Appendix H – Geotechnical

Marsh Lake Dam

Ecosystems Restoration Feasibility Study

Geology and Geotechnical Appendix

OCTOBER 2010

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1. PURPOSE:

This appendix presents the general geology and specific geotechnical analysis for the Marsh Lake project.

2. SELECTED PLAN SUMMARY:

The tentatively selected plan features that require geotechnical input are listed below followed by their geotechnical-input requirement:

- Modifications to the Marsh Lake Dam to enable passive and active water level management. Provide structural section with soil parameters.
- Restore the Pomme de Terre River to its former channel near its confluence with the Minnesota River. Construct a bridge over the Pomme de Terre River to maintain access to the Marsh Lake Dam. Compute stable slopes, estimate settlement, and find suitable borrow.
- Provide for fish passage between Lac qui Parle Lake and Marsh Lake and the Pomme de Terre River. Design riprap and bedding.
- Construct rock wave-break islands in Marsh Lake to reduce wind fetch, wave action, and sediment resuspension to restore aquatic vegetation. Estimate amount of displacement expected.
- Install gated culverts in the Louisburg Grade Road to enable water level management in upper Marsh Lake. Design riprap and bedding.
- Construct recreational and educational features including a trail bridge over Marsh Lake Dam to connect with the Minnesota State Trail, fishing access on Marsh Lake, canoe access on the Pomme de Terre River, and an improved recreation area at Marsh Lake Dam. Provide structural section with soil parameters.

The selected plan is shown in the main report. Table H-1 below lists the approximate quantities of the various project features of the proposed plan along with their respective geotechnical design aspects.

Table H-1

Feature	Approximate Quantity	Geotechnical Design Aspects
Topsoil	4,000 yd^3	-Locate borrow area if not enough stripping
Excavation	35,000 yd^2	-Locate disposal area if excess
Diversion Dikes, Containment Levees (impervious fill)	35,000 yd^3	-Compute stable side slopes -Estimate settlement/displacement -Find and control areas of high seepage gradients -Locate borrow or disposal area
Breakwater Structures, Fishway Structure	125,000 TON	-Rock gradation -Rock source -Estimate settlement/displacement
Drawdown Structure	1	-Cofferdam design -Seepage analyses -Foundation design (bearing and settlement)
Louisburg Road Culverts	3	-Seepage check -Riprap design for pipe inlet/outlet
Bridges	2	Design of bridge foundations

The cost estimate assumed a sheet pile cofferdam and a thirty day dewatering effort to allow construction of the drawdown structure. The bridge over the Pomme de Terre River assumed a pile foundation. Assumptions and costs for this bridge were provided by the Minnesota DOT.

3. TOPOGRAPHY and PHYSIOGRAPHY

As the last glaciers in the southern Minnesota area retreated northward above the continental divide at Browns Valley and into the Red River Valley, vast Lake Agassiz - headwaters of the glacial River Warren - was formed. The River Warren, flowing to the southeast, began cutting and shaping the Minnesota Valley to its present form. Eventually, the retreating ice margin uncovered lower outlets, and Lake Agassiz, now draining to the north, was reduced to such a low elevation that River Warren ceased to flow. In its place, the Minnesota River became established.

The 2020 square mile, Upper Minnesota River Watershed, is one of the 13 major watersheds of the Minnesota River Basin. Situated within the Northern Glaciated Plains Ecoregion, the watershed can further be divided into three geomorphic settings: the headwaters flowing off the Coteau des Prairies, the lower basin-situated within the Blue Earth Till Plain, and the Minnesota River Valley-carved by the glacial River Warren.

The portion of the watershed within the Blue Earth Till Plain is represented by nearly level to gently sloping lands, ranging from 0-6% in steepness. Soils are predominantly loamy, with landscapes having a complex mixture of well and poorly drained soils. Drainage of depressional areas is often poor, and tile drainage is common. Water erosion potential is moderate on much of the land within this geomorphic setting.

The Coteau des Prairies or Highland of the Prairies, so named by French explorers, is a morainal plateau that occupies the headwaters of the Upper Minnesota River and several other rivers. In addition to being an impressive topographic barrier, the Coteau acts as an important drainage divide. Its well drained southwestern side sheds water into the Big Sioux River, while waters on the northeastern side flow into the Des Moines and Minnesota Rivers. The Coteau is characterized by landscapes with long northeast facing slopes which are undulating to rolling (2-18%). Soils are predominantly loamy and well drained.

Tributaries draining the Coteau and entering the Upper Minnesota River from South Dakota include the Little Minnesota River - headwaters of Big Stone Lake and the Whetstone River. Alluvial deposits at the mouth of the Whetstone River formed a natural dam and originally impounding Big Stone Lake. In 1973 a diversion was completed that directed flows of the Whetstone River directly into Big Stone Lake. Further modifications were made in the late 1980's with the completion of the Big Stone/Whetstone River Control Structure. This structure can redirect up to 1460 cubic feet per second (cfs) of flow from the Whetstone directly into the Minnesota River, bypassing the deposition of unwanted sediments and nutrients into Big Stone Lake during high flow periods.

Below Ortonville, the Minnesota is a small but distinct river. It flows for fifteen miles, passing through the Big Stone-Whetstone Reservoir (constructed during the 1970's) and further down receives the waters of the Yellow Bank River whose headwaters are also in South Dakota. The Upper Minnesota then meets Marsh Lake and Lac Qui Parle (meaning the Lake Which Talks). Both Marsh and Lac Qui Parle lakes are natural impoundments, dammed by alluvial fans of sediment deposited at the mouths of two major tributaries, the Pomme De Terre and Lac Qui Parle rivers respectively. The Pomme De Terre River comes down from the hills of the lake country to the north. The Lac Qui Parle River originates in the Coteau des Prairies, flows northeast through the prairies of the southwest, then confluences with the Minnesota River by Watson. Although they are natural reservoirs, the lakes were subject to some natural fluctuation; thus dams were built at the outlets for greater water control. The outlet of the Upper Minnesota River Watershed is below the Lac Qui Parle Reservoir, 288 miles upstream from the mouth of the Minnesota River.

Counties within the watershed include sections of Big Stone, Chippewa, Lac Qui Parle, Swift and Traverse. Land use within the watershed is primarily agricultural, with 76% of the available acres utilized for production of grain crops, mainly corn and soybeans. Of these acres, approximately 15% have been tiled to improved drainage. The majority of the crop-lands (82%) are classified as moderately productive. As of 1994, roughly eight percent of the agricultural acres within the Upper Minnesota River Watershed were classified as grasslands enrolled in the Conservation Reserve Program (CRP), a voluntary federal program that offers annual rental payments to farmers in exchange for planting areas of grass and trees on lands subject to erosion. Approximately thirty nine percent of the lands draining into the Upper Minnesota River have a high water erosion potential and twenty six percent have the potential for significant wind erosion. Water erosion potential is highest on lands draining the Coteau region.

4. REGIONAL GEOLOGY and STRATIGRAPHY

Marsh Lake is part of the Minnesota River flowage. The pertinent geology and stratigraphy are related to the last glacier that retreated from the area approximately 14000 years ago. As the glacier retreated north, the melting ice margin headed the ancestral Minnesota River. The glacier eventually retreated north of the topographic divide, near Browns Valley, and meltwater ponded behind the divide to form Glacial Lake Agassiz. When the meltwater raised the lake enough to overtop the drainage divide, a southern outlet stream, the River Warren, discharged from the lake. The River Warren carved the present oversized valley now occupied by the Minnesota River. Lake Agassiz ultimately drained to the northeast, allowing the Minnesota River to aggrade and adjust to the local conditions. The original Marsh Lake was formed by the damming effect of a delta at the mouth of the Pomme de Terre River. The present Marsh Lake is ponded behind a man-made embankment nearly two miles long that connects the lower river valley walls at elevation 950.

Bedrock- Bedrock lies at an estimated depth greater than 200 feet beneath the glacial sediments in the region. The bedrock is likely composed of Paleozoic Era, Cretaceous Period sedimentary rock or granitic intrusive rocks. The bedrock lies well below the influence of the proposed project.

Glacial Till- Overlying the bedrock are the numerous till layers that were deposited predominately out of the Des Moines lobe, though some older units are encountered in the area. Dark gray, medium stiff to hard, sandy, gravelly till was encountered in boring 09-15M at 930 feet and older borings taken in 1972 and 1986 show the average till elevation is about 927 feet except for the area just east of the concrete dam where the till surface dips to about 885. A two to three-foot- thick zone of soft to medium stiff reworked or disturbed till tops the firm till beneath the west portion of the embankment. Till deposits vary in thickness from over 300 feet deep within the Bigstone Moraine, north of the project area, to nonexistent at exposed bedrock along the Minnesota River farther downstream.

Stream sediment from Glacial River Warren- As the River Warren flowed through the underlying till it both cut channels and deposited sediments. These deposits are found as stratified sand and gravel bars, and may be interbedded with finer sediments from stagnant periods, as seen in borehole 09-17M. This unit is found locally at elevation 935 feet, and extends below the end of the borehole at elevation 905.5.

Present day Alluvium- Recent, upper level soils consist of stream sediments of the Pomme de Terre River, channel fill of organics and clays and lake sediments from Marsh Lake. Varying OH, OL and CH are encountered in most boreholes, and these fine sediments vary in thickness depending on the depositional mechanism, and the channel topography from the stream cuts. The upper portion of the alluvium is commonly highly organic and very soft to medium stiff. The lower portion is sparsely organic and stiff. It contains shells, and ranges from black to greenish gray to gray.

Embankment fill- Borings taken in 1972 and 1986, and 09-16M show the embankment material averages fourteen feet in thickness and is clay, variably silty and sandy with minor amounts of organics and roots.

5. SEISMIC RISK and EARTHQUAKE HISTORY

According to Corps of Engineers Regulation ER 1110-2-1806, Earthquake Design Analysis for Corps of Engineers Projects, the entire state of Minnesota is located within earthquake Seismic Risk Zone 0. The Uniform Building Code of the International Conference of Building Officials assigns every location in the United States to a four grade Seismic Risk Zone (0 = least risk, 3 = greatest risk).

In Minnesota there are few faults that could possibly affect the project. The Morris fault extends diagonally from the town of Morris, Minnesota to the Brainerd area in west-central Minnesota, roughly 30 miles southeast of Marsh Lake. The Morris fault, it is confined to the Precambrian bedrock and is not considered tectonically active, although some seismic activity has been associated with the Morris fault. In 1975, an earthquake with a Modified Mercalli Intensity of VI occurred near the town of Morris. This earthquake occurred about 10 miles west-northwest of Morris at a depth of 3-5 miles. It is one of the best documented earthquakes in Minnesota history, and possibly the largest. In Fargo and in Valley City, North Dakota, a Modified Mercalli Intensity of II (felt by persons at rest, on upper floors, or favorably placed) was assigned for this event. However, it was not felt north of Grand Forks, North Dakota. The Modified Mercalli Intensity Scale ranges from I (not felt) to XII (damage nearly total). Five other earthquakes have been linked to the Morris fault since the year 1860. The most recent earthquake in Minnesota occurred along the western edge of the Morris fault in 1993 near the town of Graceville. It had a magnitude of 4.1 on the Richter scale and a Mercalli Intensity of V. The Graceville earthquake occurred at an estimated depth of 7 miles.

Eighteen recorded earthquakes have occurred in Minnesota since 1860. Some are associated with glacial isostatic rebound, particularly in the northeast region of the state near Duluth. No earthquake has exceeded the magnitude or intensity of the Morris event in 1975. An approximate frequency of between 10 and 30 years has been established for minor earthquakes in Minnesota. The seismic risk assessment for the Red River Valley region relies largely on earthquake history. The absence of major or catastrophic earthquakes, coupled with the infrequency of these earthquakes in general, implies an extremely low risk level for seismic activity in the vicinity of Marsh Lake.

6. SUBSURFACE INVESTIGATIONS

A total of 21 soil borings including several test pits and several hand augers were advanced by the St. Paul District in the project area in the years from 1972 through 2009. However, for the selected plan, the 5 borings shown on Plates H-3 taken in 2009 contain the most relevant geotechnical information. Therefore, only these boring locations and logs are presented on Plate H-1 through H-3. Borings 09-18A through 09-21A are short, hand auger borings taken for environmental sampling and provide no meaningful geotechnical information. As a result, these borings were not included on Plate H-3. Limited index testing was completed to delineate the contact between the different geologic units. Tests taken from samples consist of Atterberg limits, natural moisture content, consolidation, and triaxial compression tests. Results of the all the laboratory tests taken in the Marsh Lake Dam area are shown on the Plate H-5. Table H-2, below, summarizes the consolidation tests results:

Table H-2: Consolidation Testing Summary

Formation	LL	PL	PI	Liquidity	ω_0	C_c	e_o	γ_{sat}	γ_{moist}	OCR
09-15MU - OL	47	16	31	0.60	34.7%	0.37	1.025	112.9	109.5	2.5
09-17MU - OH	81.2%	31.4%	49.8%	0.73	68.0%	0.53	1.755	97.7	97.4	1.0

7. SITE HYDROGEOLOGY

Currently insufficient data exists for a detailed site specific groundwater characterization at the Marsh Lake project site. Commonly, groundwater levels in the project area are high. Groundwater will be located within ten feet below the ground surface. Water levels fluctuate seasonally, with fall /winter conditions exhibiting the lowest measured water levels as might be expected.

8. CONSTRUCTION MATERIALS

Borrow Source. The impervious dike borrow will tentatively be obtained from an area shown on Plate H-4. Archeological investigations must be completed before any borrow sites may be used for the project. In addition, geotechnical characterization of the borrow site must occur prior to approval. The investigation should determine the thickness of topsoil present, the thickness and suitability of foundation soils for impervious borrow, and the natural moisture content and Proctor density of the soils.

Concrete Aggregate, Riprap, and Bedding. Sources for fine and coarse concrete aggregate, bedding, and riprap should be available locally. Most commercial aggregates in the Marsh Lake vicinity are obtained from sand and gravel deposits, and quarried rock located along the Minnesota River valley within 40 miles of the project site. Additional investigations will be necessary prior to plans and specifications in order to accurately quantify and test the quality of the stone product available within a reasonable radius of the area.

9. SETTLEMENT AND DISPLACEMENT:

The computer program CSETT was used to estimate the consolidation settlement expected. However, the two consolidation tests that were done for this project resulted in C_c and e_0 that varied by the formation sampled, as shown in the testing summary above in Table H-2. Soil stratigraphy from boring no. 09-17M was used to compute settlement for the diversion dike and boring no. 09-15M was used for the road raise. The CSETT input for both the diversion dike and the road raise is shown on Plate H-6 with the output on Plate H-7. The road raise was computed for two loads. The existing embankment was the first load and the proposed road raise was the second. No overbuild for settlement was included for Diversion Dike B. Table H-5 summarizes the results, below:

Table H-5: Computed Settlement

Feature	Diversion Dike A (Base Elev. 940)	Road Raise
Settlement (inches)	20	8

10. SLOPE STABILITY:

Criteria in EM 1110-2-1902 were used for this analysis. The following tables in this EM define shear strengths, pore pressures, and Factors-of-safety required for static design conditions:

Table 2-1
Shear Strengths and Pore Pressures for Static Design Conditions

Design Condition	Shear Strength	Pore Water Pressure
During Construction and End-of-Construction	Free draining soils – use drained shear strengths related to effective stresses[1]	Free draining soils – Pore water pressures can be estimated using analytical techniques such as hydrostatic pressure computations if there is no flow, or using steady seepage analysis techniques (flow nets or finite element analyses).
	Low-permeability soils – use undrained strengths related to total stresses[2]	Low-permeability soils – Total stresses are used; pore water pressures are set to zero in the slope stability computations.
Steady-State Seepage Conditions	Use drained shear strengths related to effective stresses.	Pore water pressures from field measurements, hydrostatic pressure computations for no-flow conditions, or steady seepage analysis techniques (flow nets, finite element analyses, or finite difference analyses).
Sudden Drawdown Conditions	Free draining soils – use drained shear strengths related to effective stresses.	Free draining soils – First-stage computations (before drawdown) – steady seepage pore pressures as for steady seepage condition. Second- and third-stage computations (after drawdown) – pore water pressures estimated using same techniques as for steady seepage, except with lowered water level.
	Low-permeability soils – Three-stage computations: First stage--use drained shear strength related to effective stresses; second stage--use undrained shear strengths related to consolidation pressures from the first stage; third stage--use drained strengths related to effective stresses, or undrained strengths related to consolidation pressures from the first stage, depending on which strength is lower – this will vary along the assumed shear surface.	Low-permeability soils – First-stage computations--steady-state seepage pore pressures as described for steady seepage condition. Second-stage computations – total stresses are used; pore water pressures are set to zero. Third-stage computations -- same pore pressures as free draining soils if drained strengths are used; pore water pressures are set to zero where undrained strengths are used.

[1] Effective stress shear strength parameters can be obtained from consolidated-drained (CD, S) tests (direct shear or triaxial) or consolidated-undrained (CU, $\overline{R}$) triaxial tests on saturated specimens with pore water pressure measurements. Repeated direct shear or Bromhead ring shear tests should be used to measure residual strengths. Undrained strengths can be obtained from unconsolidated-undrained (UU, Q) tests. Undrained shear strengths can also be estimated using consolidated-undrained (CU, R) tests on specimens consolidated to appropriate stress conditions representative of field conditions; however, the "R" or "total stress" envelope and associated c and ϕ, from CU, R tests should not be used.

[2] For saturated soils use $\phi = 0$. Total stress envelopes with $\phi > 0$ are only applicable to partially saturated soils.

Table 3-1
Minimum Required Factors of Safety: New Earth and Rock-Fill Dams

Analysis Condition[1]	Required Minimum Factor of Safety	Slope
End-of-Construction (including staged construction)[2]	1.3	Upstream and Downstream
Long-term (Steady seepage, maximum storage pool, spillway crest or top of gates)	1.5	Downstream
Maximum surcharge pool[3]	1.4	Downstream
Rapid drawdown	1.1-1.3[4,5]	Upstream

[1] For earthquake loading, see ER 1110-2-1806 for guidance. An Engineer Circular, "Dynamic Analysis of Embankment Dams," is still in preparation.
[2] For embankments over 50 feet high on soft foundations and for embankments that will be subjected to pool loading during construction, a higher minimum end-of-construction factor of safety may be appropriate.
[3] Pool thrust from maximum surcharge level. Pore pressures are usually taken as those developed under steady-state seepage at maximum storage pool. However, for pervious foundations with no positive cutoff steady-state seepage may develop under maximum surcharge pool.
[4] Factor of safety (FS) to be used with improved method of analysis described in Appendix G.
[5] FS = 1.1 applies to drawdown from maximum surcharge pool; FS = 1.3 applies to drawdown from maximum storage pool. For dams used in pump storage schemes or similar applications where rapid drawdown is a routine operating condition, higher factors of safety, e.g., 1.4-1.5, are appropriate. If consequences of an upstream failure are great, such as blockage of the outlet works resulting in a potential catastrophic failure, higher factors of safety should be considered.

Soils parameters for various formations are shown below in Table H-3 for the Marsh Lake borings.

Table H-3

	Unit weights		Unconsolidated-Undrained Strengths (UU)		Consolidated-Drained Strengths (CD)	
	Moist (pcf)	Saturated (pcf)	c in psf	ϕ in degrees	c' in psf	ϕ' in degrees
COMPACTED DIKE FILL (ESTIMATED FROM EARTH MANUAL)	120	120	(1300)	(0)	(0)	(25)
OH DEPOSITS TESTED (ESTIMATED)	97	97	140	0	(0)	(20)
OL DEPOSITS TESTED (ESTIMATED)	110	115	(840)	(0)	200	30
CL TESTED (ESTIMATED)	110	115	(840)	(0)	200	30
CH TESTED (ESTIMATED)	97	97	140	0	(0)	(25)
SM (ESTIMATED)	130	130	- -	- -	(0)	(33)
GW (ESTIMATED)	130	135	- -	- -	(0)	(30)

End-of-Construction (EOC) and steady state seepage design conditions apply to the diversion dikes. These stability cases were analyzed using the computer program SLOPE/W with the soil stratigraphy from boring number 09-17M. Slope stability calculations were completed using the shear strengths and unit weights shown in Table H-3, above. The pool was set equal to elevation 947.1 or maximum storage pool and the toe of slope equal to 936 for the thalweg sections and

940 for the overbank section. UU-strength values for the compacted dike fill was obtained from the *Earth Manual,* Third Edition, 1998, Table 1-3 on page 50 assuming a CL soil is used for construction. For the EOC case, shear strengths obtained from Unconsolidated-Undrained triaxial testing results were used for design. Long-term stability cases utilized CD-shear strengths, fully softened friction angles with zero cohesion, obtained from Figure 5.18 in "Soil Strength and Slope Stability", 1st Edition, page 50 (J. Michael Duncan and Stephen Wright, 2005).

