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Public Works and Government Services Canada
Telus Plaza North/Plaza Telus Nord
10025 Jasper Ave./10025 ave. Jaspe
5th floor/5e étage
Edmonton
Alberta
T5J 1S6
Bid Fax: (780) 497-3510

SOLICITATION AMENDMENT
MODIFICATION DE L'INVITATION

The referenced document is hereby revised; unless otherwise indicated, all other terms and conditions of the Solicitation remain the same.

Ce document est par la présente révisé; sauf indication contraire, les modalités de l'invitation demeurent les mêmes.

Title - Sujet	Sewer Infrastructure Upgrade
Solicitation No. - N° de l'invitation	EW038-140126/A
Amendment No. - N° modif.	004
Client Reference No. - N° de référence du client	CSC 20140126
Date	2013-06-27
GETS Reference No. - N° de référence de SEAG	PW-$PWU-201-9843
File No. - N° de dossier	PWU-3-36044 (201)
CCC No./N° CCC - FMS No./N° VME	
Solicitation Closes - L'invitation prend fin at - à / on - le	02:00 PM / 2013-07-11
Time Zone / Fuseau horaire	Mountain Daylight Saving Time MDT
F.O.B. - F.A.B.	Plant-Usine: ☐ Destination: ☑ Other-Autre: ☐
Address Enquiries to: - Adresser toutes questions à:	Ho (RPC), Hector
Buyer Id - Id de l'acheteur	pwu201
Telephone No. - N° de téléphone	(780) 497-3543 ( )
FAX No. - N° de FAX	(780) 497-3510
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Name and title of person authorized to sign on behalf of Vendor/Firm (type or print)
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This amendment #4 is to attach the GEOtech report that was missed in amendment #2.

Addendum No.1

The following changes to the Tender Documents are effective immediately. This addendum will form part of the contract documents.

Specification Division 2, Section 02 27 14:

Please add the report prepared by Midland Geotechnical and contained in the following 39 pages, to this section. This report deals with geotechnical information on the project site.

Geotechnical Investigation for Proposed New Storage Cell
Bowden Institution Sewage Infrastructure Upgrade
North of Bowden, AB

Report prepared for:

Associated Engineering Alberta Ltd.
Suite 303, 5913 – 50 Avenue
Red Deer, AB
T4N 4C4

Report prepared by:

Midland Geotechnical Ltd.
#5, 7439 – 49th Avenue Crescent
Red Deer, AB T4P 1X6

Midland File No.: RD109
March 1, 2013

February 25, 2013

Midland File No.: RD109

Associated Engineering Alberta Ltd.
Suite 303, 5913 – 50 Avenue
Red Deer, AB
T4N 4C4

Attention: **Steven Kennedy, C.Tech.**
Project Manager

Geotechnical Investigation for Proposal New Storage Cell
Bowden Institution Sewage Infrastructure Upgrade
North of Bowden, AB

1.0 INTRODUCTION

Midland Geotechnical Ltd. (Midland) presents herein our geotechnical engineering recommendations for the proposed new storage cell for the Bowden Institution Sewage Infrastructure Upgrade. This report provides geotechnical engineering recommendations for: berm design; liner placement and berm construction; topsoil stripping depths; desludging of the existing facultative cell; fill and compaction specifications for modification of the existing clay-lined facultative cell; and, associated construction considerations. Attachments to this report include borehole logs, a borehole locations plan, laboratory test results, and results of stability analyses performed for the proposed cell.

The scope of work for this investigation was outlined in Midland's proposal of June 7, 2012 (Midland Proposal No. MG107), and included the following:

- A geotechnical investigation to assess subsurface soil and groundwater conditions, as well as subsequent groundwater level monitoring after completion of the drilling investigation;
- Laboratory testing of selected samples for moisture content, Atterberg Limit determinations, grain-size distribution analysis, hydraulic conductivity, Unconfined Compressive Strength and soil salinity/resistivity; and,
- Preparation of a geotechnical engineering report summarizing the findings of the geotechnical drilling investigation and laboratory analyses, including our comments and recommendations for berm design, suitability of material for clay liner and berm construction, topsoil stripping depths, and associated construction considerations.

Further to the scope outlined above, Midland was requested to provide desludging and berm construction/design recommendations for the existing facultative cell, which is to be shallowed to accommodate the proposed new system. A test pit investigation was also performed at the request of Associated Engineering Alberta Ltd. (Associated Engineering), to locate a suitable source of borrow material for the construction of the proposed berm construction for both cells.

Testing or assessment of soils with respect to environmental considerations is beyond the scope of this report.

2.0 SITE AND PROJECT DESCRIPTION

The site comprises a vacant field and three existing clay-lined wastewater lagoons located approximately 6 km north of Bowden, AB to the west of Range Road 10. The site is bordered to the west and north by agricultural land, and to the south by the Bowden Institution and Annex. The vacant field was used for agricultural purposes up to and during the time of the field investigation. The field is generally flat-lying, with an overall gentle slope down toward the southwest.

The proposed development is summarized in Option 1 – Lagoon Expansion of the Predesign Report for the Bowden Institution Sewage Infrastructure Upgrade prepared by Associated Engineering for Public Works and Government Services Canada in May, 2012. The summary includes an upgrade requirement that will comprise two anaerobic cells, one facultative cell, and storage cell(s) based on the information collected in preparation for the Predesign Report including existing and anticipated capacities for the Bowden Institution.

Associated Engineering proposes to convert the existing primary pond into the Facultative pond required by modifying the pond to meet Alberta Environment (AENC) provincial design standards and to construct a 97,000 m^3 storage cell to accommodate the anticipated effluent volumes.

3.0 GEOTECHNICAL INVESTIGATION

3.1 Geotechnical Drilling Investigation

A geotechnical drilling investigation was completed on September 14, 2012, and included the drilling and sampling of a total of seven (7) boreholes using a truck-mounted rig owned and operated by All Service Drilling of Airdrie, AB. The boreholes were advanced to depths ranging from approximately 5 m to 9.5 m below the existing ground surface. Underground utility locates were provided by Midland through Alberta One-Call submission.

The soil sampling and test procedures were generally as follows:

- Samples and auger cuttings were obtained at 0.5 m to 1.0 m depth intervals for moisture content determination;
- Standard Penetration Tests (SPTs) were conducted at 1.5 m depth intervals to determine the in-situ soil consistency and relative density of the soils encountered;
- Attempts were made to obtain relatively undisturbed Shelby tube samples to determine the hydraulic conductivity and shear strength of the existing soil. Unfortunately, soil and groundwater conditions prevented the attainment of a representative sample for testing purposes;
- Groundwater levels were measured in the borehole during and upon completion of drilling, and four (4) environmental monitoring wells were installed to facilitate future water level monitoring and sampling; and,

- The remaining boreholes were backfilled, as follows:
  - Boreholes within the proposed storage cell footprint were backfilled with grout; and,
  - Boreholes outside the proposed storage cell footprint were backfilled with auger cuttings and capped with bentonite.

The soils encountered during the drilling investigation were logged and sampled by a representative of Midland. Representative samples obtained during the investigation were sent to our Red Deer laboratory for testing. Natural moisture content determinations, Atterberg Limits, and grain-size distribution analyses on selected samples were undertaken in our Red Deer laboratory. Samples for additional analyses including soil resistivity, pH, and water soluble sulphate content were submitted to an analytical laboratory for testing.

Associated Engineering was notified of the existing soil and groundwater conditions during the drilling investigation; of particular note were the unsuitable conditions for Shelby tube sample retrieval. Several alternative options to complete the hydraulic conductivity were discussed and it was mutually agreed that a manufactured liner would be the most suitable liner option, eliminating the requirements for the hydraulic conductivity testing.

3.2 Borrow Pit Investigation

A test pit investigation of the agricultural land to the west of the proposed development site was performed on September 17, 2012 at the request of Associated Engineering. The purpose of the investigation was to locate and identify suitable borrow materials, if present, for the construction of the new cell berms, modification of the proposed Facultative cell, and construction of a clay liner. The investigation was performed using a rubber-tired backhoe owned and operated by the Bowden Institution.

The test pits were advanced to depths ranging from 1.8 m to 6.0 m below the existing ground surface. A representative of Midland logged and sampled the soils encountered during the investigation. It was determined that there was no need for testing of the soils sampled in regards to the clay liner, as they were granular in nature, however they would be suitable for the intended borrow purpose of berm construction.

4.0 SUBSURFACE CONDTIONS AND LABORATORY TEST RESULTS

The soil stratigraphy encountered during the geotechnical drilling investigation is representative of the approximate borehole locations. Stratigraphy may vary with depth and lateral distance across the site.

Based on the results of the geotechnical drilling investigation, the general stratigraphy of the site comprises silty clay or sand overlying alternating layers of loose silt and soft to firm silty clay. Detailed soil descriptions are presented in the attached borehole logs.

Groundwater Conditions

Groundwater was encountered in all boreholes except borehole BH12-03 during the geotechnical drilling investigation at approximate depths of 3.0 m to 3.1 m below the existing ground surface. The groundwater level in borehole BH12-03 is inferred to be at a depth of approximately 3.0 m based on increased moisture contents determined in our Red Deer laboratory. Subsequent water level monitoring determined the depths in the monitoring wells to be as follows:

Borehole No.	Depth to Water (m)	Stick-up (m)	Depth of Water Below Ground (m)
BH12-03	4.25	0.65	3.6
BH12-05	7.1	0.85	6.25
BH12-06	3.85	0.73	3.12
BH12-07	5.6	0.70	4.9

Groundwater levels are anticipated to fluctuate seasonally and with changes in climatic conditions. Periodic monitoring of water levels is recommended prior to and during construction.

Frost Conditions

The estimated frost penetration depth in the Bowden area is approximately 1.8 m to 2.5 m below the existing ground surface based on the Freezing Index provided by Environment Canada, interpolated from the Red Deer and Calgary areas. Frost penetration depth may vary with soil composition, consistency, and snow cover.

5.0 DISCUSSIONS AND RECOMMENDATIONS

5.1 Geotechnical Engineering Design for New Storage Cell

5.1.1 Storage Cell Liner

5.1.1.1 *Clay Liner*

The preferred lining system for the proposed new storage cell is a clay liner, however, based on the results of the grain-size distribution tests, the in-situ soils and surrounding area do not contain suitable material for the construction of such a liner. Should a suitable clayey borrow material be located, it is recommended that the material have the following approximate properties in order to achieve the desired hydraulic conductivity of between $1x10^{-8}$ m/sec and $1x10^{-9}$ m/sec:

- Greater than 20 percent clay-sized particles;
- Greater than 30 percent silt-sized/clay-sized particles;
- Liquid limit equal to or greater than 30; and,
- A plasiticity index equal to or greater than 10.

If possible, this material should be tested for in-situ hydraulic conductivity using field measurement methods such as double-ring infiltrometer tests, or using laboratory methods such as one-dimensional hydraulic conductivity testing.

The borrow material should be compacted to a minimum of 98 percent Standard Proctor Maximum Dry Density (SPMDD) to achieve the afore-mentioned hydraulic conductivity range, and placed in lifts no thicker than 0.15 m. The material should be uniformly compacted at moisture contents within two to three percent above the Optimum Moisture Content (OMC).

