1.0' BGS –Steel protective casing monument set in concrete				100	
					110	
					120	0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- 2–1/2–inch I.D. ring sampler
- 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-2

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

BORING 09PA–2, ELEVATION 4417.1 FT, ROCK CORE RUNS 1 & 2
CORE MISC. BOULDERS 27.5' TO 29.5'
CORE RUN 1: DEPTH=40.0' TO 45.0', RQD=0.37, RECOVERY=90%
CORE RUN 2: DEPTH=45.0' TO 50.0', RQD=0.63, RECOVERY=100%

FIGURE B3

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO
PHOTO OF SOIL BORING 09PA-2 **CORE RUNS 1 & 2**	DRAWN BY: RLR DESIGNED BY: CRN QUALITY CHECK:	DATE: AUGUST 2009 JOB NO. 04-167 CAD NO. 04167-B02-4.DWG SHEET 4 of 8

BORING 09PA-2, ELEVATION 4417.1 FT, ROCK CORE RUNS 3 & 4
CORE RUN 3: DEPTH=50.0' TO 55.0', RQD=0.35, RECOVERY=100%
CORE RUN 4: DEPTH=55.0' TO 60.0', RQD=0.67, RECOVERY=100%

FIGURE B3

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-2 **CORE RUNS 3 & 4**	DRAWN BY: RLR	DATE: AUGUST 2009	**SHEET 5 of 8**
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B02-5 .DWG	

BORING 09PA–2, ELEVATION 4417.1 FT, ROCK CORE RUN 5
CORE RUN 5: DEPTH=60.0' TO 65.0', RQD=0.67, RECOVERY=100%

FIGURE B3

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-2 CORE RUN 5	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 6 of 8
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B02-6 .DWG	

BORING 09PA–2, ELEVATION 4417.1 FT, ROCK CORE RUNS 6 & 7
CORE RUN 6: DEPTH=65.0' TO 70.0', RQD=0.68, RECOVERY=100%
CORE RUN 7: DEPTH=70.0' TO 75.0', RQD=0.48, RECOVERY=100%

FIGURE B3

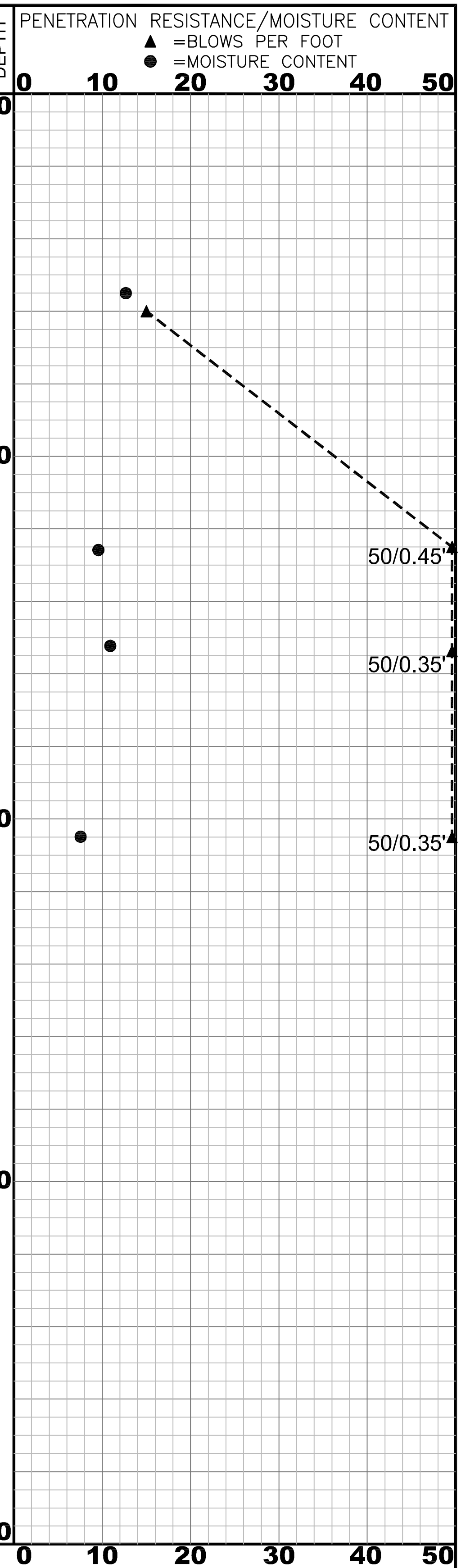
ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO
PHOTO OF SOIL BORING 09PA-2 CORE RUNS 6 & 7	DRAWN BY: RLR DESIGNED BY: CRN QUALITY CHECK:	DATE: AUGUST 2009 JOB NO. 04-167 CAD NO. 04167-B02-7.DWG SHEET 7 of 8

BORING 09PA–2, ELEVATION 4417.1 FT, ROCK CORE RUN 8
CORE RUN 8: DEPTH=75.0' TO 80.0', RQD=0.77, RECOVERY=100%

FIGURE B3

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-2 **CORE RUN 8**	DRAWN BY: RLR DESIGNED BY: CRN QUALITY CHECK:	DATE: AUGUST 2009 JOB NO. 04-167 CAD NO. 04167-B02-8.DWG	SHEET 8 of 8

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4370.76 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff to very stiff, brown, slightly moist, visible salt crystals, trace gravel and Cobbles.	7.0			0
	Clayey **GRAVEL** with Sand, very dense to hard, brown, slightly moist to dry.	9.0			
	Clayey **SAND**, very dense to hard, light brown to tan, dry.	14.0		T	10
	SHALE, hard, light brown to gray, dry, weathered, highly fractured, oxidized in joints.				
	Rock Core Run #1 Depth: 20.0' to 25.0' Coring Rate: 1.85 min/ft. Recovery: 84% **RQD**: 0.28				20
	Rock Core Run #2 Depth: 25.0' to 30.0' Coring Rate: 1.87 min/ft. Recovery: 90% **RQD**: 0.26		▼ 23.5		
	Rock Core Run #3 Depth: 30.0' to 35.0' Coring Rate: 1.87 min/ft. Recovery: 100% **RQD**: 0.78	35.0			30
	Bottom of Soil Boring: 35.0 feet				40



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-3

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

September 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B4

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4370.76 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50

Depth: 40, 50, 60, 70, 80

Logged by: Craig R. Nadeau, E.I. (09/03/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Dual Purpose Slope Inclinometer
- Top of Casing Elevation: 4372.52
- Overall length: 32.7 feet

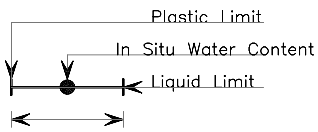
Construction:
- 2.75-inch I.D., ABS plastic inclinometer casing and 1-inch I.D. PVC plastic pipe
- Bottom of inclinometer casing at 33.5 feet due to hole caving
- Screened interval: 33.5' to 23.5' BGS
- 10-20 Sand Pack 33.5' to 20.0' BGS
- Bentonite Seal 20.0' to 18.5' BGS
- Screened interval (1" well) 18.1' to 8.1' BGS
- 10-20 Sand Pack 18.5' to 5.0' BGS
- Bentonite Seal 5.0' to 3.5' BGS
- Steel protective casing monument set in concrete

0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- I G Grab/composite sample
- I 1-3/8-inch I.D. split spoon
- II 2-1/2-inch I.D. split spoon
- III R 2-1/2-inch I.D. ring sampler
- III T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-3

St Mary River Siphon Crossing-Propsed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

September 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B4
Sheet 2 of 4

BORING 09PA-3, ELEVATION 4370.8 FT, ROCK CORE RUNS 1 & 2
CORE RUN 1: DEPTH=20.0' TO 25.0', RQD=0.28, RECOVERY=84%
CORE RUN 2: DEPTH=25.0' TO 30.0', RQD=0.26, RECOVERY=90%

FIGURE B4

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-3 CORE RUNS 1 & 2	DRAWN BY: RLR	DATE: SEPTEMBER 2009	SHEET 3 of 4
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B03-3 .DWG	

BORING 09PA-3, ELEVATION 4370.8 FT, ROCK CORE RUN 3
CORE RUN 3: DEPTH=30.0' TO 35.0', RQD=0.78, RECOVERY=100%

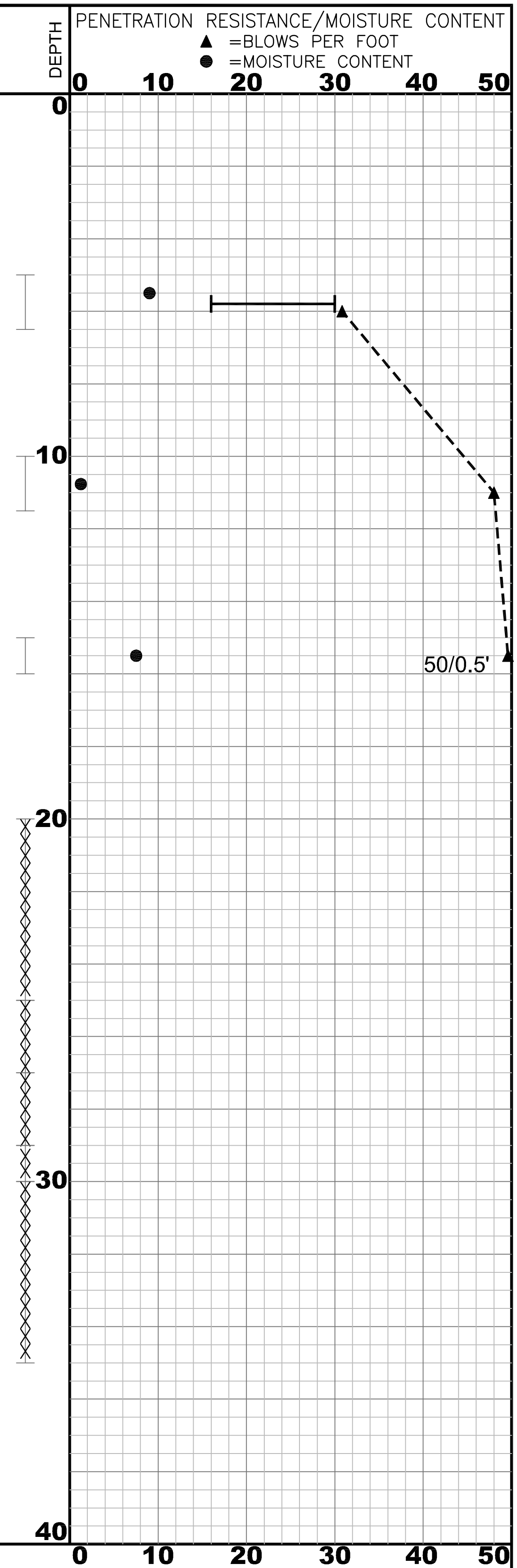
FIGURE B4

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-3 CORE RUN 3	DRAWN BY: RLR	DATE: SEPTEMBER 2009	SHEET 4 of 4
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B03-4 .DWG	

SURFACE: Native Grasses
SURFACE ELEVATION: 4308.30

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE
	Sandy **LEAN CLAY**, very stiff, brown, dry to slightly moist, minor oxidation.	6.5		
	Clayey **GRAVEL** with Sand, very dense to hard, light brown, dry to moist.	14.0		
	SANDSTONE, hard, light grayish brown to gray, dry to slightly moist, weathered, highly fractured zones with clay in fractures **Rock Core Run #1** Depth: 20.0' to 25.0' Coring Rate: 1.67 min/ft. Recovery: 60% **RQD**: 0.20 **Rock Core Run #2** Depth: 25.0' to 27.0' Coring Rate: 2.32 min/ft. Recovery: 93% **RQD**: 0.63 **Rock Core Run #3** Depth: 27.0' to 29.0' Coring Rate: 2.75 min/ft. Recovery: 85% **RQD**: 0.63 **Rock Core Run #4** Depth: 29.0' to 30.0' Coring Rate: 3.07 min/ft. Recovery: 100% **RQD**: 0.46 **Rock Core Run #5** Depth: 30.0' to 35.0' Coring Rate: 1.84 min/ft. Recovery: 100% **RQD**: 0.90	35.0	▼ 28.7	

Bottom of Soil Boring: 35.0 feet



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-4

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B5
Sheet 1 of 4

GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4308.30 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
					40	
	Logged by: Craig R. Nadeau, E.I. (08/30/09) Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.					
					50	
	Installed Dual Purpose Slope Inclinometer – Top of Casing Elevation: 4311.00 – Overall length: 37.7 feet					
	Construction: –2.75–inch I.D., ABS plastic inclinometer casing –Screened interval: 35.0' to 25.0' BGS –10–20 Sand Pack 35.0' to 20.0' BGS –Bentonite Seal 20.0' to 19.0' BGS –Cement/lime/bentonite grout 19.0' to 1.0' BGS –Steel protective casing monument set in concrete				60	
					70	
					80	0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-4
St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B5

BORING 09PA–4, ELEVATION 4308.3 FT, ROCK CORE RUNS 1–4
CORE RUN 1: DEPTH=20.0' TO 25.0', RQD=0.20, RECOVERY=60%
CORE RUN 2: DEPTH=25.0' TO 27.0', RQD=0.63, RECOVERY=93%
CORE RUN 3: DEPTH=27.0' TO 29.0', RQD=0.63, RECOVERY=85%
CORE RUN 4: DEPTH=29.0' TO 30.0', RQD=0.46, RECOVERY=100%

FIGURE B5

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO		
PHOTO OF SOIL BORING 09PA-4	DRAWN BY: RLR	DATE: AUGUST 2009		**SHEET 3 of 4**
CORE RUNS 1-4	DESIGNED BY: CRN	JOB NO. 04-167		
	QUALITY CHECK:	CAD NO. 04167-B04-3 .DWG		

BORING 09PA–4, ELEVATION 4308.3 FT, ROCK CORE RUN 5
CORE RUN 5: DEPTH=30.0' TO 35.0', RQD=0.90, RECOVERY=100%

FIGURE B5

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-4 CORE RUN 5	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 4 of 4
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B04-4 .DWG	

SURFACE: Native Grasses and Shrubs
SURFACE ELEVATION: 4286.85

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER
	Clayey **SAND**, loose to medium dense, brown, moist, occasional gravel.	7.0	
	Poorly-Graded **GRAVEL** with Sand, very dense to hard, tan, slightly moist.	11.5	
	SANDSTONE, very dense to hard, tan to blueish gray, slightly moist, weathered, highly fractured zones.	26.5	▼ 12.5
	SHALE, hard, dark gray, slightly moist, fractured.	30.3	
	SANDSTONE, hard, gray, slightly moist, fractured.	32.8	
	SHALE, hard, dark gray, slightly moist, fractured.	34.5	

Rock Core Run #1
Depth: 14.5' to 19.5'
Coring Rate: 2.49 min/ft.
Recovery: 85%
RQD: 0.23

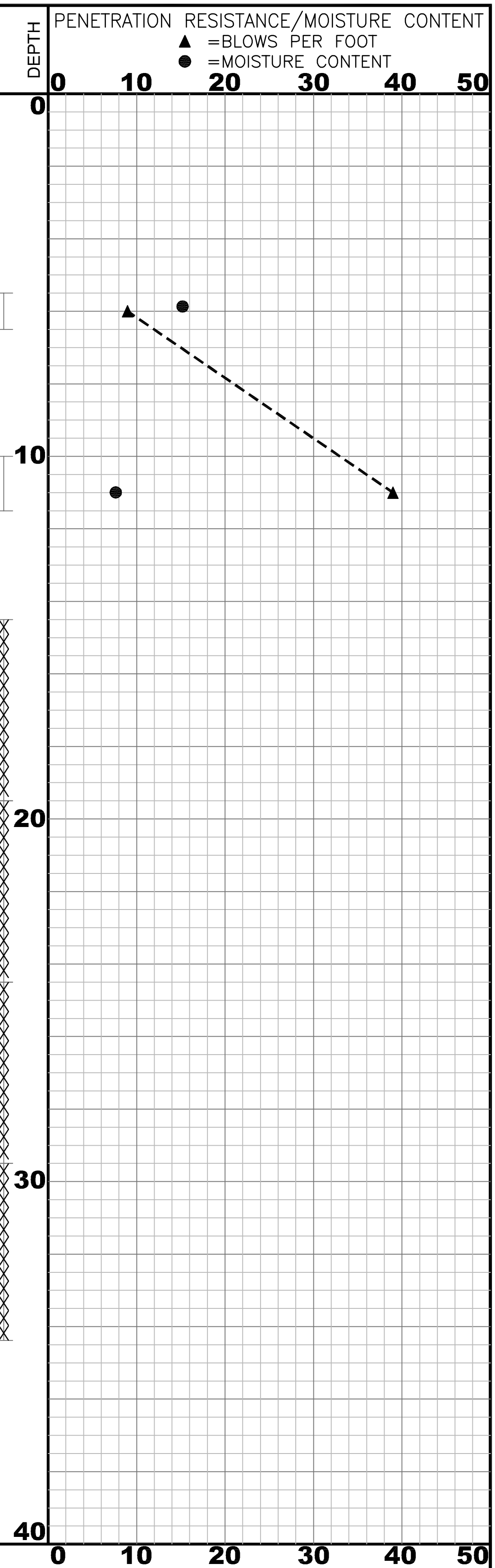
Rock Core Run #2
Depth: 19.5' to 24.5'
Coring Rate: 2.43 min/ft.
Recovery: 96%
RQD: 0.32

Rock Core Run #3
Depth: 24.5' to 29.5'
Coring Rate: 2.10 min/ft.
Recovery: 84%
RQD: 0.41

Rock Core Run #4
Depth: 29.5' to 34.5'
Coring Rate: 2.22 min/ft.
Recovery: 90%
RQD: 0.34

Bottom of Soil Boring: 34.5 feet

SAMPLE

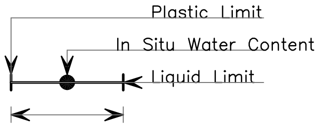


Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Log of Soil Boring 09PA-5

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B6
Sheet 1 of 4

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4286.85 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
					40	
	Logged by: Craig R. Nadeau, E.I. (08/31/09) Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.					
					50	
	Installed Nested Wells – Top of Casing Elevation: 4288.74 – Overall length: 33.1 feet					
	Construction: –1¼–inch and 1–inch PVC plastic pipe –Screened interval (1¼–inch PVC): 32.0' to 22.0' BGS –10–20 Sand Pack 32.0' to 14.5' BGS –Bentonite Seal 14.5' to 11.67' BGS –Screened interval (1–inch PVC): 11.5' to 6.5' BGS –Gravel backfill 11.67' to 5.0' BGS –Bentonite Seal 5.0' to 3.0' BGS –Steel protective casing monument set in concrete				60	
					70	
					80	0 10 20 30 40 50

LEGEND

Symbol	Description
▲	SPT blows per foot
●	Field Moisture content
▼	Groundwater Level
I G	Grab/composite sample
I	1–3/8–inch I.D. split spoon
II	2–1/2–inch I.D. split spoon
III R	2–1/2–inch I.D. ring sampler
III T	3–inch I.D. thin–walled sampler
*	No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-5

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B6

BORING 09PA–5, ELEVATION 4286.9 FT, ROCK CORE RUNS 1 & 2
CORE RUN 1: DEPTH=14.5' TO 19.5', RQD=0.23, RECOVERY=85%
CORE RUN 2: DEPTH=19.5' TO 24.5', RQD=0.32, RECOVERY=96%

FIGURE B6

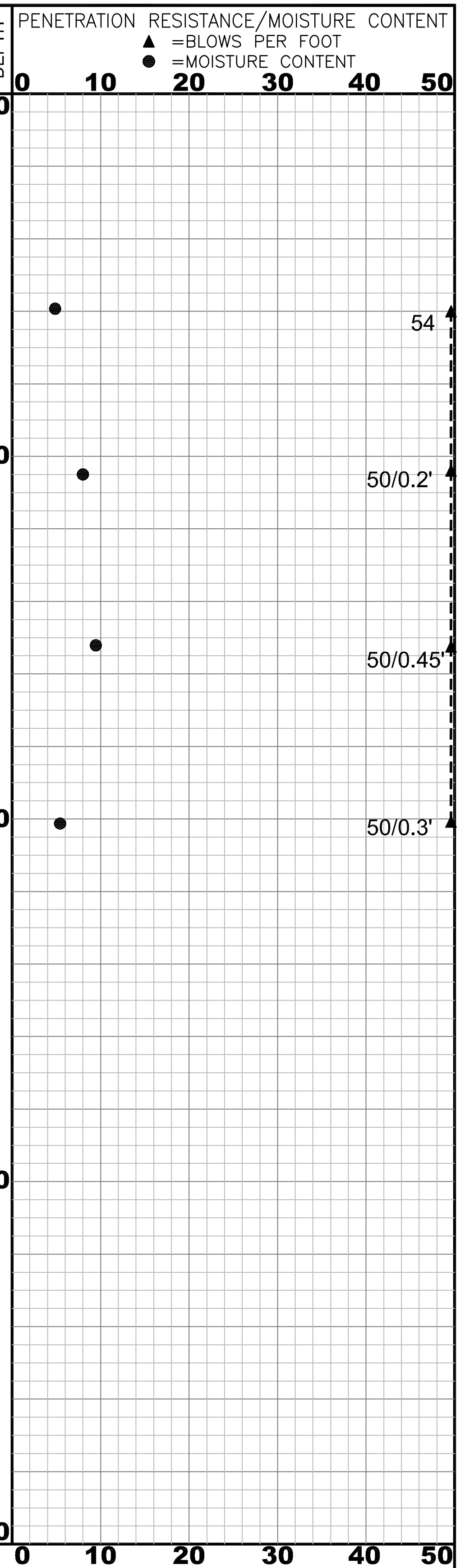
ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-5 CORE RUNS 1 & 2	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 3 of 4
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B05-3 .DWG	

BORING 09PA–5, ELEVATION 4286.9 FT, ROCK CORE RUNS 1 & 2
CORE RUN 3: DEPTH=24.5' TO 29.5', RQD=0.41, RECOVERY=84%
CORE RUN 4: DEPTH=29.5' TO 34.5', RQD=0.34, RECOVERY=90%

FIGURE B6

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-5 **CORE RUNS 3 & 4**	DRAWN BY: RLR	DATE: AUGUST 2009	**SHEET 4 of 4**
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B05-4 .DWG	

GRAPHIC LOG	SURFACE: Native Grasses, Shrubs and Trees SURFACE ELEVATION: 4284.09 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	Poorly-Graded **GRAVEL** with Sand, very dense to hard, brown, moist to wet, cobbles and boulders present.	6.5 8.0	▼		0
	SHALE, hard, grayish brown, slightly moist to dry, weathered.				10
	Rock Core Run #1 Depth: 20.0' to 25.0' Coring Rate: 2.47 min/ft. Recovery: 88% **RQD**: 0.67				20
	Rock Core Run #2 Depth: 25.0' to 30.0' Coring Rate: 1.80 min/ft. Recovery: 100% **RQD**: 0.48	30.0			30
	Bottom of Soil Boring: 30.0 feet				40



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-6

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS-BOZEMAN-KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B7
Sheet 1 of 3

GRAPHIC LOG	SURFACE: Native Grasses, Shrubs and Trees SURFACE ELEVATION: 4284.09 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
					40	
					50	
					60	
					70	
					80	

Logged by: Craig R. Nadeau, E.I. (08/29-30/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Nested Monitoring Wells
- Top of Casing Elevation: 4285.73
- Overall length: 30.4 feet

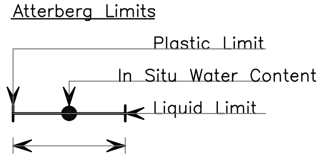
Construction:
- 1¼-inch and 1-inch I.D. PVC plastic pipe
- Screened interval (1¼-inch PVC): 30.0' to 22.0' BGS
- 10-20 Sand Pack 30.0' to 18.5' BGS
- Bentonite Seal 18.5' to 17.0' BGS
- Screened interval (1-inch PVC): 16.5' to 11.5' BGS
- 10-20 Sand Pack 17.0' to 10.0' BGS
- Bentonite Seal 10.0' to 8.5' BGS
- Screened interval (1-inch PVC): 8.4' to 3.4' BGS
- 10-20 Sand Pack 8.5' to 3.3' BGS
- Bentonite Seal 3.3' to 3.0' BGS
- Steel protective casing monument set in concrete

0 10 20 30 40 50

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery



GNP = Granular and Nonplastic

Log of Soil Boring 09PA-6

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

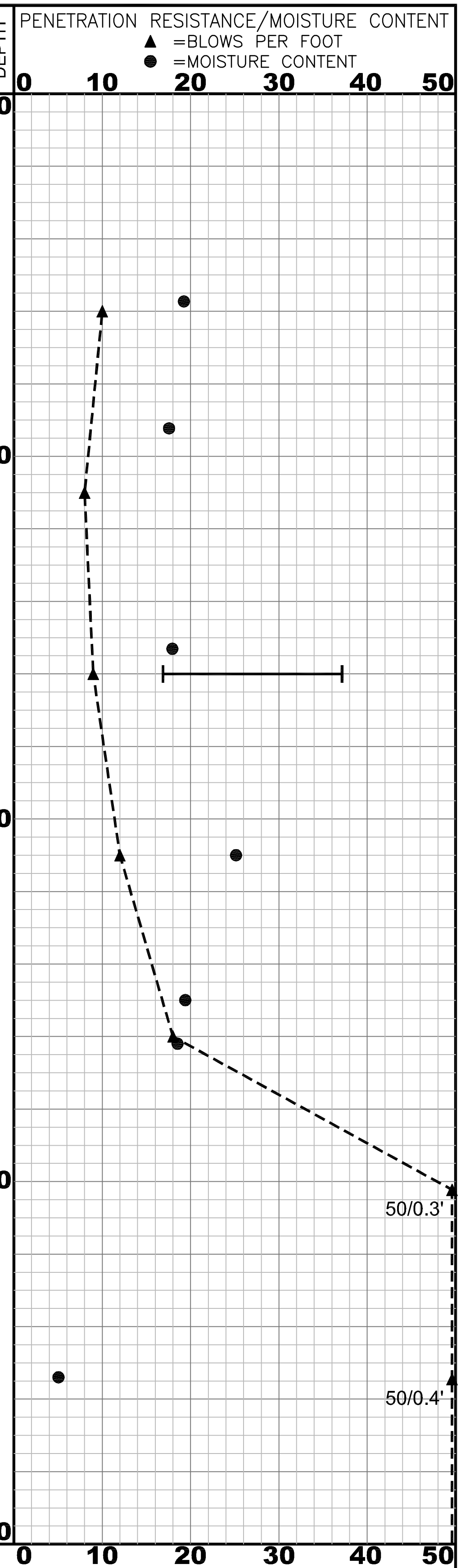
Figure No. B7
Sheet 2 of 3

BORING 09PA–6, ELEVATION 4284.1 FT, ROCK CORE RUNS 1 & 2
CORE RUN 1: DEPTH=20.0' TO 25.0', RQD=0.67, RECOVERY=88%
CORE RUN 2: DEPTH=25.0' TO 30.0', RQD=0.48, RECOVERY=100%

FIGURE B7

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO		
PHOTO OF SOIL BORING 09PA-6 CORE RUNS 1 & 2	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 3 of 3	
	DESIGNED BY: CRN	JOB NO. 04-167		
	QUALITY CHECK:	CAD NO. 04167-B06-3 .DWG		

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4324.52 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	LEAN CLAY, stiff, light brown, moist, minor sand and gravel, trace organics.				0
	q_u = 2.0 to 3.0 tsf.				
	–Large sand pockets from 10.0' to 11.5' q_u = 0.5 to 2.0 tsf.				10
	q_u = 0.5 to 1.5 tsf.				
	q_u = 0.5 to 2.0 tsf.				20
	q_u = 1.0 to 1.5 tsf.	25.5			
	Clayey **SAND** with Gravel, medium dense to dense, grayish tan, moist.	27.0			
	Clayey **GRAVEL** with Sand, very dense to hard, brown, slightly moist.			*	30
	–core boulder at 35.5'				
	SHALE, hard, grayish brown, slightly moist, highly weathered and fractured. (decreases with depth).	38.0			
	Continued to Next Page				40



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit

In Situ Water Content

Liquid Limit

Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-7

St Mary River Siphon Crossing-Proposed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B8
Sheet 1 of 4

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4324.52 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	Rock Core Run #1 Depth: 45.0' to 50.0' Coring Rate: 2.71 min/ft. Recovery: 95% **RQD**: 0.37 **Rock Core Run #2** Depth: 50.0' to 55.0' Coring Rate: 2.45 min/ft. Recovery: 100% **RQD**: 0.59	40.8 55.0	▼		40 50

