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FOUNDATION INVESTIGATION AND DESIGN REPORT
GABION WALL REMEDIATION
HIGHWAY 400 NORTH OF 17TH SIDEROAD
TOWNSHIP OF KING, ONTARIO
G.W.P. 2085-15-00

GEOCRES NO. 30M13-221

Report

to

WSP

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted for the remediation of two gabion walls located along Highway 400 north of 17th Sideroad in the Township of King, Ontario. The gabion walls are aligned parallel to the highway and are located on top of the inlet and outlet of a 1.22 m span concrete rigid frame culvert.

The purpose of this investigation was to explore the subsurface conditions in the vicinity of the embankments adjacent to the gabion walls and, based on the data obtained, to provide a borehole location plan, stratigraphic profiles, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by WSP / MMM Group (MMM) to carry out this foundation investigation under the MTO Assignment Number 2015-E-0008.

2. PROJECT AND SITE DESCRIPTION

The two gabion walls showing signs of distress are located along Highway 400 at approximately 600 m north of 17th Sideroad (approximate Station 18+808) in the Township of King, Ontario. These gabion walls are located part way up the embankment slopes of the Highway 400 Northbound Lane (NBL) and Southbound Lane (SBL). The gabion basket retaining walls are the headwalls for the culvert which has a 1.22 m span, a 1.05 m height and a 60 m length crossing under the highway. The gabion walls are approximately 2 m in height on top of 1.22 m span concrete culvert. The highway embankment in this vicinity is up to about 7 m in height.

The area adjacent to the gabion walls is vegetated and treed. The terrain in the vicinity of the site is generally flat with the highway embankment slopes at an inclination of about 2H : 1V (horizontal to vertical). Selected photographs of the immediate surroundings are presented in Appendix D.

The project area is located within the transition zone between physiographic regions known as the South Slope and the Oak Ridges Moraine. The South Slope is comprised predominantly of the Halton Till which is an interbedded complex of clayey silt to silt till and sand. This till comprises a slightly hummocky till plain, into which the surface watercourses have eroded 10 to 15 m deep gullies. The Oak Ridges Moraine is comprised of till overlying sands and gravels.

3. INVESTIGATION PROCEDURES

The site investigation and field testing for this project were carried out from March 7 to 16, 2017 and consisted of drilling and sampling six boreholes (numbered GW17-01 to GW17-06) located at the crest, slope and toe of the embankments. Boreholes GW17-01 to GW17-03 were drilled on the west side of Highway 400 NBL and Boreholes GW17-04 to GW17-06 were drilled on the east side of Highway 400 SBL. All the boreholes were terminated at depths ranging from 6.0 m to 15.7 m (Elevations 300.3 to 308.0).

Prior to the start of drilling, the borehole locations were marked in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently provided by MMM. The approximate locations of the boreholes are shown on Borehole Locations and Soil Strata drawings included in Appendix C. The coordinates and elevations of these boreholes are given on this drawing and on the individual Record of Borehole Sheets in Appendix A.

A track-mounted D50 drill rig and a tripod drill rig were used to drill and sample the boreholes. Hollow stem augers were used in conjunction with the D50 rig to advance the boreholes until the target depth was reached. Wash boring techniques were used in conjunction with the tripod. In general, soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Testing (SPT).

The drilling and sampling operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendix A.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Four standpipe piezometers were installed in selected boreholes (Boreholes GW17-01, GW17-02, GW17-05, and GW17-06). Each piezometer consisted of a 19 mm Schedule 40 PVC pipe with a 1.5 m long slotted screen enclosed in filter sand column to permit groundwater level monitoring. Piezometer installation details, groundwater level observations and water level readings are shown on the Record of Borehole sheets. Upon completion of the drilling operations, the boreholes without piezometers were abandoned in general accordance with Ontario Regulation 903 (amended by Ontario Reg. 372) (O.Reg. 903). The piezometers will be decommissioned as per O.Reg. 903 after the final set of water level readings are taken. The details of standpipe piezometer installation and borehole completion are summarized in Table 3.1.

Table 3.1 – Borehole Completion Details

Approx. Station	Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Tip Elevation (m)	Completion Details
18+808	GW17-01	9.6/301.3	9.2/301.7	Borehole backfilled with sand filter from 9.2 m to 7.0 m, bentonite holeplug from 7.0 m to 6.1 m, then bentonite holeplug and auger cuttings from 6.1 m to surface.
	GW17-02	6.3/307.4	5.7/308.0	Borehole backfilled with sand filter from 5.7 m to 3.7 m, bentonite holeplug from 3.7 m to 3.1 m, then bentonite holeplug and auger cuttings from 3.1 m to surface.
	GW17-03	15.7/301.9	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	GW17-04	15.6/302.0	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	GW17-05	6.0/308.0	5.9/308.1	Borehole backfilled with sand filter from 5.9 m to 4.0 m, bentonite holeplug from 4.0 m to 2.6 m, then bentonite holeplug and auger cuttings from 2.6 m to surface.
	GW17-06	9.6/300.3	9.2/300.7	Borehole backfilled with sand filter from 9.2 m to 7.0 m, bentonite holeplug from 7.0 m to 6.1 m, then bentonite holeplug and auger cuttings from 6.1 m to surface.

4. LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance to MTO and/or ASTM Standards, as appropriate. The results of the laboratory testing are summarized on the Record of Borehole sheets in Appendix A and are presented on the figures included in Appendix B.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendix A for details of the encountered soil stratigraphy. Representative cross sections of embankment slopes with gabion walls are presented on the "Borehole Locations and Soil Strata" drawings in Appendix C. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site conditions. It must be recognized that soil conditions may vary between and beyond borehole locations. More detailed descriptions of the individual strata are presented below.

In general, the subsurface conditions encountered in the boreholes drilled along the east side of the Highway 400 NBL and west side of the Highway 400 SBL consist of pavement structure and embankment fill overlying a deposit of typically compact sands and silts with stiff to very stiff clayey silt interlayers. A very dense sand and silt till underlies the above soils. Groundwater was measured at between 0.7 m and 1.5 m depths below the slope surface and the toe. More detailed descriptions of the individual stratum are presented below.

5.1 Pavement Structure

Boreholes on Highway 400, identified as GW17-03 and GW17-04, were drilled through an approximately 150 mm to 175 mm thick layer of asphalt and 0.6 to 0.9 m of sand fill containing trace gravel. The measured moisture contents of selected samples of the sand fill varied between 9 percent and 12 percent.

5.2 Topsoil and Organics

A layer of topsoil between 100 and 300 mm in thickness was encountered at ground surface in Boreholes GW17-01, GW17-02, GW17-05 and GW17-06.

The topsoil thickness may vary between and beyond the borehole locations, and the limited data is not suitable for estimating topsoil quantities.

In Boreholes GW17-01 and GW17-06, a 0.6 to 0.8 m thick layer of organics was encountered below the surficial sand to sandy silt fill. The organics were mixed with sandy silt to clayey silt and wood fibres. The SPT 'N' values indicated a compact condition or stiff consistency. The base of the organic layer was at 1.1 m and 1.8 m depths, or Elevations 309.8 and 308.1, in Boreholes GW17-01 and GW17-06, respectively. Measured moisture contents of samples of the organics varied from 15 percent to 32 percent.

5.3 Silty Clay to Clayey Silt Fill

Embankment fill consisting predominantly of silty clay to clayey silt fill was encountered below the topsoil, pavement structure or sandy silt fill in Boreholes GW17-02, GW17-03, GW17-04, and GW17-05. The thickness of this cohesive fill at the boreholes was between 2.5 m and 6.1 m. The base of this cohesive fill ranged between 3.7 m and 7.3 m depths, or Elevations 309.1 and 310.4.

SPT 'N' values recorded in the silty clay to clayey silt fill ranged from 9 blows to 111 blows per 0.3 m of penetration, indicating a stiff to hard consistency. The measured moisture contents of selected samples of this fill varied between 8 percent and 20 percent.

The results of grain size distribution analyses carried out on samples of this cohesive fill are presented on the Record of Borehole Sheets included in Appendix A and on Figure B1 of Appendix B. The results of the gradation testing from all the relevant boreholes are summarized below:

Soil Particles	Percentage (%)
Gravel	0 to 5
Sand	21 to 38
Silt	35 to 46
Clay	17 to 31

The result of Atterberg Limits testing results on a silty clay fill sample is presented in Figure B7 of Appendix B, and summarized below:

Index Property	Percentage (%)
Plasticity Index	9
Liquid Limit	22

The results of the Atterberg Limits testing indicate that this deposit has low plasticity with a group symbol of CL.

5.4 Sandy Silt to Silty Sand Fill

In Boreholes GW17-01, GW17-03, GW17-05, and GW17-06, layers of brown to grey sand, silty sand to sandy silt fill containing trace to some clay, trace gravel, occasional roots and rootlets, were encountered below the topsoil or pavement. The thickness of this cohesionless fill at the boreholes was between 0.4 m and 2.3 m. The base of this cohesionless fill ranged between 0.5m and 2.4 m depths, or Elevations 316.5 and 308.5.

SPT 'N' values within the cohesionless fill ranged from 3 blows to 19 blows per 0.3 m of penetration, indicating very loose to compact conditions. The measured moisture contents of samples of the fill varied between 6 percent and 21 percent.

The results of grain size distribution analysis carried out on a sample of the silty sand fill is presented on the Record of Borehole Sheets included in Appendix A and on Figure B2 of Appendix B. The result of the gradation testing is summarized below:

Soil Particles	Percentage (%)
Gravel	8
Sand	47
Silt	32
Clay	13

5.5 Sands and Silts

In all the boreholes, surficial brown to grey deposits with varying proportions of sands and silts, trace to some clay, trace gravel, occasional roots and rootlets and wood fibres, were encountered. Where fully penetrated, the thickness of the native sandy silt to silty sand was between 1.6 m and 6.1 m. The base of these cohesionless deposits ranged between 5.5 m and 13.3 m depths, or Elevations 306.0 and 304.3 in Boreholes GW17-01, GW17-03, GW17-04 and GW17-06. Boreholes GW17-02 and GW17-05 were terminated in the sands and silts at 6.3 to 6.0 m depths, or Elevations 307.4 to 308.0.

SPT ‘N’ values recorded in these cohesionless soils were typically between 9 blows and 36 blows per 0.3 m penetration indicating a loose to dense state. In Borehole GW17-02 and GW17-05, ‘N’ values of 76 blows per 0.3 m penetration to greater than 100 blows for less than 0.3 m penetration indicated very dense conditions. Moisture content of the sands and silts ranged from 5 percent to 22 percent.

The results of grain size analyses conducted on samples of the sands and silts are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figures B3 and B4 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0 to 14
Sand	3 to 58
Silt	36 to 87
Clay	5 to 13

5.6 Clayey Silt to Clayey Silt Till

Layers of brown to grey native clayey silt to clayey silt till with trace to some sand and trace gravel were encountered in Boreholes GW17-01, GW17-03 and GW17-06. Where fully penetrated in Boreholes GW17-03 and GW17-06, the thickness of the clayey silt ranged between 1.9 m and 2.2, and the base of the layers was encountered at Elevations 308.4 to 305.9. Borehole GW17-01 was terminated in the clayey silt till at 9.6 m depth, or Elevation 301.3.

SPT ‘N’ values obtained in the clayey silt ranged between 13 blows and 22 blows for 0.3 m penetration indicating stiff to very stiff consistency. Moisture contents of the native clayey silt ranged from 13 percent to 21 percent.

SPT ‘N’ values obtained in the clayey silt till were 87 to 90 blows for 0.3 m penetration indicating a hard consistency. A moisture content of 9 percent was measured in a sample.

The results of grain size analyses conducted on native clayey silt samples are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B5 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0 to 3
Sand	3 to 40
Silt	40 to 77
Clay	17 to 20

The results of Atterberg Limits tests conducted on samples of the clayey silt are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure B8 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	21 to 22
Plasticity Index	5 to 8

The results of the Atterberg Limits testing indicate the deposit to be of slight to low plasticity with a group symbol CL/CL-ML.

5.7 Sand and Silt Till

A deposit of brown to grey sand and silt till underlies the above soils in Boreholes GW17-01, GW17-03, GW17-04 and GW17-06. Where fully penetrated in Boreholes GW17-01, this cohesionless till was 1.7 m thick with the base at 7.2 m depth, Elevation 303.7. Boreholes GW17-03, GW17-04 and GW17-06 were terminated in this till at 9.6 to 15.7 m depths, or Elevations 300.3 to 302.0.

SPT 'N' values obtained in the sand and silt till ranged from 61 per 0.3 m penetration to more than 100 blows for less than 0.3 m of penetration, indicating a very dense state throughout. Moisture contents of this till ranged from 7 percent to 10 percent.

The results of grain size analyses conducted on sand and silt till samples are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figure B6 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	2 to 4
Sand	44 to 48
Silt	38 to 44
Clay	8 to 12

5.8 Groundwater Conditions

Groundwater levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. Standpipe piezometers were installed in Boreholes GW17-01, GW17-02, GW17-05 and GW17-06 to permit longer term monitoring. Water levels measured in the four installed standpipes and open boreholes are presented below.

Table 5-1. Groundwater Level Measurements

Borehole Number	Date	Groundwater Level		Comments
		Depth (m)	Elevation (m)	
GW17-01	March 13, 2017 March 28, 2017	3.2 0.7	307.7 310.2	Open borehole Piezometer (clayey silt till)
GW17-02	March 28, 2017	1.5	312.2	Piezometer (sands and silts)
GW17-03	March 7, 2017	8.7	308.9	Open borehole
GW17-04	March 8, 2017	11.4	306.2	Open borehole
GW17-05	March 28, 2017	1.5	312.5	Piezometer (fill/silt)
GW17-06	March 10, 2017 March 28, 2017	2.7 0.7	307.2 309.2	Open borehole Piezometer (sand and silt till)

The values shown in Table 5-1 are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation.

6. MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. MMM provided the northing and easting coordinates and ground surface elevations.

Walker Drilling of Utopia, Ontario, supplied and operated a track-mounted D50 drill rig and Tripod to carry out the drilling, sampling and in-situ testing operations for the boreholes.

The drilling and sampling operations in the field were supervised on a full time basis by Ms. Eckie Siu of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Overall project management was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Mr. Pouya Pishgah, P. Eng. and Dr. Sydney Pang, 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 provides foundation recommendations for the remediation of the gabion basket retaining walls associated with the Culvert C36 located under Highway 400 to the north of 17th Sideroad in the Township of King, 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.

The concrete, open footing culvert at approximate Station 18+808 has a 1.22 m span, a 1.05 m height and a 60 m length across Highway 400. The highway embankment is approximately 7 m in height at this location. There are two sections of gabion walls adjacent to and above the culvert (approx. Station 18+808) near the inlet (west) and outlet (east) areas, and are essentially performing as headwalls. One wall is situated on the embankment of the Highway 400 Northbound Lanes (NBL) and the other wall on the embankment of the Southbound Lanes (SBL). The exposed portions of each gabion wall are approximately 2 m in height above the culvert.

It is our understanding that distress on the gabion walls was first noted by MTO in 2015. Subsequent to structural inspection, MTO then decided to have a foundation investigation carried out to address the situation.

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

8. GABION WALL REMEDIATION

8.1 General

There is no archived foundation or structural design and construction/as-built drawings available for the gabion walls. Each wall is in the order of 10 m in length. These walls consist of gabion baskets each with dimensions of approximately 1 m x 1 m x 1 m. The exposed gabions indicate two-tier walls with a height of 2 m above the culvert. There is no information available to indicate whether there is any buried gabions or a widened base. Information on actual cross-sections, overall dimensions, founding levels and foundation conditions are also unavailable.

The east gabion wall on the NBL embankment (east facing) slope is outward leaning, but appears stable. The west gabion wall on the SBL embankment (west facing) slope is tilting outwards to a greater magnitude than the east wall, and its top of wall is sagging at several locations. One of the gabion baskets directly above the culvert is broken which resulted in most of the gabion stones falling onto the creek channel. It is our understanding that signs of gabion wall distress were first made known to MTO staff in the summer of 2015. There is no report or observations to date regarding adjacent slope movement, bulging, tension cracks and gullies etc.

Subsurface conditions depicted by the borehole information indicate that the gabion wall is possibly founded on the lower portion of the clayey silt fill or native sandy silt, based on the assumption that there are no buried gabions. It there is one layer of buried gabions, the three-tier wall would be founded on the compact sands and silts. It is also possible that interlayers of stiff clayey silt, and compact/stiff organics mixed with sandy silt/clayey silt may also be present at or below the gabion wall subgrade.

As part of the current investigation, MMM surveyors has provided a local topographic survey of the gabion walls and their adjacent embankment slopes from which representative slope cross-sections have been developed for stability analysis.

A site inspection visit was carried out by a member of Thurber's staff on April 4, 2017. Our site observations are as follows:

●	The east gabion wall (adjacent to Highway 400 NBL) appears largely stable with maximum horizontal outward (easterly) displacement at the centre portion of the wall up to the order of 150 to 200 mm. No visible slope distress or deformation was noted.

●	The southerly portion of the west gabion wall (adjacent to Highway 400 SBL) appears to have been laterally displaced outward (westerly) up to the order of 500 mm. Minor slope sloughing was observed immediately behind the wall. The top of wall appears to have sagged at two locations up to the order of 100 to 120 mm. The broken gabion basket with loss of stones above the culvert inlet, as noted by others, was confirmed.

8.2 Possible Causes of Instability

Based on the borehole information and the slope survey, slope stability analyses have been carried out for selected critical slope sections. The overall embankment slope stability and localized stability of a two-tier wall have been included in the analyses. Given the predominantly cohesionless subsurface conditions and the embankment fill, it is considered representative to focus on effective stress (drained) analyses.

Limit equilibrium analyses were carried out using a commercially available computer program SLOPE/W. Results of the analysis are presented graphically on Figures E1 to E14 in Appendix F and summarized in the following table.

Table 8.1
Factors of Safety from Stability Analysis

Case	Factor of Safety	Figure
West Wall – Highway 400 SBL		
Existing embankment slope (overall)	1.35	E1
Two-tier gabion wall	1.2	E2
Gabion wall with one row of anchors at 1 m spacing centre-to-centre	1.6	E3
Two-tier gabion wall (on organics)	1.05	E4
Gabion wall (on organics) with one row of anchors at 1 m spacing centre-to-centre	1.4	E5
East Wall – Highway 400 NBL		
Existing embankment slope (overall)	1.4	E6
Two-tier gabion wall	1.2	E7
Gabion wall with one row of anchors at 1 m spacing centre-to-centre	1.5	E8

Two-tier gabion wall (on organics)	1.0	E9
Gabion wall (on organics) with one row of anchors at 1 m spacing centre-to-centre	1.3	E10
West Wall – Highway 400 SBL		
Embankment slope (overall) after regrading to 2H : 1V behind gabions	1.25	E11
Lower embankment slope (local) after regrading to 2H : 1V behind gabions	1.4	E12
East Wall – Highway 400 NBL		
Embankment slope (overall) after regrading to 2H : 1V behind gabions	1.1	E13
Lower embankment slope (local) after regrading to 2H : 1V behind gabions	1.15	E14

The above results indicate that the overall embankment slopes satisfy global stability requirements with Factors of Safety (F.S.) greater than 1.3 for long term conditions. Locally, the cases for the existing two-tier gabion walls on the west and east sides yield F.S. of 1.2 which indicates potential displacement. It is anticipated that one row of anchors would increase the F.S. up to 1.5 against local instability. If the gabion walls are indeed founded on a layer of organics, the F.S. would have decreased to the order of 1 which indicates potential failure. The anchors would again increase the F.S. to enhance stability.