The overbank portion of Dike A assumes a 40 foot toe drain and a tail water of 942.0. The toe drain was needed to draw the phreatic surface away from the downstream embankment slope, in order to meet the long-term minimum required factor of safety. The steepest stable slope computed for the Dike A was 1V:4H. In order to achieve an adequate factor of safety for the Dike A, berms with a 45 foot top width; a top elevation of 940; and side slopes of 1V:4H were needed upstream and downstream. Diversion Dike B did not require a toe drain or stability berms to meet minimum required factors of safety. Selected stability analyses were checked and confirmed with the computer program UTEXAS4. All of the SLOPE/W results are shown in Table H-4 below. In all the cases, the required minimum factors of safety were met. The critical results from the stability analyses (shown in red in Table H-4) are presented on Plates H-8.

Table H-4: Computed Factor-of-Safety

			Block		Circular			
Embankment Section	Shear Strength	FS Required	Optimized	Non-opt.	Optimized	Non-opt.	Crack Defined	Notes
Dike A Thalweg Section	U-U	1.3	1.30	1.38	1.40	1.61	10' Deep	
Dike A Thalweg Section	C-D	1.5	1.66	1.78	1.65	1.68	No Crack Needed	
Dike A Overbank Section	U-U	1.3	1.31	1.38	1.30	1.48	7' Deep	
Dike A Overbank Section	C-D	1.5	1.50	1.81	1.80	1.84	No Crack Needed	With cutoff.
Dike B	U-U	1.3	1.48	1.62	1.52	1.65	Search	
Dike B	C-D	1.5	2.18	2.40	2.17	2.20	No Crack Needed	
Road Raise	U-U	1.3	2.86	3.09	2.81	2.99	Search	
Road Raise	C-D	1.5	1.57	1.87	1.58	2.27	No Crack Needed	

Means required FS not met

Means minimum FS for section

11. SEEPAGE

The amount of seepage for this project is not important because the intent of the project does not involve keeping areas from getting wet from seepage. Seepage was only considered when computing the slope stability during steady state seepage conditions. The pore water pressures used in the stability computations were from steady state conditions computed using SEEP/W. Seepage under the diversion dikes through the near surface sand layers will likely need to be cut off by construction of an impervious backfilled trench beneath the embankment to prevent piping. Seepage under and around the proposed drawdown structure will have to be analyzed as the structural design proceeds.

12. CONSTRUCTABILITY:

The culverts on Louisburg Grade Road, the breakwaters, the fishway, the fish pond notch, and the road raise can be constructed any time. However, the order of construction of excavation of the old Pomme de Terre River channel, the diversion dikes, and bridge over the Pomme de Terre River along Marsh Lake dam is important. The bridge and the excavation of the old Pomme de Terre River channel should be done first. Then Dike A should be constructed next, followed by Dike B. The Dike A needs to be constructed out of impervious fill and is significantly taller requiring compaction of its fill to be stable. This means the site will have to be dewatered. Two dewatering berms built to at least elevation 941 were taken into account in stability computations, so they will need to be left in place. The other cutoff dike that forces the water of the Pomme de Terre River to flow through its former channel can be constructed from pervious fill.

13. ROCK GRADATION:

The calculation of the minimum diameter of the 50 percent-less-than-by-weight rock for the rockfill for fishway is explained in the Hydraulic Appendix and is 1.6 feet. The layer thickness with this diameter and assuming turbulent flow conditions is 54-inches thick and its gradation is shown in Plate H-9 and Table H-5, below:

Table: H-5

Percent Less-than-by-Weight:	Maximum (lbs.)	Minimum (lbs.):
100	2330	930
50	690	470
15	350	150

14. FUTURE WORK:

- Design of an impervious cut-off of the sand layer for thalweg portion of Dike A.
- Stability evaluation of the slopes for the bridge over the Pom de Terre River, the water control structure, spillway alterations, and culvert at the Louis Grade Road.
- Seepage analysis under/around the drawdown structure.
- Define riprap gradation and extent of riprap for downstream of Louisburg Grade road culverts.
- Test the borrow sites for suitability as impervious fill; prior to borrow site approval determine the thickness of topsoil, natural moisture content, and Proctor density.

- Estimate displacement expected at the proposed breakwaters.

Bibliography

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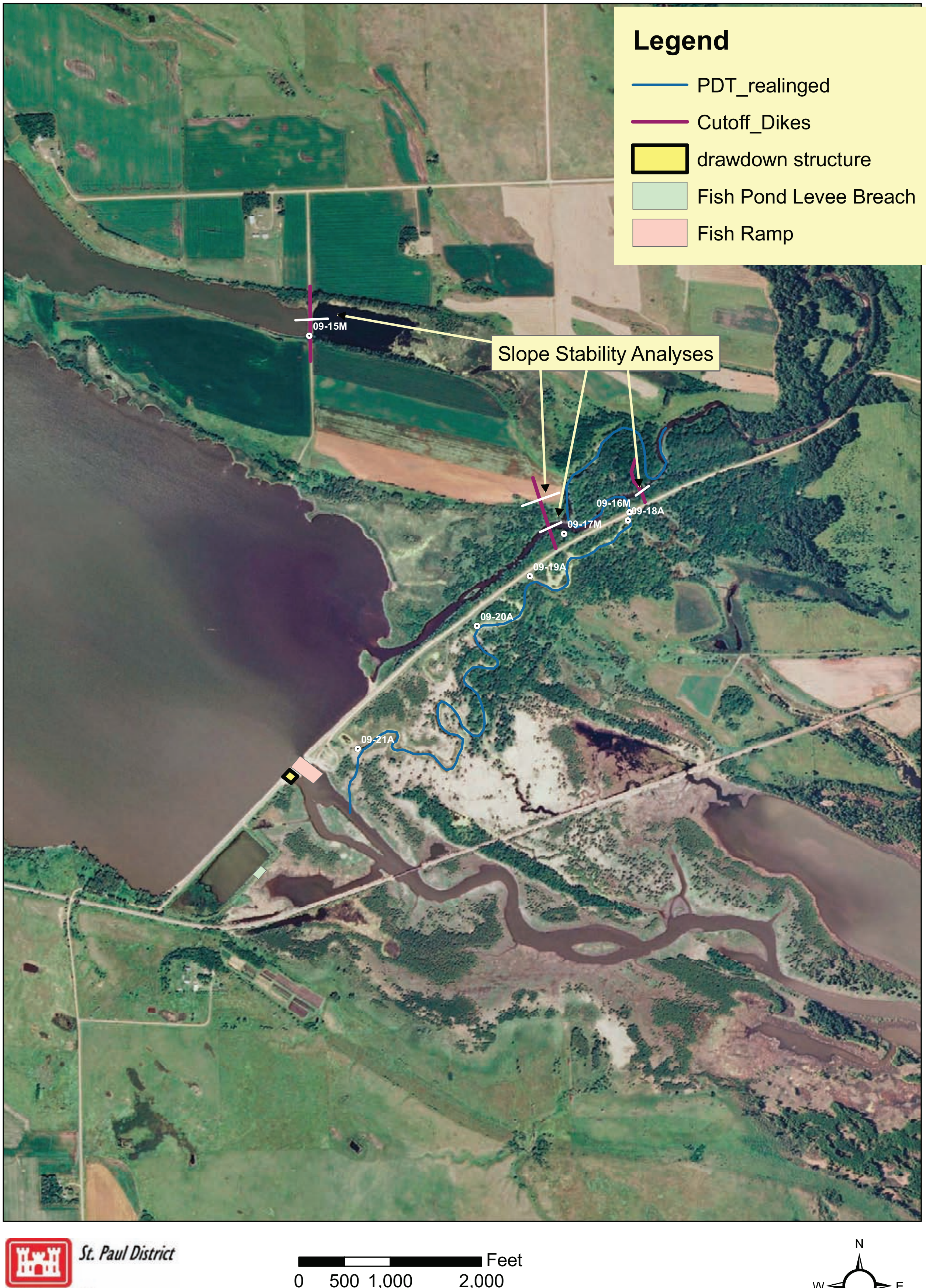
Marsh Lake Dam: Boring Locations

St. Paul District
US Army Corps of Engineers®

0 2,000 4,000 8,000 Feet

Marsh Lake Project: Boring Locations



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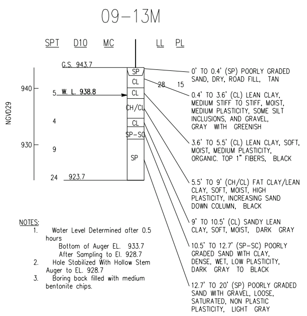
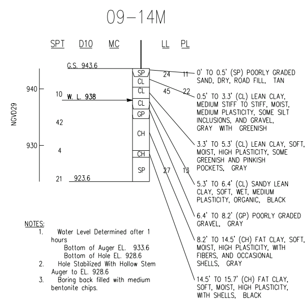
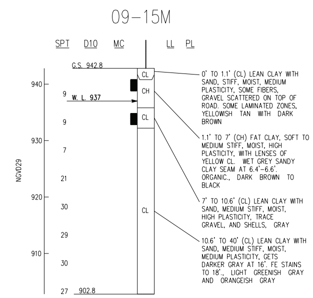


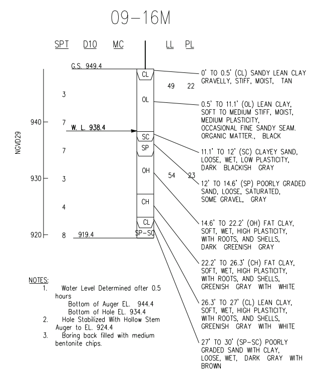
NOTES:
1. Water Level Determined after 0.5 hours
   Bottom of Auger EL. 933.7
   After Sampling to El. 928.7
2. Hole Stabilized With Hollow Stem Auger to EL. 928.7
3. Boring back filled with medium bentonite chips.



NOTES:
1. Water Level Determined after 1 hours
   Bottom of Auger EL. 933.6
   Bottom of Hole EL. 928.6
2. Hole Stabilized With Hollow Stem Auger to EL. 928.6
3. Boring back filled with medium bentonite chips.



NOTES:
1. Water Level Determined after 0.5 hours
   Bottom of Auger EL. 932.8
   Bottom of Hole EL. 927.8
2. Hole Stabilized With 4" casing to EL. 932.8
3. Undisturbed samples taken in offset hole
4. Boring Backfilled with tremied high solids bentonite grout.



NOTES:
1. Water Level Determined after 0.5 hours
   Bottom of Auger EL. 944.4
   Bottom of Hole EL. 934.4
2. Hole Stabilized With Hollow Stem Auger to EL. 924.4
3. Boring back filled with medium bentonite chips.

GENERAL BORING LEGEND

84-1M	YEAR OF BORING-BORING NUMBER, BORING TYPE (EG: M=MACHINE, A=AUGER, TP=TEST PIT, P=PIEZOMETER).
1 MAY 1984	DATE OF BORING
G.S. 1020.2	GROUND SURFACE ELEVATION AT BORING
GW	WELL GRADED GRAVELS, GRAVEL - SAND MIXTURE, LITTLE OR NO FINES
GP	POORLY GRADED GRAVELS, LITTLE OR NO FINES
GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
SW	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SM	SILTY SANDS, SAND - SILT MIXTURES
SC	CLAYEY SANDS, SAND - CLAY MIXTURES
ML	INORGANIC SILTS, LIQUID LIMIT LESS THAN 50
MH	INORGANIC SILTS, LIQUID LIMIT GREATER THAN 50
CL	INORGANIC CLAYS, LOW TO MED. PLASTICITY, LIQUID LIMIT LESS THAN 50
CH	INORGANIC CLAYS, HIGH PLASTICITY, LIQUID LIMIT GREATER THAN 50
OL	ORGANIC SILTS OR CLAYS, LOW PLASTICITY, LIQUID LIMIT LESS THAN 50
OH	ORGANIC SILTS OR CLAYS, MED. TO HIGH PLASTICITY, LIQUID LIMIT GREATER THAN 50
PT	PEAT
SP-SM	BORDERLINE MATERIAL
SP& SM	STRATIFIED MATERIAL
1	LOCATION AND SAMPLE NUMBER FOR UNDISTURBED SAMPLE
	NO RECOVERY
W.L. 726.7	WATER LEVEL ON DATE OF BORING
700.0	ELEVATION AT BOTTOM OF BORING

GENERAL BORING NOTES

1. GENERAL: THE UNIFIED SOIL CLASSIFICATION SYSTEM IS USED TO IDENTIFY BASIC SOIL TYPE. THE LEGEND REPRESENTS ONLY THE BASIC SOILS. TO COMPLETE THE CLASSIFICATION, PERTINENT INFORMATION IS ADDED TO THE RIGHT OF THE BORING STAFF, NOTES PERTAINING TO A SPECIFIC BORING ARE SHOWN BELOW THE BORING STAFF.

2. MOISTURE CONTENT: THE NATURAL MOISTURE CONTENT IN PERCENT OF DRY WEIGHT (MC) IS SHOWN TO THE LEFT OF THE BORING STAFF.

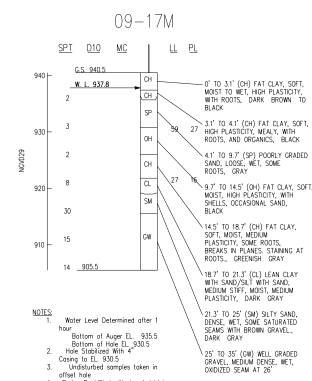
3. BLOW COUNT (SPT): BLOW COUNTS ARE SHOWN TO THE LEFT OF THE BORING STAFF AND, EXCEPT AS NOTED, ARE THE NUMBER OF BLOWS NECESSARY TO DRIVE THE SAMPLER USED A DISTANCE OF 12". STANDARD BLOW COUNTS ARE FOR A STANDARD PENETRATION TEST (SPT) USING A 1⅜" X 2" SAMPLER, 140 LB. HAMMER AND A 30" DROP. FOR NON-STANDARD BLOW COUNTS, SAMPLER SIZE, HAMMER WEIGHT AND HEIGHT OF DROP ARE AS SHOWN.

4. ATTERBERG LIMITS: LIQUID LIMIT (LL) AND PLASTIC LIMIT (PL) ARE SHOWN TO THE RIGHT OF THE BORING STAFF.

5. D_{10} SIZE: THE GRAIN SIZE IN MILLIMETERS OF WHICH 10% OF THE SAMPLE IS FINER IS SHOWN TO THE LEFT OF THE BORING STAFF.

6. ELEVATIONS REFERENCED TO N.G.V.D. 1929 ADJUSTED ELEVATION.

7. THE BORINGS SHOW SUMMARIES OF INFORMATION RECORDED ON THE ORIGINAL FIELD LOGS. THESE LOGS ARE AVAILABLE FOR INSPECTION AT THE ST. PAUL DISTRICT OFFICE. ARRANGEMENTS TO INSPECT LOGS CAN BE MADE BY CALLING (651) 290-5599.



NOTES:
1. Water Level Determined after 1 hour
   Bottom of Auger EL. 935.5
   Bottom of Hole EL. 930.5
2. Hole Stabilized With 4" Casing to EL. 930.5
3. Undisturbed samples taken in offset hole
4. Boring Backfilled with tremied high solids bentonite grout.

US Army Corps of Engineers
St. Paul District

Symbol	Description	Date	Appr.

DEPARTMENT OF THE ARMY
ST. PAUL, MINNESOTA
CORPS OF ENGINEERS
ST. PAUL DISTRICT

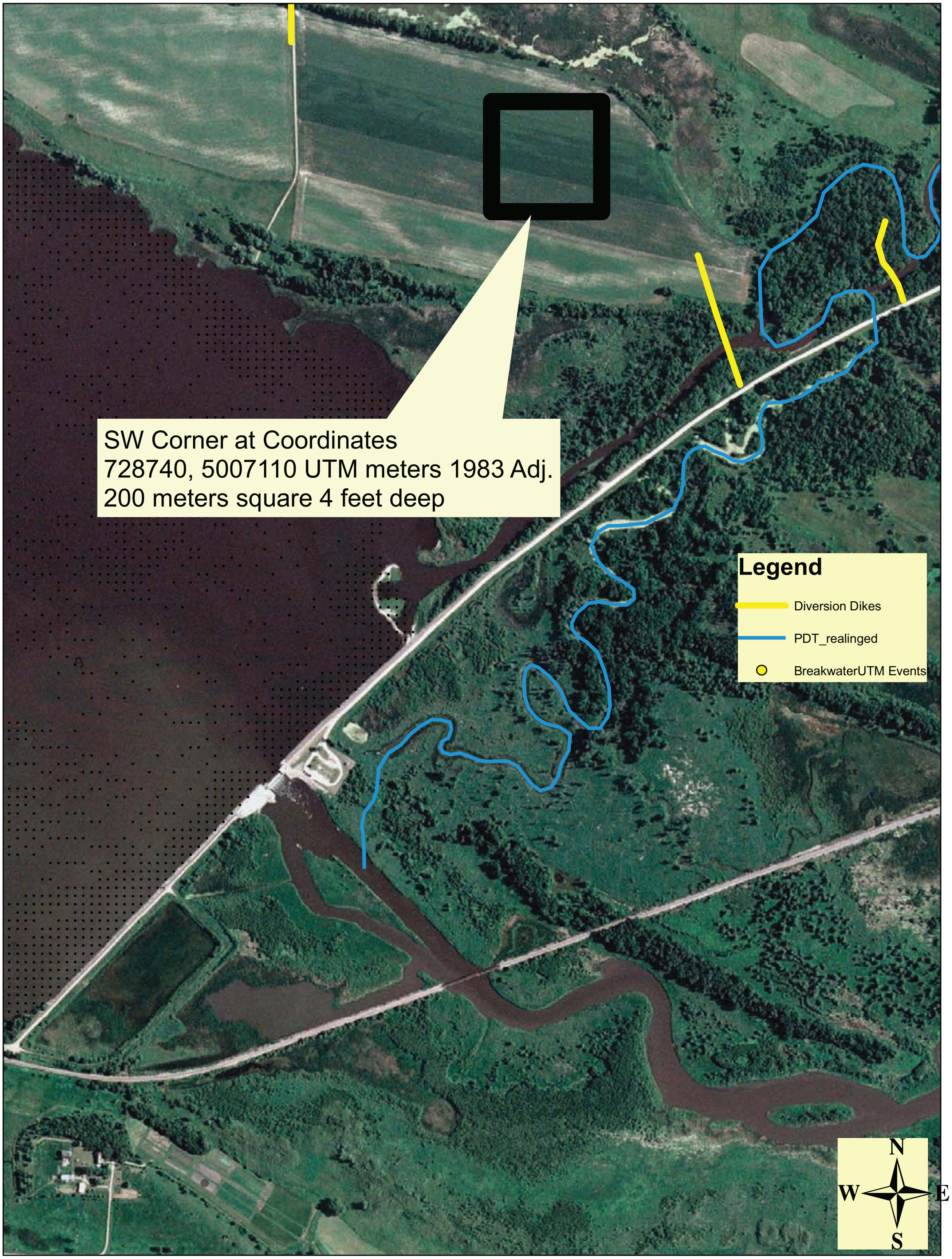
ED-D DESIGNED: JJF CHECKED: KSN DRAWN: JJF
ED-H DESIGNED: CHECKED:
SCALE: AS SHOWN DATE: OCT. 2010
CADD FILE NAME:
SOL. NO:
AE APPROVING OFFICIAL:

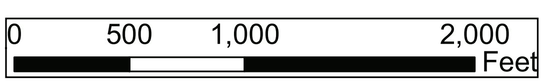
FEASABILITY STUDY
GEOLOGICAL DATA
AQUATIC ECOSYSTEM RESTORATION
MARSH LAKE DAM APPLETON, MINNESOTA
BORING LOGS
09-13M THROUGH 09-17M

DRAWING NUMBER:
SHT OF

PLATE H-3

Marsh Lake Dam: Borrow Location





St. Paul District

US Army Corps of Engineers®

SET Job#: **7223**

Extrusion Log

Date: 10/7/2009

Project/Client: Marsh Lake: Stage 1

Boring #	Sample#	Depth(ft)	Recovery (in)		Soil Description
09-17MU	1	12-14	BE:	21	Top 11.5" Organic Clay with shells and shell fragments, a few roots and rootlets, black (OH)
			AE:	20.5	Bottom 9" Lean Clay with sand and a trace of gravel and organics
					a few roots and rootlets and shell fragments, gray (CL)
09-17MU	2	15-16.5	BE:	15.5	Top 9.5" Lean Clay with a trace of gravel, gray (CL)
				15.5	Bottom 6" Silty Clay with sand and a trace of gravel, gray (CL-ML) *see below
					* Bottom has less clay and more silt than top of sample

Atterberg Limit (Plasticity Index) (ASTM:D4318)

