

G.I.-30 SEPT. 1976

GEOCRES No. 31C-135DIST. 8 REGION W.P. No. 134-74-01CONT. No. 80-34W. O. No. STR. SITE No. 28-28HWY. No. 14LOCATION Bay of Quinte,
BellevilleNo. of PAGES - —

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. REMARKS:

ENGINEERING MATERIALS OFFICE
SOIL MECHANICS SECTION

WP 134-74-01

DIST 8

HWY 14

STR SITE 28-28

Bay of Quinte Crossing
at Belleville

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FEASIBILITY
FOUNDATION INVESTIGATION REPORT

For

Bay of Quinte Crossing at Belleville
Hwy. 14, District 8, Kingston
W.P. 134-74-01, Site 28-28

INTRODUCTION

The Ministry of Transportation and Communications has proposed to replace the existing Hwy. 14 crossing of the Bay of Quinte. The crossing is presently accomplished by means of a causeway and two steel through truss type structures, one structure being a swing bridge for the purpose of accommodating marine traffic on the waterway. A route location study resulted in the decision to build a high-level structure, east of, and parallel to the existing crossing.

Because of the large scope of the project, the Soil Mechanics Section was requested to carry out a feasibility study to determine the subsurface conditions along the line of the proposed crossing. The request was contained in a memorandum dated March 22, 1977 from Mr. T.C. Kingsland, Kingston Regional Structural Planning Engineer. An investigation was subsequently carried out to establish the subsoil, bedrock and groundwater conditions existing at the site.

The pertinent factual data were provided immediately after completion of the fieldwork. In addition, recommendations were also provided verbally.

This report contains the factual data obtained from the field and laboratory work, together with recommendations pertaining to the design and construction of the structure and associated approach fills.

FIELD INVESTIGATION

The fieldwork was carried out during the period of May 24, 1977 to June 17, 1977. A total of 21 boreholes, 8 accompanied by dynamic cone penetration tests, were put down to depths of 67 feet below the bay water surface. The borings on the bay were put down by means of diamond drilling techniques using NX casing operating from a drum-floating raft. The remaining boreholes were advanced by means of a muskeg vehicle equipped with hollow stem continuous flight augers. Bedrock was proven by obtaining up to 5 feet of BXL size rock core.

SITE DESCRIPTION: PAST AND PRESENT CONDITIONS

The proposed crossing on the Bay of Quinte will connect Zwick's Park in the Town of Belleville with the Hamlet of Rossmore in Prince Edward County (Refer to Photo 1 in the Appendix).

The north approach will extend through generally flat terrain immediately east of existing Hwy. 14 within Zwick's Park (Refer to Photo 2 in the Appendix). Maps of the area prior to 1890 show the area now occupied by Zwick's Park to be largely open water except for an island. This piece of land, about 4 acres in area, was named Zwick's Island and now comprises the southwestern portion of Zwick's Park. The island was joined to the mainland by means of a causeway as part of the original 1890 Bay of Quinte Bridge. It is believed that this causeway resulted in the development of the swamp areas as shown in maps as early as the 1920's. In the 1960's the swamp area was used for sanitary landfill. The western portion has been sodded and extensively developed into a park for day users. The municipality of Belleville is presently placing clean landfill east of Hwy. 14 with the intention of developing it for recreational uses.

On the Prince Edward County side the approaches will extend partially through residential areas within the Hamlet of Rossmore (Refer to Photo 3 in the Appendix).

At the location of the proposed crossing, the Bay of Quinte is some 3000 feet wide. The depth of the main channel, at the swing bridge location, is up to 35 feet deep. Elsewhere along the proposed crossing, the bay is 10 to 15 feet deep.

The existing crossing from Zwick's Park to Rossmore, some 2750 feet, is accomplished by means of an earth causeway and two steel through truss type structures. The main structure adjacent to the Rossmore side is composed of one swing span and three fixed spans (128' fixed, 200' swing, 165' fixed and 128' fixed); and about 1000 feet north of the swing span, is a two fixed span structure (99', 108').

The original structure completed in 1891, was composed of about seventeen spans between Zwick's Island and Rossmore. The present causeway was constructed in the 1920's by placing dredged material between the piers. The original superstructure was removed and the causeway was brought up to final grade leaving the original piers in place. These piers are constructed of stone, timber and concrete cribwork and are believed to be supported on timber piles. The causeway was completed by placing 10-20 ton armour stone on the side slopes for protection against wave action (Refer to Photo 5 in the Appendix).

GEOLOGY

The site borders the physiographic regions of the "Napane Plains" and the "Prince Edward Peninsula". These regions are characterized by a thin veneer of glacial drift underlain by generally flat to undulating limestone of the Trenton-Black River Formation. At this site, limestone and shale bedrock outcrops appear on the Prince Edward County shore in the vicinity of existing Hwy. 14 (Refer to Photo 4 in the Appendix).

SUBSOIL DESCRIPTION

General

Subsoil across the site is quite variable as a result of dredging and landfill operations carried out in this area in the past. The parent subsoil consists of 11 to 13 feet of sandy gravel or medium to coarse sand underlain by 9 to 13 feet of clay or clayey silt which in turn overlies a 5 to 18 foot thick deposit of glacial till. The glacial till is underlain by limestone bedrock. On the Prince Edward County shore subsoil consists of 2 to 11 feet of sandy gravel overlying bedrock. In Zwick's Park the parent subsoil is overlain by up to 15 feet of fill material, whereas, within the bay the parent subsoil is overlain by a thin veneer up to 9 feet thick of very soft organic clay.

East of the existing causeway from the Prince Edward County side to about 1000 feet north of the shoreline, the parent subsoil beneath the bay has been dredged, in some locations down to the bedrock surface. In a few locations, up to 45 feet of organic clay has been recently deposited within the dredged areas. However, within the main channel the current has kept the dredged areas relatively free of organic clay deposits.

The locations and elevations of the borings, together with a stratigraphical profile and sections inferred from borehole data, are shown on Drawing No. 1347401-A.

A brief description of the various subsoil and bedrock types encountered and the groundwater conditions are presented in the paragraphs to follow.

Fill Material

Fill material was encountered in all borings put down in the Zwick's Park area and in the existing causeway. Fill material was also encountered in two boreholes (B.H.'s 17 & 20) put down in the bay adjacent to the causeway.

Fill material in Zwick's Park: The fill material encountered in Zwick's Park is estimated to be 3 to 15 feet thick. This fill material varies in composition from a sandy gravel to a sand with silt and inclusions and/or pockets of clayey silt. Typical grain size distribution curves for the fill material are shown in envelope form on Figure 1 of the Appendix. The results of Atterberg Limit testing on representative samples from the cohesive zones of clayey silt are plotted on the Plasticity Chart, Figure 2. The Atterberg Limits indicate that the clayey silt pockets are inorganic and of low plasticity. This fill material also contains inclusions of wood chips and organics. In these areas the organic content was found to be as high as 7% by weight.

Standard Penetration testing carried out in the fill material in Zwick's Park gave a range of 'N' values of 2 to 32 blows per foot indicating this fill has undergone slight to moderate compaction.

Fill material in the causeway: The fill material within the causeway and adjacent to it was found to be up to 41 feet deep. The composition of this fill material is a gravelly sand with a trace of silt. The result of grain size distribution testing is shown in an envelope form on Figure 1. This fill material contains a trace of shells and wood chips in isolated zones. The organic content in these zones was found to be as high as 13% by weight; however, this high organic content is attributed to the presence of wood chips and is not indicative of the deposit as a whole.

The range of Standard Penetration Test 'N' values for this fill material is 8 to 92 blows per foot, indicating that the material has been subject to a non-uniform compactive effort.

Organic Clay

This material comprises the bay bottom, being generally a thin veneer up to 9 feet thick covering the parent subsoil. In some areas where the bay bottom has been dredged for causeway fill, the bay has filled up to 46 feet of organic clay within these dredged areas. In one boring in Zwick's Park area a deposit of organic clay about 7 feet thick was encountered immediately below the fill. The material in this deposit is black, being generally plastic and composed of organic clay. Where the very deep deposits of organic clay were encountered in the bay bottom, the organic material contains appreciable amounts of silt and sand. The organic content of the deposit as determined by laboratory testing ranges from 3 to 26% by weight.

The results of laboratory and field testing are summarized below:

Moisture Content, Bulk Density and Atterberg Limits

	<u>Range</u>	<u>Average</u>
Natural Moisture Content (W%)	34-280	167
Liquid Limit (W _L %)	55- 96	74
Plastic Limit (W _p %)	29- 85	65
Plasticity Index (I _p %)	11- 26	17

Undrained Shear Strength Su

	<u>Range</u>	<u>Sensitivity</u>
Laboratory Vane Tests (psf)	50-490	3
Field Vane Tests (psf)	30-960	3

The Atterberg Limits indicate that the material is organic and of high plasticity. The natural moisture content generally decreases with depth while the undrained shear strength generally increases with depth. The undrained shear strength indicates that the deposit has a very soft to firm consistency.

Sandy Gravel to Sand

This granular deposit was encountered immediately below the fill in Zwick's Park below the organic clay deposit of the bay bottom south of the park and also immediately below the ground surface on the Prince Edward County side. On the Prince Edward County side this deposit ranges in thickness from 2 to 11 feet. Elsewhere, the thickness of this deposit varies from 11 to 13 feet. This granular stratum is composed of sandy gravel or medium to coarse sand. The results of grain size distribution testing performed on representative samples from this stratum are summarized in envelope form on Figure 3.

Standard Penetration testing gave 'N' values ranging from 4 to 53 blows per foot, generally increasing with depth. Based on these values the deposits are estimated to have a compact to very dense relative density.

Clay

This stratum was encountered in three borings (B.H. #4, 7 & 8) put down in Zwick's Park and also in three borings put down in the bay east of the causeway and north of the fixed span structure (B.H. #10, 11 & 13). This cohesive

deposit was found beneath the stratum of sandy gravel to sand and also in some locations beneath the deposit of organic clay. The thickness of the deposit is estimated to be between 9 and 13 feet. The deposit is composed of clay which is somewhat fissured and laminated. In two locations (B.H. #4 & 7) part of this deposit was found to have random layers of clayey silt.

The results of laboratory and field testing on representative samples taken from this stratum are summarized below.

Natural Moisture Content, Atterberg Limits and Bulk Density

	<u>Clay</u>		<u>Clayey Silt Layers</u>	
	<u>Range</u>	<u>Average</u>	<u>Range</u>	<u>Average</u>
Natural Moisture Content (W%)	42-72	56	30-44	36
Liquid Limit (W _L %)	58-80	69	22-35	31
Plastic Limit (W _p %)	19-24	23	14-24	18
Plasticity Index (I _p %)	39-54	46	8-17	12
Bulk Density (γ _{PCF})	97-109	104		

Undrained Shear Strengths (Su. P.S.F.)