At the west wall, if localized regrading is carried out on the embankment slopes retained by the gabions to 2H : 1V from a flatter inclination, the F.S. for local stability on the lower slope would be increased from 1.2 to 1.4, while the F.S. for global stability of the overall slope would be reduced from 1.35 to 1.25. This lower F.S. value, while less than 1.3, is considered acceptable given the circumstances. Once the slope regrading is carried out and the backside of the upper tier of gabions is free of retained soil, consideration may be given to removing these upper gabions (scenario assumed in Figures E11 and E12). However, the implications of this removal on the integrity of the remaining gabion wall must be analysed prior to implementation.

Based on the borehole information and limited wall data, it is anticipated that the gabions could be founded on the stiff to very stiff clayey silt fill or compact sands and silts. These soils are expected to provide sufficient bearing resistance for the gabions.

Based on the above analysis results, site and subsurface conditions, it is considered that the observed gabion wall distress can be attributed to one or some combination of the following:

- There is potential for settlement, tilting and sliding of the gabion baskets if they were actually founded on or just above the organics layer encountered in some of the boreholes, or on disturbed subgrade.
- Each of the gabion walls is to retain an embankment with a 2H : 1V which exert significant lateral pressure. The existing gabion wall cross section is unknown. It is, however, possible that the existing wall design is insufficient to retain the slope, which could result in the observed distress.
- The breakage of one of the gabion baskets above the culvert inlet is anticipated to have contributed at least to some of the observed wall distress and movement.

8.3 Alternatives for Remediation

This section presents discussions on alternatives for remediation of the gabion wall.

It is understood that there are environmental concerns regarding the access of the creek floodplain for construction purposes. However, depending on the selected remediation option, construction access on the floodplain may be inevitable for some of the work.

Consideration was given to the following alternatives:

- Monitoring and repair - repair the broken gabion basket and monitor potential further movement;
- Mechanical anchors – provide anchorage to gabions for enhancing stability;
- Local slope regrading on the west side – enhance local stability without jeopardizing overall stability;
- Gabion reconstruction.

The above alternatives have been considered based on no design or construction/as-built information for the gabion wall. It is recommended that MTO be asked to reconfirm that there is indeed no such information available. In addition, a designer must check that the current wall is adequate in withstanding the lateral earth pressure exerted by the slope. Table 8.2 below provides recommended geotechnical parameters for assessing overturning and sliding.

Table 8.2 – Recommended Geotechnical Parameters

Soil Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (°)	Active Earth Pressure, K_a (2H : 1V)	Coefficient of Friction (unfactored)
Embankment Fill	18	0	30	0.54	0.35
Clayey Silt	18	2	30	0.54	0.35
Sands and Silts	20	0	30	0.54	0.35
Sand and Silt Till	21	0	33	0.45	0.45

The following presents discussions and recommendations of the above alternatives.

<u>Monitoring and Repair</u>

This alternative will involve the immediate repair of the broken gabion basket with lost stones above the culvert inlet. It is recommended that the repair works should not involve any slope regrading and that no equipment should access the floodplain level. One possible scheme would be to reinstate the stones inside the broken basket and repair the mesh using portable equipment and hand tools. The feasibility of other means such as shotcreting or grouting in conjunction with reinstating the stones should be explored for repairing the broken gabion basket.

After the broken gabion basket is repaired, it is recommended that survey targets and markers be installed for monitoring of potential further movements. Survey paint marks may be applied on selected locations on the gabion walls. Iron bars such as those used for property survey by the surveyors may be installed at selected locations on the slopes directly behind the gabion walls. Movement survey of these targets and markers should be carried out periodically. This instrumentation monitoring task has been incorporated into the Contract Administration (CA) assignment. Specifications and drawings for this monitoring program is included in Appendix F.

<u>Mechanical Anchors</u>

A feasible alternative to “monitoring and repair” is to install mechanical anchors on the upper row of gabions in order to enhance wall stability and minimize further wall movement. These anchors may be tied back to the embankment fill beyond the potential slip surface.

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Figures E3, E5, E8 and E10 in Appendix E are graphical representations of stability analysis results assuming a Chance helical soil anchor model SR-3 with the trade name Stingray. The effects of the tie-backs were modelled by one row of anchors with a minimum anchor length of 6m behind the face of the gabion wall, an anchor spacing of 1 m along the wall alignment and an allowable tie-back load of 70 kN. The increase in F.S. through the use of anchors indicates that the long term stability of the gabion wall can be enhanced.

Local Slope Regrading – West Side Only

Consideration may be given to locally regrading the west embankment slope retained by the gabions to 2H : 1V from an existing flatter inclination. This scheme is intended to reduce the lateral pressures acting on the upper tier of gabions in order to decrease the potential of further wall movement. This option may be considered should the monitoring data from the CA assignment (see monitoring and repair option above) indicate further continuing wall/slope movement and all parties concerned decide to proceed with further remedial measures.

At the east wall, a similar regrading would result in F.S. in the order of 1.1 to 1.15 which are not acceptable. This regrading scheme is, therefore, not applicable on the east side.

Gabion Redesign and Reconstruction

Another alternative is to demolish the existing walls and replace them with completely redesigned new walls. This alternative will likely involve roadway protection (temporary shoring) to maintain stability of the back slopes behind the walls. The cost-effectiveness of this alternative and its implications on environmental concerns will need to be evaluated by the designer.

The recommended geotechnical parameters in Table 8.2 above may be used for designing the new gabion walls. Additional foundation analyses and recommendations including global slope stability analysis and roadway protection design will be required for detail design.

Preferred Alternative

Given that the monitoring program is in place as part of the CA assignment and the recent teleconference discussions by all parties concerned, it is considered that the “Monitoring and Repair” option is the preferred option unless further, excessive movements occur as indicated by the monitoring data. A provision has been included in the monitoring specifications to hold a teleconference amongst all parties concerned after one year of monitoring to discuss subsequent course of action regarding the gabion walls.

8.4 Preliminary Design of Helical Anchors

The gabion walls may be tied back within the stiff to very stiff embankment fill. As a guide, helical soil anchors such as the Stingray marketed by Williams, helical tiebacks marketed by Chance, or equivalent mechanical anchors may be considered. Taking into consideration the physical constraints at this site, the anchorage should only be provided to the upper tier of the gabion wall. The axial design capacities may be selected from the available products. The anchors could be spaced at 1 m intervals (one anchor per gabion basket) along the wall alignment with a rod length of 6 m and at a nominal angle of 30°. Proprietary suppliers/installers of this type of anchors should be consulted prior to finalizing the design. Proof testing of each anchor and installation requirements must be in accordance with the applicable guidelines.

9. CONSTRUCTION CONCERNS

- From a foundation engineering perspective, concerns during the remediation or reconstruction works include maintaining stability of the embankment slopes and the integrity of the gabions and the adjacent culvert.

- Other concerns include environmental restrictions on access onto the creek floodplain and erosion control during construction.

10. CLOSURE

Engineering analysis was carried out by Mr. Pouya Pishgah, P.Eng. and report preparation was carried out by Dr. Sydney Pang, P.Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.

THURBER

60 YEARS

Thurber Engineering Ltd.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT[(1)] 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

EXPLANATION OF ROCK LOGGING TERMS

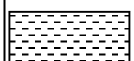
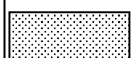
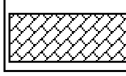
ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
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 structure are preserved.

DISCONTINUITY SPACING

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength (MPa)**	**(psi)**	**Field Estimation of Hardness***
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

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 0.1m in length or larger as a % of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index:(FI)	Frequency of natural fractures per 0.3m of core run.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	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	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and 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. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-01

METRIC

GWP# 2085-13-00 | LOCATION Gabion Walls N 4 871 171.4 E 298 318.0 | ORIGINATED BY ES

HWY 400 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.03.13 - 2017.03.13 | CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
310.9	GROUND SURFACE					
0.0 / 0.1	**TOPSOIL:** (100mm)					
310.4 / 0.5	**SAND**, some silt, trace gravel, trace roots; Loose; Brown; Frozen; (FILL)	1	SS	7		
309.8 / 1.1	**ORGANICS**, mixed with sandy silt, trace clay and wood fibres; Compact; Brown; Moist	2	SS	17	310	
	SAND, some silt, trace gravel, with wood fibres; Compact; Brown; Moist	3	SS	20	309	
308.6 / 2.3	**SAND** and **SILT**, trace gravel; Compact to Dense; Brown; Wet	4	SS	20		0 58 36 6
		5	SS	14	308	
		6	SS	34	307, 306	4 49 42 5
305.4 / 5.5	**SAND** and **SILT**, trace gravel; Very Dense; Grey; Moist; (TILL)	7	SS	71	305	4 48 38 10
303.7 / 7.2	Clayey **SILT**, some sand, trace gravel; Hard; Grey; Moist; (TILL)	8	SS	90	304, 303	
		9	SS	87	302	
301.3 / 9.6	END OF BOREHOLE AT 9.6m. WATER LEVEL AT 3.2m UPON					

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 – 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S MTO-12187.GPJ 2015TEMPLATE(MTO).GDT 4/4/17

RECORD OF BOREHOLE No GW17-01

METRIC

GWP#	2085-13-00	LOCATION	Gabion Walls N 4 871 171.4 E 298 318.0	ORIGINATED BY	ES
HWY	400	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	AN
DATUM	Geodetic	DATE	2017.03.13 - 2017.03.13	CHECKED BY	PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	COMPLETION. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.03.28 0.7 310.2										

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GW17-02

METRIC

GWP# 2085-13-00 LOCATION Gabion Walls N 4 871 173.4 E 298 325.0 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN

DATUM Geodetic DATE 2017.03.15 - 2017.03.16 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
313.7	GROUND SURFACE								
0.0 / 313.4 / 0.3	**TOPSOIL**, trace roots, wood fibres, Loose, Dark Brown, Frozen	1	SS	6					
	Silty **CLAY**, some sand, trace gravel, trace rootlets, Very Stiff, Dark Brown to Brown, Frozen to Wet (FILL)	2	SS	23					
312.3 / 1.4	Hard	3	SS	111		3	37	35	25
311.6 / 2.1	Dark Grey, Wet	4	SS	22					
		5	SS	16		3	25	45	27
310.0 / 3.7	Sandy **SILT**, trace gravel, trace rootlets, Dense to Compact, Dark Brown, Moist	6	SS	36					
309.1 / 4.6	**SAND**, some silt, trace gravel, Very Dense, Dark Grey, Wet	7	SS	81					
308.6 / 5.1	**SAND** and **SILT**, trace clay, trace gravel, Very Dense, Brown, Moist	8	SS	78					
		9	SS	76					
307.4 / 6.3		10	SS	100/ 0.175		0	43	50	7

Elevation scale: 313, 312, 311, 310, 309, 308

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

END OF BOREHOLE AT 6.3m.
Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.03.28	1.5	312.2

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-03

METRIC

GWP# 2085-13-00 LOCATION Gabion Walls N 4 871 177.6 E 298 336.1 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.07 - 2017.03.07 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
317.6	GROUND SURFACE										
0.0	**ASPHALT:** (150mm)										
0.2	**SAND**, trace gravel, Brown, Moist (FILL)	1	GS			317					
316.8 / 0.8	Sandy **SILT**, trace clay, trace gravel, Compact, Brown, Moist (FILL)	1	SS	12							
		2	SS	13		316					
315.3 / 2.3	Silty **CLAY**, some sand, trace gravel, Very Stiff, Brown, Moist (FILL)	3	SS	18		315		5	21	46	28
		4	SS	18		314					
313.0 / 4.6	Stiff	5	SS	9		313					
		6	SS	11		312, 311					
310.3 / 7.3	Clayey **SILT**, some sand, trace gravel, trace organics, topsoil stained, Very Stiff, Dark Grey, Moist	7	SS	22	∇	310, 309		3	40	40	17
308.4 / 9.2	**SAND** and **SILT**, some gravel, trace clay, Compact, Brown - Wet, Gravelly sand seam (75mm) at 9.5m	8	SS	21		308					

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-03

METRIC

GWP# 2085-13-00 LOCATION Gabion Walls N 4 871 177.6 E 298 336.1 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.07 - 2017.03.07 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	Continued From Previous Page									
	SAND and **SILT**, some gravel, trace clay Compact Brown Wet				307					
		9	SS	27		~20	14	40	41	5
306.0 11.6	**SAND** and **SILT**, some clay, trace gravel Very Dense Brown to Grey Moist (TILL)				306					
		10	SS	69	305	~10				
					304					
		11	SS	79		~10	3	44	41	12
					303					
301.9		12	SS	61	302	~10				
15.7	END OF BOREHOLE AT 15.7m. WATER LEVEL AT 8.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CEMENT TO 0.1m, THEN ASPHALT TO SURFACE.									

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL).

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-04

METRIC

GWP# 2085-13-00 | LOCATION Gabion Walls N 4 871 171.4 E 298 369.3 | ORIGINATED BY ES

HWY 400 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.03.08 - 2017.03.08 | CHECKED BY PP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
317.6	GROUND SURFACE							
0.0	**ASPHALT:** (175mm)							
0.2	**SAND**, trace gravel Compact Brown Moist (FILL)		1	GS			317	
			1	SS	13			
316.5 1.1	Silty **CLAY**, some sand, trace gravel Stiff to Very Stiff Brown Moist (FILL)		2	SS	9		316	
			3	SS	17		315	
			4	SS	17		314	1 27 41 31
			5	SS	13		313	
			6	SS	13		312, 311	
310.4 7.2	**SILT**, trace clay, trace sand, trace gravel, trace rootlets Compact Brown Moist		7	SS	18		310	
			8	SS	20		309, 308	0 6 87 7

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-04

METRIC

GWP# 2085-13-00 | LOCATION Gabion Walls N 4 871 171.4 E 298 369.3 | ORIGINATED BY ES

HWY 400 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY AN

DATUM Geodetic | DATE 2017.03.08 - 2017.03.08 | CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							
	SILT, some clay, trace sand, trace gravel Compact Grey Wet					307		
		9	SS	22			o	1 3 83 13
					▽	306		
		10	SS	24		305	o	
304.3 13.3	**SAND** and **SILT**, some clay, trace gravel Very Dense Grey Moist (TILL)					304		
		11	SS	66			o	3 45 40 12
						303		
302.0		12	SS	100/ 0.250		302	o	
15.6	END OF BOREHOLE AT 15.6m. WATER LEVEL AT 11.4m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CEMENT TO 0.2m, THEN ASPHALT TO SURFACE.							

Chart legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100. PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60. UNIT WEIGHT γ kN/m³.

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No GW17-05

METRIC

GWP# 2085-13-00 LOCATION Gabion Walls N 4 871 172.4 E 298 380.0 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Tripod COMPILED BY AN

DATUM Geodetic DATE 2017.03.16 - 2017.03.17 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
314.0	GROUND SURFACE									
0.0	**TOPSOIL:** (125mm)									
0.1	Sandy **SILT**, some gravel, trace roots Loose Dark Brown Moist (FILL)	1	SS	6		o				
313.4 / 0.6	Silty **SAND**, some clay, trace gravel Compact Brown Wet (FILL)	2	SS	11	313	o				
		3	SS	19		o	8	47	32	13
		4	SS	17	312	o				
311.6 / 2.4	Clayey **SILT**, some sand, trace gravel, trace organics and rootlets Hard to Very Stiff Brown Wet (FILL)	5	SS	38	311	o				
		6	SS	24		o				
		7	SS	33	310	o	0	38	45	17
		8	SS	27		o				
309.1 / 4.9	**SILT**, some sand, trace clay, trace gravel, mixed with organics, occasional wood fibres Compact to Very Dense Brown Wet	9	SS	24	309					
		10	SS	129/ 0.150						
308.0		11	SS	116/ 0.175			8	16	68	8
6.0	END OF BOREHOLE AT 6.0m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.									

WATER LEVEL READINGS

DATE	DEPTH(m)	ELEV.(m)
2017.03.28	1.5	312.5

Chart headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%); STRAT PLOT; GROUND WATER CONDITIONS.

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GW17-06

METRIC

GWP# 2085-13-00	LOCATION Gabion Walls N 4 871 173.4 E 298 389.0		ORIGINATED BY ES
HWY 400	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY AN
DATUM Geodetic	DATE 2017.03.10 - 2017.03.10		CHECKED BY PP

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

ELEV / DEPTH	DESCRIPTION
309.9	GROUND SURFACE
0.0	**TOPSOIL**, trace roots and rootlets: (100mm)
309.8 / 0.1	Sandy **SILT**, trace clay, trace gravel, trace roots Very Loose to Compact Brown to Grey Moist (FILL)
308.9 / 1.0	**ORGANICS**, mixed with clayey silt, trace sand Stiff Dark Grey to Dark Brown Moist
308.1 / 1.8	Clayey **SILT**, trace sand Stiff Grey Moist Black sand seam
305.9 / 4.0	**SAND** and **SILT**, trace clay Loose Grey Saturated
304.3 / 5.6	**SAND** and **SILT**, trace clay, trace gravel Very Dense Grey Moist (TILL) Some clay to clayey
300.3 / 9.6	END OF BOREHOLE AT 9.6m. WATER LEVEL AT 2.7m UPON

SAMPLE NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	3				
2	SS	14				
3	SS	12				
4	SS	14	0	3	77	20
5	SS	13				
6	SS	9	0	53	40	7
7	SS	51	2	46	44	8
8	SS	75				
9	SS	93				

Elevation scale: 309, 308, 307, 306, 305, 304, 303, 302, 301

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No GW17-06

METRIC

GWP# 2085-13-00 LOCATION Gabion Walls N 4 871 173.4 E 298 389.0 ORIGINATED BY ES

HWY 400 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2017.03.10 - 2017.03.10 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	Continued From Previous Page										
	COMPLETION. Well installation consists of 50mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.03.28 0.7 309.2										

