



**Final
FOUNDATION INVESTIGATION
AND DESIGN REPORT
UNKNOWN CREEK # 5
CULVERT REPLACEMENT
HWY 540
TOWNSHIP OF HOWLAND
AGREEMENT NO.: 5010-E-0007
WP: 5057-07-01
GWP: 5057-07-00
GEOCRES NO.: 41G-12**

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Prepared for:

Ministry of Transportation
NorthEastern Region
447 Mckeown Avenue, Suite 301
North Bay, Ontario
P1B 9S9

5 Copies - Ministry of Transportation, North Bay, ON
1 Copy - Foundations Group, Downsview, ON
1 Copy - Genivar, Ottawa, ON
1 Copy - DST Consulting Engineers Inc., Thunder Bay, ON

DST CONSULTING ENGINEERS INC.
605 Hewitson Street, Thunder Bay, Ontario P7B 5V5
Phone: 1-807-623-2929 Fax: 1-807-623-1793

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

DST Consulting Engineers Inc. (DST) has been subcontracted by Genivar who was retained by Ministry of Transportation (MTO), NorthEastern Region, to conduct a geotechnical investigation for the replacement a culvert on Highway 540 near Township of Howland. This work was carried out under Agreement No.: 5010-E-0007, Detailed Design for the Replacement/Rehabilitation of various Culverts.

This report addresses the field investigation, laboratory test program, factual report on conditions (Part 1) and recommendations for the design and construction for the proposed culvert replacement (Part 2).

2. SITE DESCRIPTION

The site is located on Highway 540, approximately 12.0 km west of junction Highway 6, in Howland Township, Sudbury Area. The structural site number is 49-066.

It is understood that the proposed replacement will involve the replacement of the existing corrugated steel pipe (CSP) culvert (Figure 2.1) which has approximately 0.5 m of cover with pre cast box structure. The existing steel ellipse culvert has dimensions of 3.0 m x 2.1 m x 24.7 m and was identified by MTO in the RFQ to be in fair to poor condition with a minor corrosion and deterioration of the barrel. Buckling was observed along the structure and some moderate flaking and section loss close to the inlet was also identified. Minor erosion and loss of embankment fill were identified around this the existing culvert at this site (Figure 2.2).

The outlet and inlet of the existing culvert are grassed and wooded (Figures 2.3 and 2.4). The embankment slopes at this location vary from 2H:1V to 3H:1V. The photographs shown in Figures 2.1 to 2.4 were taken by MTO.

Physiographic information is available from published, *Map 2223; The Physiography of Southern Ontario* by the *Department of Mines and Northern Affairs Ontario Research Foundation* for the Manitoulin area, Southern Ontario. The map indicates limestone plains are dominant in the Highway 540 region which is surrounded by escarpments and bevelled till plains with beaches and shore cliffs.



Figure 2.1 Corrugated Steel Pipe (CSP) culvert (looking south)



Figure 2.2 Minor erosion and loss of embankment (looking north)



Figure 2.3 Outlet of the existing culvert (looking west)



Figure 2.4 Inlet of the existing culvert (looking west)

3. INVESTIGATION PROCEDURES AND LABORATORY TESTING

Site work was carried out in the period of four days (October 17, 2010 to October 20, 2010) utilizing a CME 750 drill rig that was operated by DST personnel. A total of three (3) hydraulically drilled boreholes using hollow stem augers were put down for the purpose of foundation design at this site.

One borehole was advanced through the road structure at Station 10+002 offset 4.3 m right. Two boreholes were advanced near the existing culvert inlet and outlet at Station 9+997 offset 12.5 m left and Station 9+985 offset 11.5 m right respectively. The minimum number of boreholes, and depths and locations of boreholes were chosen according to the given specification in Request for Quotation (RFQ) by MTO.

The borehole locations are referenced to the MTO Station numbering system as indicated in the RFQ. The centreline of the existing culvert was assumed as Station 10+000. The ground surface elevations at the borehole locations were surveyed by DST personnel. At approximately Station 9+980 offset 12 m left a benchmark with an assigned elevation of 180.95 m was placed in a hydro pole near culvert. Borehole locations, stationing and benchmark location are shown on the Borehole Location Plan, Drawings 1. Table 3.1 summarizes the detail of borehole locations and depths.

Table 3.1 Detail of borehole locations

Borehole ID	Station	Elevation (m)	Depth (m)	Offset (m)
BH1	10+002	181.60	7.3	4.3 Lt
BH2	9+997	179.68	5.2	12.5 Rt
BH3	9+985	179.65	5.1	11.5 Lt

The fieldwork was supervised on a full-time basis by DST personnel who located the boreholes in the field, performed sampling and in-situ testing and logged the boreholes. In-situ tests included standard penetration test (SPT). The soil samples collected during drilling were identified in the field, placed in labelled containers and transported to DST's laboratory in Thunder Bay for further analysis.

Classification and index tests were subsequently performed in the laboratory on samples collected from the boreholes to aid in the selection of engineering properties. Laboratory tests

included moisture contents, particle size analyses and Atterberg limits including plastic limit and liquid limit. A total of twenty three (23) moisture contents, four (4) sieve analyses, five (5) particle analyses, and six (6) Atterberg limits have been carried out for this assignment. Laboratory test results are presented in the Boreholes Logs (Enclosures 1 to 3), and Plots (Enclosures 4 to 8).

4. DESCRIPTION OF SUBSURFACE CONDITIONS

The subsurface conditions are presented based on the information obtained during field and laboratory testing.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of asphalt overlying a fill material that is underlain by a sandy silt material followed by a clayey silt layer. The fill consists of a gravel and sand material underlying a base course of sandy crushed gravel. Auger refusals on boulders or possible bedrock were encountered at different elevations in each borehole (Table 4.1).

Table 4.1 Depths and elevations of auger refusals

Borehole ID	Depth of auger refusal (m)	Elevation of auger refusal (m)
BH1	7.3	174.3
BH2	5.2	174.5
BH3	5.1	174.6

4.1 Top Soil

The Top soil was encountered in Borehole 2 and 3 with thickness of 0.08 and 0.07 m respectively.

4.2 Asphalt

Asphalt was encountered in Borehole 1. The thickness of the asphalt is about 35 mm.

4.3 Embankment Fill

Embankment fill layer was encountered in Borehole 1 below the asphalt layer. Embankment fill layer was encountered at depth of 0.03 m for Borehole 1 with thickness of approximately 2.6 m, with corresponding elevation of 181.6 m respectively. Within the sand fill cobbles were noted during the drilling process. Grain size distributions of the fill material are reported in borehole logs (Enclosures 1) and plots (Enclosure 4).

Directly below the asphalt, a fill of predominantly sandy crushed gravel material was encountered at Boreholes 1 from 35 mm below surface to depths up to 0.3 m, corresponding to elevations of between 181.6 to 181.3 m respectively. This layer is roadbed granular layer.

Gradation analyses conducted on a sample from Borehole 1 indicates gravel, sand and fines contents of approximately 52%, 37% and 10% respectively. Moisture content was found to be 3%. This material does not classify as Granular A meeting SSP 110S13 requirements.

Directly below this sandy crushed gravel, a fill of predominantly gravel and sand materials was encountered at Boreholes 1 from 0.3 m below surface to the depths of 2.6 m corresponding to elevations of between 181.3 to 179.1 m respectively. Gradation analyses conducted on samples from Borehole 1 indicate gravel, sand, and fines contents of approximately 48%, 36% and 16% respectively. This material does not classify as Granular B, Type I meeting SSP 110S13 requirements. The moisture content of samples was between 4 and 9%.

4.4 Silt - Sandy

Soft to firm sandy silt material was encountered in Borehole 1, 2 and 3 at depths of 2.6, 0.08 and 0.07 m with thickness of 2.6, 3.1 and 3.1 m, corresponding to elevations of 179.1, 179.6 and 179.6 m respectively. Cobbles were noted within this stratum during drilling process. Gradation analyses conducted on the samples from Borehole 1 and 3 indicate gravel, sand, silt and clay contents of approximately 8 to 9%, 35 to 43%, 38 to 47% and 10 to 11% respectively. Gradation analyses conducted on samples from Borehole 2 indicate gravel, sand, and fines contents of approximately 11 to 12%, 47 to 50% and 39 to 41% respectively.

Atterberg limit test carried out on samples from Boreholes 1 and 3 indicate this material has a low plasticity with liquid limits and plasticity indexes from 13 to 18 and 3 to 6 respectively. The moisture content of samples was between 8 and 19%.

4.5 Silt

Very soft to soft silt was encountered in Boreholes 1, 2 and 3 at depth of 5.2, 3.7 and 3.7 m, with corresponding elevations of 176.4, 176.0 and 176.0 m respectively. The thickness of this stratum is 2.1, 1.5 and 1.4 m for Borehole 1, 2 and 3 respectively. Gradation analyses conducted on the samples from Borehole 1 and 3 indicate gravel, sand, silt and clay contents of approximately 0 to 7%, 16 to 29%, 60 to 76% and 4 to 7% respectively. The moisture content of samples was between 14 and 22%. Atterberg limit test carried out on a sample from Borehole 3 indicate this material has a low plasticity with liquid limit and plasticity index of 20 and 3 respectively.

4.6 Groundwater

The groundwater table was identified below the ground surface during the field investigation and visual identification of soil samples. The estimated depth of groundwater level below the ground surface elevation is given in Table 4.2. The water level in the creek at the culvert was at an elevation of approximately 178.7 m during the field investigation. The groundwater levels and water level at the culvert can be expected to vary with season and precipitation events.

Table 4.2 Probable depth of water table at Borehole Locations

Borehole ID	Borehole elevation (m)	Water table elevation (m)	Depth of water table below the ground surface (m)
BH1	181.60	178.5	3.1
BH2	179.68	178.18	1.5
BH3	179.65	178.15	1.5

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PART 2: ENGINEERING DISCUSSIONS AND RECOMMENDATIONS

5. PROJECT DESCRIPTION

DST Consulting Engineers Inc. (DST) has been subcontracted by Genivar who was retained by Ministry of Transportation (MTO), NorthEastern Region, to conduct a geotechnical investigation for the replacement a culvert on Highway 540. This proposed culvert is to be replaced by a pre-cast concrete box structure (3600 x 2400 mm). The proposed culvert invert elevation varies from 178.8 m at inlet to 178.6 m at outlet. It is understood that a staged method of construction with widening on the north side of the roadway is the preferred replacement approach. Roadway protection may be required to facilitate the staged construction.

The generalized stratigraphy of the existing embankment, based on the conditions encountered in boreholes, consists of asphalt overlying a fill material that is underlain by a sandy silt material followed by a clayey silt layer. The fill consists of a gravel and sand material underlying a base course of sandy crushed gravel. Auger refusals on boulders or possible bedrock were encountered at elevations between 174.3 to 174.6 m in Boreholes 1 to 3 respectively. Water table was indentified at the elevation of about 178.1 m during the geotechnical investigation.

This section presents interpretation of the geotechnical data presented in the factual report and presents geotechnical design recommendations and construction concerns for the proposed culvert replacement.

5.1 Precast Concrete Box Culvert

For this culvert replacement, a four sided precast concrete culvert (3600 x 2400 mm) is to be used. Open cut excavation will be used to replace the existing CSP structure.

The design of the culvert must be in accordance with the Canadian Highway Bridge Design Code CAN/CSA-S6-06 and all relevant Ministry of Transportation specification and guidelines.

5.1.1 Earth Excavation

An open cut operation along the proposed culvert alignment is proposed by MTO for the culvert replacement. This method of construction may result in traffic disturbances and may require temporary surface water ditch diversion and temporary support for traffic. It can more readily accommodate excavation of large boulders with this method, if encountered during excavation. As a minimum, the procedures should be in accordance with OPSS 902 "Construction Specifications for Excavating and Backfilling-Structures".

If organic materials are encountered during excavation, it shall be replaced by Granular A material compacted to 100% of maximum dry density. It is anticipated that the existing groundwater table will be above the invert level. Excavation below the water table can be undertaken by either dewatering of the excavation or in the wet without lowering the water table. If excavation is completed in the wet, any sub-excavated materials can be replaced with 19 mm Type I or II clear stone as defined in OPSS 1004.05.02. If fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm may be required for separation. No compaction is required of the clear stone.

5.1.2 Staged Construction

Staged construction has been identified by prime consultant, Genivar, as the preferred approach to maintain traffic during the construction of the culvert at this site. The proposed staged construction includes two (2) stages as given in Genivar Staging Drawings in Appendix 'B'. Slope stability analyses for the proposed slope geometries have been conducted and are presented in Section 5.1.4 Embankment Design.

Stage 1 is a temporary lane diversion which involves temporary detour of traffic to the northbound lane of 5.36 m width with existing side slopes of 2H:1V in the granular fill materials respectively as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 178.3 m to allow for placement of bedding materials. Use of temporary concrete barriers will be required.

Stage 2 is temporary lane diversion which involves temporary detour of traffic to the southbound lane of 5.86 m width with temporary side slope of 2.5H:1V in the granular fill materials respectively as well as the installation of level II roadway protection. Excavation adjacent the roadway protection is anticipated to an elevation of approximately 177.8 m to allow for placement of bedding material. Use of temporary concrete barriers will be required.

The final embankment foreslopes should be reinstated as presented in Section 5.1.12 Embankment Foreslopes.

5.1.3 Foundation Design

The culvert will be located approximately at the same elevation (178.8 m at inlet to 178.6 m at outlet) and location as the existing culvert. As the proposed culvert foundation is not expected to be heavily loaded, a shallow foundation is considered suitable for this site. The geotechnical resistance was estimated for the ultimate limit state (ULS) and serviceability limit state (SLS) for a maximum settlement of 25 mm. The resistance at ULS was calculated by applying load resistance factor of 0.5 according to the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-06 section 6.6.3.6, Table 6.1. The geotechnical resistance was estimated assuming a strip footing consisting of a width equal to the width of the culvert (3.6 m) and a depth of the culvert base equal to 0 m, which is a temporary worst condition prior to backfill that will be encountered during construction. Settlement of the structure can be considered negligible due to the marginal change in net loading. While ULS is not relevant at final condition due to excessive soil cover SLS is not relevant for temporary condition. Therefore SLS reported here are for final condition.

Table 5.1 Geotechnical resistances and reactions

Footing Size	Ultimate bearing capacity (kPa)	Resistance at ULS (kPa)	Resistance at SLS (kPa)
B = 3.6 m	130	65	55

The width of the sub-excavation should be twice the width of the culvert and where unsuitable or unstable soils are encountered, the foundation soils must be removed to a firm or hard soils and replaced to the foundation grade with Granular A material meeting SSP 110S13 specifications and compacted to a minimum of 95 % of standard Proctor maximum dry density. All foundation preparation should be completed as required by OPSS 422 and as indicated in Section 5.1.7 Bedding.

If sub-excavation for frost effects is carried out in the dry (with adequate dewatering controls), the material can be replaced with Granular A material meeting SSP110S13 requirements, placed and compacted in accordance with OPSS 501. If the excavation is in the wet (water is maintained at or above adjacent groundwater table) then the material should be rockfill or clear stone surrounded by geotextile, without the need for compaction. Depending on

the structural design of the culvert, partial sub-excavation (less than 1.8 m) may also be considered to reduce differential stresses associated with frost; however the exact pressures and movements cannot be accurately quantified.

5.1.4 Embankment Design

Slope stability analyses were carried out with limit equilibrium methods using Geoslope version 2004 software applying Morgenstern and Price methods. Slope stability analyses were performed under the following slope conditions with an embankment height of up to 2.5 m:

- Existing embankment with minimum 2.0H:1V foreslopes,
- Reinstated embankment with 2.5H:1V foreslopes,
- Embankment right side after culvert replacement with 2.0H:1V foreslopes
- Embankment left side after culvert replacement with 2.0H:1V foreslopes.

Results indicate that stability will meet or exceed suitable design factors of safety under both short and long term conditions for the evaluated slope configurations and are presented in Table 5.2.

Table 5.2 Summary of stability analyses

Slope Condition	Foreslope Gradient	Drained or Undrained Analyses	Factor of Safety
Stage 1: Cutting at left side Existing Embankment on left side	2H : 1V	Drained	1.3
		Undrained	1.3
Stage 2: Cutting at right side Reinstated Embankment on right side	2.5H : 1V	Drained	2.2
		Undrained	2.2
Embankment after culvert replacement, Left side	2.0H : 1V	Drained	1.7
		Undrained	1.6
Embankment after culvert replacement, Right side	2.0H : 1V	Drained	1.2
		Undrained	1.2

This analyses considered the soil parameters as defined in Table 5.3 and a water table at 1.0 m below the top of embankment in reinstated and temporary embankment conditions.

Excavation of temporary side slopes above the water table that do not support traffic should not be steeper than 1H:1V, although, flatter slopes may be required depending on construction methods. Temporary slopes above the water table supporting traffic during the construction stages should not be steeper than 2H:1V. Design of temporary slopes below the

water table will depend on the dewatering method. Embankment foreslopes should be reinstated as indicated in Section 5.1.12 Embankment Foreslopes.

The trench width must be sufficient to permit proper use of compaction equipment suited for the material to be compacted, to reach the degree of compaction required, and to accommodate within the space available as per OPSS 501, "Construction Specification for Compaction".