Logged by: Craig R. Nadeau, E.I. (08/28-29/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

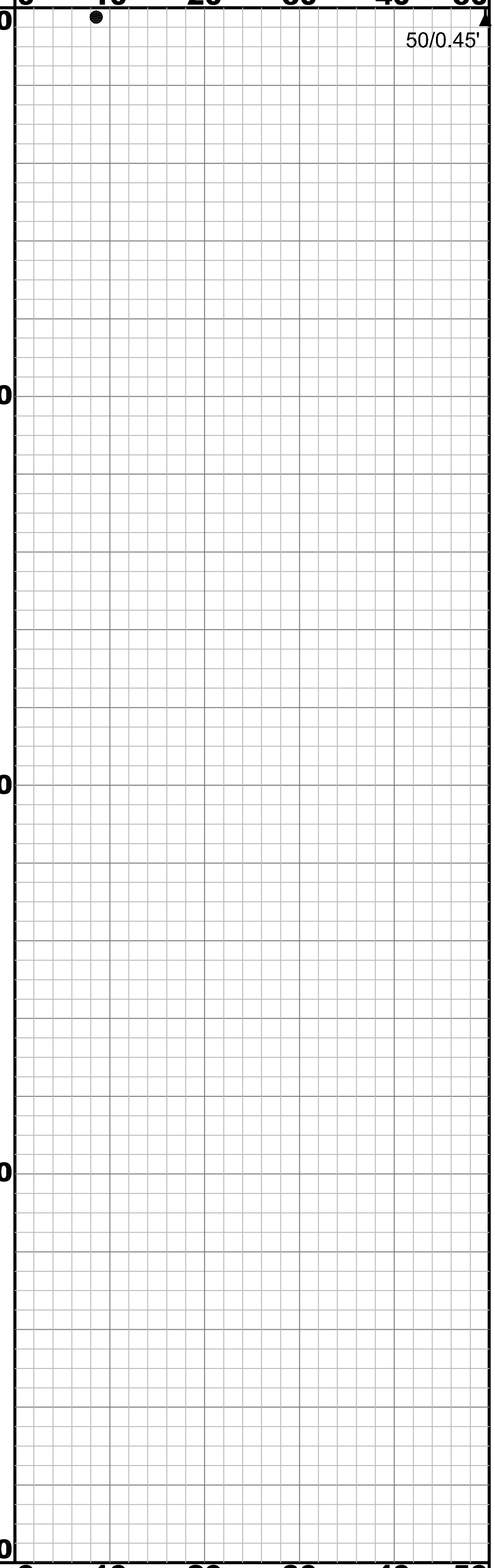
Bottom of Soil Boring: 55.0 feet

Installed Dual Purpose Slope inclinometer
- Top of Casing Elevation: 4326.46
- Overall length: 54.6 feet

Construction:
- –2.75–inch I.D. ABS plastic inclinometer casing
- –Screened interval: 55.0' to 45.0' BGS
- –10–20 Sand Pack 55.0' to 41.6' BGS
- –Bentonite Seal 41.6' to 38.0' BGS
- –Cement/lime/bentonite grout 38.0' to 1.0' BGS
- –Steel protective casing monument set in concrete

Installed Secondary Monitoring Well (separate fast–augered boring)
- Top of Casing Elevation: 4326.58
- Overall length: 41.4 feet

Construction:
- –1–inch I.D. PVC plastic pipe
- –Screened interval: 40.0' to 35.0' BGS
- –10–20 Sand Pack 40.0' to 32.3' BGS
- –Bentonite Seal 32.3' to 30.7' BGS
- –Auger cuttings 30.7' to 1.0' BGS
- –Steel protective casing monument set in concrete



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-7

St Mary River Siphon Crossing-Propsed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B8
Sheet 2 of 4

BORING 09PA–7, ELEVATION 4324.5 FT, ROCK CORE RUN 1
CORE MISC. BOULDERS 35.0' TO 40.0'
CORE RUN 1: DEPTH=45.0' TO 50.0', RQD=0.37, RECOVERY=95%

FIGURE B8

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT
NORTH OF BABB, MONTANA

PHOTO OF SOIL BORING 09PA-7
CORE RUN 1

THOMAS, DEAN & HOSKINS, INC.
ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL, MONTANA
SPOKANE, WASHINGTON
LEWISTON, IDAHO

DRAWN BY:	RLR	DATE:	AUGUST 2009	SHEET 3 of 4
DESIGNED BY:	CRN	JOB NO.	04-167	
QUALITY CHECK:		CAD NO.	04167-B07-3 .DWG	

BORING 09PA-7, ELEVATION 4324.5 FT, ROCK CORE RUN 2
CORE RUN 2: DEPTH=50.0' TO 55.0', RQD=0.59, RECOVERY=100%

FIGURE B8

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO
PHOTO OF SOIL BORING 09PA-7 CORE RUN 2	DRAWN BY: RLR DESIGNED BY: CRN QUALITY CHECK:	DATE: AUGUST 2009 JOB NO. 04-167 CAD NO. 04167-B07-4.DWG SHEET 4 of 4

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4362.37 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff, brown, moist, laminated, trace gravel. –gravel pocket from 8.0' to 8.5' q_u = 1.0 to 2.0 tsf. q_u = 1.0 to 2.0 tsf.	18.0			
	Sandy **LEAN CLAY**, very stiff, brown, moist, trace gravel, contains pockets of gypsum crystals. q_u = 1.5 to 2.0 tsf. q_u = 1.25 to 2.25 tsf.	28.0			
	LEAN CLAY, firm to very stiff, grayish brown, very moist, thinly laminated, trace gravel. q_u = 0.5 to 1.5 tsf. q_u = 2.5 tsf.				
	Poorly–Graded **GRAVEL** with Sand, hard, tan, moist to wet, cobbles and boulders.	39.0			

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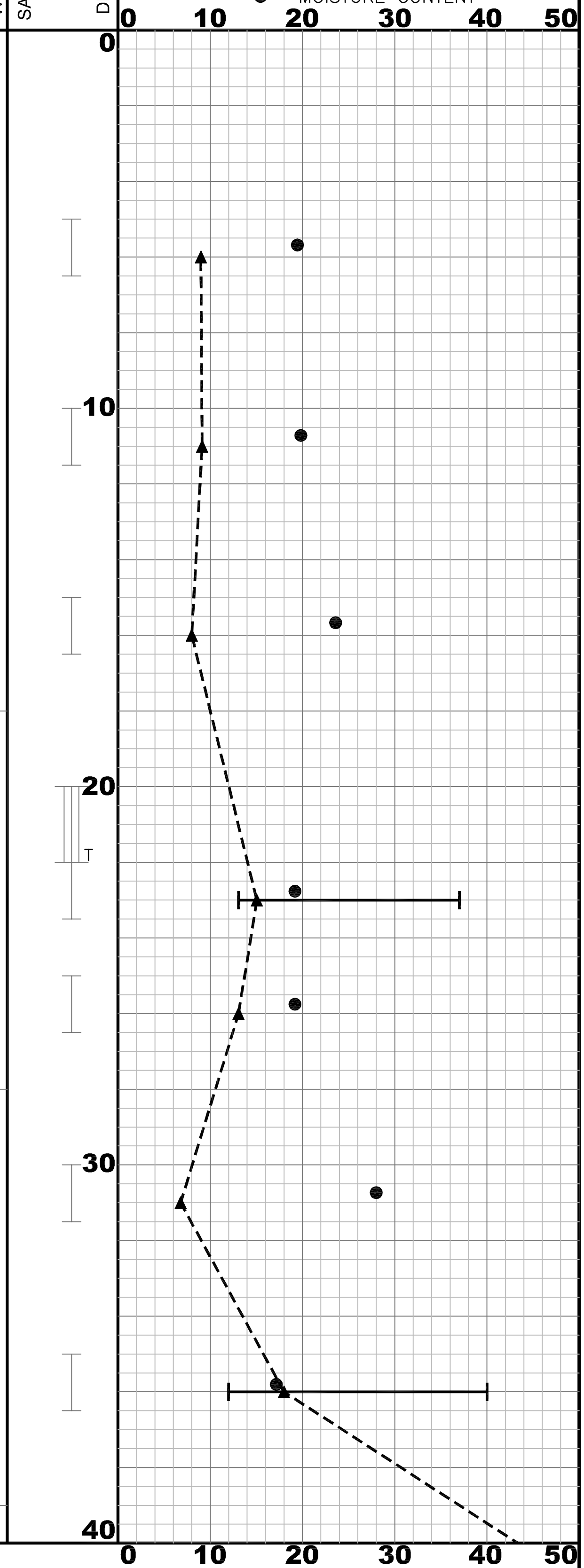
PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-8

St Mary River Siphon Crossing-Proposed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

August 2009 04-167

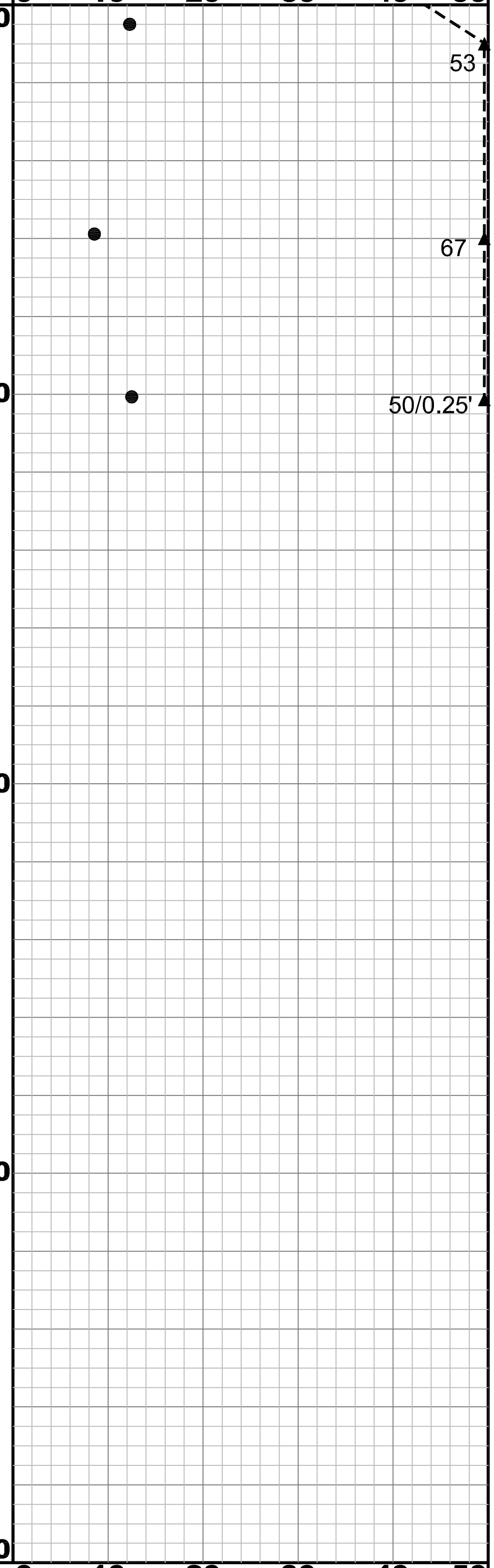
TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B9
Sheet 1 of 5

GRAPHIC LOG | SURFACE: Native Grasses and Shrubs
SURFACE ELEVATION: 4362.37

SOIL DESCRIPTION | DEPTH | GROUND WATER | SAMPLE | DEPTH | PENETRATION RESISTANCE/MOISTURE CONTENT

▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



–core boulder at 41.5'

45.7
47.0

SHALE, hard, grayish black, moist, weathered near top and decreasing with depth.

Rock Core Run #1

Depth: 50.0' to 55.0'
Coring Rate: 2.21 min/ft.
Recovery: 80%
RQD: 0.15

Rock Core Run #2

Depth: 55.0' to 60.0'
Coring Rate: 2.36 min/ft.
Recovery: 100%
RQD: 0.15

60.0

Bottom of Soil Boring: 60.0 feet

Logged by: Craig R. Nadeau, E.I. (08/27-28/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Dual Purpose Slope Inclinometer
- Top of Casing Elevation: 4364.20
- Overall length: 60.9 feet

Construction:
- –2.75–inch I.D., ABS plastic inclinometer casing
- –Screened interval: 60.0' to 50.0' BGS
- –10–20 Sand Pack 60.0' to 49.0' BGS
- –Bentonite Seal 49.0' to 47.5' BGS
- –Cement/lime/bentonite grout 47.5' to 1.0' BGS
- –Steel protective casing monument set in concrete

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-8

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

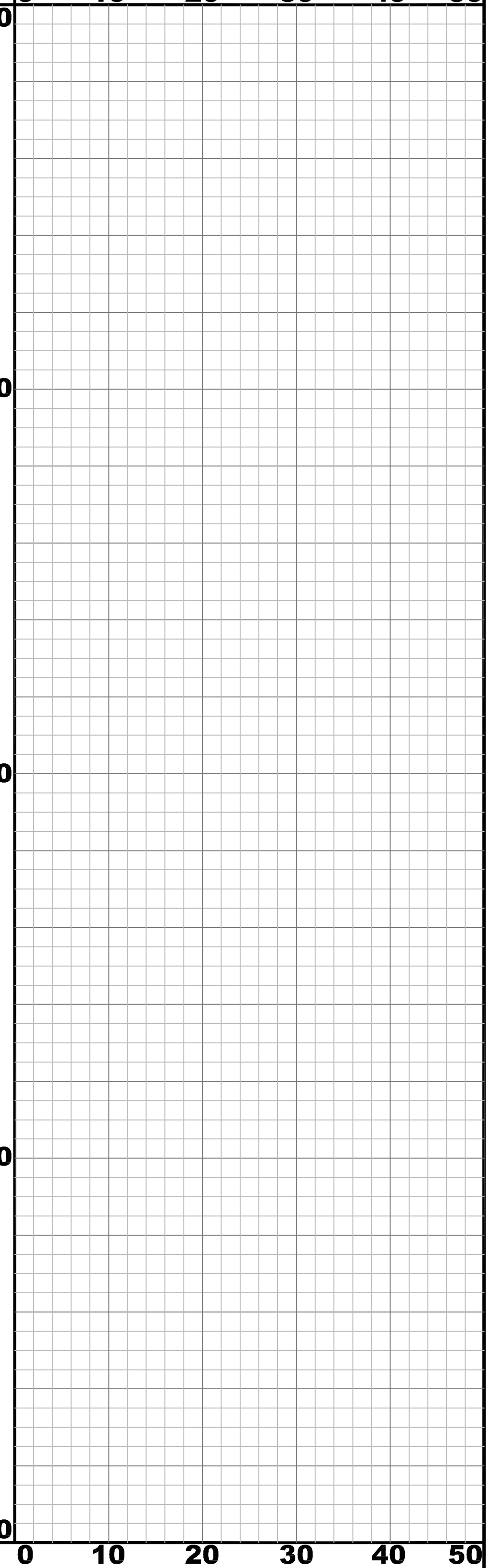
August 2009 | 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B9
Sheet 2 of 5

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4362.37 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	Installed Secondary Monitoring Well (separate fast–augering boring) – Top of Casing Elevation: 4363.14 – Overall length: 49.9 feet Construction: –1¼–inch I.D. PVC plastic pipe –Screened interval: 48.0' to 43.0' BGS –10–20 Sand Pack 48.0' to 38.0' BGS –Bentonite Seal 38.0' to 36.0' BGS –Auger cuttings 36.0' to 2.0' BGS –Steel protective casing monument set in concrete				80 90 100 110 120

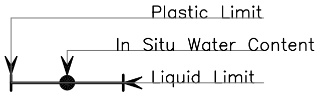
PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- 2–1/2–inch I.D. ring sampler
- 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-8

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B9
Sheet 3 of 5

BORING 09PA-8, ELEVATION 4362.4 FT, ROCK CORE RUN 1
CORE MISC. BOULDERS 41.5' TO 45.0'
CORE RUN 1: DEPTH=50.0' TO 55.0', RQD=0.15, RECOVERY=80%

FIGURE B9

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-8 **CORE RUN 1**	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 4 of 5
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B08-4 .DWG	

BORING 09PA-8, ELEVATION 4362.4 FT, ROCK CORE RUN 2
CORE RUN 2: DEPTH=55.0' TO 60.0', RQD=0.15, RECOVERY=100%

FIGURE B9

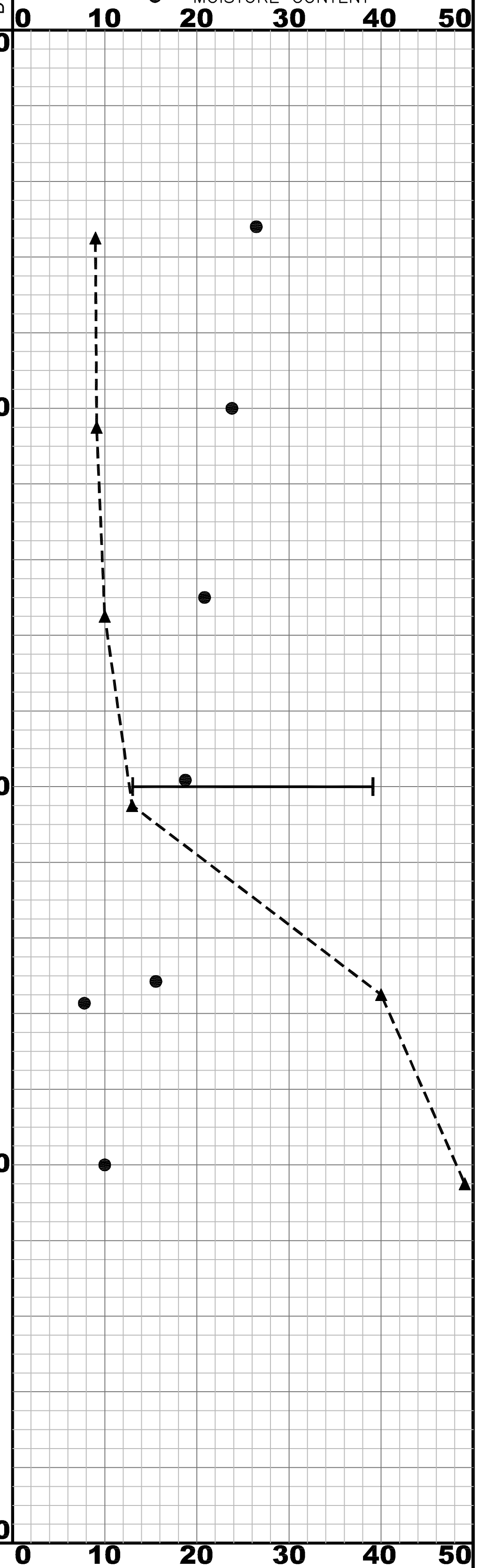
ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT NORTH OF BABB, MONTANA	TD&H	THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-8 CORE RUN 2	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 5 of 5
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B08-5 .DWG	

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4396.50 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff, brown, moist, mottled, trace gravel.				0
	q_u = 1.5 tsf.				
	q_u = 1.0 to 2.0 tsf.				10
	q_u = 1.0 to 2.0 tsf.	17.0			
	LEAN CLAY with Sand, stiff, grayish brown, moist.				
	q_u = 1.0 to 2.0 tsf.				20
		22.8	▼		
	q_u = 2.5 tsf.	25.5			
	Clayey **GRAVEL** with Sand, very dense to hard, light brown, moist.				
	–core boulders below 31.0 feet				30
	Continued to Next Page				40

PENETRATION RESISTANCE/MOISTURE CONTENT

▲ =BLOWS PER FOOT

● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- R 2–1/2–inch I.D. ring sampler
- T 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit

In Situ Water Content

Liquid Limit

Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-9

St Mary River Siphon Crossing-Proposed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B10

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4396.50 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
		41.0			40
	SHALE, hard, gray, slightly moist, highly fractured and cemented with clay, fracturing decreases with depth. **Rock Core Run #1** Depth: 45.0' to 50.0' Coring Rate: 2.75 min/ft. Recovery: 74% **RQD**: 0.13 **Rock Core Run #2** Depth: 50.0' to 55.0' Coring Rate: 2.51 min/ft. Recovery: 100% **RQD**: 0.55 **Rock Core Run #3** Depth: 55.0' to 60.0' Coring Rate: 2.45 min/ft. Recovery: 94% **RQD**: 0.37				50
		60.0			60

PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT
0 10 20 30 40 50

Bottom of Soil Boring: 60.0 feet

Logged by:	Craig R. Nadeau, E.I. (08/26-27/09)
Drilled by:	Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Dual Purpose Slope Inclinometer
- Top of Casing Elevation: 4398.14
- Overall length: 56.8 feet

Construction:
- -2.75-inch I.D., ABS plastic inclinometer casing
- -Screened interval: 55.5' to 45.5' BGS
- -10-20 Sand Pack 55.5' to 44.0' BGS
- -Bentonite Seal 44.0' to 43.0' BGS
- -Cement/lime/bentonite grout 43.0' to 1.0' BGS
- -Steel protective casing monument set in concrete

70

80

0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-9

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS-BOZEMAN-KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

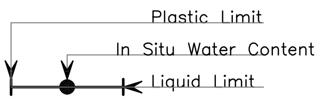
Figure No. B10

GRAPHIC LOG	SURFACE: Native Grasses and Shrubs SURFACE ELEVATION: 4396.50 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH	PENETRATION RESISTANCE/MOISTURE CONTENT ▲ =BLOWS PER FOOT ● =MOISTURE CONTENT 0 10 20 30 40 50
	Installed Secondary Monitoring Well (separate fast–augered boring) – Top of Casing Elevation: 4398.75 – Overall length: 44.5 feet Construction: –1¼–inch I.D. PVC plastic pipe –Screened interval: 43.0' to 33.0' BGS –10–20 Sand Pack 43.0' to 26.0' BGS –Bentonite Seal 26.0' to 22.0' BGS –Auger cuttings 22.0' to 2.0' BGS –Steel protective casing monument set in concrete				80 90 100 110 120	0 10 20 30 40 50

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1–3/8–inch I.D. split spoon
- 2–1/2–inch I.D. split spoon
- 2–1/2–inch I.D. ring sampler
- 3–inch I.D. thin–walled sampler
- * No sample recovery

Atterberg Limits



GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-9

St Mary River Siphon Crossing-Proposed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B10
Sheet 3 of 5

BORING 09PA-9, ELEVATION 4396.5 FT, ROCK CORE RUN 1
CORE MISC. BOULDERS 31.0' TO 42.5'
CORE RUN 1: DEPTH=45.0' TO 50.0', RQD=0.13, RECOVERY=74%

FIGURE B10

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-9 **CORE RUN 1**	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 4 of 5
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B09-4 .DWG	

BORING 09PA-9, ELEVATION 4396.5 FT, ROCK CORE RUNS 2 & 3
CORE RUN 2: DEPTH=50.0' TO 55.0', RQD=0.55, RECOVERY=100%
CORE RUN 3: DEPTH=55.0' TO 60.0', RQD=0.37, RECOVERY=94%

FIGURE B10

ST MARY RIVER SIPHON CROSSING-PROPOSED ALIGNMENT **NORTH OF BABB, MONTANA**	TD&H	**THOMAS, DEAN & HOSKINS, INC.** **ENGINEERING CONSULTANTS** GREAT FALLS–BOZEMAN–KALISPELL MONTANA SPOKANE WASHINGTON LEWISTON IDAHO	
PHOTO OF SOIL BORING 09PA-9 **CORE RUNS 2 & 3**	DRAWN BY: RLR	DATE: AUGUST 2009	SHEET 5 of 5
	DESIGNED BY: CRN	JOB NO. 04-167	
	QUALITY CHECK:	CAD NO. 04167-B09-5.DWG	

GRAPHIC LOG | SURFACE: Native Grasses | DEPTH | GROUND WATER | SAMPLE

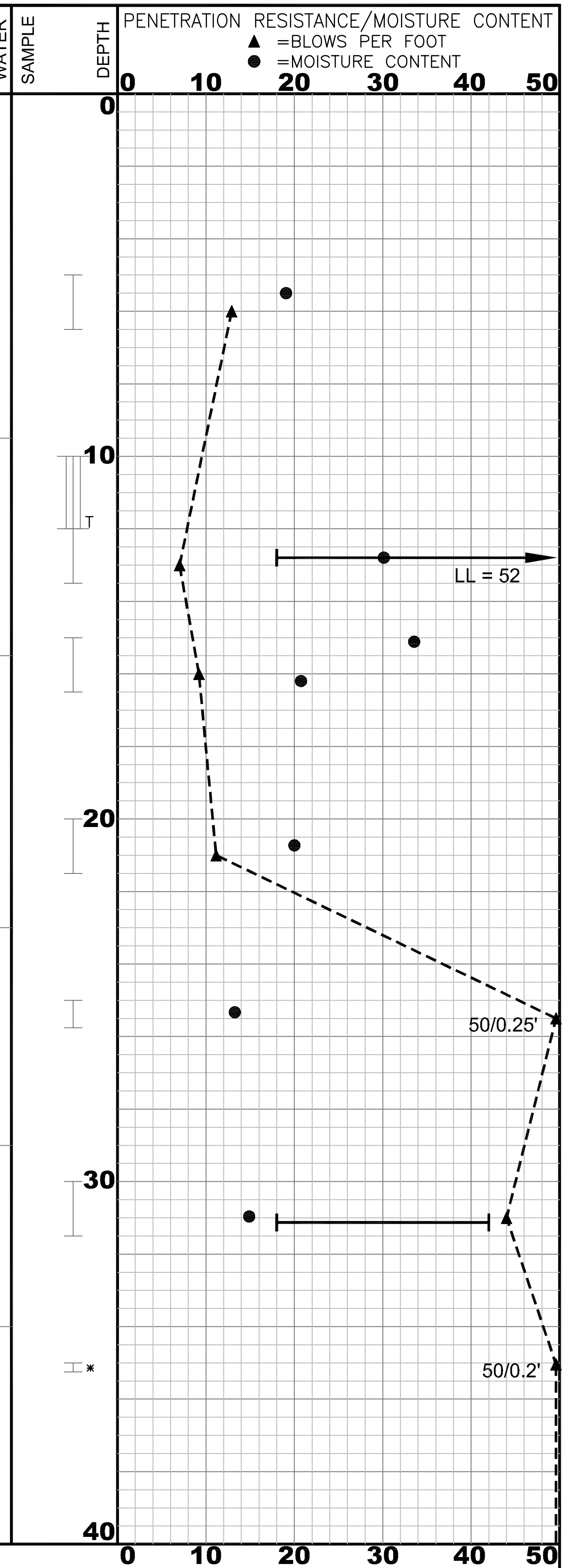
SURFACE ELEVATION: 4416.42

SOIL DESCRIPTION

Depth	Soil Description
0 – 15.5	**FAT CLAY**, stiff, brown, moist, trace organics, thinly laminated, trace mottling. q_u = 2.5 to 3.0 tsf. q_u = 0.5 to 1.0 tsf.
15.5 – 23.0	**FAT CLAY** with Sand, stiff, brown, moist, trace gravel. q_u = 0.5 to 1.0 tsf.
23.0 – 29.0	Clayey **GRAVEL** with Sand, hard, brown, wet.
29.0 – 34.0	Clayey **SAND** with Gravel, hard, brown, very moist to wet. q_u = 2.5 to 3.5 tsf.
34.0 –	Interbedded **SANDSTONE** and **SHALE**, hard, tan and dark gray, slightly moist.

