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Highfield Dam Embankment Foundation Assessment

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REPORT

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Golder Associates

Executive Summary

This report presents the results of the Foundation Assessment for Highfield Dam by Golder Associates Ltd. for Agriculture and Agri-Food Canada, Agri-Environmental Services Branch. The geotechnical engineering study report documents the field investigation, laboratory analysis, and geotechnical evaluation in support of the consideration of embankment consolidation settlement and embankment constructability issues on the soft alluvial soils and clay shale foundation.

Recent pre-design studies in support of the Highfield Dam rehabilitation conducted by Agriculture and Agri-Food Canada have identified a number of deficiencies, including inadequate freeboard, inadequate capacity to safely handle the Inflow Design Flood, and embankment stability. The pre-design study specifically recommended further geotechnical assessment of the foundation of the embankment to deal with construction on soft alluvial foundation materials.

Based on the results of the field and laboratory investigations, new geotechnical parameters were determined for the alluvial soils under and at the toe of the dam. The parameters and design cross section information were input into Geostudio 2007 analysis software for five different construction sequences including existing conditions, one stage and multi-stage construction at 6H:1V and optimized slope angles.

The results of the seepage, stability and settlement analysis indicated that all design scenarios considered will meet the factor of safety criteria in the Canadian Dam Association Dam Safety Guidelines 2007. Based on cost, constructability, and reduction of impact to wetland habitat, Golder Associates Ltd. recommends a construction scenario similar to Option 5, with the following geometry:

- Construct dam embankment above an elevation of 720.4 masl at a 3.5H:1V slope;
- Construct dam embankment below an elevation of 720.4 masl at a 5H:1V slope;
- Berm width of 5 m at elevation 720.4 masl;
- Base of berm extending approximately 21.8 m from the existing toe;
- Construction a granular blanket drain with minimum thickness of 1.2 m under the new fill; and,
- Construct the raise in two stages with the first being the berm construction and the second the dam raise.

Placement of a granular blanket drain at the toe of the dam and extending downstream for the full width of the new fill is recommended to improve seepage control and pore water pressure dissipation in the dam. Placing additional fill material on the dam to account for potential settlement should be considered for all construction scenarios. The vibrating wire piezometers installed at the dam can be used to monitor the rate of pore water pressure dissipation in order to assess the slope stability during construction.

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1.0 INTRODUCTION

This report presents the results of the Foundation Assessment for Highfield Dam by Golder Associates Ltd. (Golder) for Agriculture and Agri-Food Canada (AAFC), Agri-Environmental Services Branch (AESB). The report includes an evaluation of the consolidation and compressibility parameters of the alluvial foundation materials and identifies key geotechnical design considerations for the construction of the remedial embankment works.

Recent pre-design studies in support of the Highfield Dam rehabilitation conducted by AAFC have identified a number of deficiencies, including inadequate freeboard, inadequate capacity to safely handle the Inflow Design Flood, and embankment stability. The pre-design study specifically recommended further geotechnical assessment of the foundation of the embankment to deal with construction on soft alluvial foundation materials.

This geotechnical engineering study report documents the field investigation, laboratory analysis, and geotechnical evaluation in support of the consideration of embankment consolidation, settlement and embankment constructability issues on the soft alluvial soils and clay shale foundation.

Detailed stability analyses for the proposed embankment raise have been conducted and documented in a December 2011 report prepared by Northwest Hydraulic Consultants (NHC) and MDH Engineered Solutions (MDH), and are therefore not a requirement for this Embankment Foundation Assessment. Implications of the revised consequence rating from “High” to “Significant” in the November 2011 Dam Classification and Hydro Technical study by Golder Associates have been considered in determination of design criteria for this analysis.

This report should be read in conjunction with the “Information and Limitations of the Report”, included in Appendix A. The reader is specifically directed to this information as it is essential for the proper interpretation and usage of this report.

2.0 INVESTIGATIVE PROCEDURES

2.1 Background

Highfield Dam is owned and operated by AAFC. It is situated in Rushlake Creek, approximately 28 kilometres (km) east of the City of Swift Current in Saskatchewan. The dam is located in Sec 36 Twp 15 Rge 11 W3M. The dam is approximately 10 metres (m) high and has a crest length of 1040 m at the existing top-of-dam elevation of 724.8 m above sea level (masl). The Highfield Dam was originally constructed by the Prairie Farm Rehabilitation Administration (PFRA) in 1941 to 1942, with additional raises until 1950. The planned rehabilitation activities for Highfield Dam relevant to the Embankment Foundation Assessment include: raising the top-of-dam crest elevation to 725.7 masl to address the lack of normal freeboard above the FSL of 722.99 masl; and improving the embankment Factor of Safety to meet Canadian Dam Association (CDA) Dam Safety Guidelines by constructing a raised embankment with a downstream slope flattened to 6H:1V.

Based on information provided by AAFC and from Golder’s site reconnaissance, the downstream area of the Highfield Dam features shallow braided channels together with a number of oxbows overlaying the floodplain. Within this topography, the site presents channels of soft soils (waterlogged with brush and aquatic vegetation) and large areas of soft soils (heavy vegetation suited to soils that are frequently saturated) at lower elevations as well as large areas of raised firmer ground. Drilling investigation programs conducted by AAFC in 2009 and MDH in 2011 identified the subsoil conditions in the downstream area to consist of 2.5 to 11 m of soft alluvial deposits consisting of alluvial silts, sands and clays. High groundwater conditions were identified during the drilling program including flowing borehole conditions at completion of one of the boreholes. In the valley bottom

the previous drilling programs have identified that the alluvial deposits are underlain by clay shale. It is reported that the upper portion of the clay shale to some undetermined depth was reworked and exhibited breccias, fractures, disturbed laminations, slickensides and also glacial till and unoxidized clay shale inclusions within oxidized clay shale.

2.2 Document Review

The documents shown in Table 1 were provided by AAFC and were reviewed and used by Golder for development of this assessment.

Table 1: Document Review

Document Name	Type	Date	Author
Highfield Dam Geotechnical Pre-design Report Draft	Report	2011	C. Hill, AESB
Highfield Reservoir Existing Topography and Drill Hole Locations, 208524	Drawing	Jul. 28, 2011	G. Haack, C. Hill, AESB
Phase 1 Dam Safety Evaluation Report Highfield Dam	Report	Apr., 1989	PFRA
2011_09_27Highfield_PIEZ Report	Spreadsheet	Sept. 27, 2011	AESB
Swift Current Irrigation Project General Plan for Highfield Reservoir, 1085-C-1	Drawing	Apr., 1943	PFRA
Swift Current Irrigation Project Highfield Reservoir Outlet Duct & Outlet Control Structures, 26722	Drawing	Apr., 1943	PFRA
Highfield Dam Reservoir Topography West ½ Sec. 31-15-10W3 & Sec.36-15-11W3 and Flooded Area and Capacity Curves, 92907	Drawing	Aug., 1973	PFRA
Highfield Dam Location Plan, Profile and East and West Outlet Cross-Sections, 102819A	Drawings	Feb. 5, 1987	PFRA
AAFC/AESB Highfield Dam Service Contract No.3 Spillway Pre-Design Completion, 35525	Report	Dec. 19, 2011	Northwest Hydraulic Consultants & MDH Engineered Solutions
Highfield Dam – Dam Classification and Hydro Technical Study	Report	Nov. 2011	Golder Associates Ltd.
Saskatchewan Watershed Authority Dams Seismic Hazard Assessment Report	Report	Nov. 2009	Klohn Crippen Berger Ltd.

Golder and AAFC personnel conducted a site visit to observe existing conditions and determine access for the field investigation after the project kick-off meeting on September 9, 2011.

2.3 Site Investigation

The subsurface conditions at the downstream end of Highfield Dam were investigated between October 3 and 6, 2011 using a track mounted Acker MP5 auger mounted on a 1500 Morooka drill rig operated by Paddock Drilling Ltd. of Saskatoon, SK. A representative of Golder was on site during the investigation to record the soil stratigraphy and drilling conditions, and to collect soil samples from the boreholes drilled.

The field program consisted of drilling ten (10) boreholes to depths ranging between 3.7 and 10.7 m below ground surface (mbgs). Grab samples, Shelby Tube samples, and Standard Penetration Test samples were collected from each borehole and returned to Golder's Saskatoon Laboratory. Vibrating wire piezometers

(VWPs) were installed in four of the boreholes drilled and were covered with a locking steel casing. In addition, four Cone Penetration Tests (CPT) were conducted to depths ranging between 6.0 and 10.9 mbgs. The positions of the boreholes and CPT probes were located in the field using a handheld global positioning device as shown on Figure 1.

Disturbed samples were collected from the auger flights and the split spoon sampling tube at the intervals noted on the Record of Borehole sheets included in Appendix B. Standard penetration tests were performed at 1.5 m intervals to help evaluate the strength and consistency of the soils at depth. Shelby tube samples were collected to provide relatively undisturbed samples for further testing. The boreholes were backfilled with cuttings and bentonite chips to ground surface upon the completion of drilling.

A field log was prepared for the boreholes to record the description and relative position of the soil strata and the location of samples, in addition to other drilling notes. Samples recovered during the field investigation were returned to Golder's Saskatoon laboratory for further testing and analysis. Readings from the piezometers were obtained from a subsequent site visit on November 18, 2011.

Four 0.7 megaPascal (MPa) VWP's and dataloggers from RST Instruments were installed in boreholes AA-11-01V, 04V, 07V and 11V to depths of 5.0 m, 3.7 m, 8.8 m, and 2.7 m, respectively. The piezometers were mounted at the base of a 25 millimetres (mm) (1 inch [”]) diameter PVC pipe for installation and the borehole was backfilled by pumping a bentonite-cement grout mix through the pipe to ground surface. A lockable, protective cover was placed over each VWP to protect the cable and datalogger. Approximately 30 m of cable was provided for each VWP in order to accommodate future dam raises. Calibration records are provided in Appendix E.

Golder submitted an Aquatic Habitat Protection Permit Application to the Saskatchewan Ministry of Environment prior to beginning the field investigation, but did not receive approval in advance of drilling. As such, the boreholes were placed outside of wetland areas and the drill rig was manoeuvred to avoid tracking through areas where wetland habitat was identified. Best management practices identified in the permit application were implemented during the drilling operations.

Borehole AA-11-12V was not drilled due to the presence of water at that location.

2.4 Laboratory Testing

Testing was completed on selected samples to assess the geotechnical parameters of the soil at the site. Results of laboratory testing are included in Appendix D.

Moisture content tests were performed on all samples to evaluate the consistency of the soil both in depth, and to provide a moisture content profile at the borehole locations. Atterberg limit tests were performed to determine the plasticity characteristics of the selected cohesive soil samples. For the alluvial soils, the average Liquid Limit was 39 (±10), Plastic Limit was 25 (±9) and moisture content was 30.2 percent (%) (± 3.5%). For the shale, the average Liquid Limit was 57 (± 7), Plastic Limit was 36 (± 7) and moisture content was 32.0% (± 4.6%). Grain size analysis was completed using both the mechanical and hydrometer method. The shale samples had a high sand content, with 25% to 51% of the particles larger than the No. 200 sieve (0.075 mm).

Dry density, unconfined compression and consolidation tests were also completed on selected relatively undisturbed samples, the results of which are shown in Tables 2 and 3.

Table 2: Unconfined Compressive Strength and Dry Density Test Results

Borehole and Sample Number	Depth (mbgs)	Soil Description	Water Content (%)	Compressive Stress at Failure (kPa)	Dry Density (kg/m^3)
AA-11-03 SA 03	1.52	Cl, firm,Silty Clay, some fine sand	22.6	85.4	1,572
AA-11-08 SA 09	7.62	Cl, firm sandy Silty Clay	33.3	60.9	1,477
AA-11-09 SA 03	4.57	Cl, soft, sandy Silty Clay	28.1	76.1	-
AA-11-11 SA 07	4.57	Cl, soft, Silty Clay with fine Sand	29.9	41.7	1,396
AA-11-15 SA 03	1.52	SC-CH, firm, Clay with Fine Sand (Shale)	20.4	74.4	-

mbgs = metres below ground surface; kPa = kiloPascal; kg/m^3 = kilograms per cubic metre; % = percent

Table 3: Summary of Consolidation Test Results

Borehole and Sample Number	Depth (mbgs)	Soil Description	Initial Void Ratio, e_o	Compression Index, C_c	Re-Compression Index, C_r
AA-11-03 SA 03	1.52	Cl, firm, Silty Clay, some fine sand	1.05	0.31	0.05
AA-11-07V SA 03	1.52	Cl, wet, soft, sandy Silty Clay	0.93	0.22	0.03
AA-11-09 SA 03	4.57	Cl, soft, sandy Silty Clay	0.92	0.25	0.01

mbgs = metres below ground surface; e_o = initial void ratio; C_c = compression index; C_r = recompression index

Shelby tube samples of the alluvial soil were sent to Golder's Mississauga Laboratory to complete a consolidated undrained triaxial compression test with pore pressure measurements at effective stresses of 50 kiloPascals (kPa), 150 kPa and 300 kPa. Based on the Mohr circles generated from these tests, a cohesion value of 0 kPa and an internal friction angle of 28° were determined for the alluvial soils. The plot showing the determination of the friction angle is included in Appendix C.

3.0 ALLUVIAL FOUNDATION CHARACTERIZATION

3.1 Subsurface Conditions

3.1.1 Regional Geology

Highfield Dam is located in the Rushlake Creek alluvial floodplain, which is characterized by surficial stratified deposits of sand, silt and clay overlying the eroded glacial till plain. In the vicinity of the reservoir the till and stratified drift, also known as the Saskatoon Group, is generally less than 10 m in thickness and is underlain by the Bearpaw Formation (Maathuis, 2007). The Bearpaw formation is generally characterized by soft, gray non-calcareous marine silt and clay materials which are commonly known as shale.

3.1.2 Stratigraphy

The subsurface conditions observed during drilling are summarized on the Record of Borehole Sheets included in Appendix B. It is noted that the subsurface conditions are inferred at the borehole location only and may vary beyond the location of the borehole. Cone penetration testing results were used to confirm the observations made during drilling of the boreholes.

The general soil profile encountered at the downstream toe of the dam in the boreholes consisted of, in descending order, topsoil, alluvial soils, and clay shale. Borehole AA-11-01V varied from the typical soil profile in that a layer of oxidized glacial clay till material was observed between the alluvial soils and the shale, which is

consistent with borehole BH 32 drilled by the PFRA. The till contact at that location was marked by a wet gravel seam. Photographs of samples taken from Boreholes AA-11-01V, AA-11-03, and AA-11-07V are provided in Appendix G showing the soil profile with depth.

The alluvial soils consisted of poorly sorted silty sands, sandy silty clays and silty clays. Except for a layer of silty clay near ground surface which ranged in depth from 0.3 to 1.5 mbgs, no other distinct or continuous layers were noted in the alluvium in the boreholes drilled. The topsoil thickness observed was generally less than 50 mm at the borehole locations.

The depth to the shale contact increased from the dam abutments to the centre of the dam, with a maximum observed depth of 9.8 mbgs in Borehole AA-11-09. The shale was observed at a depth of 0.6 mbgs in Borehole AA-11-15 and at a depth of 9.1 mbgs in Borehole AA-11-07V. At the shale contact, the clay material had a high plasticity, but also a high sand content.

No rocks were noted in the boreholes during the drilling investigation.

3.1.3 Groundwater

The ground at the base of the dam was observed to be damp and soft with numerous wetland areas. Previous geotechnical investigations have indicated a potential for flowing conditions in boreholes drilled at the site.

Flowing artesian conditions were observed in two of the boreholes drilled, AA-11-03 and AA-11-10. The water level above ground surface at the time of drilling was less than 0.13 m in both boreholes. In order to plug the boreholes, cuttings and bentonite chips were back spun in the boreholes. Sloughing was noted in most of the boreholes drilled. It should be noted that flowing conditions may take longer to develop in boreholes founded in clay as opposed to those founded in sand due to the low hydraulic conductivity of the clays. Generally, the presence of topsoil and vegetation at the ground surface will inhibit flow above ground surface. It is expected that the wetlands in the area are partially fed by groundwater flow.

Golder returned to the site on November 18, 2011 to take readings from the VWP's installed during the field investigation. The Model DT2011 Vibrating Wire Loggers were programmed to take pore water pressure readings at 12 hour intervals. A summary of the readings for each VWP are shown in Table 4, along with the calculated pressure head.

Table 4: Vibrating Wire Piezometer Readings from November 18, 2011

VWP Number	Estimated Ground Surface Elevation (masl)	Approximate Elevation of VWP (masl)	Pore Water Pressure (kPa)	Calculated Pressure Head (masl)
AA-11-01V	717.2	712.17	45.9	716.8
AA-11-04V	717.9	714.24	30.7	717.4
AA-11-07V	717.9	709.06	105.0	719.8
AA-11-11V	717.6	714.86	20.7	717.0

masl = metres above sea level; kPa = kiloPascal; m = metre

Ground surface elevations at the VWP locations were estimated from the topographic contour plan provided by AAFC. Pressure heads above ground surface indicate that given a pathway to ground surface, the groundwater

would attempt to reach that elevation given enough time. Spouting of groundwater is not expected at this location.

3.2 Design Parameters

3.2.1 Geotechnical Parameters

The geotechnical parameters provided in Table 5 are based on the results of the field and laboratory investigations conducted by Golder.

Table 5: Geotechnical Parameters

Parameter	MDH Alluvium	Golder Alluvium
Coefficient of consolidation, c_v	Not provided	$4.3x10^{-3}$ to $1.8 x10^{-3}$ cm^2/s
Coefficient of permeability (hydraulic conductivity), k	$1x10^{-6}$ m/s	$1.3x10^{-7}$ m/s
Coefficient of compressibility, m_v	Not provided	$4.7x10^{-5}$ / kPa
Pore pressure generation parameter, A	Not provided	0.90
Pore pressure generation parameter, B	Not provided	0.98
Mohr-Coulomb effective stress shear strength parameter, c'	0 kPa	0 kPa
Mohr-Coulomb effective stress shear strength parameter, Φ'	20°	28°
Saturated Unit Weight, γ	20 kN/m^3	19 kN/m^3

cm^2/s = square centimetre per second; m/s = metre per second; kPa = kiloPascal; kN/m^3 = kiloNewton per cubic metre

The values shown for c_v, k, and m_v in Table 5 were obtained from the consolidation test data, of which sample AA-11-07V SA 03 was assumed to be the most representative of the alluvial soil behaviour. The coefficient of compressibility is based on the rate change of void ratio over stress and the initial void ratio of the samples. While permeability can also be interpreted from the consolidation test data, the average permeability of the alluvial soils was determined from the CPT data, which was more conservative. Saturated unit weight of the alluvial soil was calculated from the dry density and water content test results. The remainder of the parameters shown in Table 5 were determined from the consolidated undrained triaxial test.

The additional parameters shown in Table 6 were used for development of a model for stability analysis of the proposed embankment foundation.

Table 6: Geotechnical Soil Parameters

Material	Unit Weight, γ (kN/m^3)	Hydraulic Conductivity, k (m/s)	Cohesion, c' (kPa)	Phi, ϕ (Degrees)
Granular Toe Drain	19	$1x10^{-4}$	0	35
Embankment Fill	21	$5x10^{-8}$	7	25
Embankment Fill (original)	21	$5x10^{-8}$	0	20
Oxidized Clay Shale (residual)	22	$1x10^{-9}$	2	10
Oxidized Clay Shale (normal)	22	$1x10^{-9}$	10	15
Unoxidized Clay Shale	Assumed to be impenetrable			

kN/m^3 = kiloNewton per cubic metre; m/s = metre per second; kPa = kiloPascal

Investigation of the existing embankment was outside of Golder's scope for this project, therefore the stability parameters for the dam fill and clay shale developed by MDH Engineered Solutions Corp. and AAFC were used for development of the model. The parameters previously assumed for the alluvial soils are more conservative than those determined by Golder during this investigation.

3.2.2 Design Cross Section

In addition to the geotechnical parameters previously described, the following physical parameters were used in the development of the construction model.

- Initial Conditions:
  - Crest Elevation = 724.0 masl (The existing dam elevation is stated at 724.8 masl, however the elevation at the chosen cross section was 724.0 masl based on the topographic plan provided to Golder).
  - Downstream Slope = 3.5H:1V
  - Upstream Slope = 3H:1V
  - Assumed Base of Fill = 717.2 masl
- Final Conditions:
  - Crest Elevation = 725.7 masl
  - Crest Width = 6 m
  - Downstream Slope = 6H:1V
  - Upstream Slope = 3H:1V
- Full Supply Level of the Reservoir = 722.99 masl

The design cross section selected was based on the greatest depth to shale contact at approximately the mid-point of the dam embankment. Proximity to previously and newly drilled borehole locations was also a factor in the selection of the design cross section. The cross section dimensions are based on the topographic plan provided by AAFC (Drawing Number 208524). Figure 2 shows the design cross section of the dam used for development of the construction model.

4.0 STAGED CONSTRUCTION MODELLING

The staged construction sequences of the downstream dam raise were modelled to examine the sensitivity of the foundation response to various staged configurations for the proposed dam raise. Options examined included:

- Option 1 – Existing conditions;
- Option 2 – Construct a 6H:1V downstream slope in three stages of stage increments of 2.3 m with granular blanket drain;
- Option 3 – Construct a 6H:1V downstream slope in one stage with granular blanket drain;

- Option 4 – Construct a 5H:1V slope and include a granular blanket drain; and
- Option 5 – Construct a 5 m wide berm with a 5H:1V downstream slope, with the upper 5.3 m of the raised dam having a slope of 3.5H:1V and include a granular blanket drain.

The goal of the modelling process was to identify a preferred construction sequence and downstream slope configuration that addressed the consolidation and settlement performance based on the prediction of pore water pressure generation, pore water pressure dissipation rates, and mobilized shear stresses in the alluvial foundation unit and the upper portion of the oxidized clay shale foundation. All sequences assumed that a granular blanket drain was installed at the toe of the existing dam under the new fill to dissipate pore water pressures generated by the new fill and to capture seepage that is currently occurring at the toe of the dam.

Analysis of pore water pressure dissipation and mobilized shear stresses was performed for the design cross section of the dam using the computer software SEEP/W and SIGMA/W, marketed by GEO-SLOPE International Ltd. (2007).

4.1 Seepage and Settlement

A linear elastic analysis of multi-staged and full stage construction was performed using GeoStudio 2007 SEEP/W and SIGMA/W finite element software, and slope stability analysis was performed using SLOPE/W. The computed stress and pore water pressure in the soils from the analysis were used to establish the rate of loading and estimate the short term factor of safety during construction. The numerical results of the analysis are included in Appendix F. Figures F.1 to F.25 show the modelled construction sequence, the geometry and boundary conditions, predicted pore-water pressures, estimated settlement, and estimated short term factor of safety immediately following construction for each construction sequence.

Assumptions made for the analysis include:

- initial steady state flow conditions;
- the alluvial soils were saturated prior to construction;
- initial stress conditions are defined by a linear elastic model;
- initial head conditions are generated from a two-dimensional steady state seepage analysis;
- Poisson's ratio is 0.33 for all materials; and
- Effective E Modulus (E') is 15 MPa for all materials except the granular drain, which has a modulus of 50 MPa.

For the stress/strain and hydraulic boundary conditions both horizontal and vertical displacements were fixed at the bottom boundary. Horizontal displacements were fixed at the left and right boundaries. A total head of 722.99 masl was added to the right (upstream) boundary for the reservoir, and a total head of 717.3 masl was added to the left (downstream) boundary, with the assumption that groundwater is at or near ground surface. The bottom boundary was assumed to be undrained.

Maximum deformation is predicted to occur at the toe of the existing dam, where the greatest fill height will be placed over the existing ground. Based on the geotechnical parameters determined for the alluvial soils, an estimate of settlement due to consolidation and the time to consolidate was calculated. Due to the variable soil

arrangement of the alluvial soils, actual settlement and consolidation may differ from the calculated values. No settlement of the fill or oxidized shale was considered. The settlements were calculated at the midpoint of the alluvial soil layer, with the following results:

- The estimated maximum settlement due to consolidation at the toe of the dam for Options 2 and 3 was 430 mm, with 1.29 years for the alluvial materials to reach 90% consolidation.
- The estimated maximum settlement due to consolidation at the centre of the dam for Options 2 and 3 was 130 mm, with 1.05 years for the alluvial materials to reach 90% consolidation.
- The estimated maximum settlement due to consolidation at the toe of the dam for Option 4 was 399 mm, with 1.36 years for the alluvial materials to reach 90% consolidation.
- The estimated maximum settlement due to consolidation at the centre of the dam for Option 4 was 115 mm, with 1.16 years for the alluvial materials to reach 90% consolidation.
- The estimated maximum settlement due to consolidation at the toe of the dam for Option 5 was 330 mm, with 1.32 years for the alluvial materials to reach 90% consolidation.
- The estimated maximum settlement due to consolidation at the centre of the dam for Option 5 was 115 mm, with 1.16 years for the alluvial materials to reach 90% consolidation.
- Settlement was also calculated with the SIGMA/W model as shown in Figures F.6, F.9, F.12, F.16, F.20, and F.24 in Appendix F. Settlements computed by the SIGMA/W models at the midpoint of the alluvial layer at the toe of the dam were approximately: 446 mm for Option 2, 431 mm for Option 3, 376 mm for Option 4, and 281 mm for Option 5 (staged). Settlements computed by the SIGMA/W models at the midpoint of the alluvial layer at the centre of the dam were approximately: 64 mm for Option 2, 76 mm for Option 3, 101 mm for Option 4, and 111 mm for Option 5 (staged).
- The time required for consolidation is primarily a function of the drainage path for pore-water pressure dissipation, and the soil hydraulic properties.

Pore water pressures in the SEEP/W model using a transient analysis initially peaked and then dissipated over time. Initial pore water conditions for each construction sequence are included in Figures F.2, F.5, F.8, F.11, F.15, F.19 and F.23 in Appendix F. The analysis suggests that construction should occur over a minimum 35 day period for Option 2, 20 day increments for Option 3 or in 30 day increments for the Options 4 and 5 in order to dissipate the pore water pressures to pre-construction levels and maintain the slope stability over the construction period.

4.2 Slope Stability

As per the Canadian Dam Association (CDA) 2007 Guidelines, a minimum factor of safety of 1.3 is required for satisfactory performance of upstream and downstream slope stability for the short-term condition immediately after construction, and a factor of safety of 1.5 is required for the downstream slope stability for the long-term condition where the reservoir level is at normal operating levels.

Stability analyses were performed for the design cross section of the dam using the computer software SLOPE/W. The analyses were performed using the Morgenstern-Price limit equilibrium method with the half-sine inter-slice force function. Analyses were performed to evaluate the slope stability conditions when the

reservoir level is at its full supply elevation at points prior to and after construction of the new dam slope. With time following the completion of the dam raise, the factor of safety increases because of the dissipation of construction induced pore water pressures in the foundation soils. The analyses included a staged construction approach to achieve a minimum short term factor of safety of 1.3. Even though a staged construction approach was used in design, the software assumes that the load for each stage is applied instantaneously.

Pore water pressures were generated in the deformation and seepage models and used as a basis for the slope stability analysis. Figures F.3, F.7, F.10, F.13, F.17, F.21, and F.25 in Appendix F show the modelled critical slip surfaces for each of the construction sequences immediately after loading. The calculated factor of safety for the different construction scenarios is shown in Table 7.

Table 7: Calculated Factor of Safety for Slope Stability

Construction Sequence	Downstream Slope		Upstream Slope
	Short Term	Long Term	Short Term
Required Factor of Safety	**1.3**	**1.5**	**1.3**
Option 1 - Existing Conditions	-	1.46	-
Option 2 - One Stage with 6H:1V Slope	1.38	1.66	1.33
Option 3 - Multi-Stage with 6H:1V Slope	1.57	1.65	1.32
1st Stage	1.72	1.83	1.33
2nd Stage	1.80	1.91	1.37
3rd Stage	1.57	1.65	1.32
Option 4 - One stage with 5H:1V Slope	1.35	1.58	1.34
Option 5 – One stage with 5H:1V Slopes & Toe Berm	1.35	1.59	1.42
Option 5 – Multi-stage with 5H:1V Slopes & Toe Berm	1.47	1.59	1.43

The factor of safety generated by the SLOPE/W model confirms that the dam in its existing condition does not meet the CDA guidelines for long term slope stability. However, the computed factor of safety is improved from the previous study (MDH 2011) due to the improved geotechnical parameters for the alluvial soils used in the SLOPE/W model. MDH reported a long term factor of safety of 1.19 for the existing downstream slope with a full supply level of 722.2 masl. The results of the analysis indicate that the factor of safety for all options may be improved by building them with a staged construction approach. The critical slip surface for all construction sequences occurred at the shale interface and not in the alluvial soils.

The report by MDH (MDH 2011) indicated that the existing dam is not meeting the CDA Dam Safety Guideline for the full supply level (FSL), probable maximum flood (PMF), and seismic conditions. Rapid drawdown of the reservoir was also considered by MDH, but was not impacted by the downstream slope and as such has been omitted from this report. MDH used the following parameters in their report:

- FSL = 722.2 masl
- PMF = 723.9 (static head conditions).
- Peak Ground Acceleration (Seismic) = 0.059g (where g is the acceleration due to gravity)

However, review of the CDA guidelines have indicated that due to the reduction in the risk consequence rating from High to Significant, analysis for the PMF is no longer required. Rather, the design flood should be based on

an Inflow Design Flood (IDF) for a storm event with a return period somewhere between 1 in 100 years and 1 in 1000 years. Additionally the hazard for a seismic event should be calculated for a 1 in 1000 year probability of exceedance as opposed to a 1 in 2500 year probability. The CDA Guideline also recommends that the mean rather than median hazard values be used for seismic slope stability analysis.

After discussions with the AAFC, Golder requested a copy of the Saskatchewan Watershed Authority (SWA) Dams Seismic Hazard Assessment Report completed by Klohn Crippen Berger Ltd. for the SWA for their dams in November 2009. Although the SWA does not operate a dam in the Swift Current area, they do have six dams located in the southern portion of the province. In the report the dams (Qu'Appelle, Buffalo Pound, Avonlea, Summercove, West Poplar and Stelcam Weir) have been assigned PGA values ranging between 0.016 and 0.031g. Golder reviewed the dam locations and determined that a value of 0.025g would not be unreasonable for a dam at this location. The CDA guidelines allow site classification based on the NBCC, which can be classified as Site Class E due to the presence of low strength, high plastic soils greater than 3 m thick at this location. Based on Table 5.17 on page 88 of the SWA report, the recommended amplification factor for this site classification is 2.49. Multiplying the PGA by the amplification factor provides an Earthquake Design Ground Motion factor of 0.062g at Highfield Dam.

The passage of the inflow design flood was based on a 1 in 500 year IDF, which provides a freeboard of 0.7 m and a water elevation of 725.0 masl in the reservoir, as provided by AAFC.

The construction sequence with the lowest factor of safety (Option 5, multi-stage) and Existing Condition were re-analysed to determine the impact of seismic and design storm conditions on the slope stability as shown in Table 8. Conditions were assumed to be static for the seismic event and transient for the 1 in 500 year IDF as it is assumed that water would be drained from the reservoir before static conditions could be established for the IDF event. The 1 in 500 year IDF was not considered for Option 1 as the reservoir would overtop the dam.

Table 8: Calculated Factor of Safety for Slope Stability for IDF & Seismic Conditions

Construction Sequence	Seismic = 0.062g	1:500 yr IDF = 725.00 masl
Required Factor of Safety	**1.0**	**1.5**
Option 1 – Existing Conditions	1.12	-
Option 5 – Multi-stage with 3.5H:1V upper slope, 5 m wide toe berm and 5H:1V toe berm slope	1.10	1.51

IDF = Inflow Design Flood; masl = metres above sea level; yr = year; g = acceleration due to gravity

The computed factor of safety is above CDA Dam Safety Guidelines for all scenarios considered.

4.3 Sensitivity Analysis

A sensitivity analysis was performed on the model under existing conditions to determine the sensitivity of the model to the following geotechnical parameters for the alluvial soils: unit weight, phi, hydraulic conductivity, and downstream boundary conditions. Only one parameter was changed for each analysis, with all other parameters the same as previously stated. The results of the sensitivity analysis are shown in Table 9. The parameters used by Golder and MDH are noted in the table in addition to other typical values that could be expected for this type of soil.

Table 9: Sensitivity Analysis for Option 1 - Existing Conditions Model

Parameter Changed	Value	Factor of Safety
Required Factor of Safety	**-**	**1.5**
Phi for Alluvial Soil	20° (MDH value)	1.14
	28°(Golder value)	1.46
	30°	1.55
Unit Weight of Alluvial Soil	18 kN/m^3	1.38
	19 kN/m^3 (Golder value)	1.46
	20 kN/m^3 (MDH value)	1.54
Hydraulic Conductivity of Alluvial Soil	1.0x10^{-6} m/s (MDH value)	1.50
	1.3x10^{-7} m/s (Golder value)	1.46
	1.0x10^{-9} m/s	1.38
Downstream Boundary Elevation	717.3 masl	1.46
	716.8 masl (Golder value)	1.46
	716.2 masl	1.46

kN/m^3 = kiloNewton per cubic metre; m/s = metres per second; masl = metres above sea level

The results of the sensitivity analysis indicate that the factor of safety is sensitive to phi, the friction angle of the alluvial foundation soil. The parameters selected by Golder for analysis were based on results of laboratory testing on alluvial soils described in Section 2.4. Decreasing the hydraulic conductivity and the downstream water level results in improvements to the factor of safety. Decreasing the unit weight and phi reduces the factor of safety.

5.0 RECOMMENDATIONS

Based on the results of the embankment foundation analysis, any of the construction sequences considered may be feasible for the dam raise. As such, other factors such as cost, constructability, and reduction of impact to wetland habitat should be taken into account for selection of the dam construction sequence. Based on these factors, Golder recommends a construction scenario similar to Option 5, with the following geometry:

- construct dam embankment above an elevation of 720.4 masl at a 3.5H:1V slope;
- construct dam embankment below an elevation of 720.4 masl at a 5H:1V slope;
- berm width of 5 m at elevation 720.4 masl;
- base of berm extending approximately 21.8 m from the existing toe;
- construct a granular blanket drain with minimum thickness of 1.2 m under the new fill; and
- construct the raise in two stages with the first being the berm construction and the second the dam raise.

Placement of a granular blanket drain at the toe of the existing dam and extending downstream for the full width of the new fill is recommended to improve seepage control and pore water pressure dissipation following berm and embankment raise construction. Placing additional fill material on the dam to account for potential settlement should be considered for all construction scenarios.

6.0 CONSTRUCTION CONSIDERATIONS

The following considerations are recommended for the construction of Option 5 described in this report, but are not intended to supersede specifications for construction or detailed design of this option.

- Placement of additional fill over low level outlets has not previously been considered for this project. The structural stability of these original concrete structures, including the foundation, should be considered and accommodated in the final design of this project.
- Settlement of the dam embankment of up to 115 mm may be expected at the centre of the dam. The crest of the dam should be overbuilt or an allowance made for repair and backfilling of the dam over time as settlement occurs.
- Long embankments often experience an optical illusion where the dam appears to sag in the centre, which may cause alarm to observers. Overbuilding at the centre of the dam can reduce this effect.
- The amount of stripped ground surface exposed should be kept to a minimum to improve construction conditions. Stripping the topsoil and vegetation will encourage ponding and seepage at the base of the dam resulting in wet and muddy conditions. Placement of geotextile fabric over soft ground and/or immediate placement of the granular blanket drain will improve construction conditions at the site.
- Replace stripped topsoil on top of the finished slope and seed with non-invasive plants suited for this location to reduce the erosion and sedimentation potential of the newly constructed slope.
- Fill should be placed in lifts of approximately 150 mm compacted thickness. Depending on the rate of fill placement, it is possible that the pore water pressures generated from construction activities will have dissipated by the time each stage is completed along the full length of the dam. The vibrating wire piezometer lead wires can be raised and used to monitor the rate of pore water pressure dissipation during construction.
- AAFC should contact the Saskatchewan Ministry of the Environment directly with inquiries relating to the necessity of acquiring an Aquatic Habitat Protection Permit for work in the wetland area downstream of the dam. While generally AHPP's are not required on federal land, there is the potential that the construction will affect downstream wetlands that fall under provincial jurisdiction. Accommodation for species at risk indentified in previous reports will be necessary.
- AAFC should also contact Saskatchewan Ministry of the Environment with inquiries relating to site clearing and nesting of migratory birds. If clearing is conducted in Saskatchewan between April 1 and July 31 of any year, pre-construction surveys should be completed no more than 7 days prior to clearing activities to identify and avoid disturbance to occupied nests. If no occupied nests are found, clearing can proceed without implementation of additional mitigation measures. If an occupied nest is identified, no activity is recommended within 30 m or more (depending on the species) of the nest until it is no longer occupied. Consideration should be given to topsoil stripping and placement of the granular blanket drain prior to the spring thaw for this reason, and to reduce problems with wet ground conditions.

7.0 CLOSURE

The findings of this report are based on data and information collected during investigations conducted by Golder Associates Ltd.'s personnel. If conditions encountered at the surface or at depth during construction of the proposed structure appear to be different than those indicated in the report or if the assumptions stated herein are not in keeping with the design, this office should be notified in order that the recommendations can be reviewed and adjusted, if necessary.

Soil conditions, by their nature, can be highly variable across a site. The placement of fill and prior construction activities on a site can contribute to the unknown variables in near surface soil conditions. The data presented in this report represents soil conditions encountered at the sampling locations tested during this time period. Soil and/or groundwater conditions may vary with location, depth, and time across a site. Differences in sampling methodology and analytical techniques may also cause variations in results. A contingency should be included in any construction budget to allow for the possibility of variations in soil conditions that may result in modification of the design and construction procedures.

This report was prepared for Agriculture and Agri-Food Canada for the proposed works described in the text. The findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. No other warranty, express or implied, is given.

Report Signature Page

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Association of Professional Engineers & Geoscientists of Saskatchewan

CERTIFICATE OF AUTHORIZATION

Golder Associates Ltd.
Number C0230

Permission to Consult held by:

Discipline	Sk. Reg. No.	Signature
GEOTECHNICAL	6039	Phil Bruch

\\sas1-s-filesrv1\data\active\2011\1362\11-1362-0114 aafc highfield dam - swift current, sk\5000 reporting\final report\23 jan 12 _11-1362-0114-rep-01 highfield foundation assessment report.docx

8.0 REFERENCES

Agriculture and Agri-Food Canada, Agri-Environmental Services Branch. July 2011. Highfield Reservoir Existing Topography and Drill Hole Locations. Drawing Number: 208524.

Canadian Dam Association. 2007. *Dam Safety Guidelines 2007*.

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Maathuis, Harm and Mark Simpson. 2007. *Groundwater Resources of the Swift Current (72J) area, Saskatchewan*. Saskatchewan Research Council. SRC Publication No. 12178-1E07.

