P. MACHIBRODA ENGINEERING LTD.

CONSULTING
GEOTECHNICAL
GEOENVIRONMENTAL
ENGINEERS AND
GEOSCIENTISTS

SASKATOON
806 – 48TH STREET EAST
SASKATOON, SK
S7K 3Y4

PHONE:
(306) 665-8444
FAX:
(306) 652-2092

E-MAIL:
pmel.sk@machibroda.com

WEB:
www.machibroda.com

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SLOPE STABILITY STUDY AND DEWATERING ASSESSMENT EAST BANK SOUTH SASKATCHEWAN RIVER OUTLOOK, SASKATCHEWAN

PMEL FILE NO. 12451
OCTOBER 26, 2017

PREPARED FOR:

TOWN OF OUTLOOK
BOX 518
OUTLOOK, SASKATCHEWAN
S0L 2N0

ATTENTION: MR. TRENT MICHELMAN

EXECUTIVE SUMMARY

P. Machibroda Engineering Ltd. (PMEL) was authorized by the Town of Outlook to complete a slope stability study and dewatering assessment for the East Bank of the South Saskatchewan River, located approximately between Park Avenue and Progress Avenue, in Outlook, Saskatchewan. Based on the investigation conducted by PMEL in 2015, it was theorized that lowering the groundwater table by approximately 20 metres could raise the Factor of Safety of the slope to 1.2.

Dewatering options analyzed included horizontal drains and vertical dewatering wells. Horizontal drains are installed horizontally into a slope at different angles form horizontal and rely on gravity drainage. Vertical dewatering wells would be deep wells that rely on pumping.

Based on the results of our study, Horizontal drains could theoretically lower the groundwater table by approximately 6 metres in the lower slope (west half), but would have little impact on groundwater levels in the upper slope. The limitations of the horizontal drains are due to the limits on installation length in comparison to the slope length and the low permeability of the soil. Theoretically, a vertical well could lower the groundwater by 6 metres at a distance of approximately 5 metres from the well. However, based on the modelling results, horizontal drains and/or vertical pumping wells would not be effective in sufficiently dewatering the slope to stabilize it. In general this is due to the permeability of the in-situ soils being too low for dewatering to be effective. In other words the clay rich soils at the site are too tight to allow for effective removal of enough groundwater to significantly lower the water table elevation.

Due to the size of the landslide and the depth of the slip surface, PMEL is of the opinion that there are practical, cost effective solutions to stabilize this slope. Structures/properties on the slope have a high risk of further damage due to ongoing slope movement. Properties located along the crest of the slope are considered to be at risk of being impacted by slope movement if the landslide regresses further upslope of the crest (in areas it has not already regressed upslope).

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1.0 INTRODUCTION

1.1 General

The following report has been prepared on the results of a slope stability study and dewatering assessment conducted for the East Bank of the South Saskatchewan River, located approximately between Progress Avenue and the Skytrail Bridge, in Outlook, Saskatchewan.

Authorization to proceed with this investigation was provided on December 16, 2016 via the signed Consulting Agreement. The Terms of Reference for this investigation were presented in P. Machibroda Engineering Ltd. (PMEL) Proposal No. 12451REV1, dated December 16, 2016.

The field test drilling and sampling were conducted between January 18, 19, 20 and 21, 2017. Groundwater level monitoring and slug tests were conducted on February 14, March 14, April 17 and September 28, 2017. Slope inclinometer readings were conducted on February 14, April 17, and September 28, 2017.

1.2 Past Reports

PMEL completed slope stability studies of the East Bank of the South Saskatchewan River in 2008 (refer to PMEL Report No. S08-6559, dated November 19, 2008) and 2015 (refer to PMEL Report No. 9551, dated August 31, 2015).

The 2008 investigation theorized that the probable failure mode was a deep seated composite failure and recommended that slope inclinometers be installed to determine the elevation of the slip plane and rate of lateral slope movement.

The 2015 investigation determined the slip plane was between 32 and 35 metres below existing grade and the landslide was actively moving. Due to the depth of the slip plane and size of the landslide, lowering of the groundwater table was considered as the only feasible option for increasing the stability of the slope.

2.0 FIELD INVESTIGATION

Twelve (12) test holes, located as shown on the Site Plan, Drawing No. 12451-1, were drilled using powered drilling equipment. Test Hole Nos. 17-1A to 17-5B, inclusive, were 150 mm in diameter and dry drilled using our truck-mounted continuous flight auger drilling equipment. The test holes were extended to depths between approximately 6 and 21 metres below existing ground surface.

Test Hole No. SI 17-1 was drilled using a truck-mounted, mud rotary drill rig and extended to a depth of 62 metres below existing grade. Soil samples were not collected during the drilling of this test hole. The purpose of this test hole was to install slope inclinometer casing.

Test hole drill logs were compiled during test drilling to record the soil stratification, the groundwater conditions, the position of unstable sloughing soils and the depths at which cobblestones and/or boulders were encountered.

Disturbed samples of auger cuttings and drill cuttings, collected during test drilling, were sealed in plastic bags to minimize moisture loss. The soil samples were taken to our laboratory for analysis.

Standpipe piezometers (slotted, 50 mm PVC pipe) were installed in all test holes (with the exception of SI 17-1) to monitor existing groundwater levels.

Slope inclinometer casing (85 mm diameter) was installed in Test Hole No. SI 17-1 to monitor horizontal ground movement.

3.0 FIELD DRILL LOGS

The field drill logs recorded during test drilling have been shown plotted on Drawing Nos. 12451-2 to 13E, inclusive.

The ground surface elevation at each Test Hole location was referenced to the top of the top bolt of a fire hydrant located along Progress Avenue near the northwest corner of the Hospital, approximately as shown on the Site Plan, Drawing No. 12451-1. A datum elevation of 540.345 metres was provided by Associated Engineering for the top of bolt of the fire hydrant.

3.1 Soil Profile

In general, the subgrade soil conditions consisted of a surficial layer of topsoil overlying glacial till extending to depths estimated to range from 25 to 30 metres below existing grade. The clay shale which extended to a depth of at least 47 metres below grade, was underlain by wet sand and silt that extended to a depth of at least 62 metres below existing grade, the maximum depth explored during this field investigation.

Inter/intra till silt deposits, of variable thickness, were encountered in Test Hole Nos. 2A, 2B, 3A and 3B. Inter/intra till sand lenses/layers were encountered throughout the glacial till.

Mud rotary drilling was conducted below a depth of 20.5 metres (Test Hole No. SI 17-1). Since this method did not allow extensive sampling, the soil stratigraphy below this depth was estimated.

3.2 Groundwater Conditions and Sloughing

Groundwater seepage and sloughing conditions were encountered during test drilling. The depths at which groundwater seepage and sloughing conditions were encountered have been shown on the field drill logs, as shown on Drawing Nos. 12451-2 to 13E, inclusive.

A summary of the groundwater levels recorded in the standpipe piezometers installed during this investigation and the 2008 investigation has been presented in Table I.

TABLE I. RECORDED GROUNDWATER LEVELS

Test Hole No.	Piezometer Rim Elevation* (metres)	Piezometer Tip Elevation (metres	Ground Surface Elevation* (metres	Recorded Groundwater Levels (metres)		
				February 14, 2017	April 17, 2017	September 28, 2017
08-1*	513.0	471.3	512.0	506.3	506.4	505.9
08-4*	507.5	477.9	506.7	499.6	499.6	499.3
14-1A	537.7	528.2	536.7	--	--	532.5
17-1A	536.9	515.3	535.8	515.5	516.2	520.1
17-1B	536.9	523.9	535.9	524.2	527.4	528.3
17-1C	536.7	529.9	535.8	Dry	Dry	Dry
17-2A	512.3	491.4	511.4	500.0	505.6	508.1
17-2B	512.5	501.0	511.4	502.3	506.2	509.8
17-3A	538.2	517.3	537.3	518.0	519.9	523.7
17-3B	538.2	526.8	537.3	527.8	528.5	528.7
17-4A	532.3	511.3	531.3	525.2	525.0	524.6
17-4B	532.3	521.1	531.3	525.8	525.7	525.3
17-5A	522.6	506.6	521.7	506.8	508.1	512.9
17-5B	522.7	517.3	521.7	519.3	519.9	518.5

*Piezometers installed in PMEL's 2008 investigation (S08-6559)
**Piezometer installed in PMEL's 2015 investigation (9551), water level was measured at 532.6 metres on May 4, 2016.

The water elevation of the South Saskatchewan River was 495.0 metres on December 21, 2016.

Higher water levels should be expected during and/or following spring snowmelt and/or periods of precipitation.

3.3 Hydraulic Conductivity Test

The results of hydraulic conductivity (bail response) tests conducted during this investigation have been tabulated and presented in Table II. The bulk saturated hydraulic conductivities were calculated utilizing the Bouwer and Rice (1976) method. Each test consisted of removing or adding a known volume of water to produce a change in the hydraulic head within the monitoring wells.

The water levels within the monitoring wells were then allowed to recover and the response was measured with respect to time.

TABLE II. SUMMARY OF HYDRAULIC CONDUCTIVITY TEST RESULTS

Well No.	Screen Interval (metres)	Soil Type	Hydraulic Conductivity (m/sec)
08-1	41.2 - 41.7*	Clay Shale	5×10^{-7}
08-4	29.1 - 29.6*	Clay Shale	3×10^{-7}
17-1B	10.5 - 12.0	Glacial Till	3×10^{-7}
17-2A	18.8 - 19.8	Glacial Till	4×10^{-8}
17-2B	9.5 - 10.5	Glacial Till	3×10^{-7}
17-3B	9.5 - 10.5	Glacial Till	2×10^{-7}
17-4A	19.0 to 20.0	Glacial Till	9×10^{-8}
17-4B	9.4 to 9.4	Glacial Till	1×10^{-7}
17-5B	14.0 - 15.0	Glacial Till	8×10^{-7}

*Piezometer screen was not sand packed.

Review of the results revealed that the in-situ hydraulic conductivity varied between 8×10^{-7} and 4×10^{-8} m/s. The average in-situ hydraulic conductivity was 3×10^{-7} and 4×10^{-7} for the glacial till and clay shale, respectively.

3.4 Slope Inclinometer Survey

A new slope inclinometer (SI) was installed as part of this investigation (SI 17-1). The results of the SI readings have been shown plotted in Appendix B. SI readings of SI 14-1, SI 15-1, SI 15-2 and SI 17-1 were conducted on February 14, April 17 and September 28, 2017. The baseline slope inclinometer reading for Slope Inclinometer No. SI 17-1 was conducted on February 14, 2017.

The summarized cumulative displacement and incremental change of the slope indicator readings have been presented as “Profile Change” and “Tilt Change” on the slope inclinometer plots, respectively.

An examination of the SI plots revealed the following:

- In SI 17-1 approximately 10 mm of lateral slope movement (total cumulative displacement) was measured between February 14 and September 28, 2017. The plots revealed that a slip plane was located approximately 36.7 metres below existing grade (Geodetic Elevation of approximately 486.4 metres). This equates to on average approximately 1.3 mm of lateral slope movement per month.

- In SI 15-1 approximately 35 mm of lateral slope movement was measured between May 5, 2016 and February 14, 2017, and approximately 14 mm between February 14 and September 28, 2017 at approximately 32 metres below existing grade (Geodetic Elevation of approximately 475 metres). A total of 92 mm (sum of A and B axis movement) of lateral slope movement has been measured since the initial readings of SI 15-1 (April 29, 2015). This equates to on average approximately 3 mm of lateral slope movement per month. The movement appears to have slowed down in 2017, in comparison to the first year of monitoring (2015).

- In SI 14-1 approximately 2 mm of lateral slope movement was measured between February 14, and April 17, 2017. Negligible movement was measured between April 17, and September 28, 2017. As noted in the 2015 Geotechnical Report, this SI was likely not installed deep enough to fully capture the slip plane. However, based on the SI plots, it appears that a slip plane is located at approximately 19.5 metres below existing grade in the glacial till and at 33 metres below existing grade near the glacial till and clay shale interface.

- No measurements could be obtained in SI 15-2 due to the SI casing having been sheared off at the slip plane (approximately 35 metres below existing grade) sometime between May, 2016 and February, 2017. Between April 29, 2015 and May 4, 2016 approximately 5 to 6 mm of lateral movement per month was measured at this location.

4.0 LABORATORY ANALYSIS

The soil classification and index tests performed during this investigation consisted of a visual classification of the soil, water contents, Atterberg limits, unit weights and grain size analysis.

The results of soil classification and index tests conducted on representative samples of soil recovered from this site have been plotted alongside the depth at which the samples were recovered as shown on Drawing Nos. 12451-2 to 13E, inclusive.

The results of the grain size distribution analysis have been presented in Appendix C.

5.0 SLOPE AND SEEPAGE ANALYSIS

5.1 Theoretical Slope Stability and Seepage Analysis

The theoretical seepage and slope stability analysis were performed using the SEEP/W and SLOPE/W computer programs, respectively, available through Geo-Slope International Ltd[1]. The Morgenstern-Price Method of slices was used for all analysis in the stability models (utilizing a half-sine side force function).

5.1.1 Surface Geometry

The surface geometry of the subject site was interpreted from a survey of the subject site conducted by Associated Engineering.

5.1.2 Soil Stratigraphy

The stratigraphic units as well as the lithologic boundaries were interpreted based on the results of the drilling investigations conducted by PMEL. The general soil conditions consisted of a surface layer of glacial underlain by clay shale bedrock. The slope was analyzed for circular and composite failures.

[1] Geo-Slope International Ltd., 2007. Slope/W User's Manual, A Comprehensive Program for Slope Stability Analysis, Geo-Slope International Ltd., Calgary, Alberta.

5.1.3 Piezometric Conditions

The piezometric conditions used for the slope stability analysis were inferred from the groundwater levels recorded during this investigation. A hydrostatic pore pressure condition was used for the analysis.

It should be noted that the inferred groundwater conditions in the slope analysis were simplified and may not reflect actual conditions. The modelled groundwater conditions assumed one groundwater level impacting the entire soil profile.

5.1.4 Soil Properties

The soil properties obtained during this investigation as well as the design strength parameters used for the theoretical slope stability analysis have been presented in Table III. The soil strength parameters selected for analysis were based on published strength parameters, laboratory testing on soil samples collected during this investigation and a back analysis of the historical slope failure (see Section 5.2).

TABLE III. SOIL PARAMETERS FOR ANALYSIS

Material Type	Total Unit Weight (kN/m^3)	Effective Unit Cohesion (kPa)	Effective Internal Angle of Friction (Degrees)
Glacial Till	21.5	10	30
Clay Shale	18.5	25	20
Residual Clay Shale*	18	0	6
Bedrock - Impenetrable	--	--	--

5.2 Dewatering Options

It was theorized (refer to PMEL Report No. 9551, dated August 31, 2015) that lowering the groundwater level by 20 metres could raise the stability of the slope to a Factor of Safety of approximately 1.2.

In light of the above the effects of lowering the groundwater by installing horizontal drains and vertical dewatering wells were considered.

5.2.1 Horizontal Drains

Horizontal drains typically consist of small diameter (50 mm diameter), slotted pipe installed into the slope via horizontal drilling. The pipes can be installed at different angles above and below horizontal depending on the application and up to 300 metres in length (depending on ground conditions). In hard soil conditions the lengths are typically limited to less than 200 metres.

To determine the suitability of the horizontal drains at this site a two-dimensional (2-D) numerical model (SEEP/W - Version 7.23, proprietary software of Geo-Slope International) was developed for the site. A steady state seepage analysis was conducted to model the initial groundwater conditions as based on the groundwater monitoring and bail response tests completed as part of the investigation. To model the effectiveness of the dewatering, a slope stability model (SLOPE/W - Version 7.23, proprietary software of Geo-Slope International) was set up using the modelled initial groundwater conditions. It was assumed the slope was at or slightly below equilibrium (Factor of Safety of 1 or less). Based on these assumptions, the back analysis consisted of adjusting the soil input parameters within the failed soil mass such that the results provide a Factor of Safety of approximately one (1). The back analysis has been graphically shown on Drawing No. Appendix D-1.

Different configurations were modelled to help determine the most effective drain layout. It was assumed that two different outlets would be established, one near the toe of the slope (at slightly above river elevation), and a second mid-slope near the toe of the upper slope (and tied into an existing storm drain). Based on this, a total of five drains were input into the model.

The seepage modelling revealed that the horizontal drains could theoretically lower the groundwater table by approximately 6 metres in the lower portion of the slope (approximately west half). However, the horizontal drains had minimal effect on the groundwater table in the upper half of the slope (approximately east half around the crest of slope).

Inputting the modelled groundwater table into the slope stability model revealed that the dewatering from the horizontal drains alone raised the stability of the slope from a Factor of Safety of 0.99 to 1.02. The seepage modelling of the horizontal drains and corresponding slope stability modelling has been graphically presented on Drawing No. Appendix D-2.

5.2.2 Vertical Dewatering Wells

The effects of pumping a vertical dewatering well, installed at the crest of the slope, were assessed using an axisymmetric numerical groundwater model (SEEP/W - Version 7.23, proprietary software of Geo-Slope International). Assumptions used to setup the model included the following: a single homogenous soil layer with a saturated hydraulic conductivity of $4x10^{-7}$ m/s; a confined aquifer; a 30 metre deep groundwater table; and a 40 metres deep well.

Results of the model assessment revealed the following:

1. The theoretical drawdown for a 40 metre deep well after 1 and 5 years of pumping would be approximately 4 and 6 metres below grade, respectively, at a distance of 5 metres from the well.

2. At 40 metres from the well the predicted drawdowns would be 1.5 and 3 metres, after 1 and 5 years, respectively of pumping.

The results of the groundwater modelling have been graphically presented on Drawing No. Appendix D-3.

5.2.3 Discussion of Results

Based on the above analysis, horizontal drains and vertical dewatering wells had only a slight effect on lowering the groundwater level in the slope.

Horizontal drains had a minimal effect on the groundwater level in the upper slope (east half) whereas horizontal drains in the lower slope (west half) theoretically could lower the groundwater level by 6 metres. However, this would theoretically only raise of the stability the slope by approximately three (3) percent (from a Factor of Safety 0.99 to 1.02) which would have negligible effect on slope movement. The effectiveness of the horizontal drains is limited due to the gradient of the slope and feasible length of the horizontal drains at this site. For horizontal drains to be effective the outlet should be positioned at a low elevation and for this site that would be at the river elevation. As such, it would likely not be possible to install horizontal drains the full length of the slope due to the presence of hard soil conditions and the necessity to install them at angles.