$+^3, \times^3$: Numbers refer to Sensitivity

15-⊕-5 (20 / 10) (%) STRAIN AT FAILURE

Appendix B

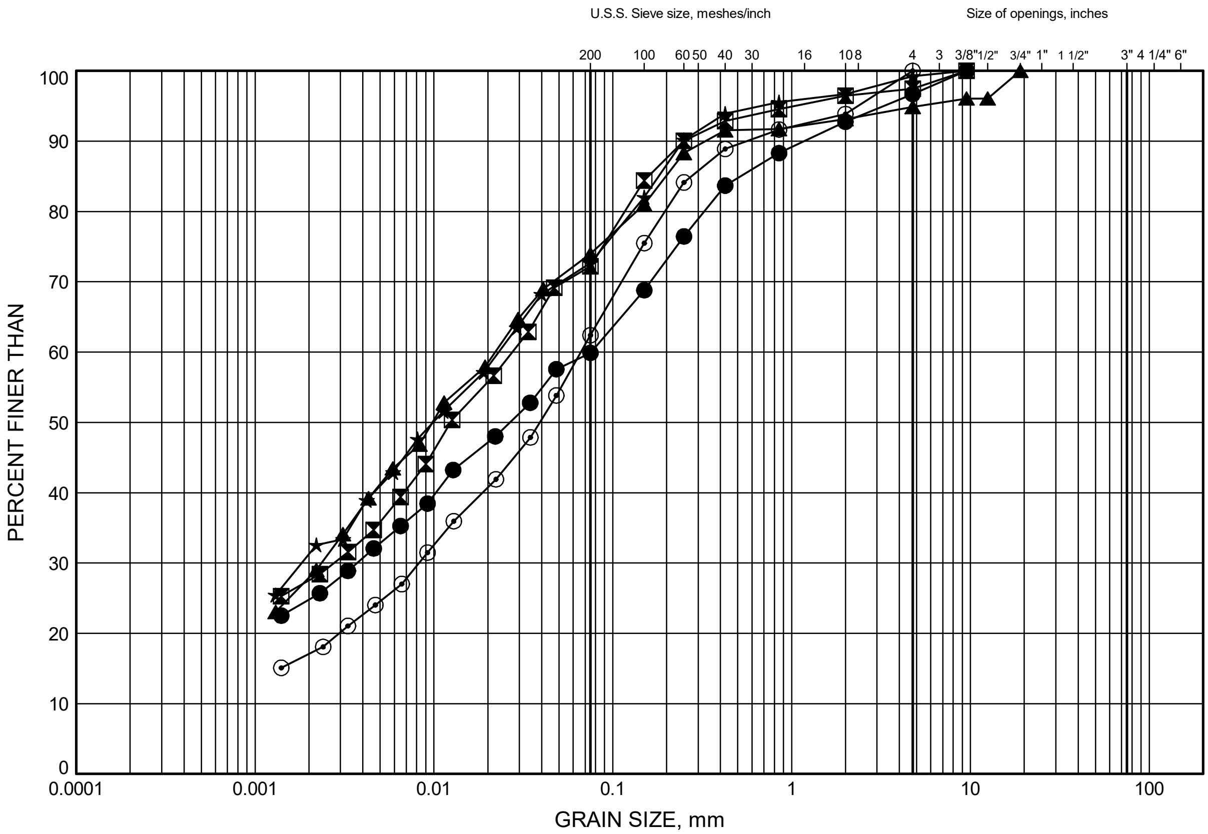
Laboratory Test Results

Gabion Walls

GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty Clay to Clayey Silt Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-02	1.75	311.95
⧗	GW17-02	3.35	310.35
▲	GW17-03	2.51	315.09
★	GW17-04	3.28	314.32
⊙	GW17-05	3.96	310.04

Date April 2017

GWP# 2085-13-00

THURBER

Prep'd MFA

Chkd. SKP

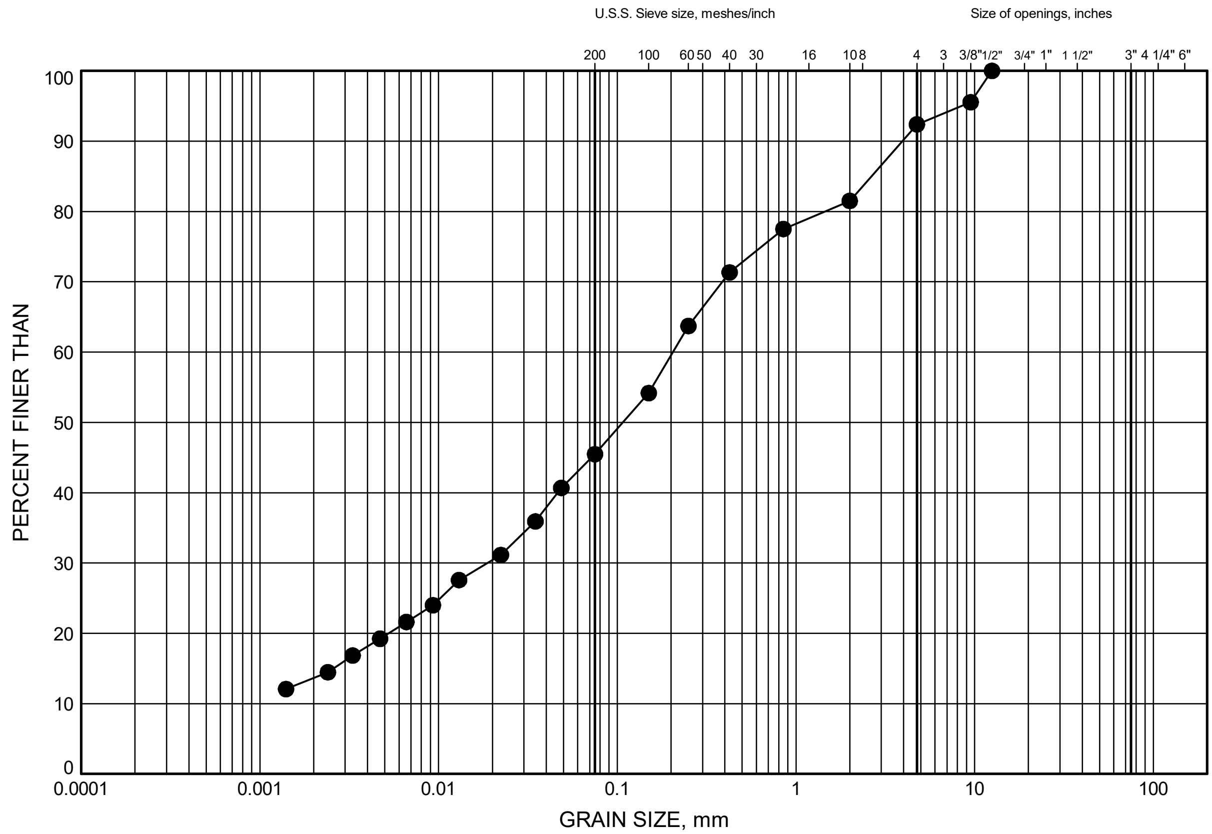
GRAIN SIZE DISTRIBUTION - THURBER MTO-12187.GPJ 4/3/17

Gabion Walls

GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty Sand Fill



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-05	1.52	312.48

Date April 2017

GWP# 2085-13-00

THURBER

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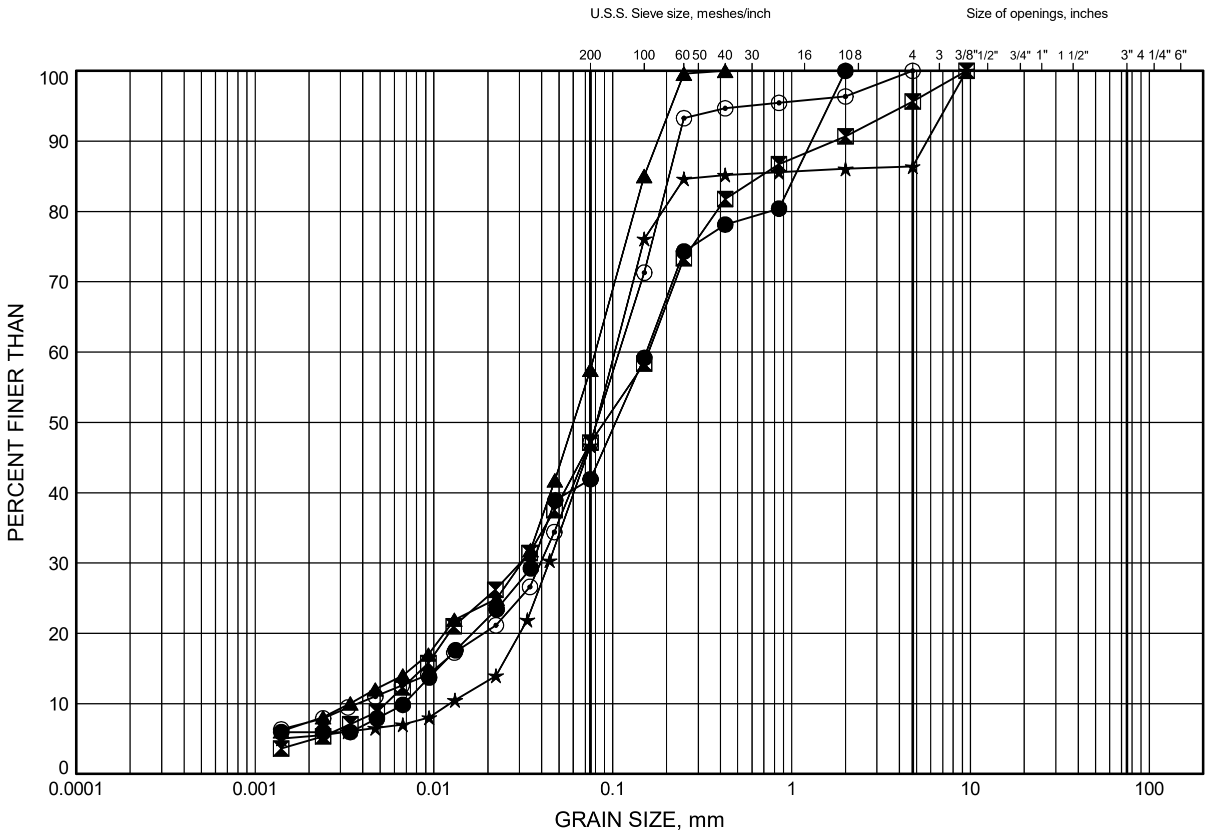
Chkd. SKP

Gabion Walls

GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty Sand to Sandy Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-01	2.59	308.31
⧗	GW17-01	4.88	306.02
▲	GW17-02	6.18	307.52
★	GW17-03	10.90	306.70
⊙	GW17-06	4.88	305.02

GRAIN SIZE DISTRIBUTION - THURBER MTO-12187.GPJ 4/3/17

Date April 2017

GWP# 2085-13-00

THURBER

Prep'd MFA

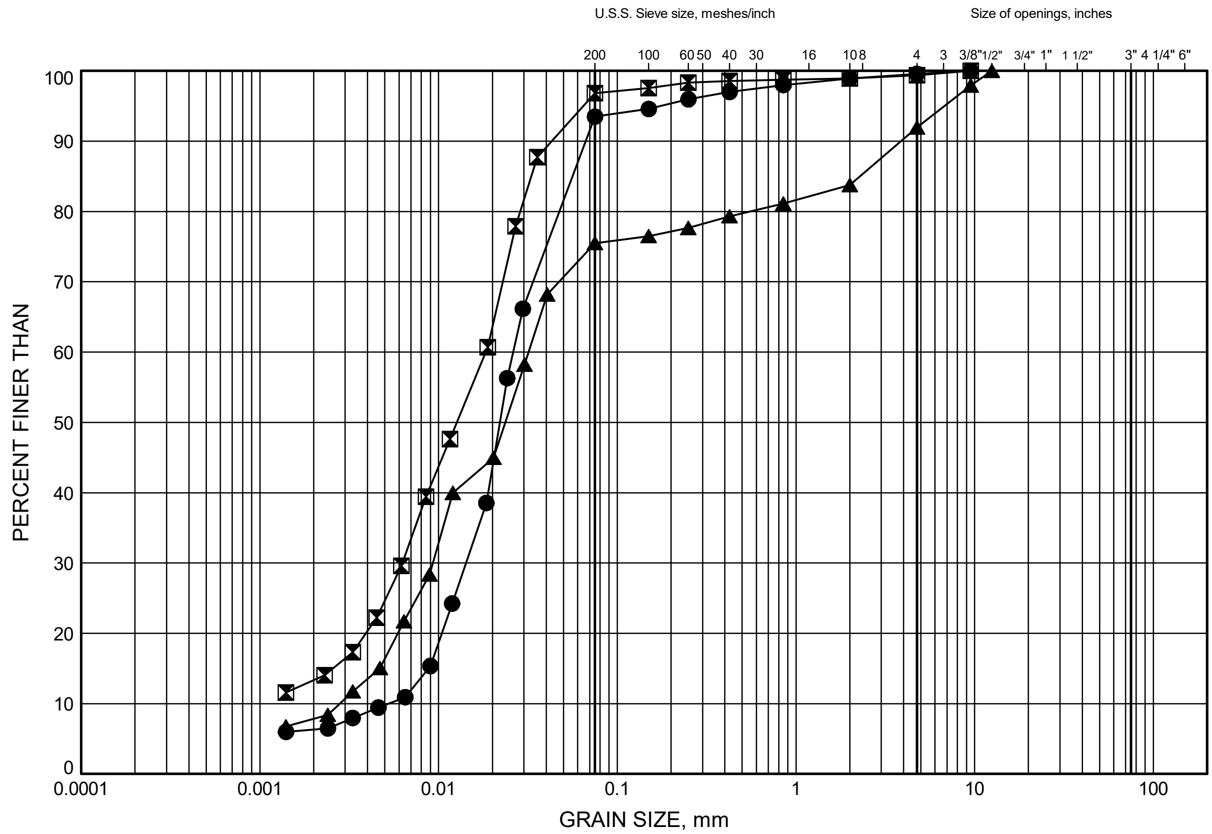
Chkd. SKP

Gabion Walls

GRAIN SIZE DISTRIBUTION

FIGURE B4

Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-04	9.37	308.23
⊠	GW17-04	10.90	306.70
▲	GW17-05	5.80	308.20

Date April 2017

GWP# 2085-13-00

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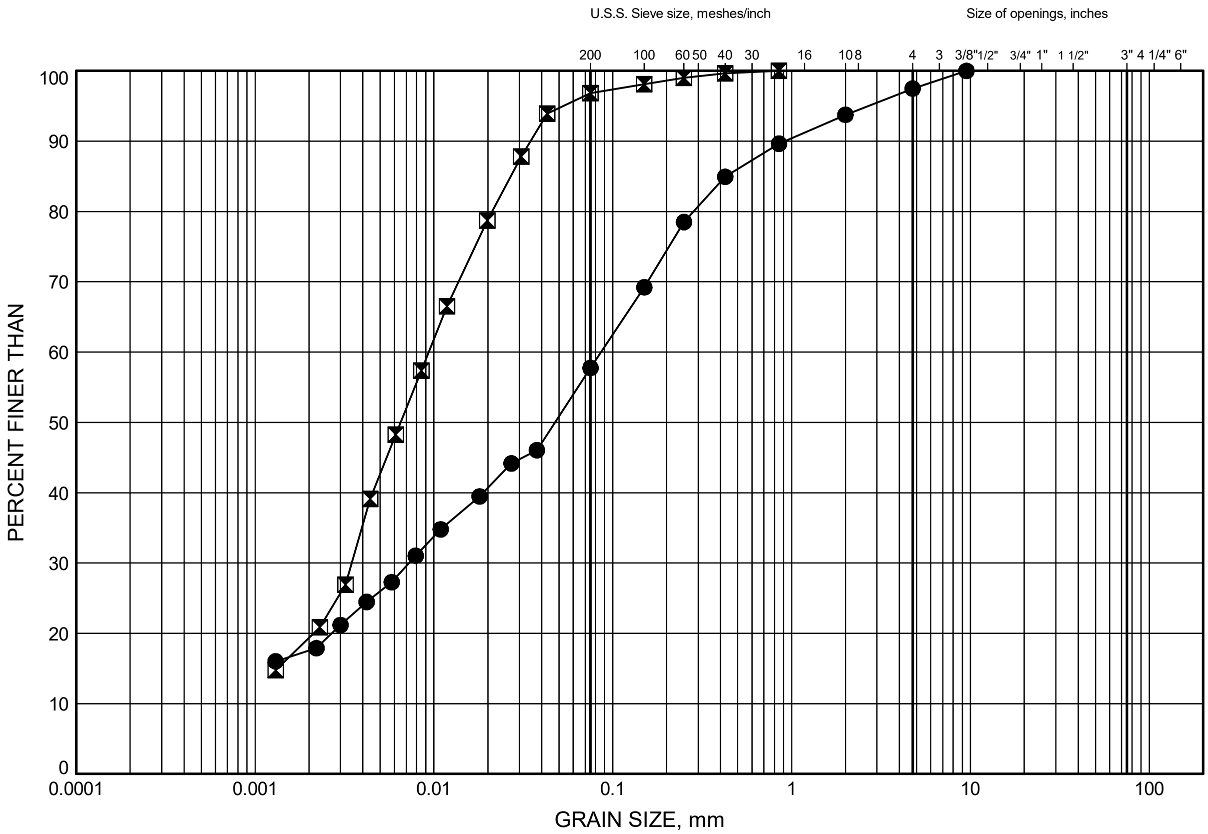
Gabion Walls
GRAIN SIZE DISTRIBUTION

FIGURE B5

Clayey Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-03	7.85	309.75
⧗	GW17-06	2.51	307.39

Date April 2017

GWP# 2085-13-00

THURBER

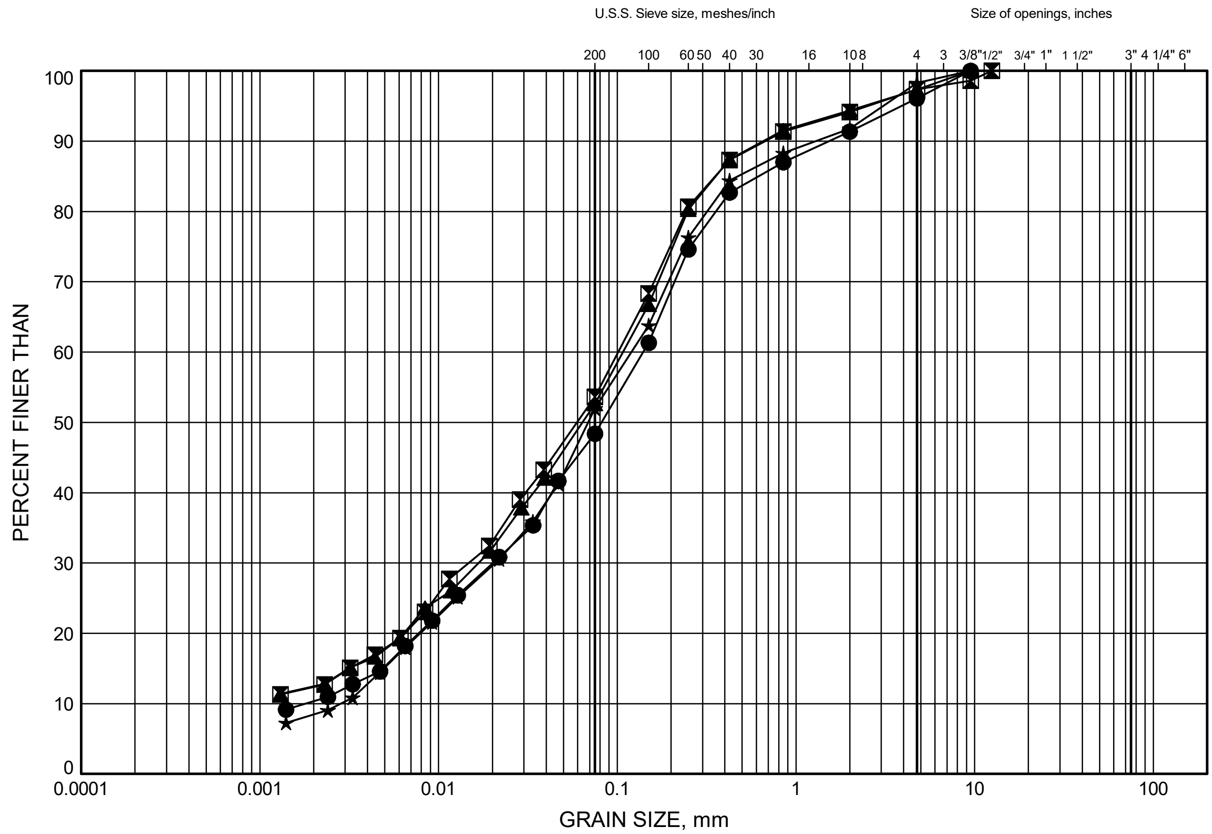
Prep'd MFA

Chkd. SKP

GRAIN SIZE DISTRIBUTION

FIGURE B6

Sand and Silt Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-01	6.32	304.58
⧗	GW17-03	13.94	303.66
▲	GW17-04	13.94	303.66
★	GW17-06	6.32	303.58