The clay liner should be constructed with a minimum thickness of 0.6 m for the base and 1.2 m for the sideslopes as per the ANEC Standards and Guidelines for Municipal Waterworks, Wastewater, and Storm Drainage Systems. This document should be followed for design and construction of any liner configuration, unless otherwise confirmed by hydrogeological and contaminant transport analysis. Erosion control methods such as granular material placed on top of the clay liner, such as rip rap, may be necessary and should be placed along the sideslopes, extending above the maximum wave height.

5.1.1.2 Bentonite/Sand Admix Liner

As alternative to importing borrow materials for a compacted clay liner from a suitable borrow source, we suggest the use of a Bentonite/Sand Admix Liner (BSAL). A BSAL replaces the need for suitable clay material by using ultra-low permeability manufactured betonite clay powder to lower the general conductivity of existing silt or sand borrow materials currently available. This method is common practice in regions where clay sources are not economically accessible to the project. This method is an ANEC approved alternative to compacted clay liners.

The final design of BSAL liners is subject to laboratory testing to determine the hydraulic conductivity of the admixture product. If Associated Engineering wishes to pursue this option, our office is willing to provide the resources for testing, design, specification, or construction QA/QC of the BSAL liner (separate from this project scope). If our office does not prepare the design, we should be provided the opportunity to review the proposed liner and revise our recommendations, as necessary.

5.1.1.3 Manufactured Liner

Another alternative to clay or admix clay liners is a manufactured liner. We recommend the use of a Linear Low Density Polyethylene (LLDPE) such as a Layfield Plastics Enviro Liner 6030/6040 (20 mil minimum) that extends to the crest of each berm. The liner should be installed as per the manufacturer’s instructions, and may need to be weighted down until water levels with the storage cell reach their optimum level, should shallow groundwater conditions be encountered during construction. This method is an ANEC approved alternative to compacted clay liners.

It is suggested that a detailed design be pursued by a registered professional for the use of a manufactured liner. If Associated Engineering wishes to purse this option, our office is willing to provide resources for testing, design, specification, or construction QA/QC of the manufactured liner (separate from this project scope). If our office does not prepare the design, we should be provided the opportunity to review the proposed liner and revise our recommendations, as necessary.

5.1.2 Berm Construction

The proposed berm slopes outlined in Associated Engineering's Predesign Report (May, 2012) for 3H:1V for interior and 4H:1V for exterior slopes are considered suitable for berm construction with either a manufactured or clay liner. Our office has performed a coupled slope/seepage stability model to confirm stability of Associated Engineering's proposed design with site specific conditions. The results of this model indicated that the proposed design is safe for construction. Details on the slope/seepage model can be found in Appendix A. It should be noted that this modelling is not a verification of liner performance, as it did not include the required information for contaminant transport modeling. If required, our office can provide these services upon request.

The proposed berm slopes allow for sufficient freeboard above the maximum expected wave height (calculated based on fetch distances provided in the preliminary design). Should a clay liner or admix liner option be chosen, erosion control measures will be necessary to maintain the thickness and integrity of the liner on the sideslopes. Recommendations for erosion control measures can be provided by Midland upon request, should a clay liner option be chosen. Periodic monitoring should be performed for the interior slopes after construction has been completed.

Exterior slopes may also be subject to erosion, and should be vegetated upon completion to minimize potential for surface drainage and wind erosion.

5.1.3 Site Preparation

The proposed storage cell footprint should be stripped of existing organics, topsoil, and any other deleterious materials to expose native undisturbed silt or clay.

Note that rainfall could result in the softening of the subgrade, and extended dry conditions could results in the drying of the subgrade. Therefore, subgrade preparation should be undertaken in one continuous operation and construction should be carried out immediately after site stripping. The subgrade should be sloped at a minimum of 2.0 % to promote positive drainage. Shallow temporary ditches may be required to control surface runoff. The subgrade may be protected by a granular layer, or by leaving approximately 150 mm of unexcavated material which would be later removed immediately prior to construction. Stripping of unsuitable materials should be undertaken with a tracked excavator equipped with a clean-out bucket. The excavator should progressively retreat from the stripped area to avoid disturbance of the exposed subgrade. The exposed subgrade should be reviewed by Midland prior to placing fill.

5.1.4 Structural Fill

Structural fill is defined as fill placed beneath any load bearing area. Imported structural fill for construction of the berms should consist of non-organic, well-graded granular material, or low plastic clay with a Liquid Limit and Plastic Limit of less than 40 percent and 20 percent, respectively.

Granular and cohesive structural fill should be placed in maximum 300 mm and 150 mm lifts, respectively, and should be compacted to a minimum of 98 percent of SPMDD. Laboratory Standard Proctor analysis (ASTM 698) and field density testing should be conducted to confirm that standards are met.

5.2 Existing Cell Modifications

5.2.1 Desludging

Desludging of the existing primary pond will require draining of the existing pond and removal/dewatering of the excavated material in a nearby temporary location, environmentally lined to prevent contamination of the surrounding area. Representative samples of the sludge will be obtained and tested at a qualified analytical laboratory to determine the concentrations of the sludge, and appropriate disposal methods/facilities. Confirmatory samples of the existing clay liner will also be obtained to determine the depth of scarification to remove biologically/chemically influenced clay before placement of fill.

5.2.2 Placement of Fill in Base of Pond

For the existing primary pond to be converted to a Facultative pond, approximately 0.1 m of fill will be required to shallow the pond to meet AENV requirements, as per the Preliminary Design Report prepared by Associated Engineering (May, 2012). As the existing pond has a clay liner, a borrow source with material meeting the grain-size distribution requirements outlined in the clay liner section above must be located.

Once desludging of the pond has been completed, the subgrade should be reviewed by Midland to confirm that the existing liner is sufficiently compact to meet a hydraulic conductivity requirement of $1x10^{-8}$ m/sec. Should the existing liner not meet the specification, re-compaction or replacement of the existing material may be necessary.

The clay fill to shallow the pond may be placed in a single lift, provided the thickness does not exceed 0.15 m. The fill should be compacted to a minimum of 98 percent SPMDD and should be placed within two to three percent above the OMC.

6.0 FIELD REVIEW AND QA/QC

It is recommended that geotechnical field review be carried out to assess the actual soil conditions encountered and confirm assumptions used in the design. Where conditions encountered differ significantly from those assumed for design, Midland should be provided the opportunity to review the design assumptions and modify the design, as appropriate. Geotechnical field reviews should include, but not be limited to, the review of all proposed subgrades/bearing surfaces, trench excavations, and quality control testing of all construction materials.

Environmental field review should be carried out during the desludging process to confirm the removal of all sludge and all sludge-influenced material, and that all such material is disposed of using appropriate methods and to a suitable location. Environmental field review should include, but not be limited to, initial sampling of the sludge material for analytical testing to determine suitable disposal methods and locations and confirmation of sludge removal via sampling for analytical testing.

Our office has the in-house resources to perform contract administration, tendering, construction management, construction QA/QC, and construction reporting. Should these services be required by Associated Engineering, our office is willing to provide a quote upon request.

7.0 OPERATIONS AND STANDARD PRACTICE MANUAL

Part of the final submission packages for projects such as dyke construction and commission include documents detailing operation of the commissioned structure. There are many important components related to the ongoing inspection, maintenance, and repair of geotechnical structure components in pond networks. The purpose of this document is to provide operators with the knowledge required for safe and sustainable operation of their facility. Our office is willing to provide support for the assembly of the geotechnical portion of this document including items such as visual dyke inspection methodology, emergency failure protocols, and general operations planning.

8.0 CLOSURE

Recommendations presented herein are to be considered preliminary and are based on the geotechnical evaluation of the findings of the boreholes completed on September 14, 2012. The material in this report reflects Midland's best judgement in light of the information available to Midland at the time of preparation of this report. If conditions other than those are noted during subsequent phases of development, Midland should be notified and given the opportunity to review and revise the current recommendations, if necessary.

This report has been prepared for the exclusive use of Associated Engineering Alberta Ltd. and their consultants and representatives for the specific application to the development described within this report. Any use of which a third party makes of this report, or any reliance on or decisions made based on it are the responsibility of such third parties. Midland accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

We appreciate the opportunity to be of service to you. If you have any questions regarding the contents of this report, or if we can be of further assistance to you on this project, please contact the undersigned.

Sincerely,
Midland Geotechnical Ltd.
A subsidiary of the Metro Testing Group of Companies

ORIGINAL DOCUMENT SIGNED

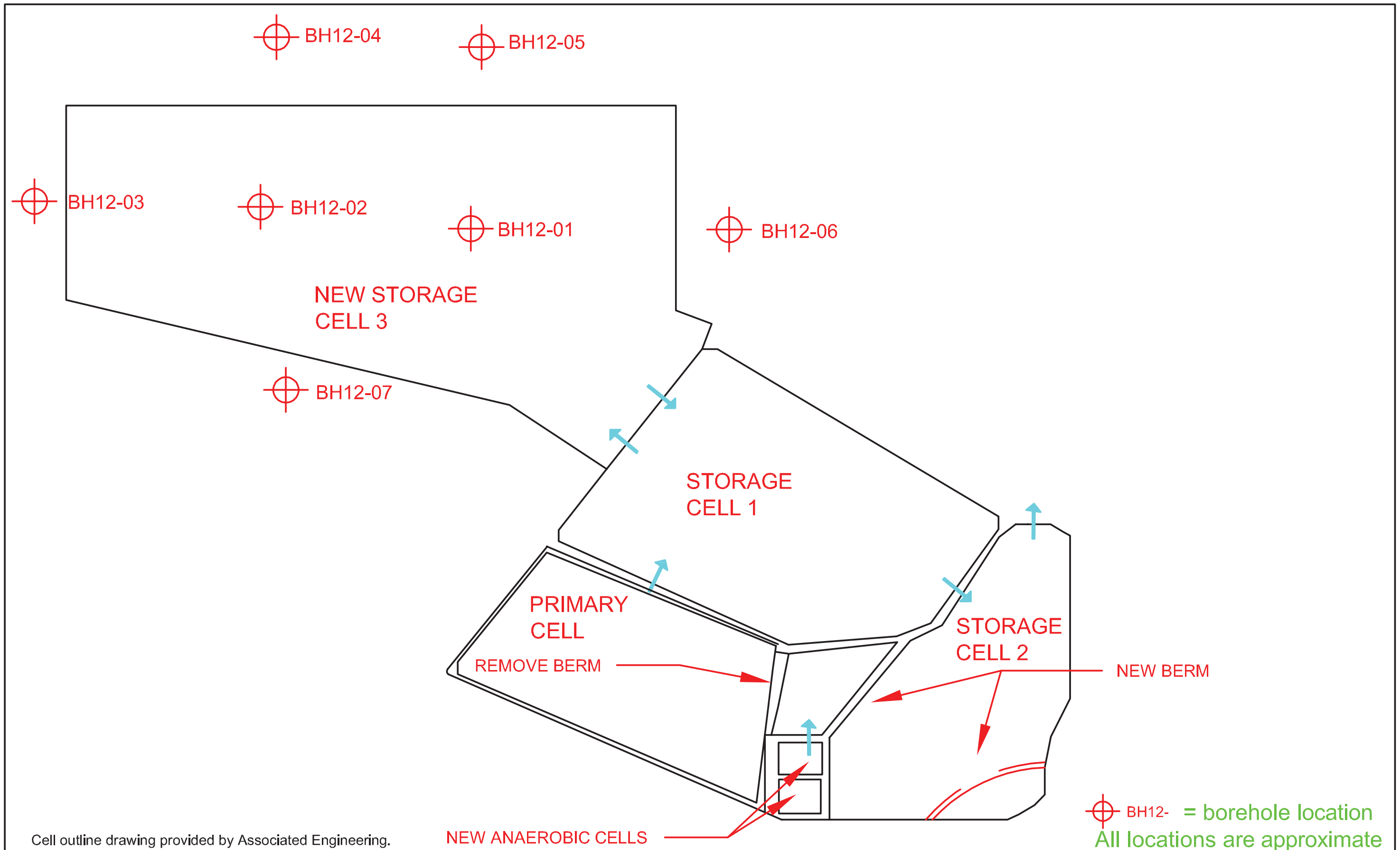
Rhonda Mellafont, B.Sc., GIT
Engineering Geologist

ORIGINAL DOCUMENT SEALED

B. A. Smale, P.Eng.
Geoenvironmental Engineer

APEGA Permit to Practice No. P11386

APPENDIX A: BOREHOLE LOCATION PLAN



Cell outline drawing provided by Associated Engineering.