	<u>Range</u>	<u>Sensitivity</u>
Field Vane Tests	800->2400	3-8
Laboratory Vane Tests	765-2830	2-4
Laboratory Unconfined Tests	825-1940	
Laboratory Quick Triaxial Tests	1740-1880	

Consolidation Tests (3 tests)

Initial Void Ratio	e ₀	1.2-2.0
Coefficient of Consolidation	c _c	0.4-1.4
Degree of Preconsolidation	P' _c - P' ₀ (PSF)	3200-6600

The results of the Atterberg Limit testing are plotted on the Plasticity Chart, Figure 4. The Atterberg Limit testing indicates that the clay deposit is generally inorganic and of high plasticity, whereas the layers of clayey silt are inorganic and of low plasticity. The Natural Moisture Content is generally between the Plastic Limit and the Liquid Limit. The consolidation testing gave a range of preconsolidation pressure of 3200 to 6600 P.S.F. in excess of the existing effective overburden pressure.

The undrained shear strength as measured by laboratory and in situ testing ranges from greater than 2400 P.S.F. to 760 P.S.F. decreasing with depth. The sensitivity as measured by vane testing (both laboratory and field testing) indicates that in general the deposit is slightly to moderately sensitive to remoulding. Furthermore, the undrained shear strengths indicate that the consistency of the deposit varies from very stiff in the upper portion changing to firm, generally decreasing with depth.

Clayey Silt

This deposit was encountered in two locations; one in Zwick's Park (B.H. #5) immediately below the sandy gravel to sand deposit and one in the bay (B.H.#12) immediately below the sandy gravel deposit. The thickness of this deposit is estimated to be 9 feet thick. The material in this stratum is clayey silt and a trace of sand with random silt and sand seams. The results of the laboratory and field testing are summarized as follows:

Moisture Content and Atterberg Limits

		<u>Range</u>	<u>Average</u>
Natural Moisture Content	(W%)	22-44	33
Liquid Limit	(W _L %)	33-36	34
Plastic Limit	(W _p %)	15-23	18
Plasticity Index	(I _p %)	10-21	16
<u>Undrained Shear Strength (Su P.S.F.)</u>			

	<u>Range</u>	<u>Sensitivity</u>
Field Vane Tests	1000-1600	2-5

The results of the Atterberg Limit testing are shown on Figure 5; the testings indicate that the clayey silt deposit is inorganic and of low plasticity. In general, the testing shows that the natural moisture content is slightly above or below the liquid limit.

Standard Penetration testing gave 'N' values ranging from 13 to 24 blows per foot. Based on these 'N' values, and together with the in situ vane testing, the deposit is estimated to have a stiff to very stiff consistency.

Glacial Till

A deposit of glacial till up to 18 feet thick was encountered in all borings except in the area of the south bank and also in areas where the parent subsoil has been completely dredged. The composition of the glacial till varies widely across the site. Beneath Zwick's Park and adjacent to it, the till is cohesive being a heterogeneous mixture of clayey silt, with sand and gravel. Elsewhere, the till deposit is granular and composed of a heterogeneous mixture of sand, gravel with some silt and clay. In some locations the glacial drift was found to contain occasional cobbles and boulders in the lower portion of the deposit. The results of laboratory testing on representative samples from this deposit are shown on the Plasticity Chart, Figure 6 and on the Grain Size Distribution Envelope, Fig. 7. The Atterberg Limits indicate that the cohesive glacial drift has an inorganic matrix of low plasticity.

The range of 'N' values from the Standard Penetration testings in this deposit is 15 blows per foot to 80 blows for 3 inches. The cohesive glacial till is estimated to have a firm to hard consistency based on 'N' values. Similarly, the relative density of the granular till is estimated to have a compact to very dense relative density that in general increases with depth.

Groundwater Conditions

Observations on the groundwater level were carried out during the fieldwork by measuring in the open boreholes. The measurements place the groundwater table at a depth of 3 feet below the existing ground surface which corresponds to elevation 246. During the time of the field investigation the water level in the bay fluctuated only slightly from elevation 245.6 to elevation 245.8.

DISCUSSION AND RECOMMENDATIONS

The Ministry of Transportation and Communications has proposed to replace the existing crossing of Hwy. 14 and the Bay of Quinte with a new two-lane high level structure about 100 feet east of and parallel to the existing crossing.

A feasibility study was initiated to assess the foundation requirements for the high level bridge and related approaches by carrying out a preliminary sub-surface investigation. The high level structure will be required to have a minimum vertical navigational clearance of 90 feet and a minimum depth of channel of 13 feet. The main navigation channel will be shifted toward the centre of the bay. The alignment of the north approach will meet the existing conditions some 1000 feet north of Zwick's Park shoreline, whereas about 500 feet south of the Rossmore shoreline, the alignment of the south approach will match existing. The existing structures are to be removed, however, the extent of the causeway removal is yet to be reconciled. The grades of the proposed structure are restricted to a maximum of 5%.

The number of spans and span details are as yet to be decided. Furthermore, the locations of the piers and abutments will depend to a large degree upon the extent of the approach fills which are in turn affected by the feasibility and economics of constructing and maintaining the fill slopes. Because of the importance of the approach fills at the feasibility stage in the planning process, this aspect will be discussed first.

Approach Embankments

North approach - Based on the preliminary profile grade as established by the Regional Planning and Design Office, the heights of profile grade above the following existing conditions at the north approach are anticipated.

Height of Profile Grade Above Average Ground Surface	up to 55 feet
Height of Profile Grade Above Bay Bottom	60 - 105 feet

Because of the generally flat terrain, fill heights will not vary significantly in the transverse direction. Longitudinally, the fill height will depend upon the profile grade at that location and upon the sloping nature of the bay bottom. However, the slope of the bay bottom at the north approach is relatively insignificant, being about 2%.

Subsoil at the north approach generally consists of up to 15 feet of fill material overlying 10 to 13 feet of firm to stiff clay or hard clayey silt which in turn overlies 2 to 4 feet of hard glacial till, followed by limestone bedrock. In one location (B.H. #5), a 7 ft. thick pocket of soft organic clay is sandwiched between the lower clayey silt stratum and the 7 ft. overlying fill material. In another location (B.H. #8) 11 feet of dense sand to sandy gravel is encountered between the lower clay stratum and a 4 foot thick deposit of fill material. Subsoil beneath the bay bottom is somewhat less competent, being a surficial veneer of very soft organic clay up to 9 feet thick overlying 10 to 13 feet of compact to dense sandy gravel which in turn overlies 10 feet of firm to stiff clay. The clay in turn is overlying a compact to very dense glacial till.

The fill material is heterogeneous in composition. In some zones it is composed of competent granular fill material but in other areas it is composed of sanitary landfill or topsoil. This fill material will be detrimental to the stability and performance of the approaches and it is, therefore, recommended that the fill material and organic clay be removed entirely within the plan limits of the proposed embankment. Backfill placed underwater should be composed of Granular 'A' to prevent segregation of material. Fill material for the remainder of the approaches should be of acceptable granular material placed and compacted according to current MTC standards.

Stability analysis in terms of total stress have been carried out to determine the stability of fills immediately after construction. In this method of analysis, stability is governed by undrained shear strength properties of the foundation and fill materials. The following data and values were used in carrying out the stability analysis.

<u>Fill Material</u>	<u>γ (pcf)</u>	<u>ϕ^0</u>	<u>S_u (psf)</u>
(Tension Cracks 5')			
Granular Material	130	30	0

The subsoil condition beneath the bay and beneath the land are somewhat different, subsoil beneath the land being slightly more competent. For this reason two sets of subsoil data were considered in the analysis. The subsoil conditions also assume that the unacceptable fill material and organic clay will be removed entirely within the plan limits of the embankment and replaced by a granular type of acceptable fill material.

Subsoil Conditions Beneath the Bay (Water Elevation 246)

<u>Elevation (Feet)</u>	<u>γ(PCF)</u>	<u>γ'(PCF)</u>	<u>ϕ^0</u>	<u>S_u (PSF)</u>
240-225	130	68	30 ⁰	0
225-220	100	38	0	1000
220-215	100	38	0	750
Below 215	140	78	35	0

Subsoil Conditions Beneath Land

<u>Elevation (Feet)</u>	<u>γ(PCF)</u>	<u>γ'(PCF)</u>	<u>ϕ^0</u>	<u>S_u (PSF)</u>
250-235	130	68	30	0
235-225	100	38	0	1500
Below 225	140	78	35	0

The longitudinal stability of the embankments will depend upon the geometry of the forward slope of the embankment, as well as the position and location of the structure's abutment. Furthermore, the longitudinal stability will depend on the location of the toe of the slope since subsoil is not as competent beneath the bay bottom as beneath the land.

The following are recommendations based on the above analysis. They are discussed according to three categories, depending upon the location of the toe of the slope with regard to the shoreline.

Case A: The toe of the slope will not extend within 20 feet of the shoreline.

- Fills up to 40 feet will be stable with forward and side slopes of 2:1.
- Fills up to 50 feet with 20 foot long counterbalancing berms at mid-height on both the forward and side slopes of the embankment would also be stable with slopes of 2:1.
- Fills up to 60 feet with 40 foot long counterbalancing berms at mid-height on both the forward and side slopes of the embankment would be stable with 2:1 slopes.

These recommendations are summarized in Figure 9, together with the critical slip circle and assumed subsoil conditions for 40 foot and 50 foot fill heights.

Case B: The toe of the slope is located within 20 feet of the shoreline but will not extend into the bay.

- Fills up to 30 feet above the average ground surface (assumed to be at elevation 250±) will be stable with forward and side slopes of 2:1.
- Fills up to 45 feet above the average ground surface will require 35 foot long berms at mid-height in both forward and transverse direction of the approaches.