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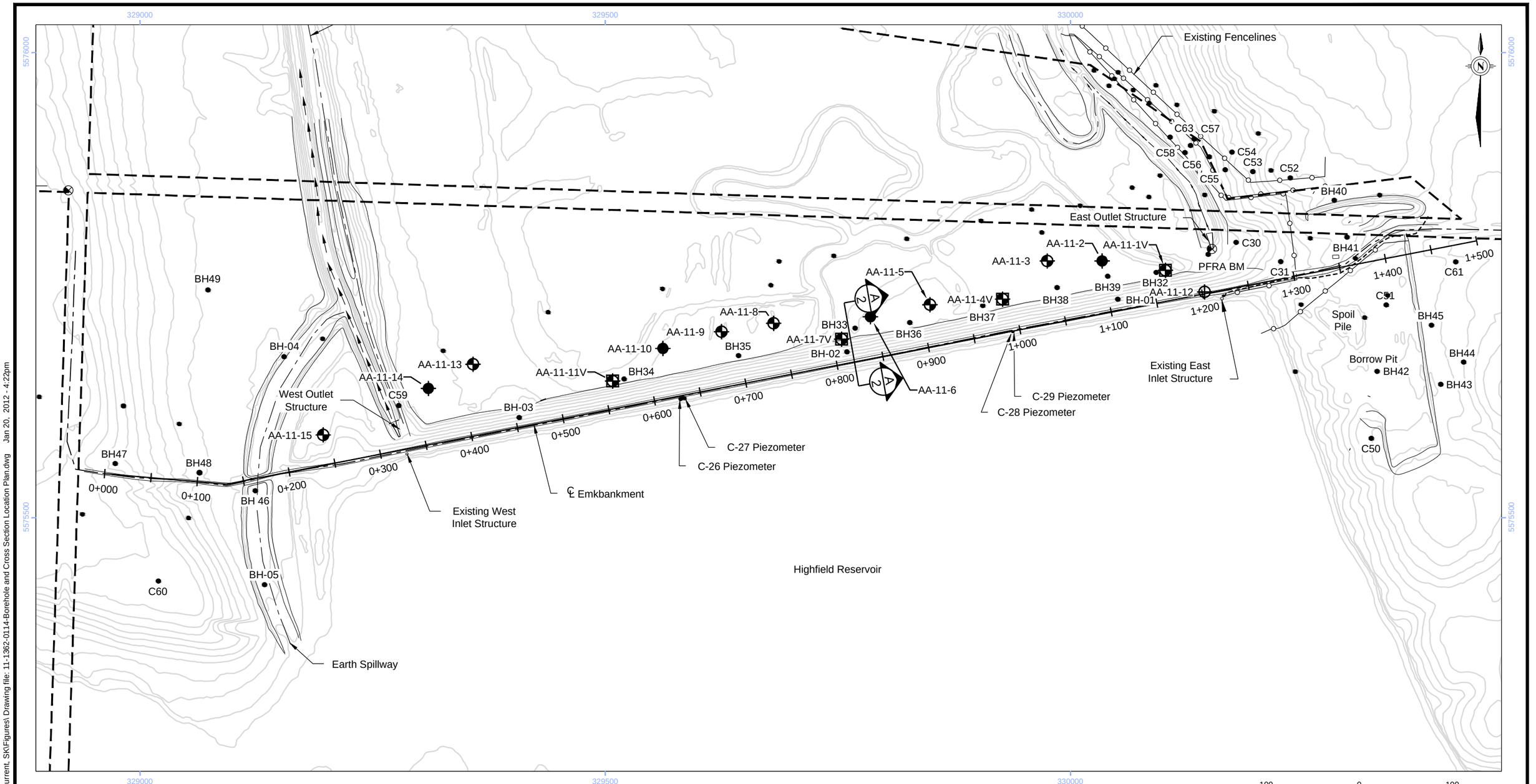
Northwest Hydraulic Consultants and MDH Engineered Solutions Corp. December 2011. *AAFC/AESB Highfield Dam Service Contract No. 3 Spillway Pre-Design Completion 35525 Final Report.*

FIGURES



Legend

- Borehole
- Vibrating Wire Piezometer
- CPT
- Borehole / Piezometer (Previous Investigation by others)

Reference:
Base plan provided by client in digital format, drawing number 208524, dated July 2011, titled "Existing Topography and Drill Hole Locations".

POINT	NORTHING (m)	EASTING (m)	DESCRIPTION
1	5575766	330102	AA-11-1V
2	5575776	330034	AA-11-2
3	5575772	329975	AA-11-3
4	5575735	329927	AA-11-4V
5	5575729	329849	AA-11-5
6	5575716	329785	AA-11-6
7	5575692	329754	AA-11-7V
8	5575709	329681	AA-11-8
9	5575700	329625	AA-11-9
10	5575682	329562	AA-11-10
11	5575647	329508	AA-11-11V
12	Not Drilled	Not Drilled	AA-11-12
13	5575665	329358	AA-11-13
14	5575639	329310	AA-11-14
15	5575589	329197	AA-11-15

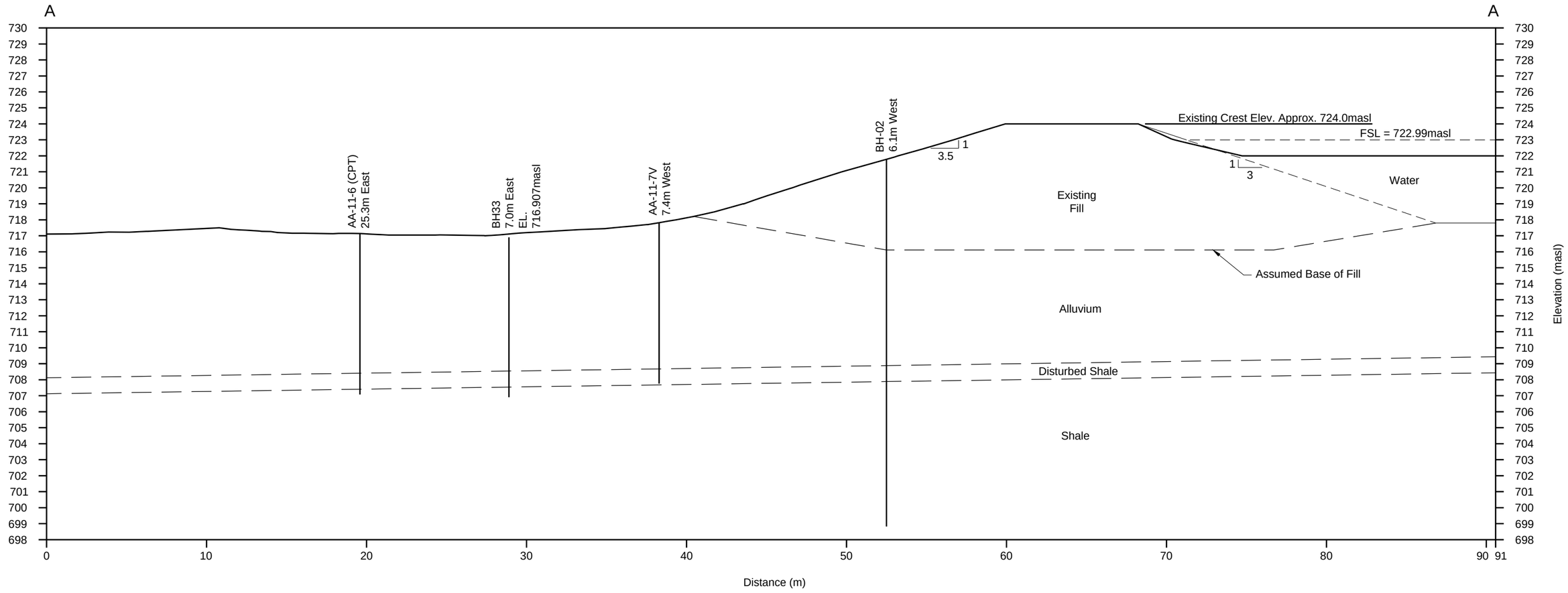
PROJECT
AAFC HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
BOREHOLE AND DESIGN CROSS SECTION LOCATION PLAN

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.
DESIGN			SCALE AS SHOWN REV. 0
CADD	BDS/TAH	11/01/12	
CHECK	LDN	11/01/12	FIGURE: 1
REVIEW	RGR	12/01/12	

G:\2011\1362\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\Figures\ Drawing file: 11-1362-0114-Borehole and Cross Section Location Plan.dwg Jan 20, 2012 - 4:22pm



A/1 SECTION A - STATION 0+825

Legend

- Cross Section Surface (from topographic plan)
- Assumed Surface
- Borehole Location

Note:
BH-02 and BH33 from previous reports by others

5 0 5
SCALE 1:250 METRES

PROJECT
AAFC HIGHFIELD DAM EMBANKMENT
FOUNDATION ASSESSMENT

TITLE
DESIGN CROSS SECTION

Golder Associates
Saskatoon, Saskatchewan

PROJECT		11-1362-0114	FILE No.	
DESIGN	LDN	14/12/11	SCALE AS SHOWN	REV. 0
CADD	TAH	11/01/12		
CHECK	LDN	11/01/12		
REVIEW	RGR	12/01/12		

FIGURE: 2

G:\2011\1362\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\Figures\Working\Geotechnical\ Drawing file: 11-1362-0114 Design Cross Section.dwg Jan 20, 2012 - 4:05pm

APPENDIX A

Information and Limitations of this Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder cannot be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect constructions costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT (continued)

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The conditions of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that he subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

APPENDIX B

Record of Borehole Sheets

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I GENERAL

p	= 3.1416
ln x,	natural logarithm of x
log10 x, or log x,	logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II. STRESS AND STRAIN

g	shear strain
D	change in, e.g. in stress: Ds
e	linear strain
e_v	volumetric strain
h	coefficient of viscosity
n	Poisson's ratio
s	total stress
s'	effective stress (s' = s - u)
s'_{vo}	initial effective overburden stress
s_1, s_2, s_3	principal stresses (major, intermediate, minor)
s_{oct}	mean stress or octahedral stress = $(s_1 + s_2 + s_3)/3$
t	shear stress
u	pore water pressure
E	modulus of deformation
G	shear modulus of deformation

III. SOIL PROPERTIES

(a) Index Properties

r(g)	bulk density (bulk unit weight*)
$r_d(g_d)$	dry density (dry unit weight)
$r_w(g_w)$	density (unit weight) of water
$r_s(g_s)$	density (unit weight) of solid particles
g'	unit weight of submerged soil ($g' = g - g_w$)
D_r	relative density (specific gravity) of solid particles ($D_r = r_s/r_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is r. Unit weight symbol is g where g = r g (i.e. mass density x acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity Index = $(w_l - w_p)$
w_s	shrinkage limit
I_l	liquidity index = $(w - w_p)/I_p$
I_c	consistency index
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_d	density index = $(e_{max} - e)/(e_{max} - e_{min})$

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation

c_c	compression index (normally consolidated range)
c_r	recompression index (overconsolidated range)
c_s	swelling index
c_o	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
s'_p	pre-consolidation pressure
OCR	Overconsolidation ratio = s'_p/s'_{vo}

(d) Shear Strength

t_p, t_r	peak and residual shear strength
f'	effective angle of internal friction
d	angle of internal friction
m	coefficient of friction = tan d
c'	effective cohesion
c_u, s_u	undrained shear strength (f = 0 analysis)
p	mean total stress $(s_1 + s_3)/2$
p'	mean effective stress $(s'_2 + s'_3)/2$
q	$(s_1 - s_3)/2$ or $(s'_1 - s'_3)/2$
q_u	compressive strength $(s_1 - s_3)$
S_t	sensitivity

Notes: 1. $t = c' + s' \tan f'$
2. Shear strength = (Compressive strength)/2

LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows

I SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled piston
WS	Wash sample

I I PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm

Dynamic Penetration Resistance: N_d
The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60^o cone attached to "A" size drill rods for a distance of 300 mm (12 in.)

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60^o conical tip and a projected end area of 10 cm^2 pushed trough ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

III SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	**N** Blows/ 300 mm or blows/ft
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	over 50

(b) Cohesive Soils

Consistency	c_u, s_u kPa	c_u, s_u psf
Very Soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very Stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

IV SOIL TESTS

w	water content
w_p	plastic limit
w_l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_r	relative density (specific gravity, G_s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction tests
SPC	Standard Proctor compaction test
pH	acidity or basicity measurement
EC	Electrical Conductivity
OC	Organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane test (LV - laboratory vane test)
g	unit weight

Note:

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-01V

SHEET 1 OF 1

LOCATION: N 5575766 E 330102

BORING DATE: Oct.3, 2011

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.34							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		CH, firm, mottled olive brown and grey, trace sand			01V-1	AS					
					01V-2	AS					
1											
					01V-3	DO	5				
2											
					01V-4	AS				MH	GROUT
3					01V-5	TO					
				713.68							Oct.3/11 ▽
		CH, wet, mottled dark brown and dark grey, some sand, trace gravel (TILL)		3.66	01V-6	AS					
4											
					01V-7	DO					
5											VW18880
				712.16							
		CH, very stiff, grey, iron staining (SHALE)		5.18	01V-8	AS					
6											
					01V-9	DO	21				
				710.79							
		END OF BOREHOLE = 6.55m		6.55							
7		NOTES: 1. Borehole open to 5.18m below ground surface upon completion of drilling. 2. Water level measured in piezometer at a depth of 3.66m below ground surface upon completion of drilling. 3. Vibrating Wire Piezometer installed at 5.03m below ground surface.									
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-03

SHEET 1 OF 1

LOCATION: N 5575772 E 329975

BORING DATE: Oct.3, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.60							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		Cl, firm, grey, some fine sand			03-1	AS					
					03-2	AS					Oct.3/11 ▽
1		- becomes wet at 0.91m									
					03-3	TO				UC DD= 1572 PP LV C	
2											
		- becomes mottled olive brown and grey below 2.23m			03-4	AS					
3				714.55							
		CH, firm, wet, mottled olive brown and grey, trace sand		3.05	03-5	DO	4				
					03-6	AS					
4											
					03-7	DO	6				
5											
					03-8	AS					
6											
					03-9	DO	9				
				710.89							
		CH, hard, grey (SHALE)		6.71							
7					03-10	AS					
					03-11	DO	45				
8				709.52							
		END OF BOREHOLE = 8.08m		8.08							
9		NOTES: 1. Borehole open to 3.05m below ground surface upon completion of drilling. 2. Water level measured in open borehole at a depth of 0.91m below ground surface upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling. 4. Artesian conditions to a height of approximately 127mm above ground surface observed.									
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-04V

SHEET 1 OF 1

LOCATION: N 5575735 E 329927

BORING DATE: Oct.3, 2011

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DATUM:

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.78							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.06							
		Cl, grey			04V-1	AS					
				717.17							
		SC, grey, fine		0.61	04V-2	AS					Oct.3/11 ▽
1				716.41							
		Cl, firm, wet, grey, sandy		1.37							
					04V-3	DO	4				GROUT
2				715.65							
		CL, soft to firm, wet, grey, sandy		2.13							
					04V-4	AS					
3					04V-5	DO	4				VW18879
				714.12							
		Cl, soft to firm, wet, grey, some fine sand		3.66	04V-6	AS					
4											
					04V-7	DO	4				
5											
6					04V-8	DO	3				
7					04V-9	AS					
				710.31							
		CH, grey (SHALE)		710.16							
		END OF BOREHOLE = 7.62m		7.62							
8		NOTES: 1. Borehole open to 3.05m below ground surface upon completion of drilling. 2. Water level measured in piezometer at a depth of 0.91m below ground surface upon completion of drilling. 3. Vibrating Wire Piezometer installed at 3.66m below ground surface.									
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-05

SHEET 1 OF 1

LOCATION: N 5575729 E 329849

BORING DATE: Oct.4, 2011

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.59							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		CL, firm, wet, mottled olive brown and grey, with sand			05-1	AS					
					05-2	AS					Oct.4/11 ▽
1											
					05-3	DO	5				
2											
					05-4	AS					
3		- very soft			05-5	DO	WH				
				713.93							
		CI, soft, wet, mottled olive brown and grey, sandy		3.66							
4					05-6	AS				MH	
					05-7	TO					
5											
					05-8	AS					
6											
					05-9	DO	3				
7					05-10	AS					
				709.67	05-11	DO	4				
8		CH, grey (SHALE)		709.51							
		END OF BOREHOLE = 8.08m		8.08							
		NOTES: 1. Borehole open to 3.05m below ground surface upon completion of drilling. 2. Water level measured in open borehole at a depth of 0.91m below ground surface upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling.									
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-07V

SHEET 1 OF 2

LOCATION: N 5575692 E 329754

BORING DATE: Oct.5, 2011

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.85							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.06							
		Cl, olive brown, trace sand			07V-1	AS					
				717.24							
		Cl, firm, wet, mottled olive brown and grey, sandy		0.61	07V-2	AS					
1											
					07V-3	TO				C PP LV	
2											Oct.5/11 ▽
3					07V-4	DO	7				
					07V-5	AS					
4											GROUT
					07V-6	DO	2				
5				712.67							
		Cl, firm, wet, mottled olive brown and grey, with fine sand		5.18	07V-7	AS					
6											
					07V-8	DO	5				
7		- granular layer at 7.47m - more clay content below 7.62m, very stiff									
					07V-9	DO	22				
8											
											VW18878
9				708.71	07V-10	AS					
		CH, grey (SHALE)		9.14							
					07V-11	AS					
10		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 25/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-07V

SHEET 2 OF 2

LOCATION: N 5575692 E 329754

BORING DATE: Oct.5, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. + Q - ● / rem V. ⊕ U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp W Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
10		*CONTINUED FROM PREVIOUS PAGE*									
		END OF BOREHOLE = 10.06m		707.79 / 10.06							
11		NOTES: 1. Borehole open to 2.44m below ground surface upon completion of drilling. 2. Water level measured in piezometer at a depth of 2.38m below ground surface upon completion of drilling. 3. Vibrating Wire Piezometer installed at 8.84m below ground surface. 4. Revised Jan. 25, 2012.									
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

LOGGED: LDN

CHECKED: RGR

Golder Associates

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 25/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-08

SHEET 1 OF 2

LOCATION: N 5575709 E 329681

BORING DATE: Oct.4, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.17							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		Cl, grey			08-1	AS			W		
				716.56							
		CL, wet, mottled olive brown and grey, with sand		0.61							
				716.26	08-2	AS			W		
1		ML, soft, wet, grey, with fine sand		0.91							Oct.4/11 ▽
					08-3	DO	3		W		
2											
					08-4	AS			W		
3											
					08-5	DO	3		W		
4					08-6	AS			W		
				712.90							
		CL, wet, grey, sandy		4.27							
5					08-7	TO					
				711.23							
6		Cl, firm, wet, mottled olive brown and grey, sandy		5.94							
					08-8	DO	6		W		
7											
					08-9	TO		○	W		UC DD= 1477 LV
8											
				708.33							
		CH, grey (SHALE)		8.84	08-10	AS			W		
9				708.03							
		END OF BOREHOLE = 9.14m		9.14							
10		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-08

SHEET 2 OF 2

LOCATION: N 5575709 E 329681

BORING DATE: Oct.4, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
10		*CONTINUED FROM PREVIOUS PAGE*									
		NOTES: 1. Borehole open to 1.52m below ground surface upon completion of drilling. 2. Water level measured in open borehole at a depth of 1.22m below ground surface upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling.									
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

LOGGED: LDN

CHECKED: RGR

Golder Associates

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-09

SHEET 1 OF 2

LOCATION: N 5575700 E 329625

BORING DATE: Oct.4, 2011

DATUM:

SAMPLER HAMMER, 64kg; DROP, 760mm

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. + Q - ● / rem V. ⊕ U - ○)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp W Wl, 20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.00							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		Cl, grey, with fine sand		716.70							
		Cl, soft, mottled olive brown and grey, sandy		0.30							Oct.4/11 ▽
1											
					09-1	DO	4				
2											
				713.95							
3		SM, wet, grey		3.05							
				713.65	09-2	DO	3			MH	
		Cl, soft, mottled brown and grey, sandy		3.35							
4											
		- 0.15m thick wet, brown, fine sand seam, coal pieces at 4.57m - firm			09-3	TO				UC PP LV C	
5											
6											
		- becomes dark grey, trace sand at 6.25m			09-4	DO	4			MH	
7											
		- becomes firm to stiff, mottled olive brown and grey at 7.62m			09-5	DO	8				
8		- becomes dark grey at 8.22m									
					09-6	DO	4				
9					09-7	DO	12				
				707.25							
		CH, grey (SHALE)		9.75							
10		*CONTINUED NEXT PAGE*									

DEPTH SCALE

1 : 50

LOGGED: LDN

CHECKED: RGR

Golder Associates

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-09

SHEET 2 OF 2

LOCATION: N 5575700 E 329625

BORING DATE: Oct.4, 2011

DATUM:

SAMPLER HAMMER, 64kg; DROP, 760mm

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

PENETRATION TEST HAMMER, 64kg; DROP, 760mm

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. + Q - ● / rem V. ⊕ U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp — W — Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
10		*CONTINUED FROM PREVIOUS PAGE*									
		CH, grey (SHALE) *(continued)*			09-8	TO			○	PP LV	
				706.33							
		END OF BOREHOLE = 10.67m		10.67							
		NOTES: 1. Borehole open to 7.92m below ground surface upon completion of drilling. 2. Water level measured in open borehole at a depth of 0.91m below ground surface upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling. 4. Artesian conditions to a height of approximately 51mm above ground surface observed.									
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-11V

SHEET 1 OF 1

LOCATION: N 5575647 E 329508

BORING DATE: Oct.5, 2011

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DATUM:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.00							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Cl, grey, some fine sand, trace organics		0.00	11V-1	AS					
					11V-2	AS					
1											Oct.5/11 ▽ GROUT
				715.48							
		SC, loose, wet, mottled brown to grey, fine		1.52	11V-3	DO	6				
2											
		- becomes dark grey at 2.29m			11V-4	AS					VW18877
3		- becomes very loose			11V-5	DO	3				
				713.34							
		Cl, soft, grey, with fine sand		3.66	11V-6	AS					
4											
					11V-7	TO				UC DD= 1396 PP LV	
5											
				711.67							
		CH, very stiff, mottled olive brown and grey, iron staining (SHALE)		5.33							
6					11V-8	DO	17				
				710.45							
		END OF BOREHOLE = 6.55m		6.55							
7		NOTES: 1. Borehole open to 3.05m below ground surface upon completion of drilling. 2. Water level measured in piezometer at a depth of 1.22m below ground surface upon completion of drilling. 3. Vibrating Wire Piezometer installed at 2.74m below ground surface.									
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-12

SHEET 1 OF 1

LOCATION:

BORING DATE:

DATUM:

DRILL RIG:

DRILLING CONTRACTOR:

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	SOIL PROFILE: STRATA PLOT	SOIL PROFILE: ELEV. / DEPTH (m)	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. +, rem V. ⊕, Q - ●, U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp, W, Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		724.05							
0		Not Drilled		0.00							
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

LOGGED:

CHECKED:

Golder Associates

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-13

SHEET 1 OF 1

LOCATION: N 5575665 E 329358

BORING DATE: Oct.6, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. + Q - ● / rem V. ⊕ U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp W Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		717.81							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		Cl, grey, some fine sand			13-1	AS					
					13-2	AS					
1				716.44							
		CH, firm, mottled olive brown and grey, sandy, iron staining (SHALE)		1.37							
					13-3	DO	7				
2											
					13-4	AS					Oct.6/11 ▽
3		- stiff		714.30	13-5	DO	13				
		END OF BOREHOLE = 3.51m		3.51							
4		NOTES: 1. Borehole open to 3.66m below ground surface upon completion of drilling. 2. Water level measured in open borehole at a depth of 2.44m below ground surface upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling.									
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: LDN

CHECKED: RGR

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

PROJECT: 11-1362-0114

RECORD OF BOREHOLE: AA-11-15

SHEET 1 OF 1

LOCATION: N 5575589 E 329197

BORING DATE: Oct.6, 2011

DATUM:

DRILL RIG: Acker MP-5

DRILLING CONTRACTOR: Paddock Drilling Ltd.

DEPTH SCALE METRES	BORING METHOD	SOIL PROFILE: DESCRIPTION	STRATA PLOT	ELEV. / DEPTH (m)	SAMPLES: NUMBER	TYPE	BLOWS/0.3m	DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m (20 40 60 80) / SHEAR STRENGTH Cu, kPa (nat V. + Q - ●, rem V. ⊕ U - ○) (20 40 60 80)	HYDRAULIC CONDUCTIVITY, k, cm/s (10^{-6} 10^{-5} 10^{-4} 10^{-3}) / WATER CONTENT PERCENT (Wp W Wl) (20 40 60 80)	ADDITIONAL LAB. TESTING	PIEZOMETER OR STANDPIPE INSTALLATION AND GROUNDWATER OBSERVATIONS
		GROUND SURFACE		722.00							
0	Power Auger Boring 127mm Dia. Solid Stem Augers	Black silty TOPSOIL		0.03							
		CI, mottled olive brown and grey, some organics			15-1	AS					
				721.39							
		SC-CH, firm, mottled olive brown and grey, iron staining (SHALE)		0.61	15-2	AS					
1											
					15-3	TO				UC	
2											
					15-4	AS					
3											
		- very stiff			15-5	DO	25				
				718.49							
		END OF BOREHOLE = 3.51m		3.51							
4		NOTES: 1. Borehole open to 3.51m below ground surface upon completion of drilling. 2. Open borehole dry upon completion of drilling. 3. Borehole backfilled to surface with cuttings and bentonite chips upon completion of drilling.									
5											
6											
7											
8											
9											
10											

DEPTH SCALE

1 : 50

LOGGED: LDN

CHECKED: RGR

Golder Associates

SK_SOIL 11-1362-0114-5000-BOREHOLES.GPJ GAL-SASK.GDT 20/01/12 SIB

APPENDIX C

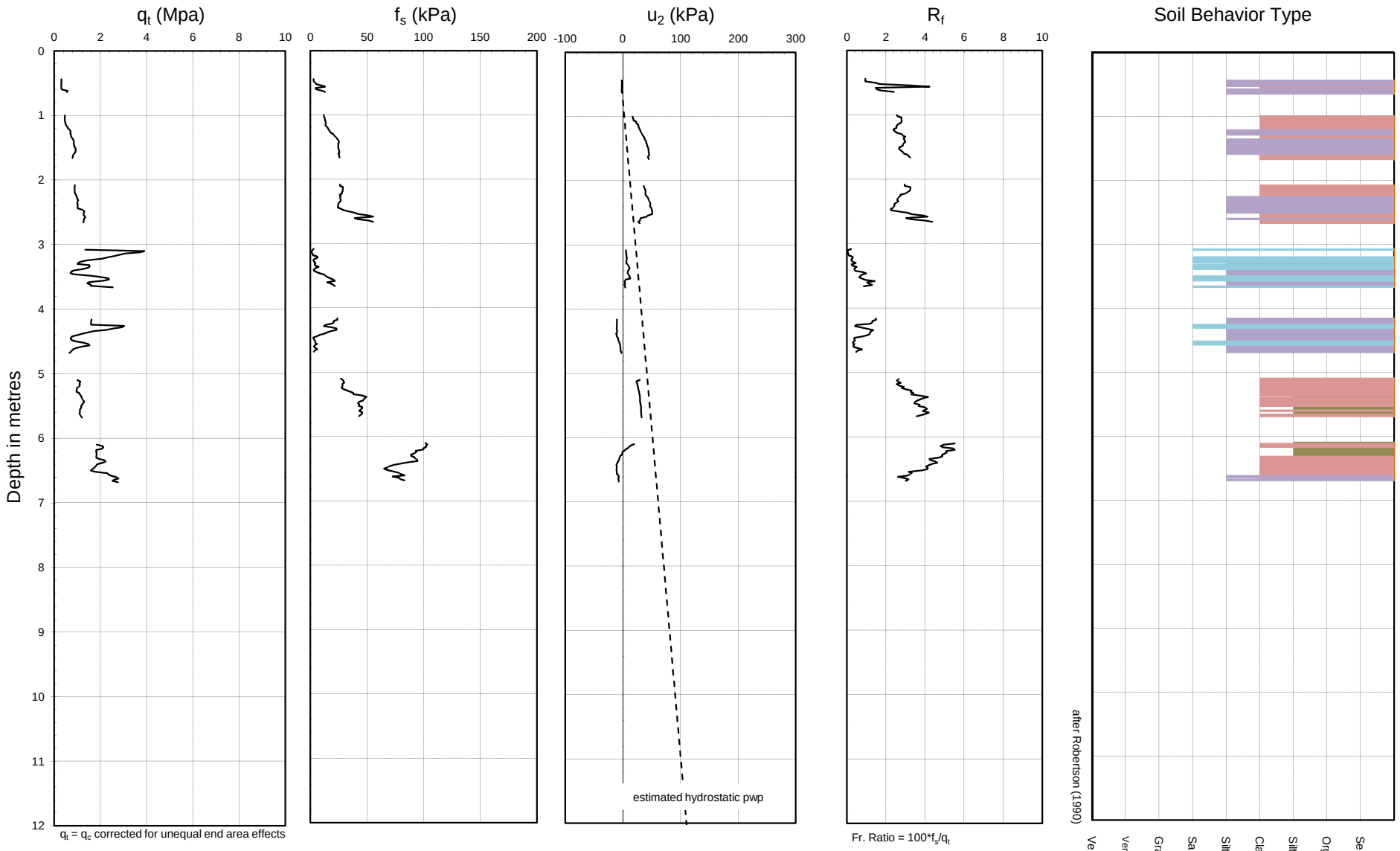
Cone Penetration Test Plots

Cone Penetration Test - CPT AA-11-02

Test Date: October 5, 2011 Operator: SCB

Location: N 5575776 E 330034

Assumed water table depth (m): 0.75



Golder Associates

Project #: 11-1362-0114

Date drawn: October 11, 2011

Drawn by: SCB

Reviewed by: JJS

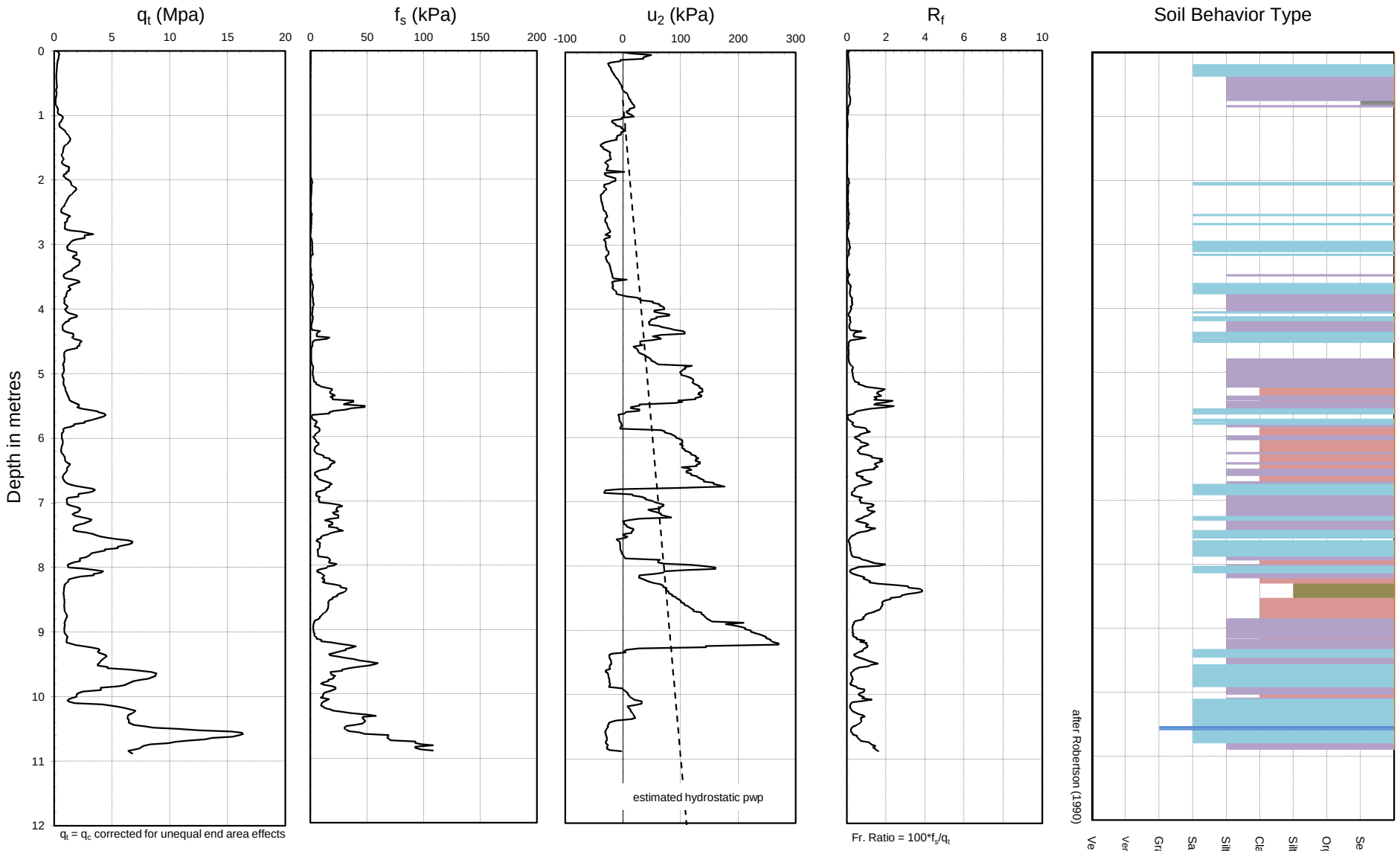
Note: data gaps due to data transmission problems during push

Cone Penetration Test - CPT AA-11-06

Test Date: October 5, 2011 Operator: SCB

Location: N 5575716 E 329785

Assumed water table depth (m): 0.75



Golder Associates

Project #: 11-1362-0114

Date drawn: October 11, 2011

Drawn by: SCB

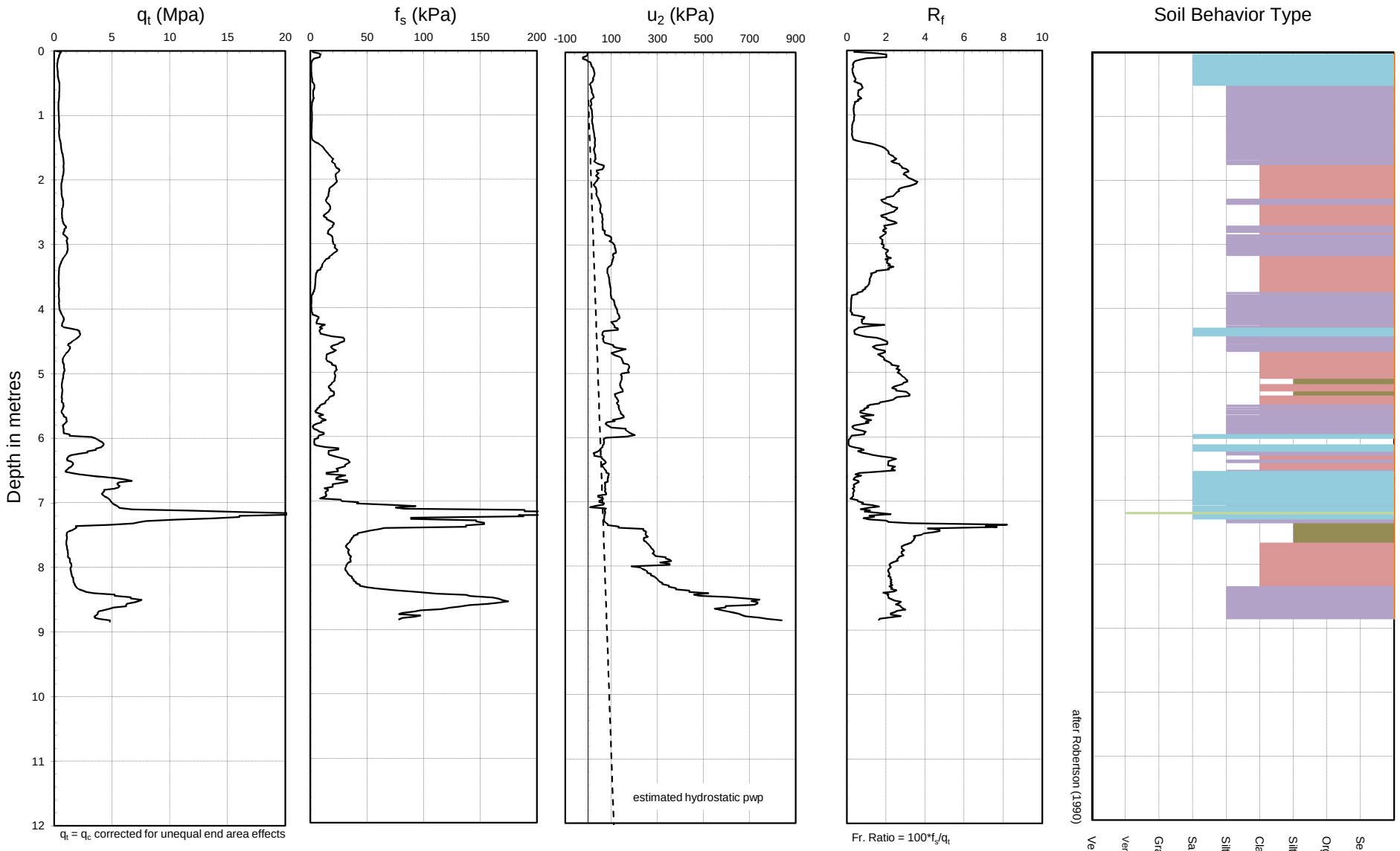
Reviewed by: JJS

Cone Penetration Test - CPT AA-11-10

Test Date: October 5, 2011 Operator: SCB

Location: N 5575682 E 329562

Assumed water table depth (m): 0.75



Golder Associates

Project #: 11-1362-0114

Date drawn: October 11, 2011

Drawn by: SCB

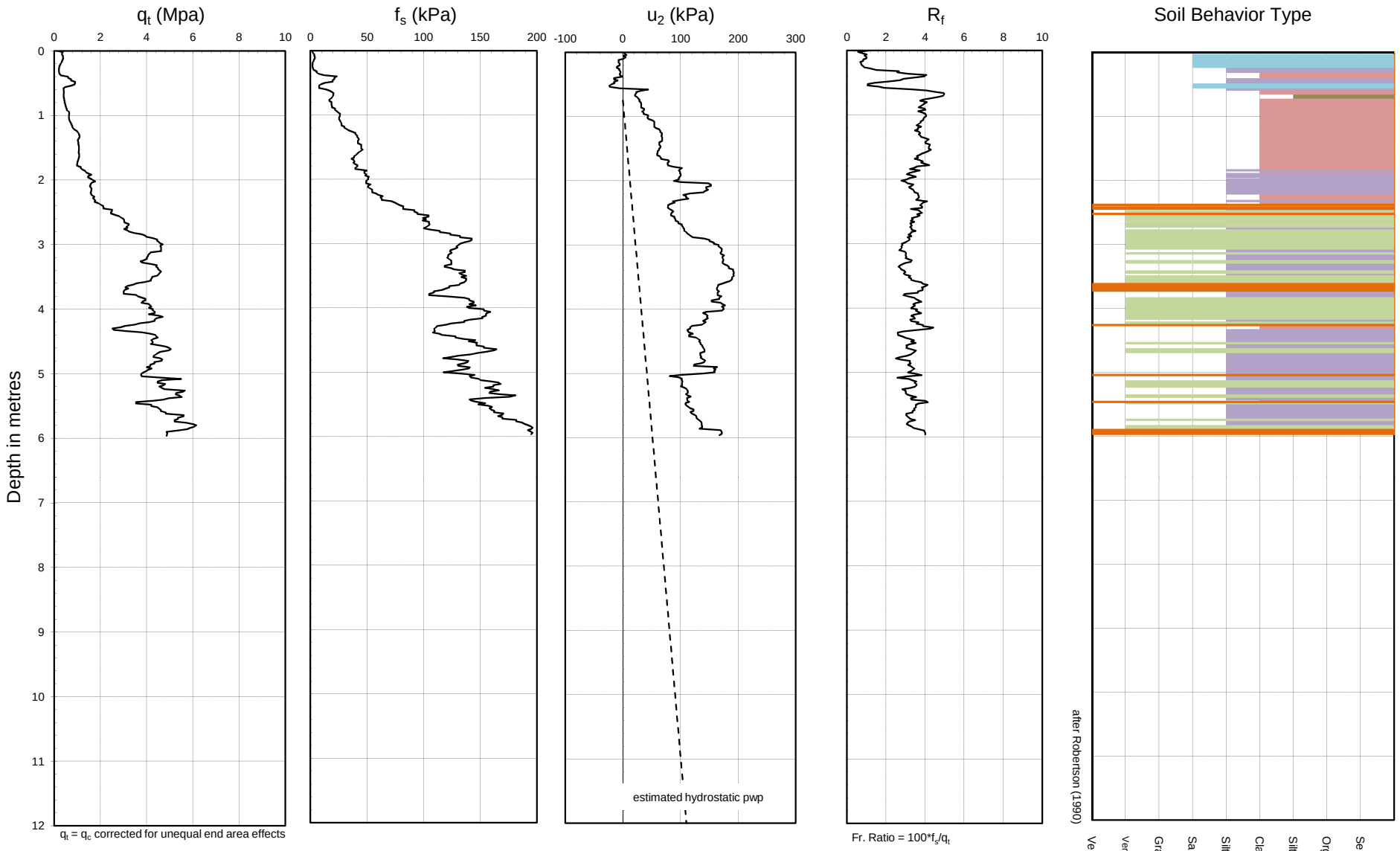
Reviewed by: JJS

Cone Penetration Test - CPT AA-11-14

Test Date: October 5, 2011 Operator: SCB

Location: N 5575639 E 329310

Assumed water table depth (m): 0.75



Project #: 11-1362-0114

Date drawn: October 11, 2011

Drawn by: SCB

Reviewed by: JJS

APPENDIX D

Laboratory Test Results

Golder Associates

GENERAL TESTING RESULTS

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / J.F. Date: November 14, 2011