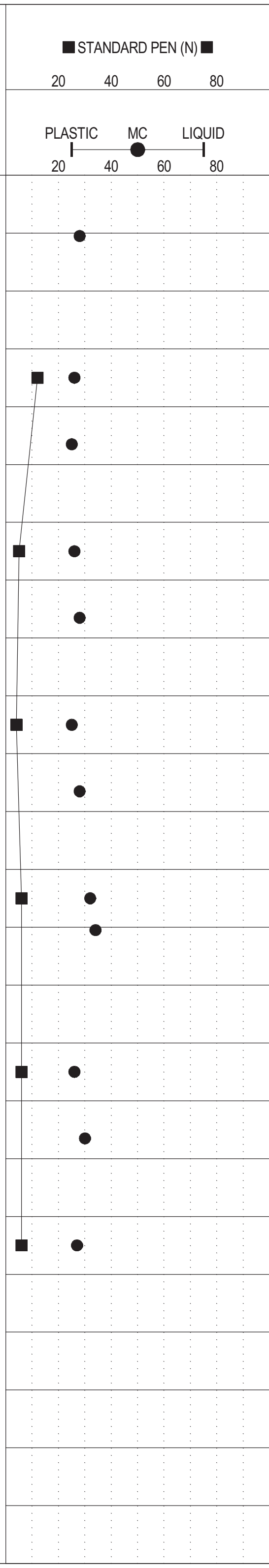
MIDLAND GEOTECHNICAL LTD.	CLIENT ASSOCIATED ENGINEERING SUITE 303, 5913 - 50 AVENUE RED DEER, AB T4N 4C4	DWN BY: RLM CHK'D BY: DG APP. RM SCALE NTS	PROJECT BOREHOLE LOCATION PLAN BOWDEN INSTITUTION SEWAGE INFRASTRUCTURE UPGRADE NORTH OF BOWDEN, AB	DATE: SEPTEMBER, 2012 PROJECT NO: RD109 REV. NO.: FIGURE No. FIGURE 1

APPENDIX B: BOREHOLE LOGS

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-01**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE: SHELBY TUBE; NO RECOVERY; SPT; DISTURBED; A-CASING; CONTINUOUS

BACKFILL TYPE: BENTONITE; PEA GRAVEL; SLOUGH; GROUT; DRILL CUTTINGS; SAND



USCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS
	TOPSOIL, clayey, black, contains trace organics.				
CI	CLAY, silty, trace to some sand, firm to stiff, brown, moist, contains silt partings and thin sand lenses.		1-1		MC = 28%
ML	SILT, sandy (fine-grained), compact, dilatent, brown, moist. -- alternating layers of silt and clay (approximately 0.15 m thickness).	SPT	1-2	12	MC = 26%
			1-3		MC = 25%
	-- GROUNDWATER ENCOUNTERED, alternating layers of silt and moist to wet sand (approximately 0.15 m to 0.2 m thickness). -- alternating layers of clayey silt and silt (approximately 0.15 m thickness).	SPT	1-4	5	MC = 26%
			1-5		MC = 28%
		SPT	1-6	4	MC = 25%
			1-7		MC = 28%
CL	CLAY, silty or SILT, clayey, firm/loose to compact, brown, moist.	SPT	1-8	6	MC = 32%
			1-9		MC = 34%
ML	SILT, trace to some clay, loose to compact, grey moist.	SPT	1-10	6	MC = 26%
			1-11		MC = 30%
		SPT	1-12	6	MC = 27%
	Borehole dry upon completion. Backfilled with grout. End of borehole at 9.5 m.				

INSTRUMENTATION DATA

Depth (m): 2, 4, 6, 8, 10

LOGGED BY: RM	COMPLETION DEPTH: 9.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12
	Page 1 of 1

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-02**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE: SHELBY TUBE, NO RECOVERY, SPT, DISTURBED, A-CASING, CONTINUOUS

BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Chart legend: ■ STANDARD PEN (N) ■ (20, 40, 60, 80); PLASTIC – MC – LIQUID (20, 40, 60, 80)

Depth (m)	USCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	INSTRUMENTATION DATA
0		TOPSOIL, clayey, black, contains trace organics.					
	CI	CLAY, silty, trace to some sand, firm to stiff, brown, moist, contains silt partings and thin sand lenses.	Shelby tube	2-1		MC = 25%	
	ML	SILT, trace clay, compact, dilatent, brown, moist.	SPT	2-2	10	MC = 19%	
2			Shelby tube	2-3		MC = 24%	
		-- GROUNDWATER ENCOUNTERED, alternating layers of silt and clay (approximately 0.15 m thickness).	SPT	2-4	7	MC = 30%	
4			Shelby tube	2-5		MC = 26% Gravel / sand / silt-size / clay-size particles (%) = 0 / 35.5 / 54.7 / 9.8.	
			SPT	2-6	12	MC = 25%	
			Shelby tube	2-7		MC = 26%	
	ML	SILT, sandy (fine-grained), trace to some clay, loose to compact, grey, moist.					
6			SPT	2-8	7		
8							
10		Borehole dry upon completion. Backfilled with grout. End of borehole at 6.5 m.					

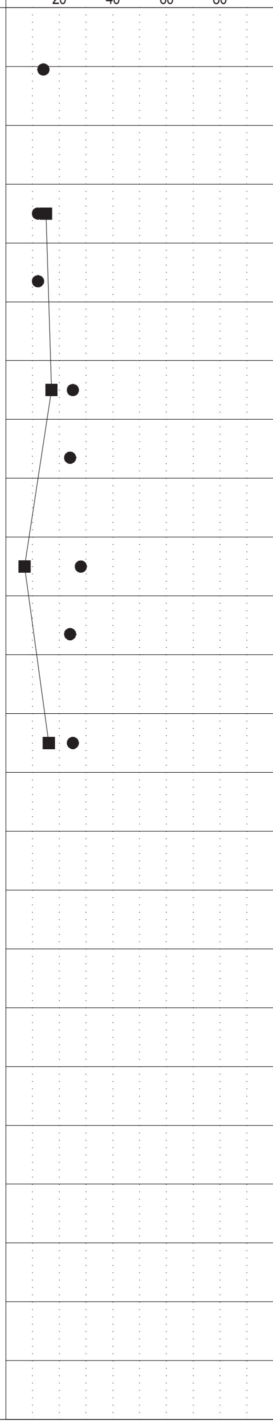
LOGGED BY: RM	COMPLETION DEPTH: 6.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-03**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE	SHELBY TUBE	NO RECOVERY	SPT	DISTURBED	A-CASING	CONTINUOUS
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND

■ STANDARD PEN (N) ■ 20 40 60 80

PLASTIC MC LIQUID 20 40 60 80



USCS	SOIL DESCRIPTION	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS
SM	SAND (fine-grained), silty, compact, brown, moist, increasing silt content with depth.	3-1		MC = 14%
		3-2	15	MC = 12%
		3-3		MC = 12%
ML	SILT, clayey, compact, dilatent, brown, moist.	3-4	17	MC = 25%
ML	SILT, sandy (fine-grained), trace clay, loose to compact, grey, wet.	3-5		MC = 24%
		3-6	7	MC = 28%
		3-7		MC = 24%
	-- medium-grained sand.			
		3-8	16	MC = 25%

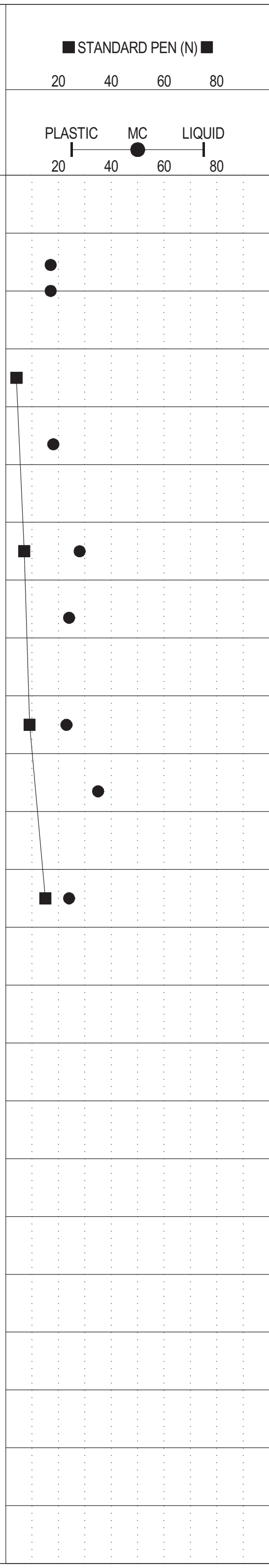
Monitoring Well Installed.
Screen from 6.5 m to 3.5 m.
Solid from 3.5 m to surface.
Sand from 6.5 m to 3.2 m.
Bentonite from 3.2 m to surface.
End of borehole at 6.5 m.