Job: 7223

Project/Client: Marsh Lake: Stage 1 /// USACE St. Paul Division

Date: 10/21/09

Sample Information & Classification

Boring #	09-13	09-14	09-15	09-15	09-16	09-16	09-17	09-17
Sample #	1	1	2	6	1	5	4	6
Depth (ft)	3-3.5	1-2	3-4	18-19	3-4	18-19	10-11	19-19.5
Type or BPF								
Soil Classification	Sandy Lean Clay (CL)	Sandy Lean Clay (CL)	Lean Clay w/sand and a trace of organic material (CL)	Sandy Lean Clay w/a little gravel (CL)	Organic Clay w/a few rootlets (OL)	Organic Clay w/a few shells and rootlets (OH)	Organic Clay w/a few shells and rootlets and a trace of sand (OH)	Lean Clay (CL)
Atterberg Limits								
Liquid Limit	27.6	23.7	46.6	27.5	49.1	54.3	58.6	27.1
Plastic Limit	14.9	11.3	21.5	12.7	22.3	22.6	27.2	16.4
Plasticity Index	12.7	12.4	25.1	14.8	26.8	31.7	31.4	10.7

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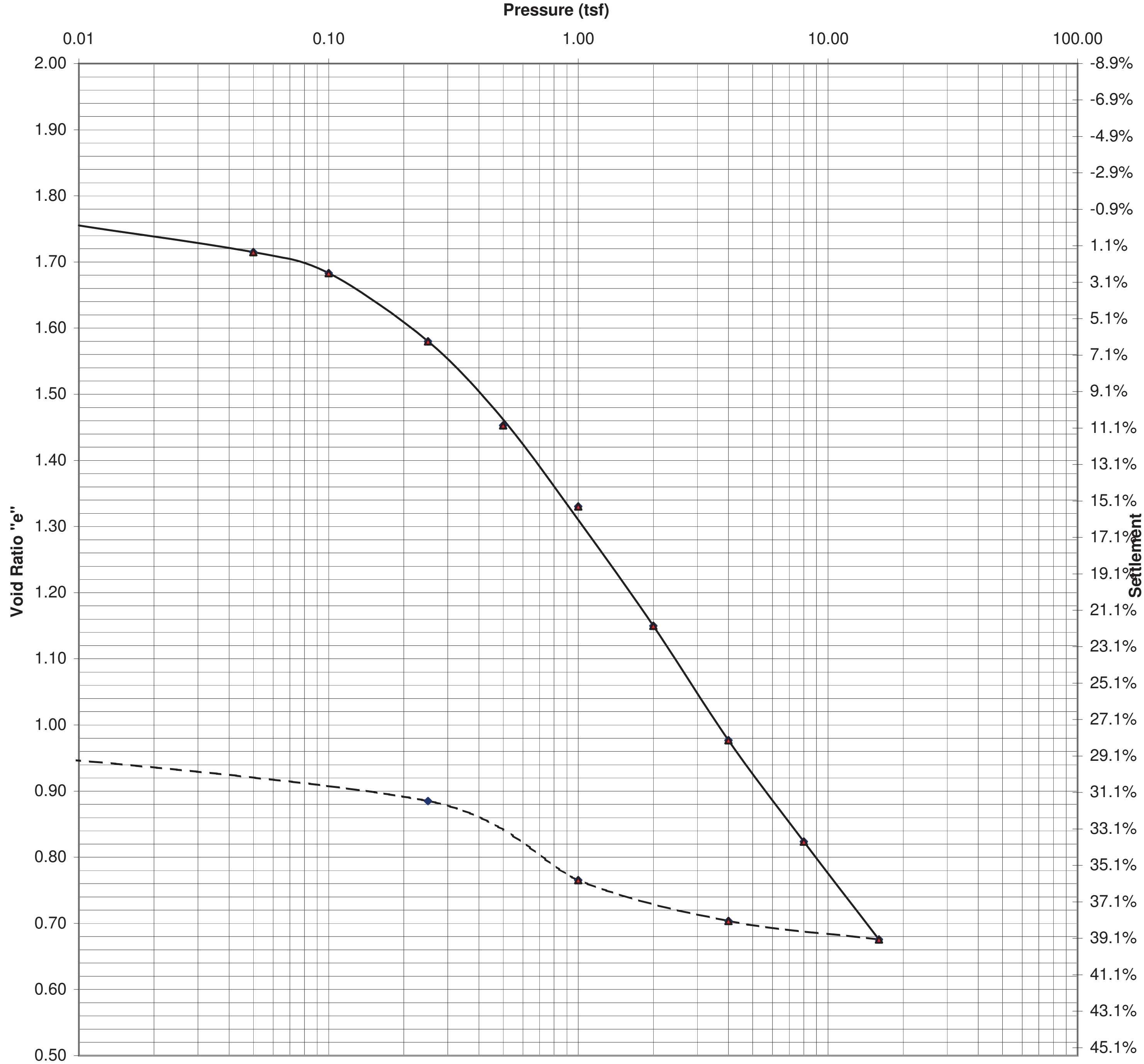
Void Ratio and % Settlement vs. Log of Pressure



Project: Marsh Lake: Stage 1			Date: 10/21/09
Sample #: SN1	Boring #: 09-17MU	Depth ft: 12-14 (Top)	Job #: 7223
Soil Type: Organic Clay w/a trace of shell fragments (OH)			
Initial W/C (%): 68.0	Dry Density (pcf): 58.0	LL: 81.2 PL: 31.4 PI: 49.8	Gs: 2.56
Organic Content (%):	Initial Height (in.): 0.748	Diameter (in.): 2.506	e_o= 1.755
Preconsolidation Pressure (Pc): 0.23 tsf	Compression Index (Cc): 0.53	Recompression Index (Cr): ≅ 0.10	
Remarks:			

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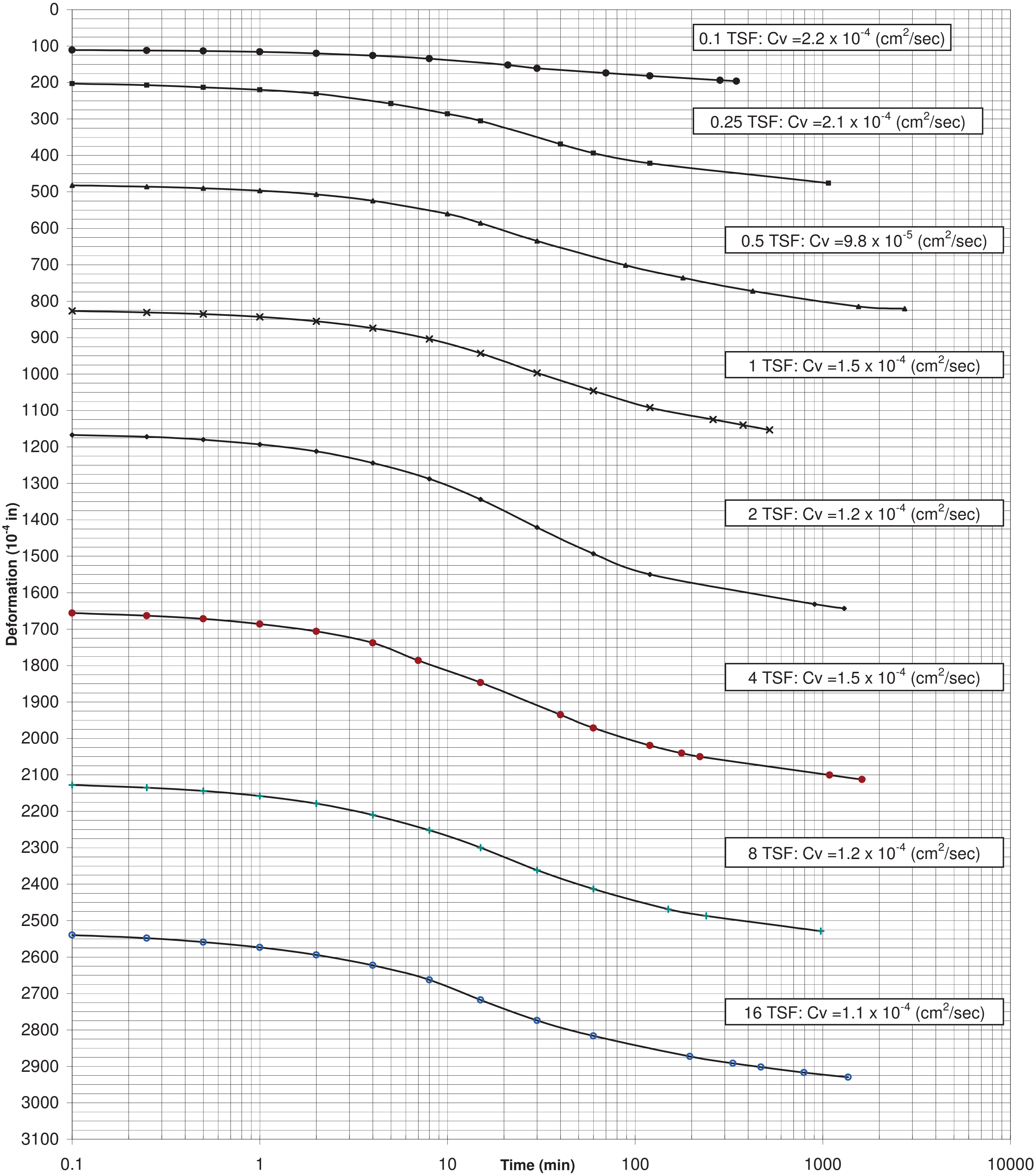
PLATE H-5

Consolidation Log of Time Curves



Project: Marsh Lake: Stage 1			Date: 10/21/09
Sample #: SN1	Boring #: 09-17MU	Depth ft: 12-14 (Top)	Job #: 7223

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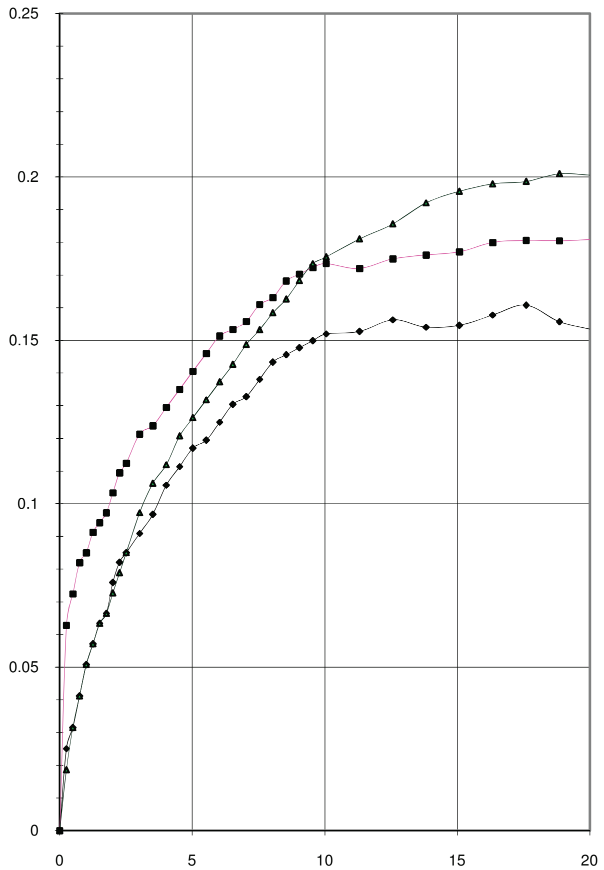
PLATE H-5

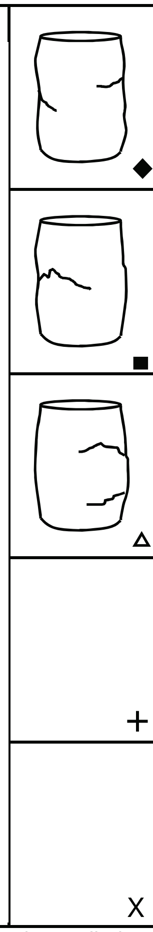
TRIAXIAL TEST ASTM: D 2850

Job No. 7223
Date: 10/13/09

Project:	Marsh Lake: Stage 1						
Boring #:	09-17MU	Sample #:	1	Type:	3T	Depth (ft):	12 - 14 (Mid-Top)
Soil Type:	Organic Clay w/a Trace of Shell Fragments (OH)						

Deviator Stress (tsf)





Failure Criterion: **Max. Deviator Stress**

Angle of internal friction, ϕ_u = **0.7 °**

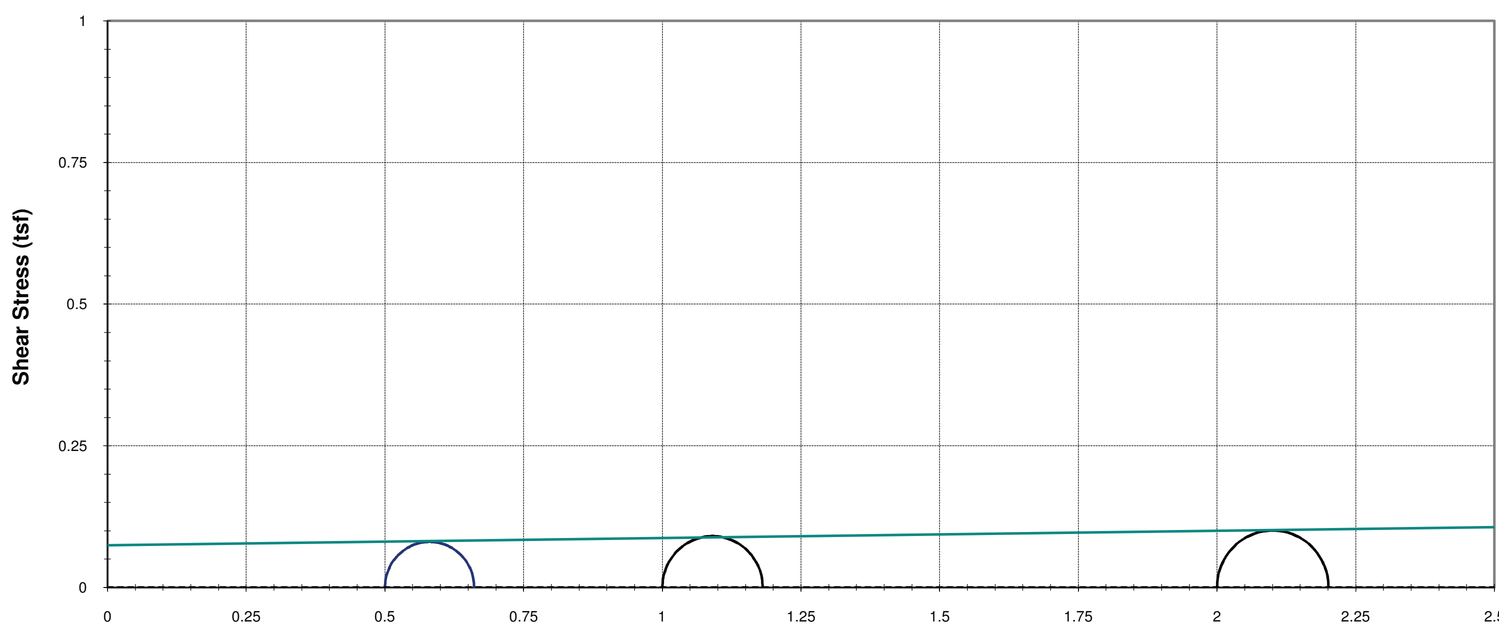
Apparent Cohesion, c_u = **0.07 (tsf)**

Test Date:	10/7/09	Liquid Limit:	81.2
Test Type:	U-U	Plastic Limit:	31.4
Strain Rate (in/min):	0.05	Plasticity Index:	49.8
Strain Rate (%/min):	1.257	Spec. Gravity (Actual):	2.56

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	3.98	3.98	3.98		
Water Content (%)	69.2	69.4	70.0		
Dry Density (pcf)	58.5	58.5	58.3		
Void Ratio	1.73	1.73	1.74		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.50	1.00	2.00		
Max. Deviator Stress (tsf)	0.16	0.18	0.20		
Ultimate Deviator Stress (tsf)	0.15	0.18	0.20		
Deviator Stress at Failure (tsf)	0.16	0.18	0.20		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	17.6	20.1	18.9		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 0.7 ° c_u= 0.07 (tsf)

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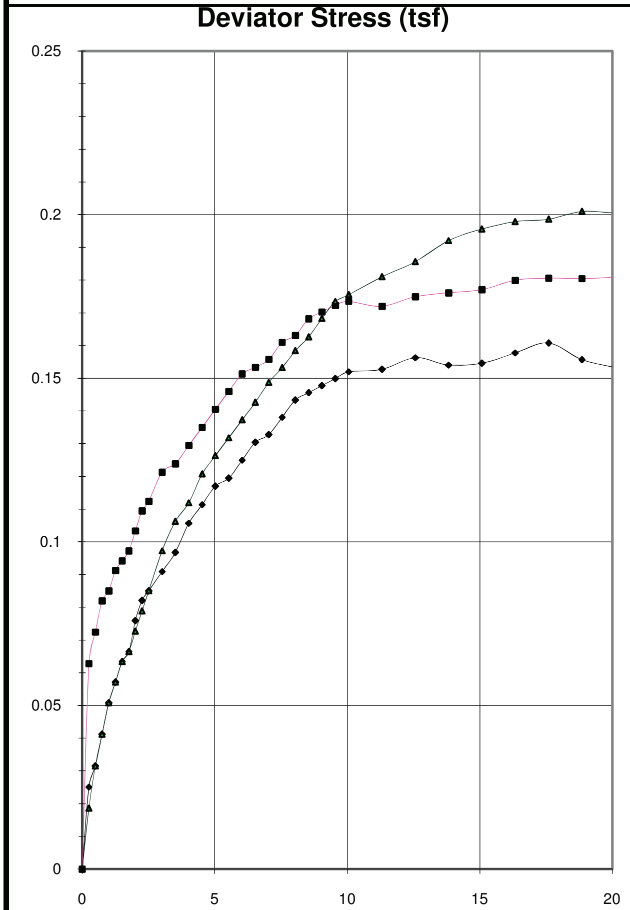
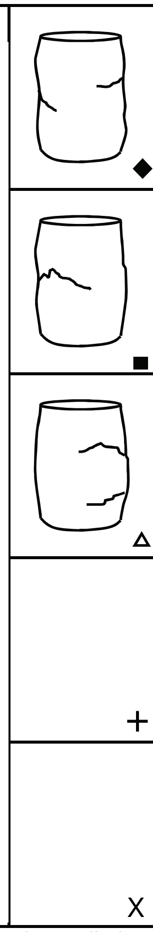
TRIAXIAL TEST ASTM: D 2850

Job No. 7223
Date: 10/13/09

Project: **Marsh Lake: Stage 1**
Boring #: **09-17MU** Sample #: **1** Type: **3T** Depth (ft): **12 - 14 (Mid-Top)**
Soil Type: **Organic Clay w/a Trace of Shell Fragments (OH)**





Failure Criterion: **Given Strain of: 15%**

Angle of internal friction, ϕ_u = **0.7 °**

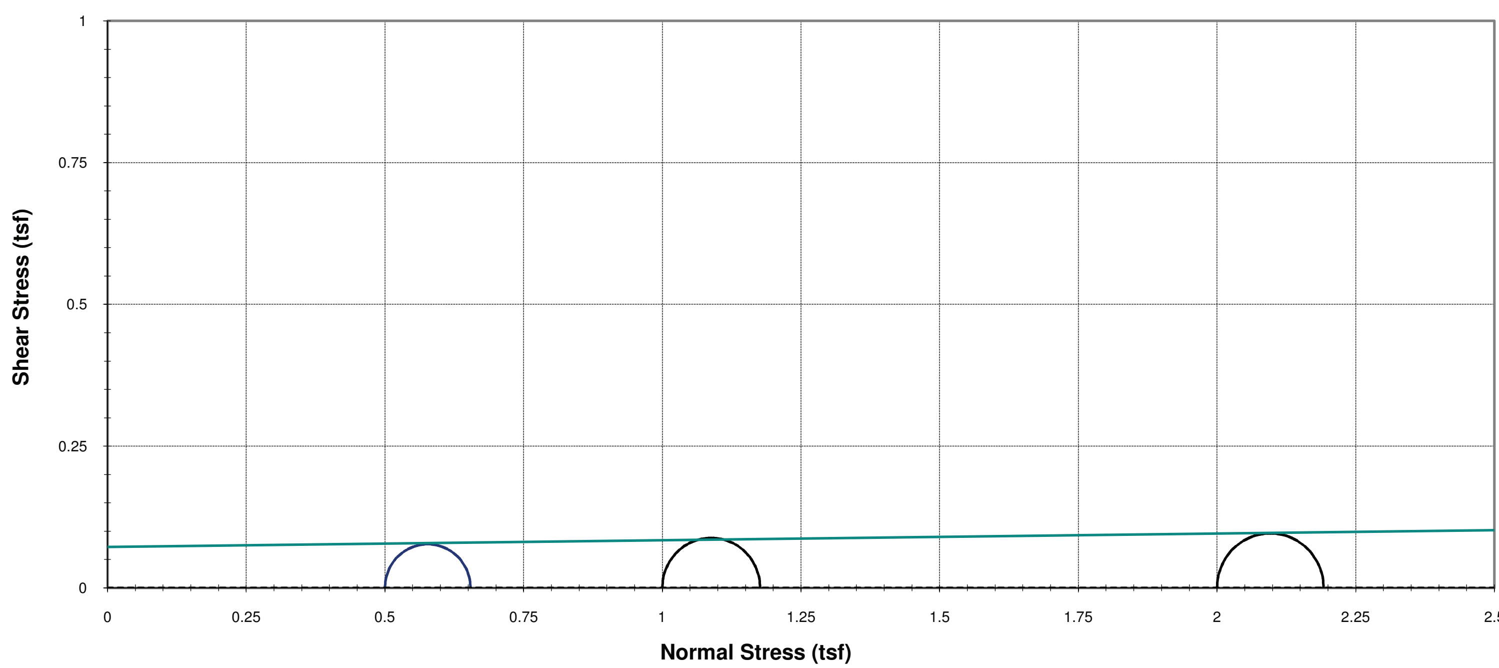
Apparent Cohesion, c_u = **0.07 (tsf)**

Test Date:	10/7/09	Liquid Limit:	81.2
Test Type:	U-U	Plastic Limit:	31.4
Strain Rate (in/min):	0.05	Plasticity Index:	49.8
Strain Rate (%/min):	1.257	Spec. Gravity (Actual):	2.56

Before Consolidation	A	B	C	D	E
Diameter (in)	1.94	1.94	1.94		
Height (in)	3.98	3.98	3.98		
Water Content (%)	69.2	69.4	70.0		
Dry Density (pcf)	58.5	58.5	58.3		
Void Ratio	1.73	1.73	1.74		
After Consolidation					
Diameter (in)					
Height (in)					
Water Content (%)					
Dry Density (pcf)					
Void Ratio					
Back Pressure (tsf)					
Minor Principal Stress (tsf)	0.50	1.00	2.00		
Max. Deviator Stress (tsf)	0.16	0.18	0.20		
Ultimate Deviator Stress (tsf)	0.15	0.18	0.20		
Deviator Stress at Failure (tsf)	0.15	0.18	0.19		
Max. Pore Pressure Buildup (tsf)	--------	--------	--------		
Pore Pressure Parameter "B"	--------	--------	--------		
Pct. Axial Strain at Failure	15.0	15.0	15.0		

"These test results are for informational purposes only and must be reviewed by a qualified professional engineer to verify that the test parameters shown are appropriate for any particular design"

Remarks: Specimens trimmed to given sizes; Allowed to adjust under applied confining pressures for about 10 minutes.