Groundwater level: 9.5

Continued to Next Page



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit, In Situ Water Content, Liquid Limit, Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-10

St Mary River Siphon Crossing-Proposed Alignment

St Mary Rehabilitation Project

North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B11

GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4416.42 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
		45.3			40

Bottom of Soil Boring : 45.3 feet

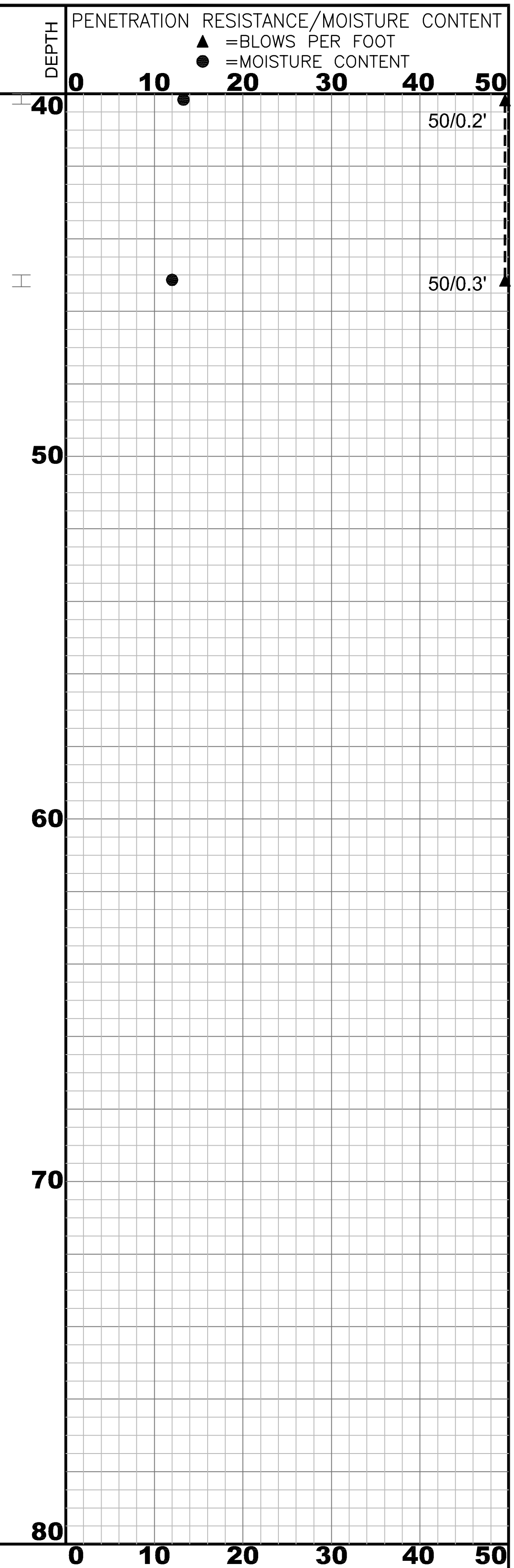
Logged by:	Craig R. Nadeau, E.I. (08/25-26/09)
Drilled by:	Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Slope Inclinometer Casing
- Top of Casing Elevation: 4418.44
- Overall length: 47.0 feet

Construction:
- 2.75-inch I.D. ABS plastic inclinometer casing
- Cement/lime/bentonite annulus grout
- Steel protective casing monument set in concrete

Installed Secondary Monitoring Well (separate fast-augered boring)
- Top of Casing Elevation: 4418.22
- Overall length: 41.0 feet

Construction:
- 1¼-inch I.D. PVC plastic pipe
- Screened interval: 40.0' to 30.0' BGS
- 10-20 Sand Pack 40.0' to 15.0' BGS
- Bentonite Seal 15.0' to 9.0' BGS
- Auger cuttings 9.0' to 2.0' BGS
- Steel protective casing monument set in concrete



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits
- Plastic Limit
- In Situ Water Content
- Liquid Limit
- Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-10

St Mary River Siphon Crossing-Propsed Alignment
St Mary Rehabilitation Project
North of Babb, Montana

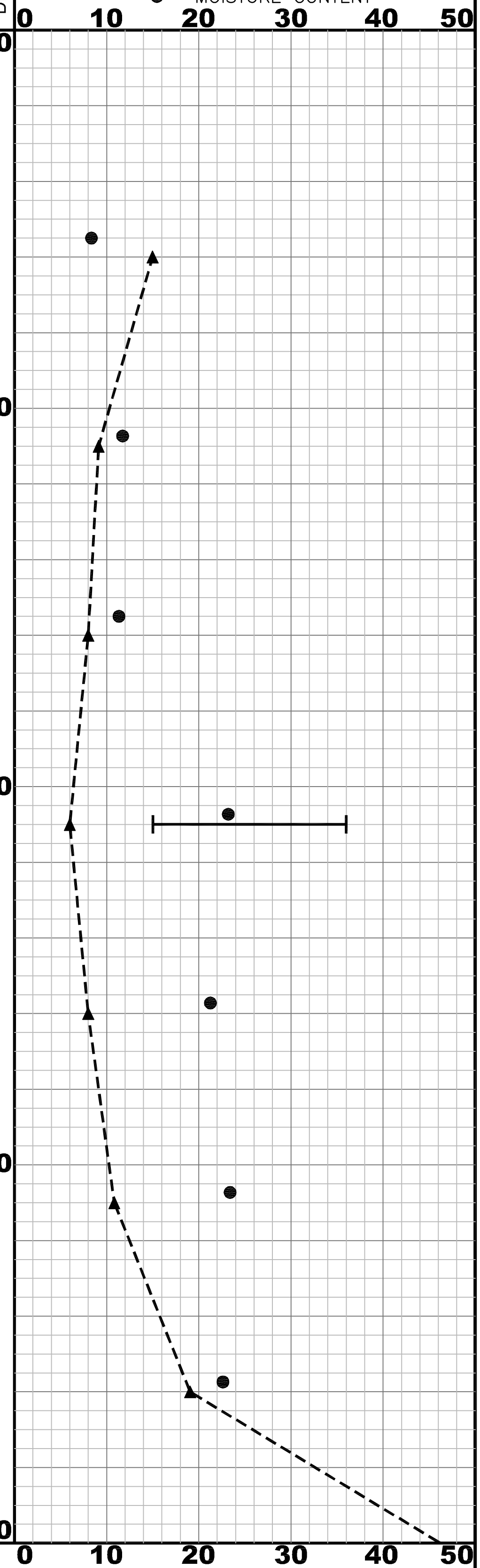
August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B11
Sheet 2 of 2

GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4450.72 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FILL: Sandy **LEAN CLAY**, firm to very stiff, light brown to dark brownish gray, moist, trace gravel increasing with depth, trace organics. q_u < 0.25 tsf.	35.3			0 10 20 30
	LEAN CLAY, stiff to hard, dark brown, moist to wet, thinly laminated. q_u = 1.0 to 2.0 tsf. Continued to Next Page	39.73	▼		40

PENETRATION RESISTANCE/MOISTURE CONTENT
▲ =BLOWS PER FOOT
● =MOISTURE CONTENT



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

▲	SPT blows per foot	Atterberg Limits	
●	Field Moisture content	Plastic Limit	
▼	Groundwater Level	In Situ Water Content	
	Grab/composite sample	Liquid Limit	
	1-3/8-inch I.D. split spoon		
	2-1/2-inch I.D. split spoon	Plastic Index	
	2-1/2-inch I.D. ring sampler		
	3-inch I.D. thin-walled sampler	GNP = Granular and Nonplastic	
*	No sample recovery		

Log of Soil Boring 09PA-11

St Mary River Siphon Crossing-Proposed Dam
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B12

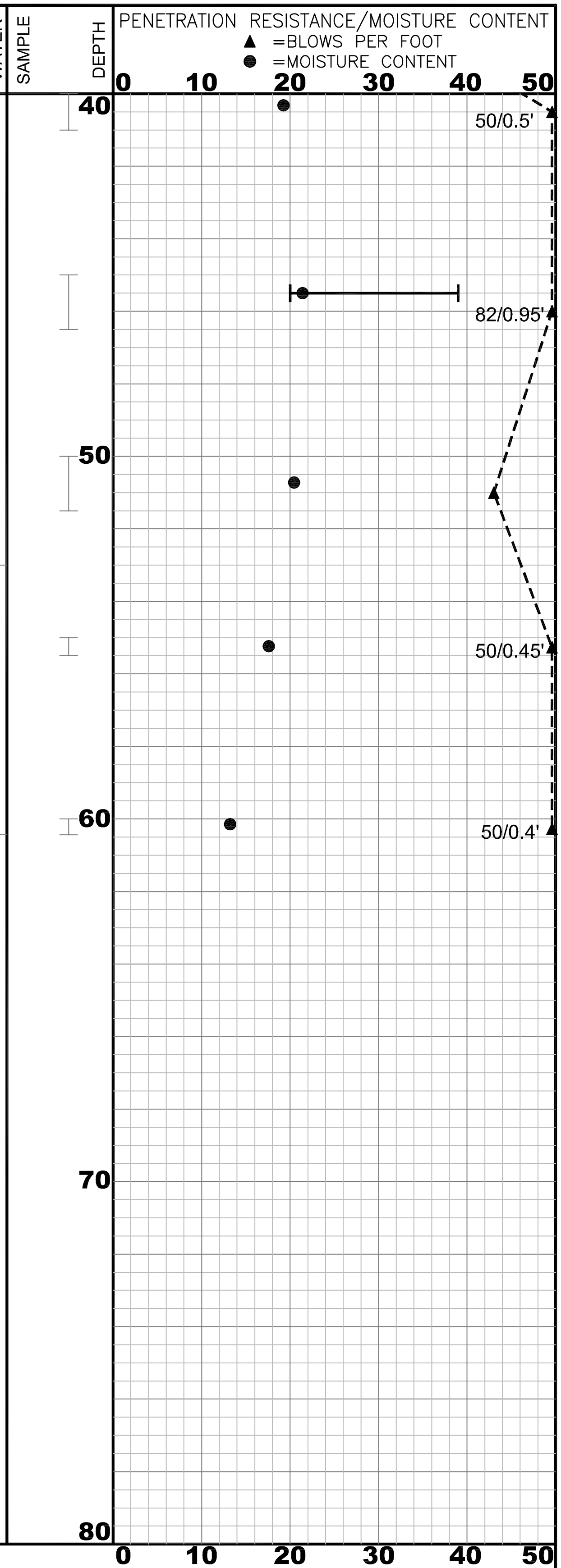
SURFACE: Native Grasses
SURFACE ELEVATION: 4450.72

GRAPHIC LOG	SOIL DESCRIPTION	DEPTH	GROUND WATER
	q_u > 4.5 tsf.		
	q_u > 4.5 tsf.		
	q_u = 3.0 to 4.5 tsf.	53.0	
	SHALE, hard, dark grayish brown, moist, weathered.	60.4	
	Bottom of Soil Boring : 60.4 feet		

Logged by: Craig R. Nadeau, E.I. (08/24/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

—No Instrumentation Installed
—Backfilled with bentonite slurry and capped with bentonite chips.



LEGEND

▲ SPT blows per foot
● Field Moisture content
▼ Groundwater Level
Grab/composite sample
1-3/8-inch I.D. split spoon
2-1/2-inch I.D. split spoon
2-1/2-inch I.D. ring sampler
3-inch I.D. thin-walled sampler
* No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-11

St Mary River Siphon Crossing-Propsed Dam
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B12

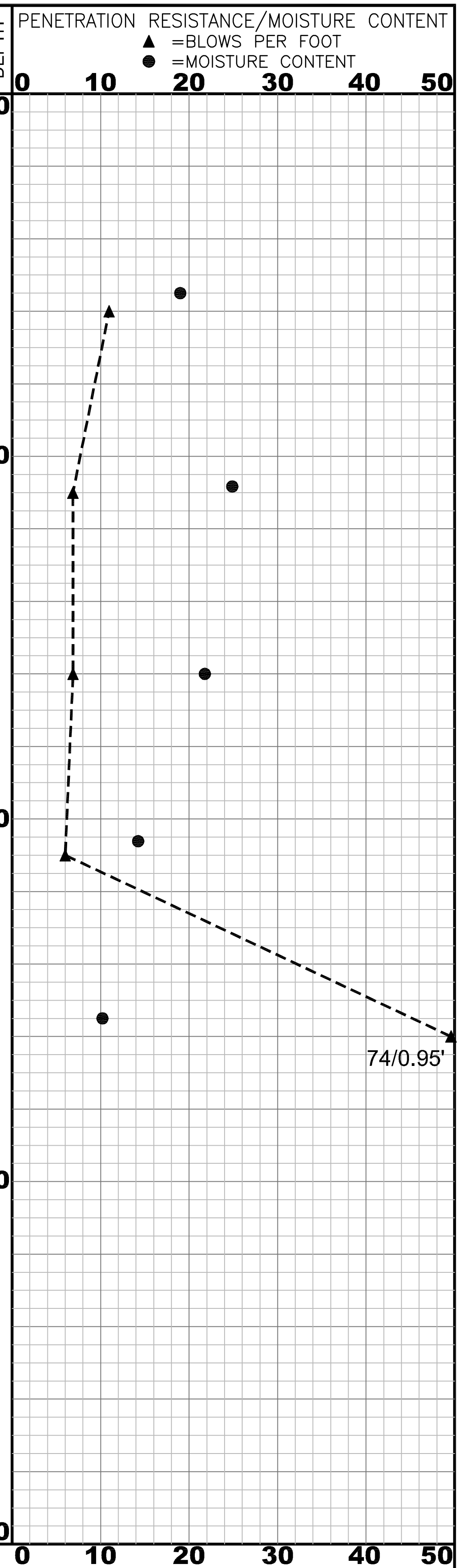
GRAPHIC LOG	SURFACE: Native Grasses SURFACE ELEVATION: 4410.75 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY, stiff, brown, moist, minor mottling (increasing with depth), sand increasing with depth.	4.1	▼		0
	q_u = 1.0 to 2.0 tsf.				
	q_u < 2.5 tsf.				10
	q_u = 0.0 to 2.0 tsf.	18.0			
	Poorly-Graded **SAND**, loose, brown, wet.	23.5			20
	SHALE, hard, dark gray, slightly moist.	26.5			
	Bottom of Soil Boring: 26.5 feet				30

Logged by: Craig R. Nadeau, E.I. (08/24/09)

Drilled by: Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

Installed Groundwater Monitoring Well
- Top of Casing Elevation: 4412.9
- Overall length: 26.5 feet

Construction:
- 1¼-inch I.D. PVC plastic pipe
- Screened interval: 25.0' to 15.0' BGS
- 10-20 Sand Pack 25.0' to 5.0' BGS
- Bentonite Seal 5.0' to 3.0' BGS
- Steel protective casing monument set in concrete



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- 2-1/2-inch I.D. ring sampler
- 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits: Plastic Limit; In Situ Water Content; Liquid Limit; Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-12

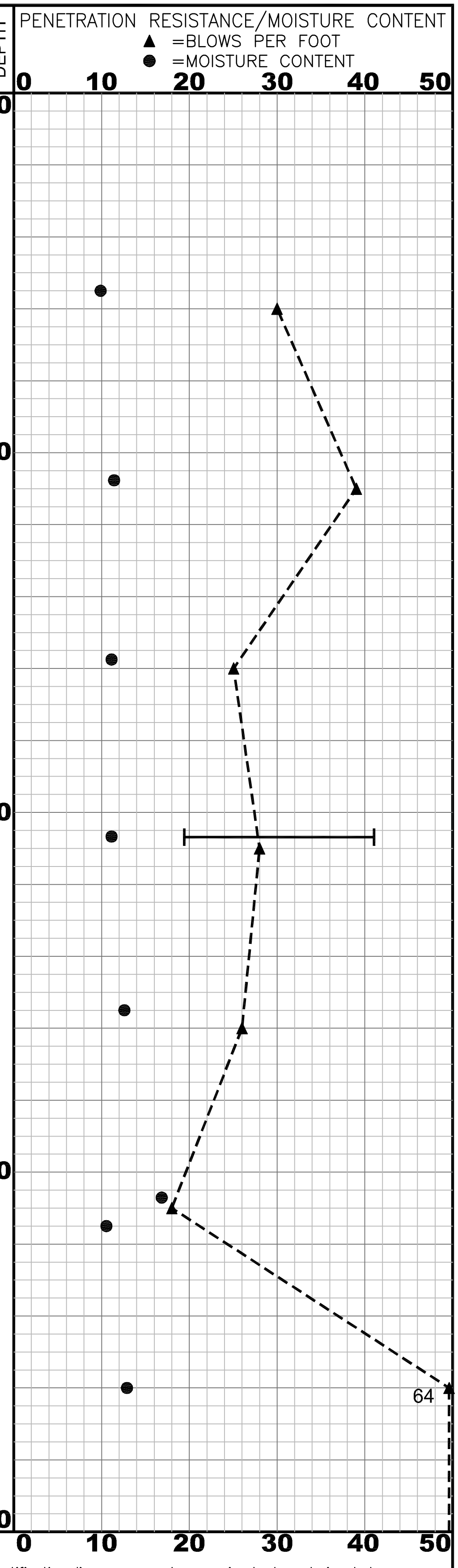
St Mary River Siphon Crossing-Proposed Dam
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS
GREAT FALLS–BOZEMAN–KALISPELL MONTANA; SPOKANE WASHINGTON; LEWISTON IDAHO

Figure No. B13
Sheet 1 of 1

GRAPHIC LOG	SURFACE: Cleared Pad — Disturbed Ground SURFACE ELEVATION: 4440.26 SOIL DESCRIPTION	DEPTH	GROUND WATER	SAMPLE	DEPTH
	FAT CLAY with Sand, very stiff to hard, light brown to tan, dry to slightly moist, visible salts and minor oxidation, thinly laminated.	25.5	▼		0
		31.4			10
	SHALE, very stiff to hard, dark gray, slightly moist to moist, weathered (decreasing with depth), highly weathered zones throughout.				20
					30
	Continued to Next Page				40



Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

LEGEND

- ▲ SPT blows per foot
- ● Field Moisture content
- ▼ Groundwater Level
- G Grab/composite sample
- 1-3/8-inch I.D. split spoon
- 2-1/2-inch I.D. split spoon
- R 2-1/2-inch I.D. ring sampler
- T 3-inch I.D. thin-walled sampler
- * No sample recovery

Atterberg Limits

Plastic Limit

In Situ Water Content

Liquid Limit

Plastic Index

GNP = Granular and Nonplastic

Log of Soil Boring 09PA-13

St Mary River Siphon Crossing-Proposed Dam

St Mary Rehabilitation Project

North of Babb, Montana

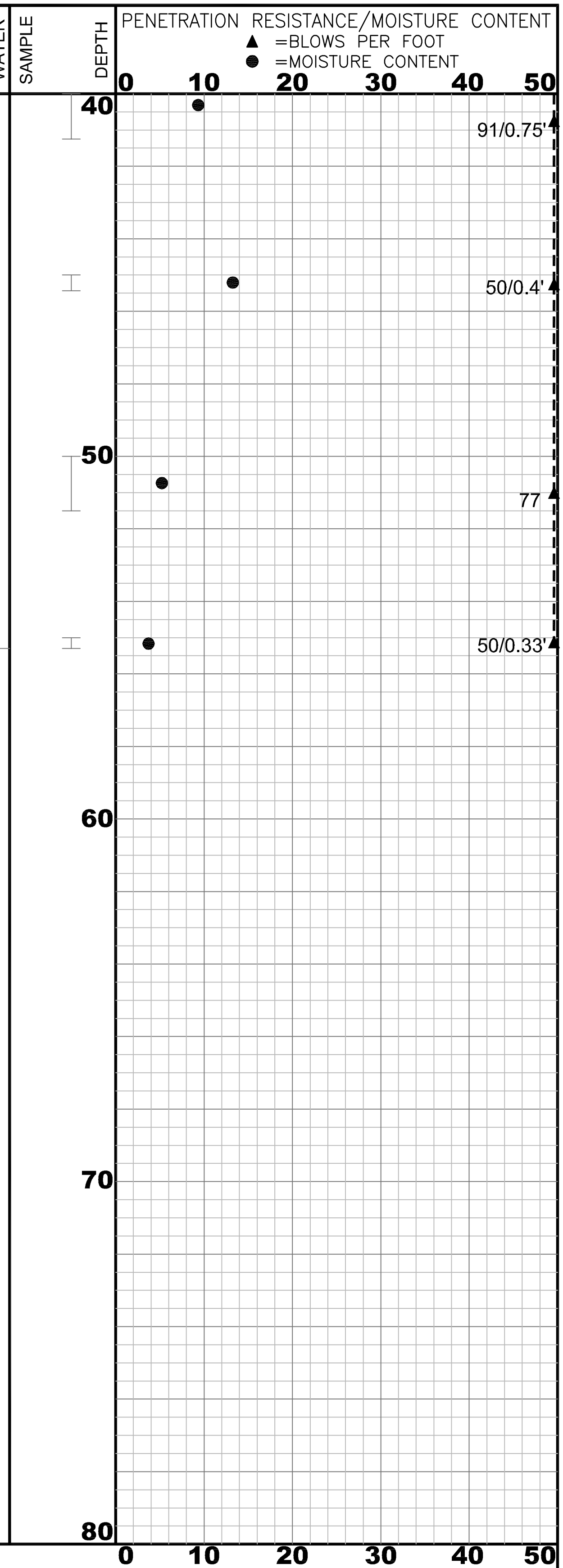
August 2009 04-167

TD&H THOMAS, DEAN & HOSKINS, INC. ENGINEERING CONSULTANTS GREAT FALLS–BOZEMAN–KALISPELL SPOKANE LEWISTON MONTANA WASHINGTON IDAHO

Figure No. B14

Sheet 1 of 2

GRAPHIC LOG	SURFACE: Cleared Pad — Disturbed Ground SURFACE ELEVATION: 4440.26 SOIL DESCRIPTION	DEPTH	GROUND WATER
	Bottom of Soil Boring : 55.33 feet	55.33	



Logged by:	Craig R. Nadeau, E.I. (08/24-25/09)
Drilled by:	Haztech Drilling using a truck-mounted BK-81 drill rig with 8-inch HSA.

—No Instrumentation Installed
—Boring backfilled with auger cuttings.

LEGEND

Symbol	Description
▲	SPT blows per foot
●	Field Moisture content
▼	Groundwater Level
I G	Grab/composite sample
I	1-3/8-inch I.D. split spoon
II	2-1/2-inch I.D. split spoon
III R	2-1/2-inch I.D. ring sampler
III T	3-inch I.D. thin-walled sampler
*	No sample recovery

Atterberg Limits

Plastic Limit
In Situ Water Content
Liquid Limit
Plastic Index

GNP = Granular and Nonplastic

Note: The stratification lines represent approximate boundaries between soil types. Actual boundaries may be gradual or transitional.

Log of Soil Boring 09PA-13

St Mary River Siphon Crossing-Propsed Dam
St Mary Rehabilitation Project
North of Babb, Montana

August 2009 04-167

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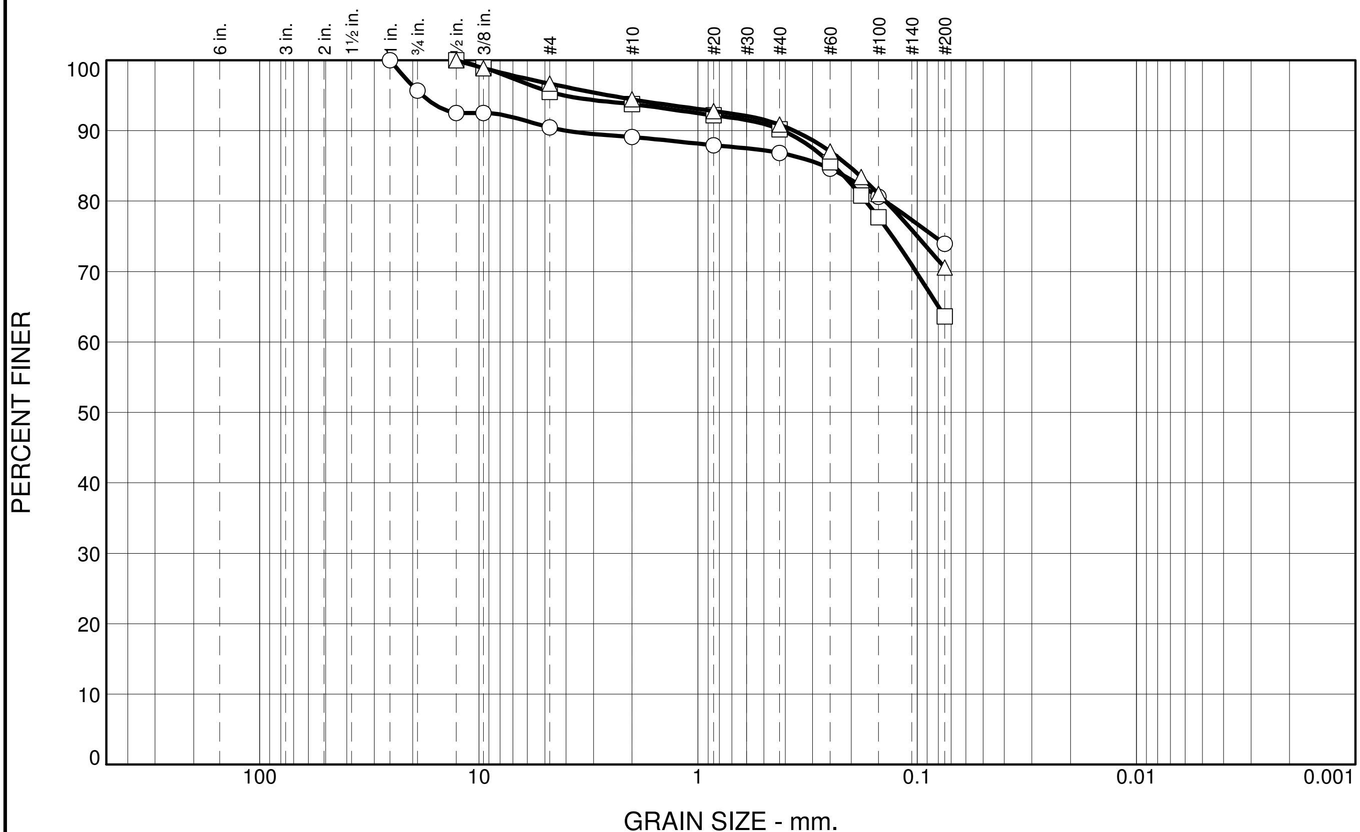
GREAT FALLS–BOZEMAN–KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure No. B14

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	9.5	16.6	73.9		CH	70	21	49
□	0.0	4.5	31.9	63.6		CL	37	13	24
△	0.0	3.3	26.1	70.6		CL	39	13	26

SIEVE inches size	PERCENT FINER ○	□	△
1"	100.0		
3/4"	95.7		
1/2"	92.5	100.0	100.0
3/8"	92.5	99.0	98.9
	GRAIN SIZE		
D_{60}			
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	90.5	95.5	96.7
#10	89.1	93.8	94.4
#20	87.9	92.2	92.8
#40	86.8	90.2	90.9
#60	84.6	85.5	87.1
#80	82.2	80.8	83.4
#100	80.6	77.7	81.0
#200	73.9	63.6	70.6

Material Description

○ Fat CLAY with Sand

□ Sandy Lean CLAY

△ Lean CLAY with Sand

REMARKS:

○ Report No. A-2516-206

□ Report No. A-2479-206

△ Report No. A-2487-206

○ Location: 09PA-2 Depth: 15.0 - 16.5 ft Sample Number: A-2516

□ Location: 09PA-8 Depth: 22.0 - 23.5 ft Sample Number: A-2479

△ Location: 09PA-9 Depth: 19.5 - 21.0 ft Sample Number: A-2487

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GREAT FALLS - BOZEMAN - KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

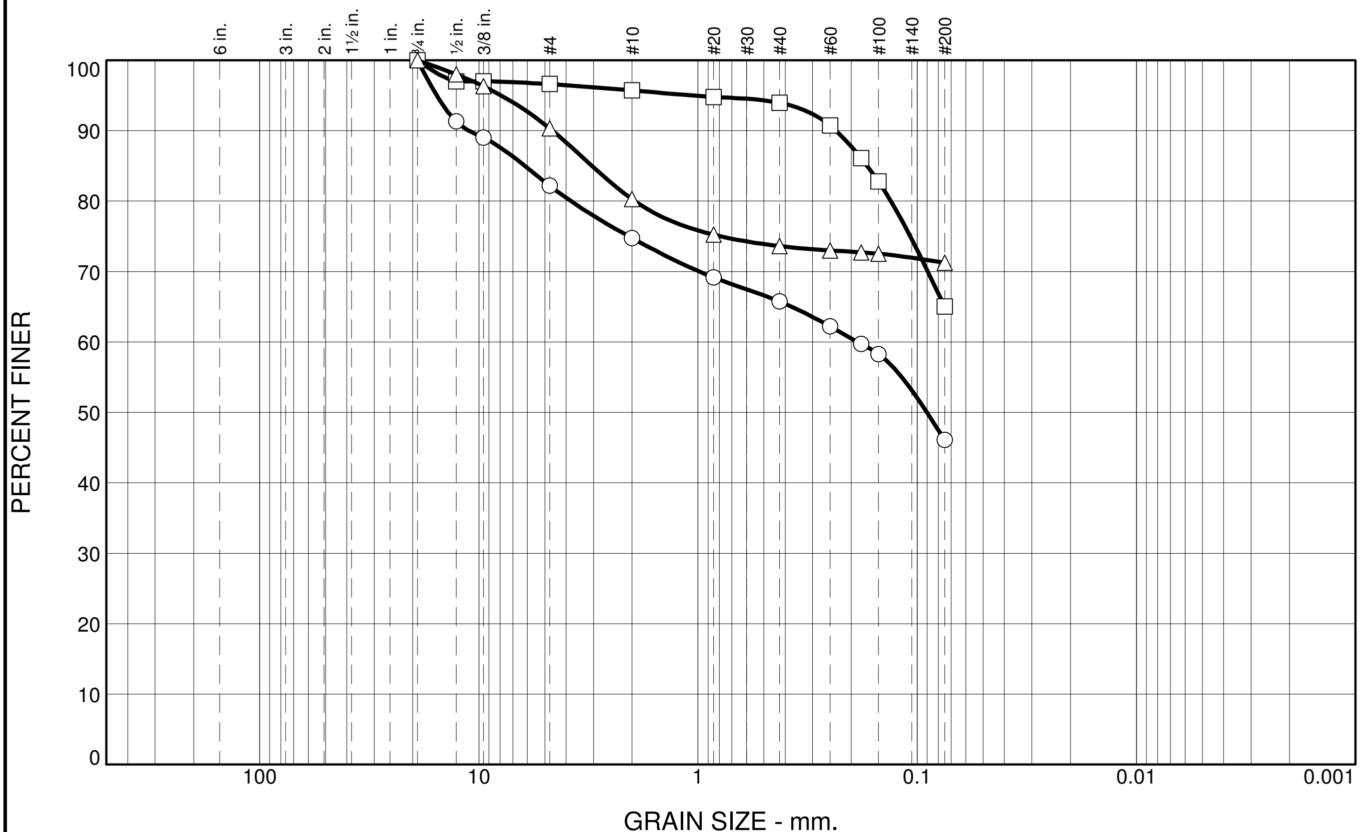
Client: Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