Depth (m): 2, 4, 6, 8, 10

LOGGED BY: RM	COMPLETION DEPTH: 6.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-04**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE	SHELBY TUBE	NO RECOVERY	SPT	DISTURBED	A-CASING	CONTINUOUS
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND



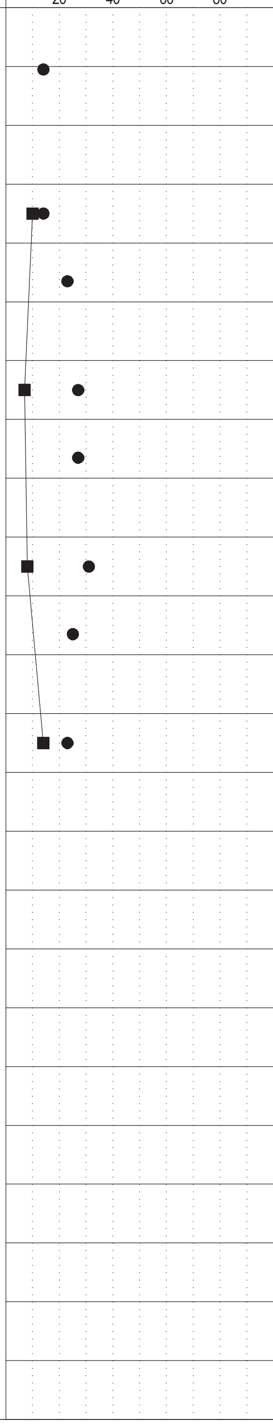
Depth (m)	USCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	INSTRUMENTATION DATA	Depth (m)
		TOPSOIL, clayey, black, contains trace organics.						
	ML	SILT, sandy, trace to some clay, dilatent, grey, damp to moist.	Shelby tube	4-1		MC = 17% MC = 17%		
2			SPT	4-2	4			2
			Shelby tube	4-3		MC = 18%		
		-- GROUNDWATER ENCOUNTERED, alternating layers of clay and silt (approximately 0.15 m thickness).	SPT	4-4	7	MC = 28%		
4			Shelby tube	4-5		MC = 24% Gravel / sand / silt-size / clay-size particles (%) = 0 / 26.4 / 48.9 / 24.7.		4
			SPT	4-6	9	MC = 23%		
			Shelby tube	4-7		MC = 35%		
6			SPT	4-8	15	MC = 24%		6
		Borehole dry upon completion. Backfilled with cuttings and capped with bentonite. End of borehole at 6.5 m.						
8								8
10								10

LOGGED BY: RM	COMPLETION DEPTH: 6.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-05**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE	SHELBY TUBE	NO RECOVERY	SPT	DISTURBED	A-CASING	CONTINUOUS
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND

Depth (m) | ■ STANDARD PEN (N) ■ 20 40 60 80 | PLASTIC MC LIQUID 20 40 60 80



Depth (m)	USCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS
		TOPSOIL, clayey, black, contains trace organics.				
	CI	CLAY, silty, trace sand, firm to stiff, grey, moist.	Shelby tube	5-1		MC = 14%
	ML	SILT, sandy, trace to some clay, dilatent, grey, damp to moist.				
2			SPT	5-2	10	MC = 14%
			Shelby tube	5-3		MC = 23%
		-- GROUNDWATER ENCOUNTERED, alternating layers of clay and silt (approximately 0.15 m thickness).	SPT	5-4	7	MC = 27%
4		-- SAND, silty to SILT, sandy.	Shelby tube	5-5		MC = 27% Gravel / sand / silt-size / clay-size particles (%) = 0 / 50.1 / 36.3 / 13.6.
		-- compact/stiff.	SPT	5-6	8	MC = 31%
			Shelby tube	5-7		MC = 25%
6			SPT	5-8	14	MC = 23%
		Monitoring Well Installed. Screen from 6.5 m to 3.5 m. Solid from 3.5 m to surface. Sand from 6.5 m to 3.2 m. Bentonite from 3.2 m to surface. End of borehole at 6.5 m.				
8						
10						

LOGGED BY: RM	COMPLETION DEPTH: 6.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-06**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE: SHELBY TUBE, NO RECOVERY, SPT, DISTURBED, A-CASING, CONTINUOUS

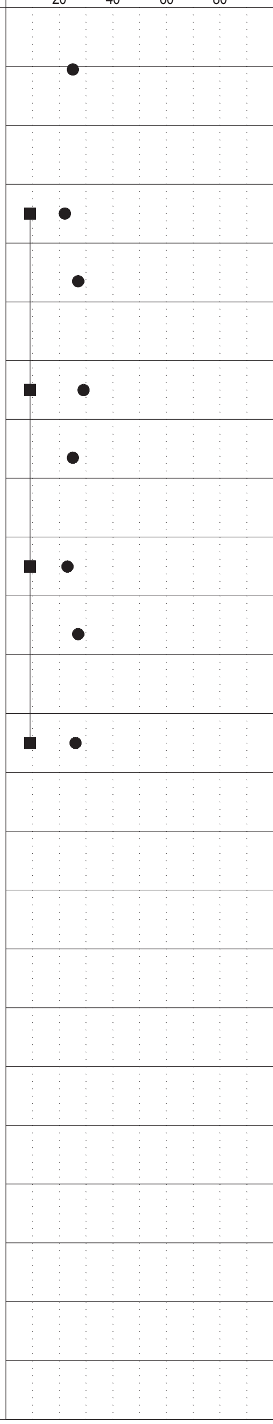
BACKFILL TYPE: BENTONITE, PEA GRAVEL, SLOUGH, GROUT, DRILL CUTTINGS, SAND

Depth (m)	STANDARD PEN (N) 20 40 60 80 / PLASTIC MC LIQUID 20 40 60 80	USCS	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	INSTRUMENTATION DATA	Depth (m)
				TOPSOIL, clayey, black, contains trace organics.						
				SILT, sandy, some clay, firm to stiff, grey, moist.						
					Shelby tube	6-1		Gravel / sand / silt-size / clay-size particles (%) = 0 / 30.9 / 51.4 / 17.7.		
2										2
				-- GROUNDWATER ENCOUNTERED.	SPT	6-2	14	MC = 29%		
		ML			Disturbed	6-3		MC = 22%		
4										4
					SPT	6-4	9	MC = 23%		
					Disturbed	6-5				
6					SPT	6-6	7			6
				Monitoring Well Installed. Screen from 6.5 m to 3.5 m. Solid from 3.5 m to surface. Sand from 6.5 m to 3.2 m. Bentonite from 3.2 m to surface. End of borehole at 5.0 m.						
8										8
10										10

LOGGED BY: RM	COMPLETION DEPTH: 5.0 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

Associated Engineering	Bowden Institution Sewage Infrastructure Upgrade	BOREHOLE NO: **BH12-07**
All Service Drilling	6 km North of Bowden, AB	PROJECT NO: RD109
Solid Stem Auger		ELEVATION:

SAMPLE TYPE	SHELBY TUBE	NO RECOVERY	SPT	DISTURBED	A-CASING	CONTINUOUS
BACKFILL TYPE	BENTONITE	PEA GRAVEL	SLOUGH	GROUT	DRILL CUTTINGS	SAND



Depth (m)	USCS	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE NO	SPT (N)	OTHER TESTS COMMENTS	INSTRUMENTATION DATA
0		TOPSOIL, clayey, black, contains trace organics.					
	ML	SILT, clayey, trace sand, firm to stiff, grey, moist.	Shelby tube	7-1		MC = 25%	
			SPT	7-2	9	MC = 22%	
2			Shelby tube	7-3		MC = 27%	
		-- GROUNDWATER ENCOUNTERED.	SPT	7-4	9	MC = 29% Gravel / sand / silt-size / clay-size particles (%) = 0 / 6.7 / 68.3 / 25.0.	
4			Shelby tube	7-5		MC = 25%	
			SPT	7-6	9	MC = 23%	
			Shelby tube	7-7		MC = 27%	
6			SPT	7-8	9	MC = 26%	
6.5		Monitoring Well Installed. Screen from 6.5 m to 3.5 m. Solid from 3.5 m to surface. Sand from 6.5 m to 3.2 m. Bentonite from 3.2 m to surface. End of borehole at 6.5 m.					
8							
10							

LOGGED BY: RM	COMPLETION DEPTH: 6.5 m
REVIEWED BY: RM	COMPLETION DATE: 12/9/12

APPENDIX C: Laboratory Results

MIDLAND GEOTECHNICAL LTD.
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P: (403) 346-1920 F: (403) 346-1912 www.midlandgeo.ca

ATTERBERG LIMITS

CLIENT: Associated Engineering
PROJECT: Bowden Institute
BOREHOLE #: BH12-01
SAMPLE #: 1-4
DEPTH (m): 3

PROJECT #: RD109
DATE SAMPLED:
SAMPLED BY: RM
DATE TESTED: 3-Nov-12
TESTED BY: JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	23	25
CONTAINER NO.	2	13
WT OF WET SAMPLE + TARE	14.5	15.0
WT OF DRY SAMPLE + TARE	11.2	11.6
TARE OF CONTAINER	1.4	1.3
WT OF WATER	3.3	3.4
WT OF DRY SOIL	9.8	10.3
WATER CONTENT %	33.54	32.91
CORR'D WATER CONTENT %	33.2	32.9

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

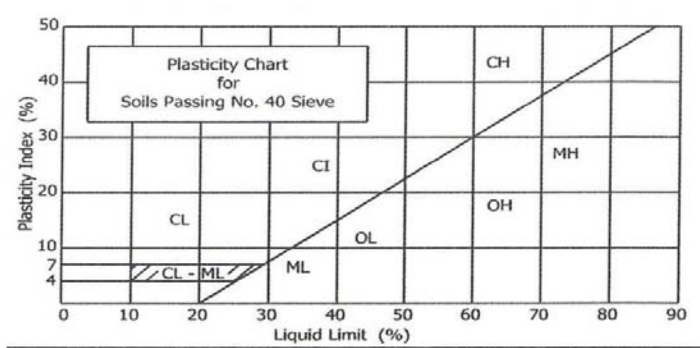
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.	39	45
WT OF WET SAMPLE + TARE	8.1	7.7
WT OF DRY SAMPLE + TARE	7.0	6.7
TARE OF CONTAINER	1.4	1.4
WT OF WATER	1.1	1.0
WT OF DRY SOIL	5.7	5.3
WATER CONTENT %	18.9	18.9

Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
33.1	18.9	14.2

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	52
WT OF WET SAMPLE + TARE	68.2
WT OF DRY SAMPLE + TARE	57
TARE OF CONTAINER	14.2
WT OF WATER	11.2
WT OF DRY SOIL (Wo)	42.8
WATER CONTENT (W) %	26.2



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P: (403) 346-1920 F: (403) 346-1912 www.midlandgeo.ca

ATTERBERG LIMITS

CLIENT:	Associated Engineering	PROJECT #:	RD109
PROJECT:	Bowden Institute	DATE SAMPLED:	
BOREHOLE #:	BH12-03	SAMPLED BY:	RM
SAMPLE #:	3-5	DATE TESTED:	3-Nov-12
DEPTH (m):	3.8	TESTED BY:	JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	21	22
CONTAINER NO.	35	1
WT OF WET SAMPLE + TARE	14.9	14.2
WT OF DRY SAMPLE + TARE	12.2	11.7
TARE OF CONTAINER	1.3	1.4
WT OF WATER	2.7	2.5
WT OF DRY SOIL	10.9	10.3
WATER CONTENT %	24.98	24.49
CORR'D WATER CONTENT %	24.5	24.1