Total ϕ_u: 0.7 ° c_u= 0.07 (tsf)

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Hydraulic Conductivity Test Data

Project: Marsh Lake: Stage 1 Date: 10/20/2009

Reported To: USACE -Geotech. & Geology Section Job No.: 7223

Boring:	09-17 MU						
Sample No.:	2						
Depth (ft.):	15 - 17 (Bot)						
Location:							
Sample Type:	5" TWT						
Soil Type:	Silty Clay (CL-ML)						
Atterberg Limits							
LL							
PL							
PI							
Permeability Test							
Before Test Conditions: Saturation %:							
Before Test Conditions: Porosity:							
Before Test Conditions: Ht. (in):	2.97						
Before Test Conditions: Dia. (in):	2.88						
Before Test Conditions: Dry Density (pcf):	106.7						
Before Test Conditions: Water Content:	26.3%						
Test Type:	Falling						
Max Head (ft):	5.0						
Confining press. (Effective-psi):	6.9						
Trial No.:	12 - 16						
Water Temp ℃:	20.0						
% Compaction							
% Saturation (After Test)	98.0%						
Coefficient of Permeability							
K @ 20 ℃ (cm/sec)	**7.8×10^{-7}**						
K @ 20 ℃ (ft/min)	**1.5×10^{-6}**						
Notes:							

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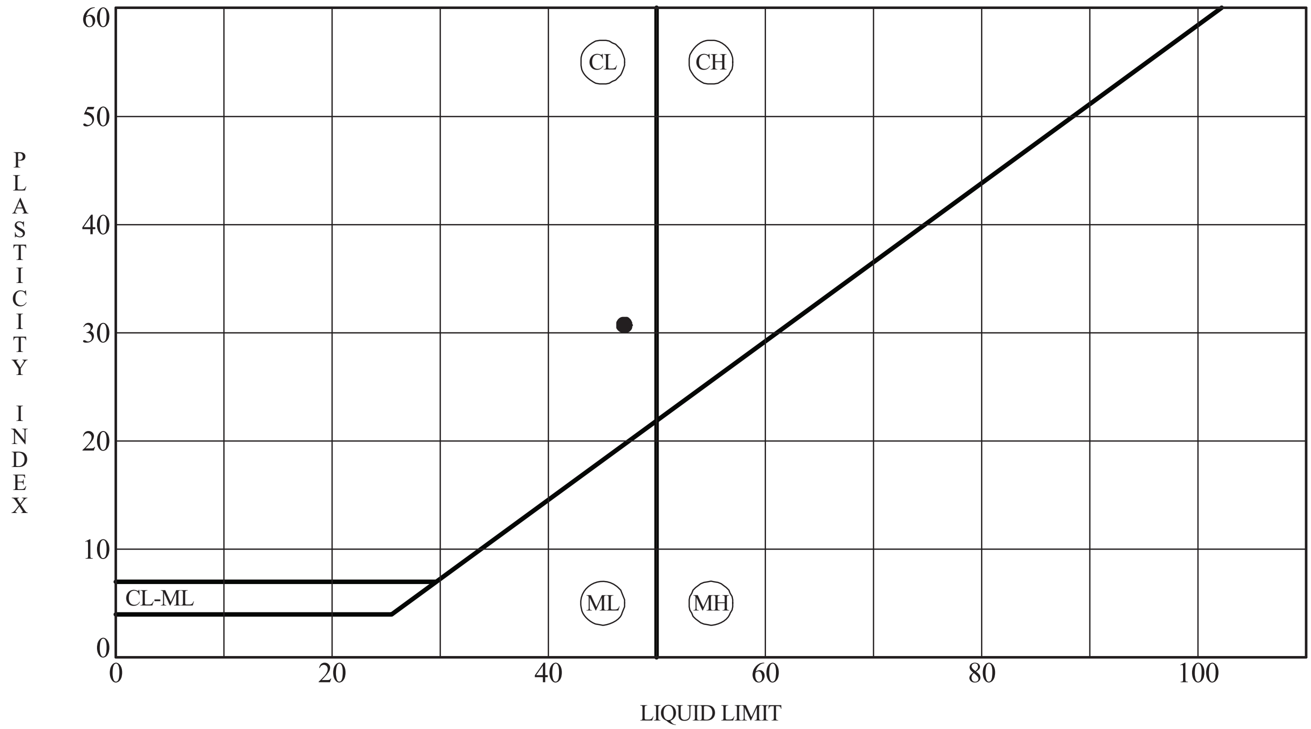
Borehole	Depth feet	Liquid Limit	Plastic Limit	Plasticity Index	%<#200 Sieve	Class-ification	Water Content (%)	Dry Density (pcf)	Organic Content (%)	Specific Gravity	Electrical Resistivity (ohm-cm)
09-15MU	8-10	47	16	31						2.638	

LAB SUMMARY GEO LAB BL-09-05055.GPJ BRAUN.GDT 12/7/09 12:19

Braun Project BL-09-05055
Marsh Lake: Stage 2
Marsh Lake

LABORATORY RESULTS SUMMARY

BRAUN[SM] INTERTEC



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**09-15MU**	**8.0'-10.0'**	**47**	**16**	**31**		

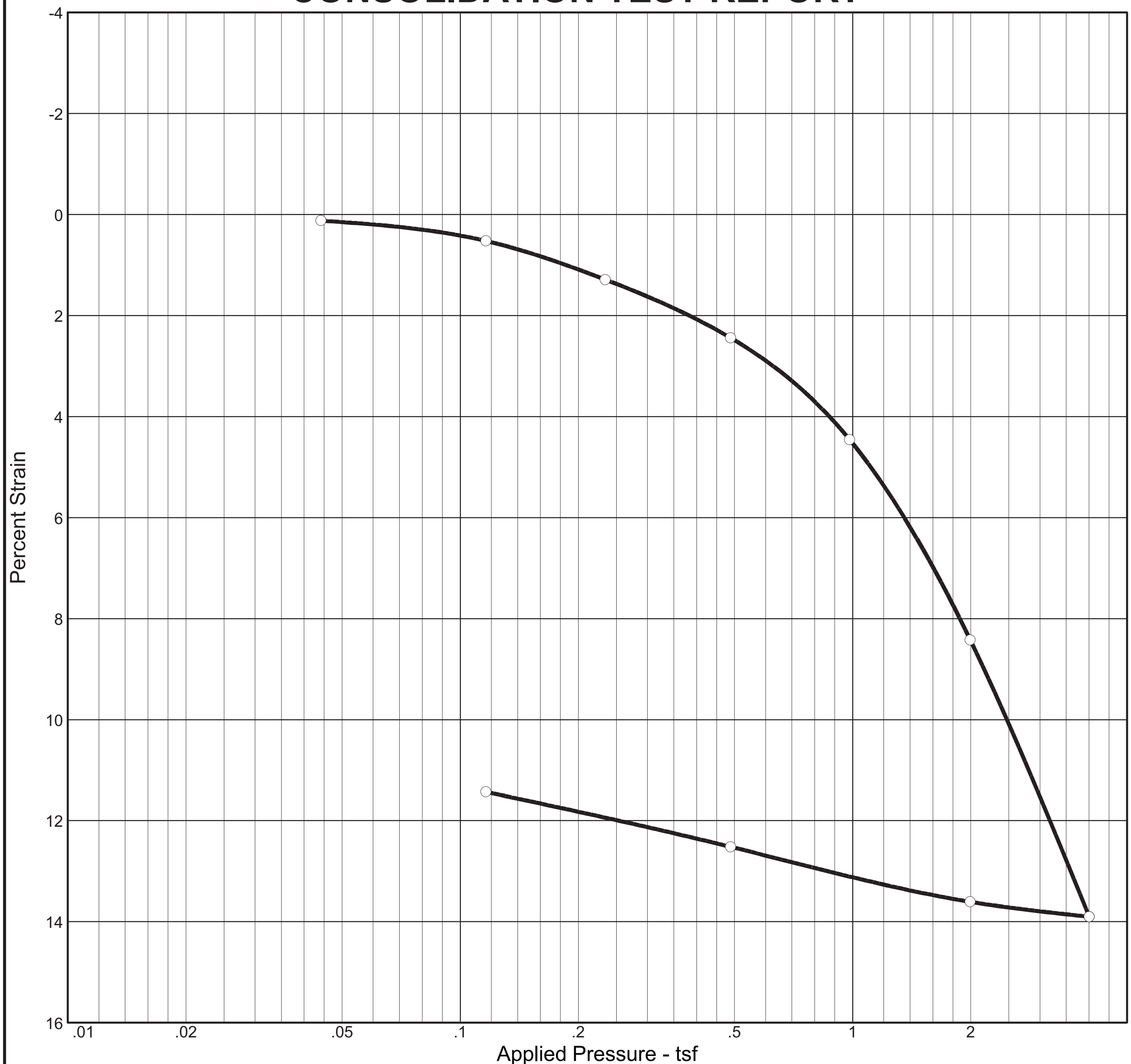
Braun Project BL-09-05055
Marsh Lake: Stage 2
Marsh Lake

ATTERBERG LIMITS RESULTS

BRAUN INTERTEC

ATTERBERG LIMITS BL-09-05055.GPJ BRAUN.GDT 12/7/09 12:19

CONSOLIDATION TEST REPORT



Natural		Dry Dens. (pcf)	LL	PI	Sp. Gr.	Overburden (tsf)	P_c (tsf)	C_c	C_r	Swell Press. (tsf)	Heave %	e_o
Sat.	Moist.											
89.4 %	34.7 %	81.3	47	31	2.638		1.27	0.37	0.03			1.025

MATERIAL DESCRIPTION	USCS	AASHTO
Organic Clay, black (OL)	OL	

Project No. BL-09-05055 **Client:** US Army Corps of Engineers

Project: Marsh Lake: Stage 2
Marsh Lake, MN

Location: Boring 09-15MU, #2, 8-10'

BRAUN INTERTEC

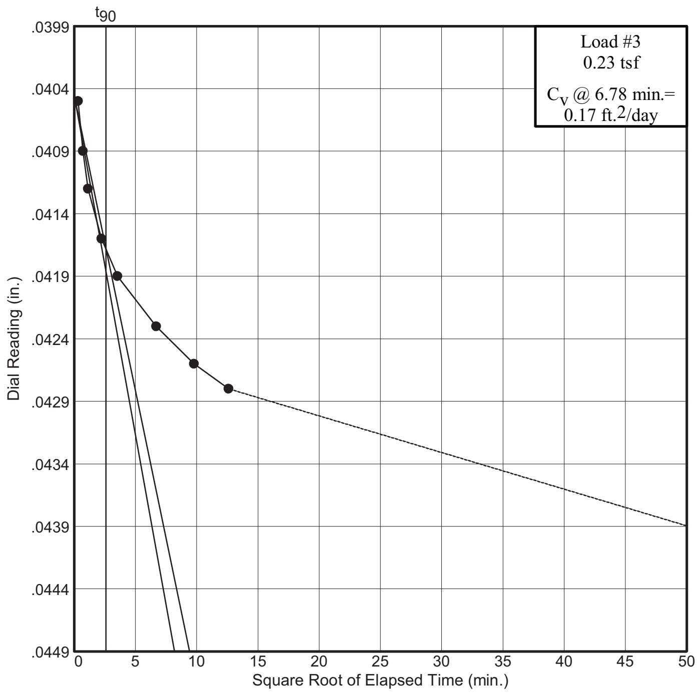
Remarks:
ASTM D 2435

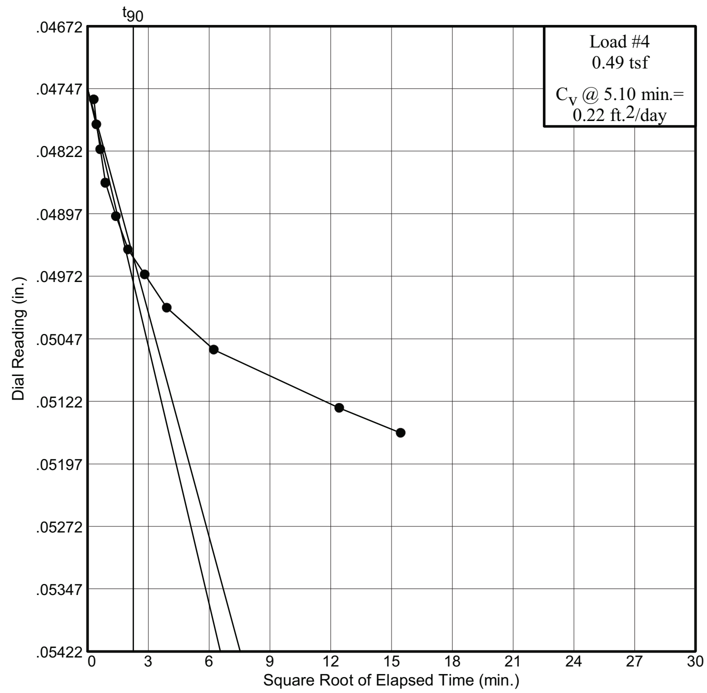
Figure 1

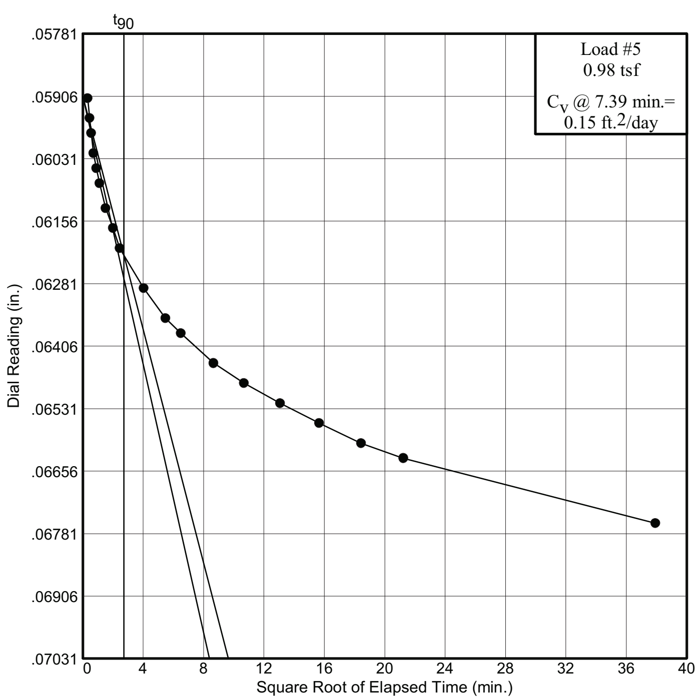
PLATE H-5

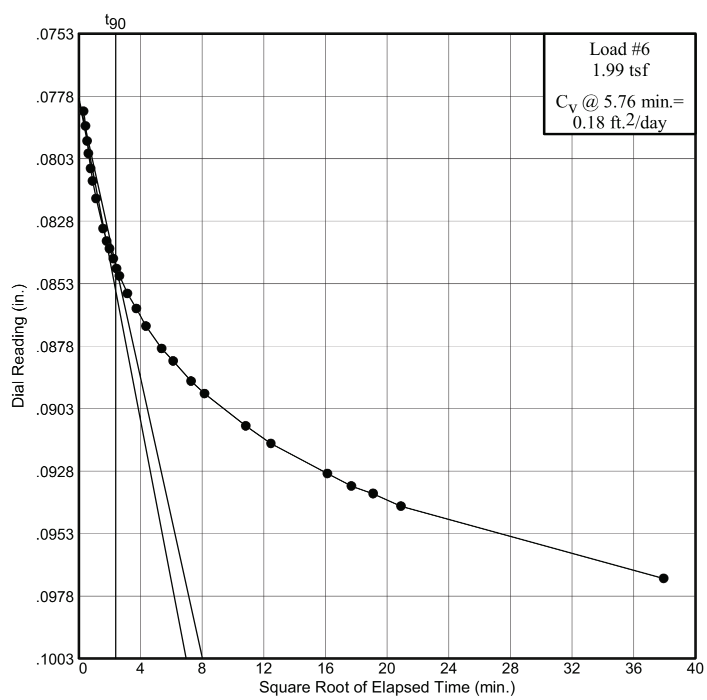
Dial Reading vs. Time

Project No.: BL-09-05055
Project: Marsh Lake: Stage 2
Marsh Lake, MN
Location: Boring 09-15MU, #2, 8-10'









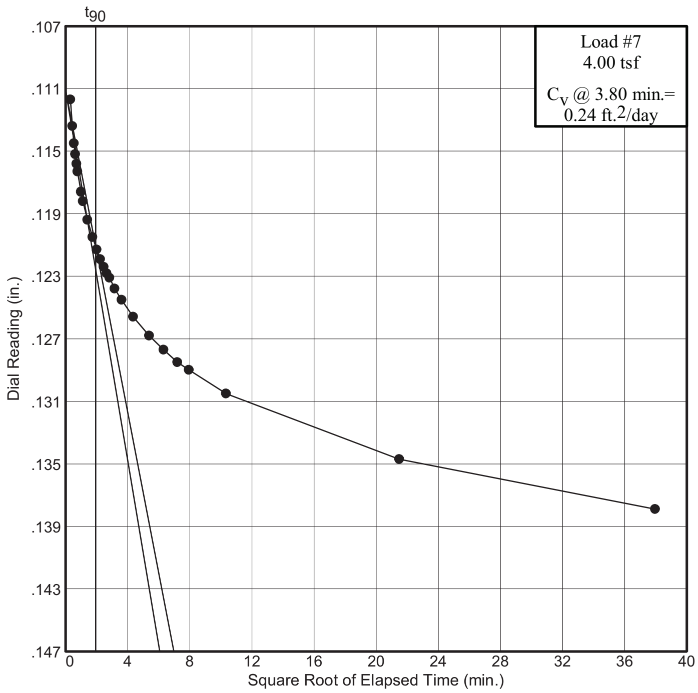
BRAUN INTERTEC

Figure 2

PLATE H-5

Dial Reading vs. Time

Project No.: BL-09-05055
Project: Marsh Lake: Stage 2
Marsh Lake, MN
Location: Boring 09-15MU, #2, 8-10'



BRAUN INTERTEC

Figure 3

PLATE H-5

CONSOLIDATION TEST DATA

Client: US Army Corps of Engineers
Project: Marsh Lake: Stage 2
Marsh Lake, MN
Project Number: BL-09-05055

Sample Data

Source:
Sample No.: #2
Elev. or Depth: 8-10' **Sample Length(in./cm.):**
Location: Boring 09-15MU, #2, 8-10'
Description: Organic Clay, black (OL)
Liquid Limit: 47 **Plasticity Index:** 31
USCS: OL **AASHTO:** **Figure No.:** 1
Testing Remarks: ASTM D 2435

Test Specimen Data

TOTAL SAMPLE	BEFORE TEST	AFTER TEST
Wet w+t = 142.80 g.	**Consolidometer # =** 4	**Wet w+t =** 121.65 g.
Dry w+t = 113.83 g.		**Dry w+t =** 99.40 g.
Tare Wt. = 30.42 g.	**Spec. Gravity =** 2.638	**Tare Wt. =** 30.83 g.
Height = .74 in.	**Height =** .74 in.	
Diameter = 2.49 in.	**Diameter =** 2.49 in.	
Weight = 104.68 g.	**Defl. Table =** #4-2008	
Moisture = 34.7 %	**Ht. Solids =** 0.3676 in.	**Moisture =** 32.4 %
Wet Den. = 109.6 pcf	**Dry Wt. =** 77.69 g.*	**Dry Wt. =** 68.57 g.
Dry Den. = 81.3 pcf	**Void Ratio =** 1.025	**Void Ratio =** 0.794
	Saturation = 89.4 %	

*** Initial dry weight used in calculations**

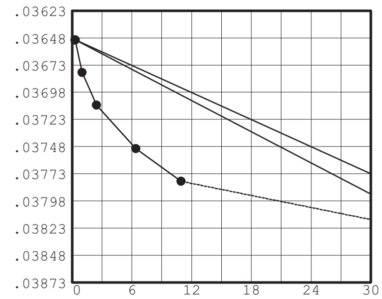
End-of-Load Summary

Pressure (tsf)	Final Dial (in.)	Machine Defl. (in.)	C_v (ft.^{2}/day)	C_α	Void Ratio	% Compression /Swell
start	0.03440				1.025	
0.04	0.03540	0.00010			1.023	0.1 Comprs.
0.12	0.03860	0.00030			1.015	0.5 Comprs.
0.23	0.04450	0.00050	0.17		0.999	1.3 Comprs.
0.49	0.05340	0.00080	0.22		0.976	2.4 Comprs.
0.98	0.06860	0.00100	0.15		0.935	4.5 Comprs.
1.99	0.09860	0.00150	0.18		0.855	8.4 Comprs.
4.00	0.13990	0.00200	0.24		0.744	13.9 Comprs.
1.99	0.13720	0.00150			0.750	13.6 Comprs.
0.49	0.12840	0.00080			0.772	12.5 Comprs.
0.12	0.11980	0.00030			0.794	11.4 Comprs.