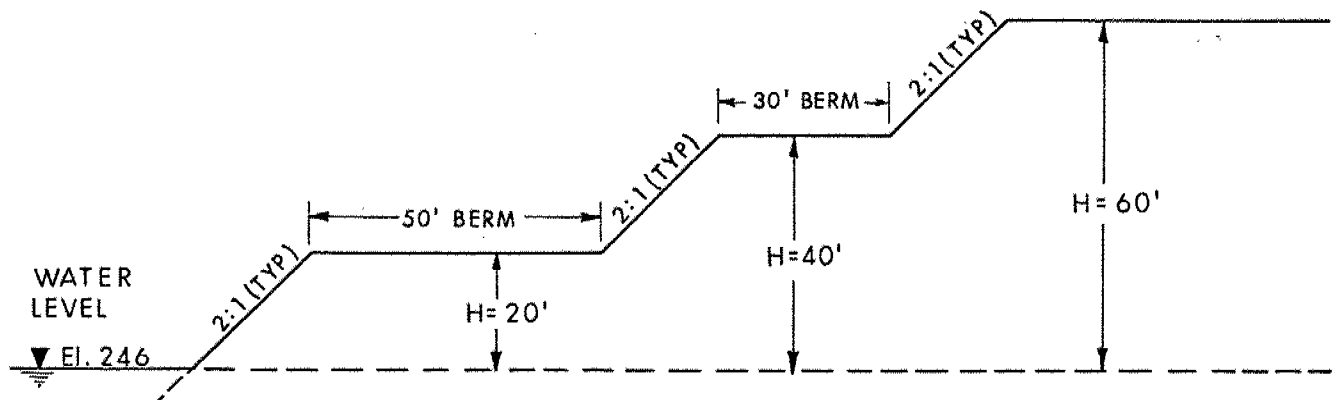
- Fills up to 55 feet above the average ground surface will be stable with 60 foot long counterbalancing berms at mid-height on both the forward and side slopes of the embankment with slopes not steeper than 2:1.

These recommendations are shown on Figure 10, together with the critical slip circles and the assumed subsoil stratigraphy.

Case C: The toe of the slope extends past the shoreline into the bay.

- Fill heights up to 20 feet above the water line will be stable with side slopes of 2:1.
- Fills up to 40 feet above the waterline with 50 foot long counterbalancing berms at midheight on both the forward and side slopes of the embankment would be stable with 2:1 slopes.
- Fill heights of up to 60 feet above the water line would require the following berm configuration for stability against deep seated rotational failure (also see sketch below):

berm at 1/3 height 50 feet long
berm at 2/3 height 30 feet long
all side slopes 2:1 maximum



Case C

A minimum of 50 foot transition taper should be provided between the different geometrical configuration, i.e. between a Case C and Case A or between a Case A and Case B condition.

Due to the presence of the underlying compressible clay stratum, fill will undergo settlements as a result of the consolidation of the clay deposit. To estimate settlements the stress distribution was computed by the Purdue Method and consolidation characteristics of the clay deposit were based on three laboratory consolidations tests. An estimate of the field e -log p curve was made from the laboratory curve by means of a graphical procedure after Schmertmann, 1953. The calculations indicate that a 40 foot fill with side slopes of 2:1 and no berms will undergo a settlement of approximately 5-6 inches; furthermore, it is estimated that 90% of the settlement will occur within 4 months after construction. Calculations were also carried out for a 60 foot fill with 40 feet mid-height berms and slopes of 2:1. The expected settlement for this fill is 7-9 inches, 90% of which would occur within 4 months after completion of the fill. The above magnitudes of settlement are applicable to fill heights located on the land. The consolidation testing indicated that the clay stratum beneath the bay would undergo about 2-3 times the settlement of clay stratum beneath land subject to the same loading conditions.

If settlements of such magnitudes are detrimental to the performance of the approaches and the pavement, the fills should be constructed and left in place for 4-6 months prior to paving. It is calculated that this preloading period would allow about 90% of the settlement to occur.

South approach: Based on the preliminary profile grade the height of fills above the following existing conditions at the south approach are anticipated.

Height of Profile Grade Above Average Ground Surface up to 15 feet

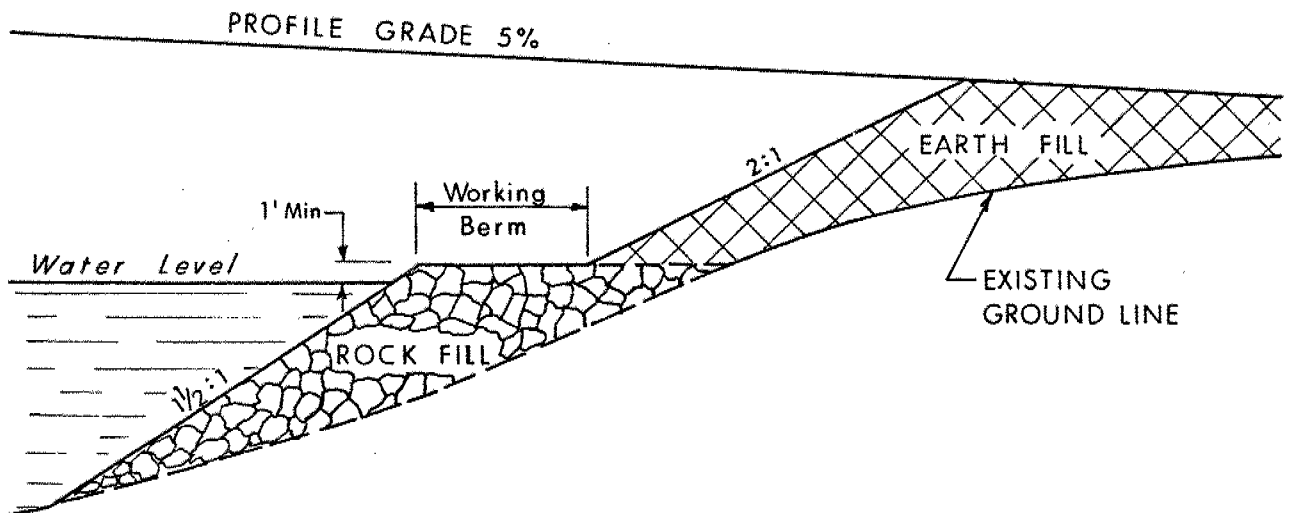
Height of Profile Grade Above Bay Bottom at Pier Stop up to 62 feet

Again, generally flat terrain is prevalent at the south approach and the fill heights will not vary appreciably in the transverse directions. However, due to the sloping nature of the bay bottom and the 5% profile grade, fill height will vary considerably in the longitudinal direction, increasing as the approaches extend outward from shore.

Subsoil at the south approach is comprised of 2 to 11 feet of loose to compact sand to sandy gravel overlying limestone bedrock.

The subsoil is such that the anticipated fill heights will be stable with respect to deep seated rotational failure with forward and side slopes of 2 horizontal to 1 vertical. If the forward slopes extend into the bay the embankment should be constructed by placing rockfill to extend to a height of one

foot above the water level with side and forward slopes of $1\frac{1}{2}$ to 1. The fill may then be completed by the placing of earthfill with a slope of 2 to 1. It may be advantageous for construction to provide a 10 foot berm between the crest of the rockfill slope and the toe of the earthfill slope. See sketch below.



Furthermore, the earthfill should be protected against wave action by rip-rapping to an elevation as per hydrological requirements.

Structure Foundations

As mentioned earlier, details of the spans and pier locations are as yet not finalized. However, one proposal put forward is that the structure be comprised of 12 spans of equal length (250'), the centre span to cross the relocated main channel where the present 2 fixed-span structure is located. This centre span is required to have a minimum vertical navigational clearance of 90 feet above the water level. Highway grades are to be limited to a maximum of 5%.

At this stage in the design it is felt that detailed recommendations concerning the construction and design of the structure foundations is not warranted. Only concepts or alternatives will be presented at this stage and further elaboration or clarification will be provided by this office as required.

Because of the widely differing subsoil conditions, foundation requirements for the southern and northern portion will be discussed separately.

Southern portion: On the southern portion subsoil consists of up to 46 feet thick deposits of very soft organic clay underlain by up to 5 feet of very dense glacial till overlying bedrock. Within the main channel bedrock is exposed at the bay bottom at a depth of about 35 feet.

Within the southern portion of the proposed line the subsoil conditions are such that virtually no lateral support will be provided to the structure foundations. The structure foundations must provide the sufficient and adequate internal lateral rigidity to be considered in this particular area. The following alternatives are put forward for consideration.

The structure may be supported on large diameter concrete caissons socketted into the bedrock surface. Construction would require that caissons be provided with a permanent liner. The bedrock conditions are such that foundations may be designed for a maximum allowable load of 30 t.s.f. The sizing of the caissons would be based on the slenderness ratio. To reduce the dewatering problems it may be advantageous to extend the caissons to the underside of the deck and in this manner construct the pile caps to serve also as the pier caps.

Alternatively, the foundation may be accomplished by constructing cofferdams and supporting the structure foundation directly on the bedrock surface. In this manner the structure foundation would have to be brought up by means of mass or reinforced concrete. For this scheme proposed, an extensive dewatering scheme would be essential for construction purposes.

Alternatively, the structure may be supported on steel tubular piles keyed into the bedrock surface to provide sufficient lateral resistance. Tubular piles should be sized according to the slenderness ratio.

Northern portion: Subsoil conditions on the northern portion are somewhat more competent. Subsoil consists of a thin veneer of very soft organic clay up to 9 feet thick overlying 11 to 13 feet of sand or sandy gravel followed by 9 to 13 feet of clay which in turn overlies 5 to 18 feet of glacial till. The glacial till overlies limestone bedrock. The following alternatives are provided for consideration.

The structure foundation may be founded on steel 'H' piles, steel tube piles, or concrete caissons founded on the bedrock surface. Piles constructed in this fashion may be designed for maximum allowable load, i.e. 100 tons/pile for a 12 BP 74 steel 'H' pile. Again, concrete caissons may be used but for construction purposes it will be necessary to use a permanent liner.

General considerations: The bedrock depths are quite variable across the stratigraphical profile of the proposed line, being from 33 to 63 feet below the water level. At this stage in the feasibility planning where the type of structure foundation has yet to be decided, there does not appear to be any advantage in the saving of pile lengths, etc., in shifting the alignment slightly to the east or west. However, depending on the type of foundation chosen for the southern portion, it may be advantageous to shift the proposed line to avoid the causeway fill, thus simplifying the construction of the cofferdams. Conversely, if piles are chosen it may be advantageous to shift the alignment toward the causeway fill to take advantage of the lateral support offered to the piles by the causeway fill.

MISCELLANEOUS

The fieldwork was supervised by Mr. M. MacLean, Project Engineer, and Mr. J. White, Student Engineer, using equipment owned and operated by Atcost Soil Drilling Inc., Concord, Ontario.

This report was written by Mr. M. MacLean with the assistance of Miss Y. Jamani, Student Engineer, and was reviewed by Mr. M. Devata, Supervising Engineer.