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

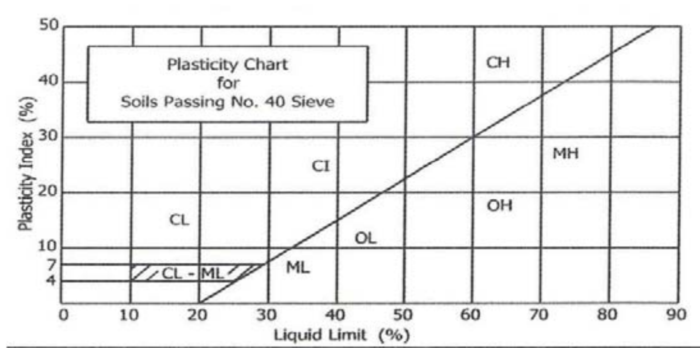
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.		
WT OF WET SAMPLE + TARE		
WT OF DRY SAMPLE + TARE		
TARE OF CONTAINER		
WT OF WATER		
WT OF DRY SOIL		
WATER CONTENT %		

Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
24.3		

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	93
WT OF WET SAMPLE + TARE	69.6
WT OF DRY SAMPLE + TARE	58.8
TARE OF CONTAINER	14
WT OF WATER	10.8
WT OF DRY SOIL (Wo)	44.8
WATER CONTENT (W) %	24.1



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ATTERBERG LIMITS

CLIENT: Associated Engineering
PROJECT: Bowden Institute
BOREHOLE #: BH12-04
SAMPLE #: 4-5
DEPTH (m): 3.8

PROJECT #: RD109
DATE SAMPLED:
SAMPLED BY: RM
DATE TESTED: 3-Nov-12
TESTED BY: JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	29	29
CONTAINER NO.	3	21
WT OF WET SAMPLE + TARE	15.4	12.9
WT OF DRY SAMPLE + TARE	12.0	10.0
TARE OF CONTAINER	1.3	1.4
WT OF WATER	3.5	2.9
WT OF DRY SOIL	10.6	8.7
WATER CONTENT %	32.83	33.33
CORR'D WATER CONTENT %	33.4	33.9

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

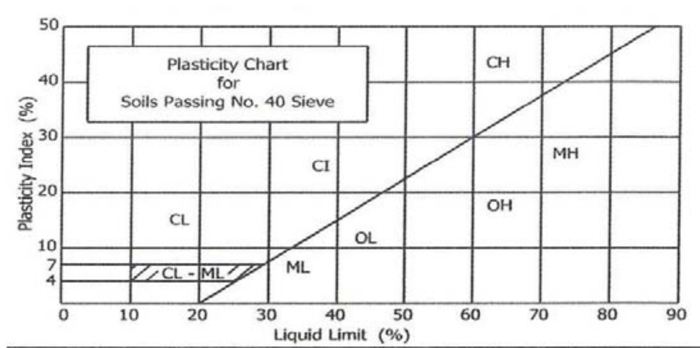
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.	8	41
WT OF WET SAMPLE + TARE	6.8	8.0
WT OF DRY SAMPLE + TARE	6.0	7.0
TARE OF CONTAINER	1.3	1.3
WT OF WATER	0.8	1.0
WT OF DRY SOIL	4.7	5.7
WATER CONTENT %	16.7	17.3

Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
33.7	17.0	16.7

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	61
WT OF WET SAMPLE + TARE	66.2
WT OF DRY SAMPLE + TARE	56.4
TARE OF CONTAINER	14.2
WT OF WATER	9.8
WT OF DRY SOIL (Wo)	42.2
WATER CONTENT (W) %	23.2



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P: (403) 346-1920 F: (403) 346-1912 www.midlandgeo.ca

ATTERBERG LIMITS

CLIENT: Associated Engineering
PROJECT: Bowden Institute
BOREHOLE #: BH12-05
SAMPLE #: 5-5
DEPTH (m): 3.8

PROJECT #: RD109
DATE SAMPLED:
SAMPLED BY: RM
DATE TESTED: 3-Nov-12
TESTED BY: JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	26	27
CONTAINER NO.	14	11
WT OF WET SAMPLE + TARE	15.3	13.7
WT OF DRY SAMPLE + TARE	12.4	11.1
TARE OF CONTAINER	1.3	1.3
WT OF WATER	2.9	2.6
WT OF DRY SOIL	11.1	9.8
WATER CONTENT %	26.21	26.15
CORR'D WATER CONTENT %	26.3	26.4

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

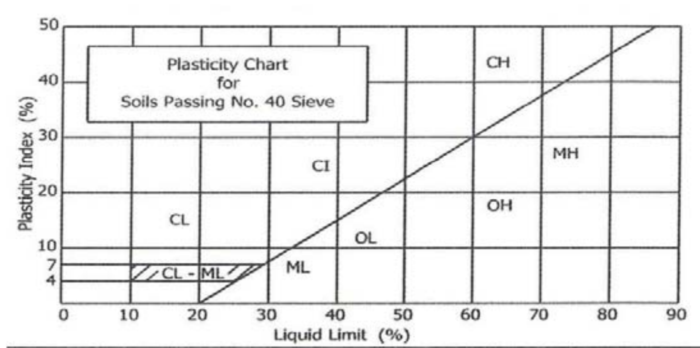
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.		
WT OF WET SAMPLE + TARE		
WT OF DRY SAMPLE + TARE		
TARE OF CONTAINER		
WT OF WATER		
WT OF DRY SOIL		
WATER CONTENT %		

Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
26.4		

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	20
WT OF WET SAMPLE + TARE	66.8
WT OF DRY SAMPLE + TARE	55.6
TARE OF CONTAINER	13.6
WT OF WATER	11.2
WT OF DRY SOIL (Wo)	42.0
WATER CONTENT (W) %	26.7



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ATTERBERG LIMITS

CLIENT:	Associated Engineering	PROJECT #:	RD109
PROJECT:	Bowden Institute	DATE SAMPLED:	12-Sep-12
BOREHOLE #:	BH12-06	SAMPLED BY:	RM
SAMPLE #:	6-2	DATE TESTED:	6-Nov-12
DEPTH (m):	2	TESTED BY:	JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	23	23
CONTAINER NO.	2	14
WT OF WET SAMPLE + TARE	14.7	13.6
WT OF DRY SAMPLE + TARE	11.9	11.0
TARE OF CONTAINER	1.4	1.3
WT OF WATER	2.8	2.6
WT OF DRY SOIL	10.6	9.8
WATER CONTENT %	26.70	26.54
CORR'D WATER CONTENT %	26.4	26.3

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

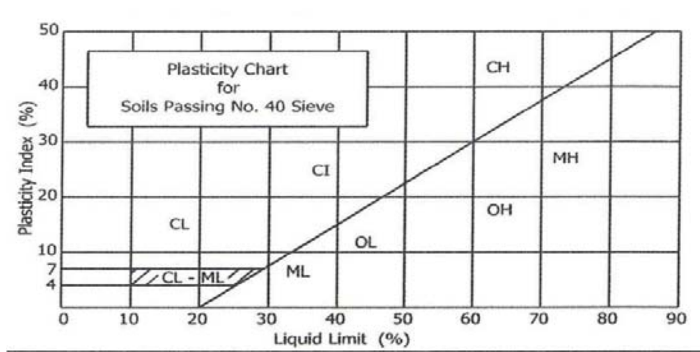
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.	3	41
WT OF WET SAMPLE + TARE	6.3	6.2
WT OF DRY SAMPLE + TARE	5.6	5.6
TARE OF CONTAINER	1.3	1.3
WT OF WATER	0.7	0.7
WT OF DRY SOIL	4.3	4.2
WATER CONTENT %	16.8	16.1

Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
26.4	16.4	10.0

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	7
WT OF WET SAMPLE + TARE	68.8
WT OF DRY SAMPLE + TARE	59
TARE OF CONTAINER	14.6
WT OF WATER	9.8
WT OF DRY SOIL (Wo)	44.4
WATER CONTENT (W) %	22.1



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ATTERBERG LIMITS

CLIENT:	Associated Engineering	PROJECT #:	RD109
PROJECT:	Bowden Institute	DATE SAMPLED:	12-Sep-12
BOREHOLE #:	BH12-07	SAMPLED BY:	RM
SAMPLE #:	7-4	DATE TESTED:	6-Nov-12
DEPTH (m):	3	TESTED BY:	JW

LIQIUD

TRIAL N0.	1	2
NO. OF BLOWS	23	24
CONTAINER NO.	13	11
WT OF WET SAMPLE + TARE	14.0	13.6
WT OF DRY SAMPLE + TARE	11.2	10.9
TARE OF CONTAINER	1.3	1.3
WT OF WATER	2.8	2.7
WT OF DRY SOIL	9.9	9.6
WATER CONTENT %	28.23	27.80
CORR'D WATER CONTENT %	27.9	27.7

BLOW FACTORS

NUMBER	ASTM	ALB.
20	0.974	0.9753
21	0.979	0.9807
22	0.985	0.9858
23	0.990	0.9907
24	0.995	0.9954
25	1.000	1.0000
26	1.005	1.0044
27	1.009	1.0087
28	1.014	1.0128
29	1.018	1.0168
30	1.022	1.0206

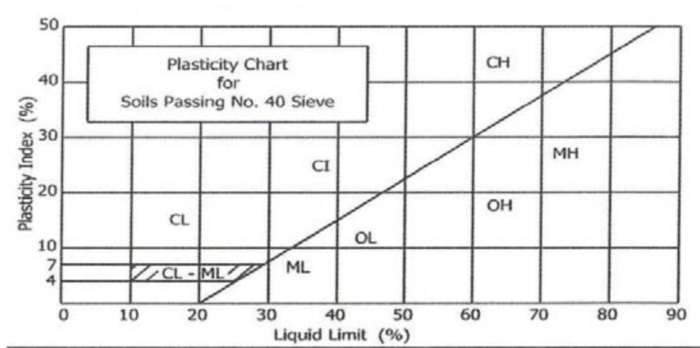
PLASTIC

TRIAL N0.	1	2
CONTAINER NO.	1	8
WT OF WET SAMPLE + TARE	6.7	5.9
WT OF DRY SAMPLE + TARE	5.9	5.2
TARE OF CONTAINER	1.3	1.3
WT OF WATER	0.8	0.7
WT OF DRY SOIL	4.6	3.9
WATER CONTENT %	17.3	16.6

