



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 401 – HIGHWAY 15 INTERCHANGE IMPROVEMENTS
HIGH FILL EMBANKMENTS
KINGSTON, ON**

**Agreement No. 4015-E-0013
G.W.P. 4059-11-00**

GEOCRES Number: 31C-251

Report

to

WSP | MMM Group

September 15, 2016

File No. 12093



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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted at the location of proposed improvements to the Highway 15 Interchange on Highway 401 in the City of Kingston, Ontario. The proposed improvements include widening of the N/S-W and W-N/S ramps and embankments and of Highway 15 at the north ramp terminal.

No previous foundation investigation information was available for the subject embankments.

The purpose of this investigation was to obtain subsurface information at the site and, based on the data obtained, to provide a model of the subsurface conditions including a borehole location plan, records of boreholes, laboratory test results and a written description of the subsurface conditions.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to WSP | MMM Group (WSP | MMM) under MTO Agreement Number 4015-E-0013.

2 SITE DESCRIPTION

The Highway 401 and Highway 15 interchange has an existing underpass structure that carries Highway 15 over Highway 401. For the purpose of this report, Highway 401 is assumed to run west-east and Highway 15 is assumed to run north-south. Highway 15 consists of two lanes of traffic in each direction, and Highway 401 is a four-lane (two lanes in each direction) divided freeway. The interchange also includes a single on- or off-ramp in each quadrant (E-N/S, N/S-W, W-N/S and N/S-E ramps).

The site lies within the physiographic region known as the Napanee Plain, which is generally characterized by limestone plains, covered by a discontinuous thin layer of drift. Geological mapping indicates that knobs of Precambrian rock are also present in the area, including the west half of the N/S-W ramp. Locally, the bedrock is exposed at several locations including both sides of Highway 401 near the bridge structure, and portions of Highway 15, the E-N/S ramp, the N/S-W ramp and the N/S-E ramp.

The N/S-W ramp is approximately parallel to the Highway 401 westbound lanes. The easternmost portion of the ramp, from the intersection with Highway 15 to approximately 100 m west of the intersection is on a fill section up to approximately 8 m high. The north side of the embankment is sloped at approximately 2H:1V and is vegetated with wild grasses and brush. This embankment slope wraps around the northwest corner of the intersection with Highway 15 and extends up the west side of Highway 15, with a decreasing height. A residential property is located in the northwest quadrant of the intersection at the toe of slope. The south side of the N/S-W ramp embankment slopes down to Highway 401 at approximately 3H:1V and is vegetated with wild grasses and brush. West of this fill section, the ramp extends through a rock cut section. No evidence of settlement or stability concerns were noted.

The W-N/S ramp starts approximately parallel to the Highway 401 eastbound lanes and then turns away to meet Highway 15 at a signalized intersection. An existing park and ride lot is present at the southwest corner of the intersection of the ramp and Highway 15. A motel and commercial properties are present on the west side of Highway 15 south of the park and ride lot. The ramp is located on a fill embankment up to 8 m high. The existing slopes are graded at approximately 1.5H:1V and covered with rock fill. Wild grasses, brush and small trees are present at the toe of slope. A small area with stagnant surface water is also present at the toe of slope on the south side. No evidence of settlement or stability concerns were noted.

Selected photographs of the ramps and embankments are attached in Appendix D.

3 SITE INVESTIGATION AND FIELD TESTING

The borehole investigation and field testing program was carried out between April 12 and 19, 2016. The program consisted of drilling and sampling seven boreholes with boreholes spaced approximately every 50 m along the length of the high fill embankment widening areas. Boreholes 16-1, 16-2 and 16-3 were located along the N/S-W ramp with Borehole 16-1 located at the crest of the existing embankment and Boreholes 16-2 and 16-3 located at the toe of the existing outside embankment slope. Boreholes 16-4, 16-5, 16-6 and 16-7 were located along the W-N/S ramp with Borehole 16-4 located at the crest of the existing embankment and Boreholes 16-5, 16-6 and 16-7 located at the toe of the existing outside embankment slope. The

approximate locations of the boreholes are shown on the Borehole Location Plans and Soil Strata Drawings provided in Appendix A.

Prior to the start of drilling, the borehole locations were established in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently determined by Thurber based on chainage and benchmarks included on the base plans provided by WSP | MMM.

A truck-mounted drill rig equipped with hollow stem augers was used to drill and sample the boreholes on the roadway. A portable tripod drill rig was used to drill and sample the toe of slope boreholes. Soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT). The boreholes were advanced to depths ranging from 1.5 m to 17.4 m, with some boreholes reaching refusal. In-situ shear vane testing was attempted within cohesive soil deposits.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the recovered soil samples in labelled containers, and transported the samples to Thurber's laboratory for further examination and testing.

The boreholes were backfilled with soil cuttings mixed with bentonite. The upper portion of the boreholes through the existing embankments were backfilled with the existing granular material and premium grade asphalt patch.

Results of the field drilling and sampling are presented on the Record of Borehole sheets in Appendix B.

4 LABORATORY TESTING

All recovered soil samples were subjected to Visual Identification and to Natural Moisture Content determination. Selected soil samples were subjected to Grain Size Distribution analyses (sieve and hydrometer) and Atterberg Limit testing. The results of this laboratory testing program are shown on the Record of Borehole sheets in Appendix B and on the Figures in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix B for details of the soil stratigraphy encountered in the boreholes. An overall description of the stratigraphy encountered at the N/S-W and W-N/S ramp embankments is given in the following sections; however, the factual data presented in the record of boreholes governs any interpretation of the site conditions. It should be noted that soil conditions may vary between and beyond the borehole locations.

5.1 N/S-W Ramp

In general, the subsurface conditions encountered in the boreholes in the area of the proposed high fill embankment widening consist of granular fill over clayey embankment fill overlying a native clay deposit. A thin deposit of silty sand over inferred bedrock was encountered in one of the three boreholes (16-3). More detailed descriptions of the individual strata are presented below.

5.1.1 Granular Embankment Fill

A layer of asphalt 80 mm in thickness was encountered at ground surface in Borehole 16-1 which was drilled through the existing shoulder of the N/S-W ramp.

The asphalt was underlain by sand with silt and gravel fill that extended to a depth of 3.0 m below surface (elevation 109.7 m).

The SPT N-value for the granular embankment fill ranged from 11 to 19 blows per 0.3 m penetration, indicating a compact state. The colour of the granular fill is brown. The moisture content of the granular fill ranged from 3% to 7%. The results of grain size analysis conducted on one sample of the granular fill material are presented on Figure C1 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	18
Sand	71
Silt and Clay	11

5.1.2 Sandy Clay with Gravel: Embankment Fill

Sandy clay with gravel fill was encountered below the granular fill in Borehole 16-1. The thickness of the sandy clay embankment fill was 4.6 m. The base of the embankment fill was encountered at elevation 105.1 m.

The SPT N-value for the embankment fill ranged from 3 to 14 blows per 0.3 m penetration; this fill is generally described as having a firm consistency. The water content of the recovered embankment fill samples ranged between 19% and 38%. The colour of the embankment fill is dark grey.

The results of grain size analysis conducted on one sample of the sandy clay fill are presented on Figure C1 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	16
Sand	29
Silt	30
Clay	25

Atterberg limit testing was carried out on a sample of the sandy clay fill. The liquid limit was 42% and the plasticity index was 21%. The sample can be classified as clay of intermediate plasticity (CI). The results are presented on Figure C5 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	21
Liquid Limit	42
Plasticity Index	21

5.1.3 Rootmat

Rootmat, 50 mm to 100 mm in thickness, was encountered at surface in both toe of slope boreholes (16-2 and 16-3).

5.1.4 Silty Sand Fill

A silty sand fill was encountered below the rootmat in Borehole 16-2. The base of this fill material was encountered at elevation 104.9 m, 0.8 m below ground surface.

The SPT N-value for this silty sand fill was 4 blows per 0.3 m penetration, indicating a loose state. The water content of the silty sand fill sample was 11%. The colour is brown.

A thin organic layer was encountered at the base of the silty sand fill, possibly compressed vegetation and topsoil.

5.1.5 Clayey Silt

A 0.5 m thick clayey silt layer was encountered below the rootmat in Borehole 16-3. The base of this fill material was encountered at elevation 105.6 m.

The SPT N-value for this clayey silt was 7 blows per 0.3 m penetration, indicating a firm state. The water content of the sample was 34%. The colour is brown.

5.1.6 Clay

A native clay deposit was encountered in all boreholes beneath the fill or thin surficial deposits. This layer was observed to range from 2.8 m to greater than 9.8 m in thickness. Boreholes 16-1 and 16-2 were terminated within this deposit at termination elevations of 95.4 m and 96.6 m respectively. The base of this layer in Borehole 16-3 was at elevation 102.9 m. This deposit contained trace organic material near its surface.

The SPT N-values in the clay deposit ranged from 6 to 69 blows per 0.3 m penetration. In conjunction with measured field vane shear strengths ranging from 78 to greater than 106 kPa, the clay was found to have a typically stiff to very stiff consistency.

Borehole 16-1 was extended by carrying out a dynamic cone penetration test (DCPT) from elevation 95.4 m to 93.0 m. The DCPT blow counts ranged from 8 to 16 blows per 0.3 m penetration; the material was inferred to be a continuation of the clay deposit.

The colour of the clay is brown to greyish brown. The water content of the clay samples ranged from 22% to 51%.

The results of grain size analyses conducted on eight samples of the clay are presented on Figure C2 and Figure C3 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	0 to 6
Silt	32 to 47
Clay	52 to 65

Atterberg limit testing was carried out on eight samples of the clay. The clay can be classified as clay of intermediate to high plasticity (CI to CH). The results are presented on Figure C5 and Figure C6 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	16 to 25
Liquid Limit	40 to 62
Plasticity Index	21 to 39

5.1.7 Silty Sand

A native soil deposit of silty sand was encountered just below the clay in Borehole 16-3. The thickness of this layer in Borehole 16-3 was 0.4 m with the base elevation of 102.4 m. The SPT N-value for this deposit was 24 to greater than 100 blows per 0.3 m penetration, indicating a

compact to very dense state. The water content of the recovered sample was 20%. The colour of this deposit is brown.

Grain size analysis conducted on a sample of the soil are presented on Figure C4 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	88
Silt and Clay	12

5.1.8 Refusal

Refusal on inferred bedrock was encountered below the silty sand in Borehole 16-3 at elevation 102.4 m.

5.1.9 Groundwater Conditions

Free water was not observed in any of the boreholes at the time of drilling.

5.2 W–N/S Ramp

In general, the subsurface conditions encountered in the boreholes in the area of the W–N/S ramp consist of granular fill overlying a clay deposit, overlying a thin layer of silty sand/sandy silt overlying refusal on inferred bedrock. More detailed descriptions of the individual strata are presented below.

5.2.1 Embankment Fill

A layer of asphalt 150 mm in thickness was encountered at ground surface in Boreholes 16-4 which was drilled through the outside shoulder of the existing ramp.

The asphalt was underlain by gravel fill with silt and sand extending to a depth of 2.1 m below surface (elevation 105.8m) in Borehole 16-4. The SPT N-values for this upper fill ranged from 29 to 40 indicating a compact to dense state. The water content of all three samples tested was 3%.

The upper granular fill was underlain by a fill layer of cobbles and gravel, some sand (possible rock fill). This layer is 1.3 m thick and extended to elevation 104.6 m. The SPT N-values within this layer were 8 and 100 blows for 75 mm of penetration, suggesting a loose to very dense state. Sample recovery within this layer was limited. The low SPT N-value of 8 may have been due to voids between cobbles. Asphalt was found in the tip of the split spoon sampler in sample SS-5 at an elevation of 104.6 m.

The possible rock fill layer was underlain by a 0.9 m thick fill layer of brown sand with silt some gravel extending to elevation 103.6 m. The sand fill layer was underlain by a 3.9 m thick silty sand to silty gravel fill containing occasional to frequent cobble sized particles. The base of the embankment was noted at 8.2 m below the road surface (elevation 99.8 m). The SPT N-value for the lower embankment fill ranged from 8 to 29 blows per 0.3 m penetration, indicating a loose to compact state. The water content of the recovered lower embankment fill samples ranged between 6% and 15%. The colour of the lower embankment fill is brown to greenish-brown.

The results of grain size analysis conducted on three samples of the embankment fill are presented on Figure C7 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	1 to 58
Sand	27 to 89
Silt and Clay	10 to 15

5.2.2 Rootmat

Rootmat, 50 mm in thickness, was encountered at surface in all three toe of slope boreholes (16-5, 16-6 and 16-7).

5.2.3 Silt

A 0.5 m to 0.8 m thick silt layer was encountered below the rootmat in boreholes 16-5, 16-6 and 16-7. The base elevation of this material ranged from 97.0 m to 102.1 m. This silt contained variable amounts of sand and clay, and ranges from sandy silt to clayey silt to silt, some sand.

The SPT N-values within the silt deposit ranged from 4 to 12 blows per 0.3 m penetration, indicating a loose to compact state. The water content of the silty material ranged from 34% to 40%. The colour is brown.

5.2.4 Clay

A native clay deposit was encountered in all boreholes. This deposit was found just beneath the base of the embankment fill in Borehole 16-4, and below the silt deposit in the toe of slope boreholes. This layer was observed to range from 0.6 m to 4.2 m in thickness. The base of this material ranged from elevation 93.7 m to 98.7 m.

The SPT N-values within the clay deposit ranged from 3 to 38 blows per 0.3 m penetration. In conjunction with measured field vane shear strengths ranging from 72 to greater than 106 kPa, the clay was found to have a typically stiff to very stiff consistency.

The colour of the clay is brown to grey. The water content of the clay samples ranged from 31% to 53%.

The results of grain size analyses conducted on four samples of the clay are presented on Figure C8 in Appendix C. The results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	1 to 5
Silt	35 to 46
Clay	50 to 64

Atterberg limit testing was carried out on four samples of the clay. The clay can be classified as clay of intermediate to high plasticity (CI to CH). The results are presented on Figure C10 in Appendix C and summarized in the table below.

Test	%
Plastic Limit	17 to 26
Liquid Limit	44 to 60
Plasticity Index	27 to 38

5.2.5 Sandy Silt

A native soil deposit of sandy silt was encountered just below the clay in Borehole 16-6. The thickness of this layer was 0.8 m with the base elevation at 92.8 m. The SPT N-value for this deposit was 31 blows per 0.3 m penetration, indicating a dense state. The water content of recovered samples was 23% and 25%. The colour of this deposit is brown.

Grain size analysis conducted on a sample of the soil are presented on Figure C9 in Appendix C. These results are summarized in the following table.

Soil Particles	%
Gravel	0
Sand	42
Silt	32
Clay	26

5.2.6 Refusal

Refusal on inferred bedrock was encountered below the clay in all boreholes at elevations ranging from 92.8 m to 98.7 m.

5.2.7 Groundwater Conditions

Free water was observed in Boreholes 16-6 and 16-7 at depths of 0.05 m and 0.2 m, respectively (elevations 97.8 and 97.7 m).