Sample Identification				Laboratory Test Results										
Borehole #	Sample #	Depth (m)	Sample Type	Water Content (%)	Plastic Limit	Liquid Limit	Plasticity Index	% Passing #200	SHT Group Index	ASTM Group Index	Dry Density (kg/m^3)	Pocket Penetrometer (kPa)	Lab Vane (kPa)	
AA-11-01V	01V-01	0.30-0.46	AS	32.3										
AA-11-01V	01V-02	0.76-0.91	AS	29.2										
AA-11-01V	01V-03	1.52-1.98	DO	34.4	18	53	35							
AA-11-01V	01V-04	2.29-2.44	AS	32.6										
AA-11-01V	01V-05	3.05-3.66	TO											
AA-11-01V	01V-06	3.81-3.96	AS	36.4										
AA-11-01V	01V-07	4.57-5.03	DO	40.3	20	66	46	84.6	20.0	41.4				
AA-11-01V	01V-08	5.33-5.49	AS	36.0										
AA-11-01V	01V-09	6.10-6.55	DO	34.6	22	65	43	53.6	13.3	18.8				
AA-11-03	03-01	0.30-0.46	AS	33.9										
AA-11-03	03-02	0.76-0.91	AS	30.7	15	43	28	79.8	15.8	21.3				
AA-11-03	03-03	1.52-2.13	TO	26.7							1572	36	80	
AA-11-03	03-04	2.29-2.44	AS	30.9										
AA-11-03	03-05	3.05-3.51	DO	35.7	17	60	43	93.1	20.0	43.2				
AA-11-03	03-06	3.81-3.96	AS	32.6										
AA-11-03	03-07	4.57-5.03	DO	23.9										
AA-11-03	03-08	5.33-5.49	AS	35.7										
AA-11-03	03-09	6.10-6.55	DO	41.9										
AA-11-03	03-10	6.86-7.01	AS	47.4										
AA-11-03	03-11	7.62-8.08	DO	59.1										
AA-11-04V	04V-01	0.30-0.46	AS	30.7										
AA-11-04V	04V-02	0.76-0.91	AS	28.4	13	27	14	47.7	3.8	3.0				
AA-11-04V	04V-03	1.52-2.13	DO	27.2	15	33	18	60.8	8.4	7.9				
AA-11-04V	04V-04	2.29-2.44	AS	27.4										
AA-11-04V	04V-05	3.05-3.51	DO	22.7										
AA-11-04V	04V-06	3.81-3.96	AS	30.0										
AA-11-04V	04V-07	4.57-5.03	DO	34.0	13	45	32	80.4	17.0	24.6				
AA-11-04V	04V-08	6.10-6.55	DO	35.9										
AA-11-04V	04V-09	7.32-7.47	AS	51.1										
AA-11-05	05-01	0.30-0.46	AS	33.7										
AA-11-05	05-02	0.76-0.91	AS	30.9										
AA-11-05	05-03	1.52-1.98	DO	26.1										
AA-11-05	05-04	2.29-2.44	AS	28.4										
AA-11-05	05-05	3.05-3.51	DO	25.7										
AA-11-05	05-06	3.81-3.96	AS	30.6										
AA-11-05	05-07	4.57-5.18	TO											
AA-11-05	05-08	5.33-5.49	AS	27.4	14	38	24							
AA-11-05	05-09	6.10-6.55	DO	31.4										
AA-11-05	05-10	6.86-7.01	AS	27.2										
AA-11-05	05-11	7.62-8.08	DO	20.7										
AA-11-07V	07V-01	0.30-0.46	AS	38.3										
AA-11-07V	07V-02	0.76-0.91	AS	30.3	15	33	18							

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GENERAL TESTING RESULTS

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / J.F. Date: November 14, 2011

Sample Identification				Laboratory Test Results									
Borehole #	Sample #	Depth (m)	Sample Type	Water Content (%)	Plastic Limit	Liquid Limit	Plasticity Index	% Passing #200	SHT Group Index	ASTM Group Index	Dry Density (kg/m^3)	Pocket Penetrometer (kPa)	Lab Vane (kPa)
AA-11-07V	07V-03	1.52-2.13	TO	41.4								0	36
AA-11-07V	07V-04	3.05-3.51	DO	30.5									
AA-11-07V	07V-05	3.81-3.96	AS	25.8									
AA-11-07V	07V-06	4.57-5.03	DO	33.4									
AA-11-07V	07V-07	5.33-5.49	AS	32.9									
AA-11-07V	07V-08	6.10-6.55	DO	30.8	12	33	21	50.9	7.1	6.6			
AA-11-07V	07V-09	7.62-8.08	DO										
AA-11-07V	07V-10	8.84-9.14	AS	33.1									
AA-11-07V	07V-11	9.75-10.06	AS	39.8									
AA-11-08	08-01	0.30-0.46	AS	32.1									
AA-11-08	08-02	0.76-0.91	AS	29.9									
AA-11-08	08-03	1.52-2.13	TO	21.3									
AA-11-08	08-04	2.29-2.44	AS	28.7									
AA-11-08	08-05	3.05-3.51	DO	30.1	Non - Plastic			59.6					
AA-11-08	08-06	3.81-3.96	AS	24.9									
AA-11-08	08-07	4.57-5.18	TO										
AA-11-08	08-08	6.10-6.55	DO	34.6	13	46	33	76.8	17.2	23.8			
AA-11-08	08-09	7.62-8.23	TO	25.8							1477		68
AA-11-08	08-10	8.84-9.14	AS	45.4									
AA-11-09	09-01	1.52-1.98	DO	23.6	16	33	17						
AA-11-09	09-02	3.05-3.51	DO	34.0									
AA-11-09	09-03	4.57-5.18	TO	21.3								12	61
AA-11-09	09-04	6.10-6.55	DO	50.4									
AA-11-09	09-05	7.62-8.08	DO	31.9	15	46	31						
AA-11-09	09-06	8.53-8.99	DO	31.8									
AA-11-09	09-07	9.14-9.60	DO	39.2									
AA-11-09	09-08	10.06-10.67	TO	32.2								>200	>250
AA-11-11V	11V-01	0.30-0.46	AS	36.7									
AA-11-11V	11V-02	0.76-0.91	AS	33.1									
AA-11-11V	11V-03	1.52-1.98	DO	27.6	18	27	9	42.5	1.5	0.7			
AA-11-11V	11V-04	2.29-2.44	AS	27.8									
AA-11-11V	11V-05	3.05-3.51	DO	25.3									
AA-11-11V	11V-06	3.81-3.96	AS	26.6	12	34	22	55.7	8.9	8.4			
AA-11-11V	11V-07	4.57-5.18	TO	40.7							1396	48	53
AA-11-11V	11V-08	6.10-6.55	DO	29.7									
AA-11-13	13-01	0.30-0.46	AS	45.8									
AA-11-13	13-02	0.76-0.91	AS	39.0									
AA-11-13	13-03	1.52-1.98	DO	37.1	20	61	41	74.6	19.9	30.5			
AA-11-13	13-04	2.29-2.44	AS	35.5									
AA-11-13	13-05	3.05-3.51	DO	37.6									
AA-11-15	15-01	0.30-0.46	AS	39.6									
AA-11-15	15-02	0.76-0.91	AS	27.7	18	49	31	49.4	10.4	10.7			

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

Golder Associates

GENERAL TESTING RESULTS

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / J.F. Date: November 14, 2011

Sample Identification				Laboratory Test Results										
Borehole #	Sample #	Depth (m)	Sample Type	Water Content (%)	Plastic Limit	Liquid Limit	Plasticity Index	% Passing #200	SHT Group Index	ASTM Group Index	Dry Density (kg/m^3)	Pocket Penetrometer (kPa)	Lab Vane (kPa)	
AA-11-15	15-03	1.52-2.13	TO	30.0								>200	209	
AA-11-15	15-04	2.29-2.44	AS	26.0										
AA-11-15	15-05	3.05-3.51	DO	28.5	23	53	30	48.4	10.2	10.2				

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

UNCONFINED COMPRESSIVE STRENGTH

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / G.P. Date: November 14, 2011

Borehole #: AA-11-03 Sample #: 03-03
Source:
Visual Description of Sample: Firm, moist, mottled olive brown and grey, SILTY CLAY, some fine sand.
Date Sample Received: October 12, 2011

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	0	0.0	0.0%	4114.59	0
0.5	0.635	62	90.4	0.4%	4133.13	21.9
1.0	1.270	111	158.3	0.9%	4151.83	38.1
1.5	1.905	153	219.1	1.3%	4170.71	52.5
2.0	2.540	189	272.4	1.8%	4189.75	65.0
2.5	3.175	220	316.0	2.2%	4208.98	75.1
3.0	3.810	243	348.0	2.7%	4228.37	82.3
3.5	4.445	250	357.7	3.1%	4247.95	84.2
4.0	5.080	255	364.6	3.6%	4267.71	85.4
4.5	5.715	250	357.7	4.0%	4287.66	83.4
5.0	6.350	224	321.8	4.5%	4307.79	74.7

Proving Ring: PR5

Sample Dimensions

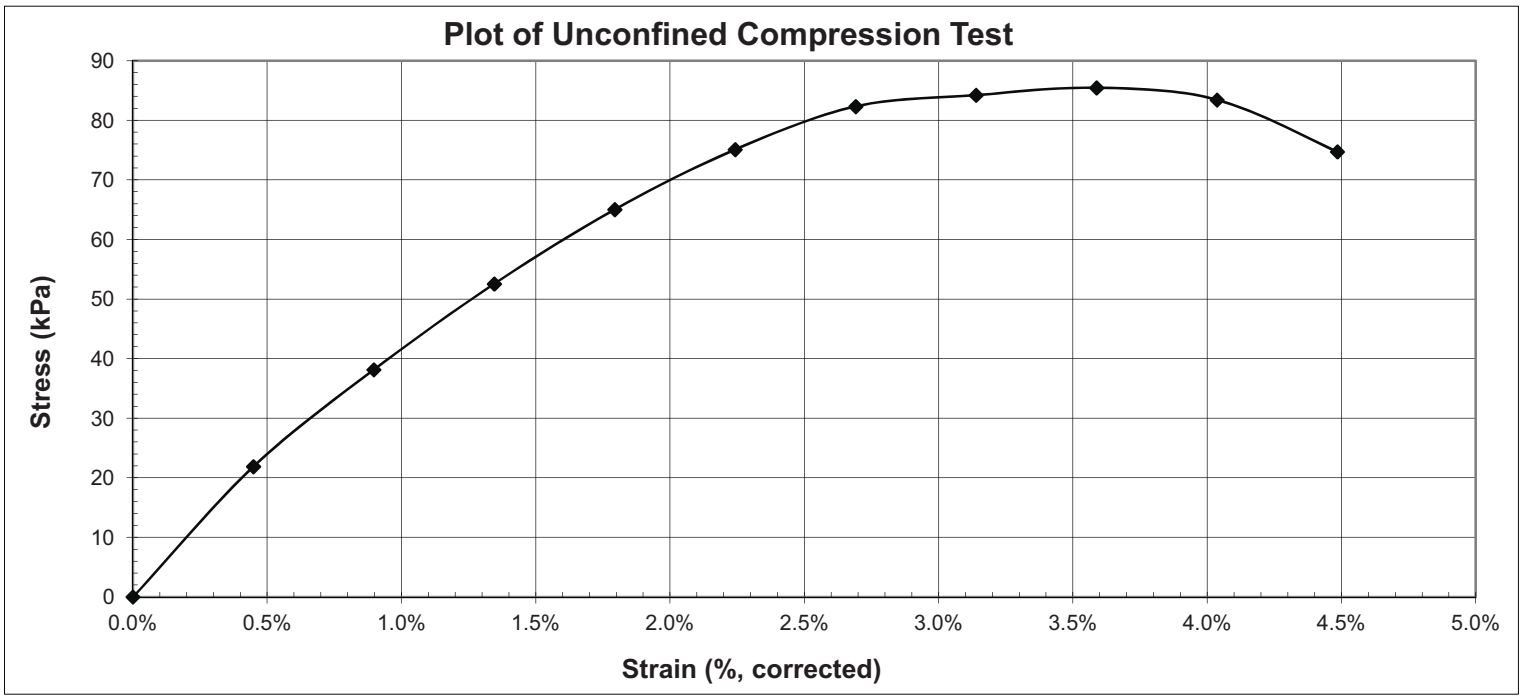
Diameter (mm)	72.38
Length (mm)	141.59

Water Content

Tare #	495
Wet + tare (g)	117.66
Dry + tare (g)	101.93
Water (g)	15.73
Tare (g)	32.31
Dry Soil (g)	69.62
Water Content	22.6%

Test Results

Compressive Stress at Failure (kPa)	85.4
Strain at Failure (%)	3.6
Undrained Shear Strength (kPa)	42.7
Water Content	22.6%



1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

UNCONFINED COMPRESSIVE STRENGTH

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / G.P. Date: November 14, 2011

Borehole #: AA-11-08 Sample #: 08-09
Source:
Visual Description of Sample: Firm, wet, mottled olive brown and grey, Sandy SILTY CLAY.
Date Sample Received: October 12, 2011

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	0	0.0	0.0%	3951.39	0
0.5	0.635	53	77.3	0.4%	3965.50	19.5
1.0	1.270	79	114.6	0.7%	3979.71	28.8
1.5	1.905	101	143.3	1.1%	3994.03	35.9
2.0	2.540	119	170.3	1.4%	4008.44	42.5
2.5	3.175	135	193.4	1.8%	4022.97	48.1
3.0	3.810	149	213.0	2.1%	4037.59	52.8
3.5	4.445	159	228.5	2.5%	4052.33	56.4
4.0	5.080	167	241.1	2.8%	4067.17	59.3
4.5	5.715	171	247.3	3.2%	4082.12	60.6
5.0	6.350	172	248.9	3.6%	4097.18	60.7
5.5	6.985	173	250.5	3.9%	4112.36	60.9
6.0	7.620	172	248.9	4.3%	4127.64	60.3
6.5	8.255	169	244.2	4.6%	4143.04	58.9

Proving Ring: PR5

Sample Dimensions

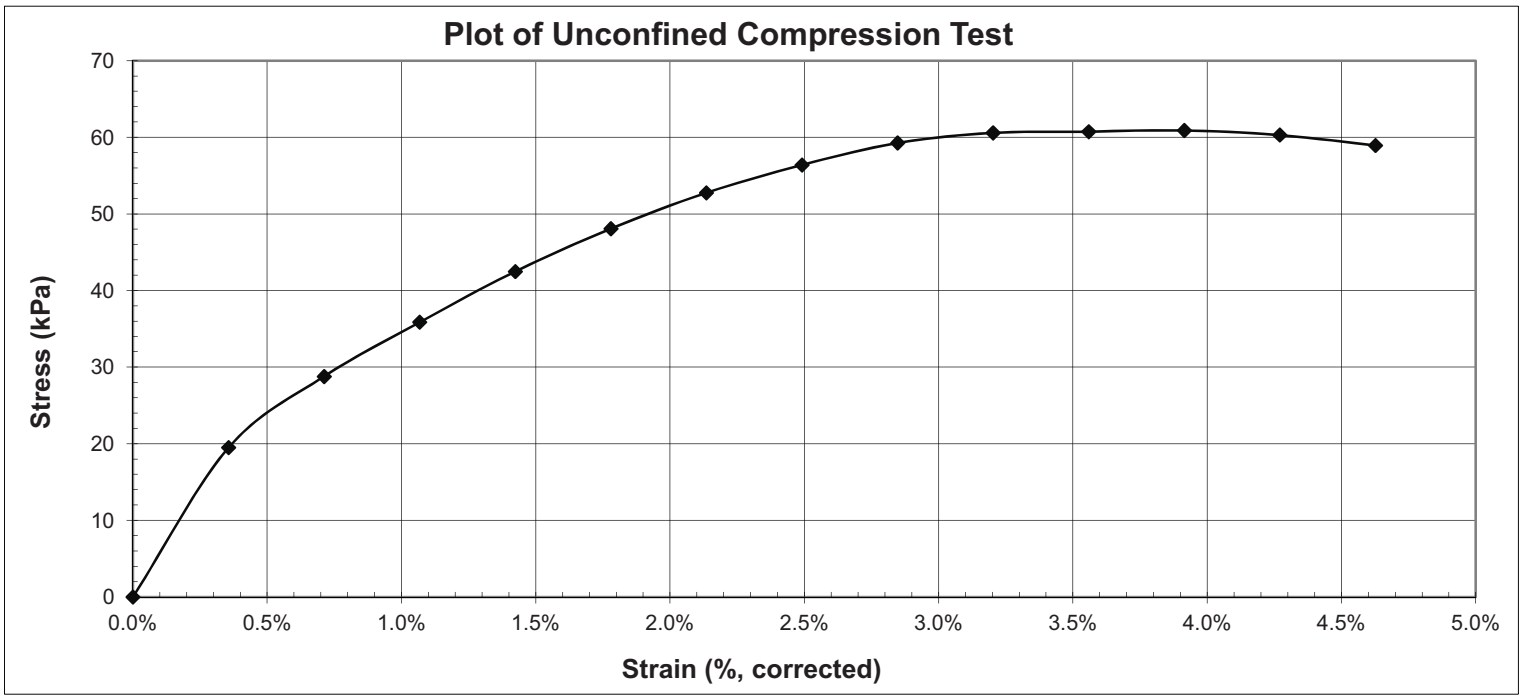
Diameter (mm)	70.93
Length (mm)	178.45

Water Content

Tare #	337
Wet + tare (g)	96.00
Dry + tare (g)	80.04
Water (g)	15.96
Tare (g)	32.06
Dry Soil (g)	47.98
Water Content	33.3%

Test Results

Compressive Stress at Failure (kPa)	60.9
Strain at Failure (%)	3.9
Undrained Shear Strength (kPa)	30.5
Water Content	33.3%



1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

UNCONFINED COMPRESSIVE STRENGTH

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / G.P. Date: November 14, 2011

Borehole #: AA-11-09 Sample #: 09-03
Source:
Visual Description of Sample: Soft, moist, mottled olive brown and grey, SILTY CLAY, trace sand.
Date Sample Received: October 12, 2011

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	0	0.0	0.0%	4131.67	0
0.5	0.635	37	53.7	0.4%	4148.26	13.0
1.0	1.270	82	118.5	0.8%	4165.00	28.4
1.5	1.905	115	164.3	1.2%	4181.86	39.3
2.0	2.540	148	211.6	1.6%	4198.87	50.4
2.5	3.175	172	248.9	2.0%	4216.01	59.0
3.0	3.810	191	275.1	2.4%	4233.30	65.0
3.5	4.445	208	298.7	2.8%	4250.72	70.3
4.0	5.080	216	310.2	3.2%	4268.29	72.7
4.5	5.715	220	316.0	3.6%	4286.01	73.7
5.0	6.350	225	323.2	4.0%	4303.88	75.1
5.5	6.985	227	326.0	4.4%	4321.89	75.4
6.0	7.620	229	328.7	4.8%	4340.05	75.7
6.5	8.255	231	331.5	5.2%	4358.37	76.1
7.0	8.890	232	332.9	5.6%	4376.85	76.0
7.5	9.525	231	331.5	6.0%	4395.48	75.4
8.0	10.160	229	328.7	6.4%	4414.27	74.5

Proving Ring: PR5

Sample Dimensions

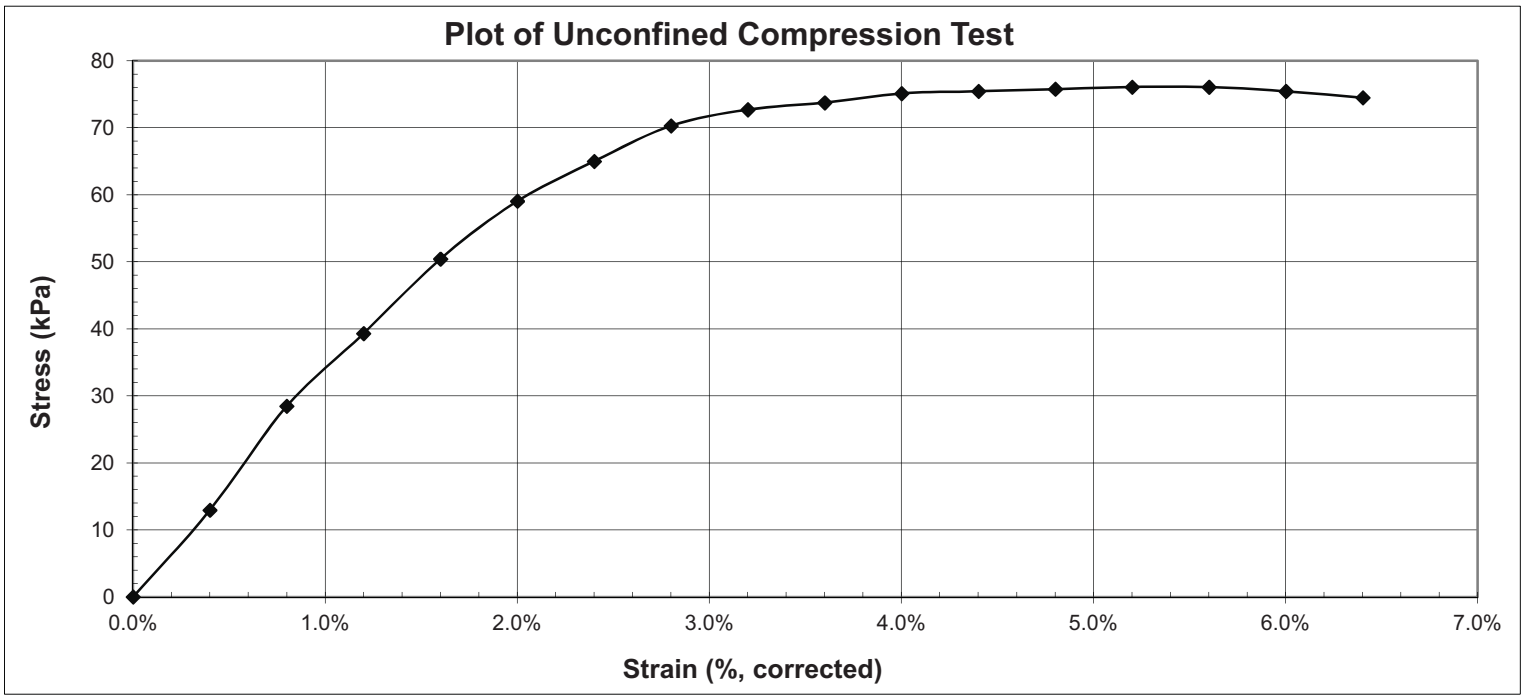
Diameter (mm)	72.53
Length (mm)	158.70

Water Content

Tare #	711
Wet + tare (g)	106.95
Dry + tare (g)	90.45
Water (g)	16.50
Tare (g)	31.83
Dry Soil (g)	58.62
Water Content	28.1%

Test Results

Compressive Stress at Failure (kPa)	76.1
Strain at Failure (%)	5.2
Undrained Shear Strength (kPa)	38.0
Water Content	28.1%



1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

UNCONFINED COMPRESSIVE STRENGTH

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / G.P. Date: November 14, 2011

Borehole #: AA-11-11 Sample #: 11-07
Source:
Visual Description of Sample: Soft, moist, grey, SILTY CLAY with fine SAND.
Date Sample Received: October 12, 2011

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	0	0.0	0.0%	4143.07	0
1.0	0.635	25	36.0	0.4%	4161.40	8.6
2.0	1.270	40	58.2	0.9%	4179.89	13.9
3.0	1.905	54	78.8	1.3%	4198.54	18.8
4.0	2.540	65	94.8	1.8%	4217.37	22.5
5.0	3.175	74	107.9	2.2%	4236.36	25.5
6.0	3.810	82	118.5	2.6%	4255.53	27.8
7.0	4.445	89	127.5	3.1%	4274.87	29.8
8.0	5.080	95	135.3	3.5%	4294.38	31.5
9.0	5.715	101	143.3	4.0%	4314.08	33.2
10.0	6.350	107	152.3	4.4%	4333.96	35.1
11.0	6.985	111	158.3	4.8%	4354.02	36.4
12.0	7.620	114	162.8	5.3%	4374.27	37.2
13.0	8.255	118	168.8	5.7%	4394.70	38.4
14.0	8.890	121	173.3	6.2%	4415.33	39.3
15.0	9.525	123	176.3	6.6%	4436.15	39.8
16.0	10.160	126	180.8	7.0%	4457.17	40.6
17.0	10.795	129	185.0	7.5%	4478.40	41.3
18.0	11.430	131	187.8	7.9%	4499.82	41.7

Proving Ring: PR5

Sample Dimensions

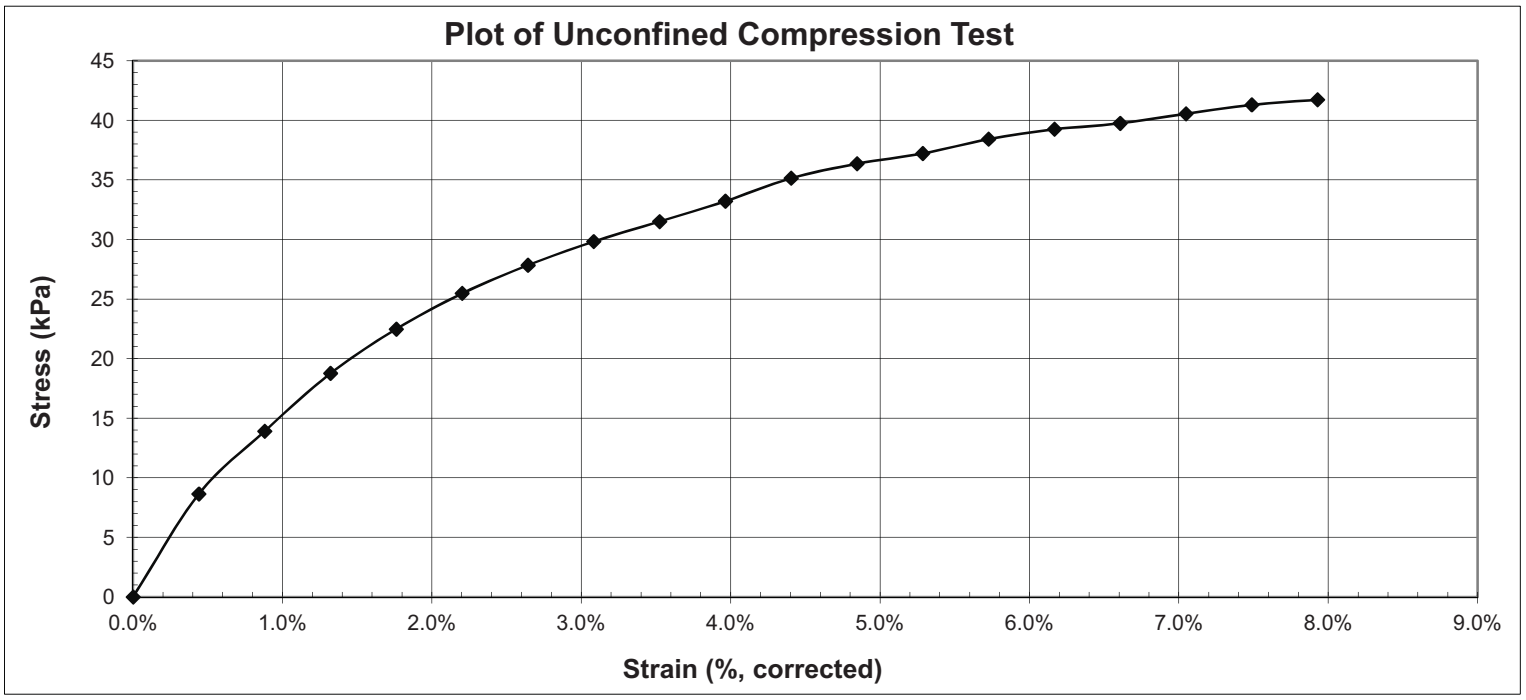
Diameter (mm)	72.63
Length (mm)	144.17

Water Content

Tare #	509
Wet + tare (g)	97.40
Dry + tare (g)	82.31
Water (g)	15.09
Tare (g)	31.80
Dry Soil (g)	50.51
Water Content	29.9%

Test Results

Compressive Stress at Failure (kPa)	41.7
Strain at Failure (%)	7.9
Undrained Shear Strength (kPa)	20.9
Water Content	29.9%



1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

UNCONFINED COMPRESSIVE STRENGTH

Project #: 11-1362-0114 Phase: 3000
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: R.S. / G.P. Date: November 14, 2011

Borehole #: AA-11-15 Sample #: 15-03
Source:
Visual Description of Sample: Very stiff, moist, mottled olive brown and grey, fine SAND with CLAY, Fe staining (SHALE).
Date Sample Received: October 12, 2011

Time (min)	Strain Dial (mm)	Load Dial (1/1000 in)	Load (N)	Unit Strain	Corr Area (mm^2)	Stress (kPa)
0.0	0.000	0	0.0	0.0%	4131.67	0
0.5	0.635	52	75.9	0.5%	4150.78	18.3
1.0	1.270	106	150.8	0.9%	4170.06	36.2
1.5	1.905	156	223.8	1.4%	4189.53	53.4
2.0	2.540	180	260.3	1.8%	4209.18	61.8
2.5	3.175	202	290.0	2.3%	4229.01	68.6
3.0	3.810	220	316.0	2.8%	4249.04	74.4
3.5	4.445	201	288.6	3.2%	4269.25	67.6

Proving Ring: PR5

Sample Dimensions

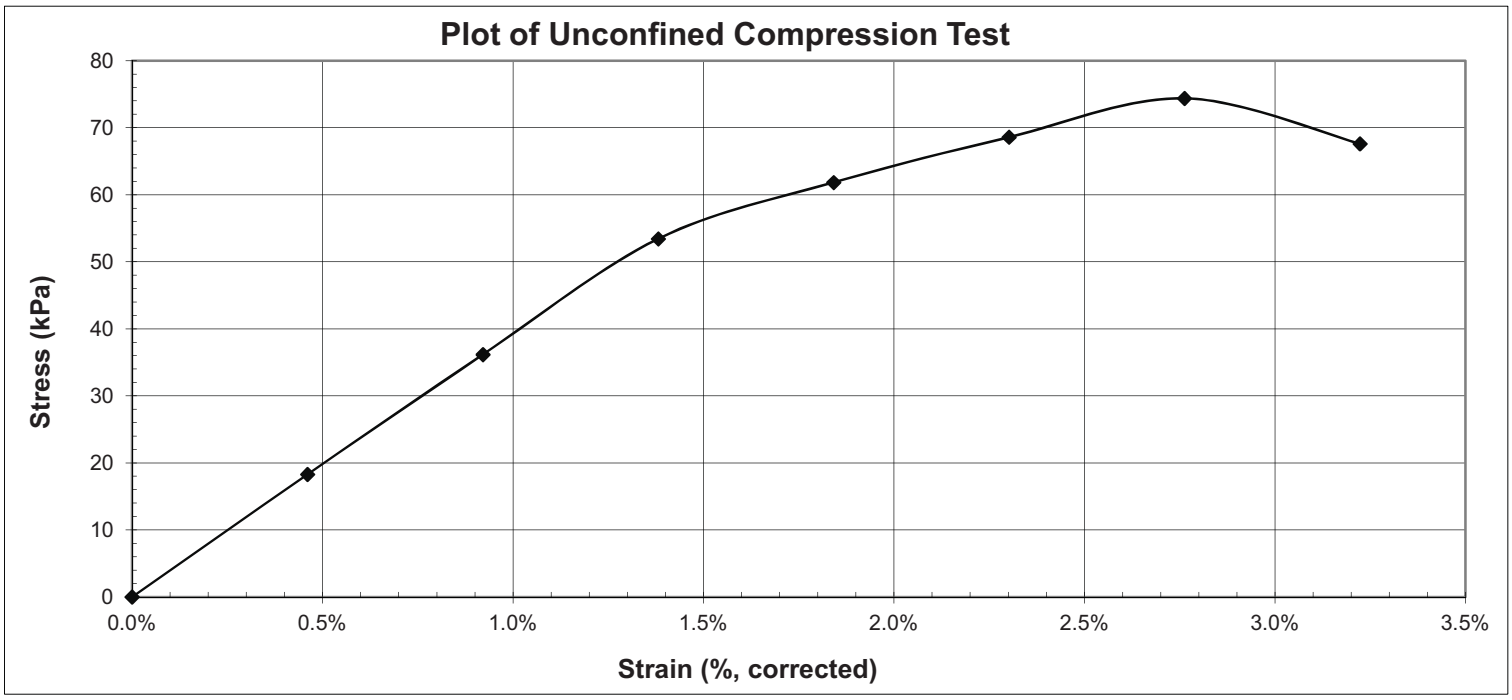
Diameter (mm)	72.53
Length (mm)	137.93

Water Content

Tare #	267
Wet + tare (g)	84.33
Dry + tare (g)	75.45
Water (g)	8.88
Tare (g)	32.02
Dry Soil (g)	43.43
Water Content	20.4%

Test Results

Compressive Stress at Failure (kPa)	74.4
Strain at Failure (%)	7.9
Undrained Shear Strength (kPa)	37.2
Water Content	20.4%



1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GRAIN SIZE ANALYSIS - ASTM D422

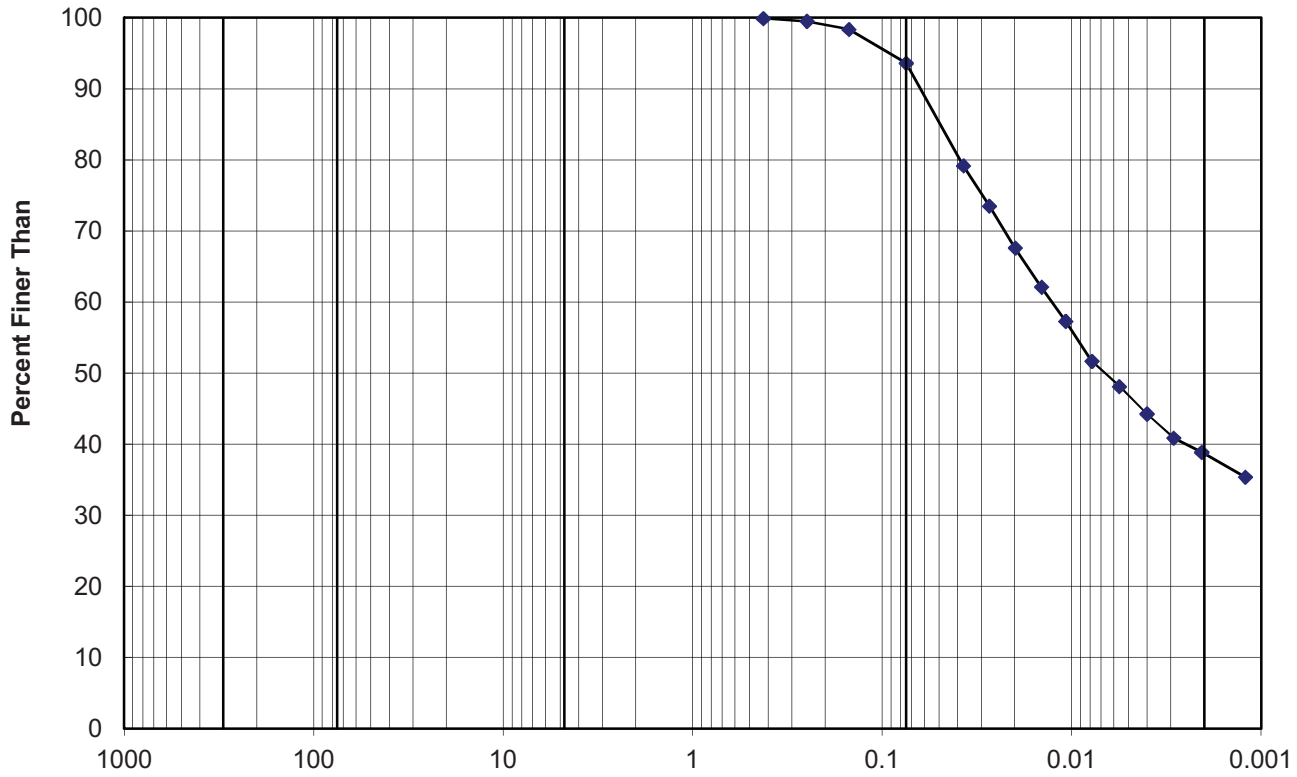
(Mechanical & Hydrometer)

Project #: 11-1362-0114
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: C.Z. / R.S.

Phase: 3000
Date: November 10, 2011

Borehole #: AA-11-01V Sample #: 01V-04
Source:
Date Sample Received: October 12, 2011

Graphical Analysis



BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		Coarse	Fine	Coarse	Medium	Fine		

Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
152	100
76	100
38	100
19	100
9.5	100
4.75	100
2.00	100
0.850	100
0.425	100
0.250	99
0.150	98
0.075	94
0.037	79
0.027	73
0.020	68
0.014	62
0.011	57
0.008	52
0.006	48
0.004	44
0.003	41
0.002	39
0.001	35

Comments:

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GRAIN SIZE ANALYSIS - ASTM D422

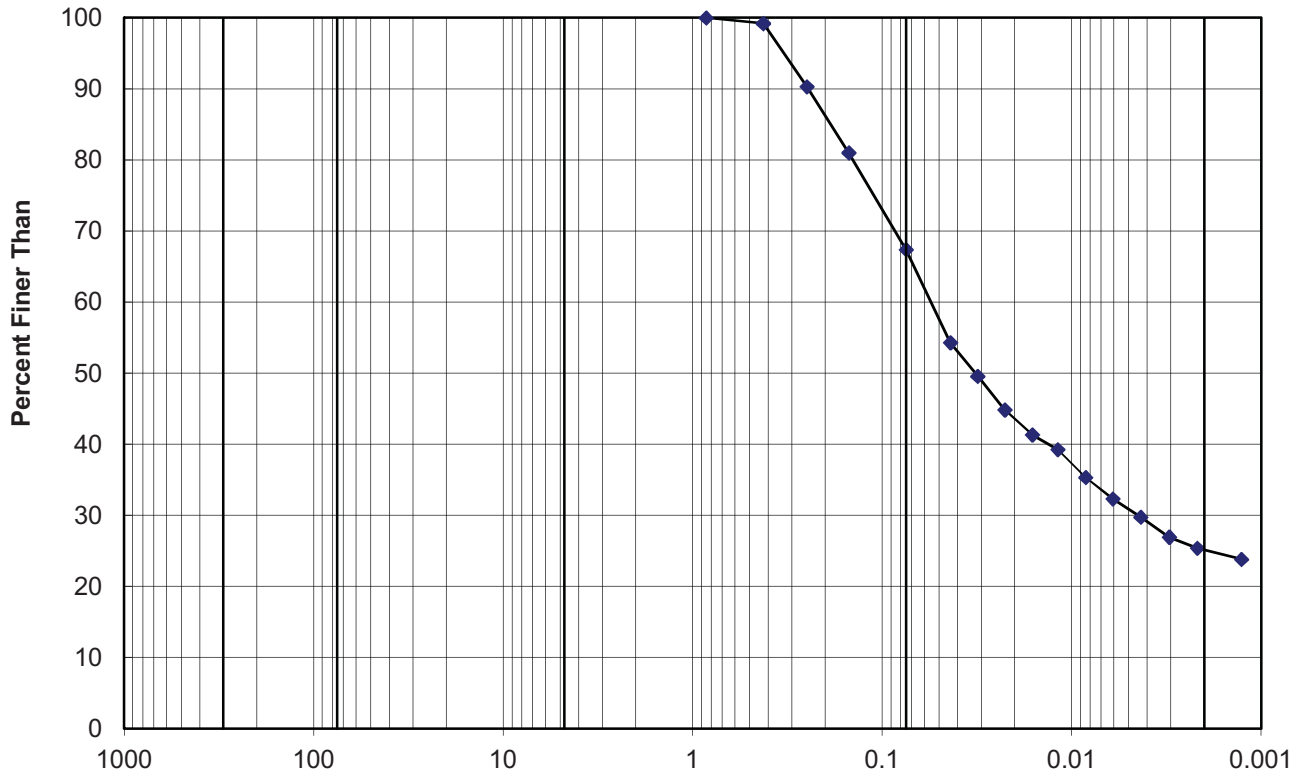
(Mechanical & Hydrometer)

Project #: 11-1362-0114
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: C.Z. / R.S.