M MacLean

M. MacLean, P. Eng.
Project Engineer

M. Devata

M. Devata, P. Eng.
Supervising Engineer



MD/MM/gs
November, 1977

APPENDIX

RECORD OF BOREHOLE No 1

W P 134-74-01 LOCATION Sta 435+83 o/s 104' Rt & Exist. Hwy. 14 ORIGINATED BY JW
 DIST 8 HWY 14 BOREHOLE TYPE Solid Stem Augers COMPILED BY SC
 DATUM Geodetic DATE May 25, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH						WATER CONTENT (%)
253.1	Ground Surface													
251.6	Sandy Gravel					*								
1.5	Refusal to Augering Probable Bedrock End of Borehole						250							
	* Note: Water Level Not Established													

RECORD OF BOREHOLE No 2

W P 134-74-01 LOCATION Sta 436+56 o/s 105' Rt & Exist. Hwy. 14 ORIGINATED BY JW
 DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers & BXL Rock Coring COMPILED BY SC
 DATUM Geodetic DATE May 25, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH				WATER CONTENT (%)				
								○ UNCONFINED	+ FIELD VANE							
								● QUICK TRIAXIAL	x LAB VANE							
246.5	Ground Surface										20	40	60			
0.0	Sandy Gravel		1	SS	12	240					○				36 55 5 4	
	Some Silt		2	SS	9						○				50 31 15 4	
	Trace Clay		3	SS	5						○				33 30 29 8	
	Trace Shells															
	Loose to Compact															
	Boulders															
236.0	Limestone		4	RC EXL	REC 95%	230									RQD 86%	
10.5	Bedrock		5	RC EXL	REC 100%											RQD 80%
	Sound		6	RC BXL	REC 93%											RQD 70%
	Shale Bed															
220.2	End of Borehole															
26.3	End of Borehole															

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RECORD OF BOREHOLE No 4

W P 134-74-01 LOCATION Sta 469+29 o/s 178' Rt. 6 Exist. Hwy. 14 ORIGINATED BY JW
DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Coring Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 27, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100				
248.9	Ground Surface															
0.0	Fill		1	SS	17	*										
	Sand and Gravel with Inclusions and Layers of Clayey Silt		2	SS	4											
			3	SS	PH											
			4	SS	2											
	Trace of Organic Matter With Cobbles and Boulders		5	SS	14											
233.9			6	SS	11											
15.0	With Sand		7	SS	8											
	Clay Laminated and Stiff Fissured		8	TW	PH											
220.9	With Random Layers of Clayey Silt		9	TW	PM											
218.8	Glacial Till Hard		10	SS	42											
30.1	Limestone Bedrock		11	RC	REC											
213.7	Sound			BXL	100%											
35.2	End of Borehole															
	* Note: Water Level Not Established															

RECORD OF BOREHOLE No 5

W P 134-74-01 LOCATION Sta 471+83 o/s 60' RT. 6 Exist. Hwy. 14 ORIGINATED BY JW
DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers & Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 26, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100				
250.7	Ground Surface															
0.0	Fill		1	SS	22	*										
	Sand and Gravel with Inclusions and Layers of Clayey Silt		2	SS	3											
243.7			3	SS	14											
7.0	Organic Clay		4	SS	1											
			5	TW	PH											
236.7	Soft		6	TW	PH											
14.0	Clayey Silt with Random Silt and Sand Seams Hard		7	SS	24											
			8	SS	16											
227.7			9	SS	13											
23.0	Glacial Till		10	SS	80/3"											
224.3	Ref. Mixture Clayey Silt Sand and gravel Hard		11	SS	20/3"											
26.4	Refusal to Augering Probable Bedrock End of Borehole															
	* Note: Water Level Not Established															

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 7

W P 134-74-01 LOCATION Sta 467+06 o/s 92' RT & Exist. Hwy. 14 ORIGINATED BY JW
DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers, BXL Rock Coring & Dynamic Cone COMPILED BY SC
DATUM Geodetic DATE May 30, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT Y PCF	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
249.1	Ground Surface													
0.0	Fill Sand and Gravel some Silt, Trace of Clay Organic Material in upper 2 feet Cobbles at 3', 5', & 10'		1	SS	12								Om 4.2%	46 25 19 10
			2	SS	32									33 52 13 2
238.1			3	SS	31									
11.0	Sand Medium to Coarse Trace of Shells Compact		4	SS	15									2 93 (5)
			5	SS	28									3 87 (10)
			6	SS	27									0 4 24 72
227.1			7	SS	17									
22.0	Clay with Random Layers of Clayey Silt		8	SS	8									
			9	SS	3									
218.6	Firm to Stiff													
30.5	Glacial Till Hard		10	TW	PH								139	
216.3														
32.8	Limestone Bedrock			RC	REC									
210.8	Sound		11	BXL	100%									RQD 63%
38.3	End of Borehole													

RECORD OF BOREHOLE No 8

W P 134-74-01 LOCATION Sta 469+56 o/s 52' Rt. & Exist. Hwy. 14 ORIGINATED BY JW
DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers & Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 31, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT Y PCF	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
249.3	Ground Surface													
0.0	Fill Sand & Clayey Silt Some Organics		1	SS	5	*							Om 7.1%	7 54 29 10
245.8			2	SS	44									60 30 7 3
3.5	Sandy gravel		3	SS	38									
	Sand medium to Coarse		4	SS	16/ 6"									6 87 (7)
234.3	Dense													
15.0	Clay Laminated & Fissured Stiff		5	SS	8								109	
			6	TW	PH								107	
			7	TW	PH									
224.2														
25.1	Glacial Till Hard		8	SS	55									19 25 27 29
220.6	Het. Mix Clayey Silt, Sand and Gravel													
28.7	Refusal to Augering Probable Bedrock End of Borehole													

*Note: Water level not
Established

+3, x5: Numbers refer to
Sensitivity
15 \div 5 (%) STRAIN AT FAILURE
10

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RECORD OF BOREHOLE No 10

W P 134-74-01 LOCATION Sta. 466+00 o/s 205' RT. & Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing, BXL Rock Coring & Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 26, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION [%]
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH PSF						
245.8	Water Surface							20 40 60 80 100						GR SA SI CL
0.0	Water							○ UNCONFINED + FIELD VANE						
237.8	Bay Bottom							● QUICK TRIAXIAL x LAB VANE						
8.0	Organic Clay V. Soft							400 800 1200 1600 2000						
229.3			1	SS	10									
16.5			2	SS	2									
	Clay Fissured and Laminated Stiff		3	TW	PM									
215.8			4	TW	PM									
30.0														
213.3	Glacial Till Hard		5	SS	76									4 64 8 24
32.5	Sound Limestone Bedrock		6	RC	REC									
208.3	With Shaly Sections			BXL	97%									RQD 70%
37.5	End of Borehole													

RECORD OF BOREHOLE No 11

W P 134-74-01 LOCATION Sta 463+10 o/s 130' RT & Exist. Hwy 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing, & Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 27, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH PSF							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE						
245.8	Water Surface							20 40 60 80 100						GR SA SI CL	
0.0	Water														
240.5	Bay Bottom														
238.8	Organic Clay Very Soft		1	SS	13		240						4.0%		
7.0	Sandy Gravel Trace of Silt Compact to Dense		2	SS	20				○					67 22 9 2	
			3	SS	25				○					58 32 (10)	
			4	SS	34										
			5	SS	42										
			6	SS	49		230		○					50 41 (9)	
225.8			7	SS	16										
20.0	Clay Fissured Laminated Firm to Stiff		8	TW	PH		220		x 2				109		
			9	SS	6				+ 5						
									+ 3						
215.8															
30.0	Glacial Till Het. Mix: of Sand and Gravel some Clayey Silt		10	SS	15					○				39 31 20 10	
210.5	Compact to Very Dense		11	SS	170										
35.3	Refusal to Driving Casing Probable Bedrock End of Borehole									110/ 4"					

+3, x5: Numbers refer to
Sensitivity

20
15
10
5
5 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 12

W P 134-74-01 LOCATION Sta 460+79 o/s 243' RT. of Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing, BXL Rock Coring, & Dynamic Cone Test COMPILED BY SC
DATUM Geodetic DATE May 31, 1977 CHECKED BY JP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT LIMIT			UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W _p	W	W _L	WATER CONTENT (%)		
245.8	Water Surface													GR SA SI CL
0.0	Water													
237.8	Bay Bottom													
235.8	Organic Clay Very Soft		1	SS	29								Om 3.0%	
10.0	Sandy Gravel Trace of Silt Compact to Dense		2	SS	27									58 24 13 5
225.3	Clayey Silt Trace of Sand Firm to Stiff		3	SS	53									41 46 (13)
20.5	Glacial Till Het. Mixture Sand, Silt, Trace of Clay Compact		4	TW	PM									
216.3	Glacial Till Het. Mixture Sand, Silt, Trace of Clay Compact		5	SS	19									
29.5	Glacial Till Het. Mixture Sand, Silt, Trace of Clay Compact		6	SS	26									
206.8	Limestone Bedrock		7	EC	REC	100%								
39.8	End of Borehole													

RECORD OF BOREHOLE No 13

W P 134-74-01 LOCATION Sta 457+81 o/s 80' RT @ Exist. Hwy. 14 ORIGINATED BY MM
 DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX casing, BXL Rock Coring & Dynamic Cone Test COMPILED BY SC
 DATUM Geodetic DATE June 2, 1977 CHECKED BY df

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.8	Water Surface																
0.0	Water																
236.5	Bay Bottom																
9.3	Organic Clay																
230.0	Very Soft		1	SS	9											W=161.5%	
15.8	Sandy Gravel Trace of Silt Compact		2	SS	34												57 34 8 1
			3	SS	15												
219.0			4	SS	14												
26.8	Clay Fissured Stiff		5	TW	PM											97	
			6	SS	5												
207.8			7	SS	30												
38.0	Glacial Till Het. Mix of Sand and Gravel Trace of Clayey Silt Compact to Very Dense		8	SS	55												
			9	SS	146												
191.3																	
54.5	Sound Limestone Bedrock		10	RC	REC												RQD 97%
186.0	With Shaly Sections			BXL	100%												
59.8	End of Borehole																

+³, x⁵: Numbers refer to 20
Sensitivity 15 5 (%) STRAIN AT FAILURE
10

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RECORD OF BOREHOLE No 14

W P 134-74-01 LOCATION Sta 464+58 o/s 196' RT @ Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Continuous Vane Tests COMPILED BY SC
DATUM Geodetic DATE June 6, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH PSF					WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE					W _p ———— ○ ———— W _L				
								● QUICK TRIAXIAL × LAB VANE									
245.8	Water Surface							400	800	1200	1600	2000	20	40	60	PCF	GR SA SI CL
0.0	Water																
238.0	Bay Bottom						240										
7.8	Organic Clay Very Soft		1	TP	PM		x2							W= 270% W _L = 87% W _p = 67%	64		
229.0							+8										
							+2										
16.8	Refusal to Pushing Vane End of Borehole						230										

RECORD OF BOREHOLE No 15

W P 134-74-01 LOCATION Sta 461+14 o/s 20' LT @ Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SC
DATUM Geodetic DATE June 6, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH					WATER CONTENT (%)				
252.0	Ground Surface															GR SA SI CL	
0.0	Fill					*	250										
246.6	Sand, Gravel and Cobbles																
5.4	Refusal to Augering End of Borehole																
	* Note: Groundwater Not encountered																

