Peto MacCallum Ltd.
CONSULTING ENGINEERS

FOUNDATION INVESTIGATION AND DESIGN REPORT
SWAMP AND HIGH FILL CROSSINGS

for

HIGHWAY 69 FOUR-LANING
FROM 5.3 KM SOUTH OF HIGHWAY 529 (NORTH JUNCTION)
NORTHERLY TO 2.2 KM NORTH OF HIGHWAY 529, 7.5 KM
G.W.P. 5112-07-00
MAGNETAWAN FIRST NATION / WALLBRIDGE TOWNSHIP, ONTARIO

VOLUME 1

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PML Ref.: 09TF043
Index No.: 387FIR and 388FDR
GEOCRES No.: 41H-148
March 11, 2015

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TABLE OF CONTENTS

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FOUNDATION INVESTIGATION REPORT
SWAMP AND HIGH FILL CROSSINGS
for
Highway 69 Four-Laning
From 5.3 km South of Highway 529 (North Junction) Northerly
to 2.2 km North of Highway 529 (North Junction), 7.5 km
G.W.P. 5112-07-00
Magnetawan First Nation / Wallbridge Township, Ontario

1. INTRODUCTION

Realignment and four-laning of an approximately 7.5 km long section of Highway 69 that extends from 5.3 km south of Highway 529 (north junction) to 2.2 km north of Highway 529 (north junction), some 90 km south of Sudbury, is planned. This report was prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The study corridor of the project extends from Station 16+020 to 23+636 in the Magnetawan First Nation and the Township of Wallbridge, Highway 69 centreline. A total of 11 swamp and high fill crossings were identified in the Request for Proposal (RFP) for foundation investigation within the twinning section of the Highway 69 alignment from approximate Station 16+020 to 19+370. A total of 18 swamp and high fill crossings were identified for foundation investigation within the East Shift section of the highway alignment from approximate Station 19+370 to 23+636. For ease of reference, the crossings have been designated sequentially in the 100 series from 101 to 111 for the twinning section and from 112 to 124 for the East Shift section including 5 crossings at ramps and side roads. The locations of all the crossings listed below are also provided in Table 1 and shown on the Key Plan (Drawing 1), attached.

Figures, records of borehole and cone penetration tests as well as foundation drawings are provided in Appendices as listed in the Table of Contents.

PML CROSSING No.	STATION LIMITS (Highway 69 Centreline)	LENGTH, m
Magnetawan First Nation		
101	16+075 to 16+125 (NBL)	50
102	16+530 to 16+585 (NBL)	55
103	16+695 to 16+735 (NBL)	40
104	16+795 to 16+837.5 (NBL)	42.5
105	16+925 to 17+030 (NBL)	105
106	17+537.5 to 17+610 (NBL)	72.5

PML CROSSING No.	STATION LIMITS (Highway 69 Centreline)	LENGTH, m
Magnetawan First Nation		
107	17+700 to 17+870 (NBL)	170
108	18+220 to 18+250 (NBL)	30
109	18+580 to 18+650 (NBL)	70
110	18+780 to 18+970 (NBL)	190
111	19+030 to 19+060 (NBL)	30
112	19+350 to 19+460	110
113	19+750 to 19+810	60
114	19+850 to 19+955	105
115	20+175 to 20+270	95
116	20+760 to 20+970 (NBL)	210
117	20+815 to 20+880 (SBL)	65
Ramp S-E/W	20+250 to 20+300 (Ramp S-E/W chainage)	50
Ramp N-E/W	20+710 to 20+965 (Ramp N-E/W chainage)	255
Interchange Service Road	9+900 to 10+100 (Interchange Service Road chainage)	200
Wallbridge Township		
118	22+225 to 22+320	95
119	22+350 to 22+725 (NBL)	375
120	22+390 to 22+430 (SBL)	40
121	22+590 to 22+700 (SBL)	110
122	22+800 to 22+840 (SBL)	40
123	22+850 to 22+920 (NBL)	70
124	22+960 to 23+060 (NBL)	100
North Transfer Swamp 1	42+550 to 42+640 (North Transfer chainage)	90
North Transfer Swamp 2	42+960 to 43+000 (North Transfer chainage)	40

This report summarises the results of the field investigation conducted at crossings 101 to 124, Ramp S-E/W, Ramp N-E/W, Interchange Service Road, North Transfer 1 and North Transfer 2 for the project. The subsurface conditions along the sections of the alignment identified in the RFP for geotechnical investigation are provided in the Pavement Design Report under separate cover.

All elevations in this report are expressed in metres and refer to the geodetic datum.

2. SITE DESCRIPTION AND GEOLOGY

The approximately 7.5 km long section of Highway 69 to be realigned and four-laned is situated about 90 km south of Sudbury in a wooded region with open swampy areas. Land use includes limited farming and forestry exploration.

The Magnetawan First Nation reserve extends from the southern project boundary to the Magnetawan River, some 5.6 km. The residences of the Magnetawan First Nation community are mainly situated on the west side of the intersection of Highway 69 and Highway 529.

The study area is located in the physiographic region known as the Georgian Bay Fringe that includes a bedrock plain comprising exposed bedrock knobs, subordinate glacial till moraine and a peat / muck organic terrain over bedrock.

The mineral soil cover is typically less than 1 m and may vary greatly over short distances and locally extend to depths exceeding 30 m in swampy areas. The soils were deposited by glacial Lake Algonquin and later partly by Lake Nipissing. The soil cover also originated from beach and near shore deposits, deltas, subaquatic fans, quiet water deposits of silt and clay which were formed by sedimentation in and adjacent to Lake Algonquin and its successors.

Metasedimentary rocks of the Huronian Supergroup and gneisses of the Grenville Province underlie the alignment. The area has undergone considerable folding, intrusive activity, regional metamorphism and faulting. The bedrock outcrops at many locations throughout the project section.

3. INVESTIGATION PROCEDURES

The field work for the foundation investigation within the limits of 29 crossings for the project involved a total of 404 test holes comprising 344 boreholes and 60 dynamic cone penetration tests carried out during the period of October 6, 2011 to March 12, 2013. The field work for the current investigation is detailed in the following table:

PML CROSSING No.	NUMBER OF		FIELD WORK DATES
	BOREHOLES	CONES	
101	7	–	October 6, 2011; February 8, 2012
102	10	–	October 6, 2011; February 7, 2012
103	8	–	October 6, 2011; February 6 and 7, 2012
104	8	2	October 6, 2011; February 8 to 29, 2012
105	13	2	October 7, 2011; February 9 to 13, 2012
106	10	1	October 7, 2011; February 9 and 13, 2012
107	25	3	October 11, 2011; February 9 to 14, 2012
108	6	1	October 11, 2011; February 14, 2012
109	8	8	October 11, 2011; February 15 to 17, 2012
110	21	6	October 11, 2011; February 14 to 22, 2012
111	6	–	October 11, 2011; February 22, 2012
112	18	–	October 11, 2011; February 28 and 29, 2012; September 24, 2012; February 12 to 20, 2013
113	14	1	September 27 and 28, 2012; February 8 to 10, 2013
114	15	3	September 28, 2012; February 6 and 7, 2013; March 12, 2013
115	14	5	September 28, 2012; January 23 to 29, 2013; February 5, 2013
116	23	3	August 17, 2012; February 4 to 25, 2013
117	10	–	February 7 to 23, 2013
118	18	2	September 5 and 6, 2012; February 7 to 9, 2013
119	20	4	September 6 to 10, 2012; February 4 to 20, 2013
120	7	1	September 6, 2012; February 9, 2013
121	12	3	September 10, 2012; February 9 to 28, 2013

PML CROSSING No.	NUMBER OF		FIELD WORK DATES
	BOREHOLES	CONES	
122	5	1	September 11, 2012; February 20 and 21, 2013
123	8	2	September 12, 2012; February 22, 2013
124	12	3	September 13, 2012; February 23, 2013
Ramp S-E/W	4	1	January 29 and 31, February 4 and 5, 2013
Ramp N-E/W	16	2	February 8 to 28, 2013
Interchange Service Road	14	–	August 30, 2012; February 1 to 27, 2013
North Transfer Swamp 1	8	4	September 26, 2012; February 25 and 26, 2013
North Transfer Swamp 2	4	2	September 27, 2012; February 27, 2013

The test locations and drawings for each crossing are identified by a prefix identical to the PML crossing number. Numbered sequentially from left to right in the direction of increasing chainage, the test locations at each crossing are shown on the corresponding Drawings. The Records of the test holes are appended.

Except for 68 programmed locations where bedrock was exposed, the test holes were advanced to depths ranging from 0.1 to 16.7 m below existing grade with termination in most cases due to refusal on probable bedrock. Five dynamic cone penetration tests (swamps 104, 108 and 109) were typically terminated in probable compact silty/sandy soils at depths of 1.5 to 15.8 m.

The test hole locations were established in accordance with the MTO requirements indicated in the RFP and in general accordance with the requirements of the MTO Northeastern Region Pavement Design Practices and Guidelines (May 20, 1997). The reference lines of the highway alignment laid out in the field by exp Services Inc. were used to locate the programmed test holes. The geodetic elevations at the test hole locations were provided by exp Services Inc.

The test holes were advanced using a combination of methods including a track-mounted CME-75 drill rig, a tripod and manual probing/sampling. The equipment was supplied and operated by specialist drilling contractors working under the full-time supervision of members of our engineering staff. The 70- and 140-pound hammers were used with a tripod (a correction factor was applied to penetration test values obtained employing the 70-pound hammer).

Representative samples of the soils were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Thin wall (Shelby) tube samples were also recovered at selected locations. Standard penetration tests were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. In situ vane shear testing (using the MTO 'N' vane according to the procedure described in the Northern Region Pavement Design Practices and Guidelines dated May 1997) and penetrometer tests were also performed to further assess the shear strength of the cohesive soils encountered. The results of the field tests and observations are reported on the Record of Borehole sheets.

The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as the samples were retrieved and, when appropriate, by measurement of the water level in the open borehole.

Upon completion of drilling, the boreholes were backfilled with a bentonite/cement mixture in accordance with the MTO guidelines and Ontario Regulation 903 for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. The soil samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determination. Atterberg limits tests (64) and grain size distribution analyses (81) were performed on selected soil samples. Consolidation (3) and unconfined compression (7) testing was conducted on Shelby tube samples. Organic content was determined on 8 samples. The laboratory test results are appended.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole and Record of Penetration Test sheets for details of the subsurface conditions including soil classifications, inferred stratigraphy, standard and dynamic cone penetration test data, in situ vane and penetrometer undrained shear strength values as well as groundwater observations. The results of laboratory Atterberg limits testing, grain size distribution analyses, unconfined compression tests, organic and natural moisture content determination are also shown on the Record of Borehole sheets.

The stratigraphic profiles along the centrelines of the alignment of Highway 69 and the toe of embankment slopes (established from the profile received in August 2011 and revised in March and August 2012) and characteristic cross-sections are presented on the corresponding Drawings. The boundaries between soil strata have been established at the borehole locations only. Between and beyond the boreholes, the boundaries are assumed and may vary.

A general description of the subsurface conditions encountered at the swamp and high fill crossings is provided in Table 1. The shear strength / consistency of the cohesive soils noted on the Record of Borehole sheets and in the subsequent sections of the report is primarily based on in situ vane shear, unconfined compression and penetrometer tests on recovered samples. It is noteworthy that the results of penetrometer testing are variable from actual values due to sample disturbance. Less consideration was given to standard penetration test (SPT) ‘N’ values in soft to very soft clayey soils since the shear strength indicated by this technique in such soils is less reliable. A brief highlight of the findings is given below.

4.1 Swamp 101

A total of 7 boreholes were carried out in swamp 101. The alignment crosses a low-lying swamp section between Sta. 16+075 and 16+125 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a cohesive deposit of sandy clayey silt or bedrock. The bedrock surface was inferred by refusal at depths of 0.1 to 2.9 m (elevation 191.4 to 194.7). Water was at depths of 0.0 to 0.3 m (elevation 194.0 to 194.7) during and upon completion of drilling.

4.1.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 101-1 and 101-3. The silty topsoil was about 100 mm in thickness and penetrated at elevation 194.6 and 194.7.

A deposit of peat was present surficially in borehole 101-2 and under snow / ice and/or water at depths of 0.1 to 0.5 m (elevation 193.8 to 194.6) in boreholes 101-4 to 101-7. The peat was fine to coarse fibrous, with a moisture content of 173 and 287% in two determinations. This deposit was 100 to 900 mm thick and penetrated at depths of 0.2 to 1.4 m (elevation 192.9 to 194.5).

4.1.2 Clayey Silt

Directly beneath the peat at 1.4 m depth (elevation 192.9 and 193.0) in boreholes 101-4 and 101-5 was a cohesive deposit of sandy clayey silt. Firm to stiff in consistency, this deposit had a thickness of 1.5 m in the former borehole and 1.0 m in the latter and was penetrated at respective depths of 2.9 and 2.4 m (elevation 191.4 and 192.0).

The results of Atterberg limits testing and grain size distribution analysis performed on a cohesive sample are presented in respective Figures 101-PC-1 and 101-GS-1. The liquid and plastic limits of the sandy clayey silt were 19 and 14 respectively, thus giving the plasticity index of 5. The moisture content of the deposit varied between 12 and 29%.

4.1.3 Bedrock

The bedrock surface was inferred by refusal at depths of 0.1 to 2.9 m (elevation 191.4 to 194.7) in all the boreholes.

4.1.4 Groundwater

In the course of the field work, water was observed at depths of 0.0 to 0.3 m (elevation 194.0 to 194.7) in 4 boreholes. Water (100 to 200 mm deep) was present at surface in boreholes 101-6, 101-7 and under 300 mm of snow and ice in boreholes 101-4 and 101-5. No water was detected in boreholes 101-1 to 101-3 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.2 Swamp 102

A total of 10 boreholes were carried out in swamp 102. The alignment crosses a low-lying swamp section between Sta. 16+530 and 16+585 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying organic sandy silt or a cohesive deposit of clay underlain by cohesionless sand extending to bedrock. The bedrock surface was exposed (elevation 194.6 to 196.3) at five borehole locations and contacted at depths of 0.1 to 3.8 m (elevation 189.3 to 195.7) in the remaining boreholes. Water was at the surface during and upon completion of drilling.

4.2.1 Topsoil / Peat

Topsoil was identified surficially in boreholes 102-2 to 102-4. The silty topsoil was 100 to 300 mm in thickness and penetrated at elevation 194.1 to 195.7.

Covered with 200 to 400 mm of ice / water, a surficial deposit of peat was encountered at elevation 192.7 and 192.9 in boreholes 102-8 and 102-10 respectively. The fine fibrous peat was about 200 mm thick and penetrated at depths of 0.6 and 0.4 m (elevation 192.5 and 192.7).

4.2.2 Organic Sandy Silt

Directly beneath the peat at 0.4 m depth (elevation 192.7) in borehole 102-10 was organic sandy silt. Loose to compact in relative density, this unit had a thickness of about 200 mm and was penetrated at a depth of 0.6 m (elevation 192.5).

4.2.3 Clay

Overlain by the peat at 0.6 m depth (elevation 192.5) in borehole 102-8 was a cohesive deposit of clay. This deposit was 2.8 m in thickness and stiff to very stiff in consistency. Penetrometer tests on two samples of the clay indicated a shear strength of about 125 kPa. The deposit was penetrated at a depth of 3.4 m (elevation 189.7).

The results of Atterberg limits testing and grain size distribution analysis conducted on a cohesive sample are presented in respective Figures 102-PC-1 and 102-GS-1. The clay had a liquid limit of 57, plastic limit of 25, its plasticity index being 32. The moisture content of the deposit ranged from 33 to 51%.

4.2.4 Sand

Underlying the clay at 3.4 m depth (elevation 189.7) in borehole 102-8 was cohesionless sand. This stratum was 400 mm thick and compact in relative density. The sand extended to probable bedrock and was penetrated at a depth of 3.8 m (elevation 189.3).

4.2.5 Bedrock

Bedrock was exposed at elevation 194.6 to 196.3 in boreholes 102-1, 102-5 to 102-7 and 102-9. The bedrock surface was inferred by refusal at depths of 0.1 to 3.8 m (elevation 189.3 to 195.7) in the remaining boreholes.

4.2.6 Groundwater

In the course of the field work, water was observed at the surface (elevation 193.1) in boreholes 102-8 and 102-10. No water was detected in the remaining boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.3 Swamp 103

A total of 8 boreholes were carried out in swamp 103. The alignment crosses a low-lying swamp section between Sta. 16+695 and 16+735 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying organic silty sand and/or a cohesive deposit of clay, silty clay and clayey silt underlain by cohesionless silt / sand extending to bedrock. The bedrock surface was exposed (elevation 194.6) at one borehole location and contacted at depths of 0.2 to 5.5 m (elevation 187.7 to 193.1) in the remaining boreholes. Water was at depths of 0.0 to 0.3 m (elevation 192.7 to 193.2) during and upon completion of drilling.

4.3.1 Topsoil / Peat

Surficial topsoil was identified in borehole 103-7. The silty topsoil was about 200 mm thick and penetrated at elevation 193.1.

A deposit of peat was present surficially in boreholes 103-1, 103-4, 103-5 and under snow / ice at depths of 0.2 to 0.3 m (elevation 192.7 to 193.0) in boreholes 103-3, 103-6, 103-8. The peat was fine fibrous / amorphous, with a moisture content of 48 and 58% in two determinations. This deposit was 300 to 900 mm in thickness and penetrated at depths of 0.3 to 0.9 m (elevation 192.3 to 192.9).

4.3.2 Organic Silty Sand

Directly beneath the peat at depths of 0.3 to 0.7 m (elevation 192.3 to 192.9) in boreholes 103-1, 103-4 and 103-8 was organic silty sand. Having an organic content of 2.6% in one determination, this layer was very loose to loose in relative density and about 33% in moisture content. The organic silty sand was 0.2 to 1.1 m thick and penetrated at depths of 0.9 to 1.4 m (elevation 191.8 to 192.1).

The results of grain size distribution analysis performed on a sample of the organic silty sand are presented in Figure 103-GS-1.

4.3.3 Clayey Silt to Clay

Overlain by the peat or organic silty sand at depths of 0.6 to 1.4 m (elevation 191.8 to 192.6) in boreholes 103-1, 103-3, 103-4, 103-6 and 103-8 was a cohesive deposit of clay, silty clay and clayey silt. This deposit had a thickness of 0.2 to 3.5 m and was soft to stiff in consistency. The results of in situ vane testing carried out in the clayey silt yielded undisturbed shear strength values in a range of 20 to 40 kPa (soil sensitivity of 5 and 10). Penetrometer tests on cohesive samples indicated a shear strength varying widely between 12 and 100 kPa. The deposit was penetrated at depths of 1.1 to 4.9 m (elevation 188.3 to 191.9).

The results of Atterberg limits testing and grain size distribution analyses conducted on 4 cohesive samples are presented in respective Figures 103-PC-1, 103-PC-2 and 103-GS-2, 103-GS-3. The liquid and plastic limits of the clayey silt ranged from 28 to 30 and from 14 to 16 respectively, with the plasticity index of 14. The clay had a liquid limit of 56, plastic limit of 22 and 25, thus giving the plasticity index of 34 and 31. The moisture content of the clayey soils varied between 26 and 44%.

4.3.4 Silt / Sand

Non-plastic silt was encountered below the clayey silt at depths of 4.5 and 4.9 m (elevation 188.6 and 188.3) in boreholes 103-1 and 103-4 respectively. This unit was loose in relative density and about 28% in moisture content. Having a thickness of 400 mm in borehole 103-1 and 600 mm in borehole 103-4, the silt was penetrated at respective depths of 4.9 and 5.5 m (elevation 188.2 and 187.7).

Underlying the silt at a depth of 4.9 m (elevation 188.2) in borehole 103-1 was cohesionless sand. Compact in relative density, this stratum was about 300 mm thick and penetrated at 5.2 m depth (elevation 187.9).

4.3.5 Bedrock

Bedrock was exposed at elevation 194.6 in borehole 103-2. The bedrock surface was inferred by refusal at depths of 0.2 to 5.5 m (elevation 187.7 to 193.1) in the remaining boreholes.

4.3.6 Groundwater

In the course of the field work, water was observed at depths of 0.0 to 0.3 m (elevation 192.7 to 193.2) in 5 boreholes. Water was present at surface in boreholes 103-1, 103-4 and under 200 to 300 mm of snow and ice in boreholes 103-3, 103-6 and 103-8. No water was detected in boreholes 103-2, 103-5 and 103-7 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.4 Swamp 104

A total of 10 test holes comprising 8 boreholes and 2 dynamic cone penetration tests were advanced in swamp 104. The alignment crosses a low-lying swamp section between Sta. 16+795 and 16+837.5 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat over organic soils overlying a cohesive deposit of clay, silty clay and clayey silt underlain by cohesionless sandy silt / sand extending to bedrock. The bedrock surface was exposed (elevation 194.3) at one borehole location and contacted at depths of 0.5 to 8.1 m (elevation 185.4 to 193.8) in the remaining test holes. Water was at depths of 0.3 to 1.5 m (elevation 191.7 to 192.9) during and upon completion of drilling.

4.4.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 104-1, 104-7 and 104-9. The silty topsoil was 200 to 500 mm thick and penetrated at elevation 193.2 to 193.8.

A deposit of peat was present surficially in boreholes 104-3, 104-4, 104-10 and under snow / ice at 0.3 m depth (elevation 192.9) in borehole 104-6. The peat was fine to coarse fibrous and had an organic content of 9.5% in one determination. The moisture content of this deposit varied between 31 and 87%. The peat had a thickness of 300 to 600 mm and was penetrated at depths of 0.3 to 0.6 m (elevation 192.6 to 193.7) in boreholes 104-3, 104-4 and 104-10. Containing layers of organic sand, the deposit was 1.9 m thick and penetrated at a depth of 2.2 m (elevation 191.0) in borehole 104-6.

4.4.2 Organic Soils

Directly beneath the topsoil or peat at depths of 0.2 to 0.6 m (elevation 192.6 to 193.7) in boreholes 104-1, 104-3, 104-4, 104-7 and 104-10 was organic silt and/or silty/sandy soils with organics. These units were very loose to compact in relative density and 20 to 27% in moisture content. The organic soils were 0.2 to 1.2 m thick and penetrated at depths of 0.5 to 1.8 m (elevation 191.4 to 193.5).

4.4.3 Clayey Silt to Clay

Overlain by the peat or organic soils at depths of 0.5 to 2.2 m (elevation 191.0 to 193.5) in boreholes 104-1, 104-3, 104-4, 104-6, 104-7 and 104-10 was a cohesive deposit of clayey silt, silty clay and clay. This deposit had a thickness of 0.6 to 4.2 m and was typically firm to stiff in consistency. The results of in situ vane testing carried out in the clayey silt / clay yielded undisturbed shear strength values in a range of 20 to 56 kPa (soil sensitivity of 4 to 7). Penetrometer tests on cohesive samples indicated a shear strength varying widely between 25 and 137 kPa. The deposit was penetrated at depths of 1.2 to 5.6 m (elevation 187.9 to 192.5).

The results of Atterberg limits testing and grain size distribution analyses conducted on 3 cohesive samples are presented in respective Figures 104-PC-1, 104-PC-2 and 104-GS-1, 104-GS-2. The liquid and plastic limits of the clayey silt were 31 and 17 respectively, thus giving the plasticity index of 14. The clay had a liquid limit of 55 and 56, plastic limit of 21, its plasticity index being 34 and 35. The moisture content of the clayey soils varied between 21 and 66%.

4.4.4 Sandy Silt / Sand

Cohesionless sandy silt and/or sand underlay the clayey silt / clay at depths of 1.5 to 5.6 m (elevation 187.9 to 192.5) in boreholes 104-4, 104-7 and 104-10. These strata were 0.3 to 2.5 m in total thickness and very loose to compact in relative density (SPT-‘N’ values of 2 to 21), their moisture content ranging from 19 to 21%. The sandy silt / sand was penetrated at depths of 1.8 to 8.1 m (elevation 185.4 to 192.2).

The results of grain size distribution analyses performed on 2 samples of the sandy silt and sand are presented in Figures 104-GS-3 and 104-GS-4 respectively.

4.4.5 Bedrock

Bedrock was exposed at elevation 194.3 in borehole 104-2. The bedrock surface was inferred by refusal at depths of 0.5 to 8.1 m (elevation 185.4 to 193.8) in the remaining test holes.

4.4.6 Groundwater

In the course of the field work, water was observed in 3 boreholes. Groundwater was measured in boreholes 104-4, 104-6 and 104-7 to be at depths of 0.3 to 1.5 m (elevation 191.7 to 192.9). No water was detected in boreholes 104-1 to 104-3, 104-9 and 104-10 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.5 Swamp 105

A total of 15 test holes comprising 13 boreholes and 2 dynamic cone penetration tests were advanced in swamp 105. The alignment crosses a low-lying swamp section between Sta. 16+925 and 17+030 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / clay underlain by cohesionless sandy silt / silt extending to bedrock. The bedrock surface was exposed (elevation 197.0) at one borehole location and contacted at depths of 0.1 to 3.8 m (elevation 192.1 to 198.2) in the remaining test holes. Water was at 0.3 m depth (elevation 195.7 to 195.8) during and upon completion of drilling.

4.5.1 Fill

Surficial fill composed of topsoil was identified in borehole 105-11. The fill was about 400 mm thick and penetrated at elevation 196.2.

4.5.2 Topsoil / Peat

Topsoil was present surficially in boreholes 105-1, 105-13 and 105-15. The silty topsoil was 100 to 300 mm in thickness and penetrated at elevation 195.6 to 198.2.

A surficial deposit of peat was present in boreholes 105-3, 105-4, 105-7 to 105-9 and 105-12. This deposit was encountered under snow / ice or the fill at depths of 0.3 to 0.4 m (elevation 195.8 to 196.5) in boreholes 105-5, 105-10 and 105-11. The peat was fine to coarse fibrous and had an organic content of 5.1% in one determination. With a moisture content reaching 462 and 559%, this deposit was 0.2 to 1.4 m thick and penetrated at depths of 0.2 to 1.7 m (elevation 194.6 to 196.1).

4.5.3 Organic Clayey Silt

Directly beneath the peat at 1.4 m depth (elevation 194.6) in borehole 105-4 was organic clayey silt. This unit was soft to firm in consistency and about 38% in moisture content. The organic clayey silt had a thickness of 400 mm and was penetrated at a depth of 1.8 m (elevation 194.2).

4.5.4 Clayey Silt / Clay

Overlain by the peat at depths of 0.2 to 1.1 m (elevation 195.0 to 196.1) in boreholes 105-7, 105-10 and 105-12 was a cohesive deposit of clayey silt / clay. Firm in consistency, this deposit was 0.3 to 2.1 m thick and penetrated at depths of 1.0 to 3.2 m (elevation 192.9 to 195.1).

The results of Atterberg limits testing and grain size distribution analyses conducted on 2 cohesive samples are presented in respective Figures 105-PC-1, 105-PC-2 and 105-GS-1, 105-GS-2. The liquid and plastic limits of the clayey silt were 24 and 16 respectively, thus giving the plasticity index of 8. The clay had a liquid limit of 53, plastic limit of 23, its plasticity index being 30. The moisture content of the clayey soils varied between 23 and 45%.

4.5.5 Sandy Silt / Silt

Underlying the organic clayey silt in borehole 105-4 and clayey silt in borehole 105-10 at respective depths of 1.8 and 1.0 m (elevation 194.2 and 195.1) was cohesionless sandy silt / silt. This stratum was 200 to 300 mm in thickness and compact in relative density. The sandy silt / silt was penetrated at depths of 2.1 and 1.2 m (elevation 193.9 and 194.9).

4.5.6 Bedrock

Bedrock was exposed at elevation 197.0 in borehole 105-14. The bedrock surface was inferred by refusal at depths of 0.1 to 3.8 m (elevation 192.1 to 198.2) in the remaining test holes.

4.5.7 Groundwater

In the course of the field work, water was observed in 3 boreholes. Groundwater was measured in boreholes 105-4, 105-7 and 105-10 to be at 0.3 m depth (elevation 195.7 to 195.8). No water was detected in boreholes 105-1, 105-3, 105-5, 105-8, 105-9, 105-11 to 105-15 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.6 Swamp 106

A total of 11 test holes comprising 10 boreholes and 1 dynamic cone penetration test were advanced in swamp 106. The alignment crosses a low-lying swamp section between Sta. 17+537.5 and 17+610 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying sandy soils containing a cohesive deposit of clay / clayey silt and extending to bedrock. The bedrock surface was exposed (elevation 197.9 and 198.4) at two borehole locations and contacted at depths of 0.3 to 2.7 m (elevation 194.7 to 198.9) in the remaining test holes. Water was at depths of 0.3 to 0.4 m (elevation 197.1 to 197.6) during and upon completion of drilling.

4.6.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 106-1, 106-7 and 106-11. With a moisture content of 62%, the sandy/silty topsoil was 300 to 400 mm thick and penetrated at elevation 197.6 to 198.9.

A deposit of peat was present surficially in boreholes 106-3, 106-6, 106-8 and under snow / ice and/or water at depths of 0.5 and 0.3 m (elevation 196.9 and 197.4) in boreholes 106-2 and 106-9 respectively. The peat was fine fibrous and had a moisture content of 116% in one determination. The peat was 200 to 600 mm thick and penetrated at depths of 0.4 to 0.7 m (elevation 196.7 to 197.2).

4.6.2 Silty Sand

Directly beneath the peat in boreholes 106-2 and 106-9 at respective depths of 0.7 and 0.5 m (elevation 196.7 and 197.2) was silty sand with organics. This unit was very loose in relative density and about 28% in moisture content. The silty sand had a thickness of 700 mm in the former borehole and 300 mm in the latter and was penetrated at depths of 1.4 and 0.8 m (elevation 196.0 and 196.9).

4.6.3 Clay / Clayey Silt

Overlain by the silty sand in boreholes 106-2 and 106-9 at respective depths of 1.4 and 0.8 m (elevation 196.0 and 196.9) was a cohesive deposit of clay / clayey silt. Firm to stiff in consistency, this deposit was 1.3 and 0.6 m thick respectively and penetrated at depths of 2.7 and 1.4 m (elevation 194.7 and 196.3).

The results of Atterberg limits testing and grain size distribution analyses conducted on 2 cohesive samples are presented in respective Figures 106-PC-1 and 106-GS-1, 106-GS-2. The liquid and plastic limits of the clay were 52 and 21 respectively, thus giving the plasticity index of 31. The moisture content of the clayey soils varied between 22 and 29%.

4.6.4 Sand / Sand and Gravel

Underlying the topsoil / peat at 0.4 m depth (elevation 197.6 and 197.1) in boreholes 106-1 and 106-3 or clay at a depth of 1.4 m (elevation 196.3) in borehole 106-9 was cohesionless sand / sand and gravel. This stratum was 0.2 to 1.9 m in thickness and loose to compact in relative density (SPT-‘N’ values of 5 to over 10), its moisture content ranging from 20 to 26%. The sandy silt / sand was penetrated at depths of 0.6 to 2.3 m (elevation 195.7 to 196.9).

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure 106-GS-3.

4.6.5 Bedrock

Bedrock was exposed at elevation 197.9 and 198.4 in boreholes 106-4 and 106-5 respectively. The bedrock surface was inferred by refusal at depths of 0.3 to 2.7 m (elevation 194.7 to 198.9) in the remaining test holes.

4.6.6 Groundwater

In the course of the field work, water was observed in 4 boreholes. Groundwater was measured in boreholes 106-1 to 106-3 and 106-9 to be at depths of 0.3 to 0.4 m (elevation 197.1 to 197.6). No water was detected in boreholes 106-4 to 106-8 and 106-11 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.7 Swamp 107

A total of 28 test holes comprising 25 boreholes and 3 dynamic cone penetration tests were advanced in swamp 107. The alignment crosses a low-lying swamp section between Sta. 17+700 and 17+870 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying silty/sandy soils and/or a cohesive deposit of silty clay / clayey silt extending to bedrock. The bedrock surface was exposed at five borehole locations (elevation 197.7 to 199.9) and contacted at depths of 0.1 to 11.6 m (elevation 186.1 to 198.6) in the remaining test holes. Water was at the surface during and upon completion of drilling.

4.7.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 107-1, 107-4, 107-5 and 107-26. The silty topsoil was 100 to 600 mm thick and penetrated at elevation 197.4 to 198.6.

A deposit of peat was present surficially in boreholes 107-2, 107-6, 107-7, 107-9, 107-11 and under snow / ice and water at depths of 0.3 to 0.8 m (elevation 196.4 to 197.6) in boreholes 107-8, 107-10, 107-12, 107-13, 107-18, 107-20, 107-23, 107-24. The peat was fine to coarse fibrous and had an organic content of 7.4% in one determination. The moisture content of this deposit varied widely between 23 and 767%. The peat had a thickness of 0.1 to 1.7 m and was penetrated at depths of 0.1 to 2.5 m (elevation 194.7 to 198.0).

4.7.2 Silty/Sandy Soils

Directly beneath 0.7 m of snow / ice and water at elevation 197.0 in borehole 107-27 or the peat at depths of 0.9 to 2.5 m (elevation 194.7 to 196.5) in boreholes 107-18, 107-20, 107-23 and 107-24 were cohesionless soils of variable granulometric composition (silt, sandy silt, silty sand, sand). These units were very loose to very dense (SPT-'N' values of 0 to over 100) and had a moisture content of 24 to 30%. The silty/sandy soils were 0.2 to 1.3 m thick and penetrated at depths of 0.9 to 3.3 m (elevation 194.2 to 196.8).

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure 107-GS-1.

4.7.3 Silty Clay / Clayey Silt

Overlain by 2.1 m of snow / ice and water at elevation 195.7 in borehole 107-17 or the peat, silty/sandy soils at depths of 0.6 to 3.3 m (elevation 194.2 to 197.3) in boreholes 107-10, 107-18, 107-20, 107-23 and 107-24 was a cohesive deposit of silty clay / clayey silt. This deposit had a thickness of 0.8 to 5.4 m and was soft to very stiff, typically firm in consistency. The results of in situ vane testing carried out in the cohesive deposit yielded undisturbed shear strength values in a range of 12 to 52 kPa (soil sensitivity of 2 to 3). The deposit was penetrated at depths of 1.5 to 8.7 m (elevation 188.9 to 196.4).

The results of Atterberg limits testing and grain size distribution analyses conducted on 4 cohesive samples are presented in respective Figures 107-PC-1, 107-PC-2 and 107-GS-2, 107-GS-3. The liquid and plastic limits of the silty clay ranged from 42 to 47 and from 19 to 20 respectively, thus giving the plasticity index of 23 and 27. The clayey silt had a liquid limit of 30 and 31, plastic limit of 16 and 20, its plasticity index being 11 and 14. The moisture content of the clayey soils varied between 23 and 80%.

4.7.4 Gravelly Sand

Underlying the silty clay at 8.7 m depth (elevation 188.9) in borehole 107-20 was cohesionless gravelly sand. This stratum was very dense (SPT-'N' value of 53) and had a moisture content of about 9%. The gravelly sand was 900 mm thick and penetrated at a depth of 9.6 m (elevation 188.0).

The results of grain size distribution analysis performed on the gravelly sand sample are presented in Figure 107-GS-4.

4.7.5 Bedrock

Bedrock was exposed at elevation 197.7 to 199.9 in boreholes 107-3, 107-14, 107-16, 107-22 and 107-28. In the remaining test holes, the bedrock surface was inferred by refusal at depths of 0.1 to 5.5 m (elevation 191.9 to 198.6), locally in boreholes 107-20 and 107-21 at depths of 9.6 and 11.6 m (elevation 188.0 and 186.1).

4.7.6 Groundwater

In the course of the field work, water was observed in 12 boreholes. Water was present at surface (elevation 197.2 to 198.2) in boreholes 107-7, 107-8, 107-10, 107-12, 107-13, 107-17 to 107-20, 107-23, 107-24 and 107-27. No water was detected in the remaining boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.8 Swamp 108

A total of 7 test holes comprising 6 boreholes and 1 dynamic cone penetration test were advanced in swamp 108. The alignment crosses a low-lying swamp section between Sta. 18+220 and 18+250 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying silty sand and/or a cohesive deposit of silty clay extending to bedrock. The bedrock surface was contacted at depths of 0.1 to 3.1 m (elevation 192.6 to 199.3). Water was at depths of 0.0 to 0.3 m (elevation 195.5 to 195.7) during and upon completion of drilling.

4.8.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 108-1, 108-3 and 108-7. The silty topsoil was 100 to 300 mm thick and penetrated at elevation 195.6 to 199.3.

A deposit of peat was present surficially in borehole 108-2 and under ice and water at 0.6 m depth (elevation 195.1) in borehole 108-4. The peat was coarse fibrous and about 56% in moisture content. The peat had a thickness of 200 mm in the former borehole and 400 mm in the latter and was penetrated at respective depths of 0.2 and 1.0 m (elevation 195.5 and 194.7).

4.8.2 Silty Sand

Directly beneath the peat at 1.0 m depth (elevation 194.7) in borehole 108-4 was silty sand. This unit was 400 mm thick and loose in relative density (SPT-‘N’ value of 4). The silty sand was penetrated at a depth of 1.4 m (elevation 194.3).

4.8.3 Silty Clay

Overlain by the peat at 0.2 m depth (elevation 195.5) in borehole 108-2 or by the silty sand at a depth of 1.4 m (elevation 194.3) in borehole 108-4 was a cohesive deposit of silty clay. This deposit was 0.1 and 1.7 m in thickness and soft to stiff in consistency. The silty clay was penetrated at depths of 0.3 and 3.1 m (elevation 195.4 and 192.6).

The results of grain size distribution analysis conducted on a cohesive sample are presented in Figure 108-GS-1. The moisture content of the silty clay varied between 45 and 59%.

4.8.4 Bedrock

The bedrock surface was inferred by refusal at depths of 0.1 to 3.1 m (elevation 192.6 to 199.3) in all the test holes.

4.8.5 Groundwater

In the course of the field work, water was observed at depths of 0.0 to 0.3 m (elevation 195.5 to 195.7) in 2 boreholes. Water was present at surface in borehole 108-4 and under 300 mm of snow and ice in borehole 108-5. No water was detected in boreholes 108-1 to 108-3 and 108-7 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.9 Swamp 109

A total of 16 test holes comprising 8 boreholes and 8 dynamic cone penetration tests were advanced in swamp 109. The alignment crosses a low-lying swamp section between Sta. 18+580 and 18+650 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt, silty clay and clay underlain by cohesionless sandy soils extending to bedrock. The bedrock surface was exposed (elevation 193.1 and 193.3) at two borehole locations and contacted at depths of 0.2 to 16.7 m (elevation 171.5 to 192.3) in the remaining boreholes. Water was at 0.3 m depth (elevation 187.3 to 189.0) during and upon completion of drilling.

4.9.1 Topsoil / Peat

Surficial topsoil was present in boreholes 109-3, 109-14 and 109-16. The silty topsoil was 200 to 300 mm thick and penetrated at elevation 191.3 to 192.3.

A deposit of peat was overlain by 0.6 to 1.2 m of snow / ice and water at elevation 186.4 to 188.7 in boreholes 109-5, 109-8 and 109-10. The fine fibrous peat had a thickness of 0.3 to 1.0 m and was penetrated at depths of 1.1 to 1.6 m (elevation 186.0 to 187.7).

4.9.2 Organic Soils

Organic silty clay was identified below the peat at 1.6 m depth (elevation 186.0) in borehole 109-10. Soft in consistency, the organic silty clay was 300 mm thick and penetrated at a depth of 1.9 m (elevation 185.7).

Directly beneath the peat at 1.1 m depth (elevation 187.1) in borehole 109-5 was sand with organics. Loose in relative density and 300 mm in thickness, this unit was penetrated at a depth of 1.4 m (elevation 186.8).

4.9.3 Clayey Silt to Clay

Underlying the peat or organic soils at depths of 1.4 to 1.9 m (elevation 185.7 to 187.7) in boreholes 109-5, 109-8 and 109-10 was a cohesive deposit of clayey silt, silty clay and clay. This deposit was 2.8 to 14.2 m in thickness and soft to stiff, typically firm in consistency. The results of in situ vane testing carried out in the clay / silty clay yielded undisturbed shear strength values in a range of 16 to 40 kPa (soil sensitivity of 2 to 6). Penetrometer tests on cohesive samples indicated a shear strength varying widely between 25 and 112 kPa. The deposit was penetrated at depths of 4.4 to 15.6 m (elevation 172.6 to 184.9).

The results of Atterberg limits testing and grain size distribution analyses conducted on 5 cohesive samples are presented in respective Figures 109-PC-1 to 109-PC-3 and 109-GS-1 to 109-GS-3. The clayey silt had a liquid limit of 24, plastic limit of 15, thus giving the plasticity index of 9. The liquid and plastic limits of the silty clay ranged from 43 to 49 and from 17 to 20 respectively, with the plasticity index of 23 to 29. The clay had a liquid limit of 60, plastic limit of 25, its plasticity index being 35. The moisture content of the clayey soils varied between 27 and 79%.

4.9.4 Sand

A layer of cohesionless sand was encountered below the clay at 15.6 m depth (elevation 172.6) in borehole 109-5. This stratum was compact in relative density (SPT-‘N’ value of 27) and had a moisture content of 10%. The sand was 1.1 m thick and penetrated at a depth of 16.7 m (elevation 171.5).

4.9.5 Bedrock

Bedrock was exposed at elevation 193.1 and 193.3 in boreholes 109-1 and 109-15 respectively. The bedrock surface was inferred by refusal at depths of 0.2 to 16.7 m (elevation 171.5 to 192.3) in the remaining test holes with the exception of dynamic cone penetration tests 109-2, and 109-4 terminated in probable compact sandy silt at respective depths of 15.2 and 15.8 m (elevation 174.1 and 173.3).

4.9.6 Groundwater

In the course of the field work, water was observed at 0.3 m depth (elevation 187.3 to 189.0) in 3 boreholes. Water (300 to 900 mm deep) was under snow and ice in boreholes 109-5, 109-8 and 109-10. No water was detected in boreholes 109-1, 109-3, 109-14 to 109-16 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.10 Swamp 110

A total of 26 test holes comprising 21 boreholes and 5 dynamic cone penetration tests were advanced in swamp 110. An additional dynamic cone penetration test was performed beside one borehole. The alignment crosses a low-lying swamp section between Sta. 18+780 and 18+970 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / silty clay and/or cohesionless sand / silty sand extending to bedrock. The bedrock surface was exposed (elevation 195.6 to 199.7) at seven borehole locations and contacted at depths of 0.1 to 8.4 m (elevation 187.0 to 198.8) in the remaining test holes. Water was at depths of 0.2 to 0.3 m (elevation 193.7 to 196.4) during and upon completion of drilling.

4.10.1 Topsoil / Peat

Surficial topsoil was present in boreholes 110-12, 110-16 to 110-18 and 110-26. The sandy topsoil was also identified under snow / ice and water at a depth of 0.5 m (elevation 194.1) in borehole 110-23. The topsoil was 100 to 500 mm in thickness and penetrated at depths of 0.1 to 0.7 m (elevation 193.9 to 198.8).

A deposit of peat was present surficially in boreholes 110-6, 110-20 and under snow / ice and water at depths of 0.2 to 0.7 m (elevation 193.3 to 196.0) in boreholes 110-3, 110-5, 110-8, 110-10, 110-11, 110-22. The peat was fine to coarse fibrous and had an organic content of 77.5% in one determination. The moisture content of this deposit varied widely between 67 and 575%. The peat was 0.2 to 1.6 m thick and penetrated at depths of 0.4 to 2.2 m (elevation 192.3 to 194.5).

4.10.2 Clayey Silt / Silty Clay

Overlain by the peat (and sand in one borehole) at depths of 0.4 to 2.2 m (elevation 192.3 to 194.5) in boreholes 110-3, 110-5, 110-8, 110-10, 110-11 and 110-22 was a cohesive deposit of clayey silt / silty clay. This deposit had a thickness of 0.3 to 4.0 m and was soft to stiff in consistency. The results of in situ vane testing carried out in the silty clay yielded undisturbed shear strength values in a range of 20 to 24 kPa (soil sensitivity of 3 to 5). The deposit was penetrated at depths of 0.7 to 6.2 m (elevation 189.1 to 193.8).

The results of Atterberg limits testing and grain size distribution analyses conducted on 4 cohesive samples are presented in respective Figures 110-PC-1, 110-PC-2 and 110-GS-1, 110-GS-2. The clayey silt had a liquid limit of 25 and 30, plastic limit of 17 and 18, thus giving the plasticity index of 8 and 12. The liquid and plastic limits of the silty clay ranged from 43 to 47 and from

18 to 21 respectively, with the plasticity index of 25 and 26. The moisture content of the clayey soils varied between 21 and 85%.

4.10.3 Sand / Silty Sand

Underlying the topsoil / peat in boreholes 110-11, 110-23 or the silty clay in boreholes 110-10, 110-22 at depths of 0.7 to 3.5 m (elevation 192.7 to 193.9) was cohesionless sand / silty sand. This stratum was typically compact in relative density and about 11% in moisture content. The sand / silty sand was 0.2 to 1.1 m thick and penetrated at depths of 0.9 to 3.8 m (elevation 192.3 to 193.6). A layer of sand probably underlay the silty clay at 6.2 m depth (elevation 189.1) and extended to bedrock at a depth of 6.9 m (elevation 188.4) in borehole 110-3.

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure 110-GS-3.

4.10.4 Bedrock

Bedrock was exposed at elevation 195.6 to 199.7 in boreholes 110-4, 110-7, 110-9, 110-14, 110-15, 110-19 and 110-24. In the remaining test holes, the bedrock surface was inferred by refusal at depths of 0.1 to 4.7 m (elevation 189.8 to 198.8), locally in boreholes 110-2 and 110-3 at depths of 6.9 and 8.4 m (elevation 188.4 and 187.0).

4.10.5 Groundwater

In the course of the field work, water was observed at depths of 0.2 to 0.3 m (elevation 193.7 to 196.4) in 7 boreholes. Water (typically 300 to 400 mm deep) was under snow and ice in boreholes 110-3, 110-5, 110-8, 110-10, 110-11, 110-22 and 110-23. No water was detected in the remaining boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.11 Swamp 111

A total of 6 boreholes were carried out in swamp 111. The alignment crosses a low-lying swamp section between Sta. 19+030 and 19+060 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying organic silty clay or a cohesive deposit of silty clay extending to bedrock. The bedrock surface was exposed (elevation 196.4 and 197.5) at two borehole locations and contacted at depths of 0.2 to 3.7 m (elevation 191.3 to 195.0) in the remaining boreholes. Water was at depths of 0.2 to 0.3 m (elevation 194.0 to 194.8) during and upon completion of drilling.

4.11.1 Topsoil / Peat

Surficial topsoil was identified in borehole 111-5. The silty topsoil was about 200 mm thick and penetrated at elevation 195.0.

A deposit of peat was present surficially in borehole 111-1 and under snow / ice and water at a depth of 1.5 m (elevation 193.5) in borehole 111-4. The fine to coarse fibrous peat had a thickness of 600 mm in the former borehole and 200 mm in the latter and was penetrated at respective depths of 0.6 and 1.7 m (elevation 194.6 and 193.3).

4.11.2 Organic Silty Clay

Organic silty clay was overlain by snow / ice and water at 0.8 m depth (elevation 193.5) in borehole 111-3. This unit was firm in consistency and about 40% in moisture content. Containing sand pockets in the lower portion, the organic silty clay was 600 mm thick and penetrated at a depth of 1.4 m (elevation 192.9).

4.11.3 Silty Clay

Underlying the peat at 1.7 m depth (elevation 193.3) in borehole 111-4 was a cohesive deposit of silty clay. This deposit was firm to stiff in consistency, with penetrometer tests indicating a shear strength of about 50 kPa. The silty clay had a thickness of 2.0 m and was penetrated at a depth of 3.7 m (elevation 191.3).

The results of Atterberg limits testing and grain size distribution analysis conducted on a sample of the deposit are presented in respective Figures 111-PC-1 and 111-GS-1. The silty clay had a liquid limit of 44, plastic limit of 20, thus giving the plasticity index of 24. The moisture content of the deposit varied between 24 and 47%.

4.11.4 Bedrock

Bedrock was exposed at elevation 197.5 and 196.4 in boreholes 111-2 and 111-6 respectively. The bedrock surface was inferred by refusal at depths of 0.2 to 3.7 m (elevation 191.3 to 195.0) in the remaining boreholes.

4.11.5 Groundwater

In the course of the field work, water was observed at depths of 0.2 to 0.3 m (elevation 194.0 to 194.8) in 2 boreholes. Water (0.5 to 1.3 m deep) was under 200 to 300 mm of snow and ice in boreholes 111-3 and 111-4. No water was detected in boreholes 111-1 and 111-5 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.12 Swamp 112

A total of 18 boreholes were carried out in swamp 112. An additional dynamic cone penetration test was performed beside one borehole. The alignment crosses a low-lying swamp section between Sta. 19+350 and 19+460, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt, silty clay and clay extending to bedrock. The bedrock surface was exposed at six borehole locations and contacted at depths of 0.1 to 11.1 m (elevation 177.7 to 195.9) in the remaining boreholes with the exception of 112-12 where rockfill was at the surface. Water was at depths of 0.0 to 3.6 m (elevation 188.1 to 191.9) upon completion of drilling.

4.12.1 Rockfill

Rockfill was present at the surface (elevation 194.7) in borehole 112-12 which was located at the east side of the existing Highway 69 NBL embankment.

4.12.2 Topsoil / Peat

Topsoil was present surficially in boreholes 112-1, 112-3, 112-11, 112-14, 112-17 and under some 300 mm of snow and ice in boreholes 112-13 and 112-15. The sandy/silty topsoil was 100 to 300 mm thick and penetrated at depths of 0.1 to 0.6 m (elevation 190.5 to 195.9).

A deposit of peat was encountered under snow and ice at depths of 0.2 to 0.6 m (elevation 188.1 and 188.8) in boreholes 112-4 to 112-7. The peat was fine to coarse fibrous and had a moisture content of 29 to 41%. This deposit had a thickness of 300 to 600 mm and was penetrated at depths of 0.5 to 1.2 m (elevation 187.5 to 188.3).

Organic silt was identified below the peat at 0.5 m depth (elevation 188.3) in borehole 112-6. This layer was very loose in relative density (SPT-‘N’ value of 3) and about 48% in moisture content. The organic silt was 900 mm thick and penetrated at a depth of 1.4 m (elevation 187.4).

4.12.3 Silty/Sandy Soils

Directly beneath the peat at 1.1 m depth (elevation 188.3) in borehole 112-4 or the topsoil at a depth of 0.3 m (elevation 192.2) in borehole 112-14 were cohesionless silty/sandy soils (sand, silty sand). These strata were very loose to loose in relative density (SPT-‘N’ values of 2 to 6), with a moisture content of 24 to 26%. The silty/sandy soils were 0.3 and 1.7 m in thickness and penetrated at depths of 1.4 and 2.0 m (elevation 188.0 and 190.5) in boreholes 112-4 and 112-14 respectively.

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure 112-GS-1.

4.12.4 Clayey Silt to Clay

Overlain by the organic or silty/sandy soils at depths of 0.5 to 2.0 m (elevation 187.4 to 191.2) in boreholes 112-4 to 112-7, 112-13 to 112-15 was a cohesive deposit of clayey silt, silty clay and clay. This deposit was 1.1 to 9.5 m thick and very soft to stiff, typically soft to firm in consistency. The results of in situ vane testing carried out in the clayey soils yielded undisturbed shear strength values in a range of 8 to 64 kPa (soil sensitivity of 1 to 16). Penetrometer tests indicated a shear strength of 13 to 175 kPa. The unconfined compression tests on Shelby tube samples gave shear strength values of 11.3 and 20.1 kPa at 2.0 and 2.4% strain, respectively. In borehole 112-4, the organic content of the clayey silt containing layers of amorphous peat was 17.4%. The deposit was penetrated at depths of 2.1 to 10.9 m (elevation 177.9 to 189.4).

The results of Atterberg limits testing and grain size distribution analyses conducted on 9 cohesive samples are presented in respective Figures 112-PC-1 to 112-PC-3 and 112-GS-2 to 112-GS-4. The liquid and plastic limits of the clayey silt were 23 to 34 and 15 to 18 respectively, with the plasticity index of 8 to 18. The silty clay had a liquid limit of 38, plastic limit of 20, its plasticity index being 18. The liquid and plastic limits of the clay ranged from 51 to 58 and from 21 to 23 respectively, thus giving the plasticity index of 30 to 35. The moisture content of the clayey soils varied between 22 and 84%.

4.12.5 Sand

Underlying the clay at 10.9 m depth (elevation 177.9) in borehole 112-6 and a depth of 3.9 m (elevation 187.8) in borehole 112-15 was cohesionless sand. Compact to dense, this unit had a thickness of 200 mm in the former borehole and 100 mm in the latter and was penetrated at respective depths of 11.1 and 4.0 m (elevation 177.7 and 187.7).

4.12.6 Bedrock

Bedrock was exposed at elevation 192.9 to 198.4 in boreholes 112-2, 112-8 to 112-10, 112-16 and 112-18. The bedrock surface was inferred by refusal at depths of 0.1 to 11.1 m (elevation 177.7 to 195.9) in the remaining boreholes with the exception of borehole 112-12 where rockfill was at the surface.

4.12.7 Groundwater

In the course of the field work, water was observed in 7 boreholes. In the process of augering, water was detected at depths of 0.3 to 3.9 m (elevation 187.8 to 191.7) in boreholes 112-4 to 112-7, 112-13 to 112-15. Upon completion of drilling, groundwater was measured in boreholes 112-4 to 112-6, 112-13 to 112-15 to be at depths of 0.0 and 3.6 m (elevation 188.1 to 191.9). No water was observed in the remaining boreholes. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.13 Swamp 113

A total of 15 test holes comprising 14 boreholes and 1 dynamic cone penetration test were advanced in swamp 113. The alignment crosses a low-lying swamp section between Sta. 19+750 and 19+810, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / silty clay / clay or cohesionless sand extending to bedrock. The bedrock surface was exposed at four borehole locations and contacted at depths of 0.1 to 4.2 m (elevation 190.1 to 198.7) in the remaining test holes.

4.13.1 Topsoil / Peat

Topsoil was present surficially in boreholes 113-1, 113-4, 113-5, 113-14 and under 300 mm of snow / ice in borehole 113-15. The silty topsoil was 100 to 200 mm in thickness and penetrated at elevation 195.1 to 198.7.

Covered with 200 to 300 mm of ice and 300 to 600 mm of water, a deposit of peat was encountered at depths of 0.6 to 0.9 m (elevation 193.1 to 193.9) in boreholes 113-7, 113-9, 113-10 and 113-13. The fine to coarse fibrous peat was 300 to 800 mm thick and penetrated at depths of 1.2 to 1.4 m (elevation 192.7 to 193.1).

4.13.2 Sand

Buried under 300 mm of snow and ice at elevation 196.2 in borehole 113-12 was cohesionless sand. Loose to compact in relative density, this unit had a thickness of 1.0 m and was penetrated at a depth of 1.3 m (elevation 195.2).

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure 113-GS-1.

4.13.3 Clayey Silt to Clay

A cohesive deposit of clayey silt, silty clay and clay underlay the topsoil or peat at depths of 0.5 to 1.2 m (elevation 192.7 to 195.1) in boreholes 113-7, 113-10 and 113-15. This deposit was 0.3 to 3.0 m in thickness and stiff to very stiff in consistency, becoming soft at depth. The results of in situ vane testing carried out in the silty clay and clay yielded undisturbed shear strength values in a range of 12 to 40 kPa (soil sensitivity of 5 to 20). Penetrometer tests indicated a shear strength decreasing with depth from 100 to 25 kPa. The unconfined compression test on a Shelby tube sample of the silty clay gave a shear strength of 12.6 kPa at 1.9% strain. The deposit was penetrated at depths of 0.8 to 4.2 m (elevation 190.1 to 194.8).

The results of Atterberg limits testing and grain size distribution analyses conducted on 2 cohesive samples are presented in respective Figures 113-PC-1, 113-PC-2 and 113-GS-2, 113-GS-3. The silty clay had a liquid limit of 49 and plastic limit of 20, thus giving the plasticity index of 29. The liquid and plastic limits of the clay were 55 and 23 respectively, with the plasticity index of 32. The moisture content of the clayey soils varied between 25 and 77%.

4.13.4 Bedrock

Bedrock was exposed at elevation 194.6 to 199.6 in boreholes 113-2, 113-6, 113-8 and 113-11. The bedrock surface was inferred by refusal at depths of 0.1 to 4.2 m (elevation 190.1 to 198.7) in the remaining test holes.

4.13.5 Groundwater

Water (300 to 600 mm deep) was under 200 to 300 mm of ice in boreholes 113-7, 113-9, 113-10 and 113-13 (elevation 193.6 to 194.3).

In the process of augering, water was detected in boreholes 113-12 and 113-15 at respective depths of 1.0 and 0.3 m (elevation 195.5 and 195.3). Upon completion of drilling, groundwater was at the surface in borehole 113-15 (elevation 195.6).

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.14 Swamp 114

A total of 18 test holes comprising 15 boreholes and 3 dynamic cone penetration tests were advanced in swamp 114. The alignment crosses a low-lying swamp section between Sta. 19+850 and 19+955, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a discontinuous cohesive deposit of clayey silt / silty clay / clay mantling bedrock. The bedrock surface was exposed at four borehole locations and contacted at depths of 0.1 to 3.9 m (elevation 190.8 to 197.4) in the remaining test holes.

4.14.1 Topsoil / Peat

Topsoil was present surficially in boreholes 114-2, 114-7, 114-13 and under some 200 mm of ice in borehole 114-15. The sandy topsoil was 100 to 500 mm in thickness and penetrated at elevation 196.0 to 197.4.

A deposit of peat was encountered under snow / ice / water at depths of 0.2 and 1.2 m in boreholes 114-1 and 114-16 respectively. The peat was coarse fibrous in the former borehole and fine fibrous in the latter, with the moisture content of about 39%. The peat had a thickness of 700 mm in borehole 114-1 and 300 mm in borehole 114-16 and was penetrated at respective depths of 0.9 and 1.5 m (elevation 195.4 and 195.0).

4.14.2 Clayey Silt to Clay

Underlying the peat at 0.9 m (elevation 195.4) in borehole 114-1 and at 1.5 m (elevation 195.0) in borehole 114-16 was a cohesive deposit of clayey silt, silty clay and clay. This deposit was stiff in consistency, becoming soft to firm at depth. The results of in situ vane testing carried out in borehole 114-1 in the upper and lower portions of the deposit yielded undisturbed shear strength values of 64 and 20 kPa (soil sensitivity of 32 and 10) respectively. The clayey soils were 0.8 to 3.0 m thick and penetrated at 3.9 m (elevation 192.4) in borehole 114-1 and at 2.3 m (elevation 194.2) in borehole 114-16.

The results of Atterberg limits testing and grain size distribution analysis conducted on a cohesive sample are presented in respective Figures 114-PC-1 and 114-GS-1. The clay had a liquid limit of 50, plastic limit of 20, thus giving the plasticity index of 30. The moisture content of the clayey soils varied between 26 and 77%.

4.14.3 Bedrock

Bedrock was exposed at elevation 193.6 to 198.8 in boreholes 114-5, 114-9, 114-11 and 114-17. The bedrock surface was inferred by refusal at depths of 0.1 to 3.9 m (elevation 190.8 to 197.4) in the remaining test holes.

4.14.4 Groundwater

Water (0.3 to 1.0 m, locally 3.5 m deep) was under 200 to 300 mm of ice in boreholes 114-3, 114-4, 114-8, 114-10, 114-12 and 114-16.

Groundwater was at 0.3 m (elevation 196.0) in boreholes 114-1 during and upon completion of drilling.

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.15 Swamp 115

A total of 19 test holes comprising 14 boreholes and 5 dynamic cone penetration tests were advanced in swamp 115. The alignment crosses a low-lying swamp section between Sta. 20+175 and 20+270, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat over organic soils overlying a cohesive deposit of clayey silt, silty clay and clay underlain by sand / silt extending to bedrock. The bedrock surface was exposed at two borehole locations and contacted at depths of 0.2 to 8.8 m (elevation 185.9 to 197.2) in the remaining test holes.

4.15.1 Topsoil / Peat

Topsoil was present surficially in test holes 115-3, 115-9, 115-17, 115-19 and under 200 mm of snow in borehole 115-15. The sandy topsoil was 100 to 300 mm in thickness and penetrated at elevation 196.1 to 197.7.

A deposit of peat was encountered under ice and water at depths of 0.7 to 1.4 m (elevation 193.2 to 195.2) in boreholes 115-5 to 115-7, 115-11, 115-13, 115-16 and 115-18. The peat was coarse fibrous to amorphous. This deposit was 300 to 400 mm thick and penetrated at depths of 1.0 to 1.7 m (elevation 192.9 to 194.9).

4.15.2 Organic Soils

Directly beneath ice and water at 0.6 m (elevation 194.7) in borehole 115-10 or the peat at depths of 1.0 to 1.7 m (elevation 192.9 to 194.9) in boreholes 115-5, 115-6, 115-11, 115-13, 115-16 and 115-18 were organic soils (silty sand, sandy silt, silt, clayey silt, silty clay). These units were very loose to loose / firm to stiff. The organic soils had a thickness of 200 to 800 mm and were penetrated at depths of 0.9 to 2.2 m (elevation 192.4 to 194.7).

4.15.3 Clayey Silt to Clay

Overlain by the topsoil / peat or organic soils at depths of 0.3 to 2.2 m (elevation 192.4 to 196.1) in boreholes 115-5 to 115-7, 115-10, 115-11, 115-13, 115-15, 115-16 and 115-18 was a cohesive deposit of clayey silt, silty clay and clay. This deposit was 0.3 to 6.3 m thick and soft to very stiff, typically firm to stiff in consistency. The results of in situ vane testing carried out in the clayey soils yielded undisturbed shear strength values in a range of 16 to 72 kPa (soil sensitivity of 4 to 26). Penetrometer tests on cohesive samples indicated a shear strength varying widely between 13 and 162 kPa. The deposit was penetrated at depths of 0.6 to 8.5 m (elevation 186.2 to 195.8).

The results of Atterberg limits testing and grain size distribution analyses conducted on 7 cohesive samples are presented in respective Figures 115-PC-1 to 115-PC-3 and 115-GS-1 to 115-GS-2. The liquid and plastic limits of the clayey silt were 31 and 19 respectively, thus giving the plasticity index of 12. The silty clay had a liquid limit of 49, plastic limit of 22, its plasticity index being 27. The liquid and plastic limits of the clay ranged from 51 to 60 and from 20 to 28, with the plasticity index of 28 to 36. The moisture content of the clayey soils varied between 27 and 85%.

4.15.4 Sand / Silt

Underlying the topsoil at 0.2 m depth (elevation 197.7) in borehole 115-9 or the clay / silty clay at depths of 1.7 to 8.5 m (elevation 186.2 to 193.6) in boreholes 115-10, 115-13 and 115-16 was cohesionless sand (non-plastic silt in borehole 115-13). Loose to compact in relative density, the sand / silt was 200 to 700 mm in thickness and penetrated at depths of 0.9 to 8.8 m (elevation 185.9 to 197.0).

4.15.5 Bedrock

Bedrock was exposed at elevation 200.0 in borehole 115-1 and elevation 198.9 in borehole 115-4. In the remaining test holes, the bedrock surface was inferred by refusal at depths of 0.2 to 5.0 m (elevation 189.6 to 197.2), locally – at the location of borehole 115-16 – at 8.8 m (elevation 185.9).

4.15.6 Groundwater

Water (0.3 to 1.1 m deep) was under 200 to 300 mm of ice in boreholes 115-5 to 115-7, 115-10, 115-11, 115-13, 115-16 and 115-18.

Groundwater was measured in borehole 115-9 to be at a depth of 0.6 m (elevation 197.3) during and upon completion of drilling.

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.16 Swamp 116

A total of 26 test holes comprising 23 boreholes and 3 dynamic cone penetration tests were advanced in swamp 116. An additional dynamic cone penetration test was performed beside one borehole. The alignment crosses a low-lying swamp section between Sta. 20+760 and 20+970 (NBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying organic sand and a cohesive deposit of clayey silt / silty clay / clay underlain by cohesionless silty sand extending to bedrock. The bedrock surface was exposed at four borehole locations and contacted at depths of 0.1 to 3.4 m (elevation 190.1 to 198.3) in the remaining test holes.

4.16.1 Topsoil / Peat

Surficial topsoil was present in boreholes 116-1 to 116-4, 116-11, 116-13 to 116-17, 116-19, 116-21, 116-25 and 116-26. The silty topsoil was about 100 mm in thickness and penetrated at elevation 193.1 to 198.3.

A deposit of peat was present surficially in borehole 116-7 and under snow / ice and/or water at depths of 0.4 to 0.7 m (elevation 192.4 to 193.2) in boreholes 116-10, 116-12, 116-20 and 116-23. The amorphous peat had a thickness of 200 to 300 mm, locally 700 mm and was penetrated at depths of 0.6 to 0.9 m (elevation 192.2 to 193.2).

4.16.2 Organic Sand

Directly beneath the topsoil at 0.1 m depth (elevation 193.1 to 196.2) in boreholes 116-2 to 116-4, 116-13 to 116-17, 116-19, 116-21, 116-25, 116-26 or the peat at a depth of 0.8 m (elevation 192.4 and 192.2) in boreholes 116-10 and 116-23 was organic sand. This unit was typically loose to compact in relative density and had a moisture content of 18 to 37%. The organic sand was 0.1 to 1.1 m thick and penetrated at depths of 0.2 to 1.9 m (elevation 191.1 to 195.6).

4.16.3 Clayey Silt to Clay

Overlain by the peat or organic sand at depths of 0.2 to 1.9 m (elevation 191.1 to 194.3) in boreholes 116-2 to 116-4, 116-7, 116-10, 116-12, 116-19 to 116-21 and 116-23 was a cohesive deposit of clayey silt / silty clay / clay. This deposit was 0.2 to 2.0 m in thickness and firm to very stiff in consistency. The results of in situ vane testing carried out in the clayey silt yielded an undisturbed shear strength value of 50 kPa (soil sensitivity of 5). Penetrometer tests indicated shear strength values in a range of 25 to 175 kPa. The clayey soils were penetrated at depths of 0.8 to 2.7 m (elevation 190.3 to 194.1).

The results of Atterberg limits testing and grain size distribution analyses conducted on 6 cohesive samples are presented in respective Figures 116-PC-1 to 116-PC-3 and 116-GS-1 to 116-GS-3. The clayey silt had a liquid limit of 26 and 32, plastic limit of 16 and 18, its plasticity index being 8 and 16. The liquid and plastic limits of the silty clay were 39 to 40 and 20 respectively, with the plasticity index of 19 and 20. The clay had a liquid limit of 50 and 53, plastic limit of 21 and 23, thus giving the plasticity index of 29 and 30. The moisture content of the clayey soils varied between 24 and 41%.

4.16.4 Silty Sand

Underlying the silty clay or clayey silt at 2.6 m depth (elevation 191.0) in borehole 116-12 and a depth of 1.6 m (elevation 191.5) in borehole 116-20 was cohesionless silty sand. Compact to dense, this stratum had a thickness of 800 mm in the former borehole and 400 mm in the latter and was penetrated at respective depths of 3.4 and 2.0 m (elevation 190.2 and 191.1).

4.16.5 Bedrock

Bedrock was exposed at elevation 193.9 to 196.9 in boreholes 116-5, 116-6, 116-8 and 116-9. The bedrock surface was inferred by refusal at depths of 0.1 to 3.4 m (elevation 190.1 to 198.3) in the remaining test holes.

4.16.6 Groundwater

Water (200 to 400 mm deep) was under 200 to 500 mm of snow and/or ice in boreholes 116-10, 116-20 and 116-23.

During drilling of borehole 116-3, water was detected at a depth of 0.6 m (elevation 193.7). Upon completion of drilling, groundwater was measured in boreholes 116-3, 116-4 and 116-7 at depths of 0.7 to 1.0 m (elevation 192.9 to 193.6).

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.17 Swamp 117

A total of 10 boreholes were carried out in swamp 117. An additional dynamic cone penetration test was performed beside one borehole. The alignment crosses a low-lying swamp section between Sta. 20+815 and 20+880 (SBL), Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying organic sand or a cohesive deposit of silty clay extending to bedrock. The bedrock surface was contacted at depths of 0.1 to 4.6 m (elevation 188.0 to 193.7).

4.17.1 Topsoil / Peat

Surficial topsoil was present in boreholes 117-1, 117-2, 117-4 and 117-9. The silty topsoil was 100 to 500 mm thick and penetrated at elevation 193.1 to 193.7.

A deposit of peat was present surficially in boreholes 117-6, 117-10 and under snow / ice and water at 0.5 m depth (elevation 192.8) in borehole 117-3. The amorphous peat had a thickness of 300 to 500 mm and was penetrated at depths of 0.5 to 0.8 m (elevation 192.5 to 192.7).

4.17.2 Organic Sand

Directly beneath the topsoil at 0.1 m depth (elevation 193.5) in borehole 117-1 and under snow / ice and water at a depth of 0.5 m (elevation 193.0) in borehole 117-7 was organic sand. This unit was 500 mm in thickness and loose to compact in relative density. The organic sand was penetrated at depths of 0.6 and 1.0 m (elevation 193.0 and 192.5) in boreholes 117-1 and 117-7 respectively.

4.17.3 Silty Clay

A cohesive deposit of silty clay was overlain by the peat at a depth of 0.8 m (elevation 192.5) in borehole 117-3 and revealed under snow / ice and water at 0.9 m depth (elevation 191.7) in borehole 117-5 and at a depth of 0.7 m (elevation 192.4) in borehole 117-8. This deposit was stiff to very stiff in consistency, becoming firm to soft at depth. The results of in situ vane testing carried out in the silty clay yielded an undisturbed shear strength value of 20 kPa (soil sensitivity of 2). Penetrometer tests indicated a shear strength ranging from 100 to 112 kPa. The unconfined compression test on a Shelby tube sample gave a shear strength of 13.1 kPa at 2.0% strain. The deposit was 1.5 to 3.4 m thick and penetrated at depths of 2.2 to 4.3 m (elevation 188.3 to 190.9).

The results of Atterberg limits testing and grain size distribution analyses conducted on 3 cohesive samples are presented in respective Figures 117-PC-1 and 117-GS-1. The silty clay had a liquid limit of 38 and plastic limit of 19 to 20, thus giving the plasticity index of 18 to 19. The moisture content of the clayey soils varied between 26 and 45%.

4.17.4 Sand and Gravel

Underlying the silty clay at 4.3 m depth (elevation 188.3) in borehole 117-5 was sand and gravel. Assessed to be dense, the sand and gravel had a thickness of 300 mm and was penetrated at a depth of 4.6 m (elevation 188.0).

4.17.5 Bedrock

The bedrock surface was inferred by refusal at depths of 0.1 to 4.6 m (elevation 188.0 to 193.7).

4.17.6 Groundwater

Except for boreholes 117-3, 117-5, 117-7 and 117-8 where water (100 to 300 mm deep) was encountered under 300 to 600 mm of snow and ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.18 Swamp 118

A total of 20 test holes comprising 18 boreholes and 2 dynamic cone penetration tests were advanced in swamp 118. The alignment crosses a low-lying swamp section between Sta. 22+225 and 22+320, Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil or peat covered with ice / water and overlying bedrock. The bedrock surface was exposed at three borehole locations and contacted at depths of 0.1 to 1.4 m (elevation 196.1 to 201.8) in the remaining test holes.

4.18.1 Topsoil / Peat

Surficial topsoil was identified in boreholes 118-3 to 118-5, 118-7, 118-8, 118-12, 118-13, 118-15 to 118-18 (covered with some 100 mm of ice in boreholes 118-13, 118-15 and 118-16). The silty topsoil was 100 to 300 mm thick and penetrated at elevation 197.2 to 201.8.

A deposit of peat was present surficially in borehole 118-14 and under ice / water at depths of 0.1 to 0.3 m (elevation 196.8 to 197.4) in boreholes 118-6, 118-10 and 118-11. The peat was amorphous and had a moisture content varying widely between 29 and 389%. The peat was 400 to 800 mm in thickness and penetrated at depths of 0.5 to 0.9 m (elevation 196.2 to 197.0).

4.18.2 Clayey Silt

Overlain by the peat at 0.5 m depth (elevation 197.0) in borehole 118-6 was a cohesive deposit of clayey silt. This deposit was stiff in consistency as determined on the basis of standard penetration testing (SPT-'N' value of 15). The clayey silt had a thickness of 0.7 m and was penetrated at a depth of 1.2 m (elevation 196.3).

4.18.3 Silty Sand

Underlying the peat at 0.9 m depth (elevation 196.6) in borehole 118-10 or clayey silt at a depth of 1.2 m (elevation 196.3) in borehole 118-6 was cohesionless silty sand. Compact in relative density, this unit was 200 mm thick and penetrated at respective depths of 1.1 and 1.4 m (elevation 196.4 and 196.1). It is noted that the silty sand in borehole 118-6 contained cobbles.

4.18.4 Bedrock

Bedrock was exposed at elevation 198.5 to 199.2 in boreholes 118-1, 118-2 and 118-20. The bedrock surface was inferred by refusal at depths of 0.1 to 1.4 m (elevation 196.1 to 201.8) in the remaining test holes.

4.18.5 Groundwater

Except for borehole 118-11 where about 100 mm of water was encountered under some 200 mm of ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.19 Swamp 119

A total of 24 test holes comprising 20 boreholes and 4 dynamic cone penetration tests were advanced in swamp 119. The alignment crosses a low-lying swamp section between Sta. 22+350 and 22+725 (NBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / clay or sand and gravel extending to bedrock. The bedrock surface was exposed at one borehole location and contacted at depths of 0.1 to 2.3 m (elevation 194.4 to 199.2).

4.19.1 Topsoil / Peat

Surficial topsoil was present in boreholes 119-1, 119-2, 119-5, 119-7, 119-13, 119-14, 119-19, 119-22 to 119-24. The silty topsoil was 100 to 400 mm thick and penetrated at elevation 196.8 to 199.2.

A deposit of peat was present surficially in borehole 119-15 and under ice / water at depths of 0.1 to 0.6 m (elevation 196.1 to 197.3) in boreholes 119-3, 119-4, 119-9 to 119-11, 119-17. The peat was amorphous and had a moisture content of 471% in one determination. The peat was 0.2 to 1.2 m in thickness and penetrated at depths of 0.6 to 1.8 m (elevation 194.9 to 197.0).

4.19.2 Silty Sand

A layer of silty sand with organic inclusions was identified below the topsoil at 0.2 m depth (elevation 196.8) in borehole 119-22. This layer was very loose in relative density (SPT-‘N’ value of 3). The silty sand was 200 mm thick and penetrated at a depth of 0.4 m (elevation 196.6).

4.19.3 Clayey Silt / Clay

Overlain by the peat at 1.8 m depth (elevation 194.9) in borehole 119-3 or by the silty sand at a depth of 0.4 m (elevation 196.6) in borehole 119-22 was a cohesive deposit of clayey silt / clay. Firm to stiff in consistency, this deposit had a thickness of 0.5 m in the former borehole and 1.9 m in the latter and was penetrated at a depth of 2.3 m (elevation 194.4 and 194.7).

The results of Atterberg limits testing and grain size distribution analysis conducted on a cohesive sample are presented in respective Figures 119-PC-1 and 119-GS-1. The liquid and plastic limits of the clay were 58 and 23 respectively, thus giving the plasticity index of 35. The moisture content of the clayey soils ranged from 33 to 38%.

4.19.4 Sand and Gravel

Underlying the peat at 0.6 m depth (elevation 196.3 to 197.0) in boreholes 119-9, 119-11, 119-15 or ice / water at a depth of 0.7 m (elevation 195.7) in borehole 119-21 was sand and gravel. This unit was 200 to 600 mm in thickness and loose to compact in relative density. The sand and gravel was penetrated at depths of 0.8 to 1.2 m (elevation 195.2 to 196.8).

4.19.5 Bedrock

Bedrock was exposed at elevation 199.2 in borehole 119-8. The bedrock surface was inferred by refusal at depths of 0.1 to 2.3 m (elevation 194.4 to 199.2) in the remaining test holes.

4.19.6 Groundwater

Except for boreholes 119-3, 119-4, 119-9 to 119-11, 119-16 and 119-21 where 100 to 700 mm of water was encountered under 200 to 500 mm of ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.20 Swamp 120

A total of 8 test holes comprising 7 boreholes and 1 dynamic cone penetration test were advanced in swamp 120. The alignment crosses a low-lying swamp section between Sta. 22+390 and 22+430 (SBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil or peat overlying bedrock. The bedrock surface was exposed at three borehole locations and contacted at depths of 0.1 to 0.9 m (elevation 196.6 to 198.0) in the remaining test holes.

4.20.1 Topsoil / Peat

Surficial topsoil was present in boreholes 120-3, 120-4 and 120-6. The silty topsoil was 100 to 300 mm thick and penetrated at elevation 197.1 to 198.0.

A deposit of peat was present surficially in test holes 120-2 and 120-5. The peat had a thickness of 600 and 900 mm and was penetrated at elevation 197.0 and 196.6 respectively.

4.20.2 Bedrock

Bedrock was exposed at elevation 198.4 to 198.7 in boreholes 120-1, 120-7 and 120-8. The bedrock surface was inferred by refusal at depths of 0.1 to 0.9 m (elevation 196.6 to 198.0) in the remaining test holes.

4.20.3 Groundwater

Groundwater was not observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.21 Swamp 121

A total of 15 test holes comprising 12 boreholes and 3 dynamic cone penetration tests were advanced in swamp 121. The alignment crosses a low-lying swamp section between Sta. 22+590 and 22+700 (SBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying cohesionless silty/sandy soils and/or bedrock. The bedrock surface was contacted at depths of 0.1 to 2.0 m (elevation 194.4 to 197.5).

4.21.1 Topsoil / Peat

Surficial topsoil was present in boreholes 121-2, 121-4, 121-6, 121-9 and 121-11. The silty topsoil was 100 to 500 mm thick and penetrated at elevation 196.6 to 197.5. It is noteworthy that boulders were encountered below the topsoil at 0.5 m depth (elevation 197.3) in borehole 121-2, extending to bedrock revealed at a depth of 0.8 m (elevation 197.0).

A deposit of peat was present surficially in test holes 121-3, 121-5, 121-10, 121-15 and under ice and/or water at depths of 0.1 to 0.9 m (elevation 195.4 to 196.5) in boreholes 121-8, 121-12 to 121-14. The peat was amorphous and had a moisture content varying between 27 and 131%. The peat was 0.1 to 1.0 m in thickness and penetrated at depths of 0.2 to 1.1 m (elevation 195.3 to 196.5).

4.21.2 Clayey Silt

Overlain by the peat at 0.2 m depth (elevation 196.5) in borehole 121-15 was a cohesive deposit of clayey silt. This deposit contained organic inclusions and was soft in consistency as determined on the basis of standard penetration testing (SPT-‘N’ value of 2). With a moisture content of about 35%, the clayey silt had a thickness of 200 mm and was penetrated at a depth of 0.4 m (elevation 196.3).

4.21.3 Silty/Sandy Soils

Underlying the peat in boreholes 121-3, 121-12 or the clayey silt in borehole 121-15 at depths of 0.4 to 0.7 m (elevation 195.9 to 196.3) was cohesionless silty/sandy soils of various granulometric composition (sandy silt, sand and silt, silty sand). This stratum was 0.7 to 1.0 m in thickness and very loose to compact in relative density. The moisture content of the sandy silt unit identified in borehole 121-3 was 24%. The stratum was penetrated at depths of 1.2 to 1.7 m (elevation 195.0 to 195.5).

The results of grain size distribution analysis performed on a sample of the sand and silt are presented in Figure 121-GS-1.

4.21.4 Bedrock

The bedrock surface was inferred by refusal at depths of 0.1 to 2.0 m (elevation 194.4 to 197.5).

4.21.5 Groundwater

Except for boreholes 121-8, 121-12 and 121-13 where water (100 to 900 mm deep) was present surficially or under some 100 mm of ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.22 Swamp 122

A total of 6 test holes comprising 5 boreholes and 1 dynamic cone penetration test were advanced in swamp 122. The alignment crosses a low-lying swamp section between Sta. 22+800 and 22+840 (SBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying cohesionless silty sand and/or bedrock. The bedrock surface was exposed at one borehole location and contacted at depths of 0.1 to 2.3 m (elevation 196.0 to 200.3) in the remaining test holes.

4.22.1 Topsoil / Peat

Surficial topsoil was present in boreholes 122-4 and 122-6. The silty topsoil had a thickness of 300 mm in the former borehole and 100 mm in the latter and was penetrated at elevation 198.6 and 200.3 respectively.

A deposit of peat was present surficially in boreholes 122-3 and 122-5. The amorphous peat was 200 and 300 mm thick and penetrated at elevation 198.7 and 198.1 respectively.

4.22.2 Silty Sand

Underlying the peat at 0.2 m depth (elevation 198.7) in borehole 122-3 and the topsoil at a depth of 0.3 m (elevation 198.6) in borehole 122-4 was cohesionless silty sand. This unit was 700 to 800 mm in thickness and loose to compact in relative density. The silty sand was penetrated at 0.9 m depth (elevation 198.0) in borehole 122-3 and a depth of 1.1 m (elevation 197.8) in borehole 122-4.

4.22.3 Bedrock

Bedrock was exposed at elevation 199.5 in borehole 122-1. The bedrock surface was inferred by refusal at depths of 0.1 to 2.3 m (elevation 196.0 to 200.3) in the remaining test holes.

4.22.4 Groundwater

Groundwater was not observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.23 Swamp 123

A total of 10 test holes comprising 8 boreholes and 2 dynamic cone penetration tests were advanced in swamp 123. The alignment crosses a low-lying swamp section between Sta. 22+850 and 22+920 (NBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised exposed bedrock or surficial peat overlying bedrock. The bedrock surface was exposed at six borehole locations and contacted at depths of 0.3 to 0.6 m (elevation 199.1 to 199.4) in the remaining test holes.

4.23.1 Peat

A deposit of peat was present surficially in test holes 123-3, 123-6, 123-8 and under ice at a depth of 0.1 m (elevation 199.6) in borehole 123-9. The amorphous peat was 300 to 600 mm thick and penetrated at depths of 0.3 to 0.6 m (elevation 199.2 to 199.4).

4.23.2 Sand

Underlying the peat at 0.4 m depth (elevation 199.3) in borehole 123-9 was cohesionless sand. This unit was 200 mm in thickness and loose to compact in relative density. The sand extended to bedrock encountered at a depth of 0.6 m (elevation 199.1).

4.23.3 Bedrock

Bedrock was exposed at elevation 200.2 to 201.3 in boreholes 123-1, 123-2, 123-4, 123-5, 123-7 and 123-10. The bedrock surface was inferred by refusal at depths of 0.3 to 0.6 m (elevation 199.1 to 199.4) in the remaining test holes.

4.23.4 Groundwater

Groundwater was not observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.24 Swamp 124

A total of 15 test holes comprising 12 boreholes and 3 dynamic cone penetration tests were advanced in swamp 124. The alignment crosses a low-lying swamp section between Sta. 22+960 and 23+060 (NBL), Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil or peat overlying bedrock. The bedrock surface was exposed at two borehole locations and contacted at depths of 0.1 to 2.3 m (elevation 196.9 to 200.8) in the remaining test holes.

4.24.1 Topsoil / Peat

Surficial topsoil was present in test holes 124-1 to 124-3, 124-9 to 124-11, 124-13 to 124-15. The silty topsoil was 100 to 500 mm thick and penetrated at elevation 198.9 to 200.8.

A deposit of peat was present surficially in test holes 124-4 and 124-6. The peat was amorphous and 67% in moisture content. The peat had a thickness of 500 mm in the former test hole and 200 mm in the latter and was penetrated at elevation 199.1 and 199.2.

4.24.2 Bedrock

Bedrock was exposed at elevation 199.2 and 200.2 in boreholes 124-5 and 124-8 respectively. The bedrock surface was inferred by refusal at depths of 0.1 to 0.6 m (elevation 198.6 to 200.8), locally 2.3 m (elevation 196.9) in the remaining test holes.

4.24.3 Groundwater

Except for borehole 124-7 where about 300 mm of water was encountered under some 300 mm of ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.25 Ramp S-E/W Swamp

A total of 5 test holes comprising 4 boreholes and 1 dynamic cone penetration test were advanced at ramp S-E/W. The alignment crosses a low-lying swamp section between Sta. 20+250 and 20+300, S-E/W ramp chainage, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised organic soils overlying a cohesive deposit of clayey silt and clay extending to bedrock. The bedrock surface was contacted at depths of 0.6 to 8.5 m (elevation 190.6 to 199.3).

4.25.1 4.14.1 Topsoil / Peat

Surficial topsoil was present in borehole SEW-5. The sandy topsoil was about 200 mm thick and penetrated at elevation 199.6.

A deposit of peat was encountered under ice and water at 1.4 m depth (elevation 198.4) in borehole SEW-1. The amorphous peat had a thickness of 300 mm and was penetrated at a depth of 1.7 m (elevation 198.1).

4.25.2 Organic Silt

Organic silt was revealed under ice and water in boreholes SEW-2 and SEW-4 at respective depths of 0.6 and 0.9 m (elevation 199.9 and 198.2). This deposit had an organic content of 3.0% in one determination. Very loose to loose in relative density (SPT-‘N’ values of 2 to 8), the organic silt was 0.6 and 1.3 m thick and penetrated at depths of 1.2 and 2.2 m (elevation 199.3 and 196.9) in boreholes SEW-2 and SEW-4 respectively.

The results of grain size distribution analysis performed on a sample of the organic silt are presented in Figure SEW-GS-1.

4.25.3 Silt

Directly beneath the topsoil at 0.2 m depth (elevation 199.6) in borehole SEW-5 was non-cohesive silt. This unit was very loose in relative density (SPT-‘N’ value of 2) and about 19% in moisture content. The silt had a thickness of 400 mm and was penetrated at a depth of 0.6 m (elevation 199.2).

4.25.4 Clayey Silt / Clay

Overlain by the peat, organic silt or silt at depths of 0.6 to 2.2 m (elevation 196.9 to 199.2) in boreholes SEW-1, SEW-4 and SEW-5 was a cohesive deposit of clayey silt / clay. This deposit was 0.9 to 5.1 m in thickness and typically soft to stiff in consistency. The results of in situ vane testing carried out in the clayey soils yielded undisturbed shear strength values in a range of 24 to 56 kPa (soil sensitivity of 6 to 14). Penetrometer tests indicated a shear strength ranging from 25 to 100 kPa. The unconfined compression test on a Shelby tube sample of the clay gave a shear strength value of 6.6 kPa at 2.0% strain. The deposit was penetrated at depths of 1.5 to 7.3 m (elevation 191.8 to 198.3).

The results of Atterberg limits testing and grain size distribution analyses conducted on 3 cohesive samples are presented in respective Figures SEW-PC-1, SEW-PC-2 and SEW-GS-2, SEW-GS-3. The liquid and plastic limits of the clayey silt were 29 and 18 respectively, thus giving the plasticity index of 11. The clay had a liquid limit of 57 and 60, plastic limit of 22 and 24, its plasticity index being 35 and 36. The moisture content of the clayey soils varied between 23 and 76%.

4.25.5 Sand

Underlying the clay at 7.3 m depth (elevation 191.8) in borehole SEW-4 was cohesionless sand. This stratum was compact in relative density (SPT-‘N’ value of 24). The sand was 1.2 m thick and penetrated at a depth of 8.5 m (elevation 190.6).

4.25.6 Bedrock

The bedrock surface was inferred by refusal at depths of 0.6 to 8.5 m (elevation 190.6 to 199.3).

4.25.7 Groundwater

Water (0.4 to 1.2 m deep) was encountered under 200 to 300 mm of ice in boreholes SEW-1, SEW-2 and SEW-4. Groundwater was not observed in borehole SEW-5 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.26 Ramp N-E/W Swamp

A total of 18 test holes comprising 16 boreholes and 2 dynamic cone penetration tests were advanced at ramp N-E/W. The alignment crosses a low-lying swamp section between Sta. 20+710 and 20+965, N-E/W ramp chainage, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat over organic sand overlying a cohesive deposit of silty clay / clay and/or cohesionless sandy soils extending to bedrock. The bedrock surface was exposed at one borehole location and contacted at depths of 0.1 to 4.2 m (elevation 188.3 to 198.5) in the remaining test holes.

4.26.1 Topsoil / Peat

Surficial topsoil was present in boreholes NEW-2 to NEW-6, NEW-9, NEW-11, NEW-13, NEW-15, NEW-17 and NEW-18 (covered with some 300 mm of snow in borehole NEW-5). The silty topsoil was 100 to 400 mm in thickness and penetrated at elevation 192.1 to 198.5.

A deposit of peat was present surficially in borehole NEW-16 and under snow / ice and water at depths of 0.6 and 0.9 m (elevation 191.2 and 191.4) in boreholes NEW-8 and NEW-10 respectively. The amorphous peat was 200 to 300 mm thick and penetrated at depths of 0.3 to 1.1 m (elevation 191.0 to 192.2).

4.26.2 Organic Sand

Organic sand was identified below snow and water in borehole NEW-7 and below the topsoil / peat at depths of 0.1 to 0.5 m (elevation 192.1 to 194.0) in boreholes NEW-5, NEW-9, NEW-15 to NEW-18. This unit was loose to compact in relative density (SPT-‘N’ values of 7 to 22) and 30% in moisture content. The organic sand had a thickness of 0.4 to 1.0 m and was penetrated at depths of 0.6 to 1.5 m (elevation 191.1 to 193.5).

4.26.3 Sandy Silt

Directly beneath the peat at 0.8 m depth (elevation 191.0) in borehole NEW-8 was a layer of sandy silt. This layer was loose in relative density (SPT-‘N’ value of 9) and about 26% in moisture content. The sandy silt was 300 mm thick and penetrated at a depth of 1.1 m (elevation 190.7).

4.26.4 Silty Clay / Clay

Overlain by the organic soils or sandy silt at depths of 0.6 to 1.5 m (elevation 190.7 to 192.1) in boreholes NEW-5, NEW-7, NEW-8, NEW-10, NEW-16 and NEW-17 was a cohesive deposit of silty clay / clay. This deposit had a thickness of 0.7 to 2.7 m and was soft to very stiff, typically firm to stiff in consistency. The results of in situ vane testing carried out in the clayey soils yielded undisturbed shear strength values in a range of 12 to 25 kPa (soil sensitivity of 2 to 4). Penetrometer tests indicated a shear strength ranging from 25 to 175 kPa. The unconfined compression test on a Shelby tube sample of the clay gave a shear strength value of 20.1 kPa at 2.4% strain. The deposit was penetrated at depths of 1.3 to 4.2 m (elevation 188.4 to 191.4).

The results of Atterberg limits testing and grain size distribution analyses conducted on 4 cohesive samples are presented in respective Figures NEW-PC-1, NEW-PC-2 and NEW-GS-1, NEW-GS-2. The liquid and plastic limits of the silty clay were 38 and 20 respectively, thus giving the plasticity index of 18. The clay had a liquid limit of 55, plastic limit of 21 to 22, with the plasticity index of 33 to 34. The moisture content of the clayey soils varied between 23 and 68%.

4.26.5 Silty Sand / Sand and Gravel

Underlying the silty clay or clay at depths of 1.8 to 3.2 m (elevation 189.1 to 190.7) in boreholes NEW-5, NEW-10 and NEW-16 were cohesionless sandy soils (silty sand, sand and gravel). This stratum was 0.1 to 1.5 m thick and compact to very dense. The sandy soils were penetrated at depths of 2.3 to 4.0 m (elevation 188.3 to 190.2).

4.26.6 Bedrock

Bedrock was exposed at elevation 199.9 in borehole NEW-1. The bedrock surface was inferred by refusal at depths of 0.1 to 4.2 m (elevation 188.3 to 198.5) in the remaining test holes.