Project No.: 04-167 Figure B15

Tested By: ○ TJR/DSM □ CRN/DSM △ CRN **Checked By:** Craig R Nadeau

Particle Size Distribution Report



	+3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PL	PI
○	0.0	17.8	36.1	46.1		SC	42	19	23
□	0.0	3.4	31.5	65.1		CL	36	15	21
△	0.0	9.7	19.0	71.3		CL	41	19	22

SIEVE inches size	PERCENT FINER ○	□	△
3/4"	100.0	100.0	100.0
1/2"	91.3	97.0	98.0
3/8"	89.0	97.0	96.3

	GRAIN SIZE ○	□	△
D_{60}	0.1875		
D_{30}			
D_{10}			

	COEFFICIENTS ○	□	△
C_c			
C_u			

SIEVE number size	PERCENT FINER ○	□	△
#4	82.2	96.6	90.3
#10	74.8	95.7	80.3
#20	69.2	94.8	75.2
#40	65.8	94.0	73.6
#60	62.2	90.8	73.0
#80	59.7	86.1	72.7
#100	58.3	82.8	72.5
#200	46.1	65.1	71.3

Material Description

○ Clayey SAND with Gravel

□ Sandy Lean CLAY

△ Lean CLAY with Sand

REMARKS:

○ Report No. A-2498-206

□ Report No. A-2448-206

△ Report No. A-2466-206

○ Location: 09PA-10 Depth: 30.0 - 31.5 ft Sample Number: A-2498
□ Location: 09PA-11 Depth: 20.0 - 21.5 ft Sample Number: A-2448
△ Location: 09PA-13 Depth: 20.0 - 21.5 ft Sample Number: A-2466

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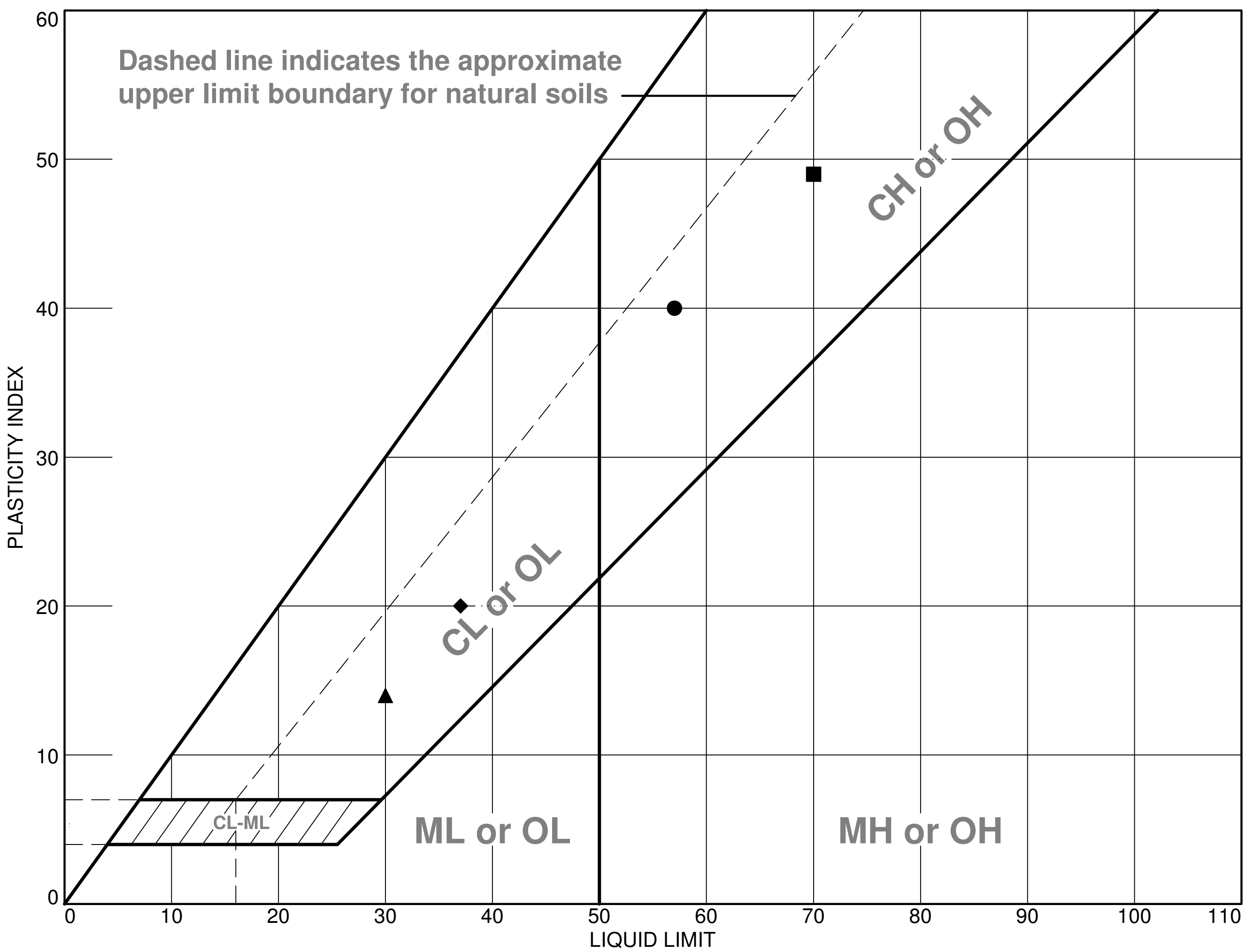
GREAT FALLS - BOZEMAN - KALISPELL MONTANA
SPOKANE WASHINGTON
LEWISTON IDAHO

Client: Department of Natural Resources
Project: St. Mary River Rehabilitation Project
North of Babb, Montana
Project No.: 04-167 Figure B16

Tested By: DSM/CRN **Checked By:** Craig R Madsen

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Fat CLAY	57	17	40			CH
■	Fat CLAY with Sand	70	21	49	86.8	73.9	CH
▲	Sandy Lean CLAY	30	16	14			CL
◆	Lean CLAY	37	17	20			CL

Project No. 04-167 **Client:** Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

● **Location:** 09PA-1 **Depth:** 12.0 - 13.5 ft **Sample Number:** A-2503

■ **Location:** 09PA-2 **Depth:** 15.0 - 16.5 ft **Sample Number:** A-2516

▲ **Location:** 09PA-4 **Depth:** 5.0 - 6.5 ft **Sample Number:** A-2526

◆ **Location:** 09PA-7 **Depth:** 15.0 - 16.5 ft **Sample Number:** A-2537

Remarks:
- ● Report No. A-2503-207
- ■ Report No. A-2516-207
- ▲ Report No. A-2526-207
- ◆ Report No. A-2537-207

TD&H **THOMAS, DEAN & HOSKINS, INC.**
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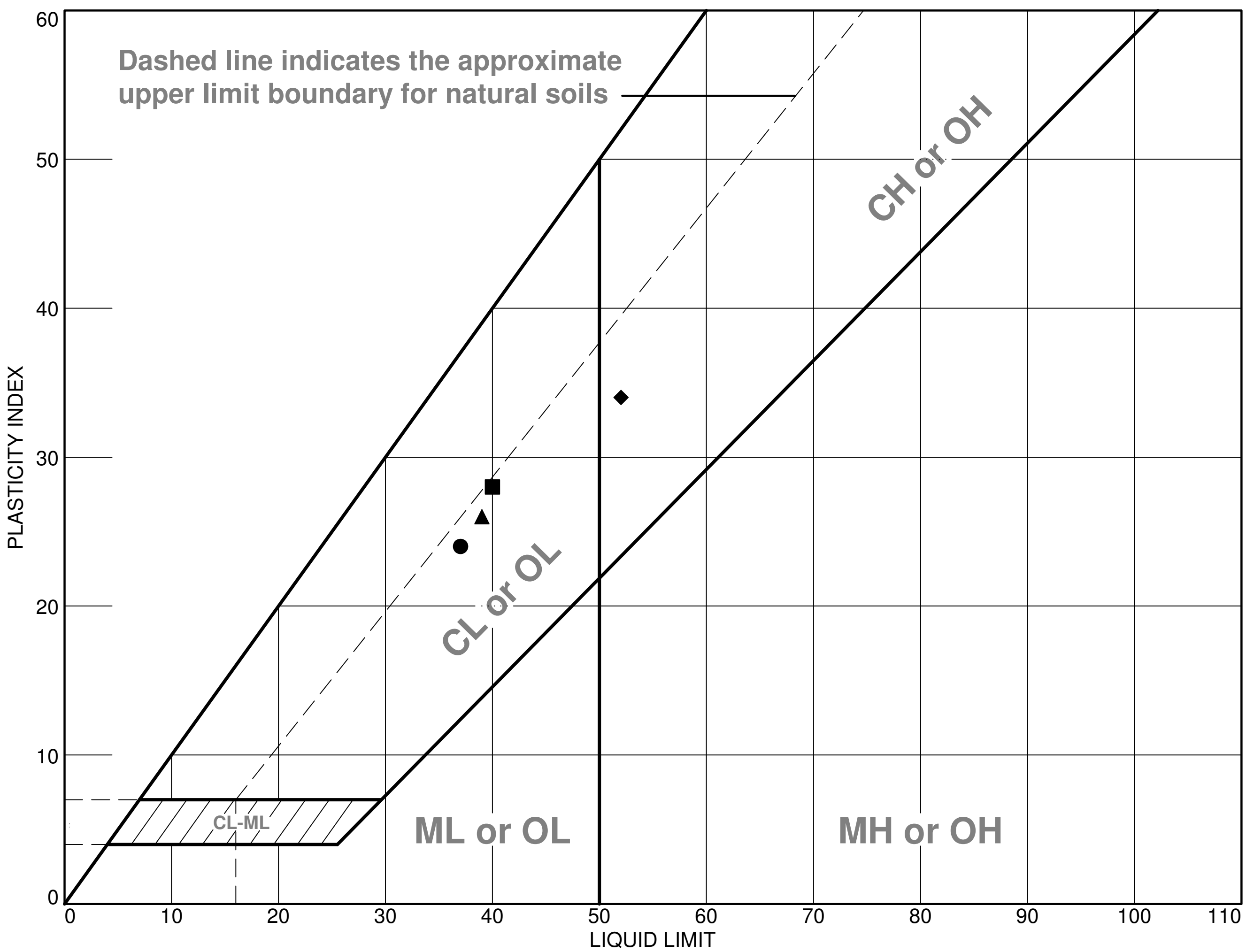
WASHINGTON
IDAHO

Figure B17

Tested By: ● TJR ■ DSM ▲ TJR ◆ DSM **Checked By:** Craig R Madsen

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Sandy Lean CLAY	37	13	24	90.2	63.6	CL
■	Lean CLAY	40	12	28			CL
▲	Lean CLAY with Sand	39	13	26	90.9	70.6	CL
◆	Fat CLAY	52	18	34			CH

Project No. 04-167 **Client:** Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

● **Location:** 09PA-8 **Depth:** 22.0 - 23.5 ft **Sample Number:** A-2479
■ **Location:** 09PA-8 **Depth:** 35.0 - 36.5 ft **Sample Number:** A-2482
▲ **Location:** 09PA-9 **Depth:** 19.5 - 21.0 ft **Sample Number:** A-2487
◆ **Location:** 09PA-10 **Depth:** 12.0 - 13.5 ft **Sample Number:** A-2493

Remarks:
● Report No. A-2479-207
■ Report No. A-2482-207
▲ Report No. A-2487-207
◆ Report No. A-2493-207

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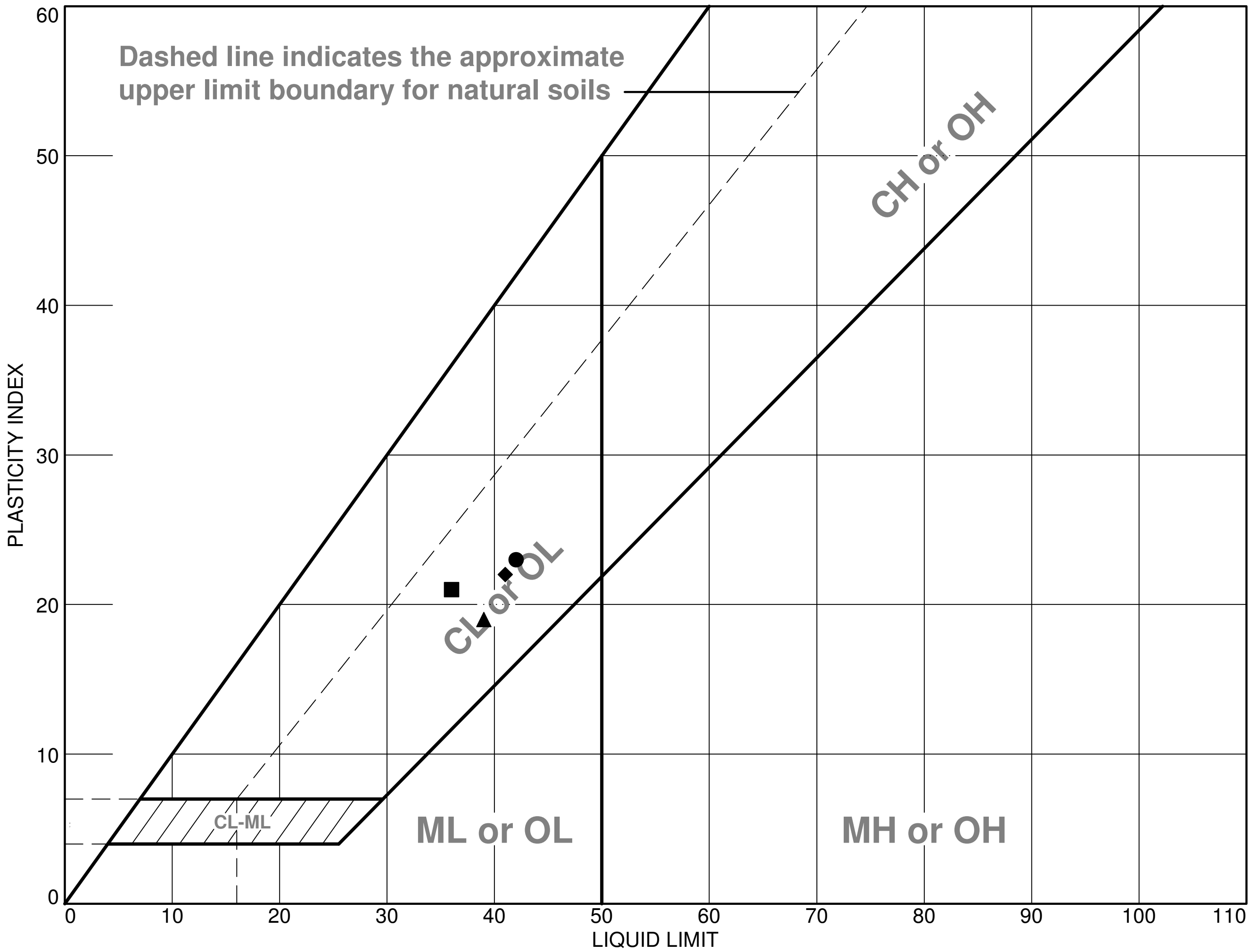
SPOKANE WASHINGTON
LEWISTON IDAHO

Figure B18

Tested By: TJR **Checked By:** Craig R Madsen

LIQUID AND PLASTIC LIMITS TEST REPORT



	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Clayey SAND with Gravel	42	19	23	65.8	46.1	SC
■	Sandy Lean CLAY	36	15	21	94.0	65.1	CL
▲	Lean CLAY	39	20	19			CL
◆	Lean CLAY with Sand	41	19	22	73.6	71.3	CL

Project No. 04-167 **Client:** Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

● **Location:** 09PA-10 **Depth:** 30.0 - 31.5 ft **Sample Number:** A-2498
■ **Location:** 09PA-11 **Depth:** 20.0 - 21.5 ft **Sample Number:** A-2448
▲ **Location:** 09PA-11 **Depth:** 45.0 - 46.5 ft **Sample Number:** A-2454
◆ **Location:** 09PA-13 **Depth:** 20.0 - 21.5 ft **Sample Number:** A-2466

Remarks:
● Report No. A-2498-207
■ Report No. A-2448-207
▲ Report No. A-2454-207
◆ Report No. A-2466-207

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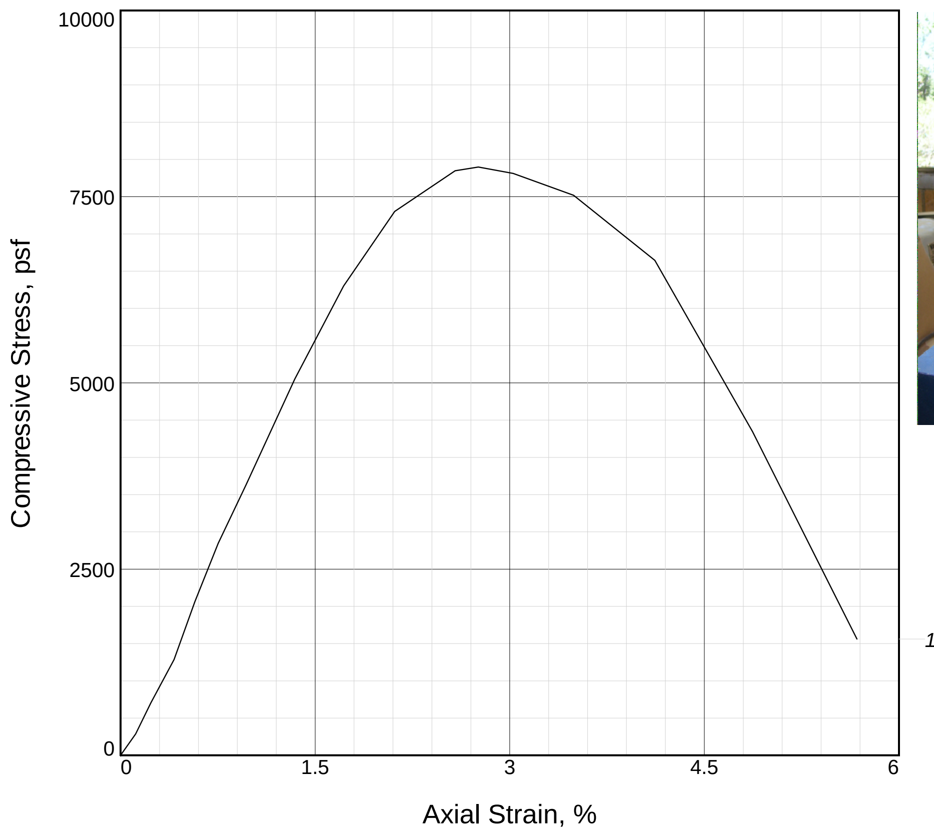
Figure B19

Tested By: TJR **Checked By:** Craig R Madean

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, psf	7898			
Undrained shear strength, psf	3949			
Failure strain, %	2.8			
Strain rate, in./min.	0.03			
Water content, %	21.3			
Wet density, pcf	126.6			
Dry density, pcf	104.3			
Saturation, %	96.3			
Void ratio	0.5854			
Specimen diameter, in.	2.86			
Specimen height, in.	5.58			
Height/diameter ratio	1.95			

Description: Fat CLAY

LL = 57	**PL =** 17	**PI =** 40	**Assumed GS=** 2.65	**Type:** Shelby Tube

Project No.: 04-167

Date Sampled: September 2009

Remarks:
Report No. A-2502-215
Limits from nearby sample (A-2503)

Figure B20

Client: Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

Location: 09PA-1

Sample Number: A-2502 **Depth:** 10.2 - 10.7 ft

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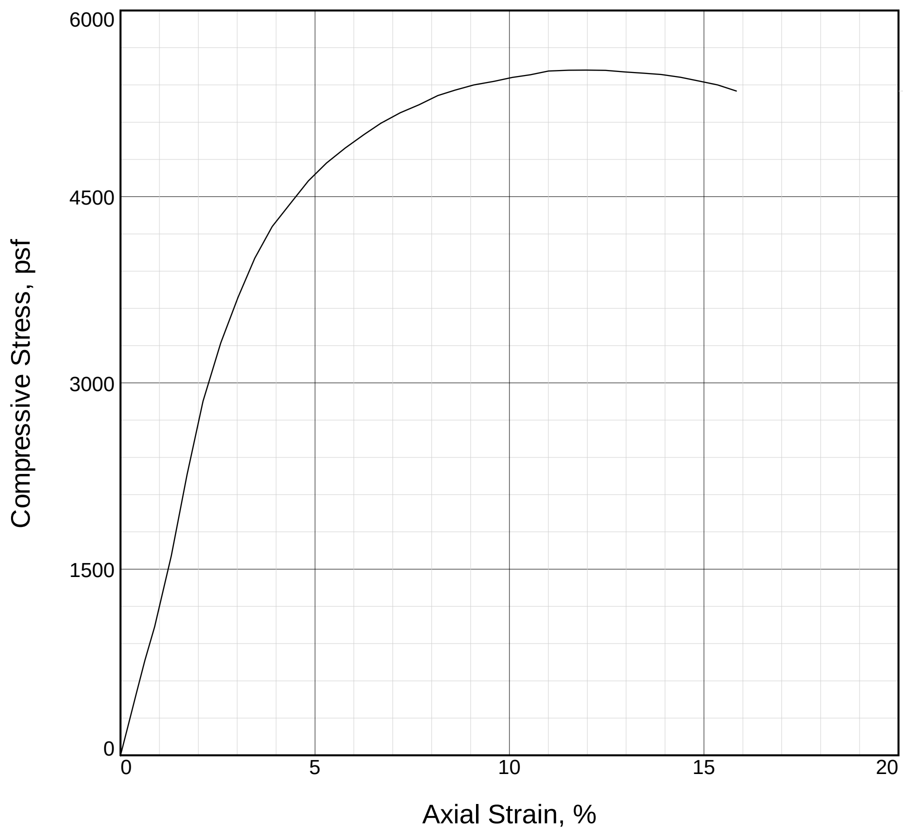
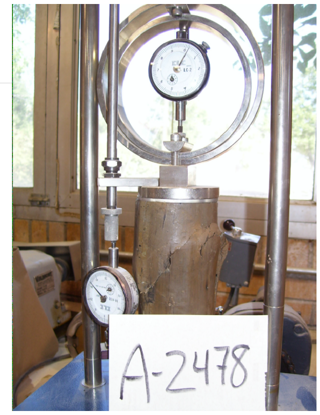
Tested By: CRN **Checked By:** Craig R Nadeau

UNCONFINED COMPRESSION TEST





Sample No.	1			
Unconfined strength, psf	5520			
Undrained shear strength, psf	2760			
Failure strain, %	12.0			
Strain rate, in./min.	0.03			
Water content, %	20.1			
Wet density, pcf	129.3			
Dry density, pcf	107.6			
Saturation, %	99.4			
Void ratio	0.5370			
Specimen diameter, in.	2.87			
Specimen height, in.	5.59			
Height/diameter ratio	1.95			

Description: Sandy Lean CLAY

LL = 37	**PL =** 13	**PI =** 24	**Assumed GS=** 2.65	**Type:** Shelby Tube

Project No.: 04-167

Date Sampled: August 2009

Remarks:
Report No. A-2478-215
Limits from nearby sample (A-2479)

Figure B21

Client: Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

Location: 09PA-8

Sample Number: A-2478 **Depth:** 20.9 - 21.5 ft

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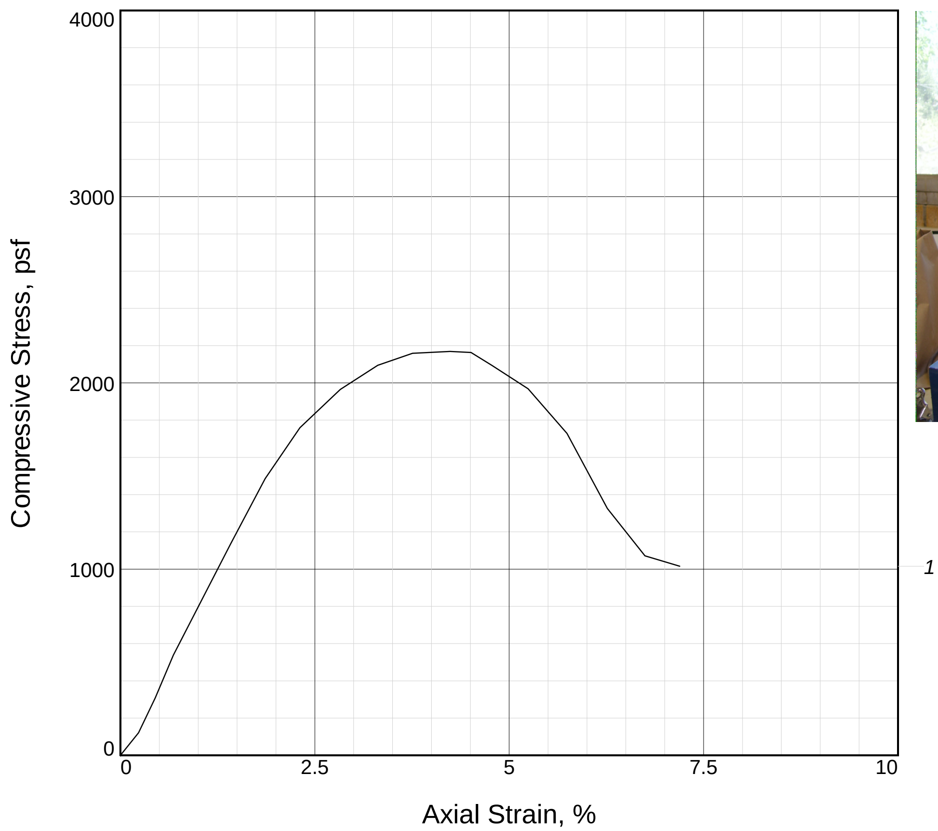
Tested By: CRN **Checked By:** Craig R Nadeau

UNCONFINED COMPRESSION TEST



Sample No.	1			
Unconfined strength, psf	2169			
Undrained shear strength, psf	1085			
Failure strain, %	4.2			
Strain rate, in./min.	0.03			
Water content, %	32.5			
Wet density, pcf	118.4			
Dry density, pcf	89.4			
Saturation, %	101.2			
Void ratio	0.8507			
Specimen diameter, in.	2.86			
Specimen height, in.	5.59			
Height/diameter ratio	1.95			

Description: Fat CLAY

LL = 52	**PL =** 18	**PI =** 34	**Assumed GS=** 2.65	**Type:** Shelby Tube

Project No.: 04-167

Date Sampled: August 2009

Remarks:
Report No. A-2492-215
Limits from nearby sample (A-2493)

Figure B22

Client: Department of Natural Resources

Project: St. Mary River Rehabilitation Project
North of Babb, Montana

Location: 09PA-10

Sample Number: A-2492 **Depth:** 10.3 - 10.9 ft

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IDAHO

Tested By: CRN **Checked By:** Craig R Nadeau

REPORT OF CORED CYLINDER TEST

Thomas, Dean & Hoskins

208 1/2 17th Street North, Great Falls, MT 59401

Report Date: 12/8/11

Report Number: B23

Project Number: 04-167-002 St. Mary River Siphon
Project: St. Mary River Siphon - Proposed Alignment
Client: DNRC - CARDD
Address: P.O. Box 201601
Helena, MT 59620-1601
Attn: Mr. John Sanders, P.E.