As the modelling showed the drains could lower the groundwater table sufficiently in the lower slope. However it would not have the reach to significantly lower the groundwater levels in the upper slope. As shown in the modelling, a drain was positioned near the toe of the upper slope. The practical depth for an outlet would likely be the limits of an open cut excavation (i.e., 4 to 6 metres). As shown in the model this was not deep enough to effectively lower the groundwater table in the upper slope. As such deeper drawndown point(s) would be required to lower the groundwater table enough to help stabilize the slope.

A review of the numerical groundwater modelling results reveals that a 40 metre deep well would only theoretically lower the groundwater table by approximately 4 metres at a distance of approximately 5 metres from the well after one (1) year of pumping. As noted above, the groundwater level would need to be lowered by at least 20 metres to help in stabilizing the slope. As such, vertical dewatering wells are not considered feasible at this site due to the in-situ soils having low permeability.

Overall, lowering the groundwater table to stabilize the slope is not considered feasible at this site. In general, the permeability of in-situ soils is too low to effectively lower the groundwater levels in the slope. In other words the clay rich soils at the site are too tight to allow for effective removal of enough groundwater to significantly lower the elevation at the groundwater table.

5.3 Further Discussion and Recommendations

The existing slopes were formed from historical landslides and the recent slope movement was due to the reactivation of these landslides along preexisting shear planes. Although the total east to west extent of the landslides was not fully investigated, signs of slope movement are evident along the slope between Park Avenue and Progress Avenue, as evident by tension cracking and damage to structures/properties observed within this vicinity. In general, slope movement appears to be occurring only below the crest of slope with the exception of an area along Tuft Crescent where a tension crack has been forming approximately 36 metres upslope of the crest of slope. This slump block, forming upslope of the crest, appears to encompass at least three residential properties where two houses appear to be fully on the slump block and one partially on the slump block (resulting in subsidence in one corner of this house). The locations of observed tension cracks have been shown on Drawing No. 12451-1.

Based on the slope inclinometers installed on the slope, the shear planes are located within the clay shale bedrock at elevations of between approximately 475 and 486 metres (approximately 32 to 36 metres below ground surface at midslope). The magnitude of lateral slope movement also varied at each slope inclinometer location. In general the slope movement has been greater in the vicinity of the Sky Trail Bridge in comparison to the portion of the slope in the vicinity of Tuft Crescent. Further, as based on tension cracking that has been observed in the vicinity of Tuft Crescent, the slope movement appears to be greater downslope of the crest in comparison to upslope of the crest. The variation in the elevation of the shear planes and magnitude of slope movement is likely due to there being different landslide blocks.

As noted in previous PMEL investigations the exact cause that initiated this recent movement is difficult to determine. However, the slope movement is likely occurring along preexisting shear planes that had formed at the time of the historical landslide activity. The shear planes are weakened layers of soil which become weaker following additional slope movement.

As such, as the existing landslide blocks move, the shear plane would have weakened further, resulting in greater risk of slope movement occurring with less changes in the slope condition (i.e., toe erosion, rise in groundwater levels, surcharge loading, etc.). It is suspected this is why a greater magnitude of slope movement has been occurred across the slope.

Based on PMEL's previous investigations, PMEL is of the opinion that due to the size of the existing landslides and depth of the shear plane, slope stabilization options consisting of slope flattening, buttressing, shear key or shear zone reinforcement were not considered feasible (both from an economic or constructability standpoint). Based on the most recent investigation, dewatering is also not considered feasible due to the low permeability of the in-situ soils. Other options like erosion control (i.e., river bank armouring) and removing surcharge loading (i.e., Sky Bridge) could possibility aid in lessening the magnitude of slope movement, but are unlikely to stabilize the slope.

Due to the sheer size of the slope and depth of the failure surface, it is of the opinion of PMEL that there are no practical/cost effective stabilization options to effectively stabilize the slope. There is a high probability the slope movement may regress upslope and further impact properties and infrastructure. Any infrastructure/structures/properties located on the slope or near/at the crest of slope are at risk of further or potential damage from slope movement. Based on the slope movement observed by PMEL since 2008, if the landslide regresses beyond the crest of slope (where it has not already) the slope movement is anticipated to be initially slow moving (i.e., less 25 mm in a year) but the rate may increase over time. As such, any damage will initially be slow in developing. It is recommended that underground utilities (water, sanitary, natural gas, etc.) are monitored closely as damage to these lines may result in greater property damage than slope movement alone.

It is recommended that the slope is continually monitored and consideration should be given in installing additional (2) slope inclinometers to monitor slope movement in different areas of the slope. This would help provide information to stakeholders to make decisions on infrastructure and properties (i.e., repairs to accommodate movement or location of new infrastructure).

6.0 LIMITATIONS

The presentation of the summary of the field drill logs, geotechnical investigation and stability/seepage modelling has been completed as authorized. Twelve, 100/150 mm diameter test holes were completed at this site. A field drill log was compiled for each Test Hole during test drilling which, we believe, was representative of the subsurface conditions at the Test Hole locations at the time of test drilling.

Variations in the subsurface conditions from that shown on the drill logs at locations other than the exact Test Hole locations should be anticipated. If conditions should differ from those reported here, then we should be notified immediately in order that we may examine the conditions in the field and reassess our recommendations in the light of any new findings.

No detectable evidence (odor or staining) of environmentally sensitive materials was detected during the actual time of the field test drilling program. If, on the basis of any knowledge, other than that formally communicated to us, there is reason to suspect that environmentally sensitive materials may exist, then additional test holes should be drilled and samples recovered for chemical analysis.

The subsurface investigation necessitated the drilling of deep test holes. Instrumentation was installed in each test hole and the hole annulus was backfilled at the completion of test drilling. Please be advised that some settlement of the backfill materials will occur which may leave a depression or an open hole. It is the responsibility of the client to inspect the site and backfill, as required, to ensure that the ground surface at each Test Hole location is maintained level with the existing grade.

This report has been prepared for the exclusive use of Town of Outlook and their agents for specific application to the slope stability study and dewatering assessment conducted for the East Bank of the South Saskatchewan River, approximately between Park Avenue and Progress Avenue, in Outlook, Saskatchewan. It has been prepared in accordance with generally accepted geotechnical engineering practices and no other warranty, express or implied, is made.

Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, is the responsibility of such Third Party. Governing Agencies such as municipal, provincial, or federal agencies having jurisdictions with respect to this development and/or construction of the facilities described herein have full jurisdiction with respect to the described development. Any other unspecified subsequent development would be considered Third Party and would, therefore, require prior review by PMEL. PMEL accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

The acceptance of responsibility for the design/construction recommendations presented in this report are contingent on adequate and/or full time inspection (as required, based on site conditions at the time of construction) by a representative of the Geotechnical Consultant. P. Machibroda Engineering Ltd. (PMEL) will not accept any responsibility on this project for any unsatisfactory performance if adequate and/or full time inspection is not performed by a representative of PMEL.

If this report has been transmitted electronically, it has been digitally signed and secured with personal passwords to lock the document. Due to the possibility of digital modification, only originally signed reports and those reports sent directly by PMEL can be relied upon without fault.

We trust that this report fulfills your requirements for this project. Should you require additional information, please contact us.

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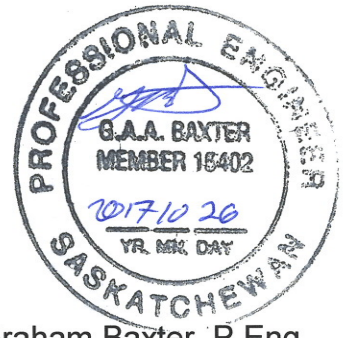

Graham Baxter, P.Eng.

Ray Machibroda, P.Eng., M.Sc.

K. Pardoski

Kelly Pardoski, P. Eng.

GB:KP:zz

Association of Professional Engineers & Geoscientists of Saskatchewan
CERTIFICATE OF AUTHORIZATION
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Discipline	SK. Reg. No.	Signature
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Geoenvironmental	6687	17-10-26

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DRAWINGS

NOTE:
1. THIS DRAWING IS FOR CONCEPTUAL PURPOSES ONLY. ACTUAL LOCATIONS MAY VARY AND NOT ALL STRUCTURES ARE SHOWN.
2. THIS DRAWING WAS COMPILED USING AN AERIAL PHOTOGRAPH PROVIDED BY ISC.

LEGEND

- PMEL TEST HOLE
- PMEL TEST HOLE (PIEZOMETER INSTALLED)
- TENSION CRACKS
- BENCHMARK
- CREST OF SLOPE
- TOE OF SLOPE

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806 – 48th STREET EAST
SASKATOON, SK
S7K 3Y4

DRAWING TITLE:

SITE PLAN - TEST HOLE LOCATIONS

PROJECT:

SLOPE STABILITY AND DEWATERING ASSESSMENT
EAST BANK OF SOUTH SASKATCHEWAN RIVER OUTLOOK, SK

APPROVED BY: GB	DRAWN BY: SD
DATE: MARCH, 2017	DRAWING NUMBER: 12451-1
SCALE: 1:5000	

PIEZO. ELEV.= 536.9 m

TEST HOLE 17-1A

ELEV: 535.8 m

DEPTH (m)	N	U	pp	γ_w	Pw	Lw	w	
0								**TOPSOIL,** organic moist, black, rootlets, frozen.
								GLACIAL TILL, clay, some sand, some silt, trace gravel, medium plastic, brown, oxide stained.
1								–frozen to 1.2 m.
							13.8	–stiff, moist below 1.2 m.
								BENTONITE SEAL
2								
3								
	13			22.2			11.9	
								–very stiff below 3.8 m.
4								–cobbles at 3.9 m.
							11.9	
5								
								50 mm diam. SCH 40, PVC RISER PIPE
								–gypsum crystals below 5.5 m.
6								
	15			22.4			12.2	
7								
							12.7	
								–sand lense, wet, seepage, sloughing 7.5 to 7.8 m.
8								
								–hard, grey below 8.5 m.
9								
	31			21.2			15.4	
10								
							15.6	
			>4.5					–cobbles at 10.5 m.
11								

CONTINUED ON NEXT PAGE

LEGEND:

FILL, SAND, CLAY

TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:

SLOPE STABILITY AND DEWATERING ASSESSMENT

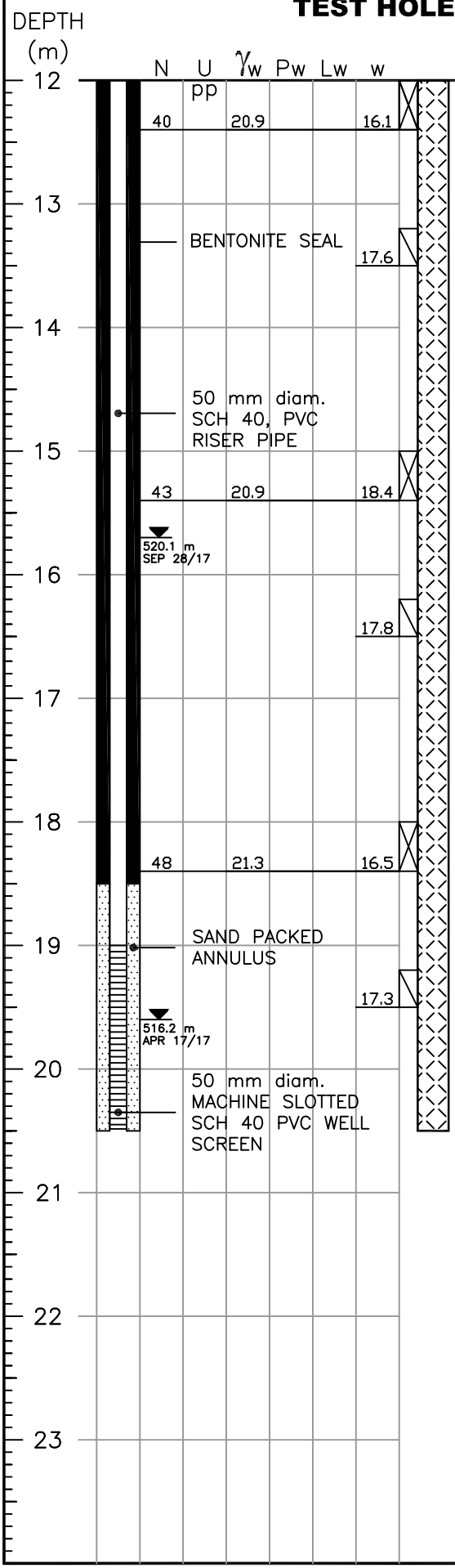
LOCATION:

EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 18/17	12451-2

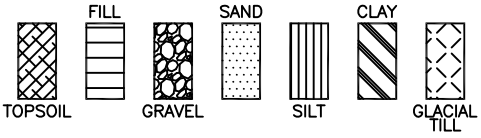
TEST HOLE 17-1A



GLACIAL TILL, clay, some sand, some silt, trace gravel, hard, medium plastic, grey.
–very stiff 12.6 to 12.8 m.

NOTE:
1. Test Hole open and dry I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 18/17	12451-2A

PIEZO. ELEV.= 536.9 m

TEST HOLE 17-1B

ELEV: 535.9 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w	
0		pp					**TOPSOIL,** organic moist, black, rootlets, frozen.
							GLACIAL TILL, clay, some sand, some silt, trace gravel, medium plastic, brown, oxide stained.
1							–frozen to 1.2 m.
							–stiff, moist below 1.2 m.
2							
3							
4							–very stiff below 3.8 m.
							–cobbles at 3.9 m.
							50 mm diam. SCH 40, PVC RISER PIPE
5							BENTONITE SEAL
							–gypsum crystals below 5.5 m.
6							
7							
							528.3 m SEP 28/17
							–sand lense, wet, seepage, sloughing 7.5 to 7.8 m.
8							
							527.4 m APR 17/17
							–hard, grey below 8.5 m.
9							
10							
							–cobbles at 10.5 m.
							50 mm diam. MACHINE SLOTTED SCH 40 PVC WELL SCREEN
11							SAND PACKED ANNULUS

NOTE:
1. Test Hole open and dry I.A.D.

LEGEND:

FILL, SAND, CLAY, TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 18/17	12451-3

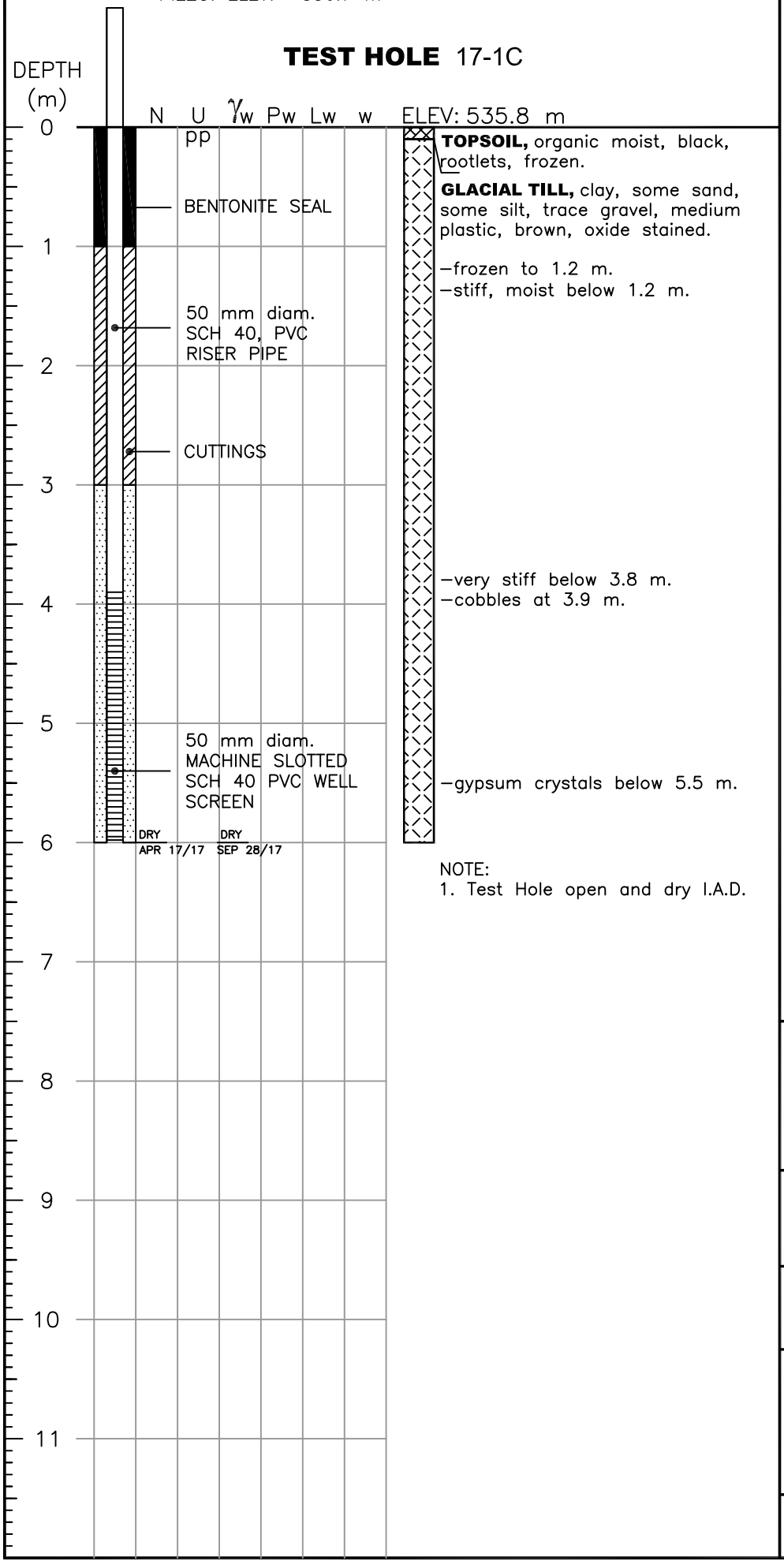
PIEZO. ELEV.= 536.7 m

TEST HOLE 17-1C

DEPTH (m)

N U γ_w Pw Lw w

ELEV: 535.8 m



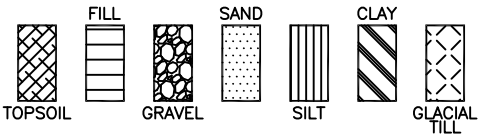
TOPSOIL, organic moist, black, rootlets, frozen.