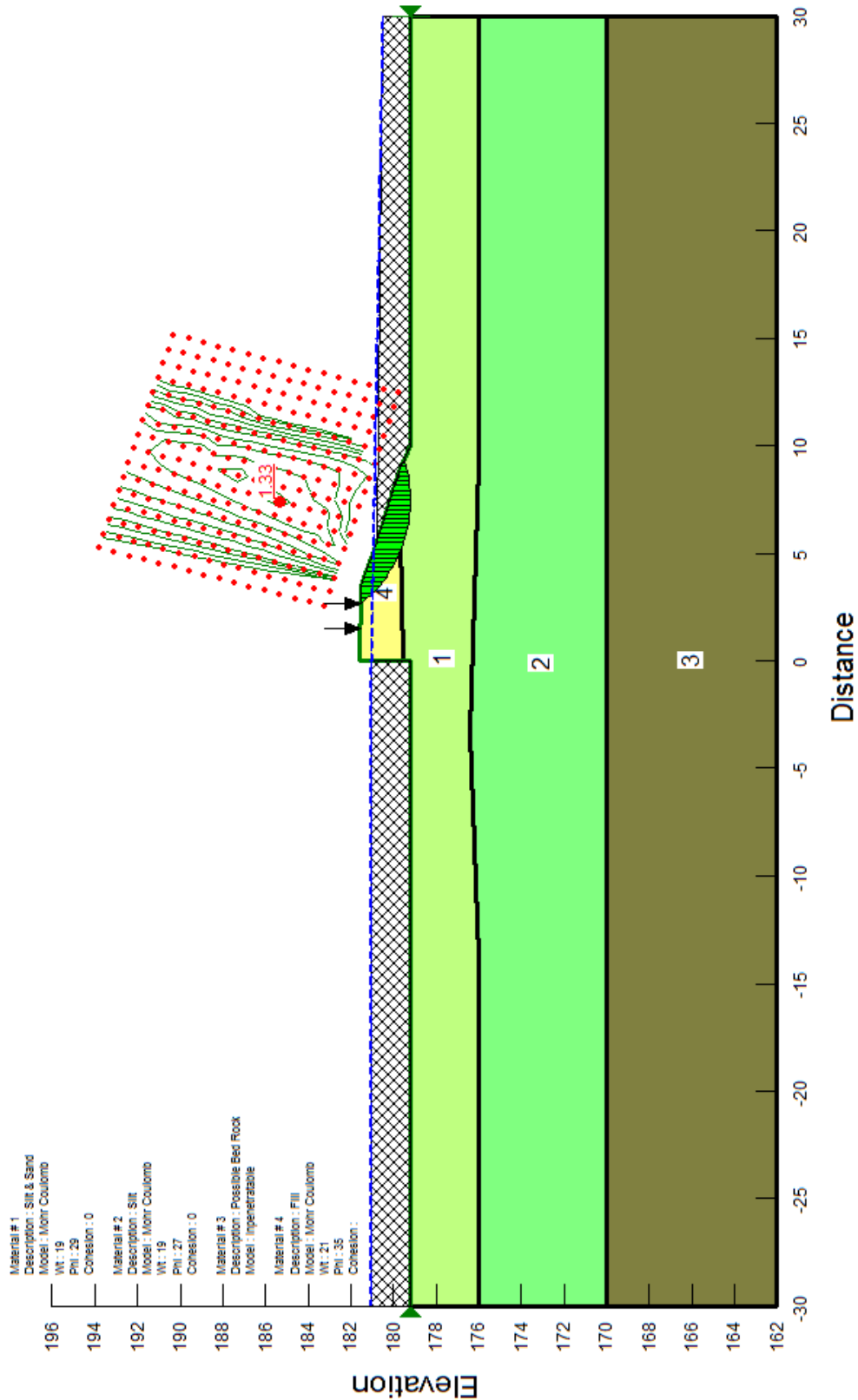


Figure 5.1 Slope stability analysis Stage 1 cutting at left side with existing 2H:1V foreslopes under drained condition

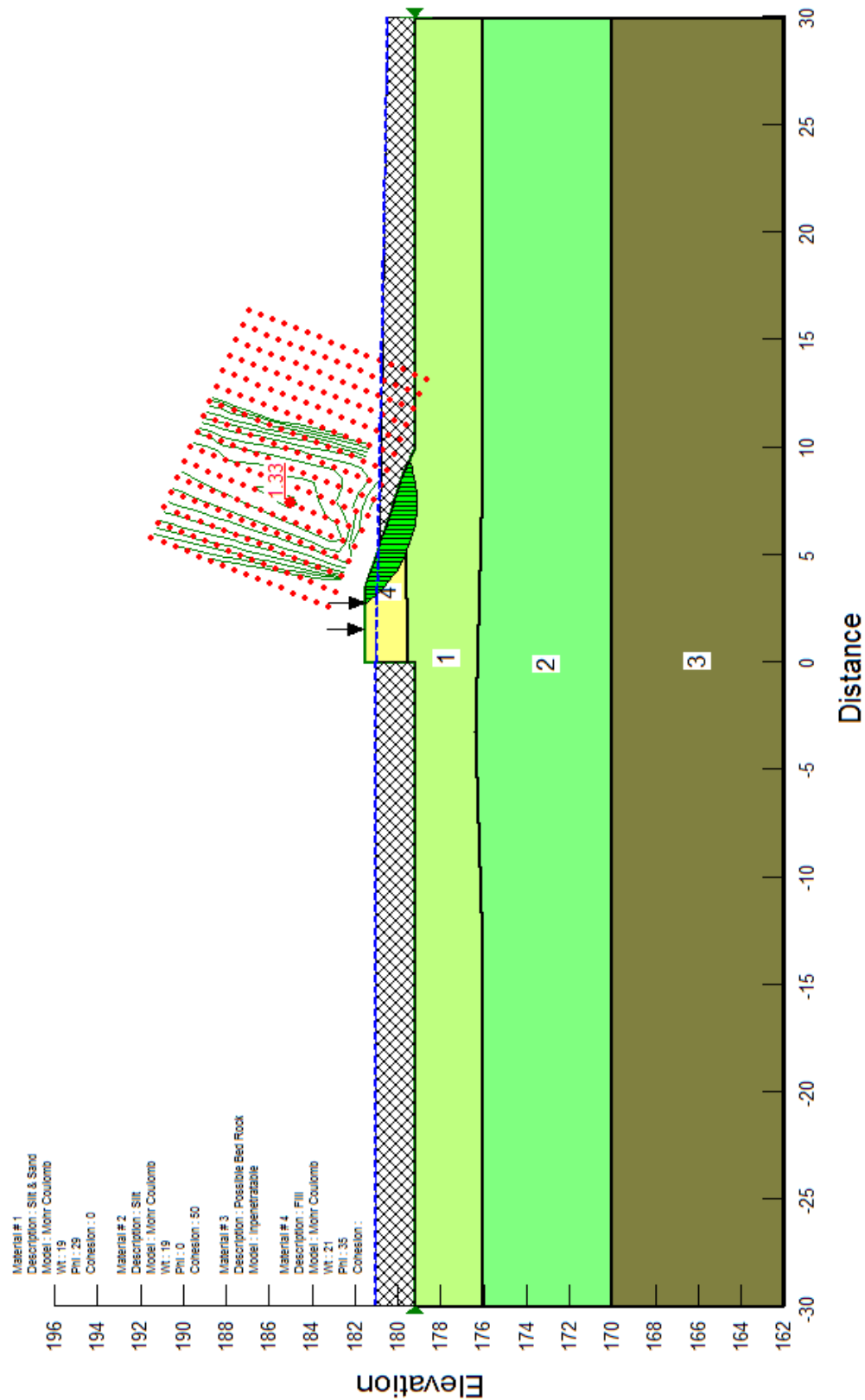


Figure 5.2 Slope stability analysis Stage 1 cutting at left side with existing 2H:1V foreslopes under undrained condition

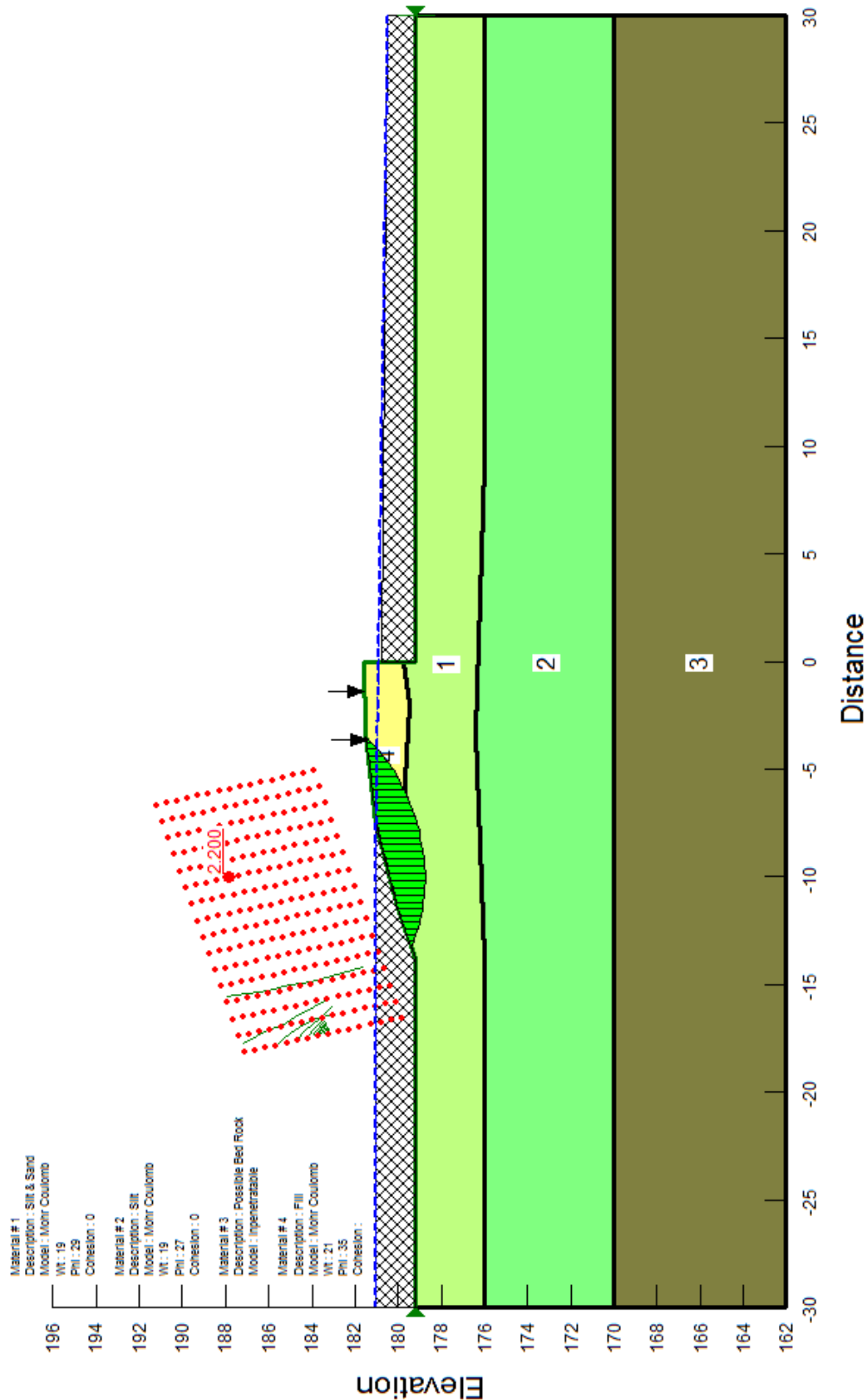


Figure 5.3 Slope stability analysis Stage 2 cutting at right side of reinstated embankment with 2.5H:1V foreslopes under drained condition

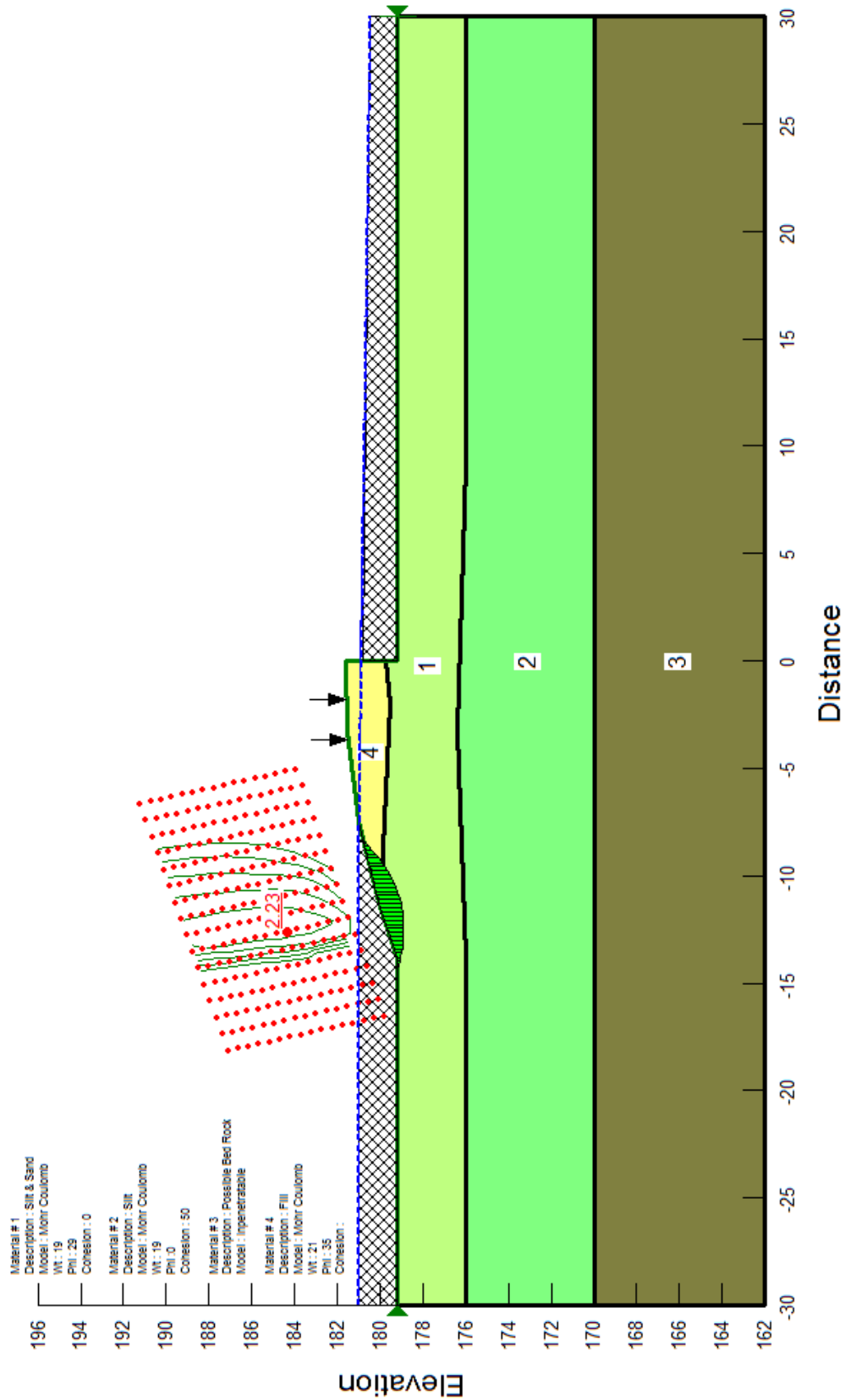


Figure 5.4 Slope stability analysis Stage 2 cutting at right side of reinstated embankment with 2.5H:1V foreslopes under undrained condition

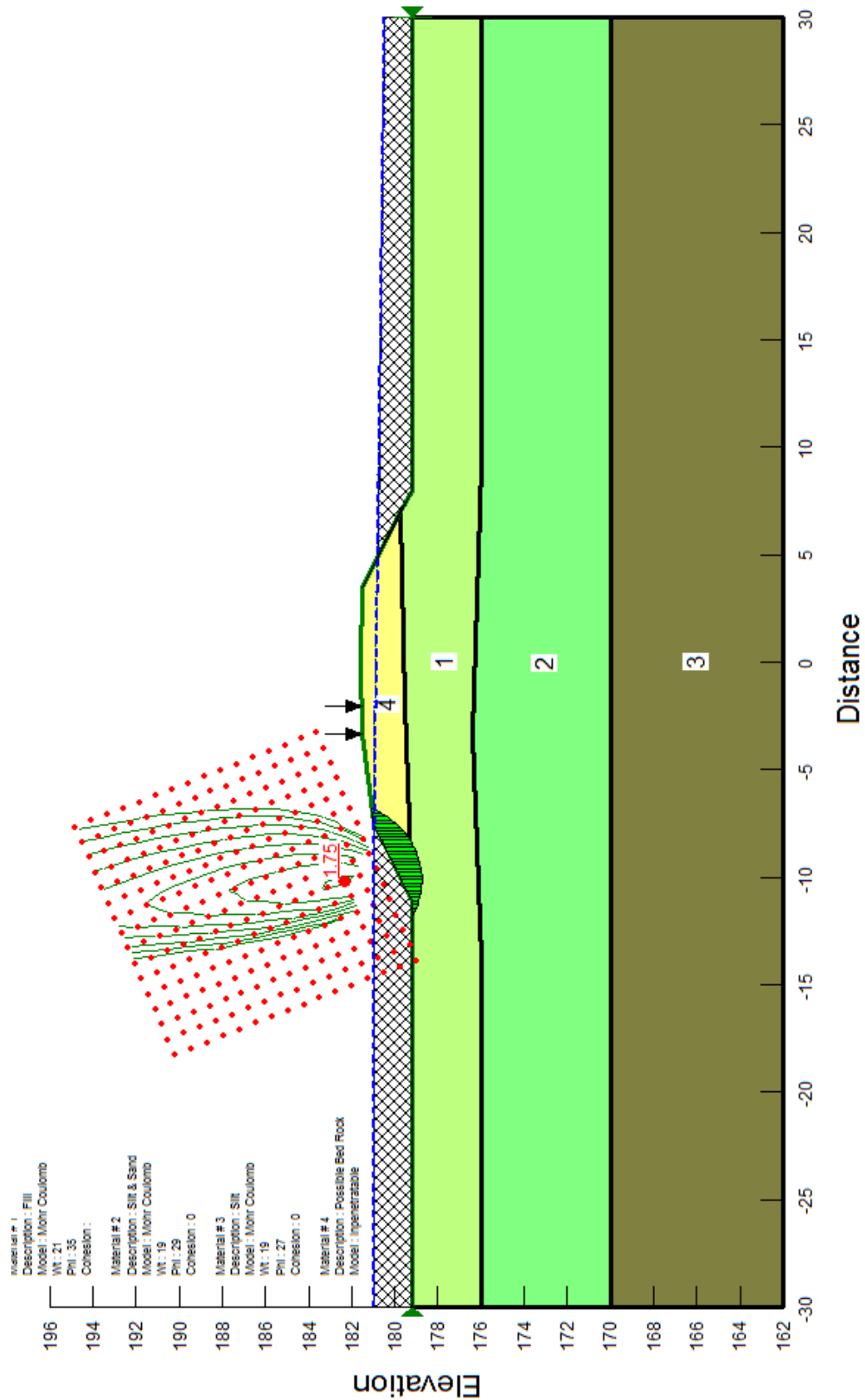


Figure 5.5 Slope stability analysis after culvert replacement left side reinstated embankment with 2H:1V foreslopes under drained condition