Phase: 3000
Date: November 10, 2011

Borehole #: AA-11-05 Sample #: 05-06
Source:
Date Sample Received: October 12, 2011

Graphical Analysis



BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		Coarse	Fine	Coarse	Medium	Fine		

Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
152	100
76	100
38	100
19	100
9.5	100
4.75	100
2.00	100
0.850	100
0.425	99
0.250	90
0.150	81
0.075	67
0.044	54
0.031	50
0.023	45
0.016	41
0.012	39
0.008	35
0.006	32
0.004	30
0.003	27
0.002	25
0.001	24

Comments:

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GRAIN SIZE ANALYSIS - ASTM D422

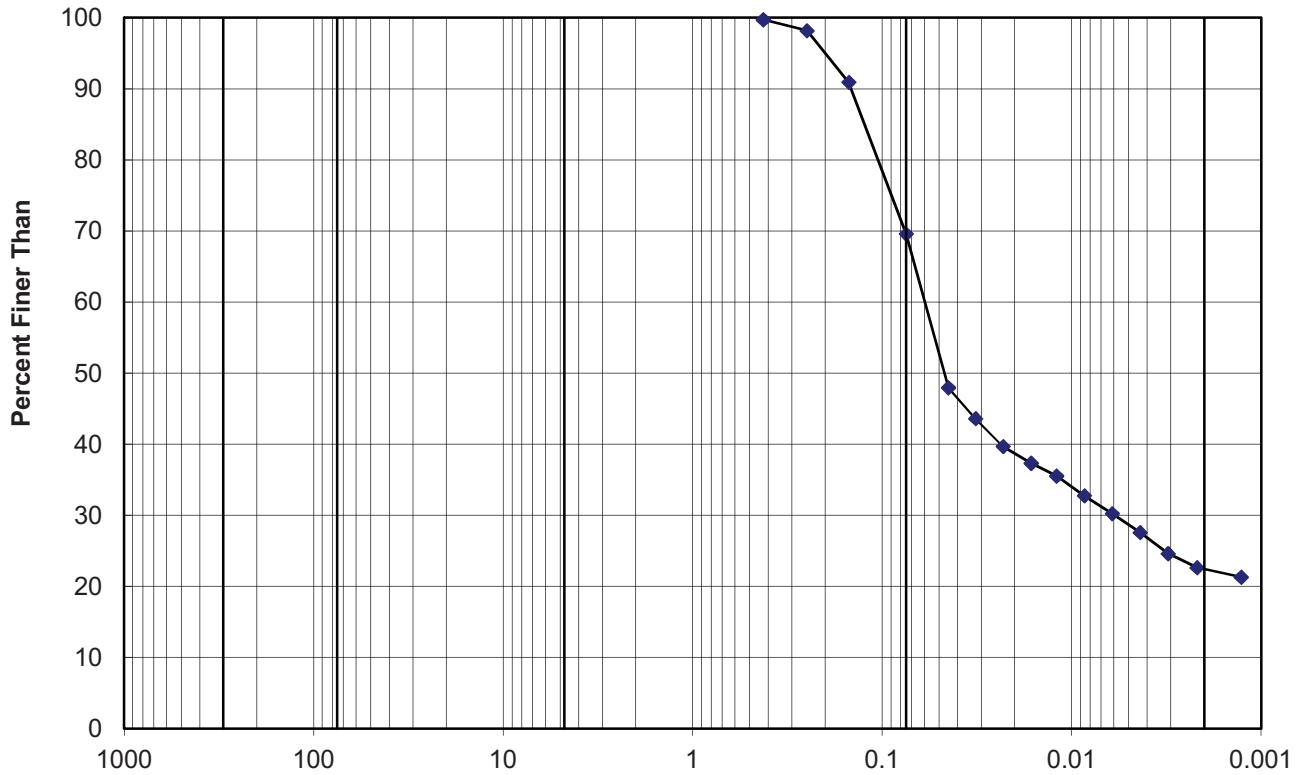
(Mechanical & Hydrometer)

Project #: 11-1362-0114
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: C.Z. / R.S.

Phase: 3000
Date: November 10, 2011

Borehole #: AA-11-07V Sample #: 07V-04
Source:
Date Sample Received: October 12, 2011

Graphical Analysis



BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		Coarse	Fine	Coarse	Medium	Fine		

Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
152	100
76	100
38	100
19	100
9.5	100
4.75	100
2.00	100
0.850	100
0.425	100
0.250	98
0.150	91
0.075	70
0.045	48
0.032	44
0.023	40
0.016	37
0.012	36
0.009	33
0.006	30
0.004	28
0.003	25
0.002	23
0.001	21

Comments:

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GRAIN SIZE ANALYSIS - ASTM D422

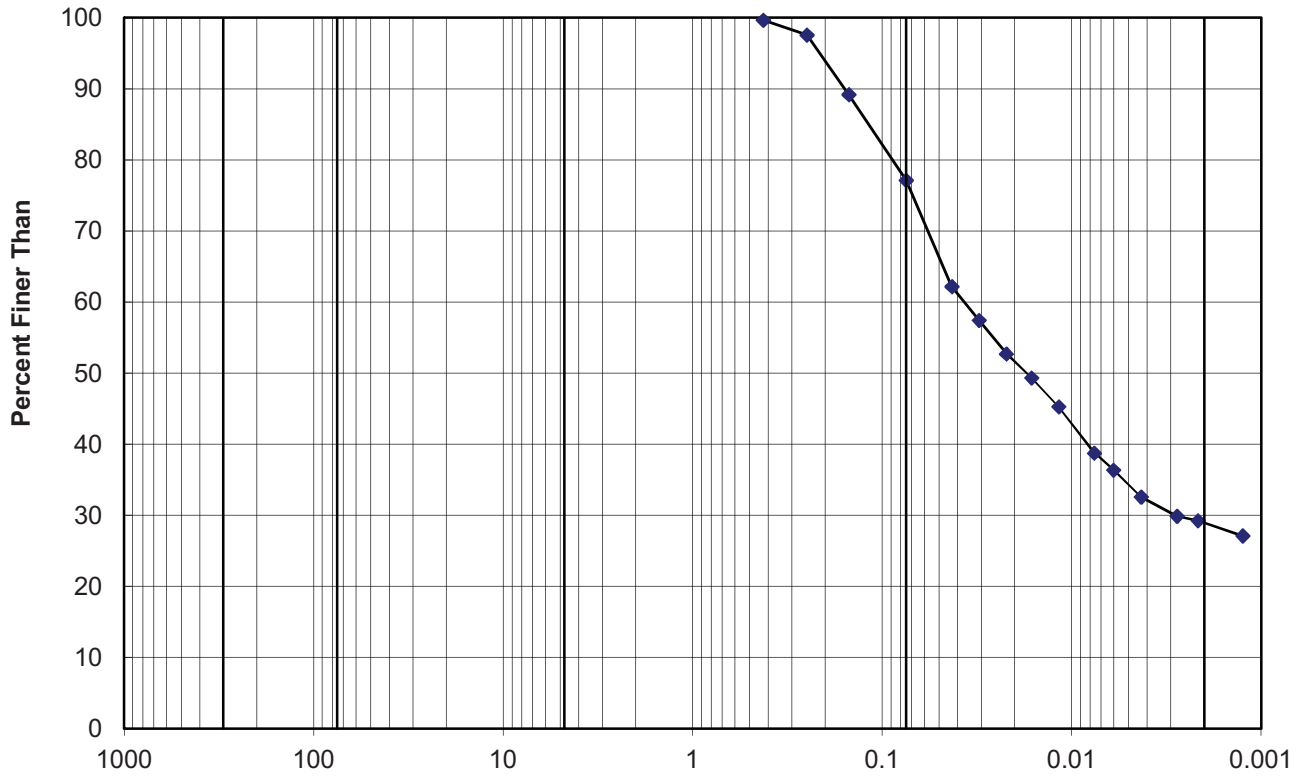
(Mechanical & Hydrometer)

Project #: 11-1362-0114
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: C.Z. / R.S.

Phase: 3000
Date: November 10, 2011

Borehole #: AA-11-09V Sample #: 09V-02
Source:
Date Sample Received: October 12, 2011

Graphical Analysis



BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		Coarse	Fine	Coarse	Medium	Fine		

Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
152	100
76	100
38	100
19	100
9.5	100
4.75	100
2.00	100
0.850	100
0.425	100
0.250	98
0.150	89
0.075	77
0.043	62
0.031	57
0.022	53
0.016	49
0.012	45
0.008	39
0.006	36
0.004	33
0.003	30
0.002	29
0.001	27

Comments:

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

GRAIN SIZE ANALYSIS - ASTM D422

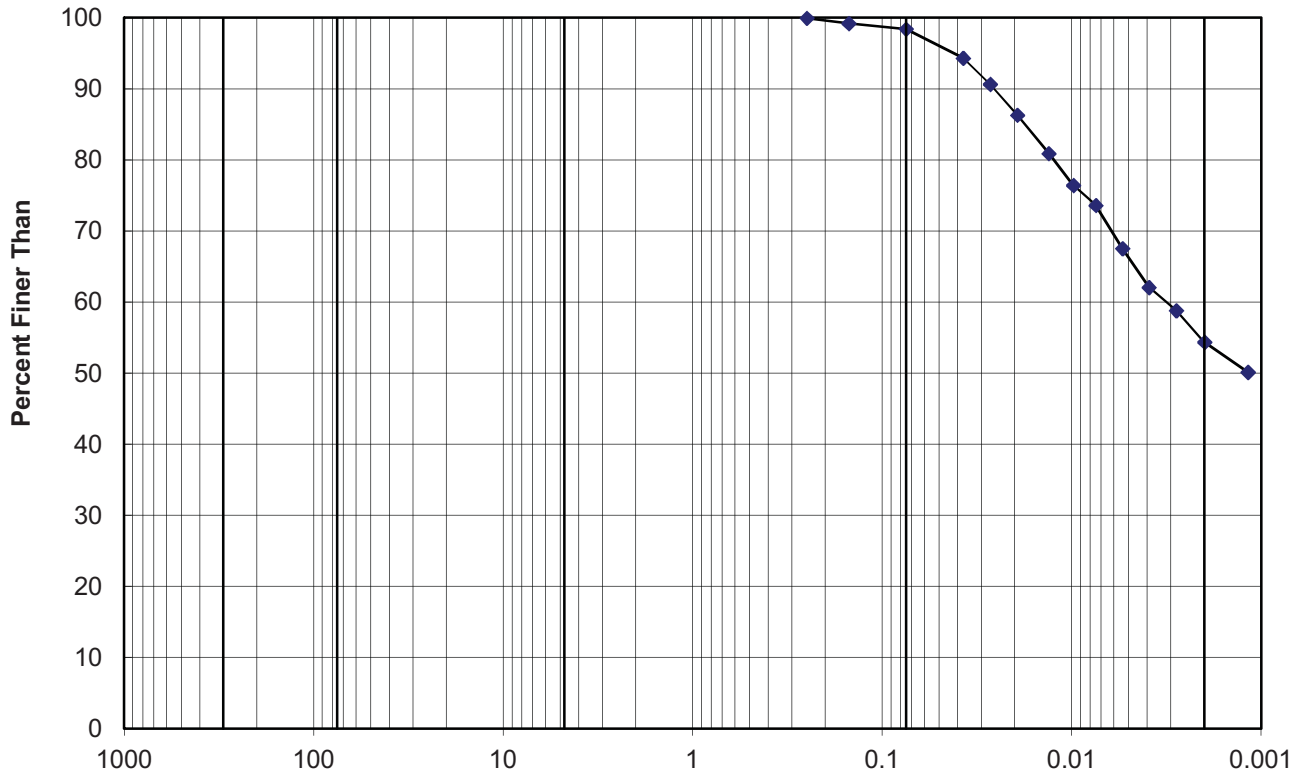
(Mechanical & Hydrometer)

Project #: 11-1362-0114
Short Title: Highfield Dam Embankment Foundation Assessment
Tested by: C.Z. / R.S.

Phase: 3000
Date: November 10, 2011

Borehole #: AA-11-09V Sample #: 09V-04
Source:
Date Sample Received: October 12, 2011

Graphical Analysis



BOULDERS	COBBLES	GRAVEL		SAND			SILT	CLAY
		Coarse	Fine	Coarse	Medium	Fine		

Grain Size Analysis Results:

Opening (mm)	Percent Passing (%)
152	100
76	100
38	100
19	100
9.5	100
4.75	100
2.00	100
0.850	100
0.425	100
0.250	100
0.150	99
0.075	98
0.037	94
0.027	91
0.019	86
0.013	81
0.010	76
0.007	74
0.005	68
0.004	62
0.003	59
0.002	54
0.001	50

Comments:

1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

ONE-DIMENSIONAL CONSOLIDATION TEST

Project #:	11-1362-0114	Phase:	3000
Short Title:	Highfield Dam Embankment Foundation Assessment		
Tested By:	D.B.	Date:	November 25, 2011
Sample:	AA-11-03 SA-03-03		

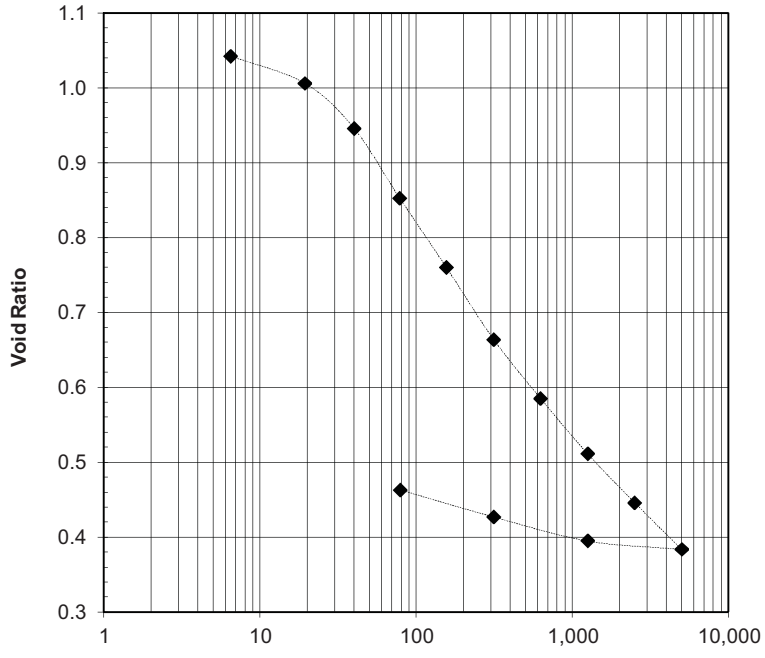
Test Results:

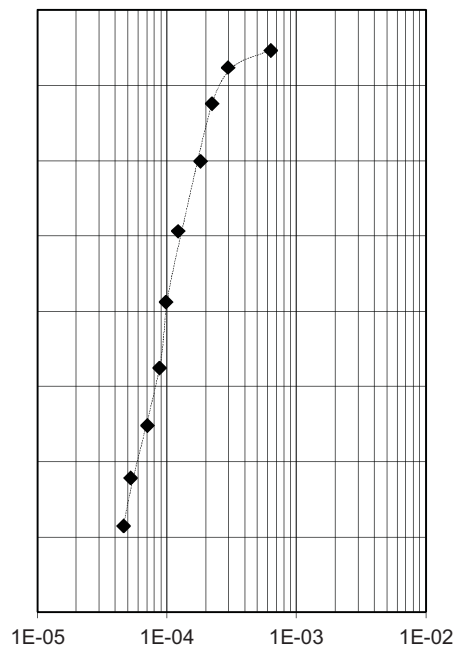
Void Ratio versus Stress		Coefficient of Consolidation	
Effective Stress (kPa)	Void Ratio	Average Void Ratio	c_v (cm^2/s)
6.5	1.04	1.05	6.3E-04
19	1.01	1.02	3.0E-04
40	0.95	0.98	2.2E-04
78	0.85	0.90	1.8E-04
156	0.76	0.81	1.2E-04
313	0.66	0.71	9.8E-05
624	0.59	0.62	8.7E-05
1251	0.51	0.55	7.1E-05
2501	0.45	0.48	5.2E-05
4999	0.38	0.42	4.6E-05
1249	0.40		
313	0.43		
79	0.46		

Sample Data:

Specific gravity:	2.7	(assumed)
Diameter:	63.9	mm
Initial height:	26.0	mm
Initial water content:	35.2	% (prior to saturation)
Initial dry density:	1316	kg/m^3 (prior to loading)
Initial void ratio:	1.05	(prior to loading)
Final water content:	17.1	%
Final dry density:	1848	kg/m^3

Comments:





1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

ONE-DIMENSIONAL CONSOLIDATION TEST

Project #:	11-1362-0114	Phase:	3000
Short Title:	Highfield Dam Embankment Foundation Assessment		
Tested By:	D.B.	Date:	November 25, 2011
Sample:	AA-11-07V SA-07V-03		

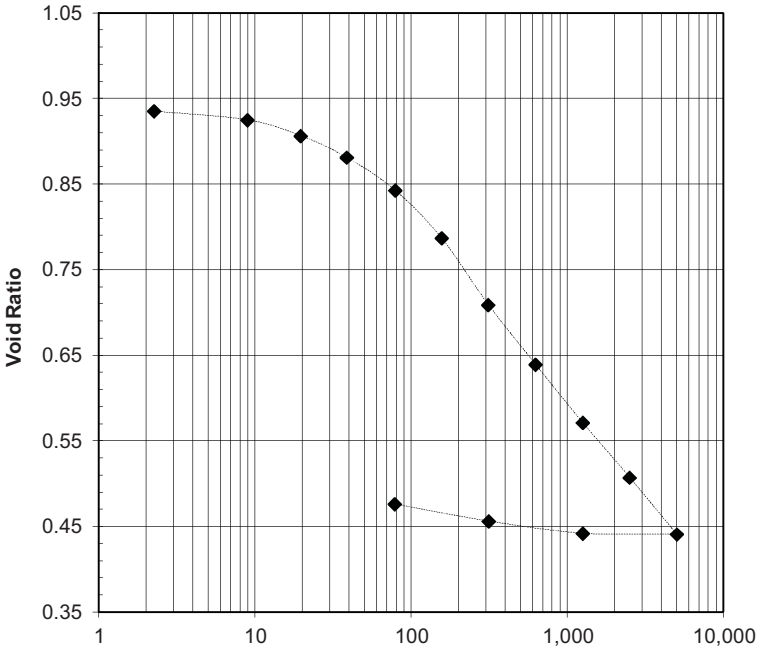
Test Results:

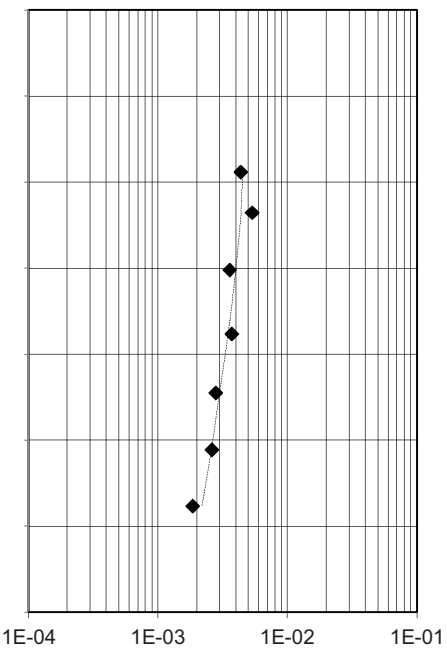
Void Ratio versus Stress		Coefficient of Consolidation	
Effective Stress (kPa)	Void Ratio	Average Void Ratio	c_v (cm^2/s)
2.3	0.93		
8.9	0.92		
20	0.91		
39	0.88		
79	0.84	0.86	4.3E-03
156	0.79	0.81	5.3E-03
311	0.71	0.75	3.6E-03
625	0.64	0.67	3.7E-03
1250	0.57	0.61	2.8E-03
2500	0.51	0.54	2.6E-03
5001	0.44	0.47	1.8E-03
1250	0.44		
313	0.46		
78	0.48		

Sample Data:

Specific gravity:	2.7	(assumed)
Diameter:	63.9	mm
Initial height:	25.2	mm
Initial water content:	33.0	% (prior to saturation)
Initial dry density:	1395	kg/m^3 (prior to loading)
Initial void ratio:	0.93	(prior to loading)
Final water content:	17.2	%
Final dry density:	1832	kg/m^3

Comments:





1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

ONE-DIMENSIONAL CONSOLIDATION TEST

Project #:	11-1362-0114	Phase:	3000
Short Title:	Highfield Dam Embankment Foundation Assessment		
Tested By:	D.B.	Date:	November 25, 2011
Sample:	AA-11-09 SA-09-03		

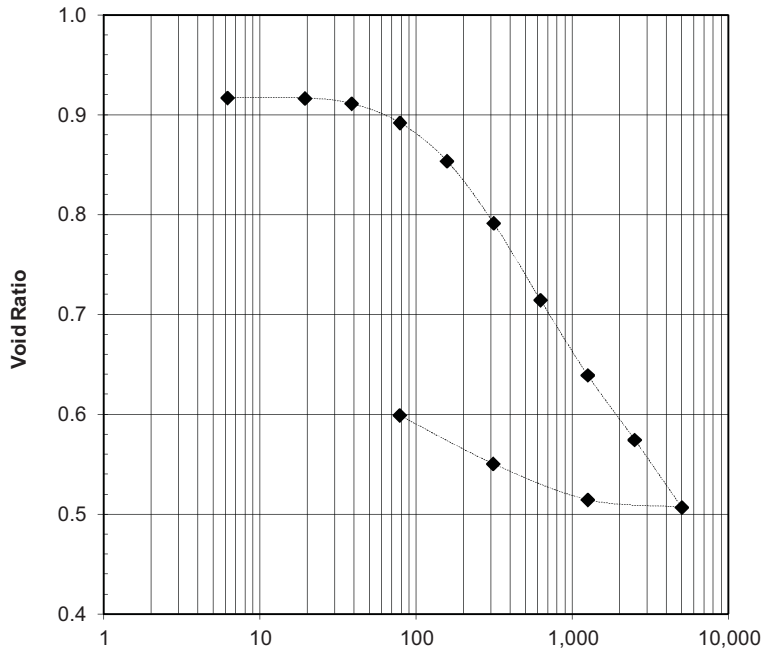
Test Results:

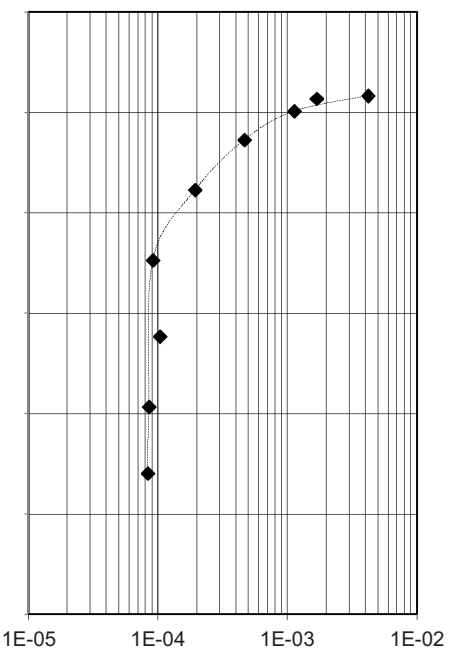
Void Ratio versus Stress		Coefficient of Consolidation	
Effective Stress (kPa)	Void Ratio	Average Void Ratio	c_v (cm^2/s)
6.2	0.92		
19	0.92	0.92	4.2E-03
38	0.91	0.91	1.7E-03
79	0.89	0.90	1.1E-03
157	0.85	0.87	4.7E-04
312	0.79	0.82	1.9E-04
624	0.71	0.75	9.2E-05
1250	0.64	0.68	1.0E-04
2501	0.57	0.61	8.5E-05
4999	0.51	0.54	8.4E-05
1250	0.51		
311	0.55		
78	0.60		

Sample Data:

Specific gravity:	2.75	(assumed)
Diameter:	63.9	mm
Initial height:	26.8	mm
Initial water content:	26.8	% (prior to saturation)
Initial dry density:	1435	kg/m^3 (prior to loading)
Initial void ratio:	0.92	(prior to loading)
Final water content:	22.9	%
Final dry density:	1722	kg/m^3

Comments:





1721 8th Street E.,
Saskatoon, Saskatchewan, S7H 0T4

Reviewed by:

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS SHEET 1 OF 4			FIGURE
TEST STAGE	A	B	C
BOREHOLE NUMBER	AA-11-C8	AA-11-05	AA-11-05
SAMPLE	-	-	-
SPECIMEN DIAMETER, cm	7.16	7.19	7.11
SPECIMEN HEIGHT, cm	13.32	13.44	12.99
NATURAL WATER CONTENT, %	23.2	34.3	-
DRY DENSITY, Mg/m^3	1.66	1.40	-
WATER CONTENT AFTER SATURATION, %	24.1	34.5	32.2
CELL PRESSURE, σ_3, kPa	325.0	285.0	435.0
BACK PRESSURE, kPa	275.0	135.0	135.0
PORE PRESSURE PARAMETER "B"	0.96	0.99	-
CONSOLIDATION PRESSURE, σc, kPa	50.0	150.0	300.0
VOLUMETRIC STRAIN DURING CONSOLIDATION, %	1.8	3.2	3.8
WATER CONTENT AFTER CONSOLIDATION, %	23.0	32.2	29.7
AVERAGE RATE OF STRAIN, %/hr	0.5	0.5	0.5
TIME TO FAILURE, HOURS	42.1	5.8	43.4
WATER CONTENT AFTER TEST, %	20.3	-	24.3
MAX. DEVIATOR STRESS, $(\sigma_1-\sigma_3)$, kPa	195.9	97.0	231.1
AXIAL STRAIN AT $(\sigma_1-\sigma_3)$ maximum, %	21.0	2.9	21.7
MAX EFFECTIVE PRINCIPAL STRESS RATIO, (σ'_1/σ'_3) maximum	3.4	2.6	3.0
DEVIATOR STRESS AT (σ'_1/σ'_3) maximum, kPa	172.8	97.0	218.2
AXIAL STRAIN AT (σ'_1/σ'_3) maximum, %	9.1	2.9	7.6
PORE PRESSURE PARAMETER, Af, AT $(\sigma_1-\sigma_3)$ maximum	-0.21	0.92	0.76
PORE PRESSURE PARAMETER, Af, AT (σ'_1/σ'_3) maximum	-0.13	0.92	0.87
FILTER DRAINS USED, y/n	y	y	y
TEST NOTES:			
CHANGED RATE OF STRAIN, %/hr	-	-	-
AXIAL STRAIN WHERE RATE OF STRAIN WAS CHANGED, %	-	-	-
FAILURE PLANE NUMBER	1.0	-	-
ANGLE OF FAILURE, DEGREES	65.0	BULGED	BULGED

Date: 11/16/2011

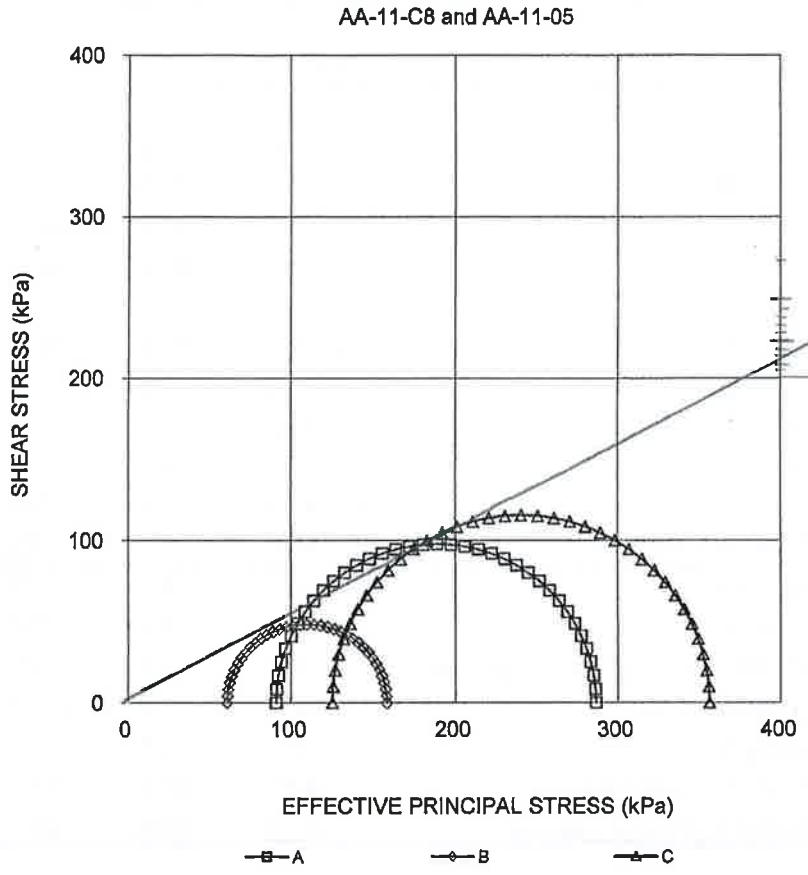
Project No. 11-1362-0114

Golder Associates

Prepared By LH

Checked By:

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS SHEET 2 OF 4	FIGURE



$\phi = \tan^{-1}\left(\frac{214\,kPa}{400\,kPa}\right)$

$\phi = 28.1°$

(Friction angle)

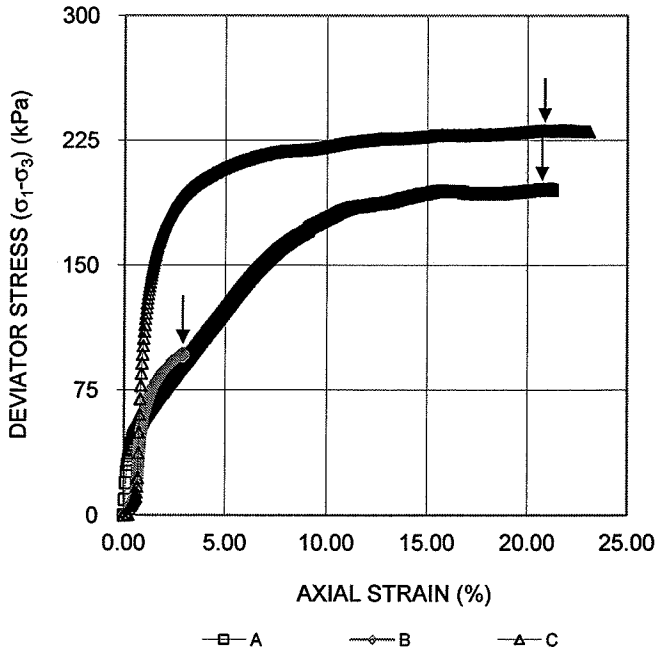
Date: 11/16/2011
Project No. 11-1362-0114

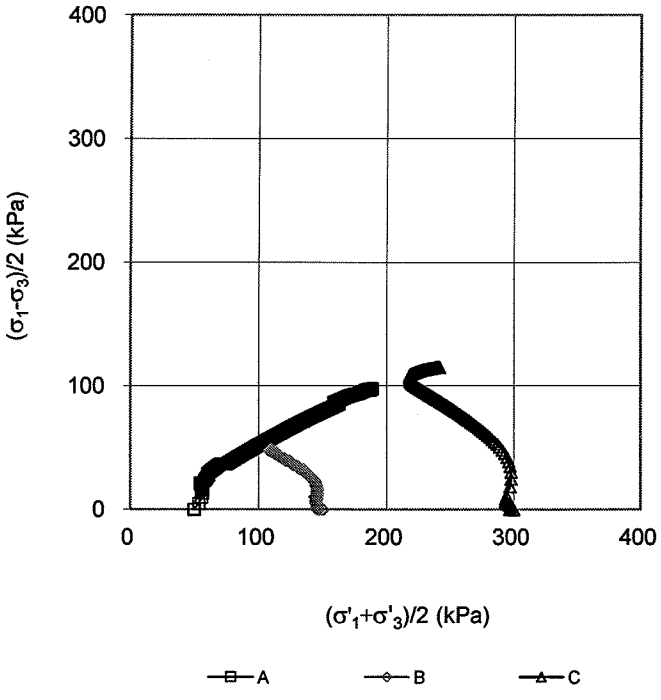
Golder Associates

Prepared By LH
Checked By:

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS SHEET 3 OF 4	FIGURE

AA-11-C8 and AA-11-05



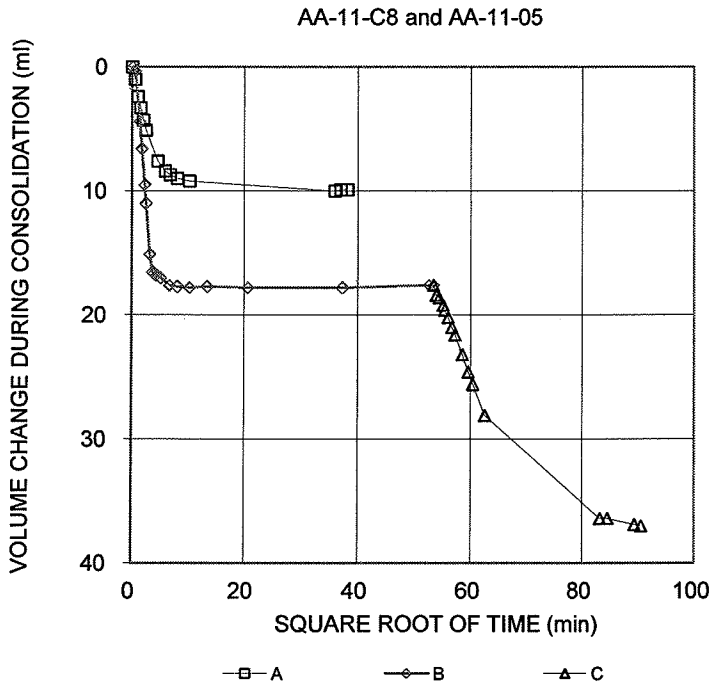


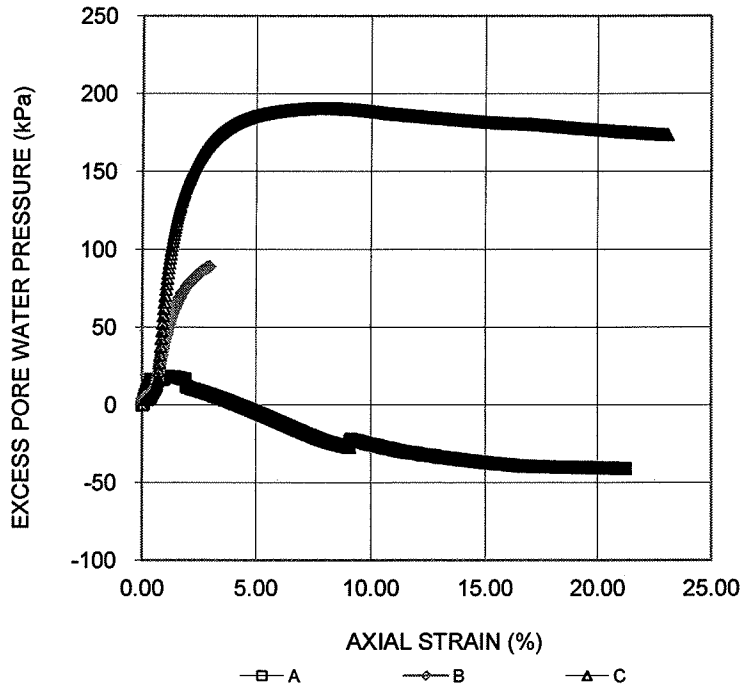
Date: 11/16/2011
Project No. 11-1362-0114

Golder Associates

Prepared By LH
Checked By:

CONSOLIDATED UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENTS SHEET 4 OF 4	FIGURE





Date: 11/16/2011

Project No. 11-1362-0114

Golder Associates

Prepared By LH

Checked By:

APPENDIX E

Vibrating Wire Piezometer Information

rst INSTRUMENTS

Calibration Record

Oct. 4/11

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
Tel: 604.540.1100 • Fax: 604.540.1005 • Toll Free: 1.800.665.5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

→ AA-11-1V
@ 840am – -6.88kPa @ 17.3°C
Baro – 100.62 kPa

Vibrating Wire Piezometer

Customer:		Golder Associate-Saskatoon
Model:		VW2100-0.7
Serial Number:		**VW18880**
Mfg Number:		1115745
Range:		700.0 kPa
Temperature:		24.3 °C
Barometric Pressure:		983.2 millibars
Work Order Number:		032886
Cable Length:		30 meters
Cable Markings:		100068 m - 100096 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 Kohms

~~Prior to install @ 924am Soaked~~
~~-5.11kPa @ 12.3°C~~
~~Baro - 100.62 kPa~~
~~→ At depth @ 12' @ 942am~~
~~27.60 kPa @ 10.2°C~~
~~Baro - 100.62 kPa~~

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	9055	9056	9056	0.9	0.14	0.01
140.0	8263	8264	8264	139.8	-0.03	-0.01
280.0	7468	7468	7468	279.2	-0.11	-0.01
420.0	6669	6668	6669	419.3	-0.10	0.01
560.0	5867	5866	5867	559.9	-0.01	0.01
700.0	5063	5062	5063	700.8	0.12	-0.01
				Max. Error (%):	0.14	0.01

Prior to install - soaked
– -5.45kPa @ 16.8°C
Baro – 100.54kPa
@ 11:07am
At depth @ 16.5'
@ 11:37am
→ 20.54kPa @ 13.4°C

Linear Calibration Factor:	**C.F.=**	**0.17528 kPa/B unit**
Regression Zero:	**At Calibration =**	**9060.9 B unit**
Temperature Correction Factor:	**Tk =**	**0.002645 kPa/°C rise**

Polynomial Gage Factors (kPa) **A:** -4.2193E-07 **B:** -0.16932 **C:** 1567.9

Pressure is calculated with the following equations:

Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$

Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	16-Sep-11	9043	21.7	1015.9

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = Hz^2 / 1000 ie: 1700Hz = 2890 B units

Technician: J. Chung *(signature)* Date: 16-Sep-11

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Applied Science Technologists and Technicians of British Columbia
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Document Number.: ELL0130K

MIG0106A

Calibration Record

Oct 4/11

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
Tel: 604.540.1100 • Fax: 604.540.1005 • Toll Free: 1.800.665.5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

→ AA-11-4V
@ 815am - -5.87 kPa @ 17.4°C
Baro - 100.62 kPa

Vibrating Wire Piezometer

Customer:		Golder Associate-Saskatoon
Model:		VW2100-0.7
Serial Number:		**VW18879**
Mfg Number:		1115744
Range:		700.0 kPa
Temperature:		24.3 °C
Barometric Pressure:		983.2 millibars
Work Order Number:		032886
Cable Length:		30 meters
Cable Markings:		100099 m - 100128 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 Kohms

→ Prior to install @ 9:24am soaked
-5.11 kPa @ 12.3°C
Baro - 100.62 kPa

→ Adopth @ 12' @ 9:42am
- 27.60 kPa @ 10.2°C
- Baro 100.62 kPa

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	8972	8974	8973	1.4	0.20	0.01
140.0	8202	8202	8202	139.7	-0.05	-0.01
280.0	7426	7426	7426	278.8	-0.17	-0.02
420.0	6644	6644	6644	419.1	-0.13	0.02
560.0	5859	5859	5859	559.9	-0.02	0.02
700.0	5071	5071	5071	701.2	0.17	-0.01
			Max. Error (%):		0.20	0.02

Linear Calibration Factor:	**C.F.=**	**0.17935 kPa/B unit**
Regression Zero:	**At Calibration =**	**8980.7 B unit**
Temperature Correction Factor:	**Tk =**	**-0.04562 kPa/°C rise**

Polynomial Gage Factors (kPa) **A:** -6.3597E-07 **B:** -0.17041 **C:** 1580.4

Pressure is calculated with the following equations:
Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$
Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	16-Sep-11	8955	21.8	1015.9

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = Hz^2 / 1000 ie: 1700Hz = 2890 B units

Technician: J. Chung CJ Date: 16-Sep-11

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Applied Science Technologists and Technicians of British Columbia
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Document Number.: ELL0130K

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Calibration Record

Oct 6/11

200 - 2050 Hartley Ave., Coquitlam, British Columbia, Canada V3K 6W5
Tel: 604.540.1100 • Fax: 604.540.1005 • Toll Free: 1.800.665.5599 (North America only)
e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

→ AA-11-7V

@ 810am – -7.22kPa @ 14.3°C
Baro - 99.88kPa

Vibrating Wire Piezometer

Customer:		Golder Associate-Saskatoon
Model:		VW2100-0.7
Serial Number:		**VW18878**
Mfg Number:		1115743
Range:		700.0 kPa
Temperature:		24.3 °C
Barometric Pressure:		983.2 millibars
Work Order Number:		032886
Cable Length:		30 meters
Cable Markings:		102171 m - 102200 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 Kohms