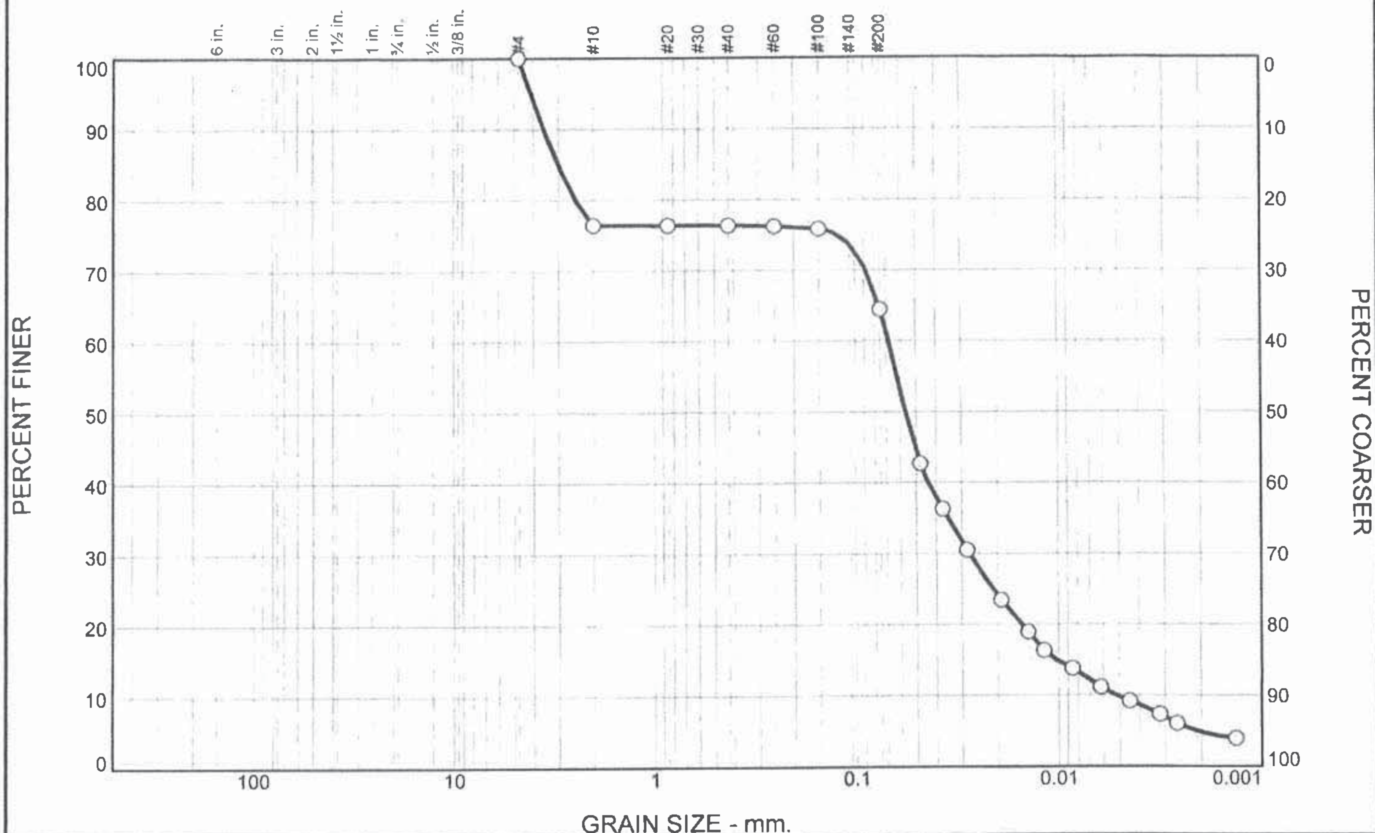
Liquid Limit	Plastic Limit	Plasticity Index
W_L	W_P	PI
27.8	17.0	10.8

NATURAL WATER CONTENT

TRIAL NO.	1
CONTAINER NO.	47
WT OF WET SAMPLE + TARE	66
WT OF DRY SAMPLE + TARE	54.4
TARE OF CONTAINER	13.8
WT OF WATER	11.6
WT OF DRY SOIL (Wo)	40.6
WATER CONTENT (W) %	28.6



Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	23.5	0.1	11.9	54.7	9.8

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	76.5		
#20	76.4		
#40	76.4		
#60	76.2		
#100	75.9		
#200	64.5		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.9942 D_{60}= 0.0682 D_{50}= 0.0564
D_{30}= 0.0275 D_{15}= 0.0103 D_{10}= 0.0052
C_u= 13.19 C_c= 2.15

Classification

USCS= AASHTO=

Remarks

Sample Number: 2-5 **Depth:** 3.8M
Location: BH12-2

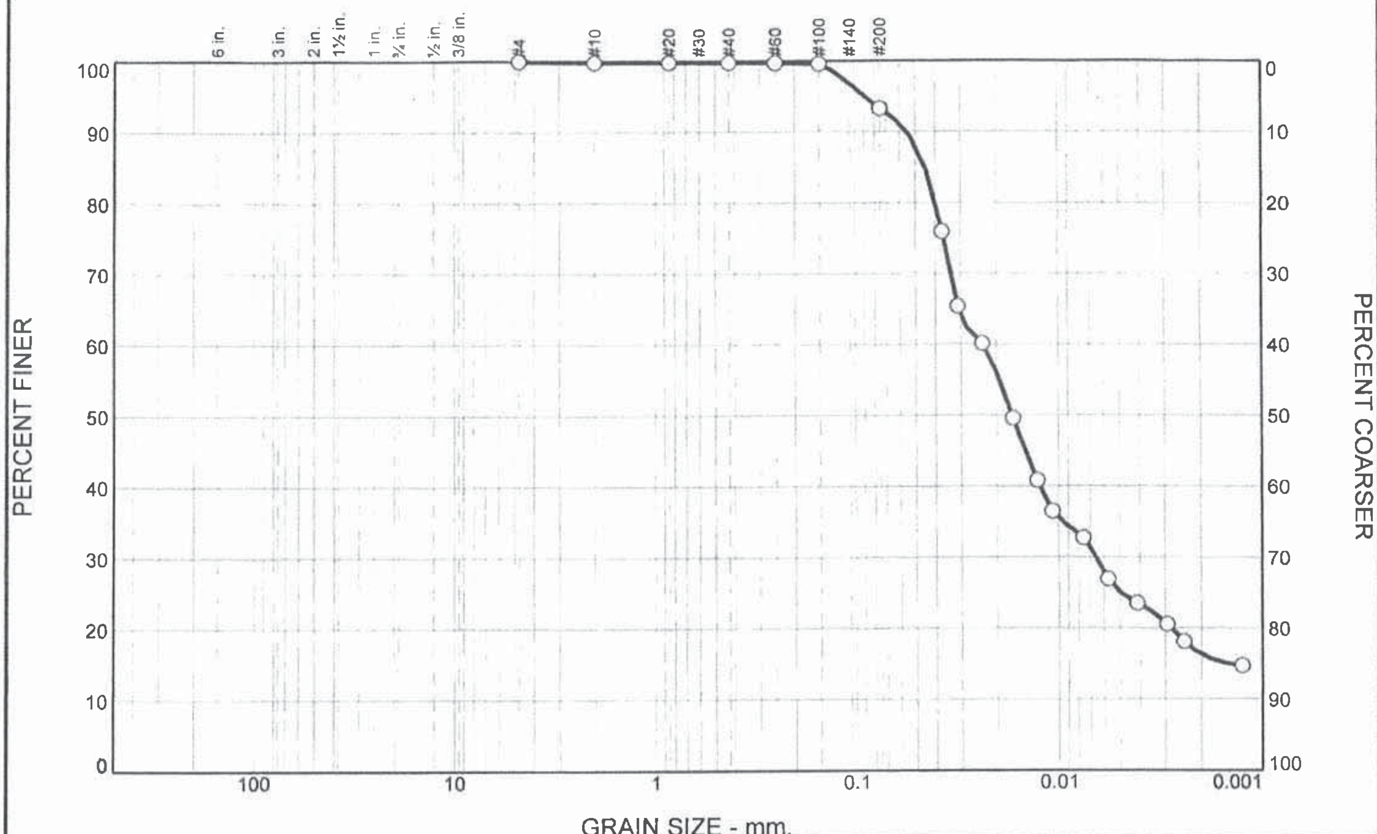
Date: NOV 6TH

Northern Geo Testing & Engineering, Ltd.
Fort St. John, BC

Client: ASSOCIATED ENGINEERING
Project: BOWOEN INSTITUTE
Project No: RD109 **Figure**

Tested By: J.A.W

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.2	0.1	6.4	68.3	25.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.8		
#20	99.8		
#40	99.7		
#60	99.7		
#100	99.6		
#200	93.3		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.0449 D_{60}= 0.0233 D_{50}= 0.0168
D_{30}= 0.0066 D_{15}= 0.0014 D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample Number: 7-4 **Depth:** 3.0M
Location: BH12-7

Date: Nov 13, 2012

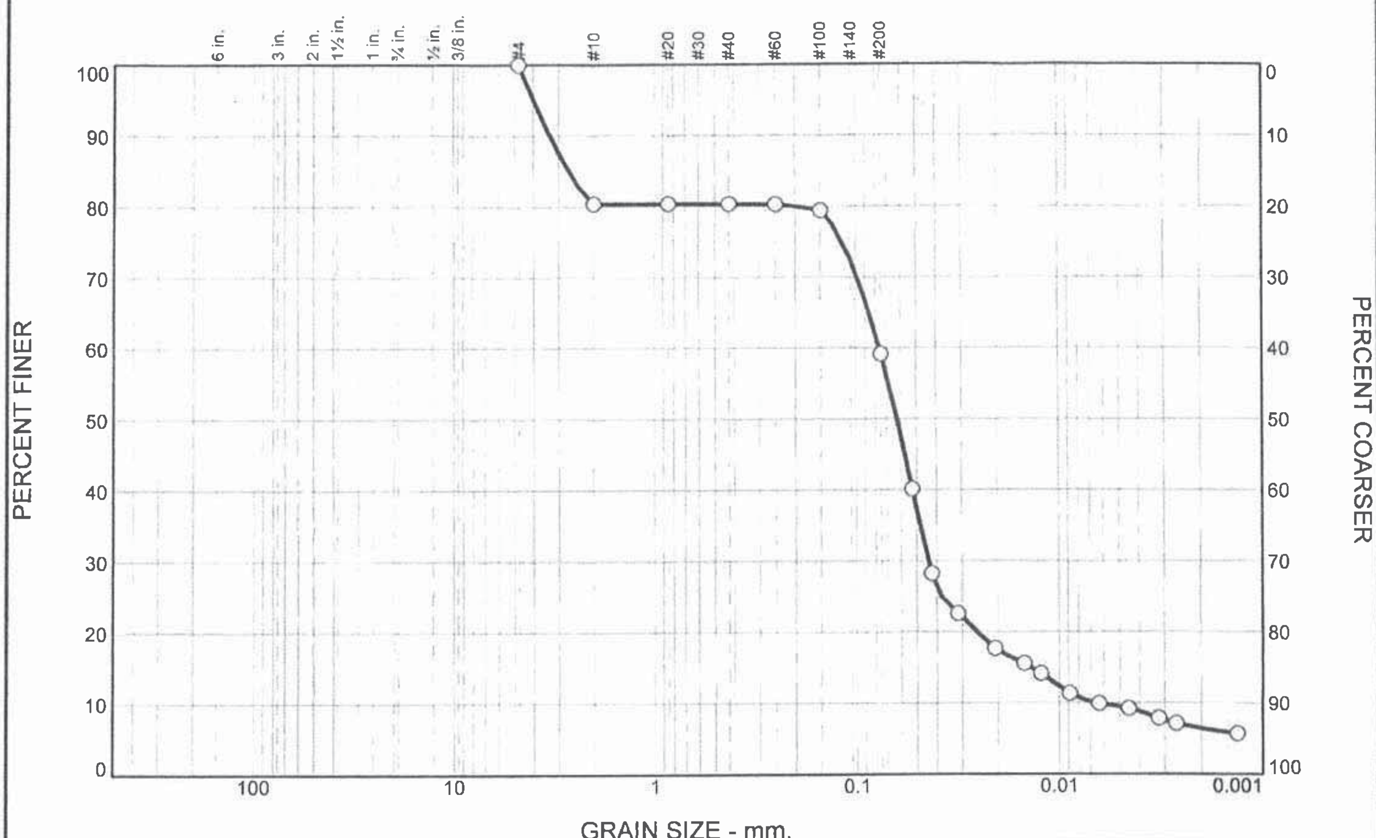
Northern Geo Testing & Engineering, Ltd.