C_c = 0.37 P_c = 1.27 tsf C_r = 0.03

Pressure: 0.12 tsf **TEST READINGS** **Load No. 2**

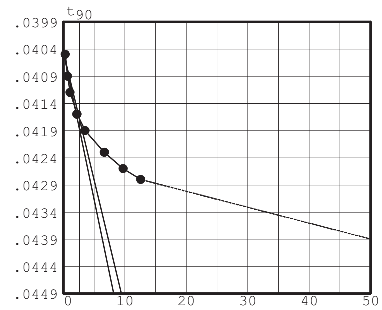
No.	Elapsed Time	Dial Reading
1	0.00	0.03540
2	0.10	0.03680
3	1.00	0.03710
4	6.00	0.03740
5	41.00	0.03780
6	120.00	0.03810
7	1445.00	0.03860



Void Ratio = 1.015 **Compression =** 0.5 %

Pressure: 0.23 tsf **TEST READINGS** **Load No. 3**

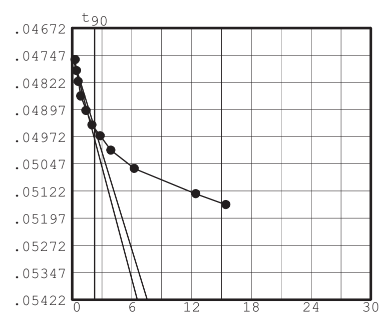
No.	Elapsed Time	Dial Reading
1	0.00	0.03860
2	0.10	0.04100
3	0.50	0.04140
4	1.25	0.04170
5	5.00	0.04210
6	12.50	0.04240
7	45.00	0.04280
8	95.50	0.04310
9	159.00	0.04330
10	2870.00	0.04450



Void Ratio = 0.999 **Compression =** 1.3 %
D_0 **=** 0.04046 D_{90} **=** 0.04169 D_{100} **=** 0.04182
C_v **at 6.8 min. =** 0.17 ft.^{2}/day

Pressure: 0.49 tsf **TEST READINGS** **Load No. 4**

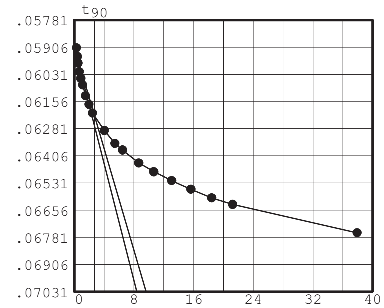
No.	Elapsed Time	Dial Reading	No.	Elapsed Time	Dial Reading
1	0.00	0.04450	11	154.50	0.05210
2	0.10	0.04840	12	239.00	0.05240
3	0.20	0.04870	13	601.00	0.05290
4	0.40	0.04900	14	1400.00	0.05340
5	0.80	0.04940			
6	2.00	0.04980			
7	4.00	0.05020			
8	8.00	0.05050			
9	15.30	0.05090			
10	39.00	0.05140			



Void Ratio = 0.976 **Compression =** 2.4 %
D_0 **=** 0.04747 D_{90} **=** 0.04949 D_{100} **=** 0.04972
C_v **at 5.1 min. =** 0.22 ft.^{2}/day

Pressure: 0.98 tsf	TEST READINGS	Load No. 5

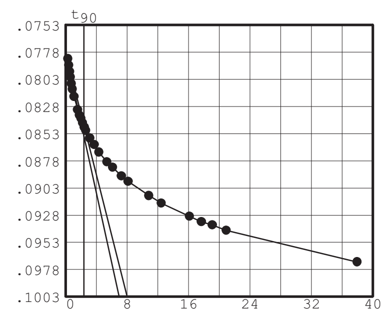
No.	Elapsed Time	Dial Reading	No.	Elapsed Time	Dial Reading
1	0.00	0.05340	11	16.30	0.06390
2	0.10	0.06010	12	30.00	0.06450
3	0.20	0.06050	13	42.30	0.06480
4	0.30	0.06080	14	75.00	0.06540
5	0.50	0.06120	15	114.00	0.06580
6	0.80	0.06150	16	171.00	0.06620
7	1.25	0.06180	17	245.00	0.06660
8	2.30	0.06230	18	340.00	0.06700
9	4.00	0.06270	19	451.00	0.06730
10	6.00	0.06310	20	1439.00	0.06860



Void Ratio = 0.935 **Compression =** 4.5 %
D_0 = 0.05907 D_{90} = 0.06224 D_{100} = 0.06259
C_v **at 7.4 min. =** 0.15 ft.^{2}/day

Pressure: 1.99 tsf	TEST READINGS	Load No. 6

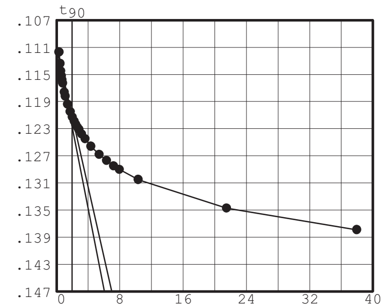
No.	Elapsed Time	Dial Reading	No.	Elapsed Time	Dial Reading
1	0.00	0.06860	15	10.00	0.08720
2	0.10	0.07990	16	14.00	0.08780
3	0.20	0.08050	17	19.00	0.08850
4	0.30	0.08110	18	29.00	0.08940
5	0.40	0.08160	19	37.50	0.08990
6	0.60	0.08220	20	53.00	0.09070
7	0.80	0.08270	21	66.50	0.09120
8	1.25	0.08340	22	117.50	0.09250
9	2.50	0.08460	23	155.50	0.09320
10	3.25	0.08510	24	260.50	0.09440
11	4.00	0.08540	25	313.00	0.09490
12	5.00	0.08580	26	365.00	0.09520
13	6.00	0.08620	27	437.00	0.09570
14	7.00	0.08650	28	1440.00	0.09860



Void Ratio = 0.855 **Compression =** 8.4 %
D_0 = 0.07790 D_{90} = 0.08461 D_{100} = 0.08535
C_v **at 5.8 min. =** 0.18 ft.^{2}/day

Pressure: 4.00 tsf	TEST READINGS	Load No. 7

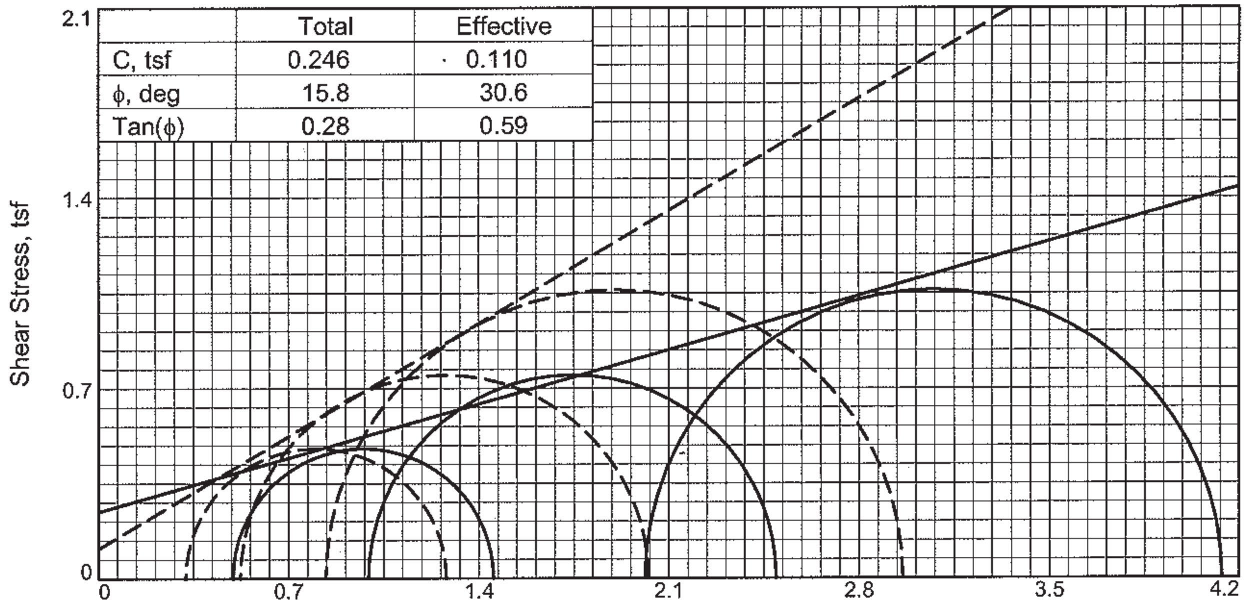
No.	Elapsed Time	Dial Reading	No.	Elapsed Time	Dial Reading
1	0.00	0.09860	14	6.00	0.12440
2	0.10	0.11370	15	7.00	0.12480
3	0.20	0.11540	16	8.00	0.12510
4	0.30	0.11650	17	10.00	0.12580
5	0.40	0.11720	18	13.00	0.12650
6	0.50	0.11780	19	19.00	0.12760
7	0.60	0.11830	20	29.00	0.12880
8	1.00	0.11960	21	40.00	0.12970
9	1.25	0.12020	22	52.00	0.13050
10	2.00	0.12140	23	63.00	0.13100
11	3.00	0.12250	24	107.00	0.13250
12	4.00	0.12330	25	462.00	0.13670
13	5.00	0.12390	26	1442.00	0.13990



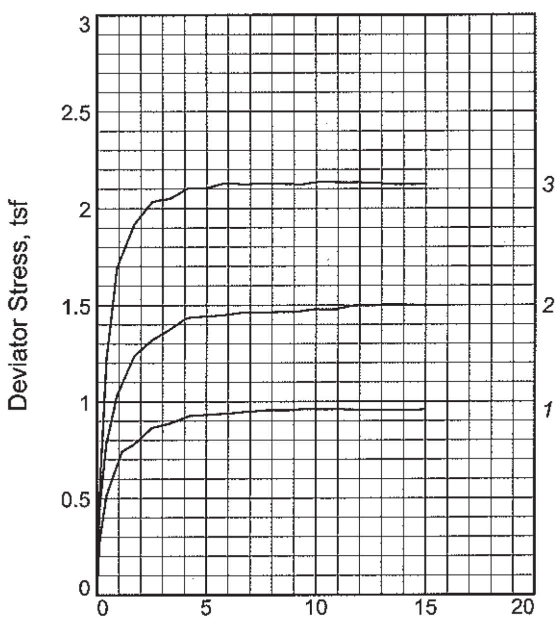
Void Ratio = 0.744 **Compression =** 13.9 %

D_0 = 0.11112 **D_{90} =** 0.12115 **D_{100} =** 0.12227

C_v at 3.8 min. = 0.24 ft.^{2}/day



	Total	Effective
C, tsf	0.246	0.110
ϕ, deg	15.8	30.6
Tan(ϕ)	0.28	0.59



Sample No.		1	2	3
Initial	Water Content, %	33.9	31.9	31.9
	Dry Density, pcf	84.7	86.2	87.9
	Saturation, %	94.8	92.5	96.5
	Void Ratio	0.9445	0.9099	0.8728
	Diameter, in.	1.43	1.41	1.40
	Height, in.	2.78	2.82	2.82
At Test	Water Content, %	34.2	31.4	28.2
	Dry Density, pcf	86.6	90.0	94.4
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.9028	0.8295	0.7452
	Diameter, in.	1.42	1.39	1.37
	Height, in.	2.76	2.78	2.75

	1	2	3
Pore Pressure Parameter B	1.0	1.0	1.0
Consolidation Pressure, tsf	0.50	1.00	2.01
Back Pressure, tsf	6.64	6.14	5.13
Cell Pressure, tsf	7.14	7.14	7.14
Peak Deviator Stress, tsf	0.96	1.51	2.14
Total Pore Pr., tsf	6.83	6.63	6.32
Ultimate Deviator Stress, tsf	0.96	1.50	2.12
Total Pore Pr., tsf	6.82	6.62	6.30
Maj. Eff. Stress at Ultimate, tsf	1.28	2.02	2.96
Min. Eff. Stress at Ultimate, tsf	0.31	0.51	0.83

Type of Test:
CU with Pore Pressures

Sample Type: Thinwall, 5", Bottom of sample

Description: Organic Clay, black (OL)

LL= 47 **PL=** 16 **PI=** 31

Assumed Specific Gravity= 2.638

Remarks: Rate of strain is 0.001 in/min. Failure criteria based on the ultimate stress which occurs at 15% strain. Samples were saturated for 10 days and consolidated for 3 days.

Figure CU Traix ASTM D 4767

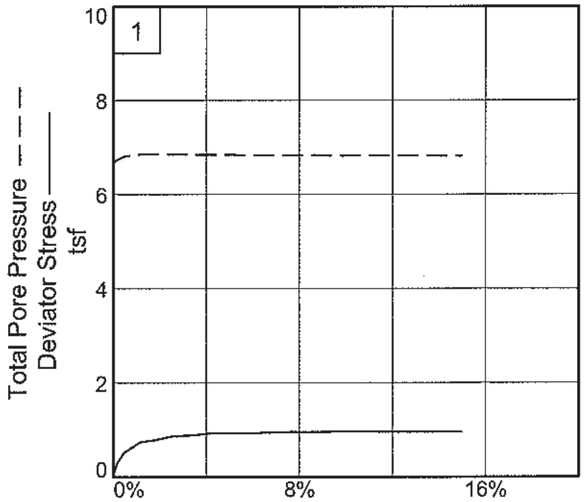
Client: US Army Corps of Engineers

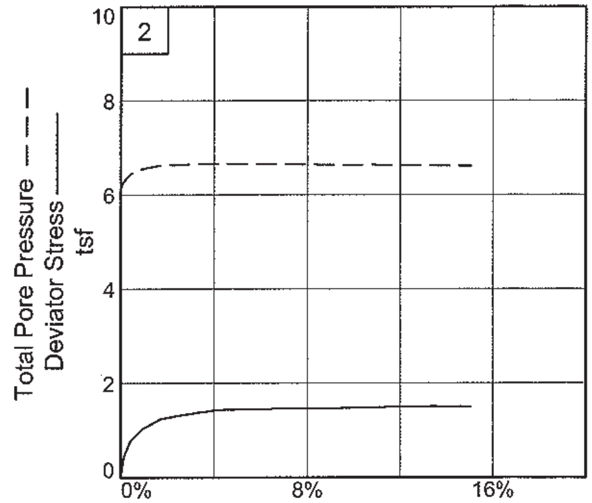
Project: Marsh Lake: Stage 2
Marsh Lake, MN

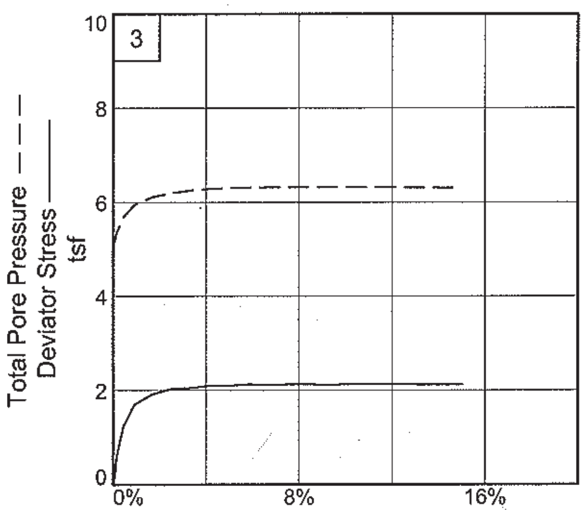
Sample Number: Boring 09-15MU, #2 **Depth:** 8-10'

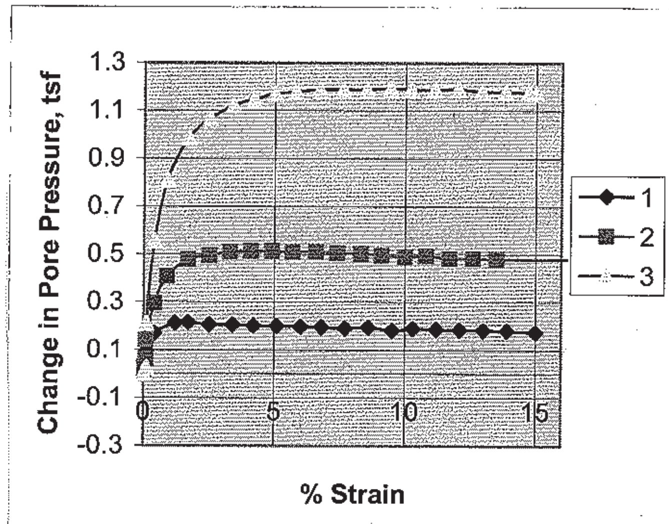
Proj. No.: BL-09-05055 **Date Sampled:**

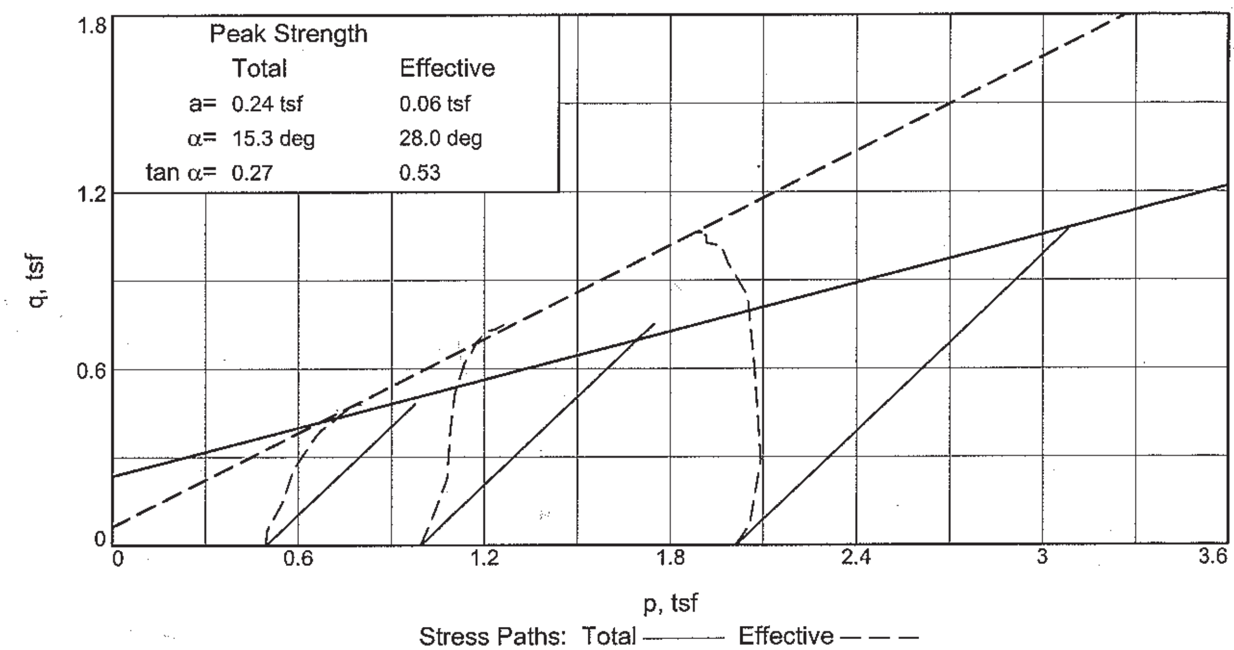
BRAUN℠
INTERTEC











Client: US Army Corps of Engineers

Project: Marsh Lake: Stage 2

Depth: 8-10' **Sample Number:** Boring 09-15MU, #2

Project No.: BL-09-05055 **Figure** _______

Braun Intertec

PLATE H-5

TRIAXIAL COMPRESSION TEST
CU with Pore Pressures

12/7/2009
12:11 PM

Date:
Client: US Army Corps of Engineers
Project: Marsh Lake: Stage 2
Marsh Lake, MN
Project No.: BL-09-05055
Depth: 8-10' **Sample Number:** Boring 09-15MU, #2
Description: Organic Clay, black (OL)
Remarks: Rate of strain is 0.001 in/min. Failure criteria based on the ultimate stress which occurs at 15% strain. Samples were saturated for 10 days and consolidated for 3 days.
Type of Sample: Thinwall, 5", Bottom of sample
Assumed Specific Gravity=2.638 **LL=**47 **PL=**16 **PI=**31
Test Method: COE uniform strain