4.26.7 Groundwater

Except for boreholes NEW-7, NEW-8 and NEW-10 where 100 to 400 mm of water was encountered under 300 to 500 mm of snow / ice, no groundwater was observed in any of the boreholes during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.27 Interchange Service Road Swamp

A total of 14 boreholes were carried out at Interchange Service Road. An additional dynamic cone penetration test was performed beside one borehole. The alignment crosses a low-lying swamp section between Sta. 9+900 and 10+100, Interchange Service Road chainage, Magnetawan First Nation.

The subsurface stratigraphy revealed in the boreholes drilled at the site generally comprised surficial topsoil / peat overlying organic silt / organic sand and a cohesive deposit of clayey silt / silty clay / clay extending to bedrock. The bedrock surface was exposed at four borehole locations and contacted at depths of 0.1 to 4.7 m (elevation 192.4 to 202.9) in the remaining boreholes.

4.27.1 Topsoil / Peat

Surficial topsoil was present in boreholes IC-8 to IC-10, IC-12 to IC-14. The silty topsoil was 100 to 400 mm thick and penetrated at elevation 196.4 to 202.9.

A deposit of amorphous peat was present under snow / ice and water at depths of 0.3 to 0.6 m (elevation 196.8 to 200.9) in boreholes IC-5, IC-6 and IC-11. The peat was 200 to 400 mm in thickness and penetrated at depths of 0.5 to 1.0 m (elevation 196.6 to 200.6).

4.27.2 Organic Silt / Organic Sand

Directly beneath snow / ice and water in borehole IC-7 or the topsoil / peat in boreholes IC-10 and IC-11 at depths of 0.4 to 0.8 m (elevation 196.6 to 200.5) was organic silt / organic sand. This unit was loose to compact in relative density and 31 to 50% in moisture content, with an organic content of 2.1% in one determination. The organic silt / organic sand was 0.3 to 1.2 m thick and penetrated at depths of 0.9 to 1.6 m (elevation 196.2 to 200.2).

The results of grain size distribution analysis performed on a sample of the organic sand are presented in Figure IC-GS-1.

4.27.3 Clayey Silt to Clay

Overlain by the organic silt / organic sand in boreholes IC-7 and IC-11 at respective depths of 1.1 and 0.9 m (elevation 200.2 and 196.2) was a cohesive deposit of clayey silt / silty clay / clay. This deposit had a thickness of 0.7 m in the former borehole and 3.6 m in the latter and was soft to very stiff in consistency. The results of two in situ vane tests carried out in the clay yielded an undisturbed shear strength value of 18 kPa (soil sensitivity of 6). Penetrometer tests indicated a shear strength ranging from 25 to 50 kPa. The unconfined compression test on a Shelby tube sample of the clay gave a shear strength value of 12.5 kPa at 2.3% strain. The deposit was penetrated at depths of 1.8 and 4.5 m (elevation 199.5 and 192.6) in boreholes IC-7 and IC-11 respectively.

The results of Atterberg limits testing and grain size distribution analyses conducted on 2 cohesive samples are presented in respective Figures IC-PC-1, IC-PC-2 and IC-GS-2, IC-GS-3. The clayey silt had a liquid limit of 32, plastic limit of 17, its plasticity index being 15. The liquid and plastic limits of the clay were 57 and 21 respectively, thus giving the plasticity index of 36. The moisture content of the clayey soils varied between 19 and 77%.

4.27.4 Silty Sand

Underlying the clay at 4.5 m depth (elevation 192.6) in borehole IC-11 was cohesionless silty sand. Compact in relative density, the silty sand was 200 mm thick and penetrated at a depth of 4.7 m (elevation 192.4).

4.27.5 Bedrock

Bedrock was exposed at elevation 201.0 to 202.5 in boreholes IC-1 to IC-4. The bedrock surface was inferred by refusal at depths of 0.1 to 4.7 m (elevation 192.4 to 202.9) in the remaining boreholes.

4.27.6 Groundwater

Water (200 to 300 mm deep) was under 100 to 600 mm of snow / ice in boreholes IC-5 to IC-7.

Groundwater was measured in borehole IC-10 to be at a depth of 0.5 m (elevation 198.0) upon completion of drilling.

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.28 North Transfer Swamp 1

A total of 12 test holes comprising 8 boreholes and 4 dynamic cone penetration tests were advanced at swamp 1 in the North Transfer. The alignment crosses a low-lying swamp section between Sta. 42+550 and 42+640, North Transfer chainage, Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / silty clay and/or cohesionless sand / silty sand extending to bedrock. The bedrock surface was contacted at depths of 0.1 to 3.5 m (elevation 192.4 to 196.0).

4.28.1 Topsoil / Peat

Surficial topsoil was present in borehole NT1-4. The silty topsoil was about 100 mm thick and penetrated at elevation 196.0.

A deposit of peat was present surficially in test holes NT1-11, NT1-12 and under ice and water at depths of 0.2 to 1.5 m (elevation 193.4 to 195.9) in boreholes NT1-1, NT1-3, NT1-5, NT1-9 and NT1-10. The peat was amorphous and had a moisture content of 28 to 40%. The peat was 100 to 700 mm in thickness and penetrated at depths of 0.3 to 1.8 m (elevation 193.1 to 195.6).

4.28.2 Clayey Silt / Silty Clay

Overlain by the peat at 1.0 m depth (elevation 194.9) in borehole NT1-1 was a cohesive deposit of clayey silt / silty clay. This deposit was stiff to very stiff in consistency and about 39% in moisture content. The results of in situ vane testing carried out in the silty clay yielded an undisturbed shear strength value of 80 kPa (soil sensitivity of 8). Penetrometer tests performed on the clayey soil samples indicated a shear strength ranging from 75 to 125 kPa. The deposit was 1.6 m thick and penetrated at a depth of 2.6 m (elevation 193.3).

4.28.3 Sand / Silty Sand

Underlying the peat at 1.0 m depth (elevation 195.6) in borehole NT1-3 or the silty clay at a depth of 2.6 m (elevation 193.3) in borehole NT1-1 was cohesionless sand / silty sand. This stratum had a thickness of 300 mm in the former borehole and 900 mm in the latter and was penetrated at respective depths of 1.3 and 3.5 m (elevation 195.3 and 192.4). The sand / silty sand was loose to dense (SPT-'N' values of 5 to 31), with the moisture content of the sand unit in a range of 16 to 19%.

The results of grain size distribution analysis performed on a sample of the sand are presented in Figure NT1-GS-1.

4.28.4 Bedrock

The bedrock surface was inferred by refusal at depths of 0.1 to 3.5 m (elevation 192.4 to 196.0).

4.28.5 Groundwater

Water (0.1 to 1.4 m deep) was encountered under 100 to 200 mm of ice in boreholes NT1-1, NT1-3, NT1-5, NT1-7, NT1-9 and NT1-10. Groundwater was not observed in borehole NT1-11 during or upon completion of drilling. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

4.29 North Transfer Swamp 2

A total of 6 test holes comprising 4 boreholes and 2 dynamic cone penetration tests were advanced at swamp 2 in the North Transfer. The alignment crosses a low-lying swamp section between Sta. 42+960 and 43+000, North Transfer chainage, Wallbridge Township.

The subsurface stratigraphy revealed in the boreholes drilled at the site comprised surficial topsoil / peat overlying a cohesive deposit of clayey silt / silty clay and/or cohesionless sandy silt / silty sand extending to bedrock. The bedrock surface was exposed at one borehole location and contacted at depths of 0.2 to 2.3 m (elevation 194.6 to 197.2) in the remaining test holes.

4.29.1 Topsoil / Peat

Surficial topsoil was present in borehole NT2-2. The silty topsoil was about 200 mm in thickness and penetrated at elevation 197.2.

A deposit of peat was present surficially in test holes NT2-4, NT2-5 and under ice and water at a depth of 0.6 m (elevation 195.8) in borehole NT2-3. The amorphous peat was 0.6 to 1.0 m thick and penetrated at depths of 0.6 to 1.5 m (elevation 194.9 to 196.9).

4.29.2 Clayey Silt / Silty Clay

Overlain by the peat at 0.6 m depth (elevation 196.9) in borehole NT2-4 was a cohesive deposit of clayey silt / silty clay. This deposit was 1.5 m in thickness and soft to stiff in consistency. The results of in situ vane testing carried out in the silty clay yielded an undisturbed shear strength value of 80 kPa (soil sensitivity of 6). A penetrometer test on the silty clay sample indicated a shear strength of 75 kPa. The deposit was penetrated at a depth of 2.1 m (elevation 195.4).

The results of Atterberg limits testing and grain size distribution analysis conducted on a cohesive sample are presented in respective Figures NT2-PC-1 and NT2-GS-1. The liquid and plastic limits of the silty clay were 38 and 20 respectively, thus giving the plasticity index of 18. The moisture content of the silty clay was about 36%.

4.29.3 Sandy Silt / Silty Sand

Underlying the peat in borehole NT2-3 or the silty clay in borehole NT2-4 at respective depths of 1.5 and 2.1 m (elevation 194.9 and 195.4) was cohesionless sandy silt / silty sand. This stratum was 200 to 300 mm thick and loose to compact in relative density. The sandy silt / silty sand was penetrated at depths of 1.8 and 2.3 m (elevation 194.6 and 195.2) in boreholes NT2-3 and NT2-4 respectively.

The results of grain size distribution analysis performed on a sample of the sandy silt are presented in Figure NT2-GS-2.

4.29.4 Bedrock

Bedrock was exposed at elevation 197.8 in borehole NT2-6. The bedrock surface was inferred by refusal at depths of 0.2 to 2.3 m (elevation 194.6 to 197.2) in the remaining test holes.

4.29.5 Groundwater

Water (200 mm deep) was under 400 mm of ice in borehole NT2-3.

Groundwater was measured in borehole NT2-4 to be at a depth of 1.2 m (elevation 196.3) upon completion of drilling.

No water was observed in the remaining boreholes in the course of the field work. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.

5. CLOSURE

Messrs. F. Portela, J. Haug, K. Daly, A. Lo and S. Aziz carried out the field investigation for this study under the supervision of Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer. The equipment was supplied by Walker Drilling Ltd. and Landcore. The laboratory testing of selected soil samples was carried out at the PML laboratory in Toronto.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. B.R. Gray, MEng, P.Eng, MTO Designated Principal Contact. Mr. C.M.P. Nascimento, P.Eng., Project Manager, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

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GD/CN/BRG:gd-mi-jk

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

PML CROSSING No.	LOCATION	No. OF TEST HOLES	PEAT / TOPSOIL THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
101	Sta. 16+075 to 16+125 (NBL) Magnetawan First Nation	7	0.1 – 0.9	0.0 – 2.9	0.1 – 2.9 (El. 191.4 – 194.7)	Topsoil or peat present in all boreholes overlies a cohesive deposit of sandy clayey silt or bedrock
102	Sta. 16+530 to 16+585 (NBL) Magnetawan First Nation	10	0.0 – 0.3	0.0 – 3.4	0.0 – 3.8 (El. 189.3 – 196.3)	Exposed bedrock in 5 boreholes. Topsoil or peat overlies organic sandy silt or a cohesive deposit of clay underlain by cohesionless sand extending to bedrock
103	Sta. 16+695 to 16+735 (NBL) Magnetawan First Nation	8	0.0 – 0.9	0.0 – 4.9	0.0 – 5.5 (El. 187.7 – 194.6)	Exposed bedrock in 1 borehole. Topsoil or peat present in most boreholes overlies organic silty sand and/or a cohesive deposit of clay, silty clay and clayey silt underlain by cohesionless silt / sand extending to bedrock
104	Sta. 16+795 to 16+837.5 (NBL) Magnetawan First Nation	10	0.0 – 0.6	0.0 – 5.6	0.0 – 8.1 (El. 185.4 – 194.3)	Exposed bedrock in 1 borehole. Topsoil or peat present in most boreholes overlies organic soils and a cohesive deposit of clay, silty clay and clayey silt underlain by cohesionless sandy silt / sand extending to bedrock
105	Sta. 16+925 to 17+030 (NBL) Magnetawan First Nation	15	0.0 – 1.4	0.0 – 3.2	0.0 – 3.8 (El. 192.1 – 198.2)	Exposed bedrock in 1 borehole. Fill, topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt / clay underlain by cohesionless sandy silt / silt extending to bedrock
106	Sta. 17+537.5 to 17+610 (NBL) Magnetawan First Nation	11	0.0 – 0.6	0.0 – 2.7	0.0 – 2.7 (El. 194.7 – 198.9)	Exposed bedrock in 2 boreholes. Topsoil or peat present in most boreholes overlies sandy soils containing a cohesive deposit of clay / clayey silt and extending to bedrock
107	Sta. 17+700 to 17+870 (NBL) Magnetawan First Nation	28	0.0 – 1.7	0.0 – 8.7	0.0 – 11.6 (El. 186.1 – 199.9)	Exposed bedrock in 5 boreholes. Topsoil or peat present in most boreholes overlies silty/sandy soils and/or a cohesive deposit of silty clay / clayey silt extending to bedrock

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

PML CROSSING No.	LOCATION	No. OF TEST HOLES	PEAT / TOPSOIL THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
108	Sta. 18+220 to 18+250 (NBL) Magnetawan First Nation	7	0.0 – 0.4	0.0 – 3.1	0.1 – 3.1 (El. 192.6 – 199.3)	Topsoil or peat present in most boreholes overlies silty sand and/or a cohesive deposit of silty clay extending to bedrock
109	Sta. 18+580 to 18+650 (NBL) Magnetawan First Nation	16	0.0 – 1.0	0.0 – 15.6	0.0 – 16.7 (El. 171.5 – 193.3)	Exposed bedrock in 2 boreholes. Topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt, silty clay and clay underlain by cohesionless sandy soils extending to bedrock
110	Sta. 18+780 to 18+970 (NBL) Magnetawan First Nation	26	0.0 – 1.6	0.0 – 6.2	0.0 – 8.4 (El. 187.0 – 199.7)	Exposed bedrock in 7 boreholes. Topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt / silty clay and/or cohesionless sand / silty sand extending to bedrock
111	Sta. 19+030 to 19+060 (NBL) Magnetawan First Nation	6	0.0 – 0.6	0.0 – 3.7	0.0 – 3.7 (El. 191.3 – 197.5)	Exposed bedrock in 2 boreholes. Topsoil or peat overlies organic silty clay or a cohesive deposit of silty clay extending to bedrock
112	Sta. 19+350 to 19+460 Magnetawan First Nation	18	0.0 – 0.6	0.0 – 7.2	0.0 – 11.1 (El. 177.7 – 198.4)	Rockfill in 1 borehole. Exposed bedrock in 6 boreholes. Topsoil or peat (and organic silt in 1 borehole) present in most boreholes overlies silty/sandy soils and a cohesive deposit of clayey silt, silty clay and clay underlain by sand extending to bedrock
113	Sta. 19+750 to 19+810 Magnetawan First Nation	15	0.0 – 0.8	0.0 – 4.2	0.0 – 4.2 (El. 190.1 – 199.6)	Exposed bedrock in 4 boreholes. Topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt, silty clay and clay or cohesionless sand extending to bedrock
114	Sta. 19+850 to 19+955 Magnetawan First Nation	18	0.0 – 0.7	0.0 – 3.9	0.0 – 3.9 (El. 190.8 – 198.8)	Exposed bedrock in 4 boreholes. Topsoil or peat overlies a cohesive deposit of clayey silt, silty clay and clay or bedrock

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

PML CROSSING No.	LOCATION	No. OF TEST HOLES	PEAT / TOPSOIL THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
115	Sta. 20+175 to 20+270 Magnetawan First Nation	19	0.0 – 0.4	0.0 – 8.5	0.0 – 8.8 (El. 185.9 – 200.0)	Exposed bedrock in 2 boreholes. Topsoil or peat present in most boreholes overlies organic soils and a cohesive deposit of clayey silt, silty clay and clay underlain by cohesionless sand / silt extending to bedrock
116	Sta. 20+760 to 20+970 (NBL) Magnetawan First Nation	26	0.0 – 0.7	0.0 – 2.7	0.0 – 3.4 (El. 190.1 – 198.3)	Exposed bedrock in 4 boreholes. Topsoil or peat present in most boreholes overlies organic sand and a cohesive deposit of clayey silt, silty clay and clay underlain by cohesionless silty sand extending to bedrock
117	Sta. 20+815 to 20+880 (SBL) Magnetawan First Nation	10	0.0 – 0.5	0.0 – 4.3	0.1 – 4.6 (El. 188.0 – 193.7)	Topsoil or peat present in most boreholes overlies organic sand or a cohesive deposit of silty clay extending to bedrock
118	Sta. 22+225 to 22+320 Wallbridge Township	20	0.0 – 0.8	0.0 – 1.2	0.0 – 1.4 (El. 196.1 – 201.8)	Exposed bedrock in 3 boreholes. Topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt and/or cohesionless silty sand extending to bedrock
119	Sta. 22+350 to 22+725 (NBL) Wallbridge Township	24	0.0 – 1.2	0.0 – 2.3	0.0 – 2.3 (El. 194.4 – 199.2)	Exposed bedrock in 1 borehole. Topsoil or peat present in most boreholes overlies silty sand and/or a cohesive deposit of clayey silt / clay or cohesionless sand and gravel extending to bedrock
120	Sta. 22+390 to 22+430 (SBL) Wallbridge Township	8	0.0 – 0.9	–	0.0 – 0.9 (El. 196.6 – 198.7)	Exposed bedrock in 3 boreholes. Topsoil or peat present in most boreholes overlies bedrock
121	Sta. 22+590 to 22+700 (SBL) Wallbridge Township	15	0.1 – 1.0	0.0 – 0.4	0.1 – 2.0 (El. 194.4 – 197.5)	Topsoil or peat present in all the boreholes overlies a cohesive deposit of clayey silt and/or cohesionless silty/sandy soils extending to bedrock

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

PML CROSSING No.	LOCATION	No. OF TEST HOLES	PEAT / TOPSOIL THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
122	Sta. 22+800 to 22+840 (SBL) Wallbridge Township	6	0.0 – 0.3	–	0.0 – 2.3 (El. 196.0 – 200.3)	Exposed bedrock in 1 borehole. Topsoil or peat present in most boreholes overlies cohesionless silty sand extending to bedrock
123	Sta. 22+850 to 22+920 (NBL) Wallbridge Township	10	0.0 – 0.6	–	0.0 – 0.6 (El. 199.1 – 201.3)	Exposed bedrock in 6 boreholes. Peat overlies cohesionless sand extending to bedrock
124	Sta. 22+960 to 23+060 (NBL) Wallbridge Township	15	0.0 – 0.5	–	0.0 – 2.3 (El. 196.9 – 200.8)	Exposed bedrock in 2 boreholes. Topsoil or peat present in most boreholes overlies bedrock
Ramp S-E/W	Sta. 20+250 to 20+300 (Ramp S-E/W chainage) Magnetawan First Nation	5	0.2 – 0.3	0.0 – 7.3	0.6 – 8.5 (El. 190.6 – 199.3)	Topsoil, peat or organic silt present in all the boreholes overlies non-cohesive silt and/or a cohesive deposit of clayey silt and clay underlain by cohesionless sand extending to bedrock
Ramp N-E/W	Sta. 20+710 to 20+965 (Ramp N-E/W chainage) Magnetawan First Nation	18	0.0 – 0.4	0.0 – 4.2	0.0 – 4.2 (El. 188.3 – 199.9)	Exposed bedrock in 1 borehole. Topsoil, peat and organic sand present in most boreholes overlies a cohesive deposit of silty clay and clay underlain by cohesionless sandy soils extending to bedrock
Interchange Service Road	Sta. 9+900 to 10+100 (Interchange Service Road chainage) Magnetawan First Nation	14	0.0 – 0.4	0.0 – 4.5	0.0 – 4.7 (El. 192.4 – 202.9)	Exposed bedrock in 4 boreholes. Topsoil or peat present in most boreholes overlies organic soils and a cohesive deposit of clayey silt, silty clay and clay underlain by cohesionless silty sand extending to bedrock

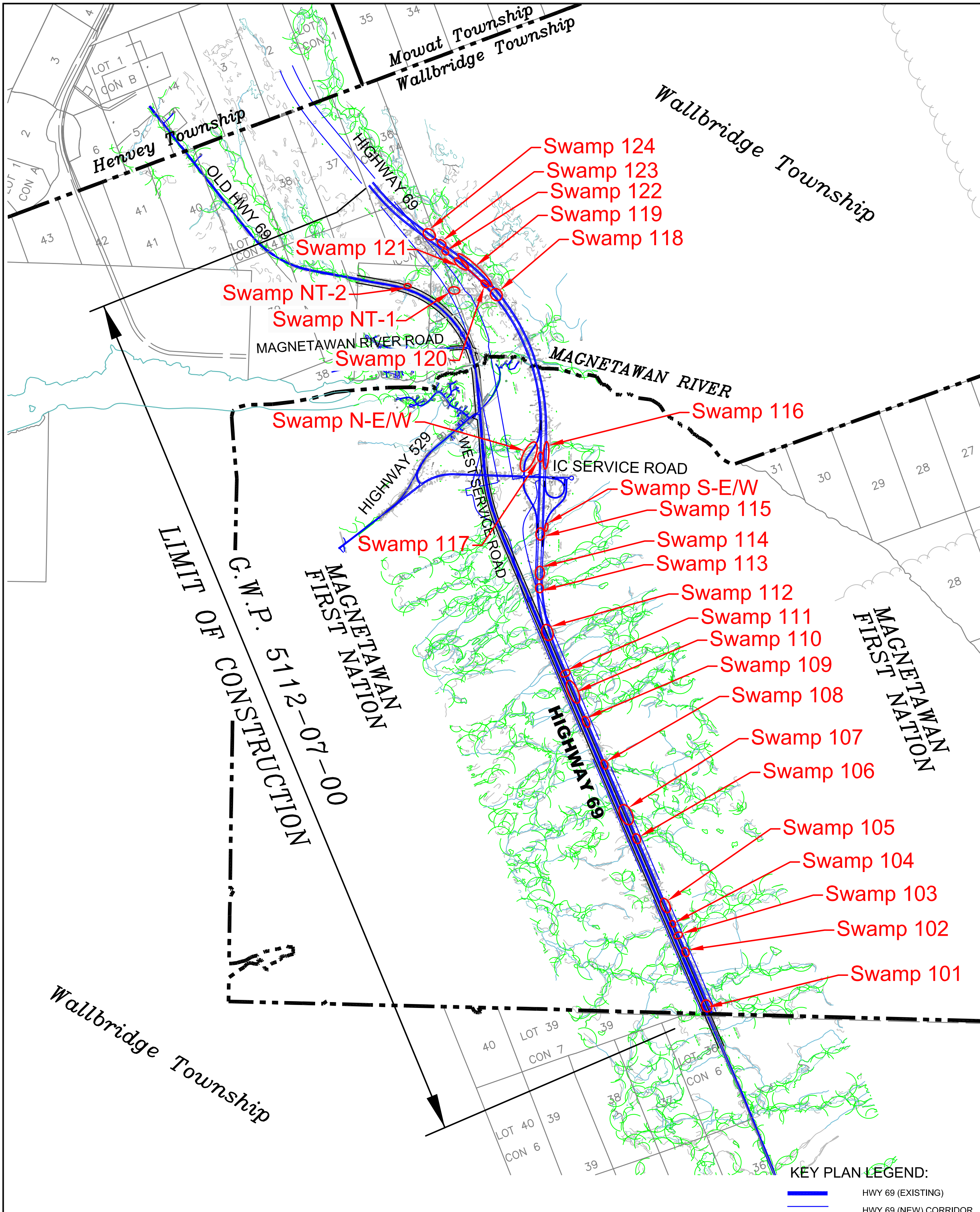
TABLE 1

SUMMARY OF SUBSOIL CONDITIONS

PML CROSSING No.	LOCATION	No. OF TEST HOLES	PEAT / TOPSOIL THICKNESS (m)	DEPTH TO BOTTOM OF CLAY (m)	DEPTH TO PROBABLE BEDROCK (m)	NOTES AND/OR SOIL PROFILE
North Transfer Swamp 1	Sta. 42+550 to 42+640 (North Transfer chainage) Wallbridge Township	12	0.0 – 0.7	0.0 – 2.6	0.1 – 3.5 (El. 192.4 – 196.0)	Topsoil or peat present in most boreholes overlies a cohesive deposit of clayey silt and silty clay and/or cohesionless sand / silty sand extending to bedrock
North Transfer Swamp 2	Sta. 42+960 to 43+000 (North Transfer chainage) Wallbridge Township	6	0.0 – 1.0	0.0 – 2.1	0.0 – 2.3 (El. 194.6 – 197.8)	Exposed bedrock in 1 borehole. Topsoil or peat present in all the boreholes overlies a cohesive deposit of clayey silt / silty clay and/or cohesionless silty/sandy soils extending to bedrock

NOTES:

1. Test holes include boreholes and dynamic cone penetration tests.
2. Thickness of peat / topsoil and depth to bottom of cohesive deposits is based on borehole data only.
3. Depth to probable bedrock is based on both borehole and dynamic cone penetration test data



KEY PLAN
SWAMPS
HIGHWAY 69 FOUR-LANING FOR 21.5 km
From 4.5 km North of Highway 64 to
8.7 km North of Highway 637
District 52, Sudbury

METRIC

0.5 km 0 0.5 1.0 km
SCALE

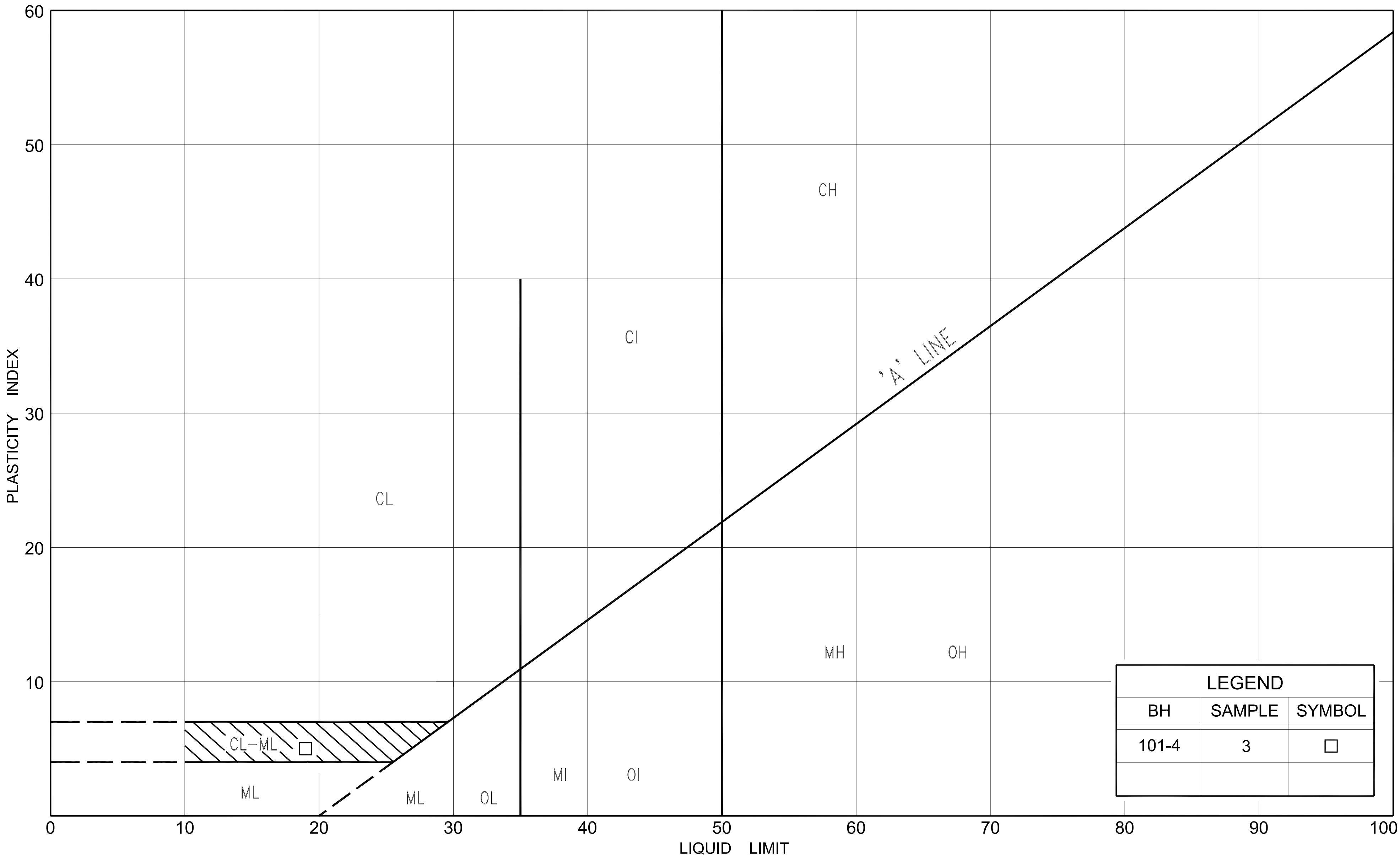
Ontario
Peto MacCallum Ltd. CONSULTING ENGINEERS
PRINCIPAL CONSULTANT
AECOM
FIGURE
1

APPENDIX A

Figures 101-PC-1 to NT2-PC-1 – Plasticity Charts

Figures 101-GS-1 to NT2-GS-2 – Results of Grain Size Distribution Analyses

Figures 112-C-1, 113-C-1 and SEW-C-1 – Consolidation Test Results

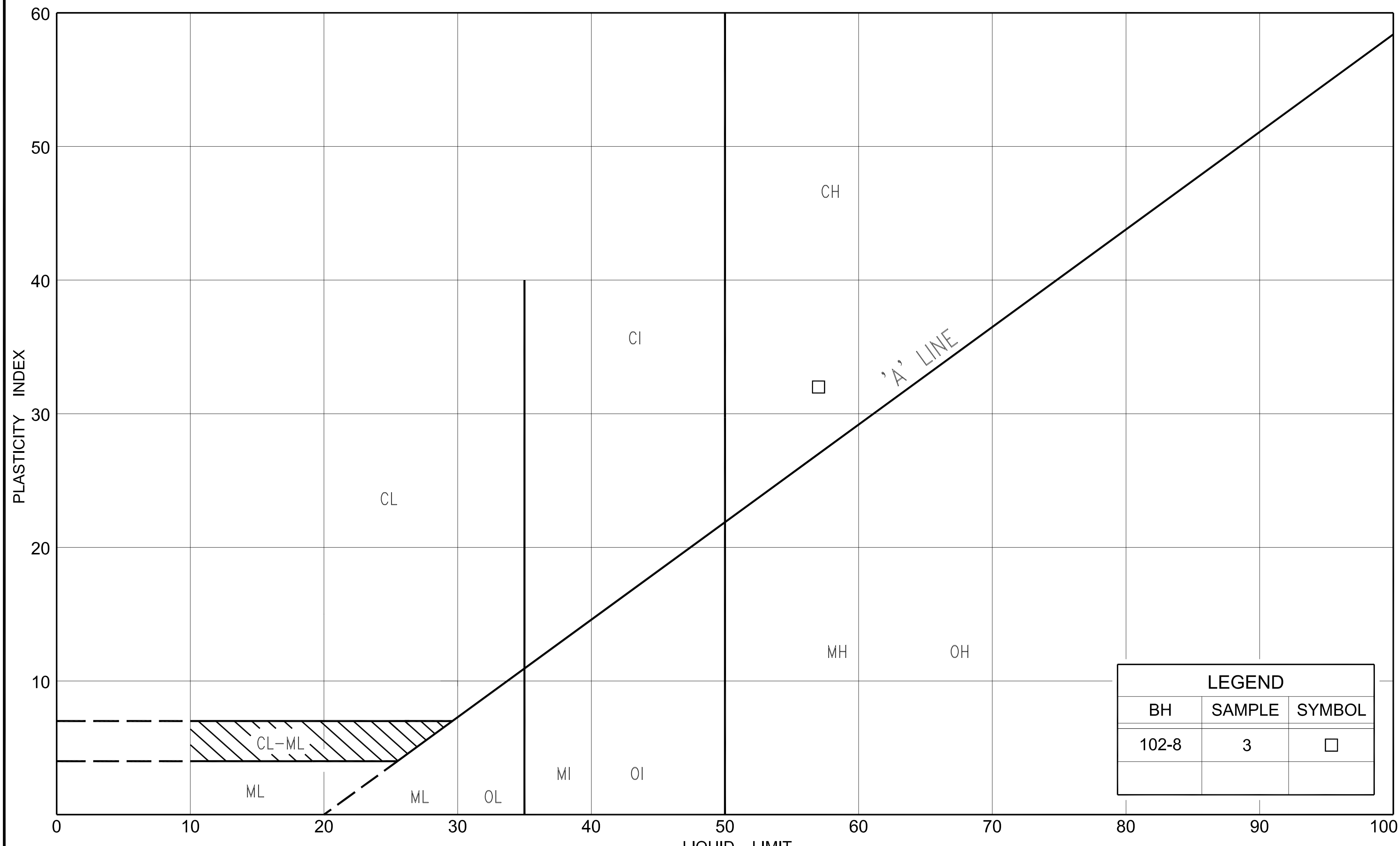


Ontario

PLASTICITY CHART

CLAYEY SILT, sandy

FIG No.	101-PC-1
HWY:	69
G.W.P. No.	5112-07-00

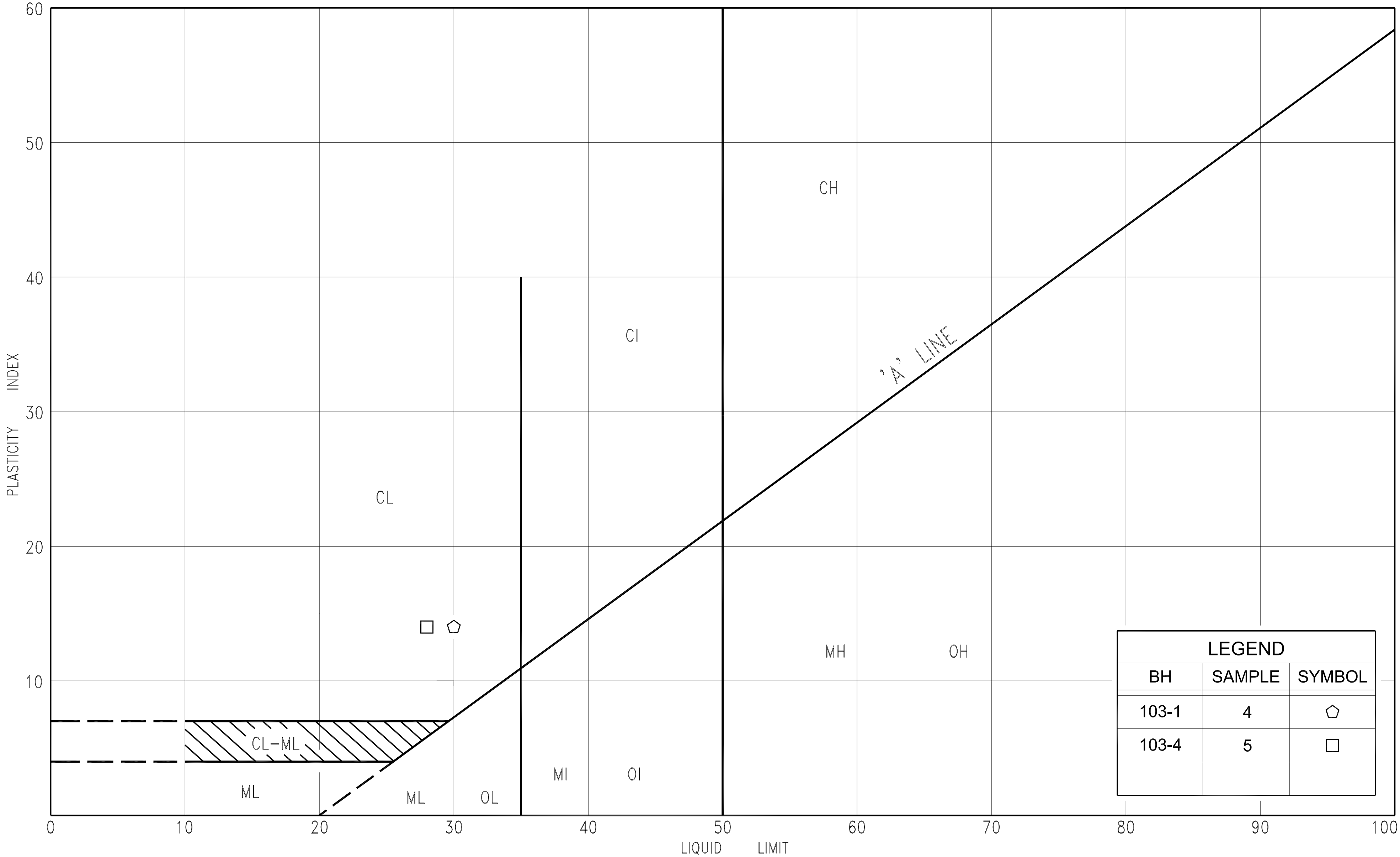


BH	SAMPLE	SYMBOL
102-8	3	□

PLASTICITY CHART

CLAY, trace sand

FIG No.	102-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

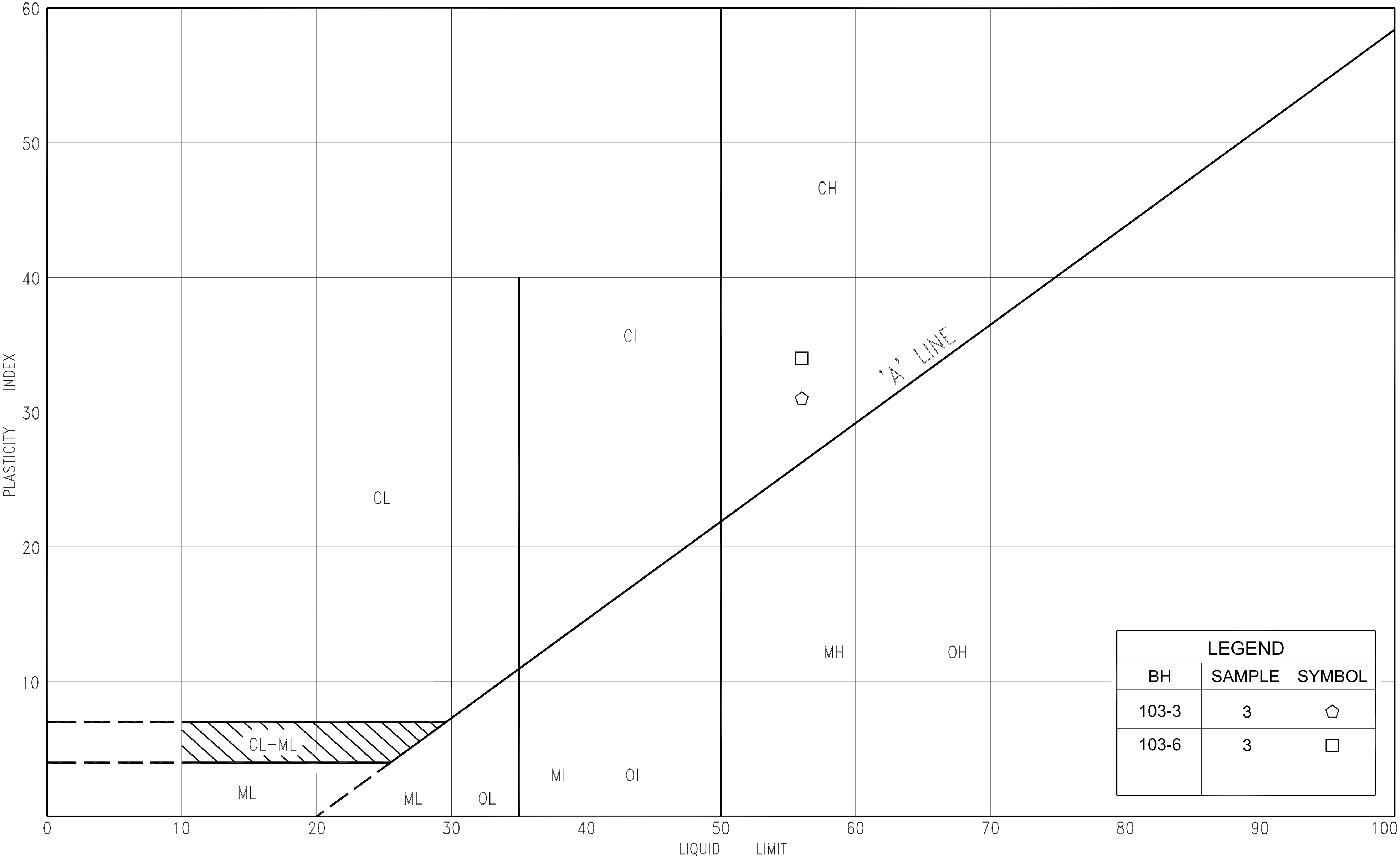
BH	SAMPLE	SYMBOL
103-1	4	⬠
103-4	5	□

Ontario

PLASTICITY CHART

CLAYEY SILT, with sand

FIG No.	103-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

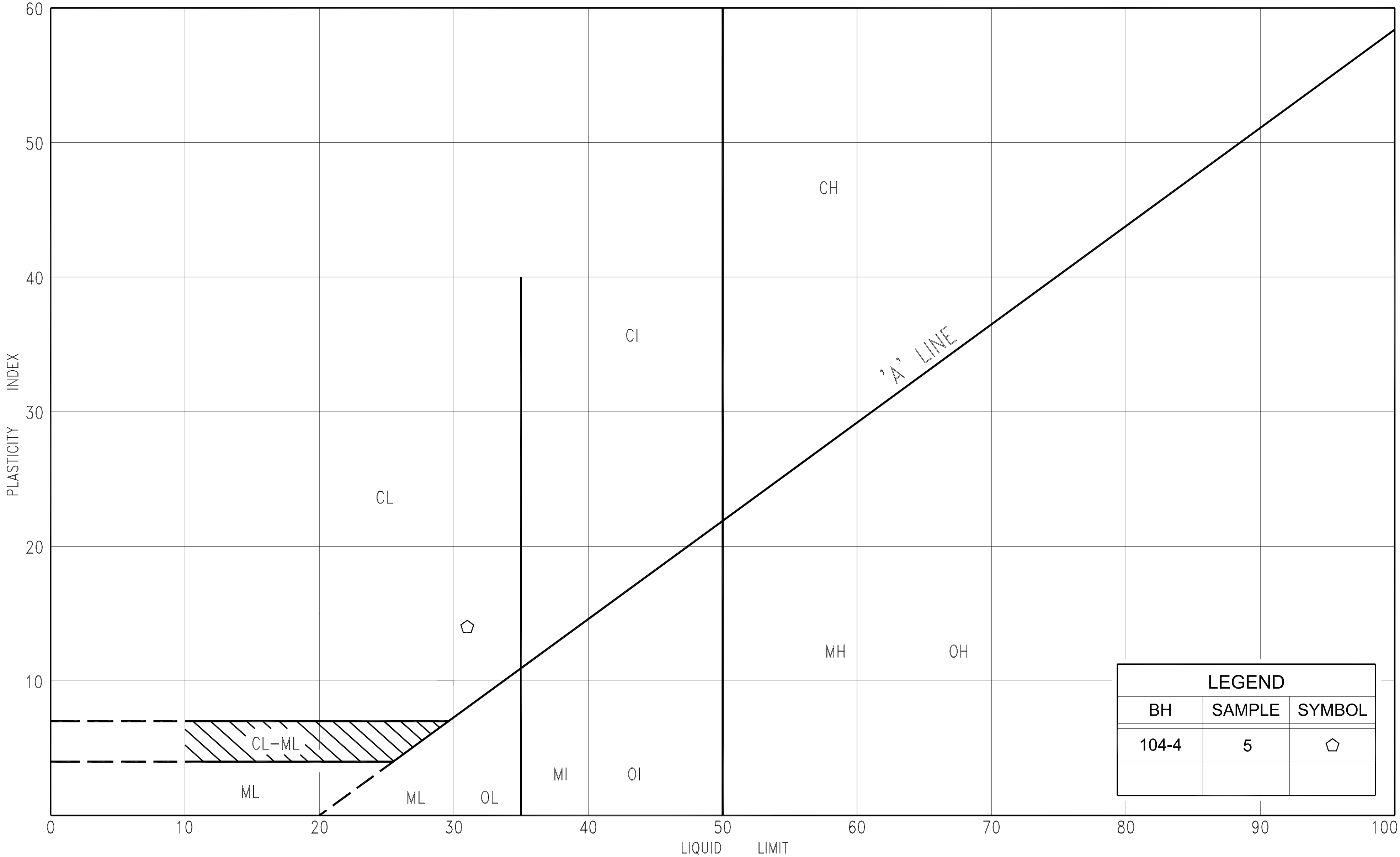
BH	SAMPLE	SYMBOL
103-3	3	⬠
103-6	3	□

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	103-PC-2
HWY:	69
G.W.P. No.	5112-07-00



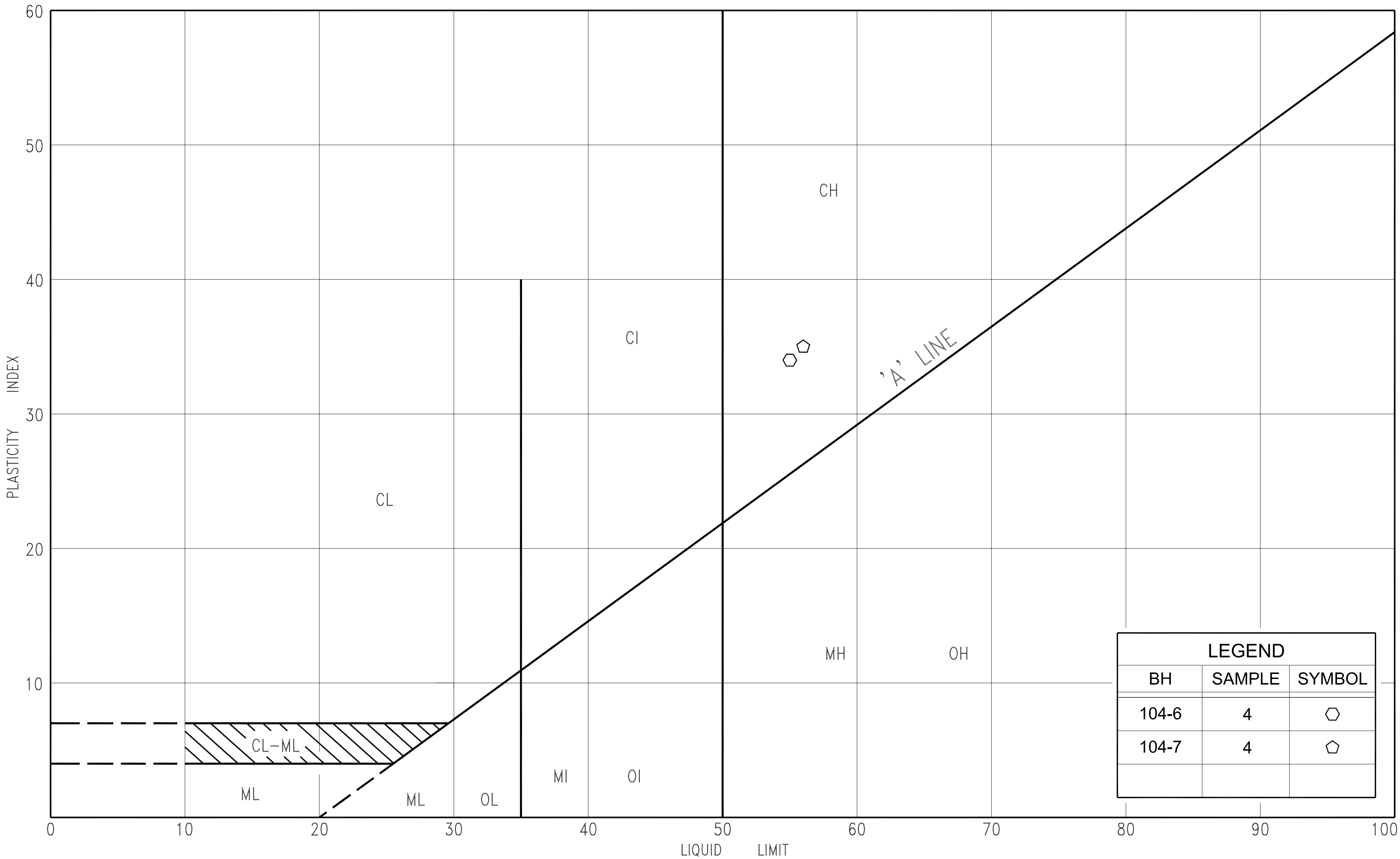
LEGEND		
BH	SAMPLE	SYMBOL
104-4	5	⬠

Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	104-PC-1
HWY:	69
G.W.P. No.	5112-07-00



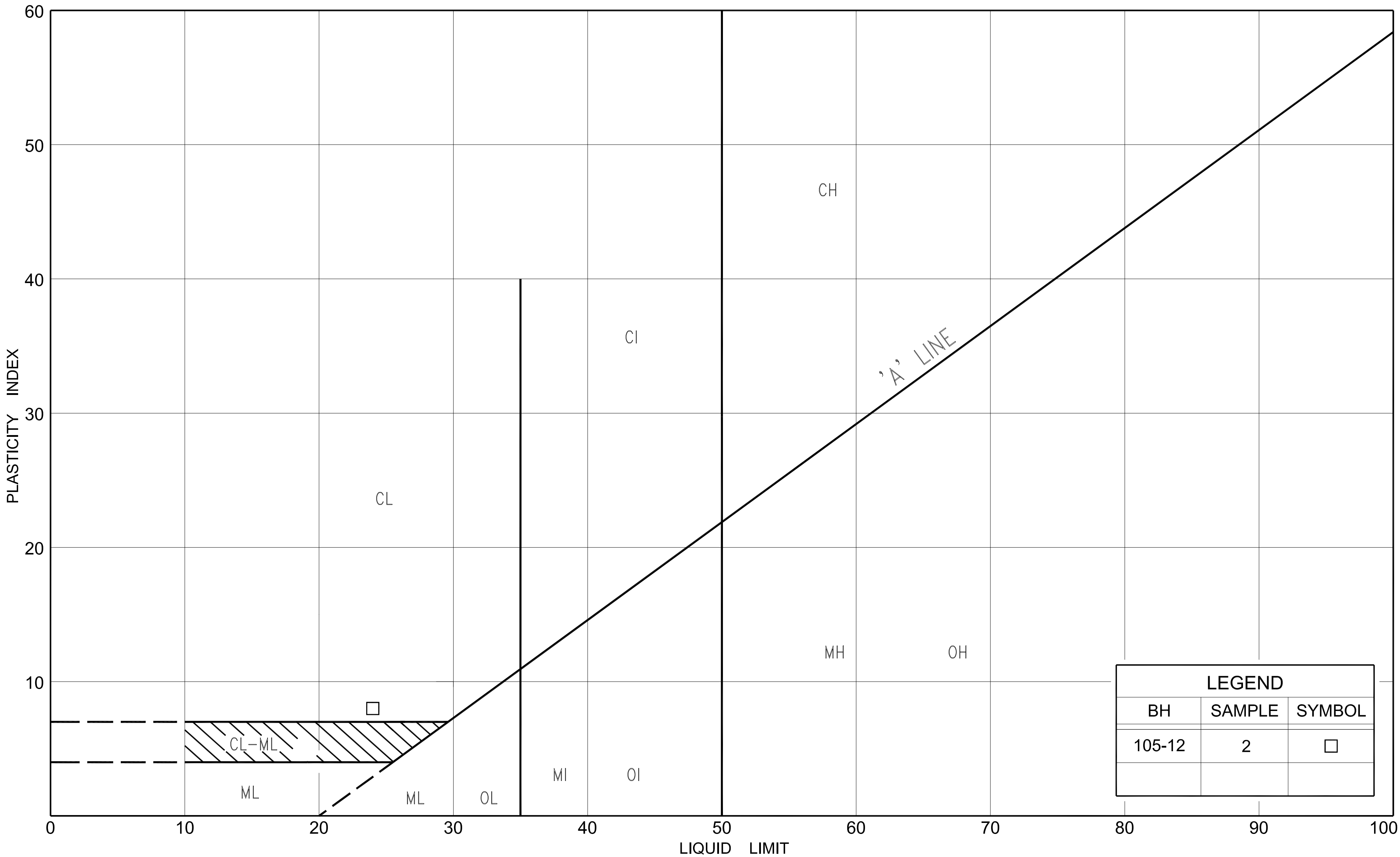
LEGEND		
BH	SAMPLE	SYMBOL
104-6	4	⬡
104-7	4	⬠

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	104-PC-2
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

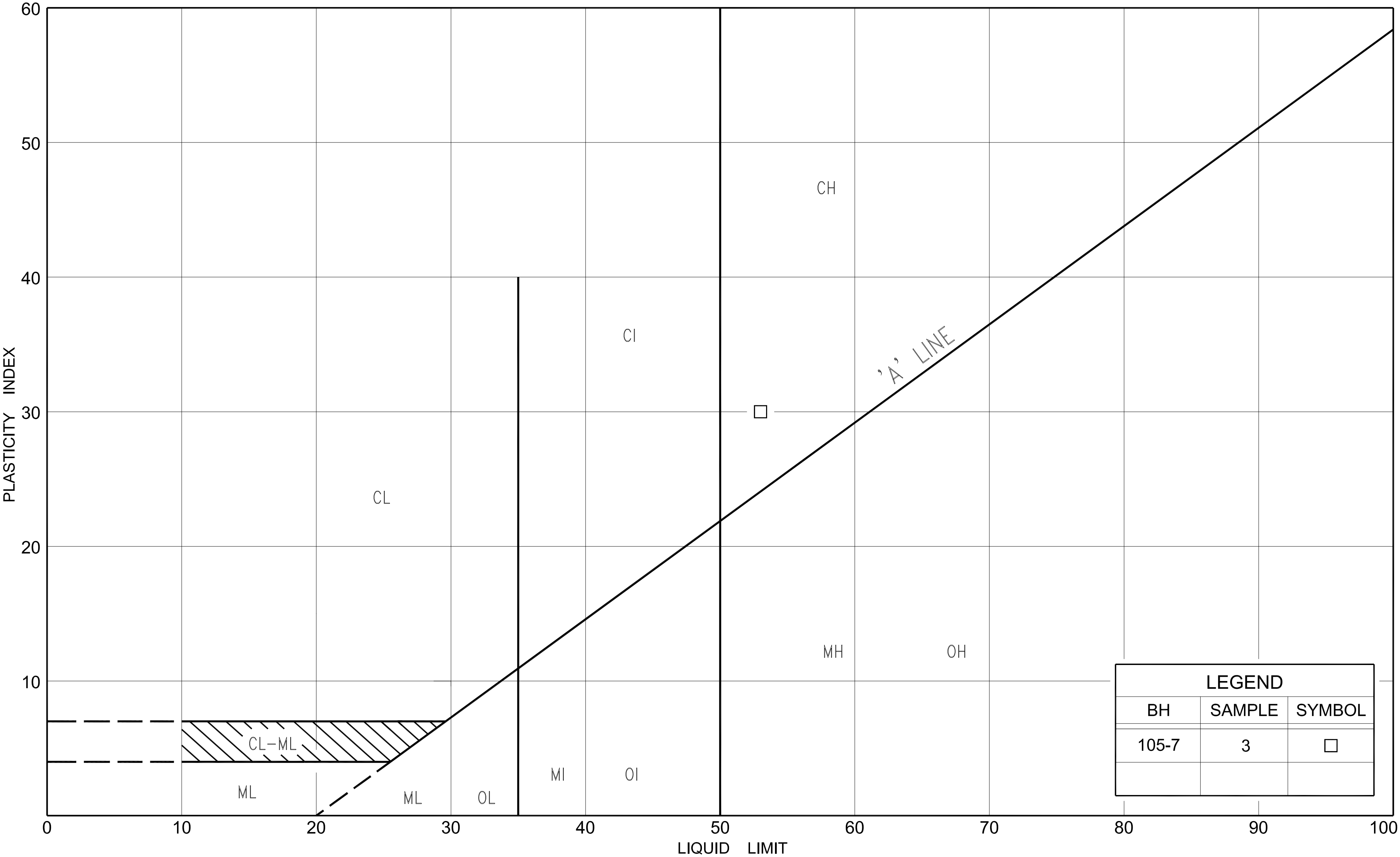
BH	SAMPLE	SYMBOL
105-12	2	□

Ontario

PLASTICITY CHART

CLAYEY SILT, with sand

FIG No.	105-PC-1
HWY:	69
G.W.P. No.	5112-07-00



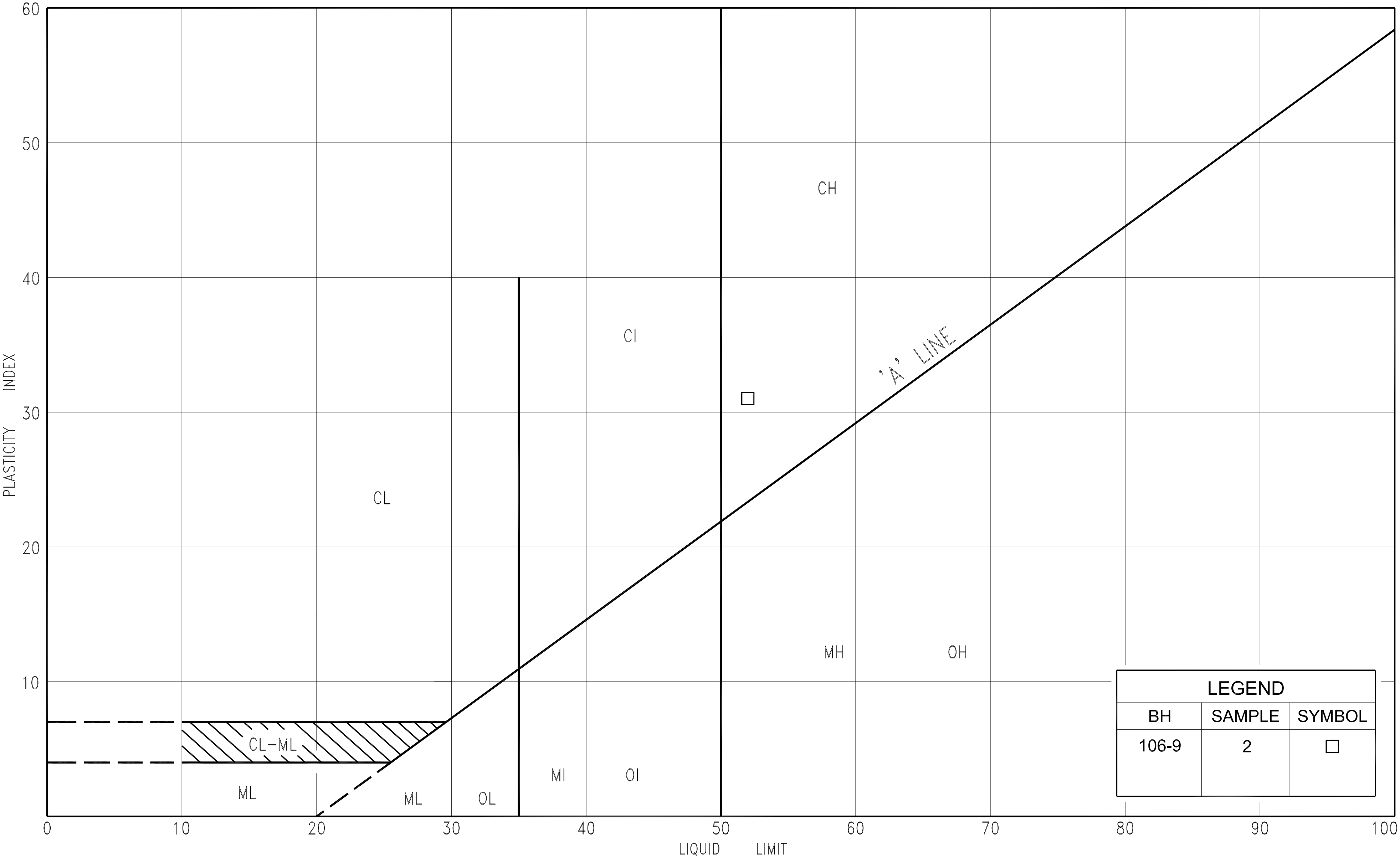
LEGEND

BH	SAMPLE	SYMBOL
105-7	3	□

PLASTICITY CHART

CLAY, trace sand

FIG No.	105-PC-2
HWY:	69
G.W.P. No.	5112-07-00



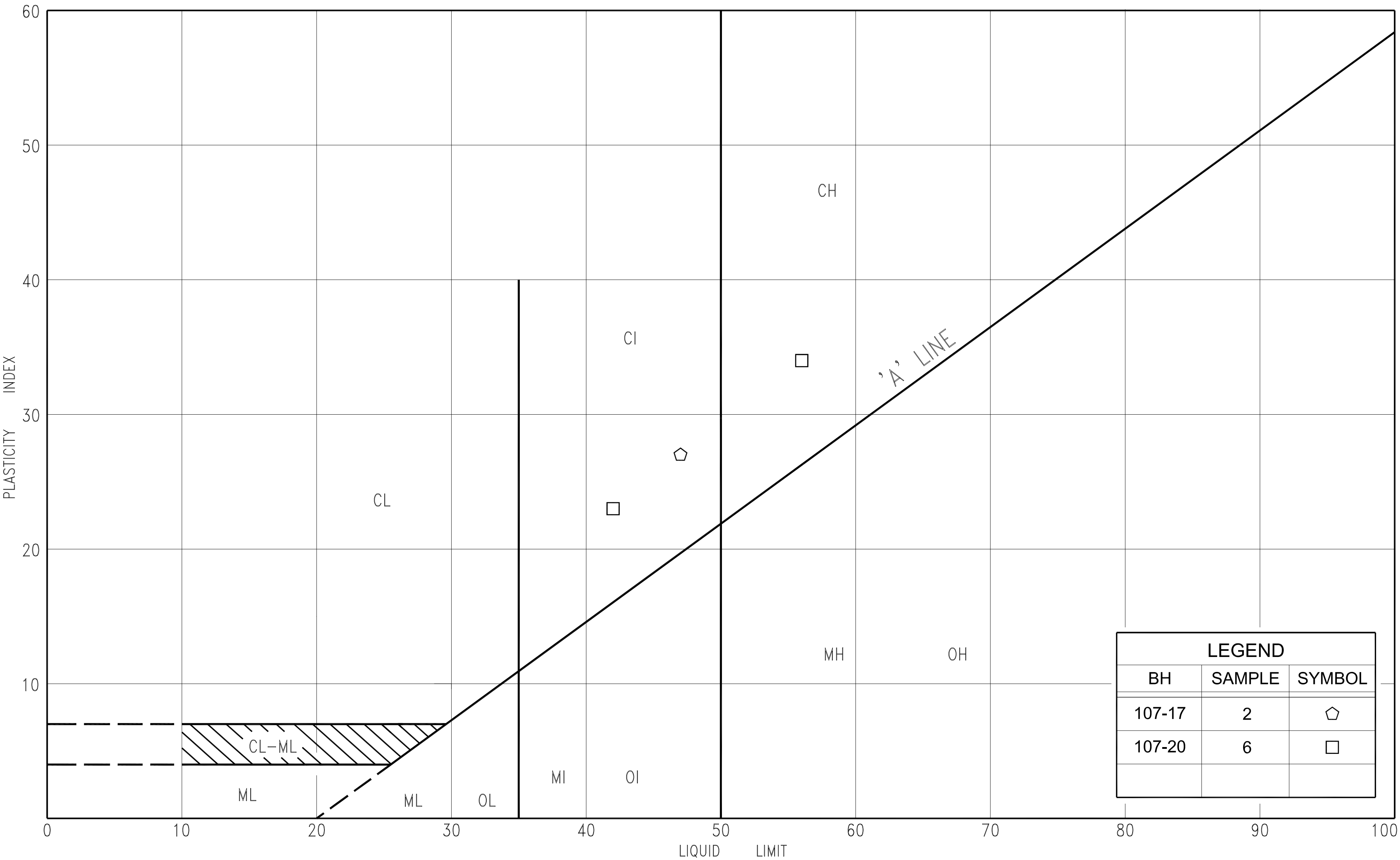
BH	SAMPLE	SYMBOL
106-9	2	□

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	106-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

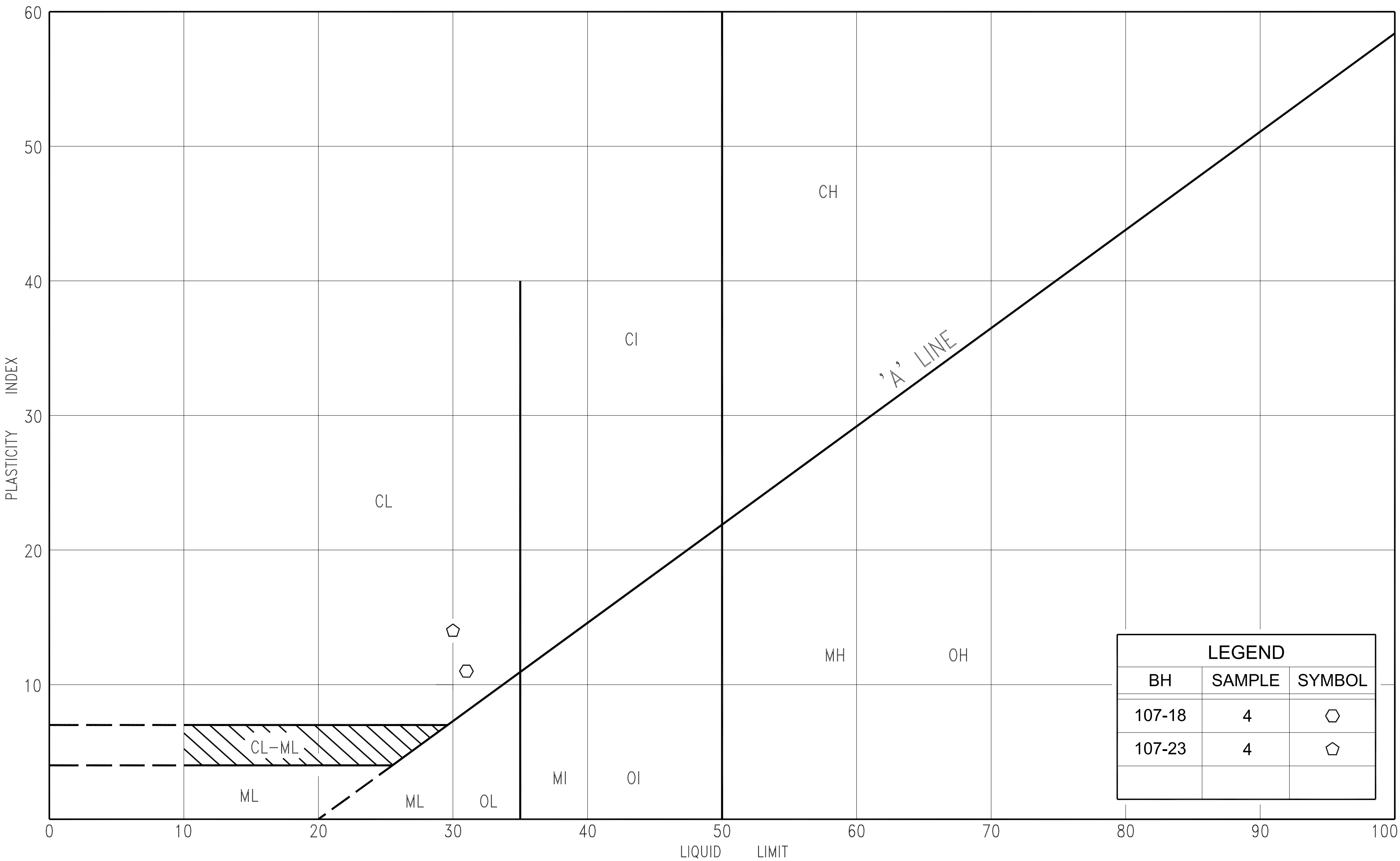
BH	SAMPLE	SYMBOL
107-17	2	⬠
107-20	6	□

Ontario

PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	107-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

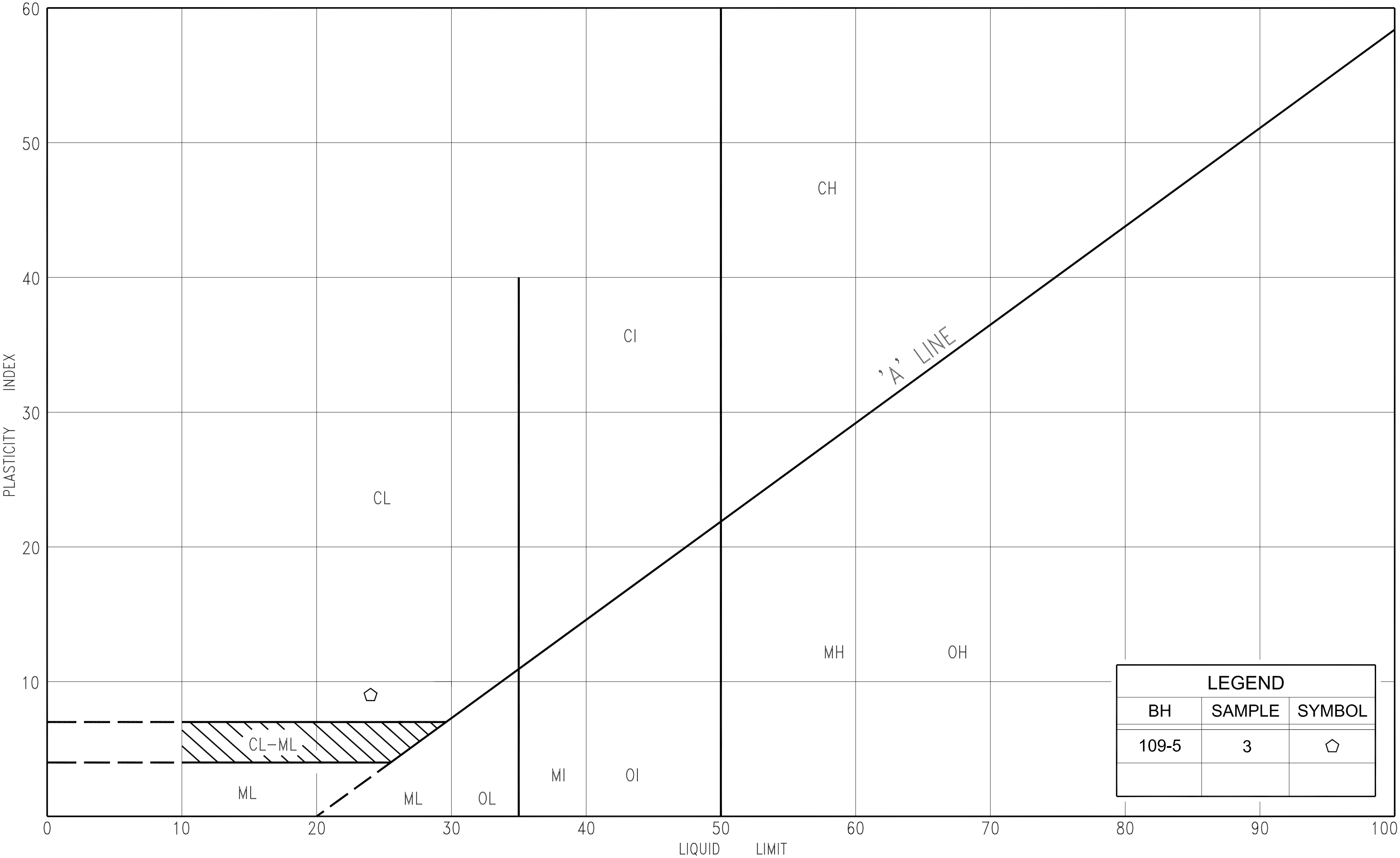
BH	SAMPLE	SYMBOL
107-18	4	⬡
107-23	4	⬠

Ontario

PLASTICITY CHART

CLAYEY SILT, some sand

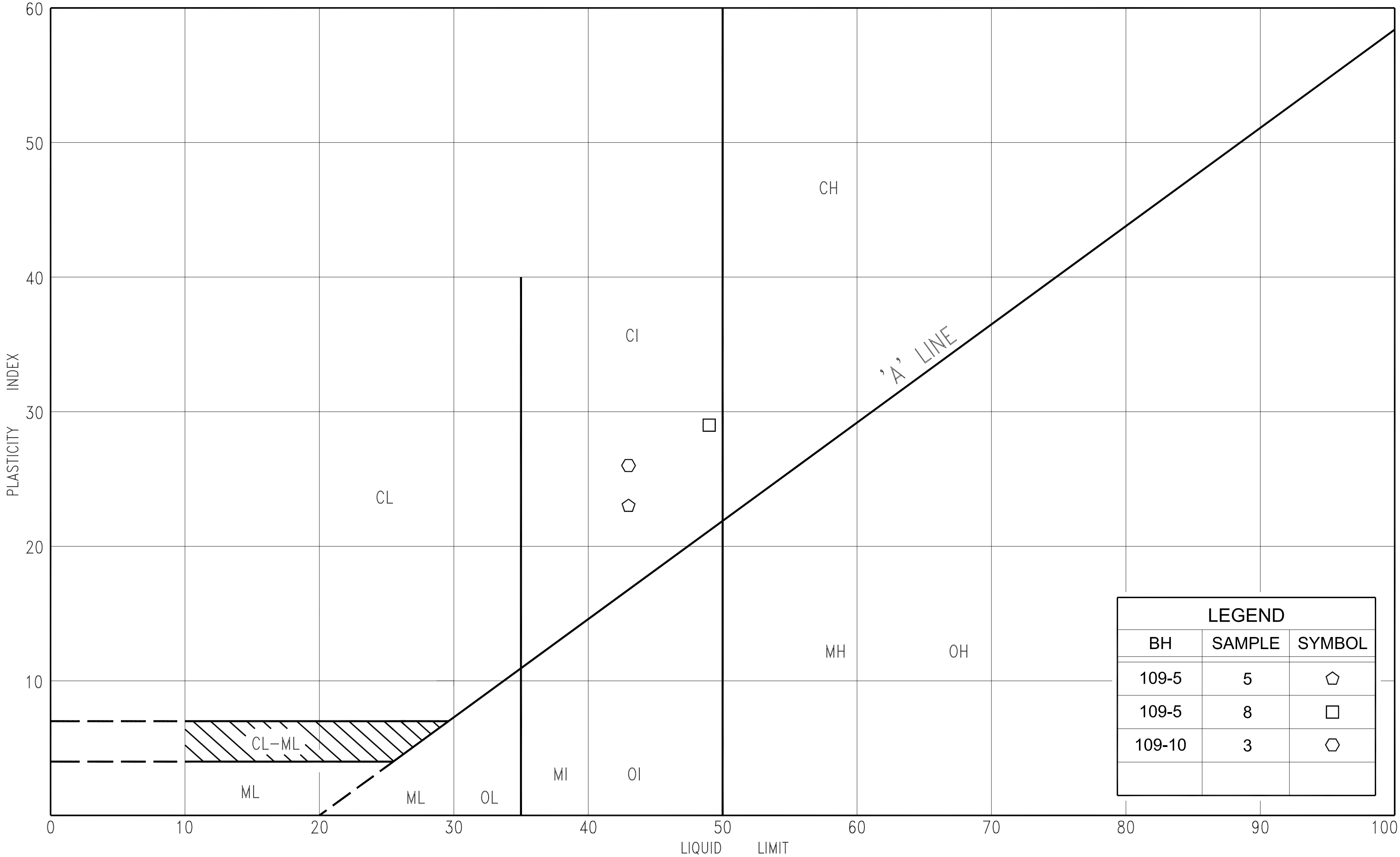
FIG No.	107-PC-2
HWY:	69
G.W.P. No.	5112-07-00



PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	109-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

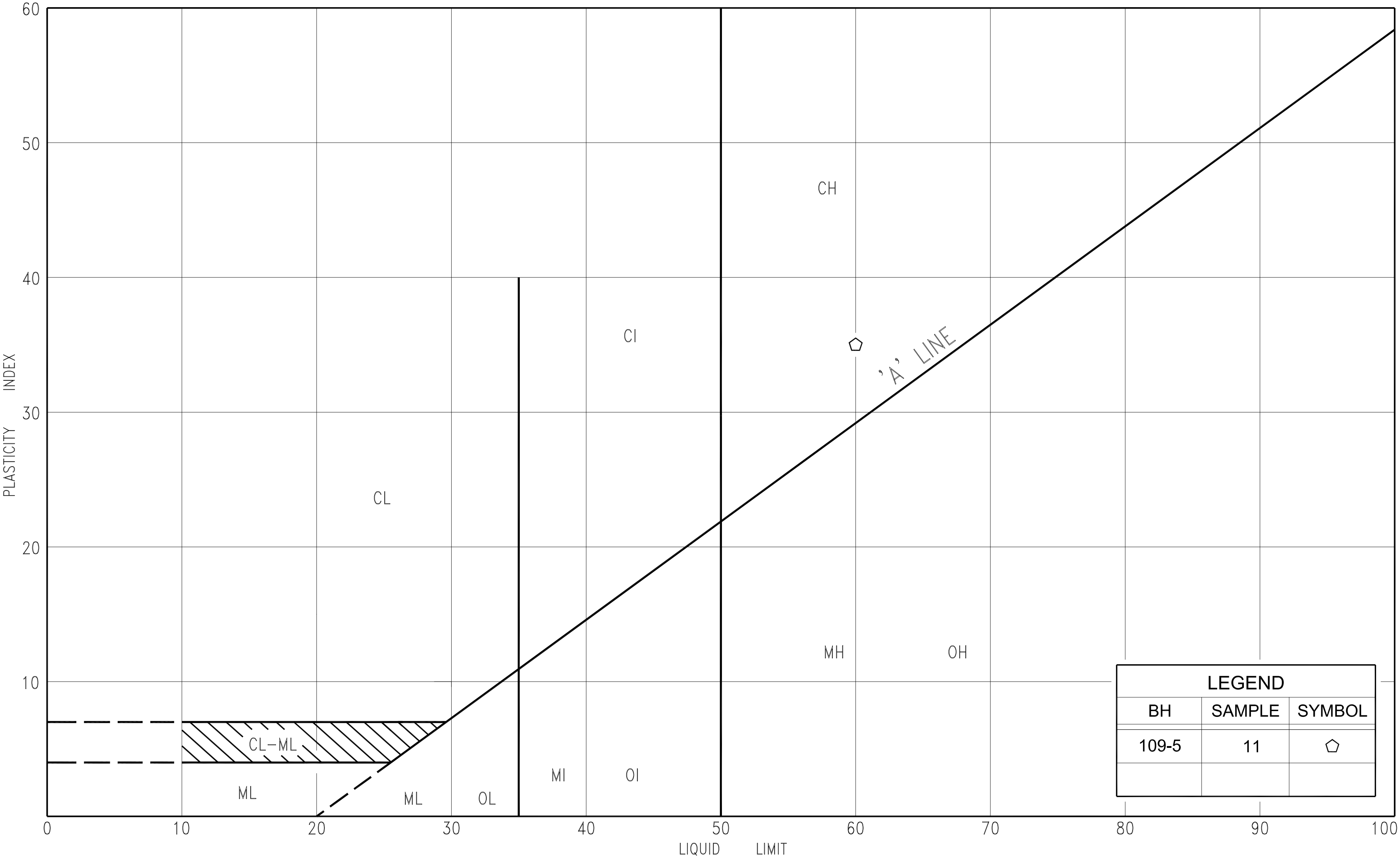
BH	SAMPLE	SYMBOL
109-5	5	⬠
109-5	8	□
109-10	3	⬡

Ontario

PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	109-PC-2
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

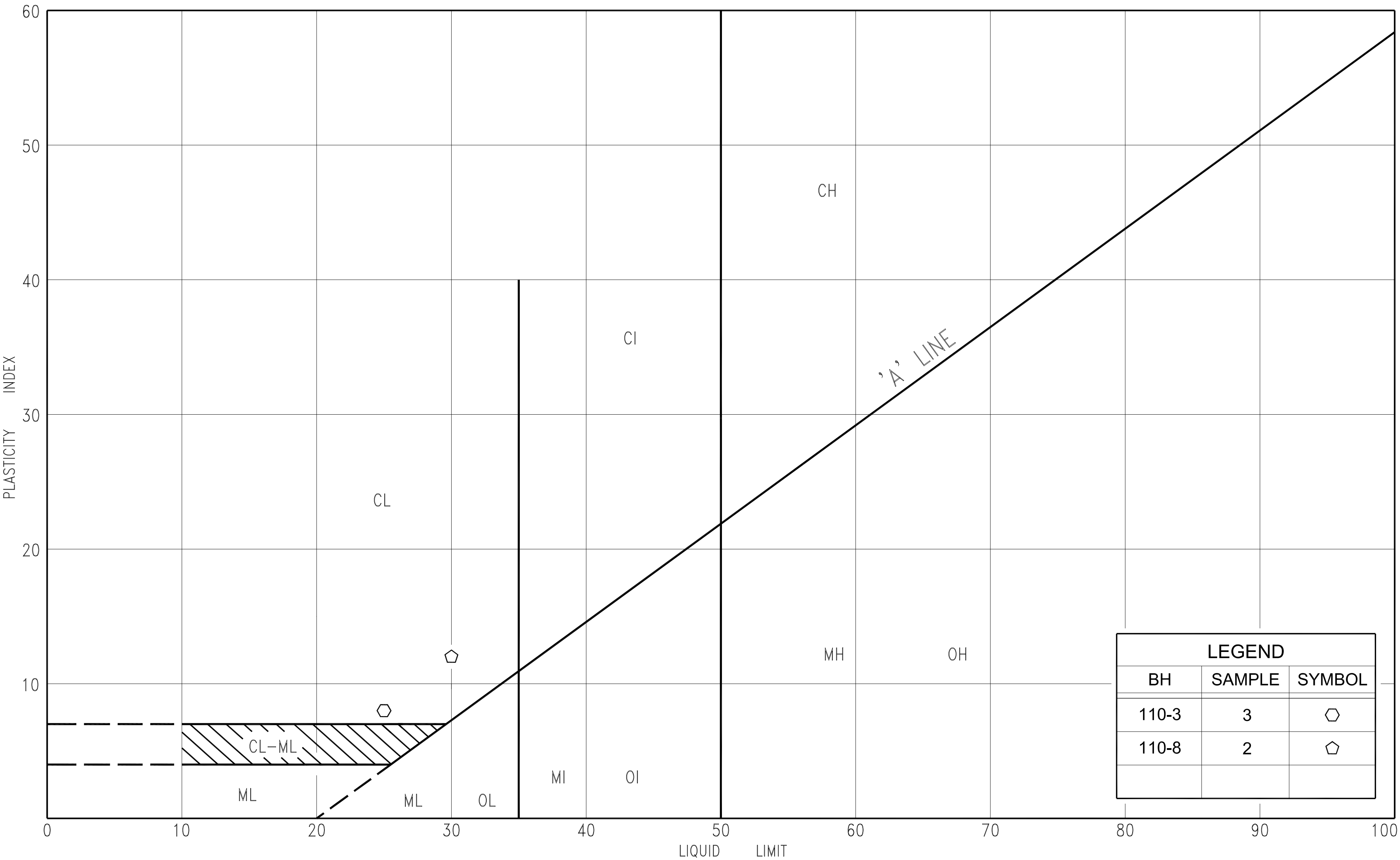
BH	SAMPLE	SYMBOL
109-5	11	⬠

Ontario

PLASTICITY CHART

CLAY

FIG No.	109-PC-3
HWY:	69
G.W.P. No.	5112-07-00



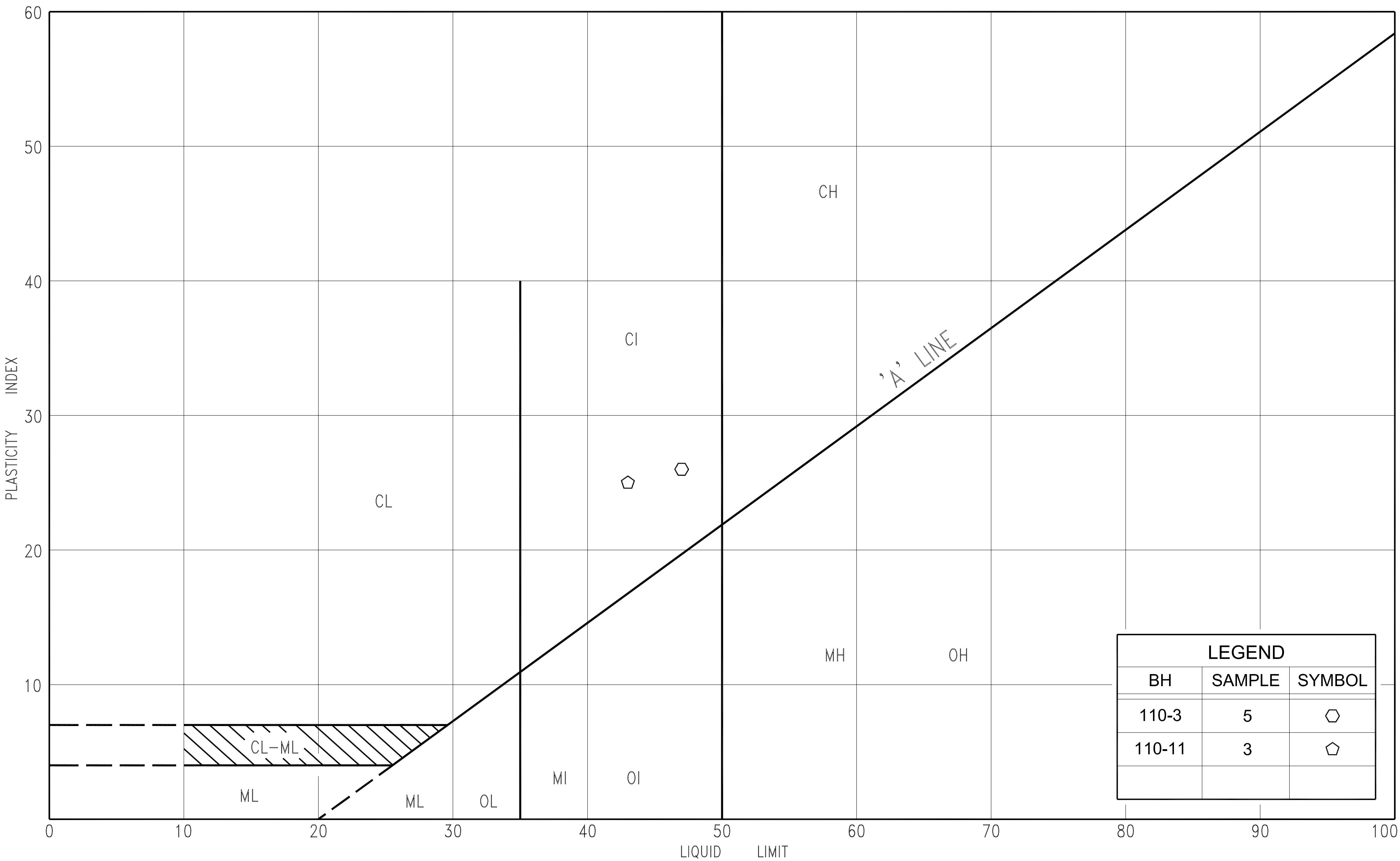
LEGEND		
BH	SAMPLE	SYMBOL
110-3	3	⬡
110-8	2	⬠

Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	110-PC-1
HWY:	69
G.W.P. No.	5112-07-00



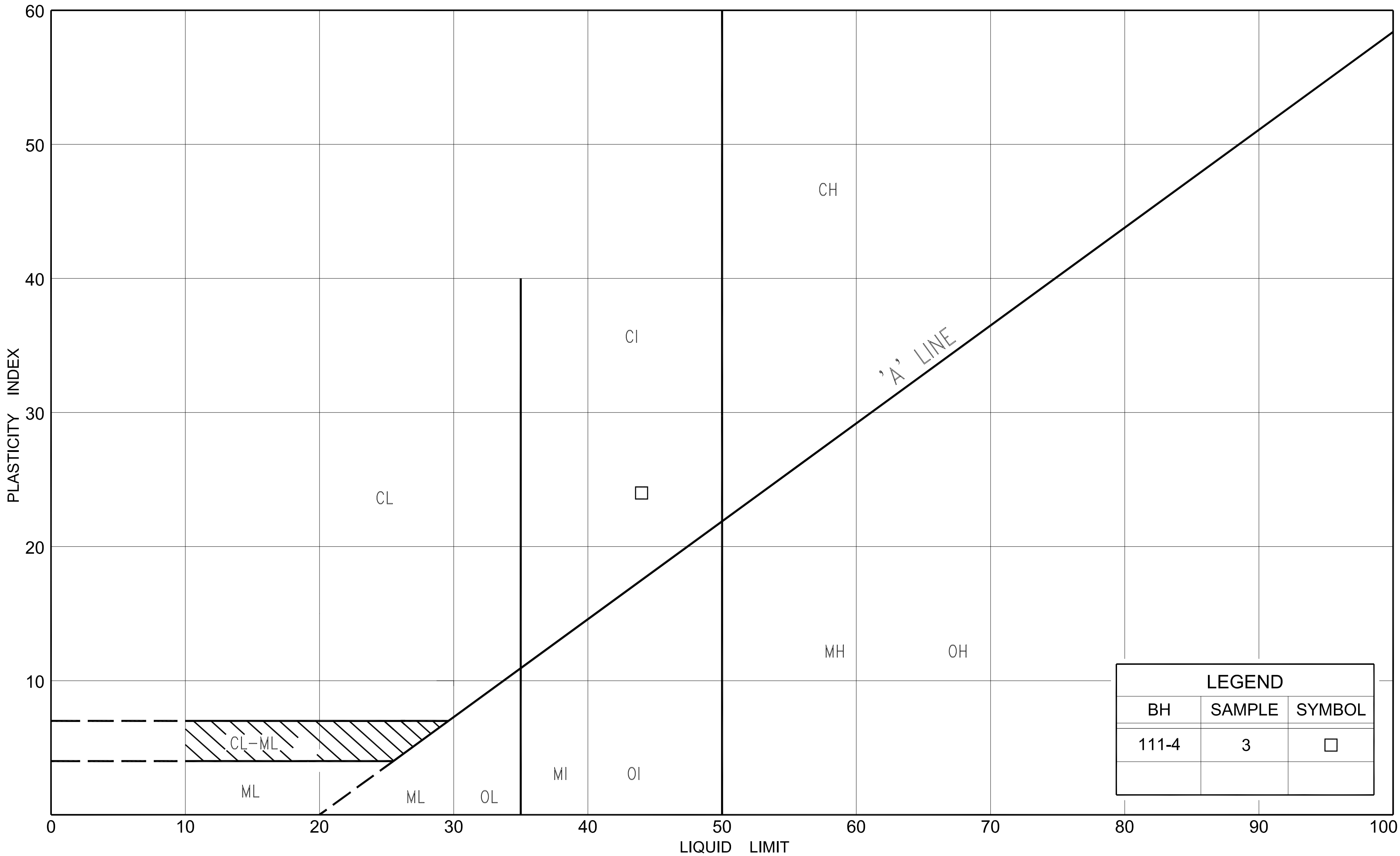
LEGEND		
BH	SAMPLE	SYMBOL
110-3	5	⬡
110-11	3	⬠