RECORD OF BOREHOLE No 16

W P 134-74-01 LOCATION Sta 467+10 o/s 242' RT. @ Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Continuous Vane Test COMPILED BY SC
DATUM Geodetic DATE June 6, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100					W _p	W	W _L				
								SHEAR STRENGTH PSF										WATER CONTENT (%)	
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE											
								400	800	1200	1600	2000							
245.8	Water Surface														20	40	60	PCF	GR SA SI CL
0.0	Water																		
239.5	Bay Bottom						240												
6.3	Organic Clay Very Soft to Soft		1	TP	PM			x2							W = 282% W _L = 92% W _p = 77%		69		
								+2											
								+3											
232.0								+3											
13.8	Refusal to Pushing Vane End of Borehole						230												

RECORD OF BOREHOLE No 17

W P 134-74-01 LOCATION Sta 453+52 o/s 84' Rt Ø Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing & BXL Rock Coring COMPILED BY SC
DATUM Geodetic DATE June 7, 1977 CHECKED BY *CP*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ PCF	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH										WATER CONTENT (%)		
								20 40 60 80 100										20 40 60		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 400 800 1200 1600 2000												
245.8	Water Surface																			
0.0	Water																			
235.0	Bay Bottom																			
10.8	Organic Clay Very Soft		1	SS	12										Om 4.0%					
232.3																				
13.5	Fill		2	SS	40											50 36 9 5				
	Sandy Gravel																			
	Trace of Silt		3	SS	7											58 39 (3)				
			4	SS	13															
			5	SS	31											36 62 (2)				
			6	SS	26															
207.8	Organic Clay																			
38.0	Hard		7	SS	19										W=102%					
202.8	Glacial Till																			
43.0	Het. Mix Sand, Gravel		8	SS	41											14 62 18 6				
	Some silt Trace of																			
	Clay Dense		9	SS	100 40"															
	Boulders		10	RC	100 40"															
192.5	Sound Limestone		11	RC	50%															
53.3	Bedrock		12	RC	REC															
187.5	With Shaly Sections			BXL	100%											RQD 90%				
58.3	End of Borehole																			



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RECORD OF BOREHOLE No 18

WP 134-74-01 LOCATION Sta 452+48 o/s 18' Lt. Exst. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Solid Stem Augers COMPILED BY SC
DATUM Geodetic DATE June 7, 1977 CHECKED BY CP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100	W _p	W	W _L		
256.0	Ground Surface		1	SS	24	**											
0.0	Fill		1	SS	24												
	Sand and Gravel with Cobbles to Boulders Very Dense																
	Compact																
	With Cobbles to Boulders V. Dense Compact																
226.0	End of Borehole																
30.0	* Description inferred from nature of auger operation and material on augers ** Note: GROUNDWATER NOT ESTABLISHED																

+3, x5: Numbers refer to
Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

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RECORD OF BOREHOLE No 19

W P 134-74-01 LOCATION Sta 447+28 o/s 145' Rt of Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing & BXL Rock Coring COMPILED BY SC
DATUM Geodetic DATE June 13, 1977 CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N' VALUES			20	40	60	80	100					
245.8	Water Surface																
0.0	Water																
234.5	Bay Bottom																
11.3	Organic Clay With Sand		1	SS	1/	24"											
	V. Soft to Firm		2	SS	own wt.												
			3	SS	2												
			4	SS	1												
			5	SS	2												
189.0	Glacial Till Het. Mix of Clayey Silt with Sand and Gravel Hard		6	SS	3												
185.5	Limestone Bedrock		7	SS	100%												
60.3	Sound		8	RC BXL	REC 100%												
180.5																	
65.3																	

+3, x5: Numbers refer to
Sensitivity

20
15
10
5
0
(%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No 20

W P 134-74-01 LOCATION Sta 444+84 o/s 90' RT. of Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing, BXL Rock Coring COMPILED BY SC
DATUM Geodetic DATE June 4, 1977 CHECKED BY *CP*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.6	Water Surface																GR SA SI CL
0.0	Water						240										
234.3	Bay Bottom																
11.3	Fill		1	SS	2								o			Om. 3.0%	
	Sandy Gravel		2	SS	8		230										
	Trace of silt with Shells with decayed and undecayed Wood Chips to Elev. 210.0'		3	SS	48								o			Om. 0.5%	11 86 (3)
			4	SS	92		220										
			5	SS	18												
							210										
			6	SS	41								o				53 42 (5)
							200										
193.6			7	SS	120								o				20 72 (8)
52.0	Glacial Till																
	Het. Mix. of sand, gravel, trace silt with cobbles and boulders up to 1" thick		8	RC	100%		190										
	Very Dense		9	RC	REC	0%											
183.3			10	RC	REC	25%											
62.3	Sound Limestone																
	Bedrock		11	RC	REC		180										RQD 80%
177.8				BXL	94%												
67.8	End of Borehole																

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HIGHWAY ENGINEERING DIVISION-ENGINEERING MATERIALS OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE No 21

W P 134-74-01 LOCATION Sta 450+20 o/s 170¹ RT. ϕ Exist. Hwy. 14 ORIGINATED BY NM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing & BXL Rock Coring COMPILED BY SC
DATUM Geodetic DATE June 15, 1977 CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ PCF	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH PSF										WATER CONTENT (%)		
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE												
245.6	Water Surface							20	40	60	80	100								
0.0	Water						240													
230.9	Bay Bottom						230													
14.7	Organic Clay with sand						220													
	Very Soft to Firm		1	SS	2		210									W=107%				
			2	SS	1/	24"	200													
198.3																				
47.3	Glacial Till		3	SS	25												0 17 71 12			
193.0	Clayey Silt with Sand Hard																			
191.3	Limestone Bedrock Sound		4	RC	REC 100%												RQD 50%			
54.3	End of Borehole																			

+3, x⁵: Numbers refer to
Sensitivity

20
15
10

5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION



Ministry of
Transportation and
Communications
Ontario

HIGHWAY ENGINEERING DIVISION-ENGINEERING MATERIALS OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE No 22

W P 134-74-01 LOCATION Sta 437+92 o/s 96' RT of Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX casing, BX Rock Coring COMPILED BY SC
DATUM Geodetic DATE June 15, 1977 CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.6	Water Surface																GR SA SI CL
0.0	Water																
226.3	Bay Bottom																
224.7	Organic Clay V. Soft		1	SS	9												15 42 35 8
222.8	Glacial Till Loose																
22.8	Sound Limestone Bedrock		2	RC	REC												RQD 80%
217.6	With Shaly Sections																
28.0	End of Borehole																

RECORD OF BOREHOLE No 23

W P 134-74-01 LOCATION Sta 439+24 o/s 73' RT. of Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing COMPILED BY SC
DATUM Geodetic DATE June 15, 1977 CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.6	Water Surface																GR SA SI CL
0.0	Water																
211.3	Bottom of Bay																
34.3	Refusal to Driving Casing Probable Bedrock End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION



Ministry of
Transportation and
Communications

HIGHWAY ENGINEERING DIVISION-ENGINEERING MATERIALS OFFICE-SOIL MECHANICS SECTION

RECORD OF BOREHOLE No 24

W P 134-74-01 LOCATION Sta 441+92 o/s 108' RT. Ø Exist. Hwy. 14 ORIGINATED BY MM
DIST 8 HWY 14 BOREHOLE TYPE Washboring with NX Casing COMPILED BY SC
DATUM Geodetic DATE June 16, 1977 CHECKED BY *EP*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA Si CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
245.6	Water Surface																
0.0	Water						240										
							230										
							220										
215.3	Bay Bottom						210										
30.3	Organic Clay With Sand V. Soft						200										
			1	SS	1												
195.3	Refusal to Driving Casing Probable Bedrock End of Borehole																
50.3																	

OFFICE REPORT ON SOIL EXPLORATION

+3, x5: Numbers refer to
Sensitivity

20
15 \diamond 5 (%) STRAIN AT FAILURE
10



Ministry of
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DIAMOND DRILL RECORD

HOLE NO. _____ SHEET NO. _____

DIP

PROPERTY W.P. 134-74-01
LOCATION Hwy. 14
Belleville, Ontario
LATITUDE _____
DEPARTURE _____
BEARING _____

90°

TOTAL FOOTAGE _____

ELEV. COLLAR _____
DATUM _____
DATE STARTED _____
DATE COMPLETED _____
DRILLED BY _____
LOGGED BY _____

FOOTAGE		FORMATION	SAMPLE NUMBER	% Shale		REMARKS
FROM	TO					
HOLE #7						
33'0"	38'3"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, horizontal breakage throughout length of core.		1%		Trenton formation RQD 45%
HOLE #2						
13'0"	20'9"	Limestone, med. grey colour, fine, med. & coarse texture		2%		Trenton formation RQD 80%
20'9"	26'3"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, broken core, 23' - 24' shale		15%		RQD 30%
HOLE #21						
52'6"	55'0"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, horizontal breakage throughout length of core, Boulders 52'6" - 53'4"		0.5%		RQD 53'4" to 55'0" - 15%
HOLE #4						
30'1"	35'2"	Limestone, med. grey colour, coarse to med. texture.		2%		RQD 45%

DATE OF EXAMINATION June 28, 1977

B.K. Glassford



HOLE NO. _____ SHEET NO. _____

DIP

90°

PROPERTY _____ W.P. 134-74-01
LOCATION _____ Hwy. 14
_____ Belleville, Ontario

LATITUDE _____
DEPARTURE _____
BEARING _____

TOTAL FOOTAGE _____

ELEV. COLLAR _____
 DATUM _____
 DATE STARTED _____
 DATE COMPLETED _____
 DRILLED BY _____
 LOGGED BY _____

[illegible]

DATE OF EXAMINATION June 28, 1977

B. K. Glassford



Ministry of
Transportation and
Communications

DIAMOND DRILL RECORD

HOLE NO. _____ SHEET NO. _____

DIP

PROPERTY LOCATION W.P. 134-74-01
Hwy. 14
Belleville, Ontario
LATITUDE
DEPARTURE
BEARING