Date April 2017

GWP# 2085-13-00

THURBER

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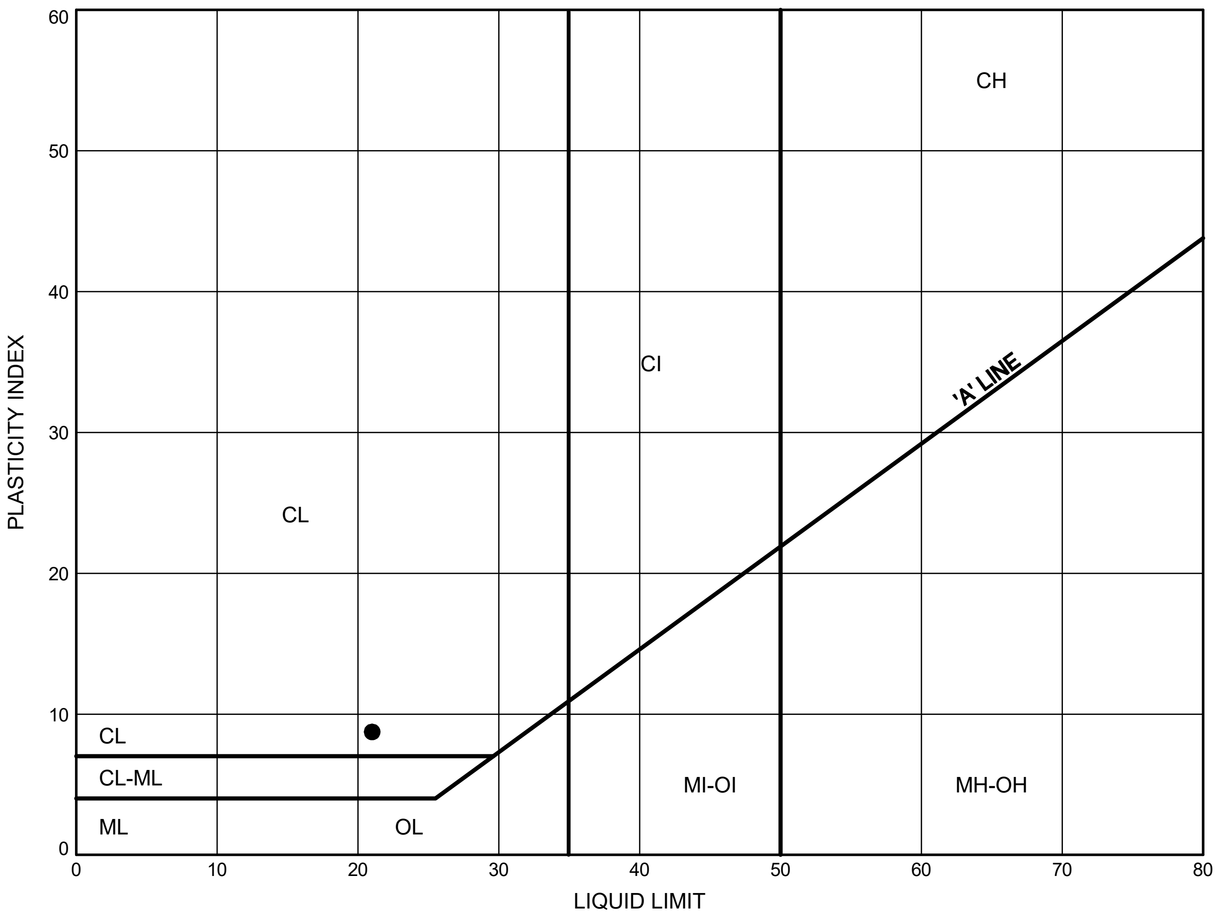
Gabion Walls

ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty Clay Fill



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-02	3.35	310.35

THURBALT MTO-12187.GPJ 4/3/17

Date April 2017

GWP# 2085-13-00

THURBER

Prep'd MFA

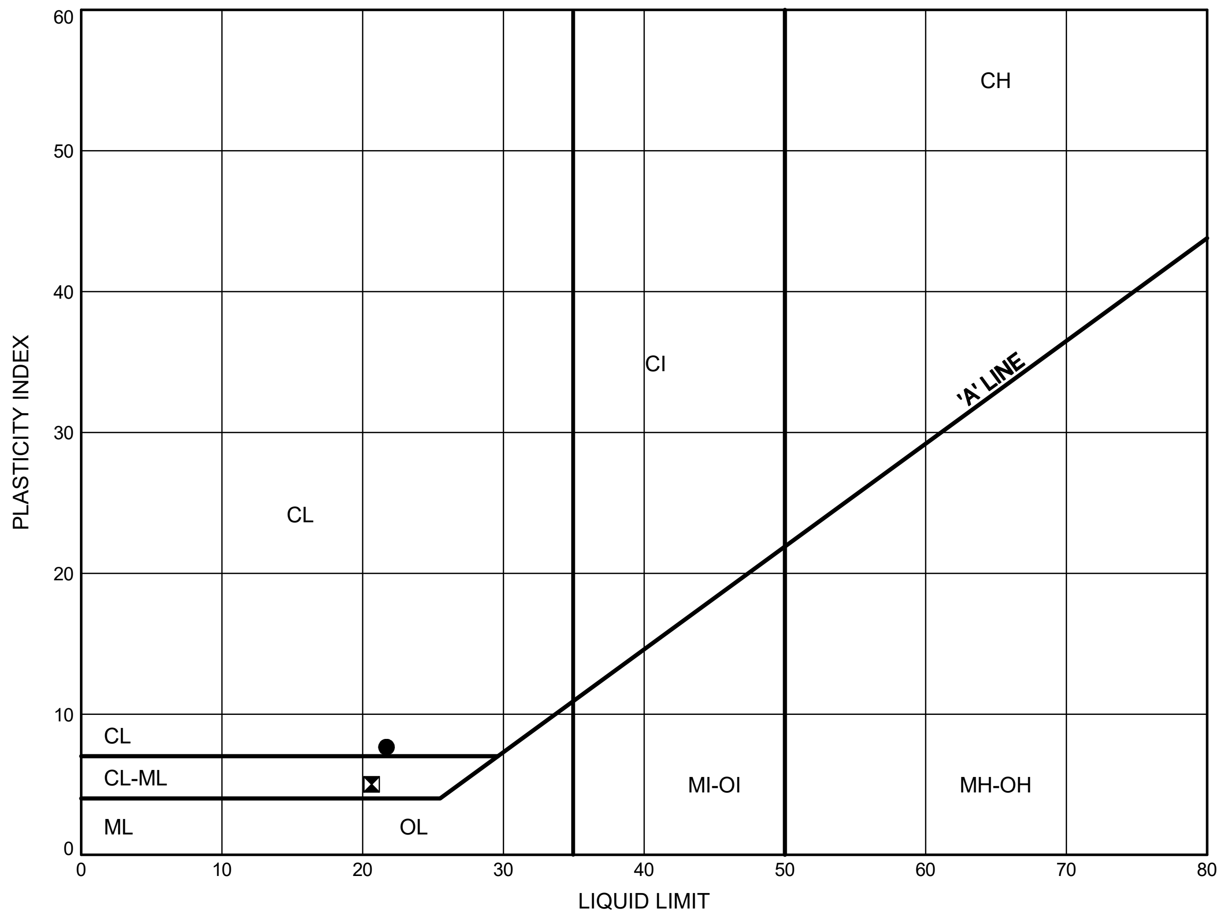
Chkd. SKP

Gabion Walls

ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Clayey Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	GW17-03	7.85	309.75
⊠	GW17-06	2.51	307.39

THURBALT MTO-12187.GPJ 4/3/17

Date April 2017

GWP# 2085-13-00

THURBER

Prep'd MFA

Chkd. SKP

Appendix C

Borehole Locations and Soil Strata Drawing

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

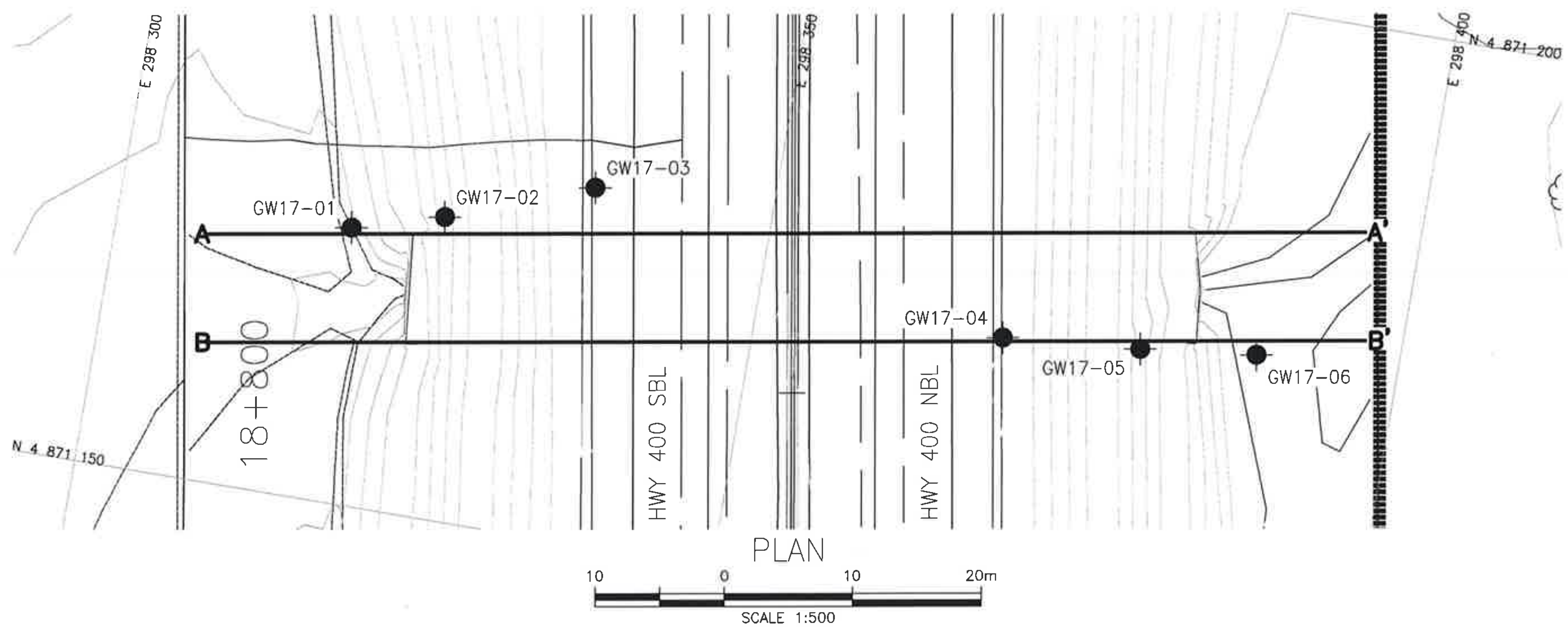
CONT No
GWP No 2085-13-00

SHEET

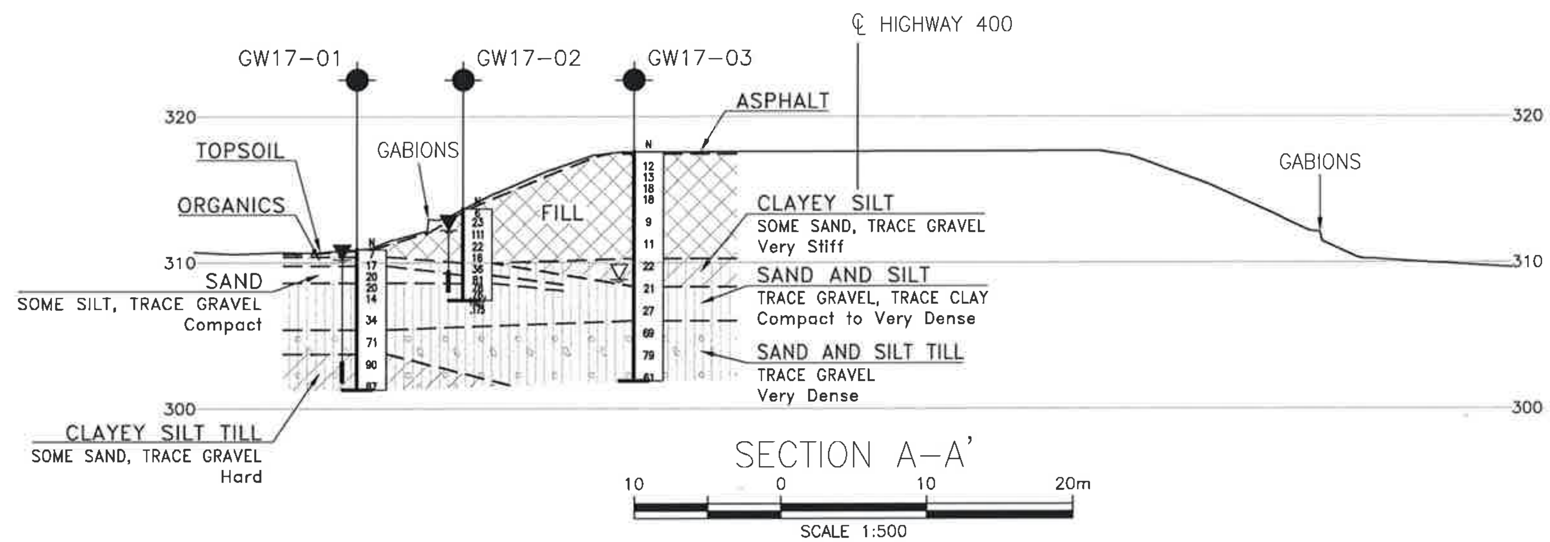
HIGHWAY 400
NORTH OF 17th SIDEROAD
GABION WALLS
BOREHOLE LOCATIONS AND SOIL STRATA

WSP

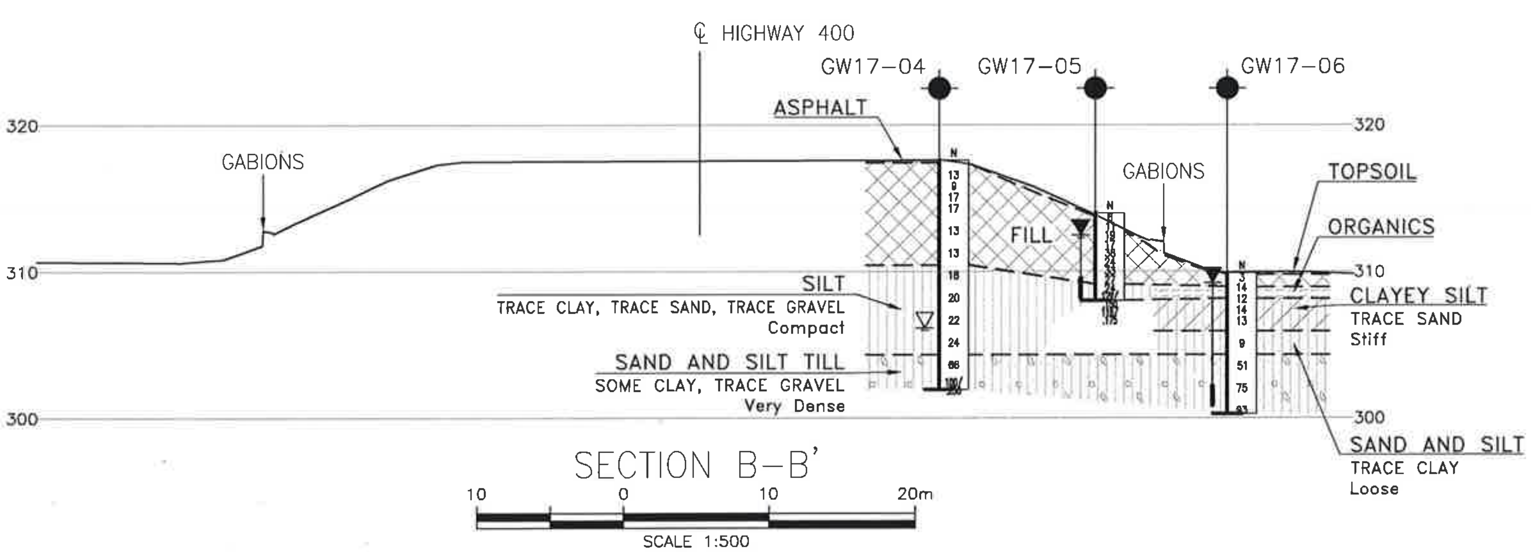
THURBER ENGINEERING LTD.