6 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario, supplied and operated a track-mounted CME 55 drill rig as well as the portable tripod drill rig to carry out the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Justin Gray E.I.T. of Thurber. Laboratory testing was carried out by Thurber in its MTO-approved laboratory.

Overall project management and direction of the field program was provided by Mr. Paul Carnaffan, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Justin Gray E.I.T. and Mr. Paul Carnaffan P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents a foundation assessment and evaluation of feasible methods for widening of the W-N/S and N/S-W ramps at the Highway 401 - Highway 15 Interchange in the City of Kingston, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

Based on the preliminary design for the Highway 401 – Highway 15 interchange improvements, it was proposed to widen the existing N/S-W ramp at the north terminal to allow for two lanes of traffic which would merge into a single lane prior to entering the speed change lane. The proposed widening was to the north side and would require widening of the high fill embankment present between approximately 21+450 and 21+575, and extending up along the west side of Highway 15. The existing north embankment slope for the N/S-W ramp is up to 8 m high and has sideslopes ranging from 1.7H:1V to 2H:1V. The slope is well vegetated. A steel-beam guiderail is present at the crest of the slope at the outside of the existing shoulder (see Photo 2 in Appendix D). The edge of the MTO right-of-way is as close as 2 m from the toe of the existing slope. Preliminary cross-sections indicated that a widening of up to 4 m at the crest of the embankment would be required. As part of the detailed design, due to the potential property

impacts associated with widening to the north side, widening to the south side of the N/S-W ramp was reviewed by the design team and ultimately selected as the preferred alternative.

Based on the preliminary design for the Highway 401 – Highway 15 interchange improvements, it is proposed to widen the existing W-N/S ramp to provide additional capacity with three lanes at the ramp terminus. The proposed widening is to be to the outside (south side) and will require widening of the high fill embankment present between approximately 70+150 and 70+325. The existing south embankment slope is up to 8 m high and is covered with rock protection (see Photo 6 in Appendix D). The slope geometry varies along the length but generally ranges from approximately 1.5H:1V to 1.8H:1V. A paved shoulder and steel-beam guiderail are present at the crest of the slope. Preliminary cross-sections indicated that a widening of up to 7 m at the crest of the embankment would be required.

The discussions and recommendations presented in this report are based on information provided by WSP | MMM and on the factual data obtained during the course of this investigation.

8 SEISMIC CONSIDERATIONS

8.1 Seismic Hazard Data

The seismic hazard data for the CHBDC is based on the fifth generation seismic model developed by the Geological Survey of Canada (GSC). Seismic hazard data for this site has been obtained from the GSC's seismic hazard calculator. The data includes peak ground acceleration (PGA), peak ground velocity (PGV), and the 5% damped spectral response acceleration values ($S_a(T)$) for the reference ground condition (Site Class C) for a range of periods (T) and for a range of return periods including the 475-year, 975-year and 2475-year events. The GSC seismic hazard calculation data sheet for this site is presented in Appendix E.

8.2 Seismic Site Class

In accordance with Table 4.1 of the CHBDC, the site has been determined to be Site Class C based on the properties of the soil within the upper 30 m of the ground profile.

8.3 Seismic Liquefaction

Based on the grain size distribution, and the highly plastic nature of the native clay, the subgrade soils at this site are classified as “not susceptible” to liquefaction during the design earthquake event

9 EMBANKMENTS

9.1 Design Considerations

The primary design considerations for the proposed embankment widenings from a foundation engineering perspective are global stability and settlement, however, additional design considerations include:

- Property constraints: the preliminary design identified that the existing N/S-W embankment was close to the edge of the Ministry right-of-way. One of the design objectives, was to specify embankment fill material for the widening that would allow for steep slopes (e.g. rock fill) in order to avoid encroachment onto private property, if possible.
- Pavement engineering requirements that the subgrade materials within the widened portion of the embankment and the existing embankment have similar characteristics within the design frost penetration depth. It is noted that granular fill is present within both the N/S-W and W-N/S embankments within the design frost depth (1.5 m), therefore, granular fill should be used within the upper 1.5 m of the embankments widenings. Rock fill, if used should be limited to below this level.

For the purpose of foundation analysis, a number of assumptions have been made that are consistent with MTO's standard highway design practices:

- Peat, topsoil, organic deposits and other deleterious material will be removed prior to constructing embankments as described in Section 9.4.
- Where new fill is placed against an existing embankment slope or on a sloping ground surface steeper than 3H:1V, the existing slope will be benched (OPSD 208.010).
- Embankments will be constructed as outlined in Section 9.4 with side slopes not steeper than:
 - 1.25H:1V for rock fill, and
 - 2H:1V for granular fill
- No material or stockpiling will be allowed above the embankment design grades without further analysis.
- Erosion protection will be provided for all earth and granular embankment slopes.

9.2 Stability Analysis

Stability analyses were carried out utilizing the commercially available slope stability program Slope/W (Version 8) of the GeoStudio software package developed by Geo-Slope International with the option for Morgenstern-Price method of slices for the limit equilibrium analyses. The analysis included the following input parameters:

- Maximum embankment height of each embankment (8 m for both) was used for all analysis
- Widening constructed with rock fill at 1.25H:1V within the lower 6.5 m and granular fill at 2H:1V within the upper 1.5 m.
- The soil stratigraphy and soil properties are provided in the slope stability model outputs in Appendix E.
- A horizontal seismic coefficient equal to one half of the site-adjusted PGA value was used for the seismic analysis case.
- Traffic loading was taken into consideration by applying a live load surcharge equal to 0.8 m of additional fill height (18 kPa) as per section 6.12.5 of the CHBDC.

The computed factors of safety against slope instability, for the widened embankment configurations are summarized in Table 10-1

Table 10-1. Summary of Slope Stability Analysis Results

Location	Fill Height ^(*)	Factor of Safety		
		Short Term (undrained)	Seismic (undrained)	Long Term (drained)
N/S-W Ramp	8 m	1.5 (Figure E1)	1.3 (Figure E2)	1.3 (Figure E3)
W-N/S Ramp	8 m	1.5 (Figure E4)	1.4 (Figure E5)	1.5 (Figure E6)

Notes: () above existing toe of slope*

Based on consideration of the risk involved and past experience with highway embankment design/monitoring, the computed factors of safety are considered appropriate.

9.3 Settlement Analysis

Settlement analysis was carried out to assess the immediate (elastic) settlement under the weight of the imposed new embankment fill materials.

Immediate settlements due to compression of the embankment foundation soils have been estimated based on elastic theory as described in CHBDC Commentary Section C6.9. The engineering parameters used in the analyses were determined by SPT and field vane tests conducted during the current study and soil index correlations.

The estimated foundation settlements are provided in Table 10-1. The estimated magnitudes of settlement are considered approximate and are expected to vary along and across the ramp alignment due to spatial variation in the thickness of the grade raise and thickness of the foundation soil deposits in addition to variability in the properties of the soil.

Table 10-1. Summary of Estimated Foundation Settlement

Location	Immediate Settlement (mm)
N/S-W Ramp	25
W-N/S Ramp	20

Settlement of the road grade on rock fill, due to particle re-orientation and degradation of the inter-particle contacts, is expected to continue at a decreasing rate with time. In accordance with the MTO document “Post-Construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity” (April 12, 2010), the magnitude of this settlement in compacted rock fill is expected to range from 0.5 to 1.0% of the embankment height within 1 year of embankment construction (90% in the first 6 months. This corresponds to approximately 15 to 30 mm of settlement at the N/S-W ramp and 30 to 60 mm of settlement at the W-N/S ramp. Additional settlement of approximately 0.1% of the embankment height is typically expected after the initial one year period.

It is noted that since the rock fill would be placed on the outside of the embankment for the widening, much of the settlement would occur within the embankment sideslopes and shoulders.

9.4 Embankment Construction

Embankment construction should be carried out in accordance with OPSS.PROV 206.

All vegetation, rootmat and organic soils should be stripped from within the footprint of the embankment widenings.

The embankment widenings should be constructed with benches as per OPSD 208.010. The maximum bench height of 1.0 m will govern the maximum lift thickness and the maximum rock fragment size. Note that the minimum width of the widening must be such that the minimum width of each lift of rock fill is sufficient to allow for compaction as per OPSS.PROV 206 section 206.07.05.02.01. A minimum width of 4.5 m is suggested. Alternatively, over-excavation within the existing embankment would be required to allow for placement of the minimum width of rock fill.

The rockfill should consist of clean hard limestone free of any shale. Suggested wording for a non standard special provision regarding rockfill material is provided in Appendix F.

Granular fill embankment slopes must be provided with erosion protection in accordance with OPSS.PROV 804.

10 CONSTRUCTION CONCERNS

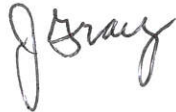
Potential construction concerns include, but are not necessarily limited to:

- The native subgrade soils are generally fine grained soils and susceptible to disturbance by construction traffic, particularly if wet. Good practices that the contractor can follow to protect the subgrade include:
 - Limiting the extent of subgrade that is exposed to the area that can be covered with embankment fill that same day.
 - Not driving equipment on the exposed subgrade; construct dedicated haul roads and/or work from one end of the alignment such that the first lift of embankment fill is placed prior to allowing traffic in that area.
- A small area of surface water was noted at the toe of slope of the W-N/S ramp. This area should be completely drained prior to excavation for the embankment widening to prevent the water from flooding into the work zone.

11 CLOSURE

Preparation of this foundation design report was carried out by Mr. Justin Gray E.I.T., and Mr. Paul Carnaffan P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng.

Justin A. Gray
Geotechnical E.I.T.



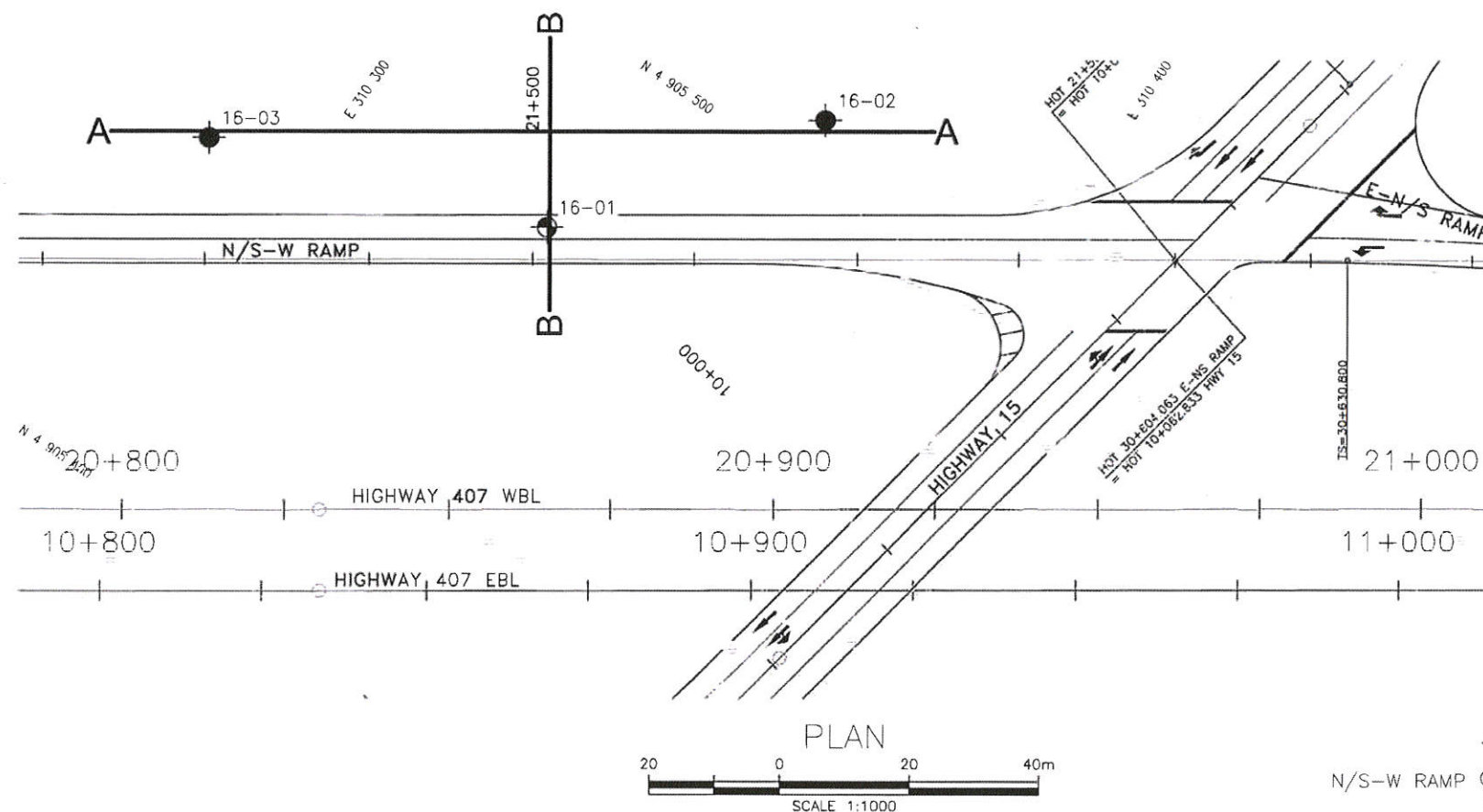
Paul Carnaffan, P.Eng.
Associate, Senior Foundations Engineer



P.K. Chatterji, P.Eng.
Principal, Designated MTO Contact

Appendix A

Borehole Location Plans



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



CONT No
GWP No 4059-11-00

HIGHWAY 401 &
HIGHWAY 15 INTERCHANGE
N/S-W RAMP
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET







THURBER ENGINEERING LTD



KEYPLAN

LEGEND

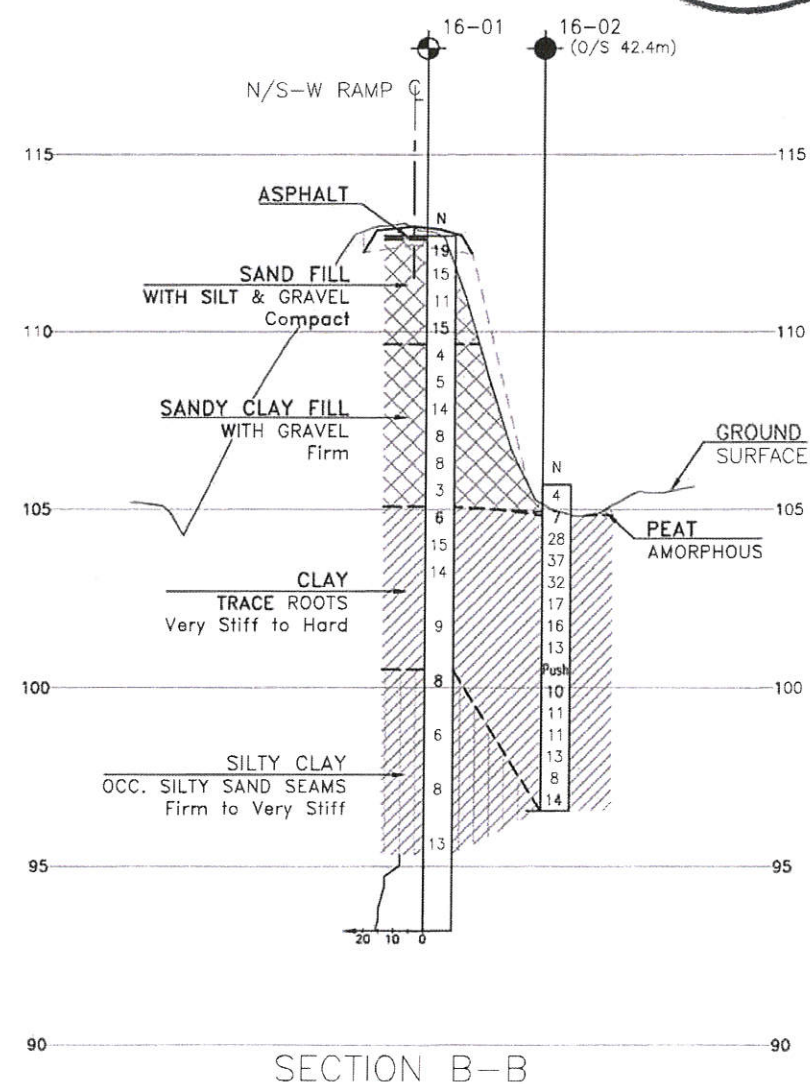
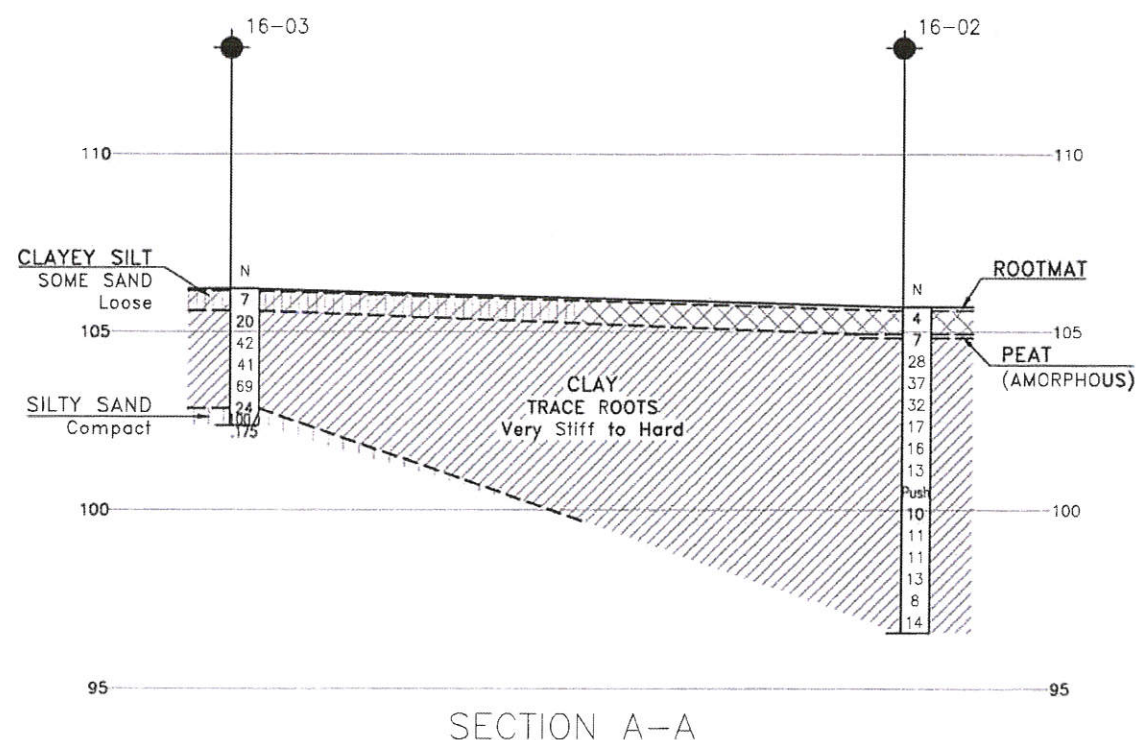
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
16-01	112.7	4 905 471.5	310 335.7
16-02	105.7	4 905 509.1	310 362.0
16-03	106.2	4 905 454.2	310 285.1

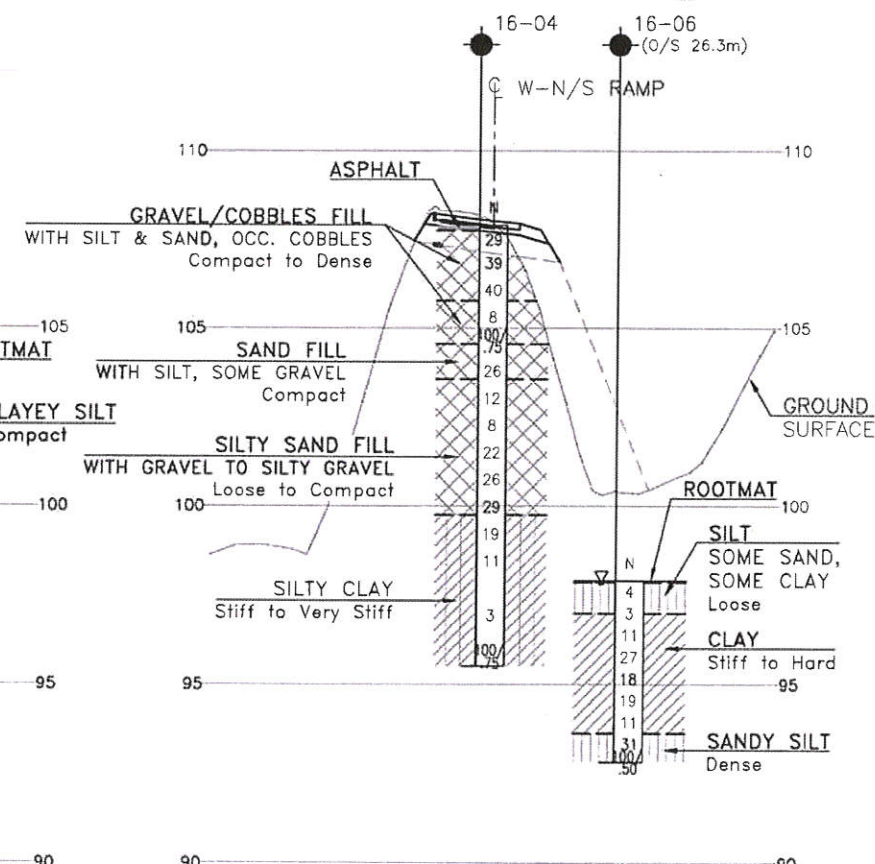
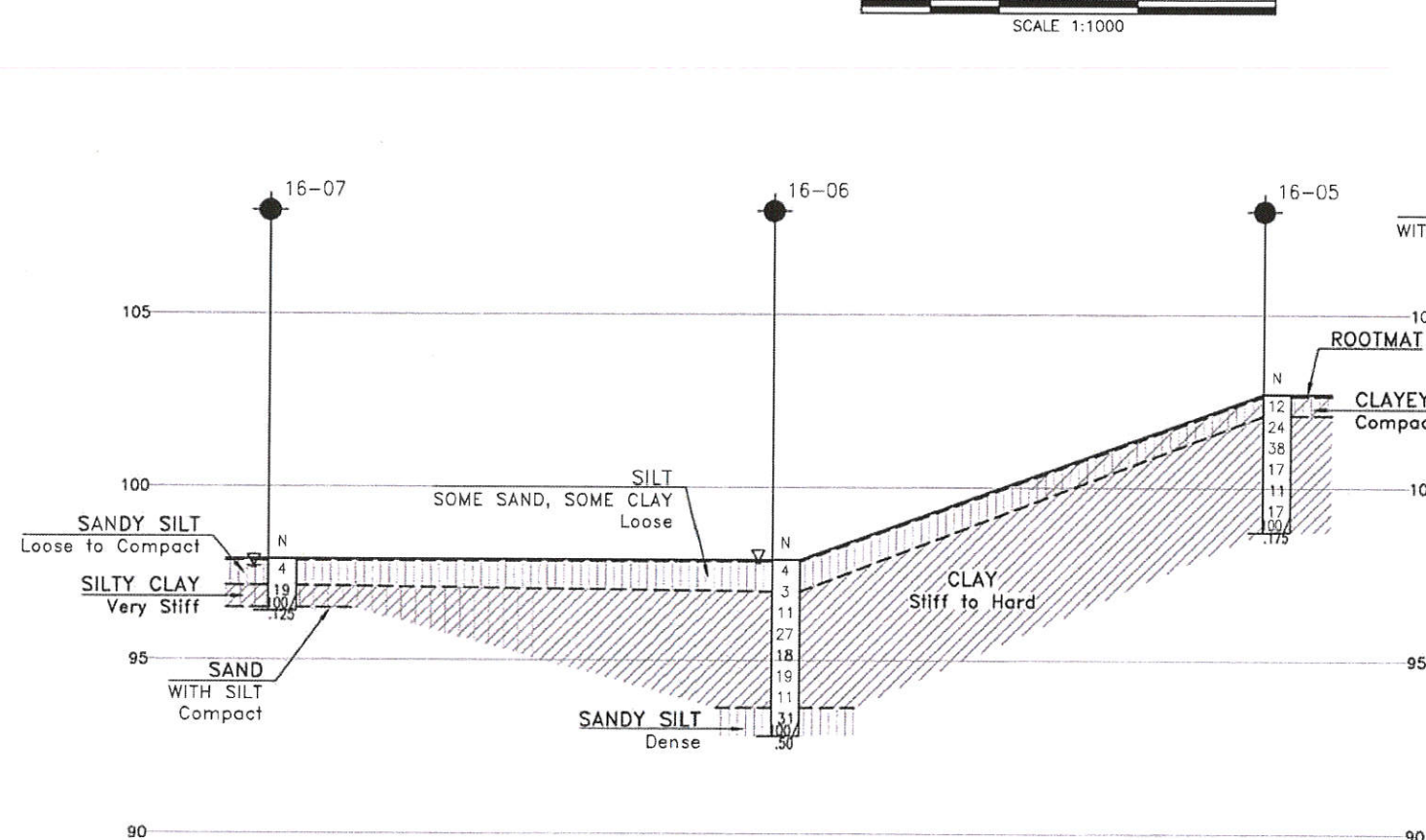
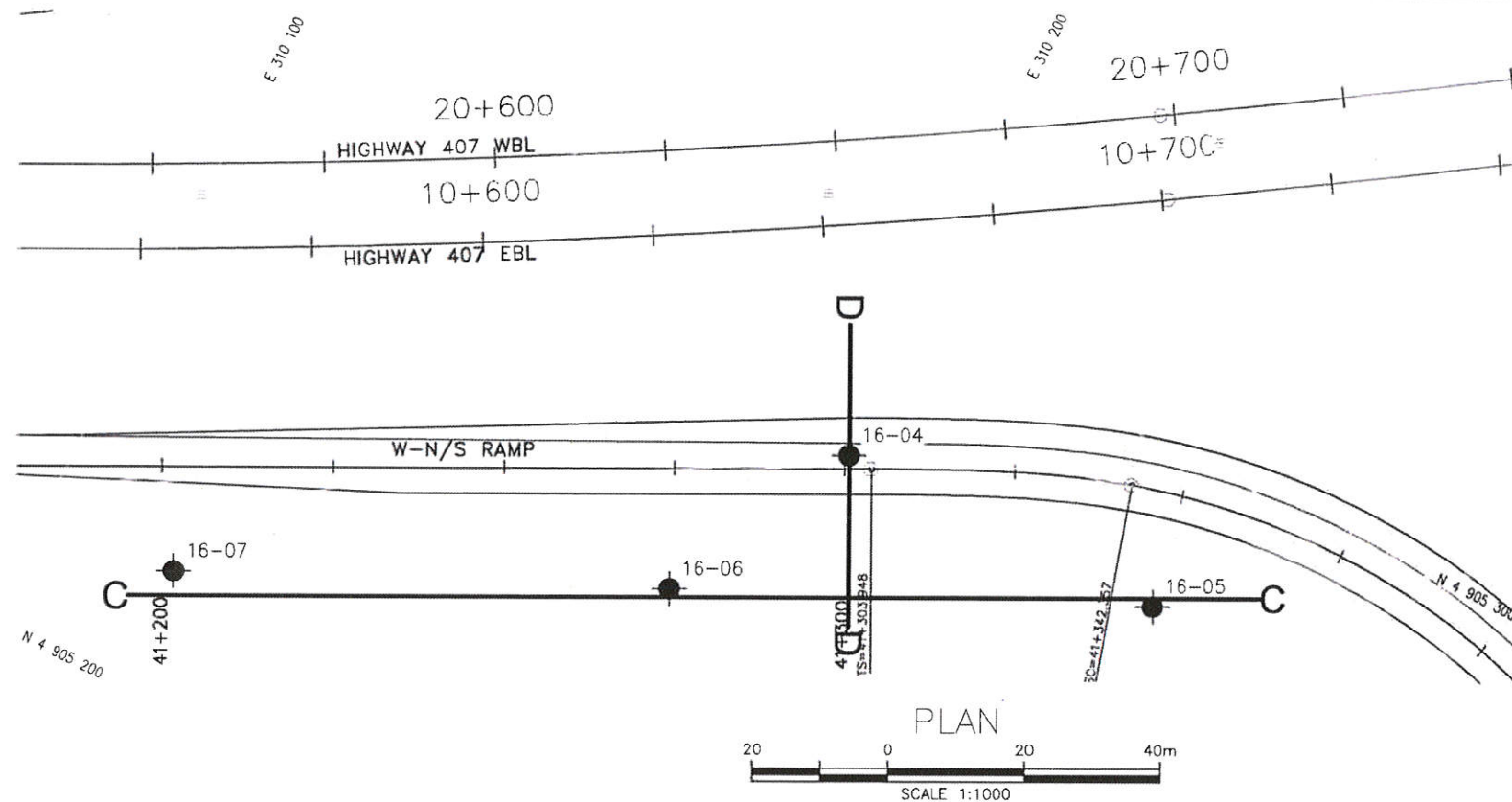
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

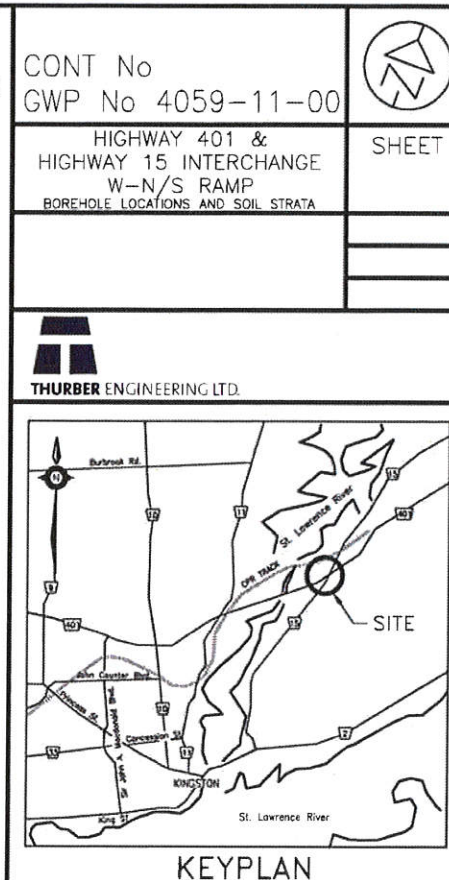
GEOCRES No. 31C-251








REVISIONS									
	DATE	BY				DESCRIPTION			
DESIGN	CM	CHK				LOAD		DATE	SEP 2016
DRAWN	NN	CHK				SUE	ISTRCT	TRW	L



METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN



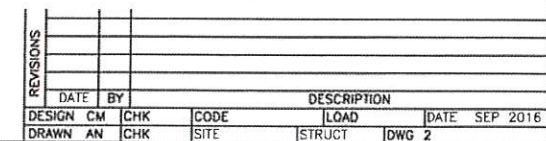
LEGEND	
	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

[illegible]

-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCREs No. 31C-251



Appendix B

Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of fragments of decayed organic matter
Till	unstratified glacial deposit which may include particles ranging in sizes from clay to boulder
Fill	material below the surface identified as placed by humans (excluding buried services)

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

Desiccated	having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.