Fort St. John, BC

Client: ASSOCIATED ENGINEERING
Project: BOWOEN INSTITUTE
Project No: RD109 **Figure**

Tested By: JAW **Checked By:** RM

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	19.6	0.0	21.3	49.6	9.5

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	80.4		
#20	80.4		
#40	80.4		
#60	80.3		
#100	79.4		
#200	59.1		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.6763 D_{60}= 0.0764 D_{50}= 0.0625
D_{30}= 0.0441 D_{15}= 0.0137 D_{10}= 0.0065
C_u= 11.70 C_c= 3.90

Classification

USCS= AASHTO=

Remarks

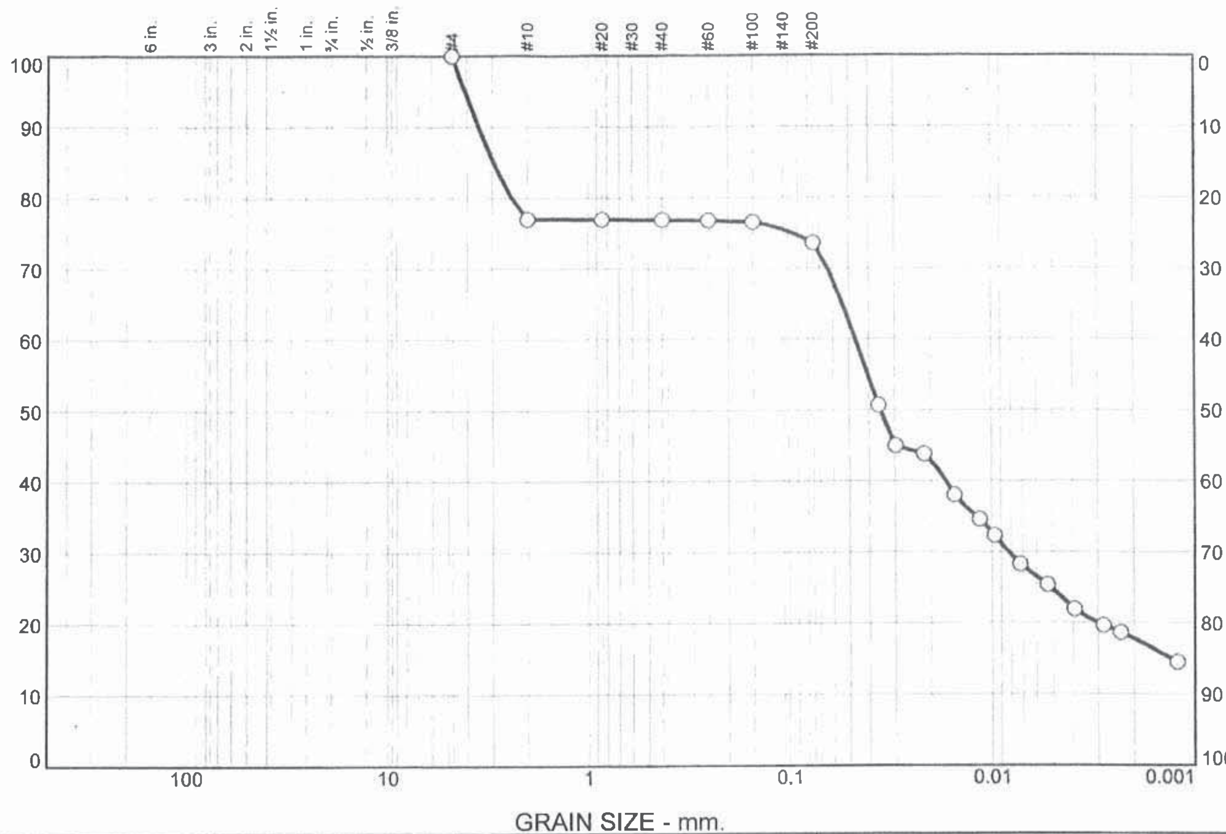
Sample Number: 3-5 **Depth:** 3.8M
Location: BH12-3

Date: NOV 07TH

Northern Geo Testing & Engineering, Ltd.	**Client:** ASSOCIATED ENGINEERING
	Project: BOWDEN INSTITUTE
Fort St. John, BC	**Project No:** RD109 **Figure**

Tested By: J.A.W

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	23.0	0.1	3.3	48.9	24.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	77.0		
#20	76.9		
#40	76.9		
#60	76.7		
#100	76.6		
#200	73.6		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.9585 D_{60}= 0.0464 D_{50}= 0.0354
D_{30}= 0.0083 D_{15}= 0.0013 D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample Number: 4-5 **Depth:** 3.8M
Location: BH12-4

Date: nov 7th 2012

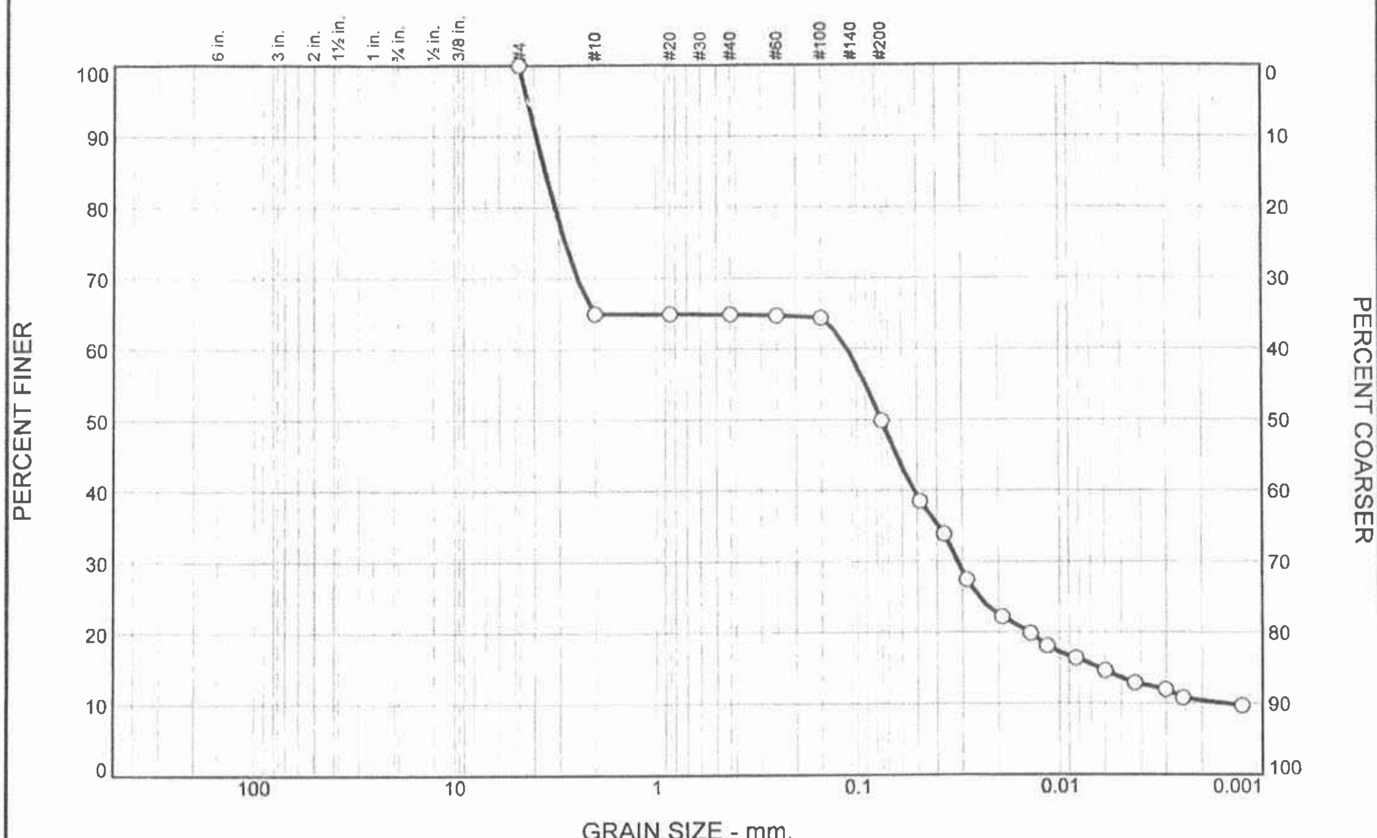
Northern Geo Testing & Engineering, Ltd.

Fort St. John, BC

Client: ASSOCIATED ENGINEERING
Project: BOWDEN INSTITUTE
Project No: RD109 **Figure**

Tested By: J.A.W

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	35.0	0.1	15.0	36.3	13.6

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	65.0		
#20	64.9		
#40	64.9		
#60	64.7		
#100	64.4		
#200	49.9		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.5220 D_{60}= 0.1117 D_{50}= 0.0753
D_{30}= 0.0316 D_{15}= 0.0064 D_{10}= 0.0015
C_u= 73.69 C_c= 5.90