Ontario

PLASTICITY CHART

SILTY CLAY, trace sand

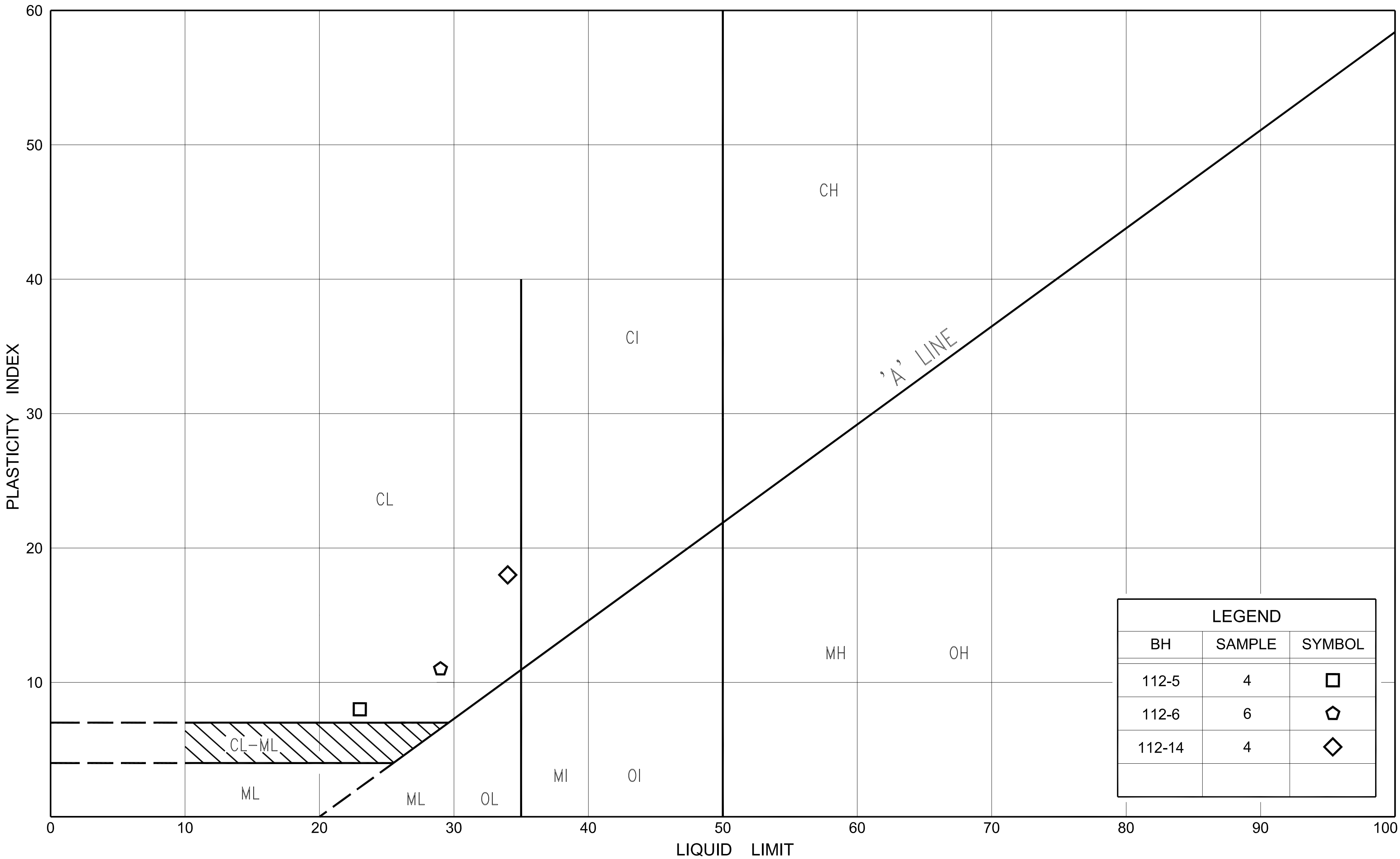
FIG No.	110-PC-2
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

BH	SAMPLE	SYMBOL
111-4	3	□

Ontario	PLASTICITY CHART SILTY CLAY, trace sand	FIG No. 111-PC-1 HWY: 69 G.W.P. No. 5112-07-00



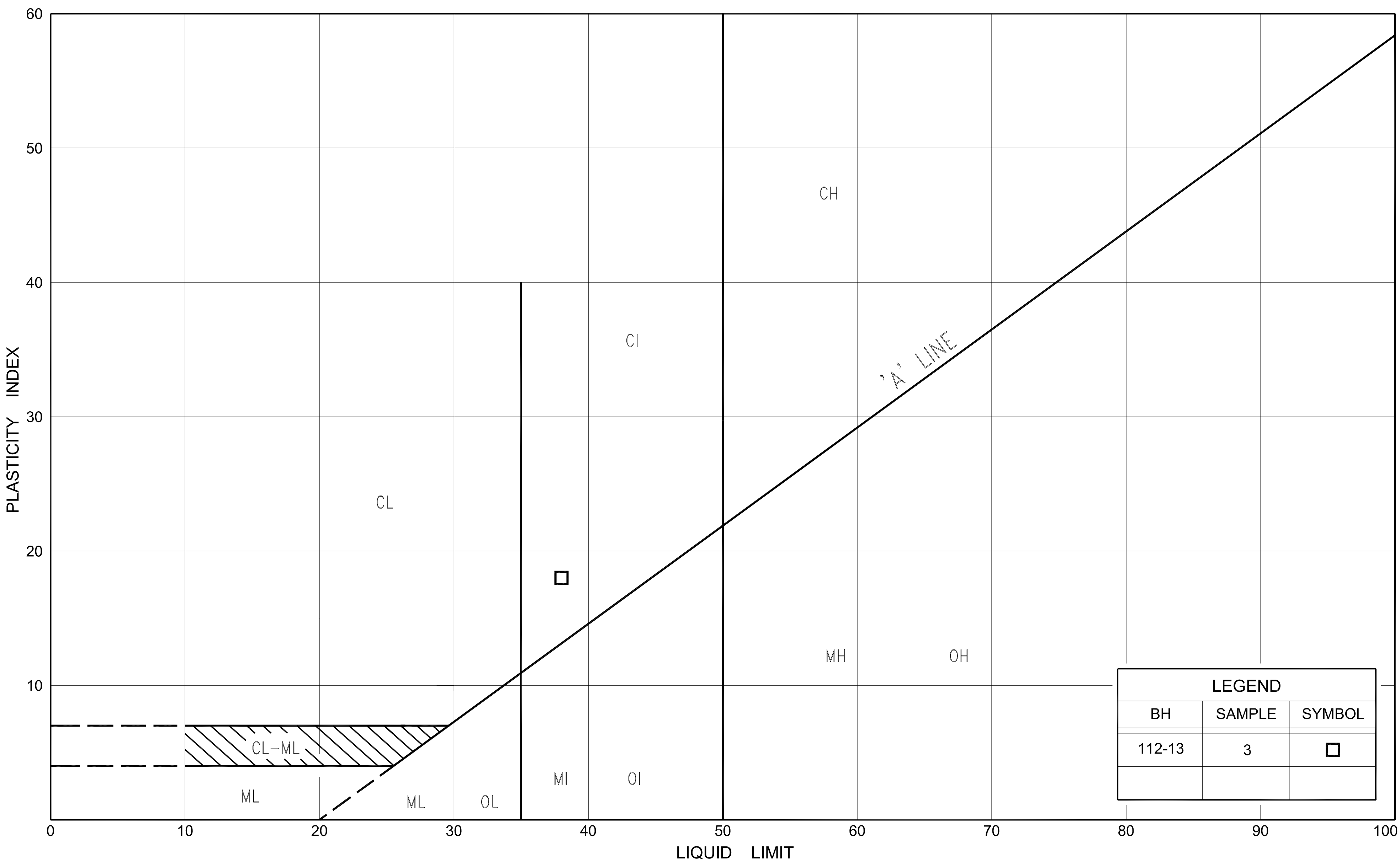
LEGEND		
BH	SAMPLE	SYMBOL
112-5	4	□
112-6	6	⬠
112-14	4	◇

Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand to sandy

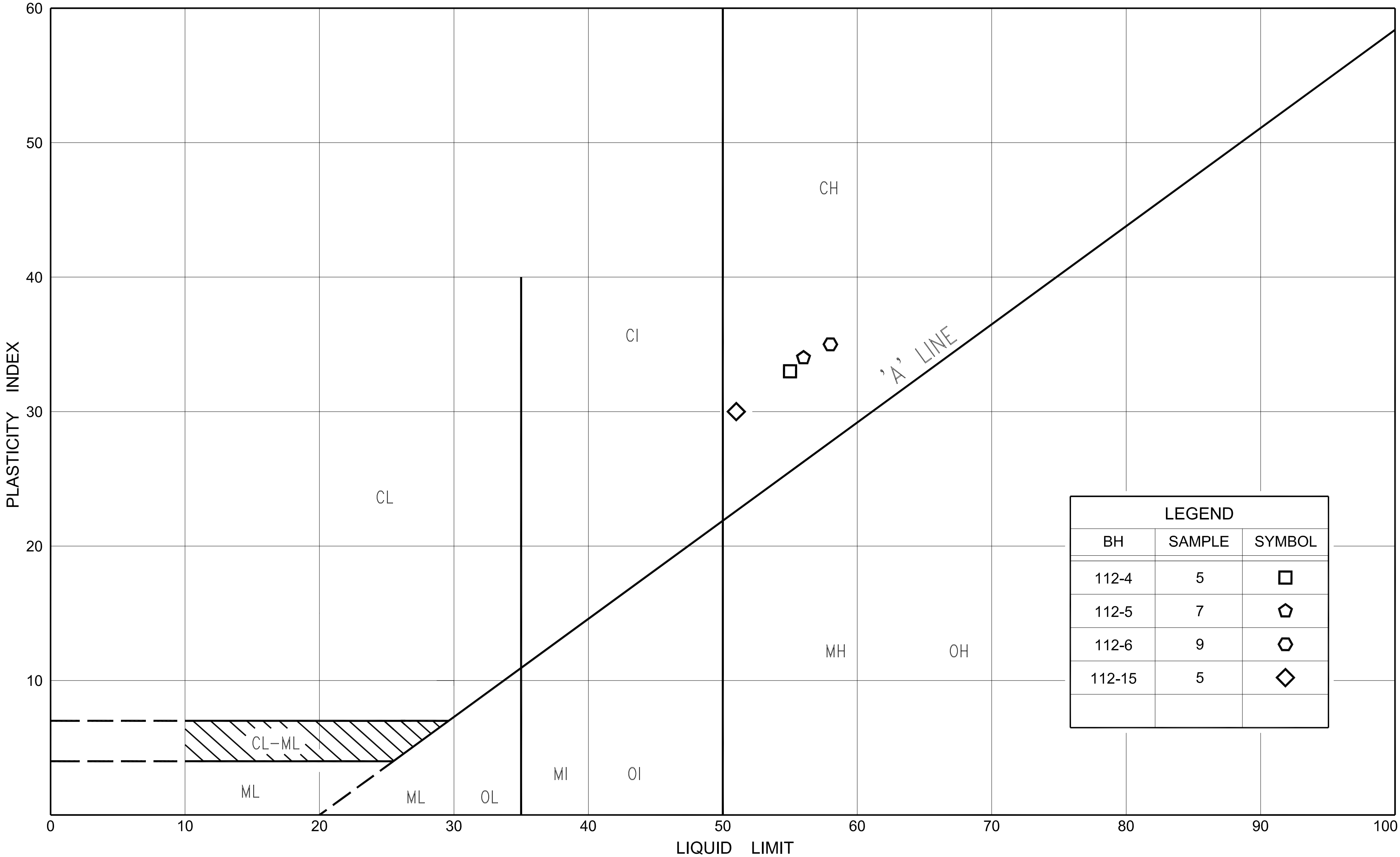
FIG No.	112-PC-1
HWY:	69
G.W.P. No.	5112-07-00



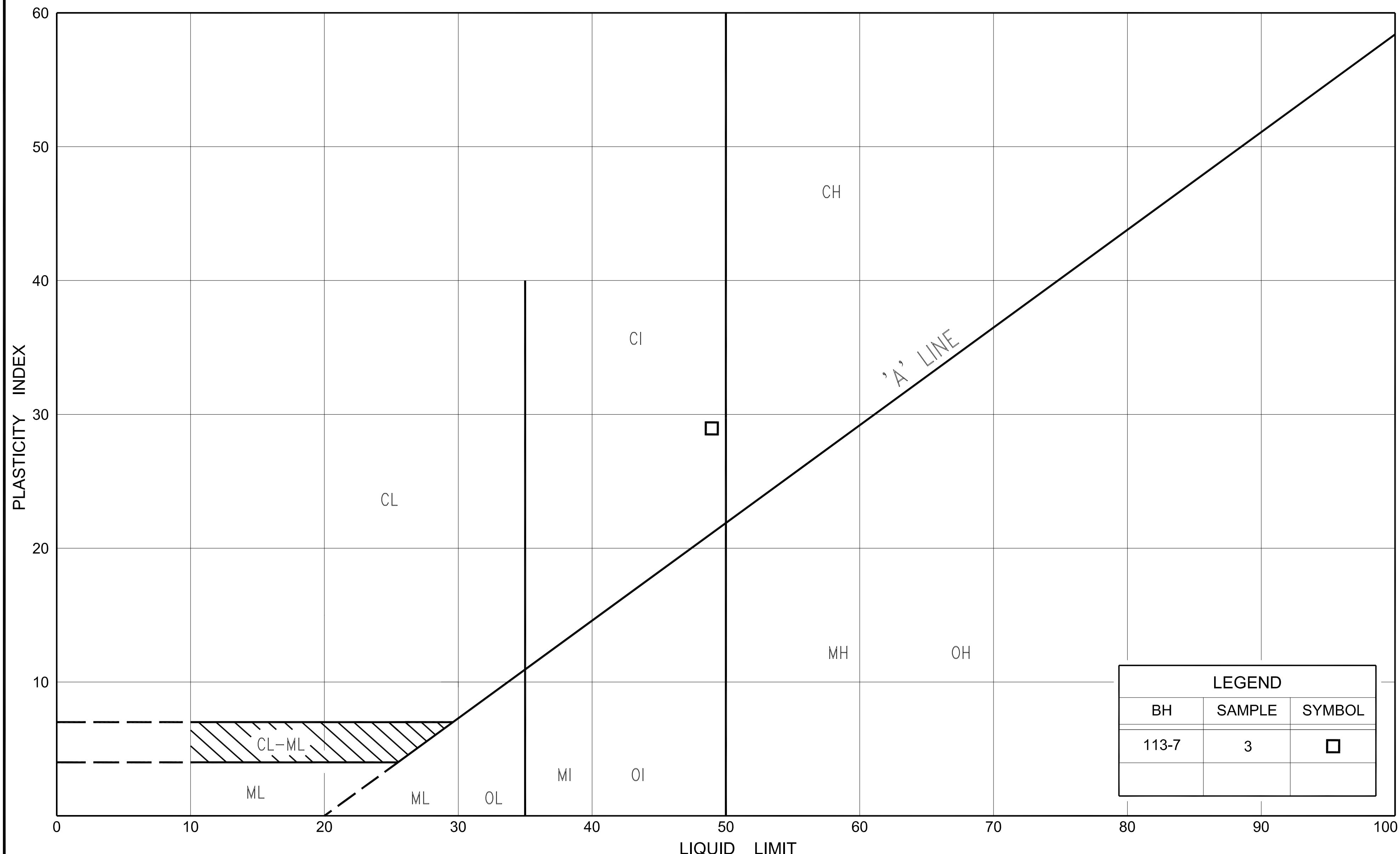
PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	112-PC-2
HWY:	69
G.W.P. No.	5112-07-00



Ontario	PLASTICITY CHART CLAY, trace sand	FIG No. 112-PC-3 HWY: 69 G.W.P. No. 5112-07-00



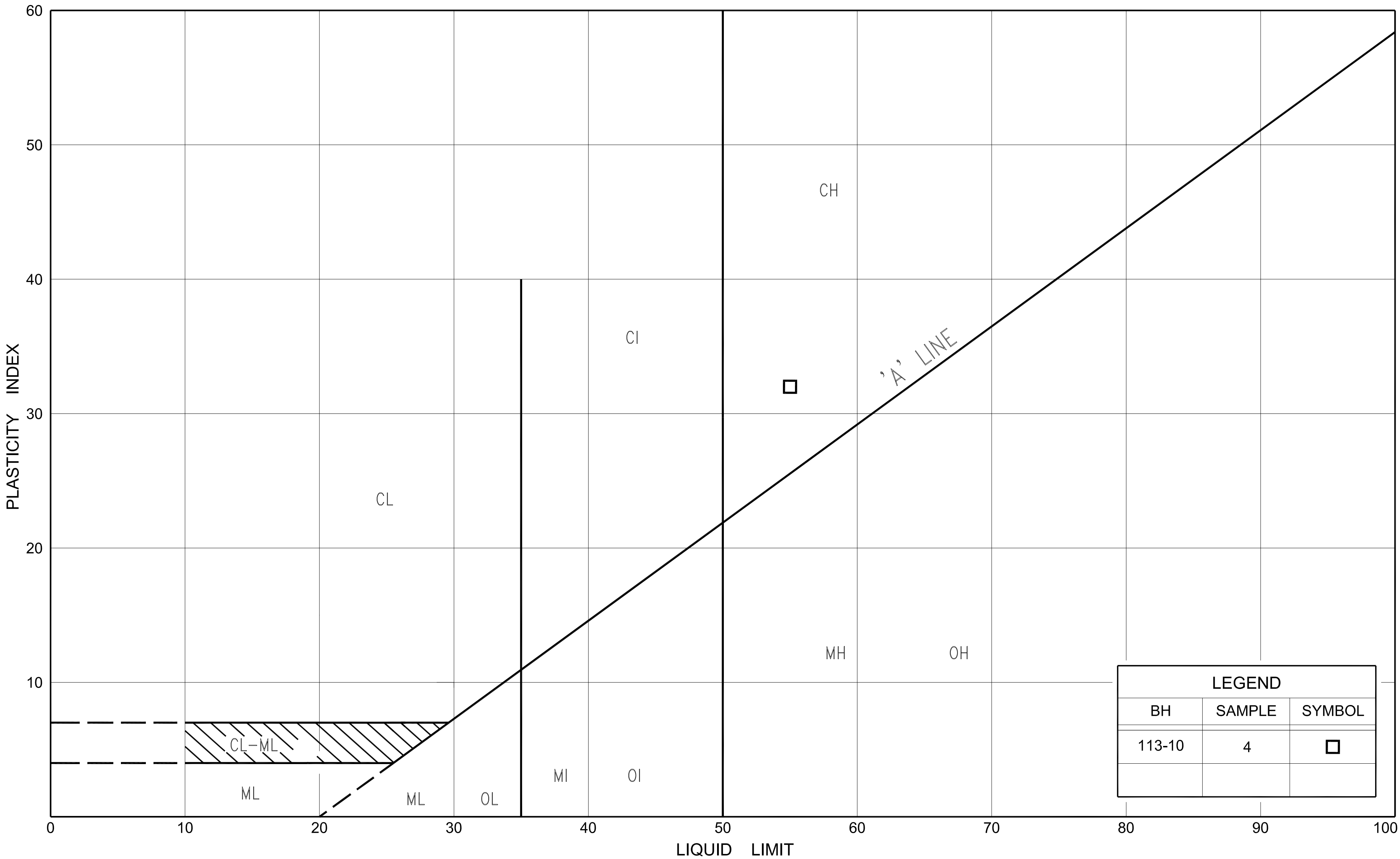
LEGEND		
BH	SAMPLE	SYMBOL
113-7	3	□

PLASTICITY CHART

SILTY CLAY, trace sand, trace gravel

FIG No.	113-PC-1
HWY:	69
G.W.P. No.	5112-07-00

Ontario



LEGEND

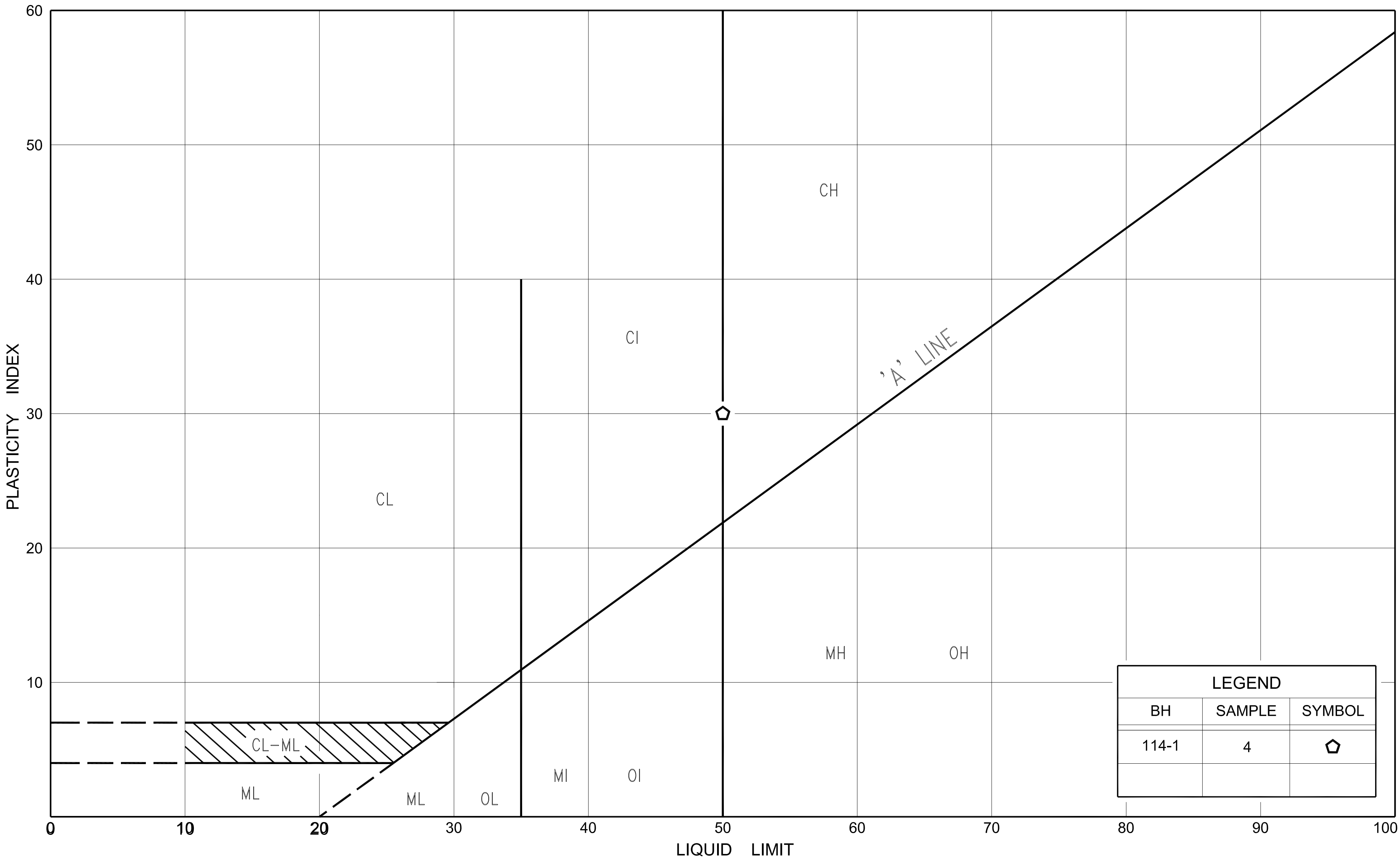
BH	SAMPLE	SYMBOL
113-10	4	□

PLASTICITY CHART

CLAY, trace sand

FIG No.	113-PC-2
HWY:	69
G.W.P. No.	5112-07-00

Ontario

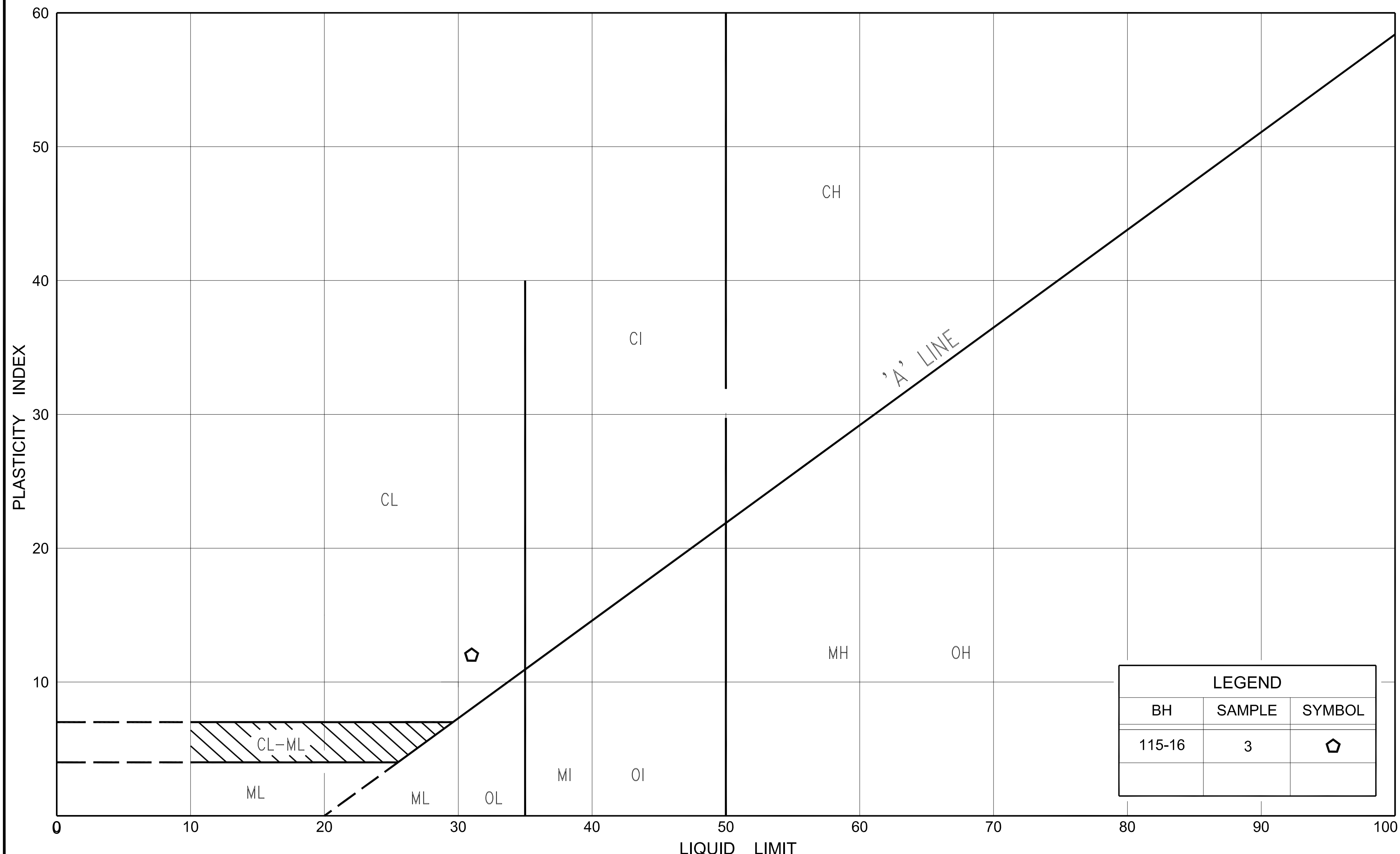


Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	114-PC-1
HWY:	69
G.W.P. No.	5112-07-00

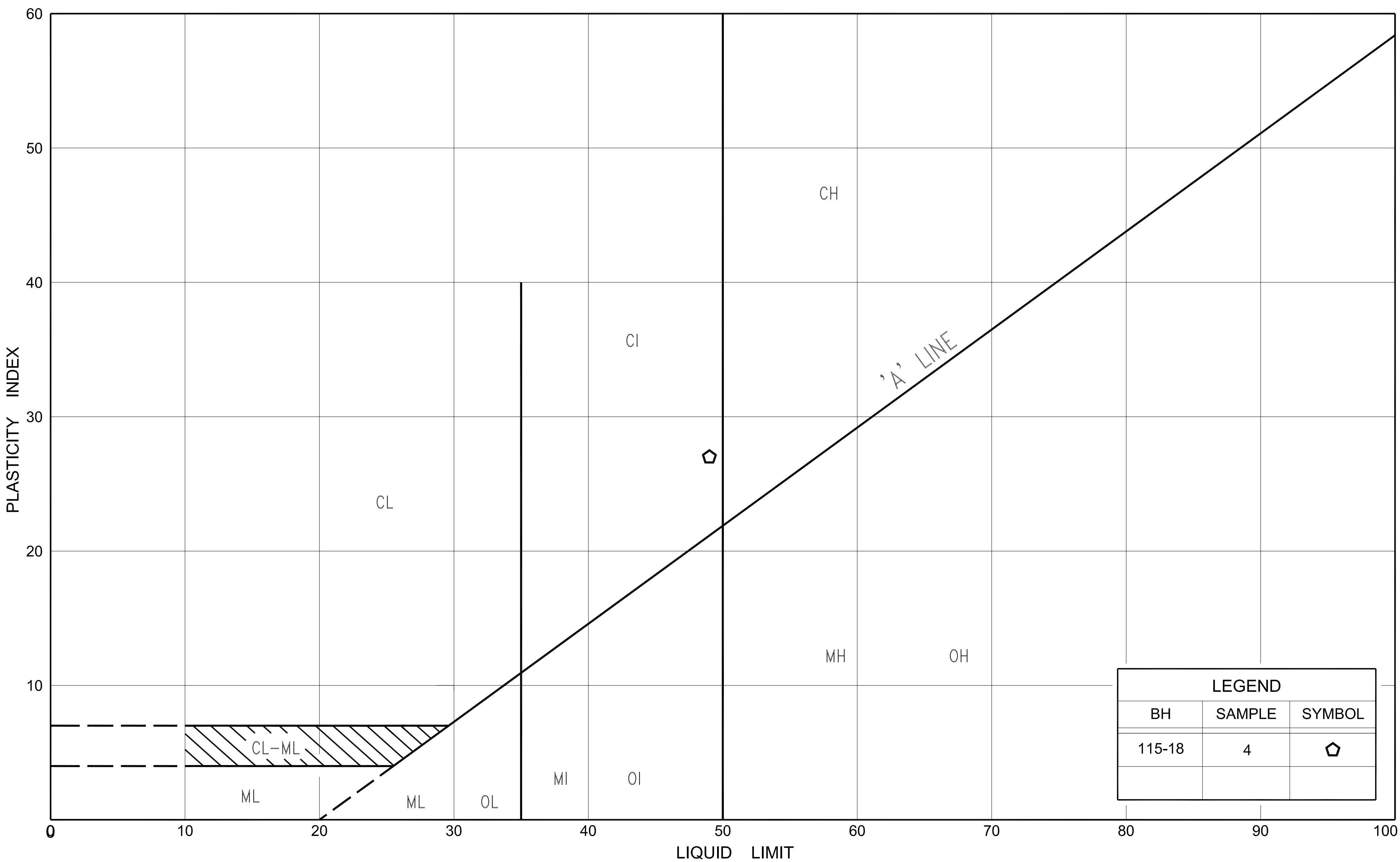


PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	115-PC-1
HWY:	69
G.W.P. No.	5112-07-00

Ontario



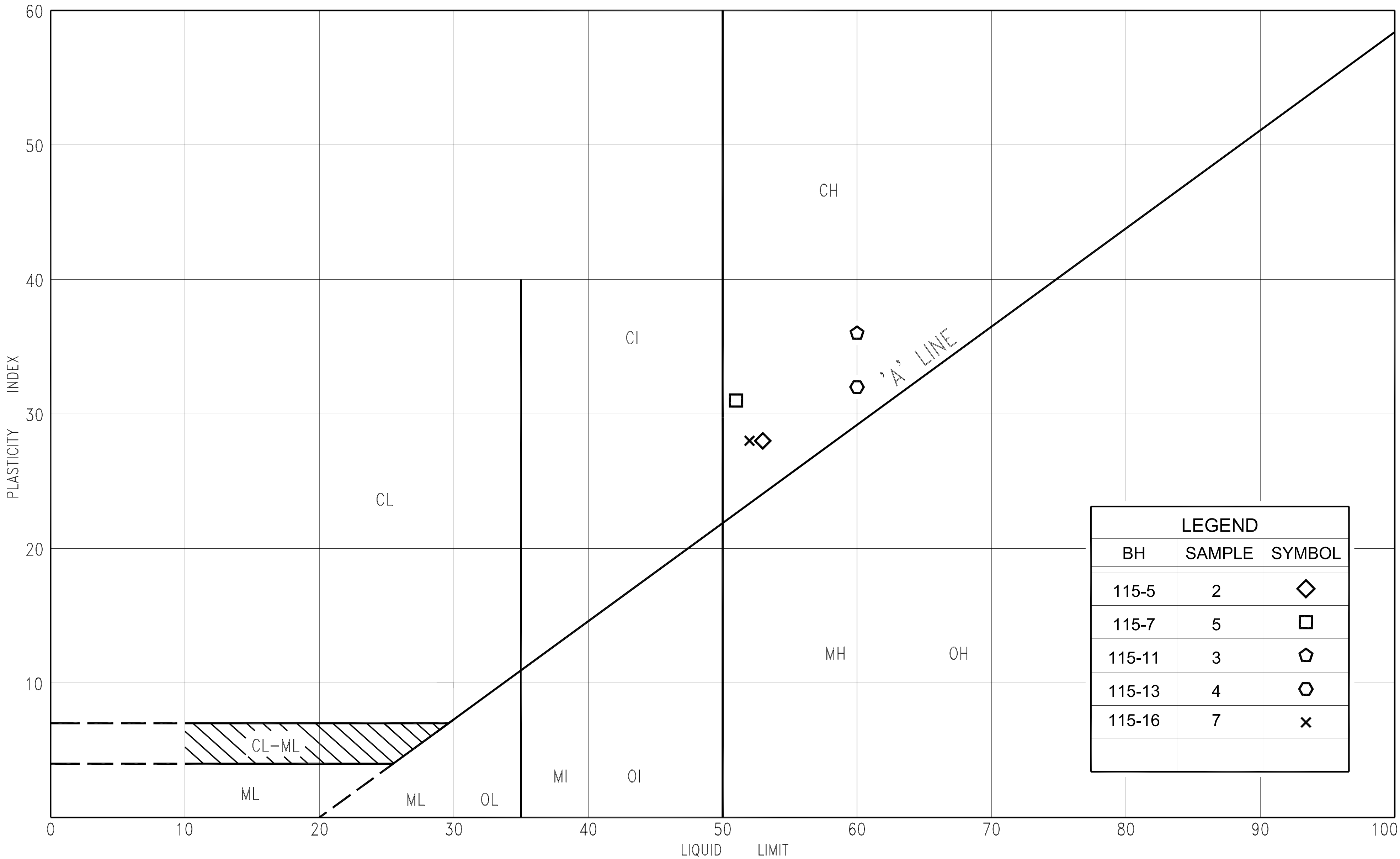
LEGEND

BH	SAMPLE	SYMBOL
115-18	4	⬠

PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	115-PC-2
HWY:	69
G.W.P. No.	5112-07-00

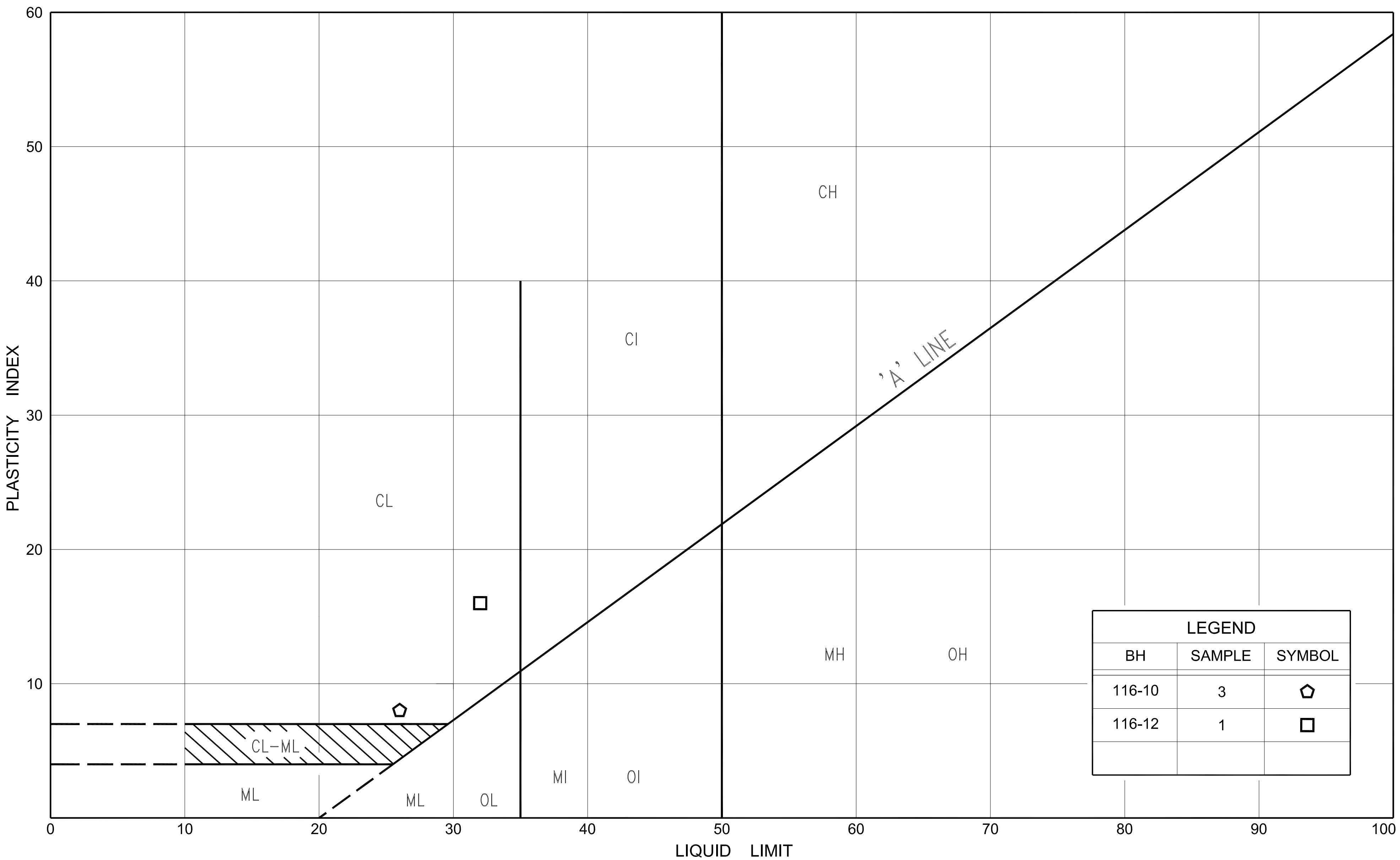


Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	115-PC-3
HWY:	69
G.W.P. No.	5112-07-00

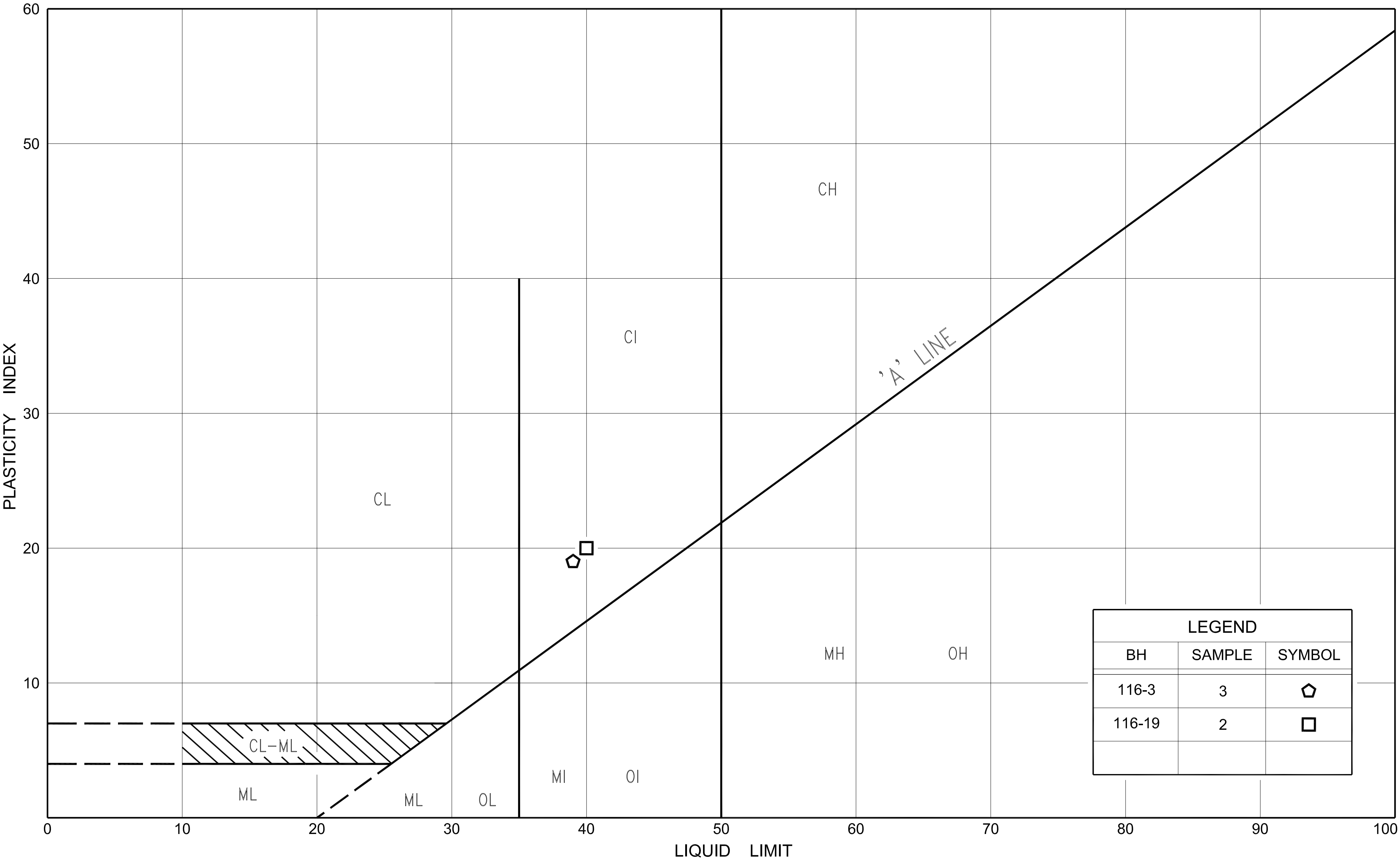


Ontario

PLASTICITY CHART

CLAYEY SILT, trace to some sand

FIG No.	116-PC-1
HWY:	69
G.W.P. No.	5112-07-00



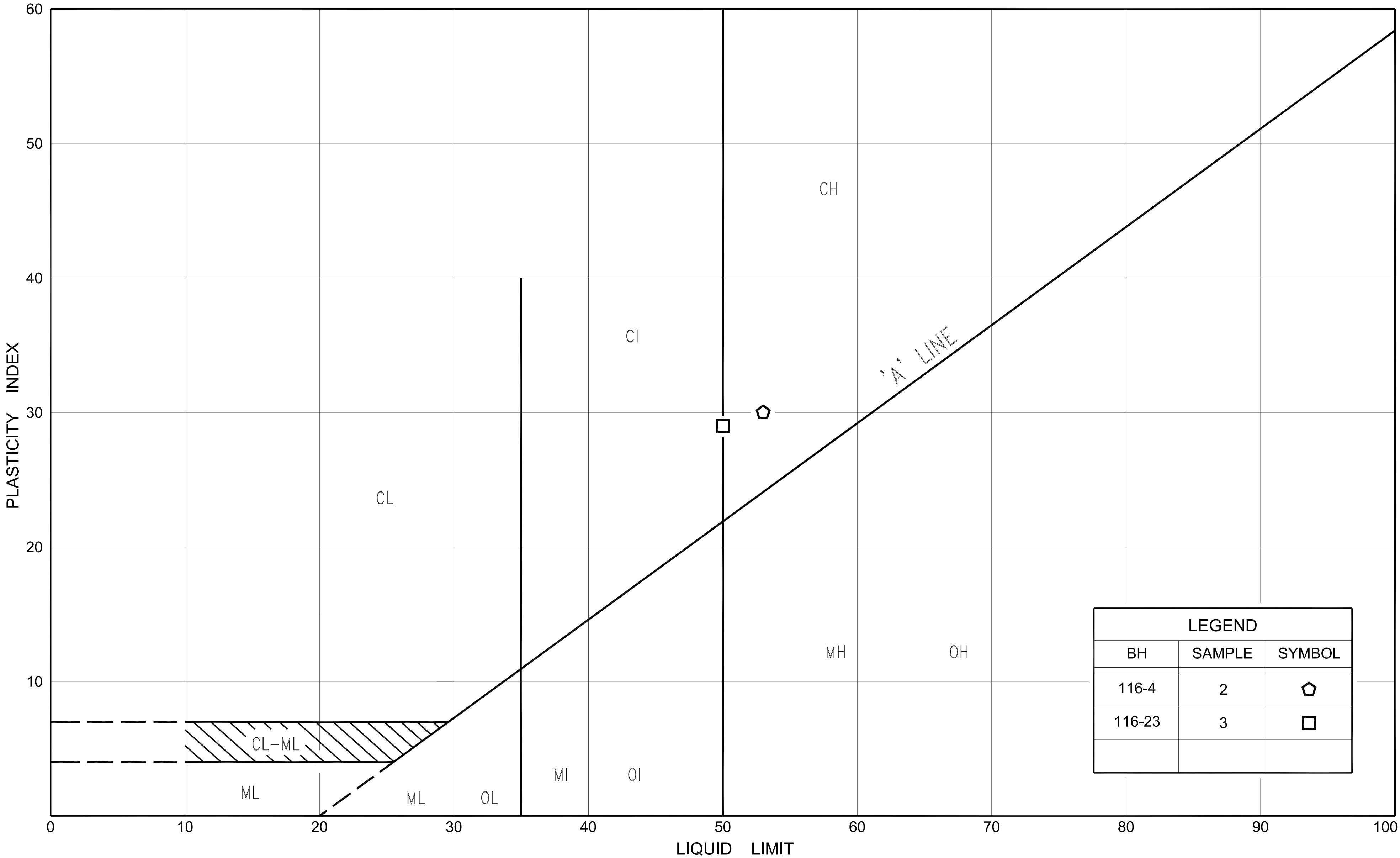
LEGEND		
BH	SAMPLE	SYMBOL
116-3	3	⬠
116-19	2	□

PLASTICITY CHART

SILTY CLAY, trace to some sand, trace to some gravel

Ontario

FIG No.	116-PC-2
HWY:	69
G.W.P. No.	5112-07-00



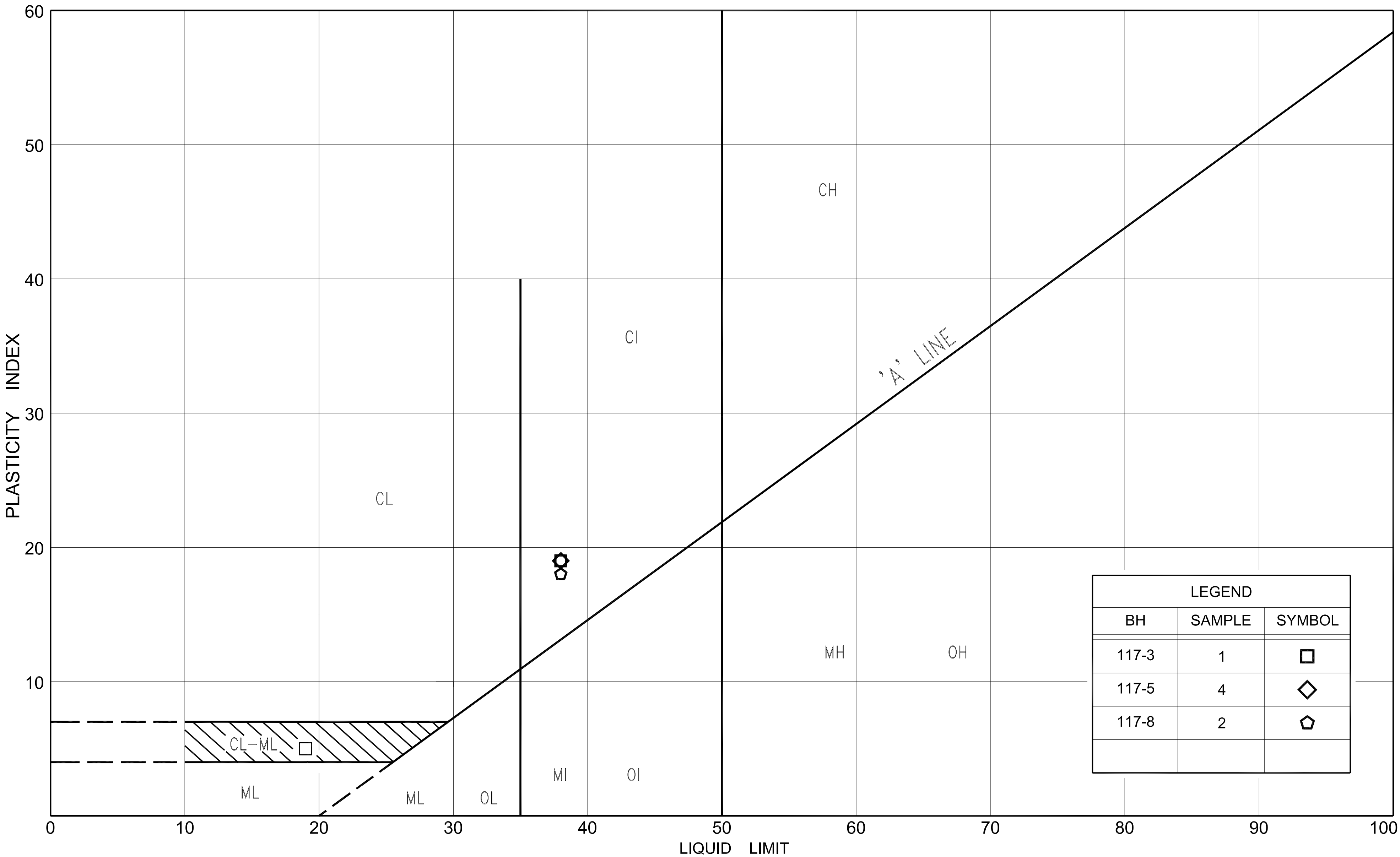
LEGEND		
BH	SAMPLE	SYMBOL
116-4	2	⬠
116-23	3	□

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	116-PC-3
HWY:	69
G.W.P. No.	5112-07-00

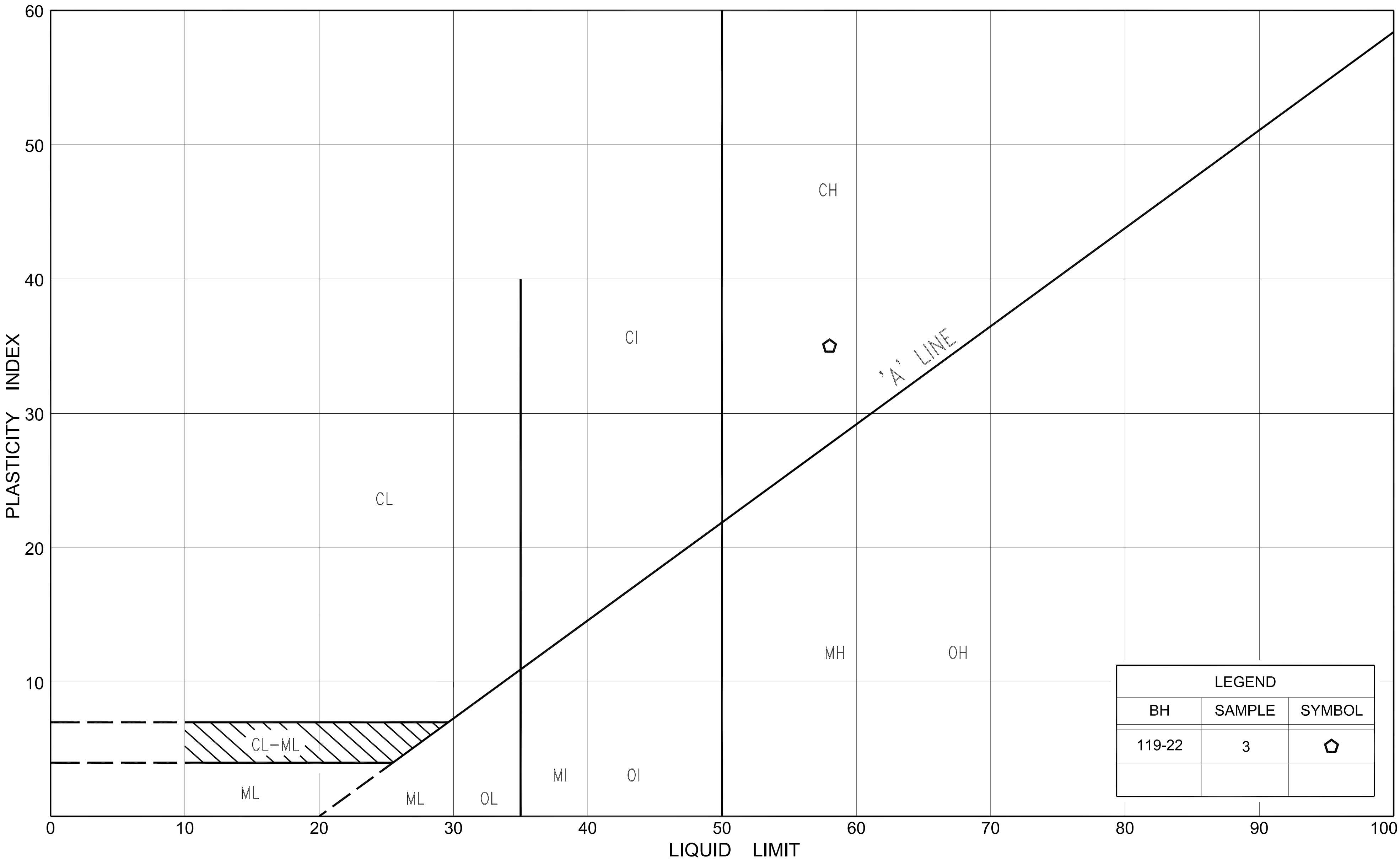


Ontario

PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	117-PC-1
HWY:	69
G.W.P. No.	5112-07-00

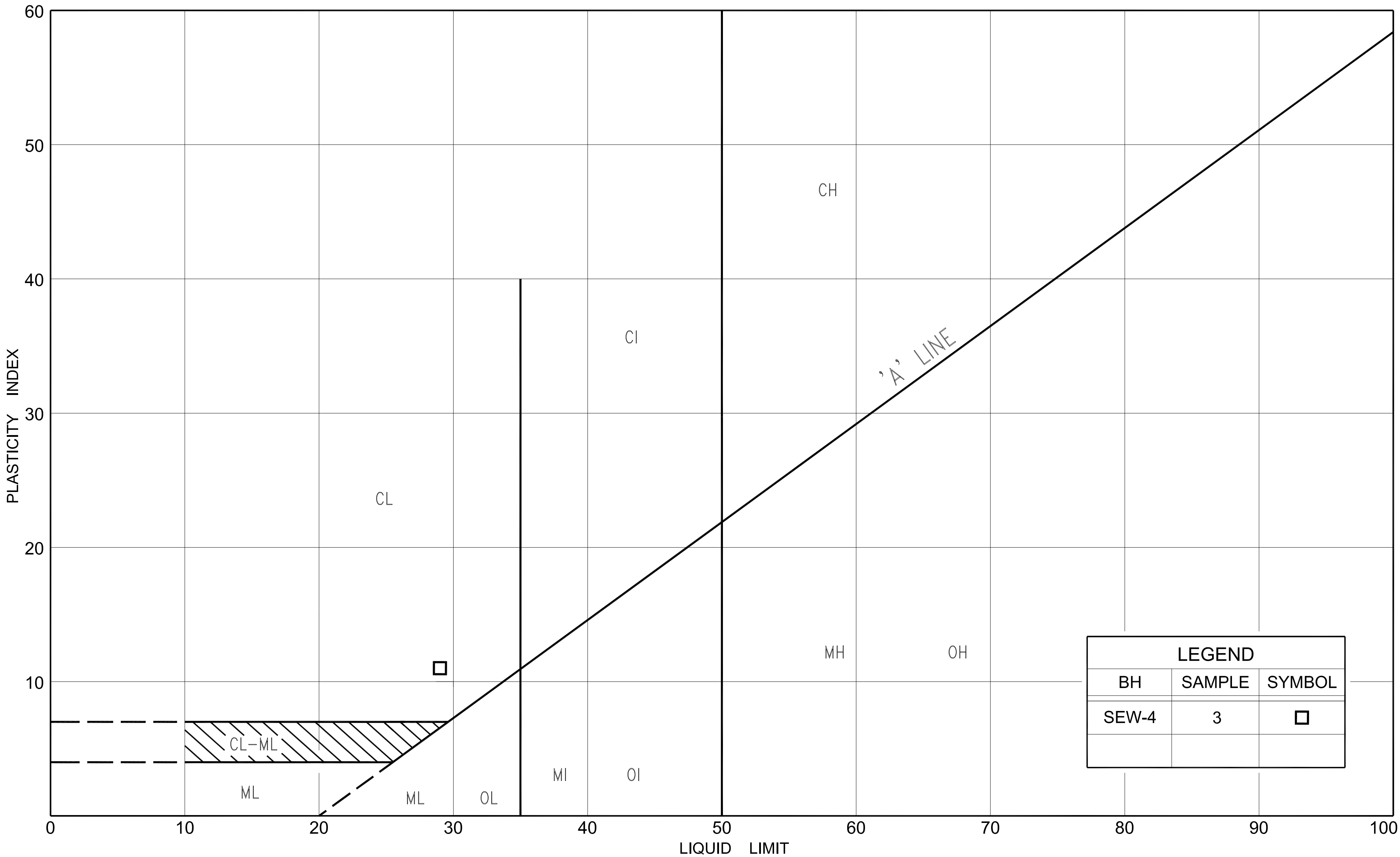


Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	119-PC-1
HWY:	69
G.W.P. No.	5112-07-00



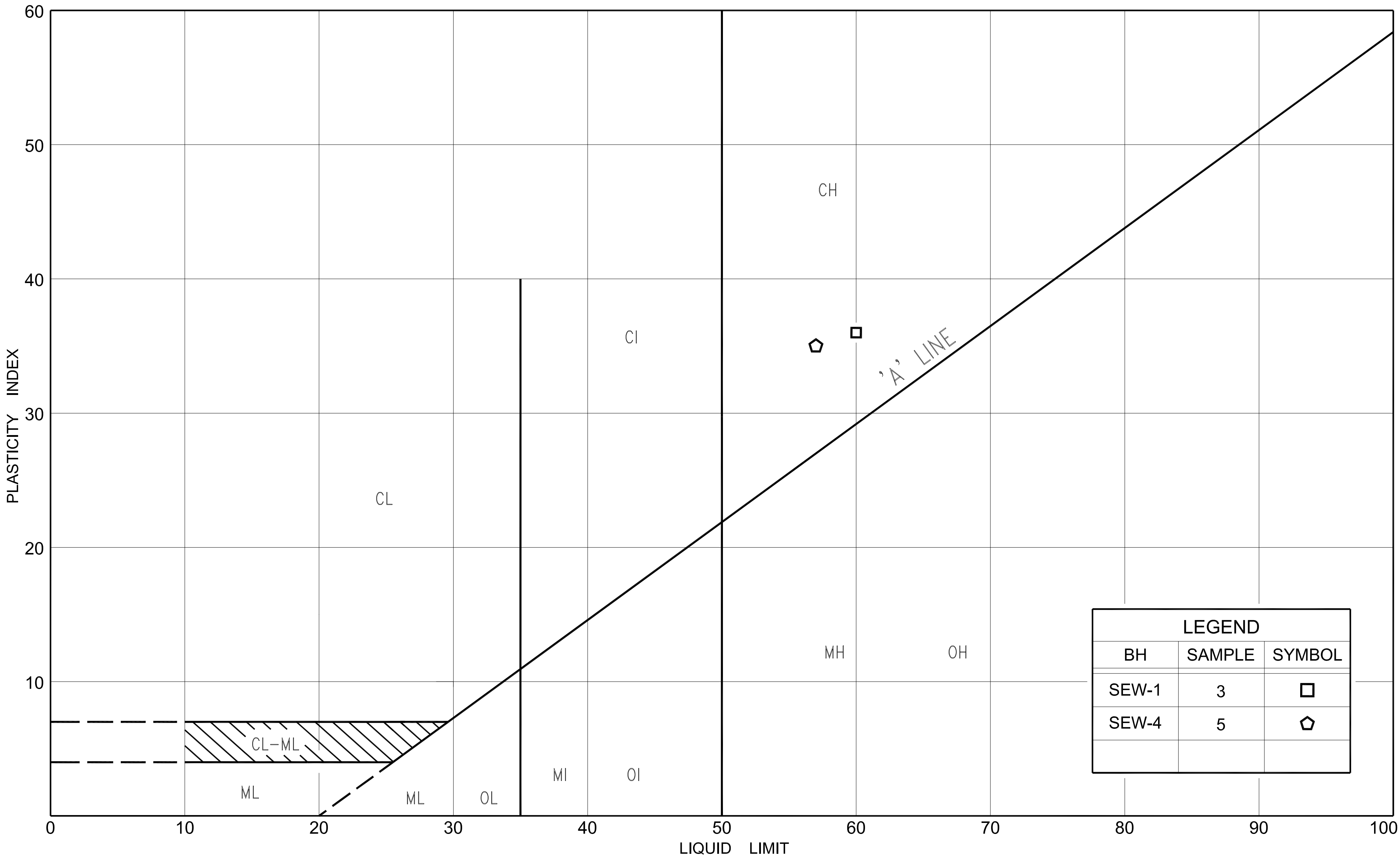
LEGEND		
BH	SAMPLE	SYMBOL
SEW-4	3	□

Ontario

PLASTICITY CHART

CLAYEY SILT, trace sand

FIG No.	SEW-PC-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

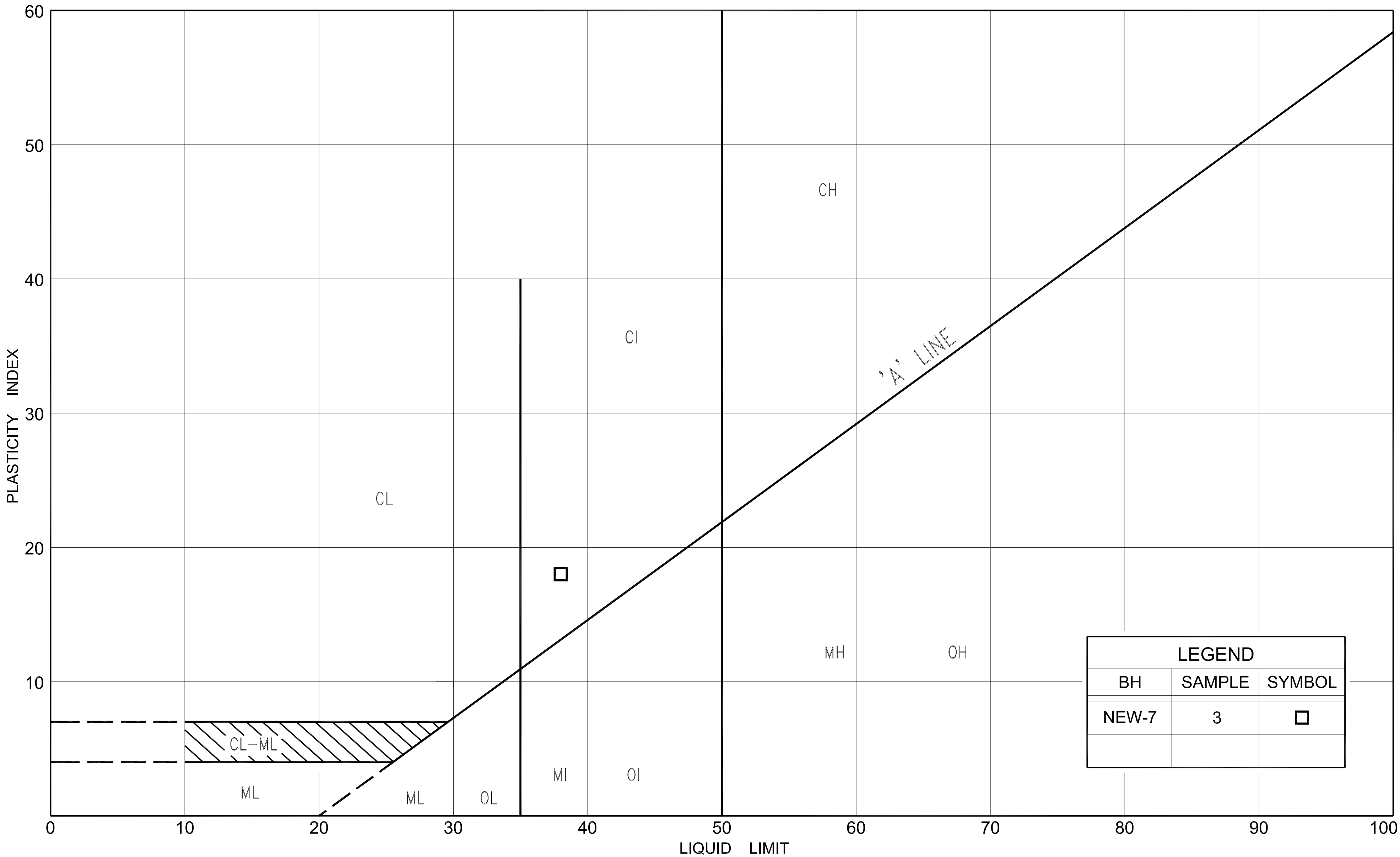
BH	SAMPLE	SYMBOL
SEW-1	3	□
SEW-4	5	⬠

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	SEW-PC-2
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

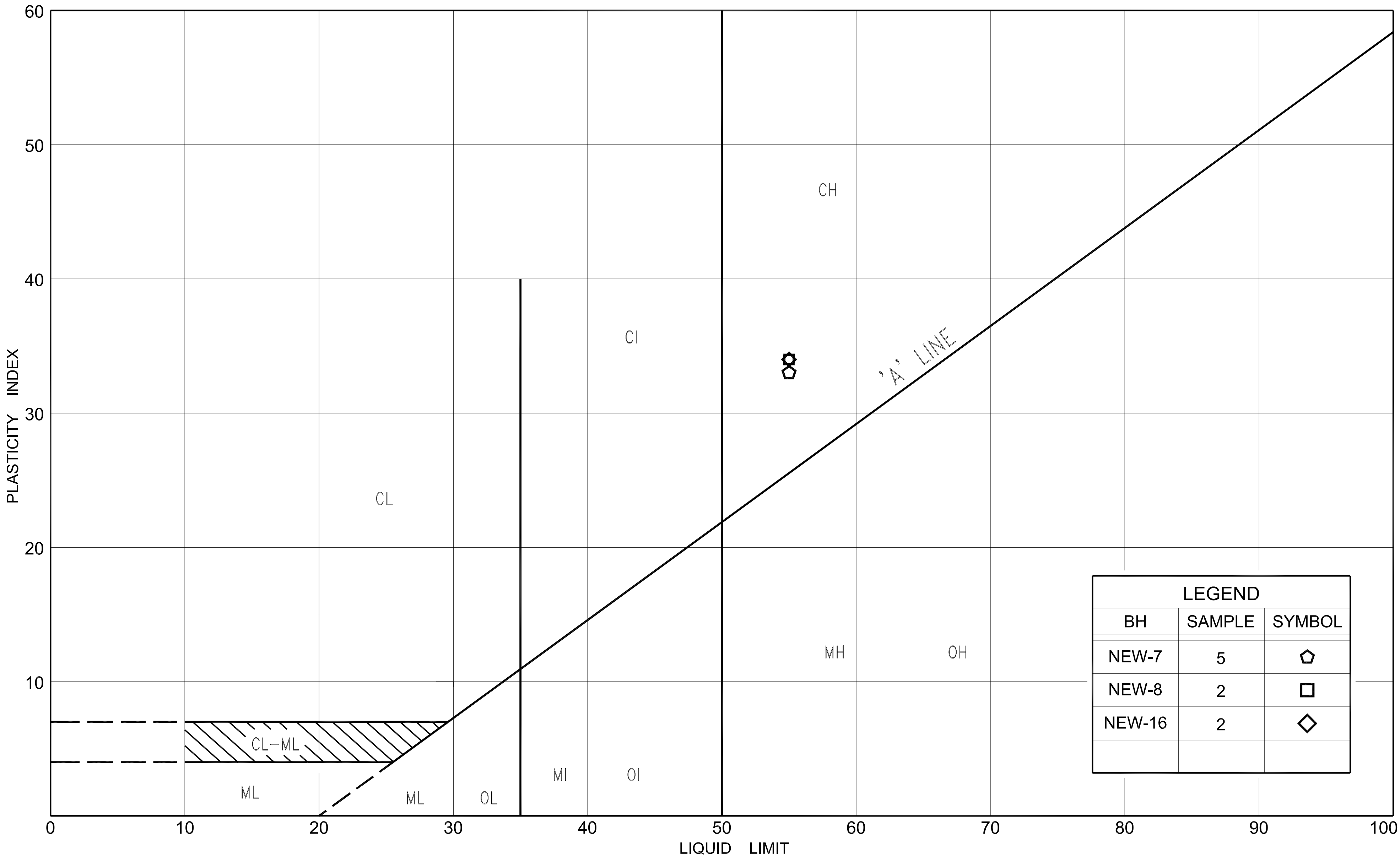
BH	SAMPLE	SYMBOL
NEW-7	3	□

Ontario

PLASTICITY CHART

SILTY CLAY, trace sand

FIG No.	NEW-PC-1
HWY:	69
G.W.P. No.	5112-07-00



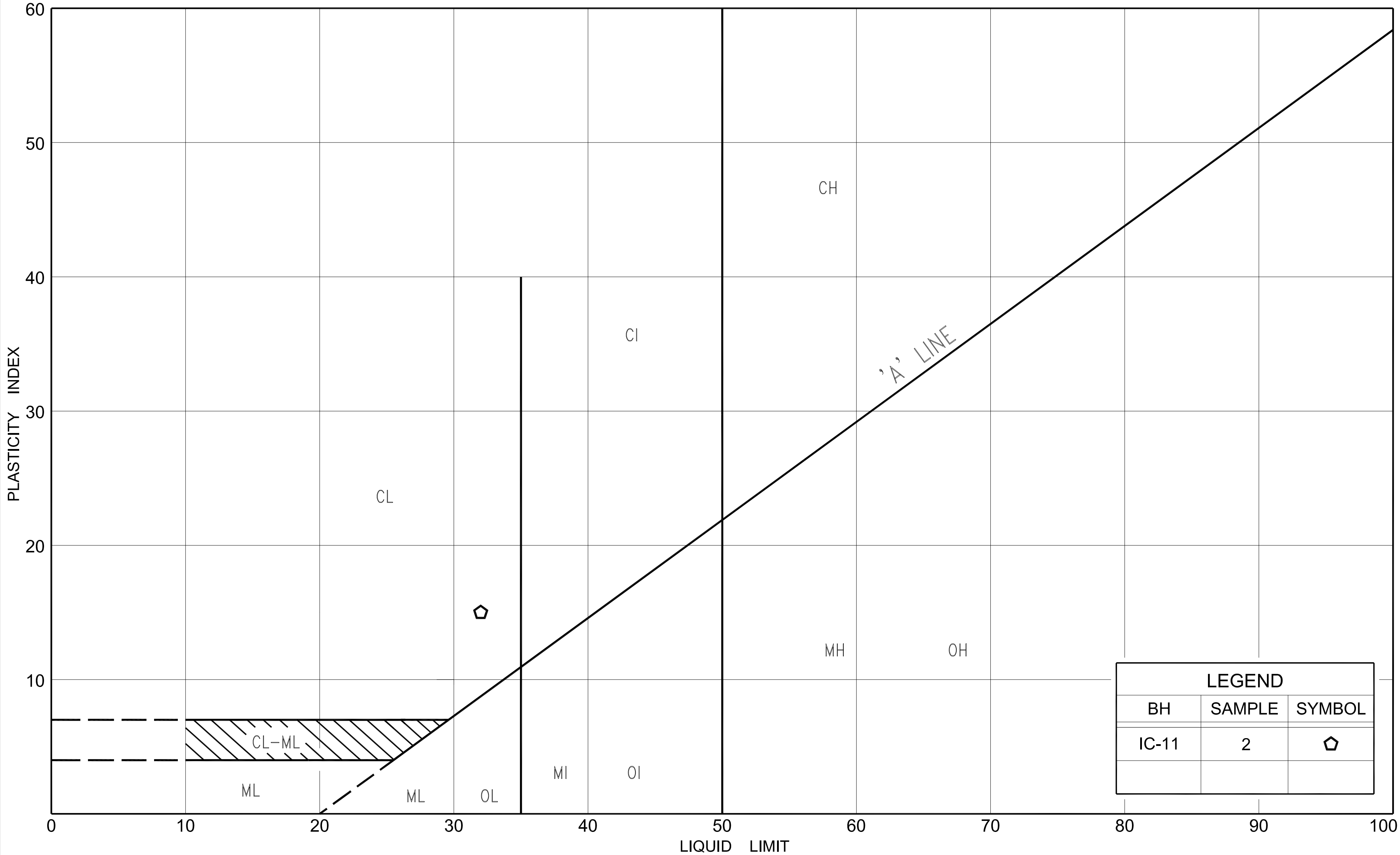
BH	SAMPLE	SYMBOL
NEW-7	5	⬠
NEW-8	2	□
NEW-16	2	◇

Ontario

PLASTICITY CHART

CLAY, trace sand

FIG No.	NEW-PC-2
HWY:	69
G.W.P. No.	5112-07-00



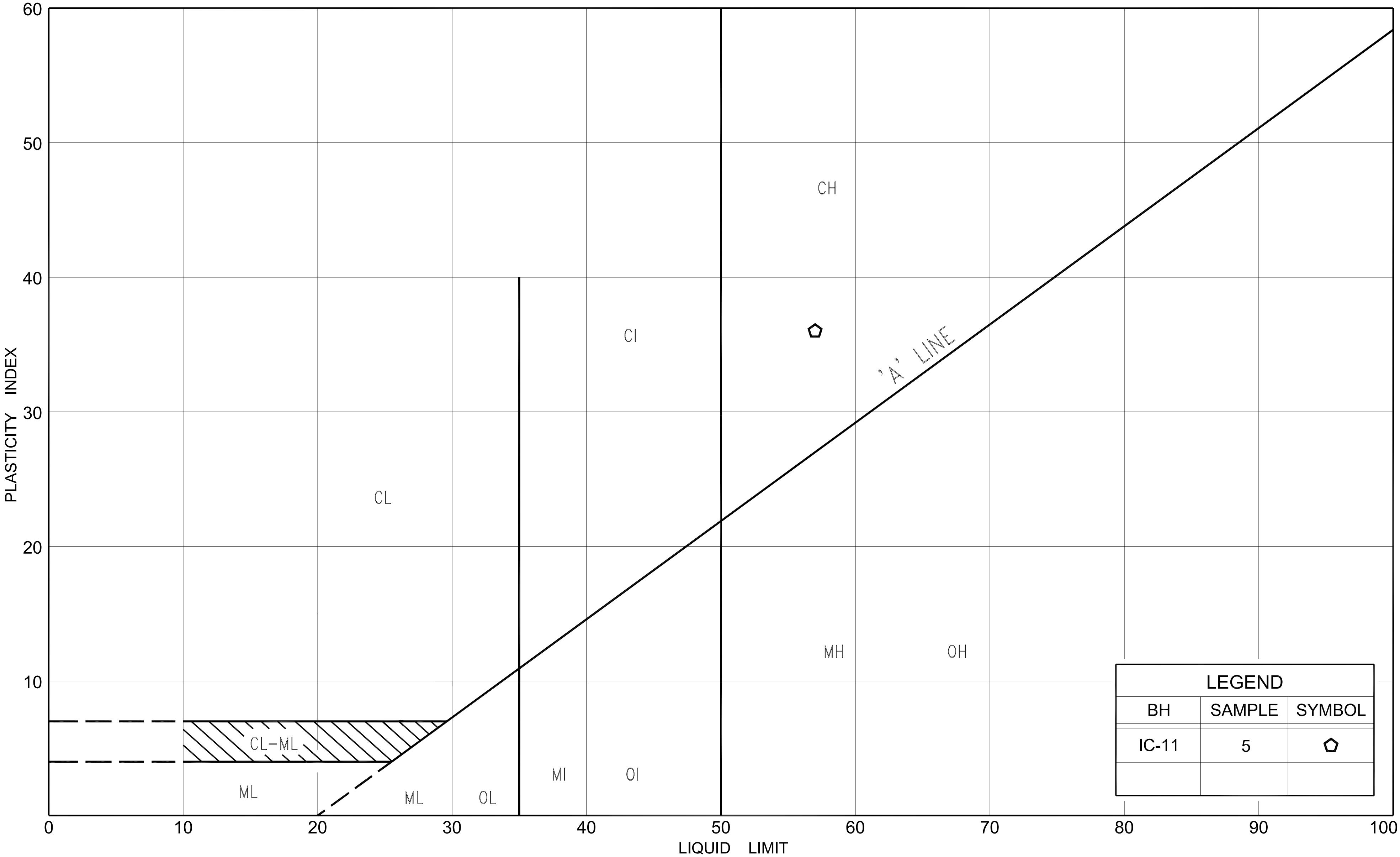
LEGEND

BH	SAMPLE	SYMBOL
IC-11	2	⬠

PLASTICITY CHART

CLAYEY SILT, some sand

FIG No.	IC-PC-1
HWY:	69
G.W.P. No.	5112-07-00



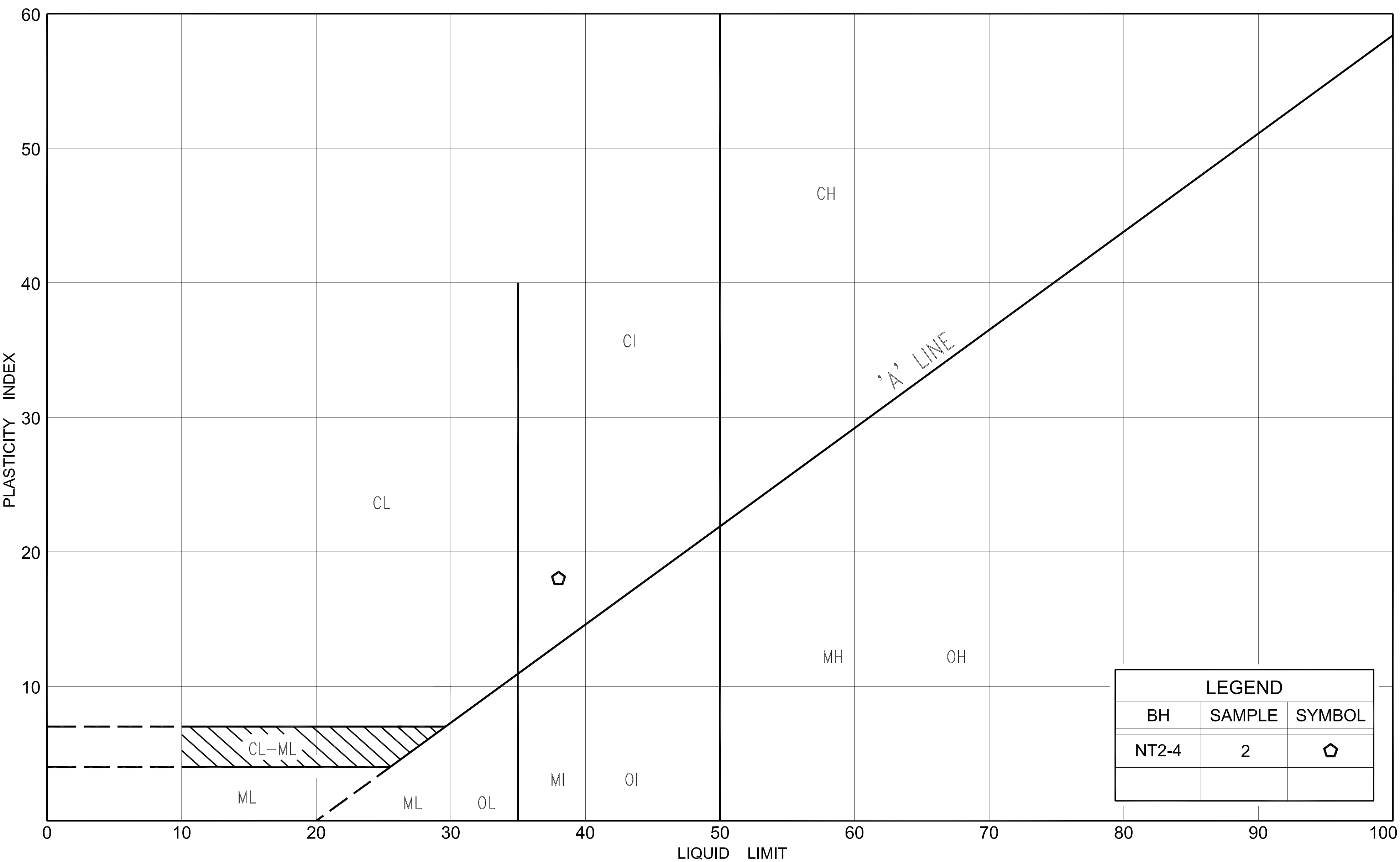
LEGEND		
BH	SAMPLE	SYMBOL
IC-11	5	⬠

Ontario

PLASTICITY CHART

SILTY CLAY, trace sand, trace gravel

FIG No.	IC PC-2
HWY:	69
G.W.P. No.	5112-07-00



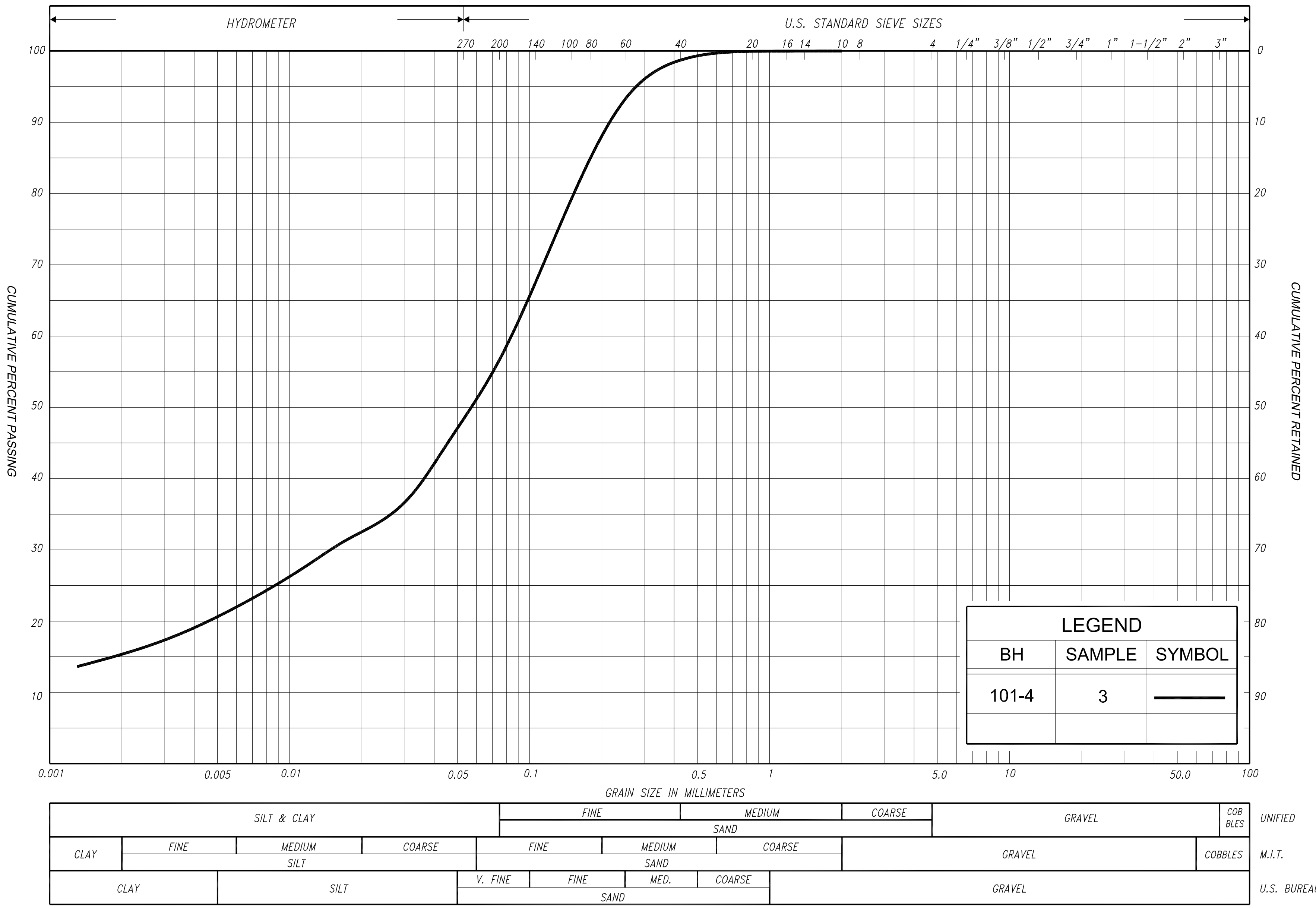
LEGEND

BH	SAMPLE	SYMBOL
NT2-4	2	⬠

PLASTICITY CHART

SILTY CLAY, trace sand, trace gravel

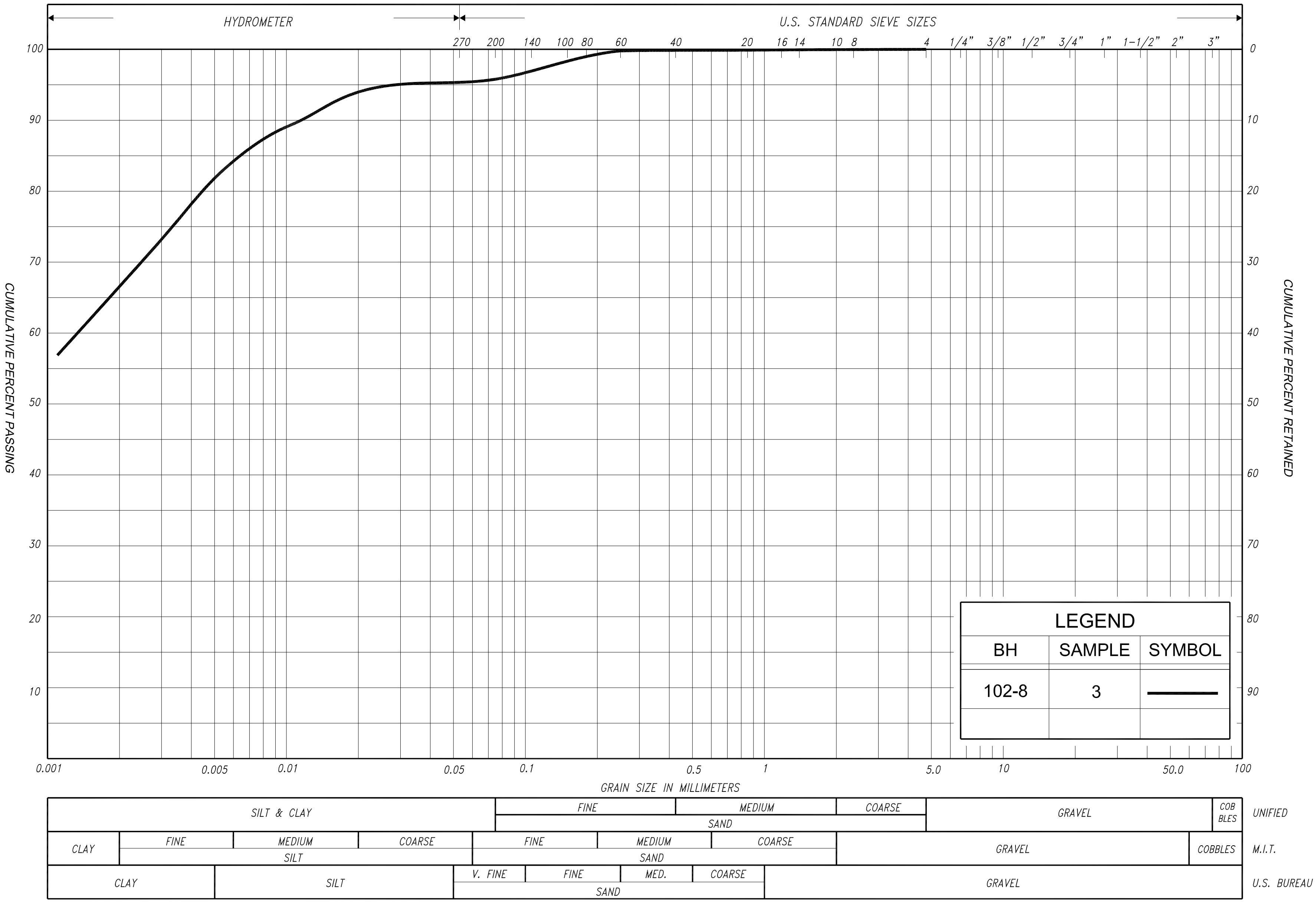
FIG No.	NT2-PC-1
HWY:	69
G.W.P. No.	5112-07-00



GRAIN SIZE DISTRIBUTION

CLAYEY SILT, sandy

FIG No.	101-GS-1
HWY:	69
G.W.P. No.	5112-07-00

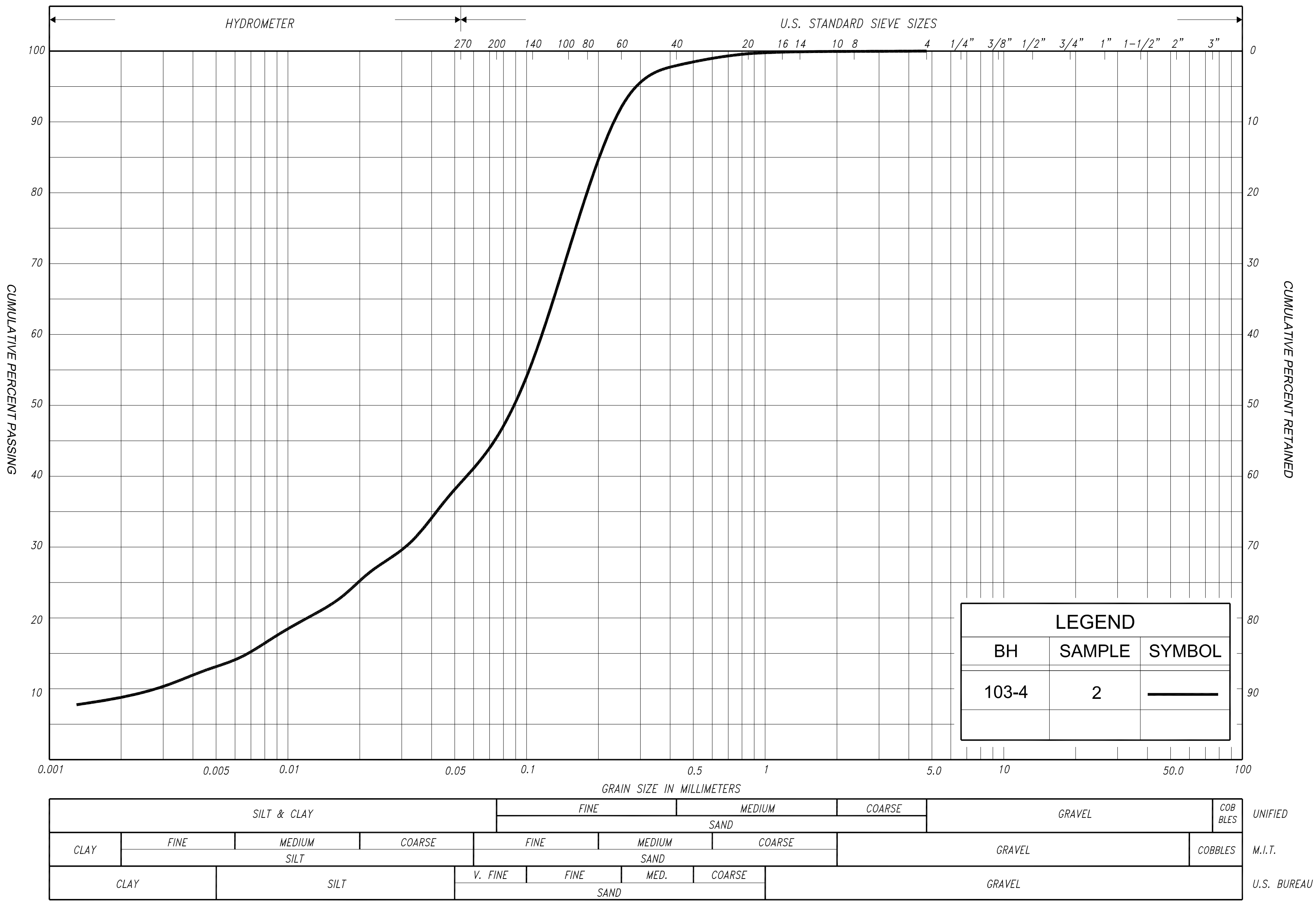


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	102-GS-1
HWY:	69
G.W.P. No.	5112-07-00