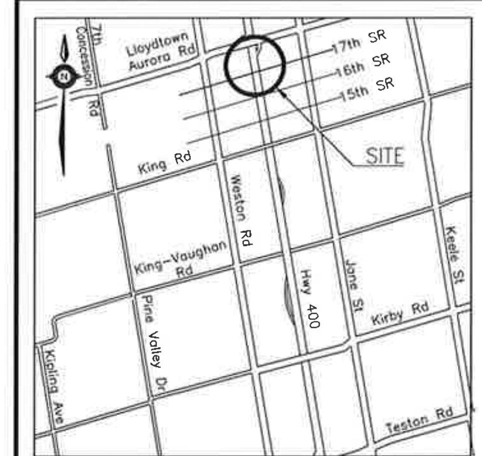
PLAN



SECTION A–A'



SECTION B–B'



KEYPLAN

LEGEND

Symbol	Description
●	Borehole (Current Investigation)
⊕	Borehole (Previous Investigation)
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
GW17-01	310.9	4 871 171.4	298 318.0
GW17-02	313.7	4 871 173.4	298 325.0
GW17-03	317.6	4 871 177.6	298 336.1
GW17-04	317.6	4 871 171.4	298 369.3
GW17-05	314.0	4 871 172.4	298 380.0
GW17-06	309.9	4 871 173.4	298 389.0

-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. 30M13-221

REVISIONS	DATE	BY	DESCRIPTION

DESIGN PP	CHK PKC	CODE	LOAD	DATE JUN 2017
DRAWN MFA	CHK PP	SITE	STRUCT	DWG 1

FILENAME: H:\Drafting\12000\12187\TED-12187-PLPR-GW.dwg
PLOTDATE: 6/27/2017 12:21 PM

MINISTRY OF TRANSPORTATION, ONTARIO

THURBER

60 YEARS

Appendix D

Selected Site Photographs

Photo 1 West Gabion Wall

Photo 2 East Gabion Wall

Appendix E

Selected Results of Stability Analyses

12187 HIGHWAY 400 - GABION WALL
WEST OF HIGHWAY 400 SBL
EXISTING CONDITION - OVERALL SLOPE

Name: EMBANKMENT FILL - Stiff to Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: CLAYEY SILT - Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 2 kPa   Phi: 30 °
Name: SANDS AND SILTS - Compact   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: SAND AND SILT TILL - Very Dense   Model: Mohr-Coulomb   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 33 °
Name: Gabion   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 10 kPa   Phi: 40 °

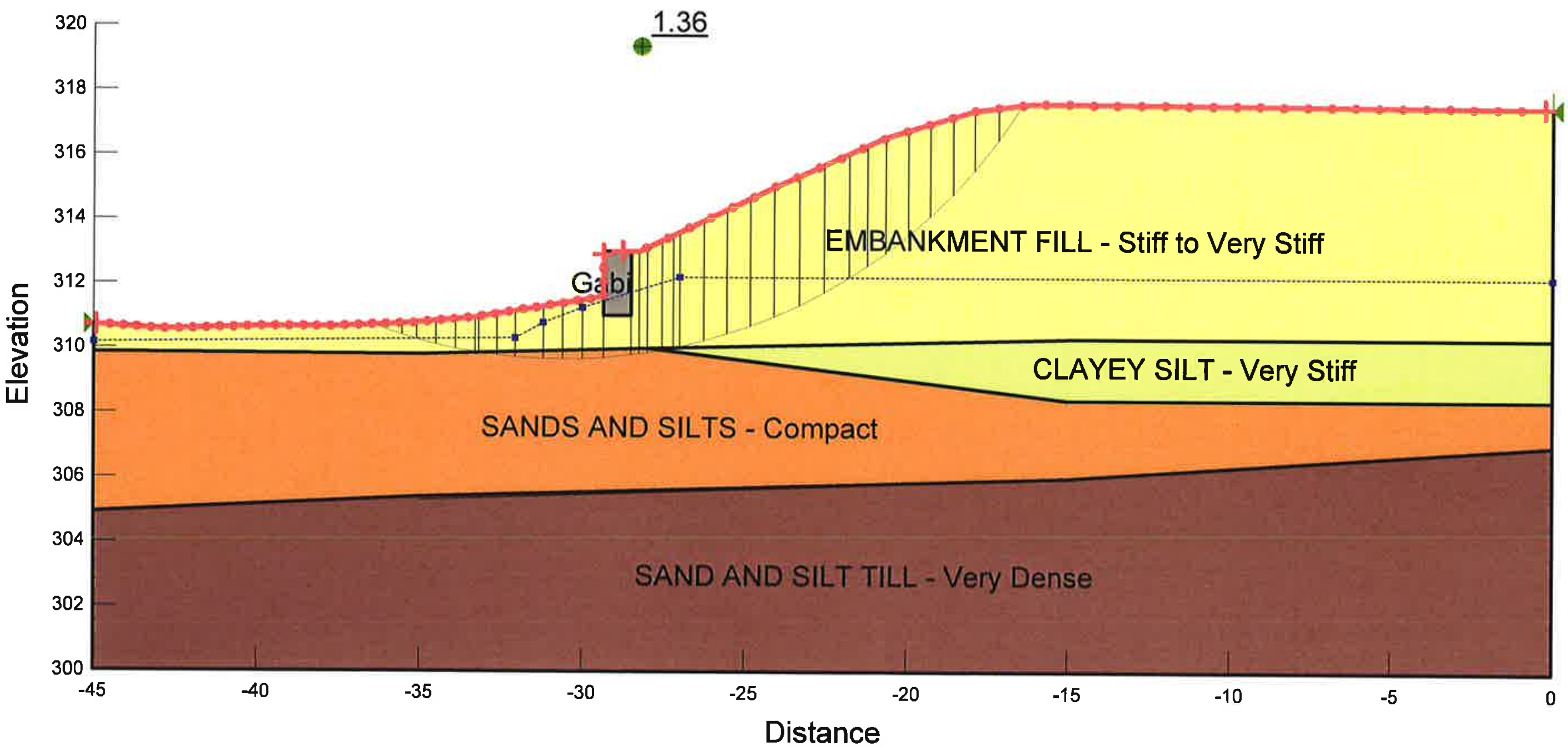


FIGURE E1

12187 HIGHWAY 400 - GABION WALL
WEST OF HIGHWAY 400 SBL
EXISTING CONDITION - GABIONS

Name: EMBANKMENT FILL - Stiff to Very Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: CLAYEY SILT - Very Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SANDS AND SILTS - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °

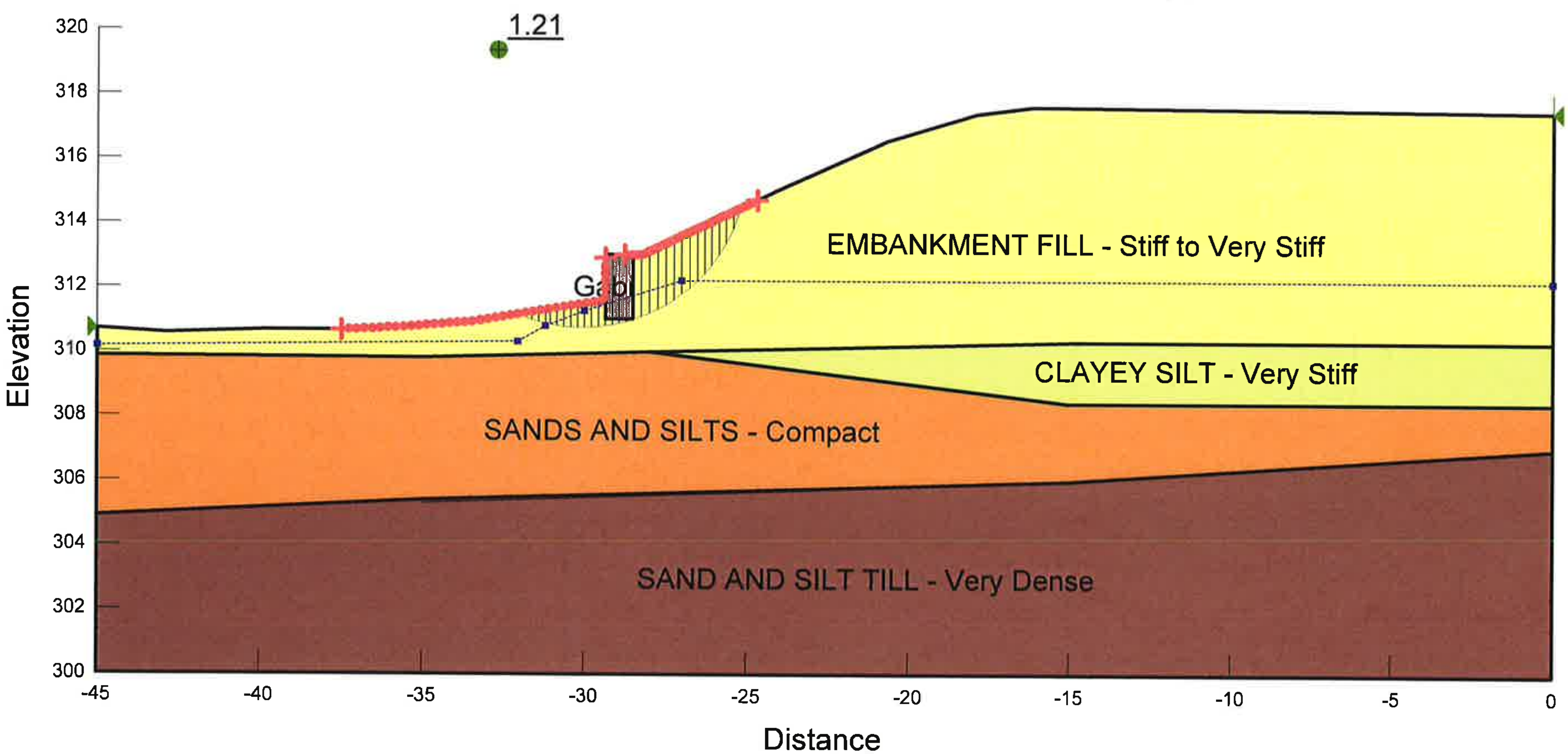


FIGURE E2

12187 HIGHWAY 400 - GABION WALL
WEST OF HIGHWAY 400 SBL
ANCHOR WITH 1 M SPACING

Name: EMBANKMENT FILL - Stiff to Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: CLAYEY SILT - Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 2 kPa   Phi: 30 °
Name: SANDS AND SILTS - Compact   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: SAND AND SILT TILL - Very Dense   Model: Mohr-Coulomb   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 33 °
Name: Gabion   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 10 kPa   Phi: 40 °

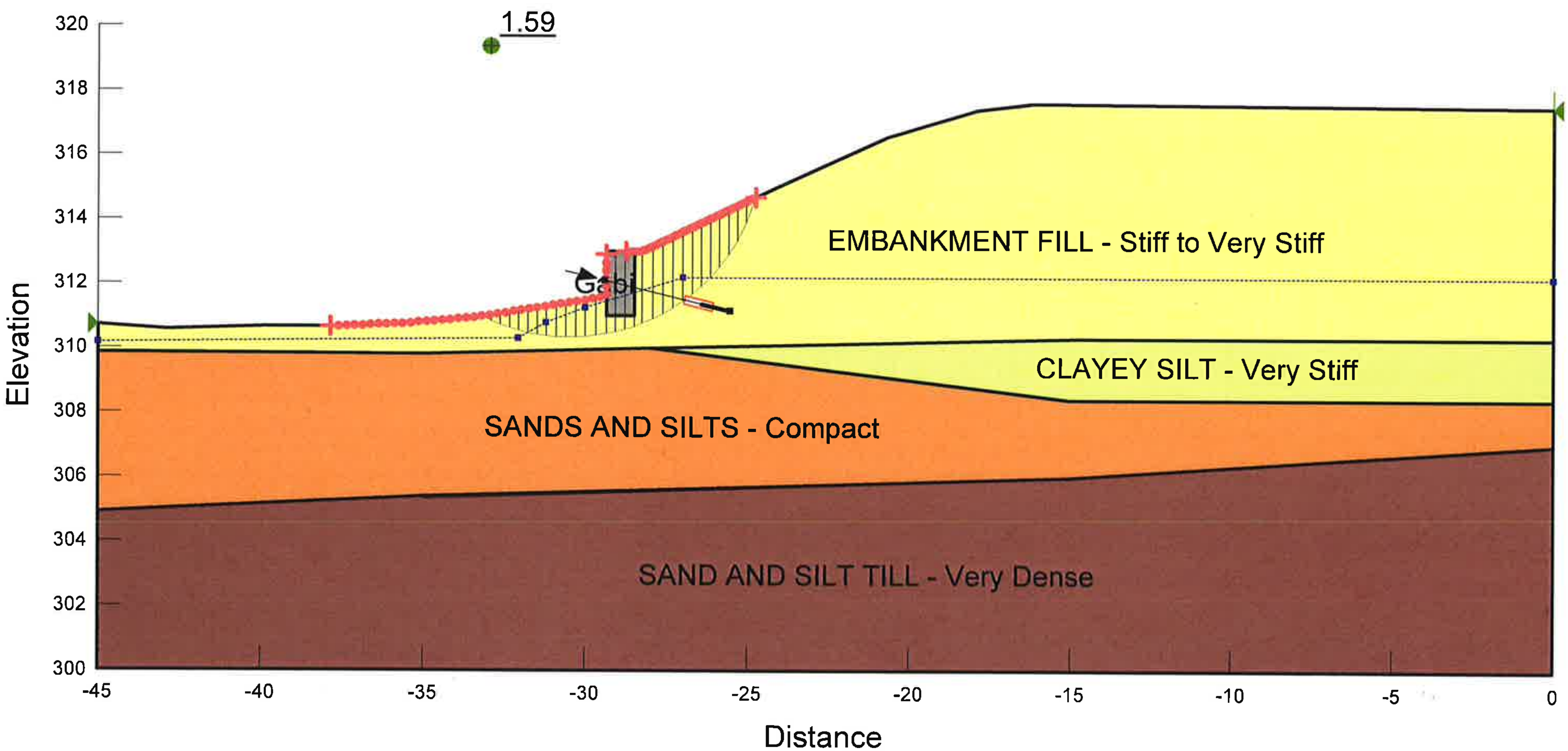


FIGURE E3

12187 HIGHWAY 400 - GABION WALL
WEST OF HIGHWAY 400 SBL
EXISTING CONDITION - GABIONS with Organic Layer

Name: EMBANKMENT FILL - Stiff to Very Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: CLAYEY SILT - Very Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SANDS AND SILTS - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °
Name: Organics Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion: 0 kPa Phi: 24 °

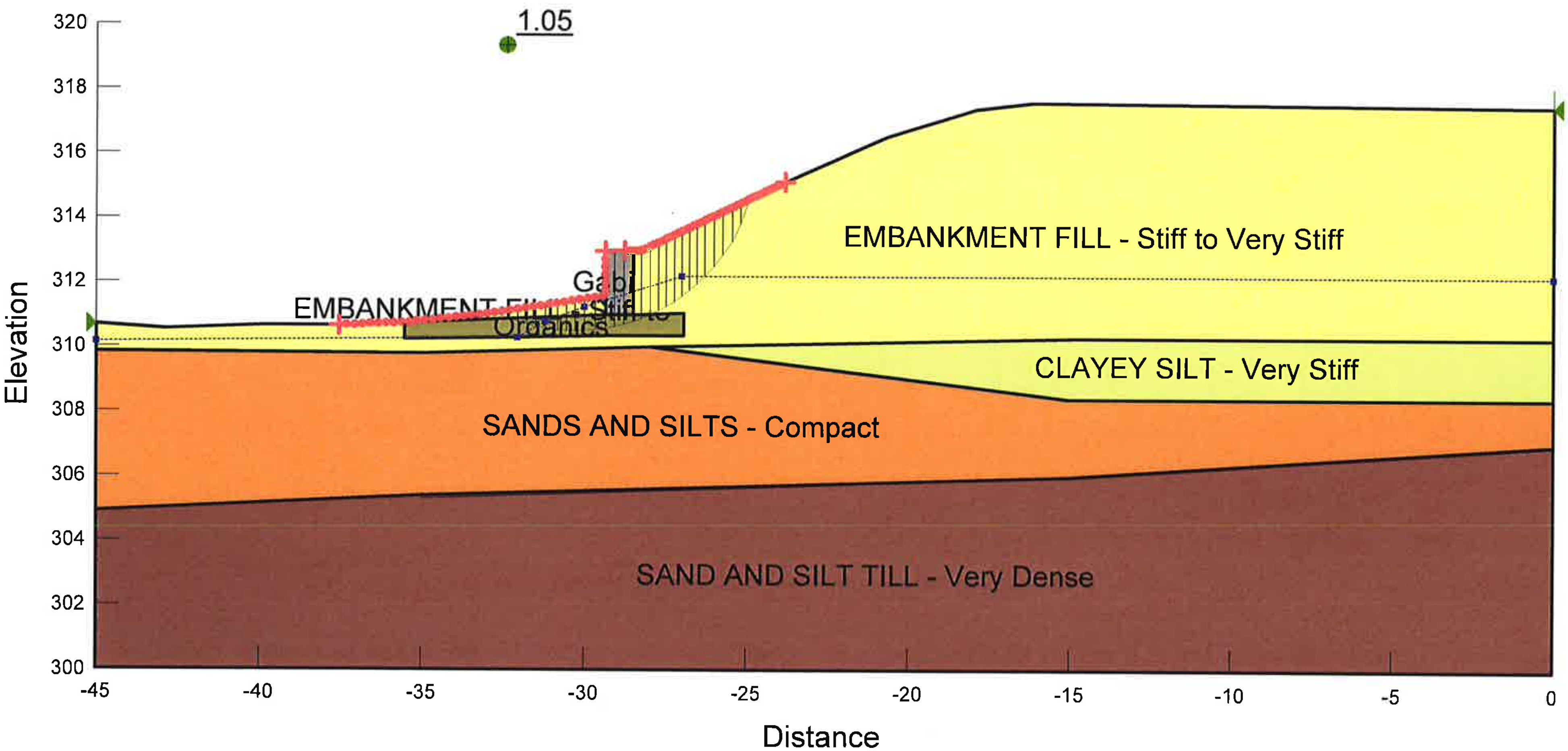


FIGURE E4

12187 HIGHWAY 400 - GABION WALL
WEST OF HIGHWAY 400 SBL
ANCHOR WITH 1 M SPACING with Organic Layer

Name: EMBANKMENT FILL - Stiff to Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: CLAYEY SILT - Very Stiff   Model: Mohr-Coulomb   Unit Weight: 18 kN/m³   Cohesion: 2 kPa   Phi: 30 °
Name: SANDS AND SILTS - Compact   Model: Mohr-Coulomb   Unit Weight: 20 kN/m³   Cohesion: 0 kPa   Phi: 30 °
Name: SAND AND SILT TILL - Very Dense   Model: Mohr-Coulomb   Unit Weight: 21 kN/m³   Cohesion: 0 kPa   Phi: 33 °
Name: Gabion   Model: Mohr-Coulomb   Unit Weight: 19 kN/m³   Cohesion: 10 kPa   Phi: 40 °
Name: Organics   Model: Mohr-Coulomb   Unit Weight: 17 kN/m³   Cohesion: 0 kPa   Phi: 24 °