SAMPLING INFORMATION (ASTM C 42)

Date Sampled: 9/16/2009 Time Sampled: N/A

Technician: CRN

Date Placed: N/A

Location of Sample: 09PA-4 (20.7 - 21.4 ft)

Supplier: N/A

Mix Number: N/A

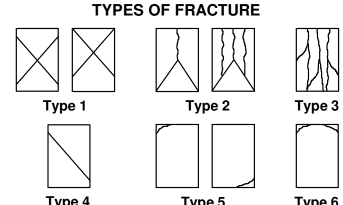
Design Strength: N/A

LABORATORY TEST RESULTS (ASTM C 39)

Specimen	Test Date	Age	Load	Diameter	Area	Un-capped Height	Capped Height	Strength	Percent of Design	Type of Fracture
A-2543	10/29/2009	N/A	37630	2.39	4.49	5.46	5.68	8380	N/A	3

Remarks: Rock core obtained during September 2009 Geotechnical Investigation

TYPES OF FRACTURE



Copies to:

Reported by:

FOR

Peter Klevberg, P.E.
Laboratory Manager

REPORT OF CORED CYLINDER TEST

Thomas, Dean & Hoskins

208 1/2 17th Street North, Great Falls, MT 59401

Report Date: 12/8/11

Project Number: 04-167-002 St. Mary River Siphon

Report Number: B24

Project: St. Mary River Siphon - Proposed Alignment

Client: DNRC - CARDD

Address: P.O. Box 201601
Helena, MT 59620-1601

Attn: Mr. John Sanders, P.E.

SAMPLING INFORMATION (ASTM C 42)

Date Sampled:

Time Sampled: N/A

Technician: CRN

Date Placed: N/A

Location of Sample: 09PA-6 (22.2 - 23.1 ft)

Supplier: N/A

Mix Number: N/A

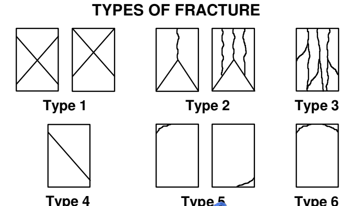
Design Strength: N/A

LABORATORY TEST RESULTS (ASTM C 39)

Specimen	Test Date	Age	Load	Diameter	Area	Un-capped Height	Capped Height	Strength	Percent of Design	Type of Fracture
A-2544	10/29/2009	N/A	17920	2.40	4.52	3.93	4.31	3960	N/A	2

Remarks: Rock core obtained during September 2009
Geotechnical Investigation

TYPES OF FRACTURE

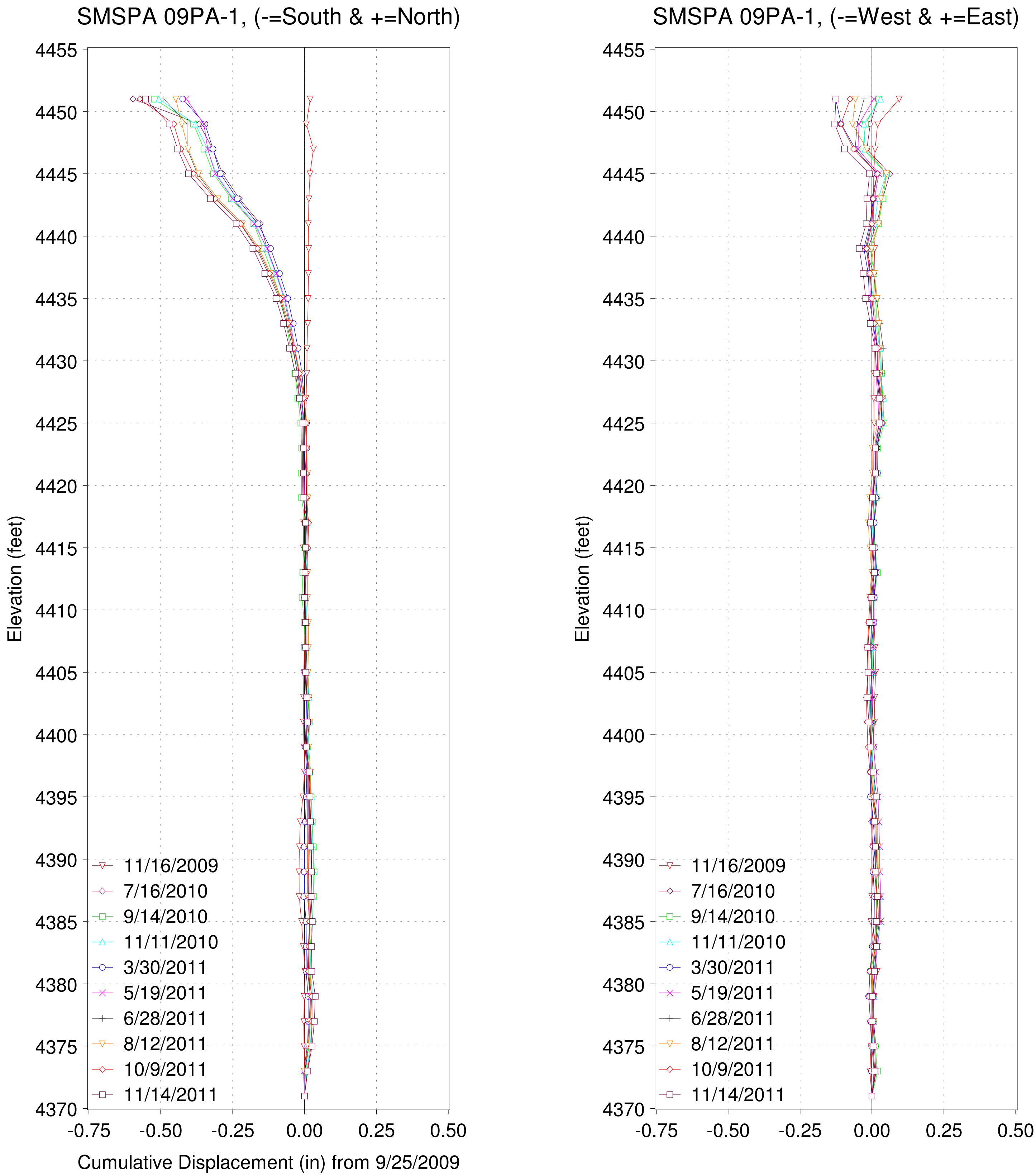


Copies to:

Reported by:

FOR

Peter Klevberg, P.E.
Laboratory Manager



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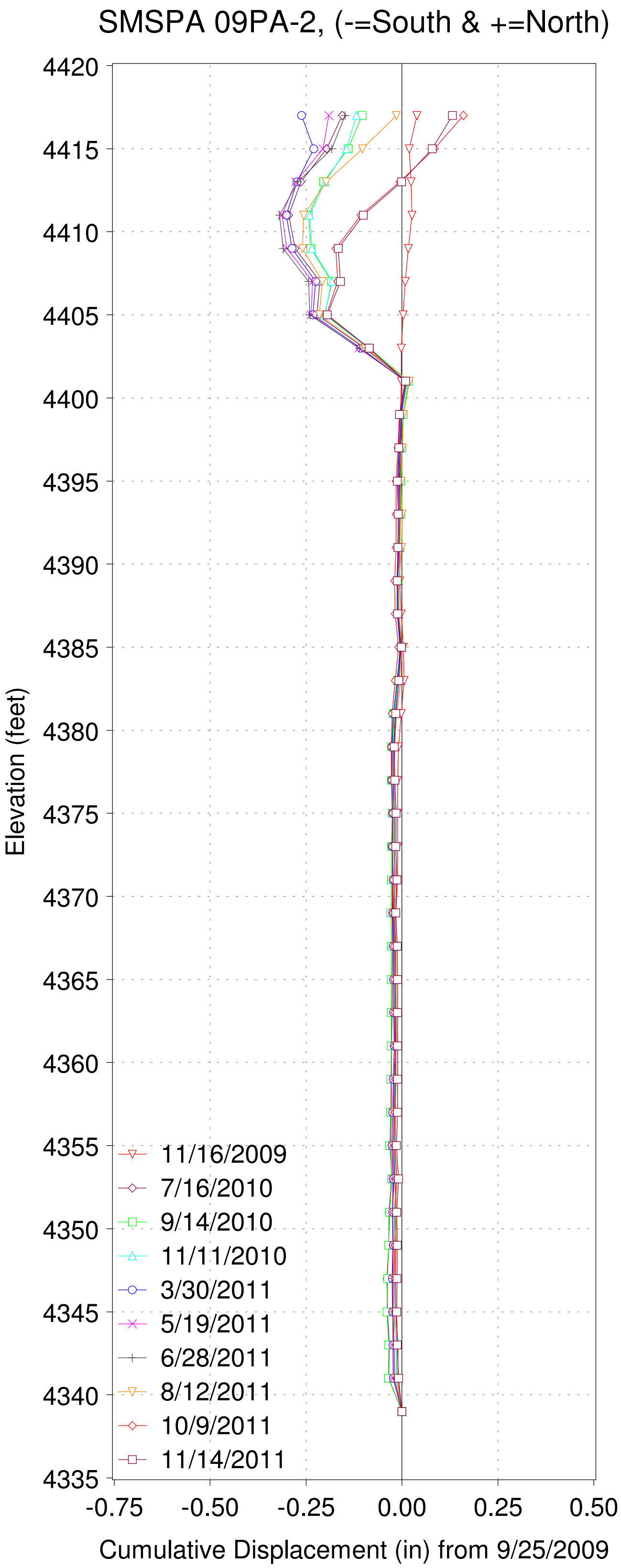
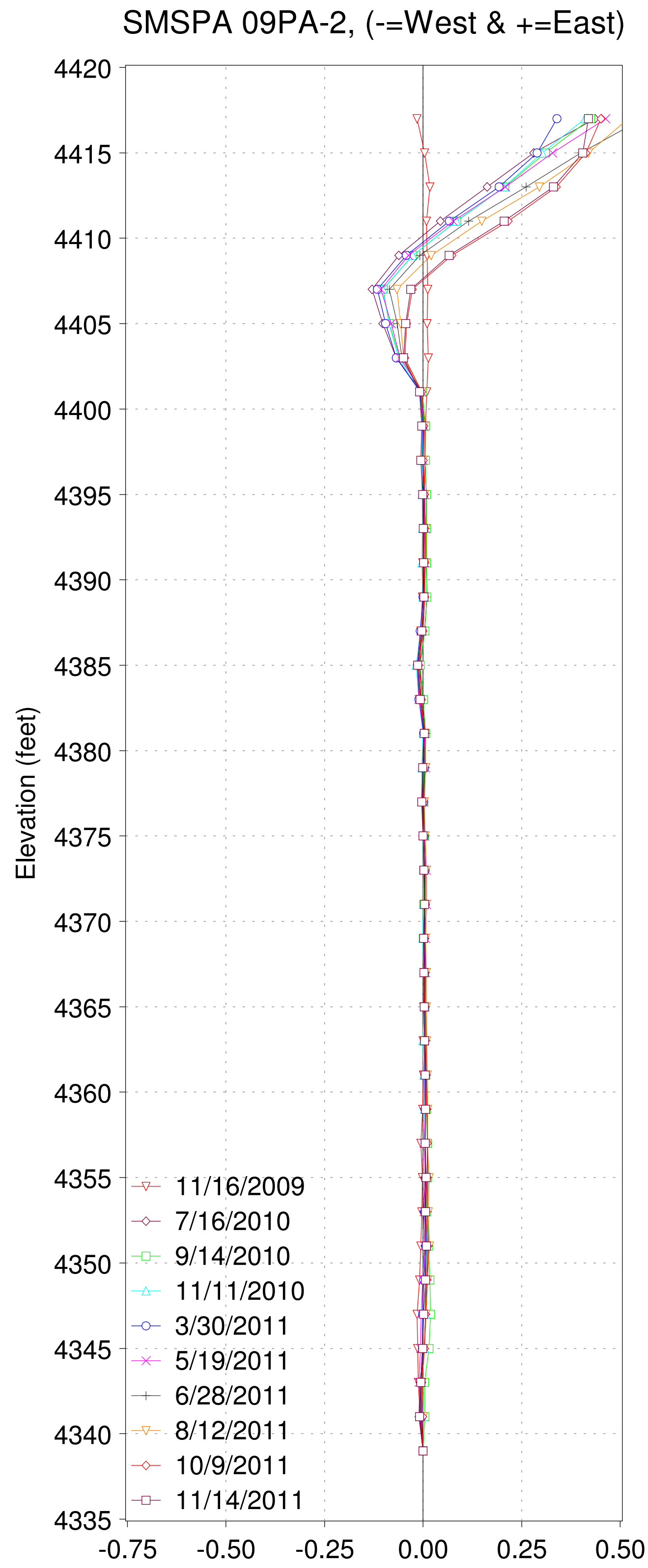
Engineering Consultants

St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crosing, Proposed Alignment, North Slope

Ground Elevation = 4450.68

Figure B25





Thomas, Dean & Hoskins, Inc.
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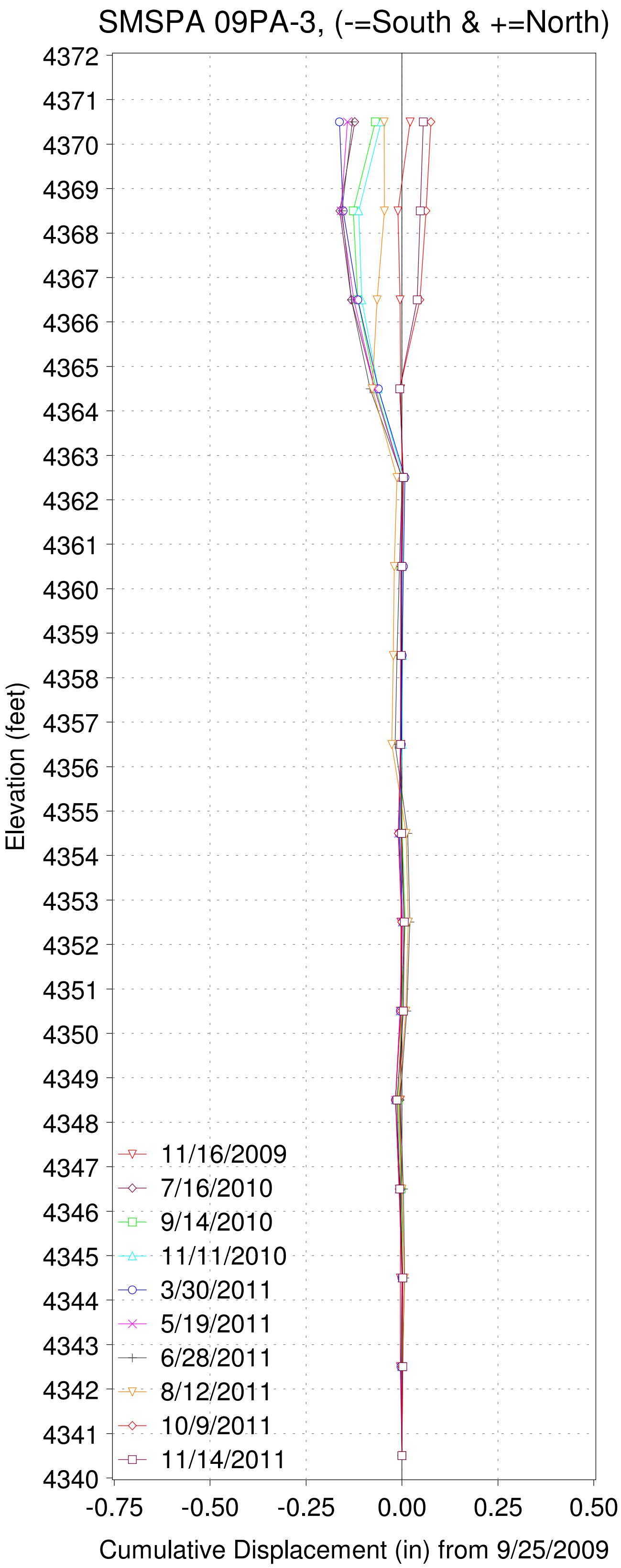
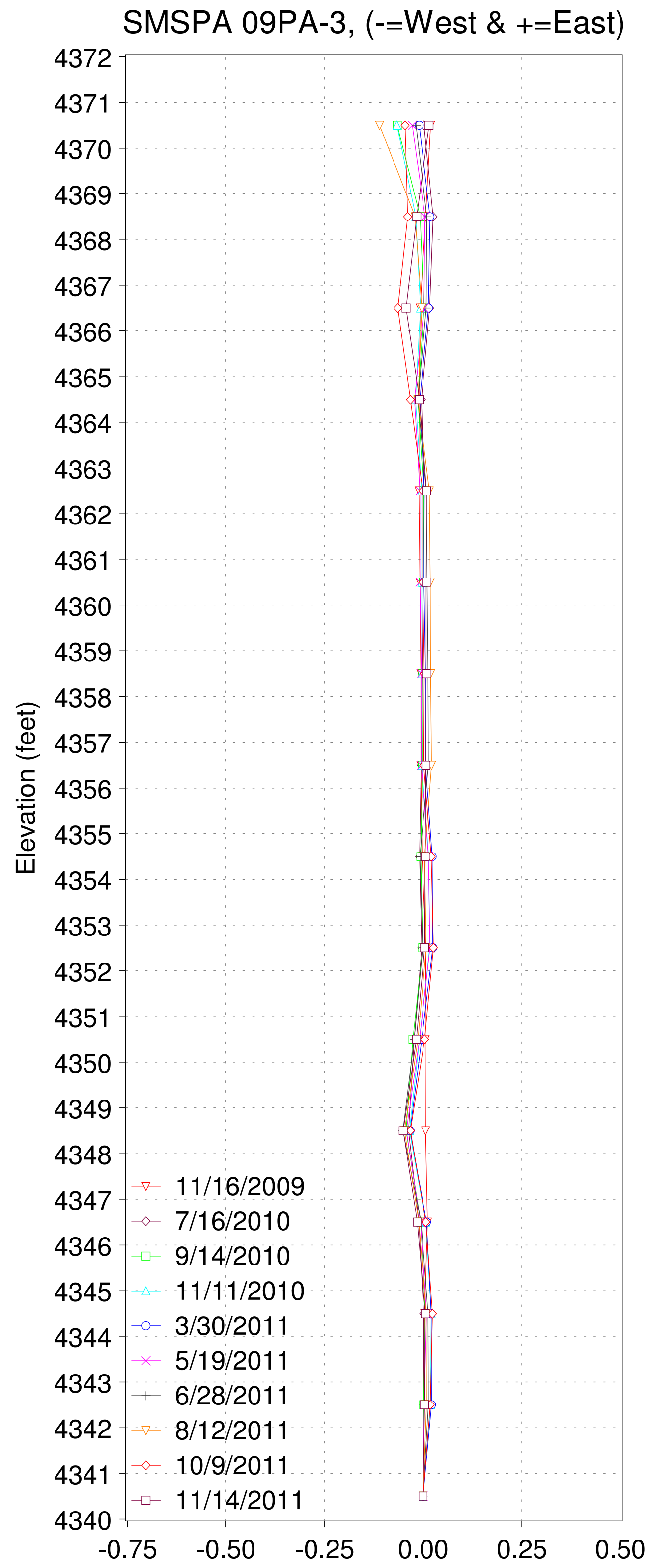
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, North Slope

Ground Elevation = 4417.08

Figure B26





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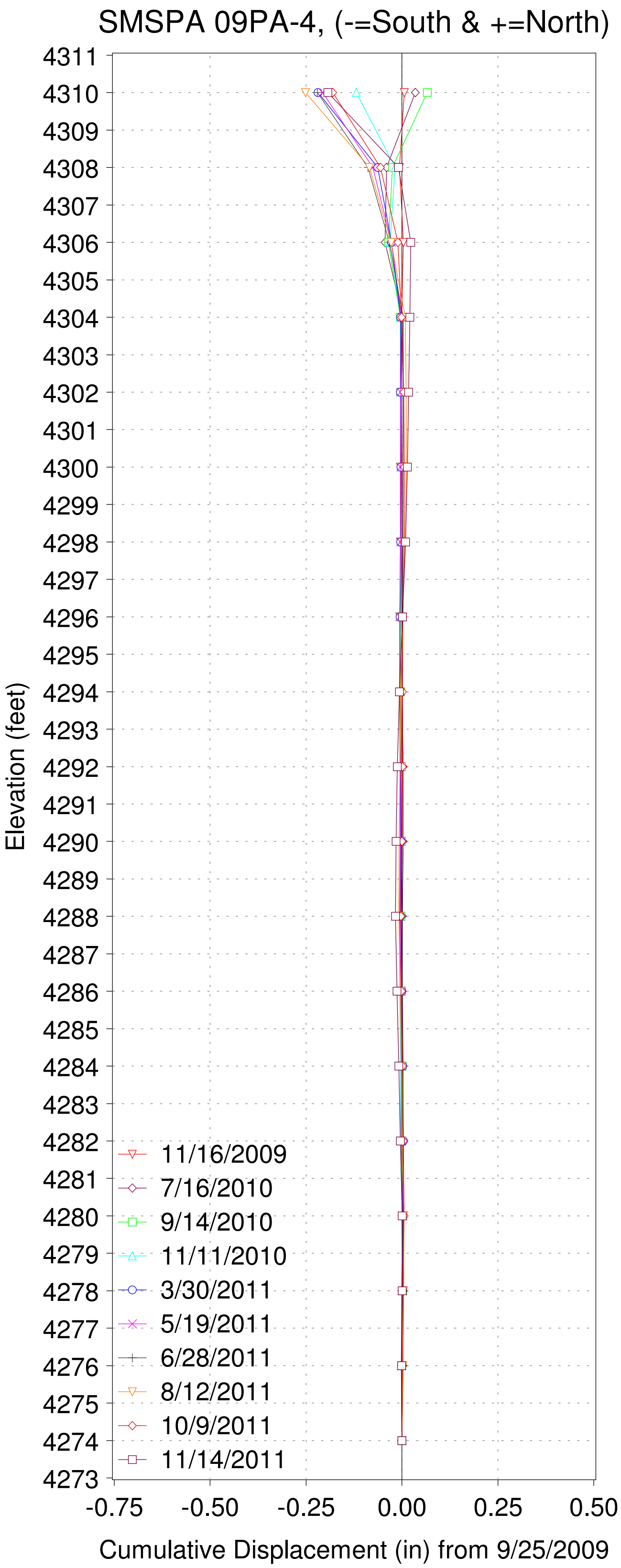
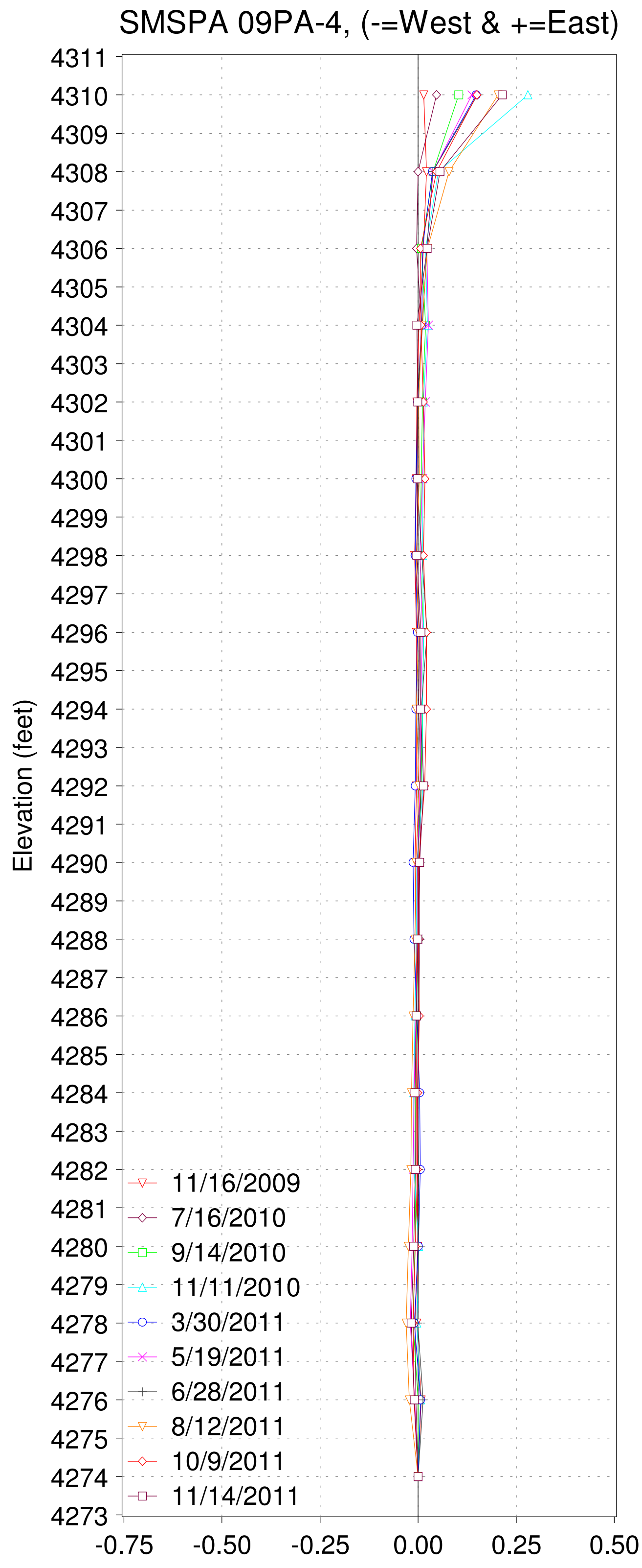
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, North Slope

Ground Elevation = 4370.76

Figure B27





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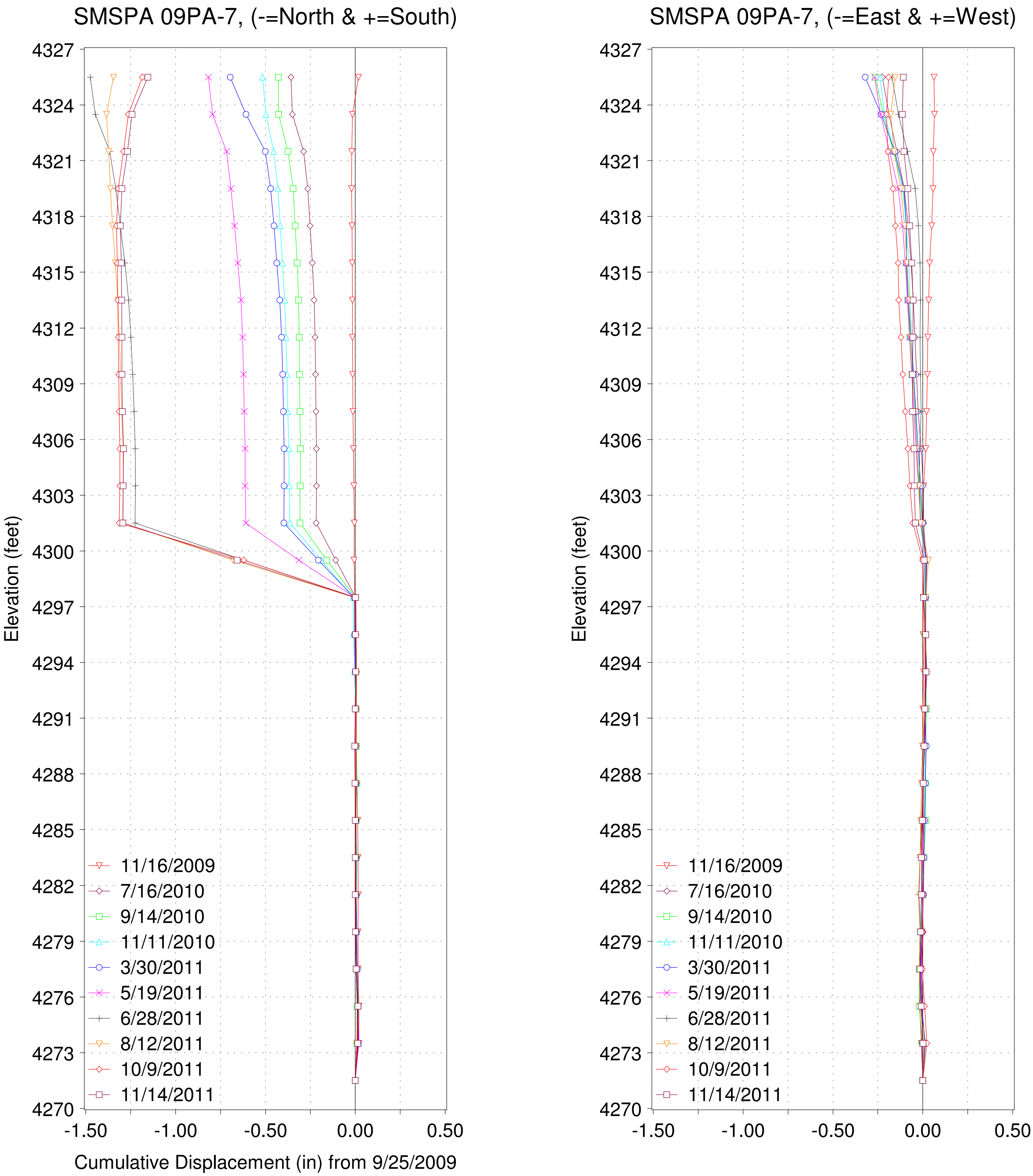
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, North Slope