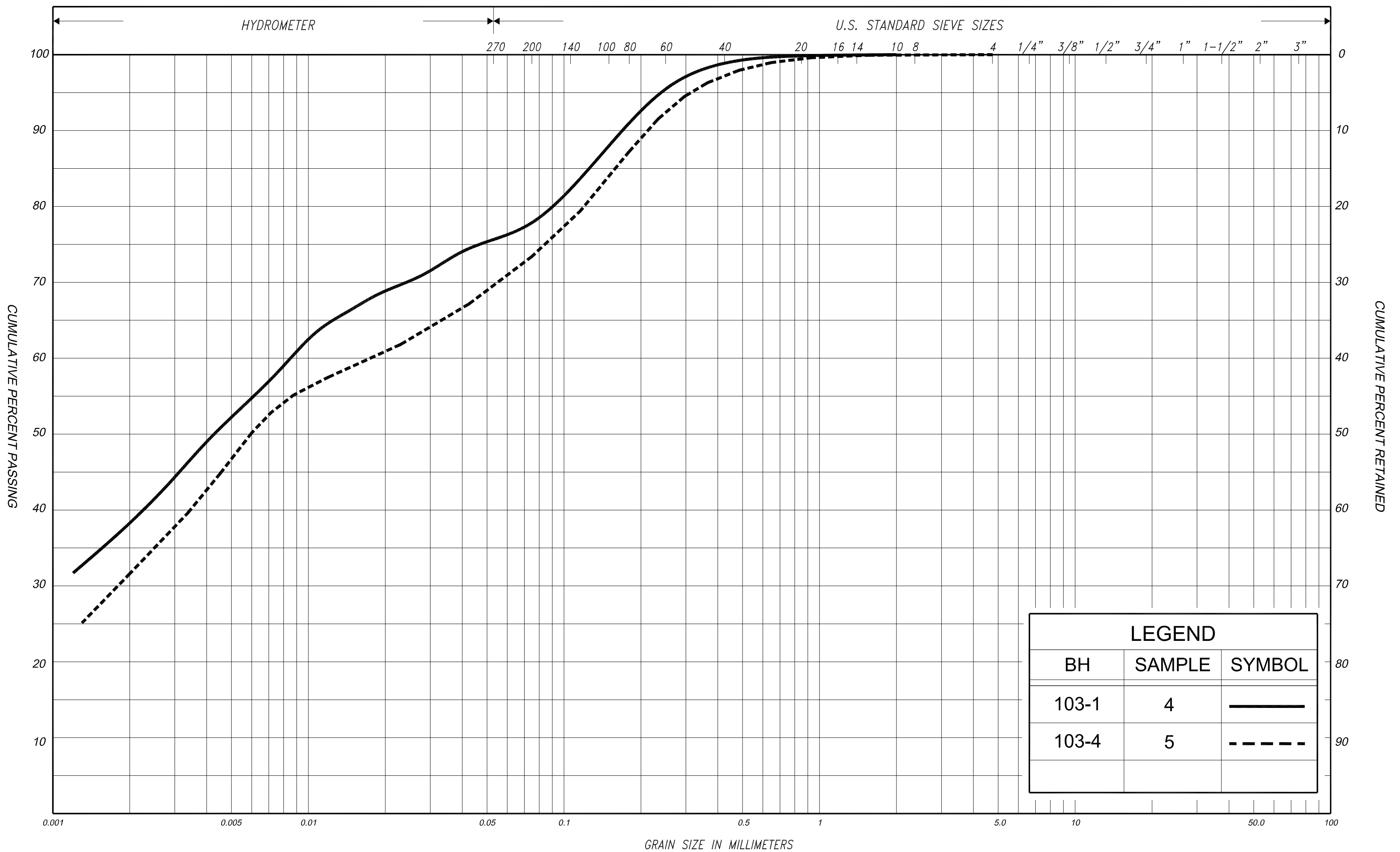


GRAIN SIZE DISTRIBUTION

ORGANIC SILTY SAND, trace clay

Ontario

FIG No.	103-GS-1
HWY:	69
G.W.P. No.	5112-07-00



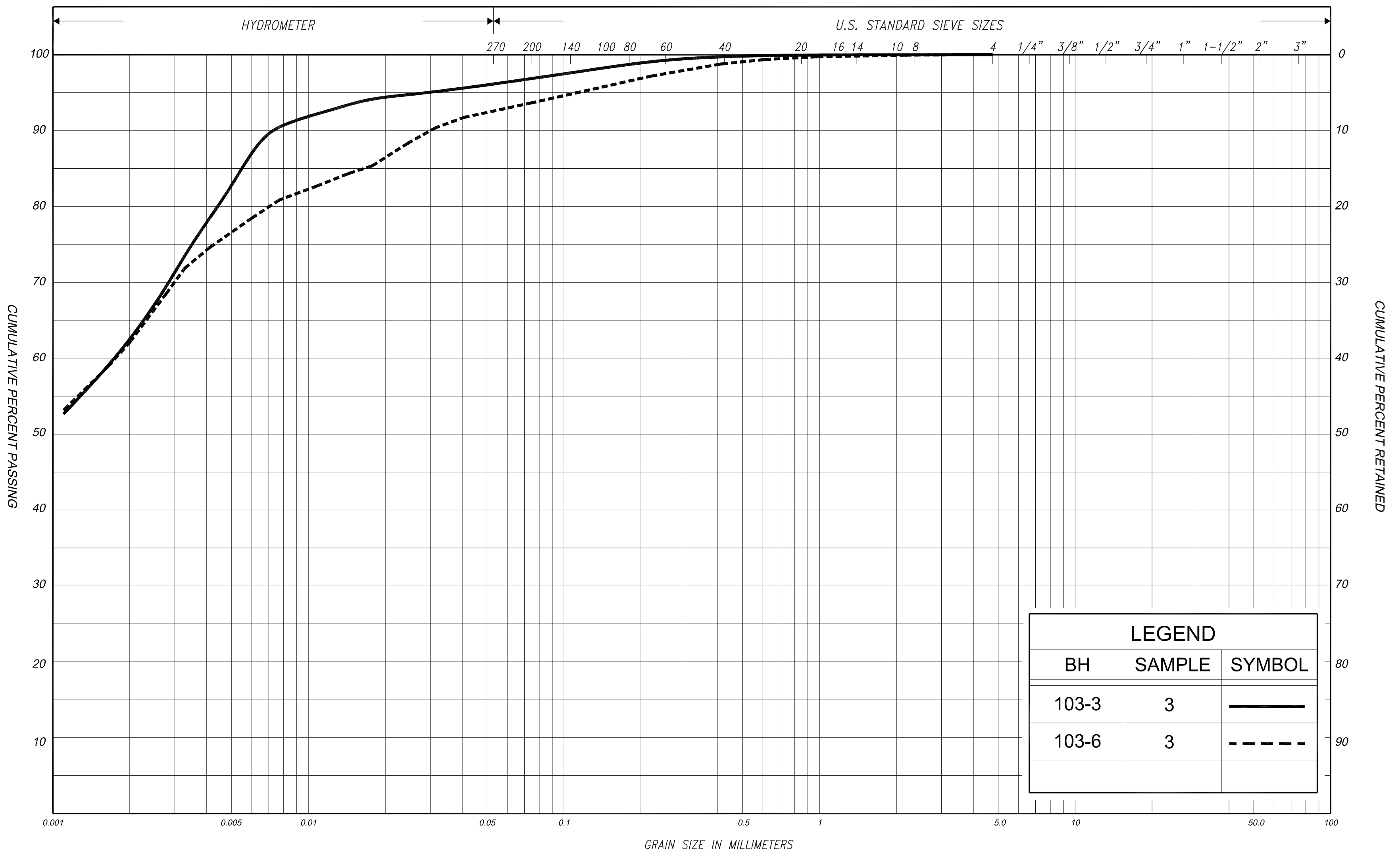
SILT & CLAY			SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL		COBBLES	UNIFIED
CLAY	SILT: FINE	SILT: MEDIUM	SILT: COARSE	SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	M.I.T.
CLAY	SILT		SAND: V. FINE	SAND: FINE	SAND: MED.	SAND: COARSE	GRAVEL		U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand

FIG No.	103-GS-2
HWY:	69
G.W.P. No.	5112-07-00



BH	SAMPLE	SYMBOL
103-3	3	———
103-6	3	- - - -

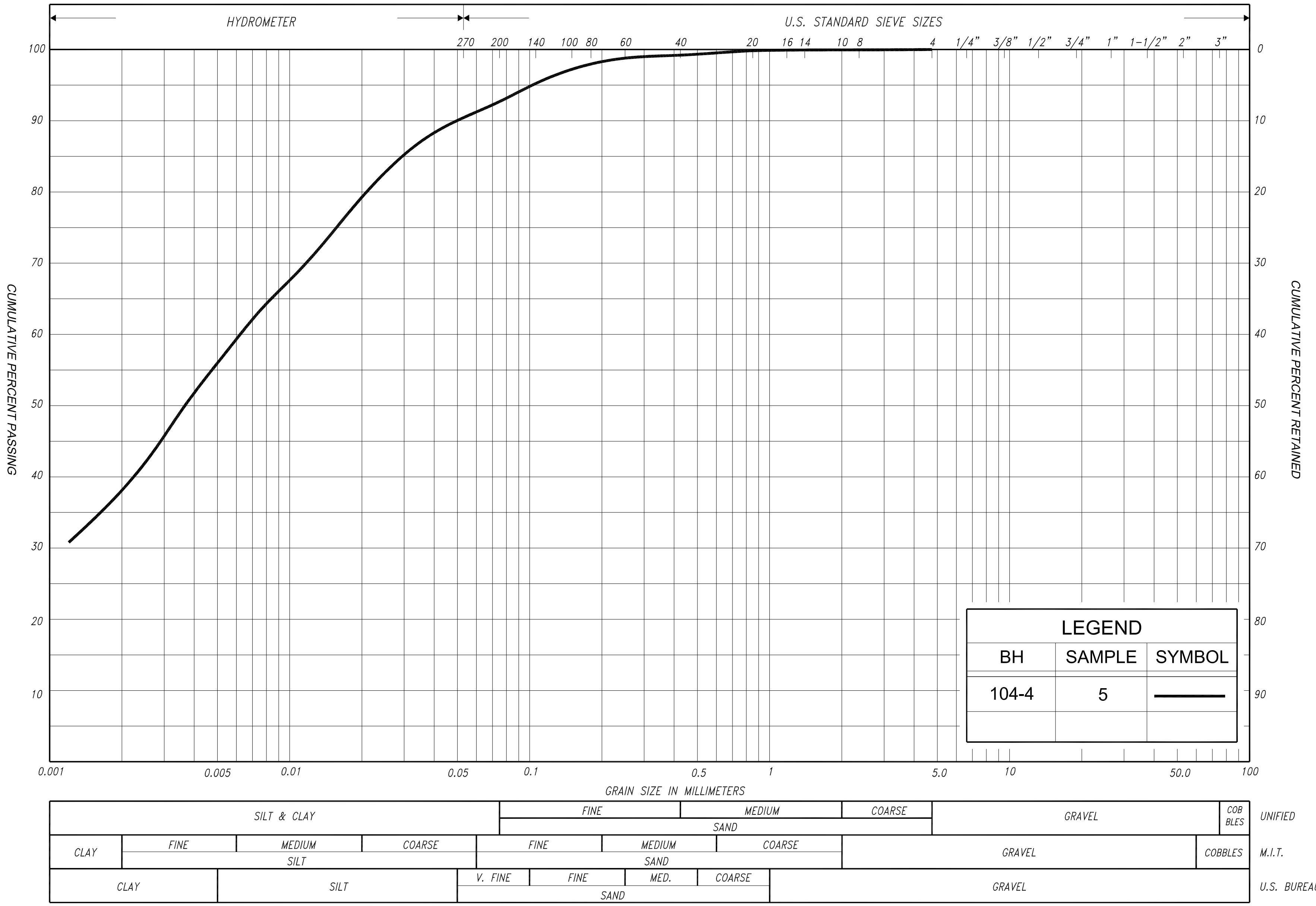
SILT & CLAY		FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	UNIFIED
CLAY	FINE / MEDIUM / COARSE SILT		FINE / MEDIUM / COARSE SAND		GRAVEL	COBBLES	M.I.T.
CLAY	SILT		V. FINE / FINE / MED. / COARSE SAND		GRAVEL		U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	103-GS-3
HWY:	69
G.W.P. No.	5112-07-00

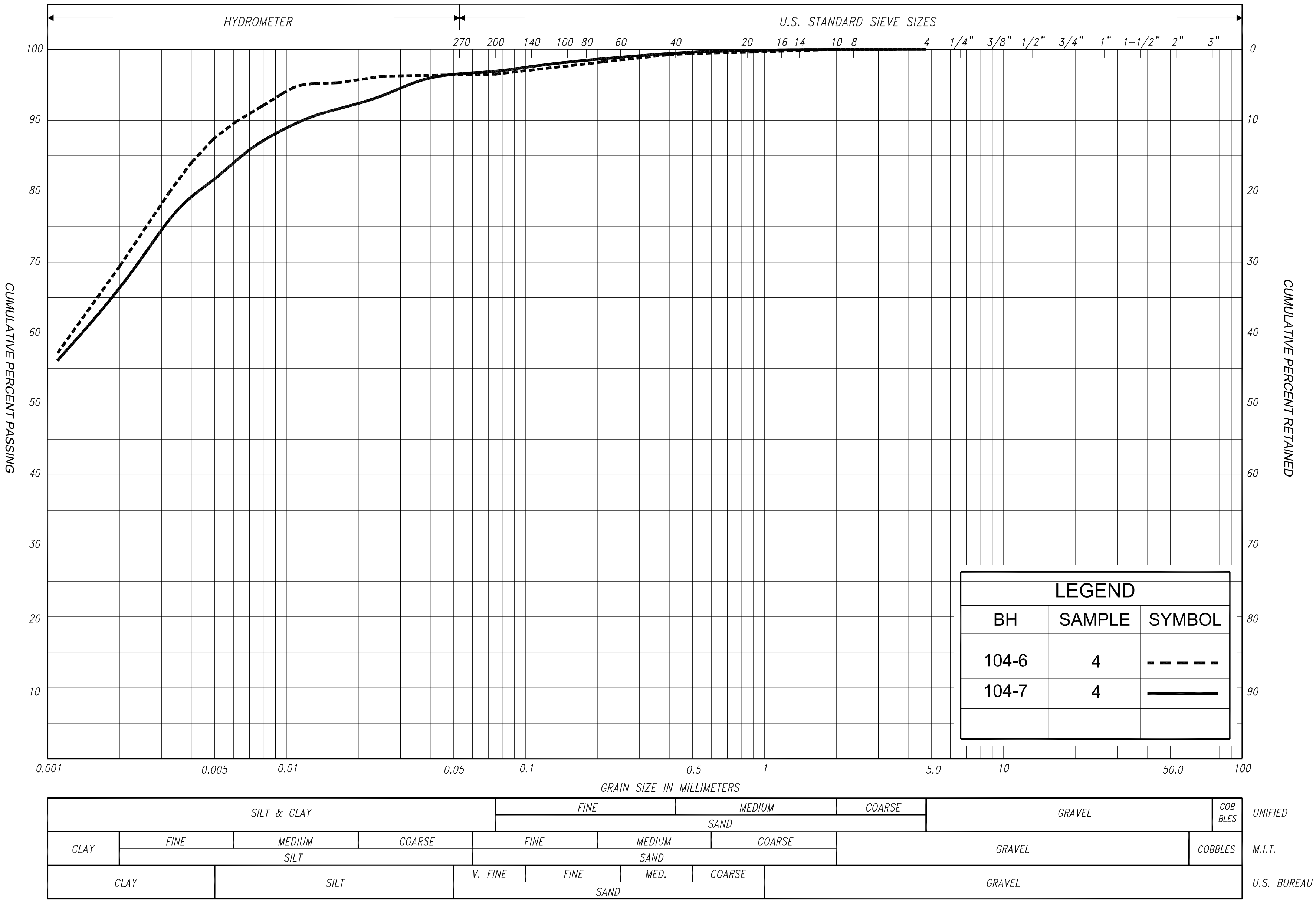


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No.	104-GS-1
HWY:	69
G.W.P. No.	5112-07-00



Ontario

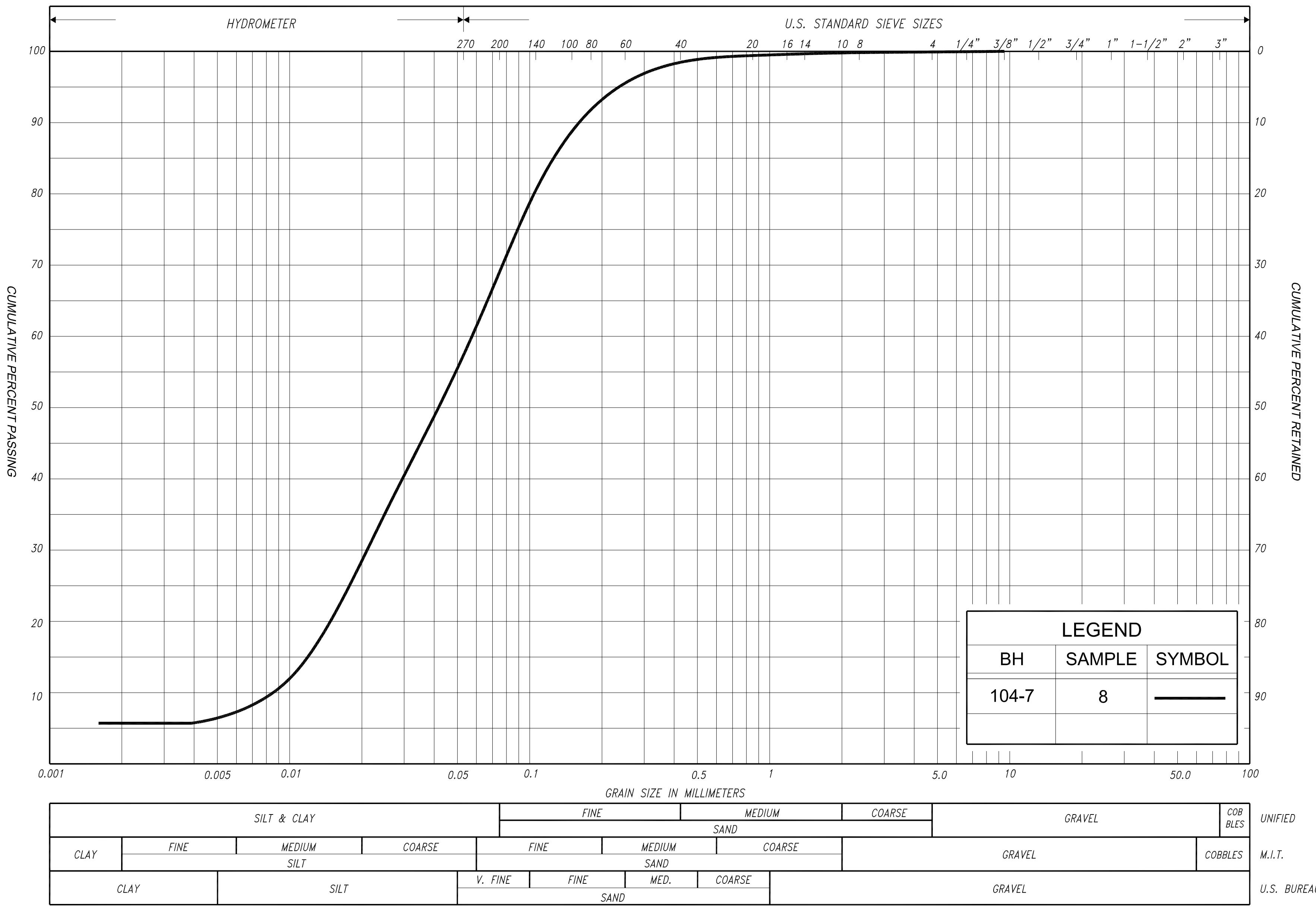
GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No. 104-GS-2

HWY: 69

G.W.P. No. 5112-07-00

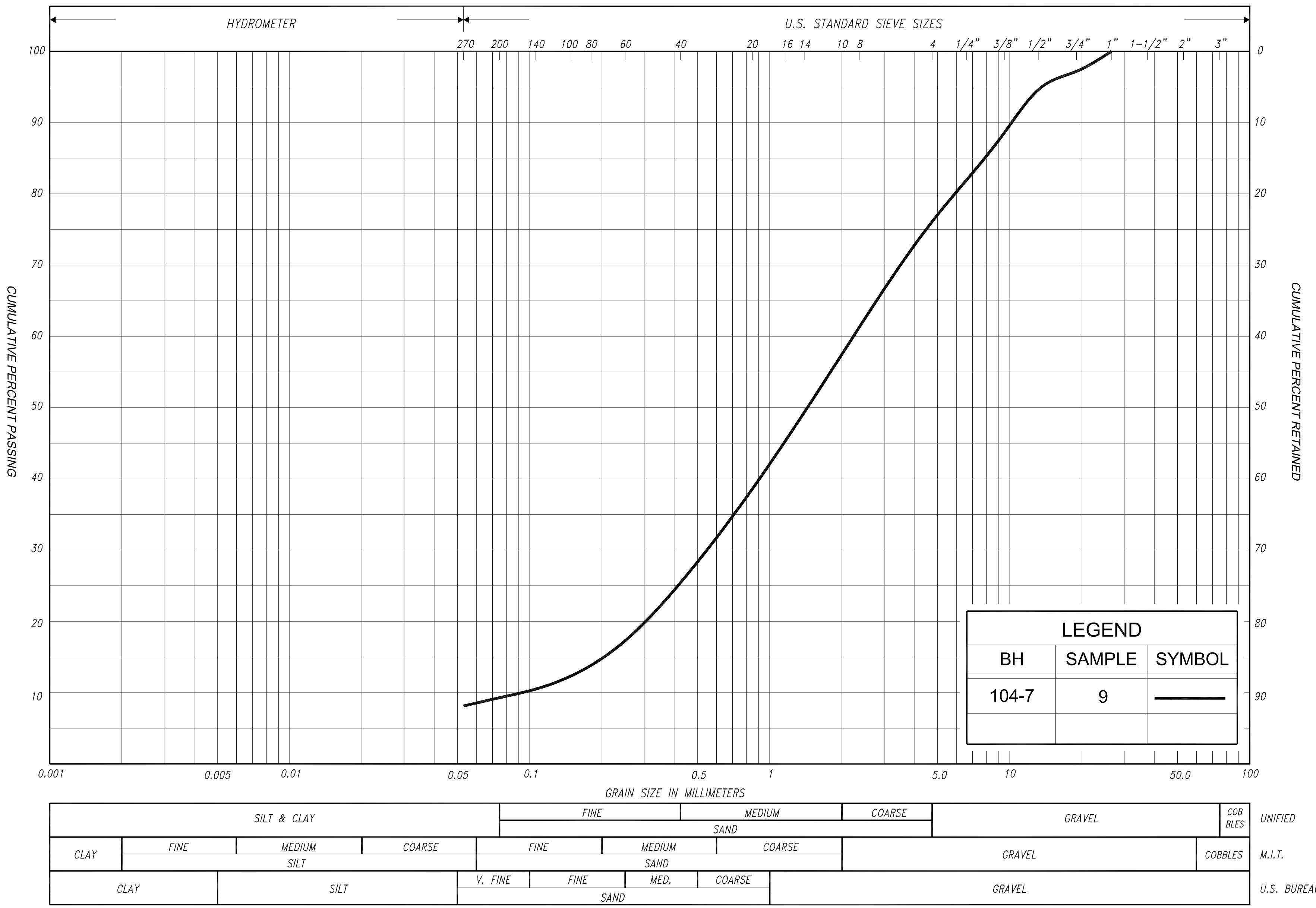


Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT, trace clay

FIG No.	104-GS-3
HWY:	69
G.W.P. No.	5112-07-00

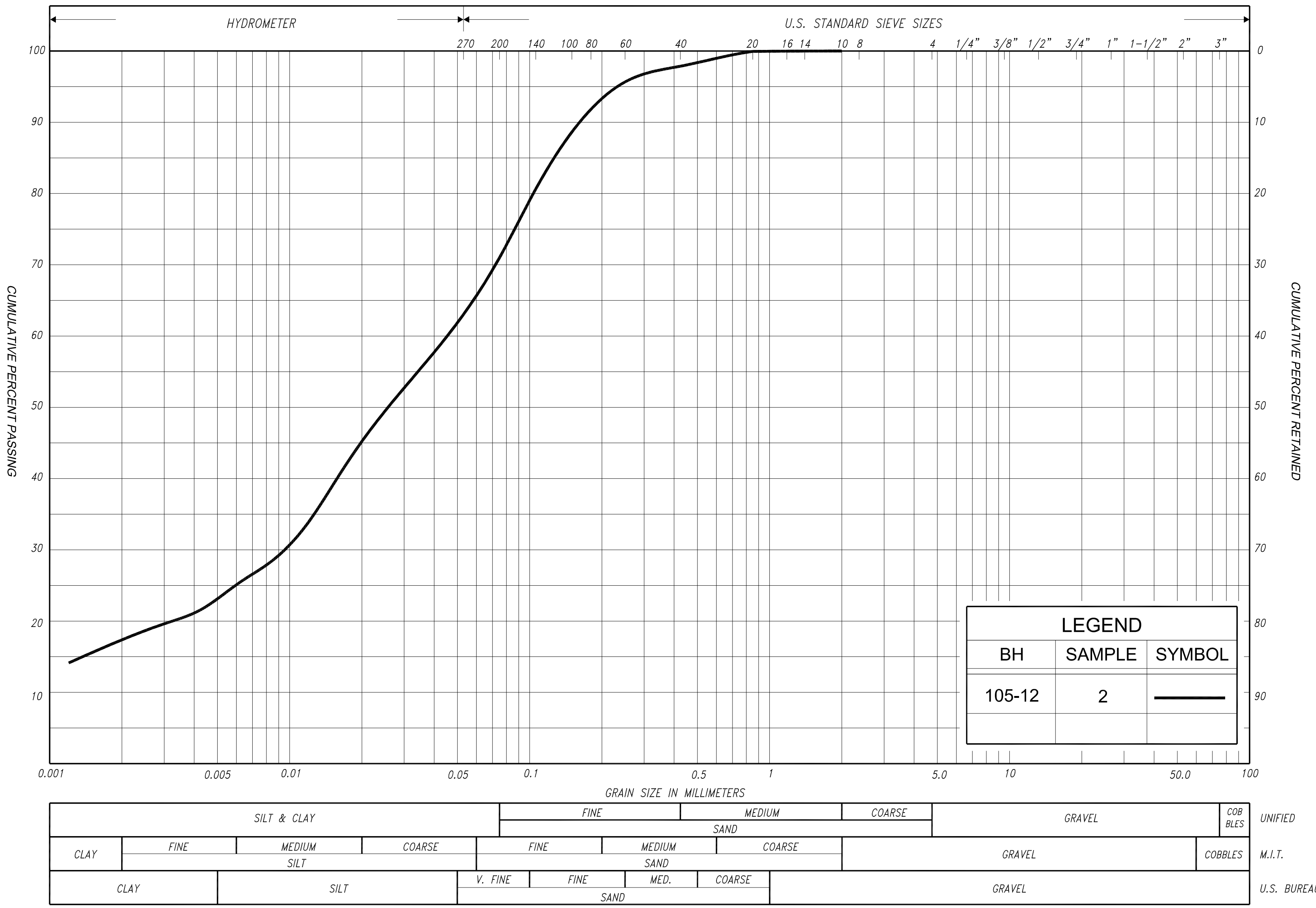


Ontario

GRAIN SIZE DISTRIBUTION

SAND, with gravel, trace silt

FIG No.	104-GS-4
HWY:	69
G.W.P. No.	5112-07-00

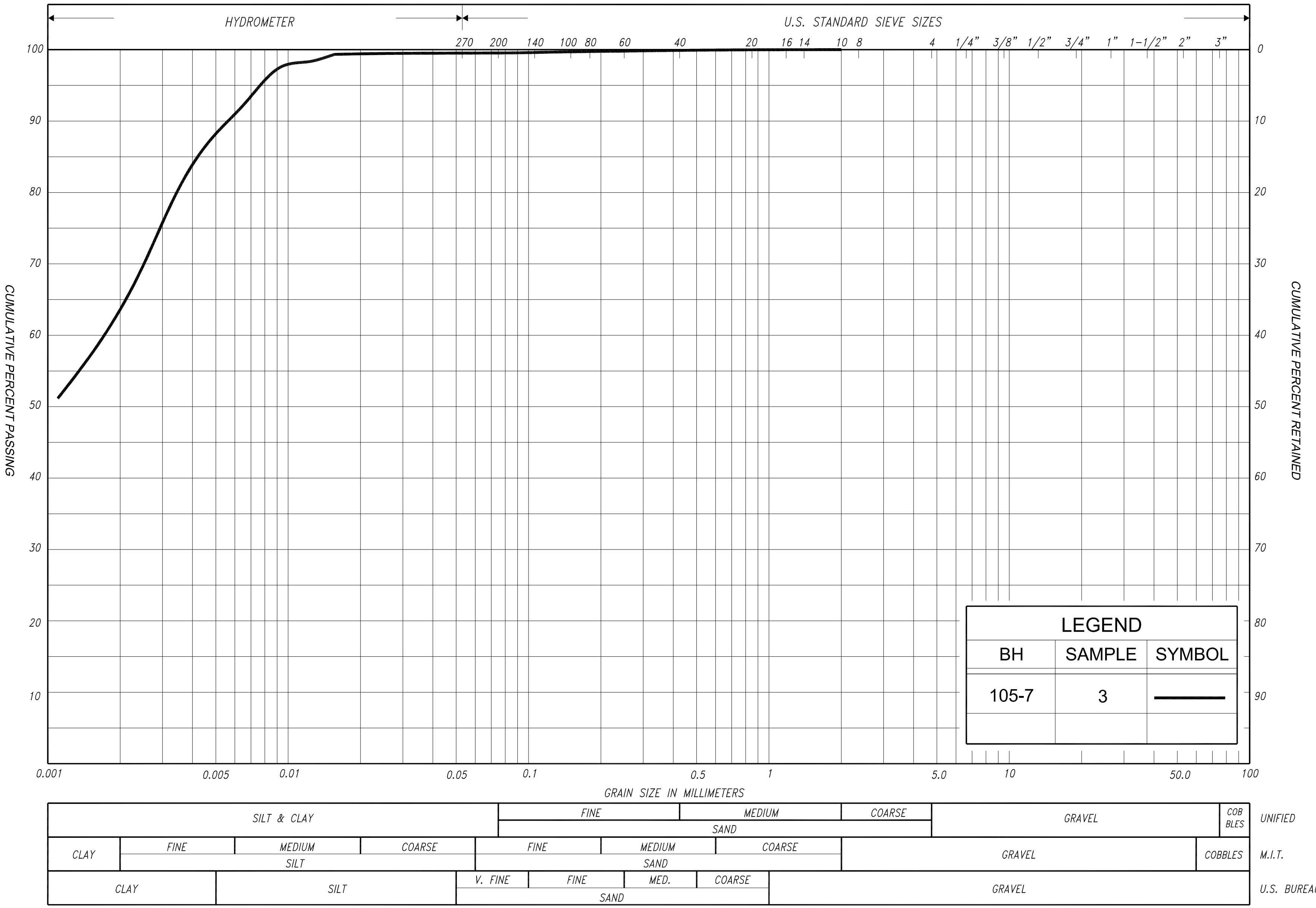


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, with sand

FIG No.	105-GS-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

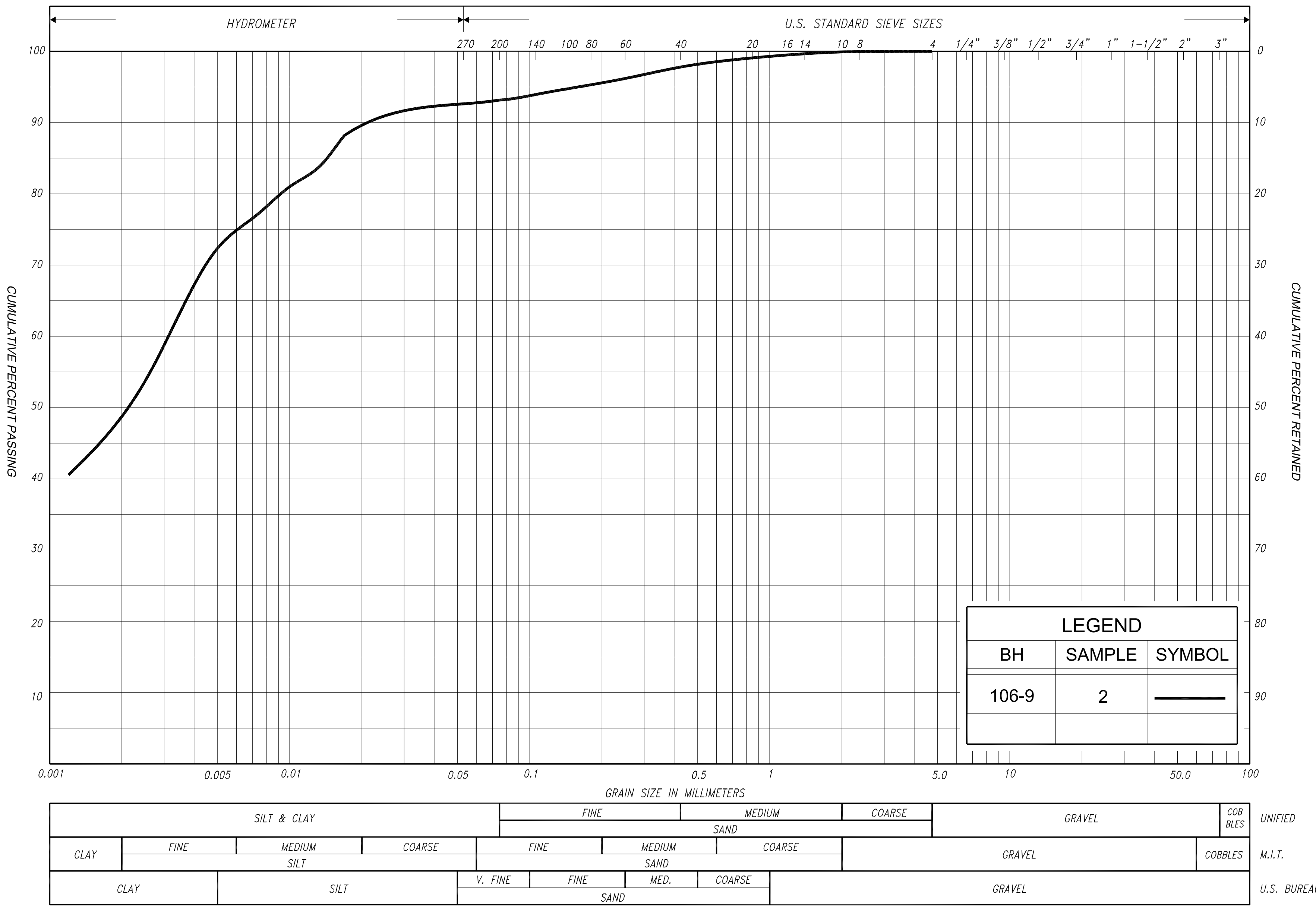
BH	SAMPLE	SYMBOL
105-7	3	———

Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	105-GS-2
HWY:	69
G.W.P. No.	5112-07-00

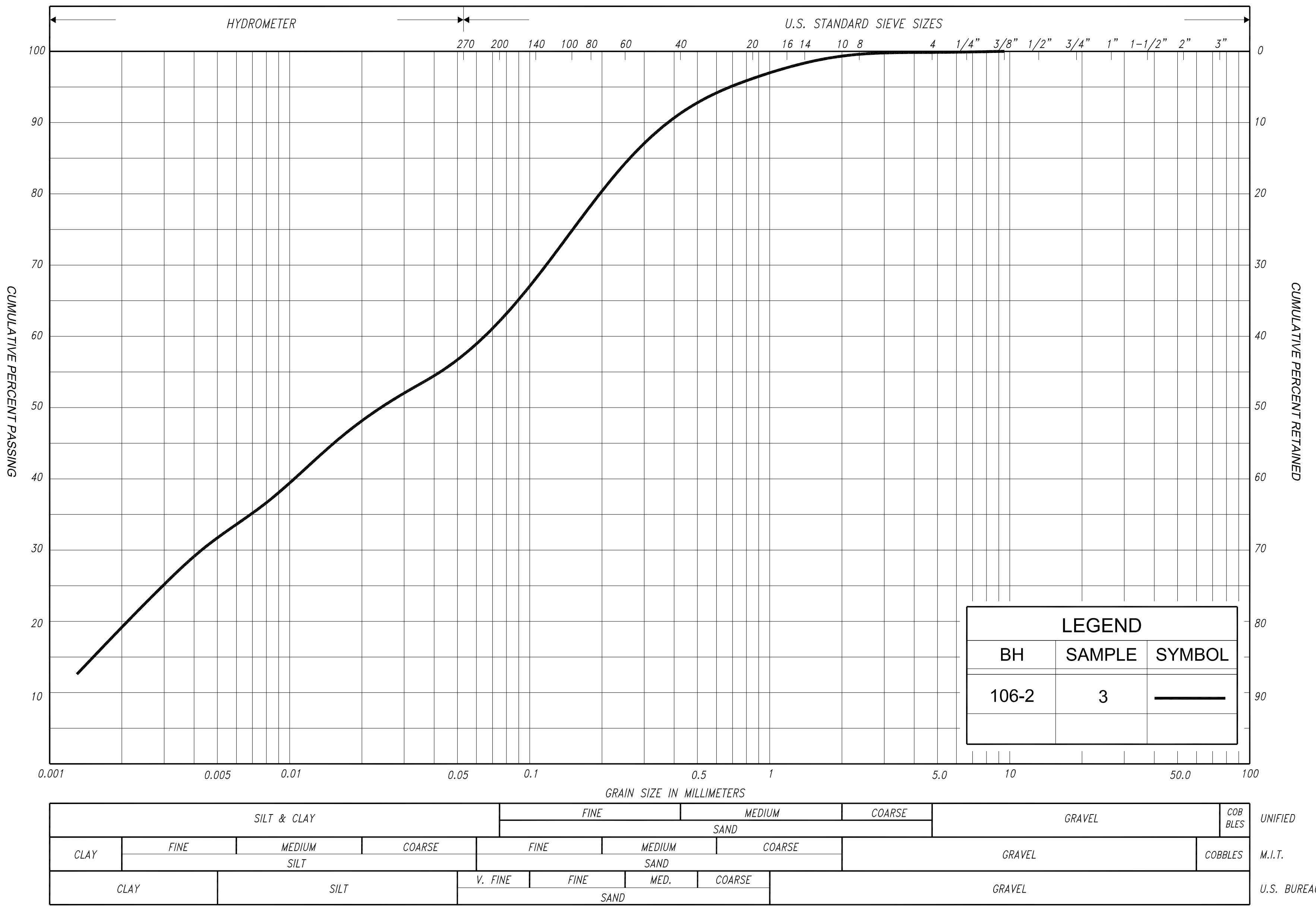


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	106-GS-1
HWY:	69
G.W.P. No.	5112-07-00

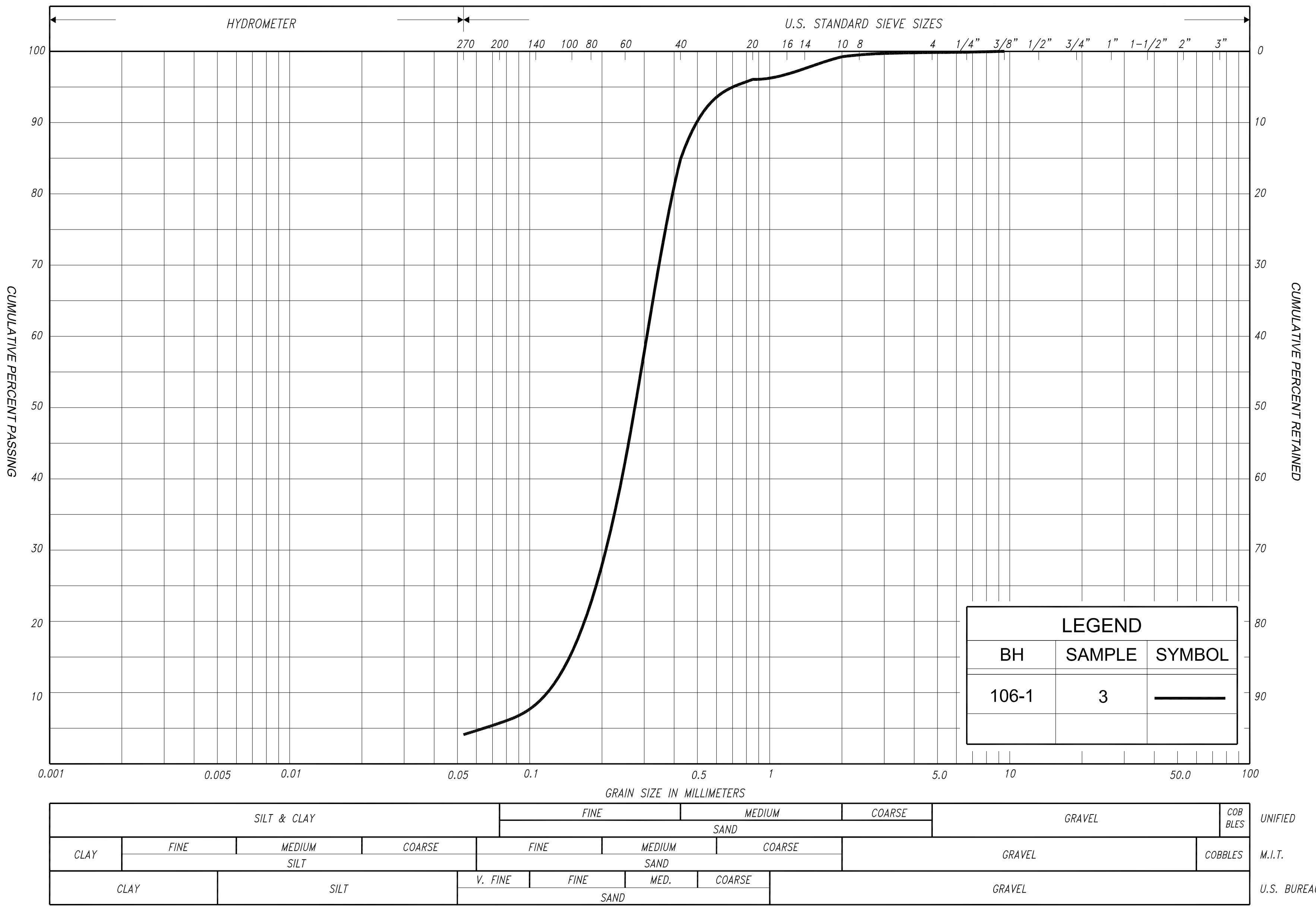


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, sandy

FIG No.	106-GS-2
HWY:	69
G.W.P. No.	5112-07-00

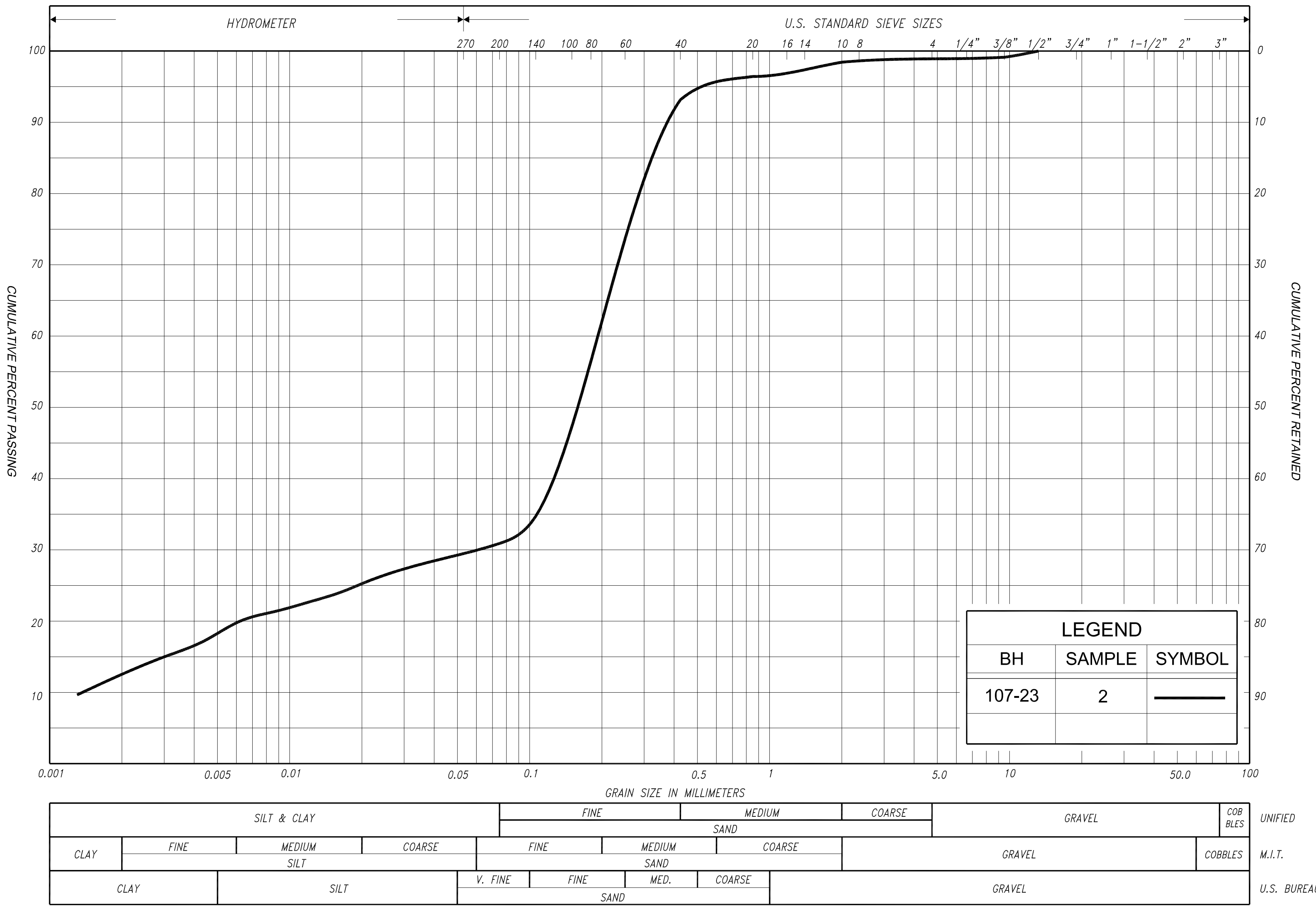


Ontario

GRAIN SIZE DISTRIBUTION

SAND, trace silt

FIG No.	106-GS-3
HWY:	69
G.W.P. No.	5112-07-00

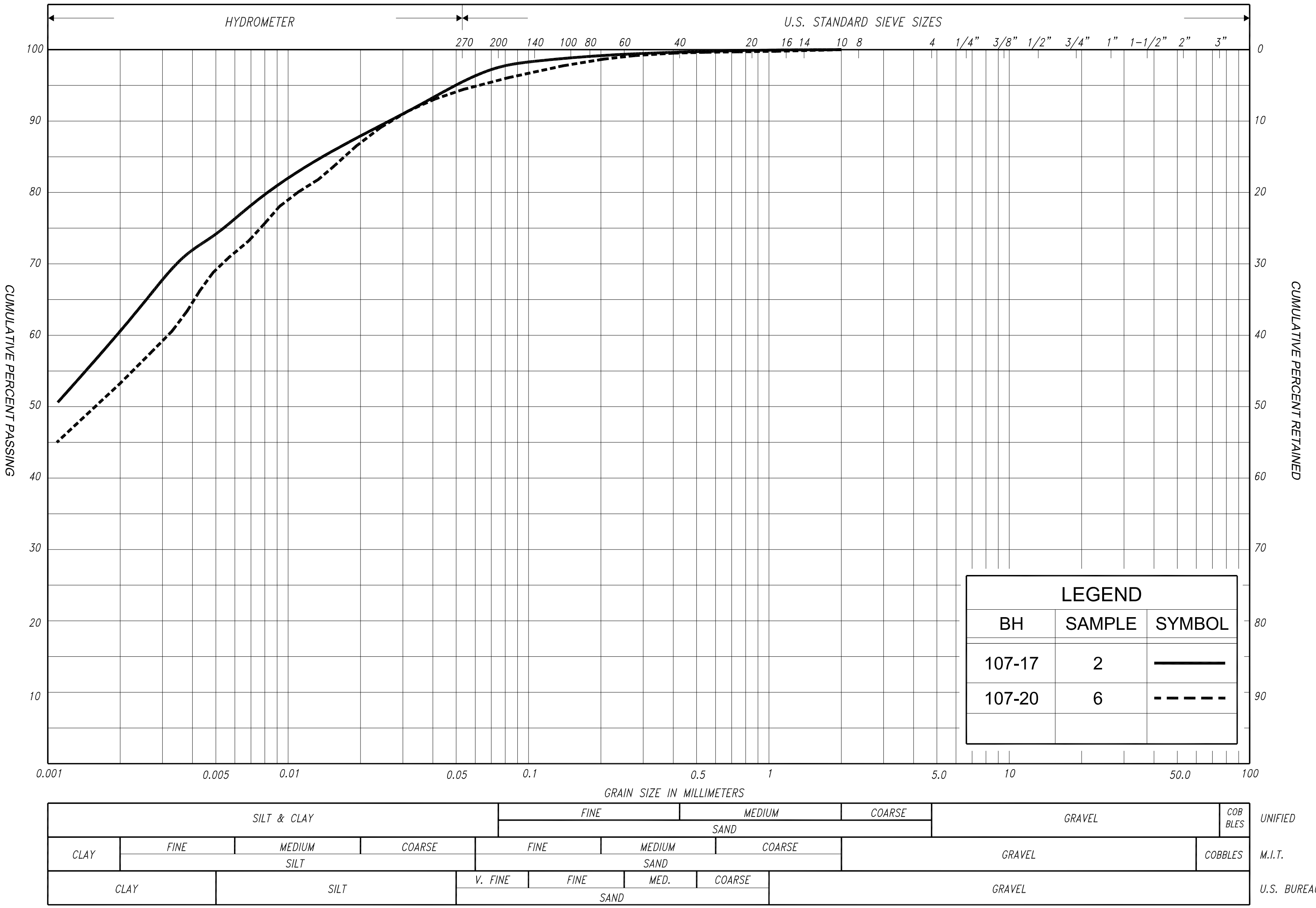


Ontario

GRAIN SIZE DISTRIBUTION

SAND, some silt, some clay, trace gravel

FIG No.	107-GS-1
HWY:	69
G.W.P. No.	5112-07-00

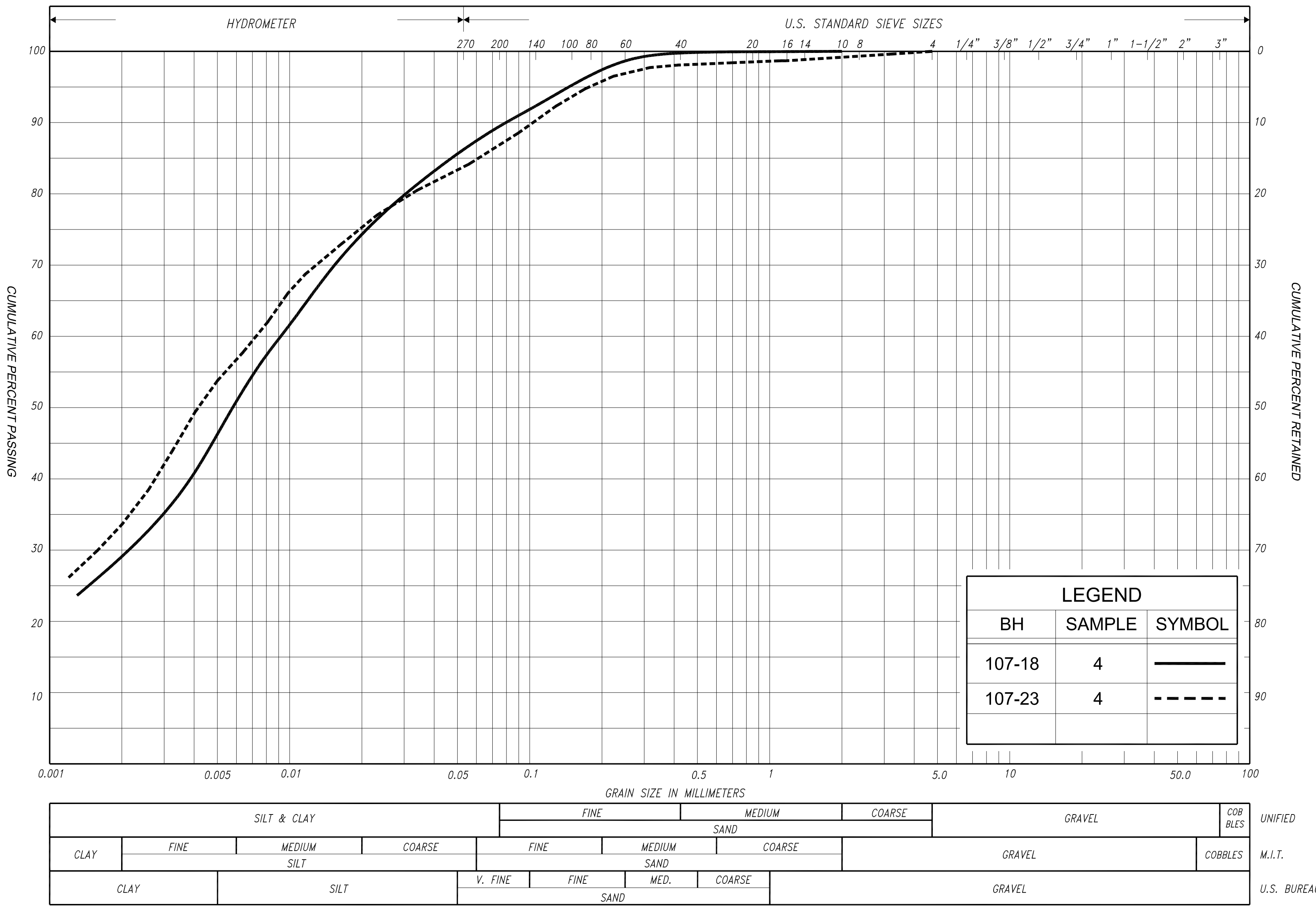


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	107-GS-2
HWY:	69
G.W.P. No.	5112-07-00

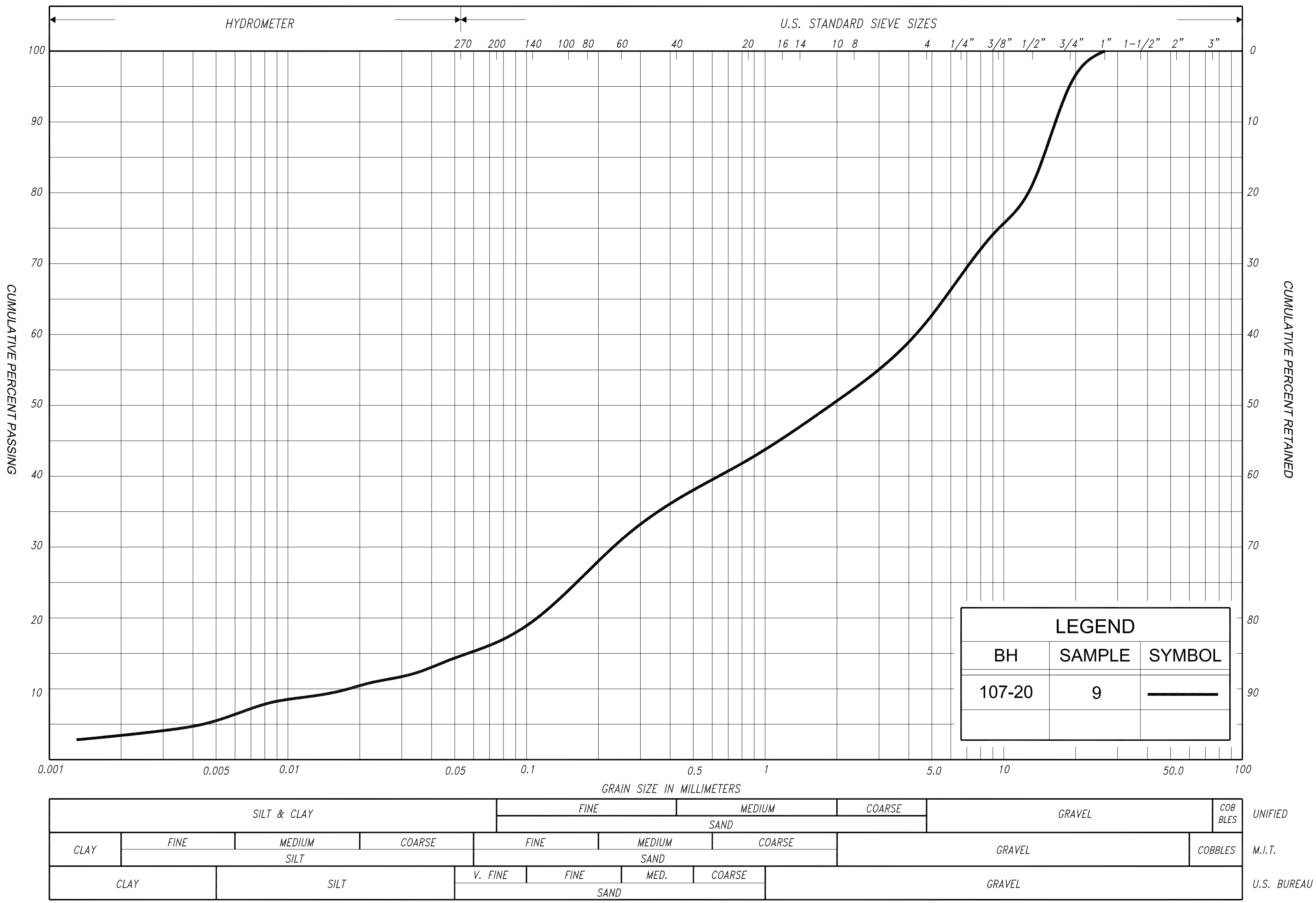


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand

FIG No.	107-GS-3
HWY:	69
G.W.P. No.	5112-07-00

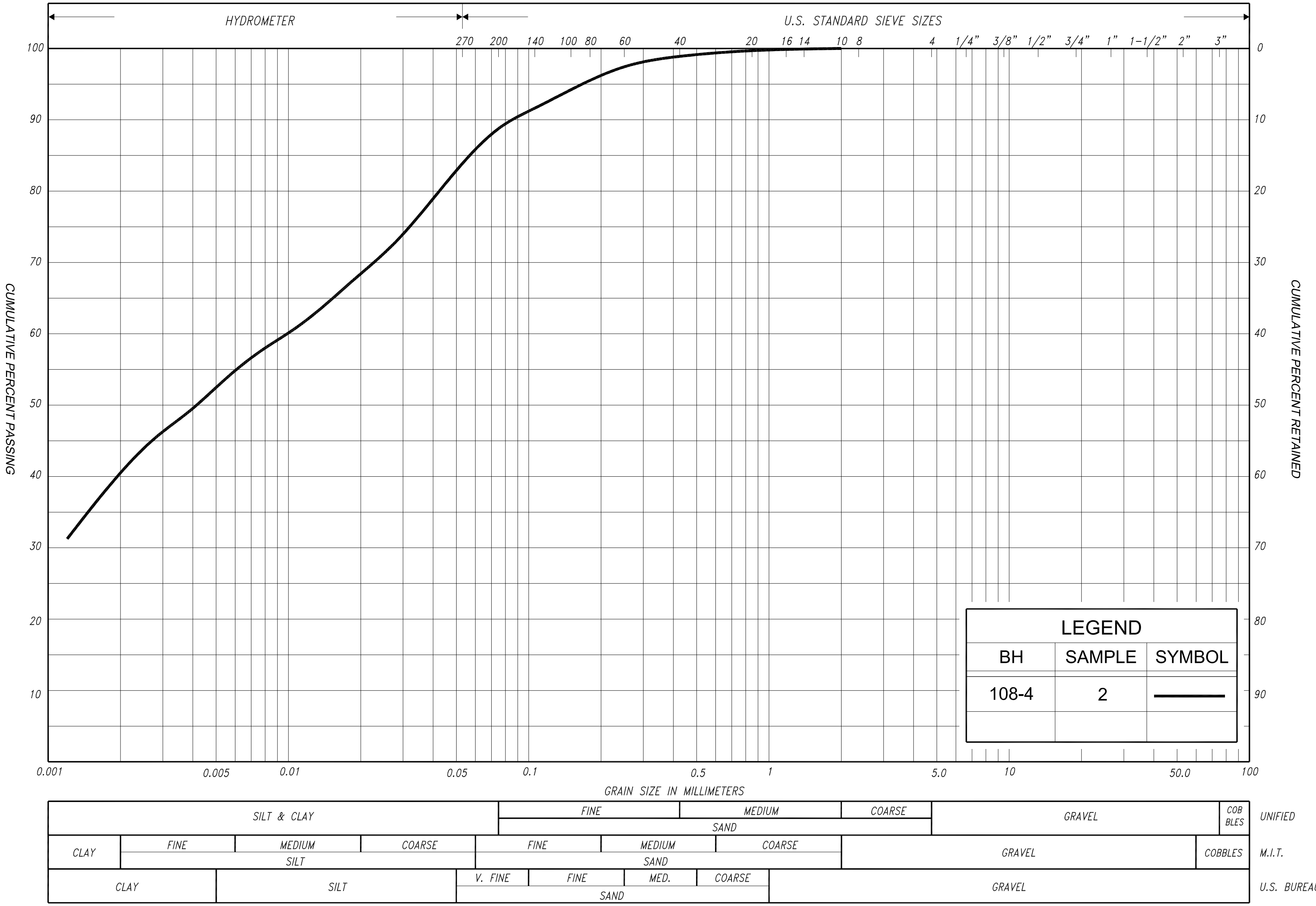


Ontario

GRAIN SIZE DISTRIBUTION

GRAVELLY SAND, some silt, trace clay

FIG No.	107-GS-4
HWY:	69
G.W.P. No.	5112-07-00

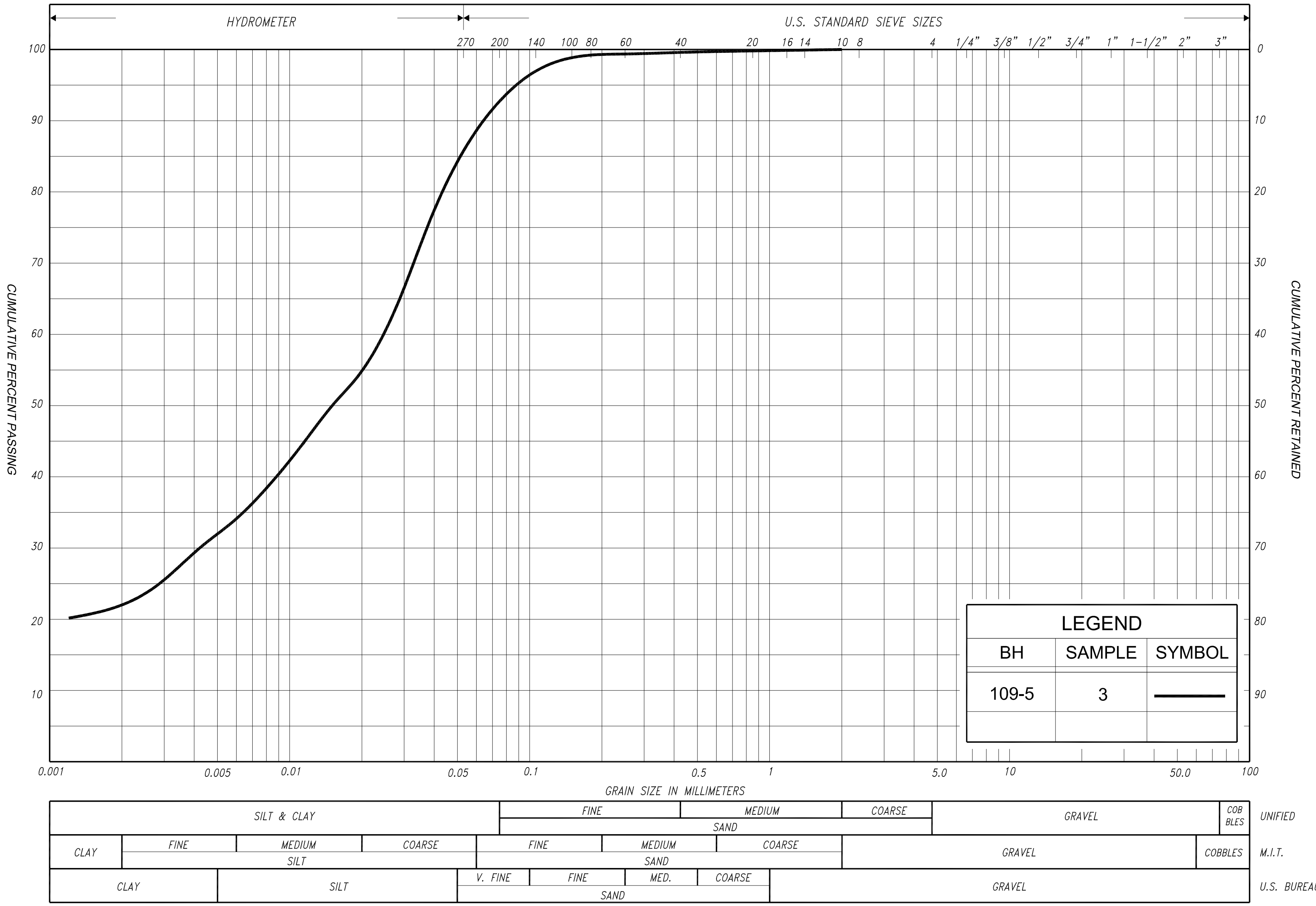


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, some sand

FIG No.	108-GS-1
HWY:	69
G.W.P. No.	5112-07-00

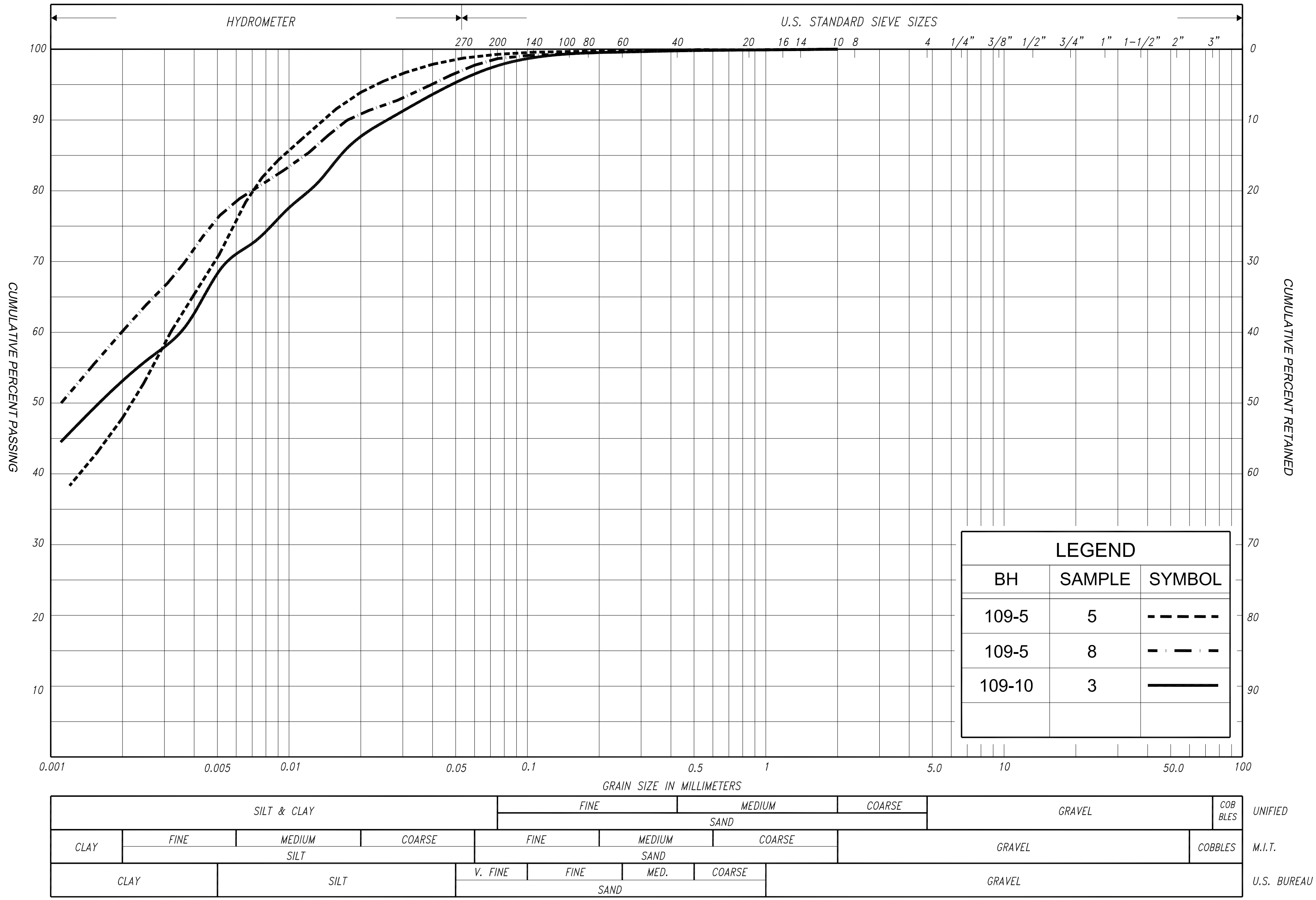


LEGEND		
BH	SAMPLE	SYMBOL
109-5	3	———

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No.	109-GS-1
HWY:	69
G.W.P. No.	5112-07-00

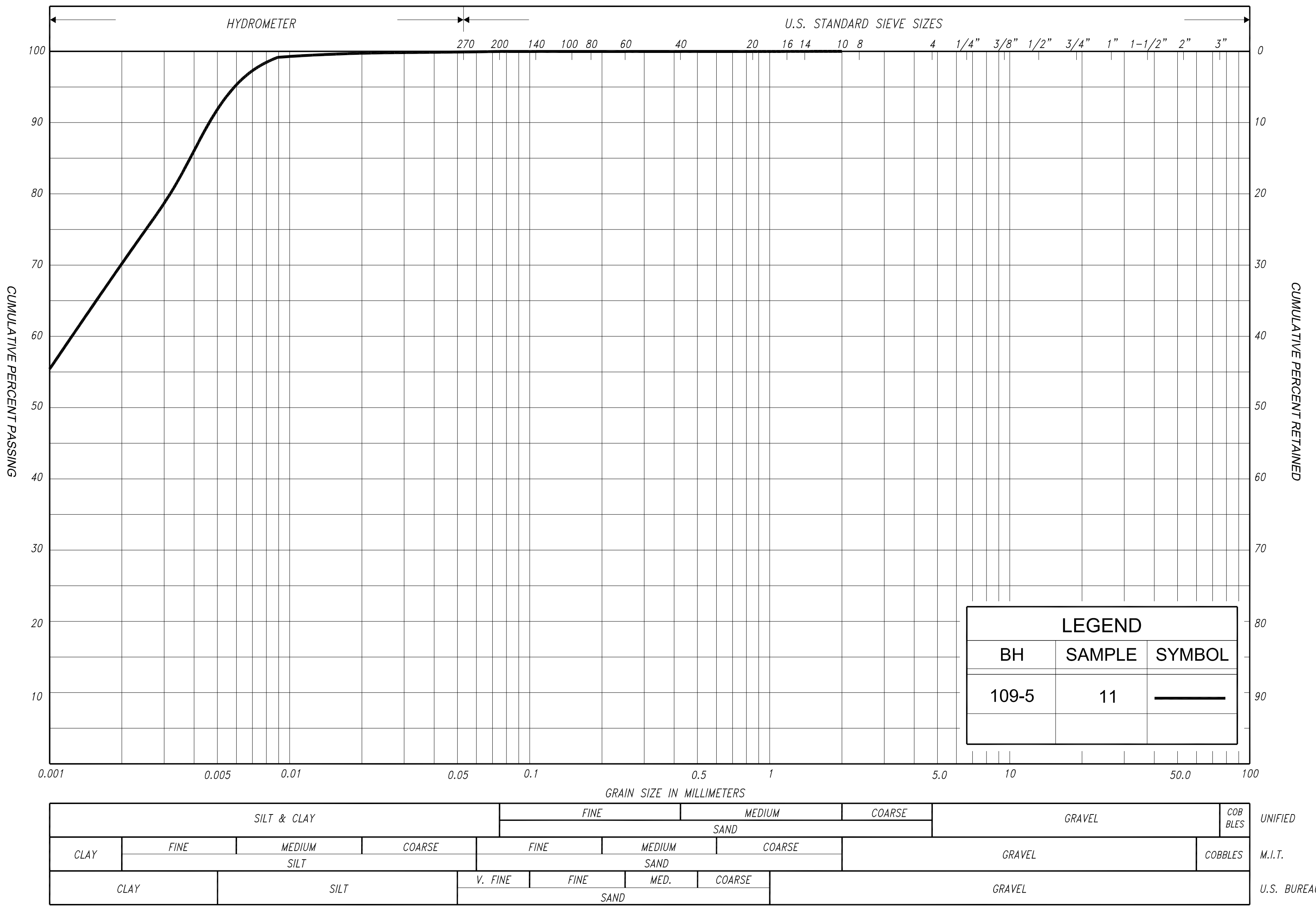


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	109-GS-2
HWY:	69
G.W.P. No.	5112-07-00

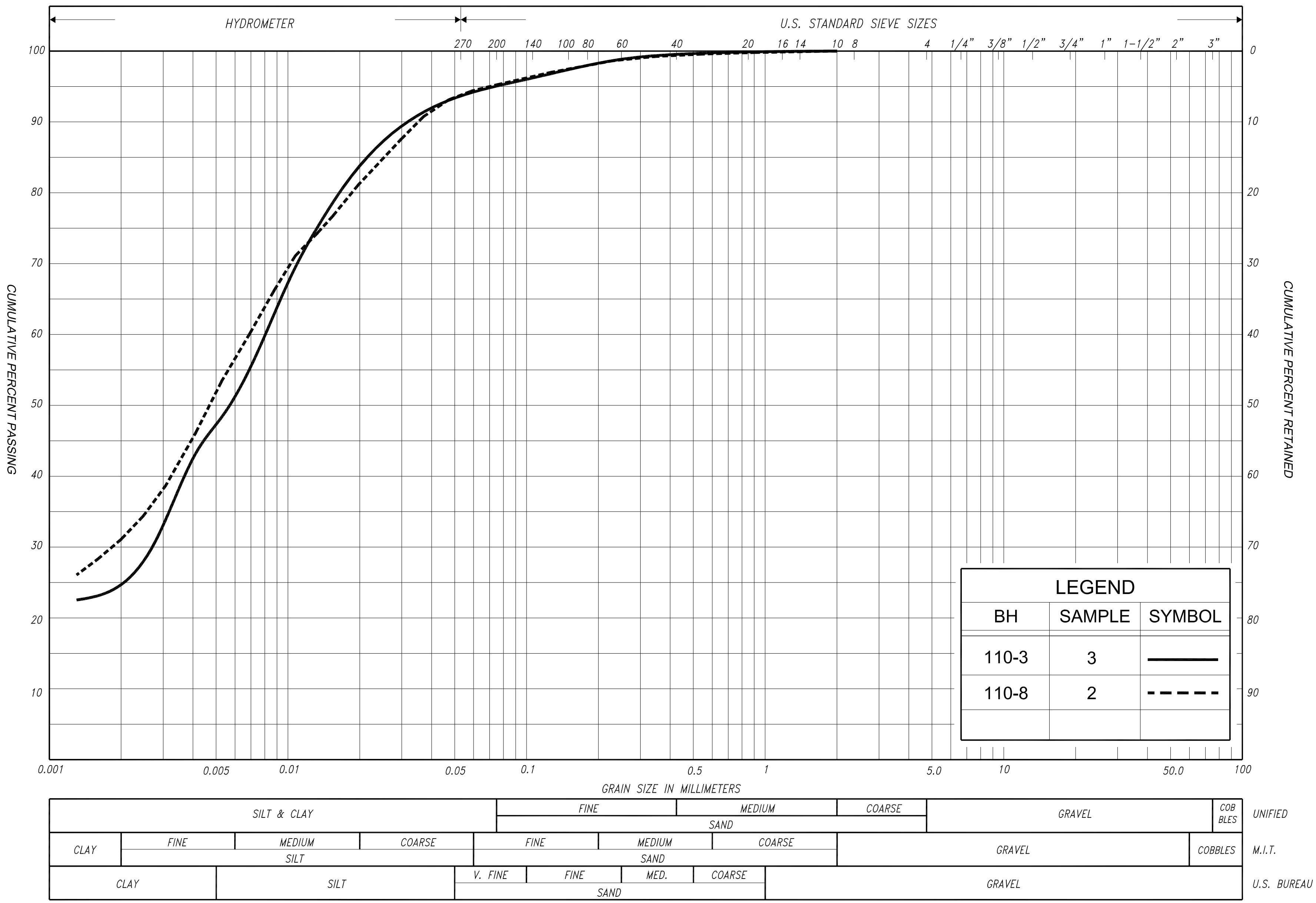


Ontario

GRAIN SIZE DISTRIBUTION

CLAY

FIG No.	109-GS-3
HWY:	69
G.W.P. No.	5112-07-00

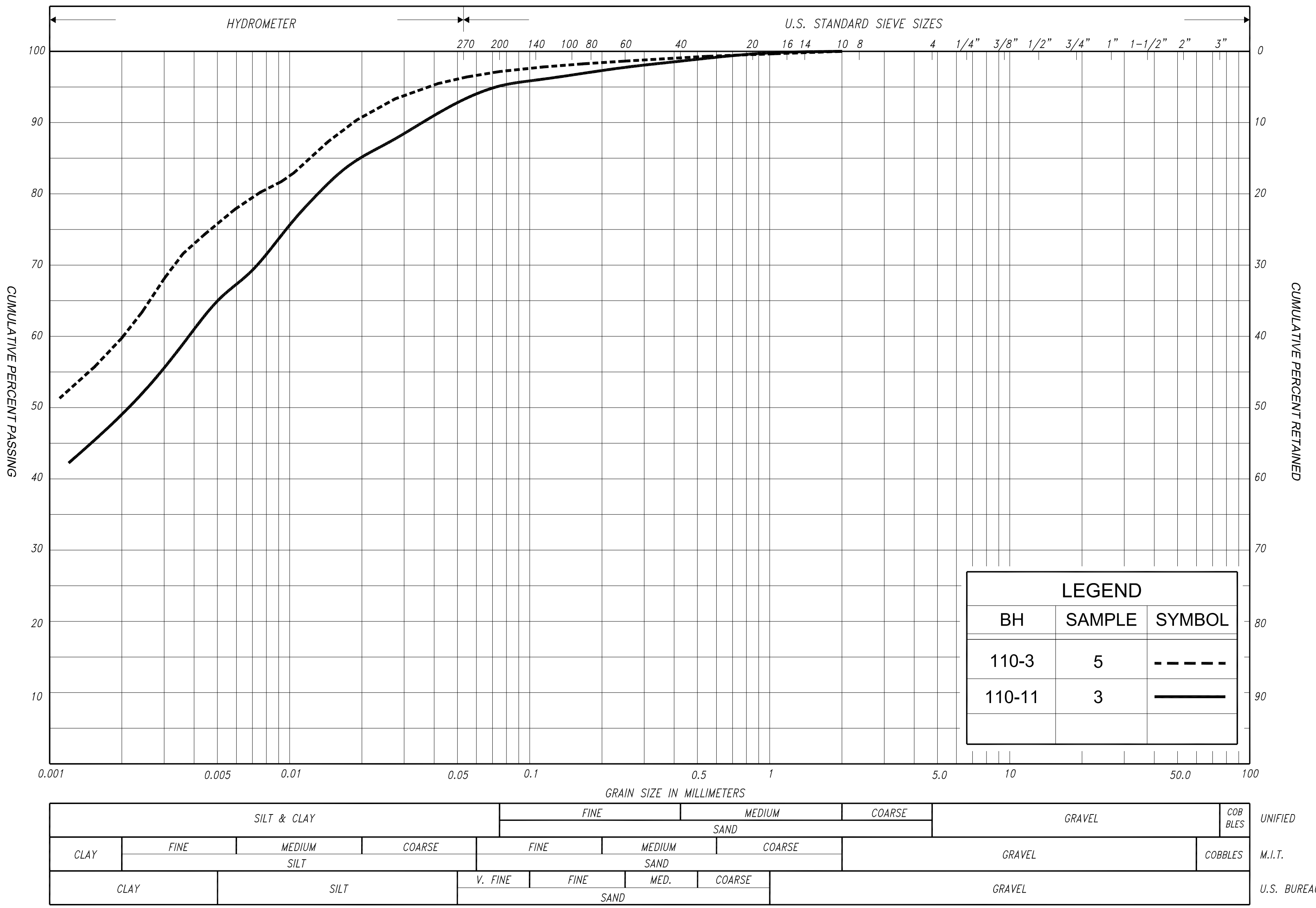


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No.	110-GS-1
HWY:	69
G.W.P. No.	5112-07-00

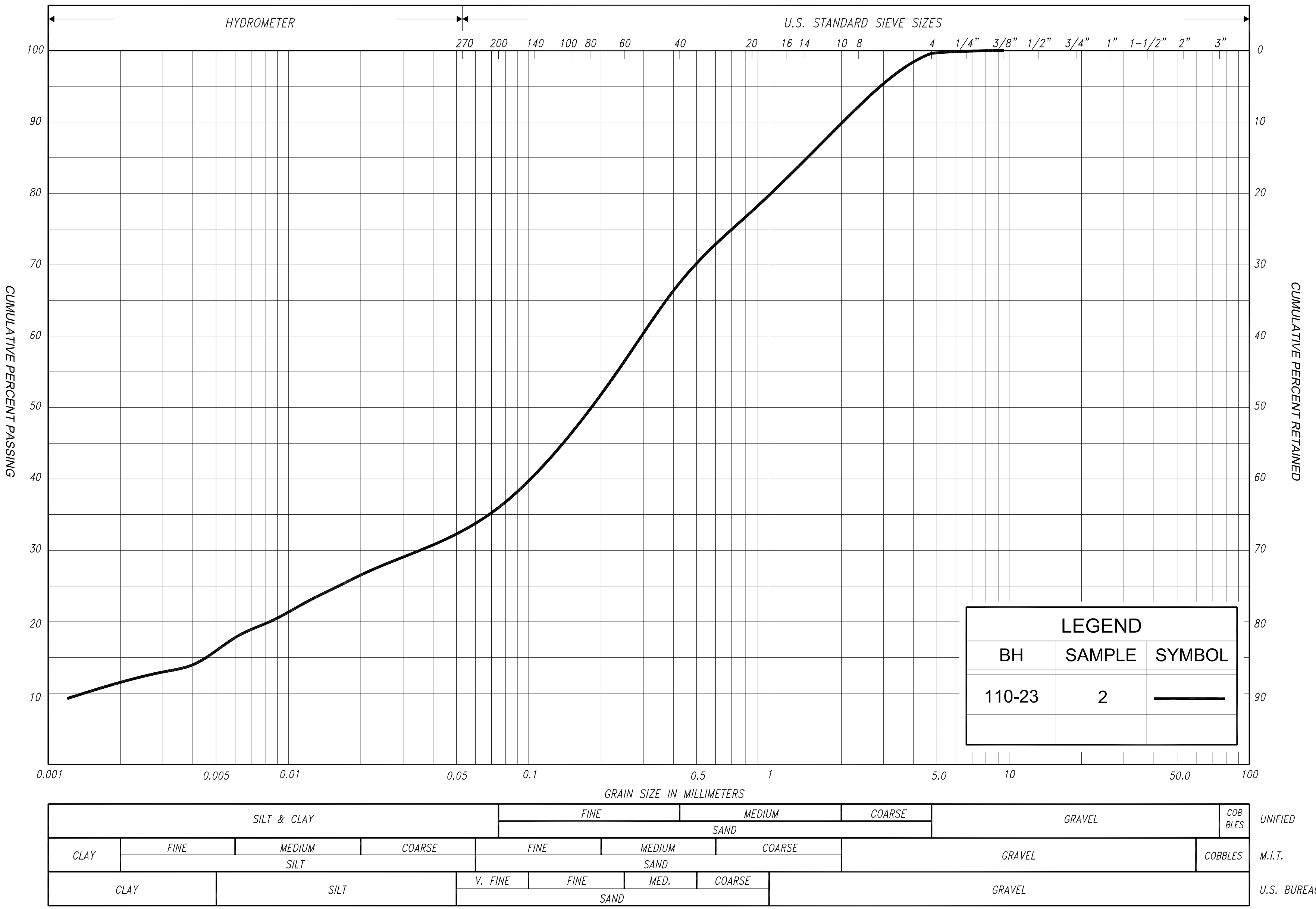


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	110-GS-2
HWY:	69
G.W.P. No.	5112-07-00

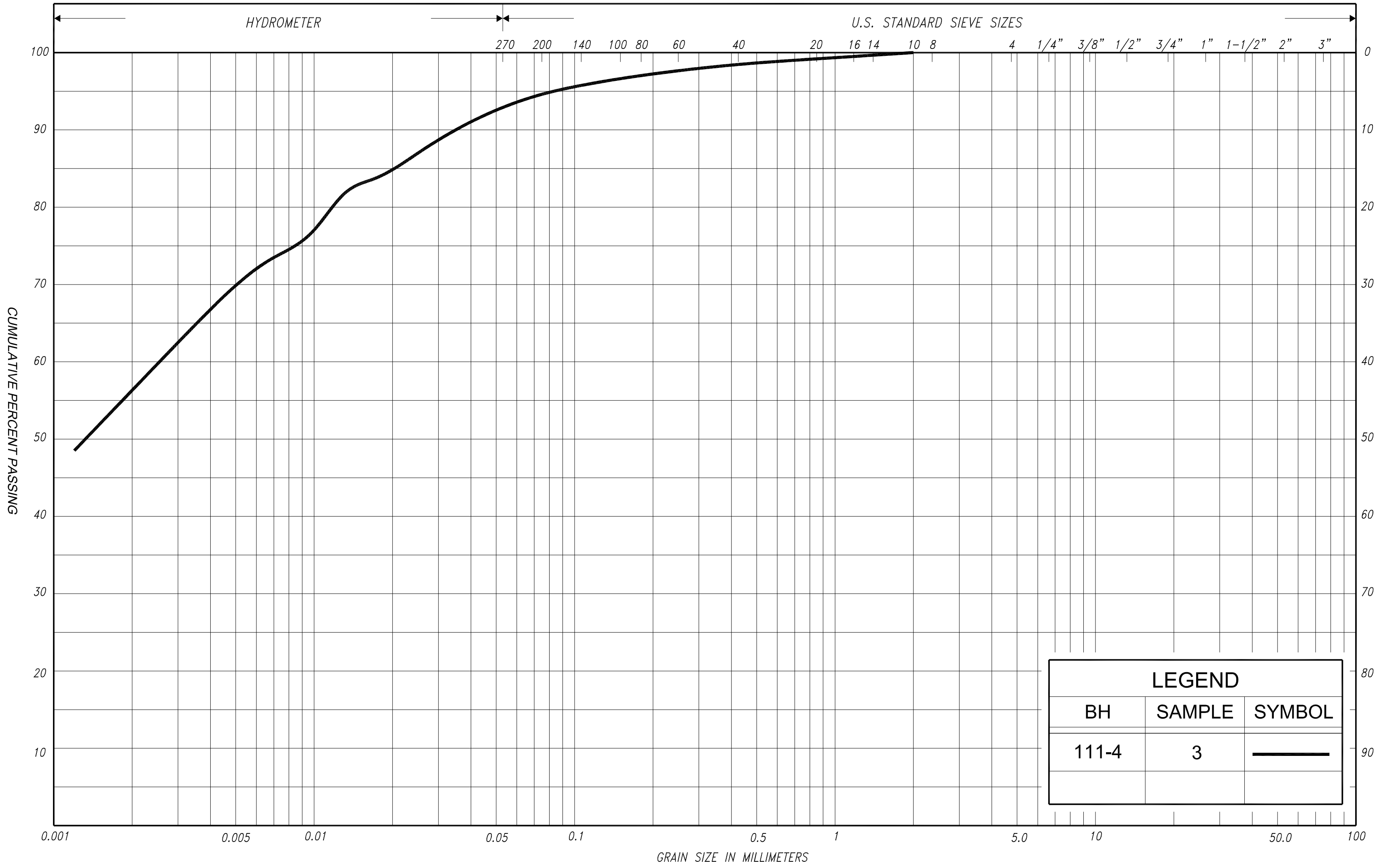


GRAIN SIZE DISTRIBUTION

SAND, with silt, some clay, trace gravel

FIG No.	110-GS-3
HWY:	69
G.W.P. No.	5112-07-00

Ontario



LEGEND		
BH	SAMPLE	SYMBOL
111-4	3	———

SILT & CLAY	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	UNIFIED

CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	M.I.T.