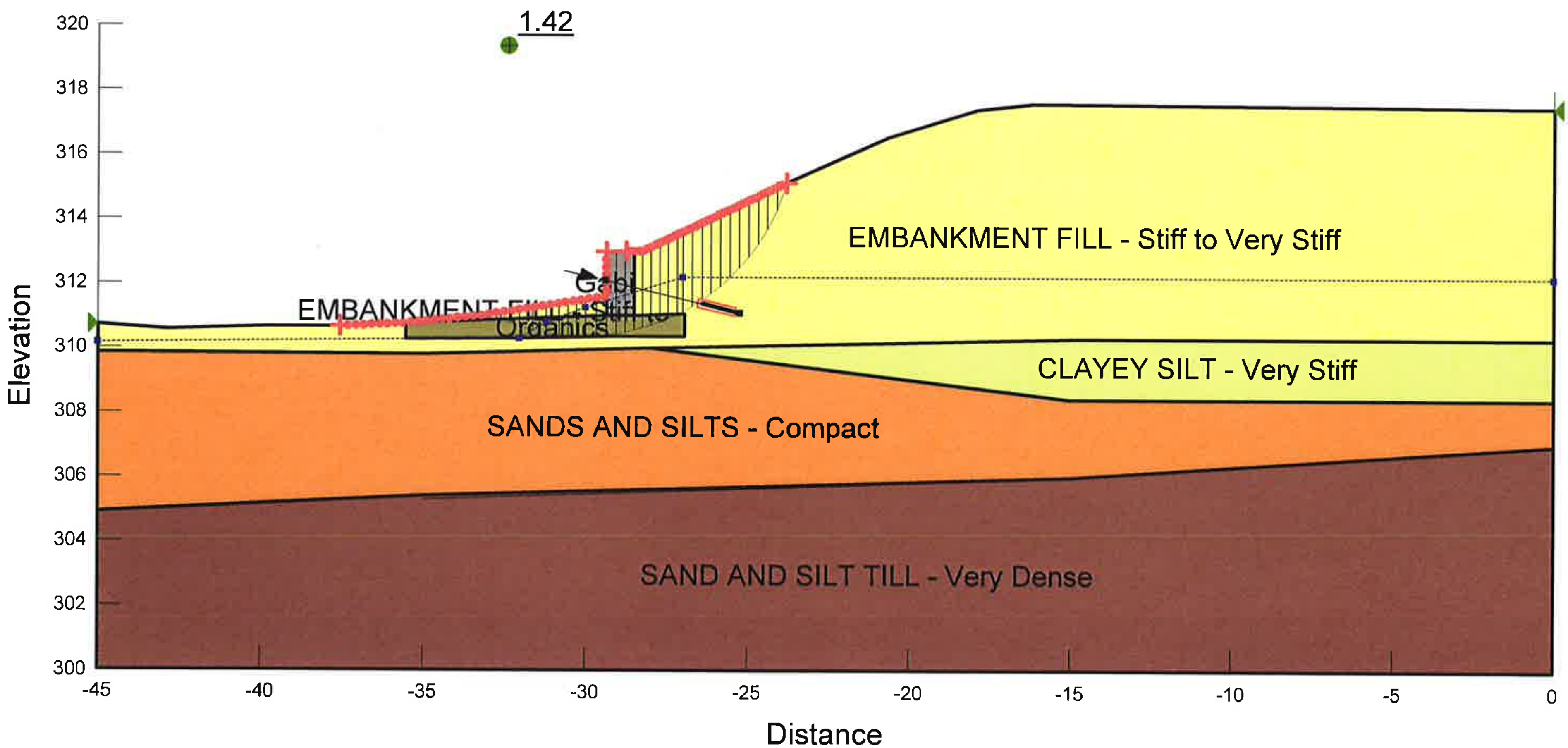


FIGURE E5

12187 HIGHWAY 400 - GABION WALL
EAST OF HIGHWAY 400 NBL
EXISTING CONDITION - OVERALL SLOPE

Name: EMBANKMENT FILL - Very Stiff/Compact Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: CLAYEY SILT - Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SILT TO SAND AND SILT - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °

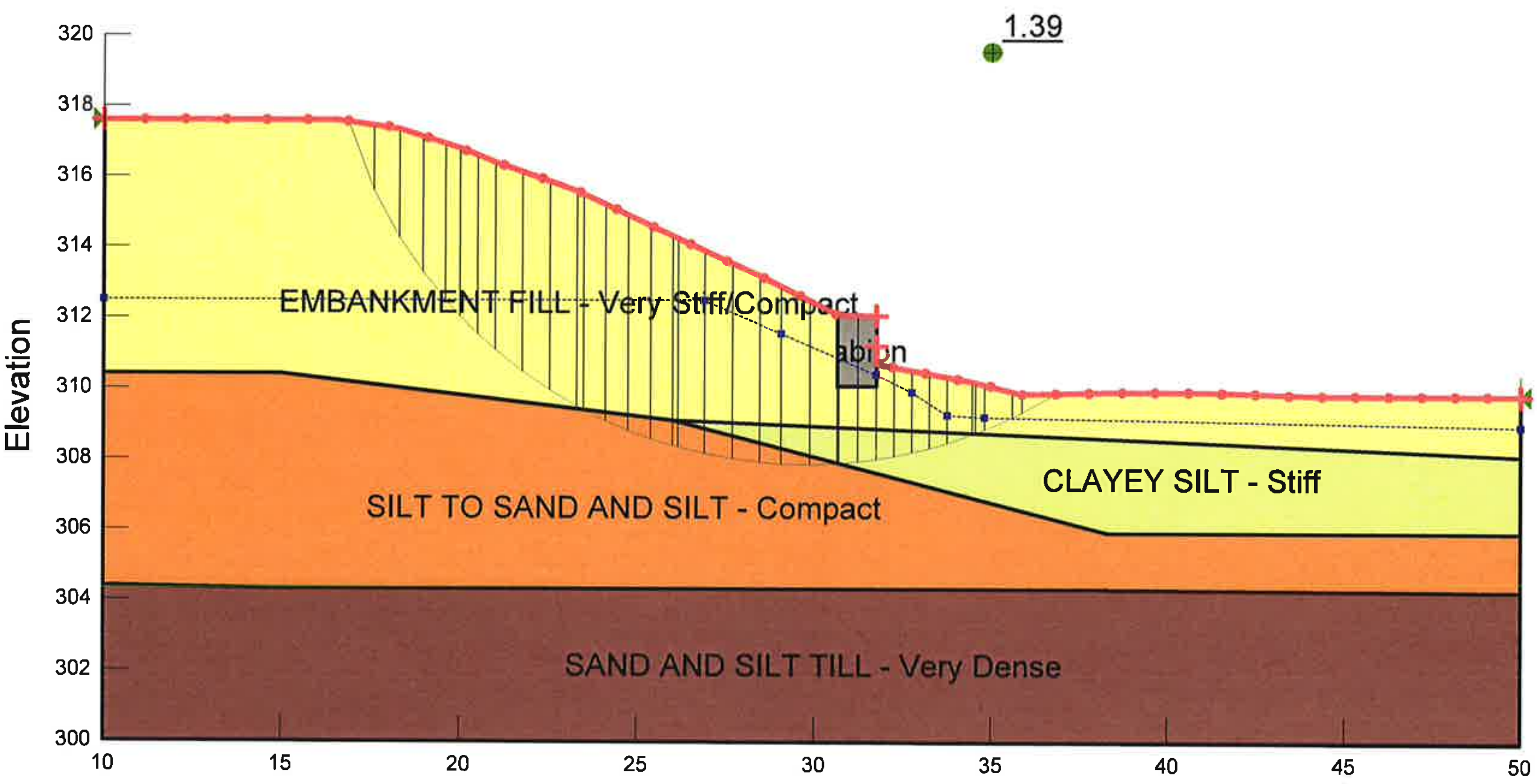


FIGURE E6

12187 HIGHWAY 400 - GABION WALL
EAST OF HIGHWAY 400 NBL
EXISTING CONDITION - GABIONS

Name: EMBANKMENT FILL - Very Stiff/Compact Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30°
Name: CLAYEY SILT - Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SILT TO SAND AND SILT - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °

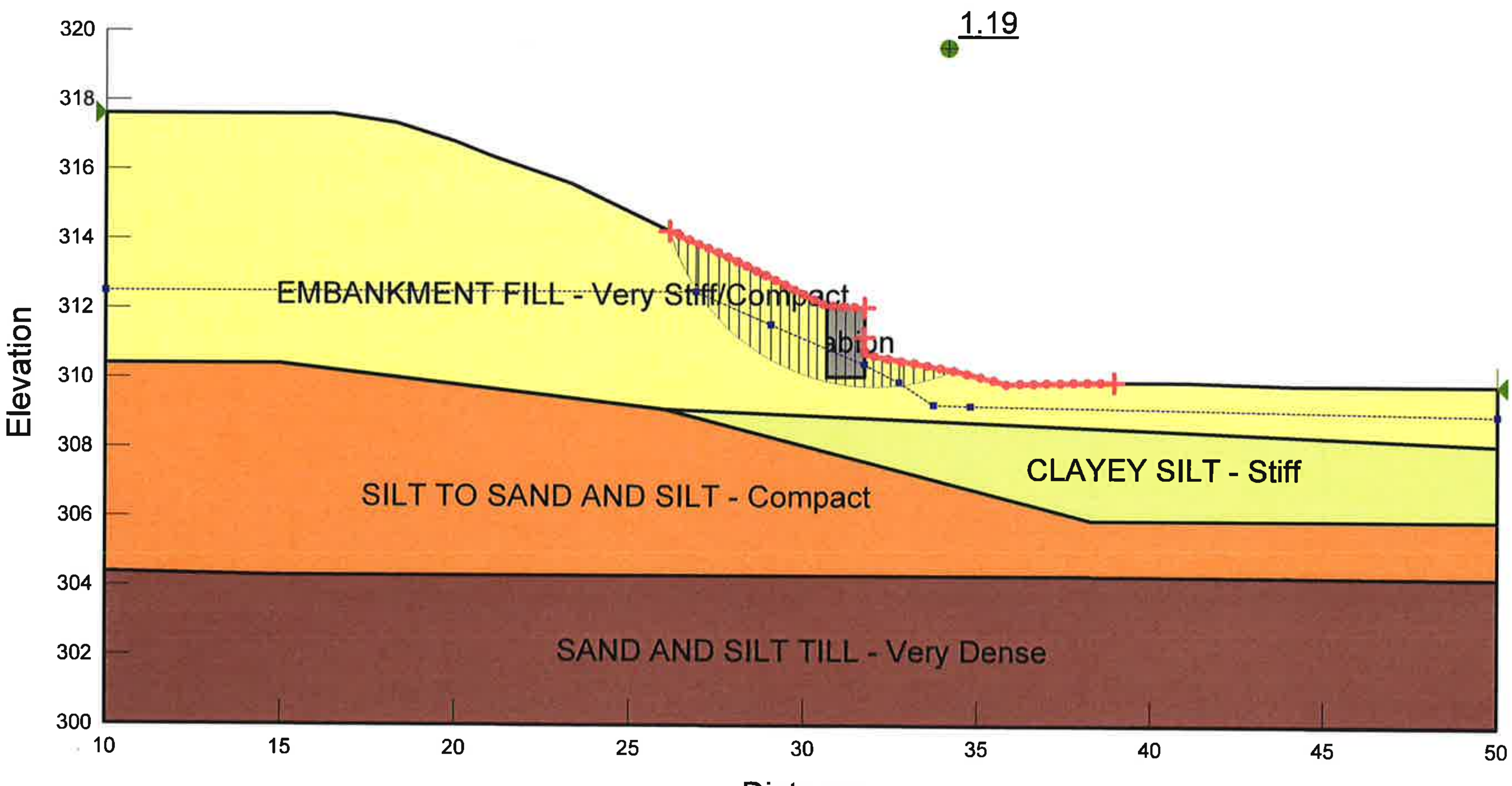


FIGURE E7

12187 HIGHWAY 400 - GABION WALL
EAST OF HIGHWAY 400 NBL
ANCHOR WITH 1 M SPACING

Name: EMBANKMENT FILL - Very Stiff/Compact Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: CLAYEY SILT - Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SILT TO SAND AND SILT - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °

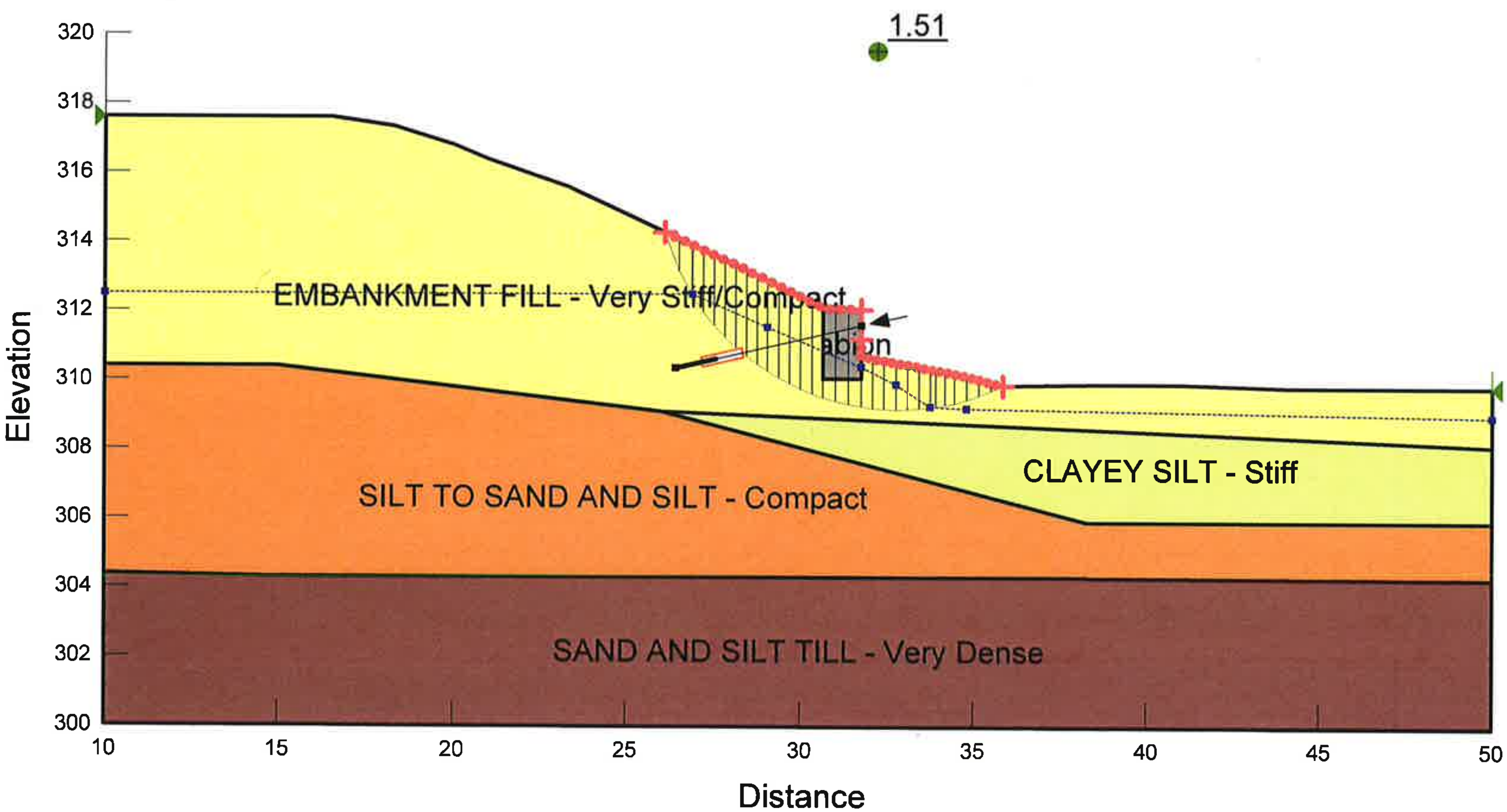


FIGURE E8

12187 HIGHWAY 400 - GABION WALL
EAST OF HIGHWAY 400 NBL
EXISTING CONDITION - GABIONS with Organic Layer

Name: EMBANKMENT FILL - Very Stiff/Compact Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: CLAYEY SILT - Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SILT TO SAND AND SILT - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °
Name: Oragnics Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion: 0 kPa Phi: 24 °

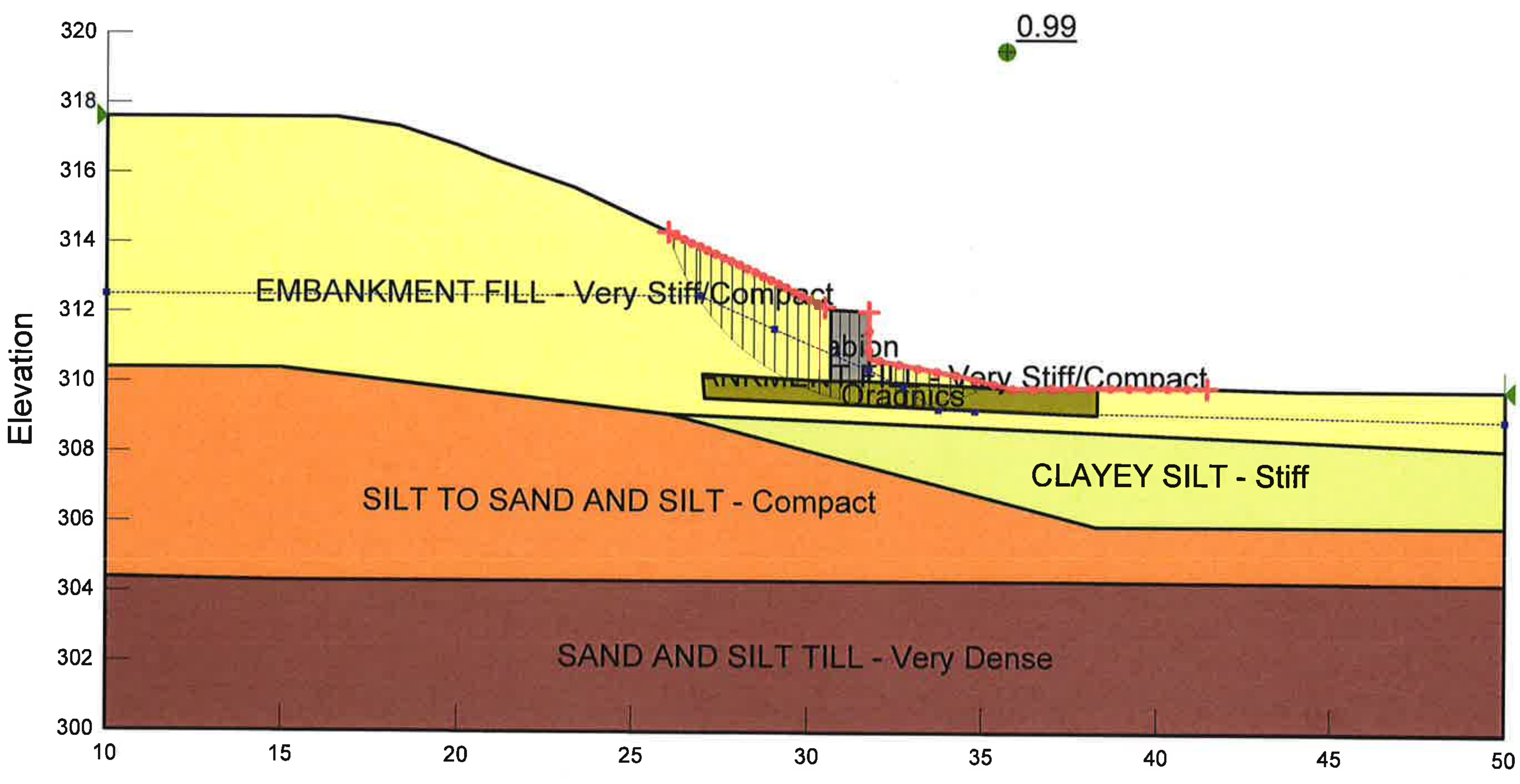


FIGURE E9

12187 HIGHWAY 400 - GABION WALL
EAST OF HIGHWAY 400 NBL
EXISTING CONDITION - GABIONS with Organic Layer

Name: EMBANKMENT FILL - Very Stiff/Compact Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 0 kPa Phi: 30°
Name: CLAYEY SILT - Stiff Model: Mohr-Coulomb Unit Weight: 18 kN/m³ Cohesion: 2 kPa Phi: 30 °
Name: SILT TO SAND AND SILT - Compact Model: Mohr-Coulomb Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 °
Name: SAND AND SILT TILL - Very Dense Model: Mohr-Coulomb Unit Weight: 21 kN/m³ Cohesion: 0 kPa Phi: 33 °
Name: Gabion Model: Mohr-Coulomb Unit Weight: 19 kN/m³ Cohesion: 10 kPa Phi: 40 °
Name: Oragnics Model: Mohr-Coulomb Unit Weight: 17 kN/m³ Cohesion: 0 kPa Phi: 24 °