90°
TOTAL FOOTAGE

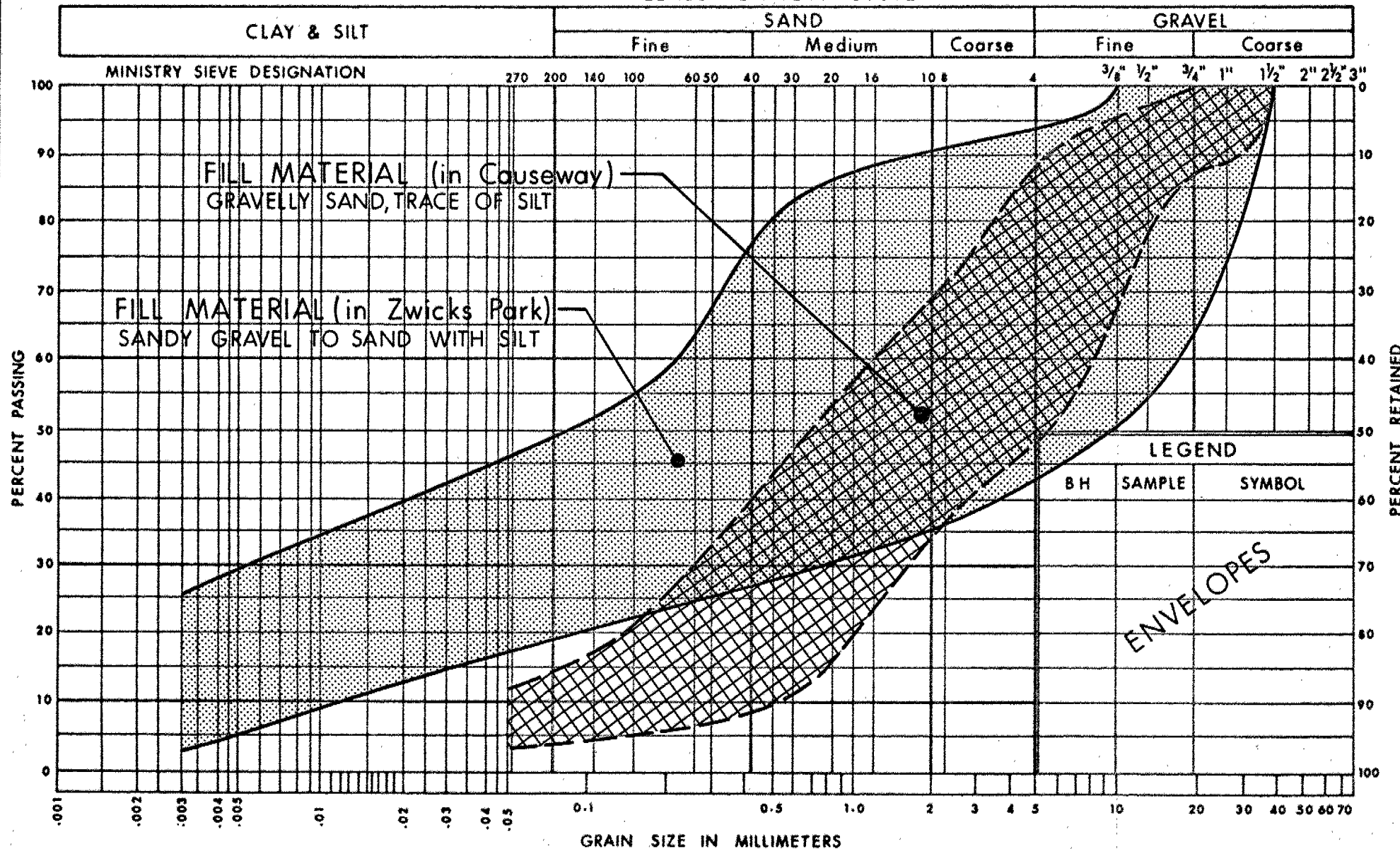
ELEV. COLLAR
DATUM
DATE STARTED
DATE COMPLETED
DRILLED BY
LOGGED BY

FOOTAGE		FORMATION	SAMPLE NUMBER	%	REMARKS
FROM	TO				
23'6"	28'9"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, horizontal breakage throughout length of core.		3%	Trenton formation RQD 18%
		HOLE #19			
61'0"	66'0"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, horizontal breakage throughout length of core.		1%	Trenton formation RQD 20%
		HOLE #20			
55'3"	68'6"	Limestone, med. grey colour, med. to fine texture, ground and lost core 55'3" to 63'0".		0.5%	Trenton formation RQD 63' to 68'6" - 80%
		HOLE #17			
50'5"	51'0"	boulders		1%	Trenton formation
51'0"	54'0"	ground and lost core			RQD 54'0" - 59'0" - 45%
54'0"	59'0"	Limestone, med. grey colour, med. texture, hard, thinly bedded, shaly sections, horizontal breakage throughout length of core.			

DATE OF EXAMINATION June 28, 1977

B. K. Glassford

UNIFIED SOIL CLASSIFICATION SYSTEM

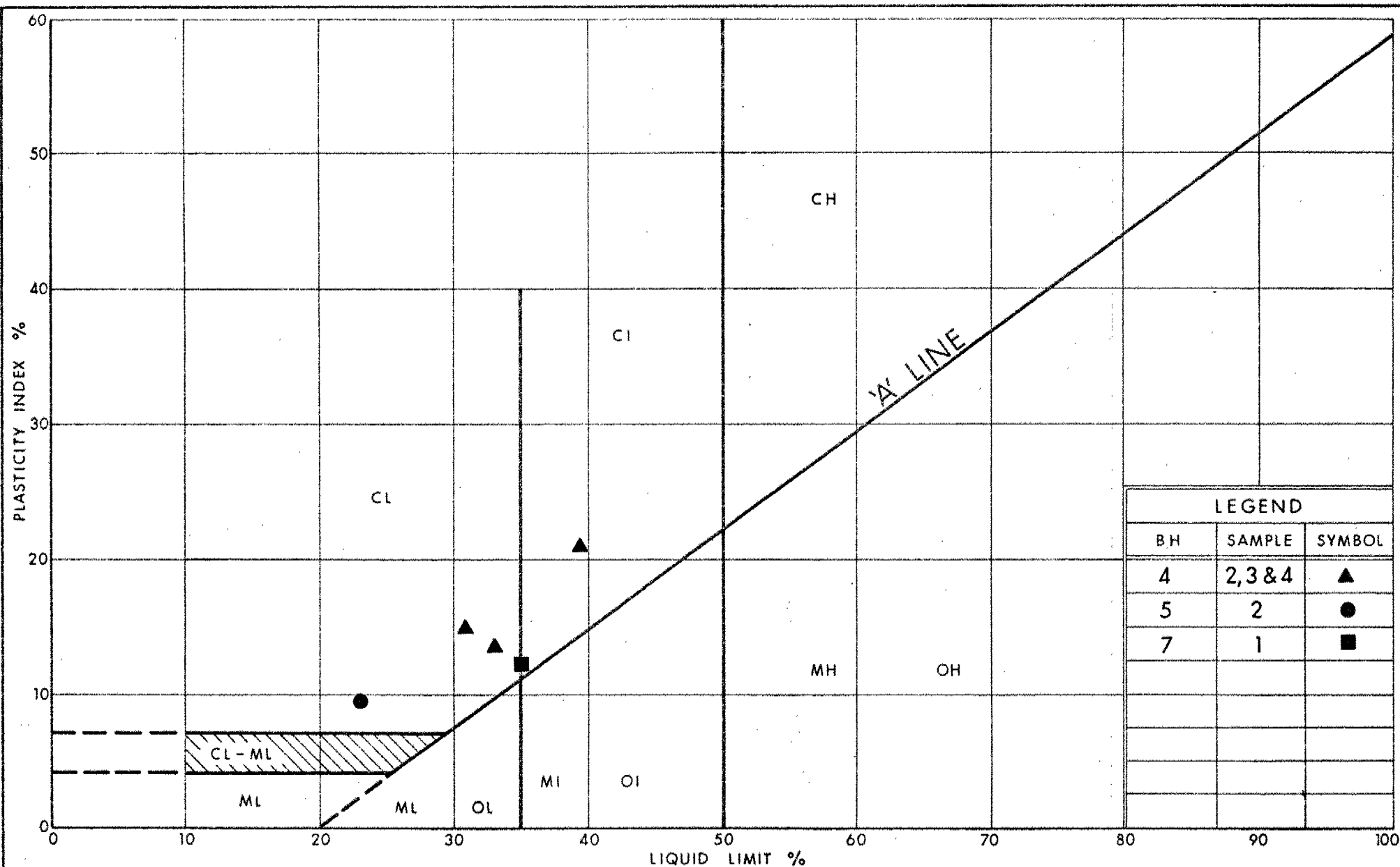


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GRAIN SIZE DISTRIBUTION FILL MATERIAL

FIG No 1

W P 134-74-01



Ontario

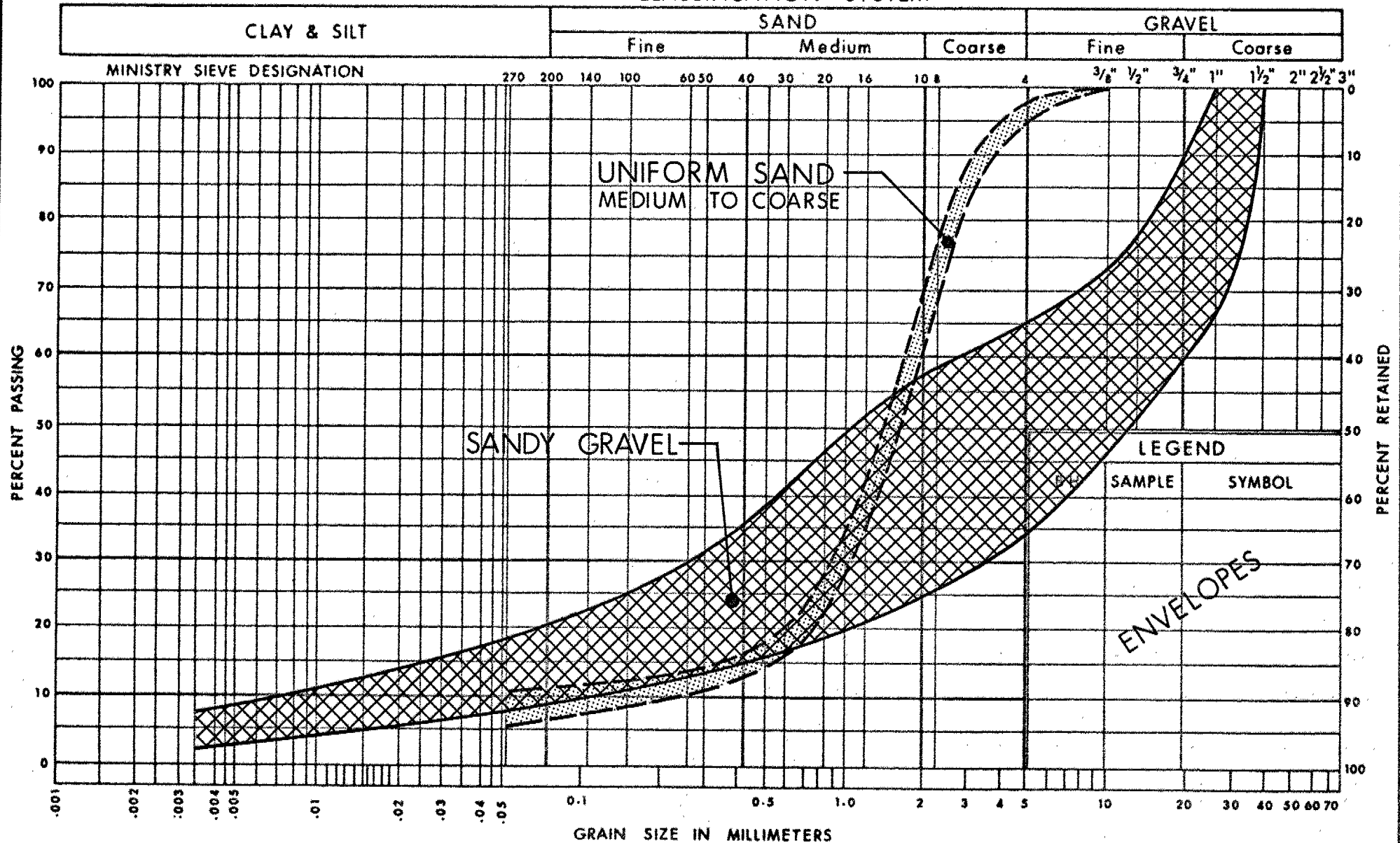
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PLASTICITY CHART
FILL MATERIAL (in Zwicks Park)
COHESIVE POCKETS OF CLAYEY SILT