Parameters for Specimen No. 1

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	101.950			161.490
Moisture content: Dry soil+tare, gms.	84.020			128.140
Moisture content: Tare, gms.	31.190			29.710
Moisture, %	33.9	35.8	34.2	33.9
Moist specimen weight, gms.	132.5			
Diameter, in.	1.43	1.43	1.42	
Area, in.^{2}	1.60	1.60	1.58	
Height, in.	2.78	2.78	2.76	
Net decrease in height, in.		0.00	0.02	
Wet Density, pcf	113.4	115.0	116.2	
Dry density, pcf	84.7	84.7	86.6	
Void ratio	0.9445	0.9445	0.9028	
Saturation, %	94.8	100.0	100.0	

Test Readings for Specimen No. 1

Consolidation cell pressure = 7.140 tsf
Consolidation back pressure = 6.644 tsf
Consolidation effective confining stress = 0.496 tsf
Peak Stress = 0.961 tsf **at reading no.** 14
Ult. Stress = 0.958 tsf **at reading no.** 20

Test Readings for Specimen No. 1

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress tsf	Minor Eff. Stress tsf	Major Eff. Stress tsf	1:3 Ratio	Pore Press. tsf	P tsf	Q tsf
0	0.0131	19.740	0.0	0.0	0.000	0.496	0.496	1.00	6.644	0.496	0.000
1	0.0141	22.000	2.3	0.0	0.103	0.448	0.551	1.23	6.692	0.500	0.052
2	0.0171	26.120	6.4	0.1	0.291	0.403	0.694	1.72	6.737	0.548	0.145
3	0.0252	31.060	11.3	0.4	0.515	0.327	0.842	2.57	6.813	0.584	0.257
4	0.0449	36.220	16.5	1.2	0.744	0.284	1.028	3.62	6.856	0.656	0.372
5	0.0597	37.070	17.3	1.7	0.778	0.282	1.060	3.76	6.858	0.671	0.389
6	0.0827	39.150	19.4	2.5	0.864	0.291	1.155	3.97	6.849	0.723	0.432
7	0.1057	39.880	20.1	3.4	0.889	0.291	1.180	4.06	6.849	0.736	0.445
8	0.1296	40.920	21.2	4.2	0.927	0.295	1.222	4.14	6.845	0.758	0.463
9	0.1539	41.260	21.5	5.1	0.933	0.296	1.229	4.15	6.844	0.762	0.466
10	0.1783	41.570	21.8	6.0	0.937	0.299	1.236	4.14	6.841	0.768	0.469
11	0.2022	42.020	22.3	6.8	0.948	0.302	1.250	4.14	6.838	0.776	0.474
12	0.2271	42.400	22.7	7.7	0.955	0.305	1.260	4.13	6.835	0.782	0.477
13	0.2510	42.630	22.9	8.6	0.955	0.301	1.256	4.17	6.839	0.779	0.478
14	0.2749	42.990	23.3	9.5	0.961	0.315	1.276	4.05	6.825	0.796	0.481
15	0.2988	43.190	23.4	10.3	0.960	0.307	1.267	4.13	6.833	0.787	0.480
16	0.3228	43.420	23.7	11.2	0.960	0.309	1.269	4.11	6.831	0.789	0.480
17	0.3477	43.580	23.8	12.1	0.957	0.312	1.269	4.07	6.828	0.791	0.479
18	0.3725	43.810	24.1	13.0	0.956	0.314	1.270	4.05	6.826	0.792	0.478
19	0.3976	44.070	24.3	13.9	0.957	0.316	1.273	4.03	6.824	0.794	0.478
20	0.4265	44.400	24.7	15.0	0.958	0.322	1.280	3.97	6.818	0.801	0.479

Parameters for Specimen No. 2

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	109.360			158.850
Moisture content: Dry soil+tare, gms.	90.220			128.690
Moisture content: Tare, gms.	30.230			29.970
Moisture, %	31.9	34.5	31.4	30.6
Moist specimen weight, gms.	130.9			
Diameter, in.	1.41	1.41	1.39	
Area, in.²	1.55	1.55	1.51	
Height, in.	2.82	2.82	2.78	
Net decrease in height, in.		0.00	0.04	
Wet Density, pcf	113.7	116.0	118.3	
Dry density, pcf	86.2	86.2	90.0	
Void ratio	0.9099	0.9099	0.8295	
Saturation, %	92.5	100.0	100.0	

Test Readings for Specimen No. 2

Consolidation cell pressure = 7.140 tsf

Consolidation back pressure = 6.145 tsf

Consolidation effective confining stress = 0.995 tsf

Peak Stress = 1.505 tsf **at reading no.** 19

Ult. Stress = 1.500 tsf **at reading no.** 21

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress tsf	Minor Eff. Stress tsf	Major Eff. Stress tsf	1:3 Ratio	Pore Press. tsf	P tsf	Q tsf
0	0.0092	19.520	0.0	0.0	0.000	0.995	0.995	1.00	6.145	0.995	0.000
1	0.0109	23.800	4.3	0.1	0.204	0.932	1.136	1.22	6.208	1.034	0.102
2	0.0130	29.050	9.5	0.1	0.454	0.853	1.307	1.53	6.287	1.080	0.227
3	0.0208	35.940	16.4	0.4	0.781	0.700	1.481	2.12	6.440	1.090	0.390
4	0.0349	41.380	21.9	0.9	1.034	0.588	1.622	2.76	6.552	1.105	0.517
5	0.0567	45.920	26.4	1.7	1.239	0.516	1.755	3.40	6.624	1.135	0.619
6	0.0789	47.850	28.3	2.5	1.318	0.501	1.819	3.63	6.639	1.160	0.659
7	0.1017	49.310	29.8	3.3	1.375	0.485	1.860	3.83	6.655	1.172	0.687
8	0.1233	50.860	31.3	4.1	1.435	0.481	1.916	3.98	6.659	1.198	0.717
9	0.1463	51.310	31.8	4.9	1.443	0.482	1.925	3.99	6.658	1.203	0.721
10	0.1692	51.710	32.2	5.7	1.448	0.486	1.934	3.98	6.654	1.210	0.724
11	0.1920	52.290	32.8	6.6	1.461	0.484	1.945	4.02	6.656	1.215	0.731
12	0.2162	52.610	33.1	7.4	1.462	0.489	1.951	3.99	6.651	1.220	0.731
13	0.2400	52.980	33.5	8.3	1.465	0.493	1.958	3.97	6.647	1.225	0.732
14	0.2629	53.320	33.8	9.1	1.466	0.499	1.965	3.94	6.641	1.232	0.733
15	0.2865	53.950	34.4	10.0	1.480	0.506	1.986	3.92	6.634	1.246	0.740
16	0.3108	54.240	34.7	10.8	1.478	0.502	1.980	3.94	6.638	1.241	0.739
17	0.3347	55.070	35.6	11.7	1.498	0.513	2.011	3.92	6.627	1.262	0.749
18	0.3596	55.420	35.9	12.6	1.498	0.512	2.010	3.93	6.628	1.261	0.749
19	0.3836	55.960	36.4	13.5	1.505	0.515	2.020	3.92	6.625	1.268	0.753
20	0.4076	56.210	36.7	14.3	1.501	0.520	2.021	3.89	6.620	1.270	0.750
21	0.4279	56.510	37.0	15.0	1.500	0.524	2.024	3.86	6.616	1.274	0.750

Parameters for Specimen No. 3

Specimen Parameter	Initial	Saturated	Consolidated	Final
Moisture content: Moist soil+tare, gms.	100.010			159.530
Moisture content: Dry soil+tare, gms.	83.300			131.880
Moisture content: Tare, gms.	30.980			31.540
Moisture, %	31.9	33.1	28.2	27.6
Moist specimen weight, gms.	132.7			
Diameter, in.	1.40	1.40	1.37	
Area, in.²	1.55	1.55	1.48	
Height, in.	2.82	2.82	2.75	
Net decrease in height, in.		0.00	0.07	
Wet Density, pcf	116.0	117.0	121.0	
Dry density, pcf	87.9	87.9	94.4	
Void ratio	0.8728	0.8728	0.7452	
Saturation, %	96.5	100.0	100.0	

Test Readings for Specimen No. 3

Consolidation cell pressure = 7.143 tsf

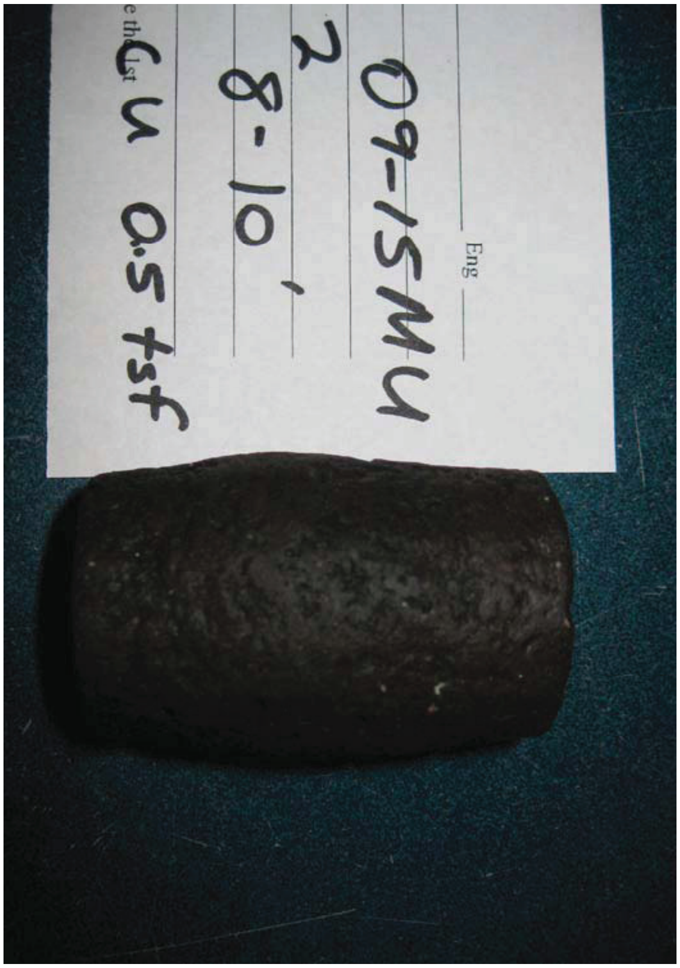
Consolidation back pressure = 5.131 tsf

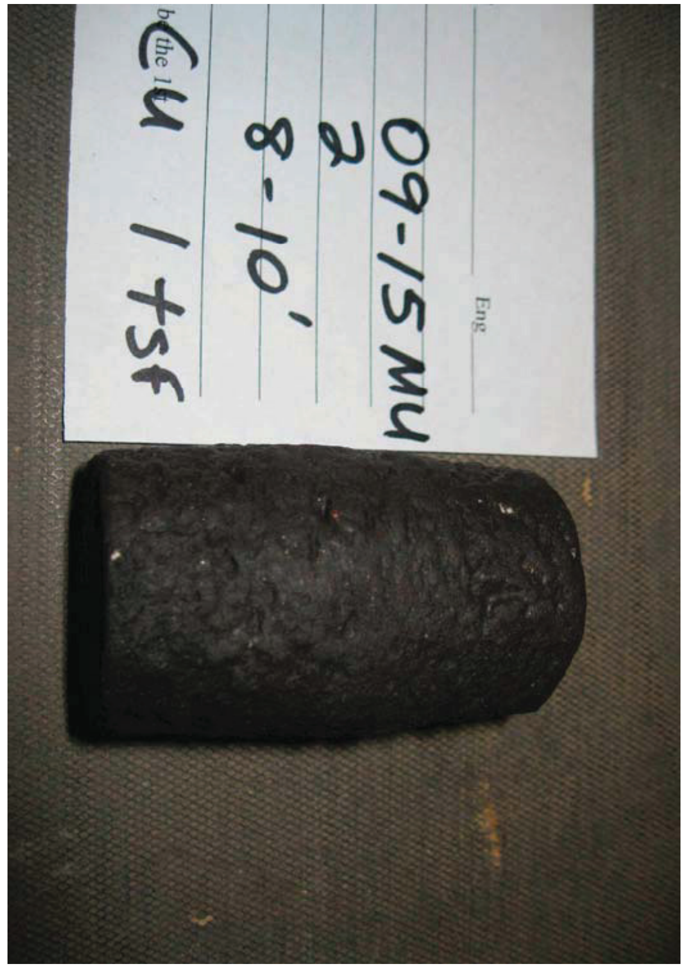
Consolidation effective confining stress = 2.012 tsf

Peak Stress = 2.138 tsf **at reading no.** 15

Ult. Stress = 2.124 tsf **at reading no.** 21

No.	Def. Dial in.	Load Dial	Load lbs.	Strain %	Deviator Stress tsf	Minor Eff. Stress tsf	Major Eff. Stress tsf	1:3 Ratio	Pore Press. tsf	P tsf	Q tsf
0	0.0099	18.700	0.0	0.0	0.000	2.012	2.012	1.00	5.131	2.012	0.000
1	0.0118	21.570	2.9	0.1	0.140	1.986	2.126	1.07	5.157	2.056	0.070
2	0.0139	30.600	11.9	0.1	0.580	1.802	2.382	1.32	5.341	2.092	0.290
3	0.0219	44.000	25.3	0.4	1.229	1.456	2.685	1.84	5.687	2.071	0.615
4	0.0348	53.710	35.0	0.9	1.693	1.203	2.896	2.41	5.940	2.049	0.846
5	0.0566	58.680	40.0	1.7	1.918	1.027	2.945	2.87	6.116	1.986	0.959
6	0.0796	61.500	42.8	2.5	2.035	0.946	2.981	3.15	6.197	1.964	1.018
7	0.1022	62.230	43.5	3.4	2.053	0.890	2.943	3.31	6.253	1.916	1.026
8	0.1245	63.720	45.0	4.2	2.105	0.863	2.968	3.44	6.280	1.916	1.053
9	0.1474	64.140	45.4	5.0	2.106	0.841	2.947	3.50	6.302	1.894	1.053
10	0.1702	65.080	46.4	5.8	2.131	0.834	2.965	3.56	6.309	1.900	1.066
11	0.1940	65.370	46.7	6.7	2.125	0.825	2.950	3.58	6.318	1.887	1.062
12	0.2189	65.910	47.2	7.6	2.128	0.823	2.951	3.59	6.320	1.887	1.064
13	0.2438	66.360	47.7	8.5	2.128	0.825	2.953	3.58	6.318	1.889	1.064
14	0.2679	66.740	48.0	9.4	2.124	0.820	2.944	3.59	6.323	1.882	1.062
15	0.2917	67.530	48.8	10.2	2.138	0.825	2.963	3.59	6.318	1.894	1.069
16	0.3159	67.890	49.2	11.1	2.133	0.824	2.957	3.59	6.319	1.891	1.067
17	0.3406	68.420	49.7	12.0	2.134	0.822	2.956	3.60	6.321	1.889	1.067
18	0.3655	68.790	50.1	12.9	2.128	0.832	2.960	3.56	6.311	1.896	1.064
19	0.3905	69.210	50.5	13.8	2.124	0.833	2.957	3.55	6.310	1.895	1.062
20	0.4144	69.730	51.0	14.7	2.124	0.836	2.960	3.54	6.307	1.898	1.062
21	0.4234	69.930	51.2	15.0	2.124	0.838	2.962	3.53	6.305	1.900	1.062





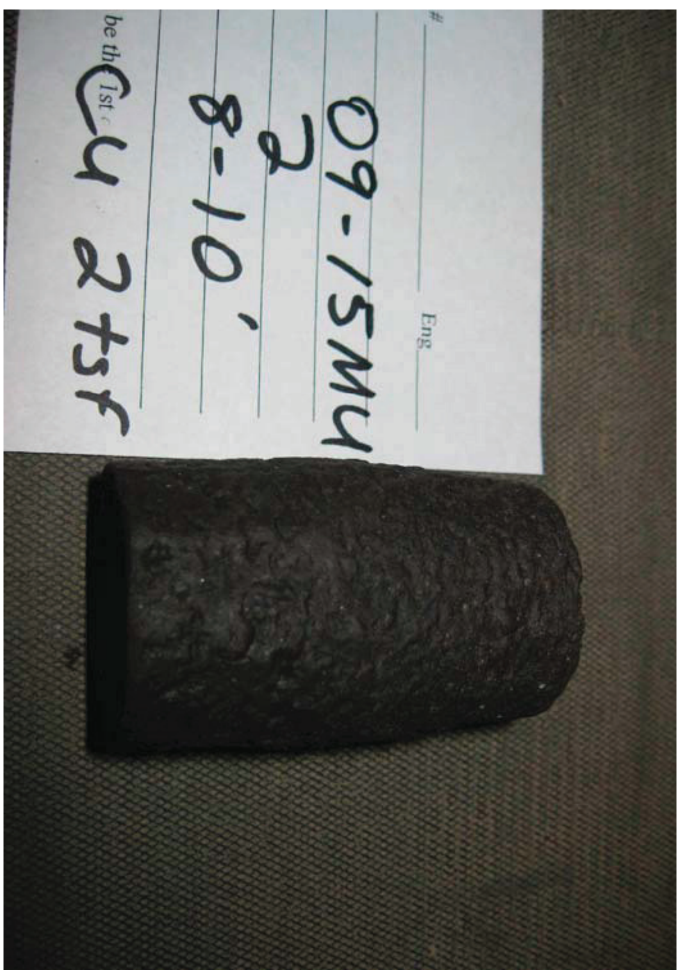


PLATE H-5

<u>CSETT INPUT</u>

```
100 TITLE
110 Marsh Lake: The diversion dike A: Thalweg Case
120 2DSO  1  6  0  0.5  125
130 -9999  936
140  1119  936
150  1189.4  953.6
160  1199.4  953.6
170  1269.8  936
180  9999  936
190 SOIL  1  936 N 100
200 SOIL  2  930.4 D 40  0.03  62  0.32
210 INDEX  0.53  600  1.755
220 SOIL  3  918.8 N 34
240 BOUS  80
250 TIMI  0.0192  2
260 OUTPUT  1144.4  1194.4  5
270 END

100 TITLE
110 Marsh Lake: The diversion dike A: Overbank Case
120 2DSO  1  6  0  0.5  125
130 -9999  940.
140  1119  940.
150  1173.4  953.6
160  1183.4  953.6
170  1237.8  940.
180  9999  940.
190 SOIL  1  940.5 D 100  0.1  7  0.32
200 INDEX  0.53  100  1.755
210 SOIL  2  936.4 N 40
220 SOIL  3  930.6 D 34  0.1  7  0.32
230 INDEX  0.53  600  1.755
240 SOIL  4  919.2 N 35
260 BOUS  80
270 TIMI  0.0192  2
280 OUTPUT  1118.4  1178.4  5
290 END
```

CSETT INPUT

```
100 TITLE
110 Marsh Lake: Initial Highway embankment Load only
120 2DSO  1  8  0  0.5  125
130 -9999  939
140  1136.6  939
150  1168  939
160  1183  944
170  1218  944
180  1223  939
190  1254.4  939
200  9999  939
210 SOIL  1  939 S 50  0.1  11  0.32
220 INDEX  0.53  138  1.755
230 SOIL  2  932.1 S 40  0.03  11  0.32
240 INDEX  0.37  550  1.025
250 SOIL  3  927.9 N 60
280 BOUS  80
290 TIMS  0.5  1  5  10  50
300 OUTPUT  1135.5  1195.5  5
310 END
```

```
100 TITLE
110 Marsh Lake: Both the  Initial Highway embankment and the proposed  road raise
120 2DSO  1  8  0  0.5  125
130 -9999  939
140  1136.6  939
150  1168  939
160  1223  952.75
170  1248  952.75
180  1303  939
190  1325  939
200  9999  939
210 SOIL  1  939 S 50  0.1  11  0.32
220 INDEX  0.53  138  1.755
230 SOIL  2  932.1 S 40  0.03  11  0.32
240 INDEX  0.37  550  1.025
250 SOIL  3  927.9 N 60
270 BOUS  80
280 TIMI  0.0192  2
290 OUTPUT  1135.5  1235.5  5
300 END
```

CSETT Settlement

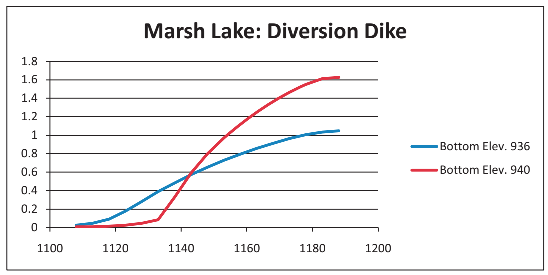
II. OUTPUT SUMMARY.