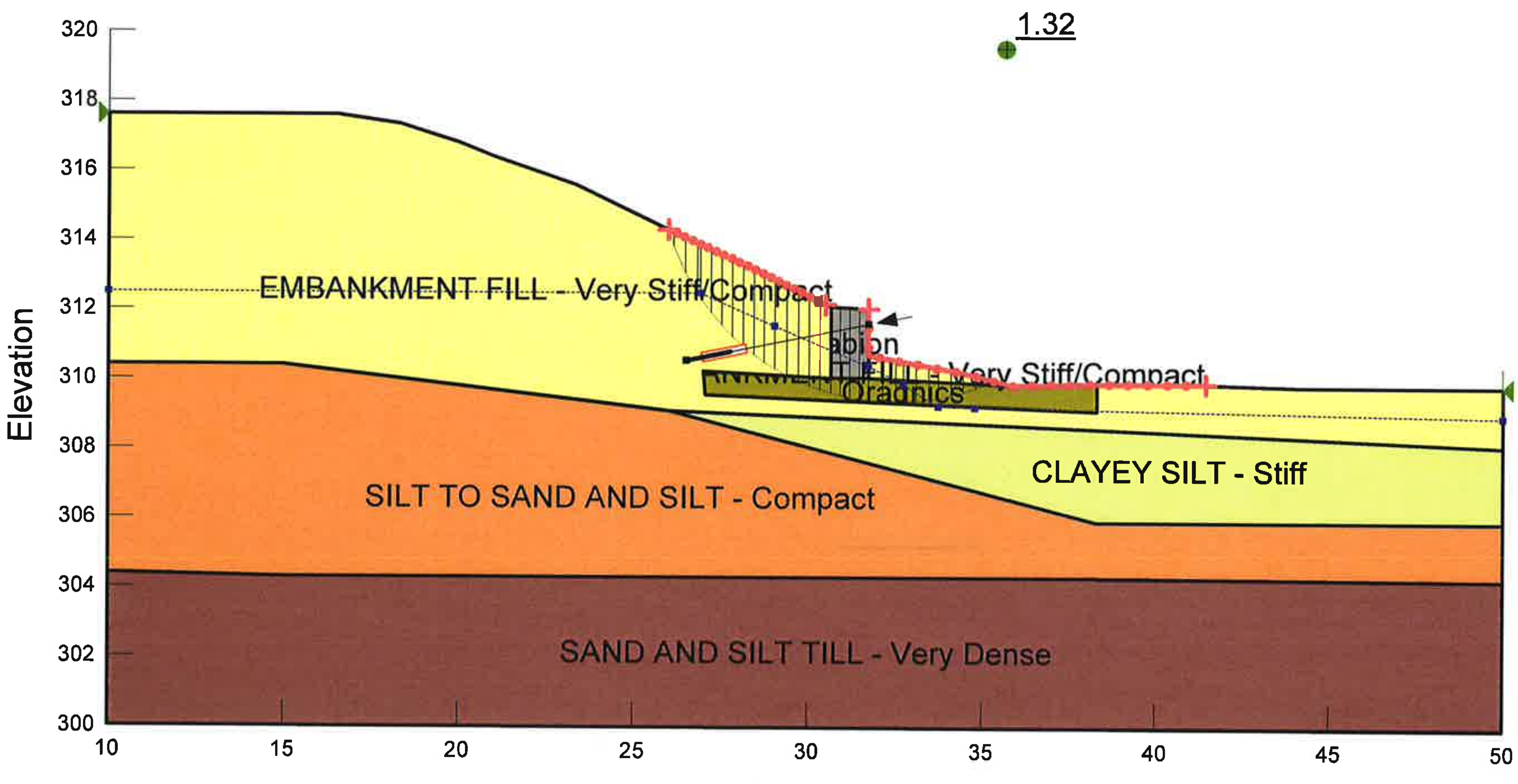
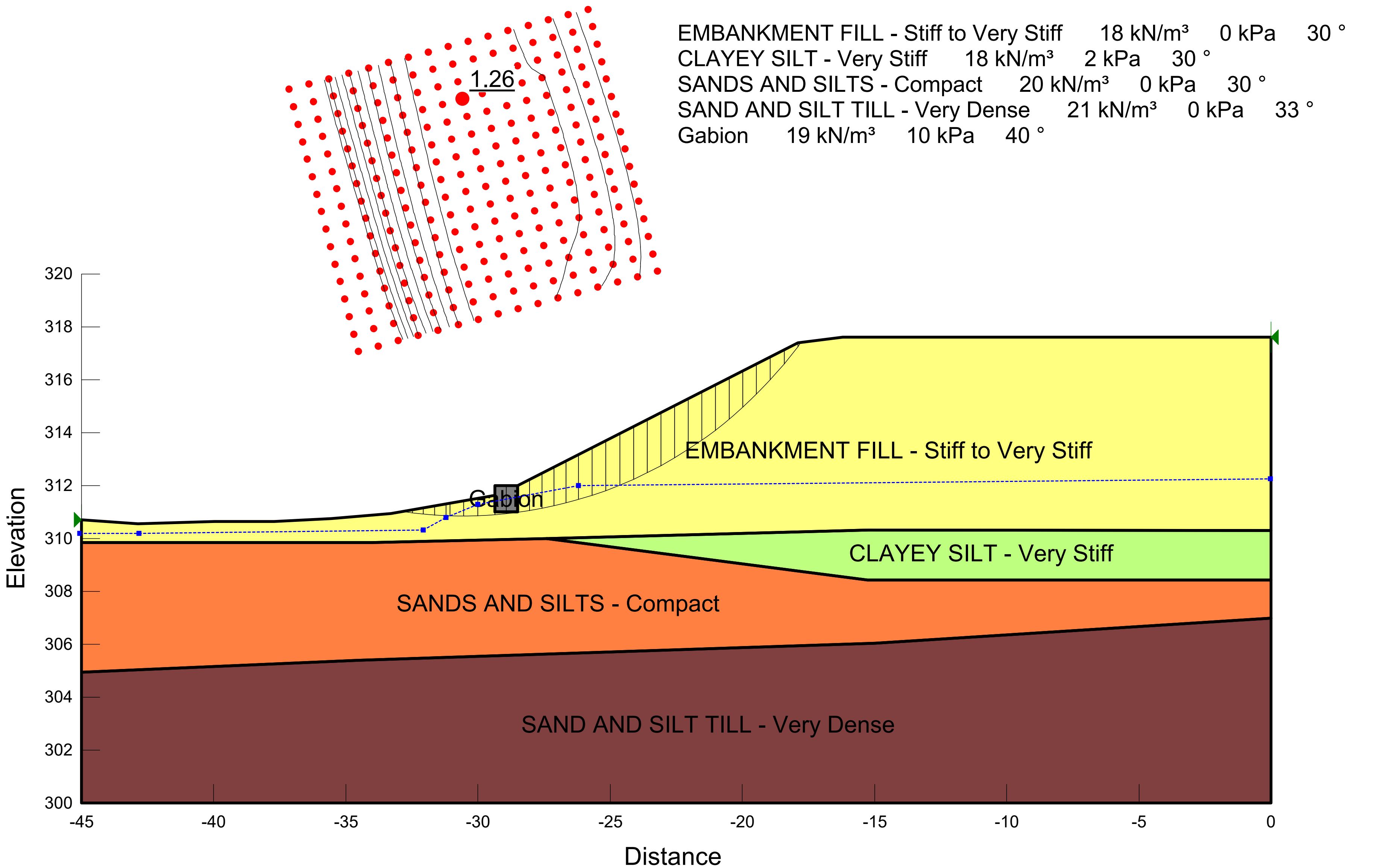


FIGURE E10

Global Stability After Slope Regrading to 2H:1V Behind Gabions
Highway 400 Gabion Wall
West of Highway 400 SBL, Section A-A'

Figure E11

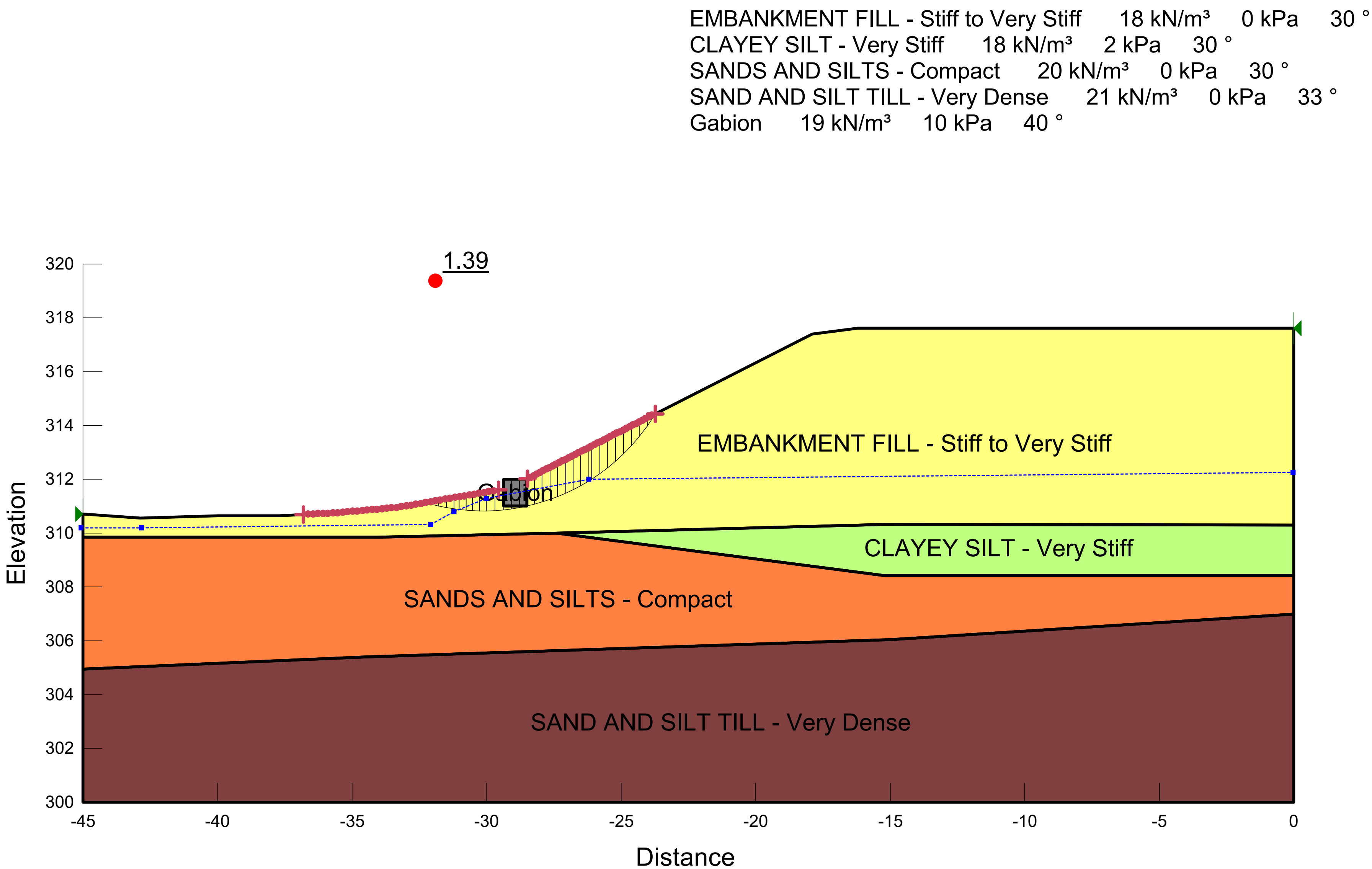


Date: May 2017
File No.: 12187

Analysis By: GRL
Reviewed By: SP

Local Stability After Slope Regrading to 2H:1V Behind Gabions
Highway 400 Gabion Wall
West of Highway 400 SBL, Section A-A'

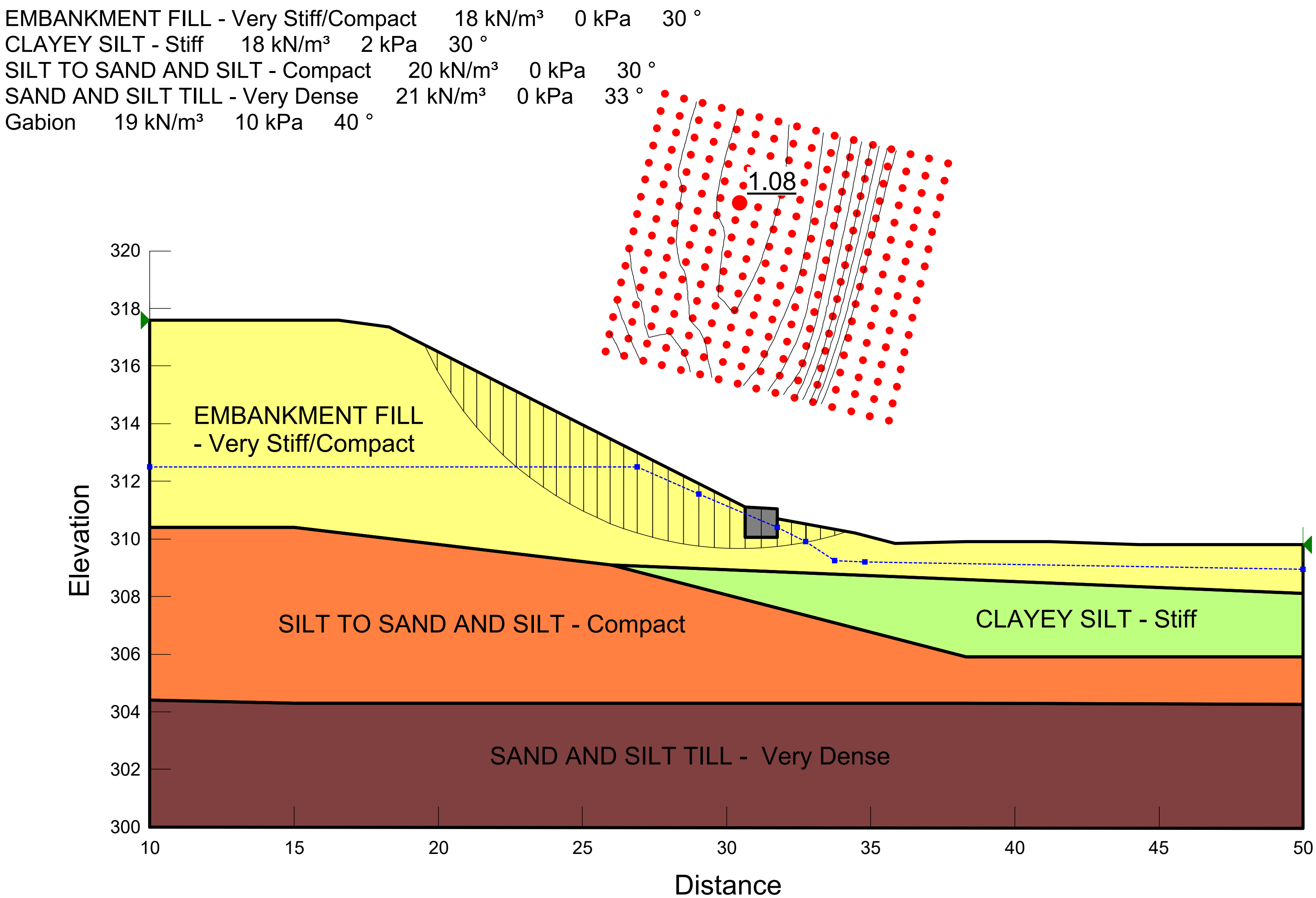
Figure E12



Date: May 2017
File No.: 12187

Analysis By: GRL
Reviewed By: SP

Global Stability After Slope Regrading to 2H:1V Behind Gabions **Figure E13**
Highway 400 Gabion Wall
East of Highway 400 NBL, Section B-B'



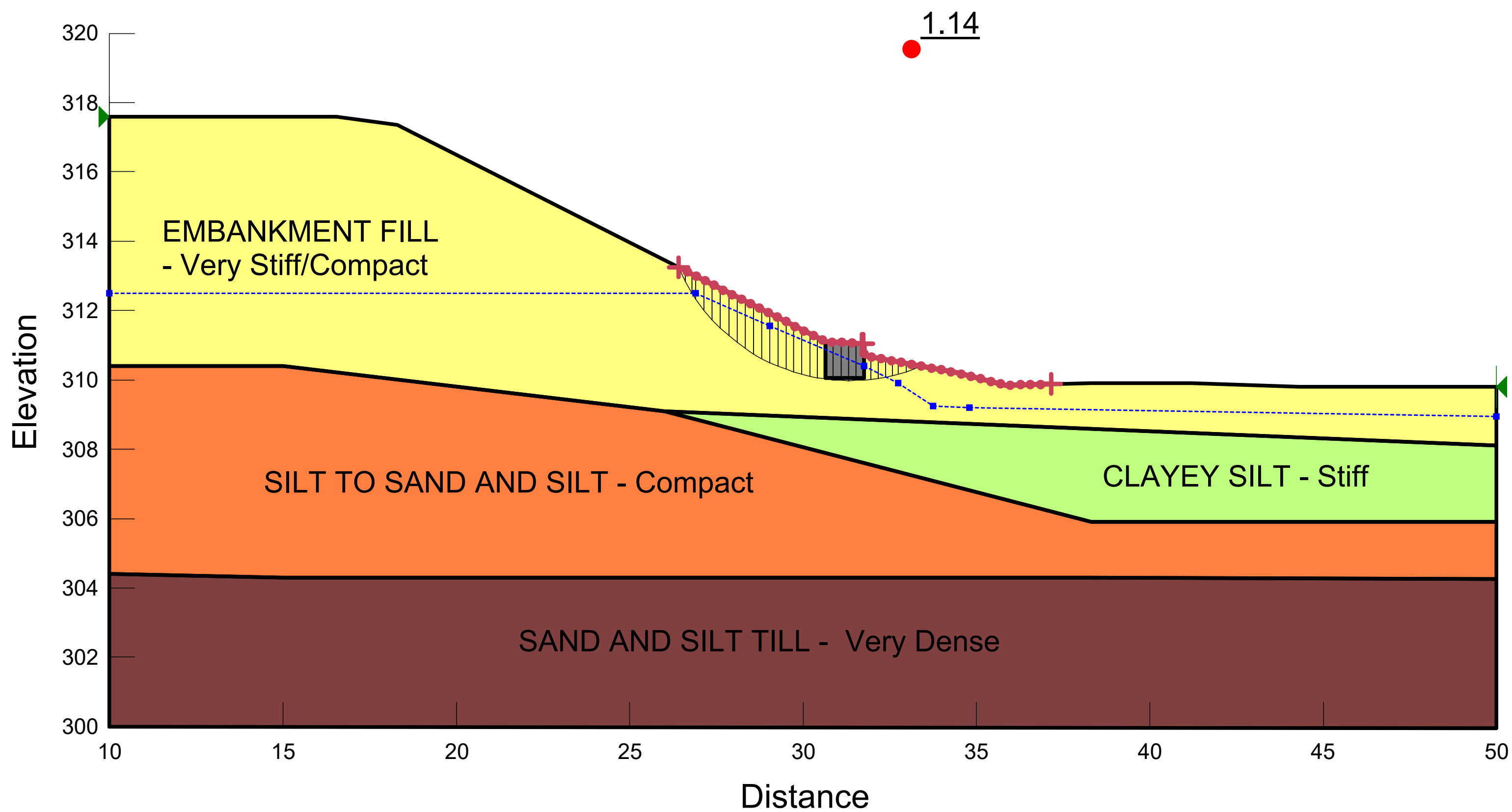
Date: May 2017
File No.: 12187

Analysis By: GRL
Reviewed By: SP

Local Stability After Slope Regrading to 2H:1V Behind Gabions
Highway 400 Gabion Wall
East of Highway 400 NBL, Section B-B'

Figure E14

EMBANKMENT FILL - Very Stiff/Compact 18 kN/m³ 0 kPa 30 °
CLAYEY SILT - Stiff 18 kN/m³ 2 kPa 30 °
SILT TO SAND AND SILT - Compact 20 kN/m³ 0 kPa 30 °
SAND AND SILT TILL - Very Dense 21 kN/m³ 0 kPa 33 °
Gabion 19 kN/m³ 10 kPa 40 °



Date: May 2017
File No.: 12187

Analysis By: GRL
Reviewed By: SP

Appendix F

Specifications and Drawings for Monitoring Program

MONITORING OF INSTRUMENTATION
GABION WALLS AND RETAINED SLOPES NORTH OF 17TH SIDEROAD
HIGHWAY 400 LLOYDTOWN-AURORA ROAD TO 16th AVENUE
GWP 2085-13-00

Special Provision

1 GENERAL

1.1 Scope

This special provision contains the requirements for the monitoring of the following instruments:

- Surface Monitoring Point (SMP)
- Slope Survey Marker (SSM)
- Gabion Survey Marker (GSM)

1.2 Purpose

The purpose of these instruments is to monitor potential movement of the west and east gabion walls and the retained Highway 400 embankment slopes.