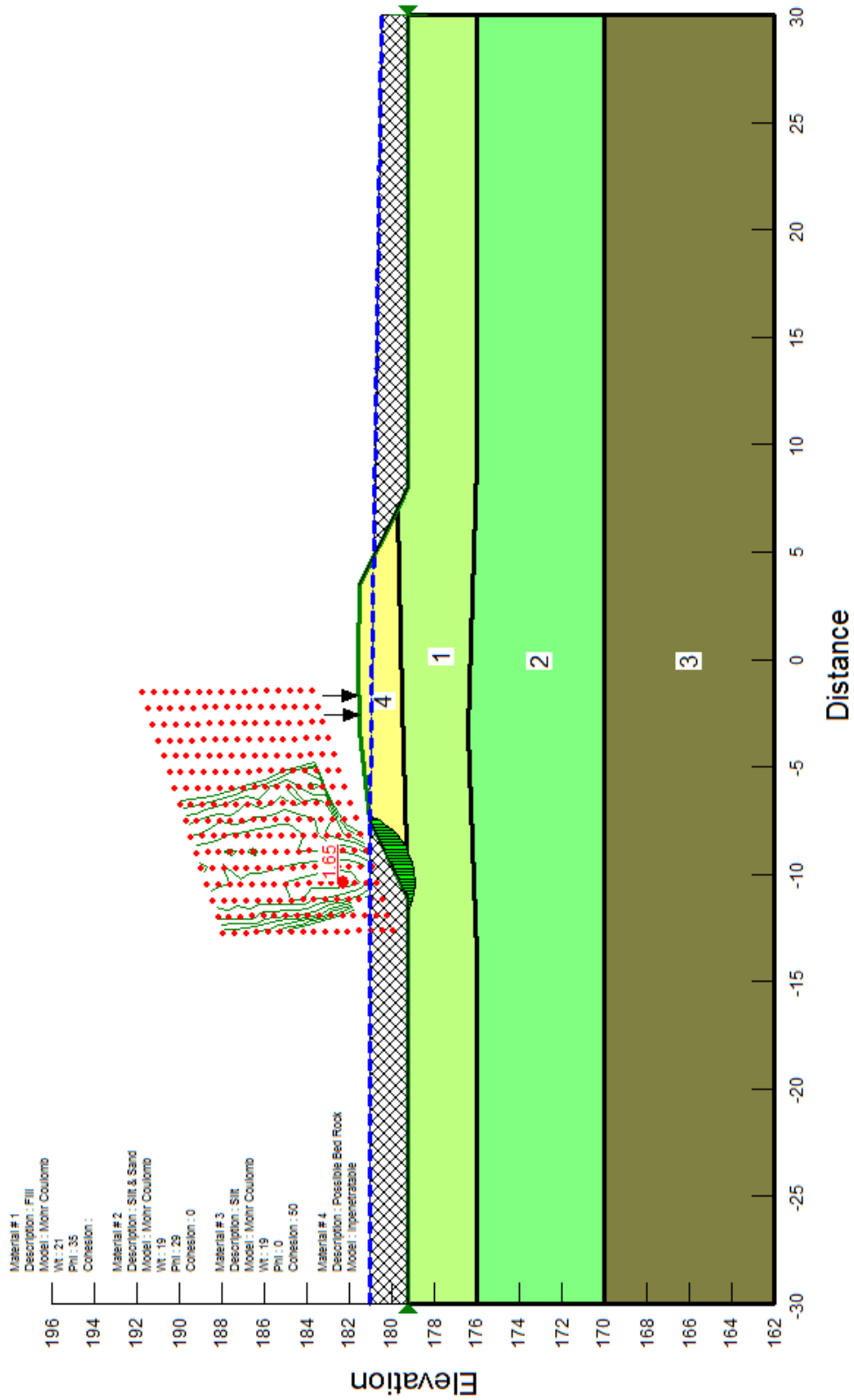


Figure 5.6 Slope stability analysis after culvert replacement left side reinstated embankment with 2H:1V foreslopes under undrained condition

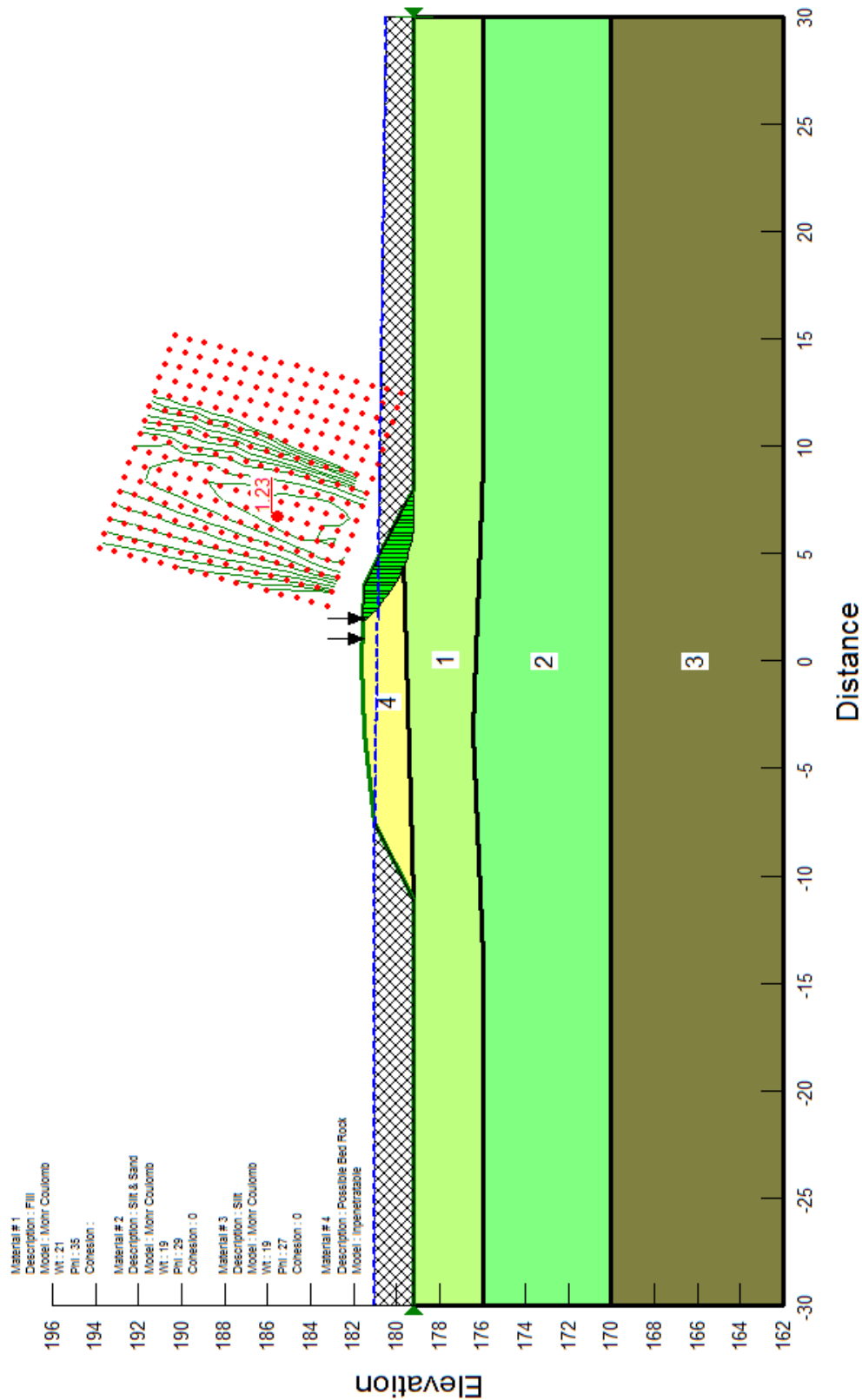
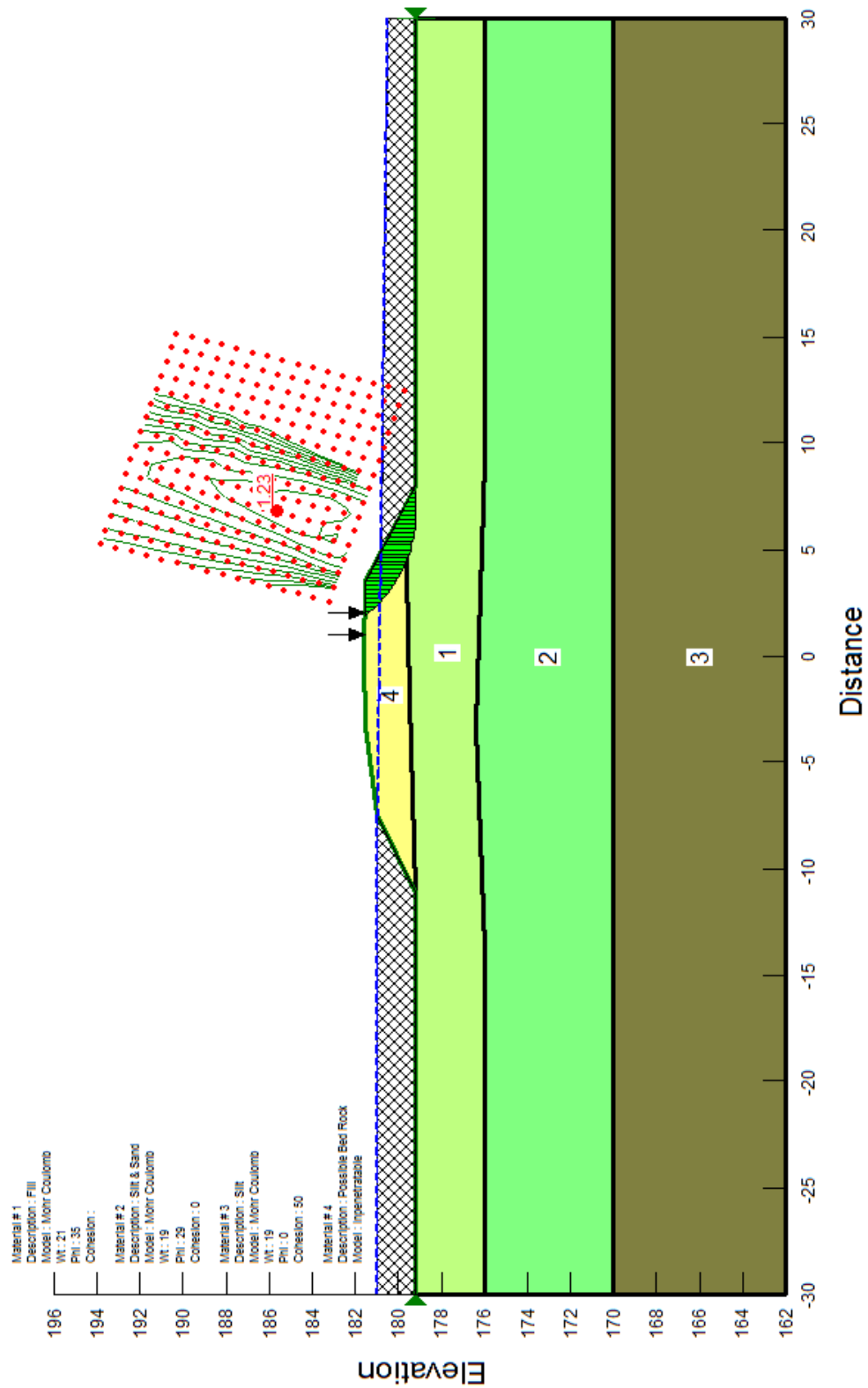


Figure 5.7 Slope stability analysis after culvert replacement right side reinstated embankment with 2H:1V granular fill foreslopes under drained condition



5.1.5 Lateral and Sliding Resistances

The analysis of horizontal and vertical effects of earth loads on the culvert can be performed considering soil parameters given in Table 5.3 and assuming linearly variation of stress change with the depth as described in Section 7.8.5.3.2 in Canadian Highway Bridge Design Code. Temporary bracing and shoring may be designed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs of specific bracing and shoring system.

It is recommended that all excavations be either adequately sloped or securely shored and braced to prevent earth caving and to provide a safe and stable work area. The design should incorporate the effects of hydrostatic pressure, traffic surcharge and retained sloping earth conditions in the bracing design.

Resistance to lateral forces/sliding resistance between the base slab for the replacement of culvert and subgrade should be calculated in accordance with section 6.7.5 of the CHBDC.

The coefficients for lateral earth pressure can be calculated using equations provided in Table 5.4. Where no significant earth movements are expected, the coefficient K_o should be used in that case.

Table 5.3 Typical soil parameters for earth loads

Soil type	Unit weight (kN/m ³)	Internal friction angle (Deg)	Interface friction angle, δ (Deg)	Intact undrained shear strength (kPa)
Silt	19	27	15	50
Silt and Sand	19	29	17	-
Granular A	21	35	17	-

Table 5.4 Lateral Earth Pressure Coefficients

Earth Pressure Coefficient	Equation*
Active Earth Pressure (K_a)	$\left(\frac{1 - \sin\phi}{1 + \sin\phi} \right)$
Passive Earth Pressure (K_p)	$\left(\frac{1 + \sin\phi}{1 - \sin\phi} \right)$
At rest (K_o)	$(1 - \sin\phi)$

* ϕ is an angle of internal friction

5.1.6 Roadway Protection

Roadway protection for this project should be constructed in accordance with the requirements of the Occupational Health and Safety Act of Ontario (OHSA), O.Reg. 213/91. According to O.Reg. 213/91, s.226, the soils in the area of interest classify as Type 3 and Type 4 if located above and below the water table respectively. Type 3 soils generally are stiff to firm and compact to loose or are previously excavated soil, exhibit signs of surface cracking, exhibit signs of seepage, if it is dry, may run easily into a conical pile and have a low degree of internal strength. Type 4 soils generally are soft to very soft and very loose in consistency, very sensitive and upon disturbance are significantly reduced in natural strength, run easily or flow unless it is completely supported before excavation procedure, have almost no internal strength, are wet or muddy and exerts substantial fluid pressure on its supporting system. In accordance with O. Reg. 213/91, s.227 (3), if an excavation contains more than one type of soil, the soil shall be classified with the highest number as described in section 226. These should be assessed and confirmed in the field as construction progresses.

Since roadway protection is required during the culvert replacement, installation of a cantilevered sheet pile system may be considered to ensure the stability of the bank and is a feasible option. The design of sheet piles may be performed using the typical soil parameters given in Table 5.3, but the designer/contractor should verify the appropriate soil parameters for the designs. The deformation of the sheet pile wall should be monitored and limited to less than 1% of the retained height. Since the embankment is not to be reduced in height, the potential of encountering rock fill, cobbles and boulders is likely. The contractor should be prepared to handle the presence of rock fill with the selection of adequate driving or vibratory equipment as well as steel thickness.

The construction methodology must be in accordance with OPSS 539 "Construction specifications for Temporary Protection Systems" and all applicable standards and regulations related to the method proposed. The contractor's method and equipment must be suitable for the site conditions and materials used.

5.1.7 Bedding

The bedding for the structure should be designed in accordance with Section 7.8.3 of the CHBDC.

For the conditions at this site, it is likely that the proposed construction will be undertaken with dewatering. The foundation soils, sensitive clay in particular, will be very

susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed shall be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement should commence immediately after the final removal of material to the foundation level has been completed.

The bedding shall be a minimum of 0.5 m thick and extend to a minimum width (half of the width of culvert) beyond all sides of the culvert. The bedding material should consist of "Granular A" as per Soil Group I in accordance with Table 7.4 of the Canadian Highway Bridge Design Code. The "Granular A" shall be in accordance to SSP 110S13. The "Granular A" should be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer compacted to a minimum of 95 % of standard Proctor maximum dry density. The middle one-third of the culvert width of the top bedding layer, having minimum thickness of 75 mm, shall be loosely placed and uncompacted. It shall be in accordance with requirements as specified in OPSS 422 "Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut".

If construction is performed without dewatering bedding material should consist of 19 mm Type I or II clear stone as defined in OPSS 1004.05.02. If fine materials are present beneath the clear stone a non-woven geotextile (OPSS 1860.07.05.01 Class II) with the filtration opening size (FOS) less than 135 µm may be required for separation. No compaction is required of the clear stone.

5.1.8 Sidefill and Overfill

The material used for culvert sidefill should not contain debris, organic matter, frozen materials, or large stones of a diameter greater than one-half the thickness of the compacted layers being placed or 100 mm, whichever is smaller. Soils shall be deposited uniformly on each side of the structure in order to prevent lateral displacement. The minimum width of the sidefill should be at least half of the culvert width in each side. The sidefill should consist of Granular A meeting SSP110S13 requirements and compacted to 95% of standard Proctor maximum dry density and in accordance with OPSS 501.