→ Prior to Install – Soaked
@ 8:52am
-6.11kPa @ 6.9°C
Baro → 99.88kPa

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	8906	8907	8907	1.4	0.20	0.01
140.0	8104	8104	8104	139.6	-0.06	-0.02
280.0	7295	7295	7295	278.9	-0.15	0.00
420.0	6481	6481	6481	419.1	-0.13	0.02
560.0	5665	5665	5665	559.6	-0.05	-0.01
700.0	4843	4842	4843	701.3	0.19	0.00
			Max. Error (%):		0.20	0.02

→ At depth @ 29'
@ 9:26 am
100.6kPa @ 13.2°C
Baro → 99.88kPa

Linear Calibration Factor:	**C.F.=**	**0.17222 kPa/B unit**
Regression Zero:	**At Calibration =**	**8914.5 B unit**
Temperature Correction Factor:	**Tk =**	**-0.04716 kPa/°C rise**

Polynomial Gage Factors (kPa) **A:** -5.9571E-07 **B:** -0.16403 **C:** 1508.3

Pressure is calculated with the following equations:
Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$
Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	16-Sep-11	8891	22.0	1015.9

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = Hz^2 / 1000 ie: 1700Hz = 2890 B units

Technician: J. Chung

Date: 16-Sep-11

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

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Document Number.: ELL0130K

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Calibration Record

Oct. 6/11

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e-mail: info@rstinstruments.com • Website: www.rstinstruments.com

AA-11-11V

not correct

@ 940am → -2.24kPa @ 14.4°C

Baro → 99.92kPa

Vibrating Wire Piezometer

Prior to Install - Soaked

@ 1000am → -6.44kPa @ 13.7°C

Baro 99.92kPa

Customer:		Golder Associate-Saskatoon
Model:		VW2100-0.7
Serial Number:		**VW18877**
Mfg Number:		1115742
Range:		700.0 kPa
Temperature:		24.3 °C
Barometric Pressure:		983.2 millibars
Work Order Number:		032886
Cable Length:		30 meters
Cable Markings:		102140 m - 102170 m
Cable Colour Code:	Red / Black (Coil)	Green / White (Thermistor)
Cable Type:		EL380004
Thermistor Type:		3 Kohms

At depth @ 91

@ 1018am

24.63 kPa

@ 15.1°C

Baro 99.92kPa

Applied Pressure (kPa)	First Reading (B units)	Second Reading (B units)	Average Reading (B units)	Calculated Linear (kPa)	Linearity Error (% FS)	Polynomial Error (% FS)
0.0	8930	8932	8931	1.6	0.22	0.01
140.0	8149	8149	8149	139.6	-0.05	-0.01
280.0	7362	7362	7362	278.6	-0.20	-0.03
420.0	6567	6567	6567	419.0	-0.15	0.03
560.0	5770	5769	5770	559.8	-0.03	0.01
700.0	4968	4967	4968	701.4	0.20	-0.01
				Max. Error (%):	0.22	0.03

Linear Calibration Factor:	**C.F.=**	**0.17657 kPa/B unit**
Regression Zero:	**At Calibration =**	**8939.9 B unit**
Temperature Correction Factor:	**Tk =**	**-0.03615 kPa/°C rise**

Polynomial Gage Factors (kPa) **A:** -7.1217E-07 **B:** -0.16667 **C:** 1545.4

Pressure is calculated with the following equations:

Linear: $P(kPa) = C.F.(Li-Lc) - [Tk(Ti-Tc)] + [0.10(Bi-Bc)]$

Polynomial: $P(kPa) = A(Lc)^2 + BLc + C + Tk(Tc-Ti) - [0.10(Bc-Bi)]$

	Date (dd/mm/yy)	VW Readout Pos. B (Li)	Temp °C (Ti)	Baro (Bi)
Shipped Zero Readings:	16-Sep-11	8918	21.9	1015.9

Li, Lc = initial (at installation) and current readings
Ti, Tc = initial (at installation) and current temperature, in °C
Bi, Bc = initial (at installation) and current barometric pressure readings, in millibars
B units = B scale output of VW 2102, VW 2104, VW 2106 and DT 2011 readouts
B units = Hz^2 / 1000 ie: 1700Hz = 2890 B units

Technician: J. Chung

Date: 16-Sep-11

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

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Certificate of Compliance

Model DT2011 Vibrating Wire Logger

RST Instruments Ltd. 200-2050 Hartley Ave. Coquitlam, BC, Canada V3K6W5

The DT2011 is designed to meet specifications without adjustments of any kind. This is to certify that SN DT05087 has been tested to, and meets, the following specifications:

Indicated B units at 3.0000 khz: 9000.0+/- 0.5
Indicated °C at 3000.0 ohms: 25.0+/-0.1
Idle current in micro amperes: 40+/-20
Correct function with VW piezometer

Technician:

date: August 31, 2011

Applicable standards: Agilent 34401A SN 36053118, Tektronics CMC251 SN TW53715, VW2100-100 SN 56812

ELL0158D

Certificate of Compliance

Model DT2011 Vibrating Wire Logger

RST Instruments Ltd. 200-2050 Hartley Ave. Coquitlam, BC, Canada V3K6W5

The DT2011 is designed to meet specifications without adjustments of any kind. This is to certify that SN DT05090 has been tested to, and meets, the following specifications:

Indicated B units at 3.0000 khz: 9000.0+/- 0.5
Indicated °C at 3000.0 ohms: 25.0+/-0.1
Idle current in micro amperes: 40+/-20
Correct function with VW piezometer

Technician:

date: August 31, 2011

Applicable standards: Agilent 34401A SN 36053118, Tektronics CMC251 SN TW53715, VW2100-100 SN 56812

ELL0158D

Certificate of Compliance

Model DT2011 Vibrating Wire Logger

RST Instruments Ltd. 200-2050 Hartley Ave. Coquitlam, BC, Canada V3K6W5

The DT2011 is designed to meet specifications without adjustments of any kind. This is to certify that SN DT05089 has been tested to, and meets, the following specifications:

Indicated B units at 3.0000 khz: 9000.0+/- 0.5
Indicated °C at 3000.0 ohms: 25.0+/-0.1
Idle current in micro amperes: 40+/-20
Correct function with VW piezometer

Technician:

date: August 31, 2011

Applicable standards: Agilent 34401A SN 36053118, Tektronics CMC251 SN TW53715, VW2100-100 SN 56812

ELL0158D

Certificate of Compliance

Model DT2011 Vibrating Wire Logger

RST Instruments Ltd. 200-2050 Hartley Ave. Coquitlam, BC, Canada V3K6W5

The DT2011 is designed to meet specifications without adjustments of any kind. This is to certify that SN DT05088 has been tested to, and meets, the following specifications:

Indicated B units at 3.0000 khz:	9000.0+/- 0.5	Idle current in micro amperes:	40+/-20
Indicated °C at 3000.0 ohms:	25.0+/-0.1	Correct function with VW piezometer	

Technician: 

date: August 31, 2011

Applicable standards: Agilent 34401A SN 36053118, Tektronics CMC251 SN TW53715, VW2100-100 SN 56812

ELL0158D

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05090
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING APPEND
Sampling Rate	FIXED
Current Interval	0 Hours 0 Minutes 2 Seconds
Start Time	Friday November 18 2011 11:50:52 AM
Current Time	Friday November 18 2011 11:51:46 AM
Battery Voltage	3.00V
Battery Life Remaining	100%
Number Of Records	25
Engineering Units	Enabled Polynomial Conversion A=-4.21930e-007 B=-1.69320e-001 C=1.56790e+003
Temperature Correction	Enabled TempCF=2.64500e-003 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
11/18/2011 11:50	45.8	8.06	8796.42
11/18/2011 11:50	45.8	8.06	8796.42
11/18/2011 11:50	45.88	8.06	8795.98
11/18/2011 11:50	45.8	8.06	8796.42
11/18/2011 11:51	45.8	8.06	8796.42
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.06	8795.98
11/18/2011 11:51	45.88	8.05	8795.98
11/18/2011 11:51	45.88	8.05	8795.98
11/18/2011 11:51	45.88	8.05	8795.98
11/18/2011 11:51	45.88	8.05	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.04	8795.98
11/18/2011 11:51	45.88	8.05	8795.98
11/18/2011 11:51	45.88	8.06	8795.98

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05089
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:33:32 PM
Current Time	Friday November 18 2011 11:19:25 AM
Battery Voltage	3.10V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-6.35970e-007 B=-1.70410e-001 C=1.58040e+003
Temperature Correction	Enabled TempCF=-4.56200e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
28/09/2011 13:33	-2.57	23.4	8987.94
29/09/2011 1:33	-1.56	22.98	8982.50
29/09/2011 13:33	-1.32	23.02	8981.14
30/09/2011 1:33	-2.14	22.92	8985.67
30/09/2011 13:33	-3.19	22.64	8991.57
1/10/2011 1:33	-3.6	22.47	8993.84
1/10/2011 13:33	-2.52	22.42	8987.94
2/10/2011 1:33	-2.44	22.41	8987.49
2/10/2011 13:33	-2.68	22.15	8988.85
3/10/2011 1:33	-2.34	22.06	8987.03
3/10/2011 13:33	-4.87	21.42	9001.11
4/10/2011 1:33	-5.86	21.23	9006.57
4/10/2011 13:33	30.75	8.65	8808.29
5/10/2011 1:33	29.82	7.93	8813.58
5/10/2011 13:33	29.83	7.81	8813.58
6/10/2011 1:33	29.75	7.74	8814.02
6/10/2011 13:33	29.67	7.68	8814.46
7/10/2011 1:33	29.84	7.63	8813.58
7/10/2011 13:33	29.76	7.6	8814.02
8/10/2011 1:33	31.84	7.58	8802.58
8/10/2011 13:33	32.56	7.57	8798.62
9/10/2011 1:33	32.56	7.55	8798.62
9/10/2011 13:33	32.32	7.55	8799.94
10/10/2011 1:33	32	7.54	8801.70
10/10/2011 13:33	31.68	7.54	8803.46
11/10/2011 1:33	31.36	7.54	8805.21
11/10/2011 13:33	31.2	7.54	8806.09
12/10/2011 1:33	31.12	7.54	8806.53
12/10/2011 13:33	31.28	7.54	8805.65
13/10/2011 1:33	31.28	7.54	8805.65
13/10/2011 13:33	31.44	7.54	8804.77
14/10/2011 1:33	31.6	7.54	8803.89
14/10/2011 13:33	31.76	7.54	8803.02
15/10/2011 1:33	31.6	7.54	8803.89
15/10/2011 13:33	31.52	7.55	8804.33
16/10/2011 1:33	31.68	7.55	8803.46
16/10/2011 13:33	31.76	7.55	8803.02
17/10/2011 1:33	31.68	7.55	8803.46
17/10/2011 13:33	32	7.56	8801.70
18/10/2011 1:33	32.08	7.56	8801.26
18/10/2011 13:33	32.16	7.56	8800.82

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05089
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:33:32 PM
Current Time	Friday November 18 2011 11:19:25 AM
Battery Voltage	3.10V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-6.35970e-007 B=-1.70410e-001 C=1.58040e+003
Temperature Correction	Enabled TempCF=-4.56200e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
19/10/2011 1:33	32.08	7.56	8801.26
19/10/2011 13:33	31.76	7.57	8803.02
20/10/2011 1:33	31.44	7.57	8804.77
20/10/2011 13:33	31.36	7.57	8805.21
21/10/2011 1:33	31.52	7.57	8804.33
21/10/2011 13:33	31.68	7.58	8803.46
22/10/2011 1:33	31.44	7.58	8804.77
22/10/2011 13:33	31.36	7.58	8805.21
23/10/2011 1:33	31.2	7.58	8806.09
23/10/2011 13:33	31.12	7.59	8806.53
24/10/2011 1:33	31.36	7.59	8805.21
24/10/2011 13:33	31.28	7.59	8805.65
25/10/2011 1:33	31.52	7.59	8804.33
25/10/2011 13:33	31.92	7.6	8802.14
26/10/2011 1:33	32.08	7.6	8801.26
26/10/2011 13:33	31.76	7.6	8803.02
27/10/2011 1:33	31.12	7.6	8806.53
27/10/2011 13:33	31.36	7.6	8805.21
28/10/2011 1:33	31.68	7.6	8803.46
28/10/2011 13:33	31.52	7.61	8804.33
29/10/2011 1:33	30.64	7.61	8809.18
29/10/2011 13:33	30.88	7.61	8807.85
30/10/2011 1:33	31.36	7.61	8805.21
30/10/2011 13:33	31.28	7.61	8805.65
31/10/2011 1:33	30.72	7.61	8808.73
31/10/2011 13:33	30.96	7.61	8807.41
1/11/2011 1:33	31.52	7.61	8804.33
1/11/2011 13:33	32.08	7.61	8801.26
2/11/2011 1:33	32.4	7.61	8799.50
2/11/2011 13:33	32	7.61	8801.70
3/11/2011 1:33	31.36	7.61	8805.21
3/11/2011 13:33	30.96	7.61	8807.41
4/11/2011 1:33	30.88	7.6	8807.85
4/11/2011 13:33	30.88	7.6	8807.85
5/11/2011 1:33	30.88	7.6	8807.85
5/11/2011 13:33	30.8	7.6	8808.29
6/11/2011 1:33	30.72	7.6	8808.73
6/11/2011 13:33	30.96	7.6	8807.41
7/11/2011 1:33	31.68	7.59	8803.46
7/11/2011 13:33	31.92	7.59	8802.14
8/11/2011 1:33	31.68	7.59	8803.46

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05089
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:33:32 PM
Current Time	Friday November 18 2011 11:19:25 AM
Battery Voltage	3.10V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-6.35970e-007 B=-1.70410e-001 C=1.58040e+003
Temperature Correction	Enabled TempCF=-4.56200e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
8/11/2011 13:33	31.92	7.59	8802.14
9/11/2011 1:33	32.8	7.58	8797.30
9/11/2011 13:33	32.95	7.58	8796.42
10/11/2011 1:33	32.48	7.58	8799.06
10/11/2011 13:33	31.2	7.57	8806.09
11/11/2011 1:33	31.2	7.57	8806.09
11/11/2011 13:33	30.48	7.57	8810.06
12/11/2011 1:33	30.16	7.56	8811.82
12/11/2011 13:33	30.4	7.56	8810.50
13/11/2011 1:33	29.84	7.55	8813.58
13/11/2011 13:33	29.76	7.55	8814.02
14/11/2011 1:33	30.08	7.54	8812.26
14/11/2011 13:33	30.16	7.54	8811.82
15/11/2011 1:33	30.8	7.53	8808.29
15/11/2011 13:33	31.44	7.53	8804.77
16/11/2011 1:33	31.92	7.52	8802.14
16/11/2011 13:33	32	7.52	8801.70
17/11/2011 1:33	31.6	7.51	8803.89
17/11/2011 13:33	30.24	7.5	8811.38
18/11/2011 1:33	30.72	7.5	8808.73

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05088
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:42:49 PM
Current Time	Friday November 18 2011 11:27:05 AM
Battery Voltage	3.08V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-5.95710e-007 B=-1.64030e-001 C=1.50830e+003
Temperature Correction	Enabled TempCF=-4.71600e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
9/28/2011 13:42	-3.27	23.3	8926.10
9/29/2011 1:42	-2.31	23.05	8920.72
9/29/2011 13:42	-2.08	23.06	8919.37
9/30/2011 1:42	-2.94	23.01	8924.31
9/30/2011 13:42	-3.94	22.71	8930.15
10/1/2011 1:42	-4.33	22.55	8932.39
10/1/2011 13:42	-3.3	22.48	8926.55
10/2/2011 1:42	-3.23	22.5	8926.10
10/2/2011 13:42	-3.45	22.25	8927.45
10/3/2011 1:42	-3.06	22.17	8925.21
10/3/2011 13:42	-5.61	21.4	8940.04
10/4/2011 1:42	-6.63	21.36	8945.89
10/4/2011 13:42	-6.93	22.79	8947.25
10/5/2011 1:42	-7.23	17.36	8950.40
10/5/2011 13:42	-6.97	16.87	8949.05
10/6/2011 1:42	-7.48	14.26	8952.66
10/6/2011 13:42	103.71	9.03	8316.26
10/7/2011 1:42	104.09	8.23	8314.24
10/7/2011 13:42	103.75	8.04	8316.26
10/8/2011 1:42	105.23	7.91	8307.78
10/8/2011 13:42	106.22	7.81	8302.14
10/9/2011 1:42	106.29	7.72	8301.74
10/9/2011 13:42	105.73	7.66	8304.96
10/10/2011 1:42	105.32	7.61	8307.38
10/10/2011 13:42	104.69	7.58	8311.01
10/11/2011 1:42	104.41	7.55	8312.62
10/11/2011 13:42	104.34	7.53	8313.03
10/12/2011 1:42	104.83	7.51	8310.20
10/12/2011 13:42	105.25	7.51	8307.78
10/13/2011 1:42	105.25	7.49	8307.78
10/13/2011 13:42	105.39	7.49	8306.98
10/14/2011 1:42	105.67	7.48	8305.37
10/14/2011 13:42	105.74	7.47	8304.96
10/15/2011 1:42	105.6	7.46	8305.77
10/15/2011 13:42	105.46	7.47	8306.57
10/16/2011 1:42	105.95	7.46	8303.75
10/16/2011 13:42	105.88	7.46	8304.16
10/17/2011 1:42	105.95	7.45	8303.75

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05088
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:42:49 PM
Current Time	Friday November 18 2011 11:27:05 AM
Battery Voltage	3.08V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-5.95710e-007 B=-1.64030e-001 C=1.50830e+003
Temperature Correction	Enabled TempCF=-4.71600e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
10/17/2011 13:42	106.3	7.45	8301.74
10/18/2011 1:42	106.44	7.45	8300.93
10/18/2011 13:42	106.58	7.45	8300.13
10/19/2011 1:42	106.24	7.44	8302.14
10/19/2011 13:42	105.6	7.45	8305.77
10/20/2011 1:42	105.11	7.44	8308.59
10/20/2011 13:42	105.32	7.44	8307.38
10/21/2011 1:42	105.81	7.44	8304.56
10/21/2011 13:42	106.02	7.44	8303.35
10/22/2011 1:42	105.46	7.44	8306.57
10/22/2011 13:42	105.53	7.44	8306.17
10/23/2011 1:42	105.32	7.43	8307.38
10/23/2011 13:42	105.46	7.44	8306.57
10/24/2011 1:42	105.82	7.43	8304.56
10/24/2011 13:42	105.6	7.44	8305.77
10/25/2011 1:42	105.96	7.43	8303.75
10/25/2011 13:42	106.38	7.43	8301.34
10/26/2011 1:42	106.59	7.43	8300.13
10/26/2011 13:42	106.1	7.43	8302.95
10/27/2011 1:42	105.32	7.43	8307.38
10/27/2011 13:42	105.75	7.43	8304.96
10/28/2011 1:42	106.17	7.43	8302.54
10/28/2011 13:42	105.68	7.43	8305.37
10/29/2011 1:42	104.55	7.43	8311.82
10/29/2011 13:42	104.97	7.43	8309.40
10/30/2011 1:42	105.68	7.43	8305.37
10/30/2011 13:42	105.39	7.43	8306.98
10/31/2011 1:42	104.83	7.43	8310.20
10/31/2011 13:42	105.11	7.43	8308.59
11/1/2011 1:42	105.75	7.42	8304.96
11/1/2011 13:42	106.31	7.43	8301.74
11/2/2011 1:42	106.59	7.42	8300.13
11/2/2011 13:42	106.1	7.43	8302.95
11/3/2011 1:42	105.39	7.43	8306.98
11/3/2011 13:42	105.04	7.43	8308.99
11/4/2011 1:42	105.04	7.42	8308.99
11/4/2011 13:42	104.97	7.43	8309.40
11/5/2011 1:42	104.97	7.43	8309.40

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05088
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING RESTARTED
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Wednesday September 28 2011 01:42:49 PM
Current Time	Friday November 18 2011 11:27:05 AM
Battery Voltage	3.08V
Battery Life Remaining	100%
Number Of Records	102
Engineering Units	Enabled Polynomial Conversion A=-5.95710e-007 B=-1.64030e-001 C=1.50830e+003
Temperature Correction	Enabled TempCF=-4.71600e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
11/5/2011 13:42	104.9	7.43	8309.80
11/6/2011 1:42	104.76	7.43	8310.61
11/6/2011 13:42	105.04	7.43	8308.99
11/7/2011 1:42	105.68	7.43	8305.37
11/7/2011 13:42	105.89	7.43	8304.16
11/8/2011 1:42	105.68	7.43	8305.37
11/8/2011 13:42	105.96	7.43	8303.75
11/9/2011 1:42	106.87	7.43	8298.52
11/9/2011 13:42	107.01	7.43	8297.71
11/10/2011 1:42	106.45	7.43	8300.93
11/10/2011 13:42	105.11	7.43	8308.59
11/11/2011 1:42	104.97	7.43	8309.40
11/11/2011 13:42	104.27	7.43	8313.43
11/12/2011 1:42	103.85	7.43	8315.85
11/12/2011 13:42	104.2	7.43	8313.83
11/13/2011 1:42	103.5	7.43	8317.87
11/13/2011 13:42	103.57	7.43	8317.47
11/14/2011 1:42	103.92	7.43	8315.45
11/14/2011 13:42	104.06	7.43	8314.64
11/15/2011 1:42	104.76	7.43	8310.61
11/15/2011 13:42	105.46	7.43	8306.57
11/16/2011 1:42	106.17	7.43	8302.54
11/16/2011 13:42	106.38	7.43	8301.34
11/17/2011 1:42	105.89	7.43	8304.16
11/17/2011 13:42	104.48	7.43	8312.22
11/18/2011 1:42	105.04	7.43	8308.99

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05087
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING APPEND
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Tuesday August 30 2011 11:00:04 AM
Current Time	Friday November 18 2011 11:32:16 AM
Battery Voltage	3.05V
Battery Life Remaining	100%
Number Of Records	160
Engineering Units	Enabled Polynomial Conversion A=-7.12170e-007 B=-1.66670e-001 C=1.54540e+003
Temperature Correction	Enabled TempCF=-3.61500e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
30/08/2011 11:00	-31.07	22.85	9104.76
30/08/2011 23:00	99999	-107.78	99999.00
31/08/2011 11:00	99999	-107.78	99999.00
31/08/2011 23:00	99999	-107.78	99999.00
1/9/2011 11:00	99999	-107.78	99999.00
1/9/2011 23:00	99999	-107.78	99999.00
2/9/2011 11:00	99999	-107.78	99999.00
2/9/2011 23:00	99999	-107.78	99999.00
3/9/2011 11:00	99999	-107.78	99999.00
3/9/2011 23:00	99999	-107.78	99999.00
4/9/2011 11:00	99999	-107.78	99999.00
4/9/2011 23:00	99999	-107.78	99999.00
5/9/2011 11:00	99999	-107.78	99999.00
5/9/2011 23:00	99999	-107.78	99999.00
6/9/2011 11:00	99999	-107.78	99999.00
6/9/2011 23:00	99999	-107.78	99999.00
7/9/2011 11:00	99999	-107.78	99999.00
7/9/2011 23:00	99999	-107.78	99999.00
8/9/2011 11:00	99999	-107.78	99999.00
8/9/2011 23:00	99999	-107.78	99999.00
9/9/2011 11:00	99999	-107.78	99999.00
9/9/2011 23:00	99999	-107.78	99999.00
10/9/2011 11:00	99999	-107.78	99999.00
10/9/2011 23:00	99999	-107.78	99999.00
11/9/2011 11:00	99999	-107.78	99999.00
11/9/2011 23:00	99999	-107.78	99999.00
12/9/2011 11:00	99999	-107.78	99999.00
12/9/2011 23:00	99999	-107.78	99999.00
13/09/2011 11:00	99999	-107.78	99999.00
13/09/2011 23:00	99999	-107.78	99999.00
14/09/2011 11:00	99999	-107.78	99999.00
14/09/2011 23:00	99999	-107.78	99999.00
15/09/2011 11:00	99999	-107.78	99999.00
15/09/2011 23:00	99999	-107.78	99999.00
16/09/2011 11:00	2.38	22.29	8918.48
16/09/2011 23:00	2.55	22.23	8917.58
17/09/2011 11:00	2.58	21.36	8917.58
17/09/2011 23:00	2.58	21.24	8917.58
18/09/2011 11:00	2.76	20.73	8916.68
18/09/2011 23:00	2.83	21.23	8916.23
19/09/2011 11:00	3.28	22.02	8913.55
19/09/2011 23:00	3.11	22.13	8914.44
20/09/2011 11:00	2.83	21.14	8916.23
20/09/2011 23:00	2.44	22.88	8918.03
21/09/2011 11:00	-10.28	16.74	8990.21

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05087
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING APPEND
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Tuesday August 30 2011 11:00:04 AM
Current Time	Friday November 18 2011 11:32:16 AM
Battery Voltage	3.05V
Battery Life Remaining	100%
Number Of Records	160
Engineering Units	Enabled Polynomial Conversion A=-7.12170e-007 B=-1.66670e-001 C=1.54540e+003
Temperature Correction	Enabled TempCF=-3.61500e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
21/09/2011 23:00	-7.24	22.46	8972.08
22/09/2011 11:00	-4.15	19.88	8955.36
22/09/2011 23:00	-3.82	22	8953.11
23/09/2011 11:00	-3.91	22.26	8953.56
23/09/2011 23:00	-4.16	22.4	8954.91
24/09/2011 11:00	-4.08	22.53	8954.46
24/09/2011 23:00	-4.02	23.05	8954.01
25/09/2011 11:00	-4.43	23.18	8956.26
25/09/2011 23:00	-4.68	23.37	8957.62
26/09/2011 11:00	-4.19	23.24	8954.91
26/09/2011 23:00	-4.02	23.24	8954.01
27/09/2011 11:00	-4.34	23.13	8955.81
27/09/2011 23:00	-4.01	22.86	8954.01
28/09/2011 11:00	-3.38	23.21	8950.40
28/09/2011 23:00	-2.4	22.98	8944.99
29/09/2011 11:00	-2.24	23	8944.09
29/09/2011 23:00	-3.12	22.94	8949.05
30/09/2011 11:00	-4.16	22.65	8954.91
30/09/2011 23:00	-4.48	22.49	8956.72
1/10/2011 11:00	-3.43	22.43	8950.85
1/10/2011 23:00	-3.35	22.43	8950.40
2/10/2011 11:00	-3.58	22.2	8951.75
2/10/2011 23:00	-3.17	22.12	8949.50
3/10/2011 11:00	-5.82	21.5	8964.39
3/10/2011 23:00	-6.78	21.03	8969.82
4/10/2011 11:00	-7.07	22.28	8971.18
4/10/2011 23:00	-7.4	17.97	8973.89
5/10/2011 11:00	-7.35	16.44	8973.89
5/10/2011 23:00	-7.74	13.82	8976.61
6/10/2011 11:00	20.86	9.76	8817.99
6/10/2011 23:00	20.24	9.34	8821.51
7/10/2011 11:00	20.16	9.24	8821.96
7/10/2011 23:00	21.43	9.18	8814.90
8/10/2011 11:00	22.06	9.13	8811.38
8/10/2011 23:00	22.06	9.08	8811.38
9/10/2011 11:00	21.43	9.06	8814.90
9/10/2011 23:00	20.96	9.03	8817.55
10/10/2011 11:00	20.41	9.02	8820.63
10/10/2011 23:00	20.09	9.01	8822.40
11/10/2011 11:00	19.93	9	8823.28
11/10/2011 23:00	20.33	8.99	8821.07
12/10/2011 11:00	20.73	8.98	8818.87
12/10/2011 23:00	20.81	8.97	8818.43
13/10/2011 11:00	21.04	8.97	8817.10
13/10/2011 23:00	21.28	8.96	8815.78

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05087
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING APPEND
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Tuesday August 30 2011 11:00:04 AM
Current Time	Friday November 18 2011 11:32:16 AM
Battery Voltage	3.05V
Battery Life Remaining	100%
Number Of Records	160
Engineering Units	Enabled Polynomial Conversion A=-7.12170e-007 B=-1.66670e-001 C=1.54540e+003
Temperature Correction	Enabled TempCF=-3.61500e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
14/10/2011 11:00	21.28	8.96	8815.78
14/10/2011 23:00	21.12	8.95	8816.66
15/10/2011 11:00	21.04	8.95	8817.10
15/10/2011 23:00	21.44	8.94	8814.90
16/10/2011 11:00	21.44	8.94	8814.90
16/10/2011 23:00	21.44	8.93	8814.90
17/10/2011 11:00	21.83	8.93	8812.70
17/10/2011 23:00	22.07	8.92	8811.38
18/10/2011 11:00	22.15	8.92	8810.94
18/10/2011 23:00	21.91	8.91	8812.26
19/10/2011 11:00	21.28	8.9	8815.78
19/10/2011 23:00	20.81	8.9	8818.43
20/10/2011 11:00	20.97	8.89	8817.55
20/10/2011 23:00	21.44	8.88	8814.90
21/10/2011 11:00	21.68	8.88	8813.58
21/10/2011 23:00	21.13	8.87	8816.66
22/10/2011 11:00	21.2	8.86	8816.22
22/10/2011 23:00	21.05	8.85	8817.10
23/10/2011 11:00	21.13	8.84	8816.66
23/10/2011 23:00	21.44	8.83	8814.90
24/10/2011 11:00	21.28	8.83	8815.78
24/10/2011 23:00	21.52	8.81	8814.46
25/10/2011 11:00	22	8.81	8811.82
25/10/2011 23:00	22.15	8.79	8810.94
26/10/2011 11:00	21.84	8.78	8812.70
26/10/2011 23:00	21.05	8.77	8817.10
27/10/2011 11:00	21.37	8.76	8815.34
27/10/2011 23:00	21.76	8.74	8813.14
28/10/2011 11:00	21.6	8.73	8814.02
28/10/2011 23:00	20.5	8.72	8820.19
29/10/2011 11:00	20.89	8.7	8817.99
29/10/2011 23:00	21.37	8.69	8815.34
30/10/2011 11:00	21.29	8.68	8815.78
30/10/2011 23:00	20.66	8.66	8819.31
31/10/2011 11:00	20.9	8.65	8817.99
31/10/2011 23:00	21.45	8.63	8814.90
1/11/2011 11:00	22	8.62	8811.82
1/11/2011 23:00	22.32	8.6	8810.06
2/11/2011 11:00	21.92	8.59	8812.26
2/11/2011 23:00	21.21	8.57	8816.22
3/11/2011 11:00	20.9	8.56	8817.99
3/11/2011 23:00	20.82	8.54	8818.43
4/11/2011 11:00	20.74	8.52	8818.87
4/11/2011 23:00	20.66	8.51	8819.31
5/11/2011 11:00	20.66	8.49	8819.31

Model	DT2011 VW Logger
Name	Single Channel VW Logger DT2011
Serial Number	DT05087
Firmware Version	v1.73 Software Version v2.21
Sampling Status	LOGGING APPEND
Sampling Rate	FIXED
Current Interval	12 Hours 0 Minutes 0 Seconds
Start Time	Tuesday August 30 2011 11:00:04 AM
Current Time	Friday November 18 2011 11:32:16 AM
Battery Voltage	3.05V
Battery Life Remaining	100%
Number Of Records	160
Engineering Units	Enabled Polynomial Conversion A=-7.12170e-007 B=-1.66670e-001 C=1.54540e+003
Temperature Correction	Enabled TempCF=-3.61500e-002 InitialTemp=24.30
Units Conversion	Enabled Pressure Input=kPa Output=kPa Offset=0.00000e+000
Sensor Label	Sensor Label

Date/Time	Eng Units	Temperature	B Units
5/11/2011 23:00	20.51	8.47	8820.19
6/11/2011 11:00	20.67	8.46	8819.31
6/11/2011 23:00	21.3	8.44	8815.78
7/11/2011 11:00	21.54	8.42	8814.46
7/11/2011 23:00	21.46	8.4	8814.90
8/11/2011 11:00	21.62	8.38	8814.02
8/11/2011 23:00	22.41	8.36	8809.62
9/11/2011 11:00	22.72	8.35	8807.85
9/11/2011 23:00	22.17	8.32	8810.94
10/11/2011 11:00	20.99	8.31	8817.55
10/11/2011 23:00	20.83	8.29	8818.43
11/11/2011 11:00	20.12	8.27	8822.40
11/11/2011 23:00	19.65	8.25	8825.04
12/11/2011 11:00	19.8	8.23	8824.16
12/11/2011 23:00	19.25	8.21	8827.25
13/11/2011 11:00	19.25	8.19	8827.25
13/11/2011 23:00	19.57	8.16	8825.49
14/11/2011 11:00	19.65	8.14	8825.04
14/11/2011 23:00	20.2	8.12	8821.96
15/11/2011 11:00	20.84	8.1	8818.43
15/11/2011 23:00	21.55	8.08	8814.46
16/11/2011 11:00	21.79	8.06	8813.14
16/11/2011 23:00	21.55	8.03	8814.46
17/11/2011 11:00	20.21	8.01	8821.96
17/11/2011 23:00	20.68	7.99	8819.31

APPENDIX F

Geostudio Analysis

Modelling Parameters

Steady state Seepage Model

Transient Seepage Analysis - Baseline Data

Material	Model	ksat (m/s)	ksat (m/day)	VWC	Mv (1/kPa)
New Fill	Saturated Only	5.80E-08	5.01E-03	0.42	1.00E-04
Fill	Saturated Only	5.80E-08	5.01E-03	0.42	1.00E-04
Alluvium	Saturated Only	1.30E-07	1.12E-02	0.42	4.73E-05
Shale (ox) - normal	Saturated Only	1.00E-09	8.64E-05	0.5	1.00E-04
Shale (ox) - residual	Saturated Only	1.00E-09	8.64E-05	0.5	1.00E-04
Shale (unox)	Saturated Only	1.00E-09	8.64E-05	-	-
Granular Drain	Saturated Only	1.00E-04	8.64E+00	0.3	1.00E-04

Linear Elastic Stress Model - Baseline Data

Material	Model	Material Category	Load Response Ratio	Elastic Modulus (kPa)	Poissons Ratio	Unit Weight (KN/m3)
New Fill	Linear Elastic	Effective Drained	--	15,000	0.33	21
Fill	Linear Elastic	Effective w/ PWP Change	1	15,000	0.33	21
Alluvium	Linear Elastic	Effective w/ PWP Change	1	15,000	0.33	19
Shale (ox) - normal	Linear Elastic	Effective w/ PWP Change	1	15,000	0.33	22
Shale (ox) - residual	Linear Elastic	Effective w/ PWP Change	1	15,000	0.33	22
Shale (unox)	Linear Elastic	Effective Drained	1	15,000	0.33	22
Granular Drain	Linear Elastic	Effective Drained	--	50,000	0.33	19

Stability Analysis Shear Strength Paramaters - Baseline

Material	Model	phi	c'
New Fill	M-P	25	0
Fill	M-P	25	0
Alluvium	M-P	28	0
Shale (ox) - normal	M-P	20	10
Shale (ox) - residual	M-P	15	2
Shale (unox)	M-P	-	-
Granular Drain	M-P	35	0

Slope Stability

File Information

Title: Highfield Dam Foundation Embankment Assessment
Created By: Nehring, Lisa
Revision Number: 290
Last Edited By: Nehring, Lisa
Date: 1/16/2012
Time: 7:15:21 PM
File Name: Option 1 - Existing Conditions.gsz
Directory: C:\Users\LNehring\Desktop\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\4000 Modelling\Models\Final Models\
Last Solved Date: 1/16/2012
Last Solved Time: 7:15:54 PM

Project Settings

Length(L) Units: meters
Time(t) Units: Days
Force(F) Units: kN
Pressure(p) Units: kPa
Strength Units: kPa
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Parent: Existing Conditions
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Parent Analysis

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 m
- Optimization Maximum Iterations: 2000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Unoxidized Shale
Model: Bedrock (Impenetrable)

Alluvium
Model: Mohr-Coulomb
Unit Weight: Multiple Trial: 19 kN/m³
- Constant Value: 19
- Probabilistic: Triangular(Min=18,Mode=19,Max=20)

Cohesion: 0 kPa
Phi: Multiple Trial: 28 °
- Constant Value: 28
- Probabilistic: Triangular(Min=20,Mode=28,Max=35)

Phi-B: 0 °

Fill
Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Oxidized Shale (Residual)
Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 2 kPa
Phi: 10 °
Phi-B: 0 °

Soft Fill
Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (10.5, 717.48378) m
Left-Zone Right Coordinate: (43.66364, 719.1) m
Left-Zone Increment: 10
Right Projection: Range
Right-Zone Left Coordinate: (58.89091, 723.7) m
Right-Zone Right Coordinate: (71.68288, 722.83037) m
Right-Zone Increment: 10
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (-10, 717.3) m
Right Coordinate: (90, 717.8) m

Regions

	Material	Points	Area (m²)
Region 1	Alluvium	1,2,3,4,5,6,7,24,28,14,15,16,21,22,30,23	863.95503
Region 2		13,25,15,14,27	56.830532
Region 3	Oxidized Shale (Residual)	16,17,20,21	100
Region 4	Unoxidized Shale	17,18,19,20	775
Region 5	Soft Fill	28,26,27,14	88.698605
Region 6	Fill	7,8,9,32,10,34,11,12,13,27,26,28,24	99.387841
Region 7		9,8,7,6,5,4,3,2,1,23,30,29	38.645
Region 8		32,9,29,31	39.738241
Region 9		31,33,34,10,32	55.096324
Region 10		33,36,35,12,11,34	39.1

Points

	X (m)	Y (m)
Point 1	10.8	717.5
Point 2	15.3	717.2
Point 3	19.6	717.1
Point 4	28.9	716.9
Point 5	34.9	717.5
Point 6	37.6	717.7
Point 7	38.3	717.8
Point 8	40.5	718.2
Point 9	41.7	718.5
Point 10	52.5	721.8

Point 11	59.9	724
Point 12	68.2	724
Point 13	71.2	722.99
Point 14	86.9	717.8
Point 15	90	717.8
Point 16	90	709.4
Point 17	90	708.4
Point 18	90	700
Point 19	-10	700
Point 20	-10	707.1
Point 21	-10	708.1
Point 22	-10	717.3
Point 23	7.1	717.3
Point 24	52.5	717.2
Point 25	90	722.99
Point 26	67.8	722.7
Point 27	72.1	722.69248
Point 28	57	717.27849
Point 29	14.4	718.6
Point 30	6.7	717.3
Point 31	23.42113	720.1
Point 32	46.93636	720.1
Point 33	40.3	722.9
Point 34	56.2	722.9
Point 35	63.1	725.7
Point 36	57.1	725.7

Critical Slip Surfaces

	Slip Surface	FOS	Center (m)	Radius (m)	Entry (m)	Exit (m)
1	580	1.46	(44.675, 732.973)	26.246	(69.2128, 723.659)	(23.8412, 717.009)

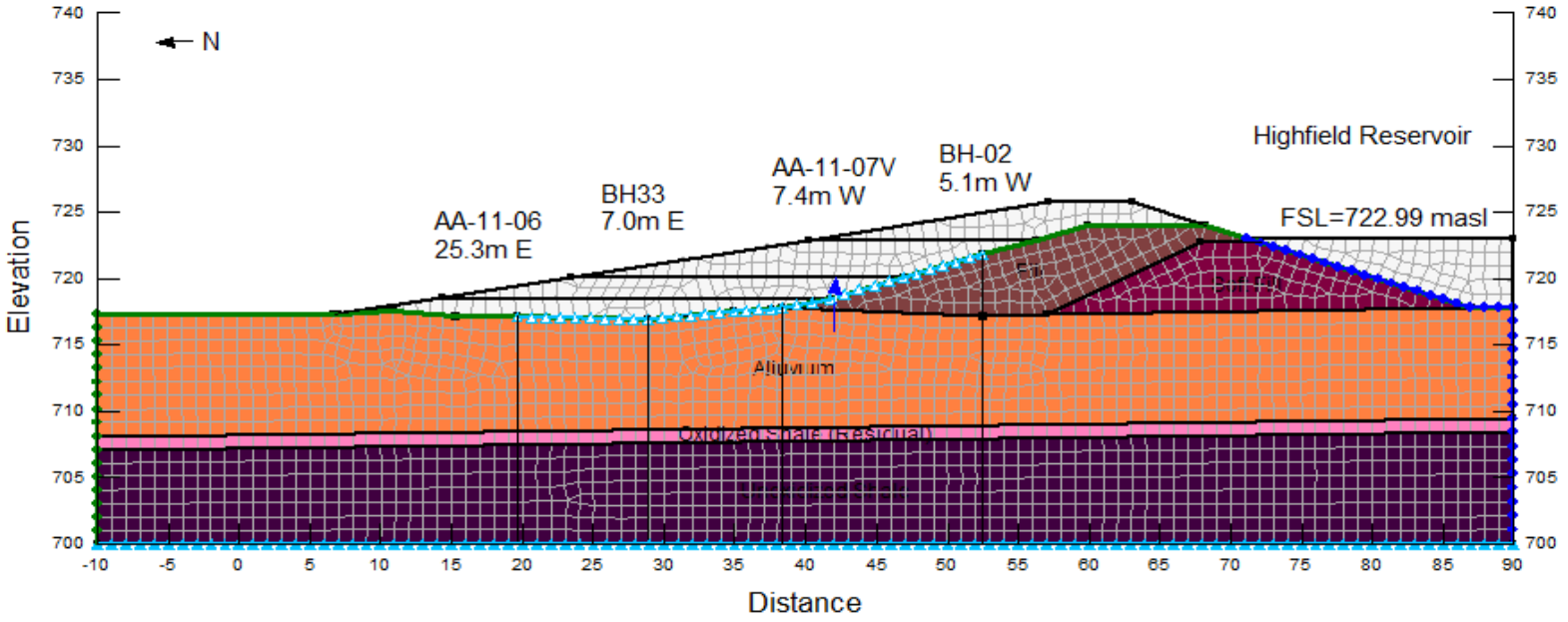
Slices of Slip Surface: 580

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
1	580	24.684335	716.0149	9.9171861	26.055679	8.580989	0
2	580	26.3706	714.19895	28.416797	70.591902	22.424901	0
3	580	28.056865	712.68625	44.246903	105.77161	32.713266	0
4	580	29.629265	711.485	57.062431	134.88862	41.38092	0
5	580	31.08779	710.53285	67.417852	159.59175	49.009731	0
6	580	32.546315	709.7111	76.57168	180.13039	55.063145	0
7	580	34.00484	709.0062	84.652234	196.87047	59.667493	0
8	580	34.81705	708.6479	88.898746	190.14935	17.853213	2