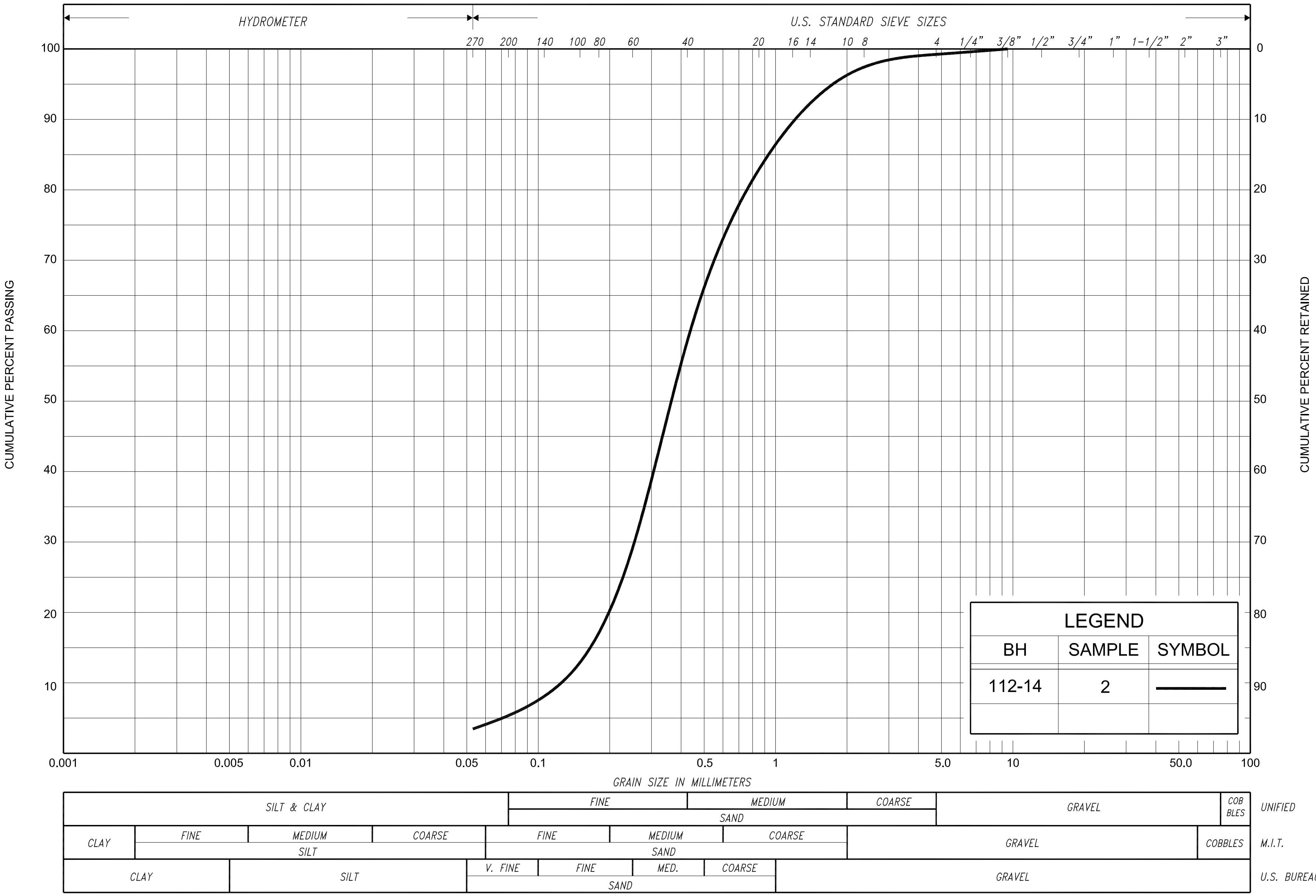
CLAY	SILT	V. FINE SAND	FINE SAND	MED. SAND	COARSE SAND	GRAVEL	U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	111-GS-1
HWY:	69
G.W.P. No.	5112-07-00

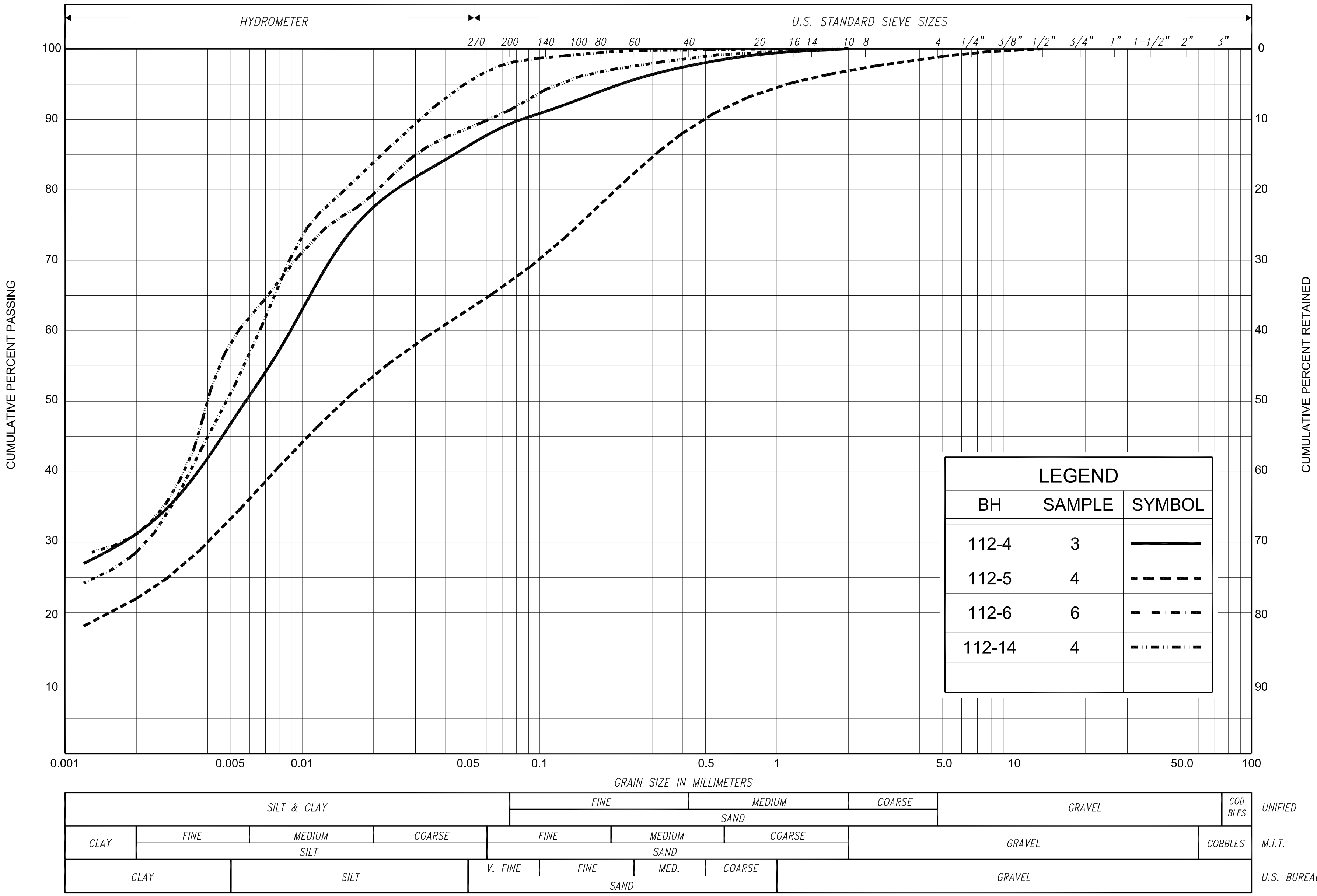


Ontario

GRAIN SIZE DISTRIBUTION

SAND, trace silt, trace gravel

FIG No.	112-GS-1
HWY:	69
G.W.P. No.	5112-07-00



LEGEND

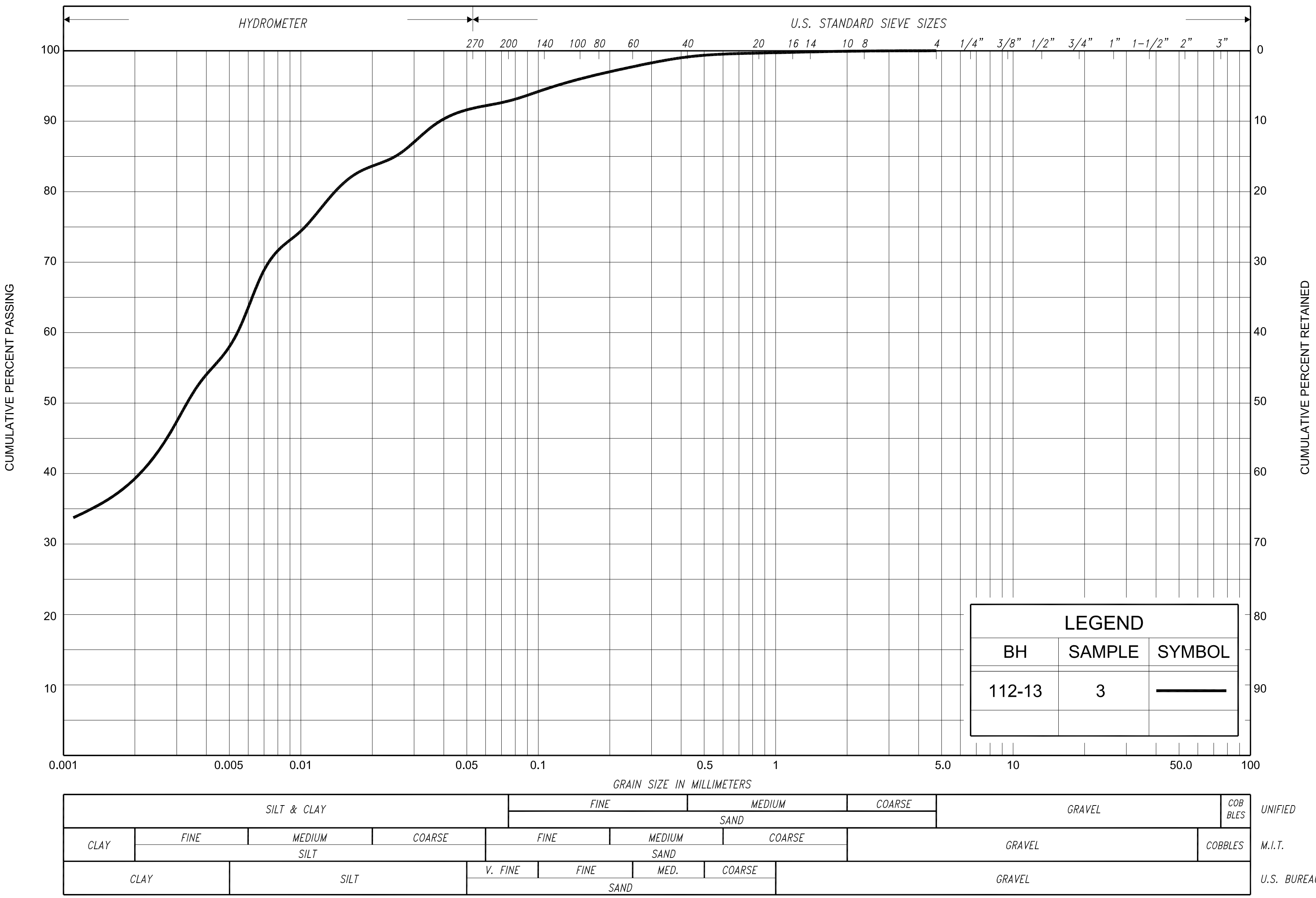
BH	SAMPLE	SYMBOL
112-4	3	solid line
112-5	4	dashed line
112-6	6	dash-dot line
112-14	4	dash-dot-dot line

Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand to sandy

FIG No.	112-GS-2
HWY:	69
G.W.P. No.	5112-07-00

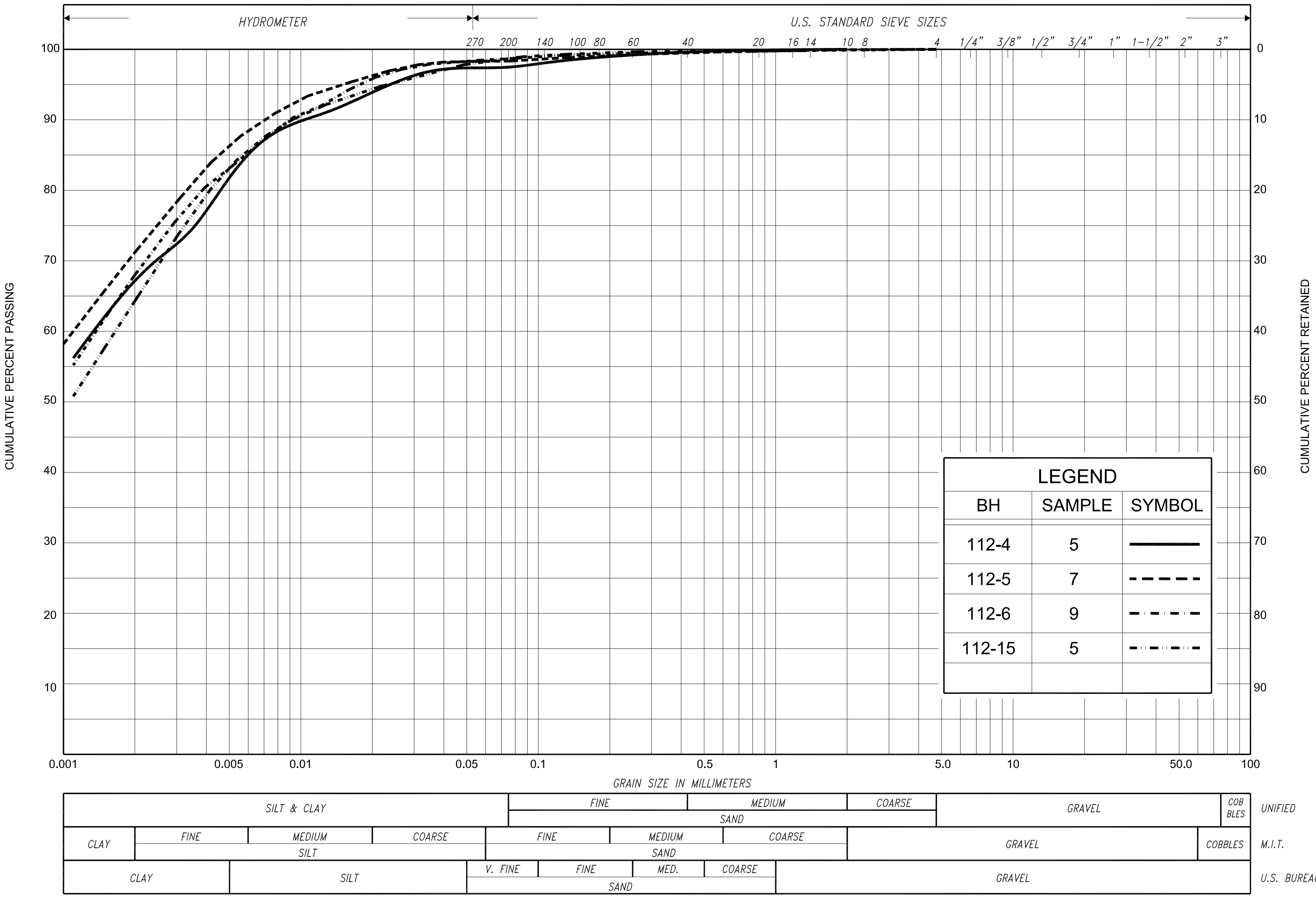


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	112-GS-3
HWY:	69
G.W.P. No.	5112-07-00



LEGEND		
BH	SAMPLE	SYMBOL
112-4	5	solid line
112-5	7	dashed line
112-6	9	dash-dot line
112-15	5	dash-dot-dot line

Ontario

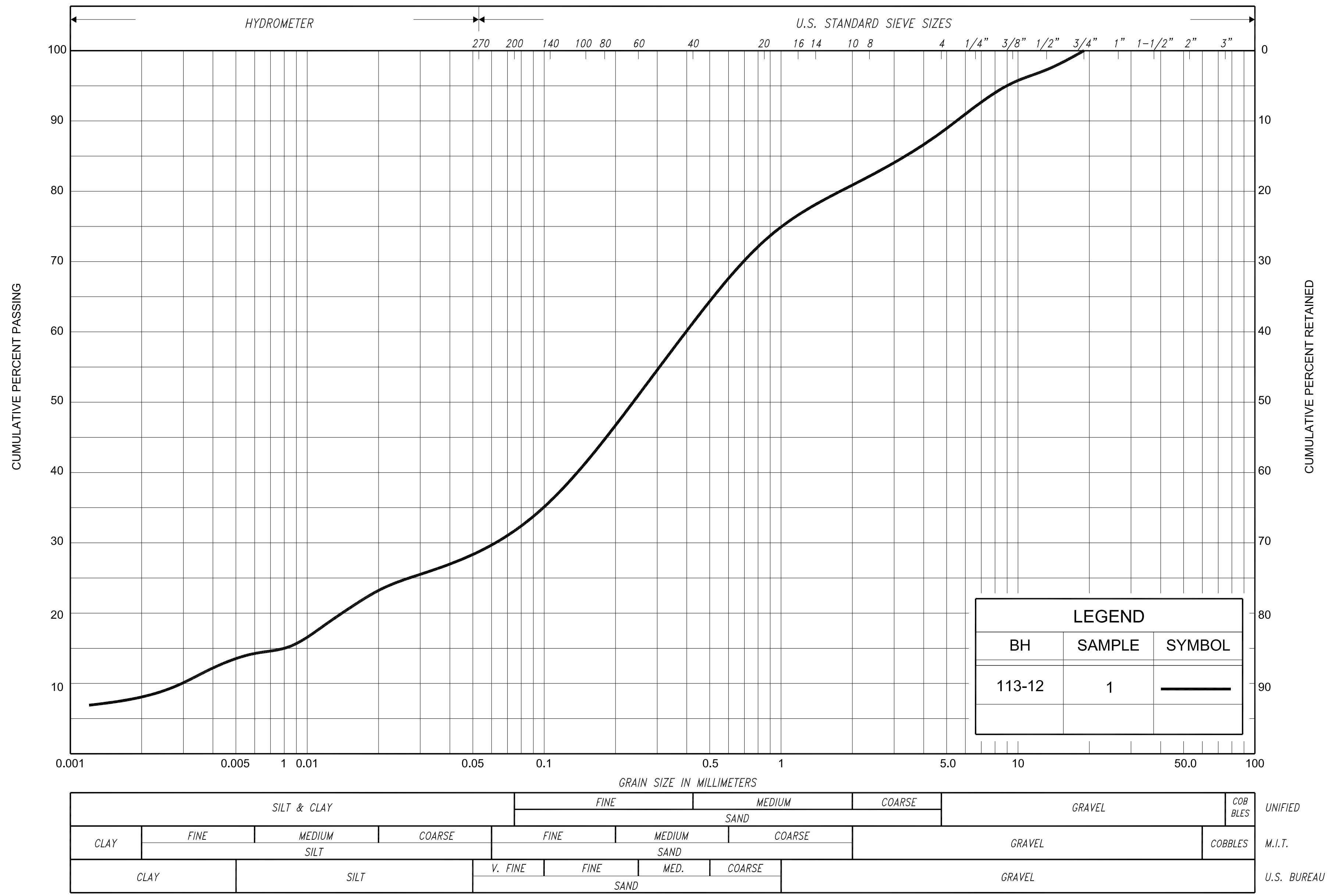
GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No. 112-GS-4

HWY: 69

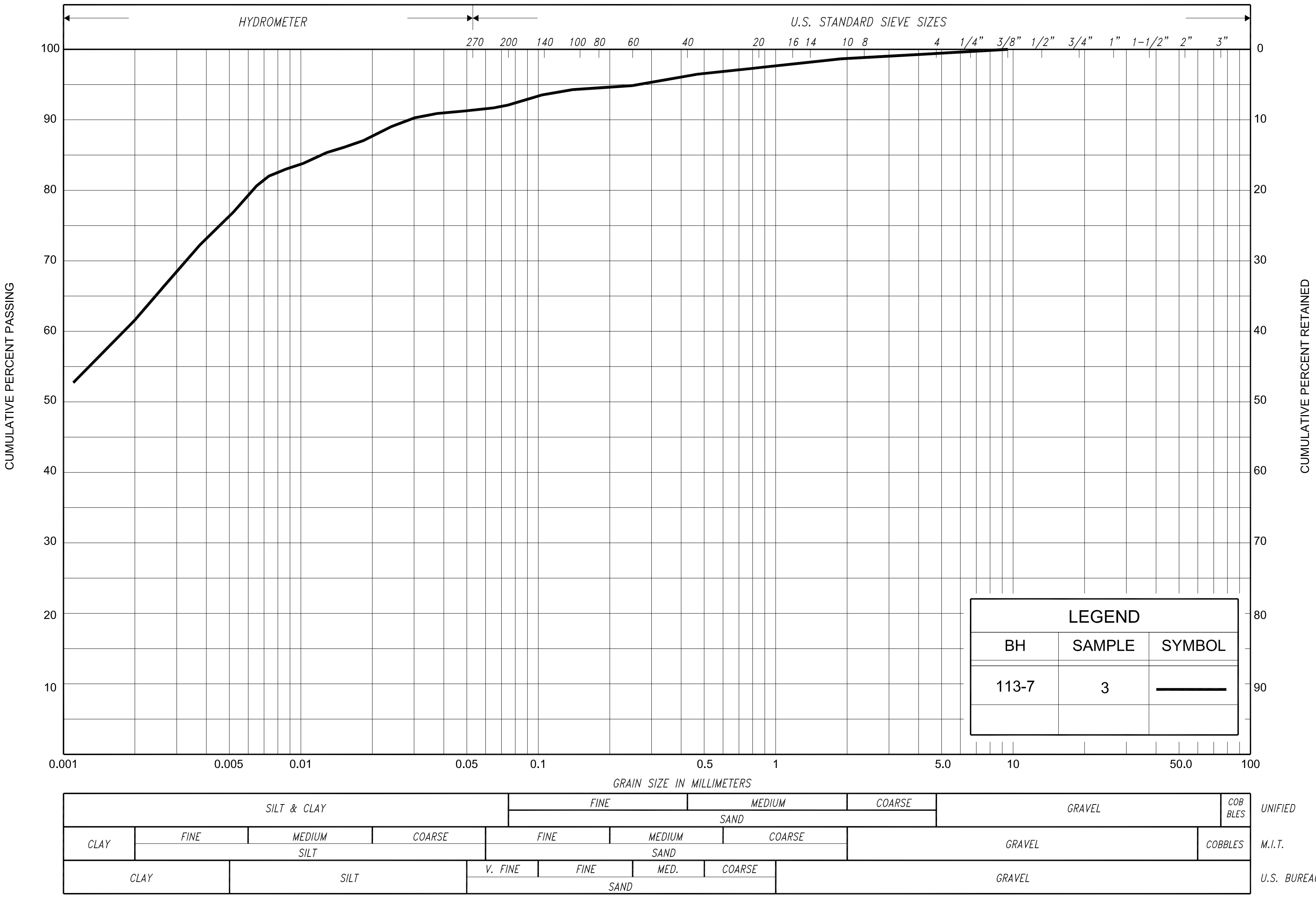
G.W.P. No. 5112-07-00



GRAIN SIZE DISTRIBUTION

SAND, with silt, some gravel, trace clay

FIG No.	113-GS-1
HWY:	69
G.W.P. No.	5112-07-00

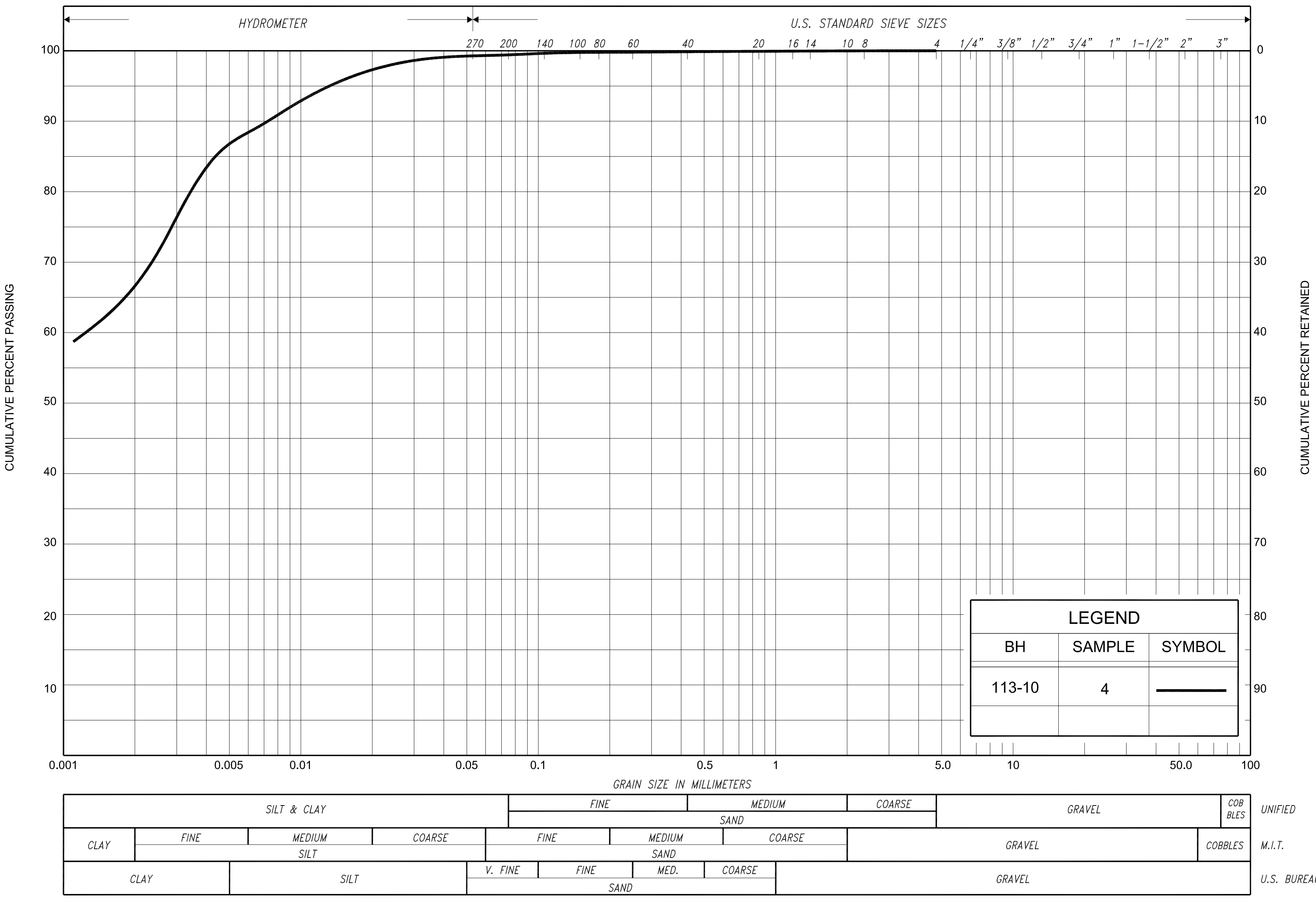


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand, trace gravel

FIG No.	113-GS-2
HWY:	69
G.W.P. No.	5112-07-00

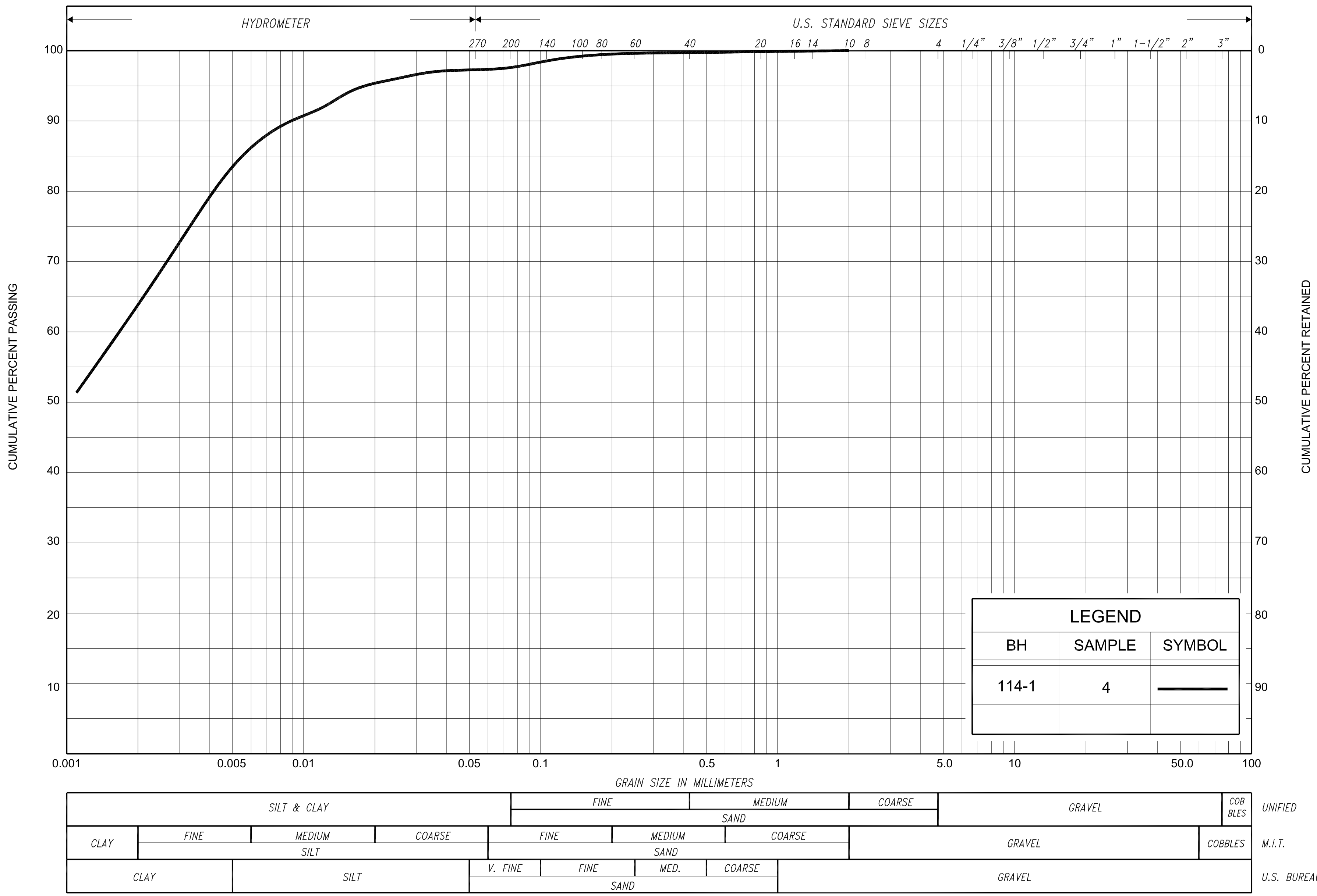


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	113-GS-3
HWY:	69
G.W.P. No.	5112-07-00

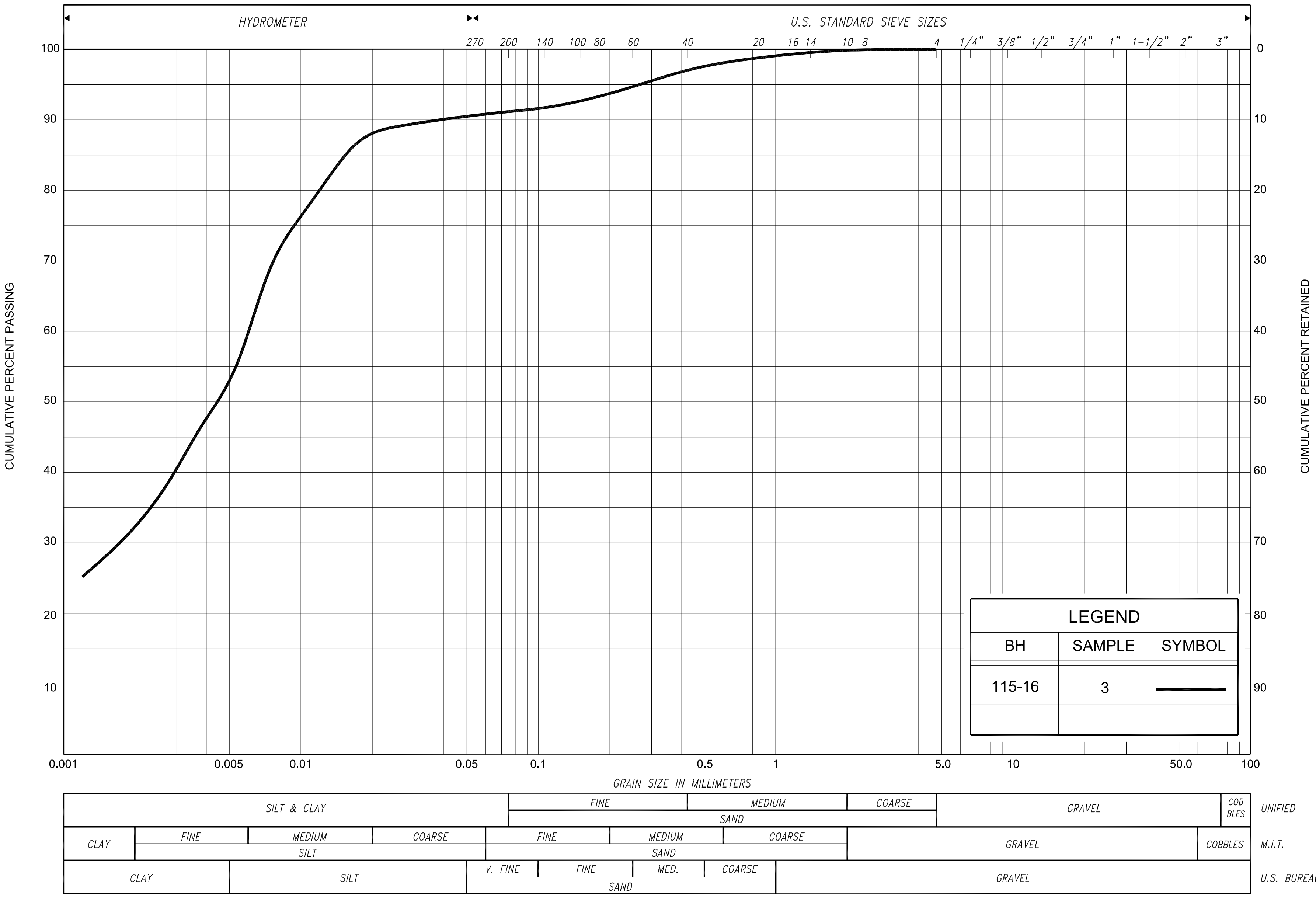


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	114-GS-1
HWY:	69
G.W.P. No.	5112-07-00



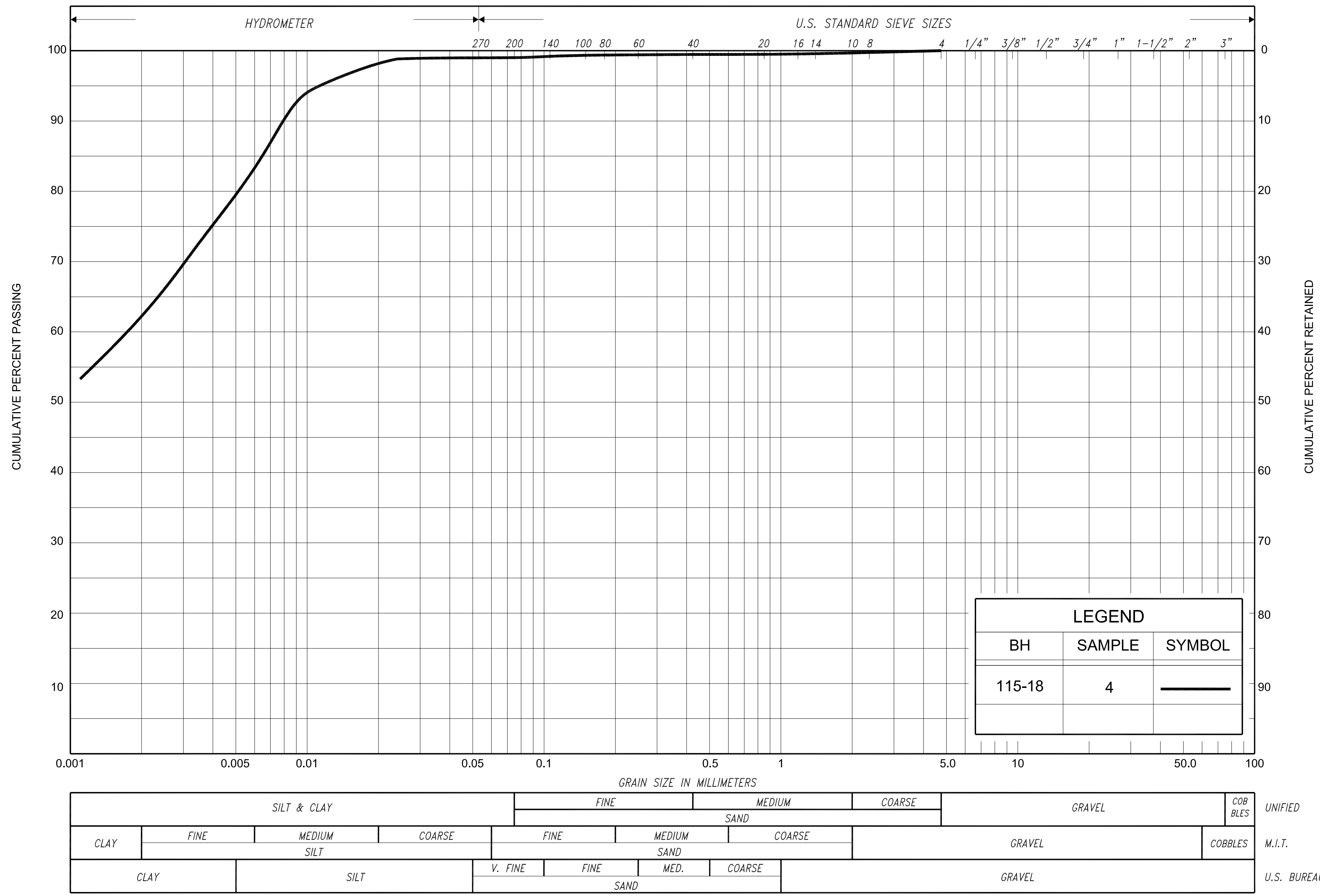
LEGEND		
BH	SAMPLE	SYMBOL
115-16	3	———

Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No.	115-GS-1
HWY:	69
G.W.P. No.	5112-07-00

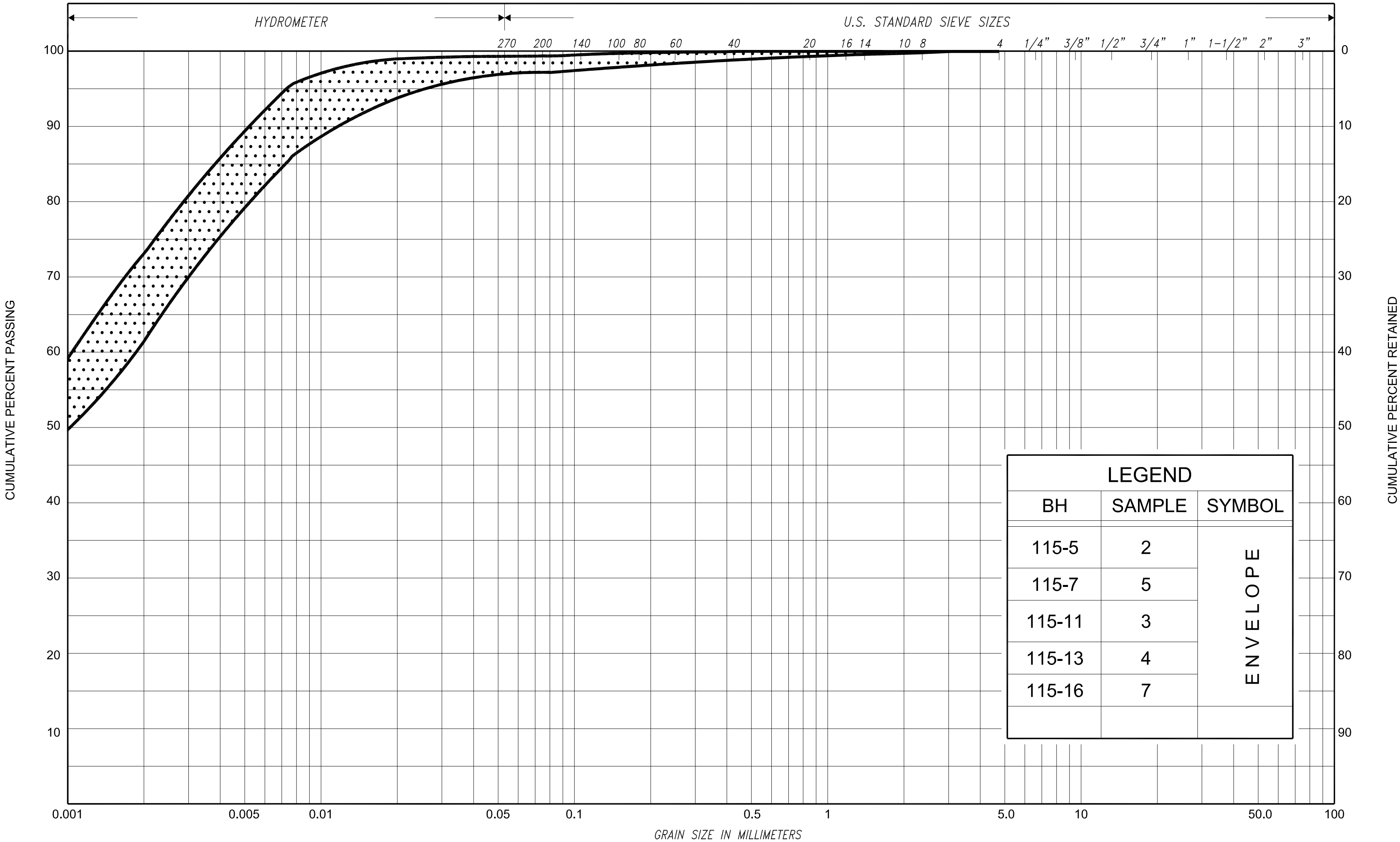


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	115-GS-2
HWY:	69
G.W.P. No.	5112-07-00



LEGEND		
BH	SAMPLE	SYMBOL
115-5	2	ENVELOPE
115-7	5	
115-11	3	
115-13	4	
115-16	7	

SILT & CLAY	SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	UNIFIED

CLAY	SILT: FINE	SILT: MEDIUM	SILT: COARSE	SAND: FINE	SAND: MEDIUM	SAND: COARSE	GRAVEL	COBBLES	M.I.T.

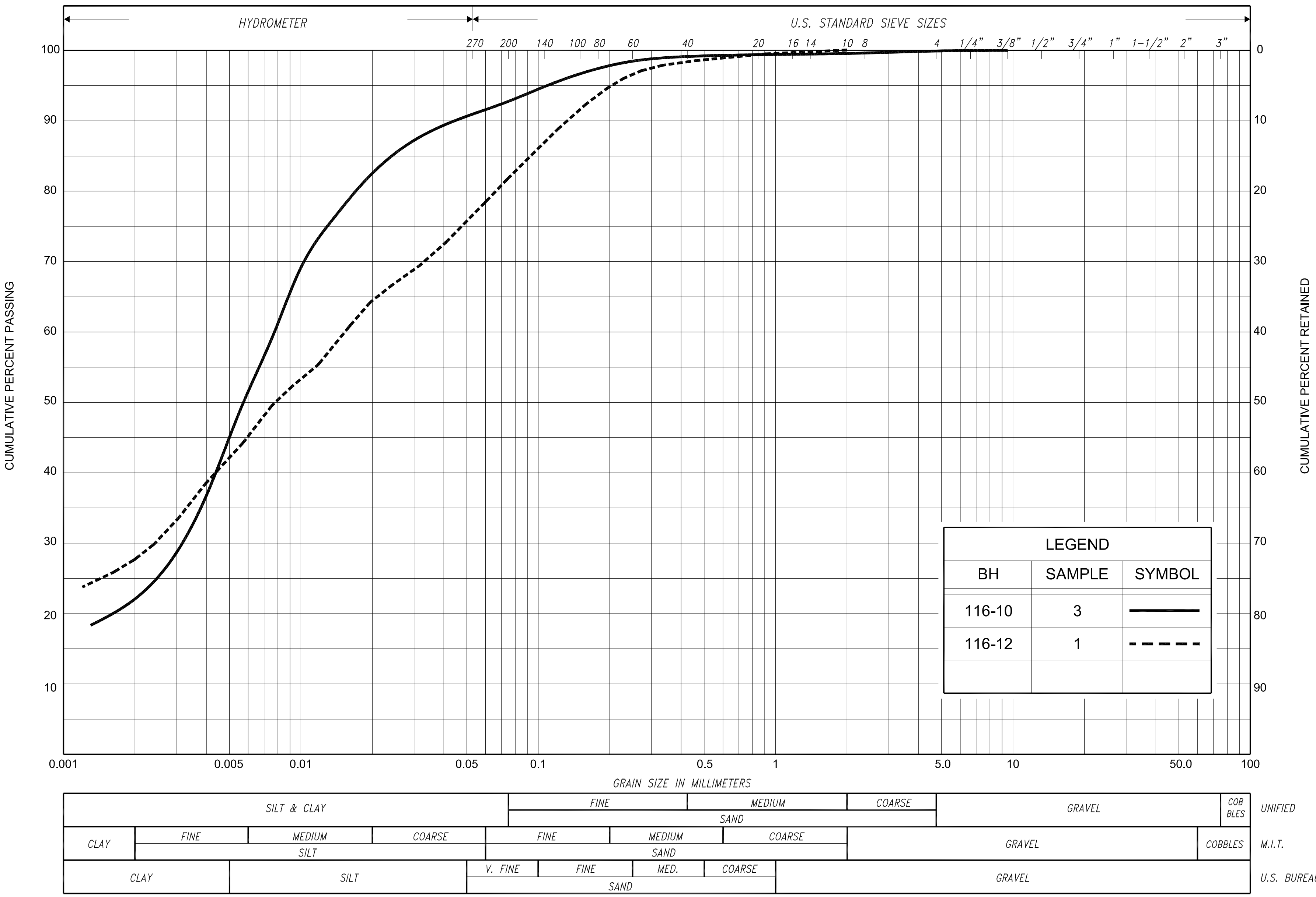
CLAY	SILT	SAND: V. FINE	SAND: FINE	SAND: MED.	SAND: COARSE	GRAVEL	U.S. BUREAU

Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	115-GS-3
HWY:	69
G.W.P. No.	5112-07-00

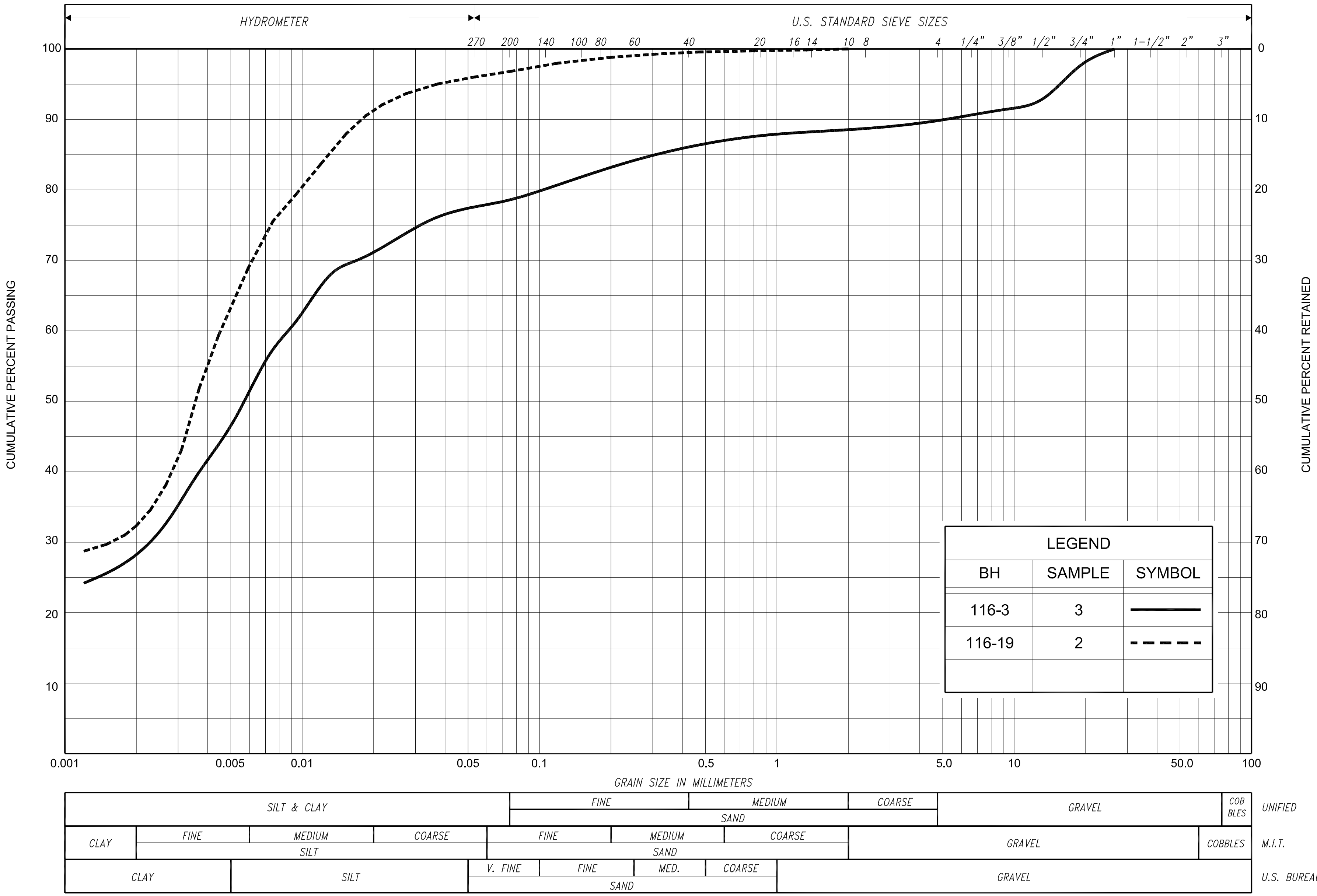


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace to some sand

FIG No.	116-GS-1
HWY:	69
G.W.P. No.	5112-07-00

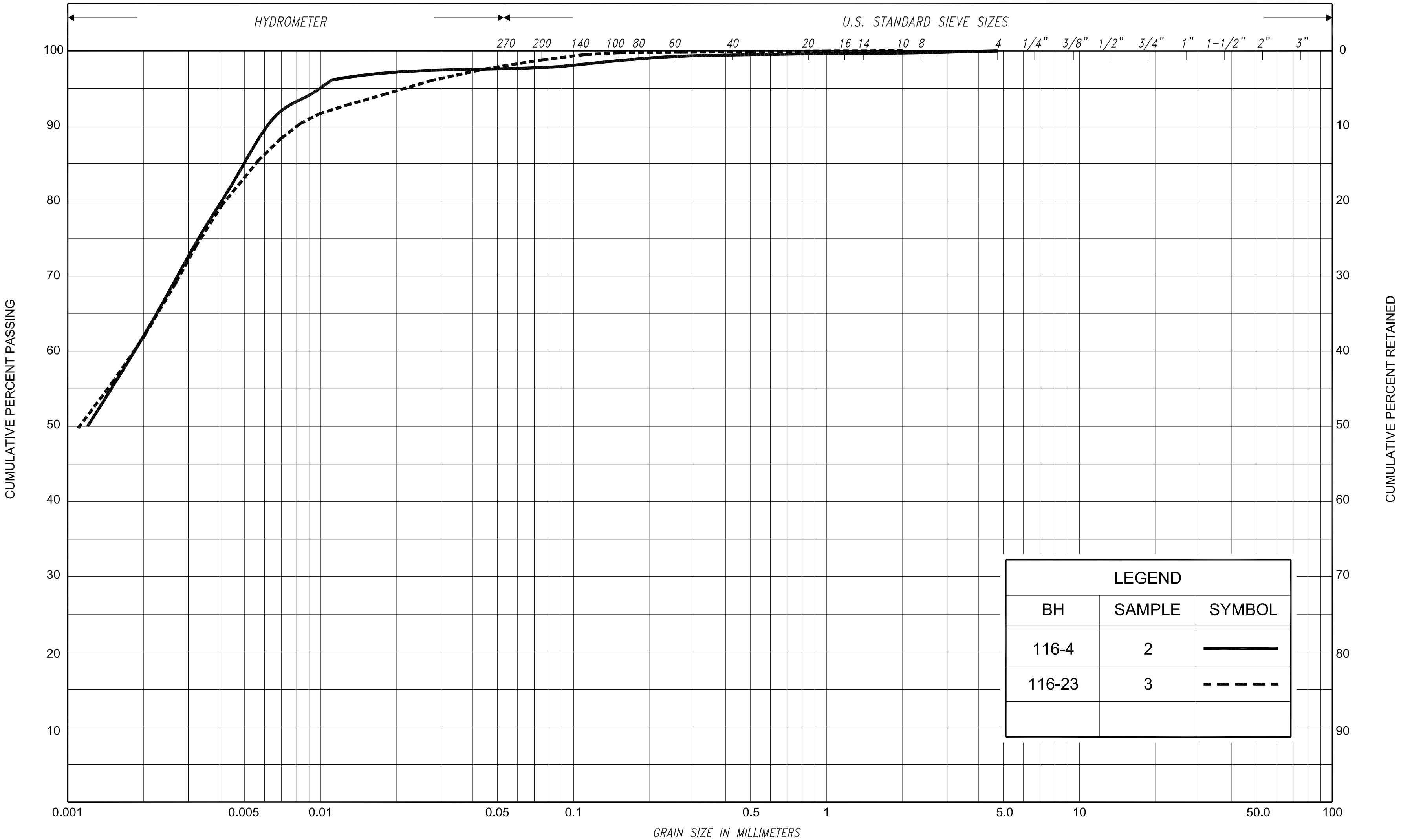


GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace to some sand, trace to some gravel

FIG No.	116-GS-2
HWY:	69
G.W.P. No.	5112-07-00

Ontario



SILT & CLAY			FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL	COBBLES	UNIFIED
CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	GRAVEL / COBBLES	M.I.T.
CLAY	SILT	V. FINE SAND	FINE SAND	MED. SAND	COARSE SAND	GRAVEL		U.S. BUREAU

LEGEND

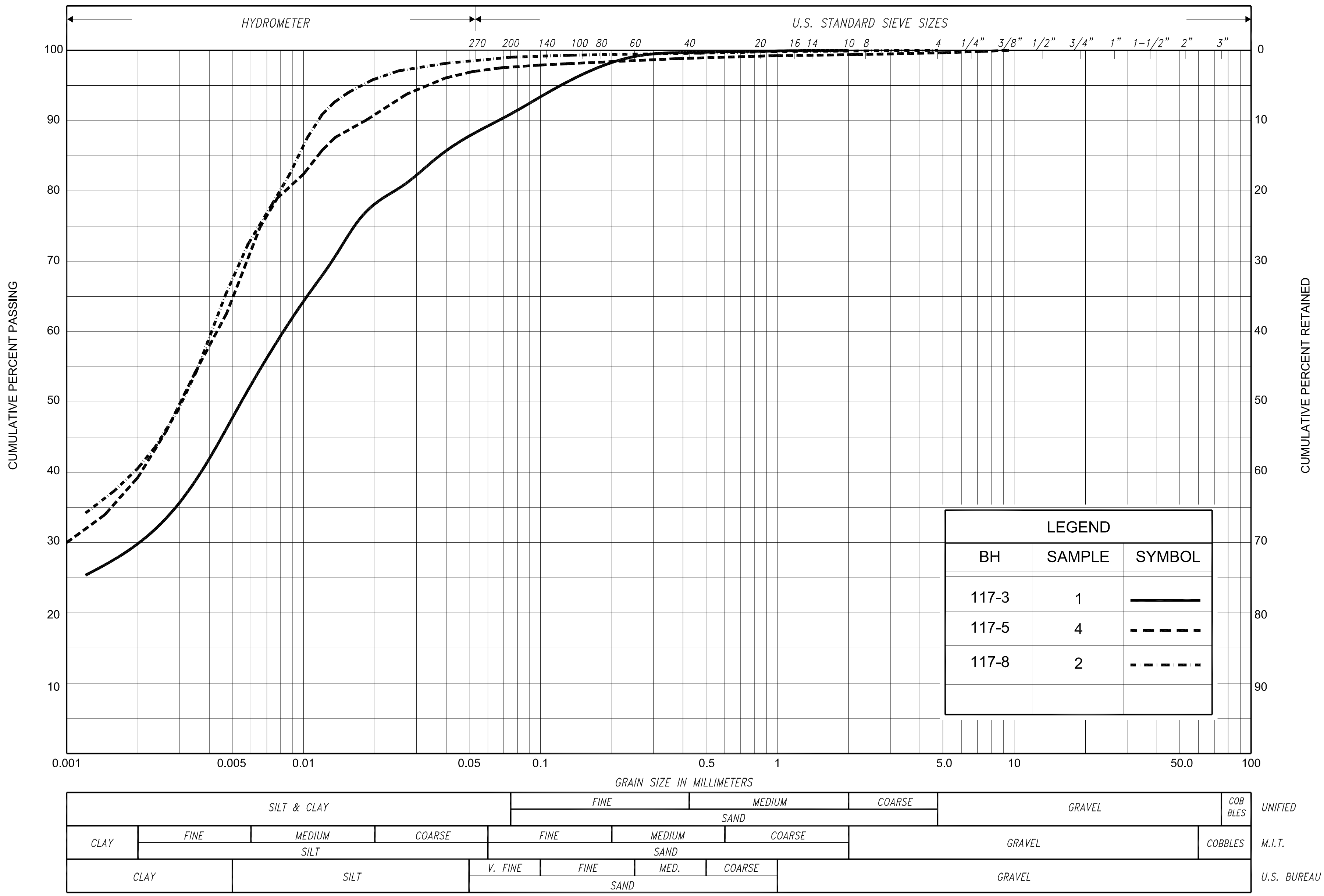
BH	SAMPLE	SYMBOL
116-4	2	——— (solid)
116-23	3	- - - - (dashed)

Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	116-GS-3
HWY:	69
G.W.P. No.	5112-07-00

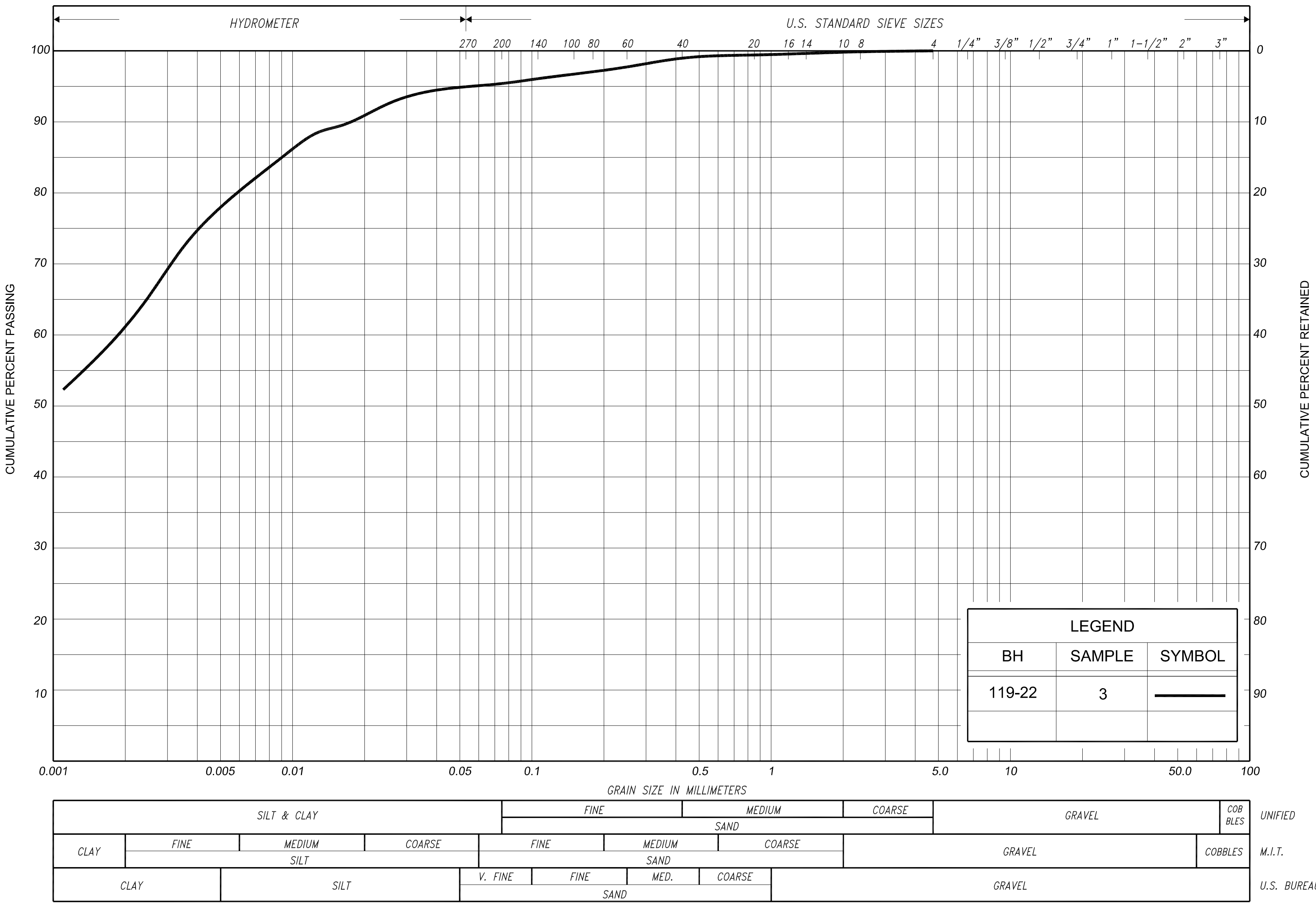


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	117-GS-1
HWY:	69
G.W.P. No.	5112-07-00

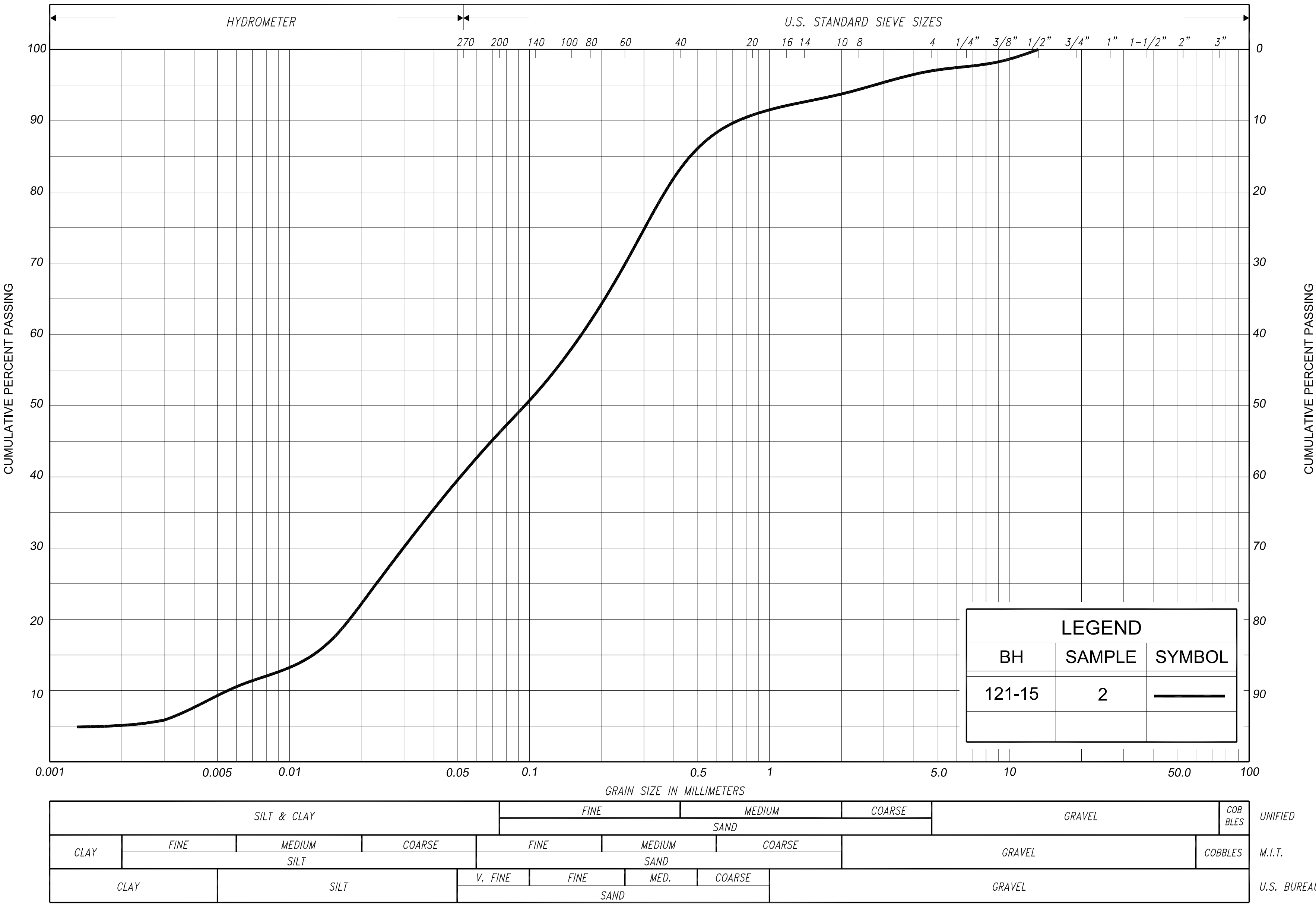


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	119-GS-1
HWY:	69
G.W.P. No.	5112-07-00

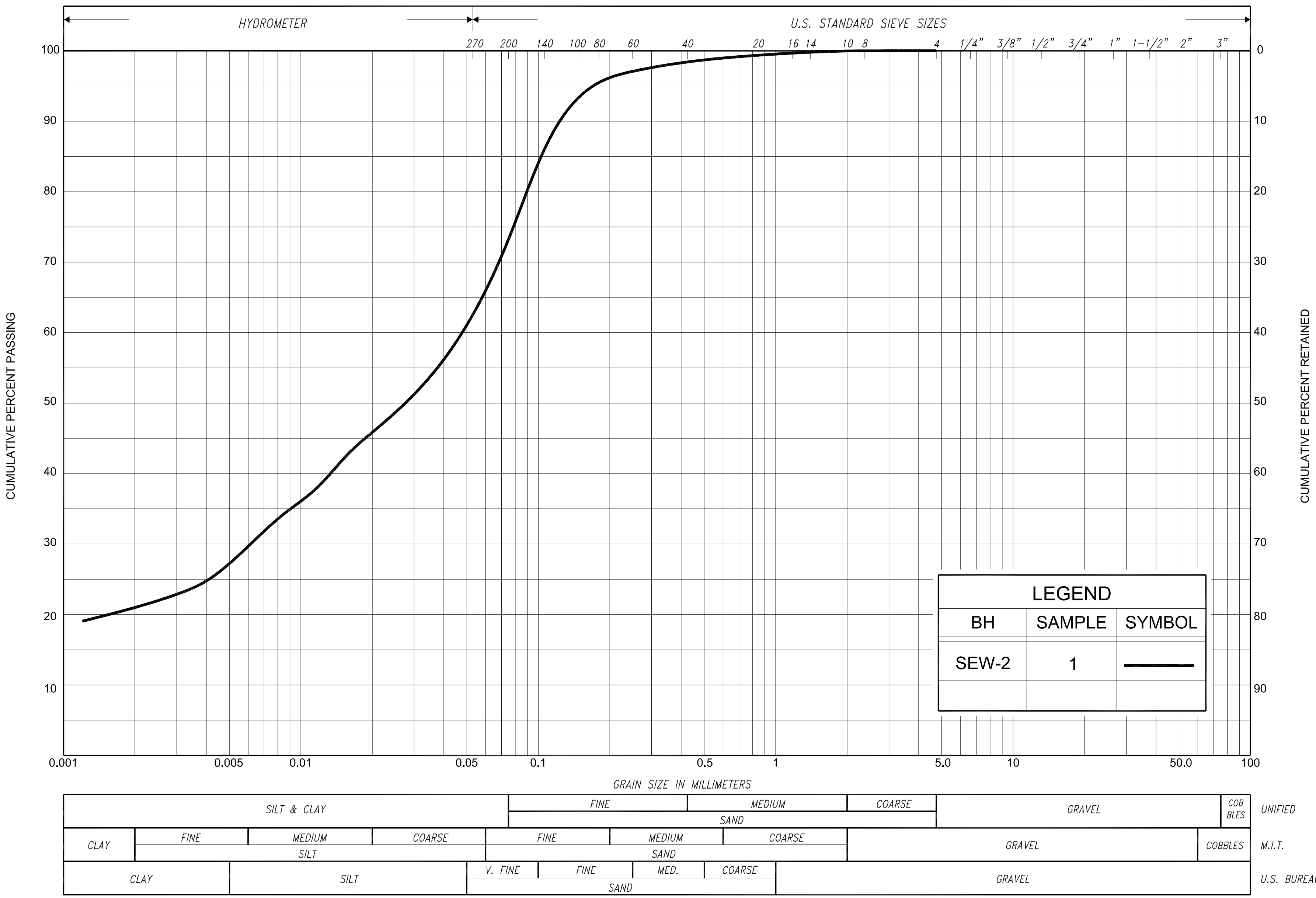


Ontario

GRAIN SIZE DISTRIBUTION

SAND and SILT, trace clay, trace gravel

FIG No.	121-GS-1
HWY:	69
G.W.P. No.	5112-07-00

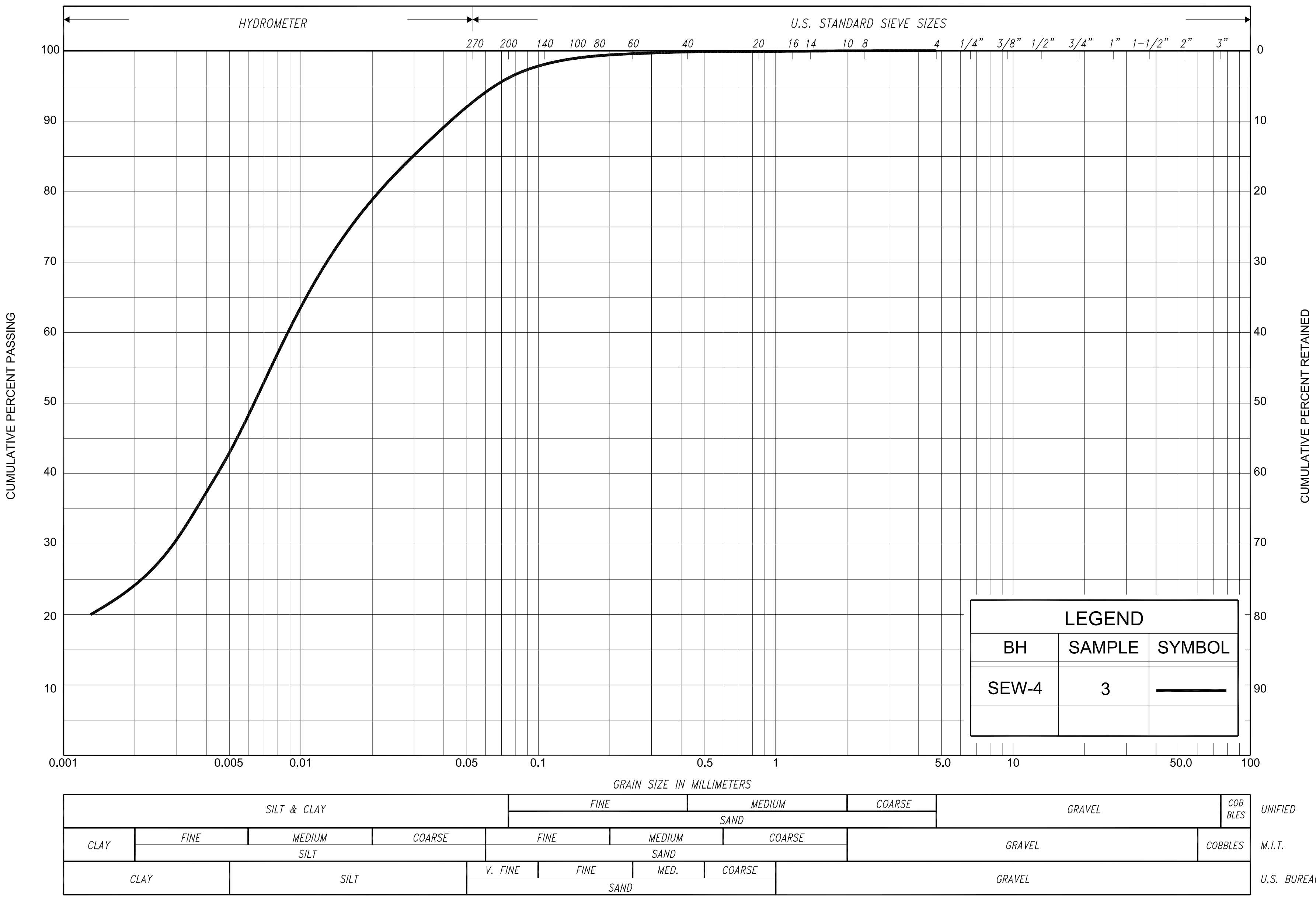


Ontario

GRAIN SIZE DISTRIBUTION

ORGANIC SILT, with sand, with clay

FIG No.	SEW-GS-1
HWY:	69
G.W.P. No.	5112-07-00

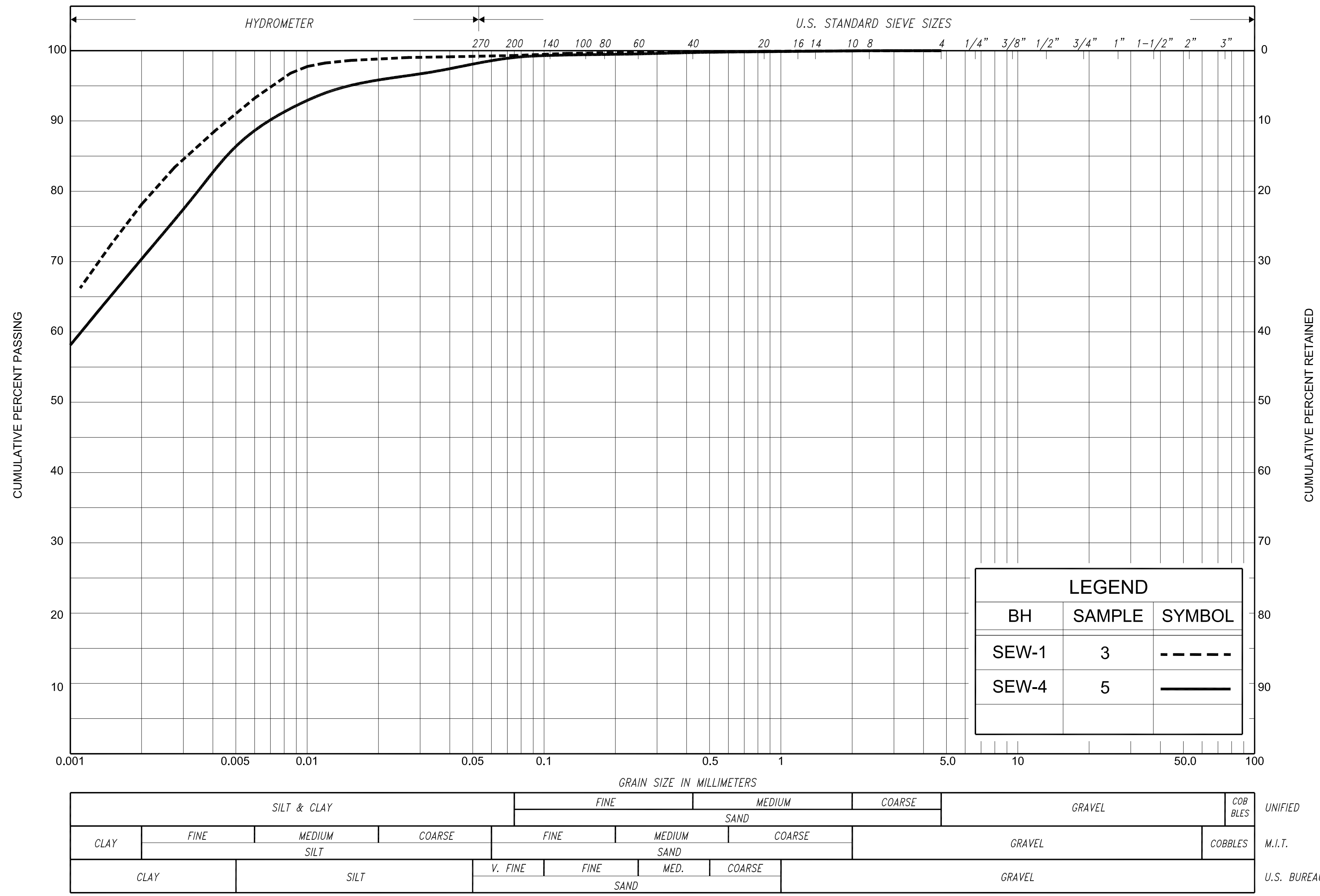


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, trace sand

FIG No.	SEW-GS-2
HWY:	69
G.W.P. No.	5112-07-00

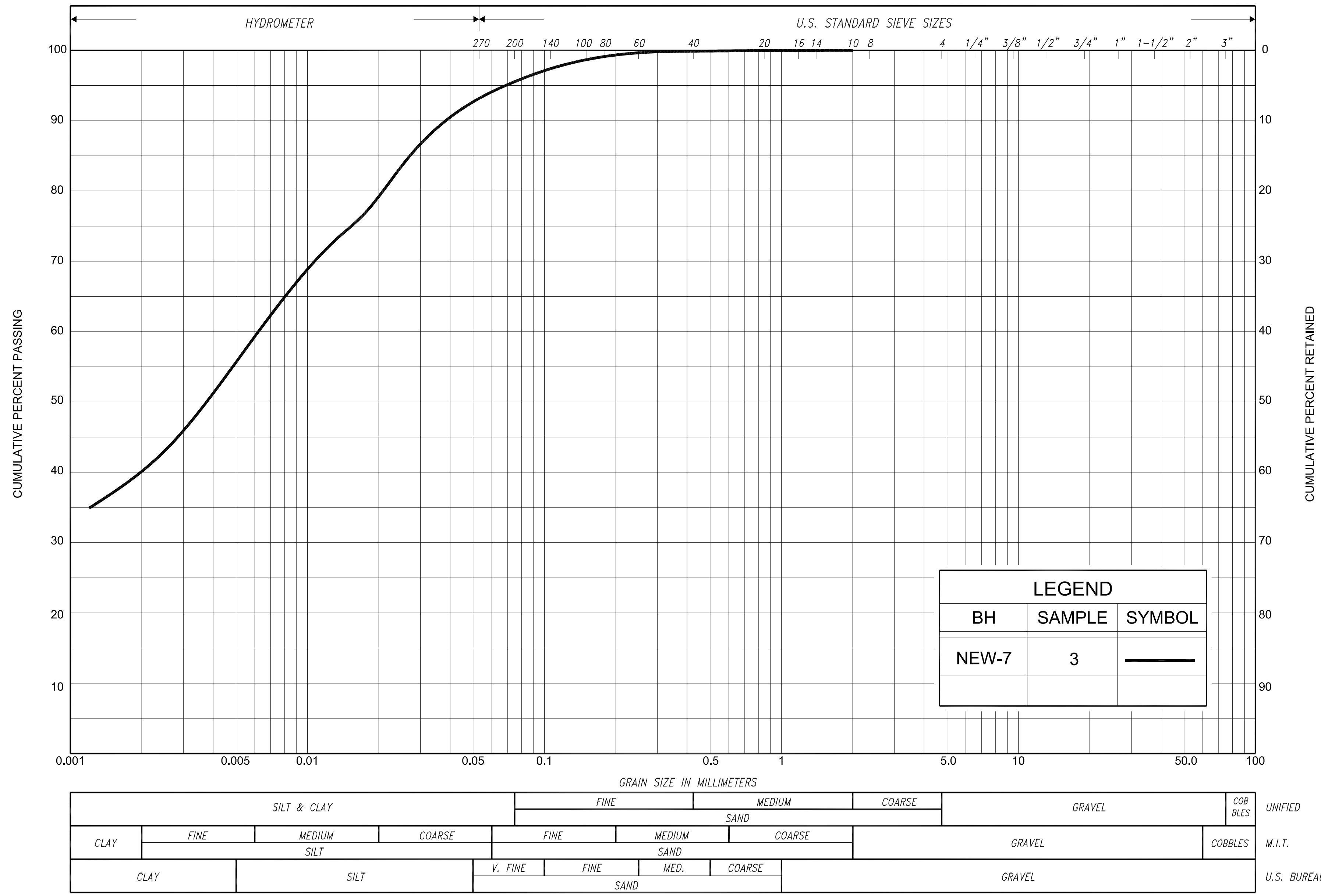


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	SEW-GS-3
HWY:	69
G.W.P. No.	5112-07-00

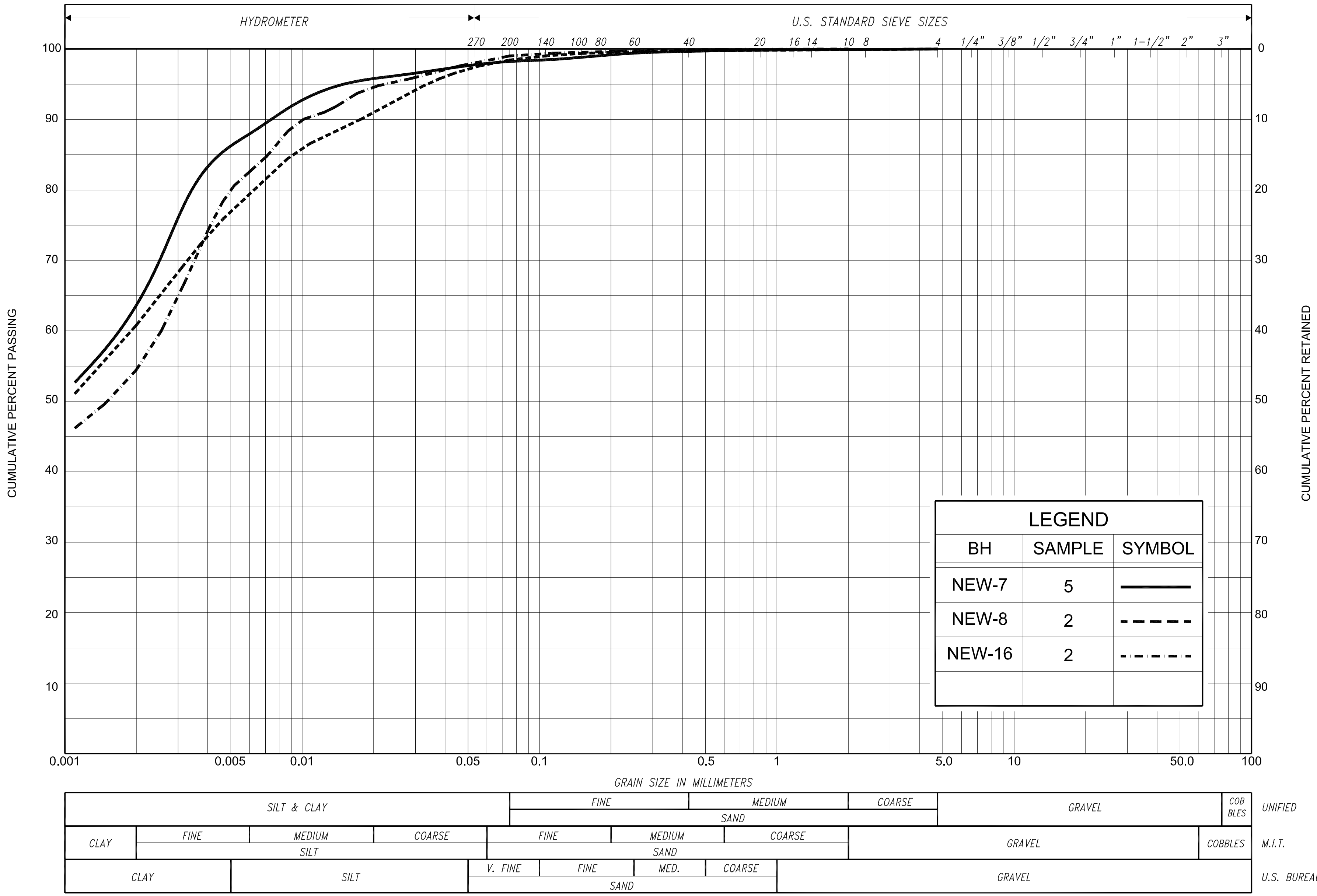


Ontario

GRAIN SIZE DISTRIBUTION

SILTY CLAY, trace sand

FIG No.	NEW-GS-1
HWY:	69
G.W.P. No.	5112-07-00



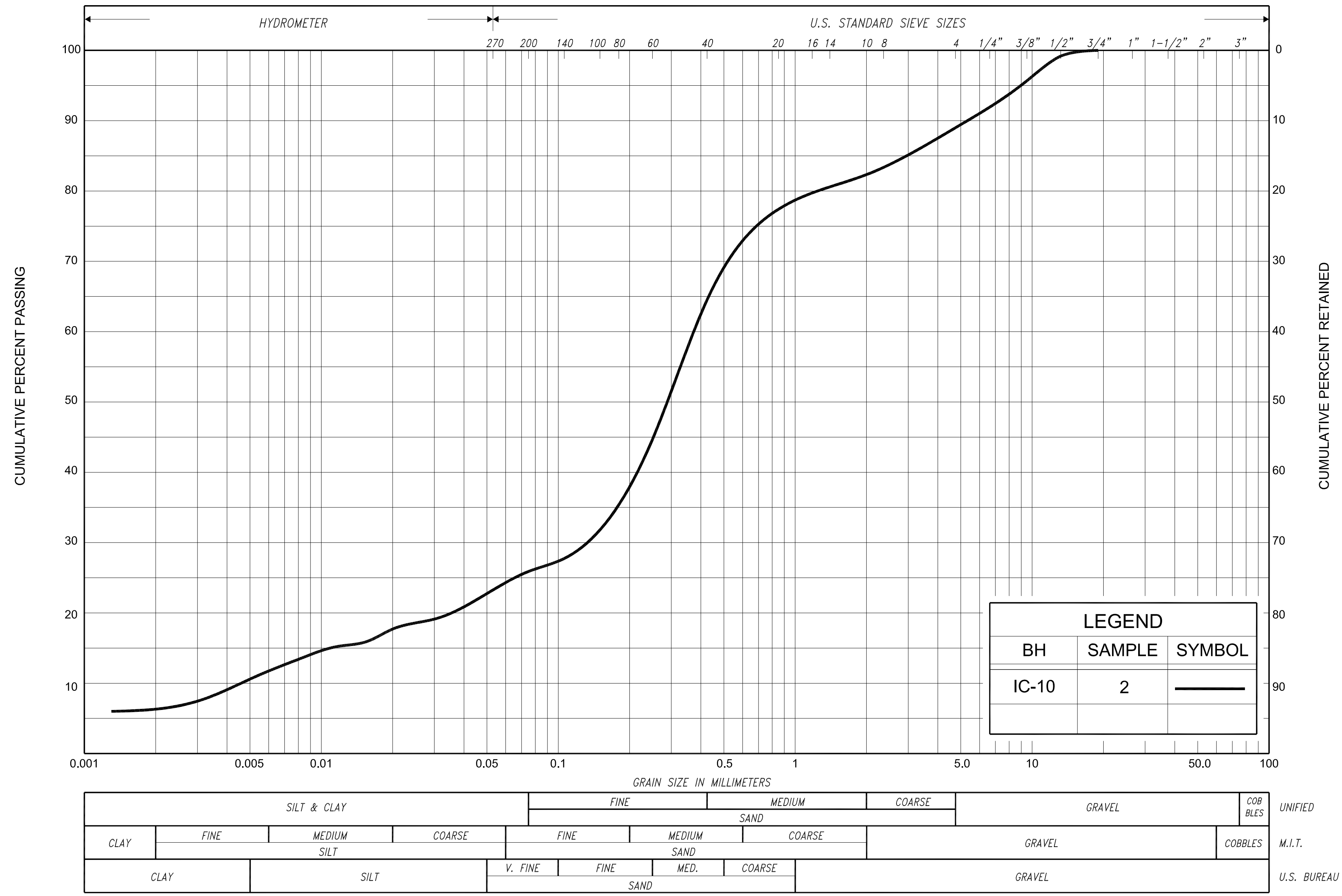
BH	SAMPLE	SYMBOL
NEW-7	5	———
NEW-8	2	– – – –
NEW-16	2	-·-·-·-

Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand

FIG No.	NEW-GS-2
HWY:	69
G.W.P. No.	5112-07-00

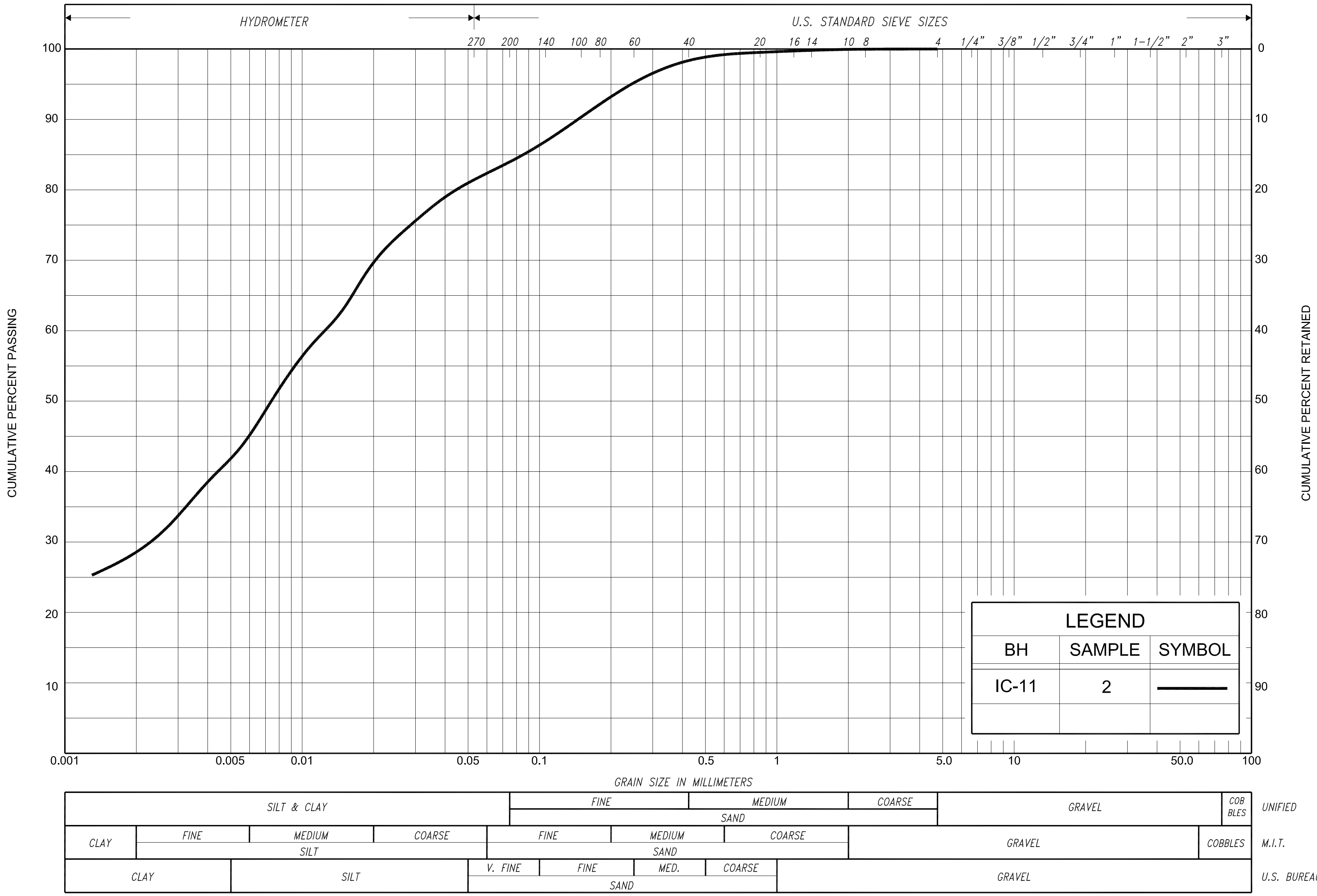


Ontario

GRAIN SIZE DISTRIBUTION

ORGANIC SAND, some silt, some gravel, trace clay

FIG No.	IC-GS-1
HWY:	69
G.W.P. No.	5112-07-00

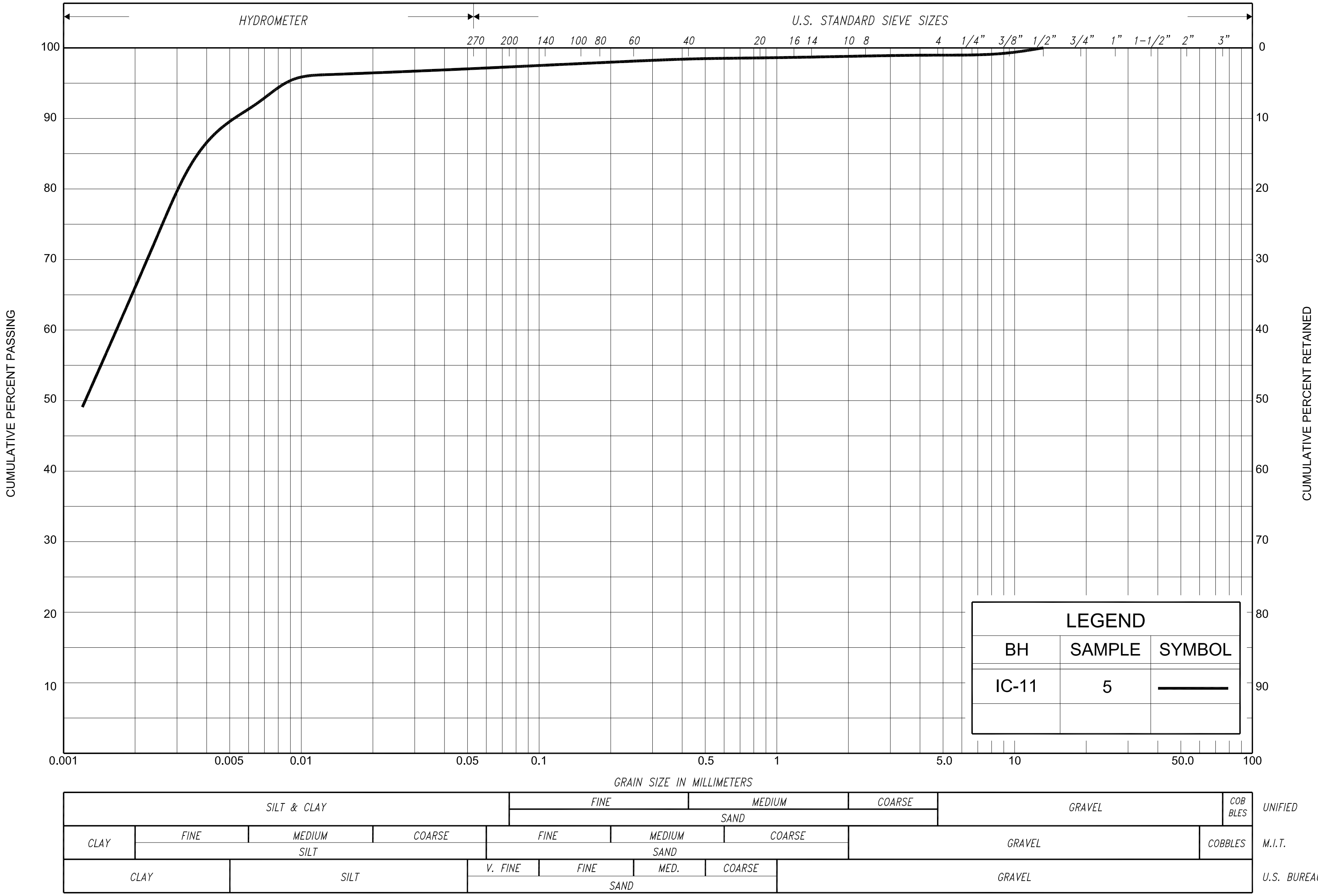


Ontario

GRAIN SIZE DISTRIBUTION

CLAYEY SILT, some sand

FIG No.	IC-GS-2
HWY:	69
G.W.P. No.	5112-07-00

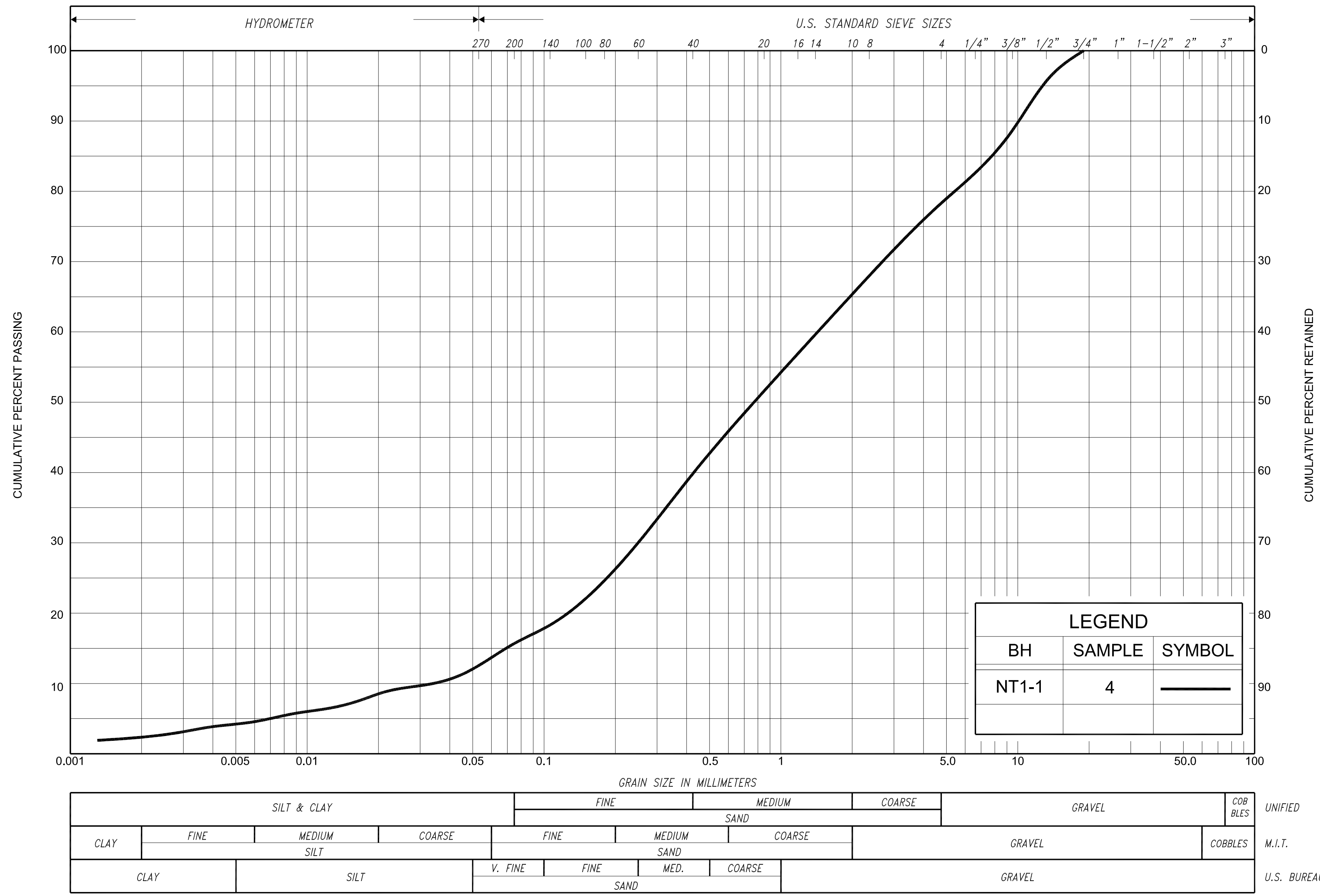


Ontario

GRAIN SIZE DISTRIBUTION

CLAY, trace sand, trace gravel

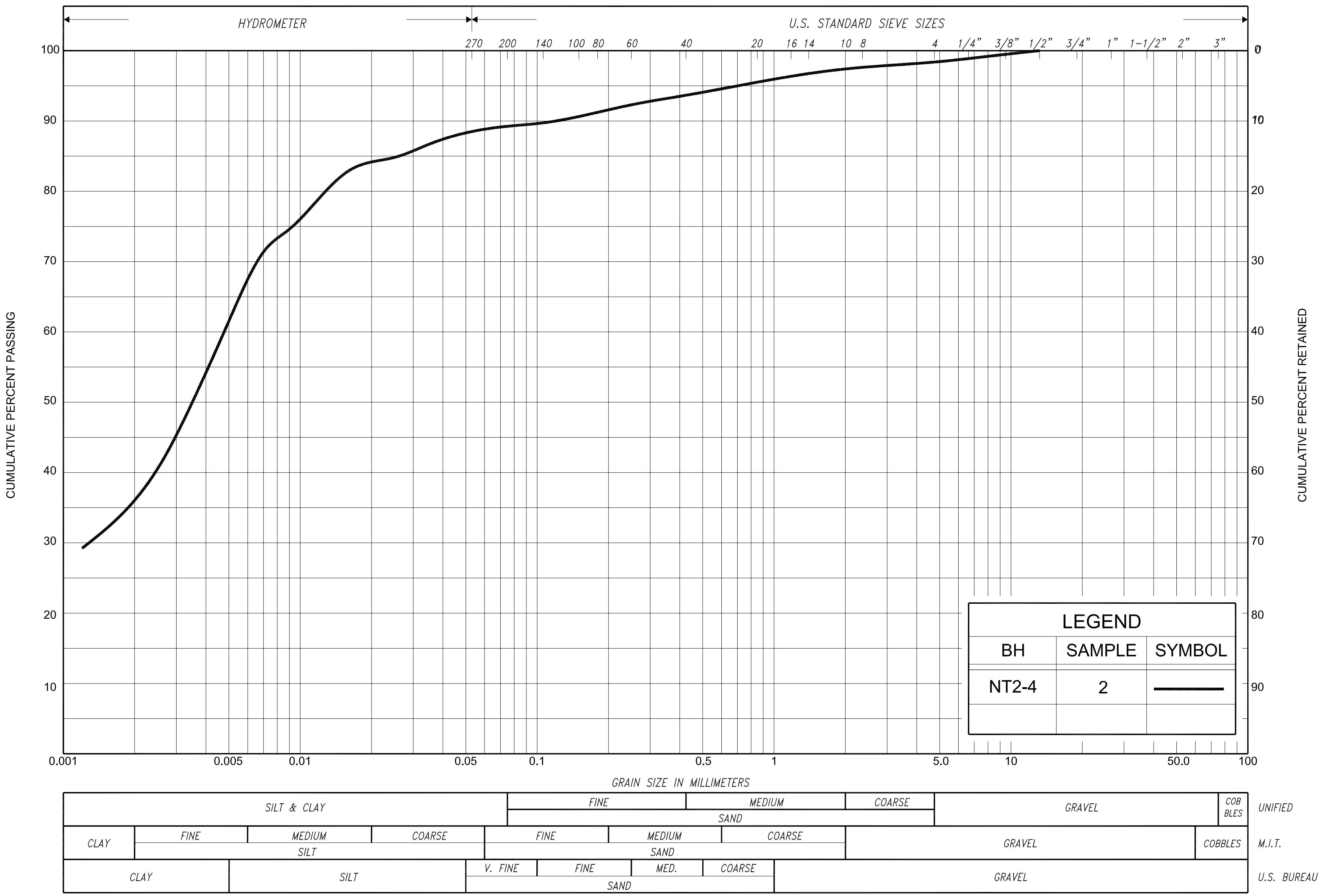
FIG No.	IC-GS-3
HWY:	69
G.W.P. No.	5112-07-00



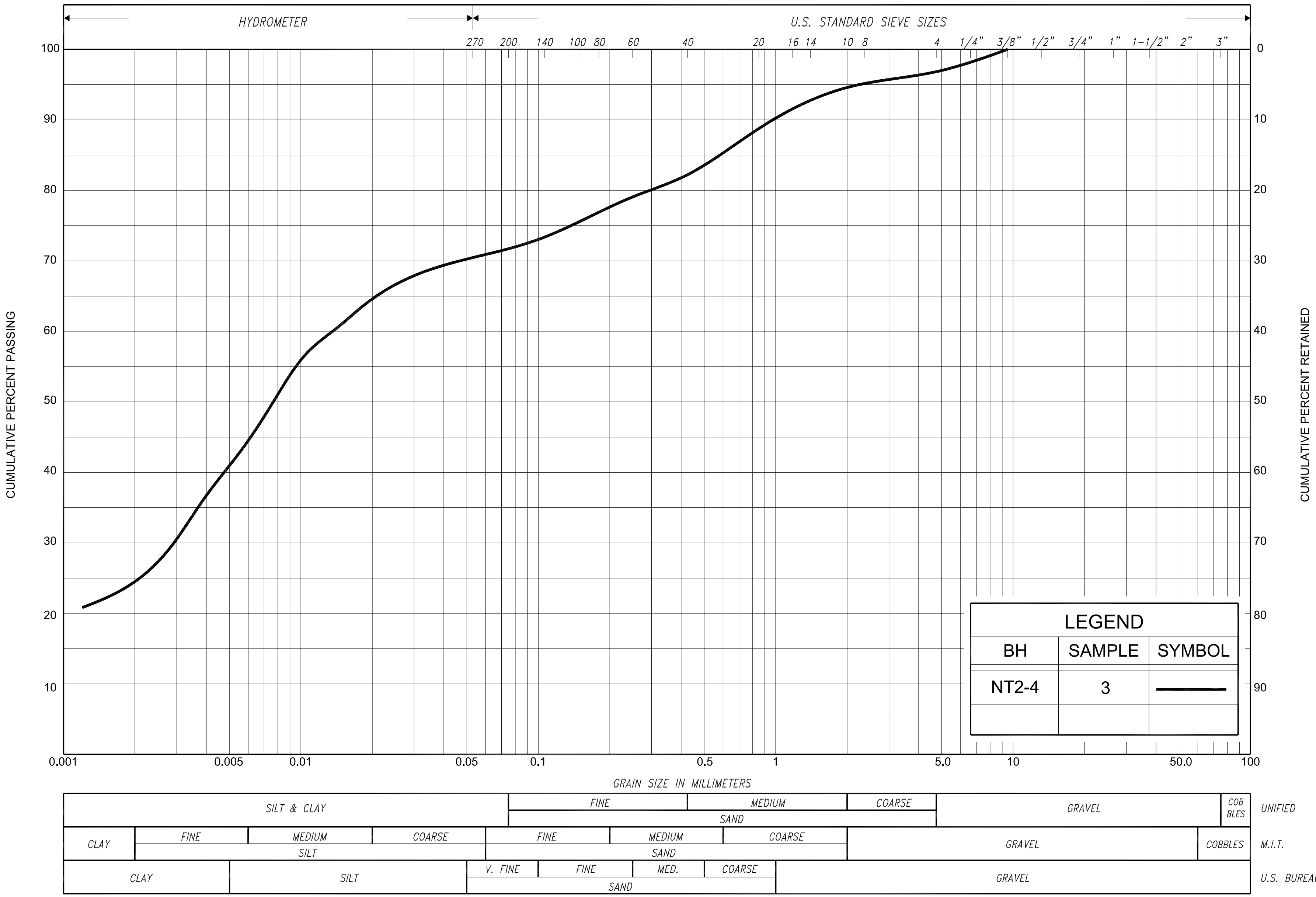
GRAIN SIZE DISTRIBUTION

SAND, with gravel, some silt, trace clay

FIG No.	NT1-GS-1
HWY:	69
G.W.P. No.	5112-07-00



Ontario	GRAIN SIZE DISTRIBUTION	FIG No.	NT2-GS-1
	SILTY CLAY, trace sand, trace gravel	HWY:	69
		G.W.P. No.	5112-07-00



Ontario

GRAIN SIZE DISTRIBUTION

SANDY SILT, trace gravel
clayey silt layers

FIG No.	NT2-GS-2
HWY:	69
G.W.P. No.	5112-07-00

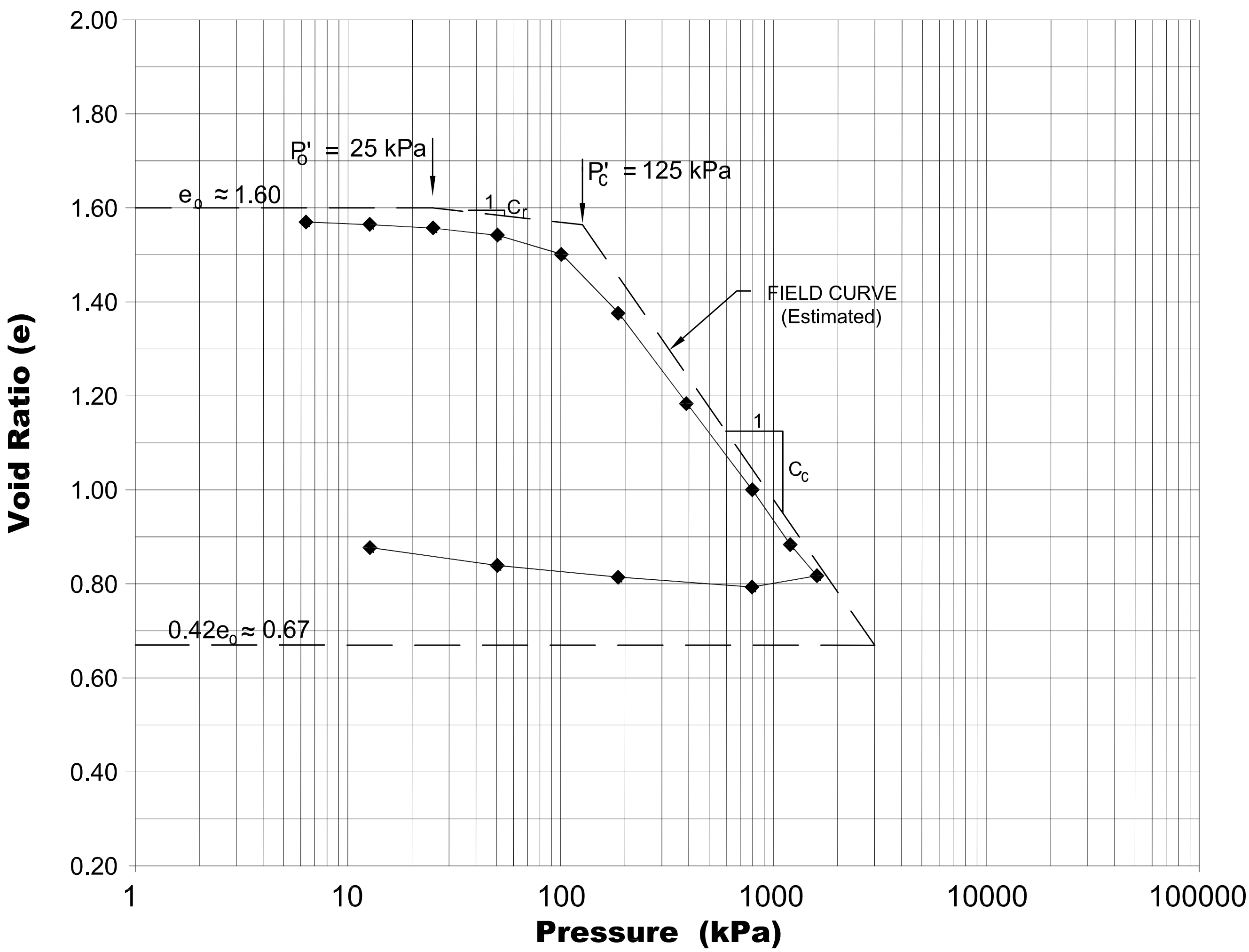
Peto MacCallum Ltd.
CONSULTING ENGINEERS

Laboratory Consolidation Test Results

Highway 69
From 5.3 km south of Highway 529 (North Junction) to
north of Highway 529 (North Junction) 7.5 km
G.W.P. 5112-07-00
District 54, Sudbury, Ontario

Swamp 112, Borehole 112-6, Sample 6
Sta. 19+384, 40.0 m Rt., Depth 3.8 - 4.3 m

Void Ratio versus Log of Pressure



SOIL TYPE: CLAYEY SILT, trace sand			
e_o ≈ 1.60 W_o = 61% γ = 16.2 kN/m^3	P'_o = 25 kPa P'_c = 125 kPa C_c = 0.64 C_r = 0.05	W_L = 29 W_P = 18 PI = 11	FIGURE No: 112-C-1 HIGHWAY: 69 MAGNETAWAN FIRST NATION G.W.P. : 5112-07-00

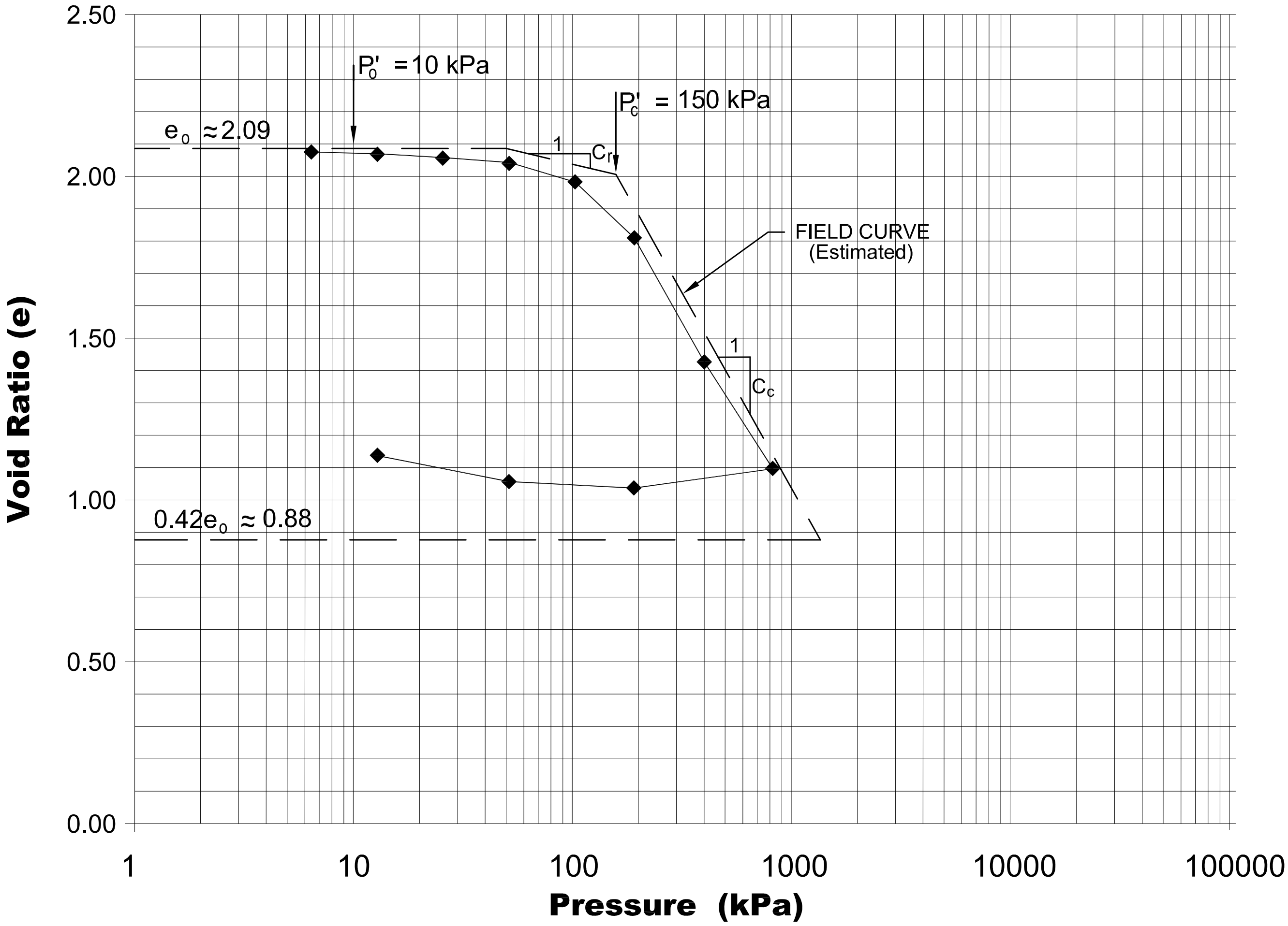
Peto MacCallum Ltd.
CONSULTING ENGINEERS

Laboratory Consolidation Test Results

Highway 69
From 5.3 km south of Highway 529 (North Junction) to
north of Highway 529 (North Junction) 7.5 km
G.W.P. 5112-07-00
District 54, Sudbury, Ontario

Swamp 113, Borehole 113-7, Sample 3
Sta. 19+772, 19.0 m Lt., Depth 2.3 - 2.7 m

Void Ratio versus Log of Pressure



SOIL TYPE: SILTY CLAY, trace sand, trace gravel (organic inclusions)			
e_o = 2.09	P'_o = 10 kPa	W_L = 49	FIGURE: 113-C-1
W_o = 77%	P'_c = 150 kPa	W_P = 20	HIGHWAY: 69
γ = 15.6 kN/m^3	C_c = 1.25	PI = 29	MAGNETAWAN FIRST NATION
	C_r = 0.07		G.W.P. 5112-07-00

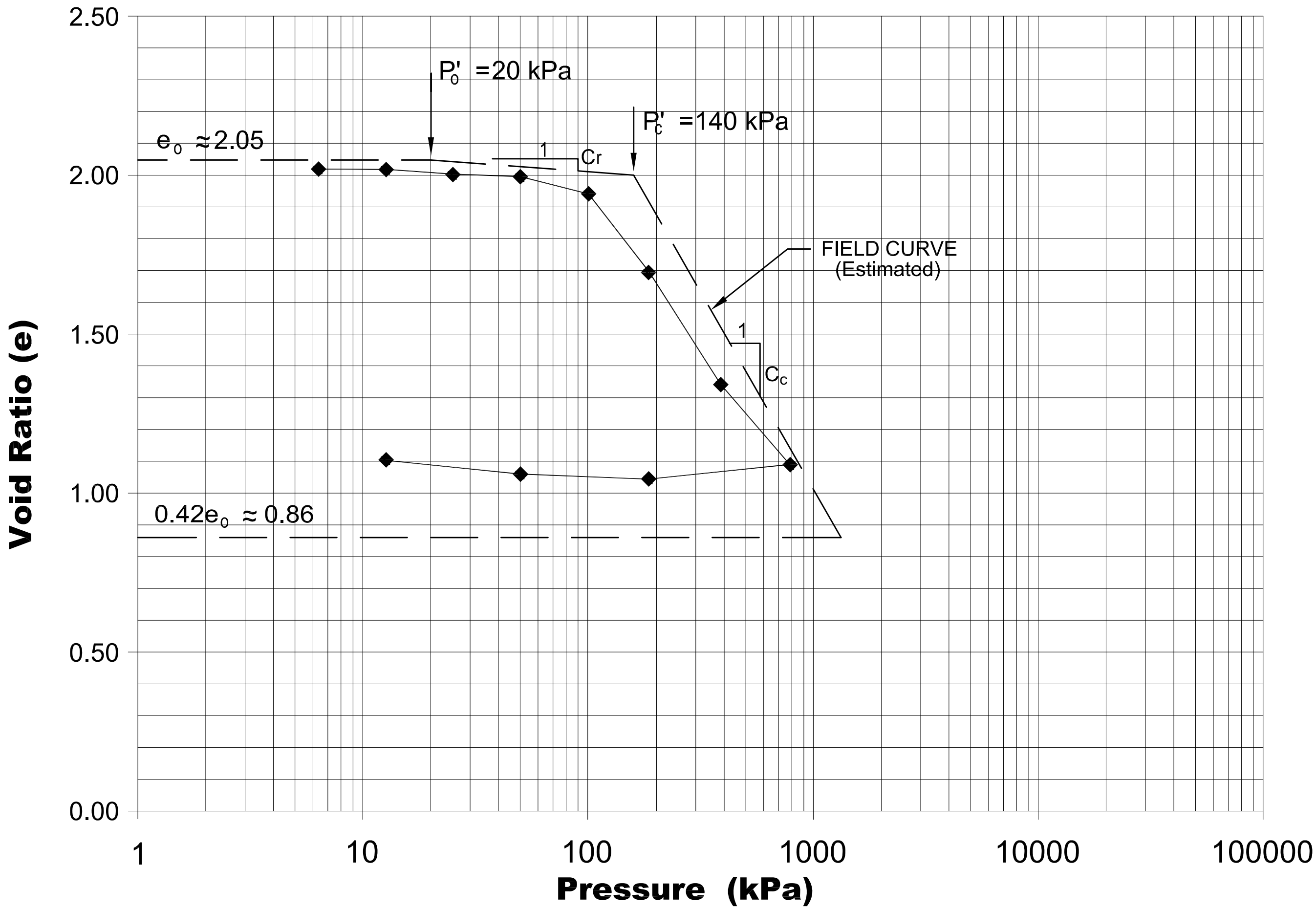
Peto MacCallum Ltd.
CONSULTING ENGINEERS

Laboratory Consolidation Test Results

Highway 69
From 5.3 km south of Highway 529 (North Junction) to
north of Highway 529 (North Junction) 7.5 km
G.W.P. 5112-07-00
District 54, Sudbury, Ontario

Ramp S-E/W, Borehole SEW-4, Sample 5
Sta. 20+287.5, 20.0 m Rt., Depth 3.8 - 4.3 m

Void Ratio versus Log of Pressure



SOIL TYPE: CLAY, trace sand			
e_o ≈ 2.05	P'_o = 20 kPa	W_L = 57	FIGURE: SEW-C-1
W_o = 75%	P'_c = 140 kPa	W_P = 22	HIGHWAY: 69
γ = 15.5 kN/m^3	C_c = 1.19	PI = 35	MAGNETAWAN FIRST NATION
	C_r = 0.06		G.W.P. 5112-07-00

FOUNDATION DESIGN REPORT
SWAMP AND HIGH FILL CROSSINGS

for

HIGHWAY 69 FOUR-LANING
FROM 5.3 KM SOUTH OF HIGHWAY 529 (NORTH JUNCTION)
NORTHERLY TO 2.2 KM NORTH OF HIGHWAY 529, 7.5 KM
G.W.P. 5112-07-00
MAGNETAWAN FIRST NATION, ONTARIO

VOLUME 1

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GEOCRES No.: 41H-148
March 11, 2015

TABLE OF CONTENTS

FOUNDATION DESIGN REPORT
SWAMP AND HIGH FILL CROSSINGS
for
Highway 69 Four-Laning
From 5.3 km South of Highway 529 (North Junction) Northerly
to 2.2 km North of Highway 529 (North Junction), 7.5 km
G.W.P. 5112-07-00
Magnetawan First Nation, Ontario

1. INTRODUCTION

Realignment and four-laning of an approximately 7.5 km long section of Highway 69 that extends from 5.3 km south of Highway 529 (north junction) to 2.2 km north of Highway 529 (north junction), about 90 km south of Sudbury is planned. This report was prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The study corridor of the project extends from Station 16+020 to 23+636 in the Magnetawan First Nation and the Township of Wallbridge, new Highway 69 centreline. From approximate Station 16+020 to 19+370 (3.3 km) the new alignment will twin the existing alignment on the right. From Station 19+370 to 23+636 (4.2 km) the alignment diverges to the east (East Shift). An intersection at Highway 529 and associated service road and ramps are planned as well as a temporary transfer from the new NBL to the existing Highway 69.

A total of 11 swamp and high fill crossings were identified for foundation investigation within the twinning section of the Highway 69 alignment from approximate Station 16+020 to 19+350. A total of 18 swamp and high fill crossings were identified for foundation investigation within the East Shift section of the highway alignment from approximate Station 19+350 to 23+636. For ease of reference, the crossings have been designated sequentially in the 100 series from 101 to 111 for the twinning section and from 112 to 124 for the East Shift section including 5 crossings at interchange ramps, transfer and side roads. The identification number and location of each crossing are listed below and also given in Table 1, attached:

PML CROSSING No.	LOCATION (NEW HIGHWAY 69 CENTRELINE)
Magnetawan First Nation	
101	Sta. 16+075 to 16+125
102	Sta. 16+530 to 16+585

PML CROSSING No.	LOCATION (NEW HIGHWAY 69 CENTRELINE)
Magnetawan First Nation	
103	Sta. 16+695 to 16+735
104	Sta. 16+795 to 16+837.5
105	Sta. 16+925 to 17+030
106	Sta. 17+537.5 to 17+610
107	Sta. 17+700 to 17+870
108	Sta. 18+220 to 18+250
109	Sta. 18+580 to 18+650
110	Sta. 18+780 to 18+970
111	Sta. 19+030 to 19+060
112	Sta. 19+350 to 19+460
113	Sta. 19+750 to 19+810
114	Sta. 19+850 to 19+955
115	Sta. 20+175 to 20+295
116	Sta. 20+760 to 20+970 (NBL)
117	Sta. 20+815 to 20+880 (SBL)
Ramp S-E/W	Sta. 20+239 to 20+300 (Ramp S-E/W chainage)
Ramp N-E/W	Sta. 20+710 to 20+965 (Ramp N-E/W chainage)
Interchange Service Road	Sta. 9+900 to 10+100 (Interchange Service Road chainage)
Wallbridge Township	
118	Sta. 22+225 to 22+320
119	Sta. 22+350 to 22+725 (NBL)
120	Sta. 22+390 to 22+430 (SBL)
121	Sta. 22+590 to 22+700 (SBL)
122	Sta. 22+800 to 22+840 (SBL)
123	Sta. 22+850 to 22+920 (NBL)
124	Sta. 22+960 to 23+060 (NBL)
North Transfer Swamp 1	Sta. 42+550 to 42+640 (North Transfer chainage)
North Transfer Swamp 2	Sta. 42+960 to 43+000 (North Transfer chainage)

This report provides recommendations for construction of embankments at the swamp and high fill crossings for both the twinning section and the East Shift section of the project. Adequate construction procedures are required to minimise post-construction settlement of the roadway surface due to consolidation of the subgrade materials. Further comments are provided on the stability of embankments and recommended construction methods based on the conditions revealed during the investigation. These comments and recommendations consider the requirements of the MTO “Embankment Settlement Criteria for Design” dated March 2, 2010.

Recommendations for construction of embankments along the sections of the alignment identified in the Request for Proposal for geotechnical investigation are provided in the Pavement Design Report under separate cover.

2. DISCUSSIONS AND RECOMMENDATIONS

2.1 General

The twinning and East Shift sections of the project are located to the east of the existing Highway 69 alignment at the swamp and high fill crossings. Within the limits of both sections, the embankment height from the existing ground surface to the proposed road grade (according to the profile provided by AECOM in August 2012) ranges from 0.0 to 9.5 m, typically from 1.5 to 4.5 m.

A summary of the subsurface conditions for each foundation area is compiled in Table 1.

The seismic site coefficient for the conditions at these crossings is assessed to be 1.0 as per clause 4.4.6 of the Canadian Highway Bridge Design Code (CHBDC). The site is located in Seismic Performance Zone 1.

All elevations in this report are expressed in metres. A list of OPSS standard specifications referenced in the report is provided in Table 2, attached.

2.2 Red Flag Issues

In general, the construction of the embankment through swamps in this section of the project may be accomplished using standard construction methods and slope configurations will remain stable in the long term, except swamp 109 where up to 15 m of compressible clay was encountered. For this swamp 109 embankment, at least a partial excavation of the clayey soils is recommended followed by preloading or surcharging for a period of 14 months to reduce the long-term settlements. In addition, analyses indicate inadequate stability in swamps located at Ramp N-E/W and Interchange Service Road. For the embankments at these two crossings, full excavation of the clayey soils is recommended to preclude any instability issues. Further discussions are presented in Section 3.3 of this report.

The “red flag” issues outlined in the preceding paragraphs and the recommended methods of overcoming these issues noted in the following sections of the report are intended to alert and aid the designer and the Contractor. These comments and recommendations are based on the conditions revealed during the investigations and no responsibility is assumed by the consultants or the MTO for alerting the Contractor to all critical issues for each foundation alternative. The requirements to deliver acceptable construction quality remain the responsibility of the Contractor.

2.3 Analysis of Site Conditions

The selection of embankment construction methods in foundation areas will depend on embankment stability and post-construction settlements as well as other factors such as environmental considerations, construction schedule and relative costs. As a first step, assessments of the stability and settlement of the proposed embankments were undertaken assuming that only site preparation comprising the excavation of surficial organic and soft materials had been carried out. Discussion of the stability and settlement of the proposed embankments without excavation of cohesive soils and of other considerations is provided in the following sections of this report.

Based on the results of these feasibility analyses, the recommendations for the selection of new embankment construction methods and configurations as required are provided in Section 3 of this report.

2.3.1 Summarised Subsurface Conditions and Geotechnical Parameters

In summary, the subsurface stratigraphy revealed in the boreholes drilled in the foundation areas generally comprised surficial topsoil / peat overlying silty / sandy soils and/or cohesive deposits of clayey silt / silty clay / clay with variable consistency underlain by cohesionless sandy soils extending to bedrock. The topsoil / peat thickness is 0.1 to 1.7 m. The depth to the base of the clayey soils is typically less than 5 m and up to 15 m in swamp 109. Bedrock is exposed discontinuously within the crossings. Groundwater was present at the surface or under snow and ice in most foundation areas.

There are numerous beaver dams along the alignment. It is anticipated that groundwater conditions will likely change when the beaver dams are removed during the highway embankment construction.

The soil parameters used in the analyses were based on the results of both field and laboratory testing and adjusted by applying engineering judgement in case of layered soil deposits.

2.3.2 Embankment Stability

The stability of new embankment sections was analysed using the limit equilibrium methods and the SLOPE/W software developed by Geo-Slope International Ltd. The software analyses numerous potential failure surfaces and establishes the critical one with a minimum factor of safety.

A summary of the engineering parameters and their typical values assumed in the calculations is as follows:

SOIL TYPE	UNIT WEIGHT (kN/m^3)	SHORT TERM		LONG TERM	
		SHEAR STRENGTH (kPa)	INTERNAL FRICTION (degree)	SHEAR STRENGTH (kPa)	INTERNAL FRICTION (degree)
Rockfill	18	0	42	0	42
Granular Fill	22	0	35	0	35
Peat (fibrous)	12	14 – 16	0	14	0
Clayey Soils (very soft to soft)	16 – 17	15 – 20	0	0 – 5	26 – 30
Clayey Soils (firm)	17 – 18	25 – 40	0	0 – 3	26 – 30
Clayey Soils (stiff)	18	50 – 75	0 – 5	0 – 3	28 – 30
Silty / Sandy Soils (very loose to compact)	17 – 19	0	28 – 32	0	28 – 30

The slope stability analyses considered the construction of new embankments at the crossings without excavation of cohesive soils. The results of the short-term (during construction) stability analyses indicate that the embankments would be stable over the existing clayey soils. The minimum factors of safety obtained are in excess of the minimum 1.3 considered adequate for embankment slopes to be stable during construction. The results of effective stress stability analyses at the crossings give minimum factors of safety exceeding the value of 1.5 (considered sufficient for embankments to be stable after construction in the long term) in all foundation areas except at Ramp N-E/W (1.44) and Interchange Service Road (1.47). Refer to Appendix A for the slope stability diagrams. The factors of safety for the short-term and long-term conditions at the crossings (except foundation areas 120 to 124 where practically no clayey soils were encountered and no stability analyses necessary) are tabulated below:

FOUNDATION AREA No.	FILL HEIGHT AT CRITICAL SECTION (m)	MINIMUM FACTOR OF SAFETY		FIGURE No.
		SHORT-TERM	LONG-TERM	
101	1.5	3.68	2.26	101A, 101B
102	2.4	4.39	1.74	102A, 102B

FOUNDATION AREA No.	FILL HEIGHT AT CRITICAL SECTION (m)	MINIMUM FACTOR OF SAFETY		FIGURE No.
		SHORT-TERM	LONG-TERM	
103	3.4	2.64	1.69	103A, 103B
104	3.6	1.77	1.90	104A, 104B
105	2.6	2.89	2.13	105A, 105B
106	3.0	1.78	1.75	106A, 106B
107	4.0	1.76	1.74	107A, 107B
108	4.8	2.30	1.51	108A, 108B
109	9.0 (no excavation)	1.47	1.51	109A, 109B
	9.0 (7 m excavation)	2.19	1.96	109C, 109D
110	3.2	1.77	1.86	110A, 110B
111	4.4	2.44	1.75	111A, 111B
112	9.0	1.48	1.50	112A, 112B
113	2.7	2.53	1.73	113A, 113B
114	2.0	4.08	1.92	114A, 114B
115	4.4	2.09	1.66	115A, 115B
116	4.0	2.98	1.56	116A, 116B
117	3.6	2.82	1.63	117A, 117B
118	3.5	2.54	1.54	118A, 118B
119	3.0	2.19	1.58	119A, 119B
Ramp S-E/W	4.0	2.29	1.57	SEW-A, SEW-B
Ramp N-E/W	7.2	1.39	1.44	NEW-A, NEW-B
Interchange Service Road	8.3	1.45	1.47	IC-A, IC-B
North Transfer Swamp 1	2.4	5.27	1.65	NT1-A, NT1-B
North Transfer Swamp 2	2.7	2.23	1.87	NT2-A, NT2-B

The analysis discounted the effect of the water present in the foundation areas to account for potential removal of the existing beaver dams during the embankment construction.

Since the factors of safety at Ramp N-E/W and Interchange Service Road are marginally insufficient for embankments to be stable in the long term, the option of leaving the cohesive soils in place is not considered to be appropriate for these crossings. Other alternatives to construct the embankments with adequate stability are discussed in Section 3.3.

The results of the slope stability analyses should be considered in conjunction with the long-term post-construction settlements discussed in the following sections.

2.3.3 Embankment Settlement

2.3.3.1 Settlement of Cohesive Soils

The consolidation settlement of the clayey soils was calculated based on the results of the consolidation tests conducted for this study and on empirical relationships for the engineering properties of the soils present at the site. The following parameters and their typical values were used in the calculation:

PARAMETERS	RANGE OF VALUES
Initial Void Ratio, e_o	0.95 – 2.05
Preconsolidation Pressure, P'_c (kPa)	125 – 250
Compression Index, C_c	0.2 – 1.2
Recompression Index, C_r	0.02 – 0.07
Coefficient of Consolidation, C_v (m^2/month)	0.2 – 0.6

A summary of settlements that would potentially occur due to the embankment construction if the cohesive soils were left in place is tabulated below:

FOUNDATION AREA No.	FILL HEIGHT (m)	CLAY THICKNESS (m)	ESTIMATED MAXIMUM SETTLEMENT (mm)	PERIOD FOR 90% COMPLETION OF CONSOLIDATION (month)
101	1.0 – 2.0	0.0 – 1.5	90	1
102	1.0 – 3.5	0.0 – 2.8	155	4
103	3.0 – 4.0	0.0 – 3.5	165	6

FOUNDATION AREA No.	FILL HEIGHT (m)	CLAY THICKNESS (m)	ESTIMATED MAXIMUM SETTLEMENT (mm)	PERIOD FOR 90% COMPLETION OF CONSOLIDATION (month)
104	3.0 – 4.0	0.0 – 4.2	175	9
105	1.5 – 3.0	0.0 – 2.1	125	2
106	2.5 – 3.5	0.0 – 1.3	80	1
107	1.5 – 4.0	0.0 – 5.4	230	15
108	3.0 – 5.5	0.0 – 1.7	125	1
109	4.0 – 9.5	0.0 – 14.2	660	107
110	0.0 – 5.0	0.0 – 4.0	200	8
111	2.5 – 4.5	0.0 – 2.0	165	2
112	0.0 – 9.0	0.0 – 9.5	375	14
113	0.0 – 3.0	0.0 – 3.0	150	4
114	1.0 – 3.5	0.0 – 3.0	140	5
115	0.0 – 4.4	0.0 – 6.3	290	21
116	1.0 – 4.5	0.0 – 2.0	155	2
117	2.5 – 4.0	0.0 – 3.4	205	6
118	3.0 – 4.5	0.0 – 0.7	70	1
119	2.5 – 4.5	0.0 – 1.9	130	2
120	3.0 – 4.0	0	0	–
121	3.0 – 5.0	0.0 – 0.2	25	1
122	2.5 – 3.0	0	0	–
123	1.0 – 2.5	0	0	–
124	2.5 – 4.0	0	0	–
Ramp S-E/W	3.0 – 4.0	0.0 – 5.1	240	14
Ramp N-E/W	2.5 – 8.0	0.0 – 2.7	210	4
Interchange Service Road	4.0 – 9.0	0.0 – 3.6	290	7
North Transfer Swamp 1	2.0 – 3.0	0.0 – 1.6	110	2
North Transfer Swamp 2	2.0 – 2.7	0.0 – 1.5	105	2

The estimated maximum settlements of the existing clayey soils in the foundation areas under the loading from new embankments range from 25 to 375 mm, locally 660 mm. About 90% of the maximum settlements would occur between 1 month (swamps 101, 106, 108, 118, 121) and 21 months (swamp 115), up to 107 months in swamp 109.

Since the time needed for completion of consolidation settlements of the cohesive soils is not excessive in most foundation areas, the option of leaving these soils in place is considered to be appropriate.

In swamps 107, 112, 115 and at Ramp S-E/W with a period for 90% completion of consolidation in a range of 14 to 21 months, settlements of 230 to 375 mm are assessed to be reduced to some 45 to 80 mm remaining after the new embankments have been preloaded for a period of 12 months. Consequently, the option of leaving the cohesive soils in place is considered to be appropriate at these crossings as well.

In foundation area 109, consolidation settlements of 660 mm are assessed to be reduced to some 440 mm remaining after the new 9 m high embankment has been preloaded for a period of 12 months. Other alternatives to construct this embankment with less post-construction settlement are discussed in Section 3.3.

2.3.3.2 Settlement of Cohesionless Soils

The settlements of the cohesionless soils to be left in place at all the crossings are estimated to be in the order of 5 to 15 mm under the maximum fill height. These settlements will occur rapidly during construction and within 3 months after fill placement.

The estimated settlements of these soils due to the new embankment loading are as follows:

FOUNDATION AREA No.	**FILL HEIGHT (m)**	**SILT / SAND THICKNESS (m)**	**ESTIMATED MAXIMUM SETTLEMENT (mm)**
101	1.0 – 2.0	0	0
102	1.0 – 3.5	0.0 – 0.4	5
103	3.0 – 4.0	0.0 – 0.7	5
104	3.0 – 4.0	0.0 – 3.6	15
105	1.5 – 3.0	0.0 – 0.3	5
106	2.5 – 3.5	0.0 – 1.9	10
107	1.5 – 4.0	0.0 – 2.0	10
108	3.0 – 5.5	0.0 – 0.4	5

FOUNDATION AREA No.	FILL HEIGHT (m)	SILT / SAND THICKNESS (m)	ESTIMATED MAXIMUM SETTLEMENT (mm)
109	4.0 – 9.5	0.0 – 1.1	15
110	0.0 – 5.0	0.0 – 1.1	10
111	2.5 – 4.5	0	0
112	0.0 – 9.0	0.0 – 1.7	15
113	0.0 – 3.0	0.0 – 1.0	10
114	1.0 – 3.5	0	0
115	0.0 – 4.4	0.0 – 0.7	10
116	1.0 – 4.5	0.0 – 0.8	10
117	2.5 – 4.0	0.0 – 0.3	5
118	3.0 – 4.5	0.0 – 0.2	5
119	2.5 – 4.5	0.0 – 0.6	10
120	3.0 – 4.0	0	0
121	3.0 – 5.0	0.0 – 1.0	10
122	2.5 – 3.0	0.0 – 0.8	10
123	1.0 – 2.5	0.0 – 0.2	5
124	2.5 – 4.0	0	0
Ramp S-E/W	3.0 – 4.0	0.0 – 1.2	10
Ramp N-E/W	2.5 – 8.0	0.0 – 1.5	15
Interchange Service Road	4.0 – 9.0	0.0 – 0.2	5
North Transfer Swamp 1	2.0 – 3.0	0.0 – 0.9	10
North Transfer Swamp 2	2.0 – 2.7	0.0 – 0.3	5

2.3.3.3 Settlement of Rockfill

The estimated magnitude of settlements resulting from compaction of the rockfill under its own weight is based on the document “Post-construction Rock Fill Settlement and Guidelines for Estimating Rock Fill Quantity” issued by MTO in September 2010. Approximately 90% of the short-term (during the first year) rockfill settlement may be expected to be complete in 6 months following construction of the embankment to full height.

The estimated values of settlement in the foundation areas are listed in Table 3, attached. Maximum rockfill settlements are 20 to 80 mm at most crossings for the option of preloading without removal of clayey soils. In swamp 109, the maximum rockfill settlement varies between 90 mm (preloading without removal of clayey soils) and 410 mm (full excavation of clayey soils). For the option of full excavation at Ramp N-E/W and Interchange Service Road, maximum rockfill settlements increase to 110 and 125 mm respectively.

2.3.3.4 Total Settlements

The summary of the consolidation and rockfill settlements is provided in Table 3. The maximum post-construction settlements range from 10 to 145 mm after 6 months of preloading and from 5 to 80 mm after 12 months of preloading (with respective values of 520 and 440 mm in swamp 109). Considering the maximum allowable settlement of 100 mm contained in the MTO “Embankment Settlement Criteria for Design” guidelines dated March 2, 2010, mitigation treatments of all swamps with excessive settlements should be carried out.

The following Section 3 outlines the available swamp and high fill treatments with an assessment of their relative advantages and disadvantages. A discussion of the treatments at specific crossings is presented in Section 3.3 of this report.

3. SWAMP AND HIGH FILL CROSSING TREATMENTS

3.1 General

The construction method for each section of the roadway embankments under consideration was reviewed and recommended using primarily the following criteria:

i) Post-construction settlement of the embankment surface due to settlement of the rockfill and consolidation of subgrade material to be acceptable (according to the “Embankment Settlement Criteria for Design” issued by MTO in March 2010).

ii) Stability of the embankment fill.

iii) Stability of excavation slopes.

iv) Maximum practical depth of excavation for the “long stick” excavator is 12 m.

The selection of the preferred treatment option for each of the swamp and high fill crossings also depends on other factors that are being considered by MTO and AECOM.

Rockfill should be employed to construct the portion of the embankment below existing original grade and/or below the water level to satisfy constructability constraints (soft soils, unstable base, working below the water table) and to minimise post-construction settlement since it would be difficult to compact earth and/or pit-run granular materials below the water table. In addition, the magnitude of construction dewatering required to enable this work to be performed in the dry may not be feasible due to environmental impacts and economic constraints. If required, earth fill and/or granular material could be employed above existing grade and/or from 1 m above the water level, whichever is higher.

The stable inclination of the embankment fill slope and the magnitude of post-construction settlement of the embankment surface and time required for essential completion of primary consolidation for each treatment option are dependent on the embankment height, the composition of the subgrade soil and the thickness and pertinent engineering properties of the clayey subgrade soil for those treatment options that do not call for full-depth excavation. The stability and settlement of these soil layers under the proposed embankments were discussed in the previous sections of this report. The following sections provide a review of each swamp and high fill crossing as applicable and recommend the preferred treatment option.

For the purposes of this report, competent soil is generally defined as loose to compact cohesionless sands or silts (standard penetration test N-values in excess of 7) cognizant of the embankment height and expected settlements. Firm to stiff clayey soils may be regarded as competent as long as the embankment remains stable and estimated post-construction settlements are acceptable.

The existing topsoil, peat and soft to very soft cohesive soils are highly compressible and generally not capable of supporting the weight of embankment fill to be placed. Consequently, these soils should be removed.

The cohesionless soils underlying the clayey soils are deemed to be competent and capable of supporting the proposed rockfill embankments. The loose to very loose silty / sandy soils may be left in place since settlement of these materials occurs rapidly during construction.

It should be noted that construction of new or extension of existing culverts is programmed as part of the four-laning project. In this regard, special embankment construction treatments may be planned at the specific culvert locations and could differ from the embankment construction methods distant from the culvert site. It may be prudent to fully excavate shallow cohesive soils to bedrock for the culvert foundations as opposed to following a general embankment construction method that leaves these soils in place.

3.2 New Embankment Construction Methods

As previously noted, the alignment of the swamp and high fill sections crosses over areas locally containing soft to firm clayey soils, similar to soils in swampy ground, which are susceptible to excessive settlements and/or slope instability. Several embankment fill construction methods were considered at the crossings of possible swamp and high fill sections. A summary of the methods along with their advantages and disadvantages is as follows:

ALTERNATIVE EMBANKMENT CONSTRUCTION METHOD		ADVANTAGES	DISADVANTAGES
Option 1	Full excavation (Involves removing all compressible cohesive soils and replacement by rockfill)	- Standardized MTO method of embankment construction - Reduced and predictable long-term settlements	- Requires disposal of excavated soil - May cause instability of existing embankments for twinning sections
Option 2	Preloading and/or surcharging (Leaves compressible cohesive soils in place and allows for preloading and/or surcharging to reduce post-construction settlements)	- Disposal of excavated soil not required - Reduction of long-term settlements	- Requires a long construction period - Post-construction settlement may be excessive - At some areas, it may require toe berms or minimum soil strength for surcharging

ALTERNATIVE EMBANKMENT CONSTRUCTION METHOD		ADVANTAGES	DISADVANTAGES
Option 3	Partial excavation and preloading / surcharging (The upper zones of compressible cohesive soils are excavated and replaced with rockfill followed by a preloading or surcharge period)	- Reduced disposal of excavated soil - Maintains stability of existing embankment on twinning construction - Reduction of long-term settlements	- Requires a long construction period - Large post-construction settlement possible - At some areas, it may require minimum soil strength for surcharging - Time to complete estimated settlements may be exceeded leading to delay of construction schedule
Option 4	Construction of a bridge to span the area / compressible soil	- No post-construction settlements on bridge section	- Typically too costly and impractical - Differential settlement of approach embankments needs to be engineered
Option 5	Lengthening the construction schedule and/or advance contracts to increase the time period between construction of the embankment and construction of the roadway pavement	- Reduced disposal of excavated soil - Reduced post-construction settlements	- Requires a long construction period - Post-construction settlement possible
Option 6	Use of lightweight fill to minimise the stress imposed on the underlying soil (independently and in conjunction with surcharging and/or wick drains)	- Reduced disposal of excavated soil - Can be constructed over weak soils	- Requires prior treatment of reduce or eliminate excessive embankment settlement to avoid damage to the EPS
Option 7	Installation of wick drains to increase the rate of consolidation and minimise the magnitude of post-construction settlement	- Reduced disposal of excavated soil - Maintain stability of existing embankment - Reduction of long-term settlements	- High mobilization charges for one fill area - Not practical for shallow compressible deposits - Very weak deposits may require a long and/or staged construction period - Potential additional costs due to inaccurate prediction of expected progress of settlement

The option 1 method of embankment construction (full excavation) normally employed by MTO in areas with low strength compressible soils involves the excavation of these poor quality soils to competent material where practical and backfilling the excavation with rockfill following the procedures stipulated in OPSD 203.010.

The preferred treatment option will be influenced by the soil profile at a particular crossing, the accepted post-construction performance (settlement), environmental considerations, design requirements, the construction schedule, construction constraints and economic considerations.

In addition, the impact on the regional hydrogeology by changes made to the natural groundwater level by installation of wick drains could be a consideration. Further, lightweight fill is not locally available and would require trucks to travel long distances with an adverse impact on both air quality and non-renewable resources.

The selection of the most appropriate construction method for the embankments at each crossing will depend on stability and post-construction settlement considerations and other factors such as environmental issues and relative costs. In general, preloading and/or surcharging without removal of clayey soils (option 2) is considered the most favourable embankment construction method.

3.3 Recommended Treatment

The recommended treatment is described separately – for the twinning section of the highway alignment (sections 3.3.1 and 3.3.2) and for the East Shift (sections 3.3.3 and 3.3.4).

3.3.1 Swamps 101 to 108, 109 (Sta. 18+605 to 18+650), 110 and 111

As indicated in Sections 2.3.2 and 2.3.3, the twinning embankments across swamps 101 to 108, 110 and 111 will be stable. As noted in Table 3, the maximum post-construction settlements are estimated to be 10 to 95 mm after 6 months of preloading and 5 to 45 mm after 12 months of preloading.

Referring to the table in Section 3.2, full excavation (option 1) is not warranted in foundation areas 101 to 108, 110 and 111 as well as within a 45 m long section from Sta. 18+605 to 18+650 in swamp 109 due to satisfactory performance of the embankments constructed with cohesive soils left in place. Taking into account the adequate stability of these embankments and the short period of time needed for completion of consolidation settlements, preloading without excavation of clayey soils (option 2) is the preferred method of construction at these crossings.

3.3.2 Swamp 109 (Sta. 18+580 to 18+605)

Since the up to 9 m high embankment in foundation area 109 would only be marginally stable in the long term and the consolidation settlements remaining after 1 year following fill placement would be excessive at some 440 mm, the preloading / surcharging (option 2) is not deemed to be feasible at this crossing. To increase embankment stability and mitigate excessive post-construction consolidation settlements, it is recommended that partial excavation to 7 m depth be undertaken within a 25 m long section from Sta. 18+580 to 18+605 and a 2 m surcharge applied for 14 months (option 3). It is noteworthy that excavation within this section should be gradually reduced to 5 m depth at the median so as not to undermine the stability of the existing embankment. In case of the recommended excavation to 7 m depth and surcharging for 14 months, the total post-construction settlement remaining at the end of the surcharge period is assessed to be 100 mm. Elsewhere in swamp 109, preloading (option 2) would be sufficient.

Partial excavation to 7 m depth requires removal of peat, loose sand and firm clayey silt / silty clay in the upper zone of the cohesive deposit. The relative advantage of this method as compared to option 2 is a reduced period of time necessary to bring post-construction settlements to acceptable values. If the embankment was only preloaded, the total settlement remaining after 1 year following fill placement would be some 140 mm. Application of a 2 m surcharge for 12 months decreases the total post-construction settlement to about 120 mm. The extension of the surcharge period to 14 months reduces this settlement to 100 mm.

Another method of embankment construction in swamp 109 – full excavation of clayey soils (option 1) – has also been analysed. In this case the maximum post-construction settlements after 6 and 12 months of preloading are estimated to be 80 and 40 mm respectively. However, the depth of excavation to 15.6 m at the location of borehole 109-5 (Sta. 18+600) would be excessive.

It is noted that options 1 and 3 involve excavation next to the existing embankment of Highway 69 and necessitate special construction procedures in accordance with MTO OPSD 203.010 and 203.020. In addition, full excavation of clayey soils would likely undermine the stability of the existing embankment, therefore it is recommended that partial excavation and surcharging (option 3) be used from Sta. 18+580 to 18+605 in swamp 109.

3.3.3 Swamps 112 to 124, Ramp S-E/W, North Transfer Swamps 1 and 2

As indicated in Sections 2.3.2 and 2.3.3, the embankments across swamps 112 to 124, at Ramp S-E/W and North Transfer swamps 1 and 2 will be stable with factors of safety in excess of 1.3 and 1.5 for short- and long-term slope stability conditions. As noted in Table 3, the maximum post-construction settlements are estimated to be 10 to 145 mm after 6 months of preloading and 5 to 80 mm after 12 months of preloading.

Referring to the table in Section 3.2, full excavation (option 1) is not warranted in these foundation areas due to satisfactory performance of the embankments constructed with cohesive soils left in place. Taking into account the adequate stability of these embankments and the long-term settlements of less than 100 mm, preloading without excavation of clayey soils (option 2) is the preferred method of construction at these crossings.

Since the total settlement in swamps 120 to 124 is not more than 20 to 55 mm, no treatment is required in these foundation areas. It is recommended to preload the embankment in swamp 118 for 1 month in view of the total settlement reaching the maximum allowable value of 100 mm.

3.3.4 Ramp N-E/W, Interchange Service Road

Since the stability of the 8 to 9 m high embankments at Ramp N-E/W and Interchange Service Road is marginal in the long term without excavation of the clayey soils, the preloading / surcharging (option 2) is deemed to be only marginally adequate at these crossings. These crossings are located over rock outcrops with sparse soil cover except in two boreholes at the Interchange Service Road (boreholes IC-7 and IC-11) and along the centre-west side of the Ramp N-E/W crossing (borehole NEW-5, -7, -8, -10, -14, -16, and -17). To mitigate long-term differential settlements of the pavements on the longitudinal and transverse directions and also to enhance embankment stability, it is recommended that full excavation (option 1) be undertaken where clayey soils are encountered. In case of the recommended full excavation, the total post-construction settlement remaining at the end of the 6-month preloading period is assessed to be 25 to 30 mm. To reduce the post-construction settlements to 100 mm in the Ramp N-E/W and Interchange Service Road crossings, it is recommended that these embankments be preloaded by 1 and 2 months, respectively.

Taking into account that the maximum thickness of clayey soils at Ramp N-E/W and Interchange Service Road is only 2.7 and 3.6 m respectively, partial excavation and preloading / surcharging (option 3) would not give any particular advantage as compared to the recommended option 1. Moreover, leaving some clayey soils under the embankments would potentially create unstable conditions.

The remaining methods of embankment construction (options 4 to 7) are considered to be impractical or too costly in the foundation areas analysed.

4. EXCAVATION CONSIDERATIONS

A summary of subsoil conditions and recommended treatment for each crossing is provided in Table 1. Excavation of the surficial topsoil, peat and organic deposits is a prerequisite for all treatment options.

The excavation geometry should generally follow the OPSD 203.010 configuration and/or as indicated in Section 5 of this report. Where worker safety is a concern, the fill, loose to compact silt / sand and firm to stiff cohesive soils are classified as Type 3 soil according to the Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Temporary cut slopes over the full depth of excavation should therefore be inclined at an angle of 45° to the horizontal for Type 3 soils. The need to excavate flatter sideslopes in very loose silty / sandy soils and if excessively soft/wet materials or concentrated seepage zones are encountered locally during construction should not be overlooked. In swampy areas, temporary slopes may need to be cut at a maximum inclination of 3 horizontal to 1 vertical (3H:1V) as required for Type 4 soils.

All construction work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local regulations.

5. CONSTRUCTION CONSIDERATIONS

Embankments on competent material should be constructed in accordance with OPSD 201.010, 201.020 (if applicable), 202.010, 203.010, 203.020 and MTO SP 206S03. The side slopes of the embankments should be inclined no steeper than 2H:1V for earth fill and 1.25H:1V for rockfill. Mid-height berms 2 m in width should be provided to limit the height of uninterrupted slopes to maximum 8 m for earth fill embankments and 10 m for rockfill embankments.

It is recommended that the embankments through swamps be constructed with rockfill. Excavated swamp and/or inorganic soil could be placed on the rockfill below grade if the inclination of the slope flattening material is not steeper than 3.5H:1V.

It is considered that the rockfill embankments constructed in accordance with these recommendations will be stable.

6. EMBANKMENT SETTLEMENT CONSIDERATIONS

Some settlement of the embankment fill surface, both during and following completion of construction, due to settlement of the rockfill under its own weight and consolidation of the subgrade soils should be expected. The magnitude of settlement for the recommended treatment option at each crossing is summarised in Table 3. The maximum post-construction settlements in foundation areas 101 to 108, 110 to 124, at Ramp S-E/W, Ramp N-E/W, Interchange Service Road and North Transfer swamps 1 and 2 are estimated to be 10 to 145 mm and 5 to 80 mm after 6 and 12 months of preloading, respectively. In swamp 109 where partial excavation to 7 m depth (Sta. 18+590 to 18+605) is recommended, the maximum post-construction settlement is assessed to be 100 mm after applying a 2 m surcharge for 14 months. For embankments constructed on rock, settlement of the subgrade will be negligible. Settlement of embankments due to compression of silty / sandy subgrade soils is expected to be in the order of 5 to 15 mm and be completed within three months following construction of the embankments.

Some loss of rockfill is likely to occur as a result of the rockfill "punching" into the very loose to loose silt / sand below the recommended excavation depths. For volume calculation purposes, the loss of rockfill should be accounted for assuming its 100 to 300 mm penetration below the base of excavation depending on the relative density of underlying soils. The maximum value of 300 mm should be applied in case of very loose cohesionless soils and lesser values for compact / dense soils.

The embankment platform through swamp and high fill crossings should be widened to accommodate the anticipated post-construction settlement of the embankment. The recommended minimum widening requirements should include accommodation of a future 200 mm thick pavement overlay. Refer to the Pavement Design Report for additional comments regarding embankment widenings.

7. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. B.R. Gray, MEng, P.Eng, MTO Designated Principal Contact. Mr. C.M.P. Nascimento, P.Eng., Project Manager, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

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GD/CN/BRG:gd-sq-mi

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS AND RECOMMENDED TREATMENT

FOUNDATION AREA No.	FILL HEIGHT (m)	DEPTH TO COMPETENT SOIL (m)	SOIL BELOW EXCAVATION BASE	DEPTH TO PROBABLE BEDROCK (m)	EXCAVATION PROCEDURE	MINIMUM RECOMMENDED TREATMENT (Note 4)
101 Sta. 16+075 to 16+125, Highway 69	1.0 – 2.0	0.1 – 1.4	Firm to stiff sandy clayey silt in 2 boreholes or bedrock	0.1 – 2.9 (El. 191.4 – 194.7)	Not required	Preloading for 1 month (option 2)
102 Sta. 16+530 to 16+585, Highway 69	1.0 – 3.5	0.0 – 0.6	Stiff to very stiff clay in 1 borehole or bedrock	0.0 – 3.8 (El. 189.3 – 196.3)	Not required	Preloading for 2 months (option 2)
103 Sta. 16+695 to 16+735, Highway 69	3.0 – 4.0	0.0 – 1.4	Firm to stiff clayey soils or bedrock	0.0 – 5.5 (El. 187.7 – 194.6)	Not required	Preloading for 3 months (option 2)
104 Sta. 16+795 to 16+837.5, Highway 69	3.0 – 4.0	0.0 – 2.2	Loose to compact silt / sand, firm to very stiff clayey silt / clay or bedrock	0.0 – 8.1 (El. 185.4 – 194.3)	Not required	Preloading for 4 months (option 2)
105 Sta. 16+925 to 17+030, Highway 69	1.5 – 3.0	0.0 – 1.8	Compact sandy silt in 1 borehole, firm to stiff clayey silt or bedrock	0.0 – 3.8 (El. 192.1 – 198.2)	Not required	Preloading for 1 month (option 2)
106 Sta. 17+537.5 to 17+610, Highway 69	2.5 – 3.5	0.0 – 0.8	Very loose to compact sandy soils or bedrock	0.0 – 2.7 (El. 194.7 – 198.9)	Not required	Preloading for 1 month (option 2)

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS AND RECOMMENDED TREATMENT

FOUNDATION AREA No.	FILL HEIGHT (m)	DEPTH TO COMPETENT SOIL (m)	SOIL BELOW EXCAVATION BASE	DEPTH TO PROBABLE BEDROCK (m)	EXCAVATION PROCEDURE	MINIMUM RECOMMENDED TREATMENT (Note 4)
107 Sta. 17+700 to 17+870, Highway 69	1.5 – 4.0	0.0 – 2.5	Very loose to very dense silty/sandy soils, firm to very stiff clayey silt / silty clay or bedrock	0.0 – 11.6 (El. 186.1 – 199.9)	Not required	Preloading for 6 months (option 2)
108 Sta. 18+220 to 18+250, Highway 69	3.0 – 5.5	0.1 – 1.0	Loose to compact silty sand or bedrock	0.1 – 3.1 (El. 192.6 – 199.3)	Not required	Preloading for 1 month (option 2)
109 Sta. 18+580 to 18+605, Highway 69	4.0 – 9.0	0.0 – 7.0	Firm silty clay or bedrock	0.0 – 16.7 (El. 171.5 – 193.1)	Earth excavation	Partial excavation to 7 m depth and surcharging for 14 months (option 3)
Sta. 18+605 to 18+650, Highway 69	4.5 – 9.5	0.0 – 1.9	Firm silty clay or bedrock	0.0 – 10.8 (El. 177.3 – 193.3)	Not required	Preloading for 5 months (option 2)
110 Sta. 18+780 to 18+970, Highway 69	0.0 – 5.0	0.0 – 2.2	Compact sand, firm to stiff clayey silt / silty clay or bedrock	0.0 – 8.4 (El. 187.0 – 199.7)	Not required	Preloading for 4 months (option 2)
111 Sta. 19+030 to 19+060, Highway 69	2.5 – 4.5	0.0 – 1.7	Firm to stiff silty clay in 1 borehole or bedrock	0.0 – 3.7 (El. 191.3 – 197.5)	Not required	Preloading for 1 month (option 2)
112 Sta. 19+350 to 19+460, Highway 69	0.0 – 9.0	0.0 – 1.4	Very loose to loose sand / silty sand, firm to stiff clayey silt / silty clay or bedrock	0.0 – 11.1 (El. 177.7 – 198.4)	Not required	Preloading for 9 months (option 2)

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS AND RECOMMENDED TREATMENT

FOUNDATION AREA No.	FILL HEIGHT (m)	DEPTH TO COMPETENT SOIL (m)	SOIL BELOW EXCAVATION BASE	DEPTH TO PROBABLE BEDROCK (m)	EXCAVATION PROCEDURE	MINIMUM RECOMMENDED TREATMENT (Note 4)
113 Sta. 19+750 to 19+810, Highway 69	0.0 – 3.0	0.0 – 1.4	Loose to compact sand in 1 borehole, very stiff to firm clayey soils or bedrock	0.0 – 4.2 (El. 190.1 – 199.6)	Not required	Preloading for 2 months (option 2)
114 Sta. 19+850 to 19+955, Highway 69	1.0 – 3.5	0.0 – 3.8	Stiff to soft clayey soils or bedrock	0.0 – 3.9 (El. 190.8 – 198.8)	Not required	Preloading for 2 months (option 2)
115 Sta. 20+175 to 20+295, Highway 69	0.0 – 4.4	0.0 – 2.2	Sand in 1 borehole, firm to very stiff clayey soils or bedrock	0.0 – 8.8 (El. 185.9 – 200.0)	Not required	Preloading for 10 months (option 2)
116 Sta. 20+760 to 20+970 (NBL), Highway 69	1.0 – 4.5	0.0 – 1.9	Firm to very stiff clayey soils or bedrock	0.0 – 3.4 (El. 190.1 – 198.3)	Not required	Preloading for 1 month (option 2)
117 Sta. 20+815 to 20+880 (SBL), Highway 69	2.5 – 4.0	0.1 – 1.0	Stiff to very stiff silty clay or bedrock	0.1 – 4.6 (El. 188.0 – 193.7)	Not required	Preloading for 3 months (option 2)
118 Sta. 22+225 to 22+320, Highway 69	3.0 – 4.5	0.0 – 0.9	Stiff clayey silt, compact silty sand or bedrock	0.0 – 1.4 (El. 196.1 – 201.8)	Not required	Preloading for 1 month (option 2)
119 Sta. 22+350 to 22+725 (NBL), Highway 69	2.5 – 4.5	0.0 – 1.8	Stiff clayey silt in 1 borehole, very loose to compact sandy soils or bedrock	0.0 – 2.3 (El. 194.4 – 199.2)	Not required	Preloading for 1 month (option 2)

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS AND RECOMMENDED TREATMENT

FOUNDATION AREA No.	FILL HEIGHT (m)	DEPTH TO COMPETENT SOIL (m)	SOIL BELOW EXCAVATION BASE	DEPTH TO PROBABLE BEDROCK (m)	EXCAVATION PROCEDURE	MINIMUM RECOMMENDED TREATMENT (Note 4)
120 Sta. 22+390 to 22+430 (SBL), Highway 69	3.0 – 4.0	0.0 – 0.9	Bedrock	0.0 – 0.9 (El. 196.6 – 198.7)	Not required	Not required
121 Sta. 22+590 to 22+700 (SBL), Highway 69	3.0 – 5.0	0.1 – 1.1	Firm clayey silt in 1 borehole, very loose to compact silty/sandy soils or bedrock	0.1 – 2.0 (El. 194.4 – 197.5)	Not required	Not required
122 Sta. 22+800 to 22+840 (SBL), Highway 69	2.5 – 3.0	0.0 – 0.8	Loose to compact silty sand or bedrock	0.0 – 2.3 (El. 196.0 – 200.3)	Not required	Not required
123 Sta. 22+850 to 22+920 (NBL), Highway 69	1.0 – 2.5	0.0 – 0.6	Loose to compact sand in 1 borehole or bedrock	0.0 – 0.6 (El. 199.1 – 201.3)	Not required	Not required
124 Sta. 22+960 to 23+060 (NBL), Highway 69	2.5 – 4.0	0.0 – 1.3	Probable loose silt in 1 test hole or bedrock	0.0 – 2.3 (El. 196.9 – 200.8)	Not required	Not required
Ramp S-E/W Sta. 20+239 to 20+300, Ramp S-E/W chainage	3.0 – 4.0	0.2 – 2.2	Very loose silt in 1 borehole, firm to stiff clayey silt or bedrock	0.6 – 8.5 (El. 190.6 – 199.3)	Not required	Preloading for 6 months (option 2)
Ramp N-E/W Sta. 20+710 to 20+965, Ramp N-E/W chainage	2.5 – 8.0	0.0 – 4.2	Compact to dense silty sand or bedrock	0.0 – 4.2 (El. 188.3 – 199.9)	Earth excavation	Full excavation (option 1) and Preloading for 1 month

TABLE 1

SUMMARY OF SUBSOIL CONDITIONS AND RECOMMENDED TREATMENT

FOUNDATION AREA No.	FILL HEIGHT (m)	DEPTH TO COMPETENT SOIL (m)	SOIL BELOW EXCAVATION BASE	DEPTH TO PROBABLE BEDROCK (m)	EXCAVATION PROCEDURE	MINIMUM RECOMMENDED TREATMENT (Note 4)
Interchange Service Road Sta. 9+900 to 10+100, Interchange Service Road chainage	4.0 – 9.0	0.0 – 4.5	Compact silty sand in 1 borehole or bedrock	0.0 – 4.7 (El. 192.4 – 202.9)	Earth excavation	Full excavation (option 1) and Preloading for 2 months
North Transfer Swamp 1 Sta. 42+550 to 42+640, North Transfer chainage	2.0 – 3.0	0.1 – 1.8	Stiff to very stiff clayey silt, loose silty sand or bedrock	0.1 – 3.5 (El. 192.4 – 196.0)	Not required	Preloading for 1 month (option 2)
North Transfer Swamp 2 Sta. 42+960 to 43+000, North Transfer chainage	2.0 – 2.7	0.0 – 1.5	Stiff silty clay, loose to compact silty sand or bedrock	0.0 – 2.3 (El. 194.6 – 197.8)	Not required	Preloading for 1 month (option 2)

NOTES:
1. Fill height is based on the profile provided by AECOM in August 2012.
2. Earth excavation of topsoil or peat is a prerequisite for any treatment in foundation areas.
3. Refer to Table 3 for alternative embankment construction methods in swamp 109, at Ramp N-E/W and Interchange Service Road.
4. Minimum Recommended Treatment will provide the maximum allowed settlement in the MTO Embankment Settlement Criteria for Design dated March 2, 2015.

TABLE 2

LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
SP 206S03	Construction Specification for Grading
OPSD-201.010	Rock Grading – Undivided Rural
OPSD-201.020	Rock Grading – Divided Rural
OPSD-202.010	Slope Flattening Using Excess Material on Earth or Rock Embankment
OPSD 203.010	Embankments Over Swamp – New Construction
OPSD-203.020	Embankments Over Swamp – Existing Slope Excavated to 1H:1V

Note: Special Provisions (SP) refer to the Ministry of Transportation documents.

TABLE 3

SETTLEMENT OF EMBANKMENT SURFACE

FOUNDATION AREA No.	RECOMMENDED TREATMENT (Note 1)	SETTLEMENT, mm							
		PRIMARY CONSOLIDATION (Note 2)	ROCKFILL	TOTAL	DURING 6 MONTHS AFTER CONSTRUCTION	DURING 1ST YEAR AFTER CONSTRUCTION	REMAINING AFTER 6 MONTHS	REMAINING AFTER 1 YEAR	MONTHS REQUIRED TO REDUCE REMAINING SETTLEMENTS TO 100 mm
101 Sta. 16+075 to 16+125	Preloading (option 2)	0 – 90	10 – 25	10 – 115	10 – 105	10 – 110	0 – 10	0 – 5	1
102 Sta. 16+530 to 16+585	Preloading (option 2)	0 – 155	5 – 20	5 – 175	5 – 165	5 – 170	0 – 10	0 – 5	2
103 Sta. 16+695 to 16+735	Preloading (option 2)	0 – 165	20 – 35	20 – 200	15 – 170	20 – 190	5 – 30	0 – 10	3
104 Sta. 16+795 to 16+837.5	Preloading (option 2)	0 – 175	20 – 30	20 – 205	15 – 160	20 – 195	5 – 45	0 – 10	4
105 Sta. 16+925 to 17+030	Preloading (option 2)	0 – 125	10 – 30	10 – 155	10 – 145	10 – 150	0 – 10	0 – 5	1
106 Sta. 17+537.5 to 17+610	Preloading (option 2)	0 – 80	20 – 25	20 – 105	20 – 95	20 – 100	0 – 10	0 – 5	1
107 Sta. 17+700 to 17+870	Preloading (option 2)	0 – 230	10 – 50	10 – 280	5 – 185	10 – 235	5 – 95	0 – 45	6
108 Sta. 18+220 to 18+250	Preloading (option 2)	0 – 125	20 – 40	20 – 165	15 – 150	20 – 155	5 – 15	0 – 10	1

TABLE 3

SETTLEMENT OF EMBANKMENT SURFACE

FOUNDATION AREA No.	RECOMMENDED TREATMENT (Note 1)	SETTLEMENT, mm							
		PRIMARY CONSOLIDATION (Note 2)	ROCKFILL	TOTAL	DURING 6 MONTHS AFTER CONSTRUCTION	DURING 1ST YEAR AFTER CONSTRUCTION	REMAINING AFTER 6 MONTHS	REMAINING AFTER 1 YEAR	MONTHS REQUIRED TO REDUCE REMAINING SETTLEMENTS TO 100 mm
109 Sta. 18+580 to 18+650	Preloading (option 2) Sta. 18+580 to 18+605	0 – 660	25 – 90	25 – 750	15 – 230	20 – 310	10 – 520	5 – 440	99
	Preloading (option 2) Sta. 18+605 to 18+650	0 – 325	25 – 100	25 – 425	15 – 355	20 – 400	10 – 70	5 – 25	5
	Partial excavation to 7 m depth and surcharging (option 3) Sta. 18+580 to 18+605 (Note 4)	0 – 305	25 – 195	25 – 500	15 – 305	20 – 380 (400 mm during 14 months)	10 – 195	5 – 120 (100 mm after 14 months)	14
	Full excavation (option 1)	0	25 – 410	25 – 410	15 – 330	20 – 370	10 – 80	5 – 40	5
110 Sta. 18+780 to 18+970	Preloading (option 2)	0 – 200	5 – 45	5 – 245	5 – 200	5 – 235	0 – 45	0 – 10	4
111 Sta. 19+030 to 19+060	Preloading (option 2)	0 – 165	15 – 45	15 – 210	10 – 195	15 – 200	5 – 15	0 – 10	1

TABLE 3

SETTLEMENT OF EMBANKMENT SURFACE

FOUNDATION AREA No.	RECOMMENDED TREATMENT (Note 1)	SETTLEMENT, mm							
		PRIMARY CONSOLIDATION (Note 2)	ROCKFILL	TOTAL	DURING 6 MONTHS AFTER CONSTRUCTION	DURING 1ST YEAR AFTER CONSTRUCTION	REMAINING AFTER 6 MONTHS	REMAINING AFTER 1 YEAR	MONTHS REQUIRED TO REDUCE REMAINING SETTLEMENTS TO 100 mm
112 Sta. 19+350 to 19+460	Preloading (option 2)	0 – 375	5 – 80	5 – 455	5 – 315	5 – 400	0 – 140	0 – 55	9
113 Sta. 19+750 to 19+810	Preloading (option 2)	0 – 150	0 – 30	0 – 180	0 – 165	0 – 175	0 – 15	0 – 5	2
114 Sta. 19+850 to 19+955	Preloading (option 2)	0 – 140	5 – 20	5 – 160	5 – 140	5 – 155	0 – 20	0 – 5	2
115 Sta. 20+175 to 20+295	Preloading (option 2)	0 – 290	0 – 50	0 – 340	0 – 195	0 – 260	0 – 145	0 – 80	10
116 Sta. 20+760 to 20+970 (NBL)	Preloading (option 2)	0 – 155	5 – 30	5 – 185	5 – 175	5 – 180	0 – 10	0 – 5	1
117 Sta. 20+815 to 20+880 (SBL)	Preloading (option 2)	0 – 205	20 – 30	20 – 235	15 – 200	20 – 225	5 – 35	0 – 10	3
118 Sta. 22+225 to 22+320	Preloading (option 2)	0 – 70	15 – 30	15 – 100	10 – 90	15 – 95	5 – 10	0 – 5	1
119 Sta. 22+350 to 22+725 (NBL)	Preloading (option 2)	0 – 130	10 – 20	10 – 150	5 – 140	10 – 145	5 – 10	0 – 5	1

TABLE 3

SETTLEMENT OF EMBANKMENT SURFACE

FOUNDATION AREA No.	RECOMMENDED TREATMENT (Note 1)	SETTLEMENT, mm							
		PRIMARY CONSOLIDATION (Note 2)	ROCKFILL	TOTAL	DURING 6 MONTHS AFTER CONSTRUCTION	DURING 1ST YEAR AFTER CONSTRUCTION	REMAINING AFTER 6 MONTHS	REMAINING AFTER 1 YEAR	MONTHS REQUIRED TO REDUCE REMAINING SETTLEMENTS TO 100 mm
120 Sta. 22+390 to 22+430 (SBL)	Not required	0	10 – 20	10 – 20	5 – 10	10 – 15	5 – 10	0 – 5	–
121 Sta. 22+590 to 22+700 (SBL)	Not required	0 – 25	15 – 30	15 – 55	10 – 45	15 – 50	5 – 10	0 – 5	–
122 Sta. 22+800 to 22+840 (SBL)	Not required	0	15 – 20	15 – 20	10	15	5 – 10	0 – 5	–
123 Sta. 22+850 to 22+920 (NBL)	Not required	0	10 – 20	10 – 20	5 – 10	10 – 15	5 – 10	0 – 5	–
124 Sta. 22+960 to 23+060 (NBL)	Not required	0	15 – 30	15 – 30	10 – 20	15 – 25	5 – 10	0 – 5	–
Ramp S-E/W Sta. 20+239 to 20+300, Ramp S-E/W chainage	Preloading (option 2)	0 – 240	20 – 45	20 – 285	15 – 190	20 – 240	5 – 95	0 – 45	6
Ramp N-E/W Sta. 20+710 to 20+965, Ramp N-E/W chainage	Full excavation (option 1)	0	20 – 110	20 – 110	15 – 85	20 – 95	5 – 25	0 – 15	1
	Preloading (option 2)	0 – 210	20 – 75	20 – 285	15 – 265	20 – 275	5 – 20	0 – 10	3

TABLE 3

SETTLEMENT OF EMBANKMENT SURFACE

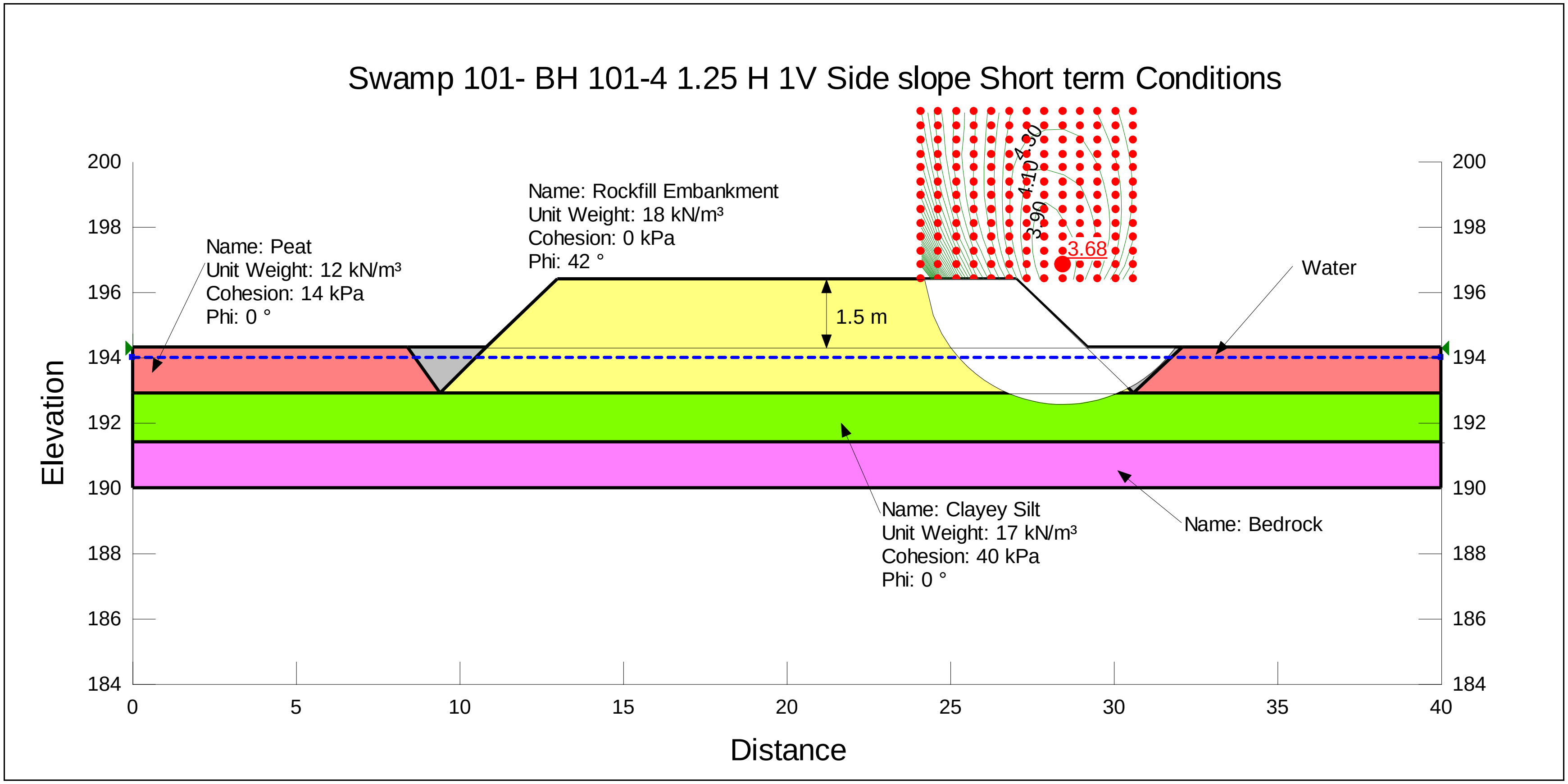
FOUNDATION AREA No.	RECOMMENDED TREATMENT (Note 1)	SETTLEMENT, mm							
		PRIMARY CONSOLIDATION (Note 2)	ROCKFILL	TOTAL	DURING 6 MONTHS AFTER CONSTRUCTION	DURING 1ST YEAR AFTER CONSTRUCTION	REMAINING AFTER 6 MONTHS	REMAINING AFTER 1 YEAR	MONTHS REQUIRED TO REDUCE REMAINING SETTLEMENTS TO 100 mm
Interchange Service Road Sta. 9+900 to 10+100, Interchange Service Road chainage	Full excavation (option 1)	0	25 – 125	25 – 125	15 – 95	20 – 105	10 – 30	5 – 20	2
	Preloading (option 2)	0 – 290	25 – 80	25 – 370	15 – 315	20 – 355	10 – 55	5 – 15	4
North Transfer Swamp 1 Sta. 42+550 to 42+640, North Transfer chainage	Preloading (option 2)	0 – 110	15 – 25	15 – 135	10 – 125	15 – 130	5 – 10	0 – 5	1
North Transfer Swamp 2 Sta. 42+960 to 43+000, North Transfer chainage	Preloading (option 2)	0 – 105	10 – 25	10 – 130	10 – 120	10 – 125	0 – 10	0 – 5	1

NOTES:

1. Refer to Section 3.2 for a description of treatment options.
2. Primary consolidation relates to cohesive soils.
3. The settlement values do not include compression of cohesionless soils that will occur during construction or within 3 months following fill placement.
4. Surcharging for swamp 109 (partial excavation to 7 m depth) should be accomplished with 2 m high granular fill for a period of 14 months.

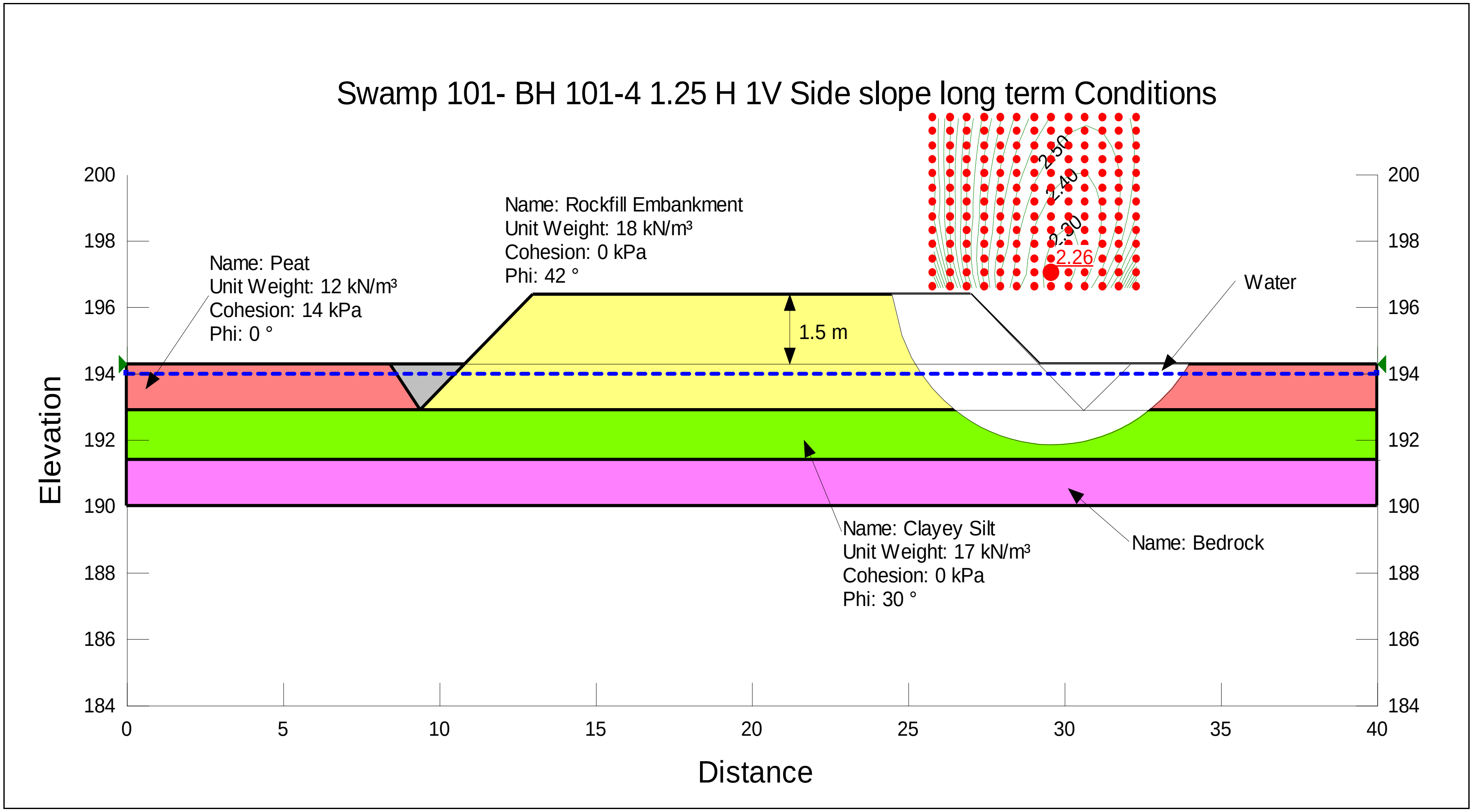
APPENDIX A

Slope Stability Diagrams for Embankments



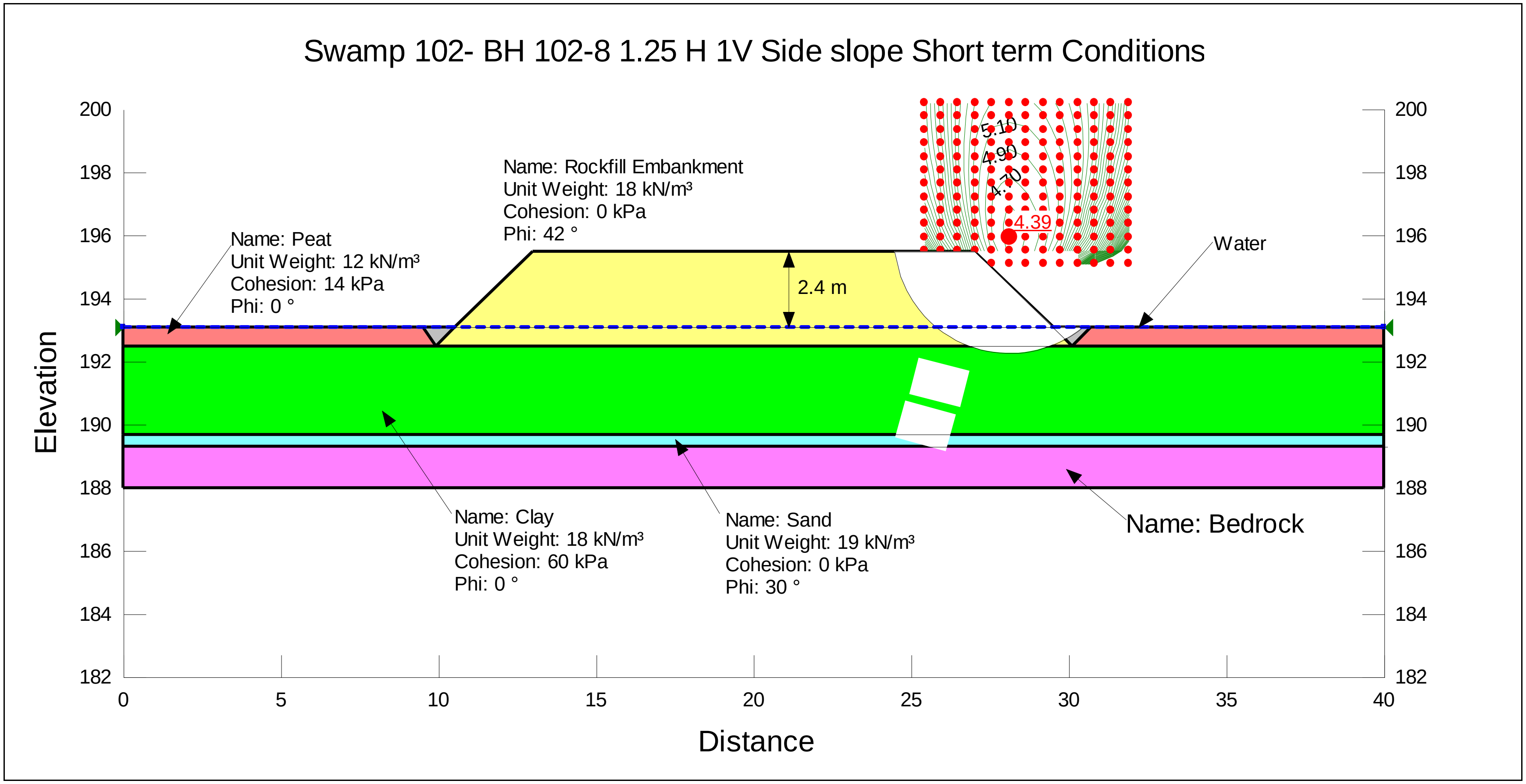
Note: Peat subexcavated below embankment. FOS = 3.68, the minimum FOS of 1.3 was met.