Overfill should consist of Granular A meeting SSP110S13 requirements and should be compacted to a minimum of 90 or 95 % of Standard Proctor Maximum Dry Density (SPMDD) respectively but not greater than the compaction or equivalent stiffness of soils in the sidefill and bedding zones. Each layer should not exceed 200 mm in thickness, loose measurement. The

backfill materials should be separated from the adjacent soil with a non-woven Class II geotextile as specified in OPSS 1860.

When the concrete culvert is installed on the undisturbed original ground and fill material is placed around and over the culvert, relative settlements between the fill adjacent to the sides of the culvert and the fill directly over the culvert generates downward frictional forces on the culvert, also effecting a load transfer. This increased load on the culvert can be represented by a column of fill of width $K \times B$, where K is a load transfer coefficient and B is the width of the culvert. For the design purpose, K can be assumed as 1.35.

5.1.9 Channel Diversion and Dewatering

The culvert shall be replaced by diverting the creek channel temporarily adjacent to the existing culvert. It is important to ensure that a flood in the channel does not cause damage to the partly constructed permanent works, to the temporary works or to plant. Floods can occur quickly and can cause significant financial consequences if adequate containment strategies are not present.

If the creek has comparatively a small amount of flow that may depend on the season, it may be feasible for the creek flow to be directed by staging construction. In order to prevent back up of water from upstream and downstream, a dyke made of sand bags has sometimes been used as a hydraulic barrier. However, a sheet pile vertical cut-off wall will provide better control of both surface and groundwater. A suitable sump and pump system will be sufficient due to low permeable nature of underlying soil to dewater and stabilize the excavation. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary. The contractor should be prepared to tackle this situation. The contractor should be alerted of the high water table and surface water, for example through a non standard special provision (NSSP).

A continuous dewatering operation must be provided to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage. The control of water from the dewatering operation should be accordance with OPSS 518 "Construction Specification for Control of Water from Dewatering Operations".

5.1.10 Erosion Control

Erosion control is essential at inlet and outlet for the successful performance of a culvert. Generally, rip-rap is used to avoid the erosion at inlet and outlet of the culvert. The rip-rap slows down the flow close to the channel bed and prevents culvert failure by the undermining.

To prevent erosion of the surrounding soils at the inlet, rip-rap Treatment shall be applied accordance with OPSD 810.020 “Rip-Rap Treatment for Ditch Inlets” and OPSS 511 and SP511S01 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

The outlet shall be rip-rapped to prevent erosion of the surrounding soils accordance with OPSD 810.010 “Rip-Rap treatment for Sewer and Culvert Outlets” and OPSS 511 and SP511S01 “Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting”.

To prevent undermining of the bedding, cut-off walls shall be installed along the entrance and exit end bottom sides of culvert. Cut-off wall should be designed based on velocity of the water flow and the type of soil underneath.

Considering the replacement of Granular A material underneath and in front of the inlet and replacement of cover material with clear stone or granular material, a clay seal should be considered to minimize underflow. A blanket clay seal should be at minimum 300 mm thick and extend 2 m beyond the fill materials. Clay seals should be constructed in accordance with OPSS 422 and have material properties as specified in OPSS 1205. Alternatively, a geosynthetic clay liner installed to manufacturer’s specifications may also be suitable.

The temporary erosion and sedimentation measures during the construction of culvert shall be controlled as described in OPSS 577 “Construction Specification for Temporary Erosion and Sedimentation Control Measures”.

5.1.11 Frost Protection

In accordance with OPSD 3090.101 “Foundation Frost Depths for Southern Ontario”, the frost penetration at this location is approximately 1.8 m. The frost susceptible soils shall not be used adjacent to the culvert wall within the depth of frost penetration from the road surface. The soils present under the culvert are frost susceptible (capable of forming thick ice lenses with the associated pressures and heave).

During winter season, ice may form inside the culvert and a low flow rate may assist the ice formation. It is expected that ice may extend to the culvert invert and frost could therefore

extend into the soils below the culverts, possibly as deep as 1.8 m. The frost heave may generate additional stresses on the culvert foundation and walls.

Three design approaches are commonly applied; designing the culvert with enough strength and rigidity to tolerate these pressures (recognizing that the maximum differential pressures and movements as a result of frost lensing cannot be accurately quantified); removing the frost susceptible soils within the frost zone; or providing adequate insulation to reduce frost penetration. As the frost penetration is extended below the invert level of the culvert, the frost protection should be in accordance with OPSD 803.010 "Backfill and Cover for Concrete Culverts, Frost Penetration Line below Top of Culvert".

Acceptable insulation to prevent frost penetration would be 125 mm Dow Styrofoam Highload 40 Insulation or an equivalent material with a compressive strength of approximately 275 kPa or greater. For a region that has a freezing index less than 3000 Fahrenheit Degree-Days it is recommended that the insulation be placed beneath the structure and extend 2.44 m from the concrete face of the buried structure.

5.1.12 Embankment Foreslopes

Existing culvert foreslopes are approximately 3H:1V to as steep as 2H:1V on the west and east embankments. The foreslopes should be reinstated with a slope not steeper than 2H:1V if being constructed with granular materials. The foreslopes should be reinstated with a slope not steeper than 1.5H: 1V if being constructed with rock fill.

5.1.13 Construction Concerns

The main construction issues that need to be addressed for this site are removal of cover/embankment materials, staged removal of the existing culvert, provisions required for temporary roadway protection, diversion of the channel, excavation below the water table, erosion at inlet and outlet culvert and undermining of culvert bedding, frost/heave in silty soil below culvert and reinstatement of the embankment fill. These items are important for the successful installation of the new culvert. Particular attention should be paid to maintain the integrity of the existing culvert during the staged method of construction.

An on-site Engineer shall be required to inspect the condition of the foundation and surrounding soils before installation of bedding and other backfills and ensure the width of trench and trench slope walls are suitable, and ensure compliance with materials placed and compaction methods.

6. REFERENCES

Canadian Highway Bridge Design Code (2006), CAN/CSA-S6-06, A National Standard of Canada, Canadian standards Association.

Municipal and Provincial Common, Volume 1 - General & Construction Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 501, 510, 511, 518, 577, 902.

Municipal and Provincial Common, Volume 3 - Drawings for Roads, Barriers, Drainage, Sanitary Sewers, Watermains and Structures, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSD 803.010, 810.010, 810.020, 3090.100.

Municipal and Provincial Common, Volume 2 - Material Specifications, "*Ontario Provincial Standard for Roads & Public Works*" Spec No. OPSS 1860.

Special Provisions, Ontario Provincial Standards, SSP110S13, SP511S01.

7. LIMITATIONS OF REPORT

A description of limitations which are inherent in carrying out site investigation studies is given in Appendix 'A', and this forms an integral part of this report.

For DST CONSULTING ENGINEERS INC.

Prepared by:



Deep Bansal, M.Eng
Jr. Project Manager

Reviewed by:



Dr. M W Bo, PhD., P. Eng, P.Geo, Int PE,
C.Geol, C. Eng, Eur Geol, Eur Eng
Principal / Director (GeoServices)

Reviewed by:



Wesley Saunders, P. Eng.
Project Manager

APPENDIX 'A'
LIMITATIONS OF REPORT

LIMITATIONS OF REPORT

GEOTECHNICAL STUDIES

The data, conclusions and recommendations which are presented in this report, and the quality thereof, are based on a scope of work authorized by the Client. Note that no scope of work, no matter how exhaustive, can identify all conditions below ground. Subsurface and groundwater conditions between and beyond the testholes may differ from those encountered at the specific locations tested, and conditions may become apparent during construction which were not detected and could not be anticipated at the time of the site investigation. Conditions can also change with time. It is recommended practice that DST Consulting Engineers be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered in the testholes. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the testhole locations and should not be used for other purposes, such as grading, excavation, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with details stated in this report. Since all details of the design may not be known, we recommend that we be retained during the final stage to verify that the design is consistent with our recommendations, and that assumptions made in our analysis are valid.

Unless otherwise noted, the information contained herein in no way reflects on environmental aspects of either the site or the subsurface conditions.

The comments given in this report on potential construction problems and possible methods are intended only for the guidance of the designer. The number of testholes may not be sufficient to determine all the factors that may affect construction methods and costs, e.g. the thickness of surficial topsoil or fill layers may vary markedly and unpredictably. The contractors bidding on this project or undertaking the construction should, therefore, make their own interpretation of the factual information presented and draw their own conclusion as to how the subsurface conditions may affect their work.

Any results from an analytical laboratory or other subcontractor reported herein have been carried out by others, and DST Consulting Engineers Inc. cannot warranty their accuracy. Similarly, DST cannot warranty the accuracy of information supplied by the client.

A P P E N D I X 'B'

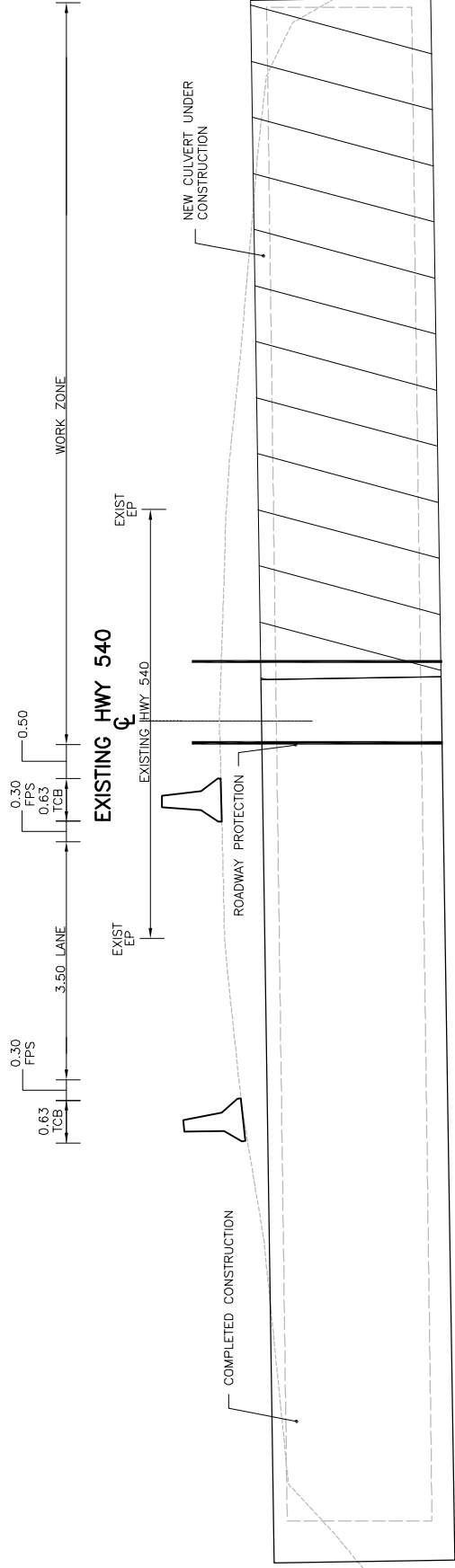
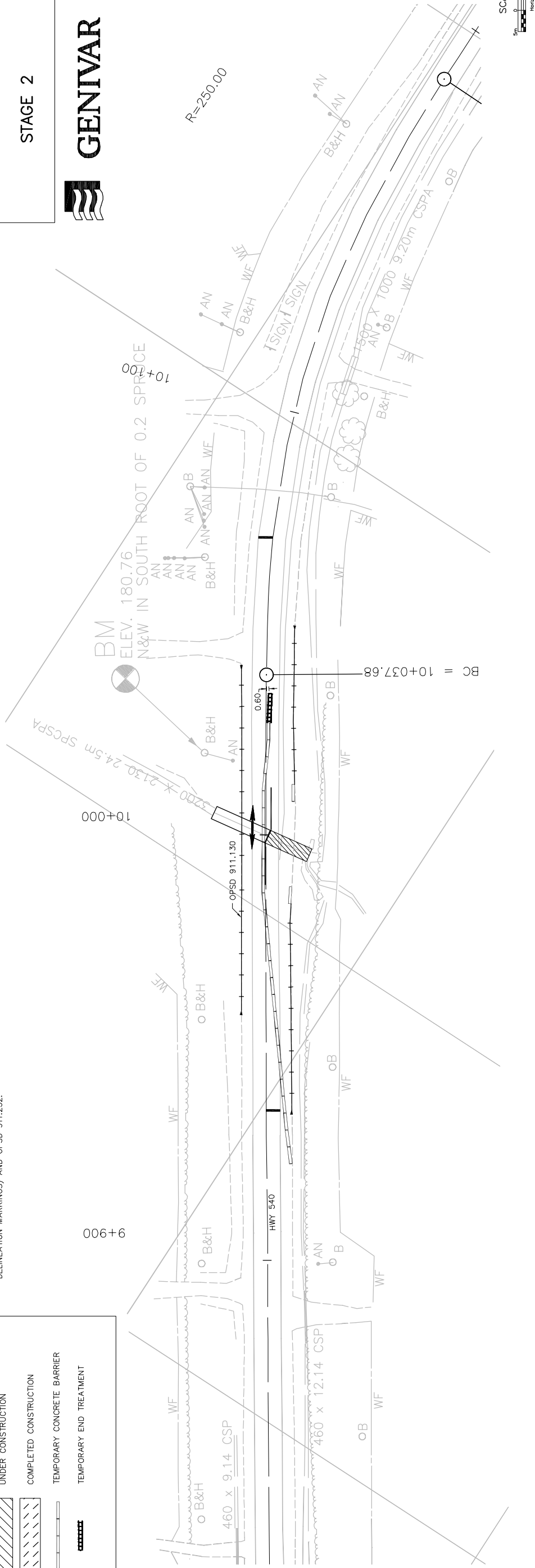
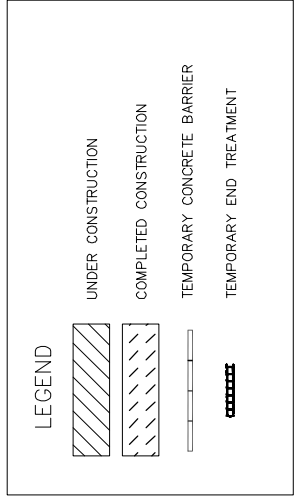
GENIVAR STAGING DRAWINGS

NOTES:

1. STAGING DRAWING TO BE READ IN CONJUNCTION WITH ONTARIO TRAFFIC MANUAL (OTM), BOOK 7 (TEMPORARY CONDITION AND BOOK 11 (PAVEMENT HAZARD AND DELINEATION MARKINGS) AND OPSD 911-232.

CONT
WP 5057-07-01

STAGE 2



METRIC

CONT No
WP No 5057-07-01

UNKNOWN CREEK #5 CULVERT
(49-066)

GENERAL ARRANGEMENT

01

DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

JOB NUM. 101-16086-00

SCOPE OF WORK:

- AINSTALL TRAFFIC CONTROL MEASURES AS PER CONTRACT
- BINSTALL ENVIRONMENTAL PROTECTIONTEMPORARY CREEK DIVERSION
- CINSTALL ROADWAY PROTECTION.
- DEXCAVATE FOR NEW CULVERT, RETAINING WALLS AND BEDDING
- EREMOVE EXISTING CULVERT
- FPLACE GRANULAR 'A' BEDDING
- GCONSTRUCT CONCRETE RETAINING WALL FOOTINGS AND WALLS
- HPLACE PRECAST CONCRETE APRON
- JPLACE PRECAST CONCRETE CULVERT SECTIONS
- KBACKFILL WITH GRANULAR 'A'
- LREINSTATE WITH TOPSOIL, SEED AND MULCH
- MREMOVE ENVIRONMENTAL PROTECTION
- NREMOVE TRAFFIC CONTROL MEASURE

GENERAL NOTES:

1. CLASS OF CONCRETE: REINFORCED CONCRETE: 30 MPa.
2. DESIGN LOADING: CHBDC 2006, CANCSA-S6-06.
3. REINFORCING STEEL SHALL BE GRADE 400, PREFIX 'C' DENOTES EPOXY COATED REINFORCING STEEL.
4. CLEAR COVER TO REINFORCING STEEL SHALL BE 70mm ± 20mm EXCEPT AS NOTED.
5. ALL DIMENSIONS ARE IN MILLIMETERS.
6. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS, DETAILS AND ELEVATIONS OF THE EXISTING STRUCTURE THAT ARE RELEVANT TO THE WORK SHOWN ON THE DRAWINGS PRIOR TO COMMENCEMENT OF THE WORK, ANY DISCREPANCIES SHALL BE REPORTED TO THE CONTRACT ADMINISTRATOR.
7. ALL CONSTRUCTION PROCEDURES AND MATERIALS SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS AS SPECIFIED ELSEWHERE IN THE CONTRACT DOCUMENTS. ALL MATERIALS SUPPLIED SHALL BE FROM MTO DESIGNATED SOURCES, WHERE APPLICABLE.
8. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL OTHER APPLICABLE CONTRACT DRAWINGS.
9. PRIOR TO COMMENCING ANY WORK, THE CONTRACTOR SHALL BE SOLELY AND FULLY RESPONSIBLE FOR CONTACTING ALL APPLICABLE UTILITY COMPANIES FOR LOCATES AND OPERATIONAL CONSTRAINTS, AND FOR PROVIDING SUCH UTILITY COMPANIES WITH DETAILS OF WORK.
10. ALL NON-SALVAGED REMOVED MATERIALS SHALL BE DISPOSED OF OFF SITE AT AN APPROVED FACILITY AS PER OPSS 180.
11. ALL AREAS AFFECTED BY CONSTRUCTION ACTIVITIES SHALL BE FULLY REINSTATED TO PRE-CONSTRUCTION OR BETTER CONDITIONS TO THE SATISFACTION OF THE CONTRACT ADMINISTRATOR INCLUDING REINSTATEMENT OF ALL VEGETATION, PATHWAYS, FENCES, AREAS USED FOR SITE ACCESS, SITE STORAGE, ETC. AS PER OPSS 572.
12. THE CONTRACTOR IS RESPONSIBLE FOR ALL SITE ACCESS TO COMPLETE THE WORK.
13. NO WORK IN WATER IS ALLOWED BETWEEN SEPTEMBER 2 AND JUNE 15.
14. IMPLEMENT EROSION AND SEDIMENT PLAN ALL ENVIRONMENTAL PROTECTION SYSTEMS TO BE FULLY EFFECTIVE IN PREVENTING CONTAMINATION OF THE ENVIRONMENT.
15. MAINTAIN CONSTANT FLOWS IN WATERWAY AT ALL TIMES.
16. ALL WORK TO BE CARRIED OUT IN THE DRY. CONTRACTOR TO MAKE OWN ASSESSMENT OF ANTICIPATED WATER LEVELS AND UNWATERING LEVELS REQUIRED.