Classification

USCS= AASHTO=

Remarks

Sample Number: 5-5 **Depth:** 3.8M
Location: BH12-5

Date: NOV 7TH

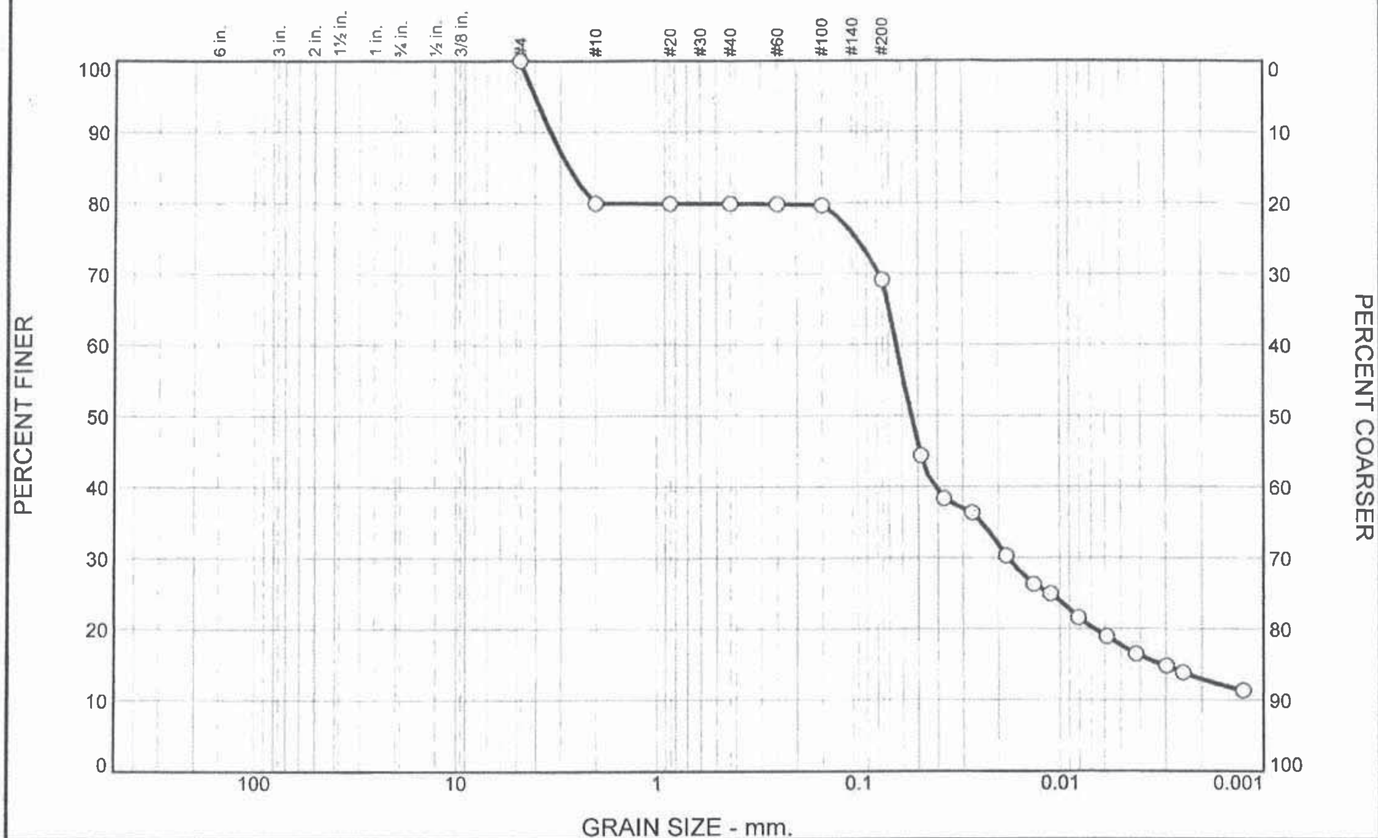
Northern Geo Testing & Engineering, Ltd.

Fort St. John, BC

Client: ASSOCIATED ENGINEERING
Project: BOWDEN INSTITUTE
Project No: RD109 **Figure**

Tested By: J.A.W

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	20.1	0.0	10.8	51.4	17.7

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	79.9		
#20	79.9		
#40	79.9		
#60	79.8		
#100	79.6		
#200	69.1		

* (no specification provided)

Material Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.7183 D_{60}= 0.0639 D_{50}= 0.0542
D_{30}= 0.0180 D_{15}= 0.0031 D_{10}=
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample Number: 6-2 **Depth:** 2.0M
Location: BH12-6

Date: NOV 7TH

Northern Geo Testing & Engineering, Ltd.

Fort St. John, BC

Client: ASSOCIATED ENGINEERING
Project: BOWDEN INSTITUTE
Project No: RD109 **Figure**

Tested By: J.A.W

APPENDIX D: MODEL ANALYSIS

MODEL OBJECTIVES

As part of the project requirements, we have prepared a coupled seepage/slope analysis to determine the general conditions of ground water flow and slope stability. The purpose of this model is to assess conceptual feasibility of the dyke design given the conceptual design parameters specified by Associated Engineering, the results of the geotechnical investigation, and sound engineering judgement on model function and material parameters. The results of model have been incorporated in recommendations given in the report, and will be discussed later in this appendix.

ANALYSIS TYPE

We have selected the use of GeoStudio 2012 for the purpose of couple seepage/slope stability modelling on this project. GeoStudio provides the needed analysis types for the proposed Bowden Dyke expansion with a reasonable level of model complexity. The two software components used in this model were SEEP/W and SLOPE/W.

SEEP/W is a finite element soil seepage modeling software that utilizes various soil behaviour theories in conjunction with finite stepping and direct equation solving to determine the characteristics of pressure distribution and flow characteristics.

SLOPE/W is a limit equilibrium modeling software that utilizes various soil behaviour models in conjunction with statics physics to determine the characteristics of force equilibrium within the limits of a defined failure mode. Broadly speaking, a limit equilibrium model contains three primary components:

Broadly speaking, a finite element/limit equilibrium model contains three primary components:

1. Selection of a numerical domain (including the selection of geometry, discretized mesh, and analysis type);
2. Selection of material properties (including the selection of material models and material model parameters); and,
3. Selection of the appropriate boundary conditions (including selection of boundary model type, boundary model parameters, and slip surface selection algorithm).

The model for this project was constructed using the iterative complexity approach. In this approach, a model is initially simplified to its most critical parameters and conditions to assess overall design feasibility. If the model successfully meets the suitable parameters of performance in its simplest and most critical form, the preliminary design is "passed" with on the condition that final design parameters should be checked in the model when they are known. If the model fails to meet suitable parameters of performance in its simplest and most critical form, detail is added to the model to more accurately determine the sensitive parameters of performance. After sensitive parameters of performance have been identified, the model can be adjusted to assess design options to mitigate failure potential and to improve design performance. This is the most appropriate approach to feasibility studies or preliminary designs, where the final design form including geometry, materials, and operations methods have not yet been finalized.

MODEL GEOMETRY

One model geometry has been assembled to assess the stability of the critical conditions of the preliminary designs. The Associated Engineering Preliminary Design Report indicates that the highest dyke conditions and head conditions will be found in storage cells, with effluent storage volumes up to 3 m deep. The perimeter dykes surrounding these ponds will be constructed with a critical freeboard depth of 1 m. The perimeter dykes shall be modeled using theoretical “imported sand” or other suitable dyke construction material. The pond liner system will be modeled as a 1.0 m thick compacted clay liner, as this liner configuration will provide the most critical conditions for slope stability (admix or manufactured clay liners tend to be more stable than most compacted clay liners). These dykes will be underlain on a series of stratified sand and till deposits as described in the body of this report (simplified to “clay” underlain by “sandy silt” in the model). Groundwater is modeled by a single phreatic surface modeled at approximately 3.5 m below ground surface. The ponded water is modeled using a boundary condition, described later in this report.

MATERIAL MODELS

The SEEP/W model was created using unsaturated/saturated material models. These models combine convention Darcy Flow Theory with Matric Suction Theory to produce a model that accurately predicts flow conditions. The material parameters for this model include the selection of: saturated hydraulic conductivity, saturated hydraulic variance factor, soil moisture characteristic curve, and hydraulic conductivity function. For the purpose of model and assessment simplicity, the latter two of the above variables were modeled using saturated hydraulic conductivity values and standard selection curves provided by the software.
The following table summarizes the material property values for the SEEP/W model:

Material Type	Saturated	Saturated	Soil Moisture	Hydraulic

	Hydraulic Conductivity	Hydraulic Variance	Characteristic Curve	Conductivity Curve
Imp. Sand	1e-5 m/s	1	Sand Till	Sand Till
Sandy Silt	1e-5 m/s	1	Sand Till	Sand Till
Clay	1e-6 m/s	1	Clay	Clay
CCL	1e-9 m/s	1	CCL	CCL

The SLOPE/W model was created using a simple Mohr/Coulomb material model type. This material model is suitable for most analyses where more complex material values have not been determined through field or laboratory analysis. Unfortunately, due to issues in collecting Shelby Tube samples during the geotechnical assessment, undrained strength values were not available for the use in this model. The material properties selected for a standard Mohr/Coulomb material model include: undrained material unit weight, undrained material cohesion, and undrained material internal angle of friction. No matric suction angle of friction was added to the analysis type for the sake of model simplicity.

The following table summarizes the material property values for the SLOPE/W model:

Material Type	Undrained Material Unit Weight	Undrained Cohesion	Undrained Internal Angle of Friction
Imp. Sand	21.0 kN/m^3	0 kPa	32°
Sandy Silt	19.5 kN/m^3	10 kPa	30°
Clay	18.0 kN/m^3	50 kPa	25°
CCL	18.0 kN/m^3	50 kPa	25°

BOUNDARY CONDITIONS

The SEEP/W model contained several boundary conditions to induce rational model performance. The effluent within the pond was modeled using a static head boundary condition of 11.5 m (3.0 m above pond bottom) to characterise static head and flow conditions through the pond. The phreatic surface for the underlying stratified deposits was modeled using a static head condition of 0 m. This was not modeled using a standard phreatic surface as it was not desired to allow a mobile phreatic for long-term analysis affects (it is not expected that the treatment plant will mobilize enough flow to dramatically increase the height of the existing phreatic surface). The downstream face of the dyke and toe run-out was bounded by a potential seepage face to allow for outward seepage to surface, where applicable.

The SLOPE/W model was conducted using the grid and radius method to select potential failure planes for analysis. The locations of the grid and radius planes were selected using an iterative method – searching for critical failure surfaces and optimizing the model to remove unreasonable failure surfaces. The phreatic surface for the SLOPE/W model was selected using the results from the SEEP/W analysis. Hydraulic stress was added for the fully filled condition and removed for the empty condition.

ANALYSIS RESULTS

The results of the analysis for the combined analysis models indicate that there are two potential critical modes of failure:

1. Rotational failure of the interior slope during emptied conditions; and,
2. Slip failure of the exterior slope during fully filled conditions.

Transient analysis was performed to identify the likelihood of rapid draw down conditions developing and causing failure of the interior slope. If the dyke is constructed using materials similar to this model, and/or if the dyke is constructed using admix or manufactured liner techniques, there is a very low probability of failure due to rapid draw down conditions. *However, it should be noted that rapid draw down conditions may cause unfavorable failures of the liner itself, and should be avoided at all times.*

The computed factor of safety against rotational failure of the interior slope during emptied conditions is approximately 2.5. This rotational failure is most likely to occur at moderate depths in the dyke itself, with a small slip surface developing at the dyke/foundation interface. Sensitivity inquiry of key variables in the slope stability analysis yield small changes to end-product factor of safety for this condition. This factor of safety is considered acceptable for construction, given the constraints discussed in this document.

The computed factor of safety against slip failure of the interior slope during emptied conditions is approximately 3.0. The slip failure is most likely to occur at shallow depths in the dyke itself, with a small slip surface developing at the dyke/foundation interface. Sensitivity inquiry of key variables in the slope stability analysis yield small changes to end-product factor of safety for this condition. This factor of safety is considered acceptable for construction, given the constraints discussed in this document.

LIMITATIONS OF INTERPRETATION

The results of the geotechnical modeling described in this document can be considered conservative by typical engineering standard. However, modeling is only a small part of the overall engineering judgement required for design and construction of any structure. The analysis and recommendations provided in this document should be combined with industry standard analysis and quality assurance during design and construction to ensure that the structure is constructed properly and safely. Should there be any major deviations to the components discussed in this document, Midland should be provided the opportunity to evaluate these changes in terms of their effect on the performance of the design.