FIGURE 101A



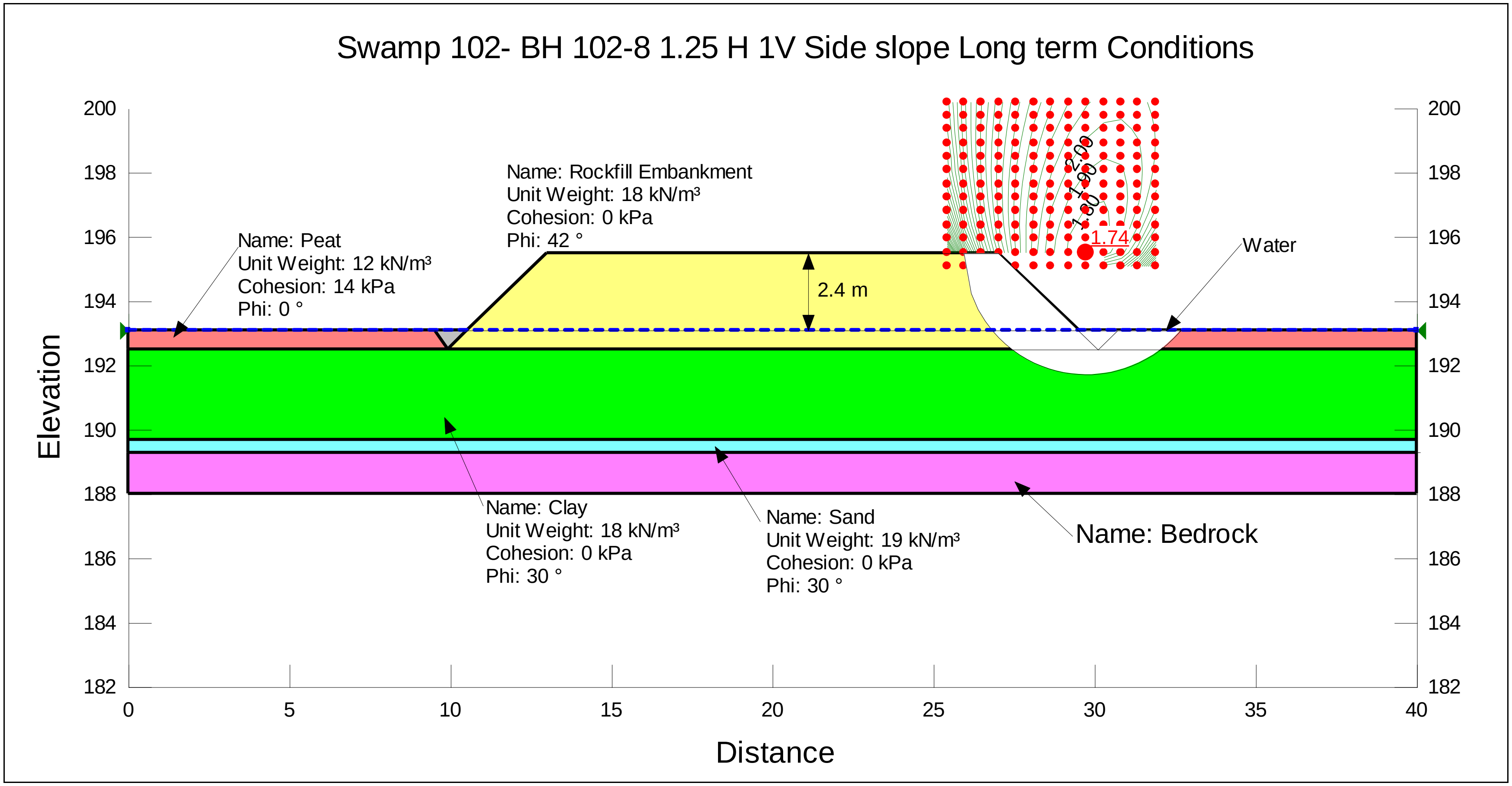
Note: Peat subexcavated below embankment. FOS = 2.26, the minimum FOS of 1.5 was met.

FIGURE 101B



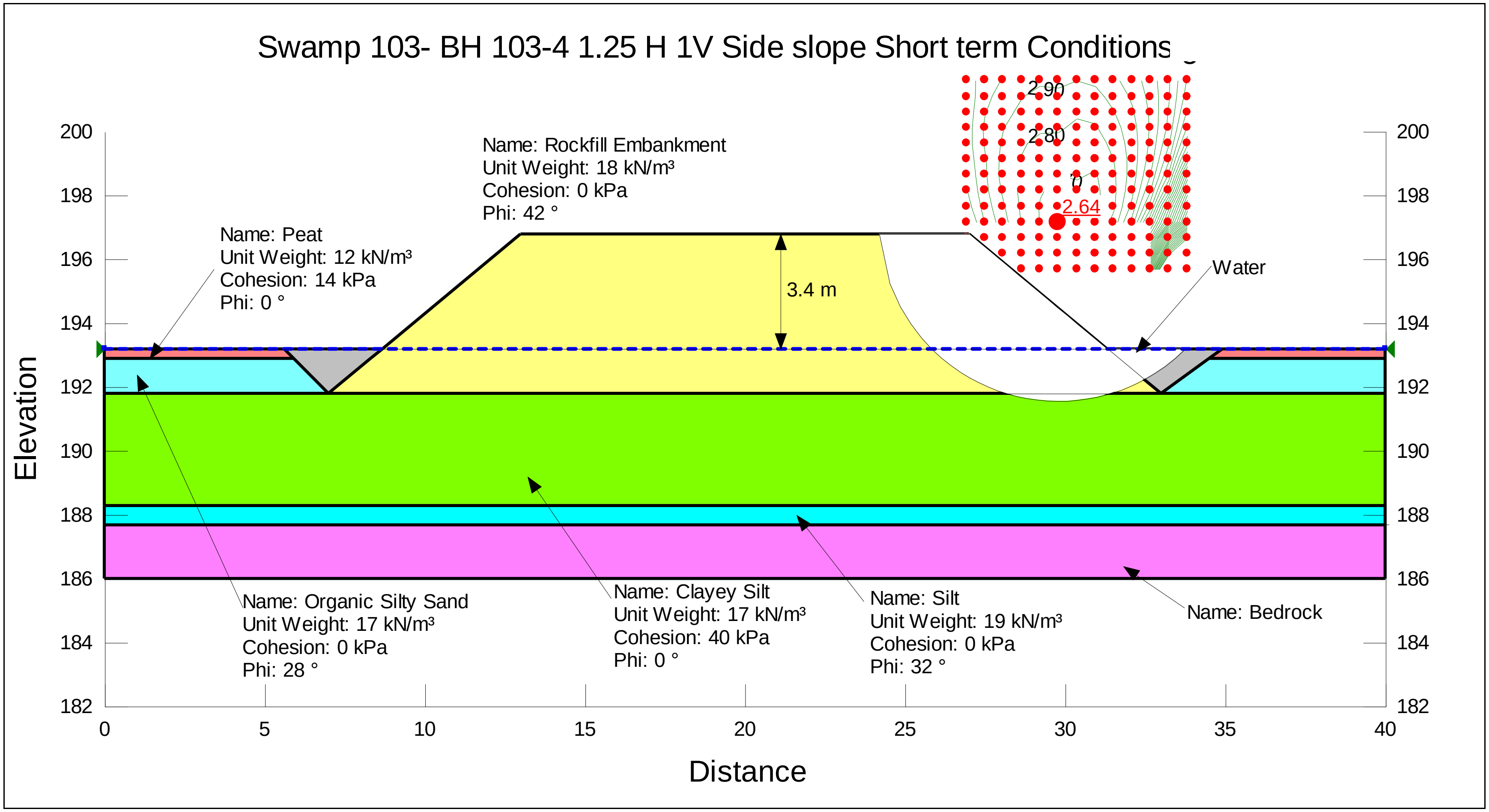
Note: Peat subexcavated below embankment. FOS = 4.39, the minimum FOS of 1.3 was met.

FIGURE 102A



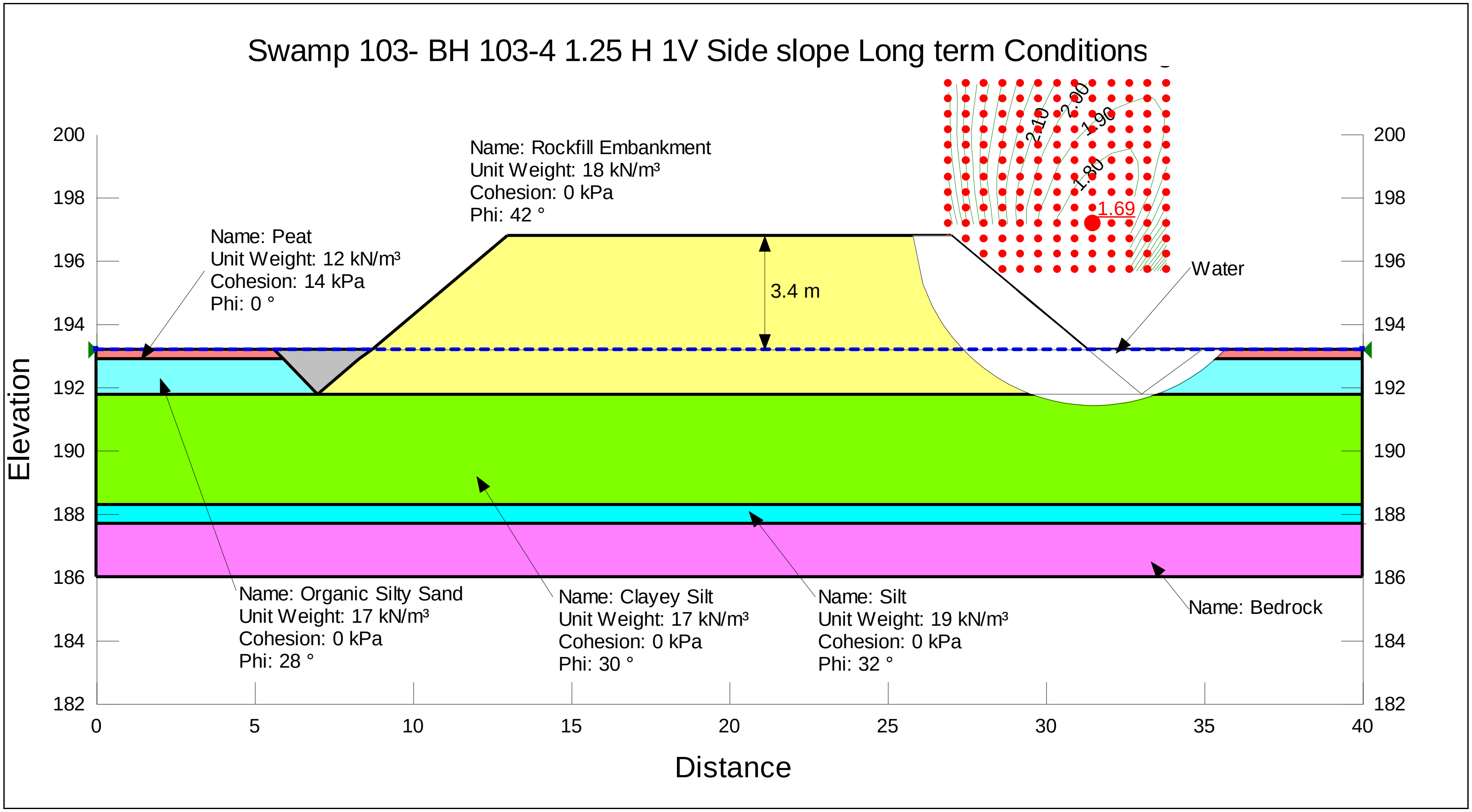
Note: Peat subexcavated below embankment. FOS = 1.74, the minimum FOS of 1.5 was met.

FIGURE 102B



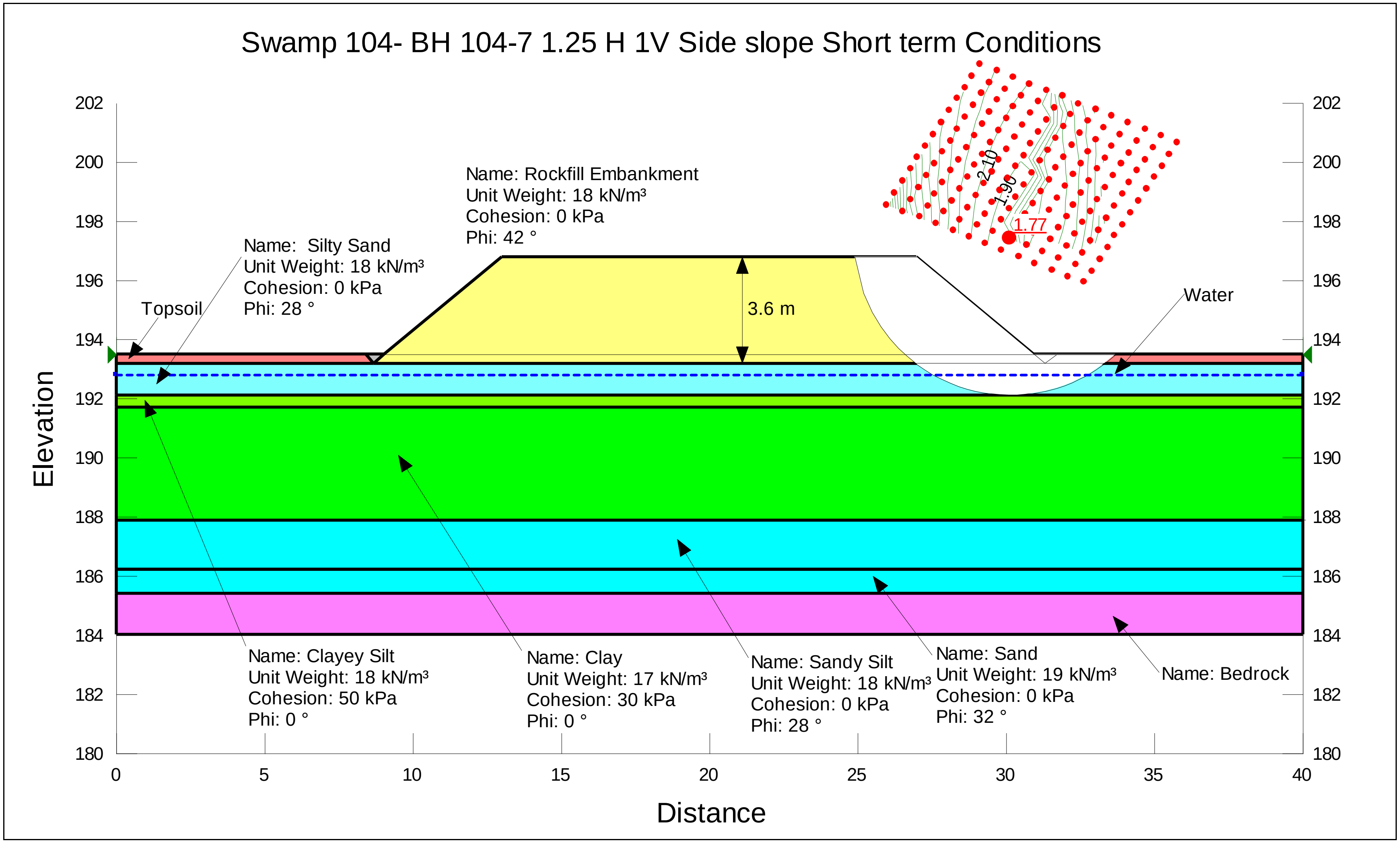
Note: Peat subexcavated below embankment. FOS = 2.64, the minimum FOS of 1.3 was met.

FIGURE 103A



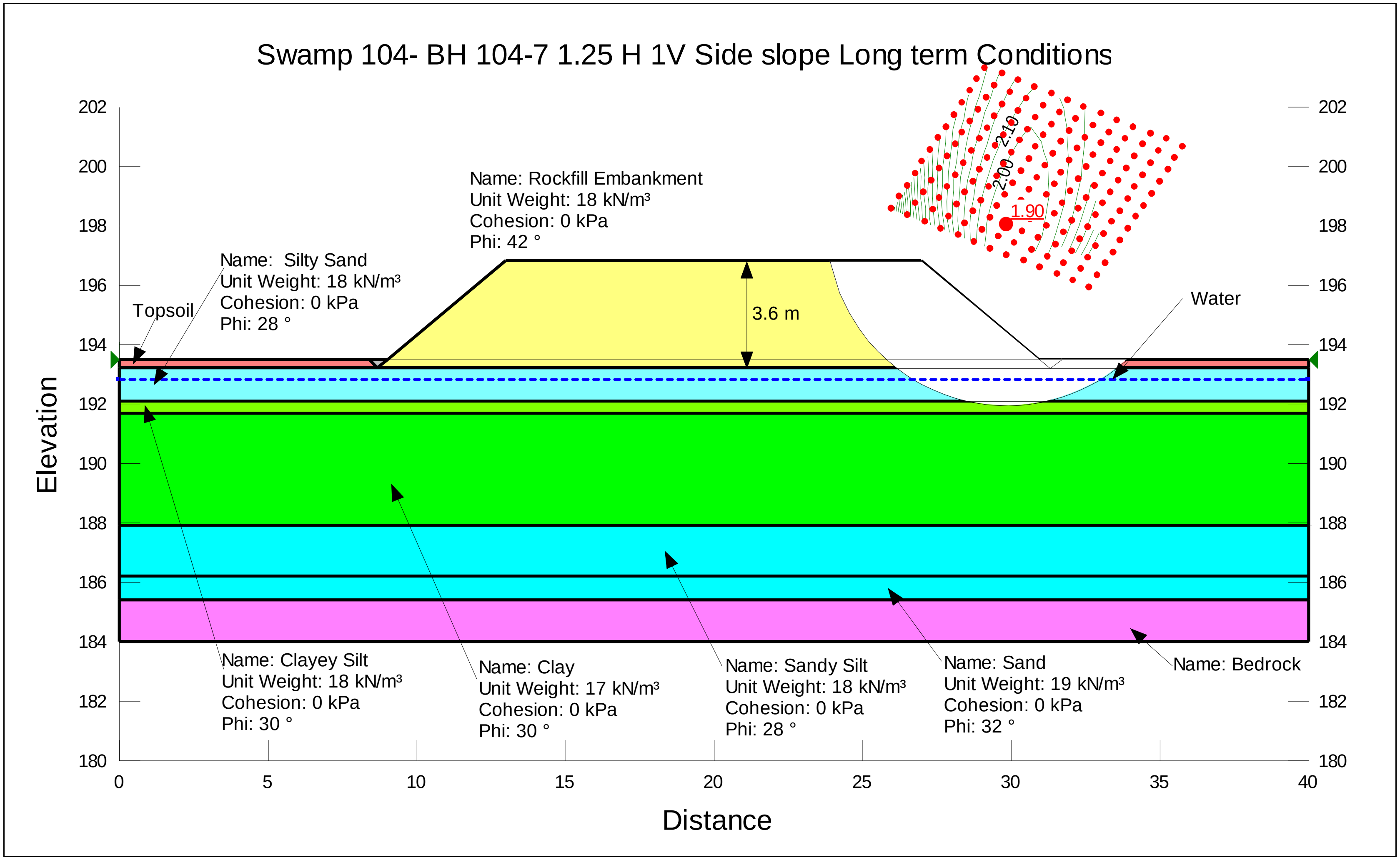
Note: Peat subexcavated below embankment. FOS = 1.69, the minimum FOS of 1.5 was met.

FIGURE 103B



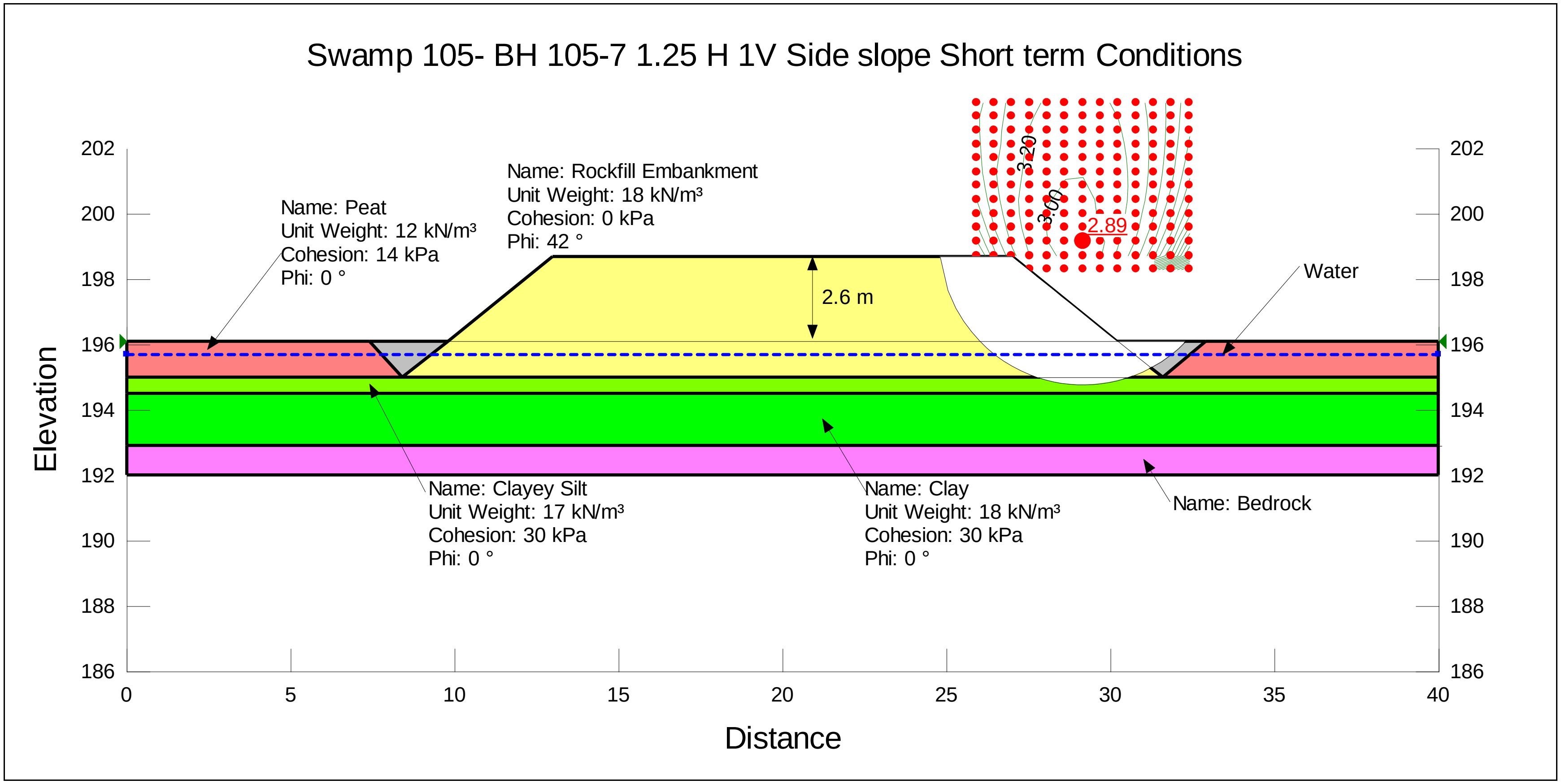
Note: Topsoil subexcavated below embankment. FOS = 1.77, the minimum FOS of 1.3 was met.

FIGURE 104A



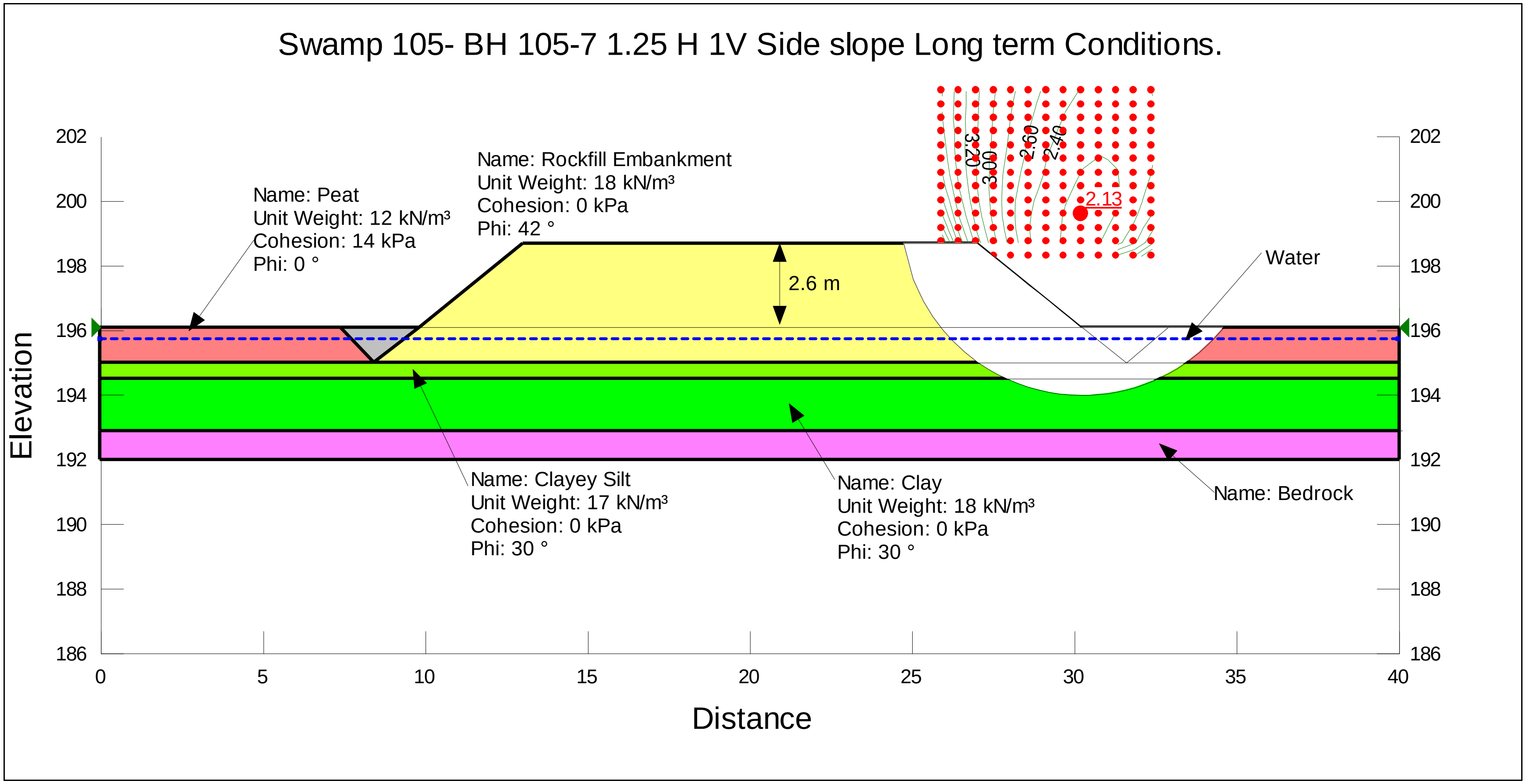
Note: Topsoil subexcavated below embankment. FOS = 1.90, the minimum FOS of 1.5 was met.

FIGURE 104B



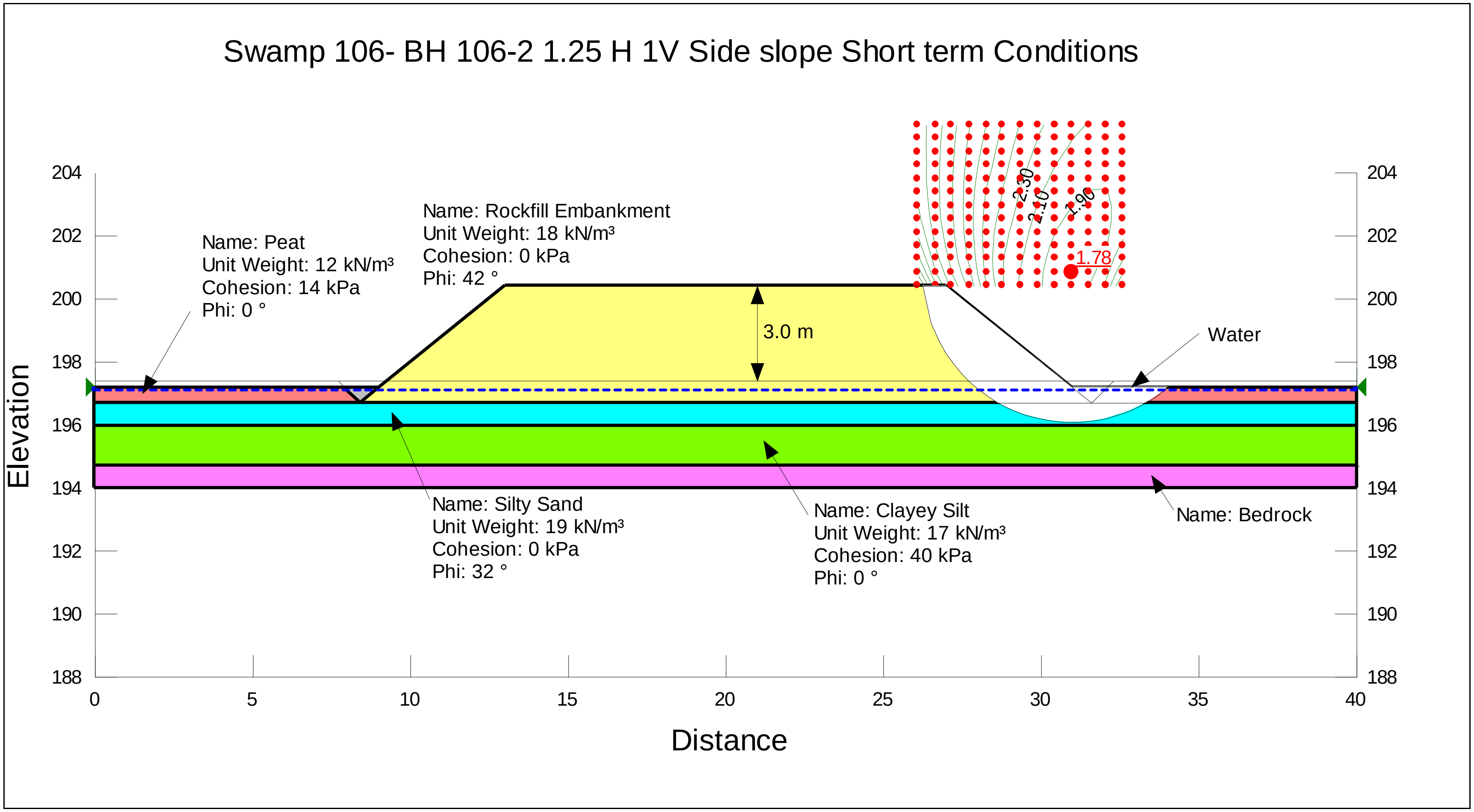
Note: Peat subexcavated below embankment. FOS = 2.89, the minimum FOS of 1.3 was met.

FIGURE 105A



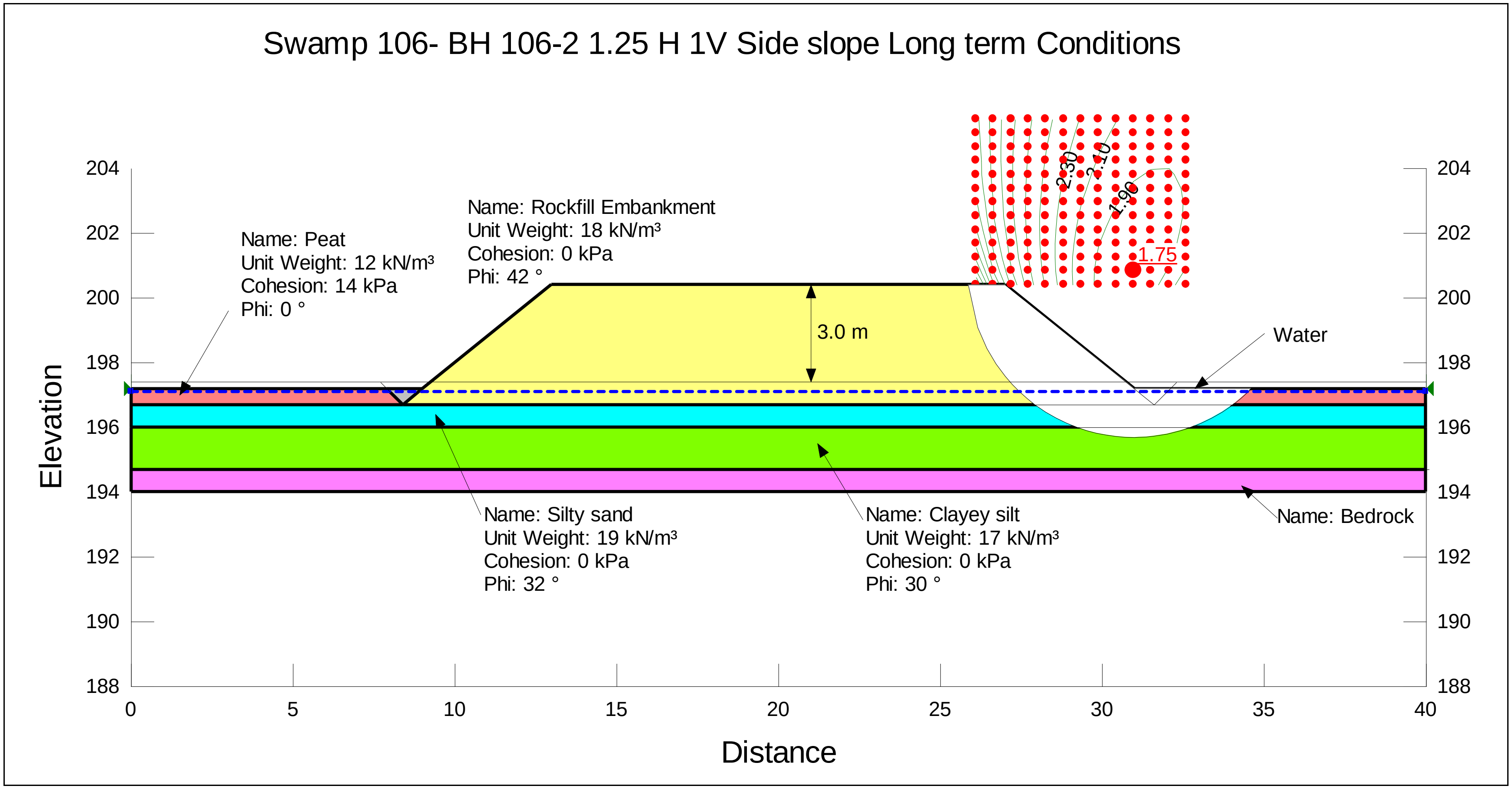
Note: Peat subexcavated below embankment. FOS = 2.13, the minimum FOS of 1.5 was met.

FIGURE 105B



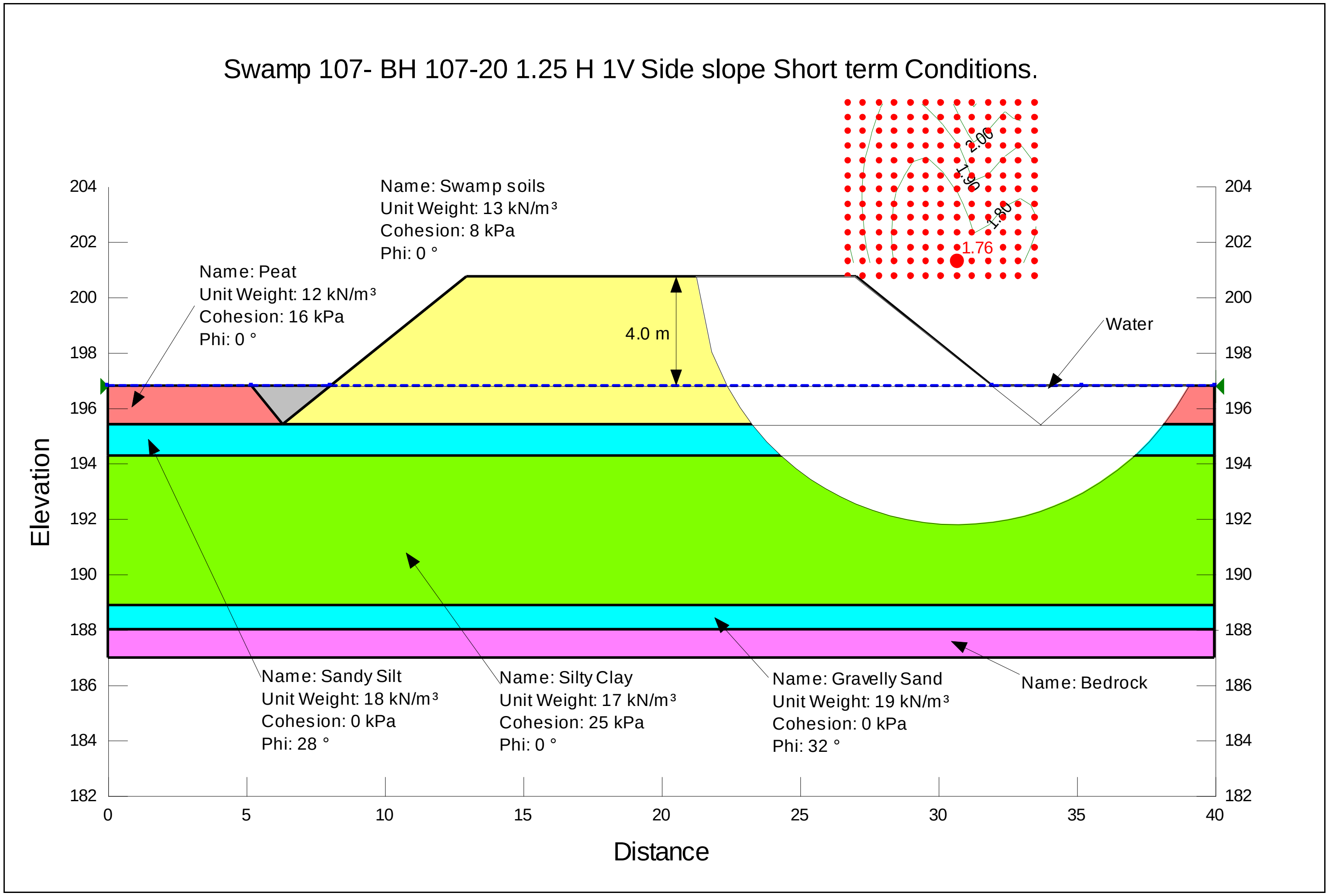
Note: Peat subexcavated below embankment. FOS = 1.78, the minimum FOS of 1.3 was met.

FIGURE 106A



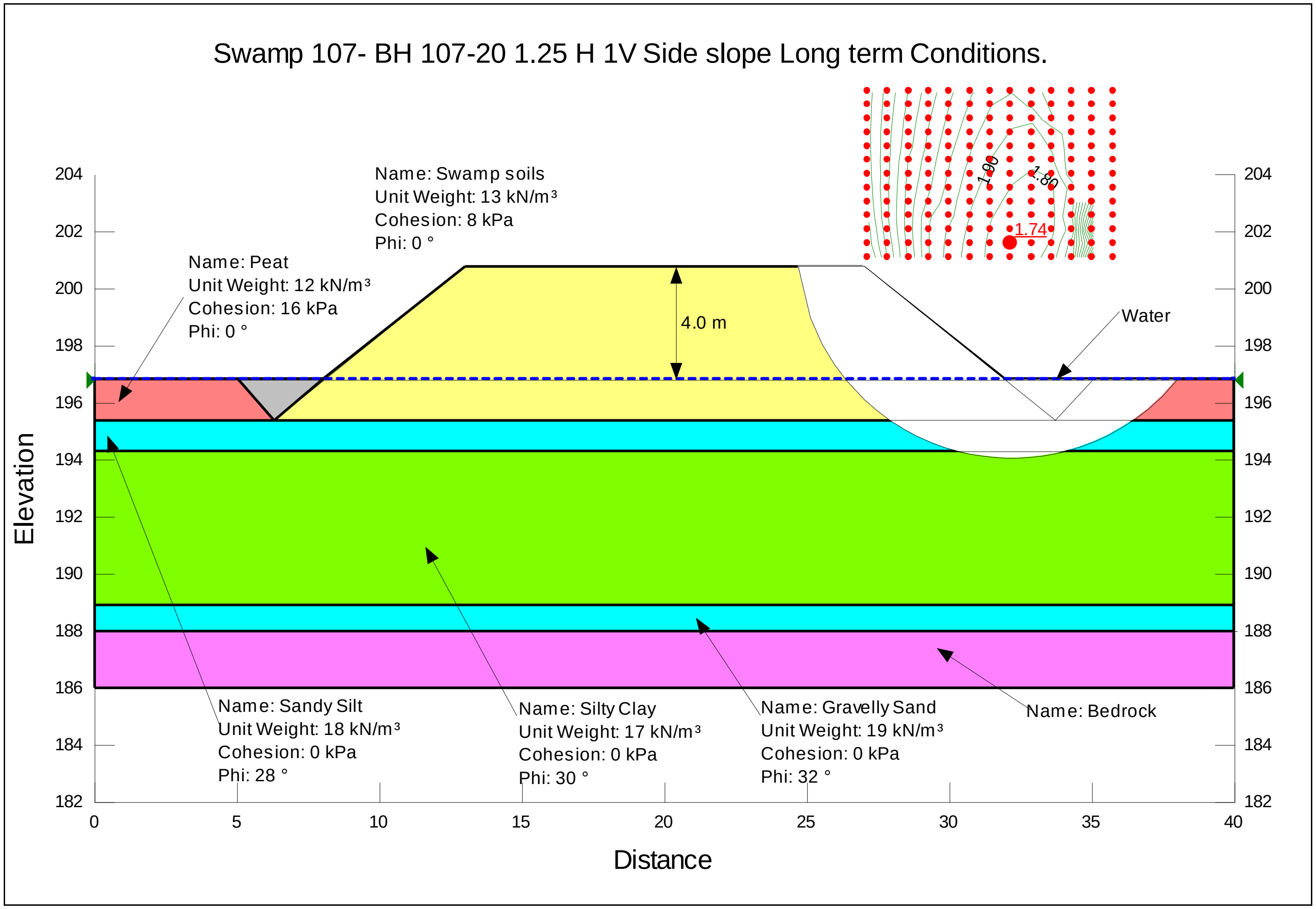
Note: Peat subexcavated below embankment. FOS = 1.75, the minimum FOS of 1.5 was met.

FIGURE 106B



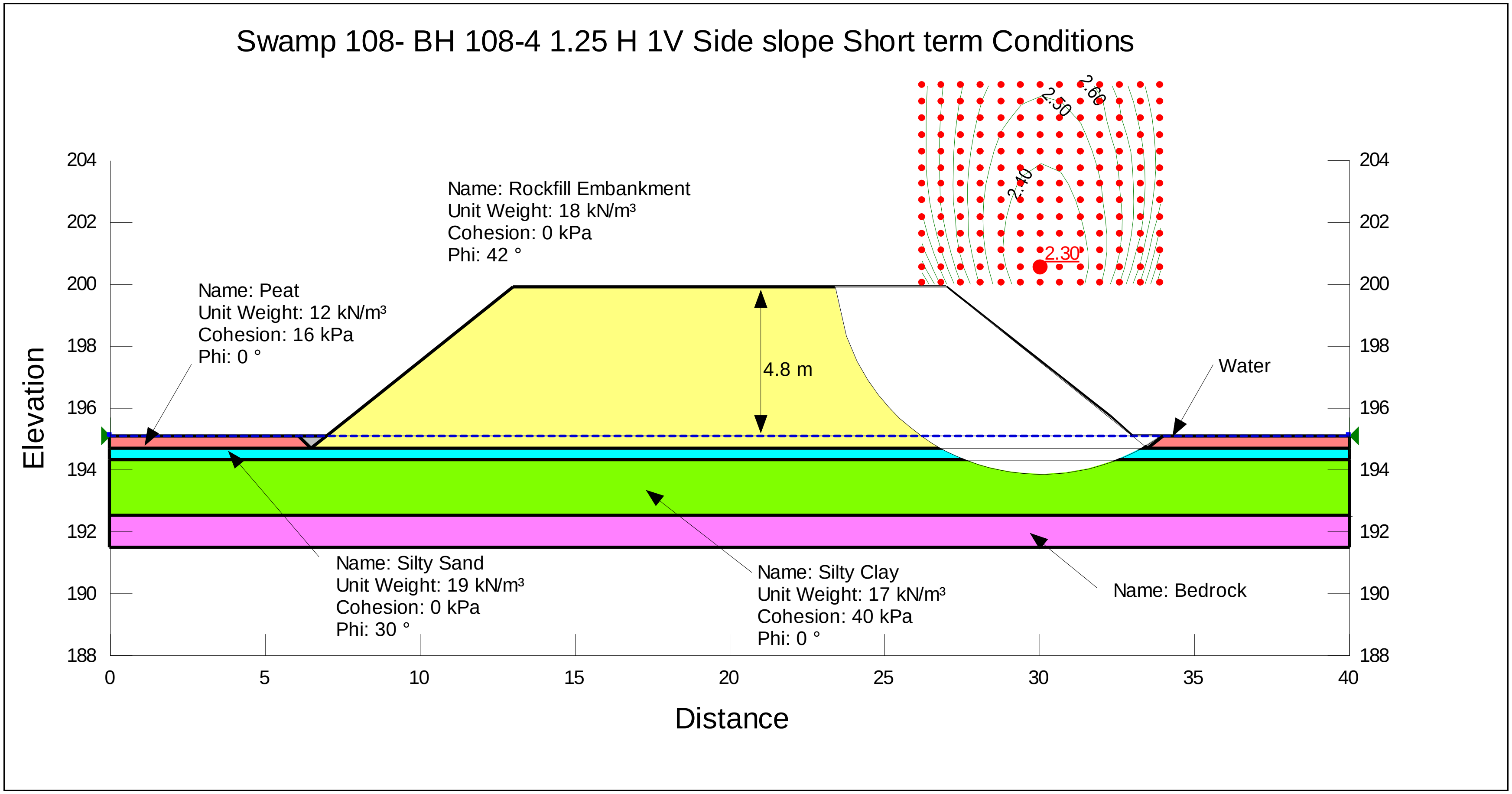
Note: Peat subexcavated below embankment. FOS = 1.76, the minimum FOS of 1.3 was met.

FIGURE 107A



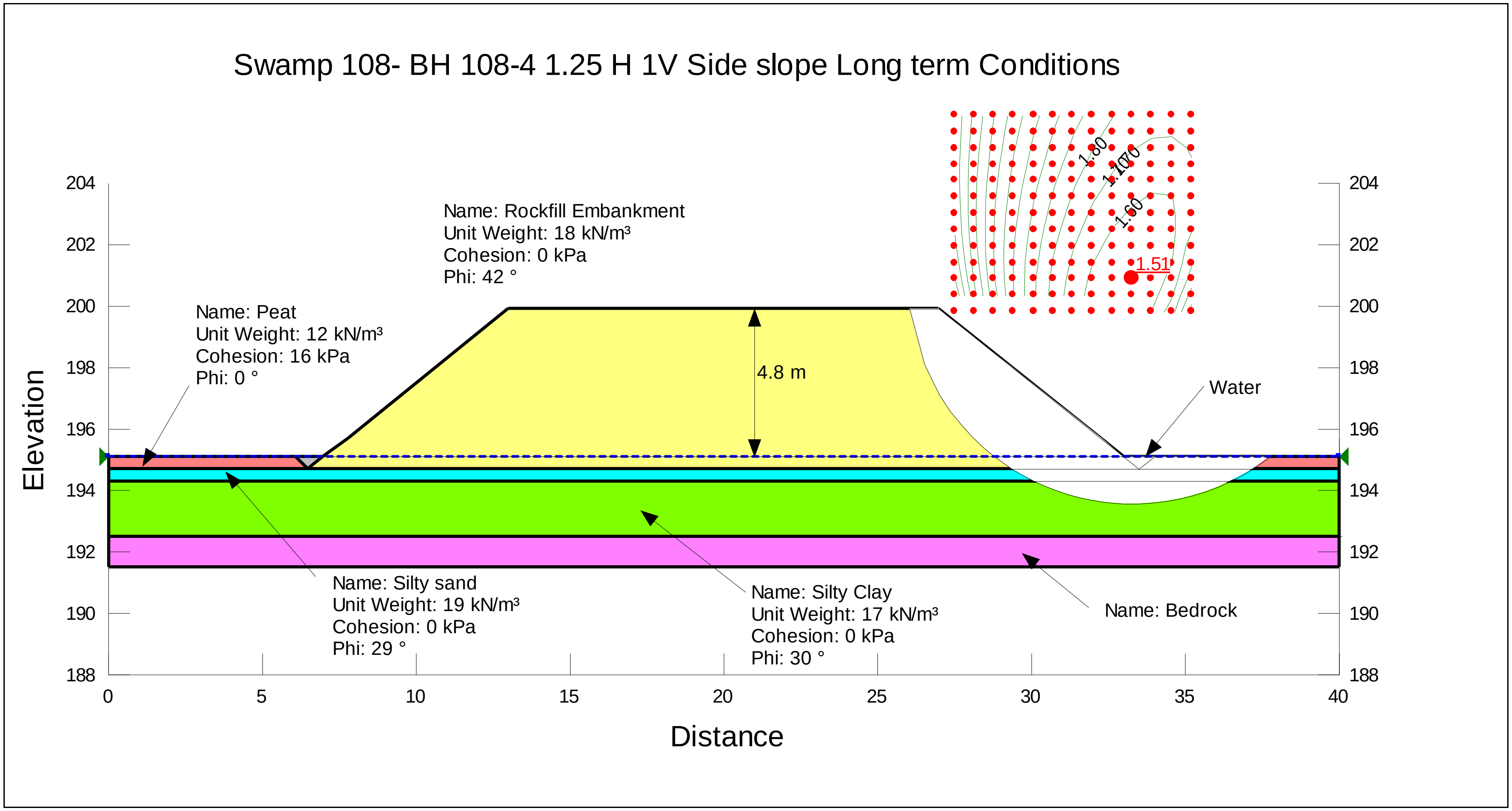
Note: Peat subexcavated below embankment. FOS = 1.74, the minimum FOS of 1.5 was met.

FIGURE 107B



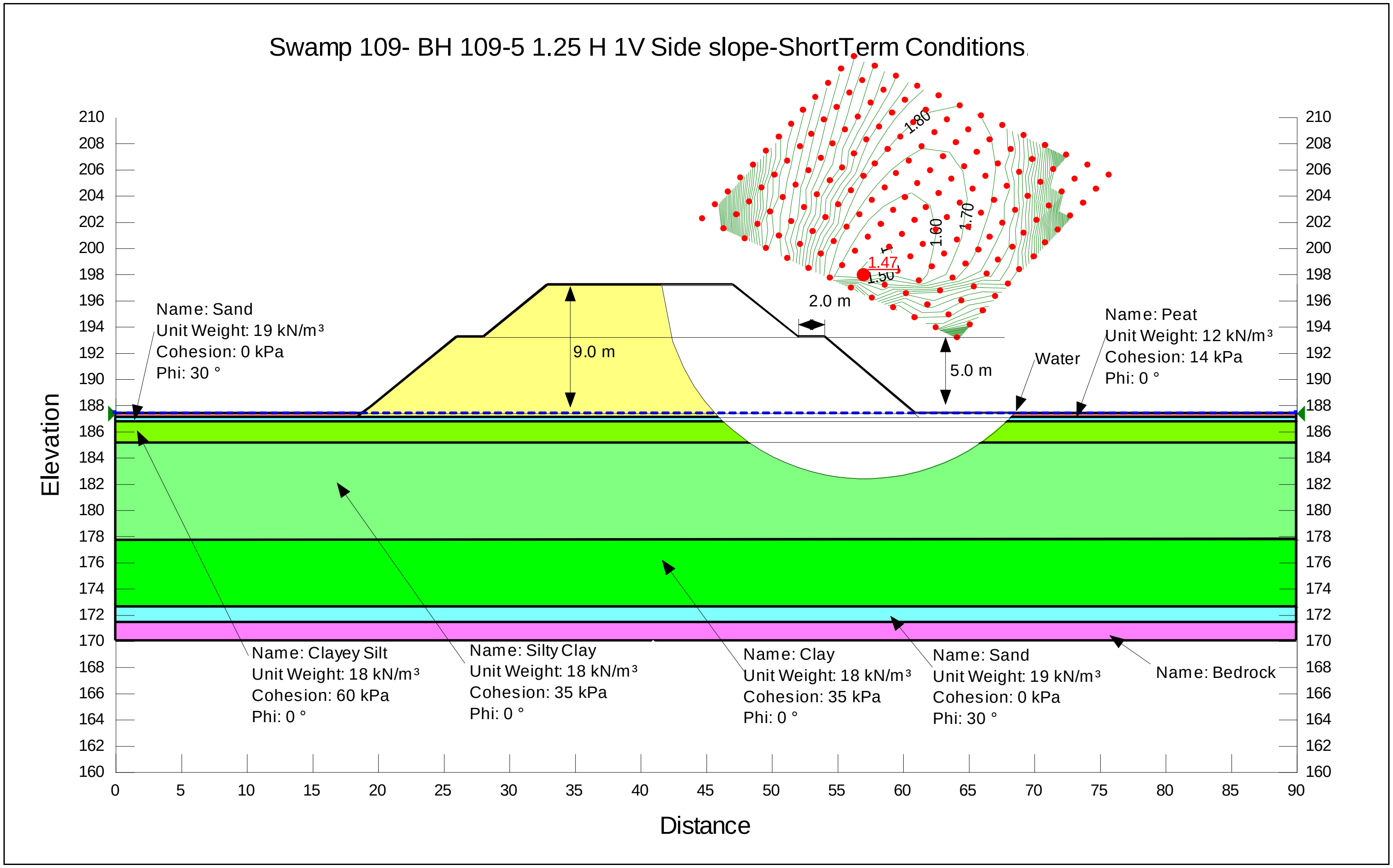
Note: Peat subexcavated below embankment. FOS = 2.30, the minimum FOS of 1.3 was met.

FIGURE 108A



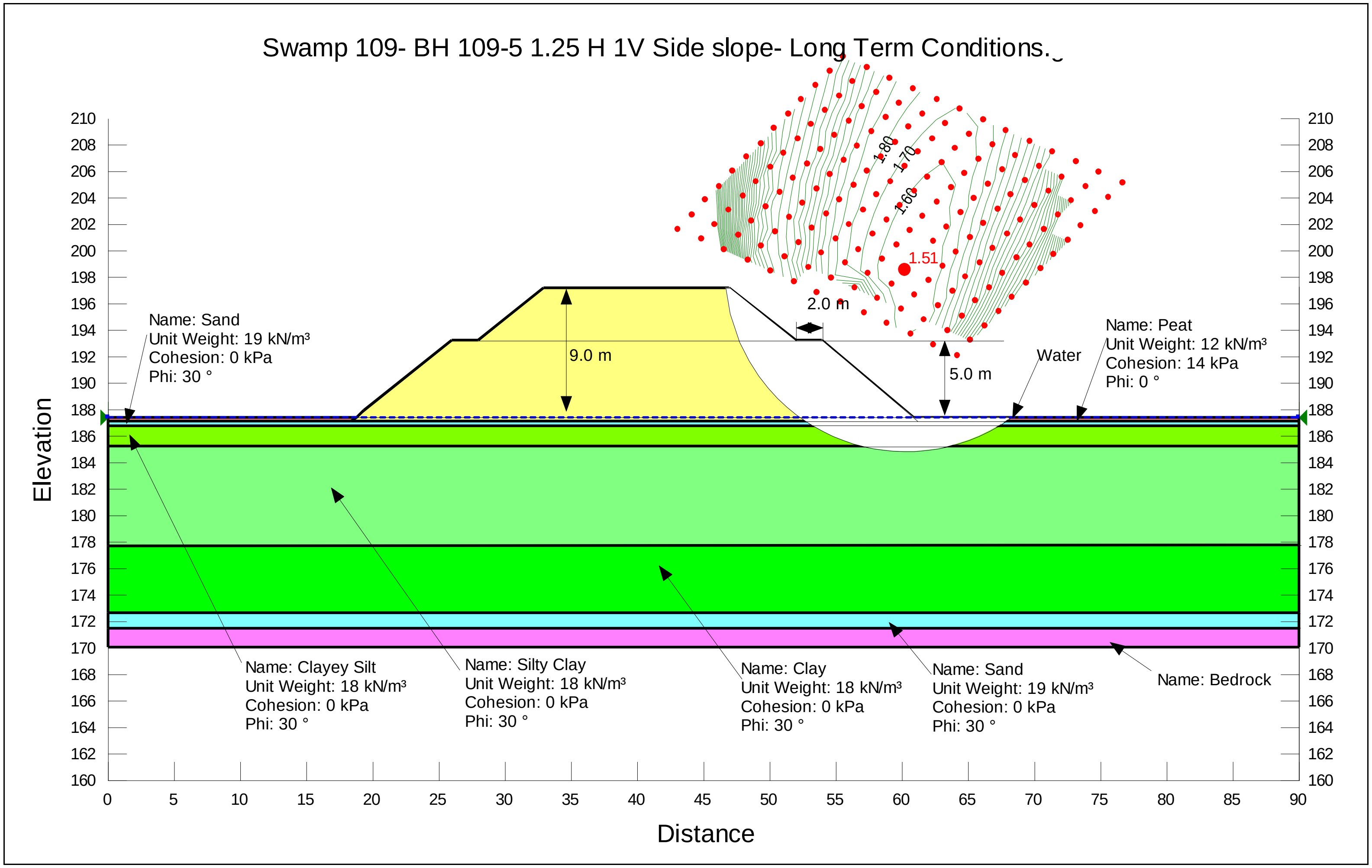
Note: Peat subexcavated below embankment. FOS = 1.51, the minimum FOS of 1.5 was met.

FIGURE 108B



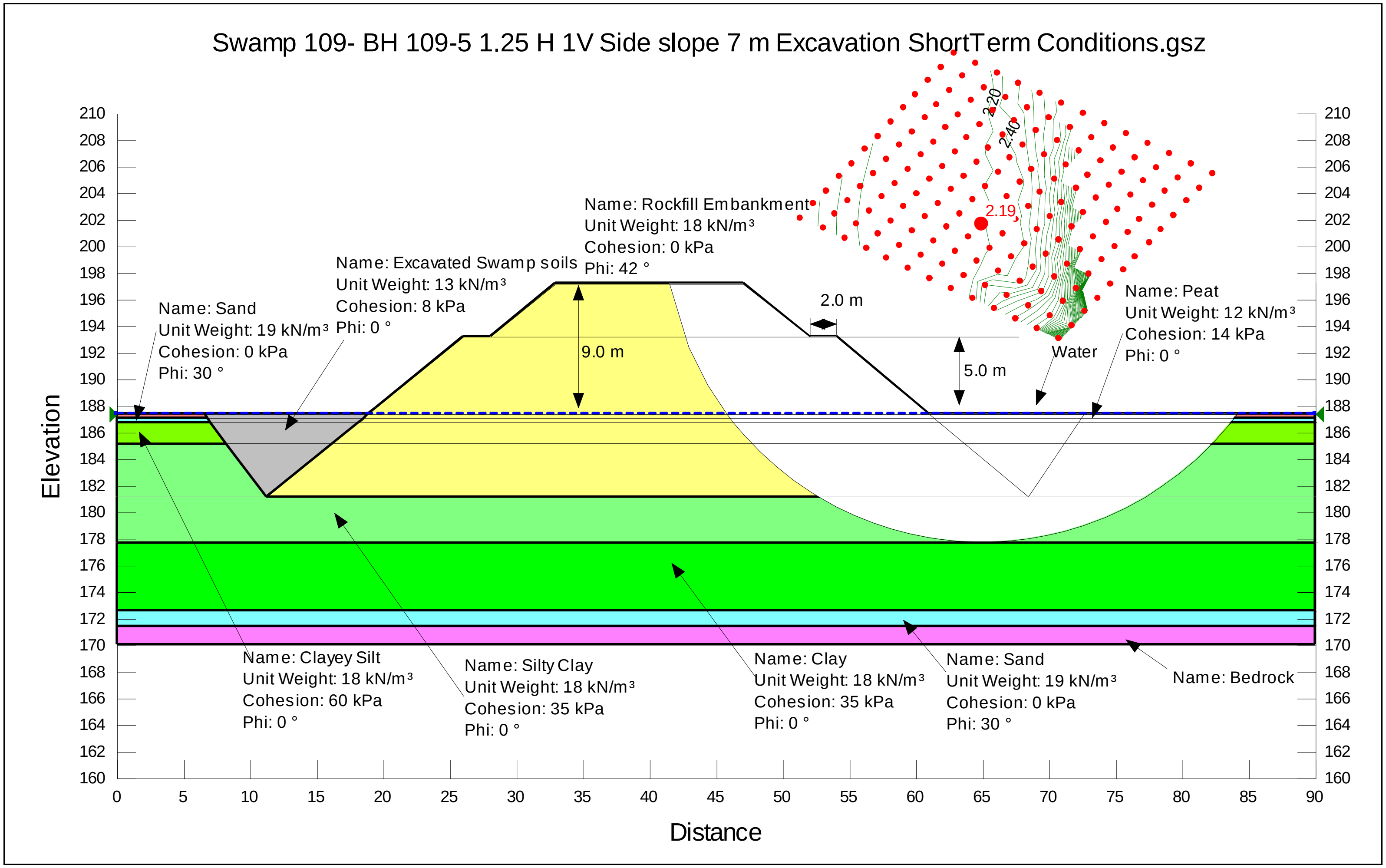
Note: Peat subexcavated below embankment. FOS = 1.47, the minimum FOS of 1.3 was met.

FIGURE 109A



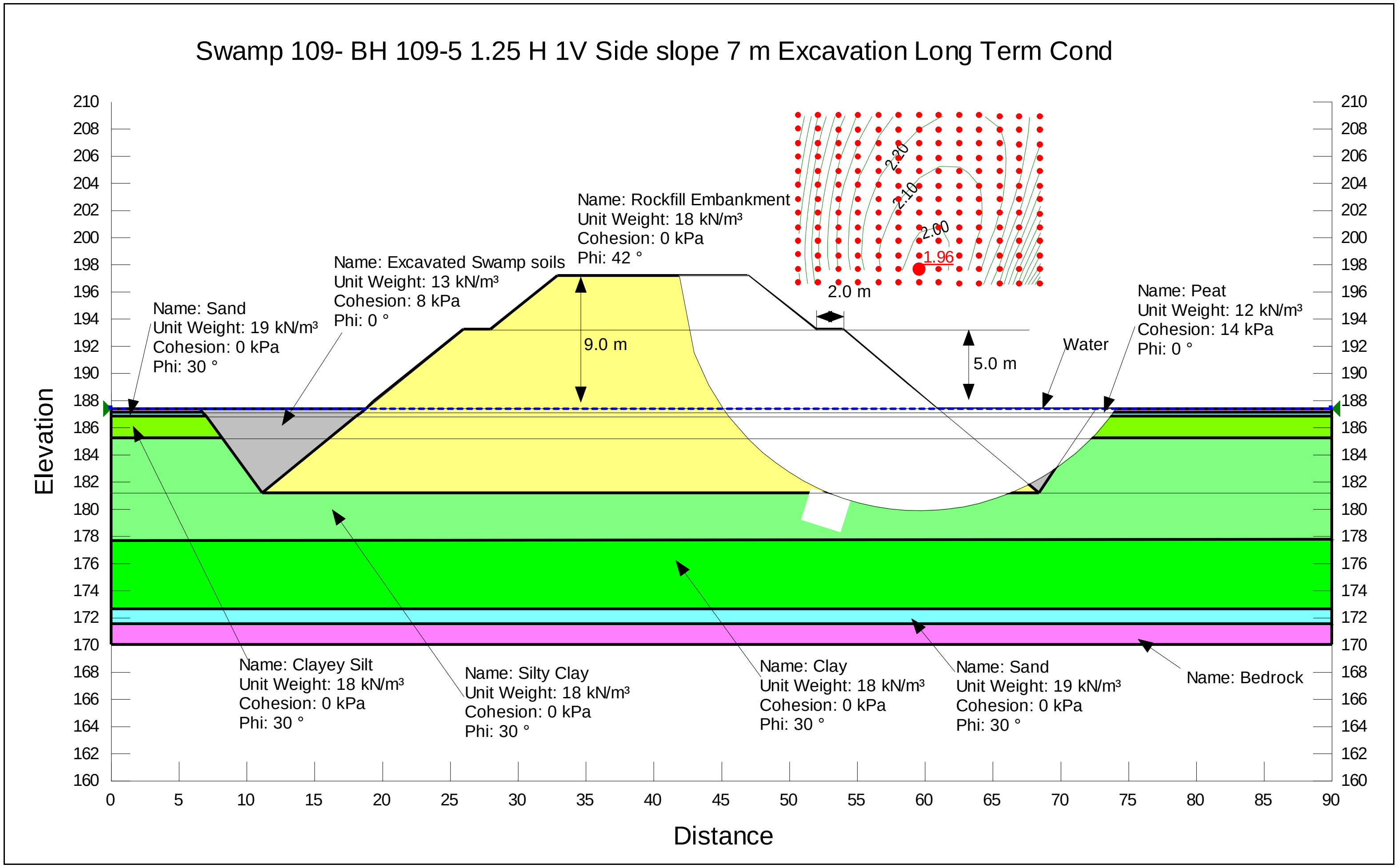
Note: Peat subexcavated below embankment. FOS = 1.51, the minimum FOS of 1.5 was met.

FIGURE 109B



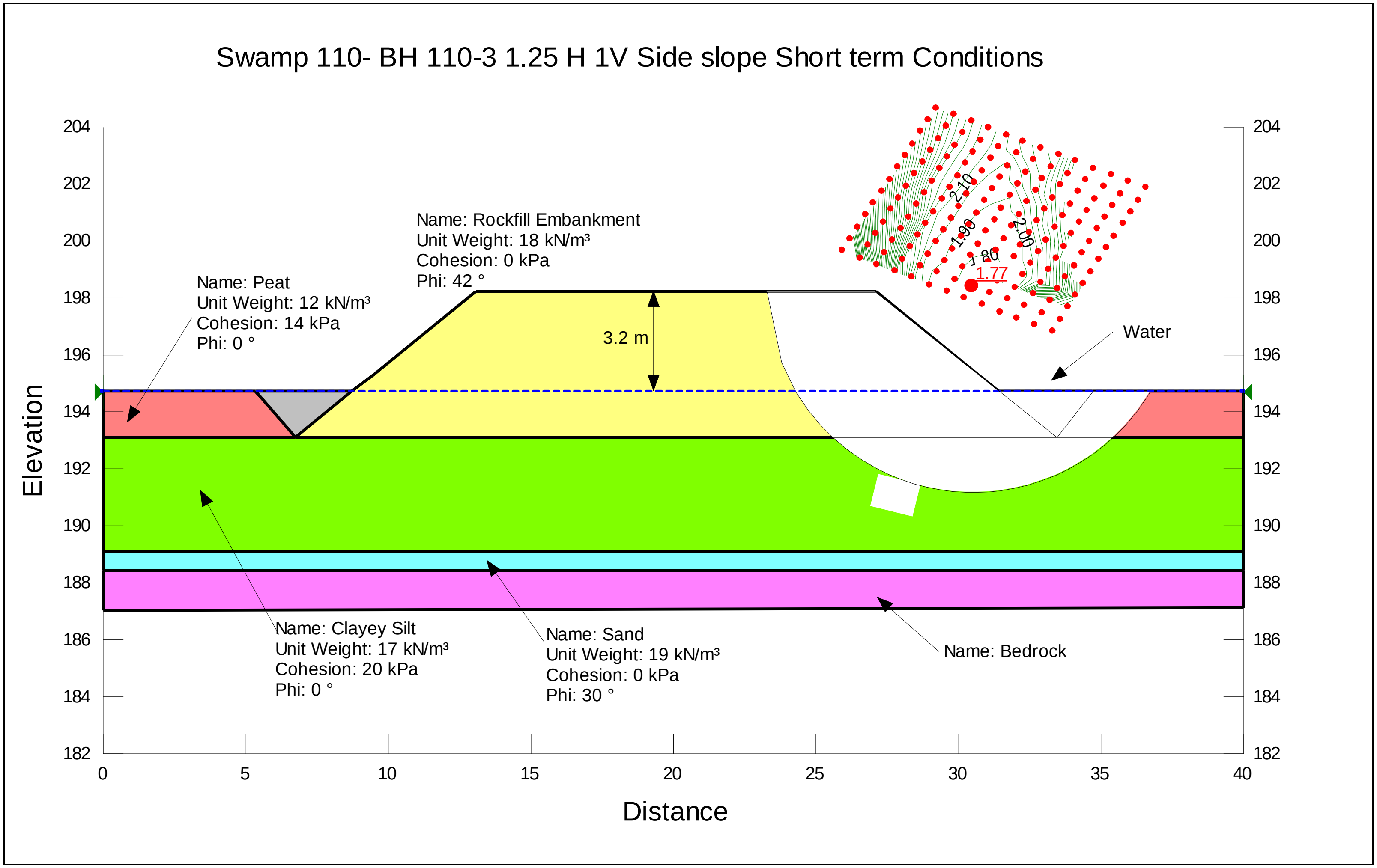
Note: Peat subexcavated below embankment. FOS = 2.19, the minimum FOS of 1.3 was met.

FIGURE 109C



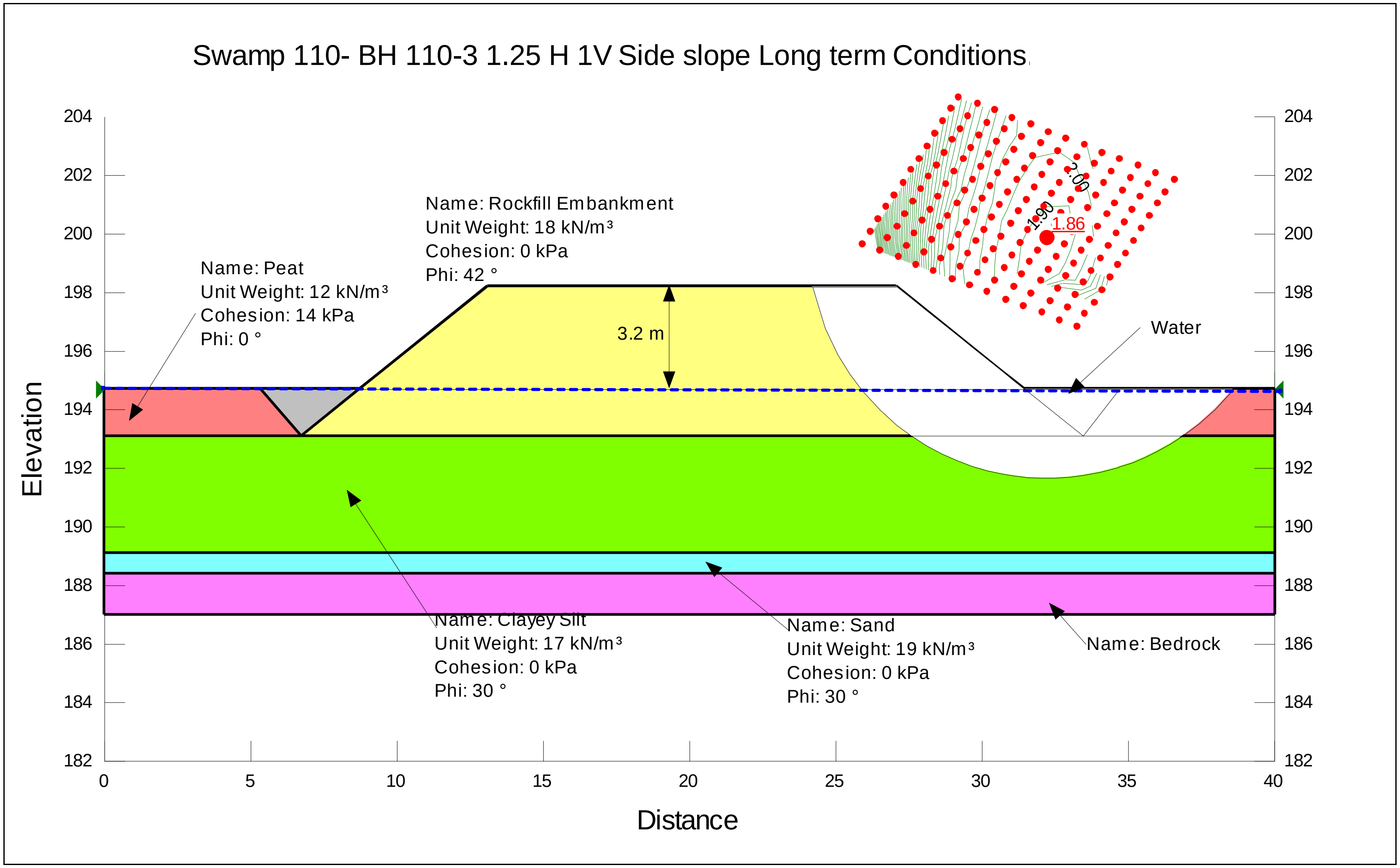
Note: Peat subexcavated below embankment. FOS = 1.96, the minimum FOS of 1.5 was met.

FIGURE 109D



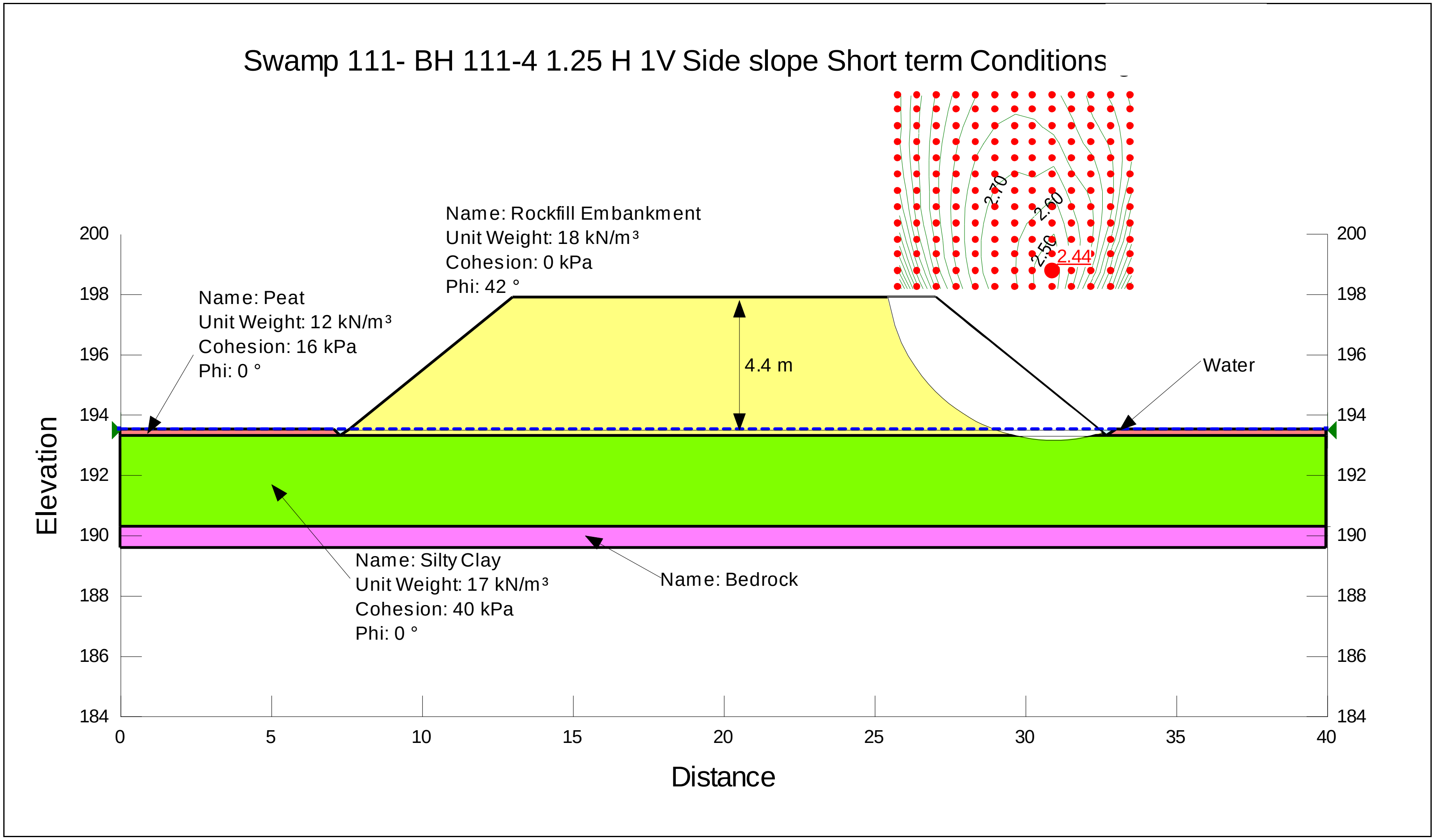
Note: Peat subexcavated below embankment. FOS = 1.77, the minimum FOS of 1.3 was met.

FIGURE 110A



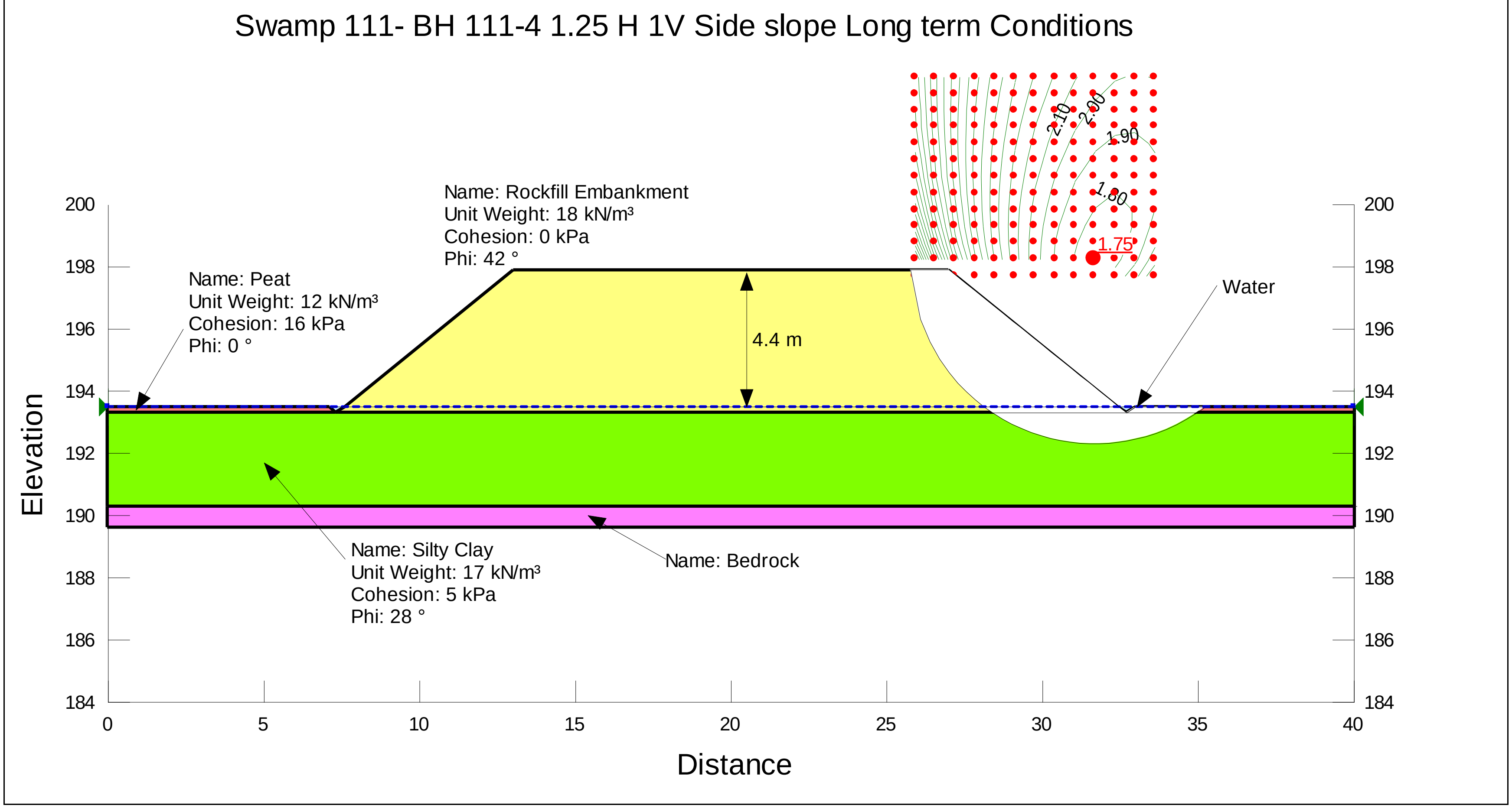
Note: Peat subexcavated below embankment. FOS = 1.86, the minimum FOS of 1.5 was met.

FIGURE 110B



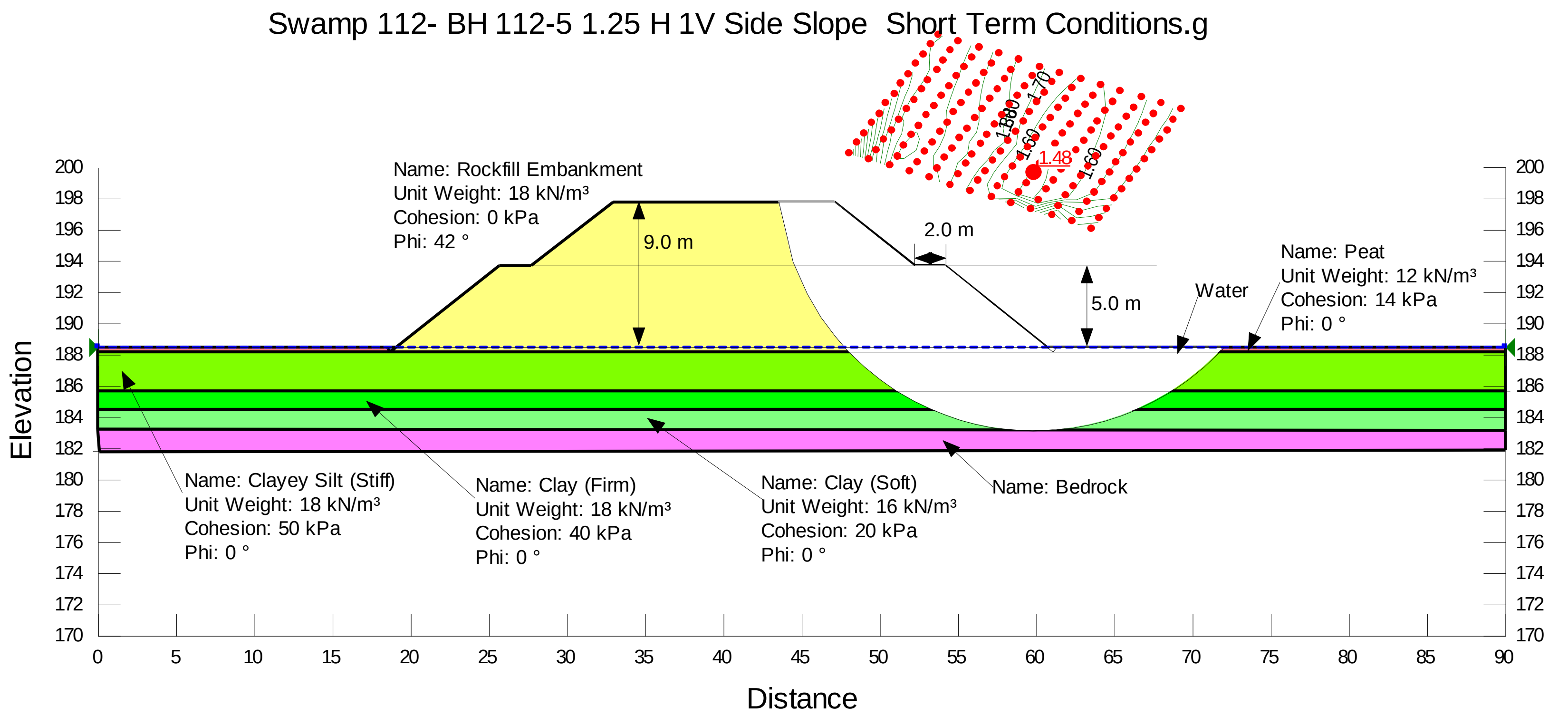
Note: Peat subexcavated below embankment. FOS = 2.44, the minimum FOS of 1.3 was met.

FIGURE 111A



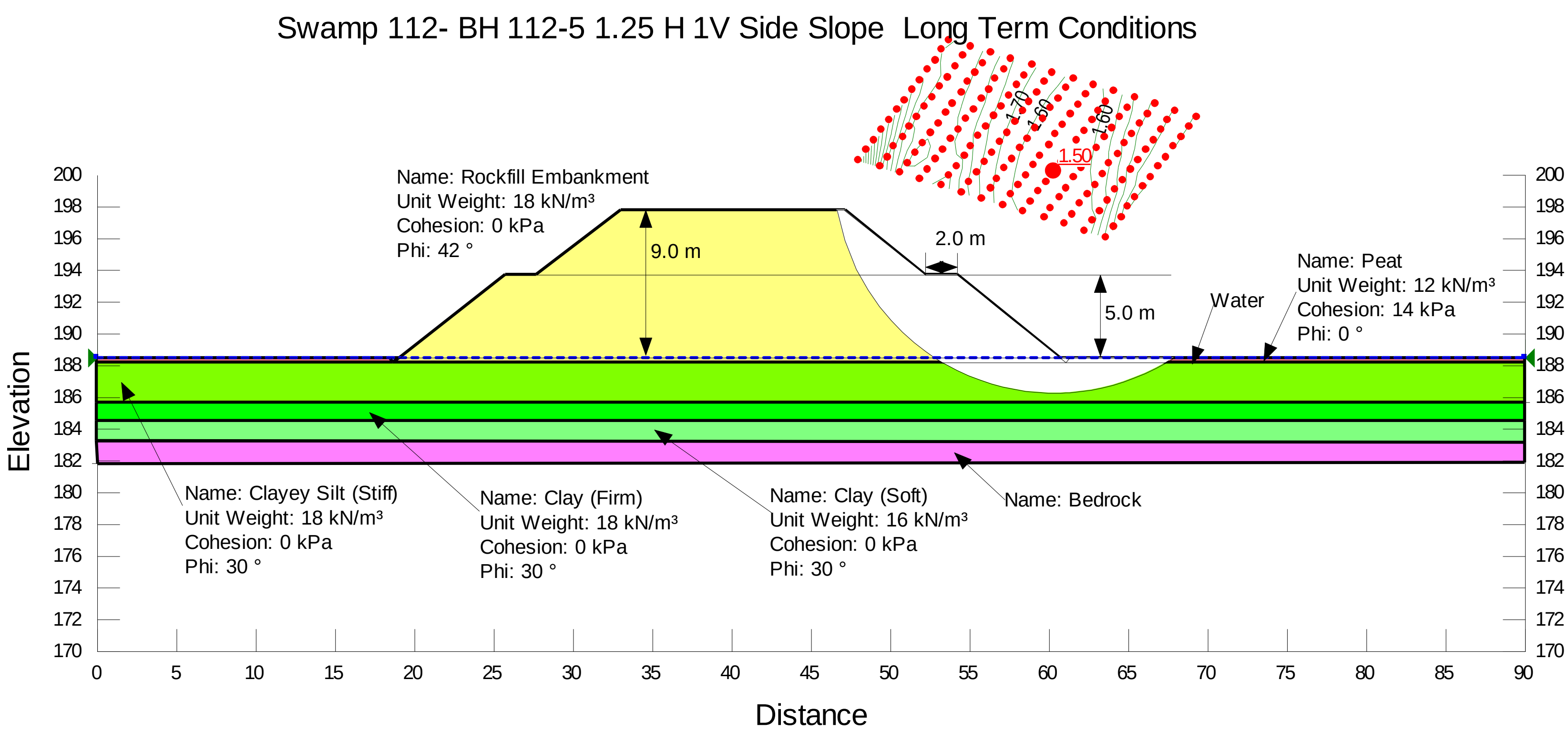
Note: Peat subexcavated below embankment. FOS = 1.75, the minimum FOS of 1.5 was met.