GLACIAL TILL, clay, some sand, some silt, trace gravel, medium plastic, brown, oxide stained.

–frozen to 1.2 m.
–stiff, moist below 1.2 m.
–very stiff below 3.8 m.
–cobbles at 3.9 m.
–gypsum crystals below 5.5 m.

NOTE:
1. Test Hole open and dry I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 18/17	12451-4

PIEZO. ELEV.= 512.3 m

TEST HOLE 17-2A

ELEV: 511.4 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w	
0		pp					**TOPSOIL,** organic moist, black, rootlets, frozen.
							BENTONITE SEAL
							GLACIAL TILL, clay, some sand, some silt, trace gravel, stiff, medium plastic, moist, brown, oxide stained.
1							–frozen to 800 m.
						26.6	**SILT,** some sand, soft, medium plastic, wet, brown, seepage.
2							
3							
	2			20	31	36.6	
	508.1 m SEP 28/17						
							–silt and clay below 3.7 m.
4							
						32.0	–oxide stained 4.5 to 7.3 m.
5							–clayey, trace sand below 5.0 m.
							50 mm diam. SCH 40, PVC RISER PIPE
				17	29	30.4	
6	505.6 m APR 17/17						
	0.0						
							CUTTINGS
7							
						18.4	**GLACIAL TILL,** clay, some silt, some sand, trace gravel, firm, medium plastic, moist, brown, oxide stained.
8							–very stiff below 7.8 m.
9							
	22			22.1		13.0	
10							
						13.2	
11							
							–sand lense, seepage at 11.8 m.

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LEGEND:

FILL, SAND, CLAY

TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

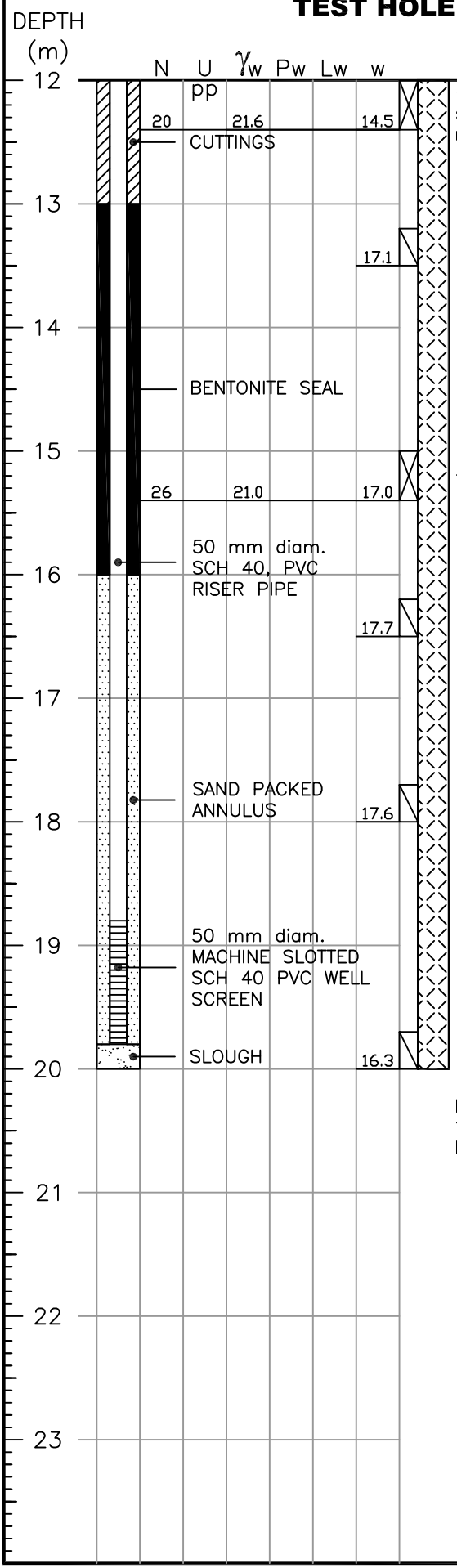
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 19/17	12451-5

TEST HOLE 17-2A

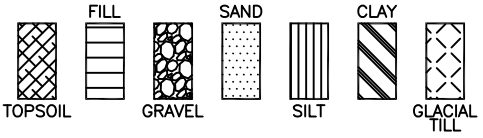


GLACIAL TILL, clay, some silt, some sand, trace gravel, very stiff, medium plastic, moist, brown.

—grey below 15.2 m.

NOTE:
1. Test Hole sloughed to 19.8 m I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

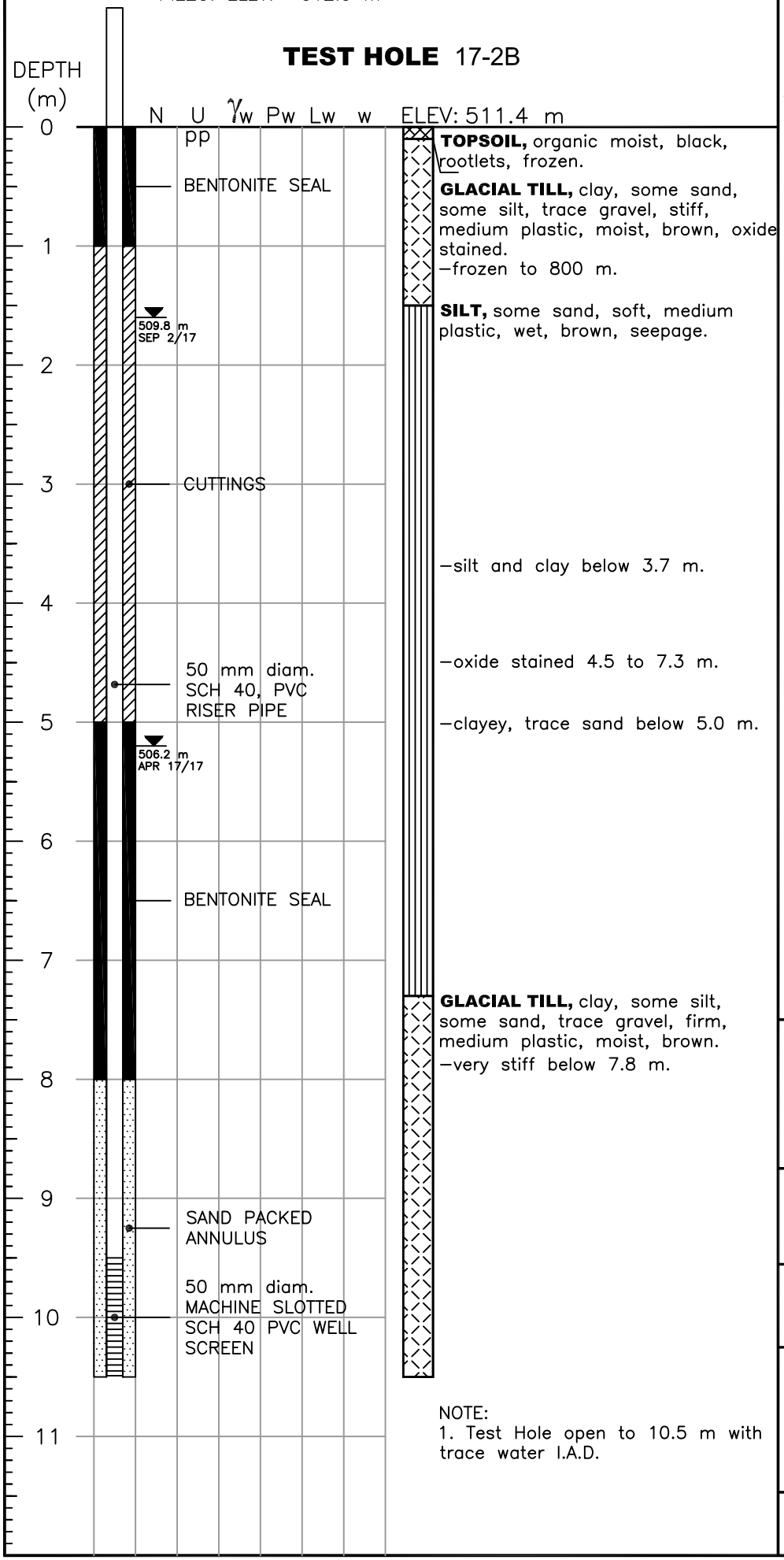
DATE DRILLED:	**DRAWING NUMBER:**
JAN 19/17	12451-5A

PIEZO. ELEV.= 512.5 m

TEST HOLE 17-2B

ELEV: 511.4 m

DEPTH (m) | N | U | γ_w | Pw | Lw | w



TOPSOIL, organic moist, black, rootlets, frozen.

GLACIAL TILL, clay, some sand, some silt, trace gravel, stiff, medium plastic, moist, brown, oxide stained.
—frozen to 800 m.

SILT, some sand, soft, medium plastic, wet, brown, seepage.

—silt and clay below 3.7 m.

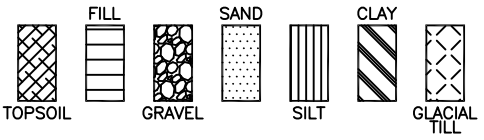
—oxide stained 4.5 to 7.3 m.

—clayey, trace sand below 5.0 m.

GLACIAL TILL, clay, some silt, some sand, trace gravel, firm, medium plastic, moist, brown.
—very stiff below 7.8 m.

NOTE:
1. Test Hole open to 10.5 m with trace water I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19/17	12451-6

PIEZO. ELEV.= 538.2 m

TEST HOLE 17-3A

ELEV: 537.3 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w	
0		pp					BENTONITE SEAL
							TOPSOIL, organic moist, black, rootlets, frozen.
							SILT, some sand, firm, low to medium plastic, damp, brown.
1							—frozen to 600 m.
	5					8.4	
2							
						7.2	
3							
							GLACIAL TILL, clay, some silt, some sand, trace gravel, very stiff, medium plastic, moist, brown.
4							—oxide stained 3.5 to 18.0 m.
	15	22.6				10.5	
5							
							50 mm diam. SCH 40, PVC RISER PIPE
						11.5	
6							CUTTINGS
7							
	20	22.1				12.1	
8							—cobbles 8.0 to 8.5 m.
						15.8	
9							—hard below 9.0 m.
10							
	41	21.6				16.1	
11							
						15.2	

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LEGEND:

TOPSOIL, FILL, GRAVEL, SAND, SILT, CLAY, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:

SLOPE STABILITY AND DEWATERING ASSESSMENT

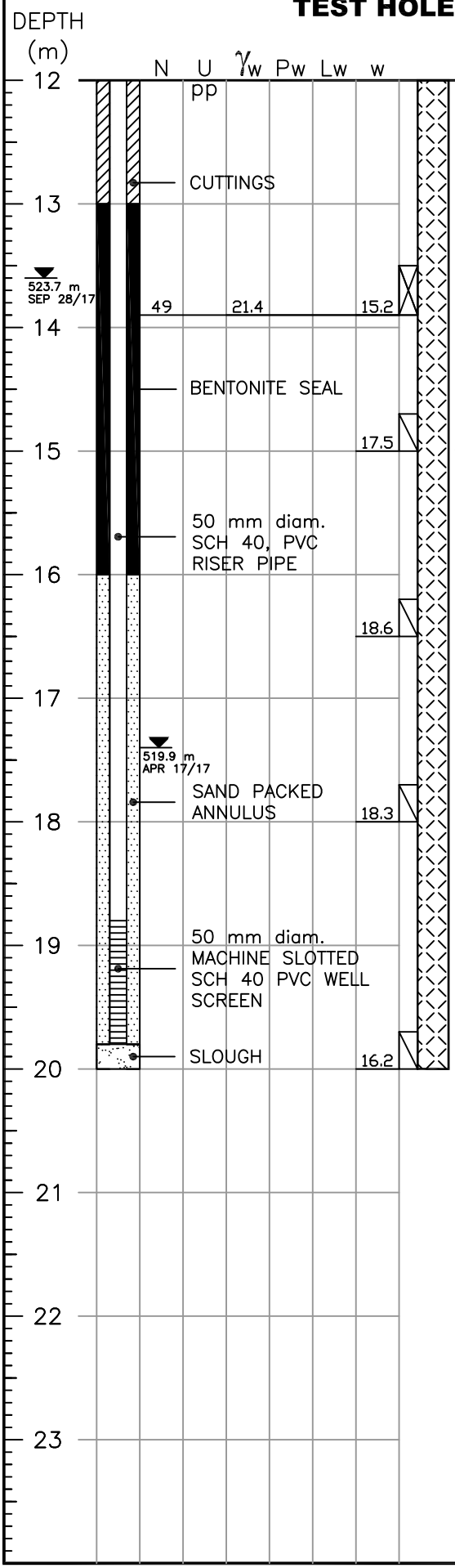
LOCATION:

EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 19/17	12451-7

TEST HOLE 17-3A

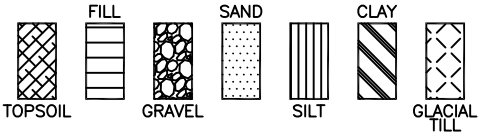


GLACIAL TILL, clay, some silt, some sand, trace gravel, very stiff, medium plastic, moist, brown, oxide stained.

—grey below 15.0 m.

NOTE:
1. Test Hole open and dry I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 19/17	12451-7A

PIEZO. ELEV.= 538.2 m

TEST HOLE 17-3B

DEPTH (m) | N | U | γ_w | Pw | Lw | w | ELEV: 537.3 m

pp

BENTONITE SEAL

CUTTINGS

50 mm diam. SCH 40, PVC RISER PIPE

BENTONITE SEAL

528.7 m SEP 28/17

528.5 m APR 17/17

SAND PACKED ANNULUS

50 mm diam. MACHINE SLOTTED SCH 40 PVC WELL SCREEN

TOPSOIL, organic moist, black, rootlets, frozen.

SILT, some sand, firm, low to medium plastic, damp, brown.
—frozen to 600 m.

GLACIAL TILL, clay, some silt, some sand, trace gravel, very stiff, medium plastic, moist, brown.
—oxide stained 3.5 to 18.0 m.

—cobbles 8.0 to 8.5 m.

—hard below 9.0 m.

NOTE:
1. Test Hole open to 10.5 m and dry I.A.D.

LEGEND:

FILL, SAND, CLAY, TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19/17	12451-8

PIEZO. ELEV.= 532.3 m

TEST HOLE 17-4A

ELEV: 531.3 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w	
0		pp					**GLACIAL TILL,** clay, some silt, some sand, trace gravel, stiff, medium plastic, moist, brown. –oxide stained 0 to 17.0 m. –frozen to 600 mm.
							BENTONITE SEAL
1						13.6	
2							
3	7			10	33	19.5	
4						12.5	50 mm diam. SCH 40, PVC RISER PIPE
5							
6	18		22.2			11.0	–very stiff below 6.0 m.
							▼ 525.0 m APR 17/17
							▼ 524.6 m SEP 28/17
7							CUTTINGS
				10	31	13.9	
8							–sand lense, seepage 8.6 to 8.9 m.
9	19		20.3			18.4	
10						16.8	
11							

CONTINUED ON NEXT PAGE

LEGEND:

FILL, SAND, CLAY, TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:

SLOPE STABILITY AND DEWATERING ASSESSMENT

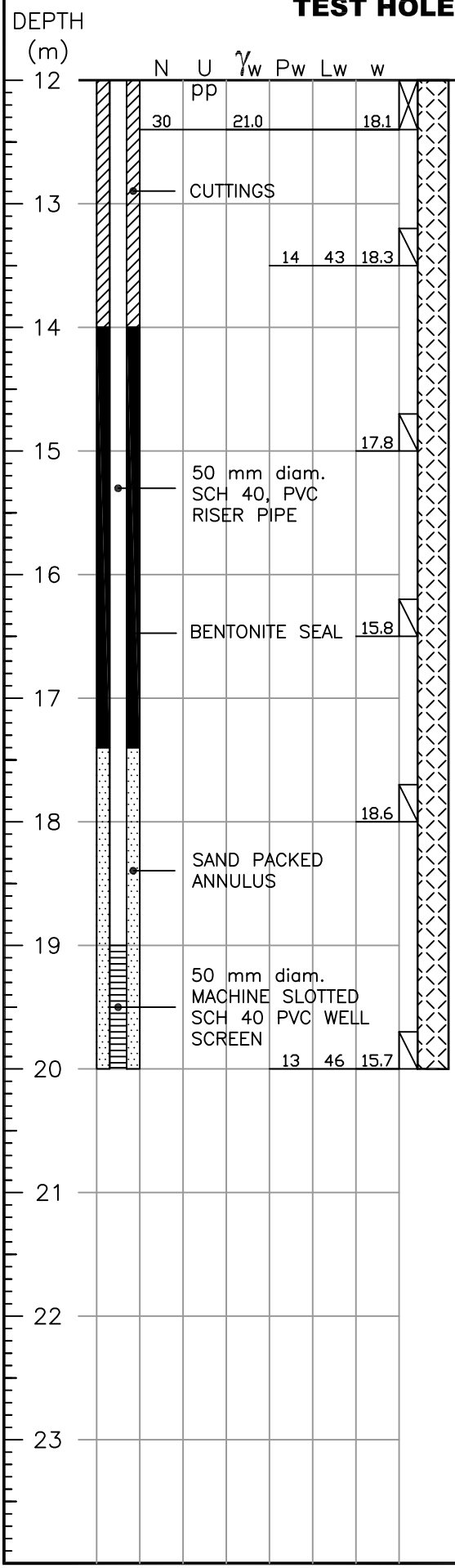
LOCATION:

EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 20/17	12451-9

TEST HOLE 17-4A

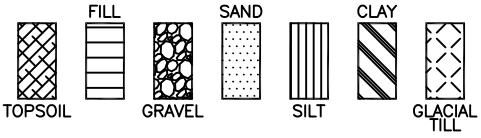


GLACIAL TILL, clay, some silt, some sand, trace gravel, hard, medium plastic, moist, brown, oxide stained.

—grey below 17.0 m.