9	580	35.557125	708.3708	92.415876	197.15339	18.46805	2
10	580	36.871375	707.9226	98.261071	208.02201	19.353816	2
11	580	37.56425	707.71835	101.04094	201.22038	17.664339	2
12	580	37.95	707.72335	101.3843	201.89724	17.723144	2
13	580	39.3	707.7409	102.66133	205.52263	18.137224	2
14	580	40.4	707.7552	103.75123	208.77236	18.518058	2
15	580	41.1	707.7643	104.46621	211.67385	18.9036	2
16	580	42.572725	707.78345	106.01506	219.0535	19.931725	2
17	580	44.31818	707.80615	107.8998	228.53447	21.271147	2
18	580	46.063635	707.82885	109.81891	237.91233	22.586326	2
19	580	47.62864	707.8492	111.55654	246.2448	23.749174	2
20	580	49.0132	707.8672	113.08758	253.56779	24.770452	2
21	580	50.397765	707.8852	114.6114	260.85468	25.786636	2
22	580	51.795025	707.90715	116.10476	267.80041	26.748037	2
23	580	53.185755	708.1553	115.3718	253.83452	24.414713	2
24	580	54.55726	708.66935	112.01144	248.16911	24.00827	2
25	580	55.721505	709.17025	108.51804	233.51898	66.464183	0
26	580	56.6	709.59635	105.3894	228.30715	65.356524	0
27	580	57.05	709.82715	103.66254	225.49137	64.77754	0
28	580	57.8	710.2584	100.32586	220.11453	63.692761	0
29	580	59.2	711.12835	93.453664	209.28339	61.587757	0
30	580	60.7	712.2113	84.602955	191.7667	56.979973	0
31	580	62.3	713.555	73.323303	167.2173	49.924324	0
32	580	63.781425	715.00585	60.88645	141.87905	43.06453	0
33	580	65.14427	716.58145	47.148112	115.23311	36.201433	0
34	580	66.812845	718.996	26.144422	79.734686	19.505261	0
35	580	68	720.94755	9.4751423	45.393299	13.07314	0
36	580	68.51314	722.01685	0.18189892	25.334493	9.1547954	0
37	580	69.01955	723.1786	-10.320089	-0.2474195	-0.11537361	7

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Soft Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 1 - Existing Condition
Steady-State Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 1 (EXISTING): MODEL GEOMETRY & BOUNDARY CONDITIONS

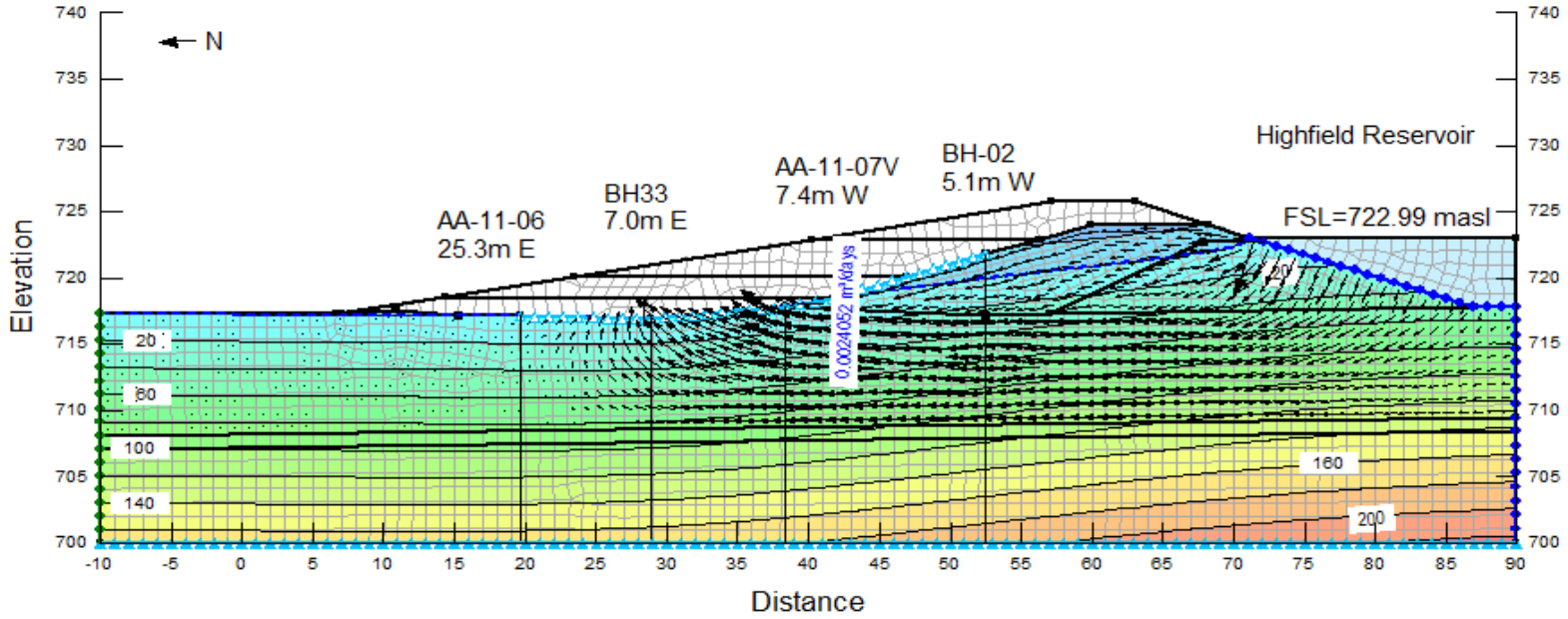
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.1

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Soft Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 1 - Existing Condition
Steady-State Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 1 (EXISTING): INITIAL PORE WATER PRESSURES AFTER LOADING

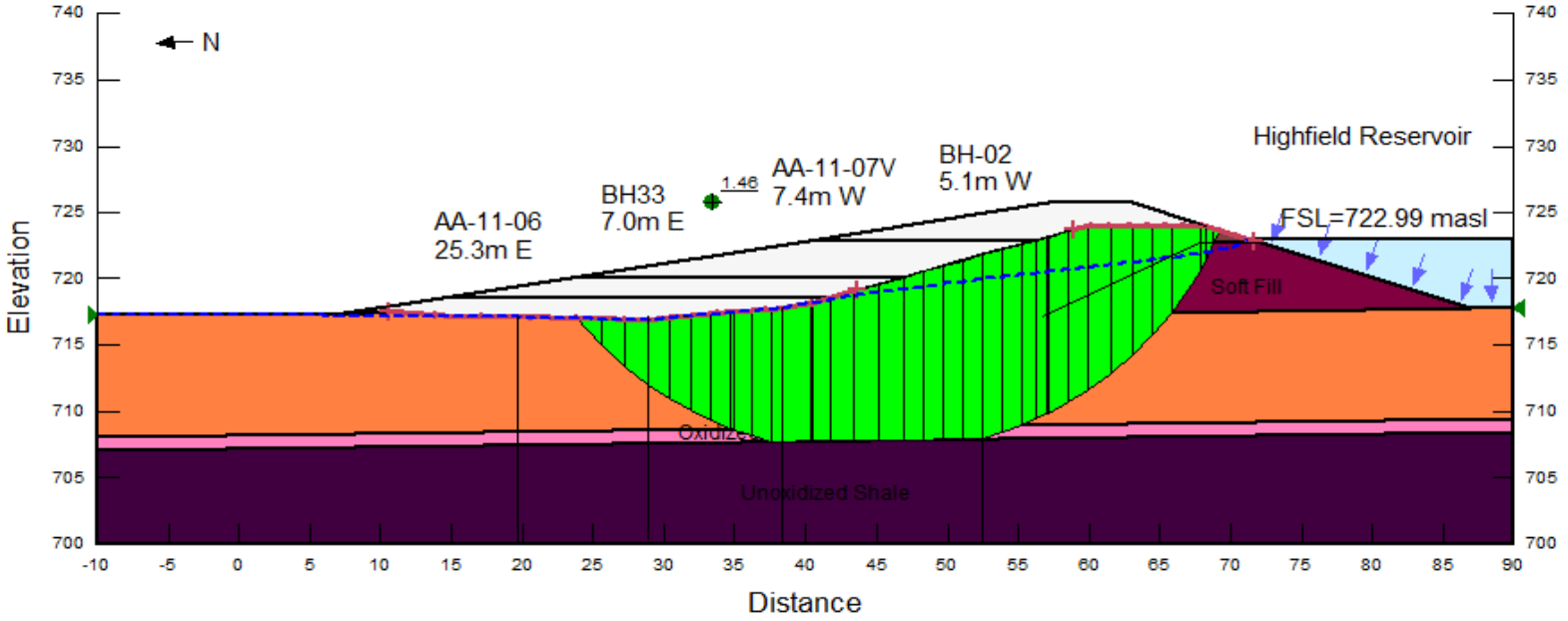
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.2

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °
Soft Fill 21 kN/m³ 0 kPa 20 °

Highfield Dam Foundation Embankment Assessment
Option 1 - Existing Condition
Slope Stability
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 1 (EXISTING): SLOPE STABILITY ANALYSIS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/1		

FIGURE: F.3

3rd Stage Transient Seepage

File Information

Title: Highfield Dam Foundation Embankment Assessment
Comments: Assessment of the Highfield Dam Emankment Alluvial Foundation Soils
Created By: Nehring, Lisa
Revision Number: 336
Last Edited By: Nehring, Lisa
Date: 1/17/2012
Time: 2:02:09 PM
File Name: Option 2 - 6 to 1 slope (staged).gsz
Directory: C:\Users\LNehring\Desktop\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\4000 Modelling\Models\Final Models\

Project Settings

Length(L) Units: meters
Time(t) Units: Days
Force(F) Units: kN
Pressure(p) Units: kPa
Mass(M) Units: kg
Mass Flux Units: kg/days
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

3rd Stage Transient Seepage

Kind: SEEP/W
Parent: 6H:1V Staged Construction 3rd Stage
Method: Transient
Settings
- Initial PWP: Parent Analysis
- Include Air Flow: No
- Exclude cumulative values: No

Control
- Apply Runoff: No

Convergence
- Convergence Type: Gauss Point K
- Convergence Settings
  - Maximum Number of Iterations: 25
  - Tolerance: 0.01
  - Maximum Change in K: 0.1
  - Rate of Change in K: 1.02
  - Minimum Change in K: 0.0001

Equation Solver: Parallel Direct
Potential Seepage Max # of Reviews: 10

Time
Starting Time: 63 days
Duration: 30 days
# of Steps: 30
Step Generation Method: Linear
Save Steps Every: 1
Use Adaptive Time Stepping: No

Materials

Unoxidized Shale

Model: Saturated Only
Hydraulic
K-Sat: 8.64e-005 m/days
Volumetric Water Content: 0.5 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

Alluvium

Model: Saturated Only
Hydraulic
K-Sat: 0.011232 m/days
Volumetric Water Content: 0.35 m³/m³
Mv: 4.73e-005 /kPa
K-Ratio: 1
K-Direction: 0 °

Fill

Model: Saturated Only
Hydraulic
K-Sat: 0.00432 m/days
Volumetric Water Content: 0.42 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

New Fill

Model: Saturated Only
Hydraulic
K-Sat: 0.00432 m/days
Volumetric Water Content: 0.42 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

Granular Drain

Model: Saturated Only
Hydraulic
K-Sat: 8.64 m/days
Volumetric Water Content: 0.3 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

Fill (Original)
Model: Saturated Only
Hydraulic
K-Sat: 0.00432 m/days
Volumetric Water Content: 0.42 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

Oxidized Shale (Residual)
Model: Saturated Only
Hydraulic
K-Sat: 8.64e-005 m/days
Volumetric Water Content: 0.5 m³/m³
Mv: 0.0001 /kPa
K-Ratio: 1
K-Direction: 0 °

Boundary Conditions

Potential Seepage Face
Review: true
Type: Total Flux (Q) 0

Reservoir Head
Type: Head (H) 722.99

Downstream Boundary
Type: Head (H) 717.3

Flux Sections

Flux Section 1
Coordinates
Coordinate: (15.3, 716.3149) m
Coordinate: (15.3, 722) m

Regions

	Material	Points	Area (m²)
Region 1	Alluvium	1,2,3,4,5,6,7,24,28,14,15,16,21,22,30,23	1029.355
Region 2		13,25,15,14,27	160.63053
Region 3	Oxidized Shale (Residual)	16,17,20,21	120
Region 4	Unoxidized Shale	17,18,19,20	945.6
Region 5	Fill (Original)	28,26,27,14	88.698605
Region 6	Fill	7,8,9,32,10,34,11,12,13,27,26,28,24	99.387841
Region 7	Granular Drain	9,8,7,6,5,4,3,2,1,23,30,29	38.645
Region 8	New Fill	32,9,29,31	39.738241
Region 9	New Fill	31,33,34,10,32	55.096324
Region 10	New Fill	33,36,35,12,11,34	39.1

Lines

	Start Point	End Point	Hydraulic Boundary
Line 1	1	2	
Line 2	2	3	
Line 3	3	4	
Line 4	5	6	
Line 5	6	7	
Line 6	14	15	Reservoir Head
Line 7	15	16	Reservoir Head
Line 8	16	21	
Line 9	21	22	Downstream Boundary
Line 10	23	1	
Line 11	13	25	
Line 12	25	15	
Line 13	16	17	Reservoir Head
Line 14	17	20	
Line 15	20	21	Downstream Boundary
Line 16	17	18	Reservoir Head
Line 17	18	19	
Line 18	19	20	Downstream Boundary
Line 19	24	7	
Line 20	13	27	Reservoir Head
Line 21	27	14	Reservoir Head
Line 22	14	28	
Line 23	28	24	
Line 24	28	26	
Line 25	26	27	
Line 26	7	8	
Line 27	8	9	
Line 28	11	12	
Line 29	12	13	

Line 30	5	4	
Line 31	22	30	Potential Seepage Face
Line 32	30	23	
Line 33	9	29	
Line 34	30	29	Potential Seepage Face
Line 35	29	31	Potential Seepage Face
Line 36	10	32	
Line 37	32	9	
Line 38	31	32	
Line 39	11	34	
Line 40	34	10	
Line 41	31	33	Potential Seepage Face
Line 42	33	34	
Line 43	33	36	
Line 44	36	35	
Line 45	35	12	

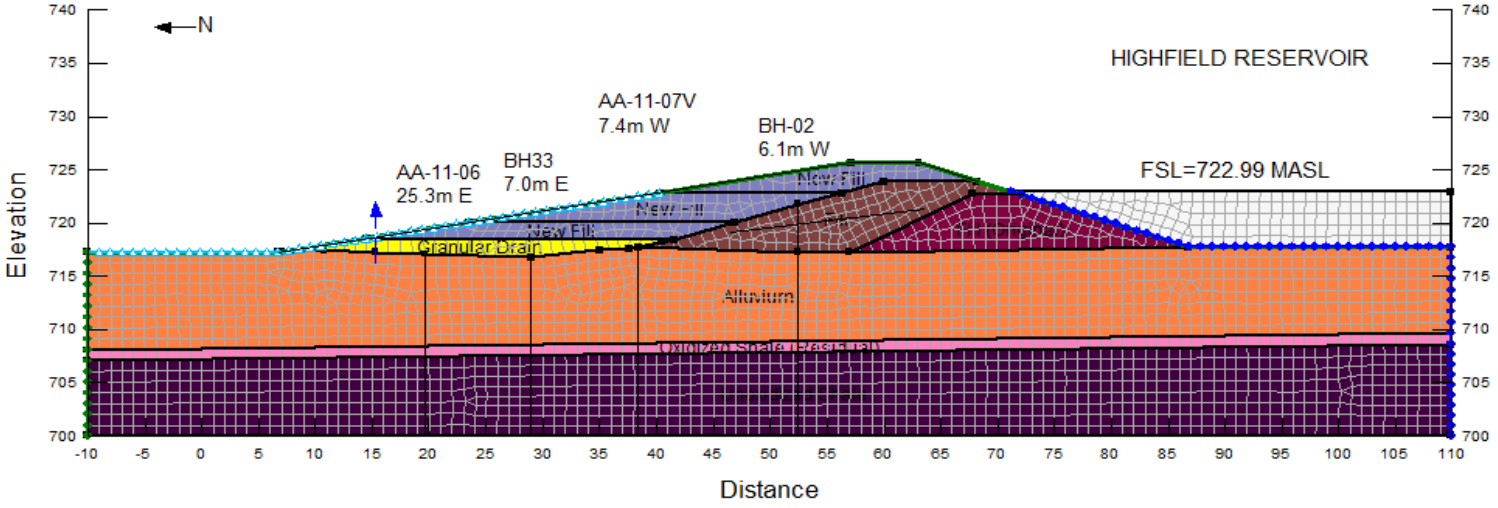
Points

	X (m)	Y (m)
Point 1	10.8	717.5
Point 2	15.3	717.2
Point 3	19.6	717.1
Point 4	28.9	716.9
Point 5	34.9	717.5
Point 6	37.6	717.7
Point 7	38.3	717.8
Point 8	40.5	718.2
Point 9	41.7	718.5
Point 10	52.5	721.8
Point 11	59.9	724
Point 12	68.2	724
Point 13	71.2	722.99
Point 14	86.9	717.8
Point 15	110	717.8
Point 16	110	709.66
Point 17	110	708.66
Point 18	110	700
Point 19	-10	700
Point 20	-10	707.1
Point 21	-10	708.1
Point 22	-10	717.3
Point 23	7.1	717.3
Point 24	52.5	717.2

Point 25	110	722.99
Point 26	67.8	722.7
Point 27	72.1	722.69248
Point 28	57	717.27849
Point 29	14.4	718.6
Point 30	6.7	717.3
Point 31	23.42113	720.1
Point 32	46.93636	720.1
Point 33	40.3	722.9
Point 34	56.2	722.9
Point 35	63.1	725.7
Point 36	57.1	725.7

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 2 - 6H:1V Staged Construction 3rd Stage
3rd Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (STAGED): MODEL GEOMETRY & BOUNDARY CONDITIONS

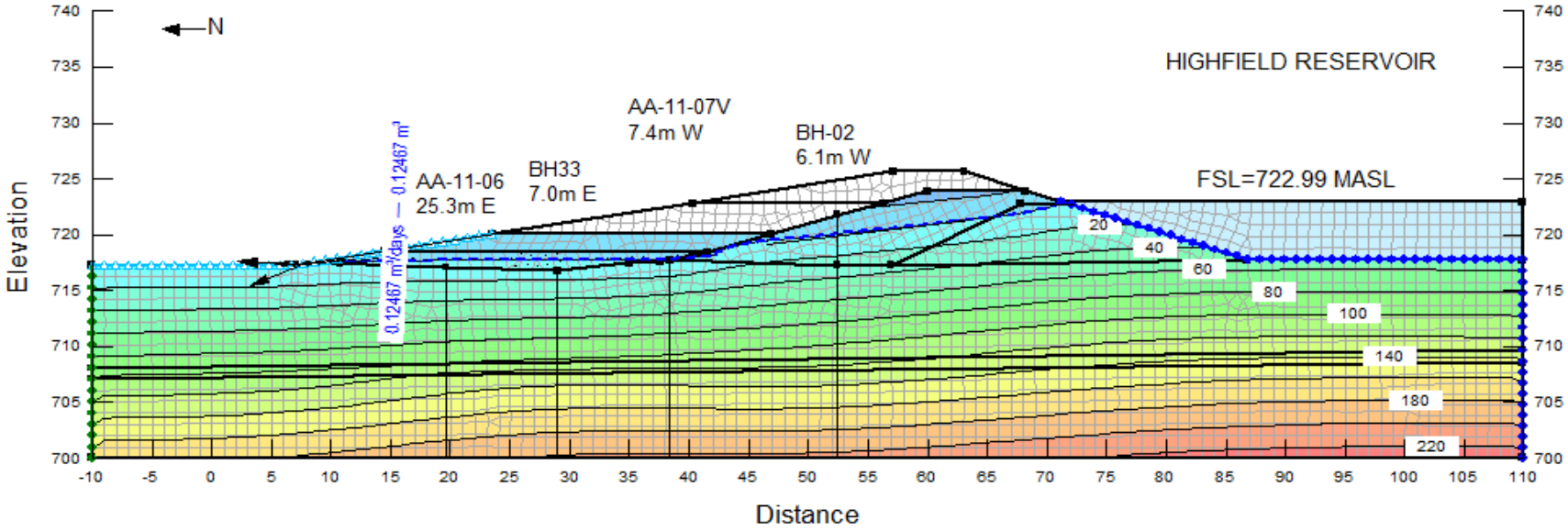
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.4

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 2 - 6H:1V Staged Construction 1st Stage
1st Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (1ST STAGE): INITIAL PORE WATER PRESSURES AFTER LOADING

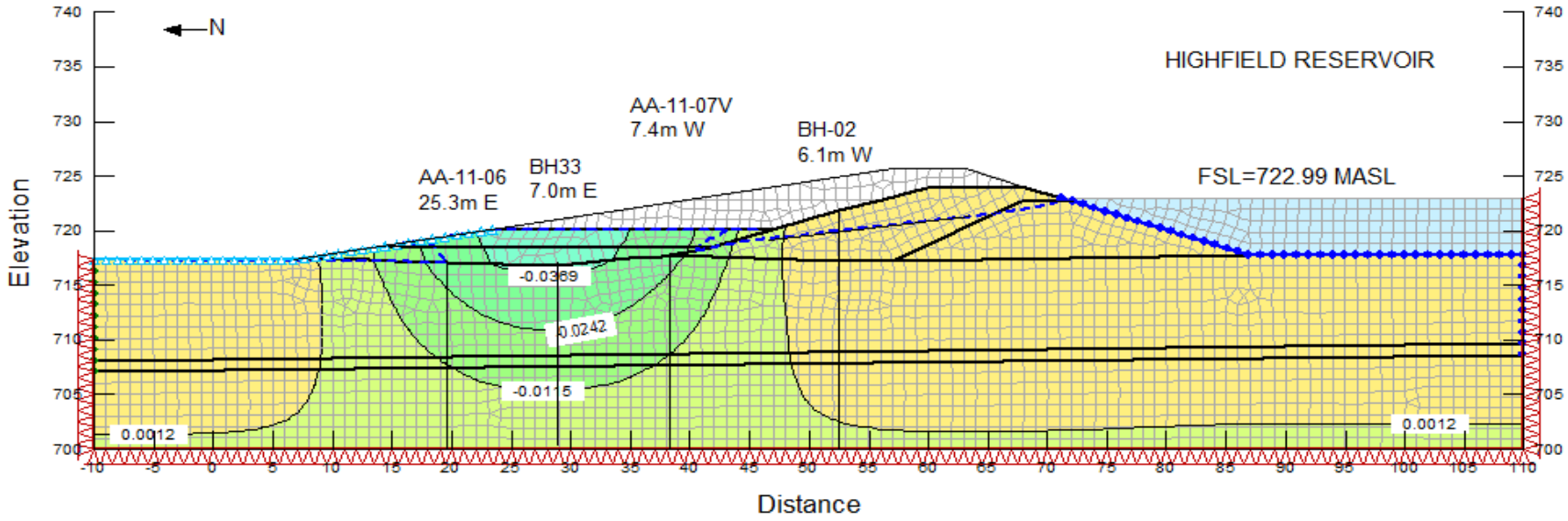
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.5

Unoxidized Shale Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Alluvium Linear Elastic 15000 kPa 0.334 Alluvium, VWC=0.42
Fill Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
New Fill Linear Elastic 15000 kPa 0.334
Granular Drain Linear Elastic 50000 kPa 0.334 Drain, VWC=0.3
Fill (Original) Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
Oxidized Shale (Residual) Linear Elastic 15000 kPa 0.334 Shale VWC=0.5

Highfield Dam Foundation Embankment Assessment
Option 2 - Existing Conditions
6H:1V Staged Construction 1st Stage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (1ST STAGE): VERTICAL SETTLEMENT DUE TO LOADING

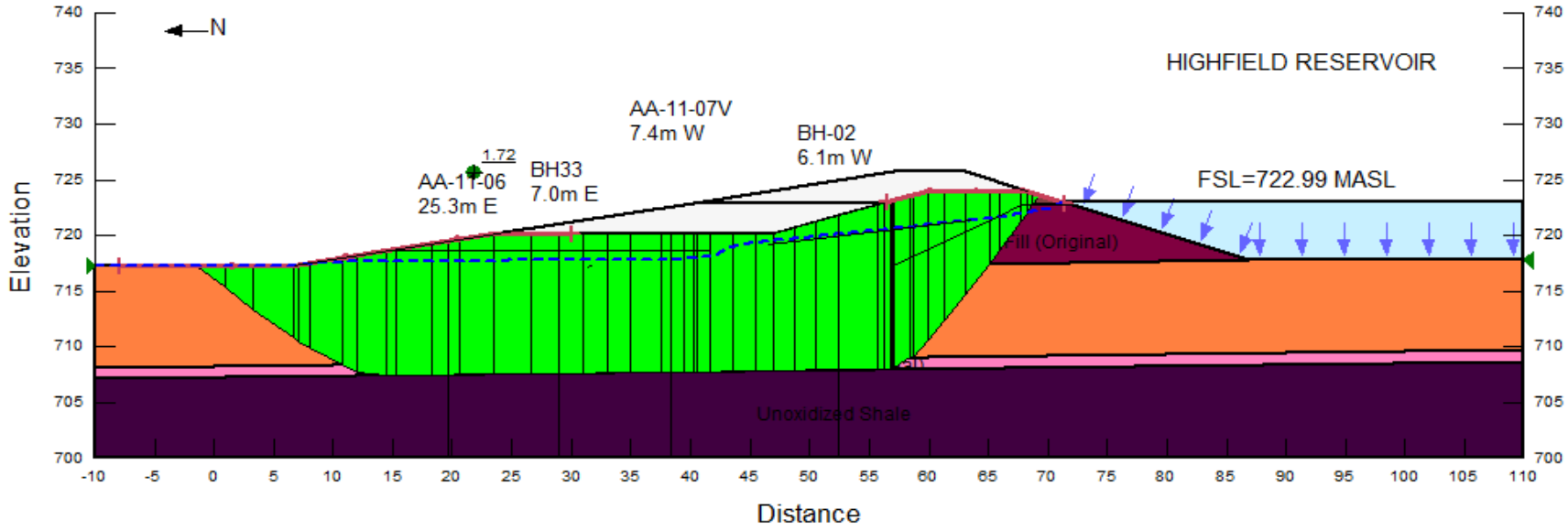
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.6

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Fill (Original) 21 kN/m³ 0 kPa 20 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °

Highfield Dam Foundation Embankment Assessment
Option 2 - 1st Stage Transient Seepage
1st Stage Slope Stability (initial)
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (1ST STAGE): SLOPE STABILITY ANALYSIS

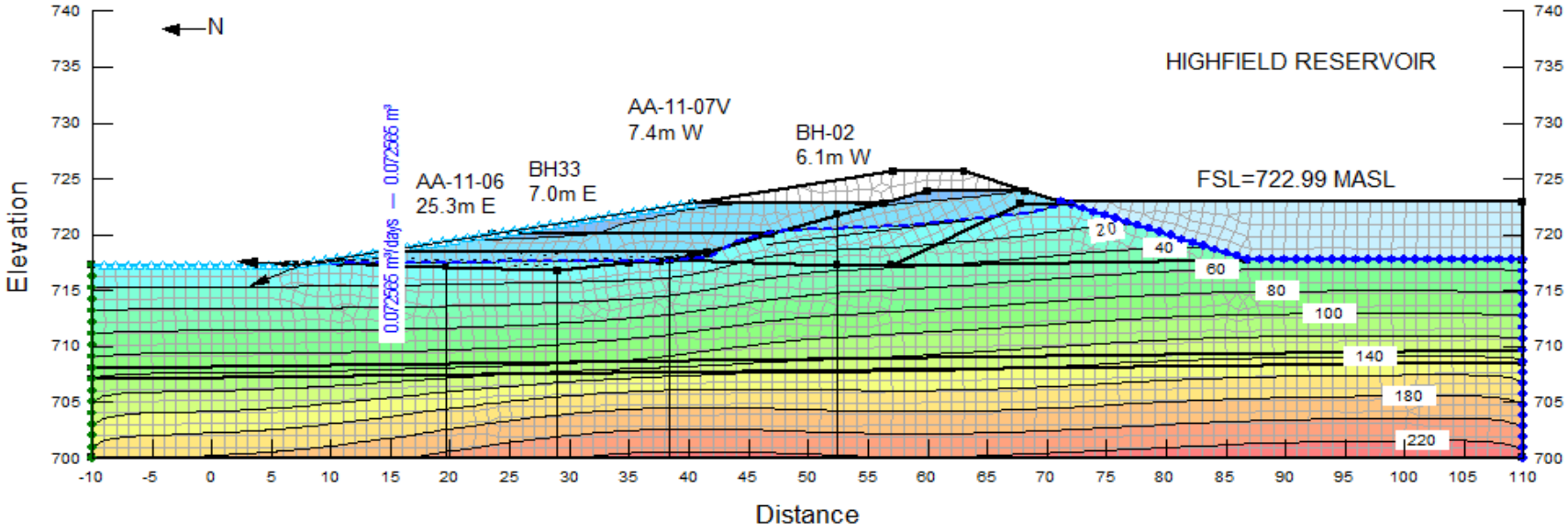
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.7

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 2 - 6H:1V Staged Construction 2nd Stage
2nd Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (2ND STAGE): INITIAL PORE WATER PRESSURES AFTER LOADING

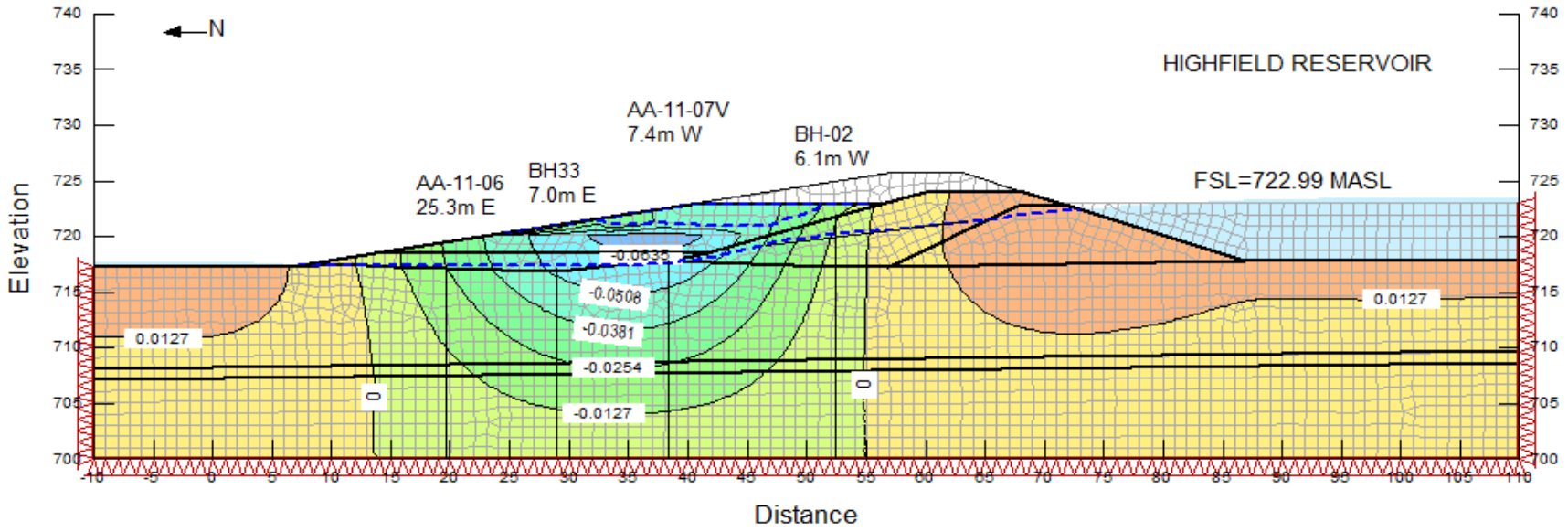
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.8

Unoxidized Shale Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Alluvium Linear Elastic 15000 kPa 0.334 Alluvium, VWC=0.42
Fill Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
New Fill Linear Elastic 15000 kPa 0.334
Granular Drain Linear Elastic 50000 kPa 0.334 Drain, VWC=0.3
Fill (Original) Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
Oxidized Shale (Residual) Linear Elastic 15000 kPa 0.334 Shale VWC=0.5

Highfield Dam Foundation Embankment Assessment
Option 2 - 1st Stage Transient Seepage
6H:1V Staged Construction 2nd Stage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

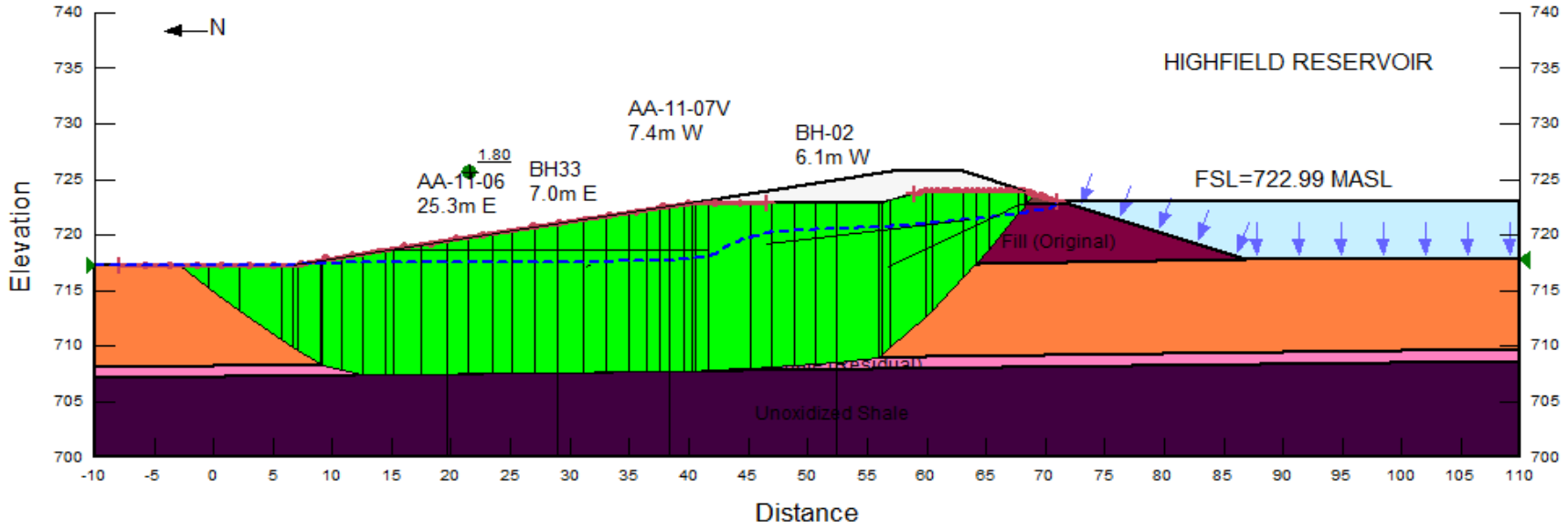
TITLE
OPTION 2 (2ND STAGE): VERTICAL SETTLEMENT DUE TO LOADING

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE N/A	REV.	
CADD			**FIGURE: F.9**		
CHECK					
REVIEW	RGR	23/01/12			

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Fill (Original) 21 kN/m³ 0 kPa 20 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °

Highfield Dam Foundation Embankment Assessment
Option 2 - 2nd Stage Transient Seepage
2nd Stage Slope Stability (initial)
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (2ND STAGE): SLOPE STABILITY ANALYSIS

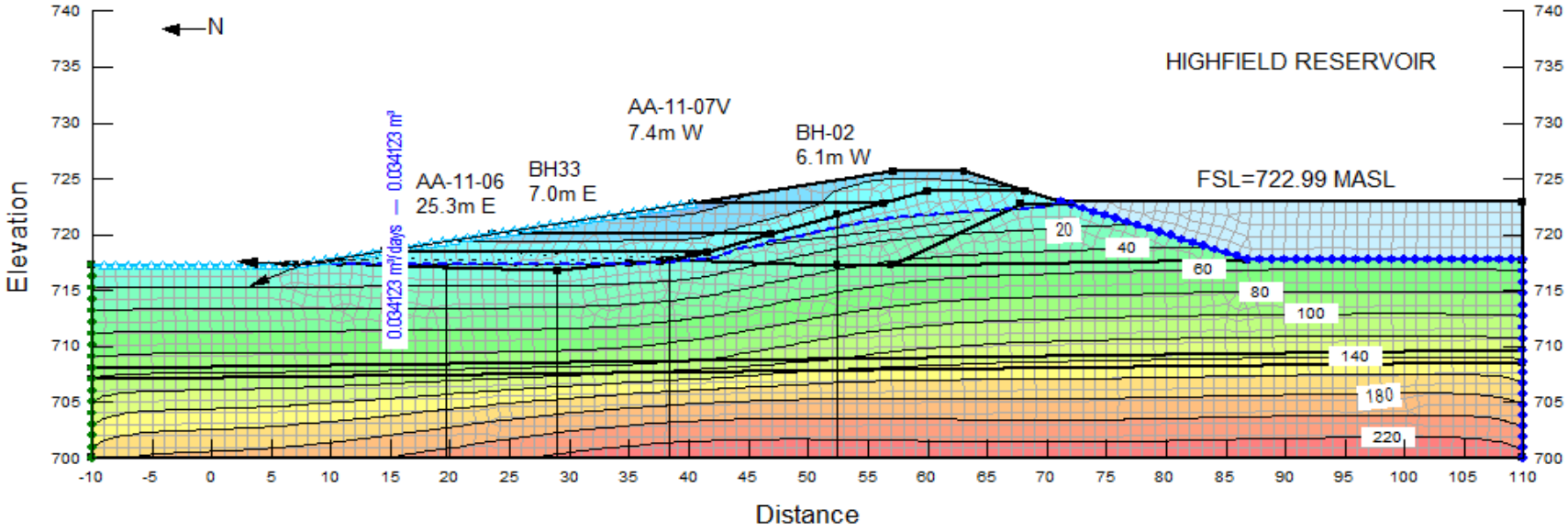
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.10

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 2 - 6H:1V Staged Construction 3rd Stage
3rd Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (3RD STAGE): INITIAL PORE WATER PRESSURES AFTER LOADING