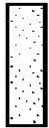


STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

Classification	Particle Size
Boulders	Greater than 200 mm
Cobbles	75 – 200 mm
Gravel	4.75 – 75 mm
Sand	0.075 – 4.75 mm
Silt	0.002 – 0.075 mm
Clay	Less than 0.002 mm

SAMPLE TYPES

SS	Split spoon samples
ST	Shelby tube or thin wall tube
DP	Direct push sample
PS	Piston sample
BS	Bulk sample
WS	Wash sample
HQ, NQ, BQ etc.	Rock core sample obtained with the use of standard size diamond coring equipment

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

Descriptive Term	Undrained Shear Strength (kPa)
Very Soft	12 or less
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved.

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length
Unconfined Compressive Strength: (UCS)	Axial stress required to break the specimen.
Fracture Index: (FI)	Frequency of natural fractures per 0.3 m of core run.

DISCONTINUITY SPACING

Bedding	Bedding Plane Spacing
Very thickly bedded	Greater than 2 m
Thickly bedded	0.6 to 2 m
Medium bedded	0.2 to 0.6 m
Thinly bedded	60 mm to 0.2 m
Very thinly bedded	20 to 60 mm
Laminated	6 to 20 mm
Thinly laminated	Less than 6 mm

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)
Extremely Strong	Greater than 250
Very Strong	100 – 250
Strong	50 – 100
Medium Strong	25 – 50
Weak	5 – 25
Very Weak	1 – 5
Extremely Weak	0.25 – 1

RECORD OF BOREHOLE No 16-1

1 OF 2

METRIC

GWP# 4059-11-00 LOCATION NS - W Ramp, Highway 401/15 Interchange N 4 905 471.5 E 310 335.7 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG
 DATUM Geodetic DATE 2016.12.04 - 2016.12.04 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
								20 40 60 80 100				w _P w w _L								
112.7																				
0.0																				
0.1																				
					</															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-1

2 OF 2

METRIC

GWP# 4059-11-00 LOCATION NS - W Ramp, Highway 401/15 Interchange N 4 905 471.5 E 310 335.7 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG
 DATUM Geodetic DATE 2016.12.04 - 2016.12.04 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								20 40 60 80 100											
								<div><div></div><div></div><div></div><div></div><div></div></div> <div>20 40 60 80 100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>				<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W_P</div><div>W</div><div>W_L</div></div> <div>WATER CONTENT (%)</div> <div>20 40 60</div>							
	Continued From Previous Page						102												
			14	SS	9														
							101												
100.5																			
12.2	CLAY (CH to CI), silty, occasional silty sand seams firm to very stiff grey		15	SS	8		100							0 5 38 57					
			16	SS	6		99												
							98												
			17	SS	8		97												
95.4			18	SS	13		96							0 0 47 53					
17.4	End of Borehole at 17.4 m Borehole dry on completion DCPT driven from 17.4 m to 19.8 m in Inferred Clay																		

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-2

1 OF 1

METRIC

GWP# 4059-11-00 LOCATION NS - W Ramp, Highway 401/15 Interchange N 4 905 509.1 E 310 362.0 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Portable COMPILED BY JAG
 DATUM Geodetic DATE 2016.04.19 - 2016.04.19 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
105.7								20	40	60	80	100				
0.0	Rootmat (100mm)		1	SS	4											
0.1	SILTY SAND loose brown															
104.9	FILL		2	SS	7		105									
104.8	Amorphous Peat (100mm)															
0.9	CLAY (CH) very stiff brown to greyish brown		3	SS	28		104									
			4	SS	37											0 3 37 60
			5	SS	32		103									
			6	SS	17		102									
			7	SS	16											0 2 42 56
101.4	CLAY (CH to CI) stiff grey		8	SS	13		101									
4.3			9	GS	Push											
			10	SS	10		100									0 1 38 61
			11	SS	11											
			12	SS	11		99									
			13	SS	13											
			14	SS	8		98									0 2 46 52
			15	SS	14		97									
96.6																
9.1	End of Borehole at 9.1 m Borehole dry upon completion															

ONTMT4S 12093.GPJ 2012TEMPLATE(MTO).GDT 5/8/16

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-3

1 OF 1

METRIC

GWP# 4059-11-00 LOCATION NS - W Ramp, Highway 401/15 Interchange N 4 905 454.2 E 310 285.1 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Portable COMPILED BY JAG
 DATUM Geodetic DATE 2016.04.19 - 2016.04.19 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE											WATER CONTENT (%) w _P w w _L	
106.2								20	40	60	80	100								
0.0	Rootmat (50mm)		1	SS	7		106													
105.6	Clayey SILT some sand firm brown		2	SS	20															
0.6	CLAY (CH), trace roots very stiff brown		3	SS	42		105													
			4	SS	41		104													
			5	SS	69															
102.9			6	SS	24		103													
3.4	SILTY SAND compact brown		7	SS	100/															
102.4																				
3.8	End of Borehole at 3.8 m on Inferred Bedrock Borehole dry on completion				175mm															

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
5
10
15
20
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-4

1 OF 2

METRIC

GWP# 4059-11-00 LOCATION W- NS Ramp, Highway 401/15 Interchange N 4 905 278.2 E 310 201.8 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG
 DATUM Geodetic DATE 2016.12.04 - 2016.04.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)								
107.9								20	40	60	80	100								
0.0	Asphalt (150mm)																			
0.2	GRAVEL with silt and sand, occasional cobble compact to dense brown FILL		1	SS	29															
			2	SS	39															
			3	SS	40															
105.8																				
2.1	COBBLES and GRAVEL, some sand, occasional void loose grey FILL		4	SS	8															
			5	SS	100/															
104.6	- Asphalt at 3.3 m				75mm															
3.4	SAND with silt, some gravel compact brown FILL		6	SS	26															
103.6	SILTY SAND with gravel to Silty GRAVEL with sand, occasional to frequent cobbles loose to compact greenish brown FILL		7	SS	12															
			8	SS	8															
			9	SS	22															
			10	SS	26															
			11	SS	29															
99.8																				
8.2	CLAY (Cl), silty stiff to very stiff brown to grey		12	SS	19															
			13	SS	11															

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-4

2 OF 2

METRIC

GWP# 4059-11-00 LOCATION W- NS Ramp, Highway 401/15 Interchange N 4 905 278.2 E 310 201.8 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Hollow Stem Auger COMPILED BY JAG
 DATUM Geodetic DATE 2016.12.04 - 2016.04.13 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	W P W W L	20 40 60	GR SA SI CL			
	Continued From Previous Page													
	CLAY (CI), silty stiff to very stiff brown to grey													
	-Wet		14	SS	3		97							0 4 46 50
								5.2 +						
							96							
95.5	-Rock fragment in tip of split spoon		15	SS	100/									
12.4	End of Borehole at 12.4 m with Auger Refusal on Inferred Bedrock Borehole dry upon completion				75mm									

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-5

1 OF 1

METRIC

GWP# 4059-11-00 LOCATION W- NS Ramp, Highway 401/15 Interchange N 4 905 278.1 E 310 251.7 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Portable COMPILED BY JAG
 DATUM Geodetic DATE 2016.04.18 - 2016.04.18 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
102.7								20 40 60 80 100						
0.0	Rootmat (50mm)		1	SS	12		102							
102.1	Clayey SILT compact brown		2	SS	24									
0.6	CLAY (CH) stiff to very stiff brown to greyish brown		3	SS	38		101							
			4	SS	17									
			5	SS	11		100							
			6	SS	17									
98.7	-Trace gravel		7	SS	100/ 175mm		99							
4.0	End of Borehole at 4.0 m on Inferred Bedrock Borehole dry upon completion													

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-6

1 OF 1

METRIC

GWP# 4059-11-00 LOCATION W- NS Ramp, Highway 401/15 Interchange N 4 905 248.9 E 310 186.9 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Portable COMPILED BY JAG
 DATUM Geodetic DATE 2016.04.18 - 2016.04.18 CHECKED BY PC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE															
97.9							20	40	60	80	100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
0.0	Rootmat (50mm)		1	SS	4							W _P	W	W _L	
	SILT, some sand, some clay loose brown		2	SS	3										
97.0															
0.9	CLAY (CH) stiff to very stiff brown to grey		3	SS	11										
			4	SS	27										
			5	SS	18										
			6	SS	19										
			7	SS	11										
93.7															
4.3	Sandy SILT dense grey		8	SS	31										
			9	SS	100/										
92.8															
5.1	End of Borhole at 5.1 m on Inferred Bedrock Water at 0.05 m on completion				50mm										

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 16-7

1 OF 1

METRIC

GWP# 4059-11-00 LOCATION W- NS Ramp, Highway 401/15 Interchange N 4 905 218.9 E 310 120.7 ORIGINATED BY JAG
 HWY 401/15 BOREHOLE TYPE Portable COMPILED BY JAG
 DATUM Geodetic DATE 2016.04.18 - 2016.04.18 CHECKED BY PC

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										
97.9								20	40	60	80	100						
0.0	Rootmat (50mm)		1	SS	4													
97.1	Sandy SILT loose to compact brown																	
0.8	CLAY (CH) , silty very stiff brown		2	SS	19		97										0	5 42 53
96.5			3	SS	100/													
96.4	SAND with silt compact brown				125mm													
1.5	End of Borehole at 1.5 m on Inferred Bedrock Water at 0.2 m on completion																	

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
5
10
(%) STRAIN AT FAILURE

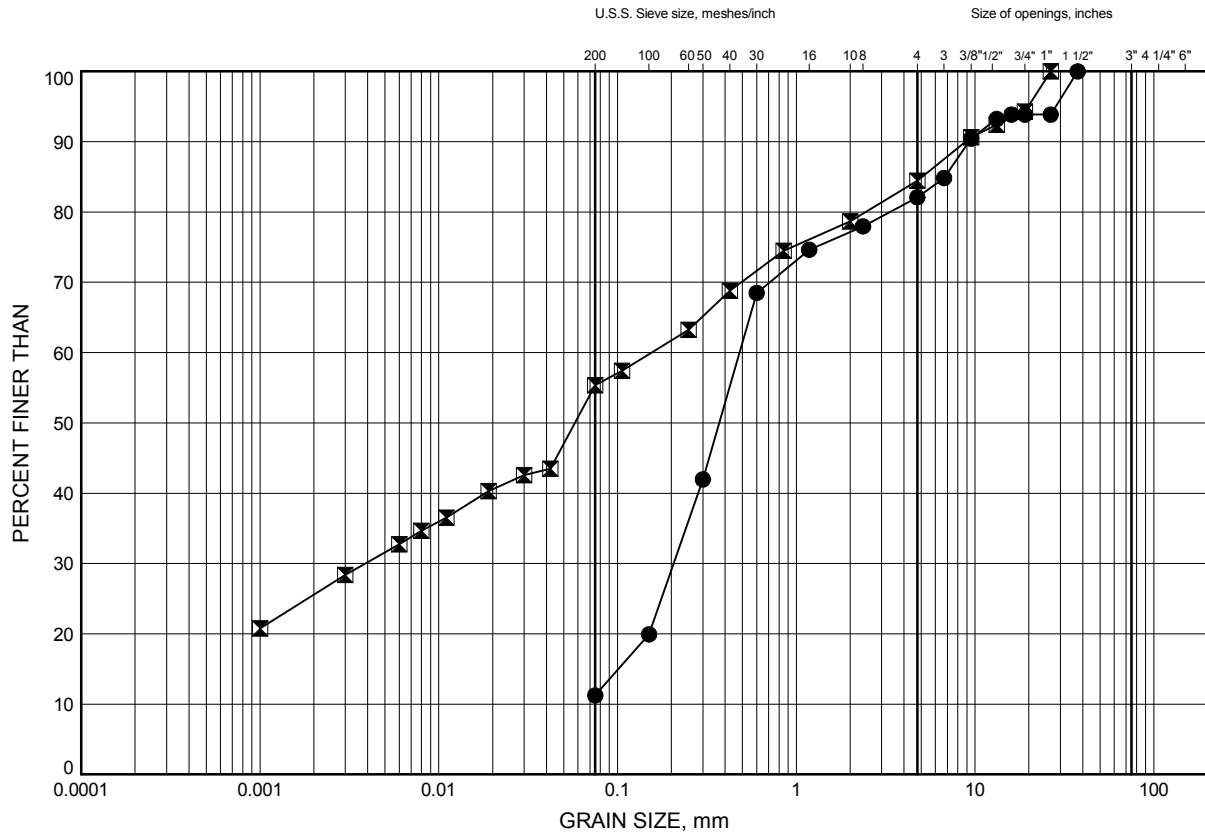
Appendix C

Laboratory Test Results

NS - W Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C1

Granular and Embankment Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	1.07	111.66
⊠	16-1	5.64	107.09