NOTE:
1. Test Hole open to 20 m and trace water I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 20/17	12451-9A

PIEZO. ELEV.= 532.3 m

TEST HOLE 17-4A

DEPTH (m)

N U γ_w Pw Lw w

ELEV: 531.3 m

0 pp

BENTONITE SEAL

1

2

3 CUTTINGS

4 50 mm diam. SCH 40, PVC RISER PIPE

5

525.7 m APR 17/17

6 525.3 m SEP 28/17

BENTONITE SEAL

7

8

9

50 mm diam. MACHINE SLOTTED SCH 40 PVC WELL SCREEN

10 SAND PACKED ANNULUS

11

GLACIAL TILL, clay, some silt, some sand, trace gravel, stiff, medium plastic, moist, brown.
—oxide stained 0 to 17.0 m.
—frozen to 600 mm.

—very stiff below 6.0 m.

—sand lense, seepage 8.6 to 8.9 m.

NOTE:
1. Test Hole open to 10.5 m I.A.D.

LEGEND:

FILL, SAND, CLAY

TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 20/17	12451-10

PIEZO. ELEV.= 522.6 m

TEST HOLE 17-5A

ELEV: 521.7 m

DEPTH (m)	N	U	pp	γ_w	Pw	Lw	w	
0								**TOPSOIL,** organic, moist, black, rootlets, frozen.
								GLACIAL TILL, clay, silty, some sand, trace gravel, firm, medium plastic, moist, brown, oxide stained.
1								—frozen to 700 mm.
							21.0	
2								
								SAND, silty, loose, poorly graded, fine grained, wet, brown, seepage.
3								
	5						17.8	**GLACIAL TILL,** clay, some silt, some sand, trace gravel, firm, medium plastic, moist, brown.
4								—oxide stained 3.2 to 11.0 m.
							15.3	
5								
6								—stiff below 5.8 m.
	13				20.6		19.6	
7								—very stiff below 6.6 m.
								—hard below 7.0 m.
							17.1	
8								
9								
	35				21.0		18.2	
10								
							19.4	
11								—grey below 11.0 m.

CUTTINGS

50 mm diam. SCH 40, PVC RISER PIPE

BENTONITE SEAL

BENTONITE SEAL

512.9 m SEP 28/17

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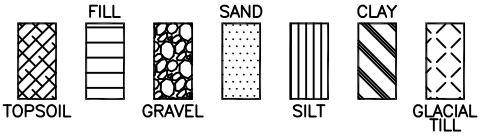
LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE | SPLIT SPOON | CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:

SLOPE STABILITY AND DEWATERING ASSESSMENT

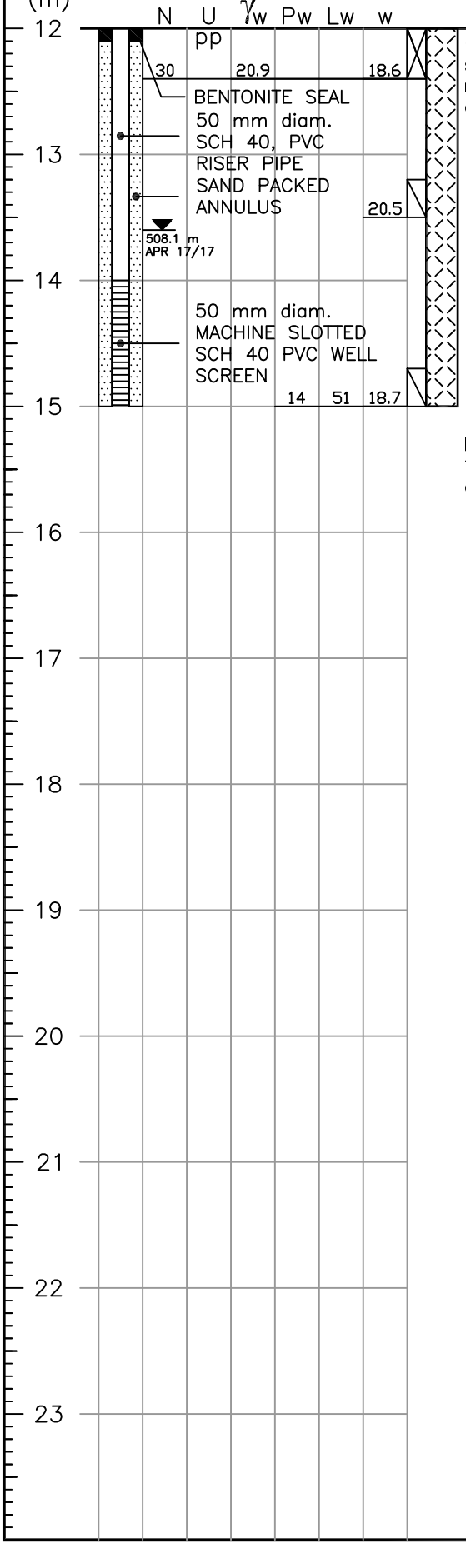
LOCATION:

EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 21/17	12451-11

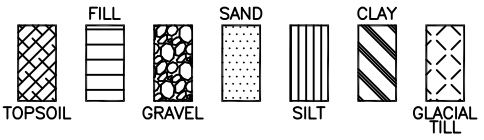
TEST HOLE 17-5A



GLACIAL TILL, clay, some silt, some sand, trace gravel, hard, medium to highly plastic, moist, grey.

NOTE:
1. Test Hole open to 15.0 m and dry I.A.D.

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 21/17	12451-11A

PIEZO. ELEV.= 522.7 m

TEST HOLE 17-5B

ELEV: 521.7 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w
0		pp				

BENTONITE SEAL

50 mm diam. SCH 40, PVC RISER PIPE

519.7 m APR 7/17

SLOUGH

518.5 m SEP 28/17

50 mm diam. MACHINE SLOTTED SCH 40 PVC WELL SCREEN

SLOUGH

TOPSOIL, organic, moist, black, rootlets, frozen.

GLACIAL TILL, clay, silty, some sand, trace gravel, firm, medium plastic, moist, brown, oxide stained.
—frozen to 700 mm.

SAND, silty, loose, poorly graded, fine grained, wet, brown, seepage.

GLACIAL TILL, clay, some silt, some sand, trace gravel, firm, medium plastic, moist, brown.
—oxide stained 3.2 to 11.0 m.

—stiff below 5.8 m.

—very stiff below 6.6 m.

—hard below 7.0 m.

NOTE:
1. Test Hole sloughed to 2.1 m I.A.D.

LEGEND:

FILL, SAND, CLAY, TOPSOIL, GRAVEL, SILT, GLACIAL TILL

w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

SHELBY TUBE, SPLIT SPOON, CUTTINGS

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 21/17	12451-12

PIEZO. ELEV.= 523.9 m
ROADBOX

TEST HOLE SI 17-1

ELEV: 523.1 m

DEPTH (m)	N	U	γ_w	Pw	Lw	w	
0		pp					**TOPSOIL,** organic, moist, black, rootlets, frozen.
							GLACIAL TILL, clay, silty, some sand, trace gravel, firm to stiff, medium plastic, moist, brown.
1							
							CEMENT/BENTONITE GROUT
2							
3							
4							
5							85 mm diam. SLOPE INCLINOMETER
6							
7							—hard below 7.0 m.
8							
9							
10							
11							

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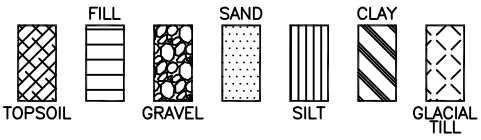
LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

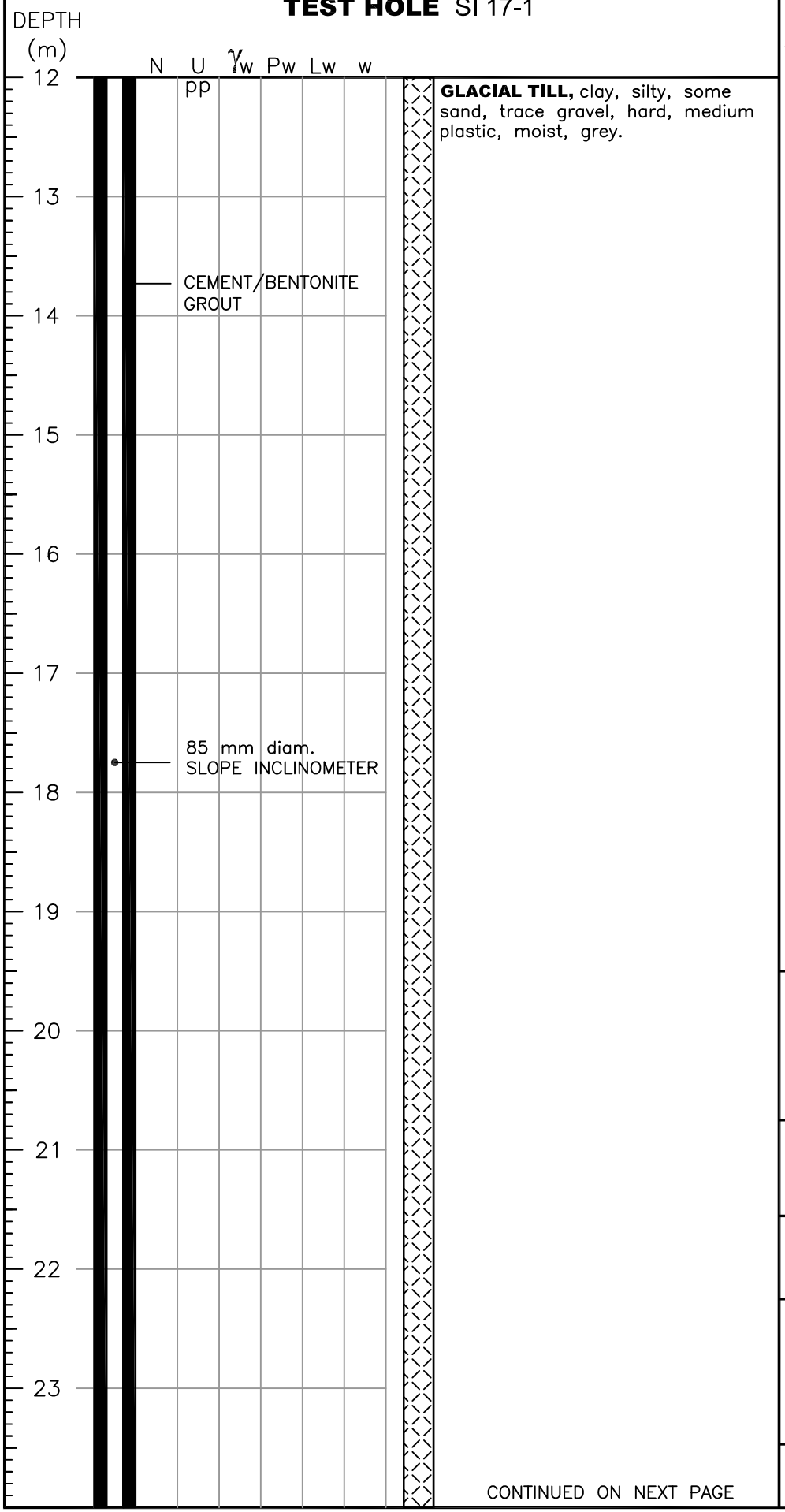
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 9, 20 & 21/17	12451-13

TEST HOLE SI 17-1



GLACIAL TILL, clay, silty, some sand, trace gravel, hard, medium plastic, moist, grey.

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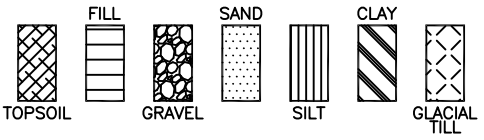
LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

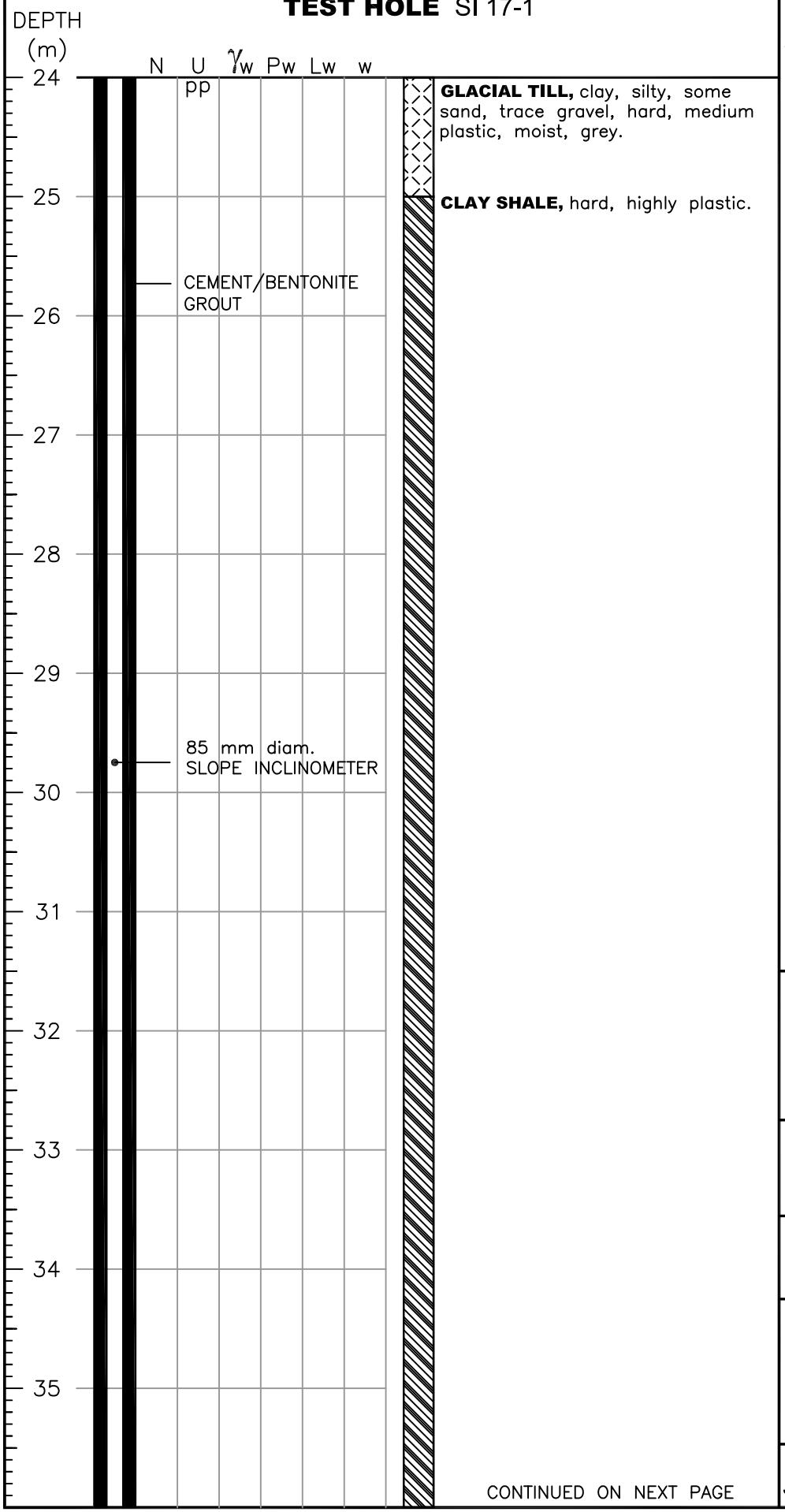
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19, 20 & 21/17	12451-13A

TEST HOLE SI 17-1



GLACIAL TILL, clay, silty, some sand, trace gravel, hard, medium plastic, moist, grey.

CLAY SHALE, hard, highly plastic.

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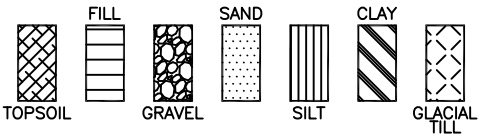
LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

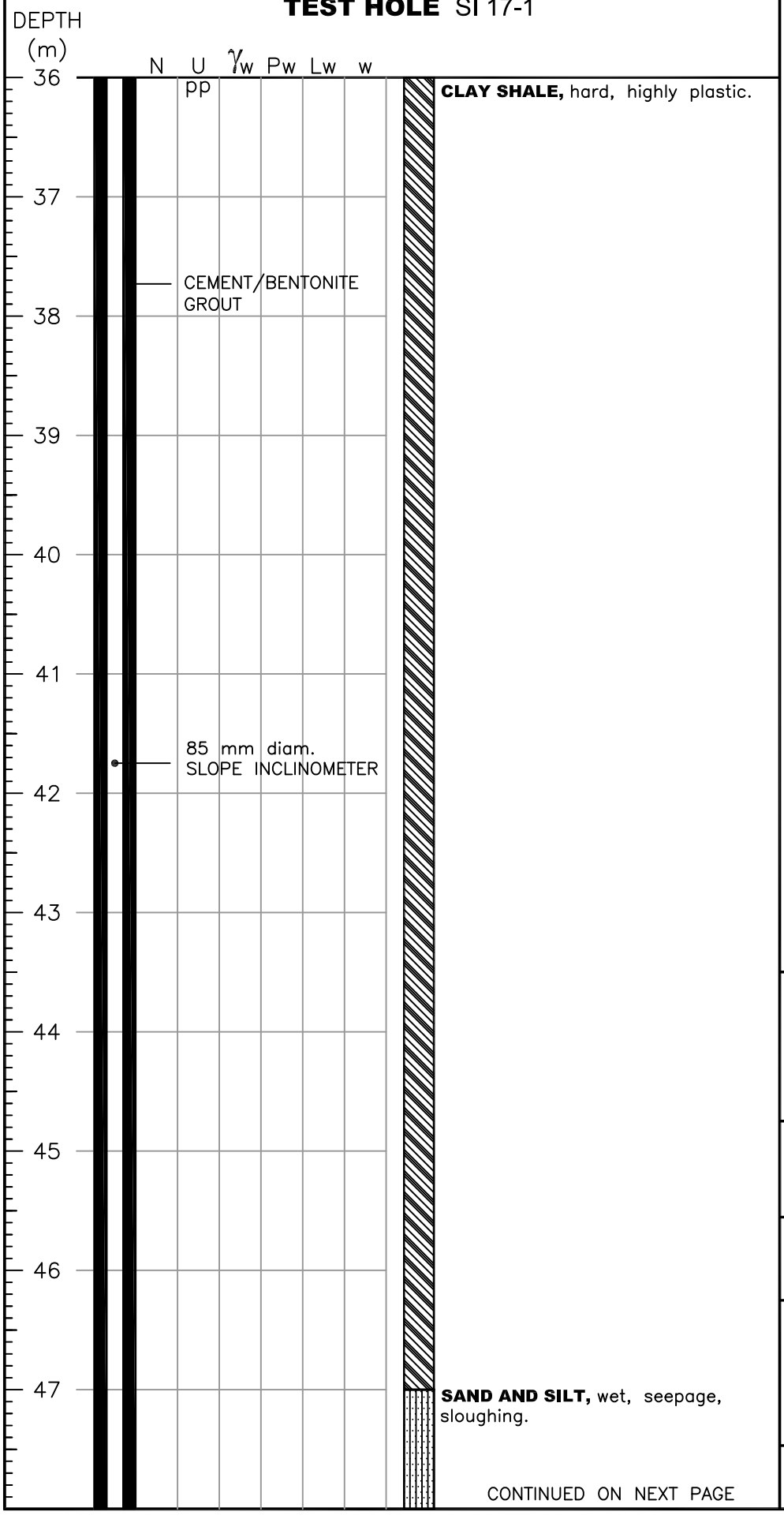
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	DRAWING NUMBER:
JAN 19, 20, & 21/17	12451-13B