FIG No 2

W P 134-74-01

UNIFIED SOIL CLASSIFICATION SYSTEM

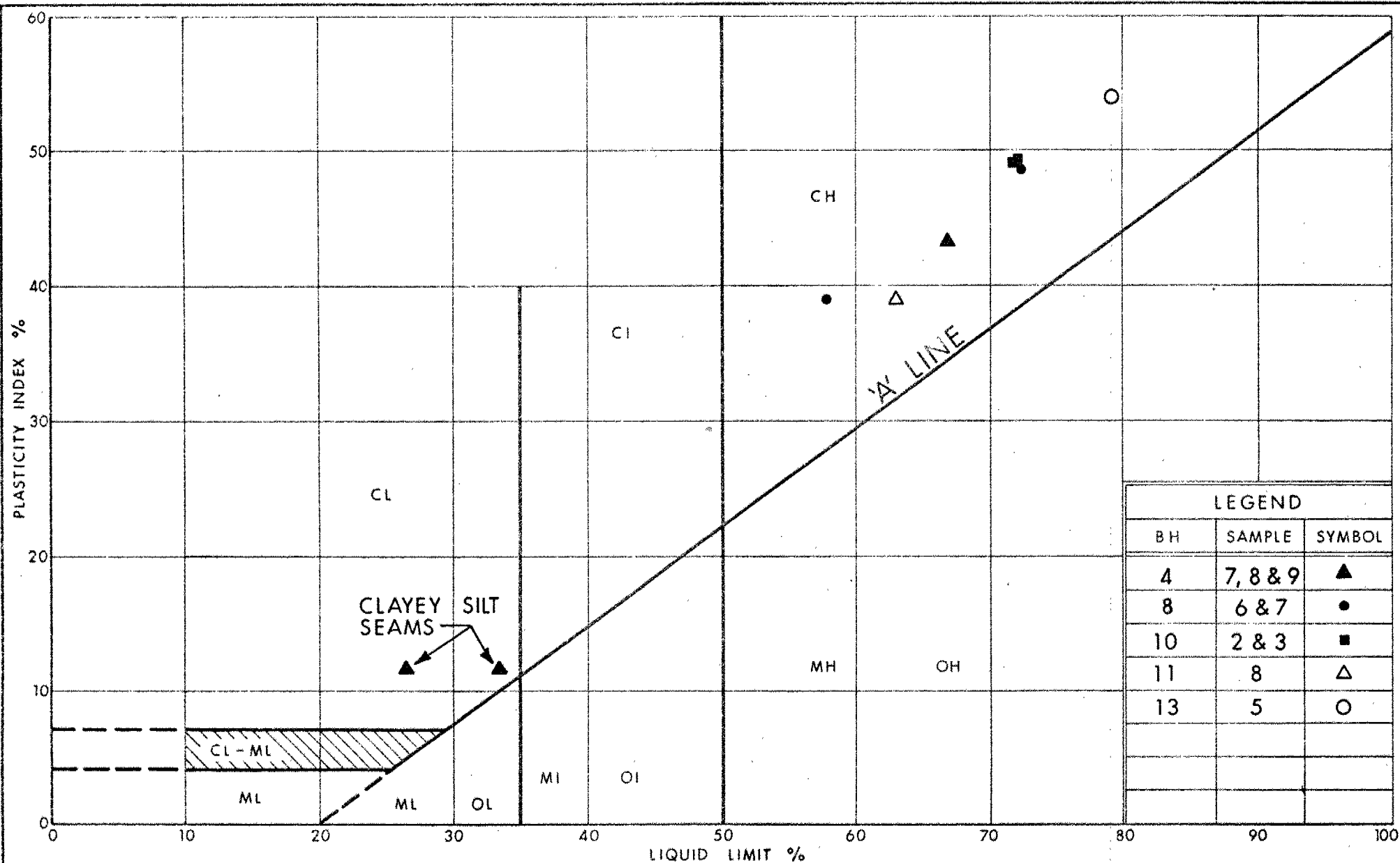


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Communications**

GRAIN SIZE DISTRIBUTION
SANDY GRAVEL TO SAND

FIG No 3

W P 134 - 74 - 01

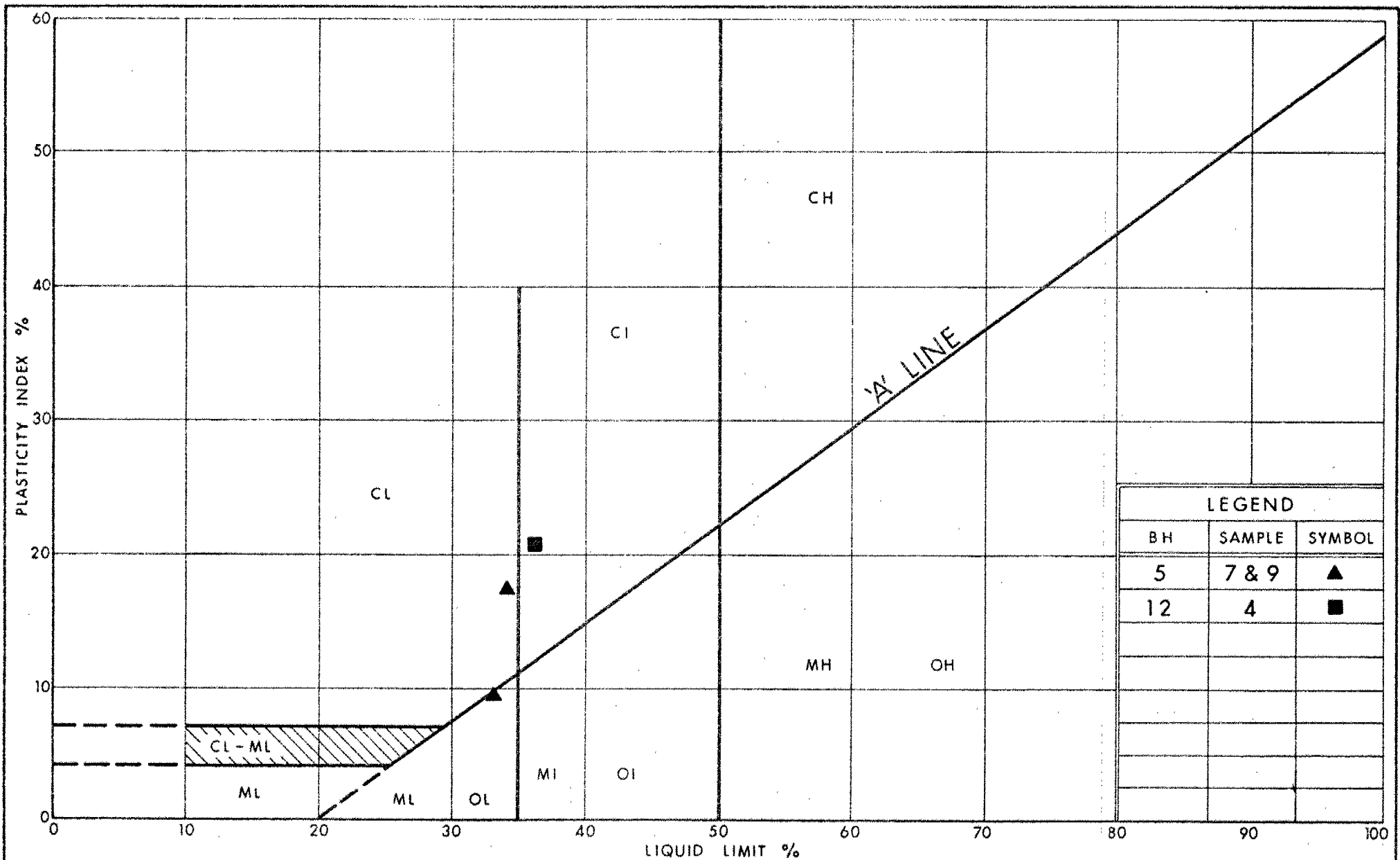


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PLASTICITY CHART CLAY WITH LAYERS OR SEAMS OF CLAYEY SILT

FIG No 4

W P 134-74-01

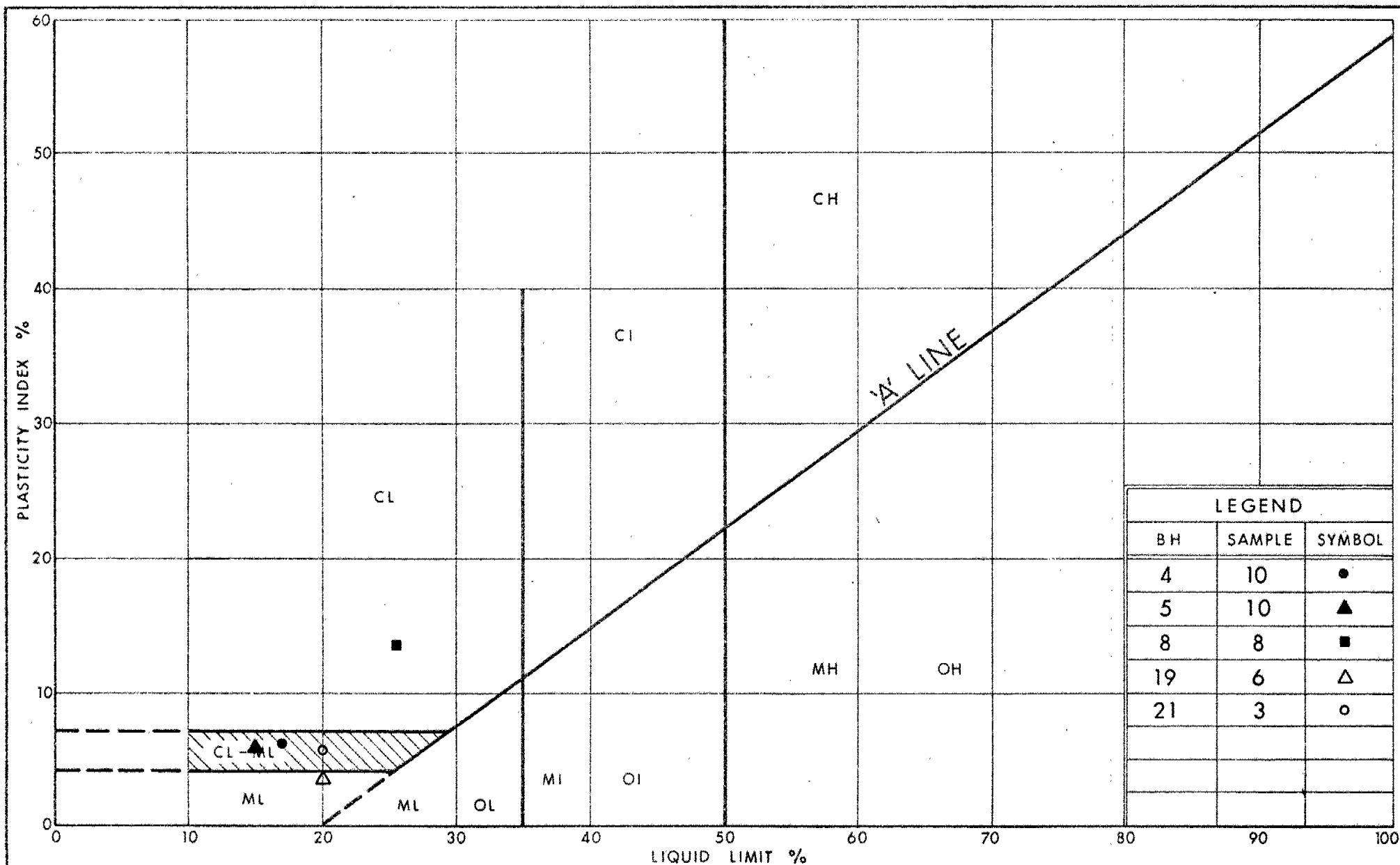


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PLASTICITY CHART CLAYEY SILT