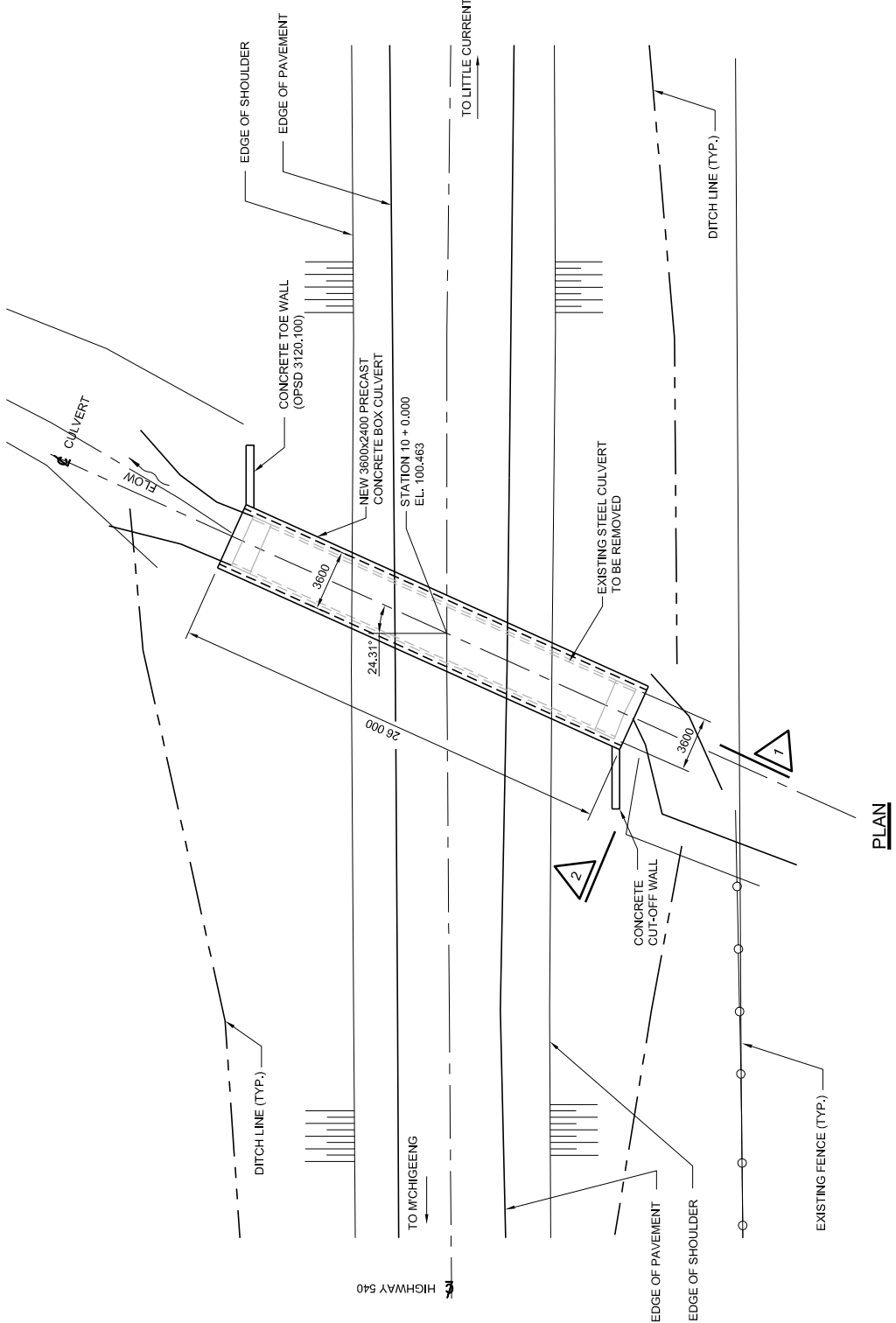
CONSTRUCTION STAGING

1. CONSTRUCTION OF THE CULVERT SHALL BE PREFORMED IN STAGES.
2. THE SCOPE OF WORK IS SHOWN FOR GENERAL INFORMATION ONLY, SOME ITEMS IN SCOPE OF WORK WILL BE REPEATED FOR STAGED CONSTRUCTION.
3. ROADWAY PROTECTION SHALL BE DESIGNED TO PERFORMANCE LEVEL 2.

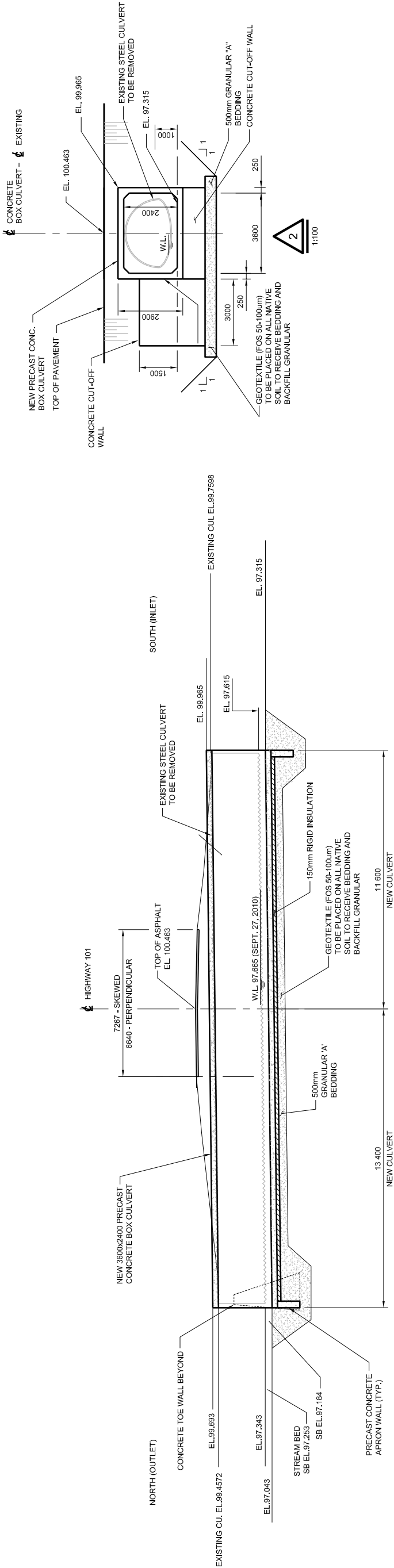
APPLICABLE STRUCTURAL STANDARD DRAWING

- OPSD 219.110 - LIGHT DUTY SILT FENCE BARRIER
- OPSD 219.180 - STRAW BALE FLOW CHECK DAM
- OPSD 219.280 - TURBIDITY CURTAIN
- OPSD 219.281 - TURBIDITY CURTAIN, SEAM DETAIL
- OPSD 3941.200 - FIGURES IN CONCRETE, SITE NUMBER AND DATE, LAYOUT

TAILWATER DURING 10 YEAR FLOOD EVENT
BASED ON ESTIMATED MAXIMUM AVERAGE
DAILY DISCHARGE OF 2.7 m³/s.



PLAN
1:200



1
1:100

2
1:100

REVISIONS		DATE	BY	DESCRIPTION
DESIGN	J.M.	CHK	L.M.	[CODE] CHBDC-A-43 LOAD CL-Ont-425 DATE OCT 2010
DRAWN	J.T.	CHK	M.B.	SITE 49-066 STRUCT SCHEME DWG. 01

A P P E N D I X 'C'

NON STANDARD SPECIAL PROVISIONS

DEWATERING STRUCTURE EXCAVATION - Item No.

Non-Standard Special Provision

902.01 SCOPE

Section OPSS 902.01 of OPSS 902 is amended by the addition of the following:

As part of the work under this item, the Contractor shall:

- Carry out any additional field investigation the Contractor deems necessary in order to engineer the unwatering systems;
- Design and install dewatering systems to construct the work in the dry;
- Carry out works necessary for the dewatering system that may include sheet piling, tremie concrete seal, sand bagging, etc.;

The Contractor is advised that the use of a suitable sump and pump system is required for working under dry conditions and to prevent disturbance of the excavation base through hydraulic heave. It should be noted that depending on the season, depth of excavation and amount of water flow through the creek may vary.

The Contractor shall provide a continuous dewatering operation to keep the excavation stable and free of water. The excavation must be monitored daily throughout the duration of excavation until the completion of backfilling to confirm this. The dewatering system must be maintained and the surrounding area monitored for impacts to items such as, but not limited to, settlement and groundwater usage.

Section OPSS 902.01 of OPSS 902 is amended by the following subsection:

902.01.01 Flow Rates

The Contractor must satisfy himself with the local conditions and anticipated water flows, levels and flow velocity to be met with during construction. He shall make his own estimate of the facilities required and difficulties to be encountered including the nature of subsurface materials and conditions. For the protection scheme water flows, the water elevation is shown on the Contract Documents.

902.03 DEFINITIONS

Section OPSS 902.03 of OPSS 902 is amended by the addition of the following:

Stamped:	Refers to drawings or details that have been reviewed and stamped "Conforms With Contract Documents". The stamp shall
-----------------	---

include the date and signature of the Quality Verification Engineer (QVE).

Quality Verification Engineer (QVE): An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of dewatering systems. The Contractor shall retain the QVE to ensure conformance with the contract document.

Dewatering System Design Engineer: An Engineer licensed to practice in the Province of Ontario who has a minimum of five (5) years of experience in the field of design and/or construction of bridges. In addition, the Dewatering System Design Engineer shall have had responsible experience in the design of at least 5 other dewatering systems. The Contractor shall retain the Dewatering System Design Engineer to ensure conformance with the contract documents and issue certificate(s) of conformance for the design.

902.04 SUBMISSION AND DESIGN REQUIREMENTS

Section OPSS 902.04 of OPSS 902 is amended by the addition of the following:

Design of components of the dewatering systems shall be in accordance with CAN/CSA-S6-00 and standard referenced therein.

Submission of Shop Drawings

All shop drawings submissions shall bear the seal and signature of the Dewatering System Design Engineer.

The Contractor shall submit to the Quality Verification Engineer shop drawings for review and stamping.

At least two weeks prior to the commencement of dewatering system construction, the Contractor shall submit to the Contract Administrator, for information purposes only, four (4) sets of stamped drawings/calculations of the dewatering system.

The Contractor shall, at least three (3) weeks prior to the commencement of the dewatering system installation, submit to the QVE for review, four sets of drawings and calculations indicating:

- the dewatering system design, including design criteria and loading;
- the location, type and dimensions of each dewatering system to be used;
- a schematic showing the configuration of all dewatering systems;
- the material and dimensions of dewatering system components to ensure stability of the design excavation and the dewatering system, and the construction sequence and schedule of each

component for which the dewatering system is designed.

The QVE shall review all calculations, construction details, shop drawings and procedures.

All submissions shall bear the seal and signature of the Dewatering System Design Engineer and QVE.

Certificates of Conformance

The Dewatering System Design Engineer shall inspect the installation of each component prior to the executing of the next stage in that dewatering system. After the installation/construction of each component, the Contractor shall submit a Certificate of Conformance to the Contract Administrator, sealed and signed by the Dewatering System Design Engineer. The Certificates of Conformance shall state that the dewatering system is in place, and has been installed in conformance with the stamped shop drawings and the Contract Drawings.

The Contractor will note that several Certificates of Conformance may be required, each to coincide with each dewatering system installation.

902.07 CONSTRUCTION

Section OPSS 902.07 of OPSS 902 is amended by the addition of the following:

All concrete work must be carried out in the dry.

Minimum dimensions for the inside face of the dewatering system shall be sufficient for installation of the new culvert.

902.10 BASIS OF PAYMENT

Section OPSS 902.10 of OPSS 902 is amended by the addition of the following:

Payment at the contract price for the dewatering systems shall be full compensation for all labour, equipment and materials to carry out the work.

NOTICE TO CONTRACTOR

Special Provision

FOUNDATION CONDITIONS

The Contractor is advised of the following conditions:

Occasional cobbles were identified with in the fill and native material within the advanced borehole locations.

The foundation soils, sensitive soil in particular, will be very susceptible to disturbance and weakening as a result of traffic, standing water and frost. Any foundation soils that could be disturbed should be protected. The bottom of the excavation on which the culvert or granular pad is to rest shall not be disturbed. The bedding placement shall commence immediately after the final removal of material to the foundation level has been completed.

A P P E N D I X 'D'

**DESCRIPTIVE TERMS FOR SOIL
CLASSIFICATION**

Descriptive Terms for soil classification:

As per the soil classification manual by MTO, the descriptive terms based on percent by mass of the whole sample, are described as per following table

Descriptive Term	Example	Percent by Mass of Sample
And (with two major soil types)	Sand and gravel	40-60
Adjective (silty)	Silty	30-40
With	Silt with fine sand	20-30
Some	Silt, some fine sand	10-20
Trace	Sand, trace of gravel	0-10

DRAWINGS

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METERS

CONT

No 5010-E-0007

GWP

No 5057-07-00

Site

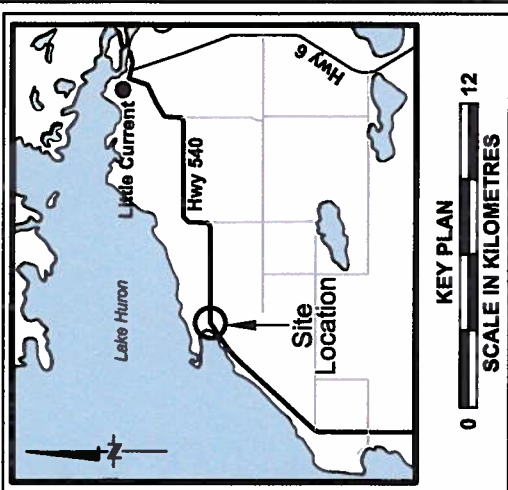
No 49-066

Geocres

No 41G-12

CULVERT REPLACEMENT
UNKNOWN CREEK CULVERT #5
Highway 540 - Howland Twp.
BOREHOLE LOCATION PLAN

SHEET



LEGEND

Borehole

Borehole with DCPT

Dynamic Cone Penetration Test (DCPT)

Rock Probe

Blows/0.3m (Std. Pen Test, 475 J/Blow)

Water level at time of investigation

Benchmark

Fill

Organics

Topsoil

Till

Bedrock

Sand

Silt

Clay

Sand & Gravel

Boulders

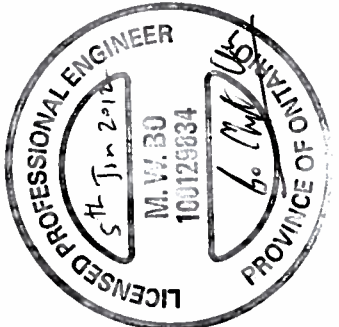
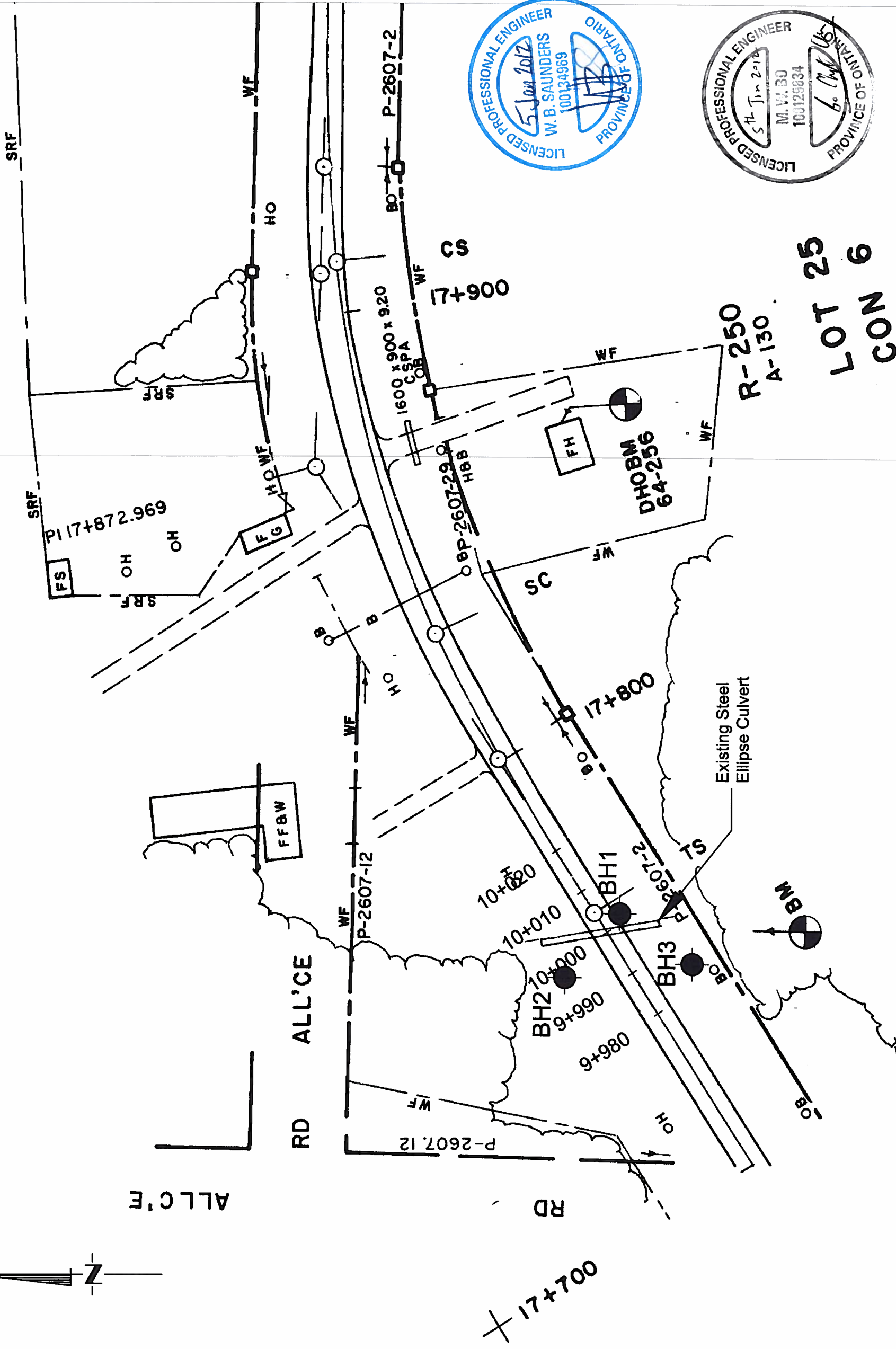
No.	Elevation	Northing	Eastings	Station	Offset
BH1	181.885	5885101	418533	10+002	4.3 m RT
BH2	178.885	5885124	418536	9+987	12.5 m LT
BH3	178.885	5885835	418533	9+985	11.5 m RT