TEST HOLE SI 17-1



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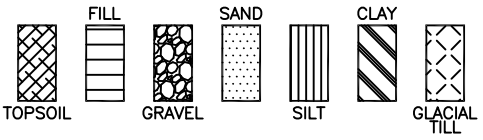


w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

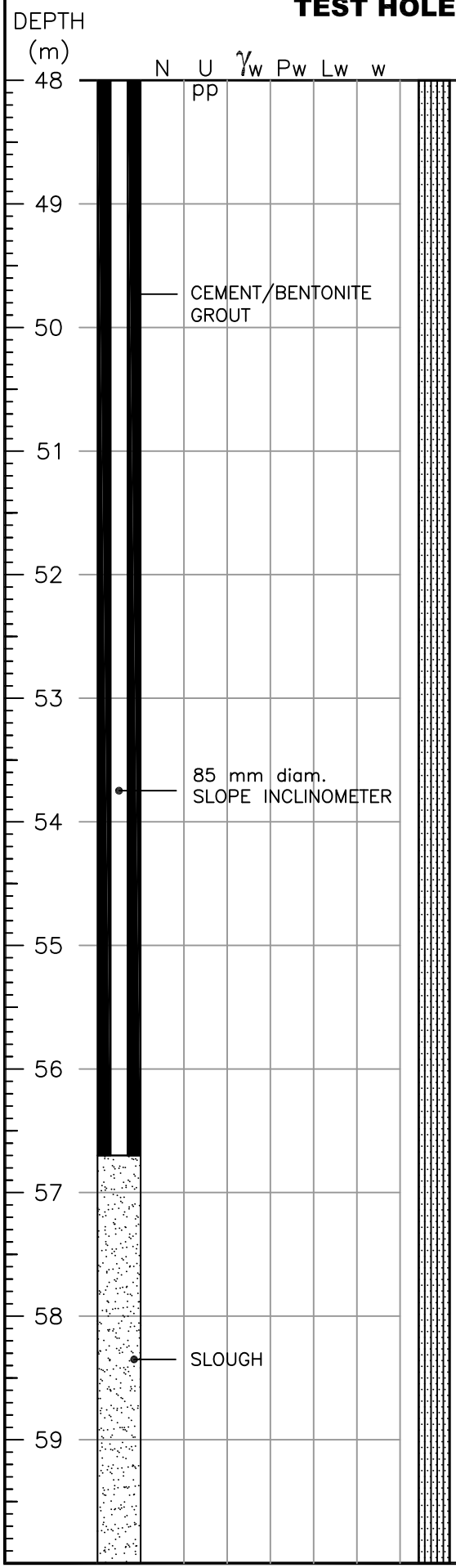
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19, 20, & 21/17	12451-13C

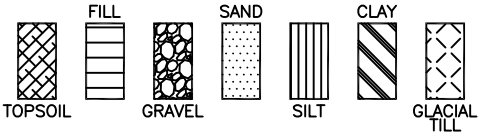
TEST HOLE SI 17-1



SAND AND SILT, wet, seepage, sloughing.

CONTINUED ON NEXT PAGE

LEGEND:



w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

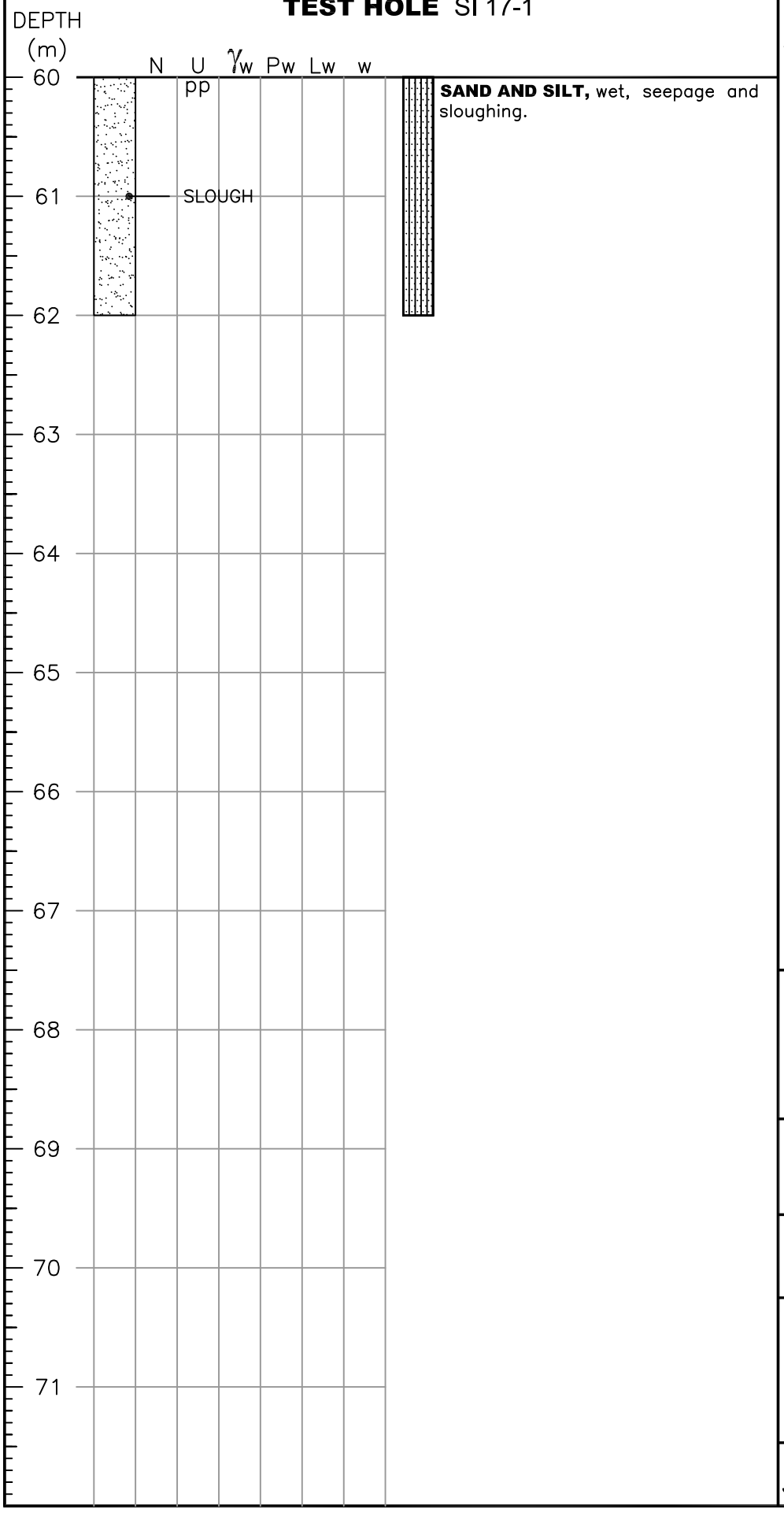
PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19, 20, & 21/17	12451-13D

TEST HOLE SI 17-1



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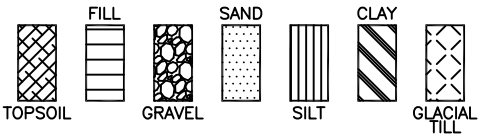


w.....WATER CONTENT (PERCENT OF DRY SOIL WEIGHT)

Lw...LIQUID LIMIT

Pw...PLASTIC LIMIT

γ_w...WET UNIT WEIGHT (kN/m^3)

U.....UNCONFINED COMPRESSIVE STRENGTH (kPa)

pp...POCKET PENETROMETER (kg/cm^2)

N.....STANDARD PENETRATION TEST (SAFETY HAMMER w/AUTOMATIC TRIP) (50/125 = BLOWS/SAMPLER PENETRATION [mm])

SO_4 .....SULPHATE CONTENT (PERCENT OF DRY SOIL WEIGHT)

P200...% PASSING No. 200 SIEVE

I.A.D.....IMMEDIATELY AFTER DRILLING

▽...RECORDED WATER LEVEL (TEST HOLE I.A.D.)

▼...RECORDED WATER LEVEL (PIEZO)

LIMITATIONS: THE FIELD DRILL LOG IS A SUMMARY OF THE SUBSURFACE CONDITIONS ENCOUNTERED AT THE SPECIFIC TEST HOLE LOCATION AT THE TIME OF TEST DRILLING. SUBSURFACE CONDITIONS MAY VARY AT OTHER LOCATIONS OF THIS SITE AND, IN TIME, MAY CHANGE AT THIS SPECIFIC TEST HOLE LOCATION.

P. MACHIBRODA ENGINEERING LTD.

FIELD DRILL LOG AND SOIL TEST RESULTS

PROJECT:
SLOPE STABILITY AND DEWATERING ASSESSMENT

LOCATION:
EAST BANK OF SOUTH SASKATCHEWAN RIVER, OUTLOOK, SK

NORTHING: **EASTING:**

DATE DRILLED:	**DRAWING NUMBER:**
JAN 19, 20, & 21/17	12451-13E

APPENDIX A

EXPLANATION OF TERMS ON TEST HOLE LOGS

CLASSIFICATION OF SOILS

Coarse-Grained Soils: Soils containing particles that are visible to the naked eye. They include gravels and sands and are generally referred to as cohesionless or non-cohesive soils. Coarse-grained soils are soils having more than 50 percent of the dry weight larger than particle size 0.080 mm.

Fine-Grained Soils: Soils containing particles that are not visible to the naked eye. They include silts and clays. Fine-grained soils are soils having more than 50 percent of the dry weight smaller than particle size 0.080 mm.

Organic Soils: Soils containing a high natural organic content.

Soil Classification By Particle Size

Clay – particles of size	< 0.002 mm
Silt – particles of size	0.002 – 0.060 mm
Sand – particles of size	0.06 – 2.0 mm
Gravel – particles of size	2.0 – 60 mm
Cobbles – particles of size	60 – 200 mm
Boulders – particles of size	>200 mm

TERMS DESCRIBING CONSISTENCY OR CONDITION

Coarse-grained soils: Described in terms of compactness condition and are often interpreted from the results of a Standard Penetration Test (SPT). The standard penetration test is described as the number of blows, N, required to drive a 51 mm outside diameter (O.D.) split barrel sampler into the soil a distance of 0.3 m (from 0.15 m to 0.45 m) with a 63.5 kg weight having a free fall of 0.76 m.

Compactness Condition	SPT N-Index (blows per 0.3 m)
Very loose	0-4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	Over 50

Fine-Grained Soils: Classified in relation to undrained shear strength.

Consistency	Undrained Shear Strength (kPa)	N Value (Approximate)	Field Identification
Very Soft	<12	0-2	Easily penetrated several centimetres by the fist.
Soft	12-25	2-4	Easily penetrated several centimetres by the thumb.
Firm	25-50	4-8	Can be penetrated several centimetres by the thumb with moderate effort.
Stiff	50-100	8-15	Readily indented by the thumb, but penetrated only with great effort.
Very Stiff	100-200	15-30	Readily indented by the thumb nail.
Hard	>200	>30	Indented with difficulty by the thumbnail.

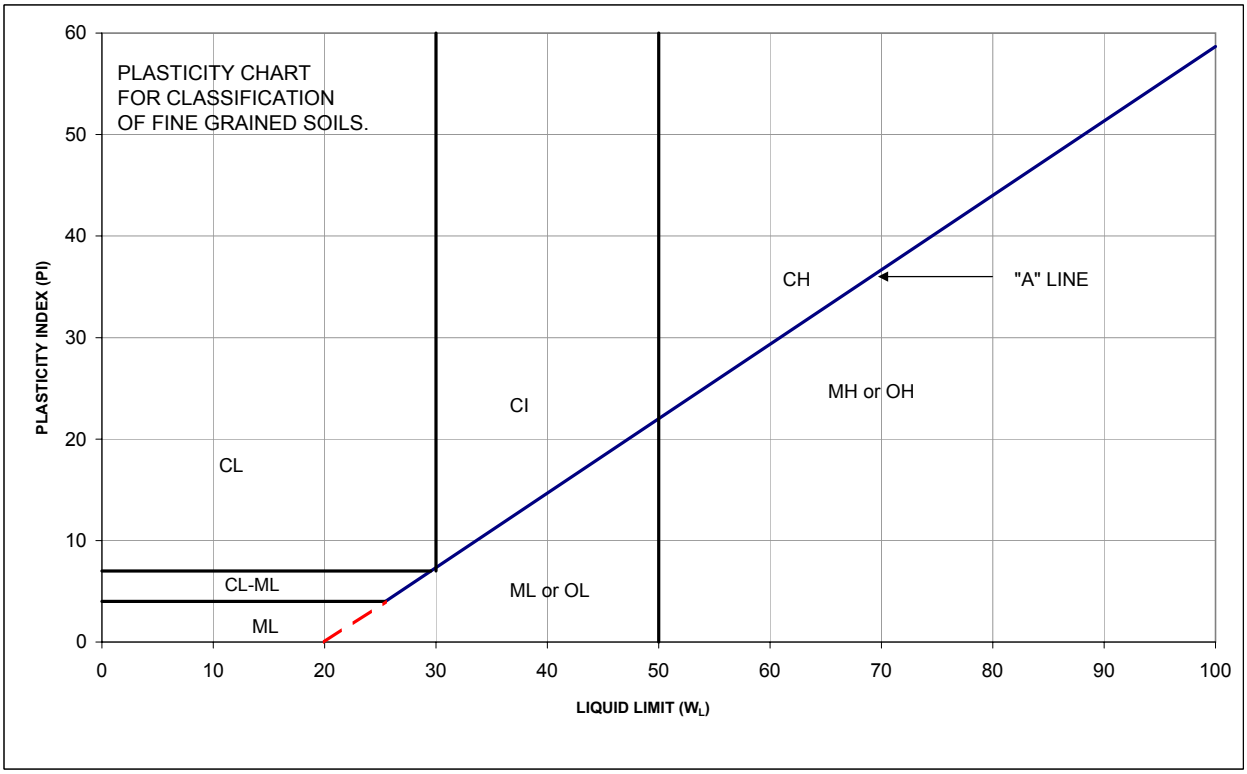
Organic Soils: Readily identified by colour, odour, spongy feel and frequently by fibrous texture.

DESCRIPTIVE TERMS COMMONLY USED TO CHARACTERIZE SOILS

Poorly Graded	- predominance of particles of one grain size.
Well Graded	- having no excess of particles in any size range with no intermediate sizes lacking.
Mottled	- marked with different coloured spots.
Nuggety	- structure consisting of small prismatic cubes.
Laminated	- structure consisting of thin layers of varying colour and texture.
Slickensided	- having inclined planes of weakness that are slick and glossy in appearance.
Fissured	- containing shrinkage cracks.
Fractured	- broken by randomly oriented interconnecting cracks in all 3 dimensions.

SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.)