Ground Elevation = 4308.30

Figure B28



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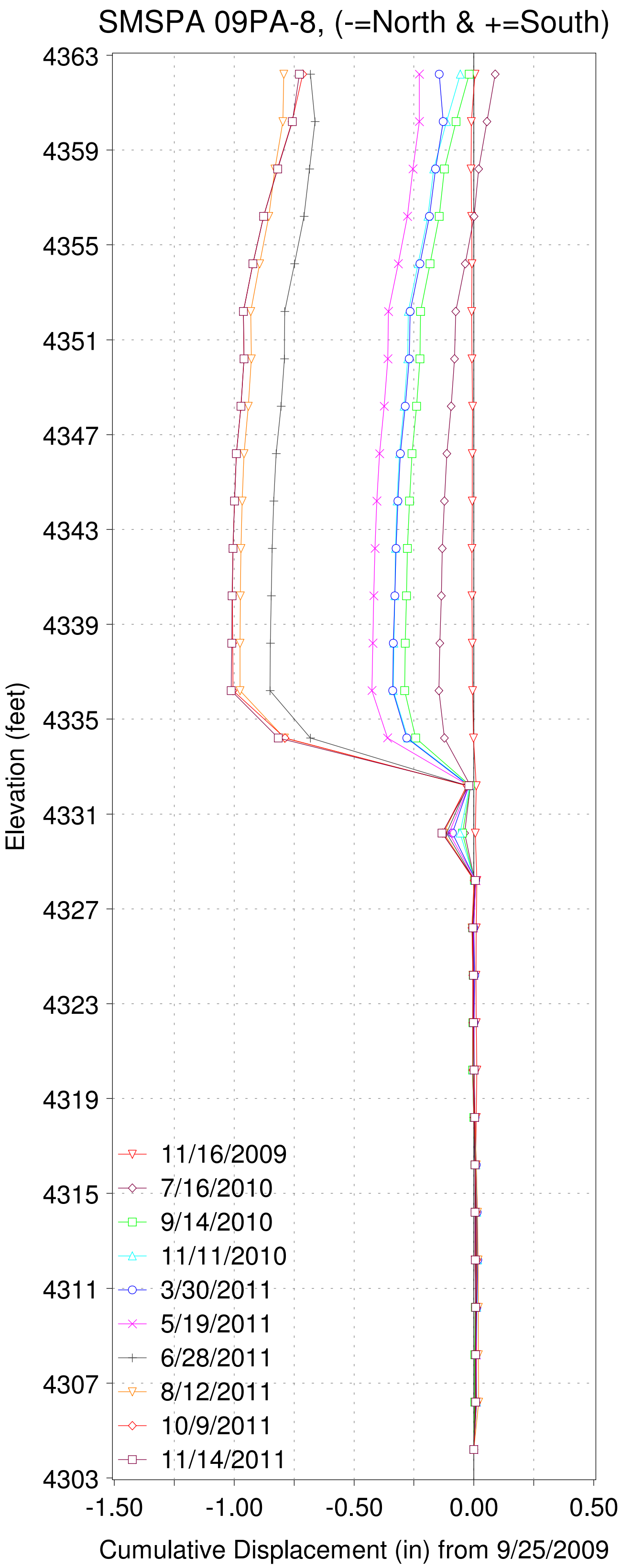
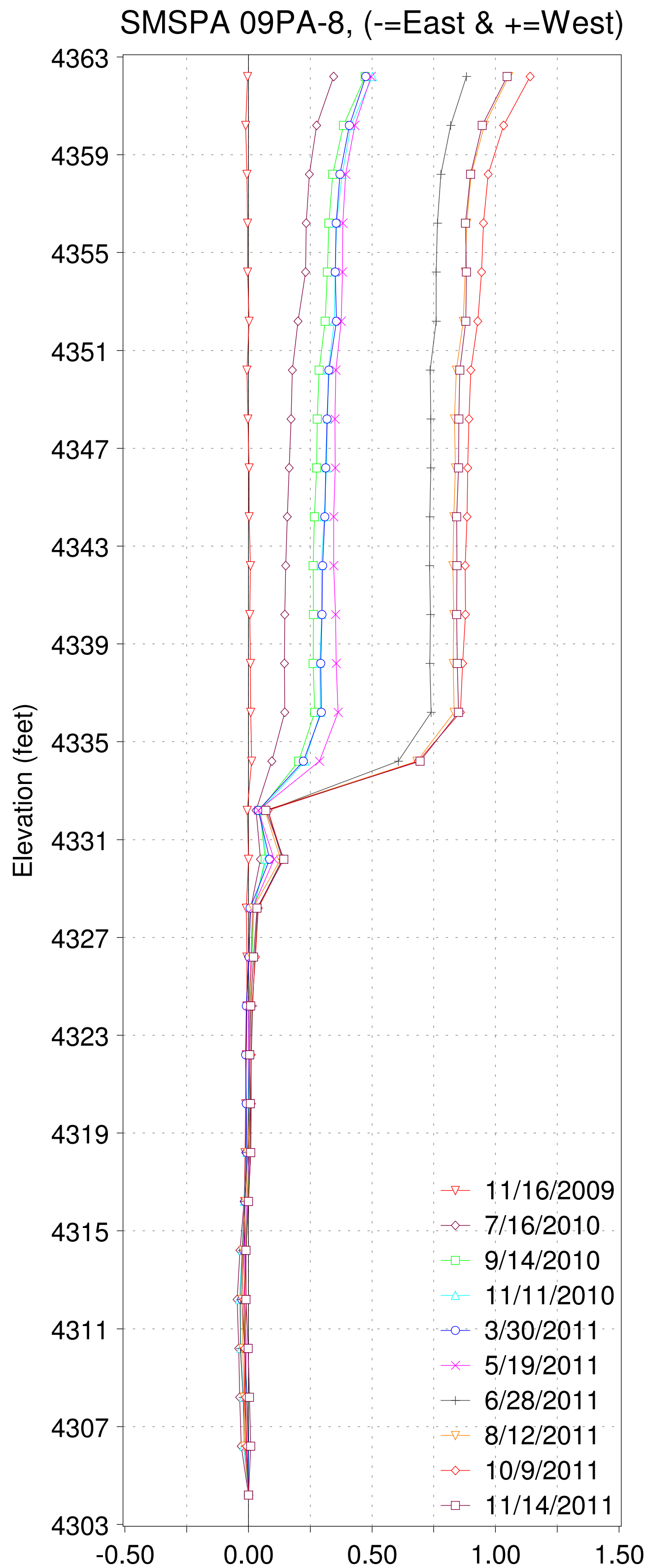
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, South Slope

Ground Elevation = 4324.52

Figure B29





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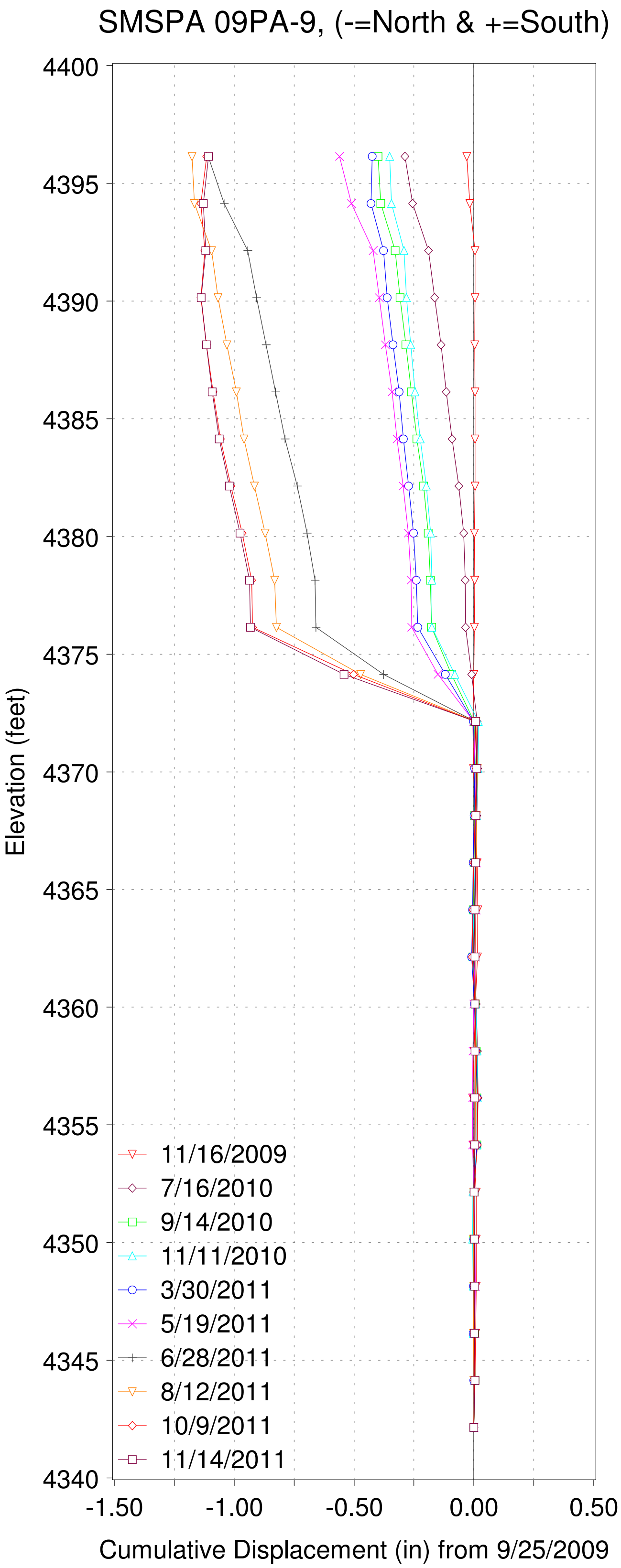
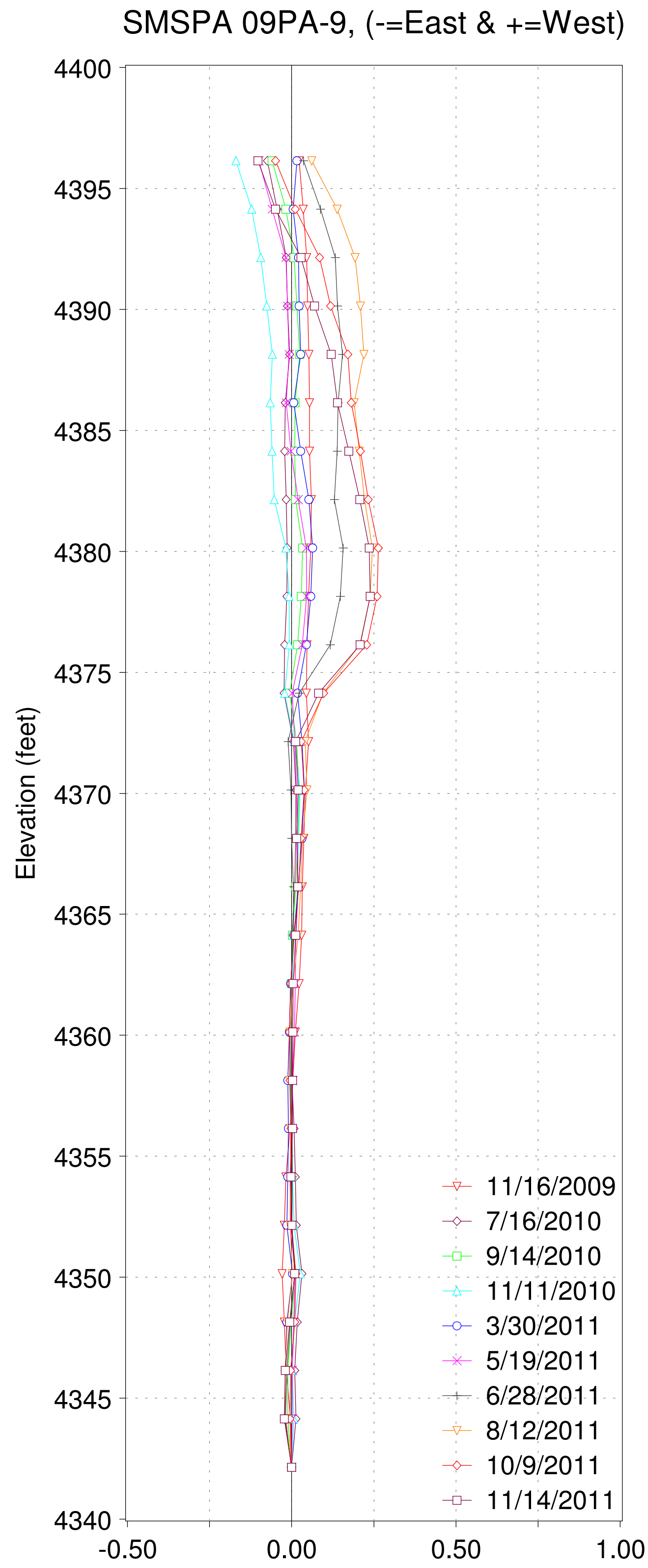
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, South Slope

Ground Elevation = 4362.37

Figure B30





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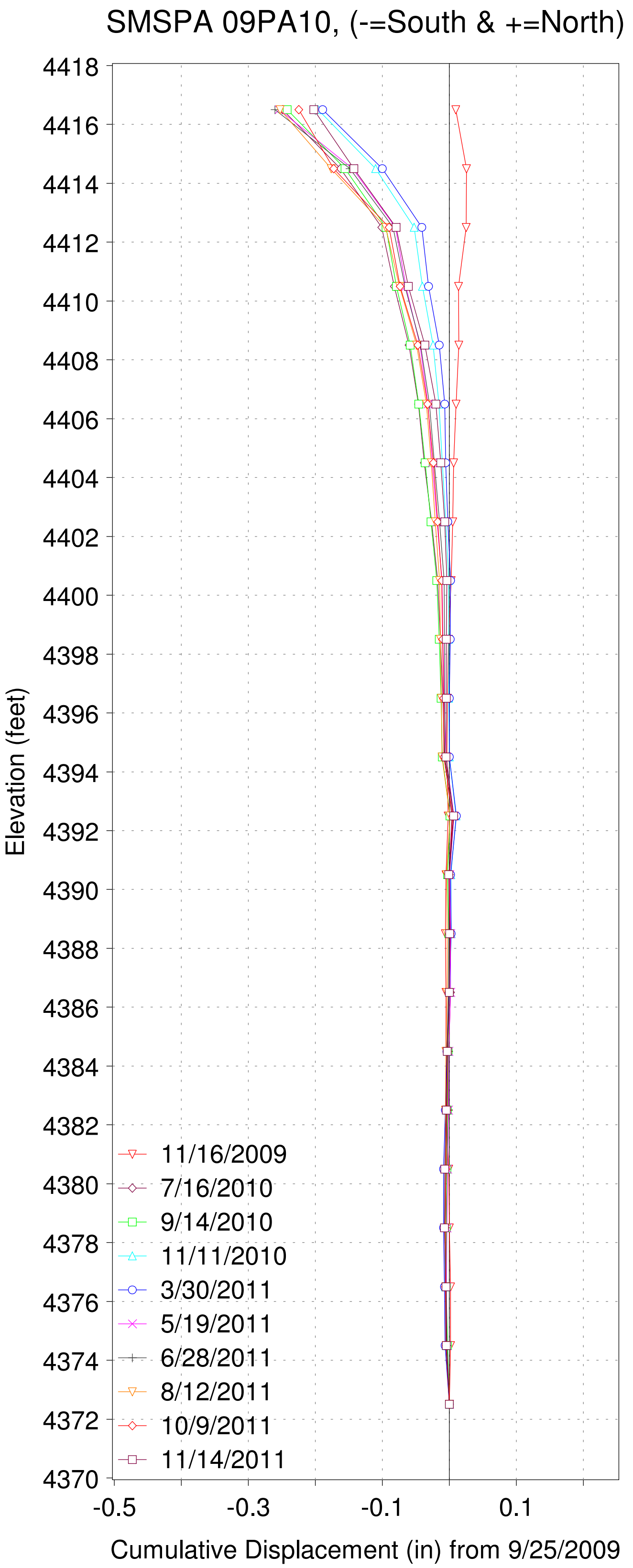
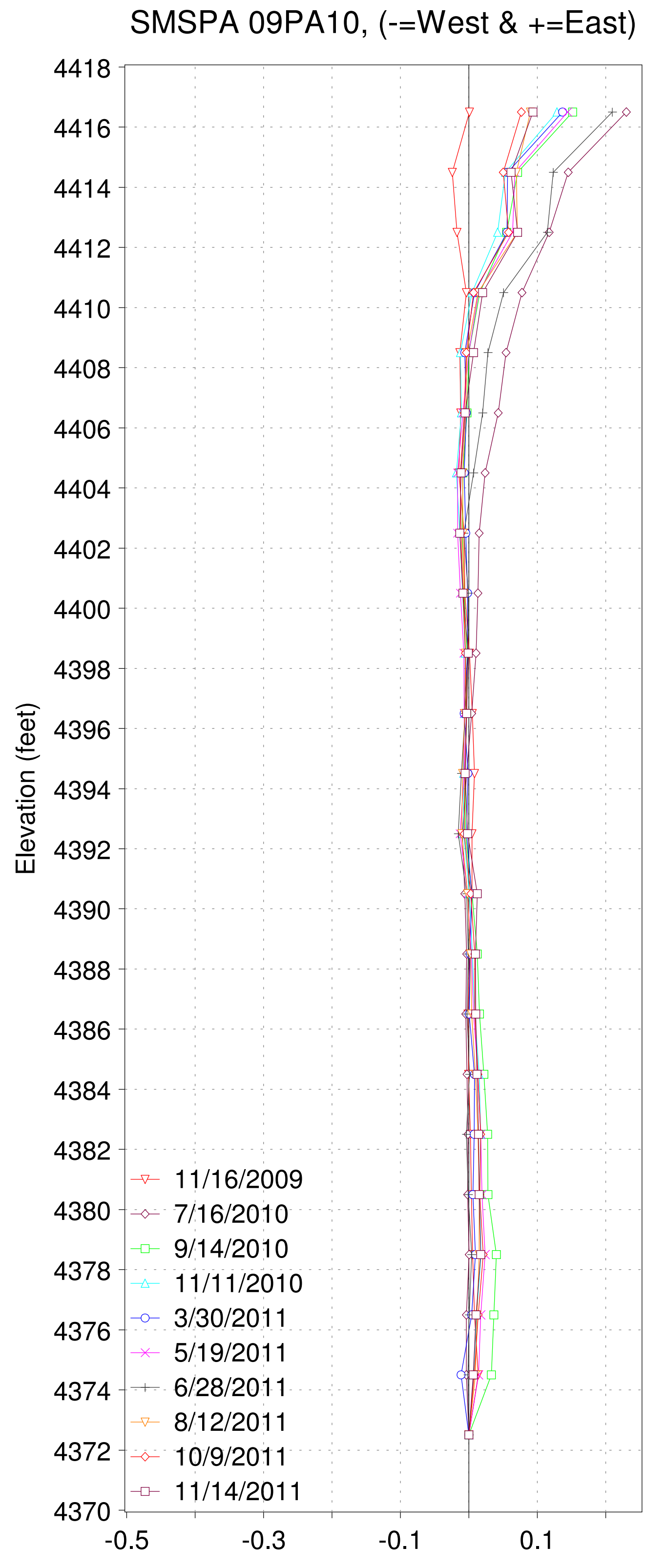
St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, South Slope

Ground Elevation = 4396.49

Figure B31





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St. Mary River Diversion & Conveyance Facilities, Near Babb, MT
St. Mary River Siphon Crossing, Proposed Alignment, South Slope

Ground Elevation = 4416.42

Figure B32

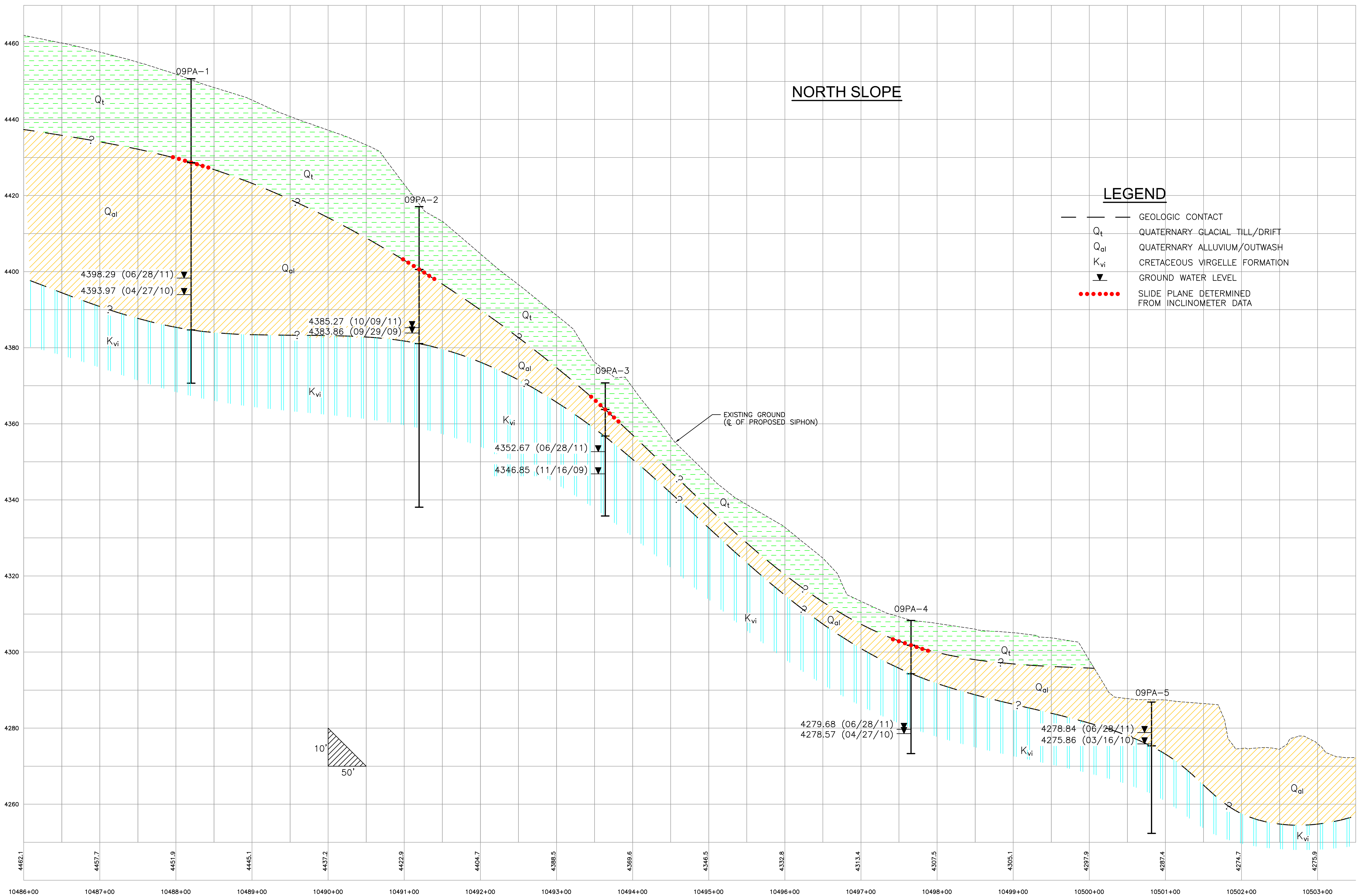

FIGURE B33

REVISIONS
BY ____ DATE ____ DESCR ____
BY ____ DATE ____ DESCR ____
BY ____ DATE ____ DESCR ____

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WASHINGTON
IDAHO
TD&H

DRAWN BY:	MWC
DESIGNED BY:	EAJ
QUALITY CHECK:	
DATE:	01.20.12
JOB NO.	04-167
FIELDBOOK	

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES FOR THE ST. MARY RIVER PROPOSED SIPHON CROSSING GEOLOGIC CROSS SECTION - NORTH SLOPE

CAD NO. 04167figB33 .DWG
SHEET 1 OF 2

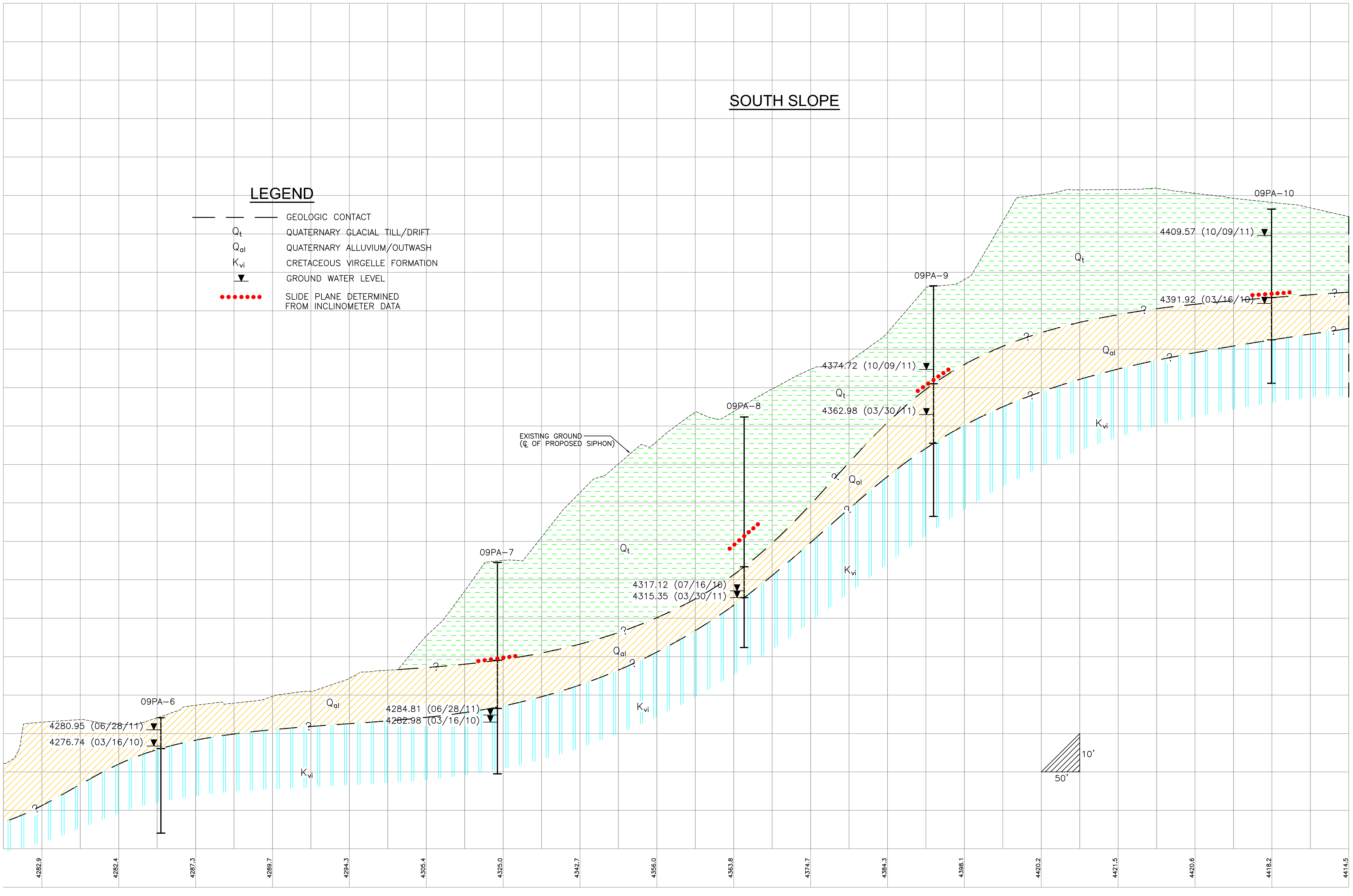

FIGURE B33

REVISIONS

BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR
BY	DATE	DESCR

THOMAS, DEAN & HOSKINS, INC.
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LEWISTON
MONTANA
WASHINGTON
IDAHO

TD&H

DRAWN BY: MWC
DESIGNED BY: EAJ
QUALITY CHECK:
DATE: 09.10.07
JOB NO. 04-167
FIELDBOOK

DNRC - CARDD
ST. MARY CANAL REHABILITATION

ST. MARY DIVERSION FACILITIES GEOTECHNICAL STUDIES
FOR THE ST. MARY RIVER PROPOSED SIPHON CROSSING
GEOLOGIC CROSS SECTION - SOUTH SLOPE