FIGURE 111B



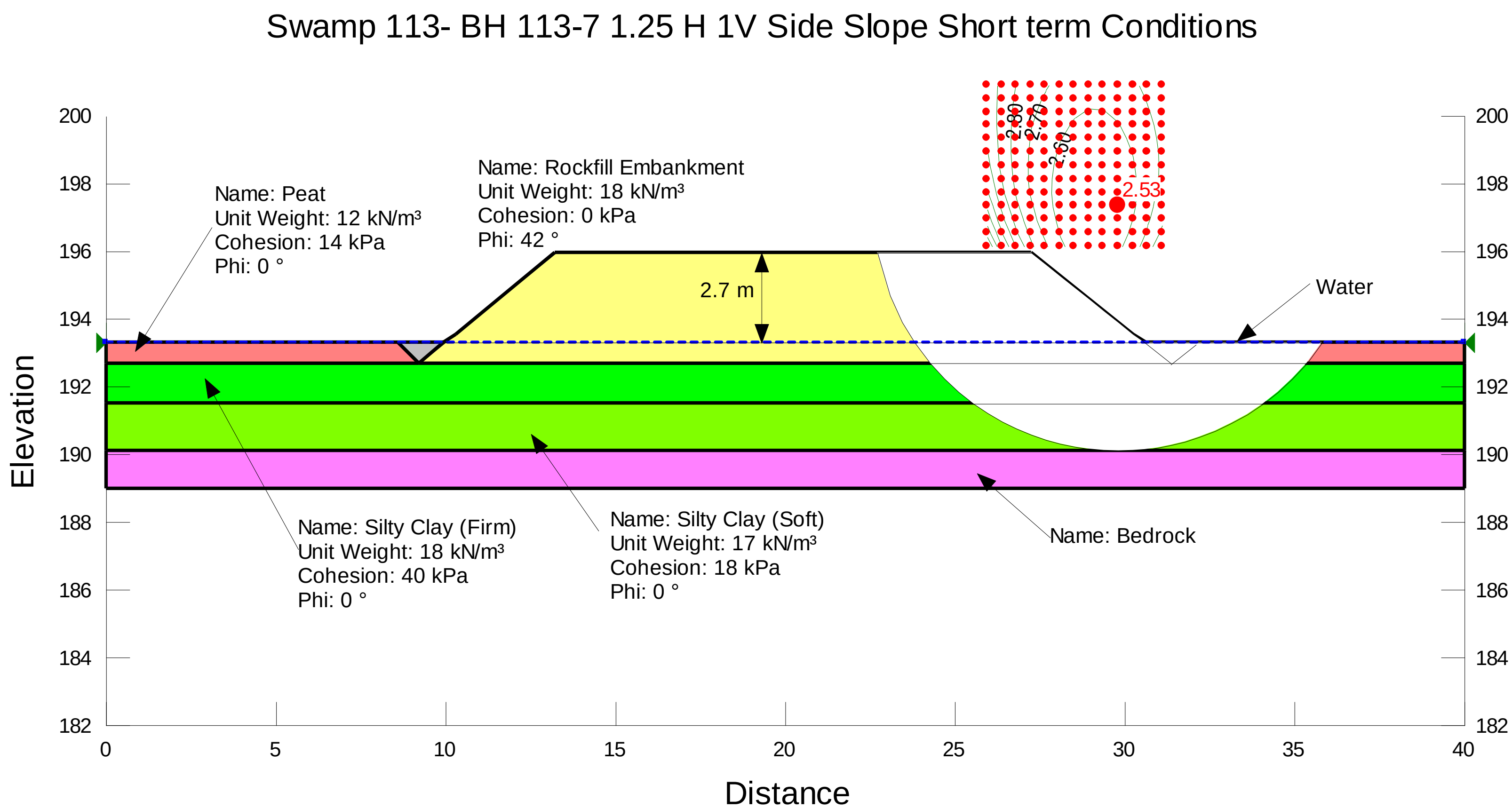
Note: Peat subexcavated below embankment. FOS = 1.48, the minimum FOS of 1.3 was met.

FIGURE 112A



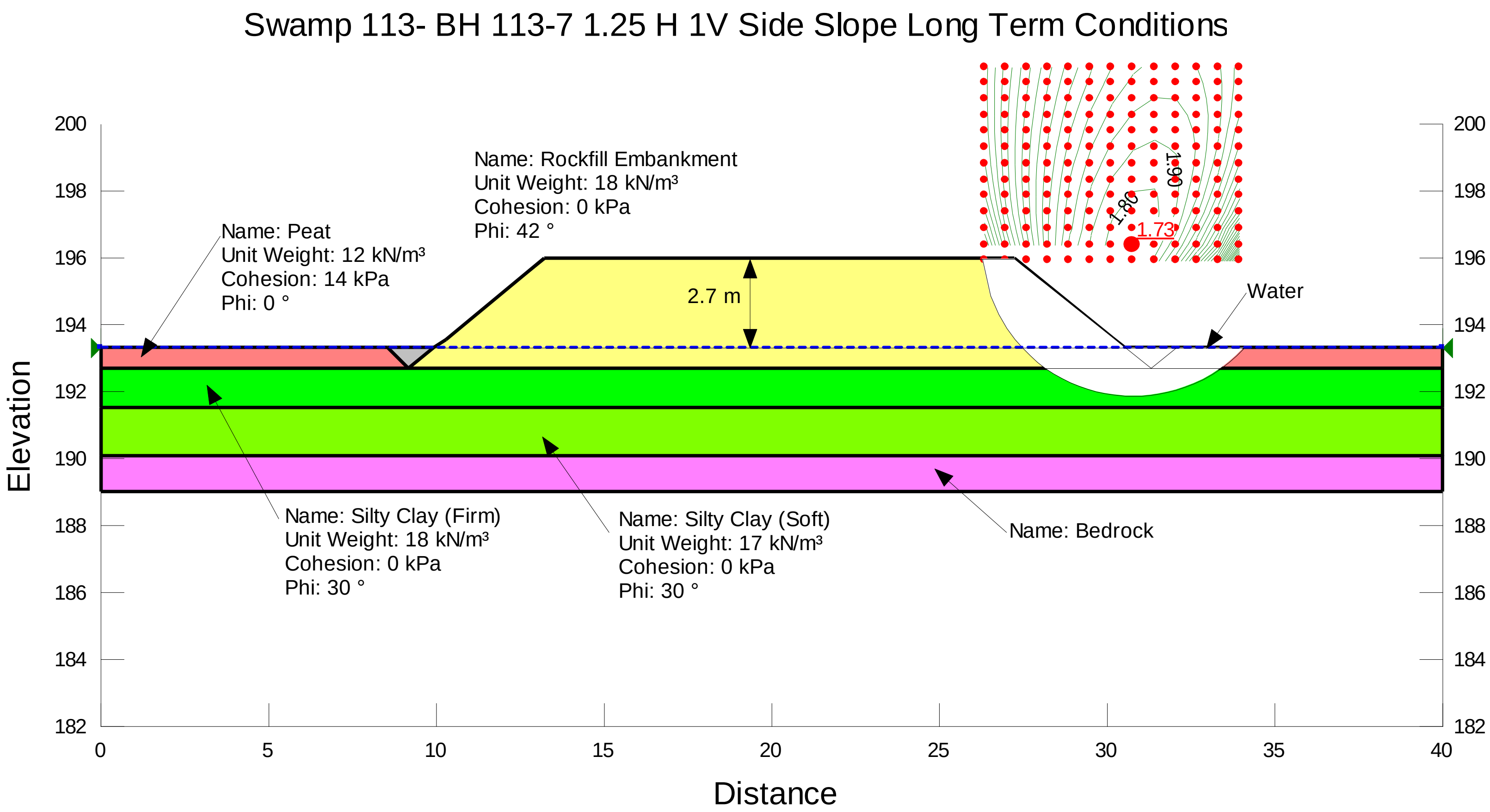
Note: Peat subexcavated below embankment. FOS = 1.50, the minimum FOS of 1.5 was met.

FIGURE 112B



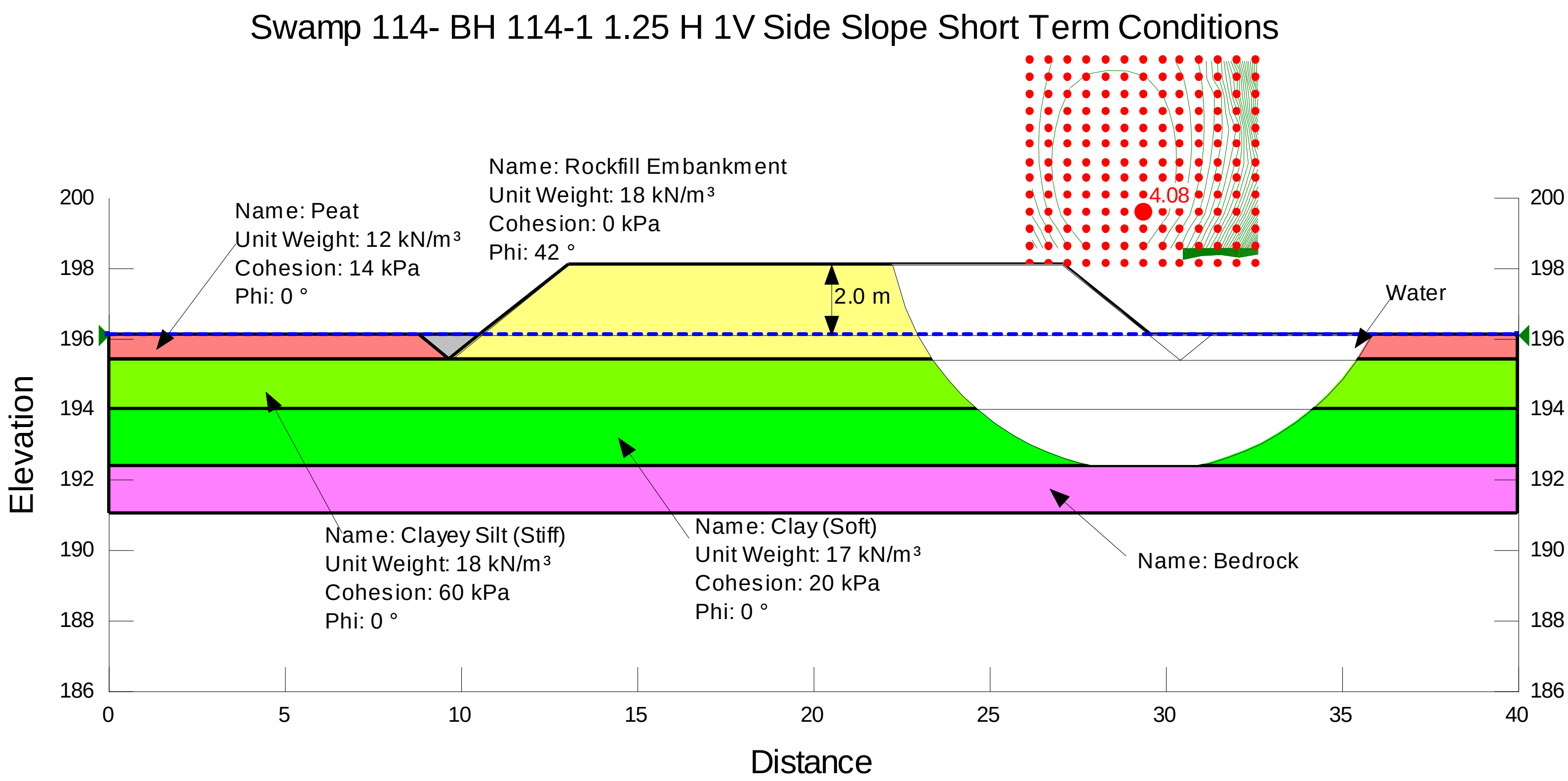
Note: Peat subexcavated below embankment. FOS = 2.53, the minimum FOS of 1.3 was met.

FIGURE 113A



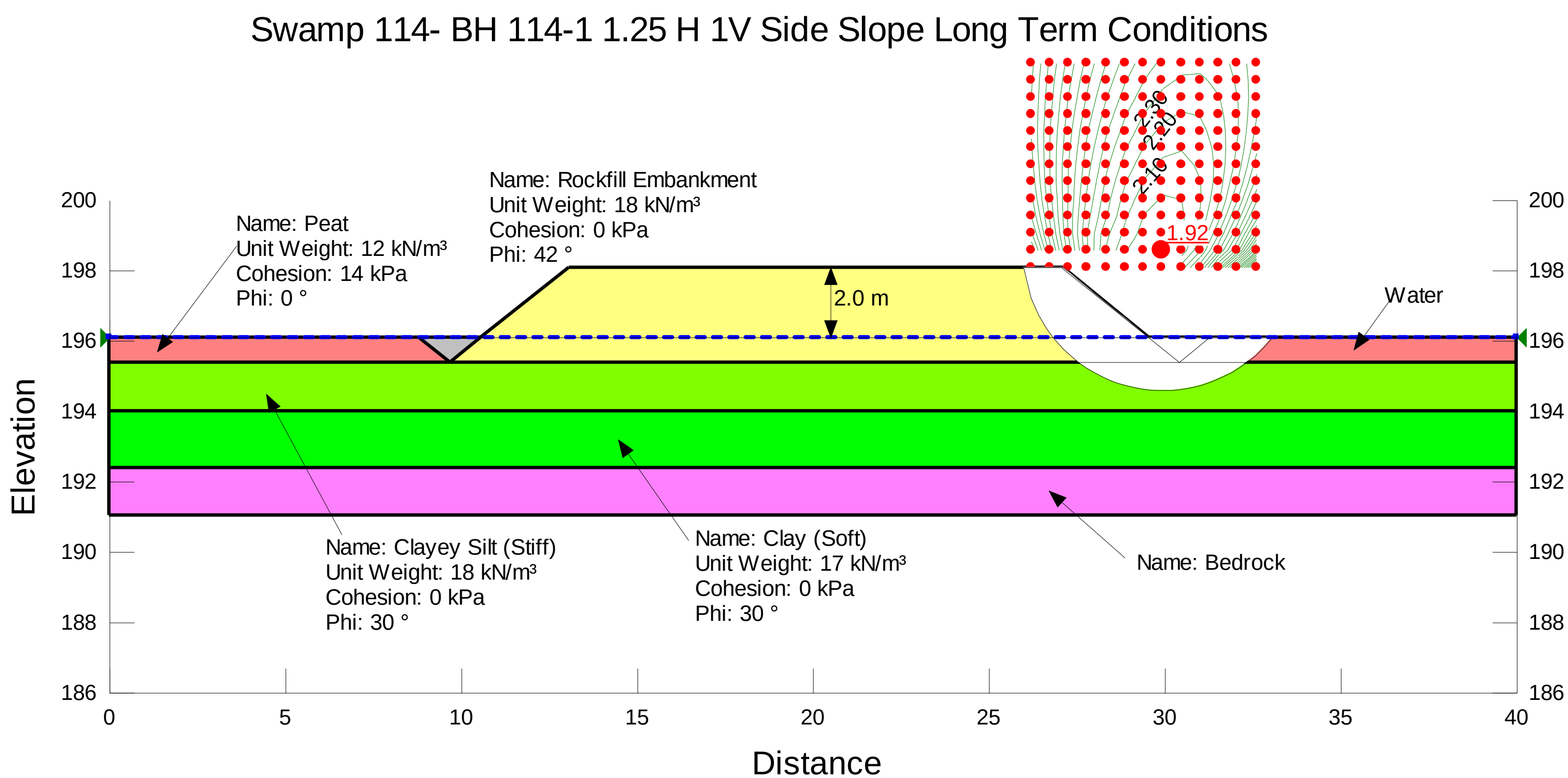
Note: Peat subexcavated below embankment. FOS = 1.73, the minimum FOS of 1.5 was met.

FIGURE 113B



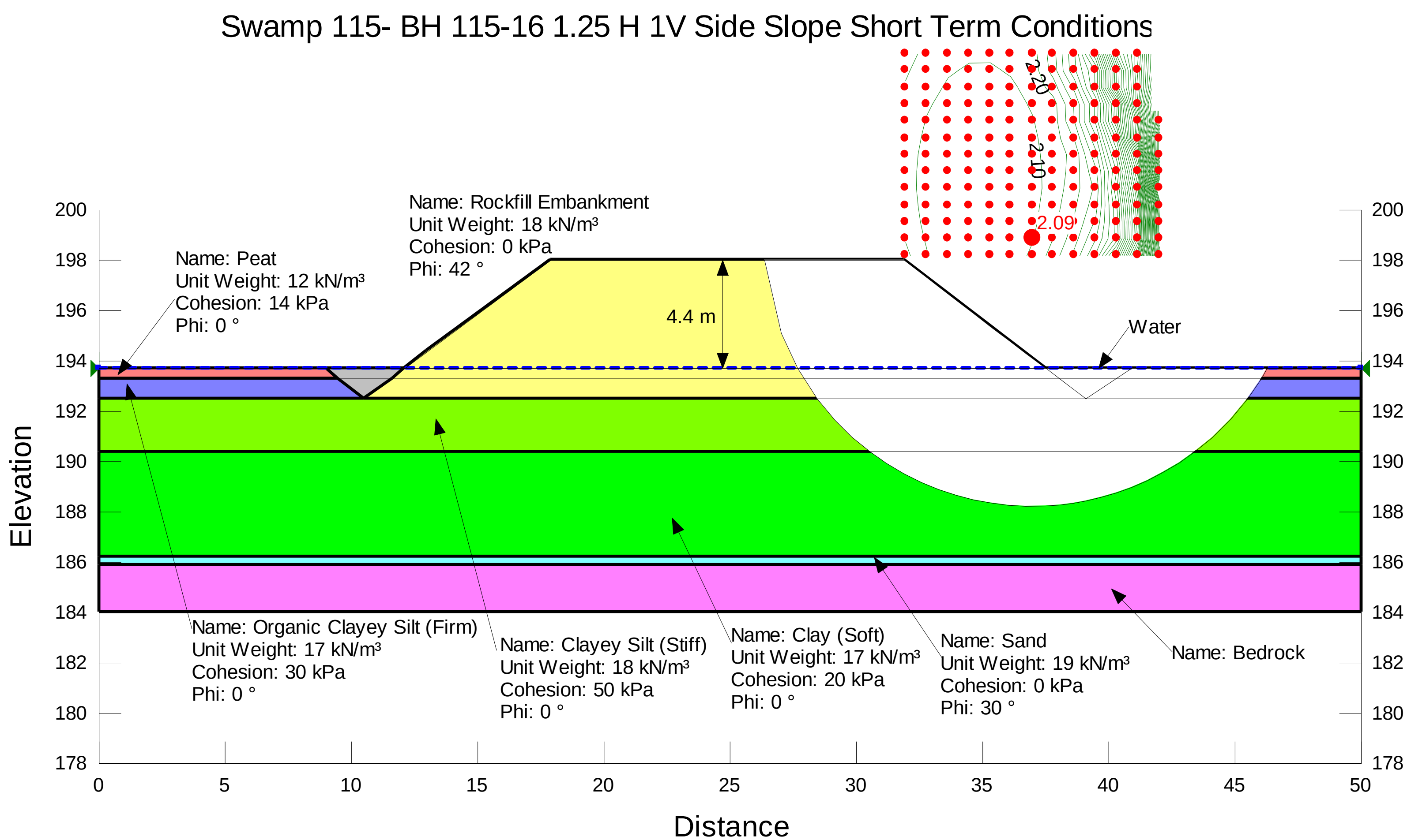
Note: Peat subexcavated below embankment. FOS = 4.08, the minimum FOS of 1.3 was met.

FIGURE 114A



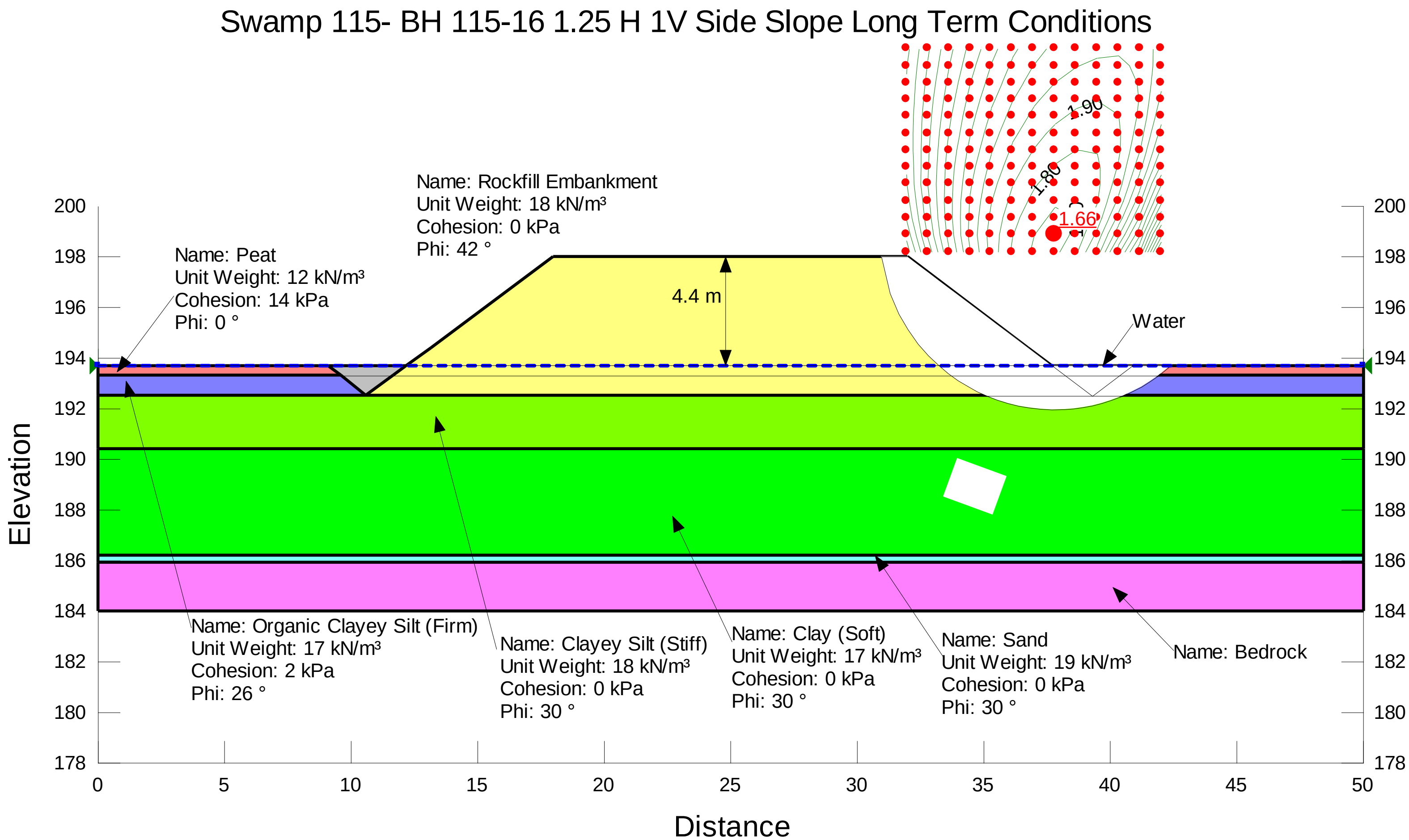
Note: Peat subexcavated below embankment. FOS = 1.92, the minimum FOS of 1.5 was met.

FIGURE 114B



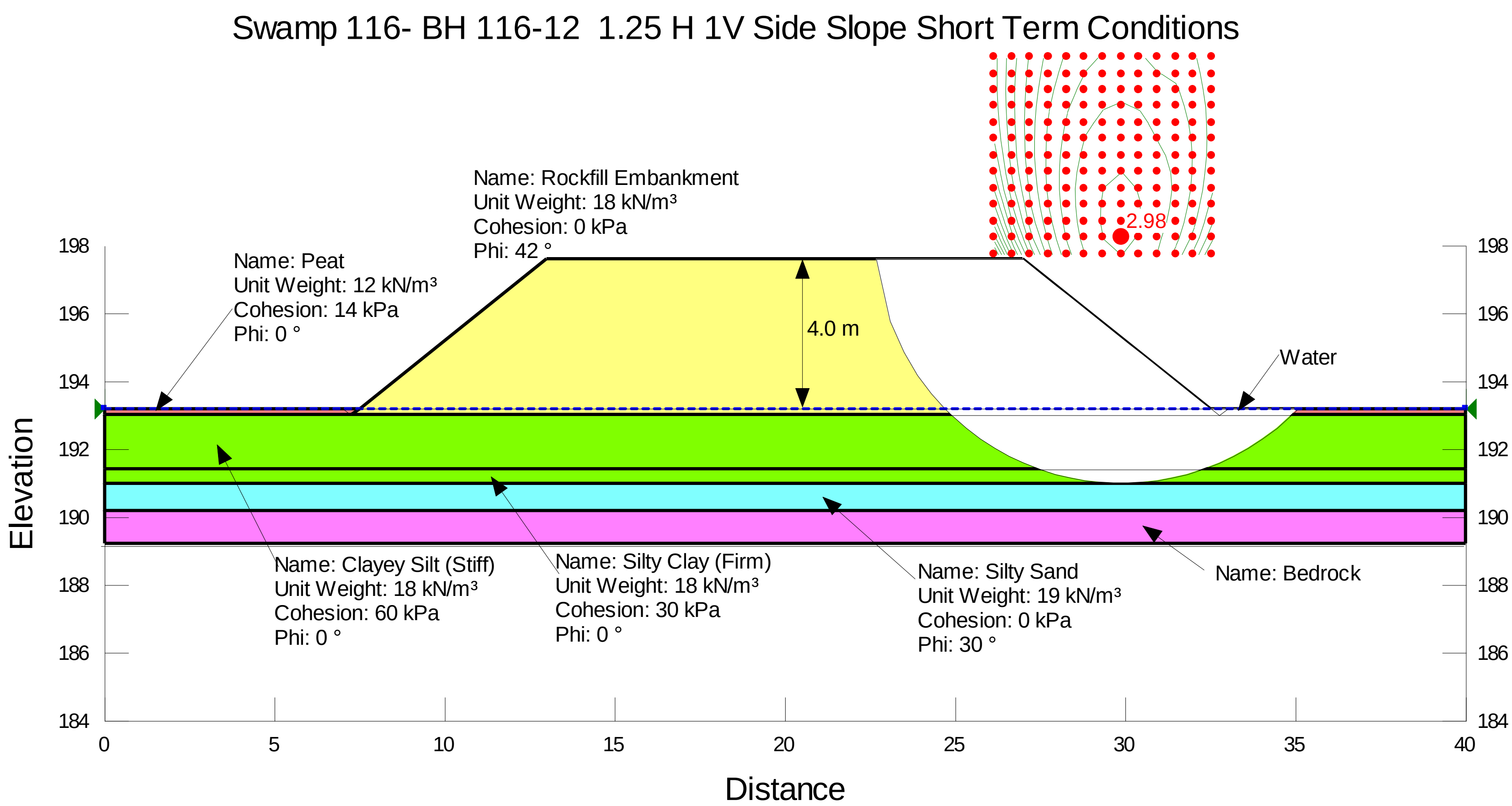
Note: Peat and organic clayey silt subexcavated below embankment. FOS = 2.09, the minimum FOS of 1.3 was met.

FIGURE 115A



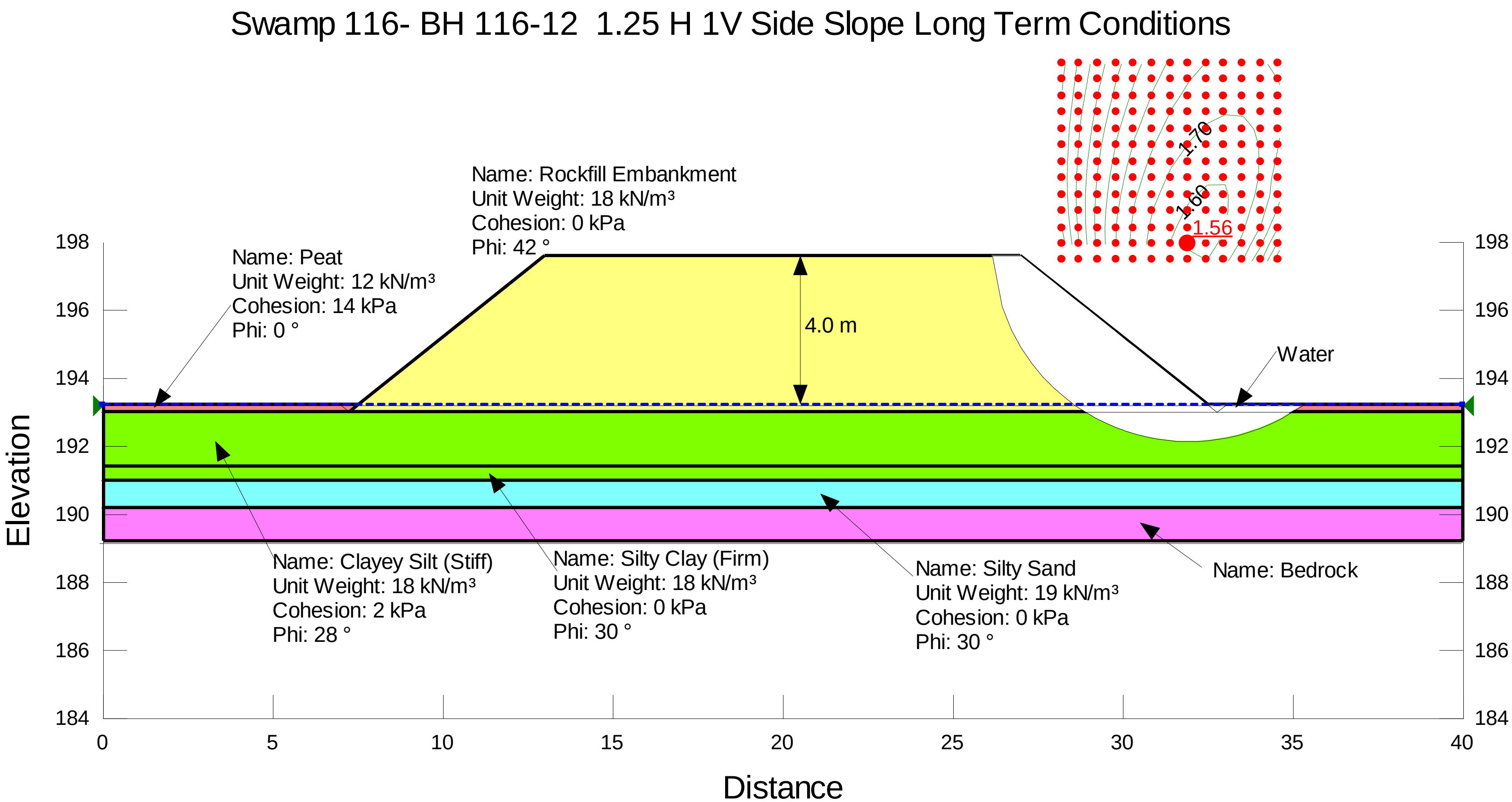
Note: Peat and organic clayey silt subexcavated below embankment. FOS = 1.66, the minimum FOS of 1.5 was met.

FIGURE 115B



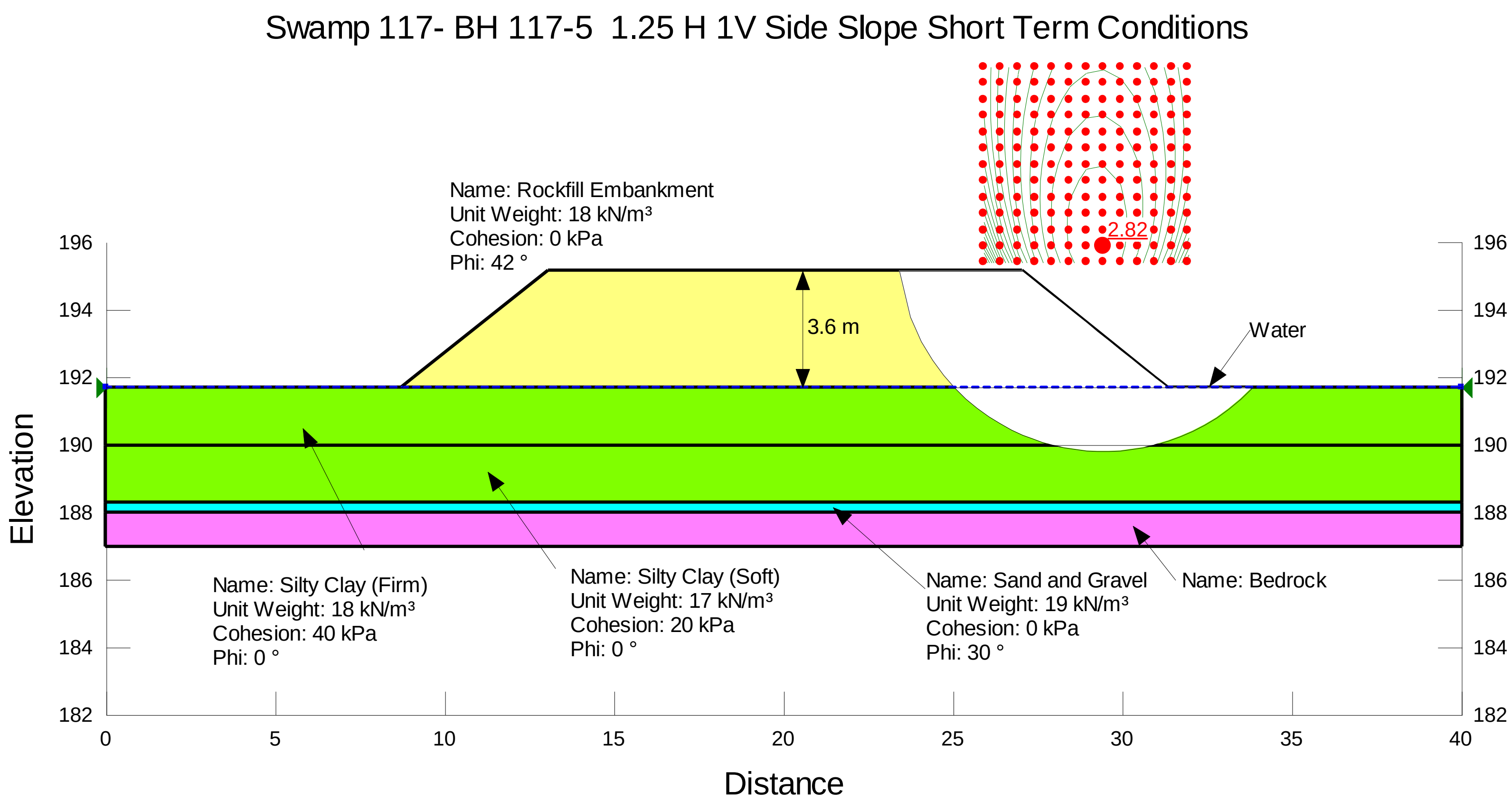
Note: Peat subexcavated below embankment. FOS = 2.98, the minimum FOS of 1.3 was met.

FIGURE 116A



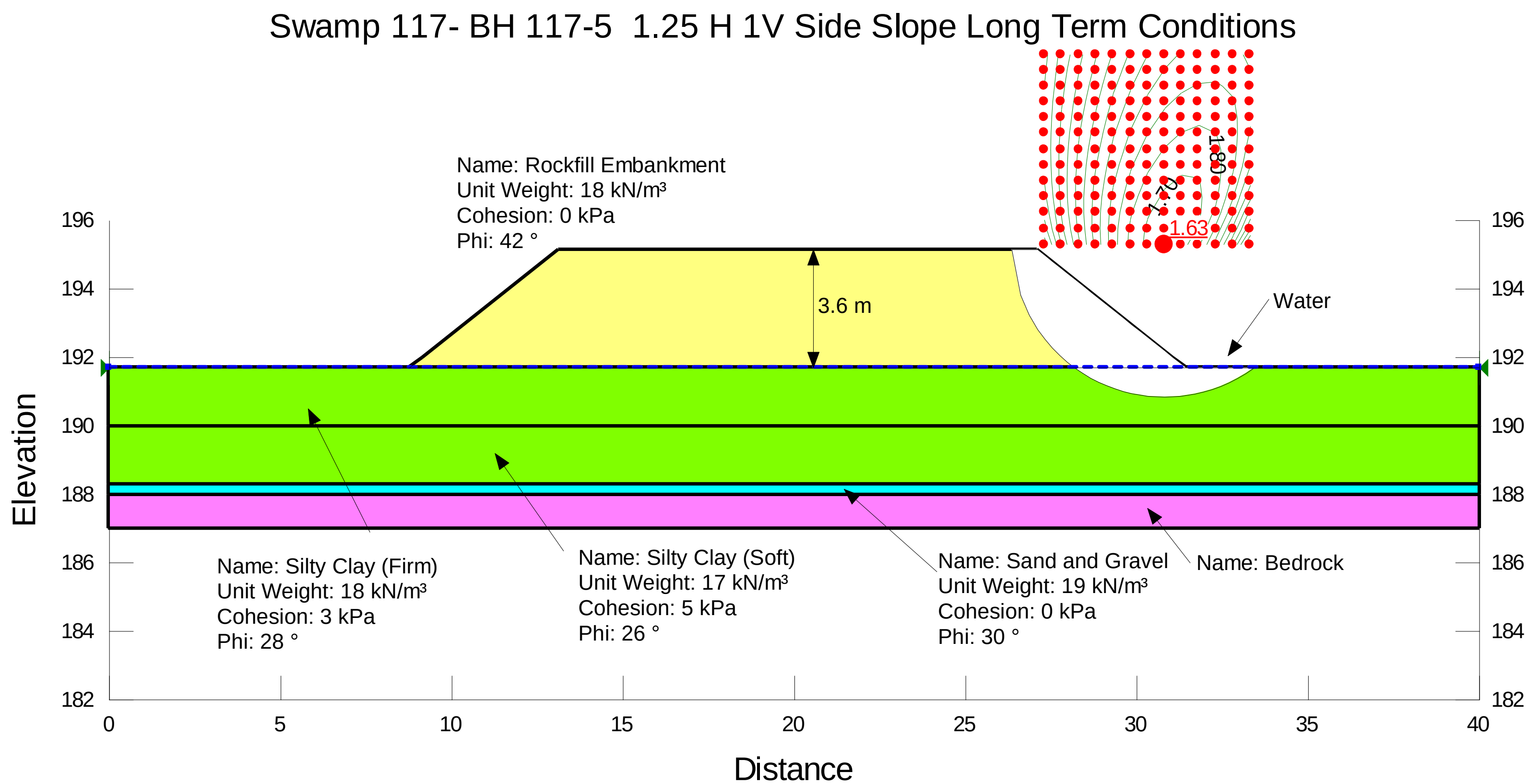
Note: Peat subexcavated below embankment. FOS = 1.56, the minimum FOS of 1.5 was met.

FIGURE 116B



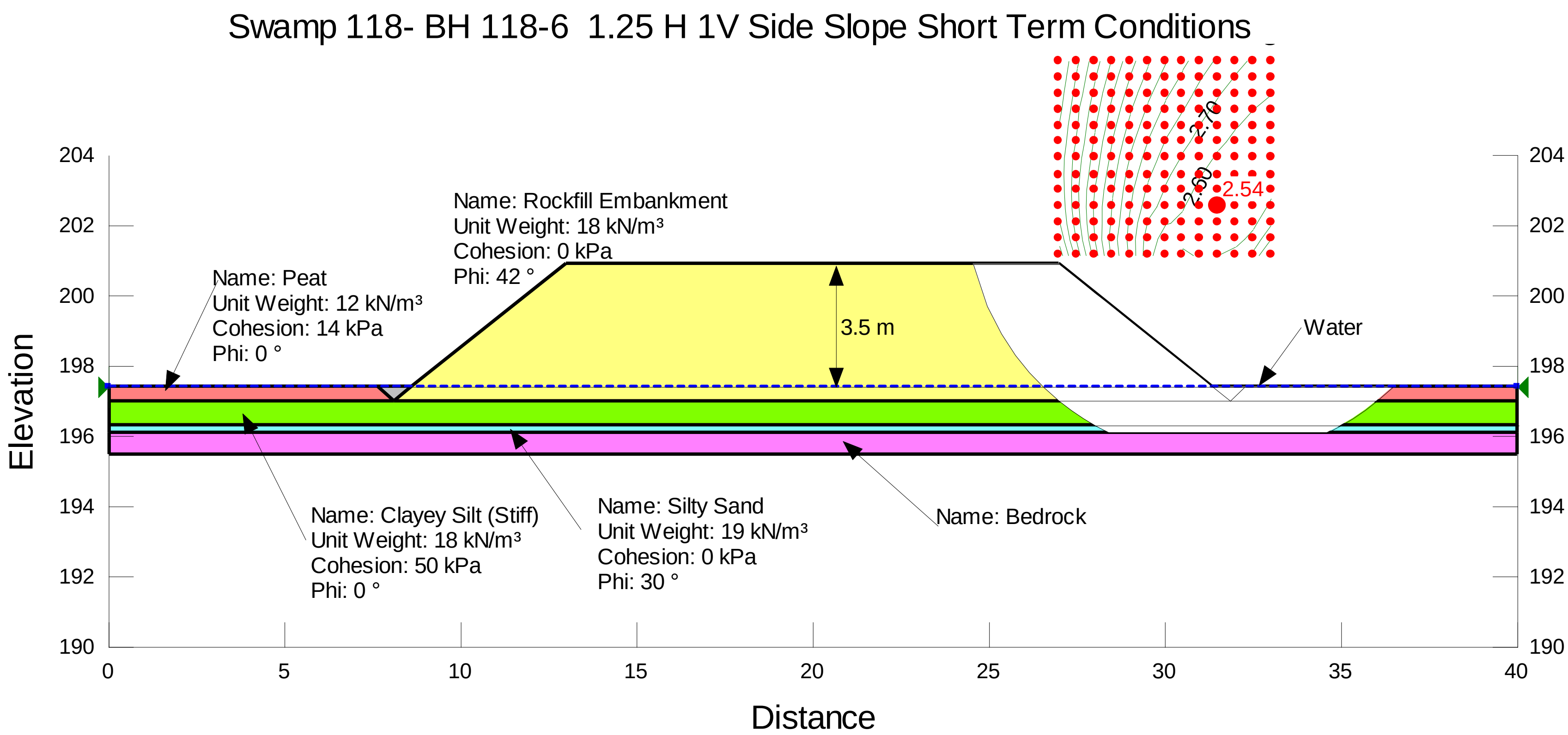
Note: FOS = 2.82, the minimum FOS of 1.3 was met.

FIGURE 117A



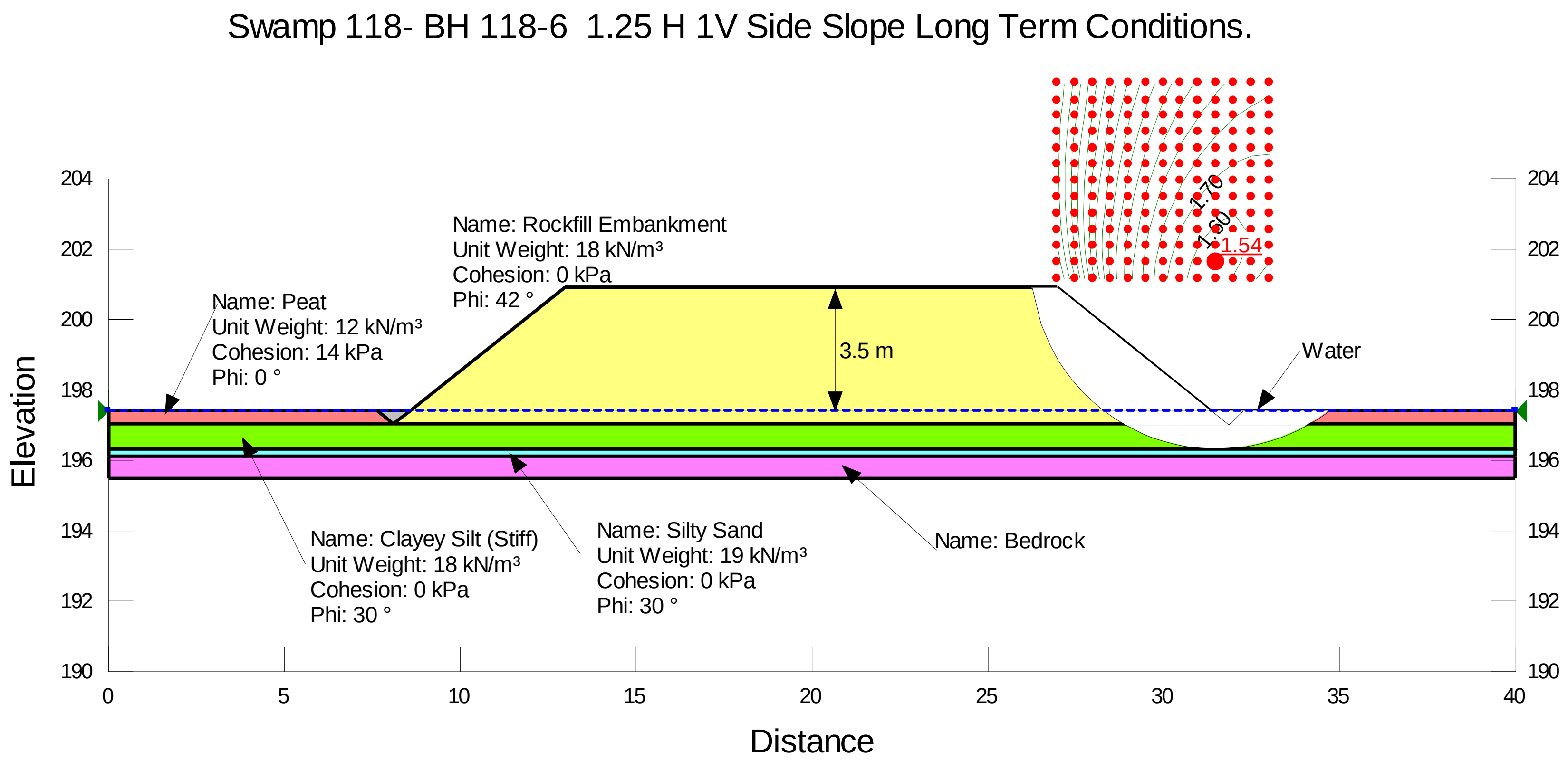
Note: FOS = 1.63, the minimum FOS of 1.5 was met.

FIGURE 117B



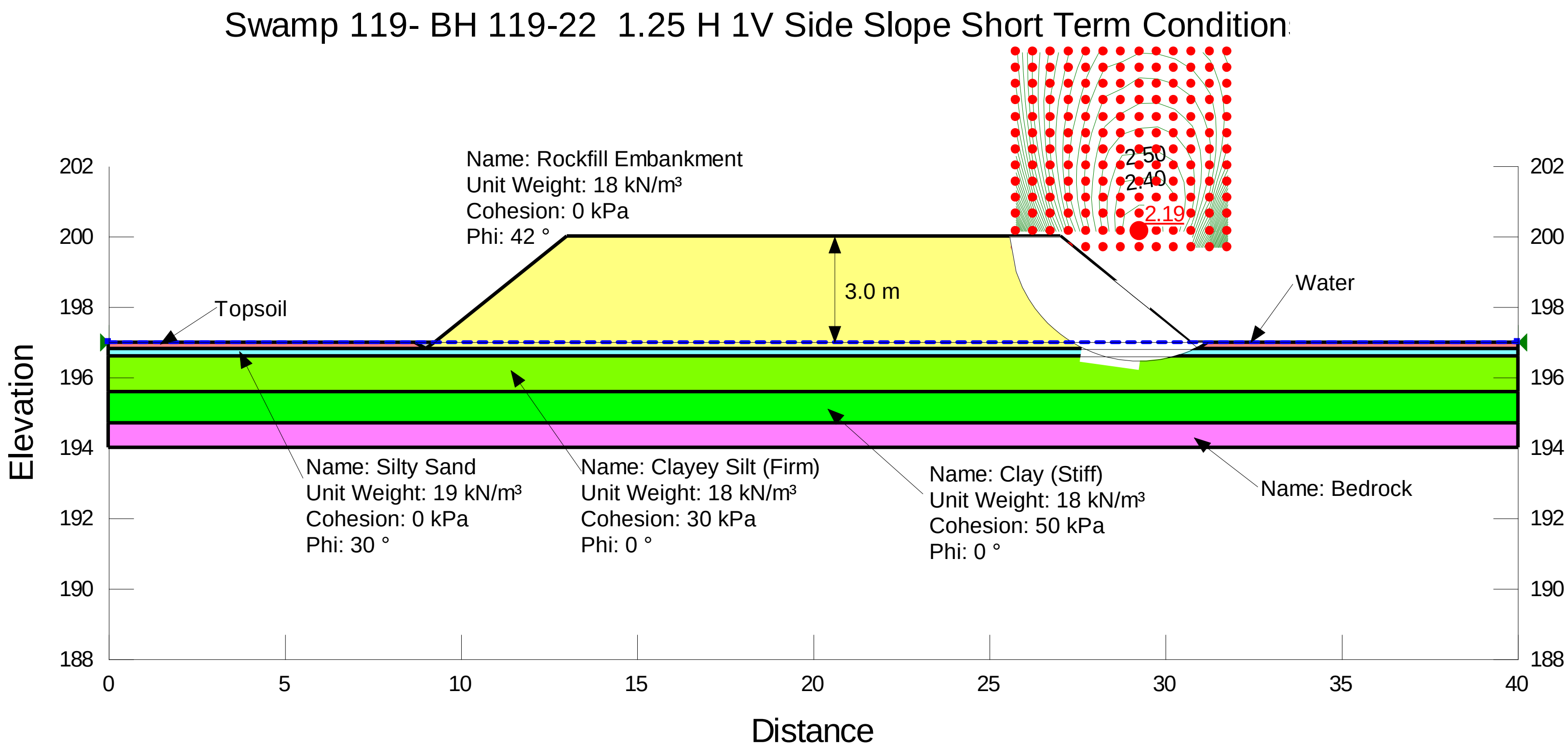
Note: Peat subexcavated below embankment. FOS = 2.54, the minimum FOS of 1.3 was met.

FIGURE 118A



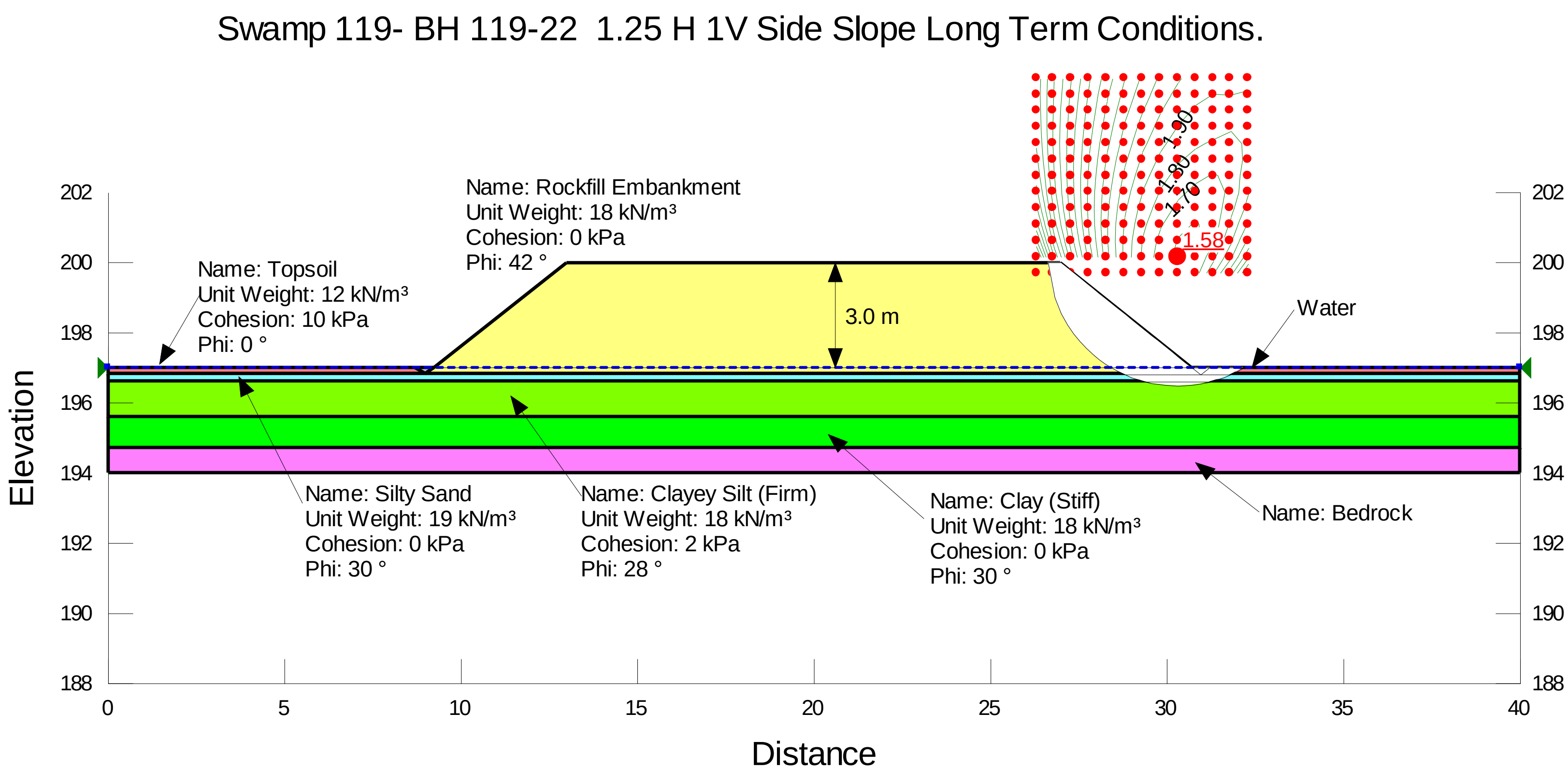
Note: Peat subexcavated below embankment. FOS = 1.54, the minimum FOS of 1.5 was met.

FIGURE 118B



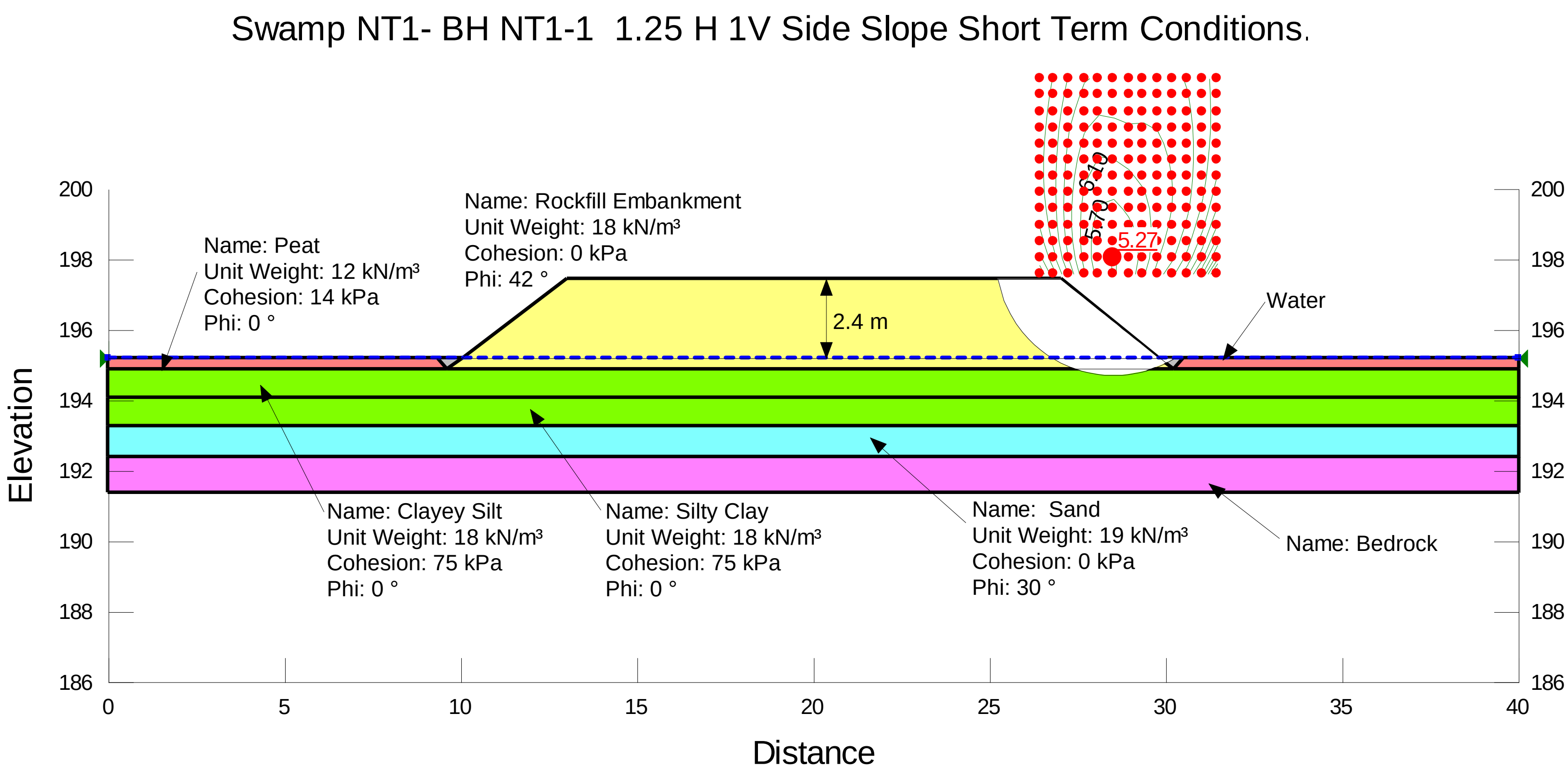
Note: Peat subexcavated below embankment. FOS = 2.19, the minimum FOS of 1.3 was met.

FIGURE 119A



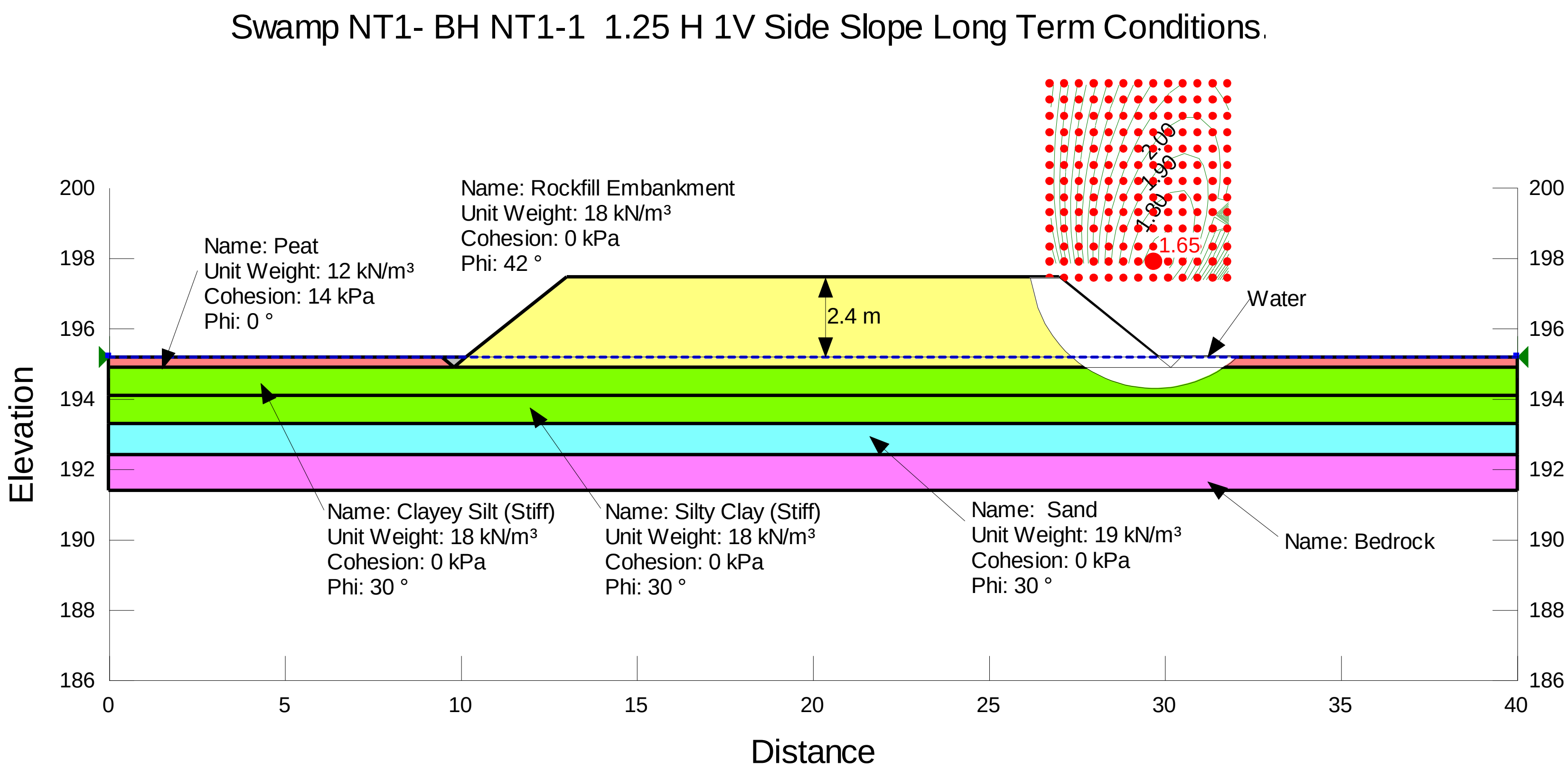
Note: Peat subexcavated below embankment. FOS = 1.58, the minimum FOS of 1.5 was met.

FIGURE 119B



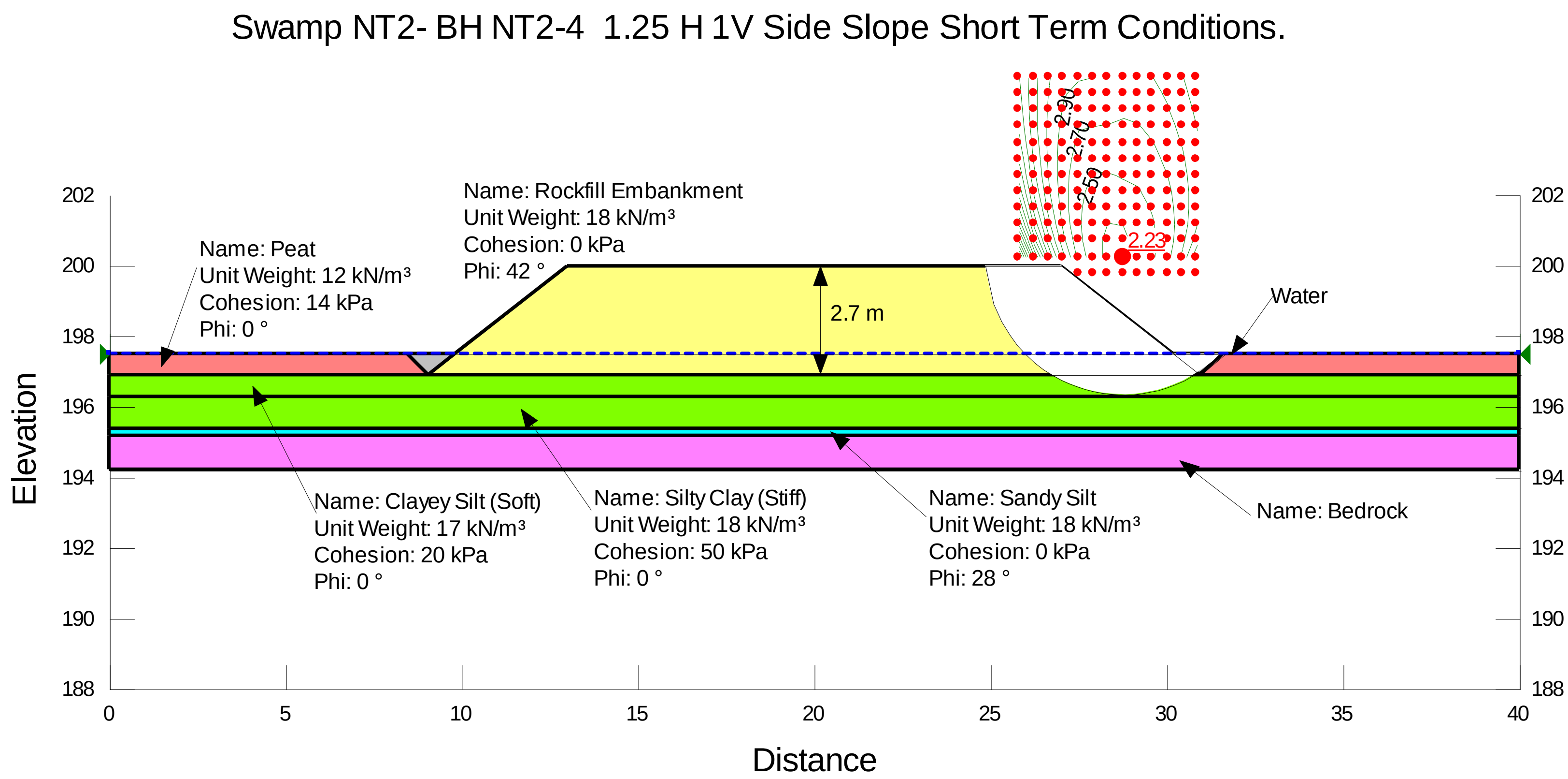
Note: Peat subexcavated below embankment. FOS = 5.27, the minimum FOS of 1.3 was met.

FIGURE NT1-A



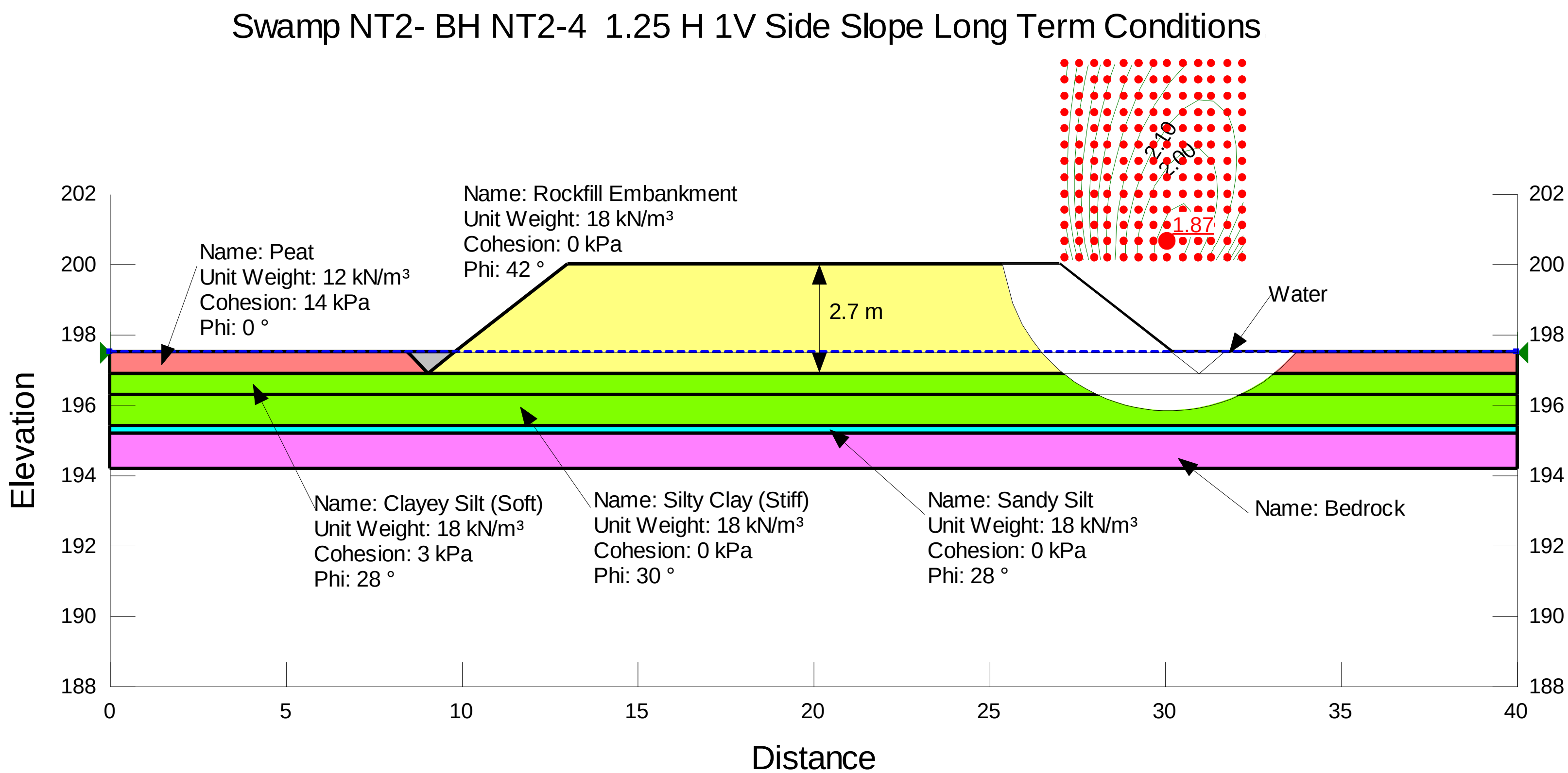
Note: Peat subexcavated below embankment. FOS = 1.65, the minimum FOS of 1.5 was met.

FIGURE NT1-B



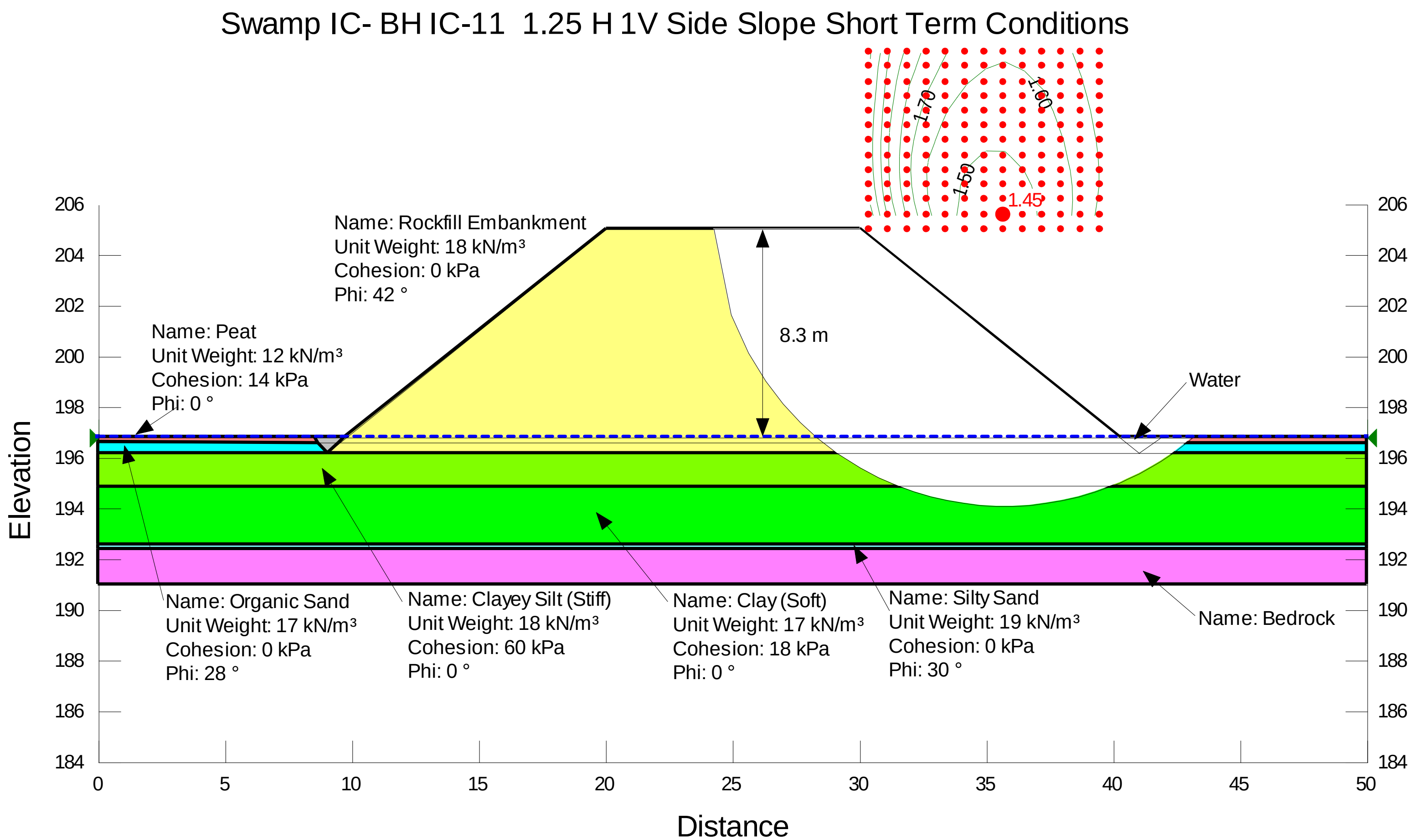
Note: Peat subexcavated below embankment. FOS = 2.23, the minimum FOS of 1.3 was met.

FIGURE NT2-A



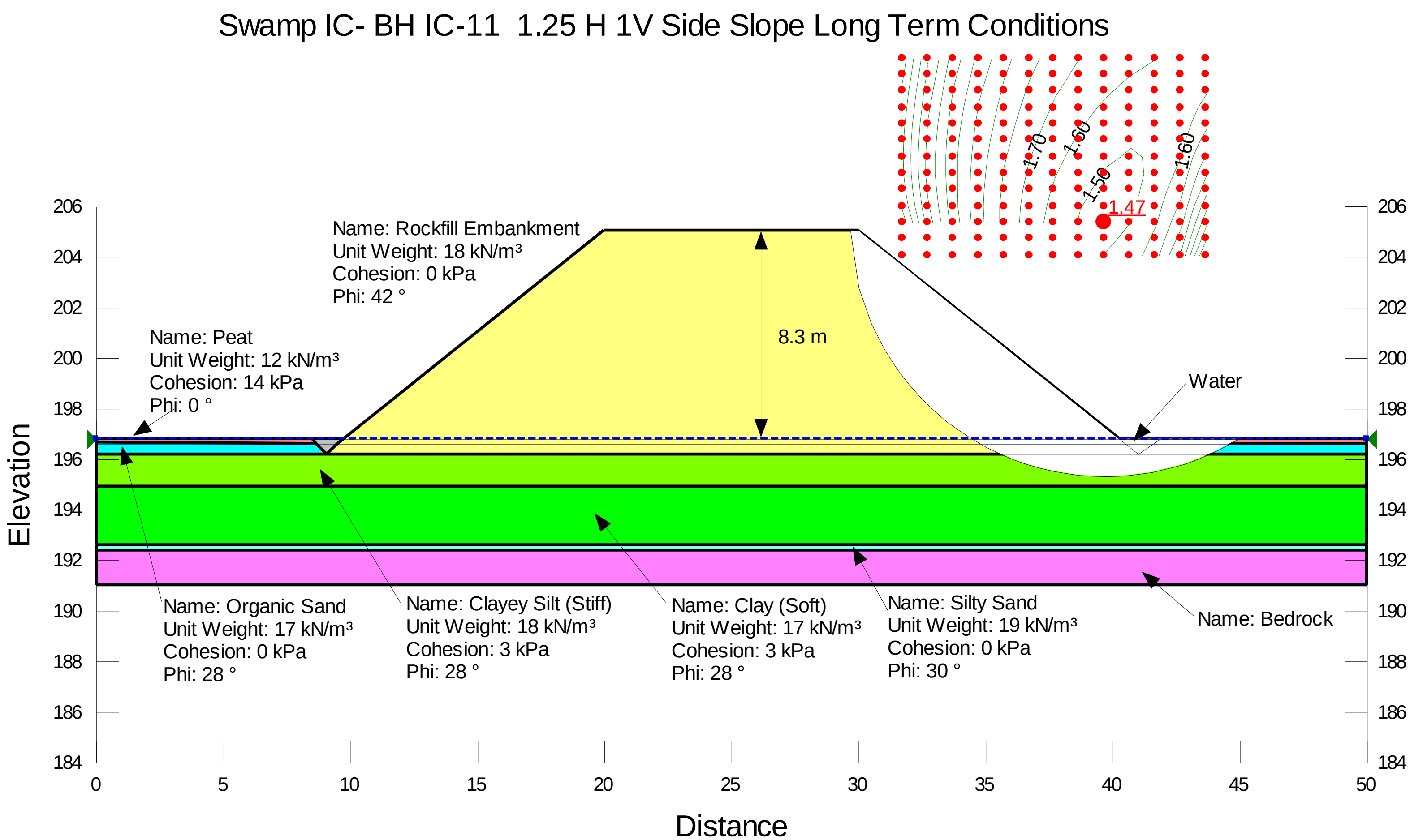
Note: Peat subexcavated below embankment. FOS = 1.87, the minimum FOS of 1.5 was met.

FIGURE NT2-B



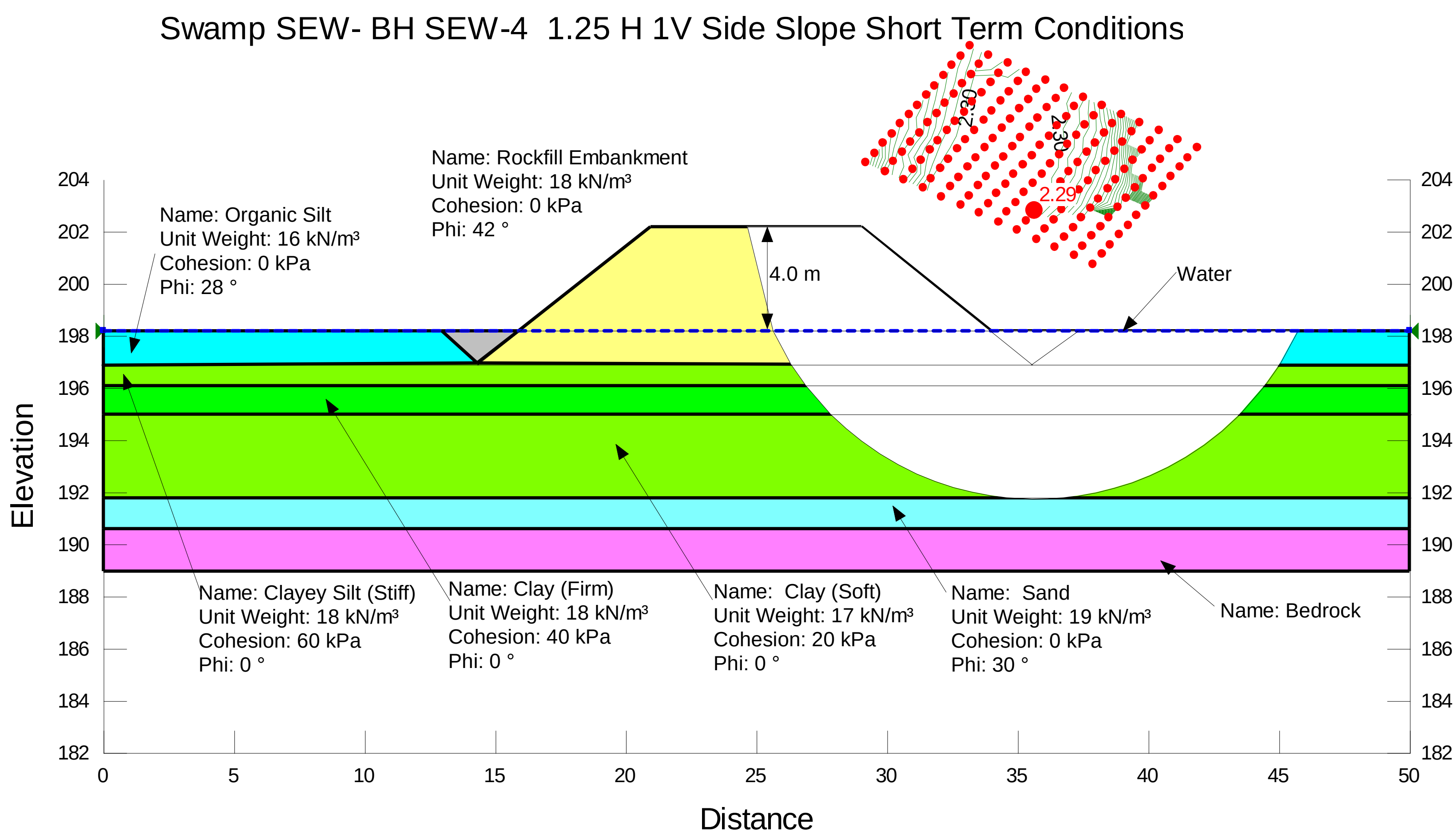
Note: Peat subexcavated below embankment. FOS = 1.45, the minimum FOS of 1.3 was met.

FIGURE IC-A



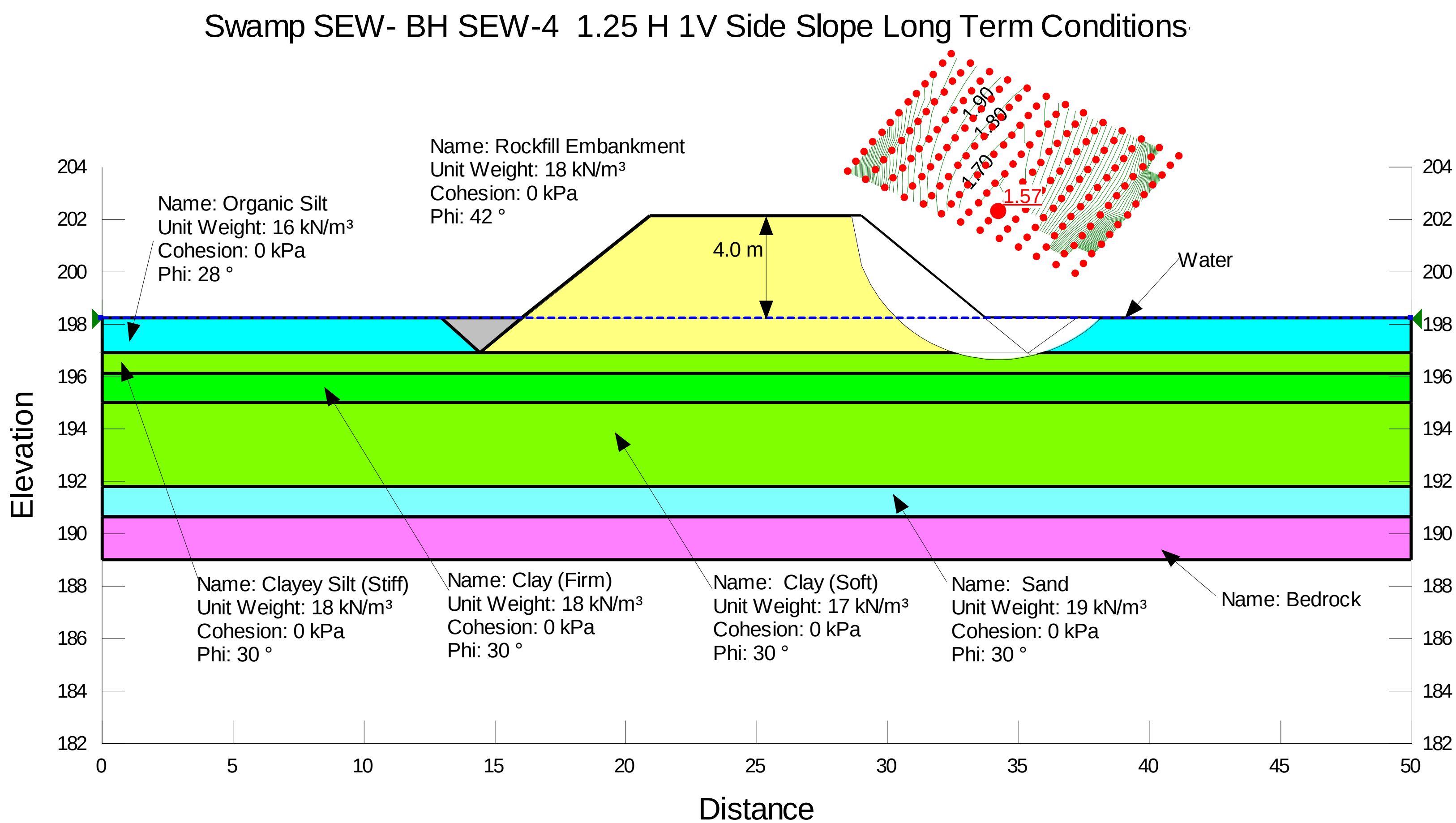
Note: Peat and organic soils subexcavated below embankment. FOS = 1.47, the minimum FOS of 1.5 was not met.

FIGURE IC-B



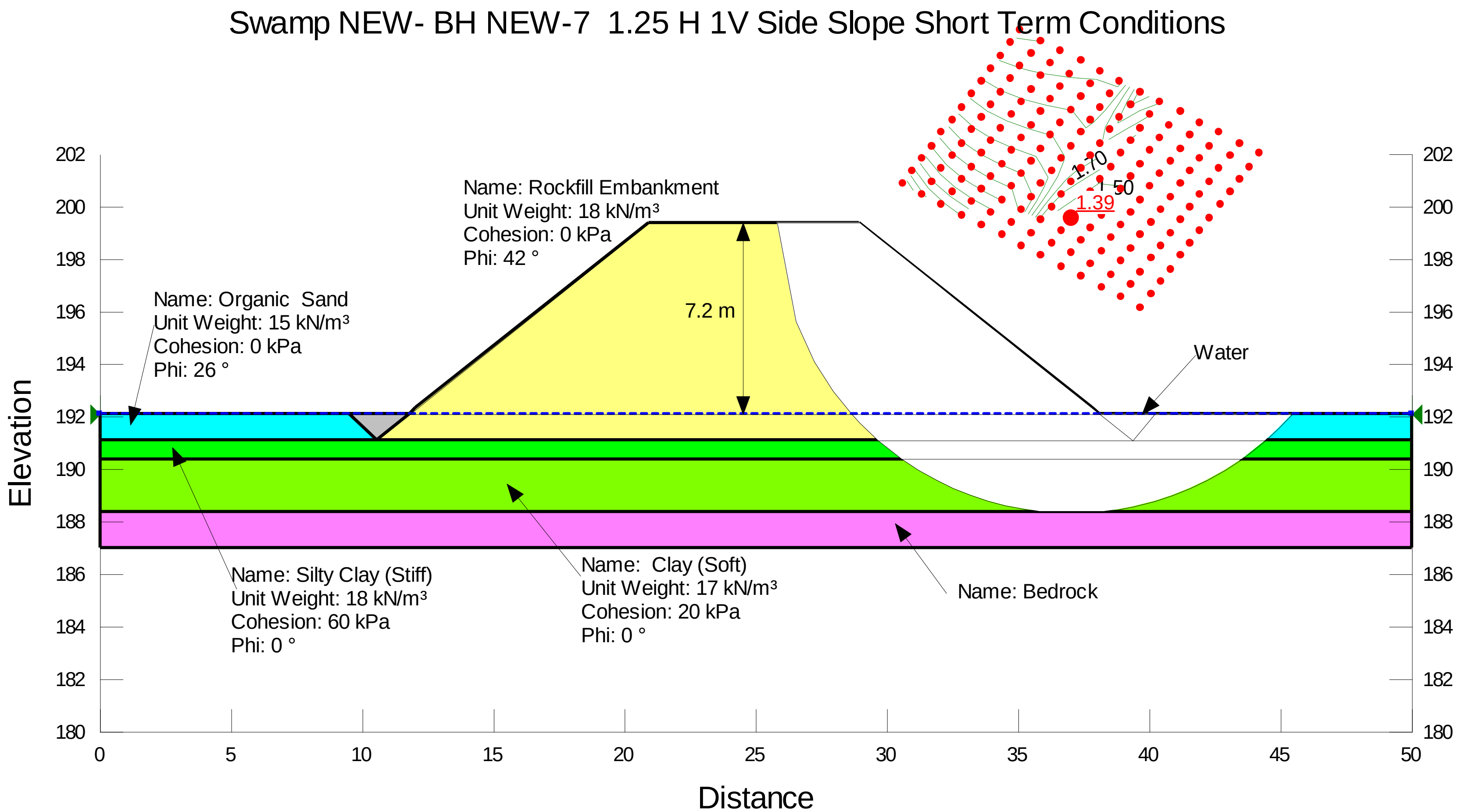
Note: Organic soils subexcavated below embankment. FOS = 2.29, the minimum FOS of 1.3 was met.

FIGURE SEW-A



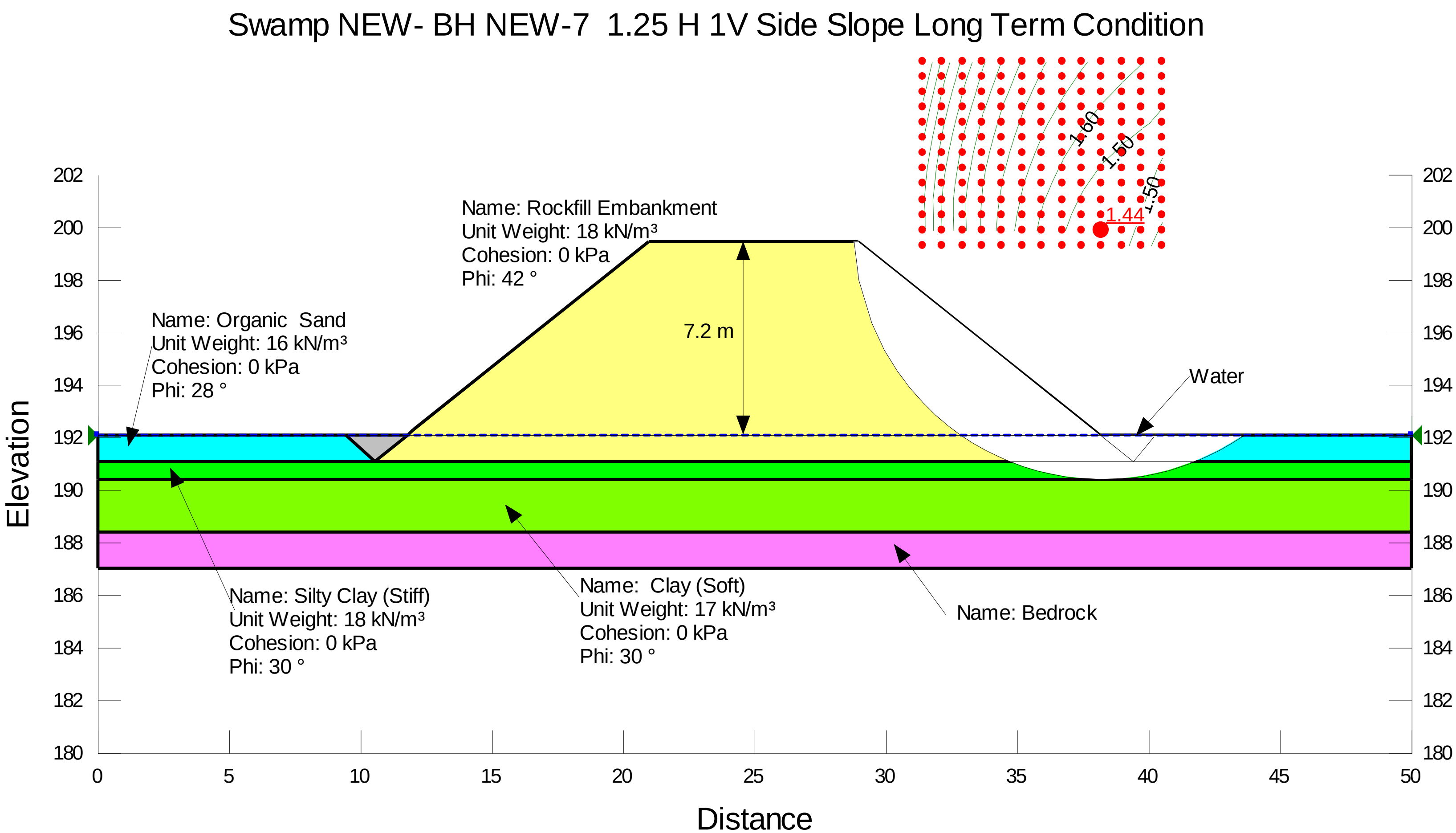
Note: Organic soils subexcavated below embankment. FOS = 1.57, the minimum FOS of 1.5 was met.

FIGURE SEW-B



Note: Organic soils subexcavated below embankment. FOS = 1.39, the minimum FOS of 1.3 was met.

FIGURE NEW-A



Note: Organic soils subexcavated below embankment. FOS = 1.44, the minimum FOS of 1.5 was not met.

FIGURE NEW-B