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA
HIGHLY ORGANIC SOILS			Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR AND OFTEN FIBROUS TEXTURE
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN NO. 200 SIEVE SIZE)	GRAVELS More than half coarse fraction larger than No. 4 sieve size	CLEAN GRAVELS	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES <5% FINES	$C_u = \frac{D_{60}}{D_{10}} > 4 \quad C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}} = 1 \text{ to } 3$
			GP	POORLY-GRADED GRAVELS AND GRAVEL-SAND MIXTURES <5% FINES	NOT MEETING ALL ABOVE REQUIREMENTS FOR GW
		DIRTY GRAVELS	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES >12% FINES	ATTERBERG LIMITS BELOW "A" LINE OR PI < 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES >12% FINES	ATTERBERG LIMITS ABOVE "A" LINE WITH PI > 7
	SANDS More than half coarse fraction smaller than No. 4 sieve size	CLEAN SANDS	SW	WELL-GRADED SANDS, GRAVELLY SANDS MIXTURES <5% FINES	$C_u = \frac{D_{60}}{D_{10}} > 6 \quad C_c = \frac{(D_{30})^2}{D_{60} \times D_{10}} = 1 \text{ to } 3$
			SP	POORLY-GRADED SANDS OR GRAVELLY SANDS <5% FINES	NOT MEETING ALL GRADATION REQUIREMENTS FOR SW
		DIRTY SANDS	SM	SILTY SANDS, SAND-SILT MIXTURES >12% FINES	ATTERBERG LIMITS BELOW "A" LINE OR PI < 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES >12% FINES	ATTERBERG LIMITS ABOVE "A" LINE WITH PI >7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSING NO. 200 SIEVE SIZE)	SILTS Below "A" line on plasticity chart; negligible organic content		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	$W_L < 50$
			MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	$W_L > 50$
	CLAYS Above 'A" line on plasticity chart; negligible organic content		CL	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS	$W_L < 30$
			CI	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS	$W_L > 30 < 50$
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	$W_L > 50$
	ORGANIC SILTS & ORGANIC CLAYS Below "A" line on plasticity chart		OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	$W_L < 50$
			OH	ORGANIC CLAYS OF HIGH PLASTICITY	$W_L > 50$



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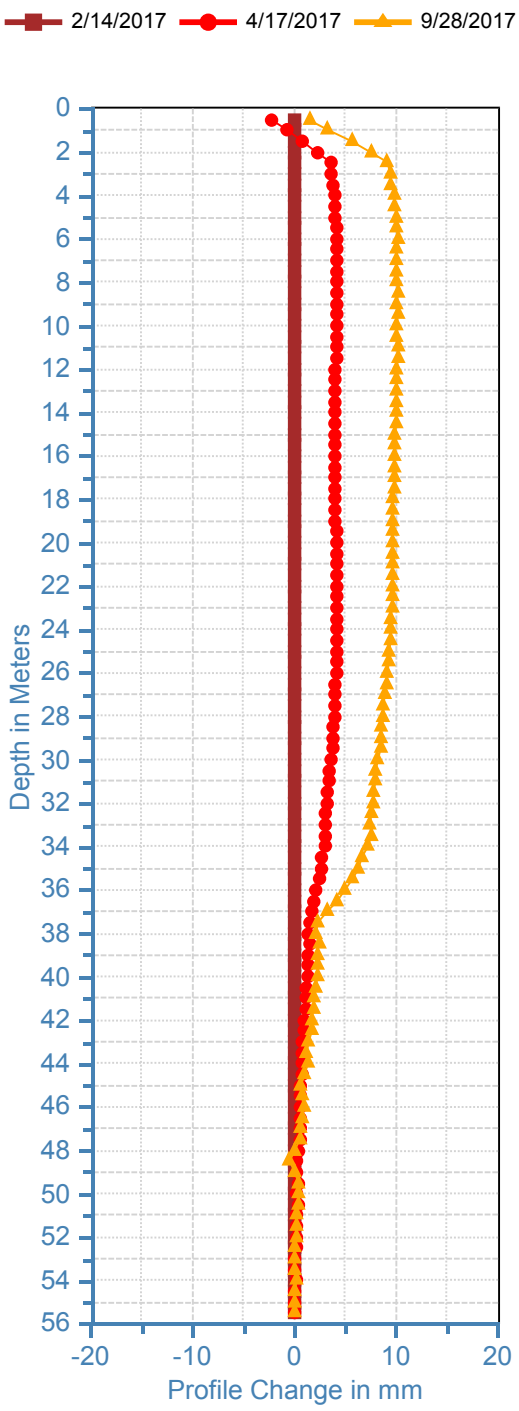
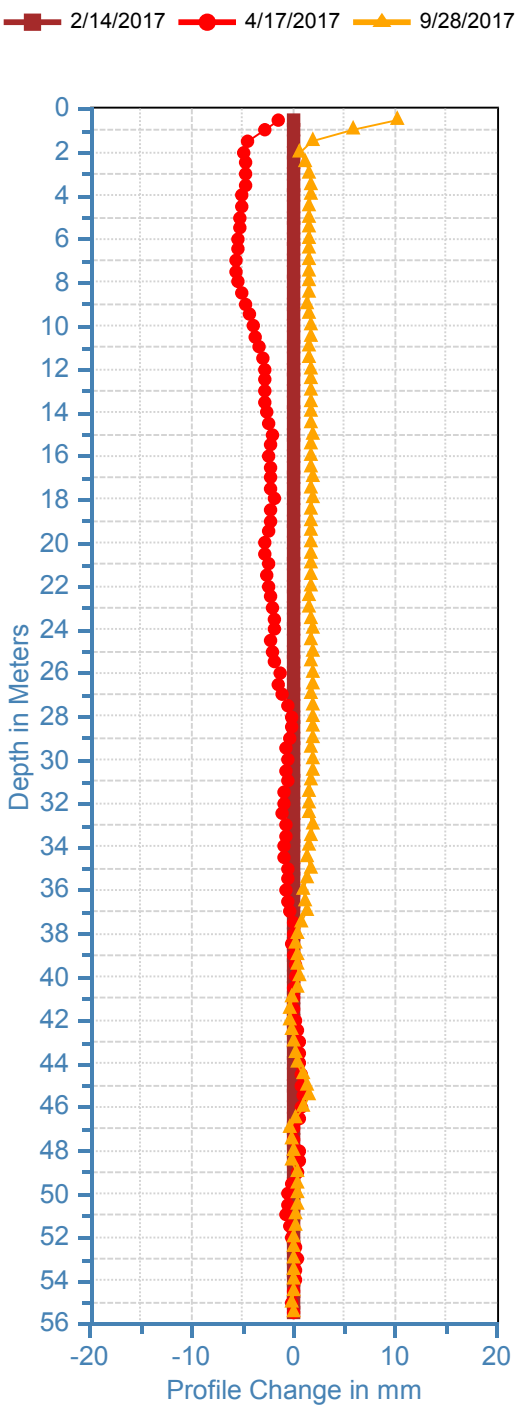
APPENDIX B
SLOPE INCLINOMETER PLOTS

12451 17-1 A



12451 17-1 B



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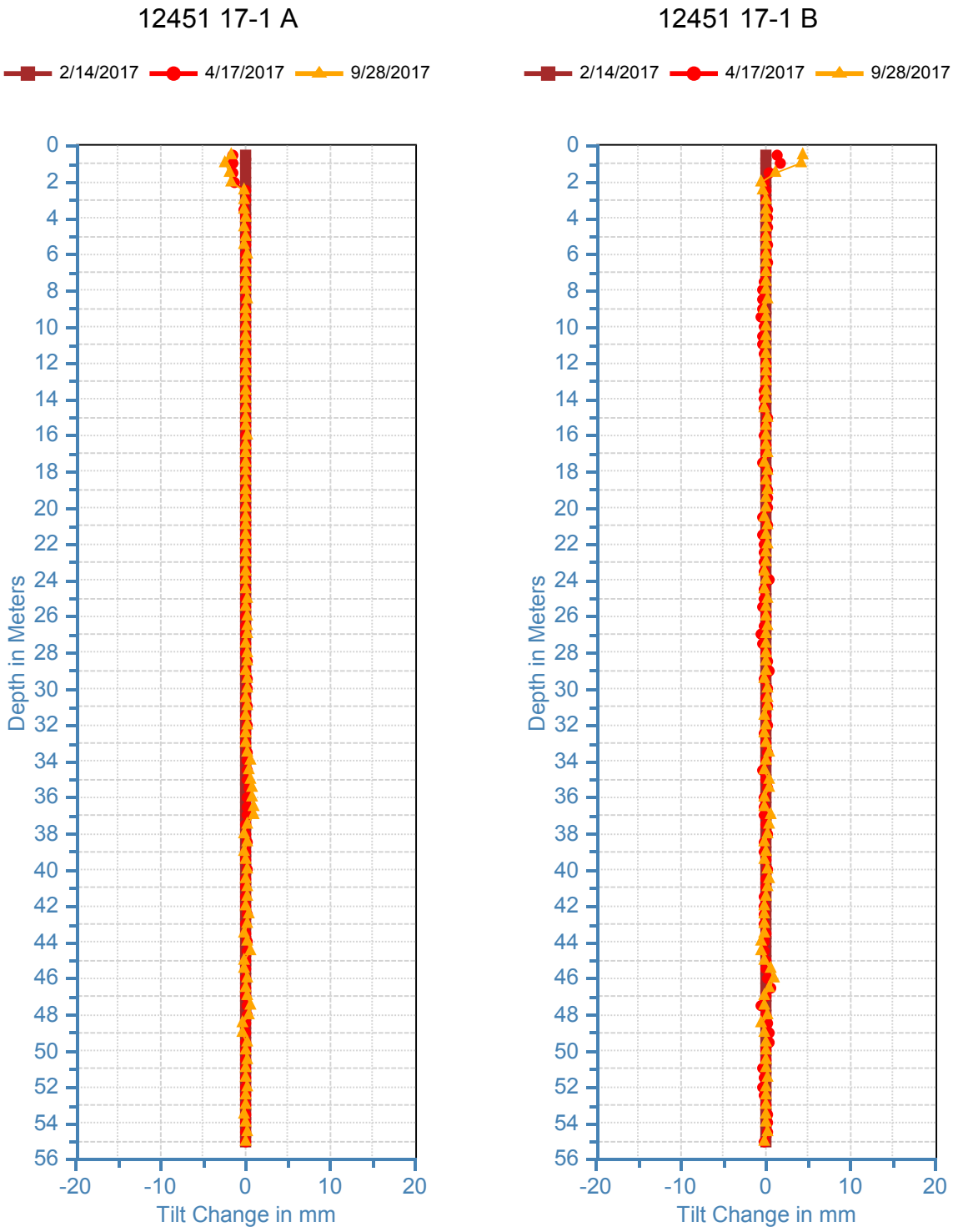
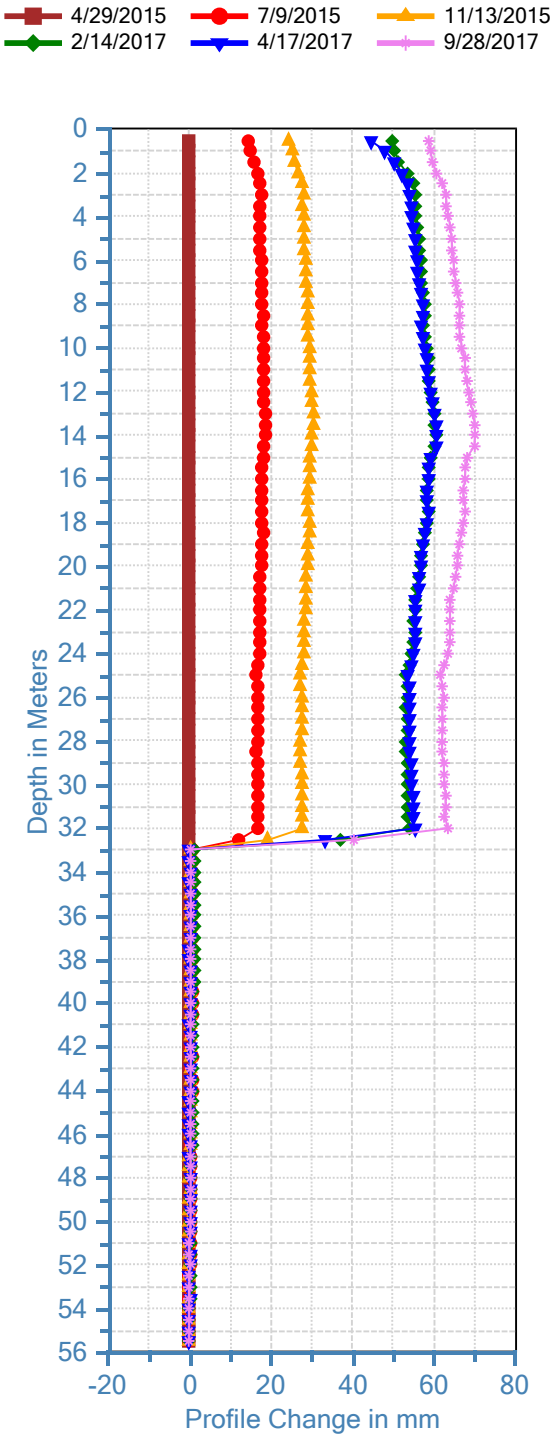
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	17-1
Drawing No.	Appendix B-1

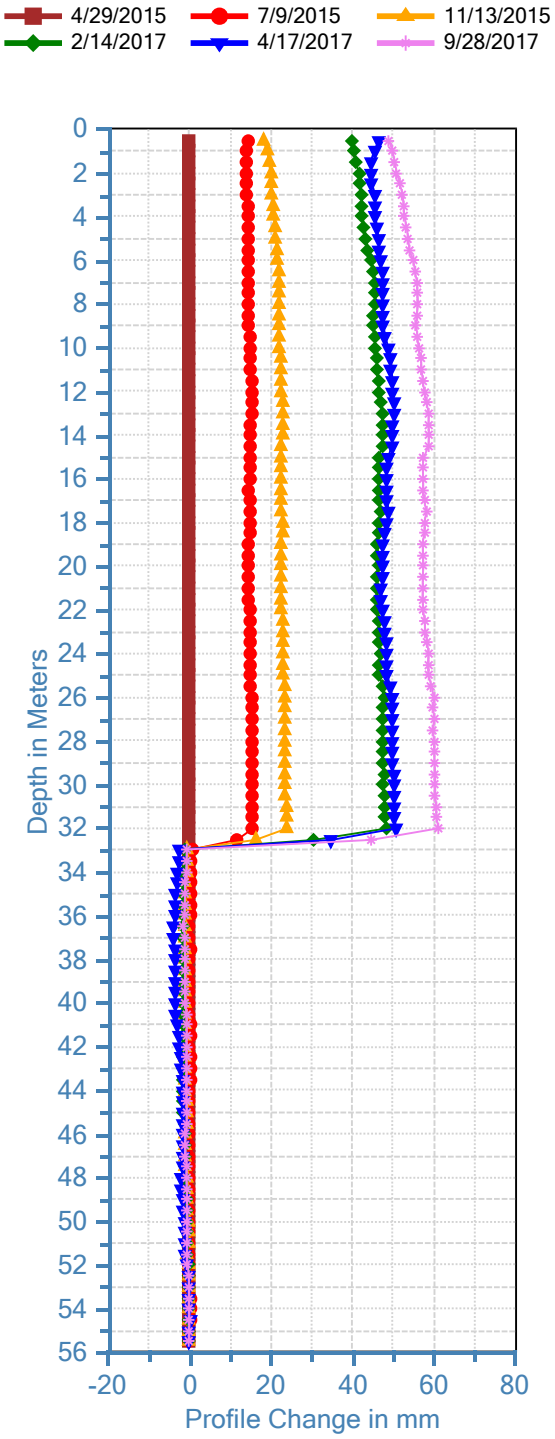


Project No.:	12451
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	17-1
Drawing No.	Appendix B-2

12451 15-1 A

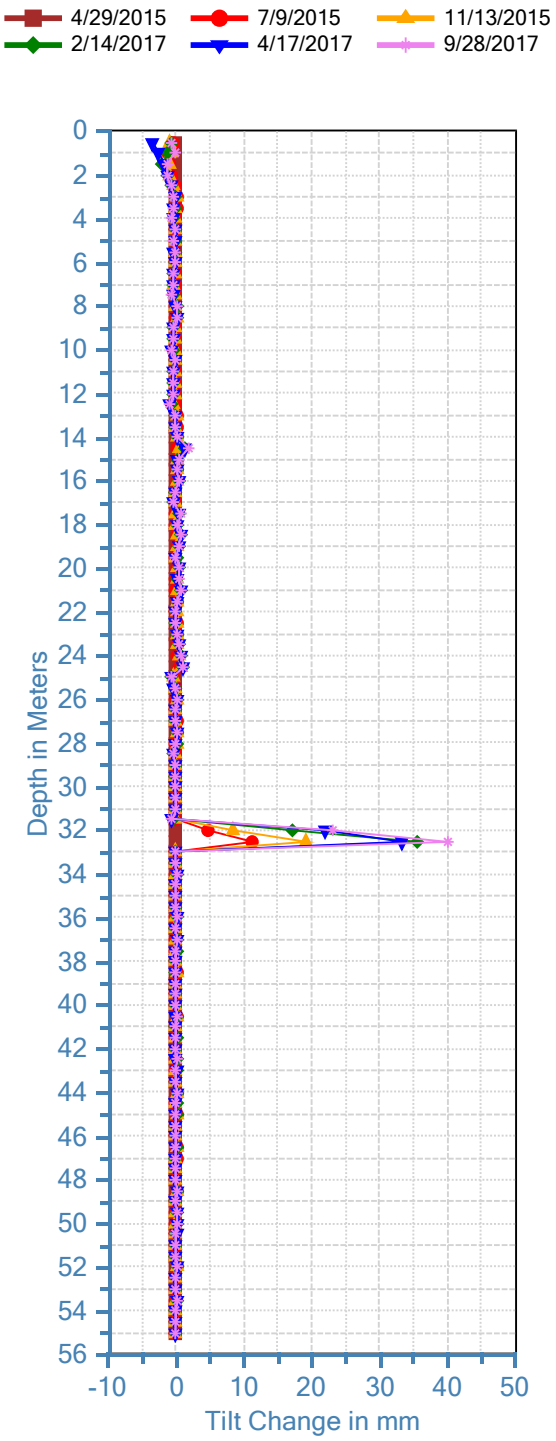


12451 15-1 B



Project No.:	12451
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	15-1
Drawing No.	Appendix B-3