CAD NO. 04167figB33 .DWG
SHEET 2 OF 2

FIGURE B34
PROPOSED ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
GEOMETRY, MATERIAL PROPERTIES, AND ELEVATED GROUND WATER LEVEL

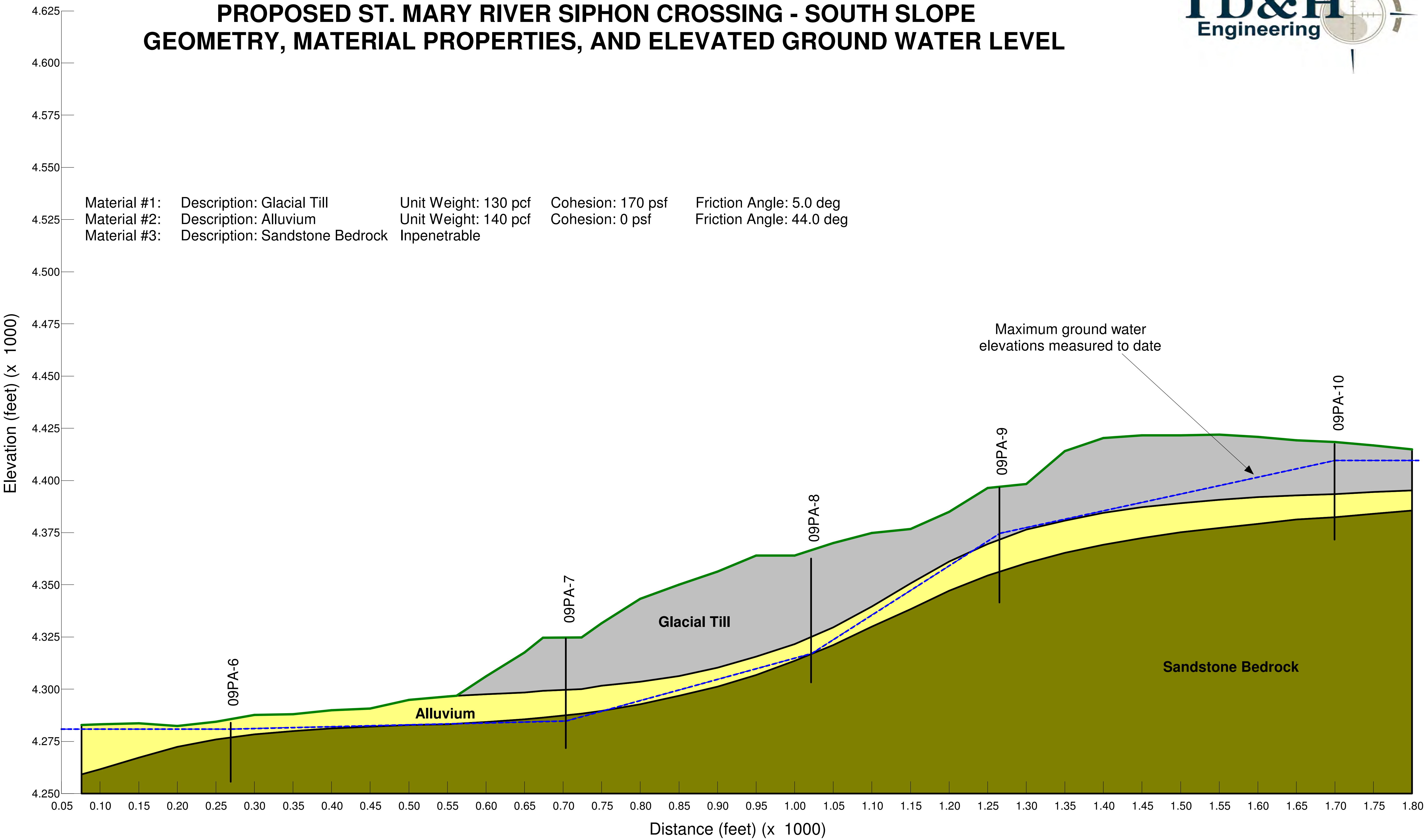


FIGURE B35
PROPOSED ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BACK ANALYSIS, BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, NONSEISMIC

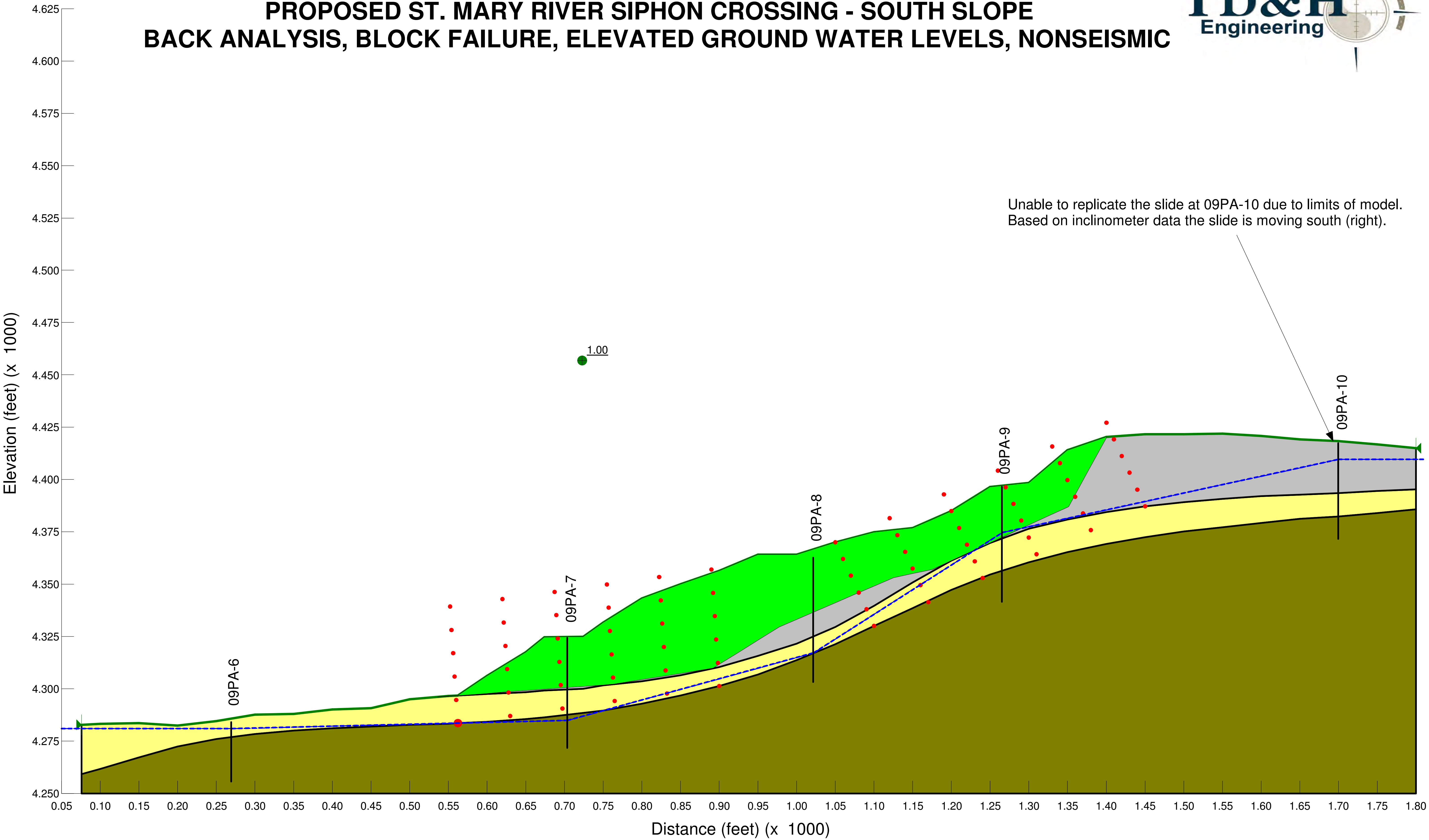


FIGURE B36
PROPOSED ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, REDUCED GROUND WATER LEVELS, NONSEISMIC

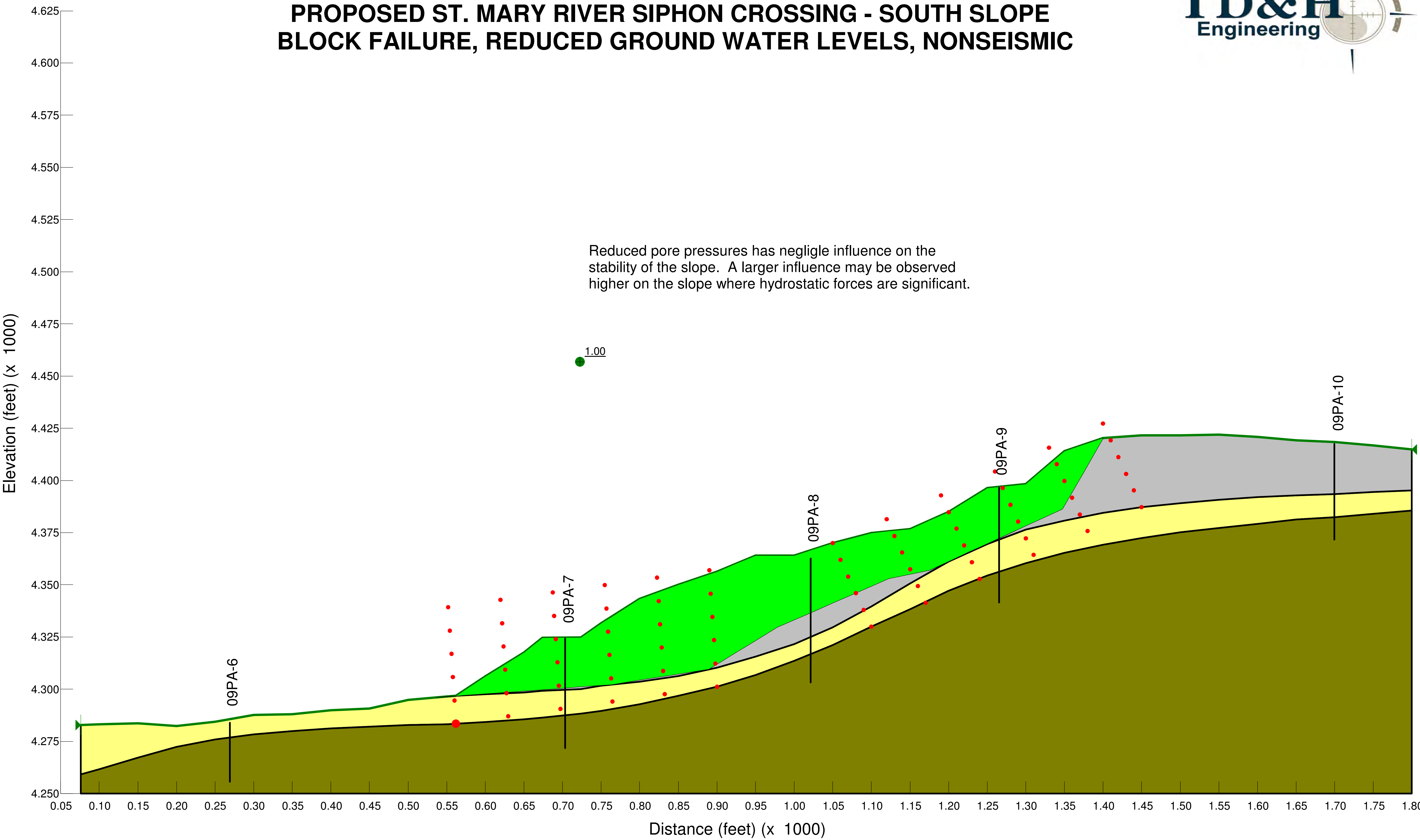


FIGURE B37
PROPOSED ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, REDUCED GROUND WATER LEVELS, SEISMIC Kh = 0.005g

TD&H Engineering

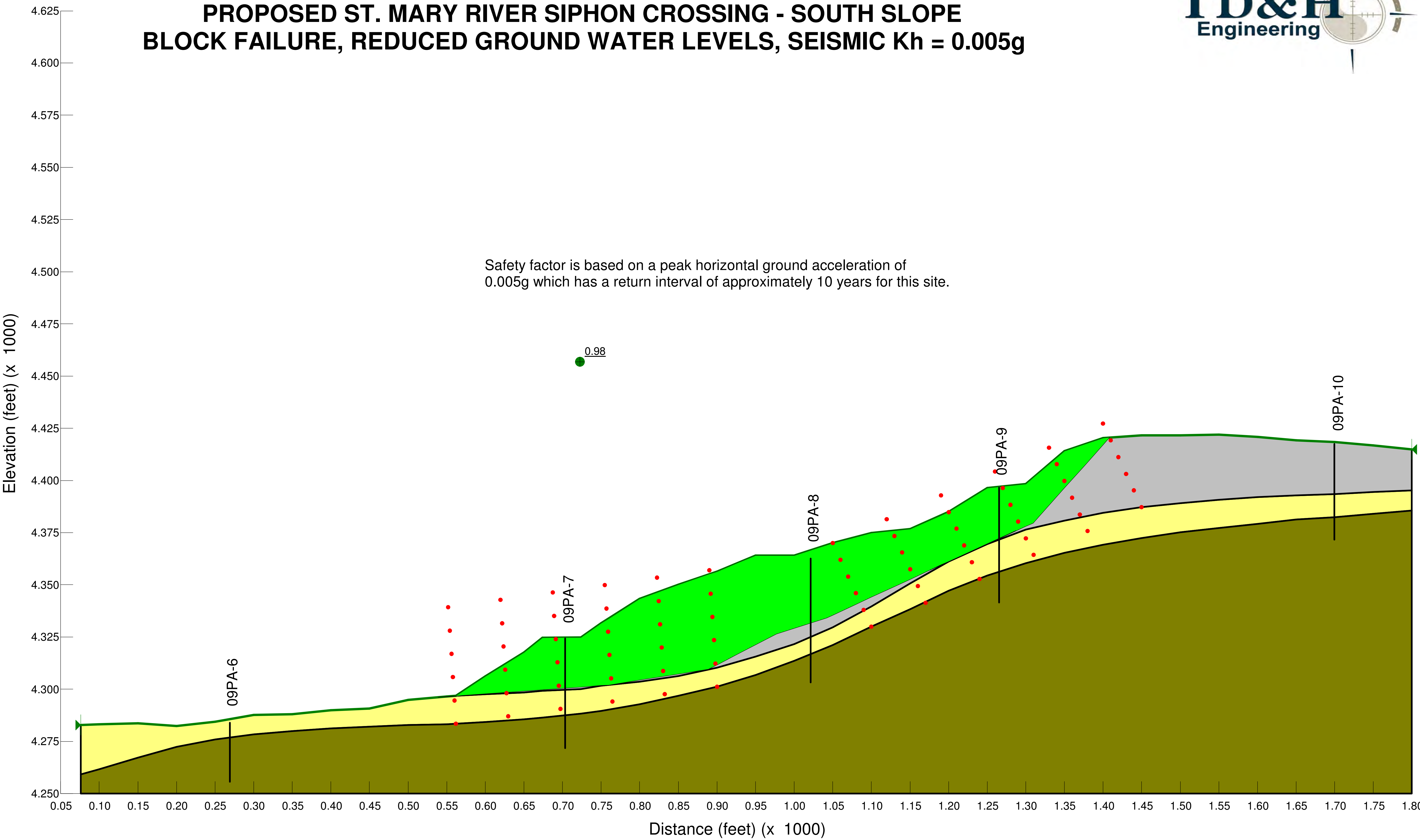


FIGURE B38
PROPOSED ST. MARY RIVER SIPHON CROSSING - SOUTH SLOPE
BLOCK FAILURE, REDUCED GROUND WATER LEVELS, SEISMIC Kh = 0.035g

TD&H Engineering

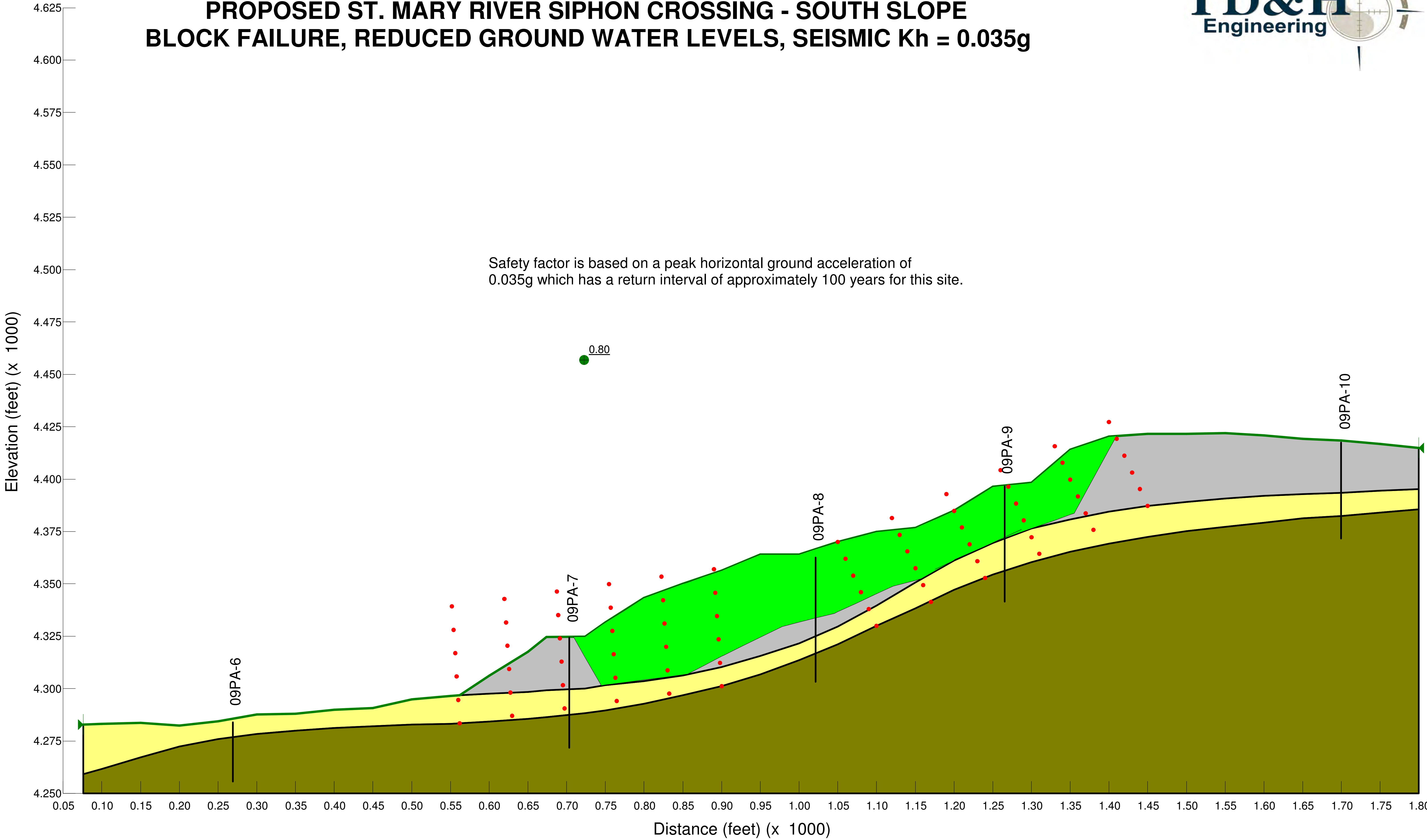


FIGURE B39
PROPOSED ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
GEOMETRY, MATERIAL PROPERTIES, AND ELEVATED GROUND WATER LEVELS

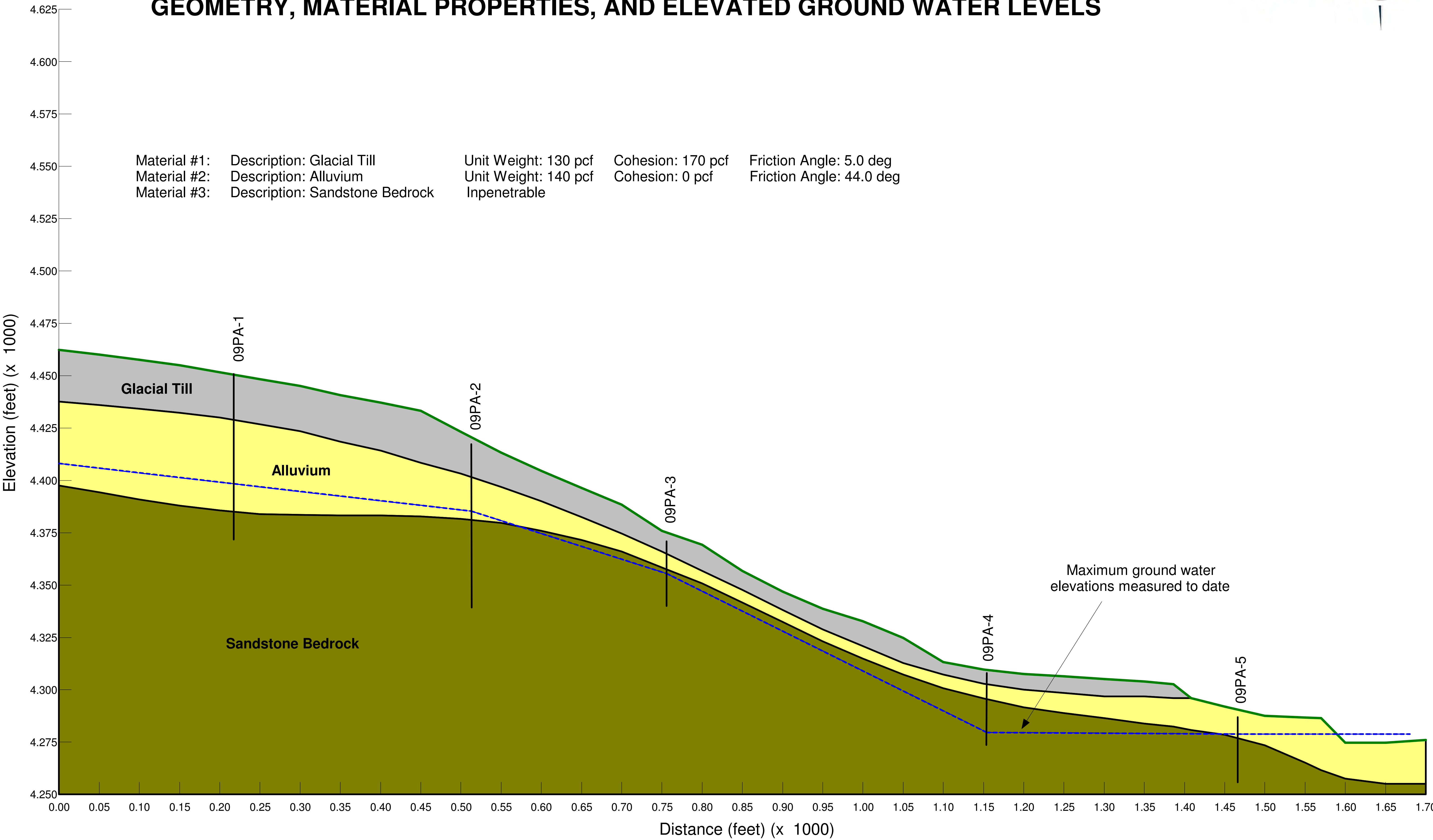


FIGURE B40
PROPOSED ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, NONSEISMIC

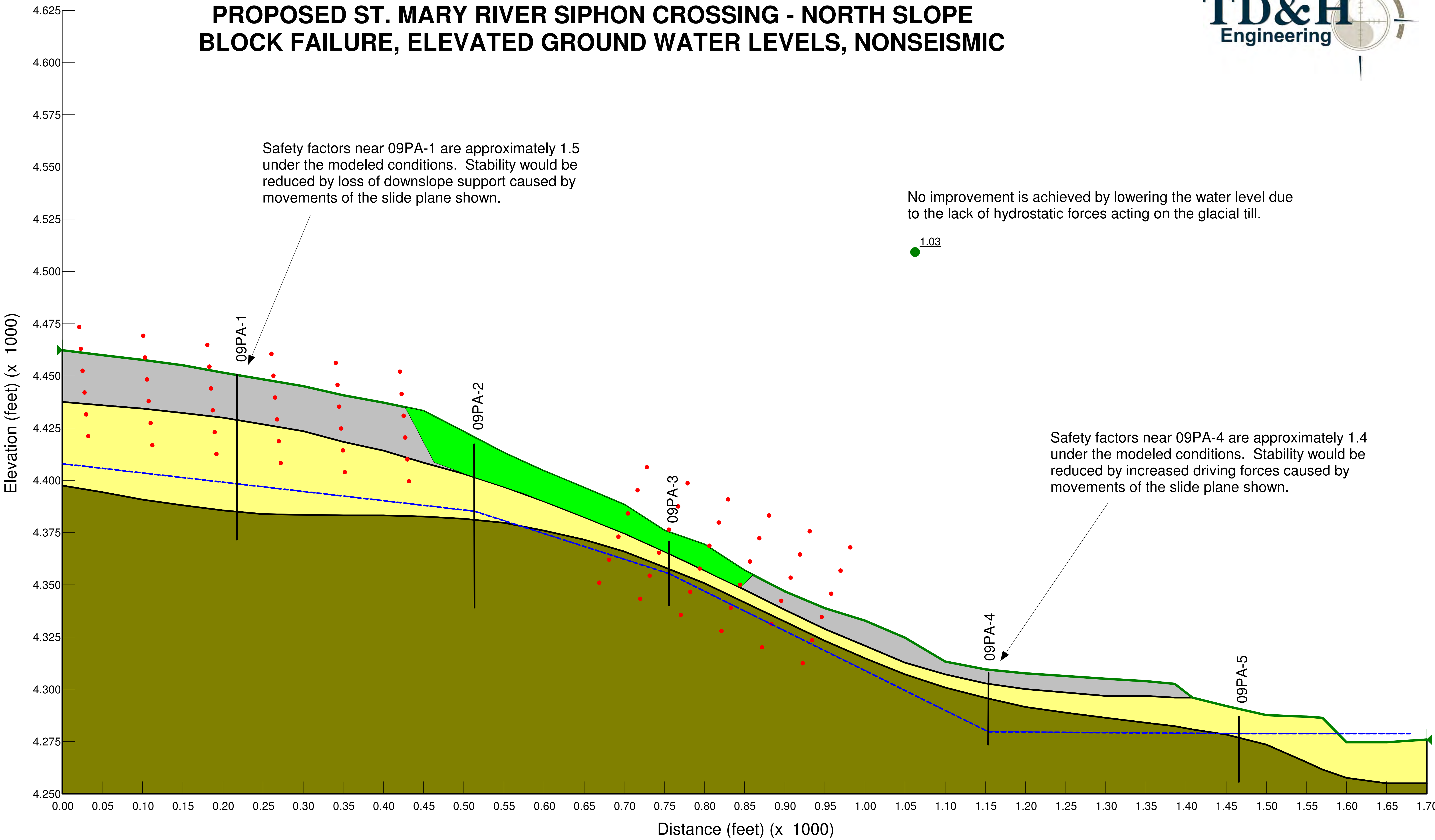


FIGURE B41
PROPOSED ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, SEISMIC Kh = 0.005g