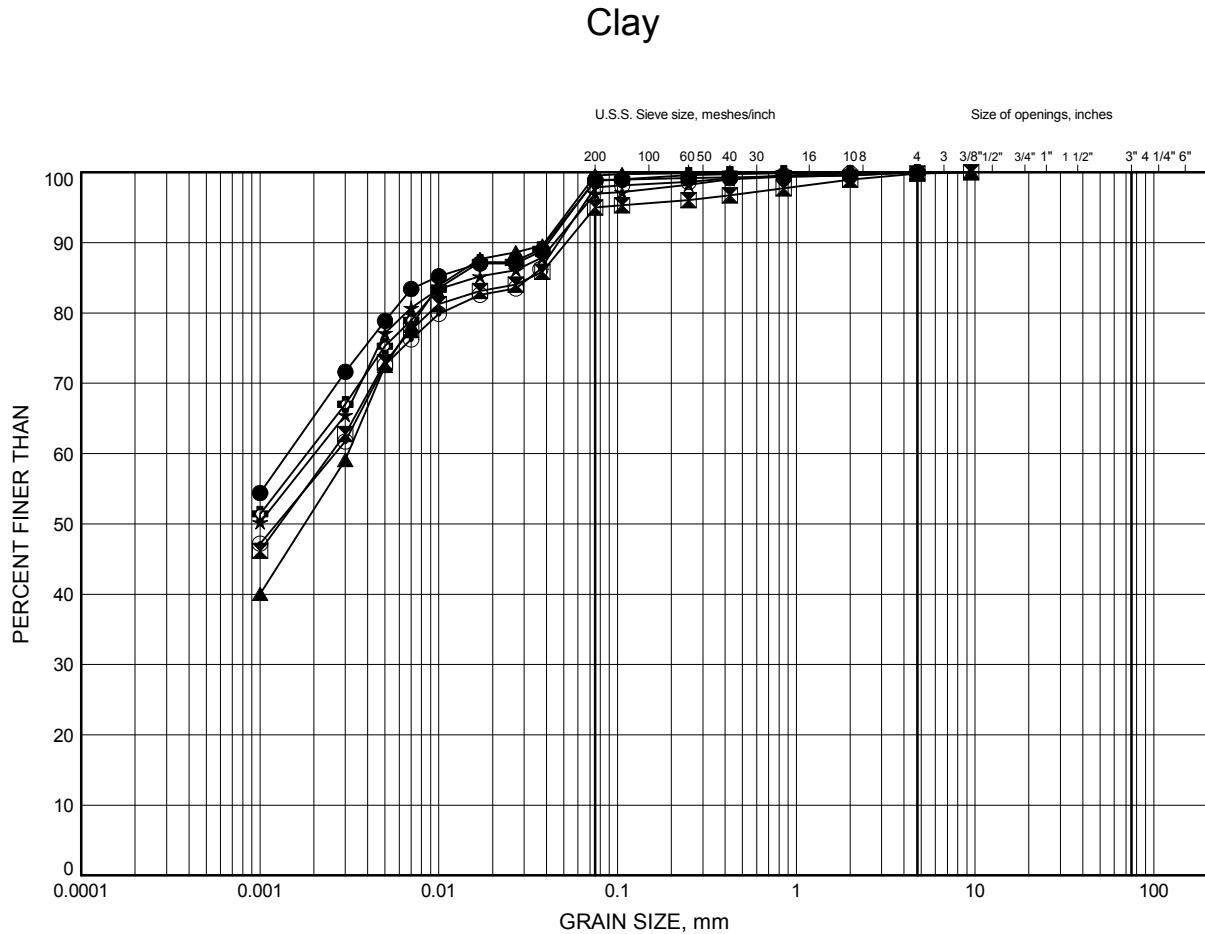
Date May 2016
 GWP# 4059-11-00



Prep'd JAG
 Chkd. PC

NS - W Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C2



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	9.45	103.28
⊠	16-1	12.50	100.23
▲	16-1	17.07	95.66
★	16-2	2.13	103.57
⊙	16-2	3.96	101.74
⊕	16-2	5.79	99.91

Date May 2016

GWP# 4059-11-00

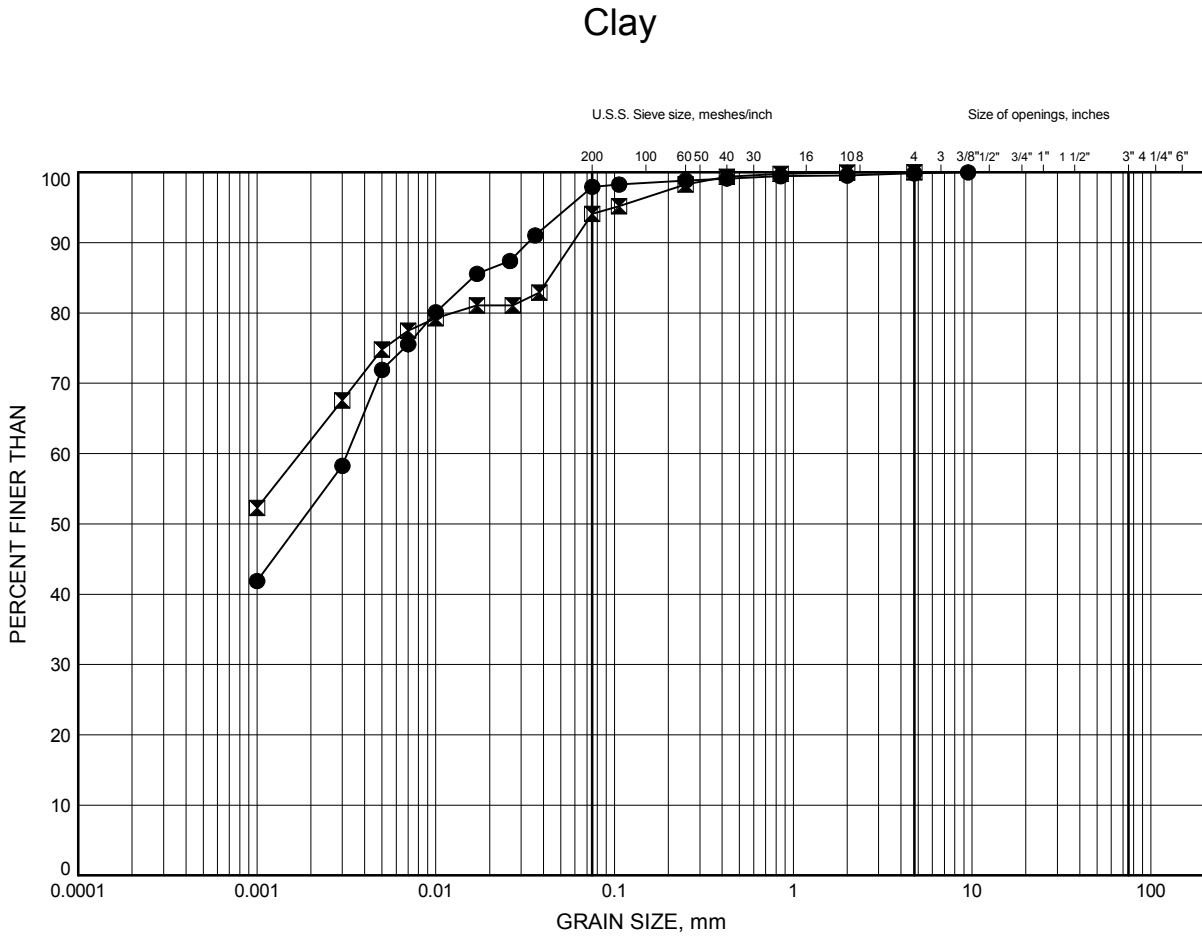


Prep'd JAG

Chkd. PC

NS - W Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

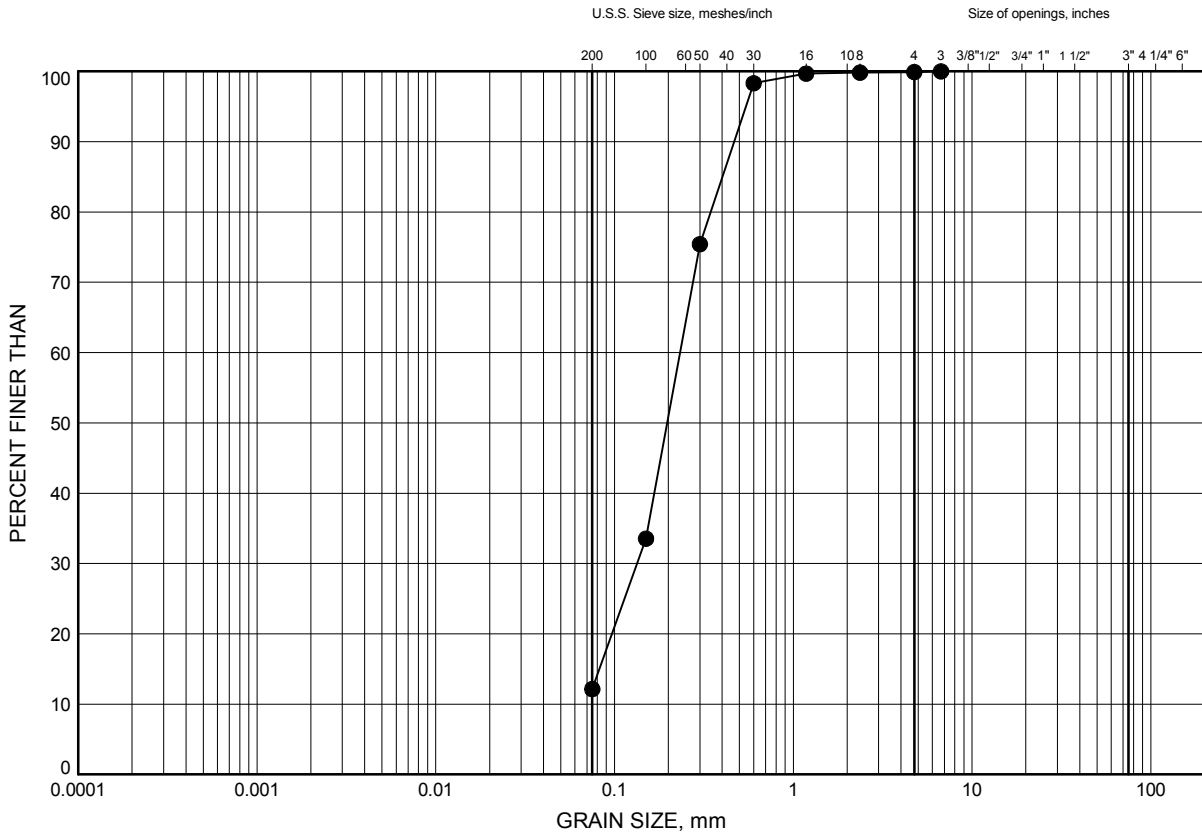
FIGURE C3



NS - W Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C4

Silty Sand



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-3	3.75	102.49

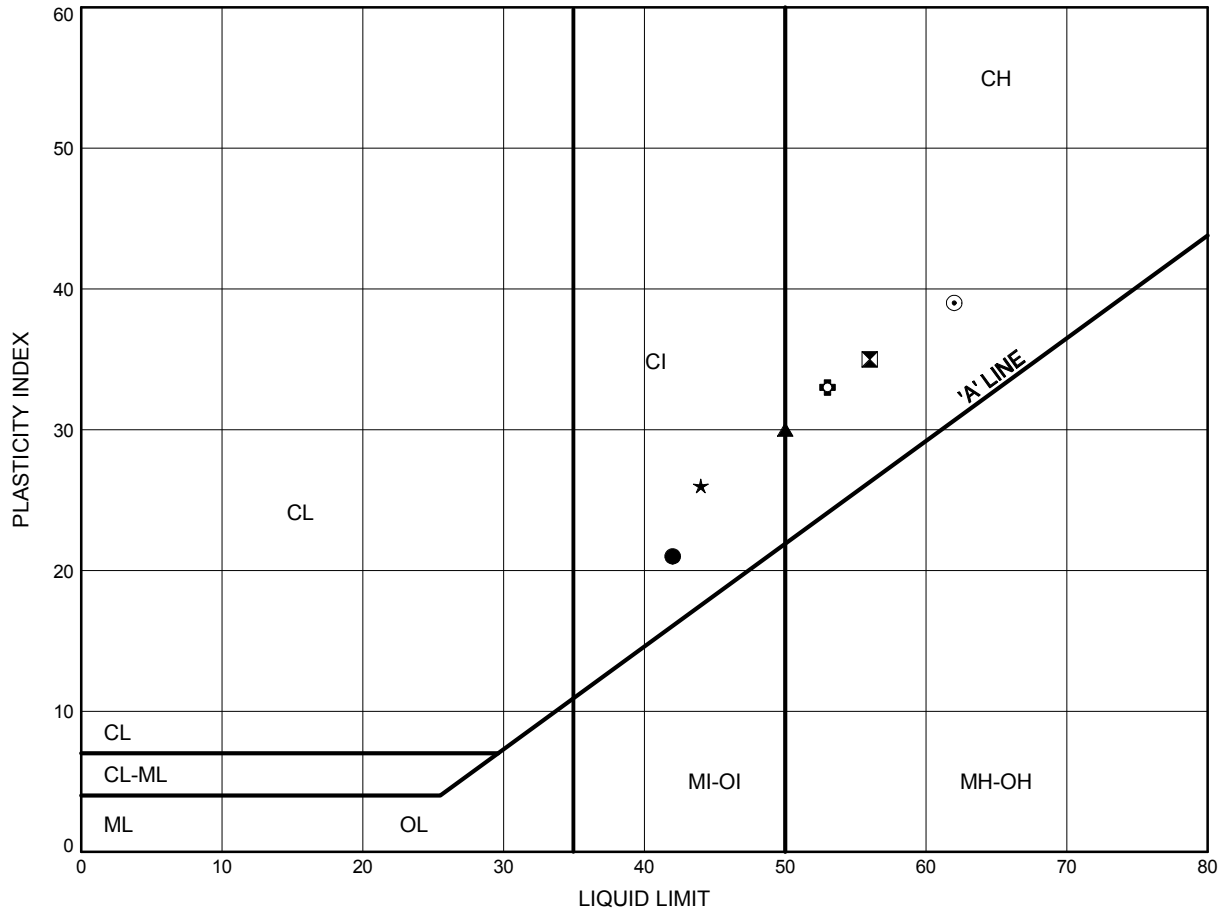
Date May 2016
 GWP# 4059-11-00



Prep'd JAG
 Chkd. PC

NS - W Ramp, Highway 15/401 Interchange
ATTERBERG LIMITS TEST RESULTS

FIGURE C5



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-1	5.64	107.09
⊠	16-1	9.45	103.28
▲	16-1	12.50	100.23
★	16-1	17.07	95.66
⊙	16-2	2.13	103.57
⊕	16-2	3.96	101.74