12451 15-1 A



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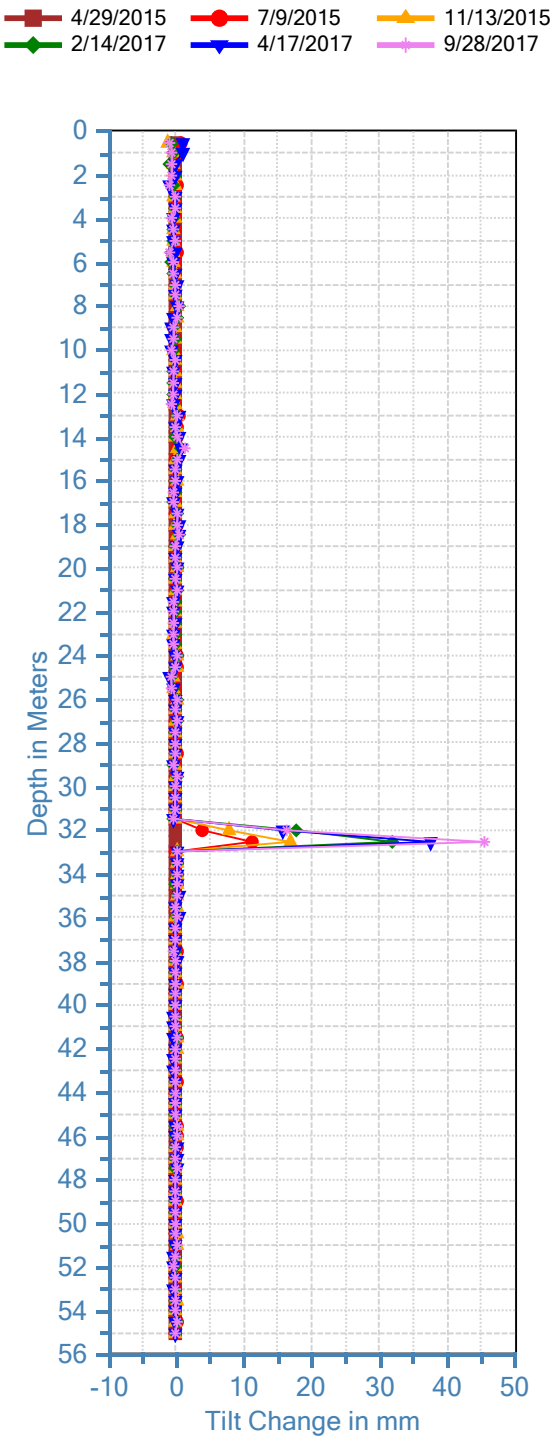
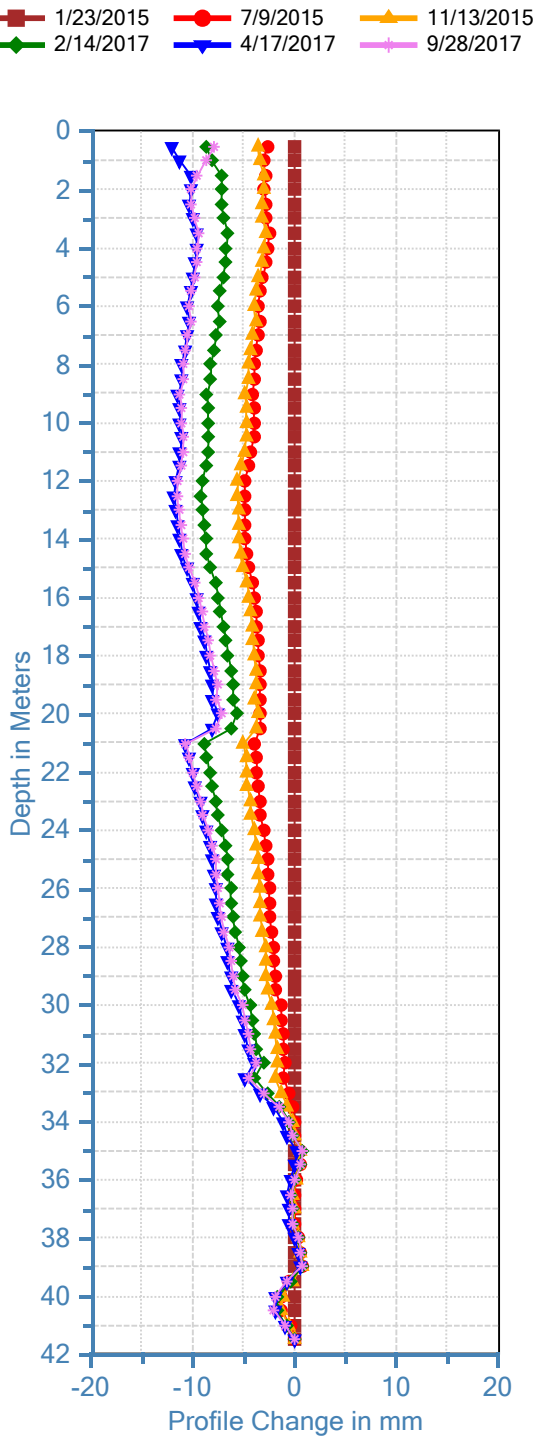
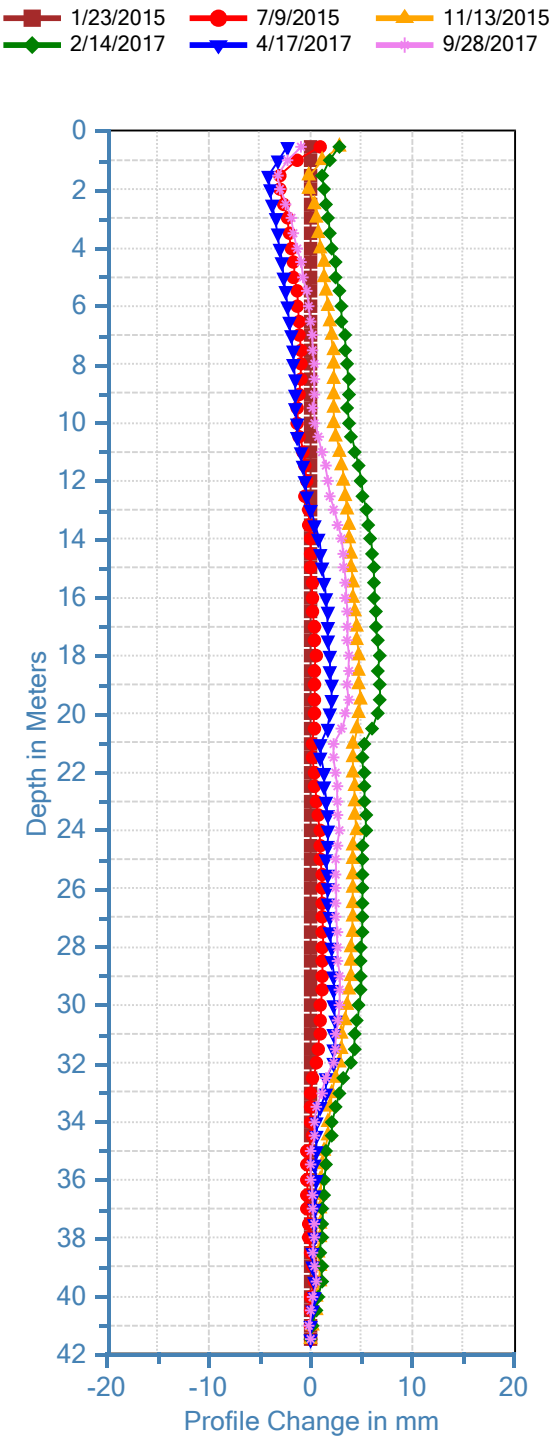


Project No.:	12451
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	15-1
Drawing No.	Appendix B-4

12451 14-1 A

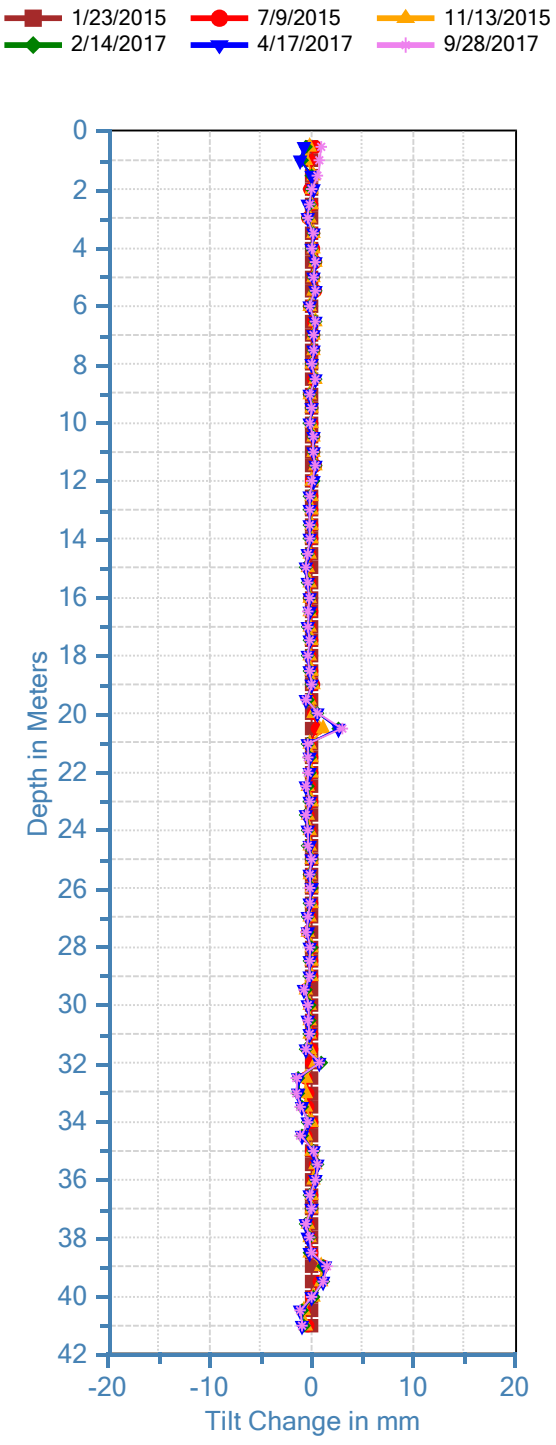


12451 14-1 B

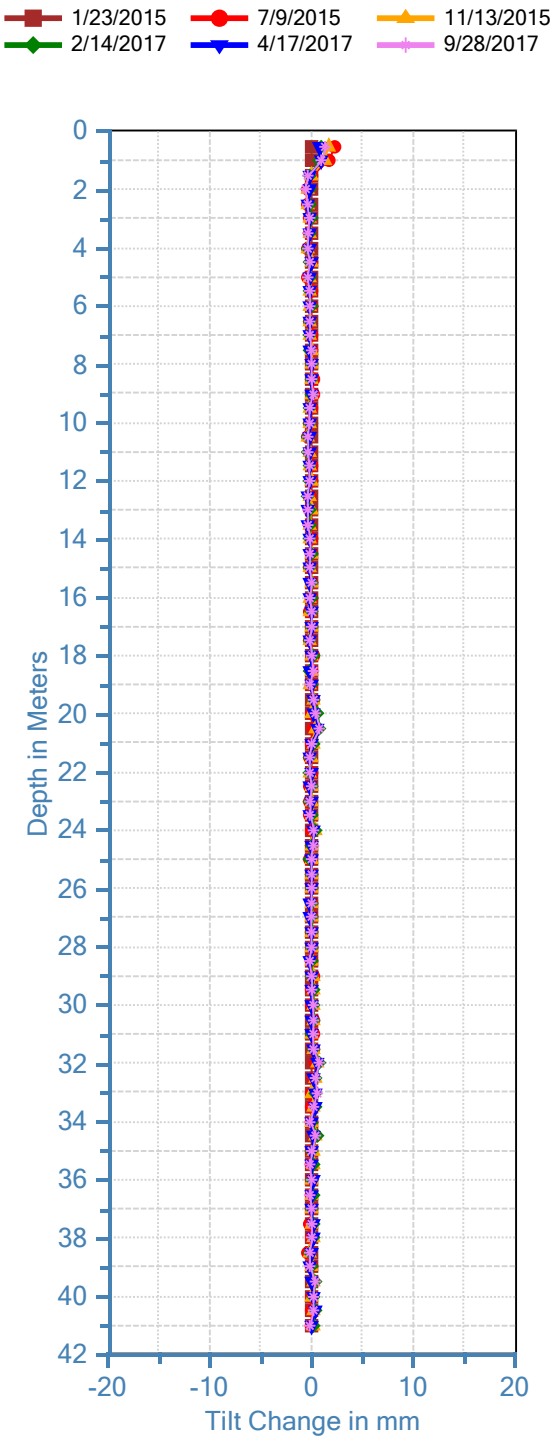


Project No.:	12451
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	14-1
Drawing No.	Appendix B-5

12451 14-1 A



12451 14-1 B



Project No.:	12451
Project Name:	Slope Stability Study
Location:	Outlook, Saskatchewan
Test Hole No.	14-1
Drawing No.	Appendix B-6

APPENDIX C
LABORATORY RESULTS

P. MACHIBRODA ENGINEERING LTD.

ASTM D422: PARTICLE SIZE ANALYSIS OF SOILS

Project: Slope Stability and Dewatering Assessment

Location: East Bank of South Saskatchewan River, Outlook, SK

Project No.: 12451

Date Tested: February 1, 2017

Test Hole No.: 17-2

Sample No.: 17

Depth (m): 6.0

Sieve Analysis:

Sieve	Diameter mm	% Finer
1.5"	38.1	100
1"	25.4	100
3/4"	19.1	100
1/2"	12.7	100
3/8"	9.5	100
# 4	4.75	100
# 10	2	100
# 20	0.85	99
# 40	0.425	97.9
#60	0.25	96.4
# 100	0.15	95.2
# 200	0.075	84.9

Hydrometer Analysis:

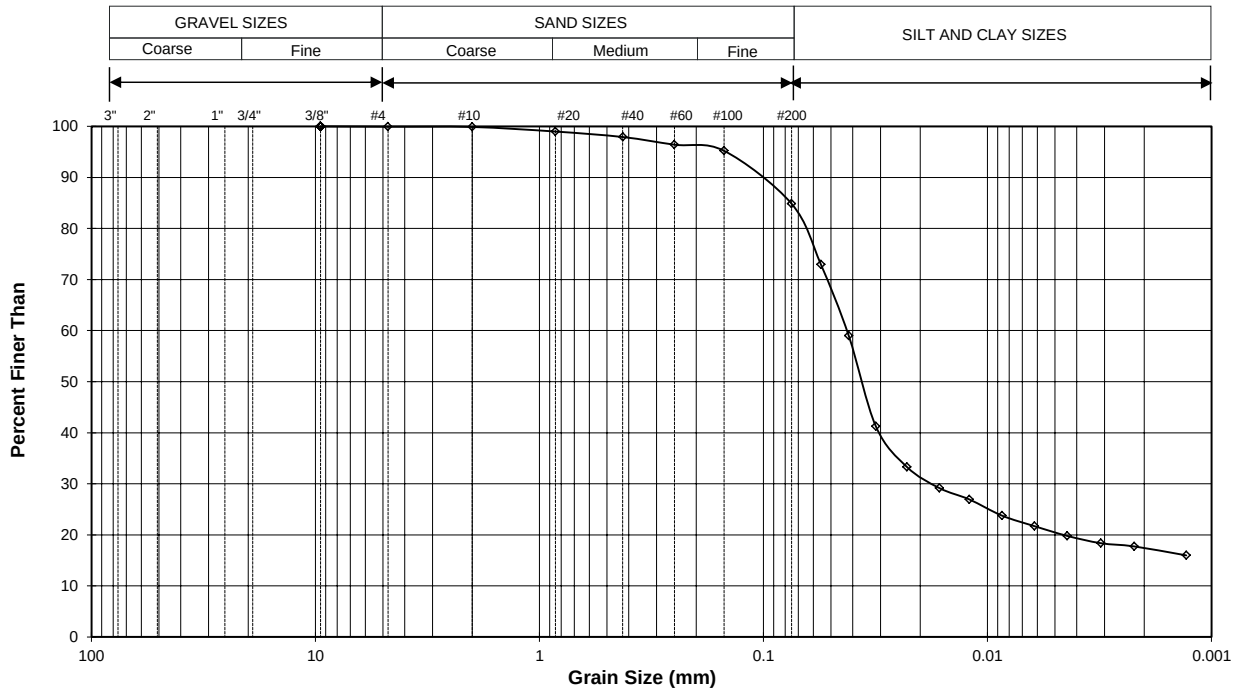
Dispersing Agent: *Sodium Hexametaphosphate*

Diameter mm	% Finer
0.0555	73.0
0.0416	59.0
0.0315	41.2
0.0229	33.3
0.0164	29.2
0.0121	27.0
0.0086	23.8
0.0062	21.7
0.0044	19.8
0.0031	18.4
0.0022	17.7
0.0013	16.0

Material Description:

% Gravel Sizes	% Sand Sizes	% Silt Sizes	% Clay Sizes
0	15	67	18

Remarks:



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Drawing No.

Appendix C-1

WE CERTIFY TESTING PROCEDURES ARE IN ACCORDANCE WITH ASTM D422 STANDARD
P. MACHIBRODA ENGINEERING LTD.

PER

P. MACHIBRODA ENGINEERING LTD.

ASTM D422: PARTICLE SIZE ANALYSIS OF SOILS

Project: Slope Stability and Dewatering Assessment

Location: East Bank of South Saskatchewan River, Outlook, SK

Project No.: 12451

Date Tested: February 1, 2017

Test Hole No.: 17-4

Sample No.: 44

Depth (m): 7.5

Sieve Analysis:

Sieve	Diameter mm	% Finer
1.5"	38.1	100
1"	25.4	100
3/4"	19.1	100
1/2"	12.7	100
3/8"	9.5	100
# 4	4.75	100
# 10	2	99
# 20	0.85	95
# 40	0.425	89.8
#60	0.25	81.8
# 100	0.15	76.8
# 200	0.075	61.5

Hydrometer Analysis:

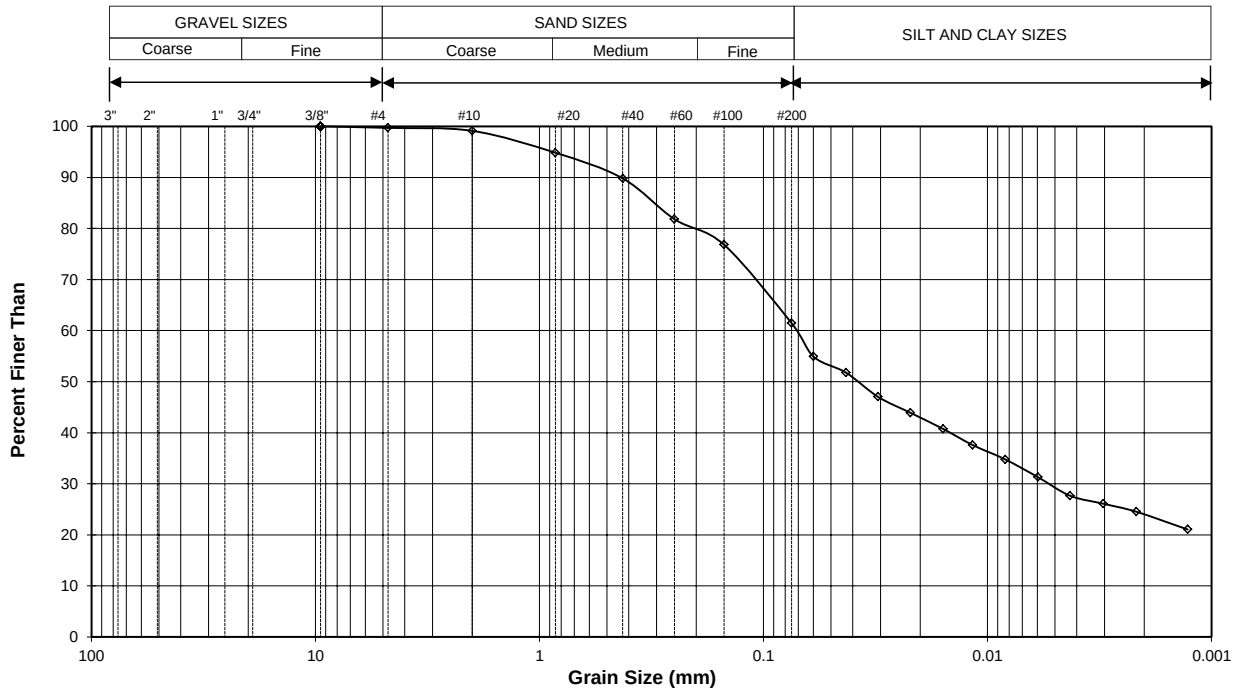
Dispersing Agent: *Sodium Hexametaphosphate*

Diameter mm	% Finer
0.0599	54.9
0.0429	51.8
0.0309	47.1
0.0221	43.9
0.0158	40.8
0.0117	37.6
0.0083	34.8
0.0060	31.3
0.0043	27.7
0.0030	26.1
0.0022	24.5
0.0013	21.1

Material Description:

% Gravel Sizes	% Sand Sizes	% Silt Sizes	% Clay Sizes
0	38	37	25

Remarks:



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Drawing No.