Note:
Auger refusal was encountered on possible
boulders or bedrock at all borehole locations

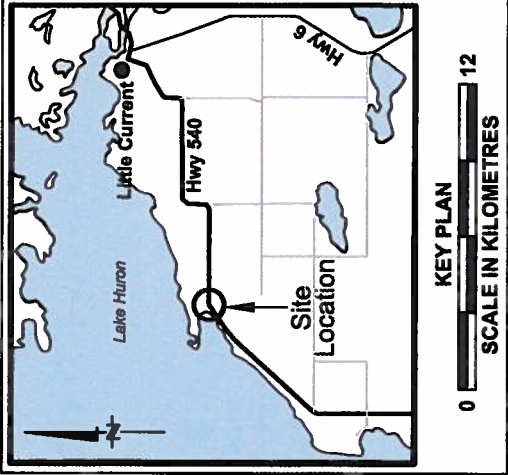
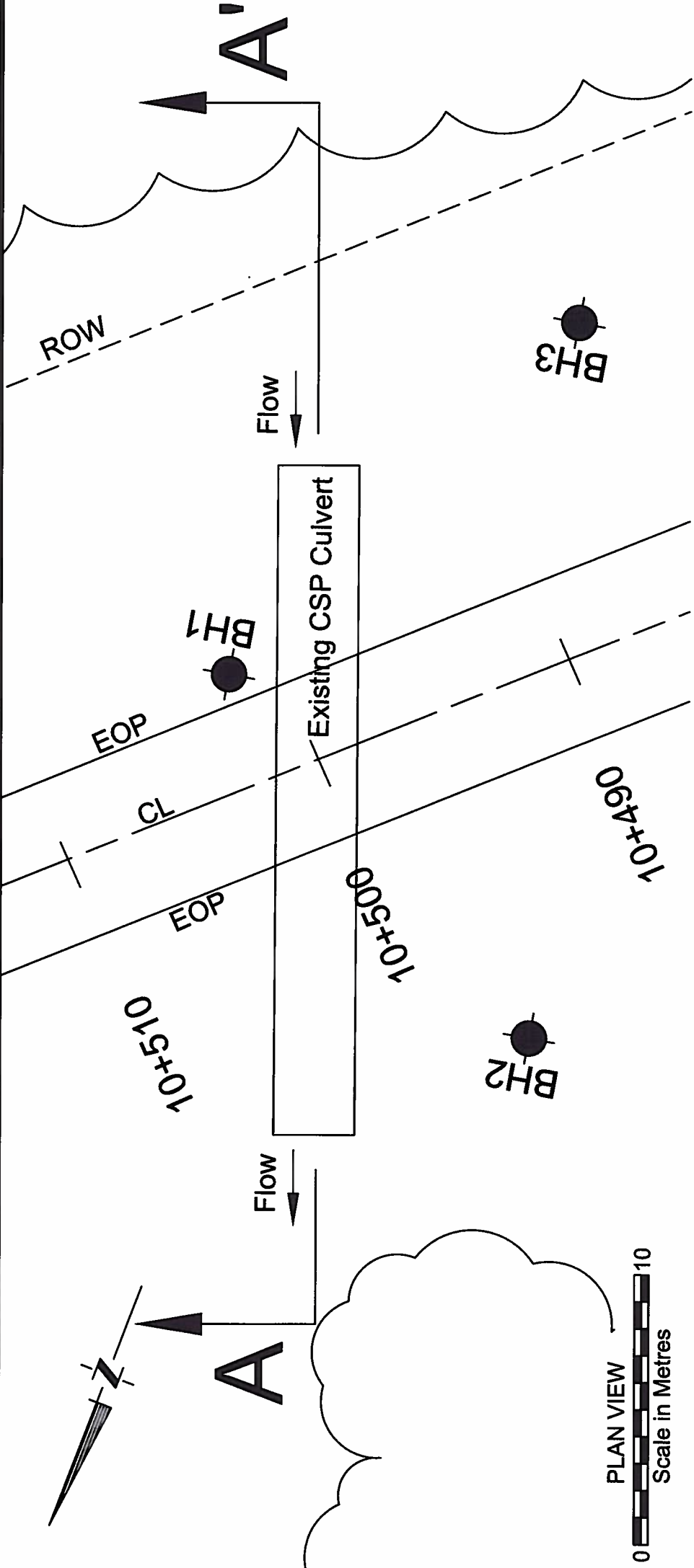
DST Consulting Engineers Inc.
805 Hewison Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2929
Fax: (807) 623-1792
Email: thunderbay@dstgroup.com

NOTES:

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.



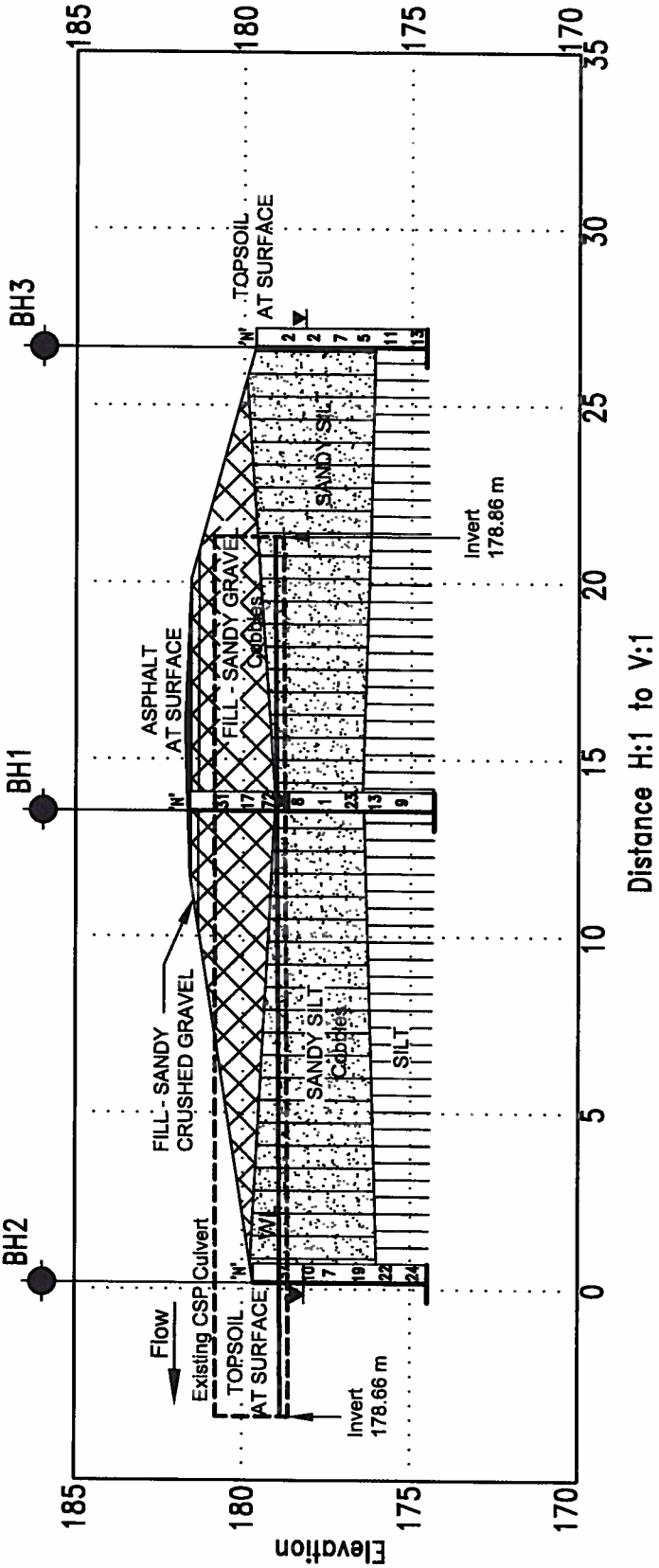
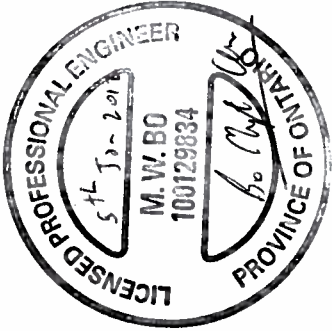
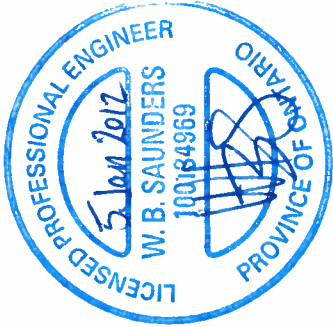
CONT	No 5010-E-0007	
GWP	No 5057-07-00	
Site	No 49-066	
Geocres	No 41G-12	
CULVERT REPLACEMENT UNKNOWN CREEK CULVERT #5 Highway 540 - Howland Twp. BOREHOLE LOCATION & SOIL STRATIGRAPHY		SHEET



LEGEND				
	Borehole		Borehole with DCPT	
	Dynamic Cone Penetration Test (DCPT)		Rock Probe	
	'N'		Blows/0.3m (Std. Pen Test, 475 J/Blow)	
	Water level at time of investigation		Benchmark	
	Fill		Organics	
	Topsoil		Till	
	Bedrock		Sand	
	Silt		Clay	
	Sand & Gravel		Boulders	

No.	Elevation	Northing	Easting	Station	Offset
BH1	181.805	5083101	418333	19+002	4.3 m RT
BH2	179.885	5089124	418336	9+997	12.5 m LT
BH3	179.855	5089685	418333	9+985	11.6 m RT

Note:
Auger refusal was encountered on possible boulders or bedrock at all borehole locations

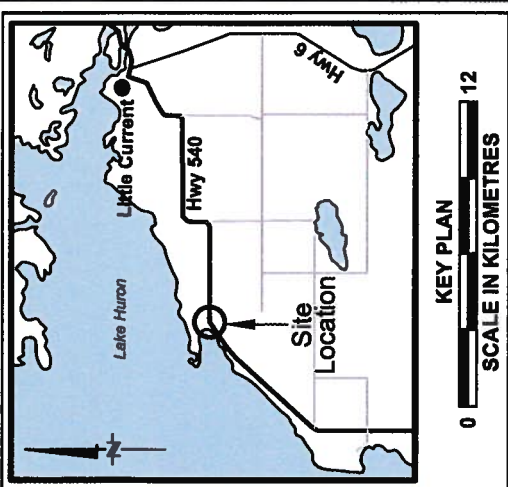


NOTE:
The boundaries between soil types have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

DST Consulting Engineers Inc.
605 Hewitson Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2828
Fx: (807) 623-1792
Email: thunderbay@dstgroup.com

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETERS + METERS

CONT	No 5010-E-0007	SHEET
GWP	No 5057-07-00	
Site	No 49-066	
Geocres	No 41G-12	
CULVERT REPLACEMENT UNKNOWN CREEK CULVERT #5 Highway 540 - Howland Twp. BOREHOLE LOCATION & SOIL STRATIGRAPHY		

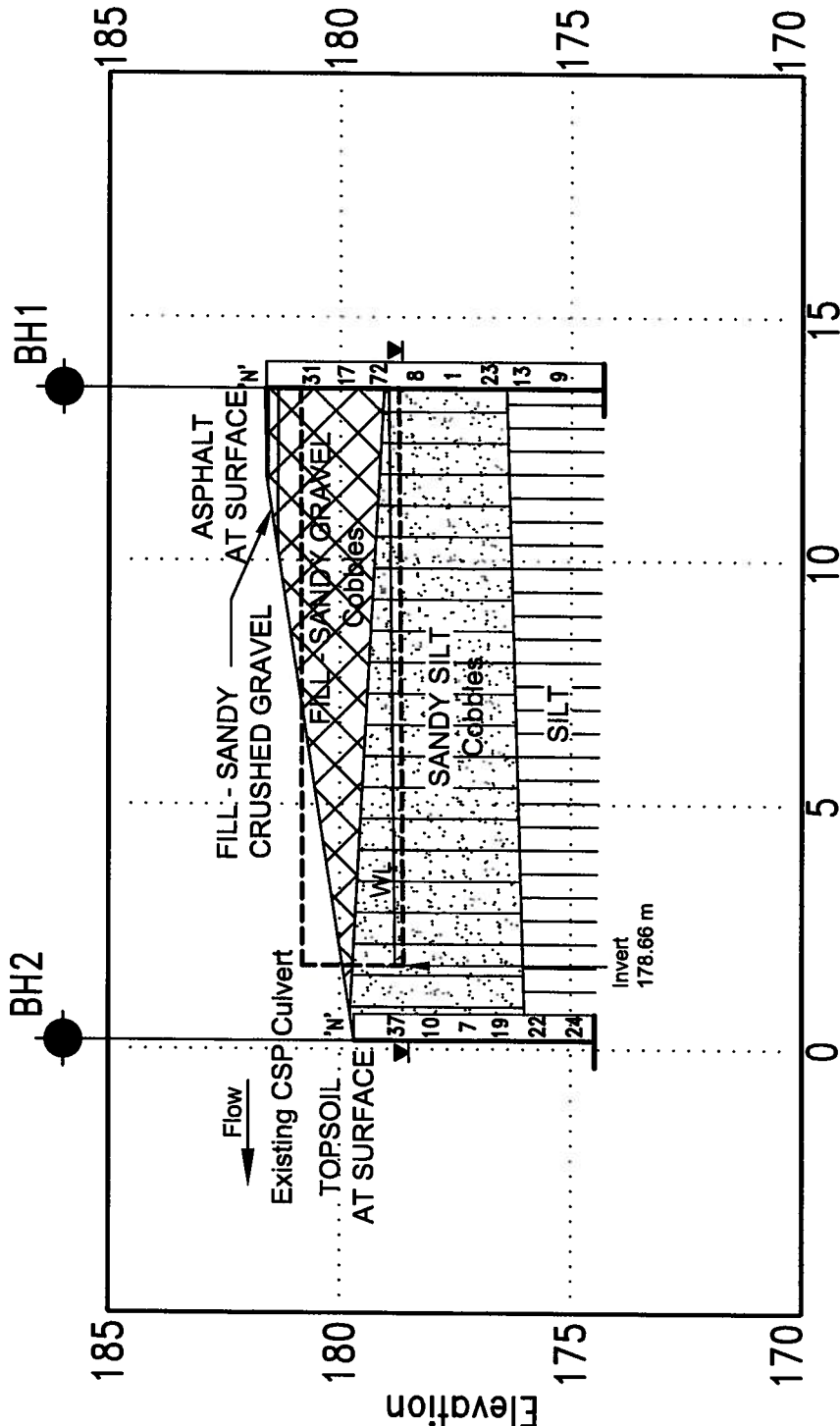
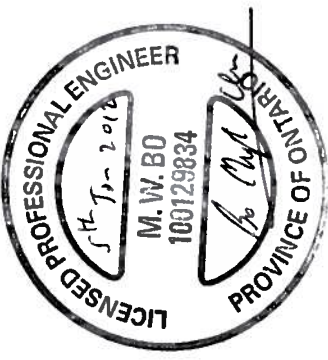
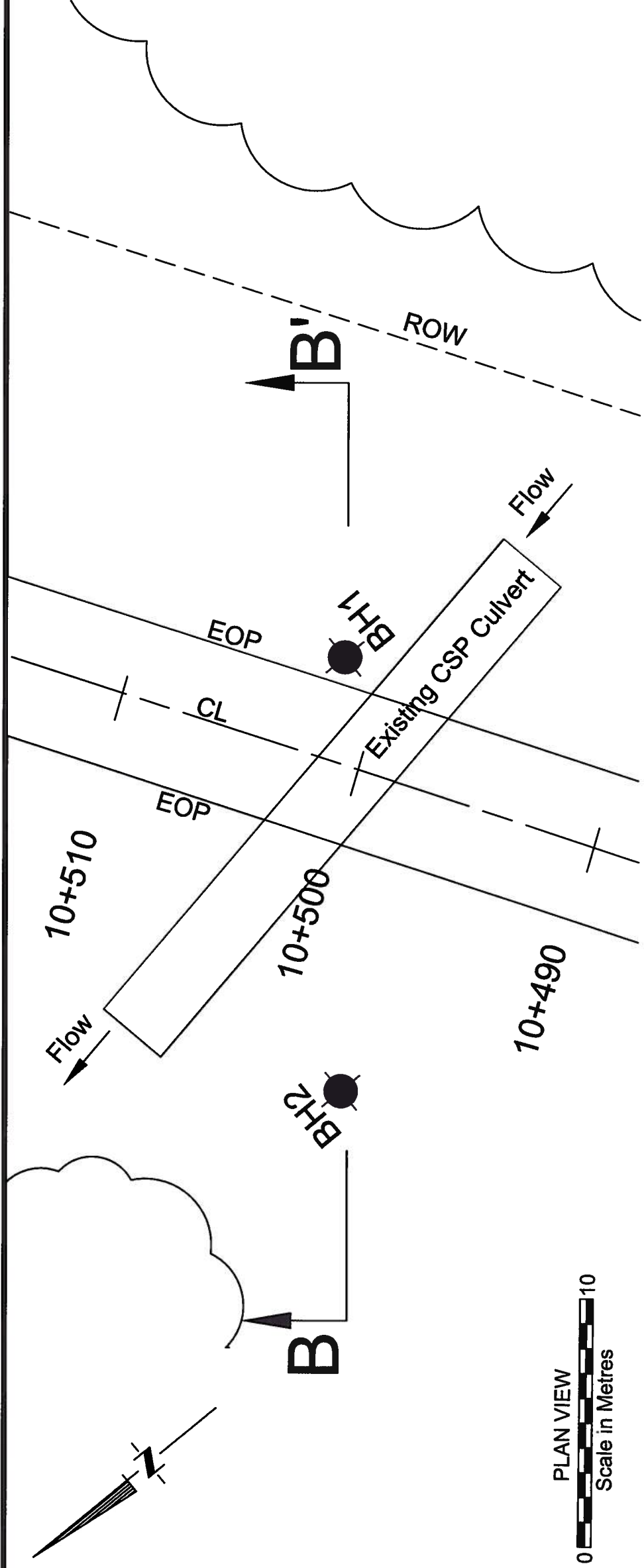