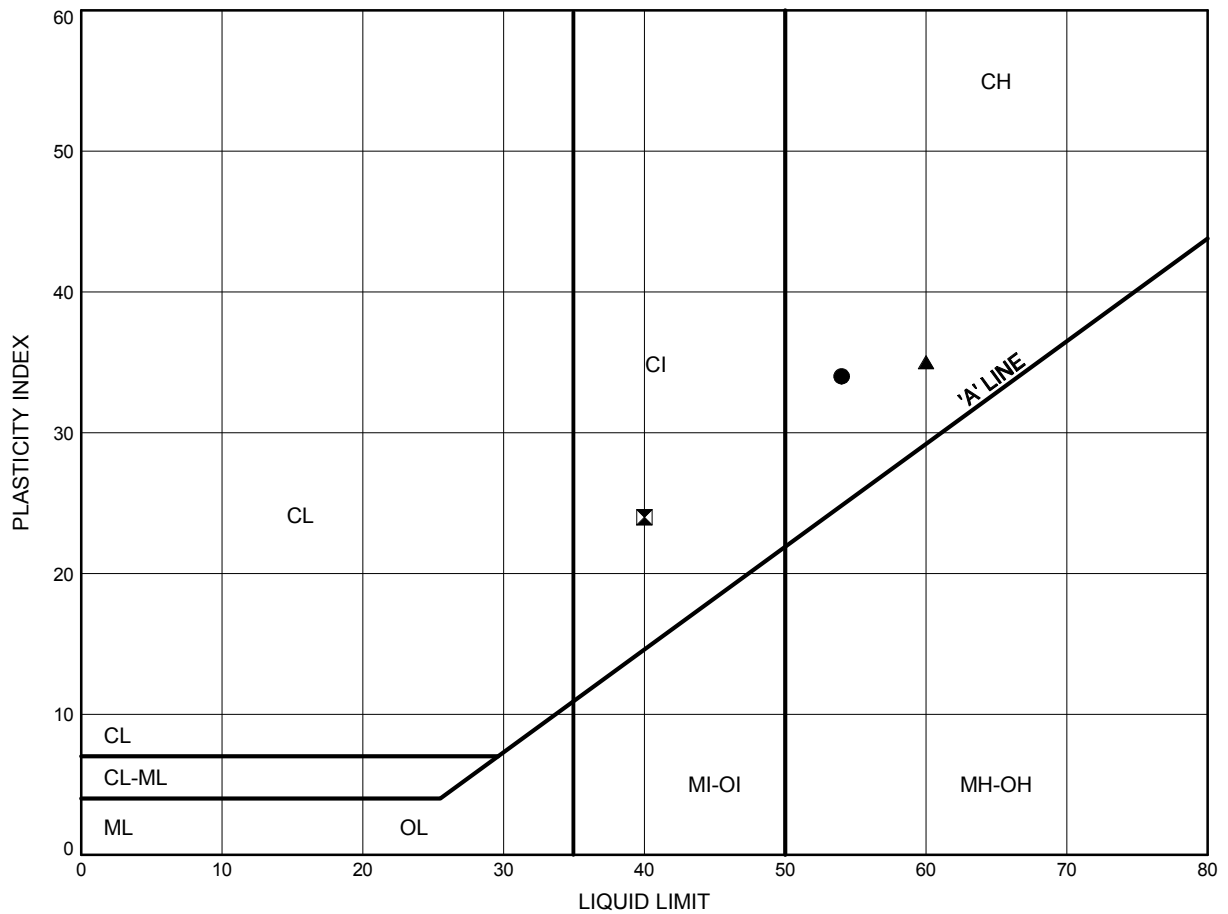
Date May 2016
 GWP# 4059-11-00



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NS - W Ramp, Highway 15/401 Interchange
ATTERBERG LIMITS TEST RESULTS

FIGURE C6



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-2	5.79	99.91
⊠	16-2	8.23	97.47
▲	16-3	1.52	104.72

Date May 2016

GWP# 4059-11-00



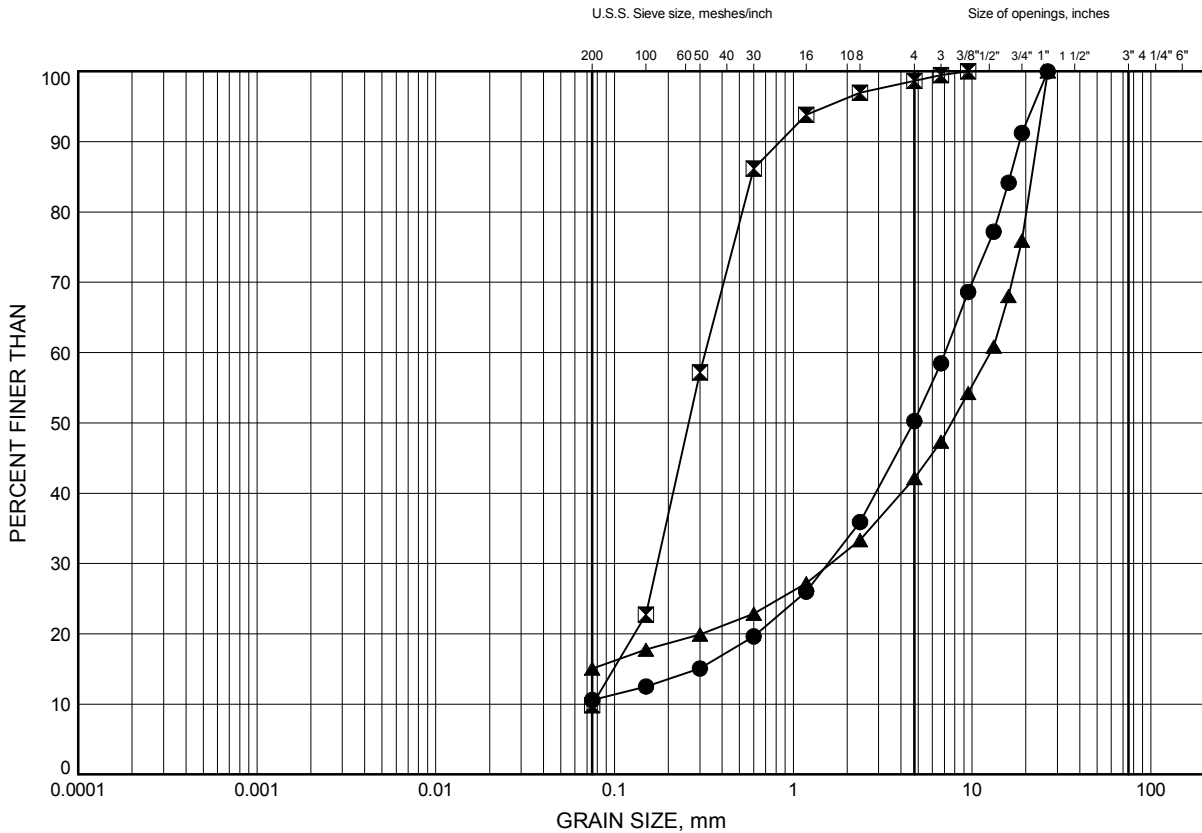
Prep'd JAG

Chkd. PC

W- NS Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C7

Granular and Embankment Fill



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	1.83	106.11
⊠	16-4	4.11	103.82
▲	16-4	7.16	100.77

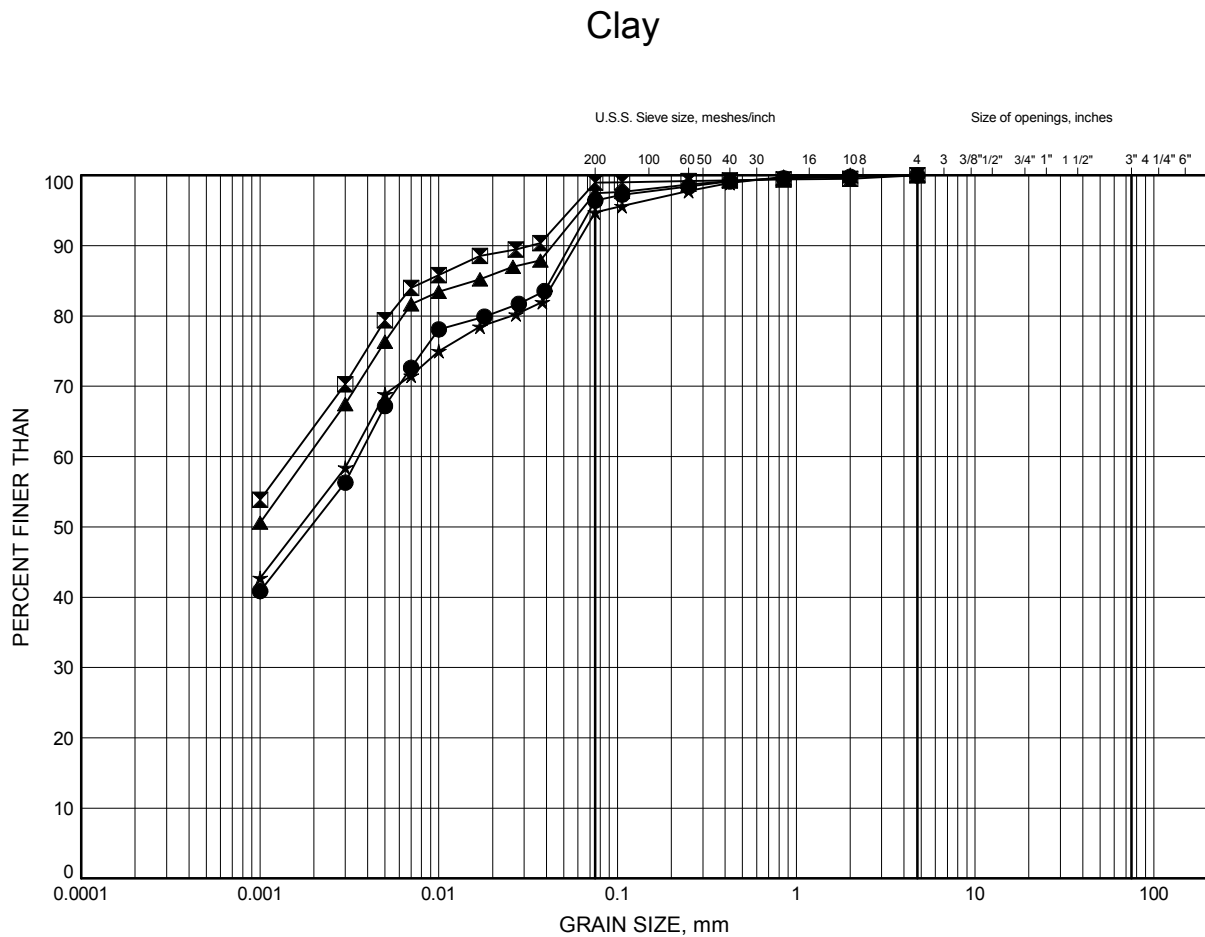
Date May 2016
 GWP# 4059-11-00



Prep'd JAG
 Chkd. PC

W- NS Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C8



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	10.97	96.96
⊠	16-5	3.35	99.38
▲	16-6	2.74	95.18
★	16-7	0.91	96.97