TITLE- Marsh Lake Diversion Dike: Bottom at 936.0

TIME	X=1108.0	X=1113.0	X=1118.0	X=1123.0	X=1128.0	X=1133.0	X=1138.0	X=1143.0	X=1148.0	X=1153.0	X=1158.0	X=1163.0	X=1168.0	X=1173.0	X=1178.0	X=1183.0	X=1188.0
(YR)	1108	1113	1118	1123	1128	1133	1138	1143	1148	1153	1158	1163	1168	1173	1178	1183	1188
----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
ULT.	0.024	0.045	0.092	0.177	0.283	0.388	0.484	0.573	0.654	0.728	0.795	0.858	0.913	0.965	1.007	1.035	1.047
0.5	0.018	0.034	0.068	0.132	0.211	0.288	0.361	0.427	0.486	0.54	0.591	0.637	0.68	0.717	0.75	0.771	0.779
1	0.024	0.045	0.092	0.176	0.279	0.383	0.478	0.567	0.646	0.718	0.785	0.847	0.904	0.954	0.996	1.024	1.034
5	0.024	0.045	0.092	0.177	0.283	0.388	0.484	0.573	0.654	0.728	0.795	0.858	0.913	0.965	1.007	1.035	1.047
10	0.024	0.045	0.092	0.177	0.283	0.388	0.484	0.573	0.654	0.728	0.795	0.858	0.913	0.965	1.007	1.035	1.047
50	0.024	0.045	0.092	0.177	0.283	0.388	0.484	0.573	0.654	0.728	0.795	0.858	0.913	0.965	1.007	1.035	1.047

TITLE- Marsh Lake Diversion Dike: Bottom at 940.0

TIME	X=1108.0	X=1113.0	X=1118.0	X=1123.0	X=1128.0	X=1133.0	X=1138.0	X=1143.0	X=1148.0	X=1153.0	X=1158.0	X=1163.0	X=1168.0	X=1173.0	X=1178.0	X=1183.0	X=1188.0
(YR)																	
----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
ULT.	0.007	0.01	0.016	0.026	0.045	0.085	0.33	0.592	0.799	0.97	1.118	1.249	1.364	1.466	1.551	1.614	1.627
0.5	0.006	0.008	0.012	0.02	0.034	0.066	0.289	0.526	0.708	0.858	0.985	1.097	1.196	1.283	1.357	1.412	1.423
1	0.007	0.01	0.016	0.026	0.045	0.084	0.329	0.591	0.795	0.966	1.113	1.244	1-Jan-00	1.459	1.543	1.606	1.62
5	0.007	0.01	0.016	0.026	0.045	0.085	0.33	0.592	0.799	0.97	1.118	1.249	1.364	1.466	1.551	1.614	1.627
10	0.007	0.01	0.016	0.026	0.045	0.085	0.33	0.592	0.799	0.97	1.118	1.249	1.364	1.466	1.551	1.614	1.627
50	0.007	0.01	0.016	0.026	0.045	0.085	0.33	0.592	0.799	0.97	1.118	1.249	1.364	1.466	1.551	1.614	1.627



II. OUTPUT SUMMARY.

TITLE- Marsh Lake existing road raise: Existing road profile

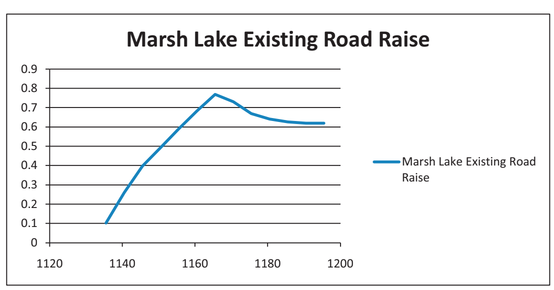
TIME	X=1135.5	X=1140.5	X=1145.5	X=1150.5	X=1155.5	X=1160.5	X=1165.5	X=1170.5	X=1175.5	X=1180.5	X=1185.5	X=1190.5	X=1195.5
(YR)													
----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
ULT.	0.012	0.014	0.015	0.028	0.035	0.05	0.083	0.235	0.393	0.499	0.56	0.58	0.583
0.5	0	0	0	0	0.001	0.007	0.023	0.085	0.15	0.194	0.218	0.224	0.225
1	0	0	0	0.006	0.017	0.022	0.036	0.147	0.259	0.335	0.374	0.384	0.386
5	0.01	0.012	0.014	0.017	0.028	0.039	0.069	0.215	0.365	0.468	0.523	0.541	0.544
10	0.011	0.013	0.015	0.023	0.035	0.048	0.078	0.229	0.385	0.491	0.549	0.567	0.573
50	0.012	0.014	0.015	0.028	0.035	0.05	0.083	0.235	0.393	0.499	0.56	0.58	0.583

TITLE- Marsh Lake existing road raise: Raised road profile

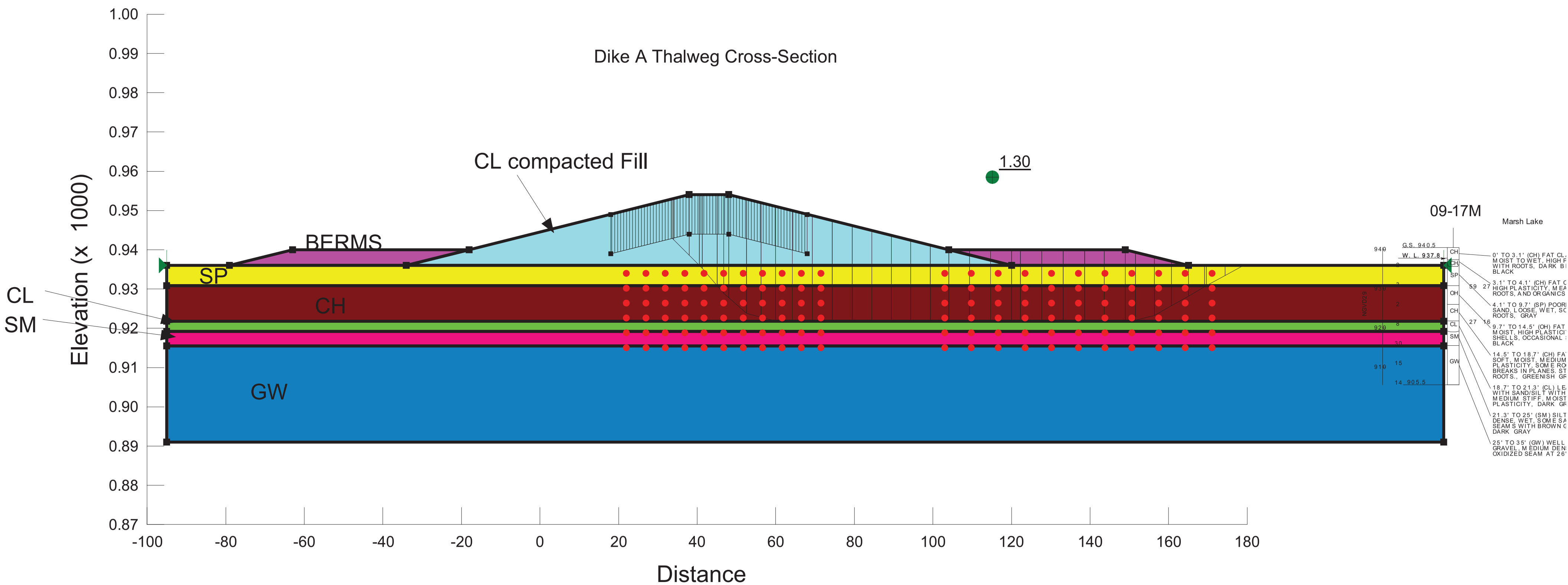
TIME	X=1135.5	X=1140.5	X=1145.5	X=1150.5	X=1155.5	X=1160.5	X=1165.5	X=1170.5	X=1175.5	X=1180.5	X=1185.5	X=1190.5	X=1195.5
(YR)													
----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
ULT.	0.114	0.274	0.413	0.52	0.624	0.732	0.851	0.965	1.063	1.14	1.186	1.199	1.202
0.5	0.03	0.093	0.147	0.188	0.226	0.268	0.315	0.361	0.4	0.433	0.451	0.454	0.454
1	0.052	0.164	0.258	0.328	0.393	0.466	0.546	0.623	0.691	0.748	0.778	0.785	0.785
5	0.095	0.247	0.375	0.476	0.569	0.674	0.781	0.889	0.981	1.06	1.099	1.11	1.113
10	0.11	0.267	0.402	0.509	0.607	0.715	0.829	0.943	1.038	1.118	1.162	1.173	1.174
50	0.114	0.274	0.413	0.52	0.624	0.732	0.851	0.965	1.063	1.14	1.186	1.199	1.202

TITLE- Marsh Lake existing road raise: Raised road profile minus existing road profile

TIME	X=1135.5	X=1140.5	X=1145.5	X=1150.5	X=1155.5	X=1160.5	X=1165.5	X=1170.5	X=1175.5	X=1180.5	X=1185.5	X=1190.5	X=1195.5
(YR)	1135.5	1140.5	1145.5	1150.5	1155.5	1160.5	1165.5	1170.5	1175.5	1180.5	1185.5	1190.5	1195.5
----	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
ULT.	0.102	0.26	0.398	0.492	0.589	0.682	0.768	0.73	0.67	0.641	0.626	0.619	0.619
0.5	0.03	0.093	0.147	0.188	0.225	0.261	0.292	0.276	0.25	0.239	0.233	0.23	0.229
1	0.052	0.164	0.258	0.322	0.376	0.444	0.51	0.476	0.432	0.413	0.404	0.401	0.399
5	0.085	0.235	0.361	0.459	0.541	0.635	0.712	0.674	0.616	0.592	0.576	0.569	0.569
10	0.099	0.254	0.387	0.486	0.572	0.667	0.751	0.714	0.653	0.627	0.613	0.606	0.601
50	0.102	0.26	0.398	0.492	0.589	0.682	0.768	0.73	0.67	0.641	0.626	0.619	0.619



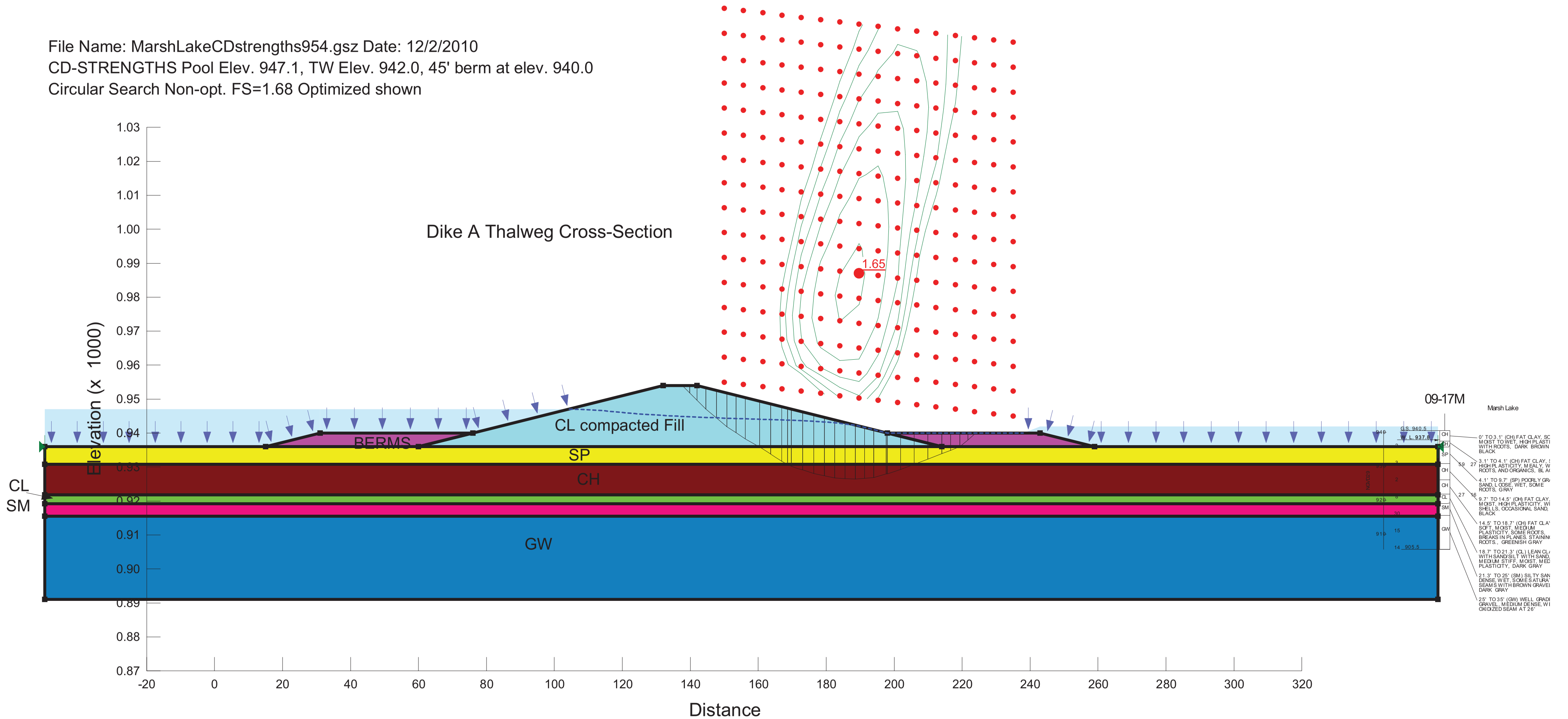
File Name: MarshLakeUUstrengthsCLtop954.gsz Date: 12/2/2010
UU-STRENGTHS 10' Crack filled with water with 45 foot berm at elev. 940.0
Non-Circular Search Non-opt. FS=1.38 Optimized Shown



CH Multiple Trial: 97 pcf Multiple Trial: 180 psf
SP Multiple Trial: 125 pcf 0 psf Multiple Trial: 30 °
SM Multiple Trial: 105 pcf 0 psf 33 °
GW Multiple Trial: 130 pcf 0 psf Multiple Trial: 30 °
CL compacted Fill Multiple Trial: 120 pcf Multiple Trial: 1300 psf
BERMS 100 pcf 300 psf
CL 97 pcf 840 psf

PLATE H-8

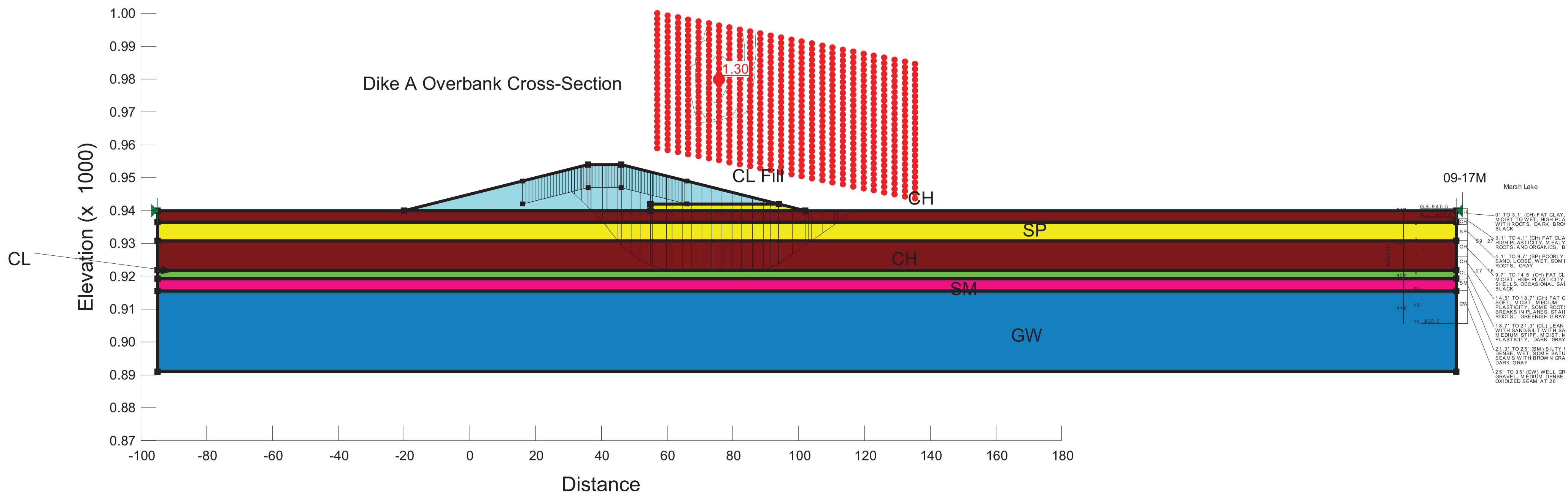
File Name: MarshLakeCDstrengths954.gsz Date: 12/2/2010
CD-STRENGTHS Pool Elev. 947.1, TW Elev. 942.0, 45' berm at elev. 940.0
Circular Search Non-opt. FS=1.68 Optimized shown



Name: CH Unit Weight: Multiple Trial: 97 pcf Cohesion: Multiple Trial: 0 psf Phi: 25 °
Name: SP Unit Weight: Multiple Trial: 125 pcf Cohesion: 0 psf Phi: Multiple Trial: 30 °
Name: SM Unit Weight: Multiple Trial: 130 pcf Cohesion: 0 psf Phi: 33 °
Name: GW Unit Weight: Multiple Trial: 130 pcf Cohesion: 0 psf Phi: Multiple Trial: 30 °
Name: CL compacted Fill Unit Weight: Multiple Trial: 120 pcf Cohesion: Multiple Trial: 0 psf Phi: 25 °
Name: BERMS Unit Weight: 100 pcf Cohesion: 300 psf Phi: 0 °
Name: CL Unit Weight: 100 pcf Cohesion: 200 psf Phi: 30 °

PLATE H-8

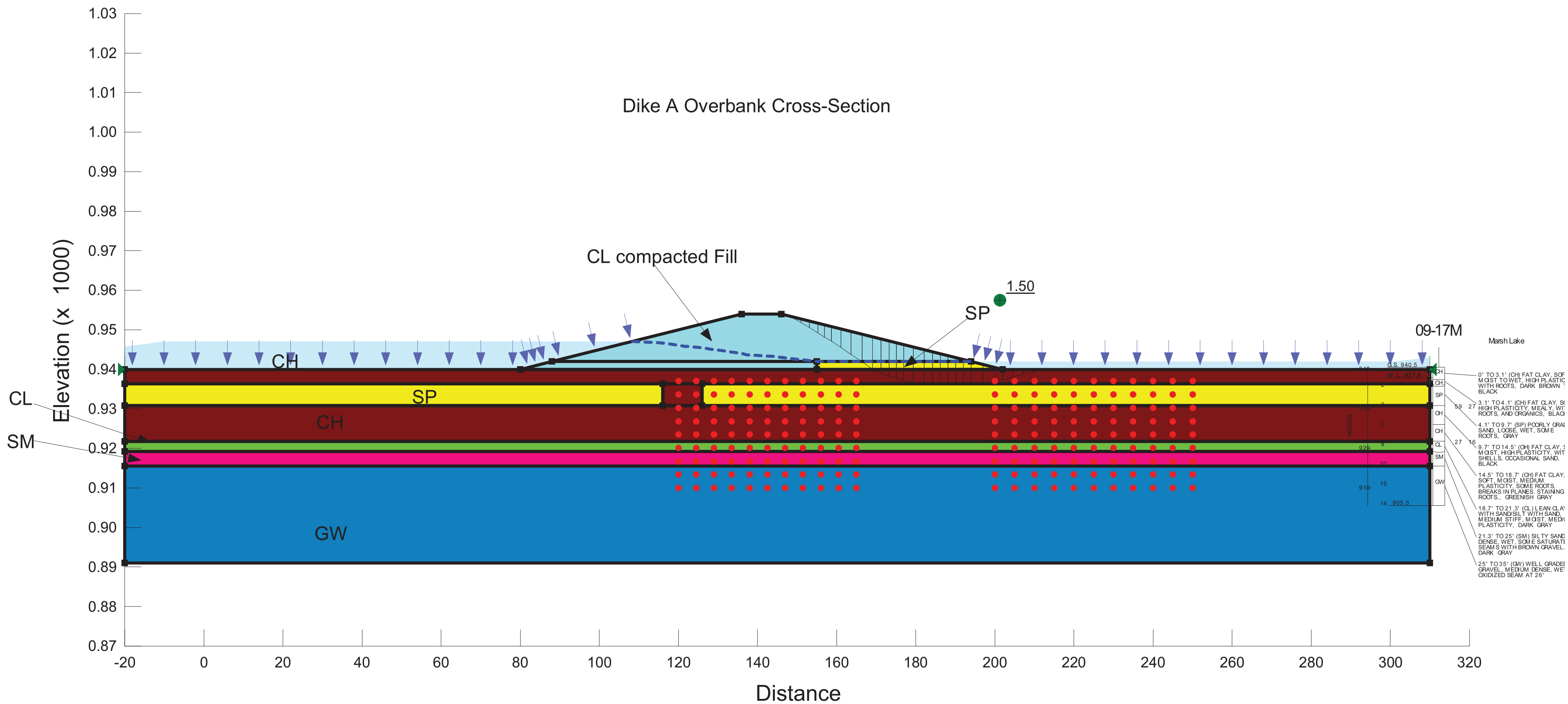
File Name: MarshLakeUUstrengthstop954Bottom940.gsz Date: 12/2/2010
UU-STRENGTHS 7' Crack depth filled with water
Circular Search Non-opt.=1.48 Optimized Shown