LEGEND			
◆	Borehole		
⊕	Borehole with DCPT		
⊕	Dynamic Cone Penetration Test (DCPT)		
⊕	Rock Probe		
●	'N'		
▽	Blows/0.3m (Std. Pen Test, 475 J/Blow)		
⊕	Water level at time of investigation.		
⊕	Benchmark		
⊕	Fill	⊕	Sand
⊕	Organics	⊕	Silt
⊕	Topsoil	⊕	Clay
⊕	Till	⊕	Sand & Gravel
⊕	Bedrock	⊕	Boulders

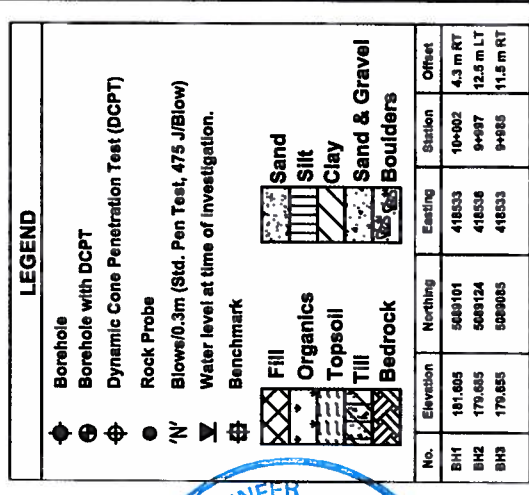
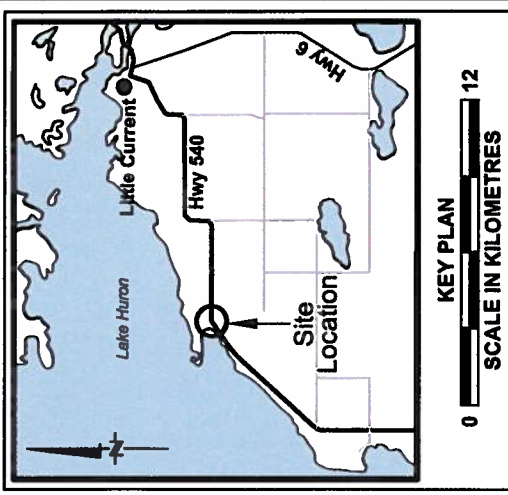
Note:
Auger refusal was encountered on possible
boulders or bedrock at all borehole locations

NOTE:
The boundaries between soil strata have been established only at borehole
locations. Between boreholes the boundaries are assumed by interpolation
and may not represent actual conditions.

DST
DST Consulting Engineers Inc.
605 Hewison Street
Thunder Bay, ON P7B 5V5
Ph: (807) 623-2828
Fax: (807) 623-1792
Email: thunderbay@dsgroup.com



CONT No 5010-E-0007 GWP No 5057-07-00 Site No 49-066 Geocres No 41G-12	
CULVERT REPLACEMENT UNKNOWN CREEK CULVERT #5 Highway 540 - Howland Twp. BOREHOLE LOCATION & SOIL STRATIGRAPHY	SHEET

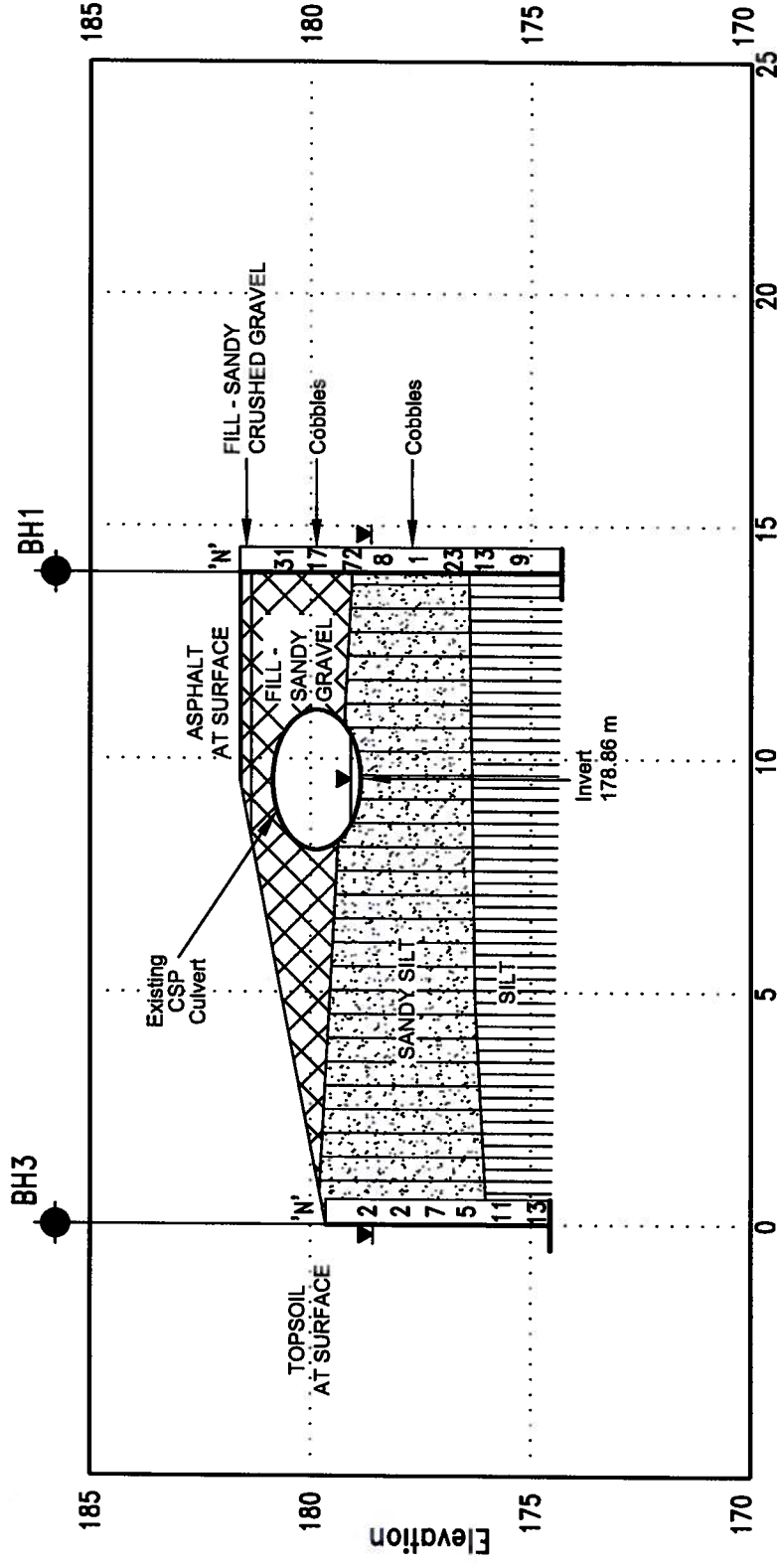
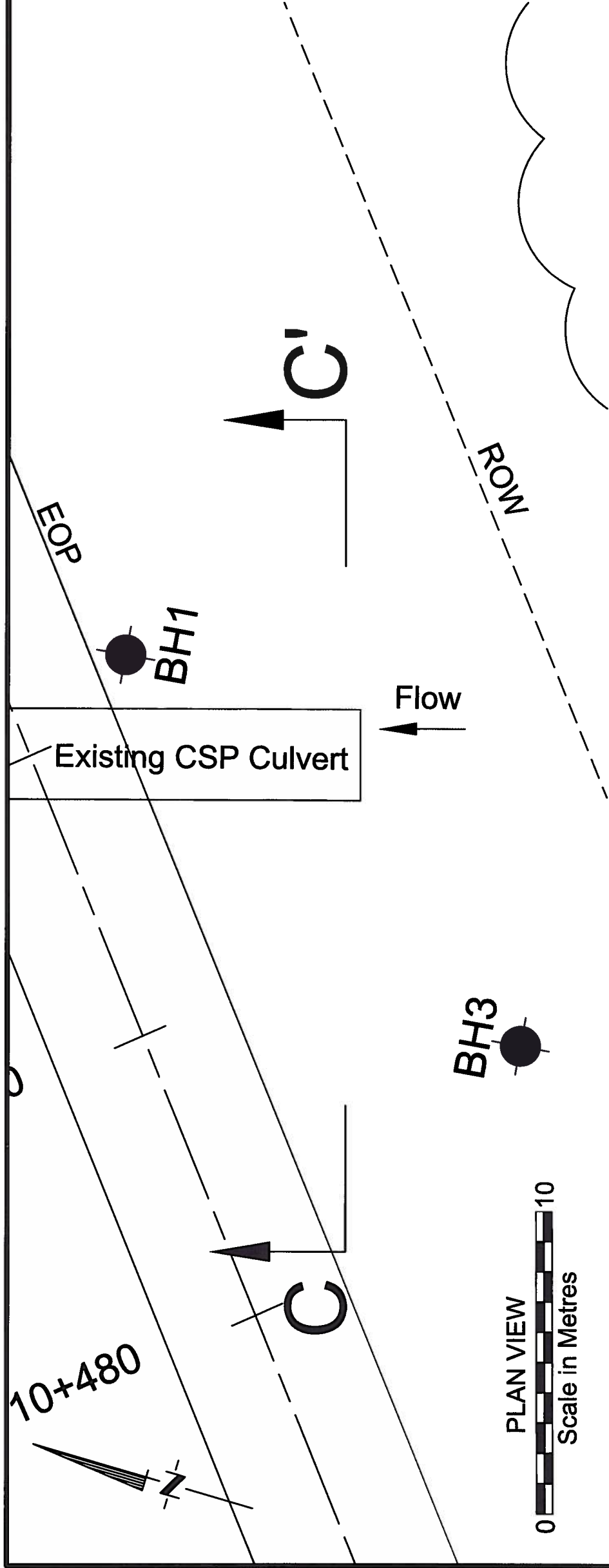


Note: Auger refusal was encountered on possible boulders or bedrock at all borehole locations

NOTE: The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed by interpolation and may not represent actual conditions.

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DRAWING 4



ENCLOSURES

RECORD OF BOREHOLE No BH1

1 OF 1

METRIC

W.P. 5057-07-01 LOCATION STA. 10+002 4.3 m RT (17T 5089101 m N, 418533 m E) ORIGINATED BY PR
DIST HWY 540 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML
DATUM Assumed DATE 2010 10 19 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED □ QUICK TRIAXIAL	✕ FIELD VANE ★ LAB VANE									
181.6	GROUND SURFACE						20	40	60	80	100				GR	SA	SI	CL
180.0	ASPHALT - 35 mm		1	AS														
184.3	FILL - CRUSHED GRAVEL - Sandy, trace silt, brown		2	SS	31													
	FILL - GRAVEL - Sandy, some silt, brown, compact to very dense																	
	- COBBLES		3	SS	17													
179.1	SILT - Sandy, some clay, trace gravel, grey, very soft to very stiff		4	SS	72													
2.6	- COBBLES		5	SS	8													
			6	SS	1													
			7	SS	23													
176.4	SILT - some sand, trace clay, layered, grey, very soft to stiff		8	SS	13													
5.2			9	SS	9													
			10	SS	1													
174.3	End of Borehole at 7.3 m Auger Refusal																	
7.3																		

ON_MOT_CS-TB-012143 - GENIVAR - #5010-E-0007 - HWY 540 - UNKNOWN CREEK #5.GPJ_DST_MIN_GDT 4/1/12

✕³, ★³: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ENCLOSURE 1

RECORD OF BOREHOLE No BH2

1 OF 1

METRIC

W.P. 5057-07-01 LOCATION STA. 9+997 12.5 m LT (17T 5089124 m N, 418536 m E) ORIGINATED BY PR
DIST HWY 540 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML
DATUM Assumed DATE 2010 10 19 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								○ UNCONFINED	✕ FIELD VANE	□ QUICK TRIAXIAL	★ LAB VANE									
179.7	GROUND SURFACE						20	40	60	80	100						GR SA SI CL			
178.9	TOPSOIL - 80 mm SILT - Sandy, some gravel, trace clay, brown, loose to dense		1	AS		▽											Anticipated water level at 1.5 m. Cave at 4.0 m. 12 47 (41)			
			2	SS	37															
	- COBBLES		3	SS	10															
			4	SS	7															
			5	SS	19												11 50 (39)			
176.0																				
3.7	SILT - with sand, trace gravel and clay, layered, grey, compact, firm		6	SS	22															
			7	SS	24											7 29 60 4				
174.5																				
5.2	End of Borehole at 5.2 m Auger Refusal																			

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc 3% STRAIN AT FAILURE

ENCLOSURE 2

ON_MOT_CS-TB-012143 - GENIVAR - #5010-E-0007 - HWY 540 - UNKNOWN CREEK #5.GPJ DST_MIN.GDT 4/1/12

RECORD OF BOREHOLE No BH3

1 OF 1

METRIC

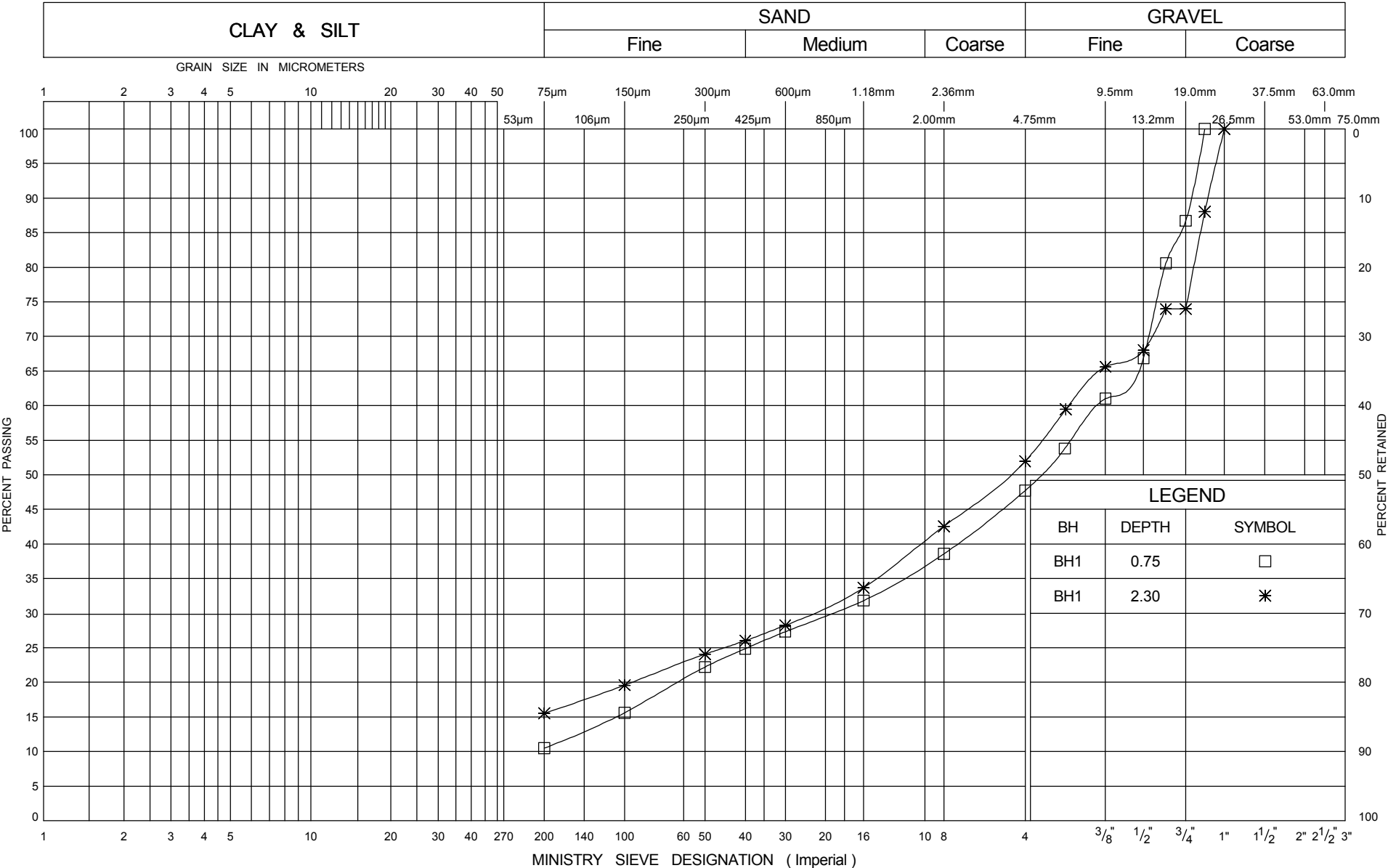
W.P. 5057-07-01 LOCATION STA. 9+985 11.5 m RT (17T 5089085 m N, 418533 m E) ORIGINATED BY PR
 DIST HWY 540 BOREHOLE TYPE Hollow Stem Auger (80 mm ID) COMPILED BY ML
 DATUM Assumed DATE 2010 10 19 CHECKED BY LP/MWB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED ✕ FIELD VANE □ QUICK TRIAXIAL ★ LAB VANE							PLASTIC LIMIT w _p NATURAL MOISTURE CONTENT w LIQUID LIMIT w _L WATER CONTENT (%)	
179.7	GROUND SURFACE					▽										
178.9	TOPSOIL - 70 mm SILT - Sandy, trace gravel and clay, trace organics, grey, soft to firm		1	AS												Anticipated water level at 1.5 m. Cave at 5.0 m.
			2	SS	2											
			3	SS	2											
			4	SS	7											
			5	SS	5											
176.0																
3.7	SILT - trace clay, some sand, grey, stiff		6	SS	11										0 18 76 6	
			7	SS	13											
174.6	End of Borehole at 5.1 m Auger Refusal															
5.1																