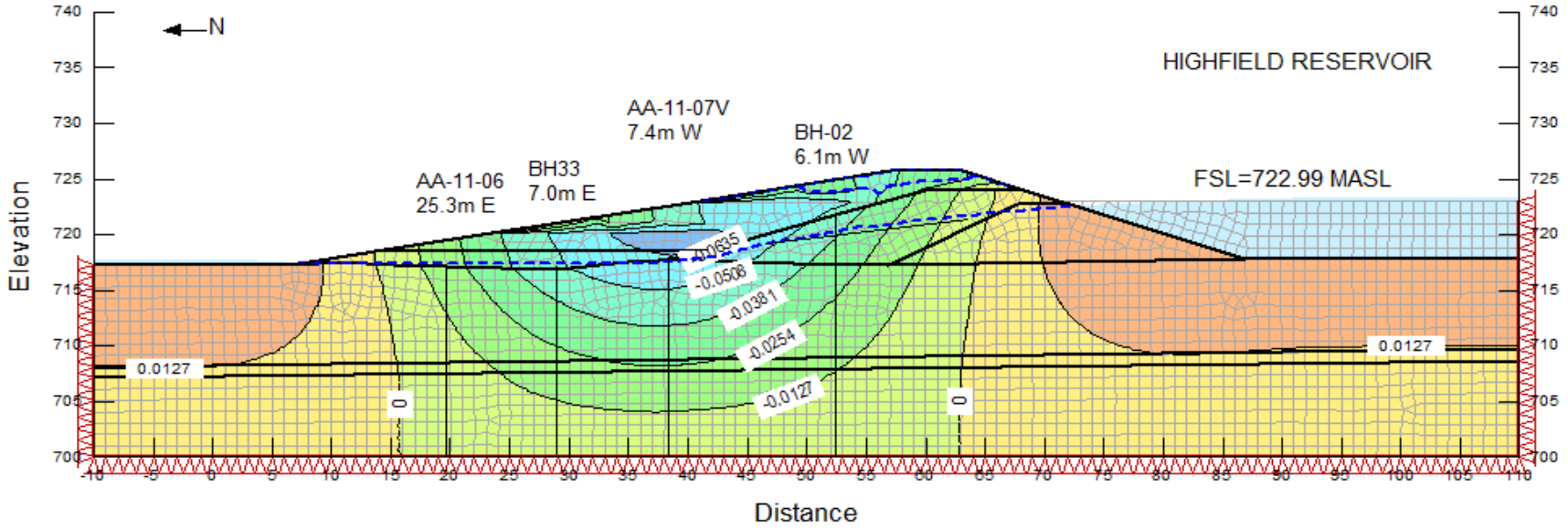
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.11

Unoxidized Shale Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Alluvium Linear Elastic 15000 kPa 0.334 Alluvium, VWC=0.42
Fill Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
New Fill Linear Elastic 15000 kPa 0.334
Granular Drain Linear Elastic 50000 kPa 0.334 Drain, VWC=0.3
Fill (Original) Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
Oxidized Shale (Residual) Linear Elastic 15000 kPa 0.334 Shale VWC=0.5

Highfield Dam Foundation Embankment Assessment
Option 2 - 2nd Stage Transient Seepage
6H:1V Staged Construction 3rd Stage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (3RD STAGE): VERTICAL SETTLEMENT DUE TO LOADING

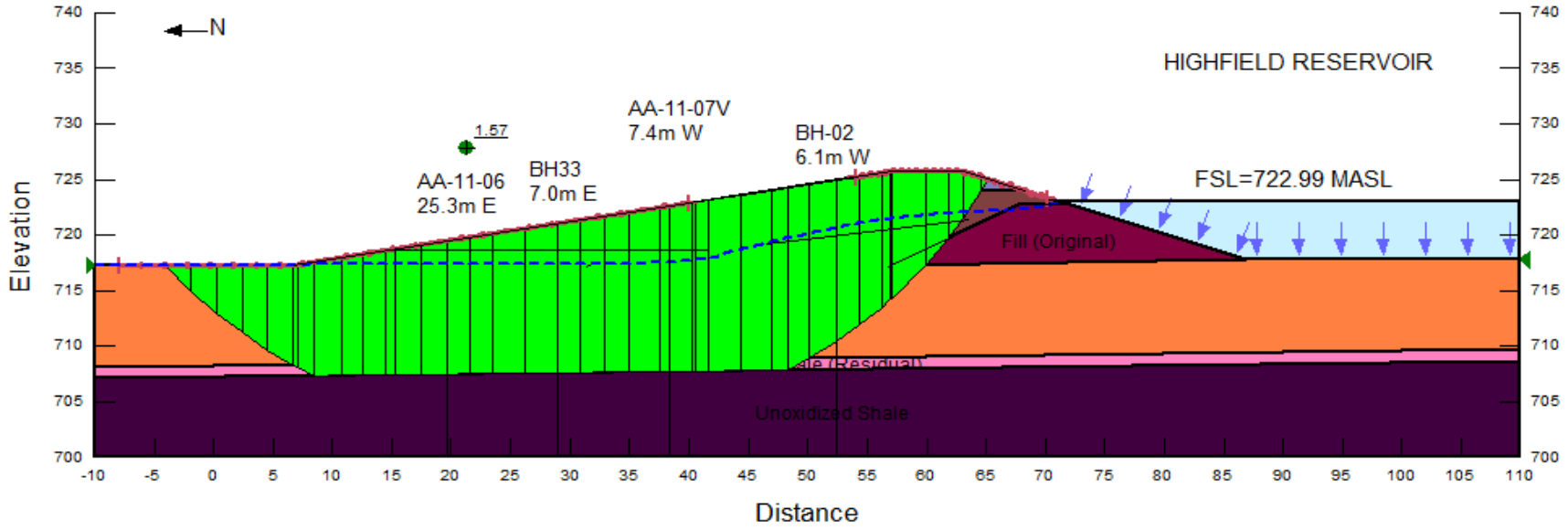
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.12

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Fill (Original) 21 kN/m³ 0 kPa 20 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °

Highfield Dam Foundation Embankment Assessment
Option 2 - 3rd Stage Transient Seepage
3rd Stage Slope Stability (initial)
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 2 (3RD STAGE): SLOPE STABILITY ANALYSIS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.13

Initial Slope Stability

File Information

Title: Highfield Dam Foundation Embankment Assessment
Created By: Nehring, Lisa
Revision Number: 308
Last Edited By: Nehring, Lisa
Date: 1/16/2012
Time: 8:59:08 PM
File Name: Option 3 - 6 to 1 slope (1 stage).gsz
Directory: C:\Users\LNehring\Desktop\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\4000 Modelling\Models\Final Models\
Last Solved Date: 1/16/2012
Last Solved Time: 9:01:30 PM

Project Settings

Length(L) Units: meters
Time(t) Units: Days
Force(F) Units: kN
Pressure(p) Units: kPa
Strength Units: kPa
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

Initial Slope Stability

Kind: SLOPE/W
Parent: Final Stage Construction
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Parent Analysis

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30
- Optimization Tolerance: 0.01
- Minimum Slip Surface Depth: 0.1 m
- Optimization Maximum Iterations: 2000
- Optimization Convergence Tolerance: 1e-007
- Starting Optimization Points: 8
- Ending Optimization Points: 16
- Complete Passes per Insertion: 1
- Driving Side Maximum Convex Angle: 5 °
- Resisting Side Maximum Convex Angle: 1 °

Materials

Unoxidized Shale
Model: Bedrock (Impenetrable)

Alluvium
Model: Mohr-Coulomb
Unit Weight: Multiple Trial: 19 kN/m³
- Constant Value: 19
- Probabilistic: Triangular(Min=18,Mode=19,Max=20)

Cohesion: 0 kPa
Phi: Multiple Trial: 28 °
- Constant Value: 28
- Probabilistic: Triangular(Min=20,Mode=28,Max=35)

Phi-B: 0 °

Fill
Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Water
Model: (None)

New Fill
Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Granular Drain
Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa

Phi: 35 °
Phi-B: 0 °

Oxidized Shale (Residual)

Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 2 kPa
Phi: 10 °
Phi-B: 0 °

Fill (Original)

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-5, 717.3) m
Left-Zone Right Coordinate: (30, 721.19391) m
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (55, 725.35082) m
Right-Zone Right Coordinate: (71, 723.05733) m
Right-Zone Increment: 25
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (-10, 717.3) m
Right Coordinate: (110, 717.8) m

Regions

	Material	Points	Area (m²)
Region 1	Alluvium	1,2,3,4,5,6,7,24,28,14,15,16,21,22,30,23	1029.355
Region 2	Water	13,25,15,14,27	160.63053
Region 3	Oxidized Shale (Residual)	16,17,20,21	120
Region 4	Unoxidized Shale	17,18,19,20	945.6
Region 5	Fill (Original)	28,26,27,14	88.698605
Region 6	Fill	7,8,9,10,11,12,13,27,26,28,24	99.387835
Region 7	Granular Drain	9,8,7,6,5,4,3,2,1,23,30,29	38.645
Region 8	New Fill	29,33,32,31,12,11,10,9	134.045

Points

	X (m)	Y (m)
Point 1	10.8	717.5
Point 2	15.3	717.2
Point 3	19.6	717.1
Point 4	28.9	716.9
Point 5	34.9	717.5
Point 6	37.6	717.7
Point 7	38.3	717.8
Point 8	40.5	718.2
Point 9	41.7	718.5
Point 10	52.5	721.8
Point 11	59.9	724
Point 12	68.2	724
Point 13	71.2	722.99
Point 14	86.9	717.8
Point 15	110	717.8
Point 16	110	709.66
Point 17	110	708.66
Point 18	110	700
Point 19	-10	700
Point 20	-10	707.1
Point 21	-10	708.1
Point 22	-10	717.3
Point 23	7.1	717.3
Point 24	52.5	717.2
Point 25	110	722.99
Point 26	67.8	722.7
Point 27	72.1	722.69248
Point 28	57	717.27849
Point 29	14.4	718.6
Point 30	6.7	717.3
Point 31	63.1	725.7
Point 32	57.1	725.7
Point 33	37.25352	722.4

Critical Slip Surfaces

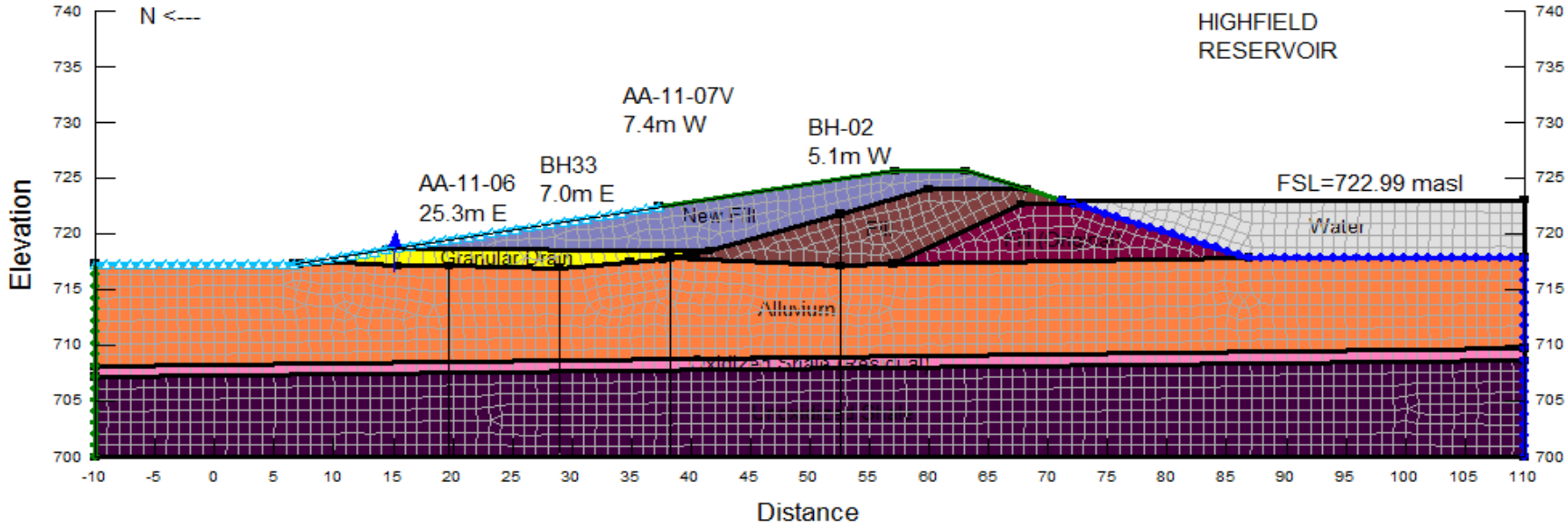
	Slip Surface	FOS	Center (m)	Radius (m)	Entry (m)	Exit (m)
1	744	1.38	(28.583, 744.322)	40.941	(64.757, 725.148)	(-2.17415, 717.3)

Slices of Slip Surface: 744

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
1	744	-1.0648795	716.1333	12.61775	29.397003	8.9216871	0
2	744	1.1536576	713.9643	36.243893	81.661634	24.149041	0
3	744	3.3721945	712.09425	56.735982	125.03146	36.313352	0
4	744	5.5907315	710.473	74.587103	161.34066	46.127684	0
5	744	6.9	709.5946	84.278068	181.31776	51.596922	0
6	744	8.068618	708.9086	91.928137	200.99928	57.994155	0
7	744	9.918618	707.89585	108.48673	210.70802	18.02437	2
8	744	10.87493	707.40825	120.18778	225.06406	18.492517	2
9	744	11.812395	707.38355	122.23991	214.29226	16.231313	2
10	744	13.537465	707.406	124.75554	219.16122	16.646268	2
11	744	14.85	707.42305	126.82262	222.95895	16.951428	2
12	744	16.375	707.4429	129.37044	227.63654	17.326965	2
13	744	18.525	707.47085	133.10501	234.16622	17.819818	2
14	744	20.7625	707.4999	137.06371	240.88292	18.306127	2
15	744	23.0875	707.53015	141.08918	247.78556	18.813451	2
16	744	25.4125	707.5604	144.99423	254.61079	19.328358	2
17	744	27.7375	707.5906	148.66704	261.37151	19.87284	2
18	744	29.9	707.6187	151.82217	267.60739	20.416058	2
19	744	31.9	707.6447	154.47195	273.3319	20.958217	2
20	744	33.9	707.6707	156.80175	279.02642	21.551507	2
21	744	36.07676	707.699	158.92296	285.19547	22.26525	2
22	744	37.42676	707.71655	160.00725	288.99657	22.744298	2
23	744	37.95	707.72335	160.38646	290.48976	22.940722	2
24	744	39.4	707.7422	161.29091	295.06596	23.588151	2
25	744	41.1	707.7643	162.11136	300.69969	24.436863	2
26	744	43.067785	707.7899	162.71268	306.69229	25.38749	2
27	744	45.803355	707.82545	162.98682	314.59491	26.732596	2
28	744	48.11446	708.3555	150.88047	288.90498	24.337446	2
29	744	49.918335	709.39345	135.05084	258.5735	65.678162	0
30	744	51.639445	710.5058	124.75655	242.35549	62.528466	0
31	744	53.625	711.96315	110.61583	220.92235	58.651019	0
32	744	55.925	713.88945	91.156941	192.34817	53.804332	0
33	744	58.22891	716.13235	67.805849	155.9501	46.867127	0
34	744	59.62891	717.635	51.358246	137.56609	31.377088	0
35	744	60.43206	718.6094	39.308389	118.85373	28.952136	0
36	744	62.03206	720.7862	13.002471	67.96924	25.631425	7
37	744	63.612485	723.152	-9.8351589	26.447948	12.332881	7
38	744	64.44099	724.57385	-19.749732	3.119383	1.4545922	7

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Water	(none)			
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 3 - Existing Conditions
Final Stage Construction
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 3 (ONE STAGE): MODEL GEOMETRY & BOUNDARY CONDITIONS

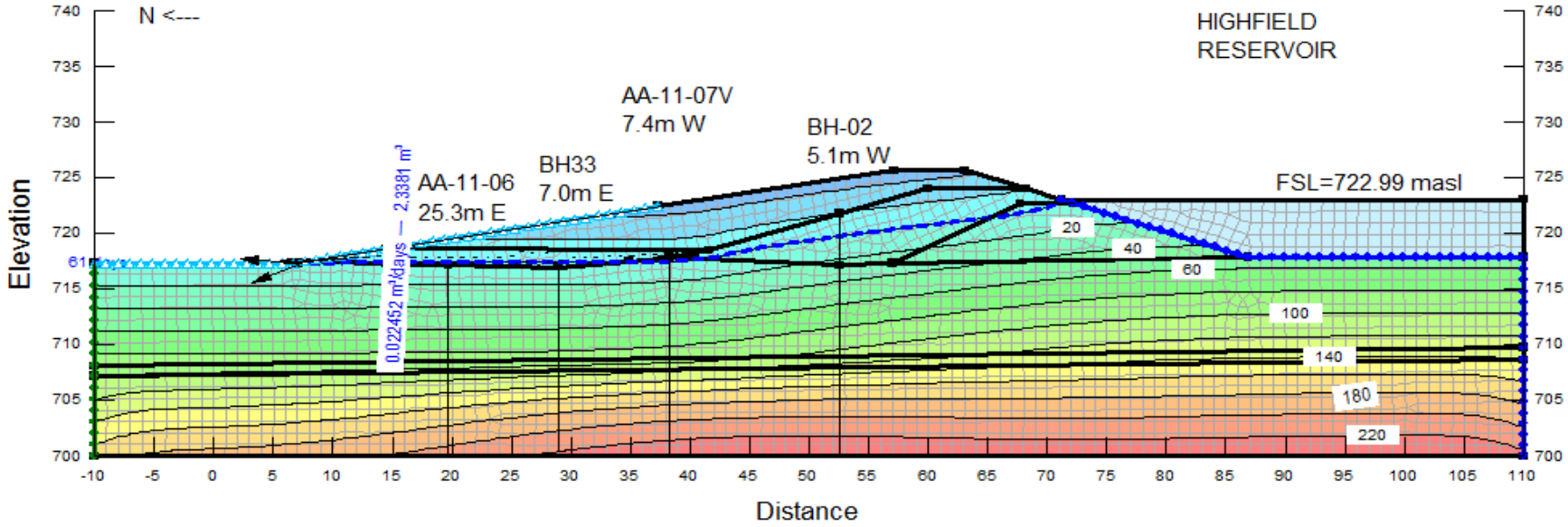
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.14

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Water	(none)			
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 3 - Existing Conditions
Final Stage Construction
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 3 (ONE STAGE): INITIAL PORE WATER PRESSURES AFTER LOADING

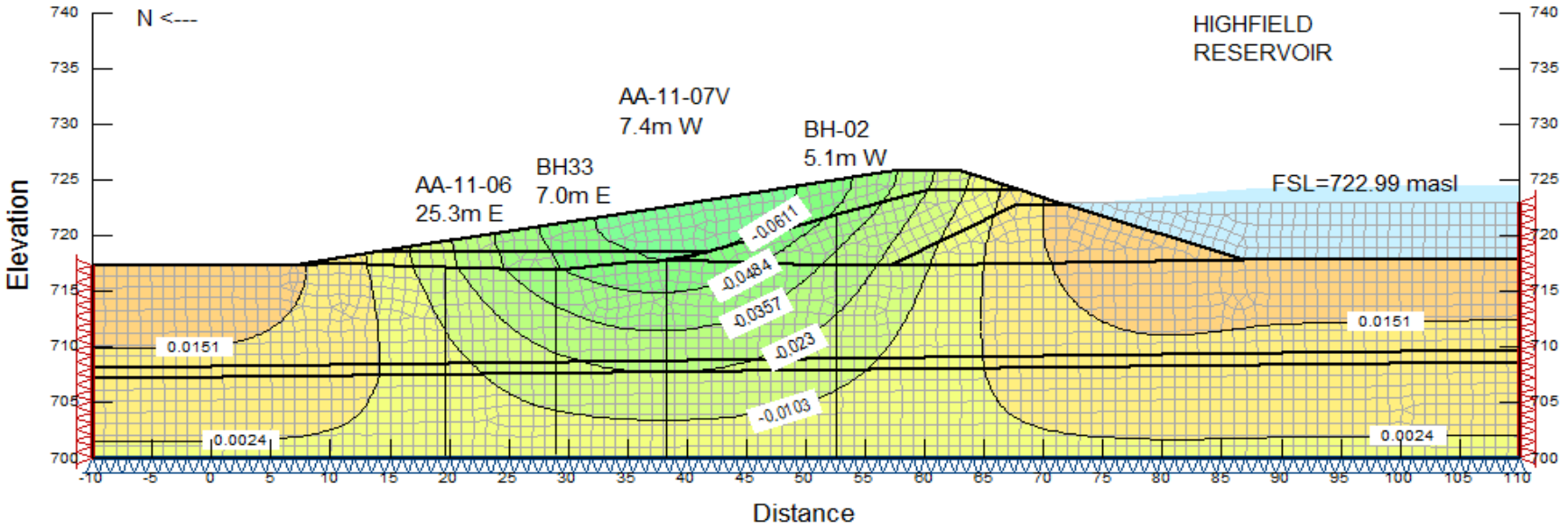
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.15

Unoxidized Shale Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Alluvium Linear Elastic 15000 kPa 0.334 Alluvium, VWC=0.42
Fill Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
Water (none)
New Fill Linear Elastic 15000 kPa 0.334
Granular Drain Linear Elastic 50000 kPa 0.334 Drain, VWC=0.3
Oxidized Shale (Residual) Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Fill (Original) Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42

Highfield Dam Foundation Embankment Assessment
Option 3 - Steady-State Seepage
One Stage Construction
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 3 (ONE STAGE): VERTICAL SETTLEMENT DUE TO LOADING

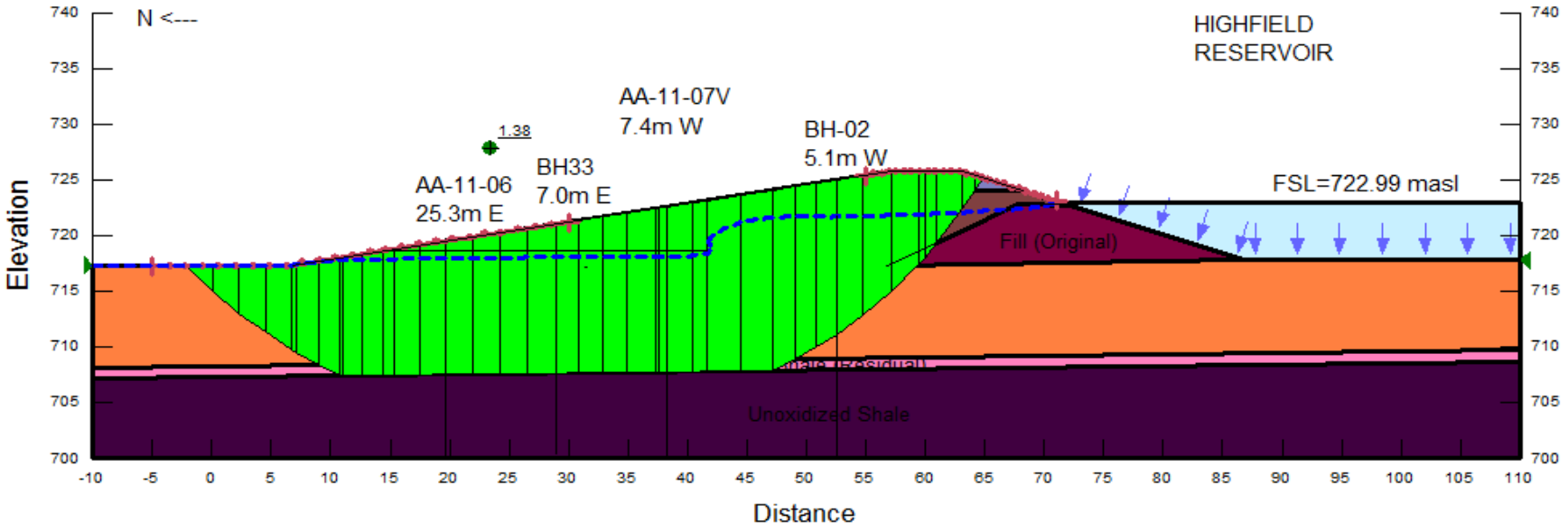
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.16

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
Water
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °
Fill (Original) 21 kN/m³ 0 kPa 20 °

Highfield Dam Foundation Embankment Assessment
Option 3 - One Stage Construction
Initial Slope Stability
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 3 (ONE STAGE): SLOPE STABILITY ANALYSIS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD			**FIGURE: F.17**		
CHECK					
REVIEW	RGR	23/01/12			

Slope Stability (initial)

File Information

Title: Highfield Dam Foundation Embankment Assessment
Comments: Assessment of the Highfield Dam Emankment Alluvial Foundation Soils
Created By: Nehring, Lisa
Revision Number: 325
Last Edited By: Nehring, Lisa
Date: 12/15/2011
Time: 7:01:51 PM
File Name: Option 4 - 5 to 1 slope (1 stage).gsz
Directory: C:\Users\LNehring\Desktop\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\4000 Modelling\Models\Final Models\
Last Solved Date: 12/15/2011
Last Solved Time: 7:03:20 PM

Project Settings

Length(L) Units: meters
Time(t) Units: Days
Force(F) Units: kN
Pressure(p) Units: kPa
Strength Units: kPa
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

Slope Stability (initial)

Kind: SLOPE/W
Parent: 5H:1V Transient Seepage
Method: Morgenstern-Price
Settings
    Side Function
        Interslice force function option: Half-Sine
    PWP Conditions Source: Parent Analysis
Slip Surface
    Direction of movement: Right to Left
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 1
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)
FOS Distribution

FOS Calculation Option: Constant

Advanced

Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 m
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Unoxidized Shale

Model: Bedrock (Impenetrable)

Alluvium

Model: Mohr-Coulomb
Unit Weight: Multiple Trial: 19 kN/m³
Constant Value: 19
Probabilistic: Triangular(Min=18,Mode=19,Max=21)
Cohesion: 0 kPa
Phi: Multiple Trial: 28 °
Constant Value: 28
Probabilistic: Triangular(Min=20,Mode=28,Max=35)
Phi-B: 0 °

Fill

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

New Fill

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Granular Drain

Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Phi-B: 0 °

Fill (Original)

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Phi-B: 0 °

Oxidized Shale (Residual)

Model: Mohr-Coulomb
Unit Weight: 22 kN/m³
Cohesion: 2 kPa
Phi: 10 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (-4, 717.35769) m
Left-Zone Right Coordinate: (40, 722.28) m
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (56, 725.48) m
Right-Zone Right Coordinate: (71, 723.05733) m
Right-Zone Increment: 25
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (-10, 717.3) m
Right Coordinate: (110, 717.8) m

Regions

	Material	Points	Area (m²)
Region 1	Alluvium	1,35,2,3,4,5,6,7,23,27,14,15,16,21,22	1031.0663
Region 2		13,24,15,14,26	160.63053
Region 3	Oxidized Shale (Residual)	16,17,20,21	120
Region 4	Unoxidized Shale	17,18,19,20	945.6
Region 5	Fill (Original)	27,25,26,14	88.698605
Region 6	Fill	7,8,9,30,10,32,11,12,13,26,25,27,23	99.387841
Region 7	Granular Drain	9,8,7,6,5,4,3,2,35,28	28.462599
Region 8	New Fill	30,9,28,29	30.749088
Region 9	New Fill	29,31,32,10,30	43.225906
Region 10	New Fill	31,34,33,12,11,32	35.18

Points

	X (m)	Y (m)
Point 1	10.8	717.5
Point 2	15.3	717.2
Point 3	19.6	717.1
Point 4	28.9	716.9
Point 5	34.9	717.5
Point 6	37.6	717.7
Point 7	38.3	717.8
Point 8	40.5	718.2
Point 9	41.7	718.5
Point 10	52.5	721.8
Point 11	59.9	724
Point 12	68.2	724
Point 13	71.2	722.99
Point 14	86.9	717.8
Point 15	110	717.8
Point 16	110	709.66
Point 17	110	708.66
Point 18	110	700
Point 19	-10	700
Point 20	-10	707.1
Point 21	-10	708.1
Point 22	-10	717.3
Point 23	52.5	717.2
Point 24	110	722.99
Point 25	67.8	722.7
Point 26	72.1	722.69248
Point 27	57	717.27849
Point 28	21.1	718.5
Point 29	29.1	720.1
Point 30	46.93636	720.1
Point 31	43.1	722.9
Point 32	56.2	722.9
Point 33	63.1	725.7
Point 34	57.1	725.7
Point 35	14.77715	717.23543

Critical Slip Surfaces

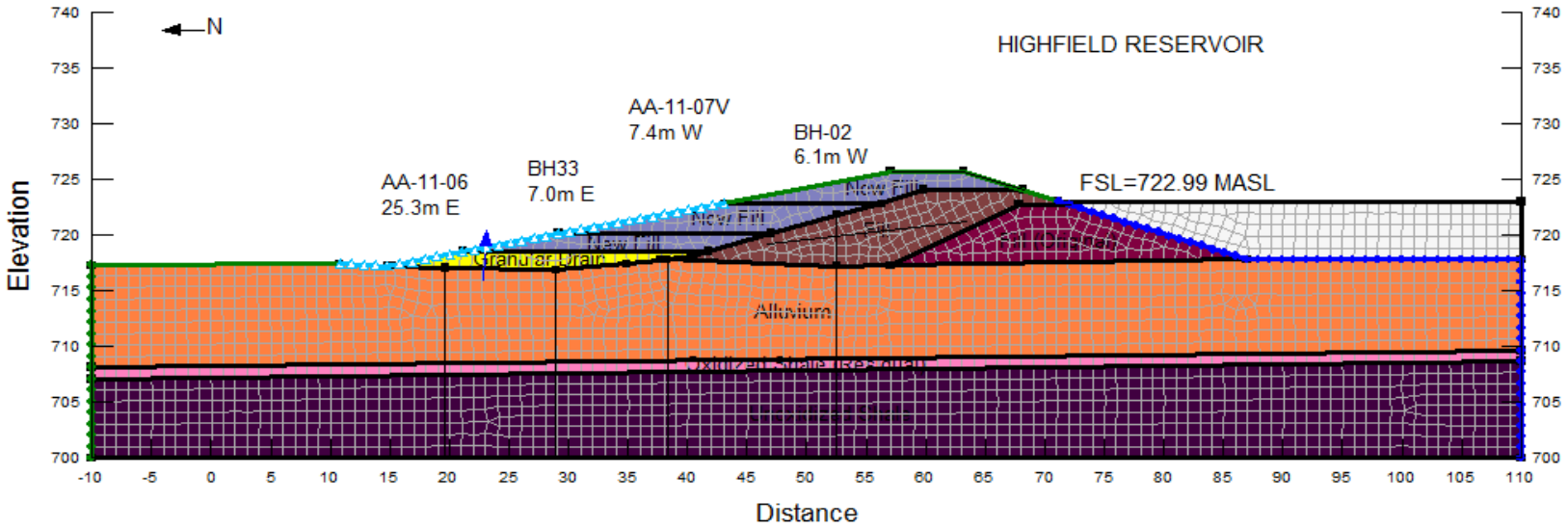
	Slip Surface	FOS	Center (m)	Radius (m)	Entry (m)	Exit (m)
1	2164	1.35	(34.389, 736.698)	32.275	(64.5528, 725.216)	(8.46194, 717.477)

Slices of Slip Surface: 2164

	Slip Surface	X (m)	Y (m)	PWP (kPa)	Base Normal Stress (kPa)	Frictional Strength (kPa)	Cohesive Strength (kPa)
1	2164	9.63097	716.07415	17.99671	43.161773	13.380501	0
2	2164	11.79429	713.69415	42.670788	95.376064	28.023892	0
3	2164	13.782865	711.89155	62.312852	133.81268	38.017134	0
4	2164	15.038575	710.86975	73.629186	156.47905	44.052053	0
5	2164	16.158925	710.0855	82.439194	179.93413	51.838977	0
6	2164	17.876775	708.98535	94.930236	212.04903	62.273169	0
7	2164	19.16785	708.2424	105.60195	211.76502	18.719413	2
8	2164	20.12018	707.75475	116.32629	226.68668	19.459515	2
9	2164	20.87018	707.5013	122.73245	219.26375	17.021074	2
10	2164	22.075	707.517	124.78944	223.64261	17.430482	2
11	2164	24.025	707.54235	128.2353	230.78047	18.08148	2
12	2164	25.975	707.56765	131.79398	237.81065	18.693599	2
13	2164	27.925	707.593	135.31163	244.74339	19.295773	2
14	2164	29	707.607	137.21841	248.524	19.626179	2
15	2164	30.066665	707.62085	139.06926	252.24244	19.955485	2
16	2164	32	707.646	142.28623	258.92463	20.566497	2
17	2164	33.933335	707.67115	145.26012	265.52407	21.20578	2
18	2164	36.25	707.70125	148.41339	273.34729	22.029216	2
19	2164	37.95	707.72335	150.43016	279.04787	22.678773	2
20	2164	39.4	707.7422	151.90988	284.36687	23.35574	2
21	2164	41.1	707.7643	153.39542	290.85052	24.237042	2
22	2164	42.4	707.7812	154.32985	295.5608	24.902828	2
23	2164	44.05909	707.80275	155.30078	301.16632	25.720031	2
24	2164	45.97727	707.8277	156.08791	307.64066	26.722838	2
25	2164	47.91469	707.8529	156.55989	314.18273	27.79316	2
26	2164	49.832355	708.3778	147.18961	286.95337	24.644123	2
27	2164	51.635845	709.4367	133.4443	256.366	65.358628	0
28	2164	53.425	710.6596	122.15285	238.37981	61.79897	0
29	2164	55.275	712.1219	108.08538	216.81331	57.811667	0
30	2164	56.6	713.2875	96.585721	199.60988	54.77892	0
31	2164	57.05	713.7163	92.291216	193.24831	53.679838	0
32	2164	58.5	715.3465	75.749988	164.58432	47.234054	0
33	2164	60.055185	717.13095	57.386099	133.63653	40.543075	0
34	2164	61.01829	718.51785	41.486985	116.33734	27.2433	0
35	2164	62.463105	720.8278	14.580286	62.336817	22.269236	7
36	2164	63.580745	722.9772	-7.415086	24.517123	11.432522	7
37	2164	64.307145	724.60785	-19.241094	0.92209302	0.42997903	7

Highfield Dam Foundation Embankment Assessment
Option 4 - 5H:1V Construction
5H:1V Transient Seepage
Project #: 11-1362-0114

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 4 (ONE STAGE): MODEL GEOMETRY & BOUNDARY CONDITIONS

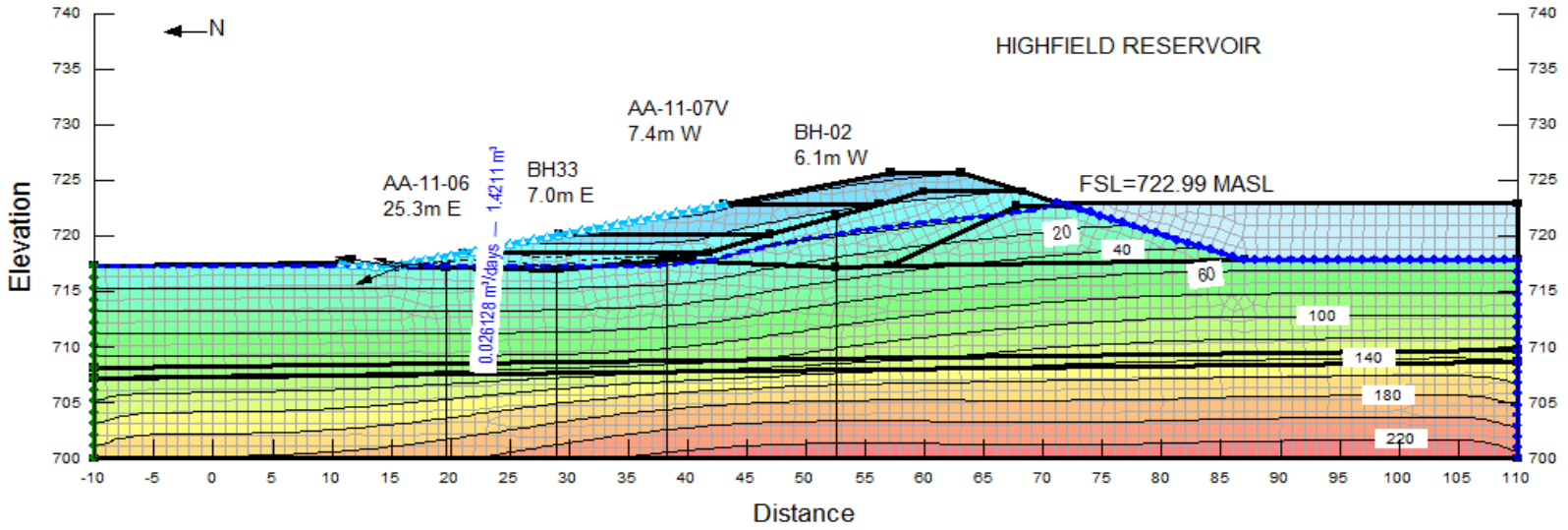
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.18

Highfield Dam Foundation Embankment Assessment
Option 4 - 5H:1V Construction
5H:1V Transient Seepage
Project #: 11-1362-0114

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 4 (ONE STAGE): INITIAL PORE WATER PRESSURES AFTER LOADING

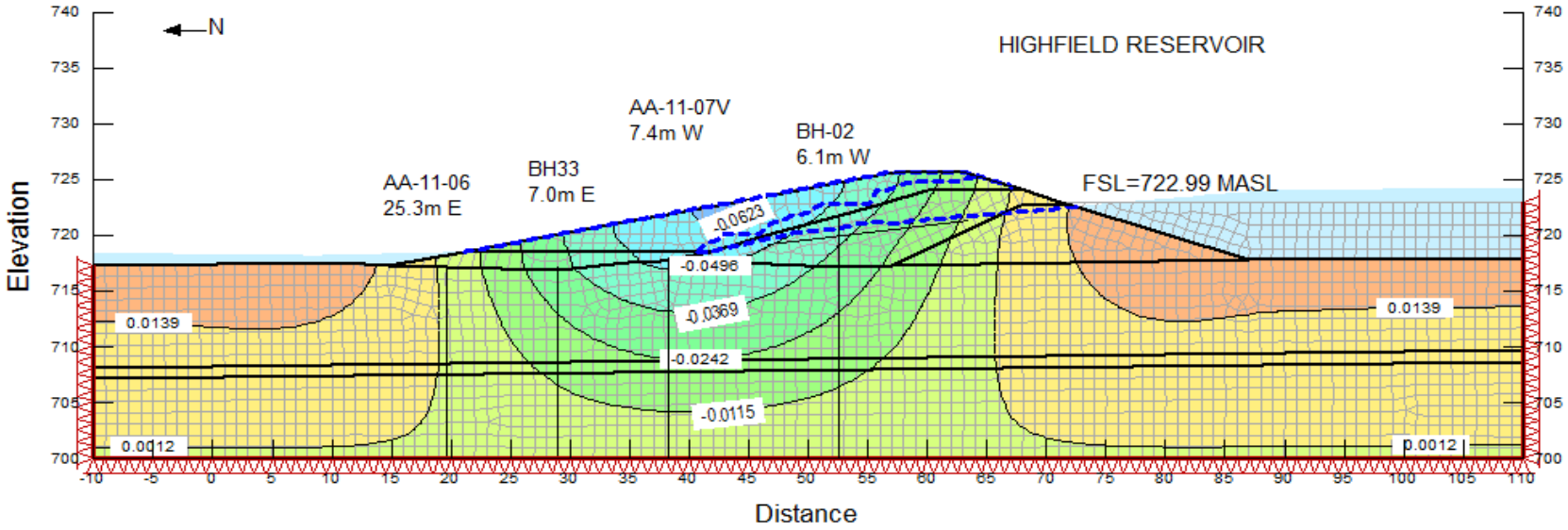
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.19

Highfield Dam Foundation Embankment Assessment
Option 4 - Existing Conditions
5H:1V Construction
Project #: 11-1362-0114

Unoxidized Shale	Linear Elastic	15000 kPa	0.334	Shale VWC=0.5
Alluvium	Linear Elastic	15000 kPa	0.334	Alluvium, VWC=0.42
Fill	Linear Elastic	15000 kPa	0.334	Fill, VWC=0.42
New Fill	Linear Elastic	15000 kPa	0.334	
Granular Drain	Linear Elastic	50000 kPa	0.334	Drain, VWC=0.3
Fill (Original)	Linear Elastic	15000 kPa	0.334	Fill, VWC=0.42
Oxidized Shale (Residual)	Linear Elastic	15000 kPa	0.334	Shale VWC=0.5