1.3 Contract Administrator's Scope of Work

The Contractor Administrator (CA) shall be fully responsible to monitor, reduce and transmit data for all monitoring instruments described herein.

The required survey monitoring of all the instruments shall be carried out by the CA's qualified surveyors.

1.4 Or equal

The term "or equal" shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

1.5 Drawings

Reference shall be made to the drawing appended to this document titled "Typical Monitoring Layout" for instrument locations.

1.6 Instrument Location

The monitoring instruments will be installed by the Contractor who will accurately survey the location of each instrument to obtain coordinates and elevations.

1.7 Survey Benchmarks

The CA's surveyors may use the non-yielding survey benchmarks (BMs) identified or established at the site by the Contractor to achieve the survey precision stipulated below.

1.8 Precision of Surveying

The monitoring points shall be surveyed to an accuracy of ± 2 millimetres or better.

2 MONITORING PROGRAM

2.1 General

The instrumentation monitoring services specified herein apply to all the SMPs, SSMs and GSMs for this site. The requirements include data collection, reduction and transmission.

The CA shall carry out the monitoring program for this project. The required tasks include the following:

- Supply suitable survey equipment required for monitoring, e.g. total-station equipment that can achieve the required precision;
- Survey all instruments using suitable equipment with no interference with the traffic on Highway 400 and the creek valley;
- Compile and reduce the survey data as described in Section 2.4.2;
- Transmit the survey data to MTO, the project designers and other parties concerned;
- Carry out visual observations during the surveying (such observations may include further distress of the gabion walls, or gullies and seepage zones on the slope face etc.);
- Assess if the Review or Alert Levels are being approached, or have been reached or exceeded, and follow the procedures outlined in Section 2.5;
- Set up a teleconference between the MTO and project designers after one year of monitoring to review the gathered monitoring data and contractual requirements regarding the gabion walls.

2.2 Purpose

The purpose of this program is to monitor potential movement of the slopes retained by the gabions and at selected locations on the gabions.

2.3 Reading Schedule and Frequency

The CA shall keep a complete record in electronic and hard copy formats of all instrumentation survey and associated data, including any observations made on the items outlined in 2.1 above at the time of each survey.

Monitoring shall commence after an acceptable set of baseline readings of an instrument is established. Monitoring is to continue as specified in this document and as required.

The minimum monitoring frequencies along with the anticipated number of readings, where applicable, are given in Table 2.1 below. The monitoring frequency is the same for each individual instrument. Instruments shall be read more or less frequently and as required.

Table 2.1 - Minimum Monitoring Frequency

STAGE	FREQUENCY	ANTICIPATED NO. OF READINGS PER INSTRUMENT (**)
Baseline Readings (*)	Three (3) readings on two (2) consecutive days	3
CA Assignment (4-year duration)	● One (1) complete set of readings two weeks after baseline readings ● One (1) complete set of readings two weeks thereafter ● One (1) complete set of monthly readings for the next two months ● One (1) complete set of readings every three months thereafter until the end of the CA assignment	19

(*) Baseline Readings: Instrument survey readings taken to establish a datum against which all subsequent readings are compared.
(**) Number of readings may vary.

2.4 Specific Requirements

2.4.1 Surveying

The spatial locations of the instruments shall be surveyed to an accuracy of plus/minus two millimetres (±2 mm) or better, and shall be reported to the nearest millimetre.

2.4.2 Data Recording and Data Reduction

For every instrument survey reading, the following information shall be recorded electronically in an Excel spreadsheet containing the following information:

- Date and time of the day
- Construction activities, if any

- Visual observation of slopes, slope crest and gabions (e.g. gully forming on the slope, further signs of gabion movement/distress)
- Instrument Number
- Instrument movement (northing, easting, elevation).

The data shall be presented in Excel spreadsheet format as follows:

- Cumulative movement (measured by differences in northings, eastings, and/or elevations) versus time for each instrument that has moved.
- Individual plots of northings, eastings and elevations may be warranted where movement occurs.

Reported information should be supplemented by sketches, diagrams and plots as necessary.

2.4.3 <u>Data Transmission</u>

All survey data obtained by the surveyors in the morning of a particular day shall be reported to the CA site staff before the end of the same day.

All survey data obtained by the surveyors in the afternoon or evening shall be reported in the same manner not later than mid-day on the next calendar day.

Any erroneous readings (e.g. readings that are clearly not in line due to survey error or inclement weather etc.) shall be rectified and the results reported accordingly on the next day.

Any unusual movements deduced by the surveyors from the field data and/or visual observations must be reported immediately to the CA site staff before leaving the site.

2.5 Criteria for Assessment

The following reference levels are to be observed:

<u>Review Level</u> – A maximum cumulative value of 15 mm relative to the baseline readings. If the Review Level is being approached, reached or exceeded, or if there are any visual observations made such as those pertaining to the possible scenarios outlined in 2.1 above, the CA shall immediately notify MTO and the project designers.

<u>Alert Level</u> – A maximum cumulative value of 25 mm relative to the baseline readings. If the Alert Level is being approached, reached or exceeded, or if there are any visual observations made such as those pertaining to the possible scenarios outlined in 2.1 above, the CA shall immediately notify the MTO and the project designers. If required, the CA shall work in conjunction with the Contractor to prepare a plan of action to secure the site.

SUPPLY AND INSTALLATION OF INSTRUMENTATION
GABION WALLS AND RETAINED SLOPES NORTH OF 17TH SIDEROAD
HIGHWAY 400 LLOYDTOWN-AURORA ROAD TO 16th AVENUE
GWP 2085-13-00

Special Provision

1 GENERAL

1.1 Scope

This special provision contains the requirements for the supply and installation of the following instruments:

- Surface Monitoring Point (SMP)
- Slope Survey Marker (SSM)
- Gabion Survey Marker (GSM)

1.2 Purpose

The purpose of these instruments is to monitor potential movement of the west and east gabion walls and the retained Highway 400 embankment slopes.

1.3 Contractor's Scope of Work

The Contractor shall be fully responsible to procure, install and protect all monitoring instruments, and to decommission the instruments as described herein.

The required survey monitoring of all the instruments shall be carried out by qualified surveyors retained by the Contract Administrator (CA).

1.4 Or equal

The term "or equal" shall be understood to indicate that the equal product is the same or better than the specified product in function, performance, reliability, quality and general configuration.

1.5 Notification

The CA shall be notified a minimum of ten (10) working days in advance of commencing the installation of instruments.

1.6 Instrument Installation Requirements

The Contractor shall be prepared to install all instruments.

1.7 Submission Requirements

The Contractor shall submit to the CA details of the proposed installation methods of all instruments including the installation schedule and details of the survey monuments/benchmarks to be used, a minimum of ten (10) working days before the start of instrument installation.

1.8 Drawings

Reference shall be made to the drawing appended to this document titled "Schematic Monitoring Layout" for instrument locations.

2 INSTALLATION

2.1 General

For the gabion walls and their retained slopes, there are six (6) Surface Monitoring Points (SMPs), thirty (30) Slope Survey Markers (SSMs) and ten (10) Gabions Survey Markers (GSMs) to be installed at this site as shown on the attached drawing referenced in Section 1.8 above. Another sixteen (16) SSMs located at 10 m offset from the ends of the gabion walls will be used as control points.

SMPs will be installed at the west and east shoulders of the Highway 400 embankment immediately above the gabion walls.

SSMs will be survey iron bars installed at selected sections of the slopes retained by and adjacent to the west and east gabion walls.

GSMs will be paint marks at the top of the west and east gabion walls.

2.2 Instrument Location

The Contractor shall accurately survey the location of each instrument to obtain coordinates.

2.3 Survey Benchmarks

The Contractor shall identify or establish non-yielding survey benchmarks (BMs) at the site in order to carry out the accurate installation of the instruments.

2.4 Materials and Equipment

The Contractor shall supply all materials and equipment required for installation of the instrumentation. Suitable total-station equipment, or equal, may be used to assist instrument installation.

2.5 Marking and Labelling

The location of any monitoring fixture shall be made clearly visible especially through the winter months when there will be snow and ice cover.

Instruments shall be clearly labelled in the field. The labelling shall last until the end of the monitoring program.

2.6 Protection of Instruments

All instruments shall be adequately protected by the Contractor such that they are not damaged throughout the duration of the CA assignment. Any instrument damaged directly or indirectly by the Contractor's work shall be immediately replaced by the Contractor at the Contractor's expense.

2.7 Installation Program

Instrument installation shall commence as soon as possible at the beginning of the CA assignment. A set of surveyed northing/easting co-ordinates and elevations shall be established for each instrument after installation and passed on to the CA for reference when establishing the baseline readings.

3 SURFACE MONITORING POINT (SMP) - SUPPLY & INSTALLATION

3.1 General

3.1.1 Scope

This Section contains the requirements for the supply and installation of SMPs.

The purpose of a SMP at this site is to monitor potential movement of a selected location on the highway shoulder above the gabion walls. The monitoring data, in conjunction with visual observations and other monitoring data, will be used to assess if there is any movement of the slopes retained by the gabion walls.

3.1.2 General Procedure

SMPs shall be rigidly affixed so as not to move relative to the paved surface on or near the shoulder to which they are attached.

3.1.3 Location

The locations of SMPs are shown on the drawing referenced in Section 1.8.

3.2 Materials

3.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SMPs.

3.2.2 Steel Markers

The Contractor shall supply hardened steel markers with an exposed convex head, similar to surveyors' PK nails, treated or coated to resist corrosion. The steel markers shall have a minimum diameter of 12 mm and have sufficient length for anchoring in the pavement and to withstand the weather conditions and effects of traffic.

The exposed nail head shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment, or equal.

3.3 Installation

3.3.1 General

The Contractor shall install the SMPs at the locations schematically shown on the drawing referenced in Section 1.8. Traffic shall be managed by the Contractor, where necessary, in accordance with the Ontario Traffic Manual (OTM), Book 7.

3.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SMP location, easting and northing co-ordinates;
- Elevation of nail head;
- Dates of installation;
- Installation notes / sketches.

4 SLOPE SURVEY MARKER (SSM) - SUPPLY & INSTALLATION

4.1 General

4.1.1 Scope

This Section contains the requirements for the supply and installation of SSMs.

The purpose of a SSM at this site is to monitor potential movement of the highway embankment slopes retained by the gabion walls. The monitoring data, in conjunction with visual observations and other monitoring data, will be used to assess if there is any slope movement.

4.1.2 General Procedure

SSMs shall be installed at the specified locations on the slopes.

4.1.3 Location

The locations of SSMs are shown on drawing referenced in Section 1.8.

4.2 Materials

4.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the SSMs.

4.2.2 Surveyors' Standard Iron Bar

The Contractor shall supply surveyors' standard iron bars in accordance with O.Reg. 525/91. Each of these iron or steel bars shall have a 25 mm square cross-section and a 120 cm length, and pointed at one end.

The exposed portion of the bar after installation shall be equipped with reflective paint or reflective tape to allow for measurements with total-station equipment, or equal.

4.3.1 Installation

4.3.1 General

The Contractor shall hammer in place the SSMs at the locations schematically shown on the drawing referenced in Section 1.8. Utility clearance shall be carried out for the proposed SSM locations as due diligence to confirm that there are no buried utilities.

4.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

- SSM location, easting and northing co-ordinates;
- Elevation of top of bar;
- Dates of installation;
- Installation notes / sketches.

5 GABION SURVEY MARKERS (GSM) - SUPPLY & INSTALLATION

5.1 General

5.1.1 Scope

This Section contains the requirements for the supply and installation of GSMs.

The purpose of a GSM is to monitor the potential movement at selected locations on the top of gabion walls. The monitoring data, in conjunction with visual observations and other monitoring data, will be used to assess if there is any gabion wall movement.

5.1.2 General Procedure

The GSM shall be a reflective paint mark at selected locations on the top of the gabions that can be conveniently sighted by survey instruments set up to obtain the survey readings.

5.1.3 Location

The locations of GSMs are shown on the drawing referenced in Section 1.8.

5.2 Materials

5.2.1 General

The Contractor shall supply all materials and equipment required for the installation of the GSMs.

5.2.2 Reflective Paint

The Contractor shall supply high quality reflective paint for installing the GSMs. The paint must be sufficiently durable and resistant to precipitation, climatic effects and any site specific conditions, and is expected to last the duration of the proposed construction.

5.3 Installation

5.3.1 General

The Contractor shall install the GSMs at the locations schematically shown on the drawing referenced in Section 1.8.

5.4 Documentation

Relevant installation details shall be recorded and documented. These include, but are not limited to:

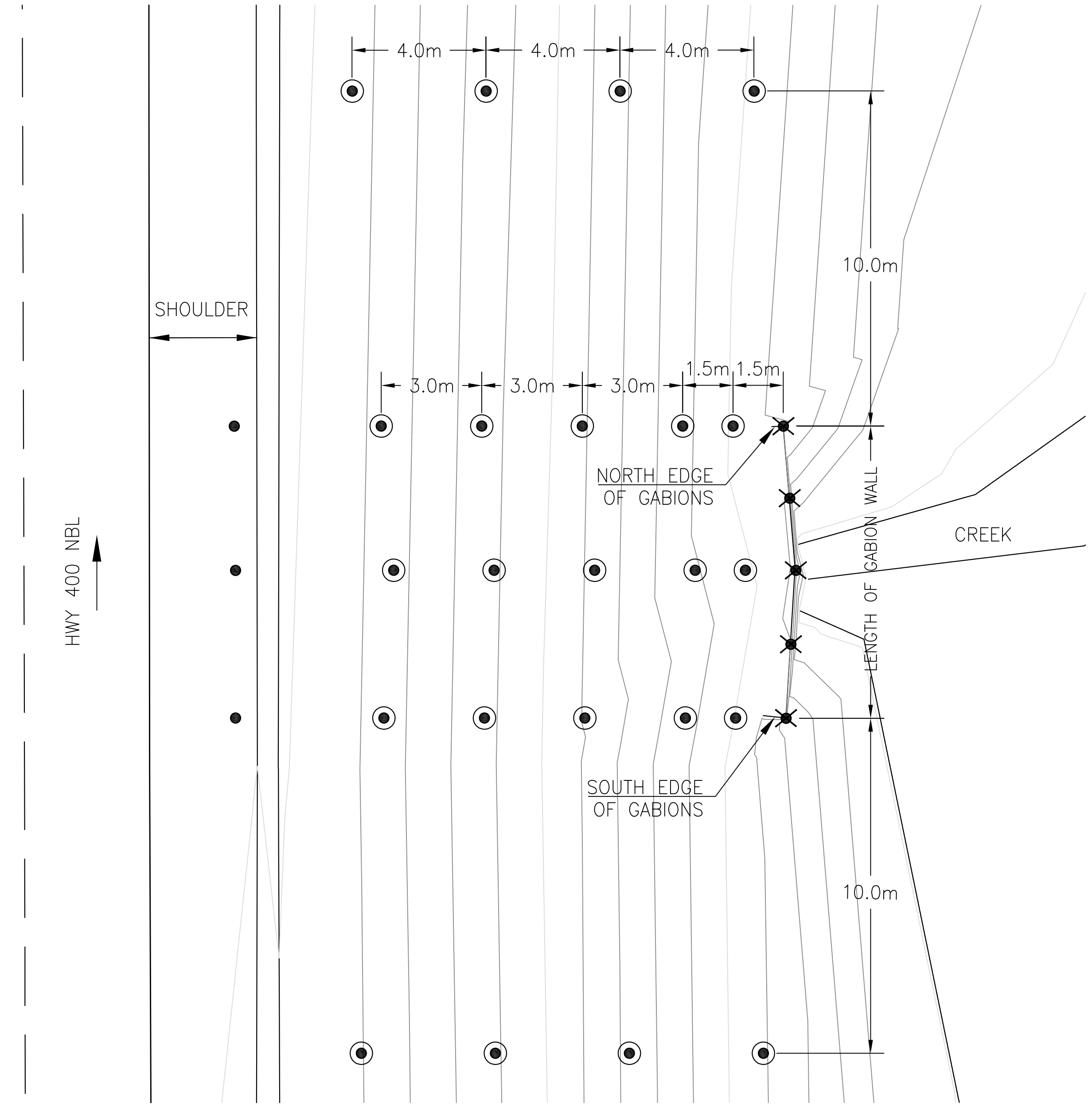
- GSM location, easting and northing co-ordinates;
- Elevation of GSM on gabions;
- Dates of installation;
- Installation notes / sketches.

6 DECOMMISSIONING OF INSTRUMENTS

6.1 General

The Contractor shall decommission all monitoring instruments covered by this document after the completion of the monitoring program as directed by the CA.

HIGHWAY 400 SBL EMBANKMENT (WEST)



HIGHWAY 400 NBL EMBANKMENT (EAST)

LEGEND:

- ● SMP FOR MONITORING POTENTIAL MOVEMENT AT HIGHWAY SHOULDER.
- ◉ SSM FOR MONITORING POTENTIAL MOVEMENT ON SLOPES.
- ✕ GSM FOR MONITORING POTENTIAL MOVEMENT OF GABIONS.

NOTE:

1. ALL MOVEMENT READINGS SHALL BE OBTAINED TO A PRECISION OF ±2mm.
2. SUITABLE SURVEY EQUIPMENT INCLUDING TOTAL STATION EQUIPMENT MAY BE USED.

BASE PLAN PROVIDED BY

WSP/MMM GROUP

HIGHWAY 400
NORTH OF 17th SIDEROAD
GABION WALLS
SCHEMATIC MONITORING LAYOUT

JOB# 12187

THURBER ENGINEERING LTD.

ENGINEER:	DRAWN:	APPROVED:
SKP	AN	SKP
DATE:	SCALE:	DRAWING No.
JUNE 2017	1:200	12187-1

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