Appendix C-2

WE CERTIFY TESTING PROCEDURES ARE IN ACCORDANCE WITH ASTM D422 STANDARD
P. MACHIBRODA ENGINEERING LTD.

PER

P. MACHIBRODA ENGINEERING LTD.

ASTM D422: PARTICLE SIZE ANALYSIS OF SOILS

Project: Slope Stability and Dewatering Assessment

Location: East Bank of South Saskatchewan River, Outlook, SK

Project No.: 12451

Date Tested: February 7, 2017

Test Hole No.: 17-4

Sample No.: 52

Depth (m): 20.0

Sieve Analysis:

Sieve	Diameter mm	% Finer
1.5"	38.1	100
1"	25.4	100
3/4"	19.1	100
1/2"	12.7	100
3/8"	9.5	100
# 4	4.75	100
# 10	2	99
# 20	0.85	97
# 40	0.425	94.2
#60	0.25	90.1
# 100	0.15	87.8
# 200	0.075	73.3

Hydrometer Analysis:

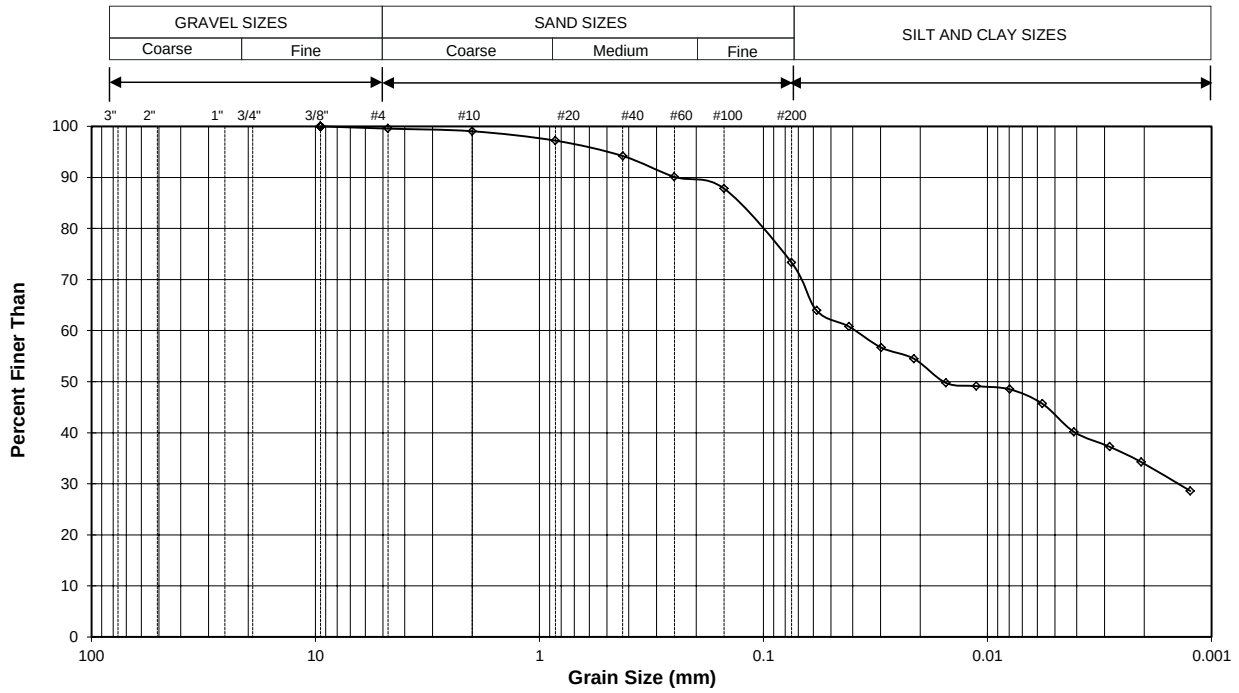
Dispersing Agent: *Sodium Hexametaphosphate*

Diameter mm	% Finer
0.0579	63.9
0.0415	60.8
0.0298	56.7
0.0213	54.5
0.0153	49.8
0.0112	49.1
0.0080	48.5
0.0057	45.7
0.0041	40.2
0.0029	37.3
0.0021	34.3
0.0012	28.6

Material Description:

% Gravel Sizes	% Sand Sizes	% Silt Sizes	% Clay Sizes
0	26	39	34

Remarks:



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Drawing No.

Appendix C-3

WE CERTIFY TESTING PROCEDURES ARE IN ACCORDANCE WITH ASTM D422 STANDARD
P. MACHIBRODA ENGINEERING LTD.

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P. MACHIBRODA ENGINEERING LTD.

ASTM D422: PARTICLE SIZE ANALYSIS OF SOILS

Project: Slope Stability and Dewatering Assessment

Location: East Bank of South Saskatchewan River, Outlook, SK

Project No.: 12451

Date Tested: February 1, 2017

Test Hole No.: 17-5

Sample No.: 62

Depth (m): 15.0

Sieve Analysis:

Sieve	Diameter mm	% Finer
1.5"	38.1	100
1"	25.4	100
3/4"	19.1	100
1/2"	12.7	99
3/8"	9.5	99
# 4	4.75	99
# 10	2	98
# 20	0.85	96
# 40	0.425	93.3
#60	0.25	90.4
# 100	0.15	88.6
# 200	0.075	77.8

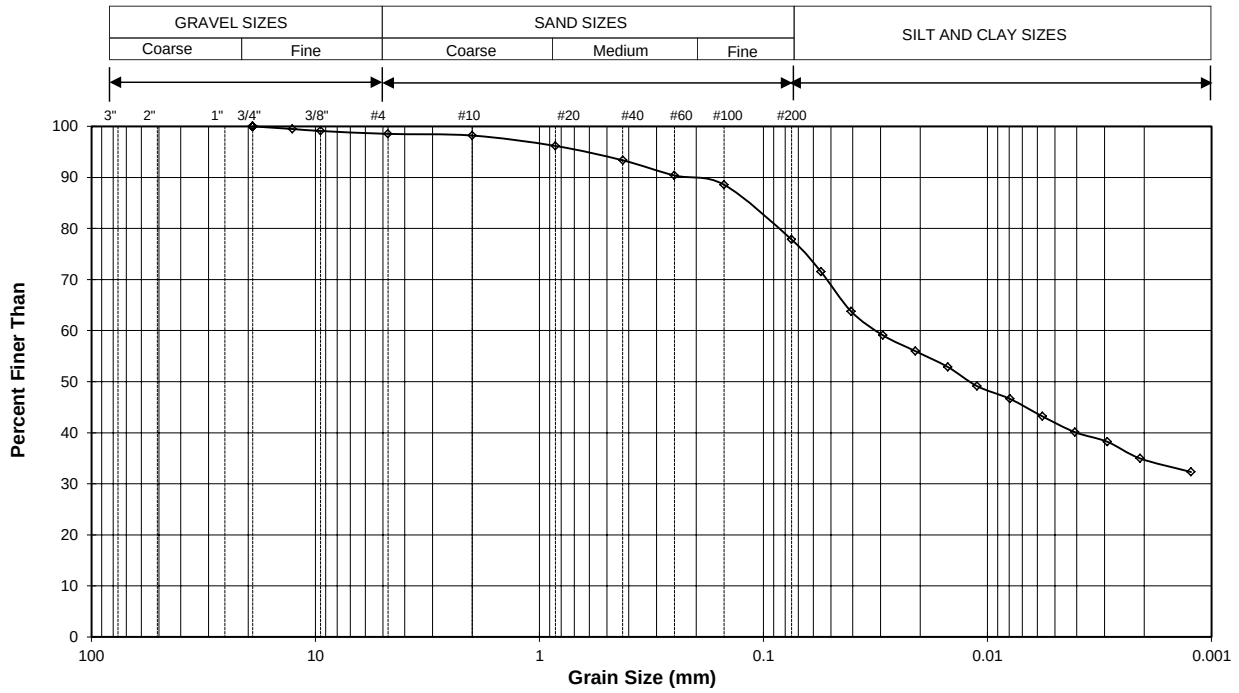
Hydrometer Analysis:

	Diameter mm	% Finer
Dispersing Agent:	0.0555	71.5
Sodium Hexametaphosphate	0.0406	63.8
	0.0293	59.1
	0.0210	56.0
	0.0150	52.9
	0.0111	49.1
	0.0079	46.6
	0.0057	43.2
	0.0041	40.1
	0.0029	38.2
	0.0021	35.0
	0.0012	32.3

Material Description:

% Gravel Sizes	% Sand Sizes	% Silt Sizes	% Clay Sizes
1	21	43	35

Remarks:



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Drawing No.

Appendix C-4

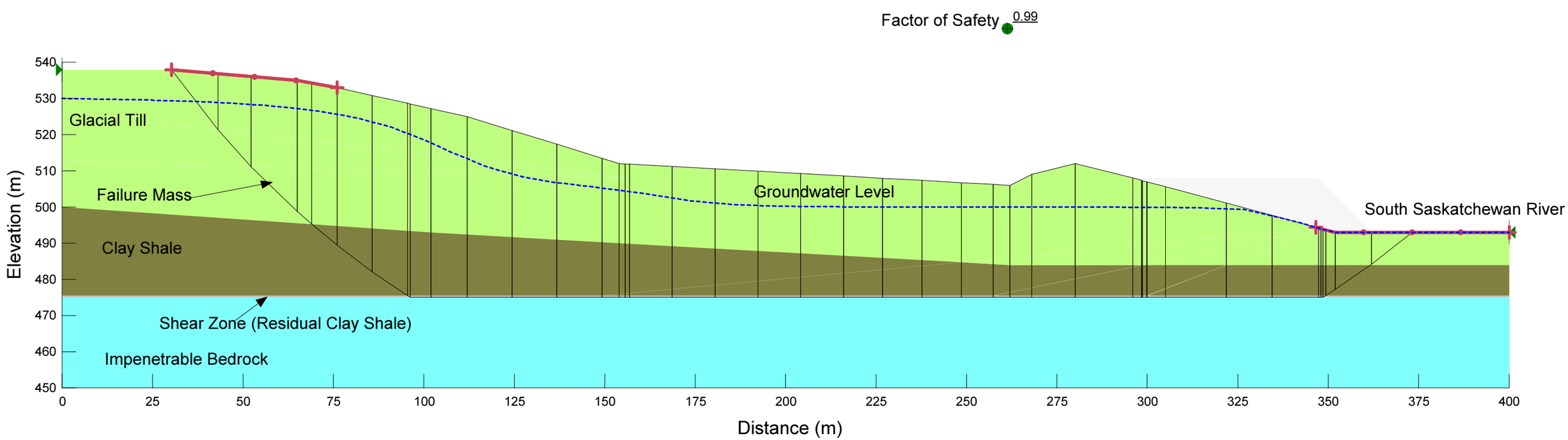
WE CERTIFY TESTING PROCEDURES ARE IN ACCORDANCE WITH ASTM D422 STANDARD
P. MACHIBRODA ENGINEERING LTD.

PER

APPENDIX D

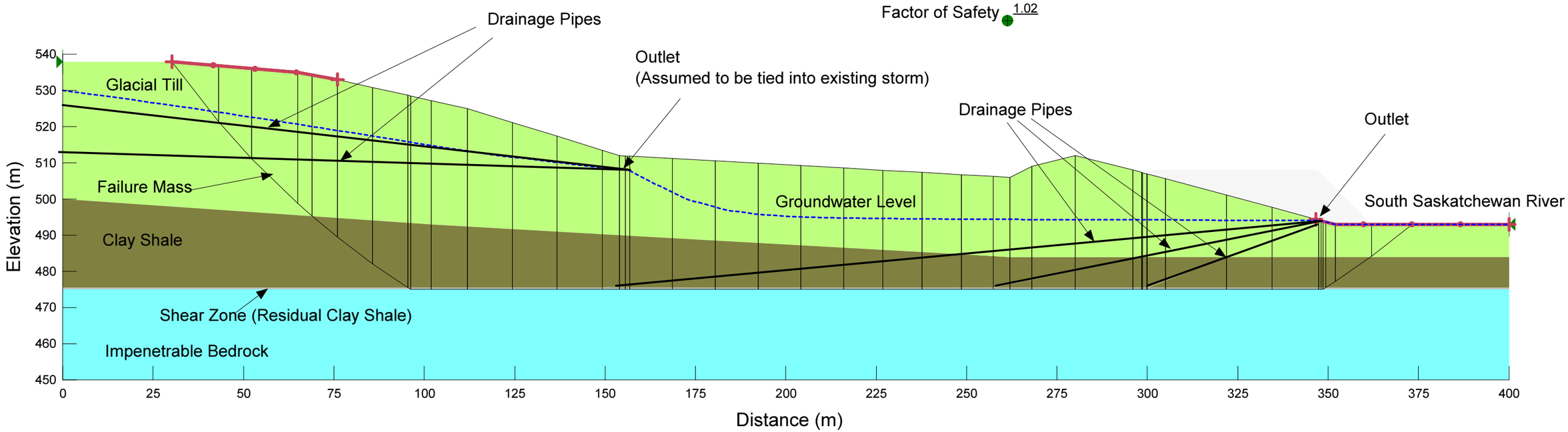
TYPICAL STABILITY AND SEEPAGE MODELLING PLOTS

CURRENT CONDITIONS - BACK ANALYSIS



Name: Glacial Till Unit Weight: 21.5 kN/m³ Cohesion: 10 kPa Phi: 30 °
Name: Clay Shale Unit Weight: 18.5 kN/m³ Cohesion: 25 kPa Phi: 20 °
Name: Shear Zone Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 6 °
Name: Impenetrable Bedrock

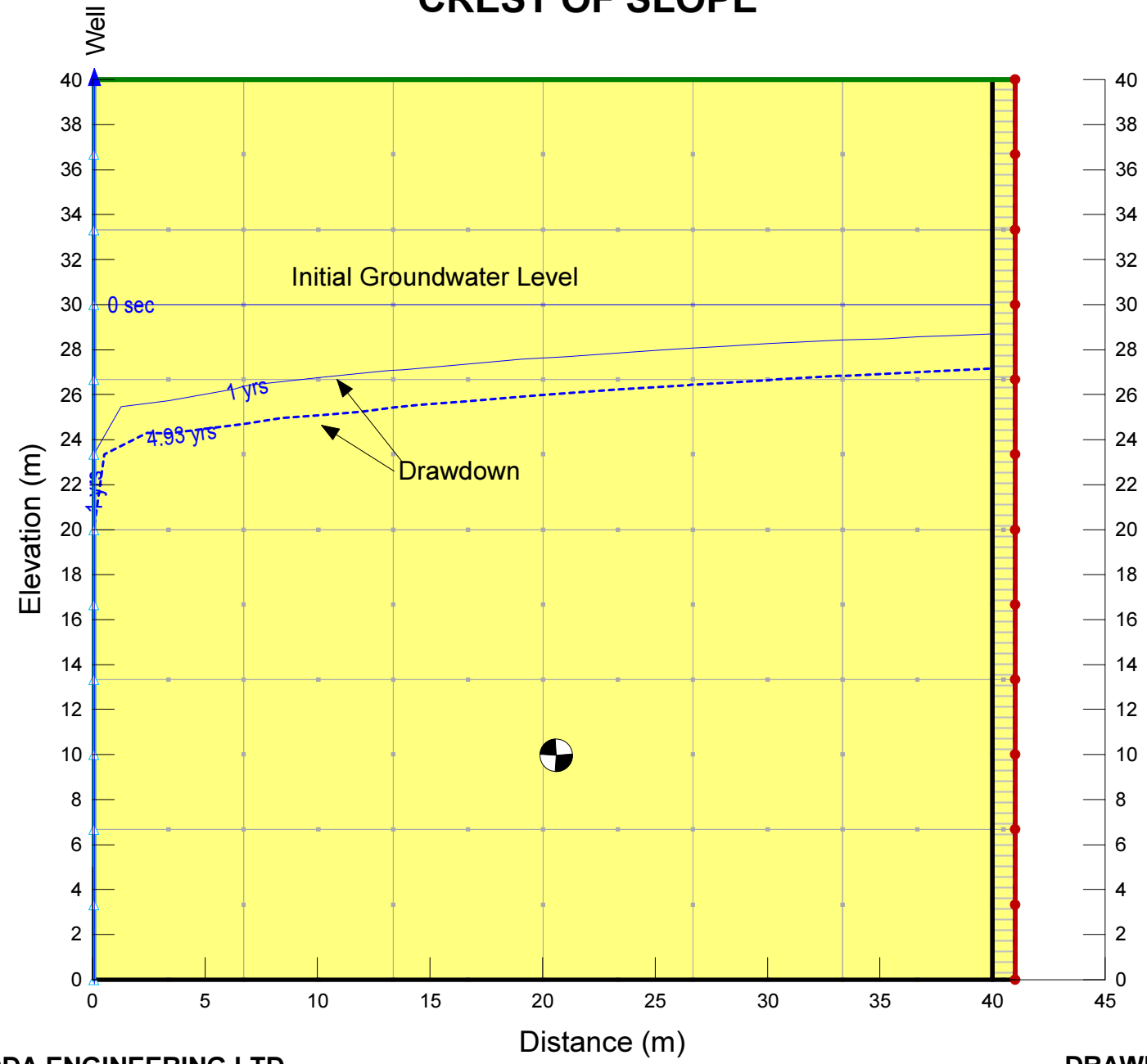
STABILITY WITH HORIZONTAL DRAINS



Name: Glacial Till Unit Weight: 21.5 kN/m³ Cohesion: 10 kPa Phi: 30 °
Name: Clay Shale Unit Weight: 18.5 kN/m³ Cohesion: 25 kPa Phi: 20 °
Name: Shear Zone Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 6 °
Name: Impenetrable Bedrock

PMEL File No. 12451

VERTICAL DEWATERING WELL
CREST OF SLOPE



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DRAWING NO. APPENDIX D-3