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 4 (ONE STAGE): VERTICAL SETTLEMENT DUE TO LOADING

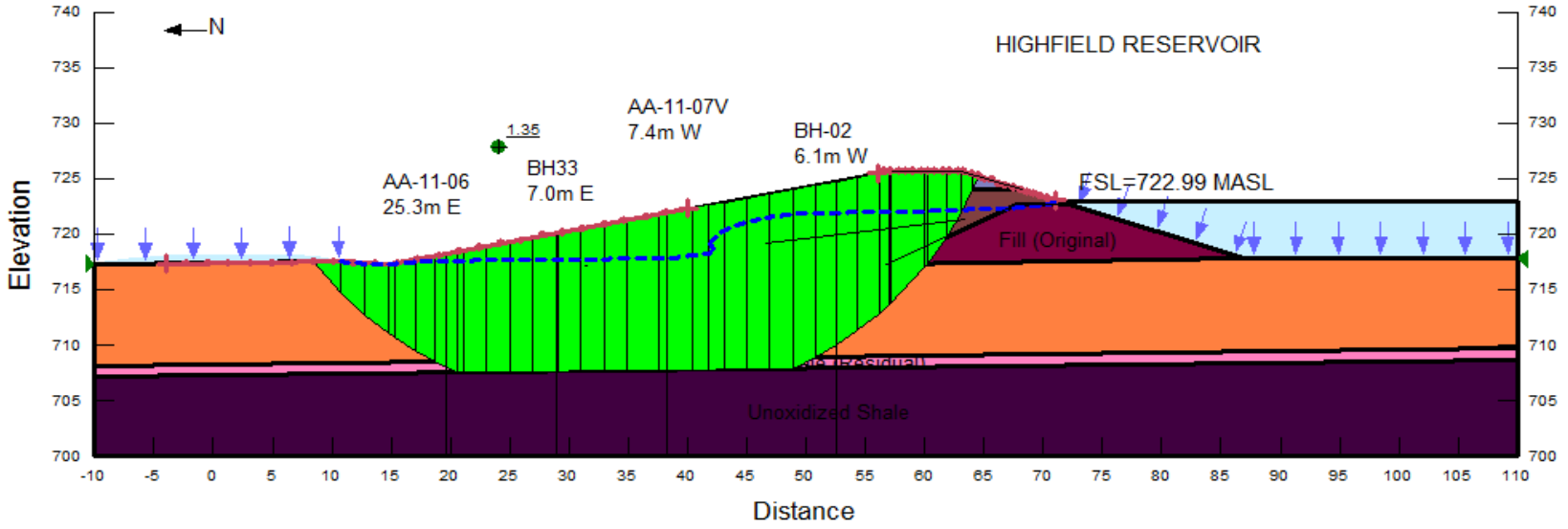
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.20

Highfield Dam Foundation Embankment Assessment
Option 4 - 5H:1V Transient Seepage
Slope Stability (initial)
Project #: 11-1362-0114

Unoxidized Shale
Alluvium Multiple Trial: 19 kN/m³ 0 kPa Multiple Trial: 28 °
Fill 21 kN/m³ 7 kPa 25 °
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Fill (Original) 21 kN/m³ 0 kPa 20 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 4 (ONE STAGE): SLOPE STABILITY ANALYSIS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.21

2nd Stage Slope Stability (final)

File Information

Title: Highfield Dam Foundation Embankment Assessment
Created By: Nehring, Lisa
Revision Number: 379
Last Edited By: Nehring, Lisa
Date: 1/17/2012
Time: 11:08:04 AM
File Name: Option 5 - 5 to 1 slope with berm (staged).gsz
Directory: C:\Users\LNehring\Desktop\11-1362-0114 AAFC Highfield Dam - Swift Current, SK\4000 Modelling\Models\Final Models\

Project Settings

Length(L) Units: meters
Time(t) Units: Days
Force(F) Units: kN
Pressure(p) Units: kPa
Strength Units: kPa
Unit Weight of Water: 9.807 kN/m³
View: 2D

Analysis Settings

2nd Stage Slope Stability (final)

Kind: SLOPE/W
Parent: 2nd Stage Transient Seepage
Method: Morgenstern-Price
Settings
- Side Function
  - Interslice force function option: Half-Sine
- PWP Conditions Source: Parent Analysis

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: No
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
- Number of Slices: 30

Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 0.1 m
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Unoxidized Shale

Model: Bedrock (Impenetrable)

Alluvium

Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 28 °
Phi-B: 0 °

Fill

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Water

Model: (None)

New Fill

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 7 kPa
Phi: 25 °
Phi-B: 0 °

Granular Drain

Model: Mohr-Coulomb
Unit Weight: 19 kN/m³
Cohesion: 0 kPa
Phi: 35 °
Phi-B: 0 °

Oxidized Shale (Residual)

Model: Mohr-Coulomb
Unit Weight: 22 kN/m³

Cohesion: 2 kPa
Phi: 10 °
Phi-B: 0 °

Fill (Original)

Model: Mohr-Coulomb
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 20 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (5, 717.3) m
Left-Zone Right Coordinate: (34, 720.4) m
Left-Zone Increment: 25
Right Projection: Range
Right-Zone Left Coordinate: (56, 725.38571) m
Right-Zone Right Coordinate: (71.06151, 723.03662) m
Right-Zone Increment: 25
Radius Increments: 10

Slip Surface Limits

Left Coordinate: (-10, 717.3) m
Right Coordinate: (110, 717.8) m

Regions

	Material	Points	Area (m²)
Region 1	Alluvium	1,2,38,3,4,5,6,7,24,28,14,15,16,21,22,23	1029.355
Region 2	Water	13,25,15,14,27	160.63053
Region 3	Oxidized Shale (Residual)	16,17,20,21	120
Region 4	Unoxidized Shale	17,18,19,20	945.6
Region 5	Fill (Original)	28,26,27,14	88.698605
Region 6	Fill	7,8,9,29,10,30,11,12,13,27,26,28,24	99.387841
Region 7	New Fill	33,36,35,9,29	30.728292
Region 8	Granular Drain	5,6,7,8,9,35,38,3,4	25.78486
Region 9	New Fill	33,34,32,31,12,11,30,10,29	53.323452

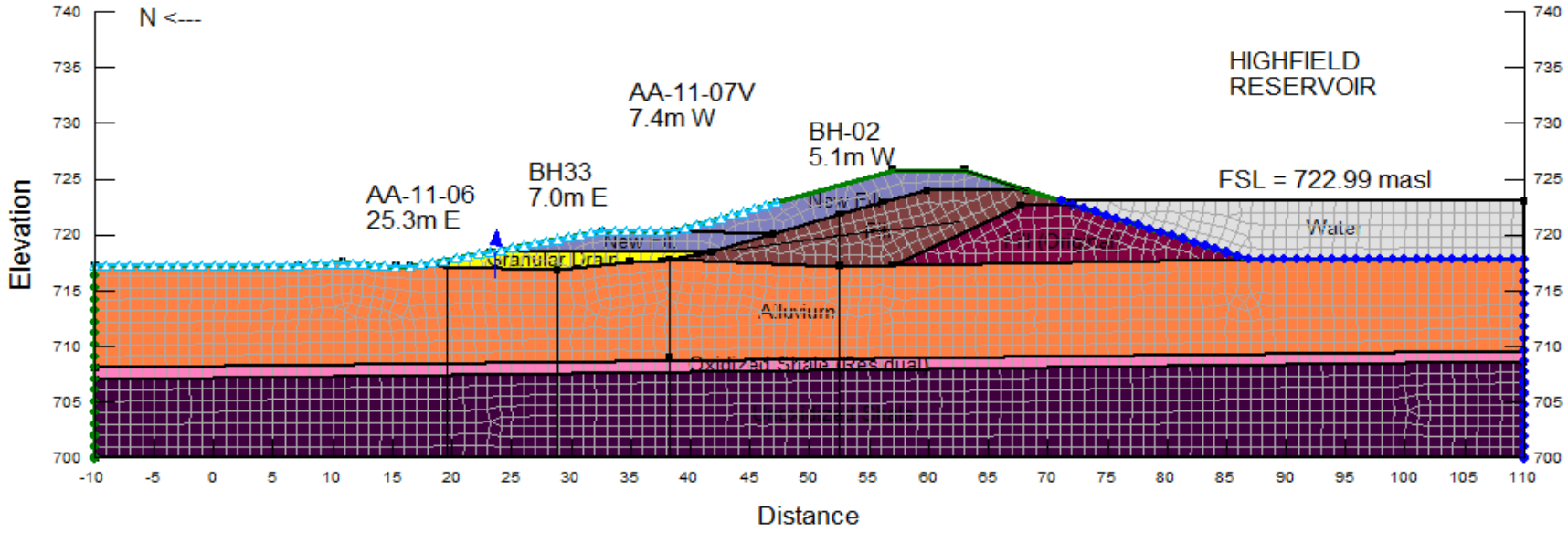
Points

	X (m)	Y (m)
Point 1	10.8	717.5
Point 2	15.3	717.2

Point 3	19.6	717.1
Point 4	28.9	716.9
Point 5	34.9	717.5
Point 6	37.6	717.7
Point 7	38.3	717.8
Point 8	40.5	718.2
Point 9	41.7	718.5
Point 10	52.5	721.8
Point 11	59.9	724
Point 12	68.2	724
Point 13	71.2	722.99
Point 14	86.9	717.8
Point 15	110	717.8
Point 16	110	709.66
Point 17	110	708.66
Point 18	110	700
Point 19	-10	700
Point 20	-10	707.1
Point 21	-10	708.1
Point 22	-10	717.3
Point 23	7.1	717.3
Point 24	52.5	717.2
Point 25	110	722.99
Point 26	67.8	722.7
Point 27	72.1	722.69248
Point 28	57	717.27849
Point 29	46.93636	720.1
Point 30	56.2	722.9
Point 31	63.1	725.7
Point 32	57.1	725.7
Point 33	38.655	720.4
Point 34	47.3	722.9
Point 35	23.155	718.5
Point 36	32.655	720.4
Point 37	38.3	708.96
Point 38	16.51321	717.17179

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Water	(none)			
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 5 - 4H:1V Raised Slope Construction
2nd Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 5 (STAGED): MODEL GEOMETRY & BOUNDARY CONDITIONS

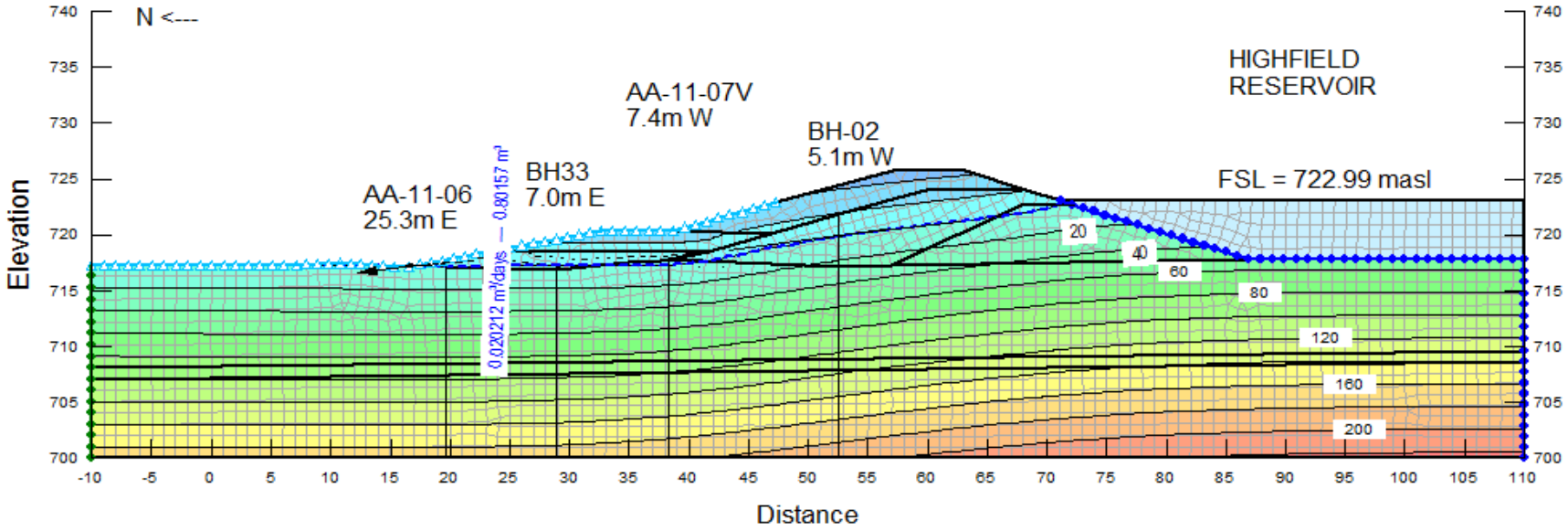
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.	
DESIGN	LDN	17/01/12	SCALE N/A	REV.
CADD				
CHECK				
REVIEW	RGR	23/01/12		

FIGURE: F.22

Unoxidized Shale	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0 /kPa
Alluvium	Saturated Only	0.011232 m/days	0.35 m³/m³	4.73e-005 /kPa
Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Water	(none)			
New Fill	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa
Granular Drain	Saturated Only	8.64 m/days	0.3 m³/m³	0.0001 /kPa
Oxidized Shale (Residual)	Saturated Only	8.64e-005 m/days	0.5 m³/m³	0.0001 /kPa
Fill (Original)	Saturated Only	0.00432 m/days	0.42 m³/m³	0.0001 /kPa

Highfield Dam Foundation Embankment Assessment
Option 5 - 4H:1V Raised Slope Construction
2nd Stage Transient Seepage
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 5 (STAGED): INITIAL PORE WATER PRESSURES AFTER LOADING

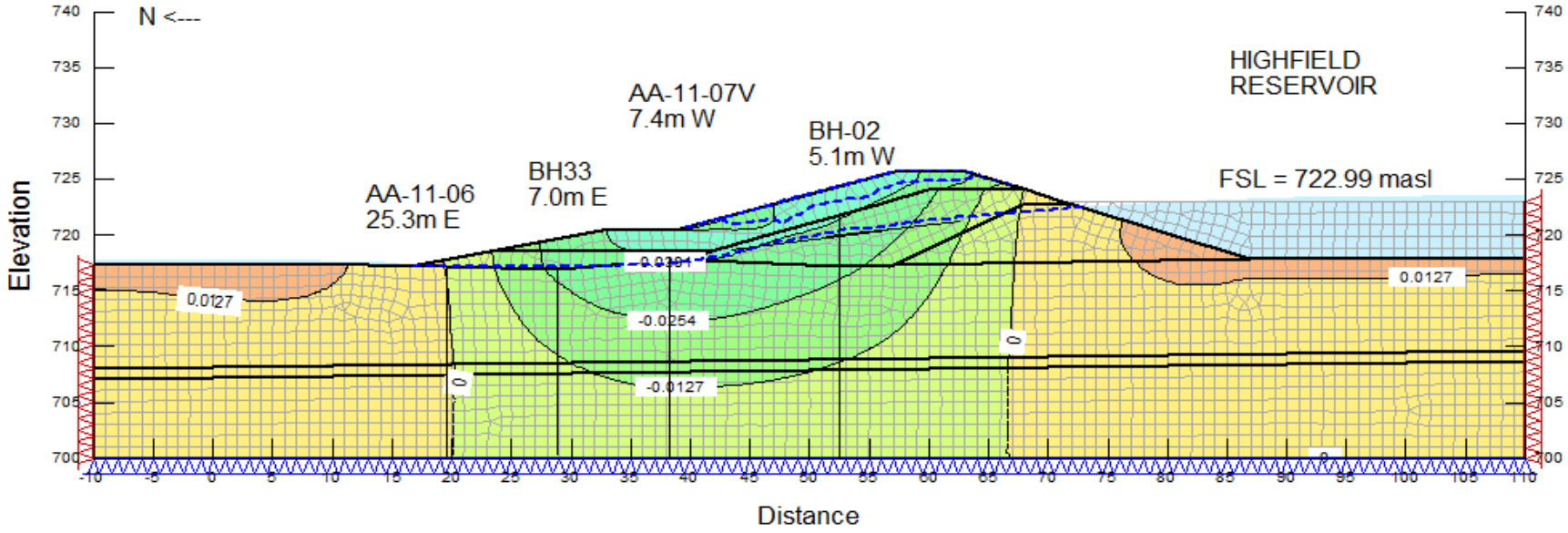
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.23

Unoxidized Shale Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Alluvium Linear Elastic 15000 kPa 0.334 Alluvium, VWC=0.42
Fill Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42
Water (none)
New Fill Linear Elastic 15000 kPa 0.334
Granular Drain Linear Elastic 50000 kPa 0.334 Drain, VWC=0.3
Oxidized Shale (Residual) Linear Elastic 15000 kPa 0.334 Shale VWC=0.5
Fill (Original) Linear Elastic 15000 kPa 0.334 Fill, VWC=0.42

Highfield Dam Foundation Embankment Assessment
Option 5 - 1st Stage Transient Seepage
4H:1V Raised Slope Construction
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 5 (STAGED):
VERTICAL SETTLEMENT DUE TO LOADING

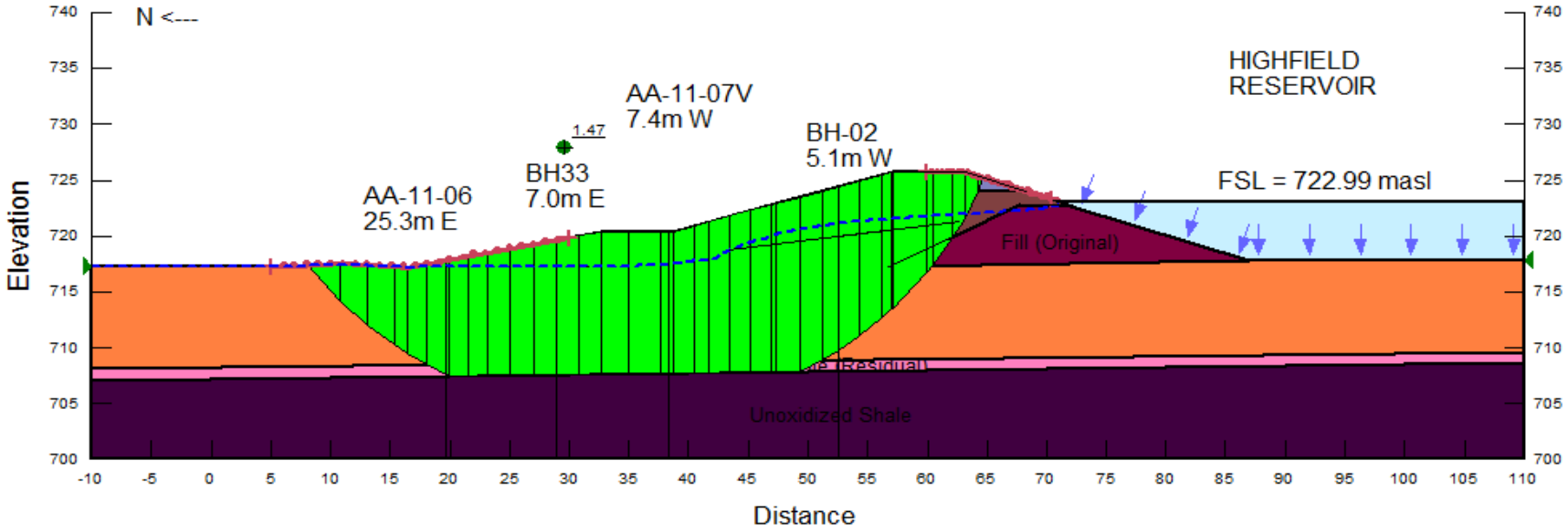
Golder Associates
Saskatoon, Saskatchewan

PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

FIGURE: F.24

Unoxidized Shale
Alluvium 19 kN/m³ 0 kPa 28 °
Fill 21 kN/m³ 7 kPa 25 °
Water
New Fill 21 kN/m³ 7 kPa 25 °
Granular Drain 19 kN/m³ 0 kPa 35 °
Oxidized Shale (Residual) 22 kN/m³ 2 kPa 10 °
Fill (Original) 21 kN/m³ 0 kPa 20 °

Highfield Dam Foundation Embankment Assessment
Option 5 - 2nd Stage Transient Seepage
2nd Stage Slope Stability (initial)
Project #: 11-1362-0114



PROJECT
HIGHFIELD DAM EMBANKMENT FOUNDATION ASSESSMENT

TITLE
OPTION 5 (STAGED): SLOPE STABILITY ANALYSIS

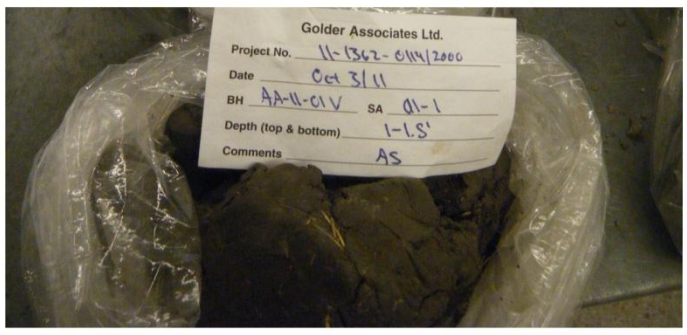
Golder Associates
Saskatoon, Saskatchewan

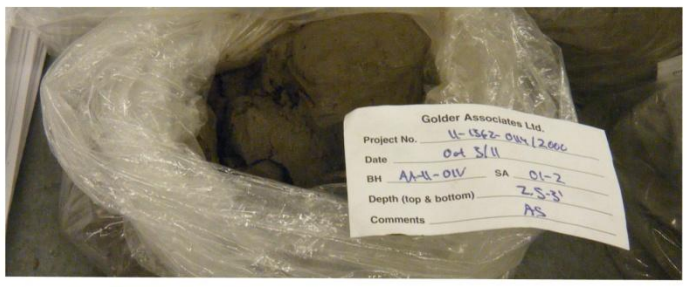
PROJECT	11-1362-0114		FILE No.		
DESIGN	LDN	17/01/12	SCALE	N/A	REV.
CADD					
CHECK					
REVIEW	RGR	23/01/12			

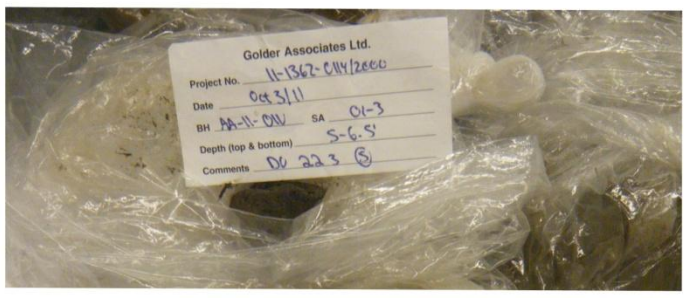
FIGURE: F.25

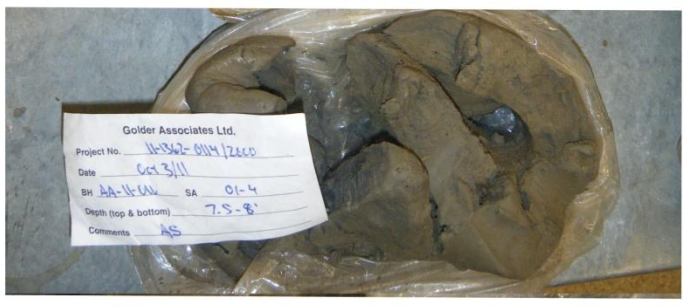
APPENDIX G

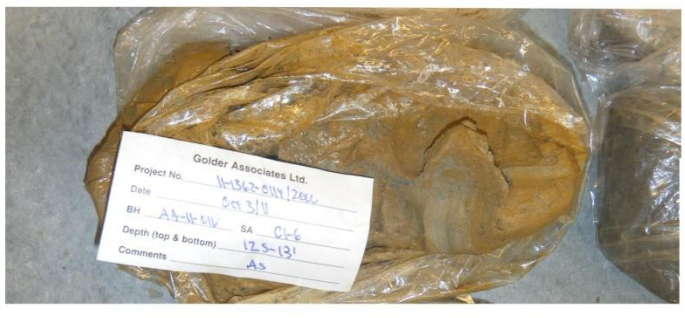
Sample Soil Profile Photos

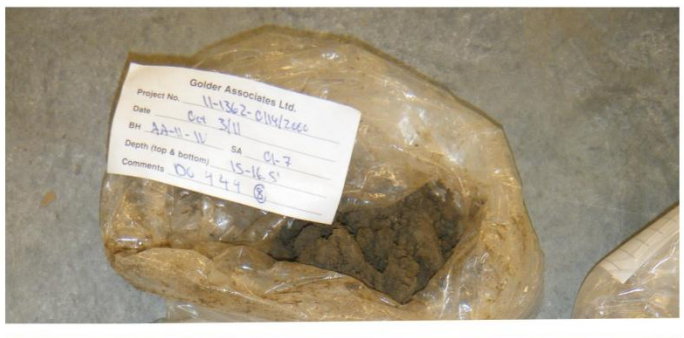


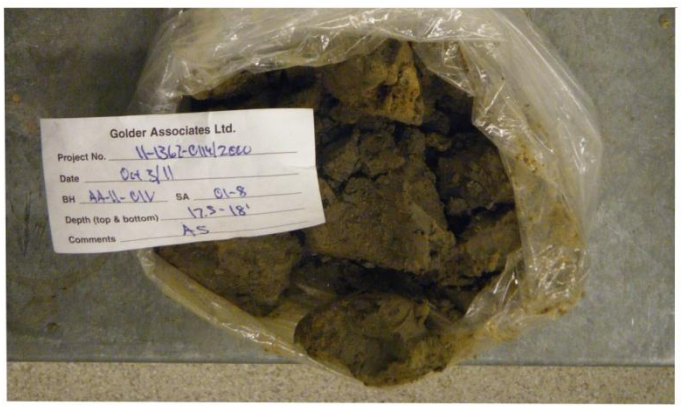


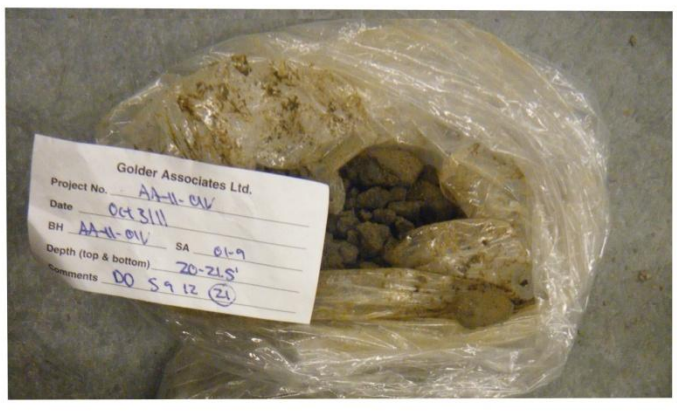




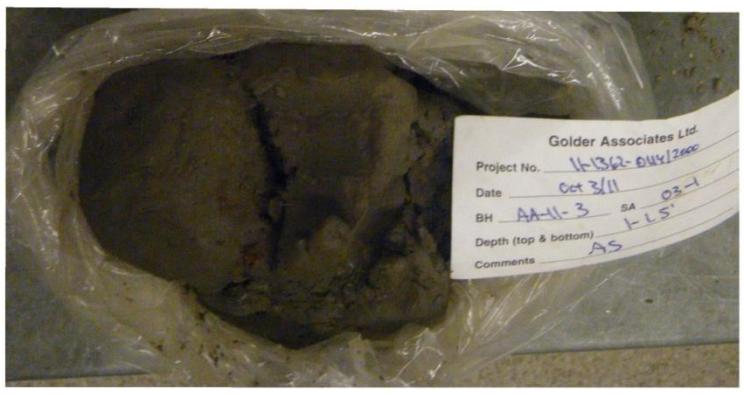


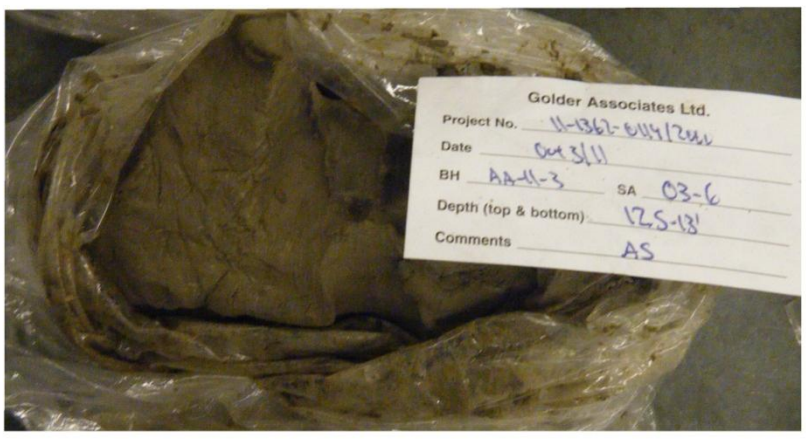


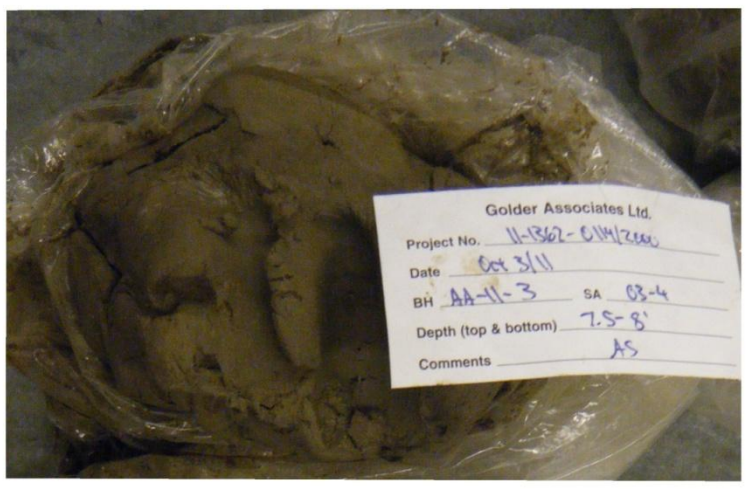


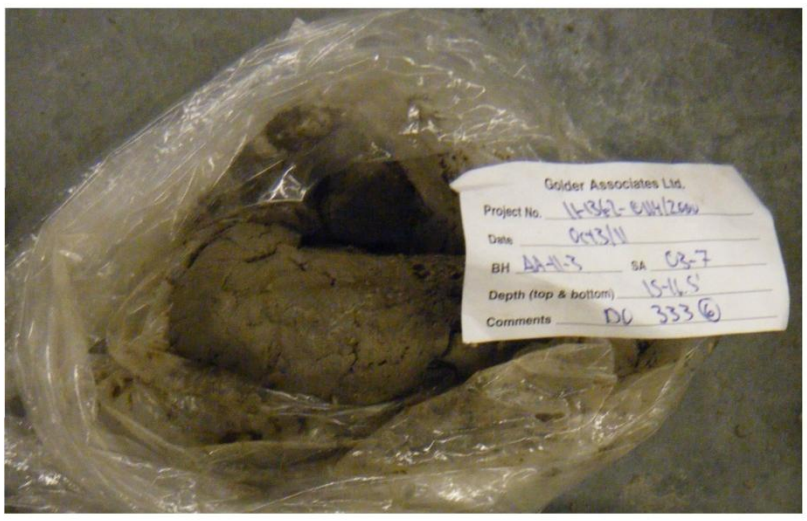


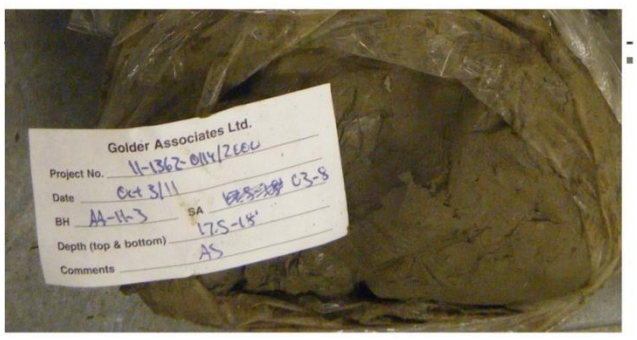
Borehole AA-11-01V Sample Soil Profile (Descending Order)

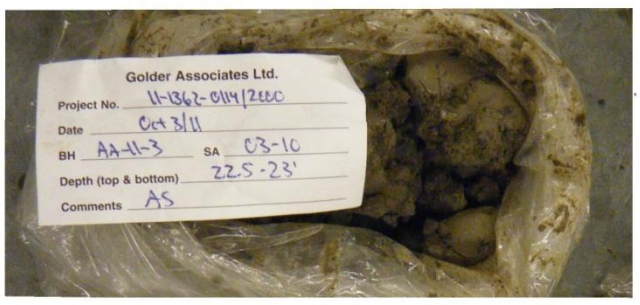


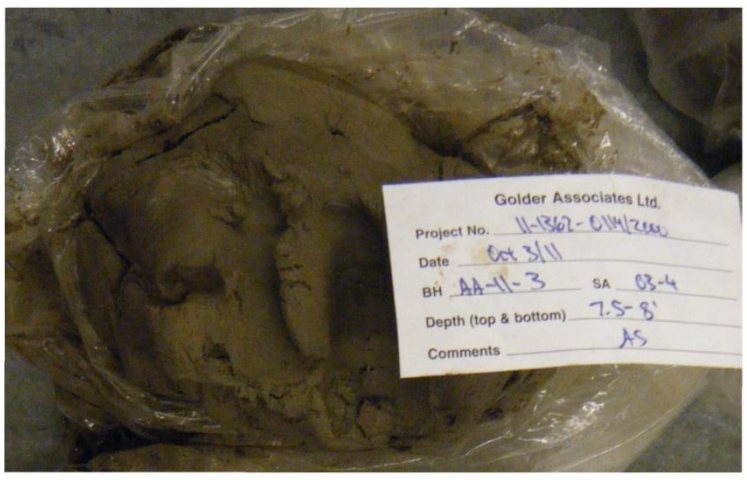


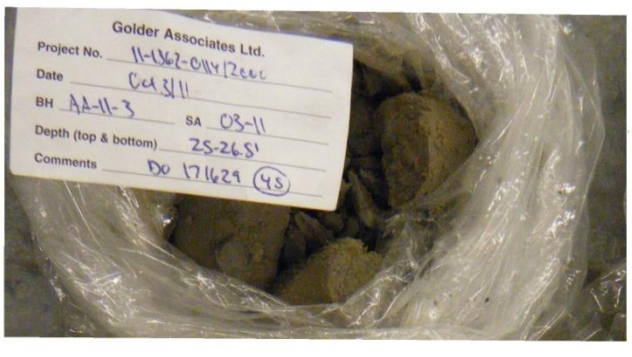




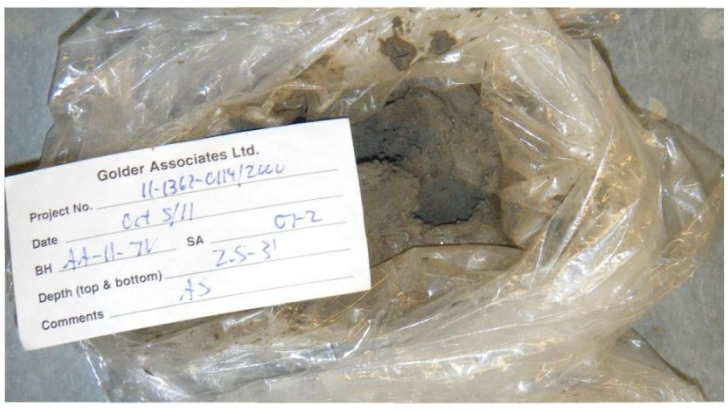


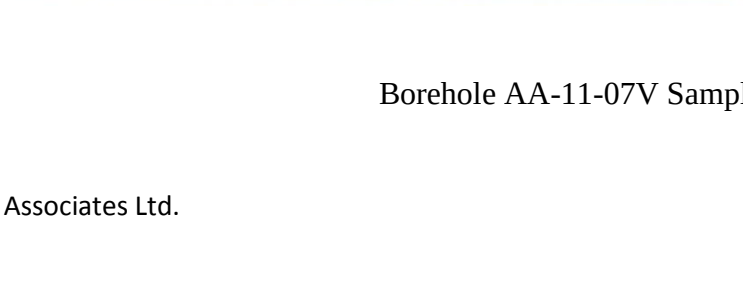


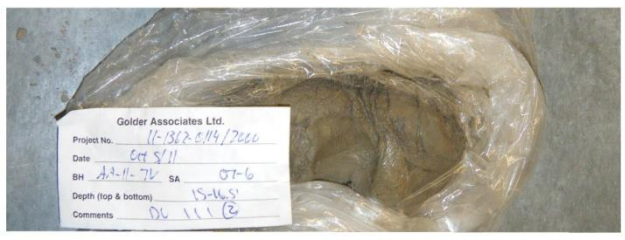


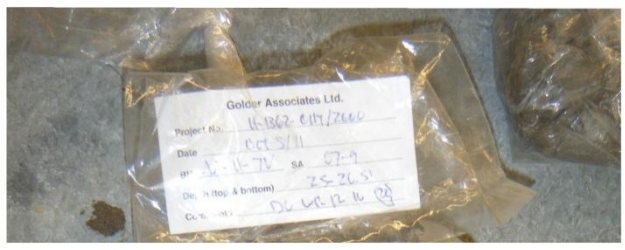


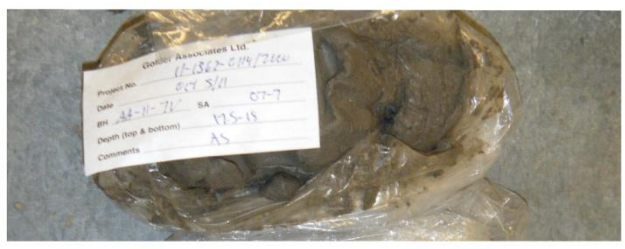
Borehole AA-11-03 Sample Soil Profile (Descending Order)

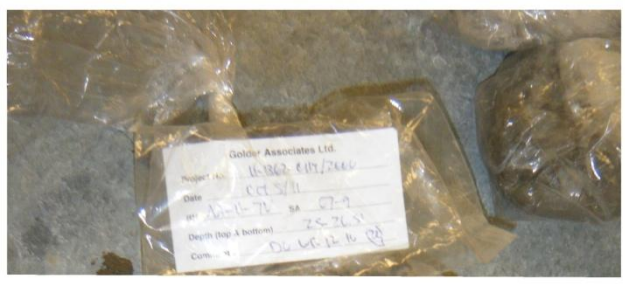


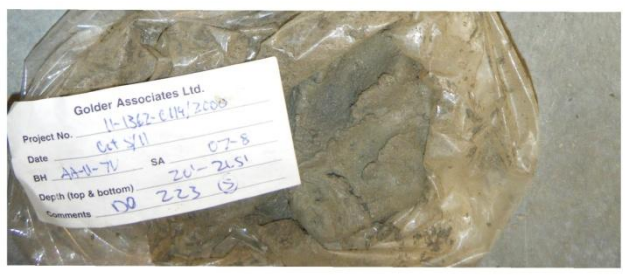


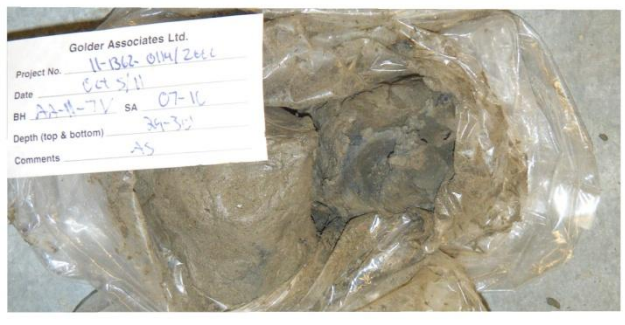


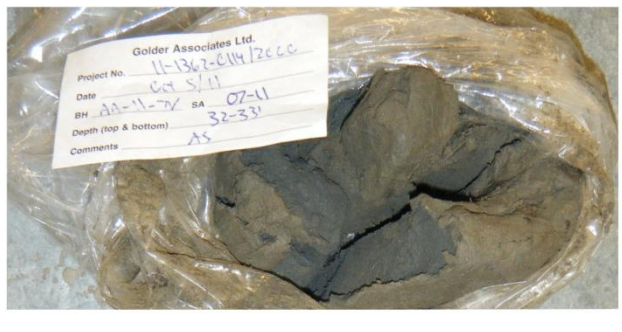












Borehole AA-11-07V Sample Soil Profile (Descending Order)

At Golder Associates we strive to be the most respected global company providing consulting, design, and construction services in earth, environment, and related areas of energy. Employee owned since our formation in 1960, our focus, unique culture and operating environment offer opportunities and the freedom to excel, which attracts the leading specialists in our fields. Golder professionals take the time to build an understanding of client needs and of the specific environments in which they operate. We continue to expand our technical capabilities and have experienced steady growth with employees who operate from offices located throughout Africa, Asia, Australasia, Europe, North America, and South America.

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