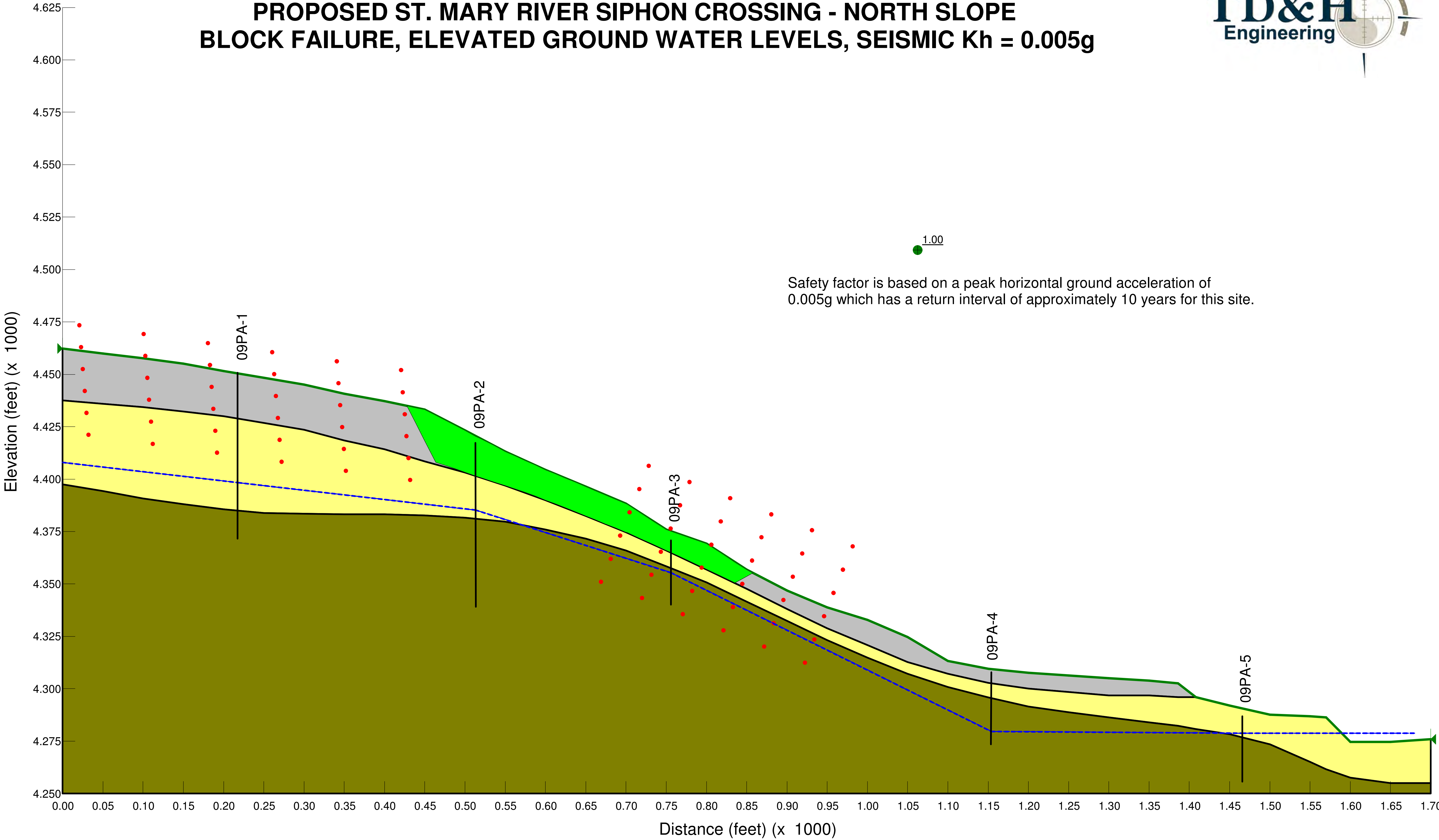
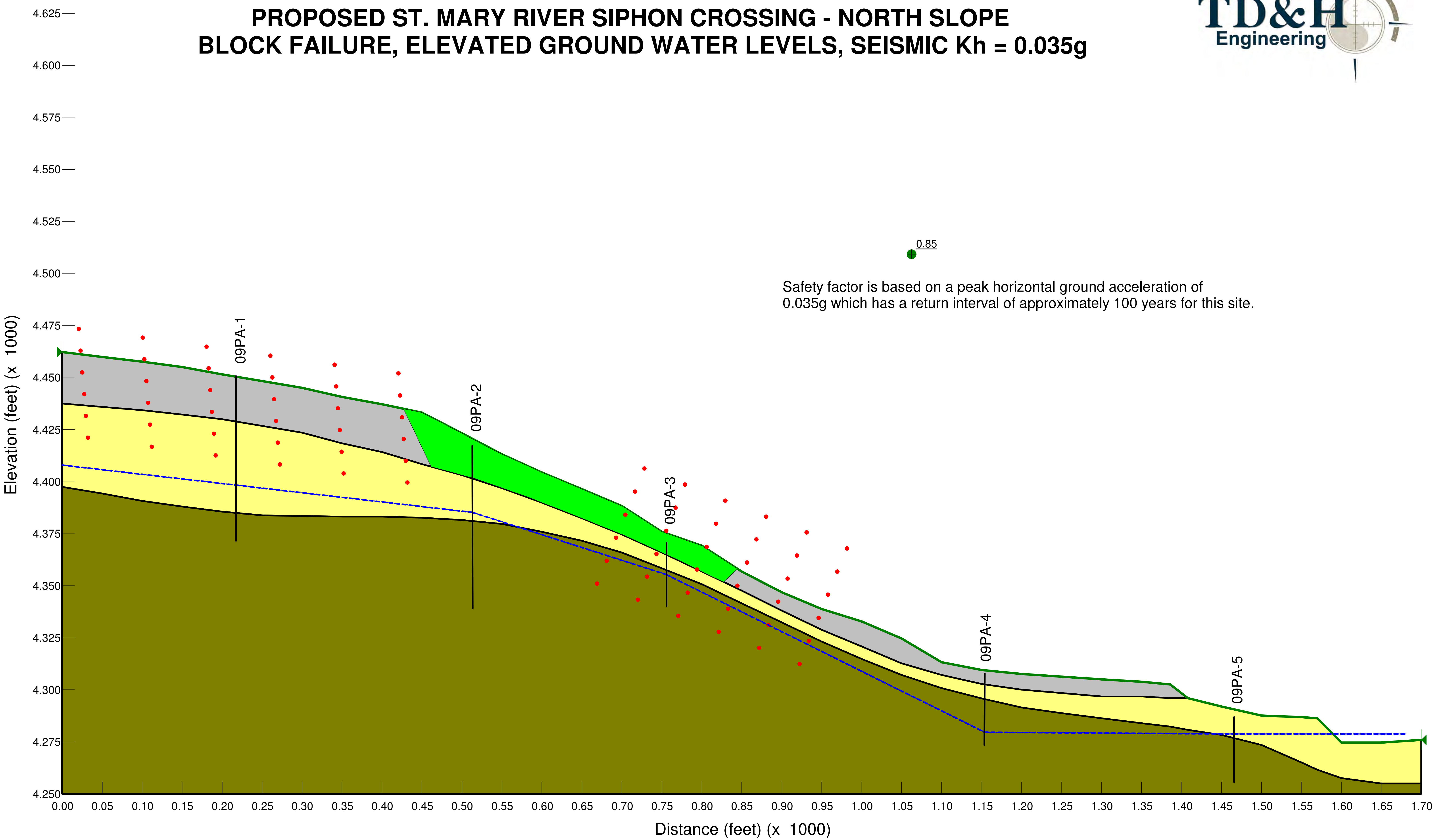


FIGURE B42
PROPOSED ST. MARY RIVER SIPHON CROSSING - NORTH SLOPE
BLOCK FAILURE, ELEVATED GROUND WATER LEVELS, SEISMIC Kh = 0.035g



APPENDIX C

THOMAS, DEAN & HOSKINS Engineering Consultants Great Falls, Kalispell, Bozeman, Montana Spokane, Washington, Lewiston, Idaho	SOIL CLASSIFICATION AND SAMPLING TERMINOLOGY FOR ENGINEERING PURPOSES

STANDARD PENETRATION TEST (ASTM D1586)

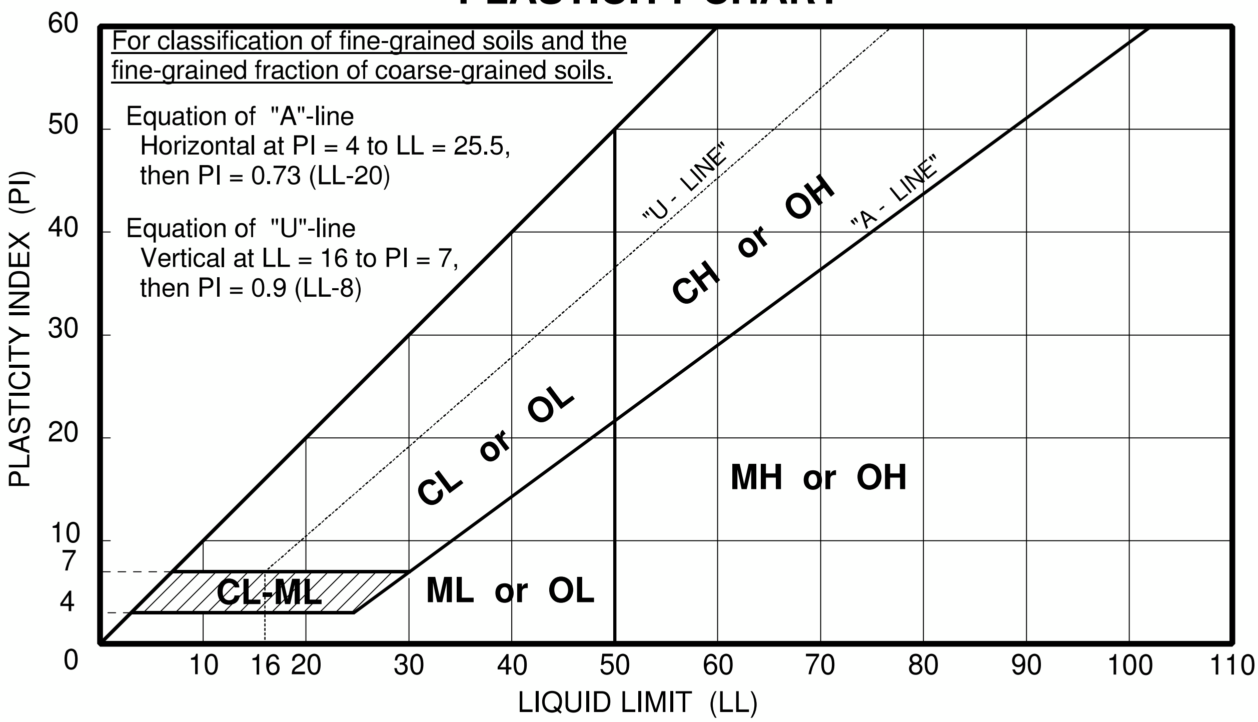
RELATIVE DENSITY*		RELATIVE CONSISTENCY*	
Granular, Noncohesive (Gravels, Sands, & Silts)	**Standard Penetration Test (blows/foot)**	**Fine-Grained, Cohesive (Clays)**	**Standard Penetration Test (blows/foot)**
Very Loose	0-4	Very Soft	0-2
Loose	5-10	Soft	3-4
Medium Dense	11-30	Firm	5-8
Dense	31-50	Stiff	9-15
Very Dense	+50	Very Stiff	15-30
		Hard	+30

*** Based on Sampler-Hammer Ratio of 8.929 E-06 ft/lbf and 4.185 E-05 ft^2/lbf for granular and cohesive soils, respectively (Terzaghi)**

PARTICLE SIZE RANGE

Sieve Openings (Inches)				Standard Sieve Sizes			
12"	3"	3/4"	No.4	No.10	No.40	No.200	<No.200
BOULDERS	COBBLES	GRAVELS		SANDS			SILTS & CLAYS
		Coarse	Fine	Coarse	Medium	Fine	(Distinguished By Atterberg Limits)

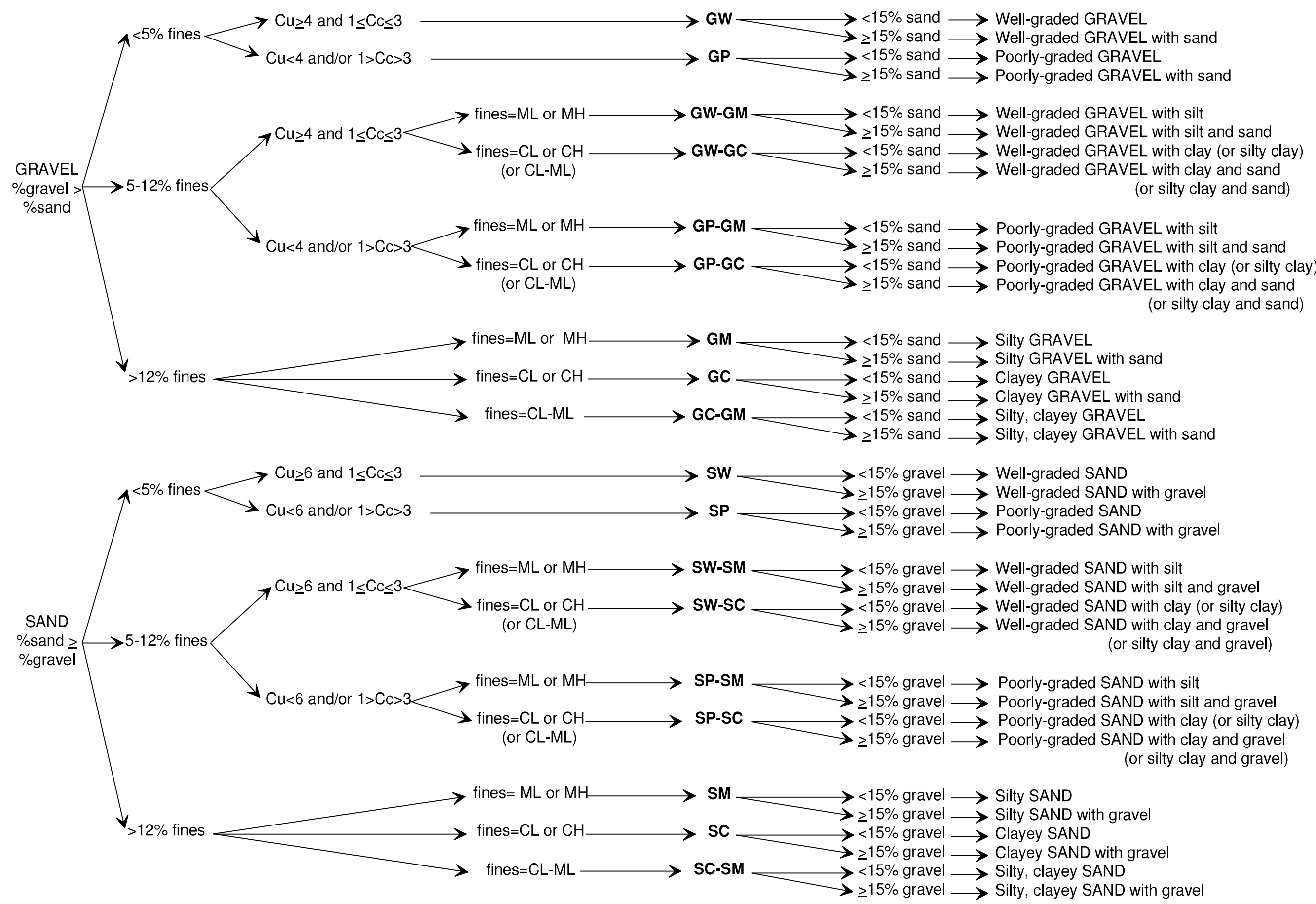
PLASTICITY CHART



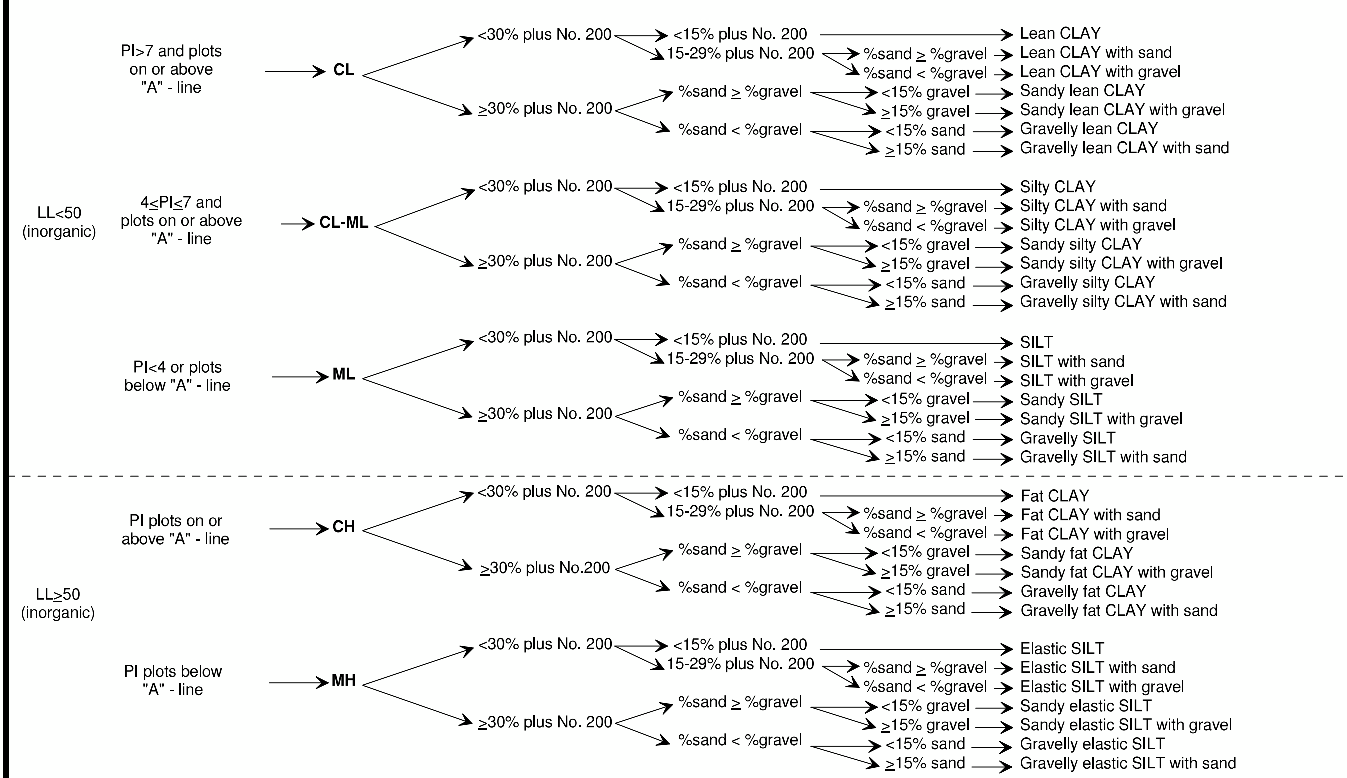
GW - Well-graded GRAVEL	SW - Well-graded SAND	CL - Lean CLAY
GP - Poorly-graded GRAVEL	SP - Poorly-graded SAND	ML - SILT
GM - Silty GRAVEL	SM - Silty SAND	OL - Organic SILT/CLAY
GC - Clayey GRAVEL	SC - Clayey SAND	CH - Fat CLAY
		MH - Elastic SILT
		OH - Organic SILT/CLAY

THOMAS, DEAN & HOSKINS
Engineering Consultants
Great Falls, Kalispell, Bozeman, Montana
Spokane, Washington, Lewiston, Idaho

ASTM D2487 CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

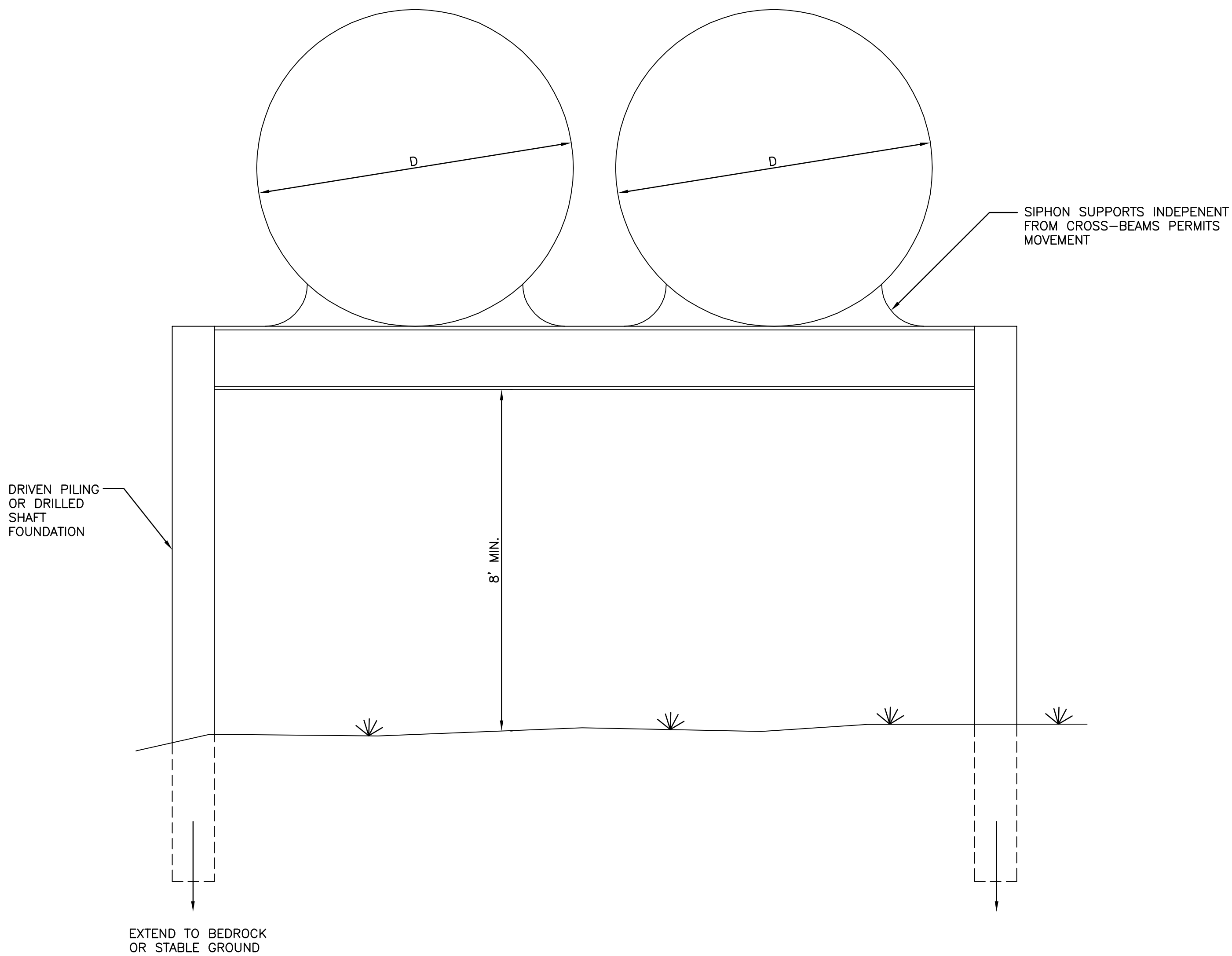


Flow Chart For Classifying Coarse-Grained Soils (More Than 50 % Retained On The No. 200 Sieve)



Flow Chart For Classifying Fine-Grained Soils (50 % Or More Passes The No. 200 Sieve)

03/98



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ST. MARY DIVERSION FACILITIES
ST. MARY RIVER SIPHON CROSSING

ELEVATED SIPHON
CONCEPTUAL DETAIL

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SPOKANE WASHINGTON
LEWISTON IDAHO

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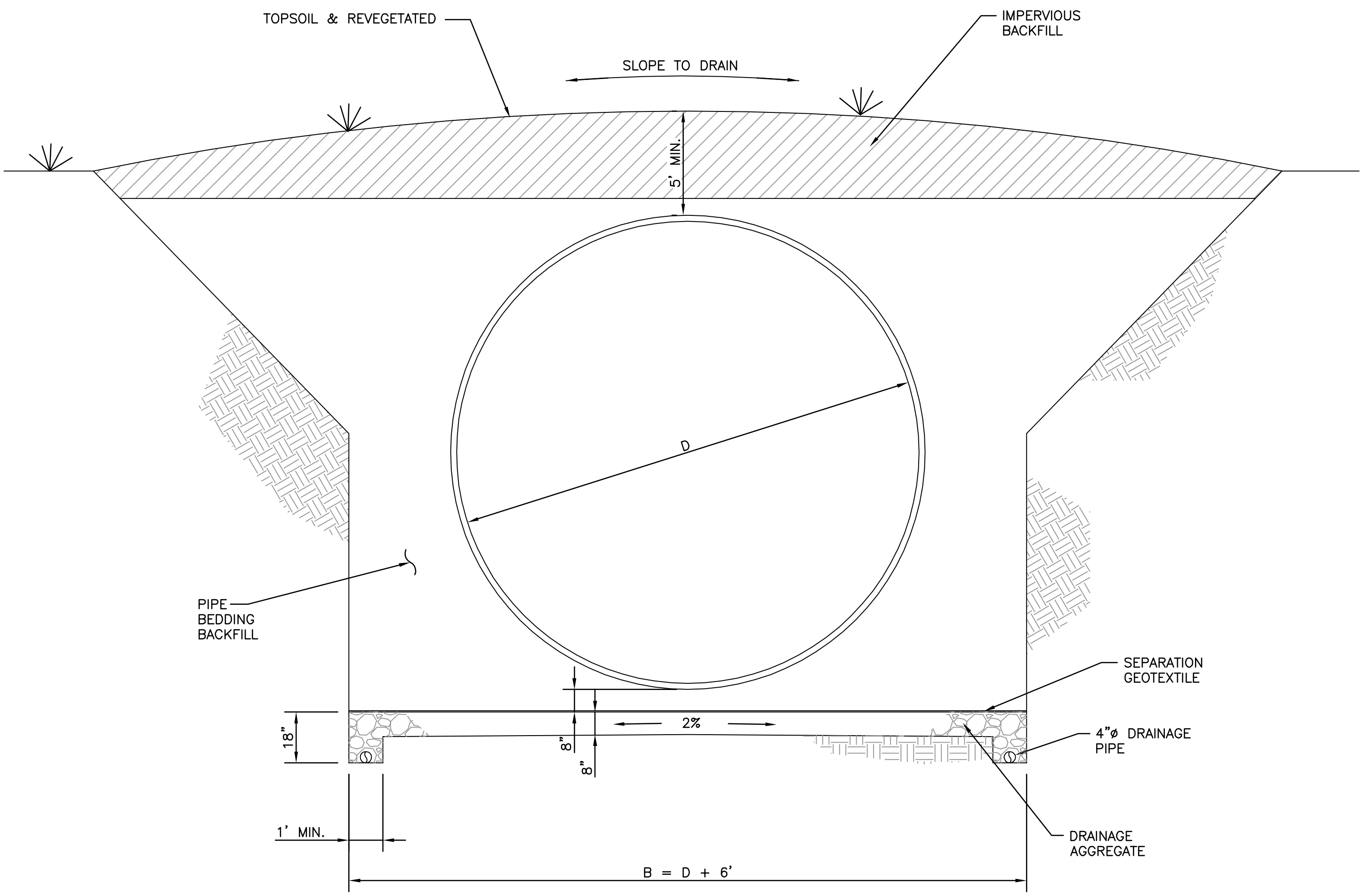
DESIGNED BY:	EAJ	JOB NO.	04-167
QUALITY CHECK:		CAD NO.	04167FigC1 .DWG

Figure C1



NOTES

1. DRAIN PIPE SHALL CONSIST OF A MINIMUM 4-INCH DIAMETER, GEOTEXTILE-WRAPPED, FLEXIBLE, SLOTTED PIPE, ADVANCED DRAINAGE SYSTEMS (ADS) WITH DRAIN GUARD OR APPROVED EQUIVALENT.
2. SEPARATION GEOTEXTILE SHALL BE GEOTEX 401, MIRAFI 140NC, DALCO 1040 OR APPROVED EQUIVALENT.
3. DRAINAGE AGGREGATE SHALL BE WASHED OR SCREENED GRAVEL CONFORMING TO THE FOLLOWING GRADATION:

SIEVE SIZE	PERCENT PASSING
1½-INCH	100
¾-INCH	75 - 95
⅜-INCH	10 - 20
NO. 4	0 - 5

4. DRAINS SHALL HAVE A POSITIVE SLOPE.

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ST. MARY DIVERSION FACILITIES
ST. MARY RIVER SIPHON CROSSING

BURIED SIPHON
CONCEPTUAL DETAIL

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SPOKANE WASHINGTON
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DRAWN BY:	RLR	DATE:	01/10/06	Figure C2
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QUALITY CHECK:		CAD NO.	04167Fig15 .DWG	