Date May 2016
GWP# 4059-11-00

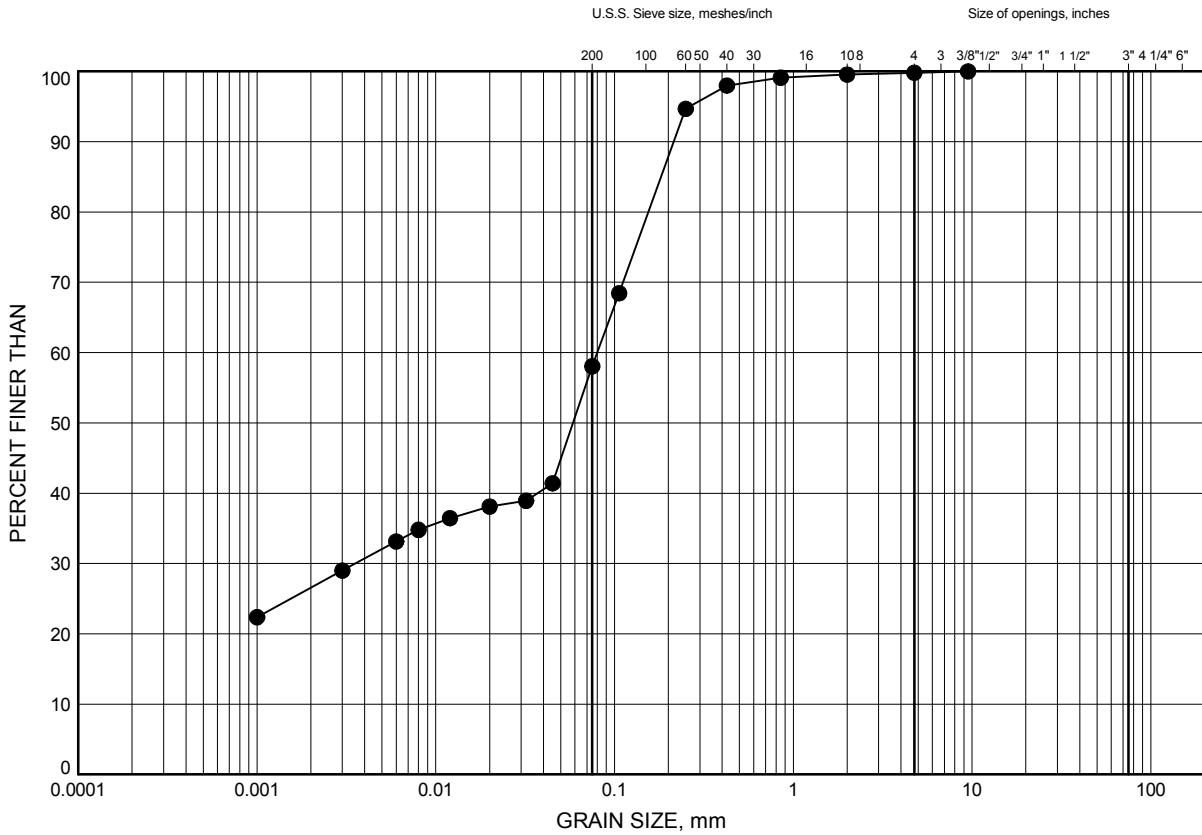


Prep'd JAG
Chkd. PC

W- NS Ramp, Highway 15/401 Interchange
GRAIN SIZE DISTRIBUTION

FIGURE C9

Sandy Silt



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-6	4.57	93.36

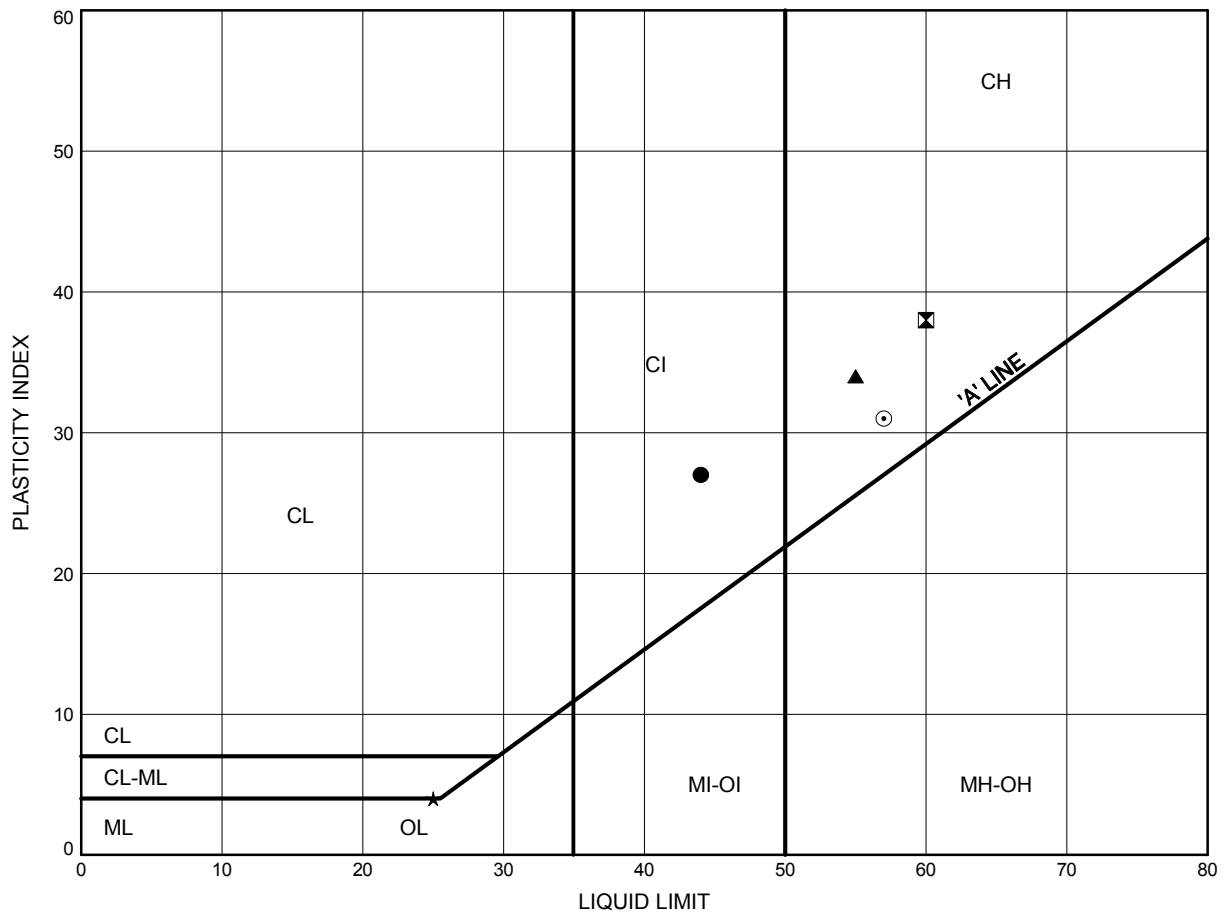
Date May 2016
 GWP# 4059-11-00



Prep'd JAG
 Chkd. PC

W- NS Ramp, Highway 15/401 Interchange
ATTERBERG LIMITS TEST RESULTS

FIGURE C10



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	16-4	10.97	96.96
⊠	16-5	3.35	99.38
▲	16-6	2.74	95.18
★	16-6	4.57	93.36
⊙	16-7	0.91	96.97

Date May 2016
 GWP# 4059-11-00



Prep'd JAG
 Chkd. PC

Appendix D

Site Photographs

Photo 1: N/S-W Ramp – looking west towards Borehole 16-1



Photo 2: N/S-W Ramp north side slope– looking west



Photo 3: W-N/S Ramp – looking east towards Borehole 16-4



Photo 4: W-N/S Ramp side slope – looking east at Borehole 16-7



Photo 5: W-N/S Ramp side slope – looking west at Borehole 16-6



Photo 6: W-N/S Ramp side slope – looking west from crest of embankment



Appendix E

Seismic Hazard Data Slope Stability Figures

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

May 26, 2016

Site: 44.289 N, 76.431 W

User File Reference: Highway 15/ 401 Interchange

Requested by: ,

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

Sa(0.05)	Sa(0.1)	Sa(0.2)	Sa(0.3)	Sa(0.5)	Sa(1.0)	Sa(2.0)	Sa(5.0)	Sa(10.0)	PGA (g)	PGV (m/s)
0.131	0.174	0.166	0.139	0.112	0.067	0.034	0.0094	0.0038	0.101	0.096

Notes. Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. *These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.*

Ground motions for other probabilities:

Probability of exceedance per annum	0.010	0.0021	0.001
Probability of exceedance in 50 years	40%	10%	5%
Sa(0.05)	0.020	0.054	0.082
Sa(0.1)	0.030	0.077	0.113
Sa(0.2)	0.031	0.077	0.110
Sa(0.3)	0.027	0.066	0.094
Sa(0.5)	0.021	0.052	0.076
Sa(1.0)	0.011	0.031	0.044
Sa(2.0)	0.0046	0.015	0.022
Sa(5.0)	0.0010	0.0035	0.0055
Sa(10.0)	0.0006	0.0015	0.0024
PGA	0.017	0.044	0.065
PGV	0.014	0.040	0.061

References

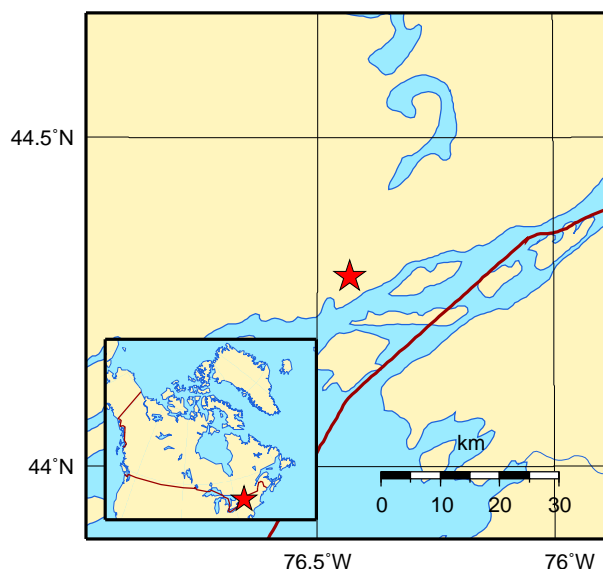
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada



Short Term Conditions

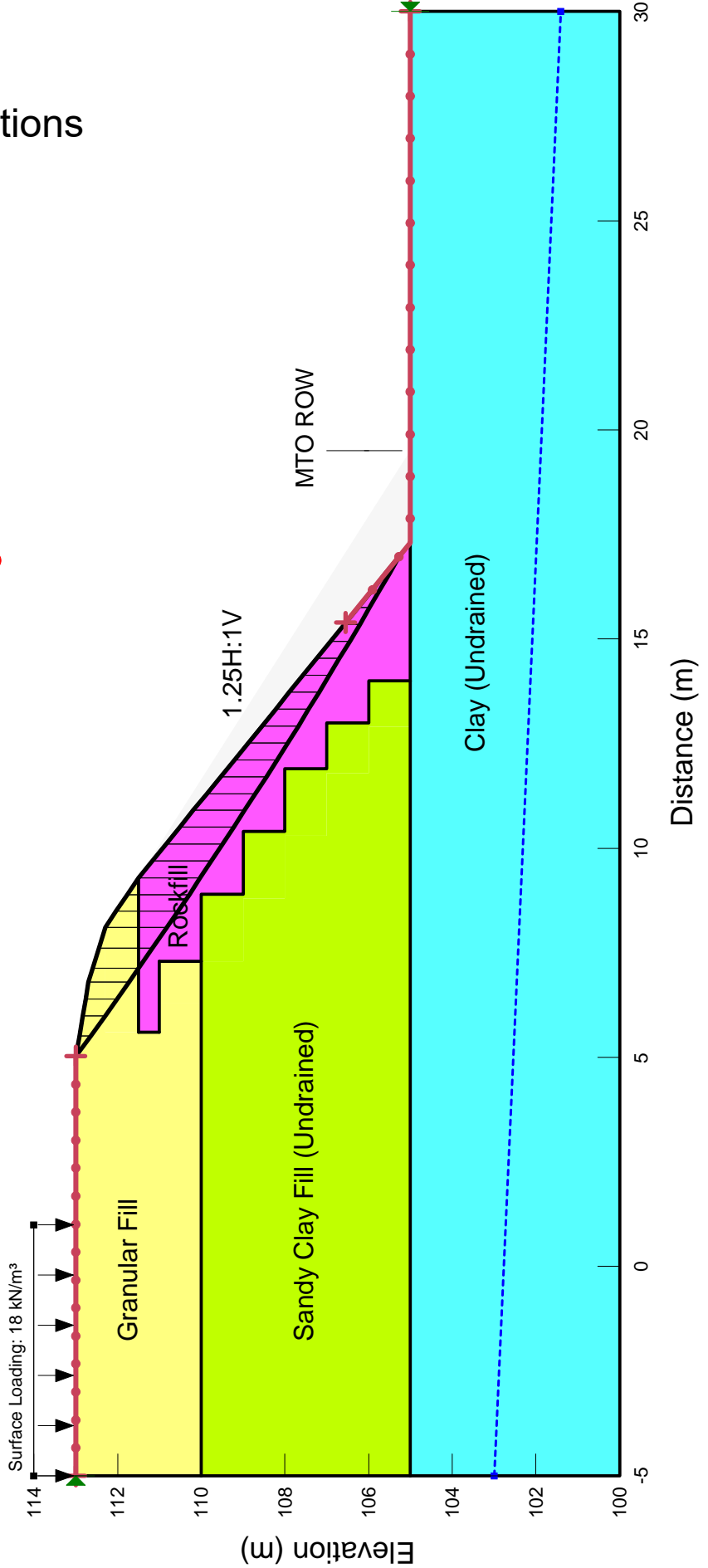


Figure E1

N/S-W Ramp
Name: Seismic
Method: Morgenstern-Price
Horz Seismic Coef.: 0.05g

Granular Fill	22 kN/m ³	0 kPa	35 °
Sandy Clay Fill (Undrained)	19 kN/m ³	50 kPa	0 °
Rockfill	18 kN/m ³	0 kPa	45 °
Clay (Undrained)	16 kN/m ³	75 kPa	0 °

1.3

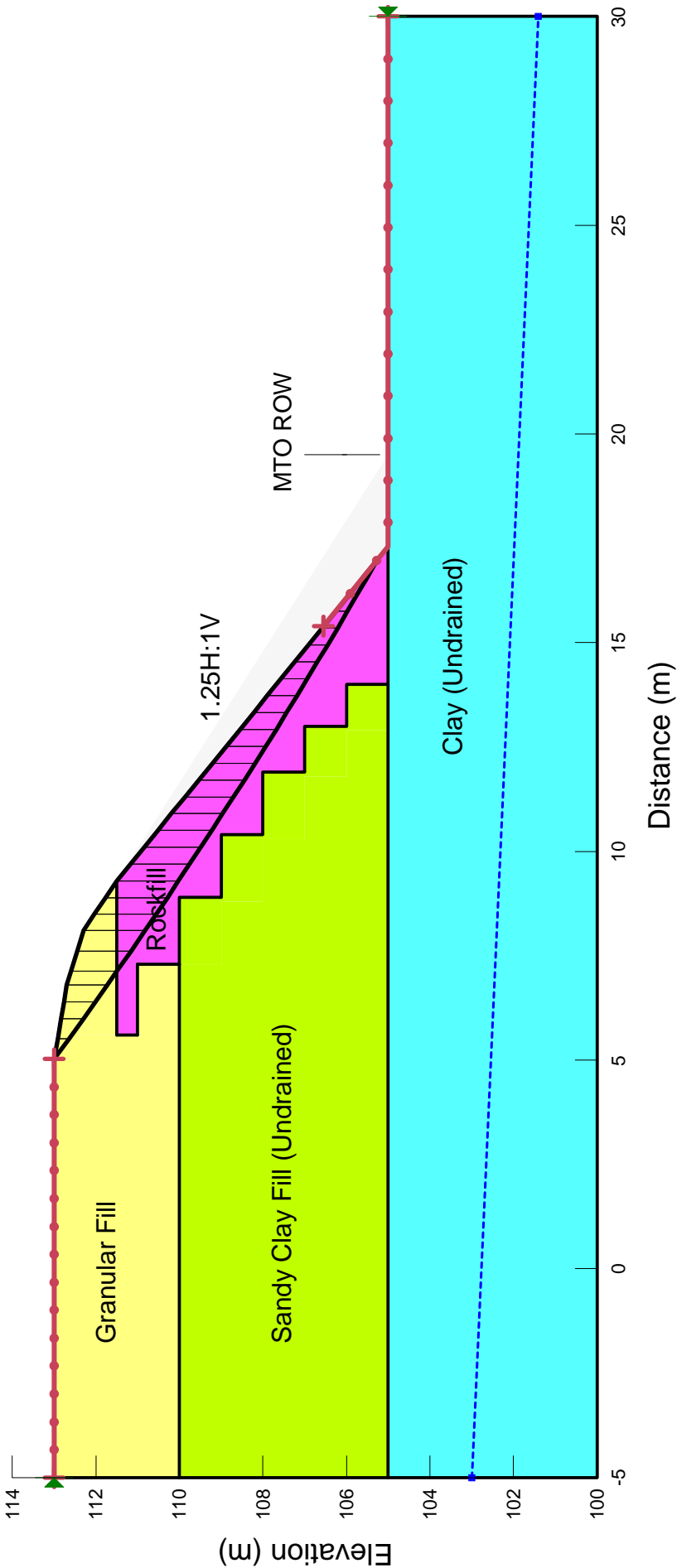


Figure E2
N/S-W Ramp
Seismic Conditions

Figure E2

N/S-W Ramp
Name: Drained
Method: Morgenstern-Price
Horz Seismic Coef.: 0g

Granular Fill	22 kN/m ³	0 kPa	35 °
Rockfill	18 kN/m ³	0 kPa	45 °
Clay (Drained)	16 kN/m ³	8 kPa	29 °
Sandy Clay Fill (Drained)	19 kN/m ³	8 kPa	28 °