\times^3, \star^3 : Numbers refer to Sensitivity \bigcirc^3 3% STRAIN AT FAILURE

ENCLOSURE 3

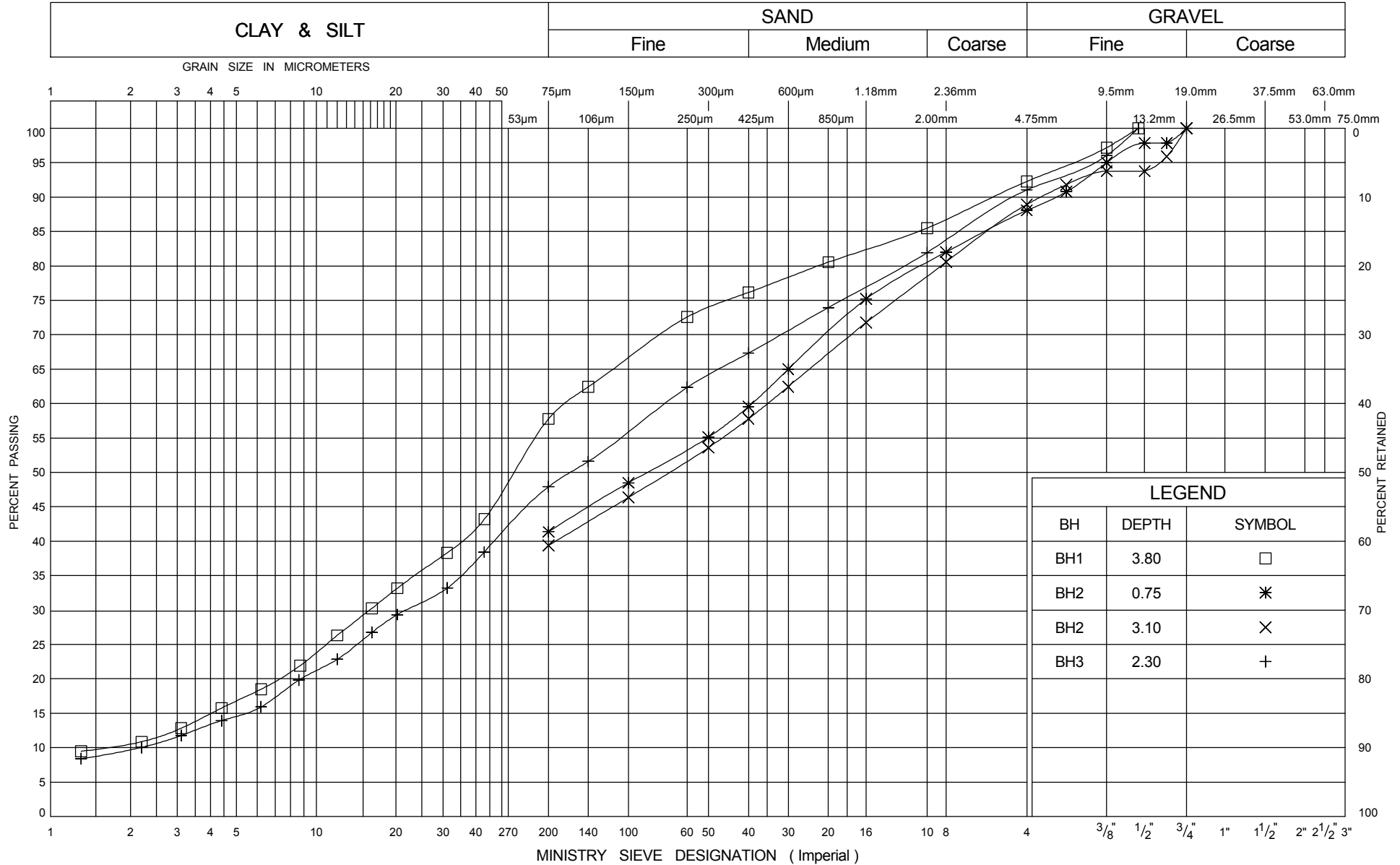
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
SANDY GRAVEL

ENCLOSURE 4
5010-E-0007 - Unknown Creek #5
HIGHWAY 540

UNIFIED SOIL CLASSIFICATION SYSTEM

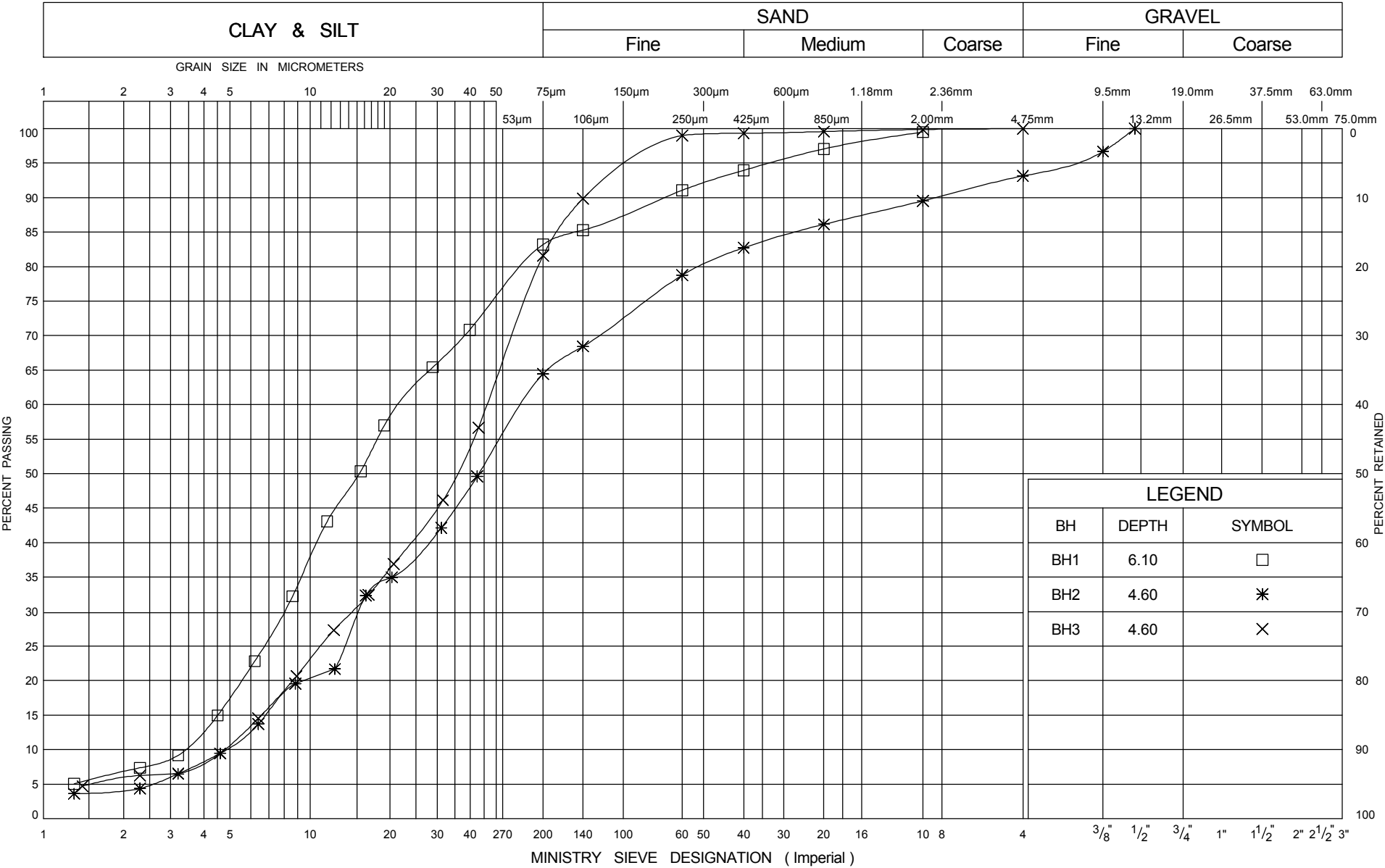


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GRAIN SIZE DISTRIBUTION SANDY SILT

ENCLOSURE 5
W P 5057-07-01
HIGHWAY 540

UNIFIED SOIL CLASSIFICATION SYSTEM



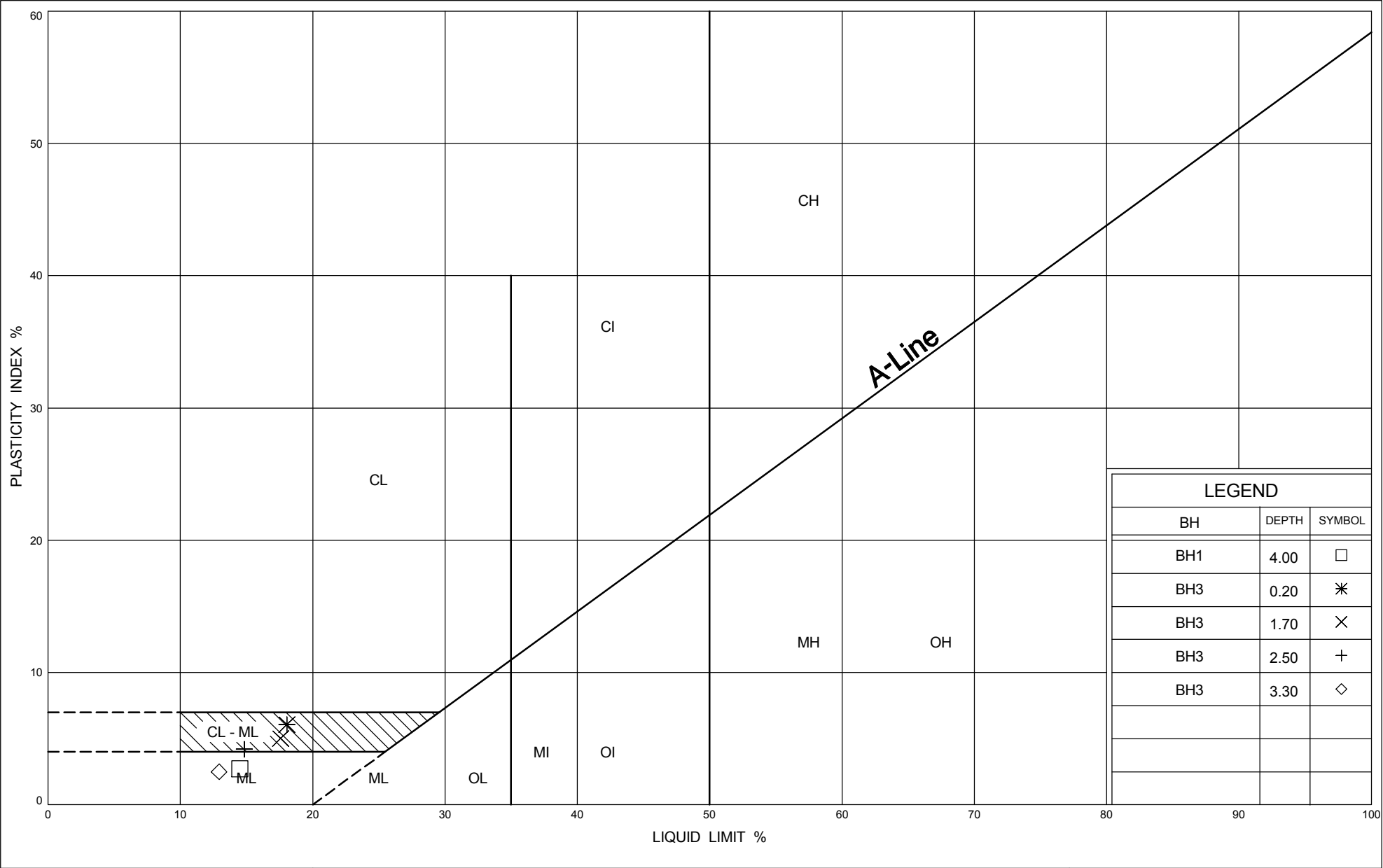
Ministry of
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Ontario

GRAIN SIZE DISTRIBUTION
SILT

ENCLOSURE 6

W P 5057-07-01

HIGHWAY 540

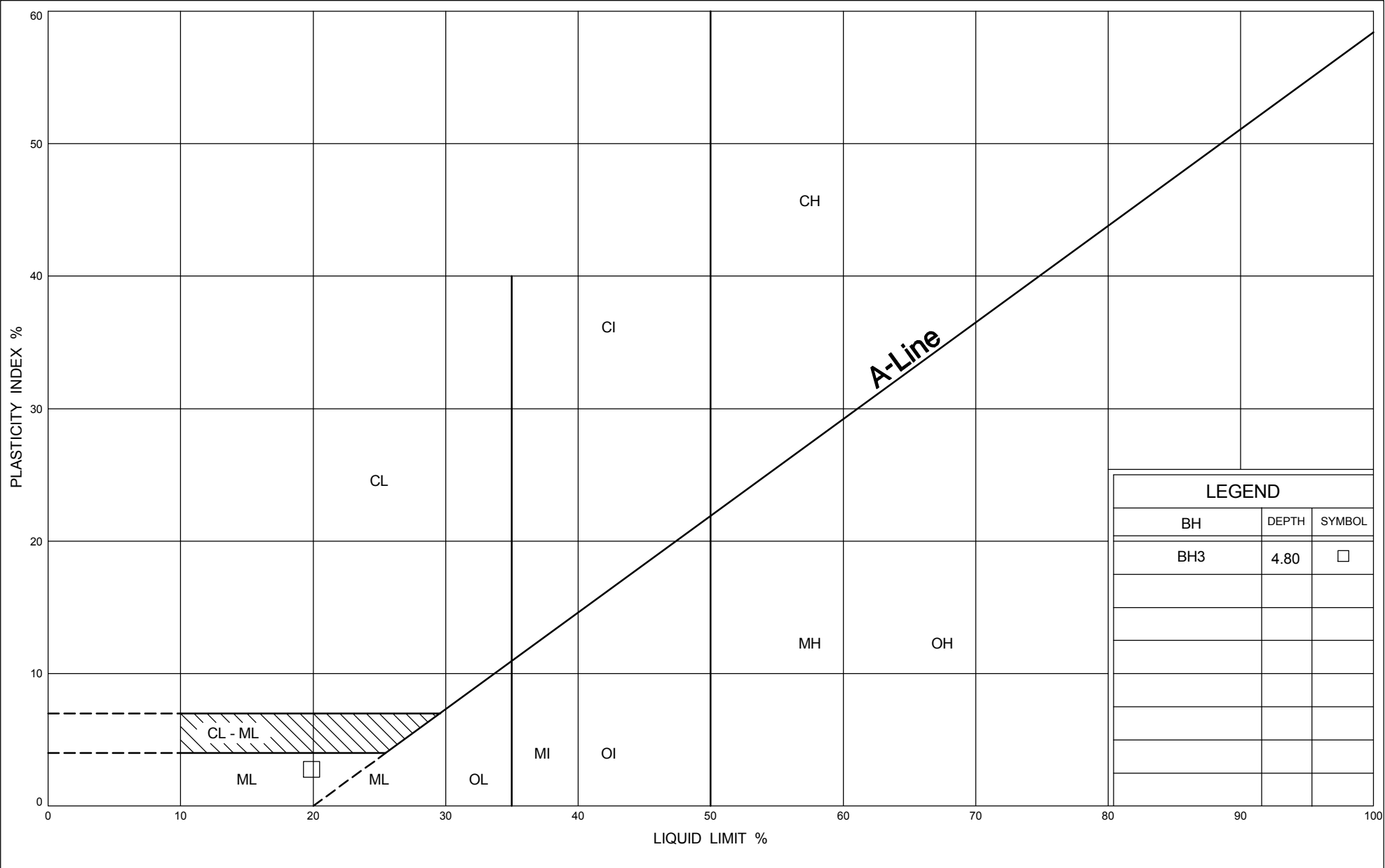


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PLASTICITY CHART SANDY SILT

ENCLOSURE 7
W P 5057-07-01
HIGHWAY 540

ONTARIO MOT PLASTICITY CHART GS-TB-012143 - GENIVAR - #5010-E-0007 - HWY 540 - UNKNOWN CREEK #5.GPJ DST_MIN.GDT 4/1/12



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PLASTICITY CHART SILT

ENCLOSURE 8

W P 5057-07-01

HIGHWAY 540