CH Multiple Trial: 97 pcf Multiple Trial: 180 psf 0 °
SP Multiple Trial: 125 pcf 0 psf Multiple Trial: 30 °
SM Multiple Trial: 105 pcf 0 psf 33 °
GW Multiple Trial: 130 pcf 0 psf Multiple Trial: 30 °
CL Fill Multiple Trial: 120 pcf Multiple Trial: 1300 psf 0 °
CL 97 pcf 840 psf 0 °

PLATE H-8

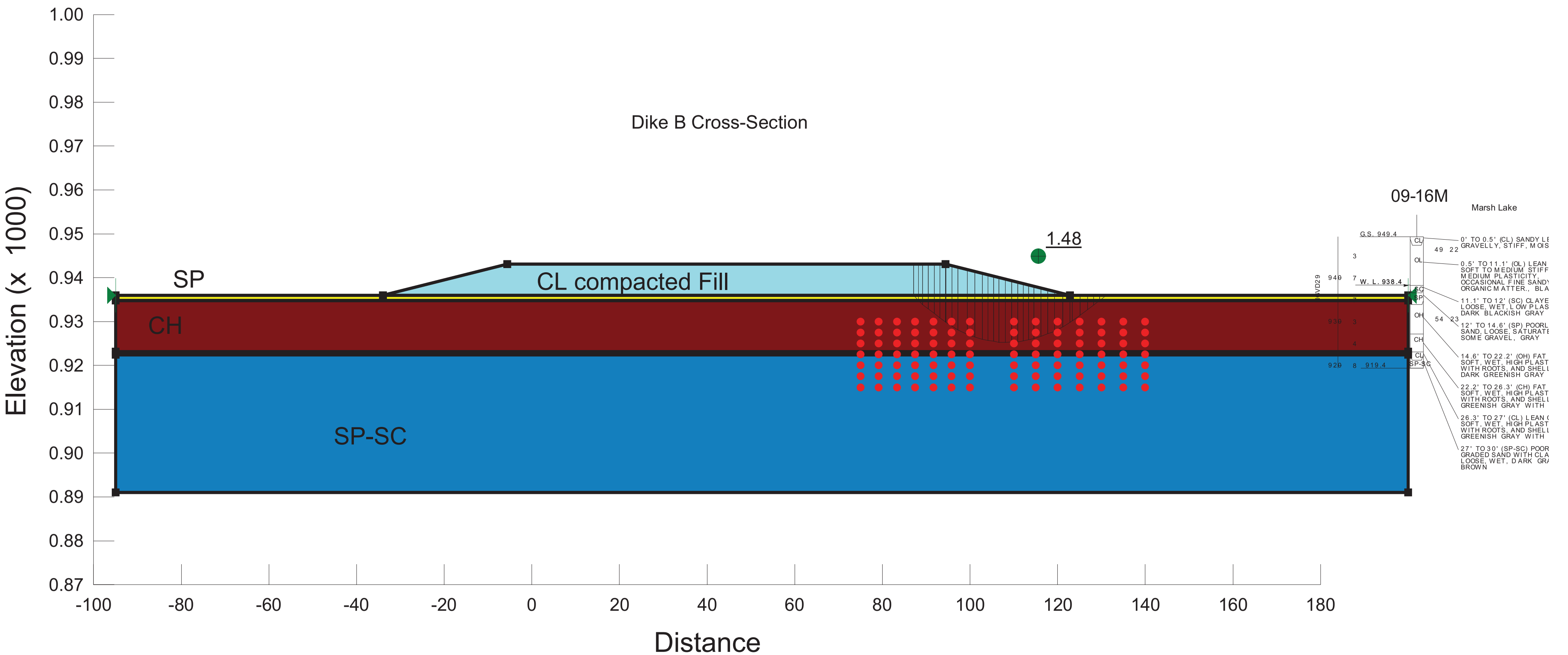
File Name: MarshLakeCDstrengths940top954.gsz Date: 12/9/2010
CD-STRENGTHS Pool Elev. 947.1, SAND CUTOFF, Downstream Water Surface Elev. 942.0
Non-Circular Search Non-opt. FS = 1.81 Optimized Shown



CH	Multiple Trial: 97 pcf	Multiple Trial: 0 psf	25 °
SP	Multiple Trial: 125 pcf	0 psf	Multiple Trial: 30 °
SM	Multiple Trial: 130 pcf	0 psf	33 °
GW	Multiple Trial: 130 pcf	0 psf	Multiple Trial: 30 °
CL compacted Fill	Multiple Trial: 120 pcf	Multiple Trial: 0 psf	25 °
CL	113 pcf	200 psf	30 °

PLATE H-8

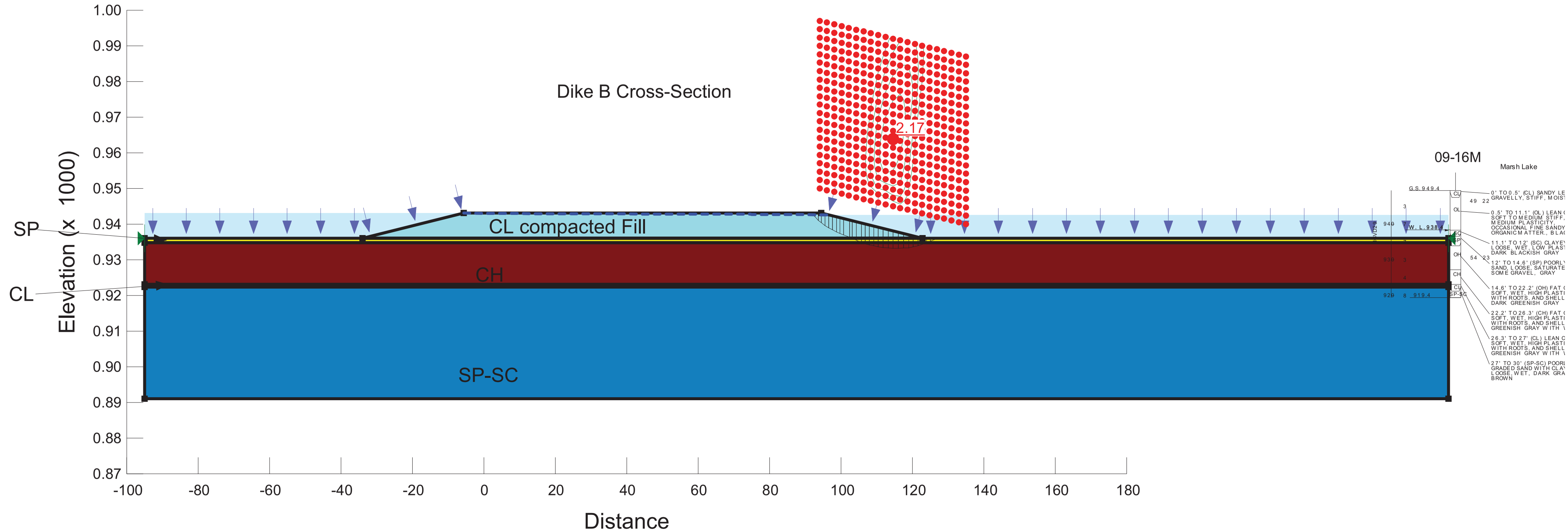
File Name: MarshLakeUUstrengthsDikeB.gsz Date: 12/2/2010
UU-STRENGTHS Search for Crack depth
Non-Circular Search Non-opt. FS = 1.62 Optimized Shown



CH Multiple Trial: 97 pcf Multiple Trial: 180 psf 0 °
SP Multiple Trial: 125 pcf 0 psf Multiple Trial: 30 °
SP-SC Multiple Trial: 130 pcf 0 psf Multiple Trial: 30 °
CL compacted Fill Multiple Trial: 100 pcf Multiple Trial: 1300 psf 0 °
CL 97 pcf 840 psf 0 °

PLATE H-8

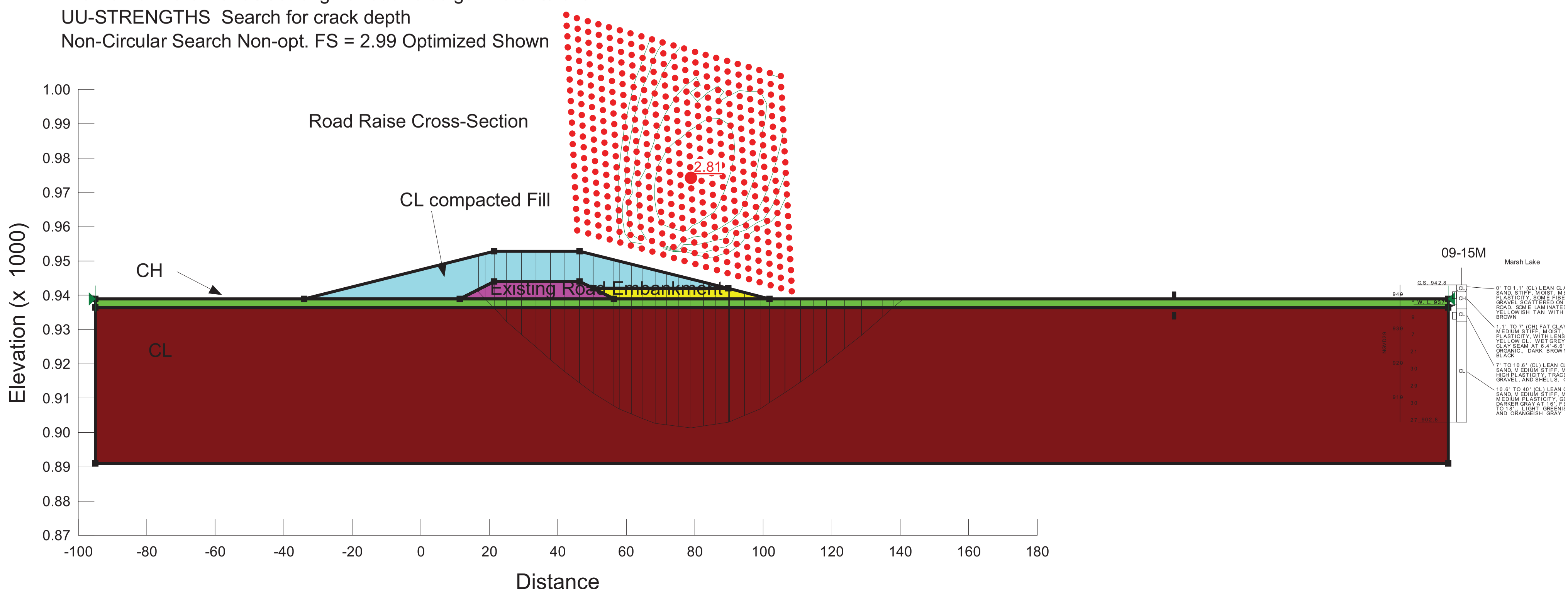
File Name: MarshLakeCDstrengthsDikeB.gsz Date: 12/2/2010
CD-STRENGTHS Downstream Water Surface Elev.=942.6
Circular Search Non-opt. FS= 2.20 Otimized Shown



CH   Multiple Trial: 97 pcf   Multiple Trial: 0 psf   25 °
SP   Multiple Trial: 125 pcf   0 psf   Multiple Trial: 30 °
SP-SC   Multiple Trial: 130 pcf   0 psf   Multiple Trial: 30 °
CL compacted Fill   Multiple Trial: 120 pcf   Multiple Trial: 0 psf   25 °
CL   97 pcf   0 psf   20 °

PLATE H-8

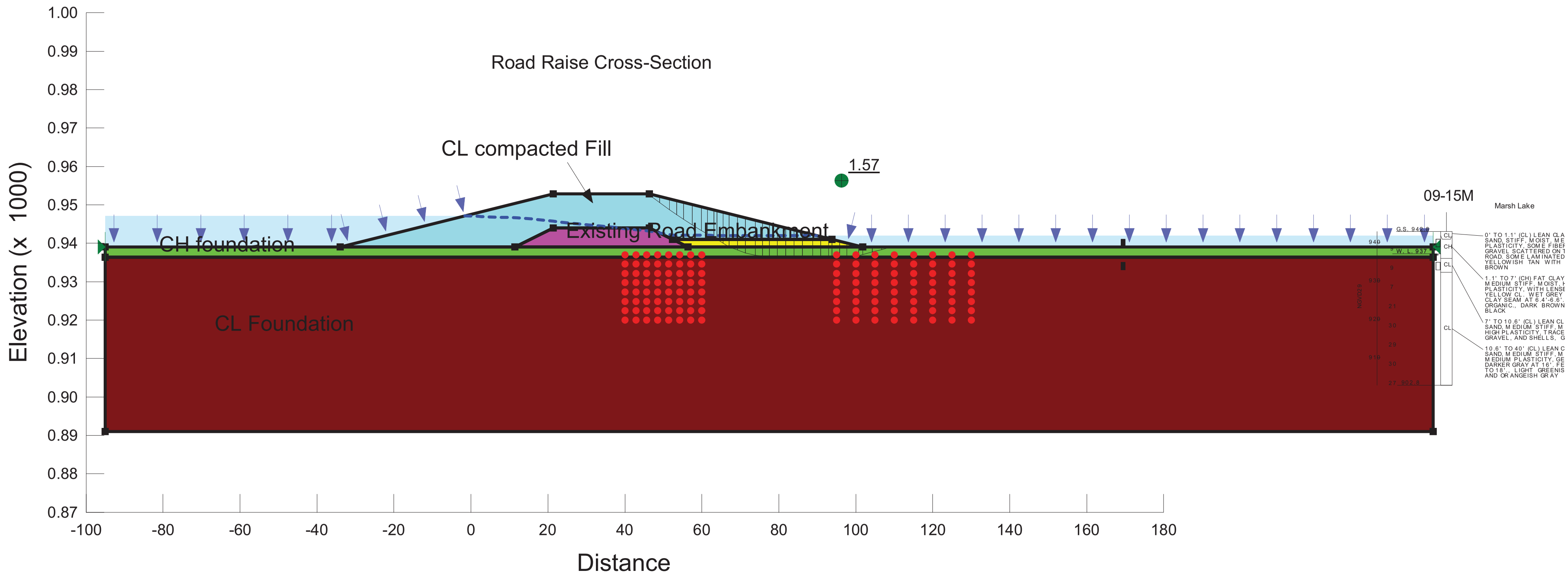
File Name: MarshLakeUUstrengthsRoadRaise.gsz Date: 3/1/2011
UU-STRENGTHS Search for crack depth
Non-Circular Search Non-opt. FS = 2.99 Optimized Shown



CL Multiple Trial: 97 pcf Multiple Trial: 840 psf 0 °
SP Multiple Trial: 125 pcf 0 psf Multiple Trial: 30 °
CL compacted Fill Multiple Trial: 120 pcf Multiple Trial: 1300 psf 0 °
Existing Road Embankment 100 pcf 1300 psf 0 °
CH 97 pcf 180 psf 0 °

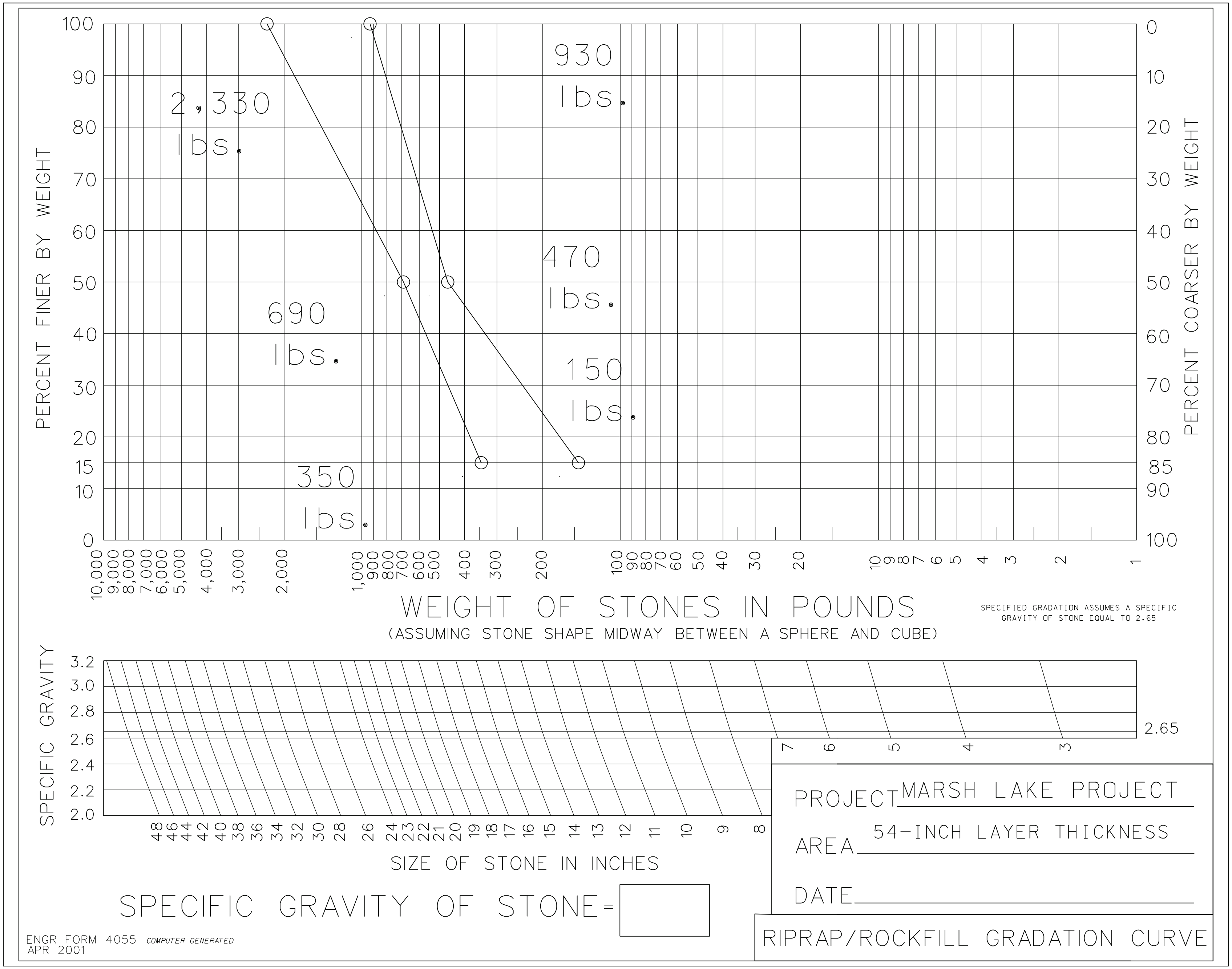
PLATE H-8

File Name: MarshLakeCDstrengthsRoadRaise.gsz Date: 12/10/2010
CD-STRENGTHS Pool Elev. 947.1, Downstream Water Surface Elev. = 942.0
Non-Circular Search Non-opt. FS=1.87 Optimized Shown



CL Foundation   Multiple Trial: 97 pcf   Multiple Trial: 200 psf   30 °
SP   Multiple Trial: 125 pcf   0 psf   Multiple Trial: 30 °
CL compacted Fill   Multiple Trial: 120 pcf   Multiple Trial: 0 psf   25 °
Existing Road Embankment   120 pcf   0 psf   30 °
CH foundation   97 pcf   0 psf   25 °

PLATE H-8



PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
2,330 lbs.
930 lbs.
470 lbs.
690 lbs.
150 lbs.
350 lbs.
WEIGHT OF STONES IN POUNDS
(ASSUMING STONE SHAPE MIDWAY BETWEEN A SPHERE AND CUBE)
SPECIFIED GRADATION ASSUMES A SPECIFIC GRAVITY OF STONE EQUAL TO 2.65
SPECIFIC GRAVITY
SIZE OF STONE IN INCHES
SPECIFIC GRAVITY OF STONE=
PROJECT MARSH LAKE PROJECT
AREA 54-INCH LAYER THICKNESS
DATE
RIPRAP/ROCKFILL GRADATION CURVE
ENGR FORM 4055 COMPUTER GENERATED
APR 2001

PLATE H-9