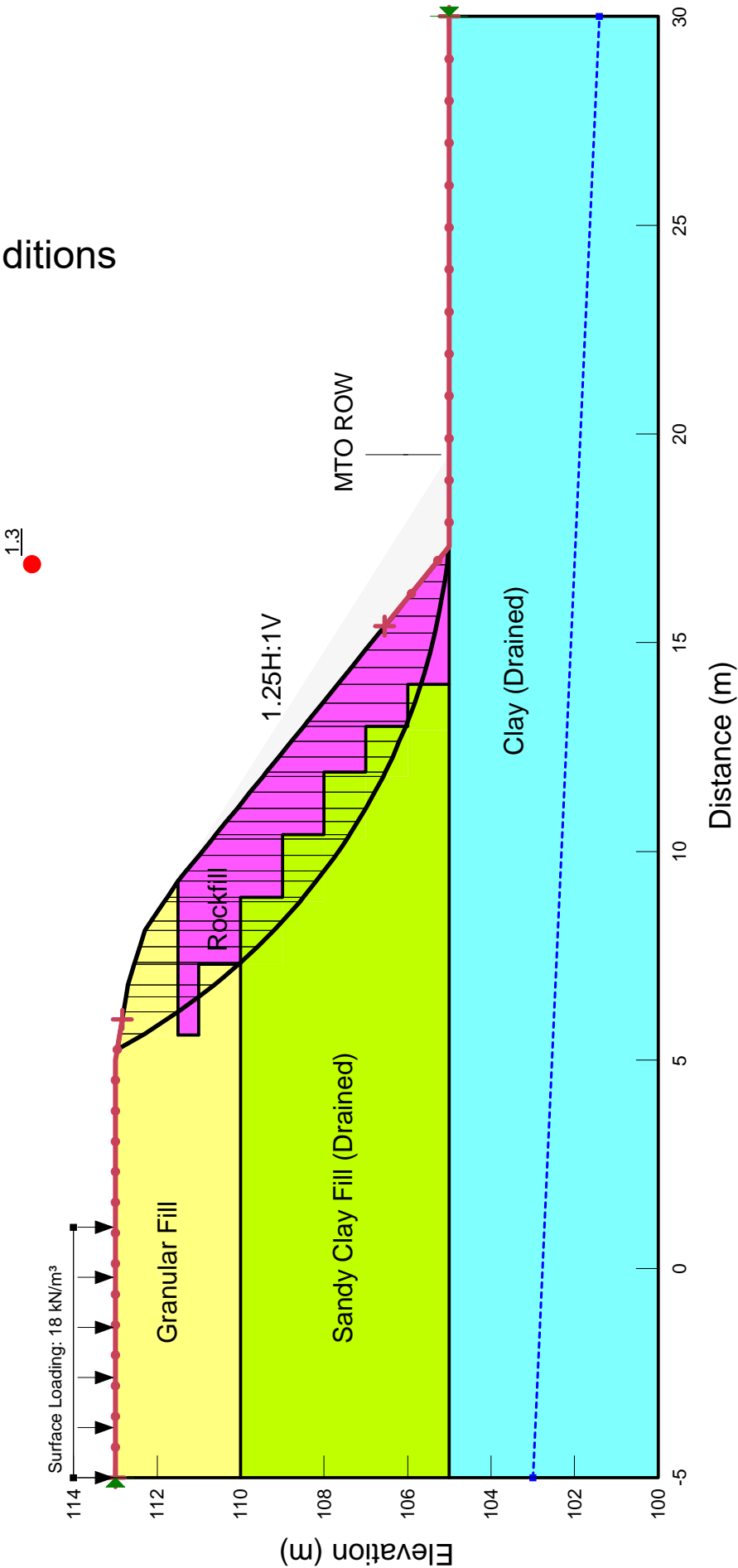


Figure E3
N/S-W ramp
Long Term Conditions

Figure E3

Name: Undrained
Method: Morgenstern-Price

Horz Seismic Coef.: 0g

Granular Fill	22 kN/m ³	0 kPa	35 °
Rockfill	18 kN/m ³	0 kPa	45 °
Clay (Undrained)	16 kN/m ³	75 kPa	0 °
Granular Embankment Fill	21 kN/m ³	0 kPa	34 °

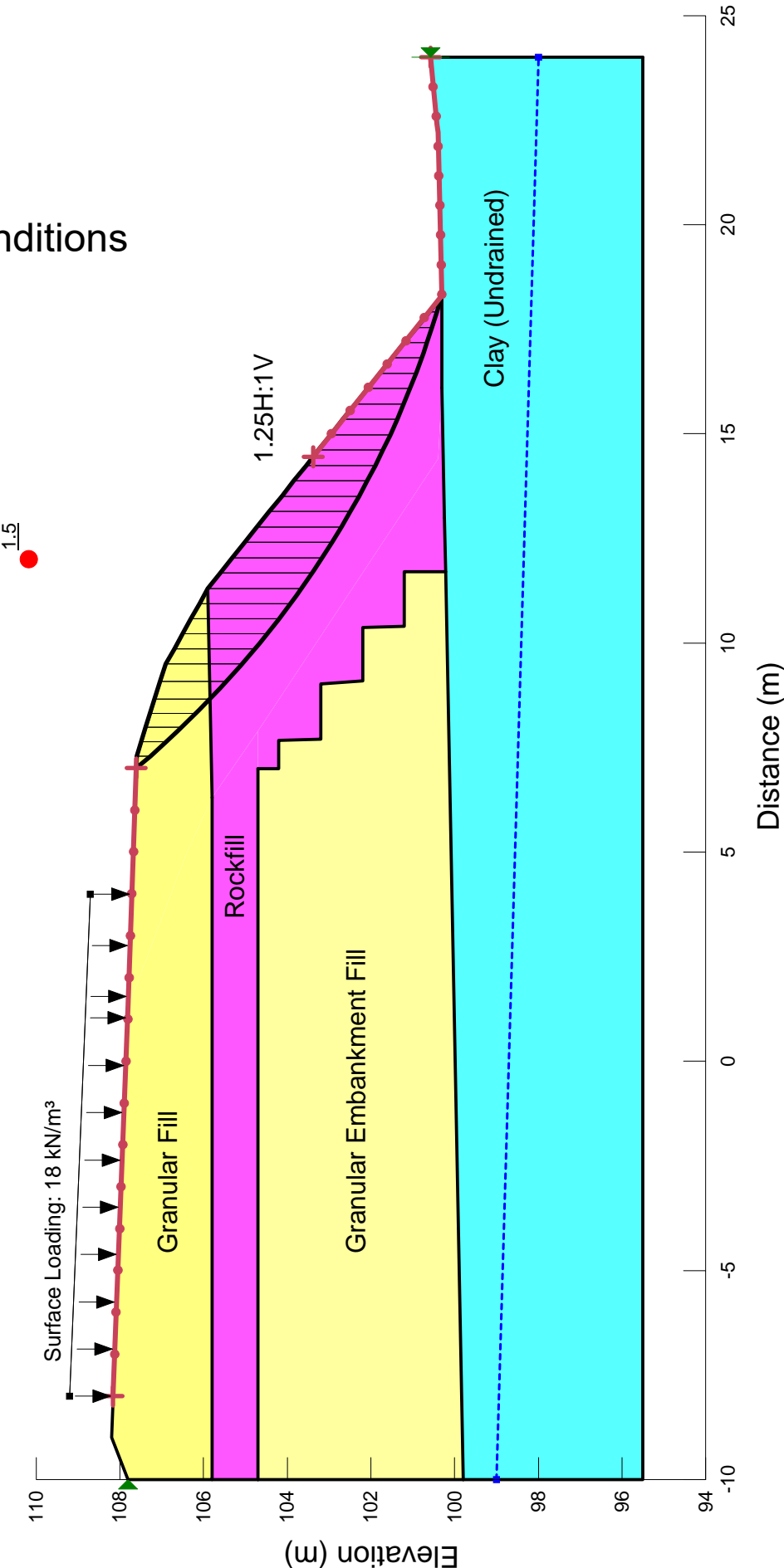


Figure E4

Name: Seismic
Method: Morgenstern-Price
Horz Seismic Coef.: 0.05g

Granular Fill	22 kN/m ³	0 kPa	35 °
Rockfill	18 kN/m ³	0 kPa	45 °
Clay (Undrained)	16 kN/m ³	75 kPa	0 °
Granular Embankment Fill	21 kN/m ³	0 kPa	34 °

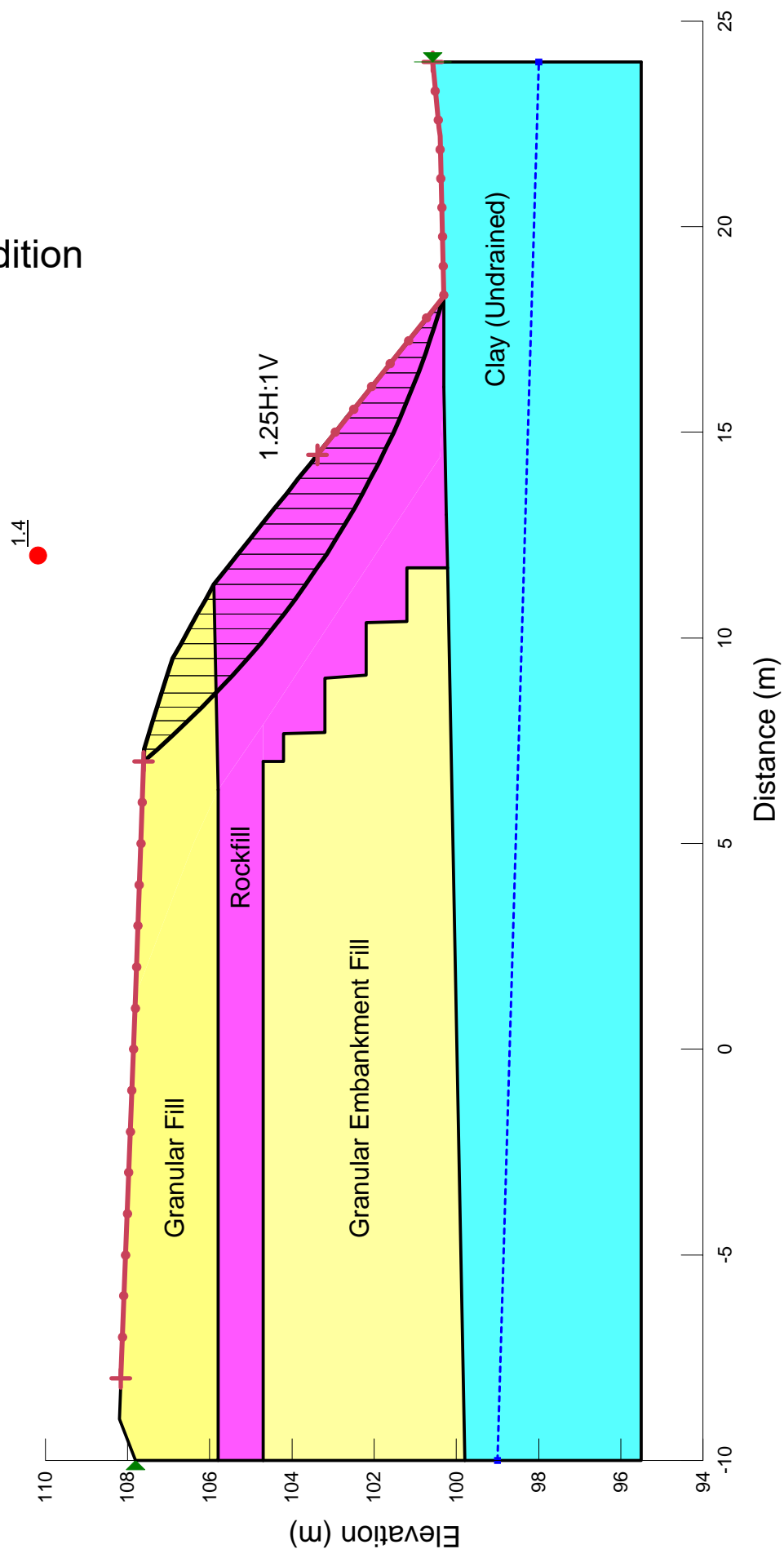


Figure E5

Name: Drained
Method: Morgenstern-Price

Horz Seismic Coef.: 0g

Granular Fill	22 kN/m ³	0 kPa	35 °
Rockfill	18 kN/m ³	0 kPa	45 °
Clay (Drained)	16 kN/m ³	8 kPa	29 °
Granular Embankment Fill	21 kN/m ³	0 kPa	34 °

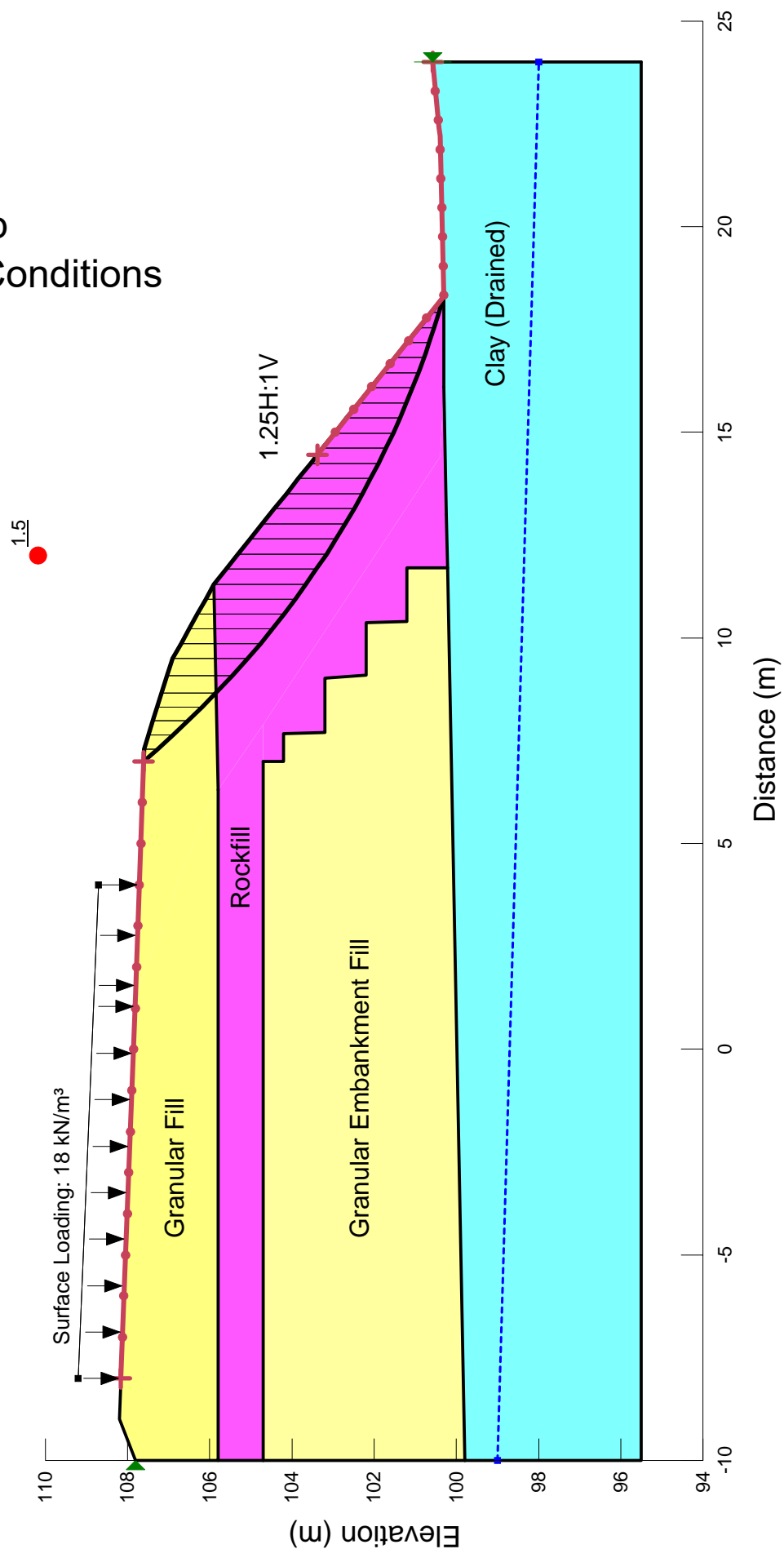


Figure E6

Appendix F

List of Referenced Specifications

Suggested NSSP Wording

LIST OF REFERENCED SPECIFICATIONS

OPSD 208.010	Benching of Earth Slopes
OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 804	Construction Specification for Seed and Cover

NSSPs

1. Suggested Text for NSSP on “Rock Fill”

“Rock fill shall consist of clean, hard, stable limestone fragments and shall be free of all shale. The rock fragments shall be well graded and shall have a maximum dimension of 650 mm.”