FIG No 5

W P 134-74-01



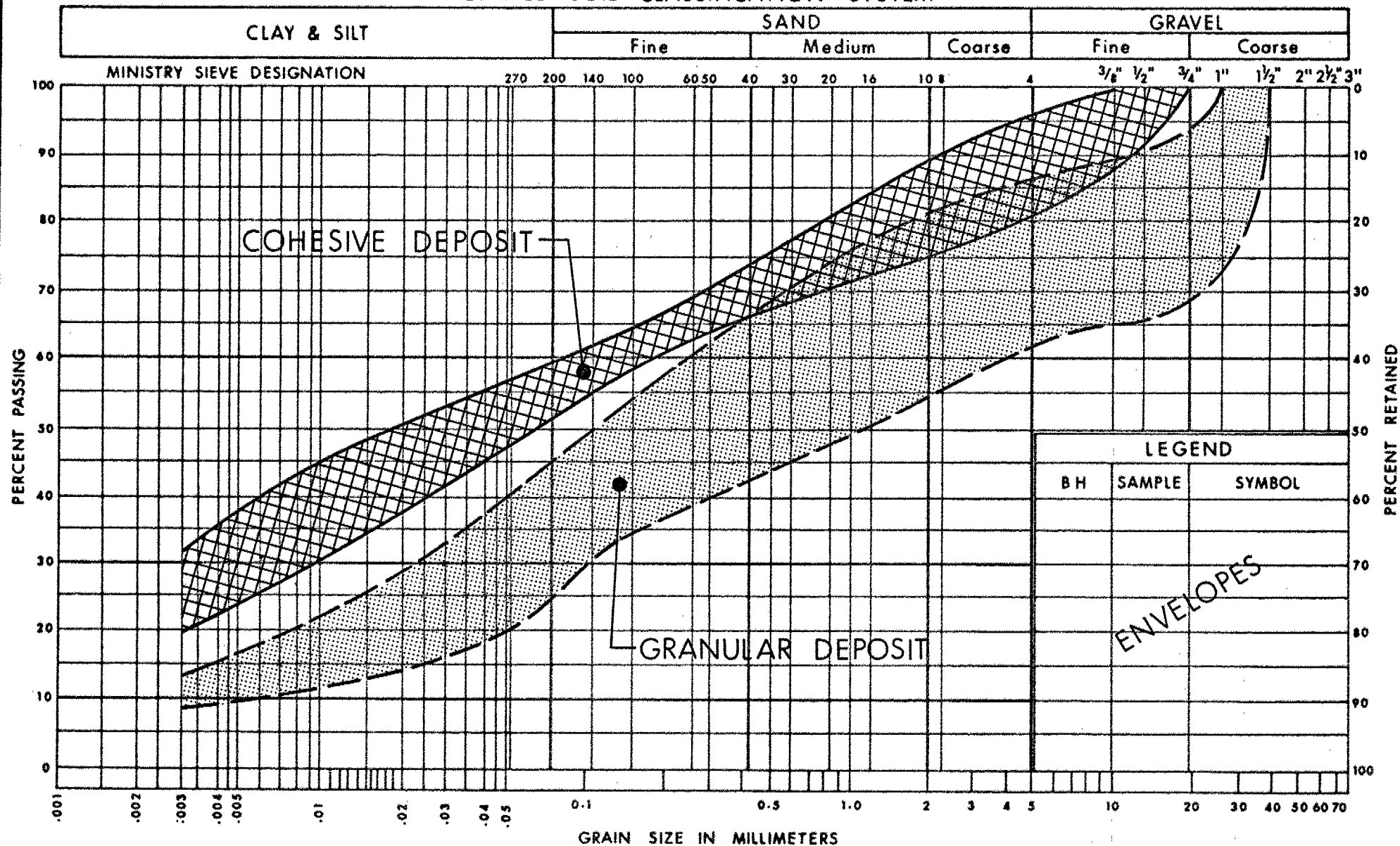
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PLASTICITY CHART GLACIAL TILL (cohesive portion)

FIG No 6

W P 134-74-01

UNIFIED SOIL CLASSIFICATION SYSTEM



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GRAIN SIZE DISTRIBUTION
GLACIAL TILL

FIG No 7

W P 134-74-01

VOID RATIO-PRESSURE CURVES

WP 134-74-01

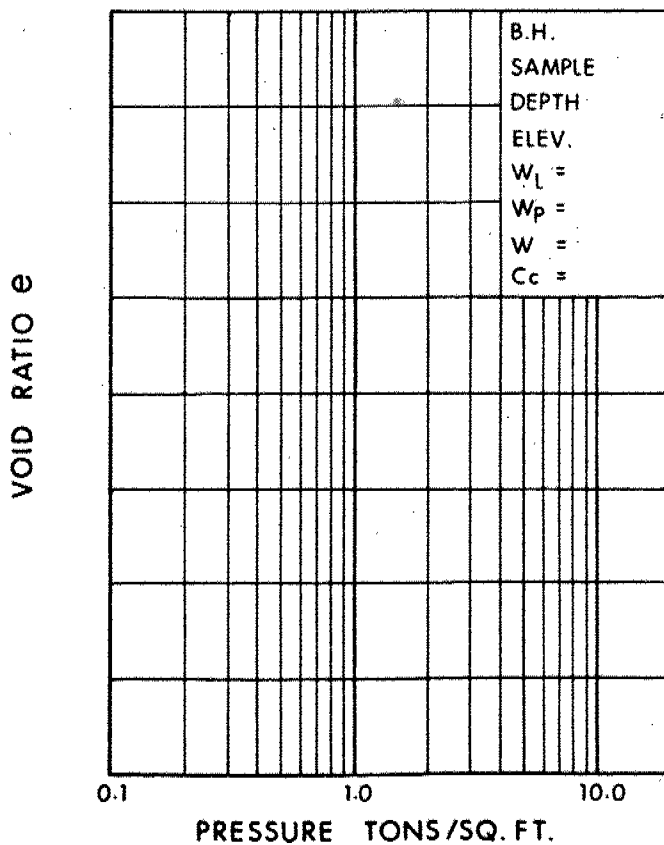
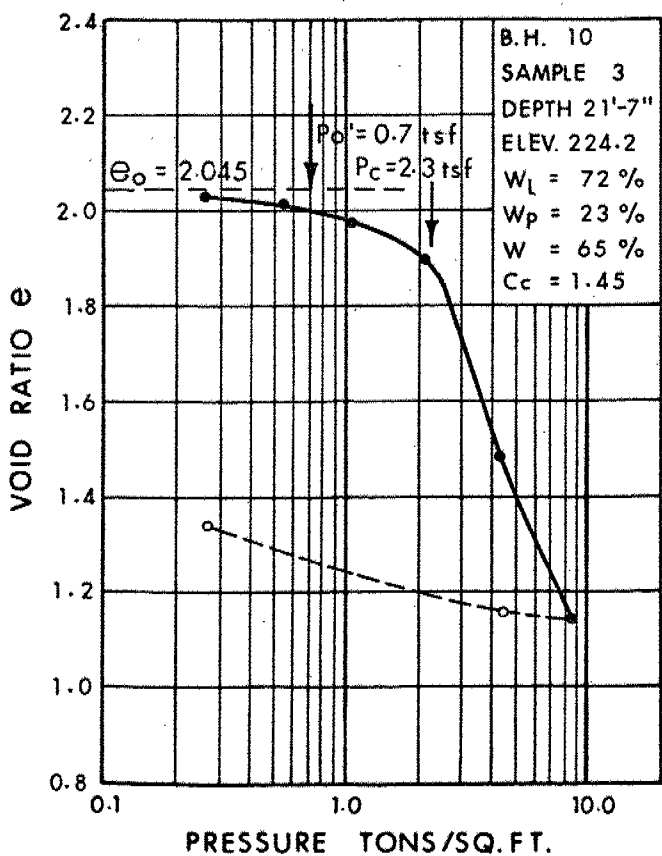
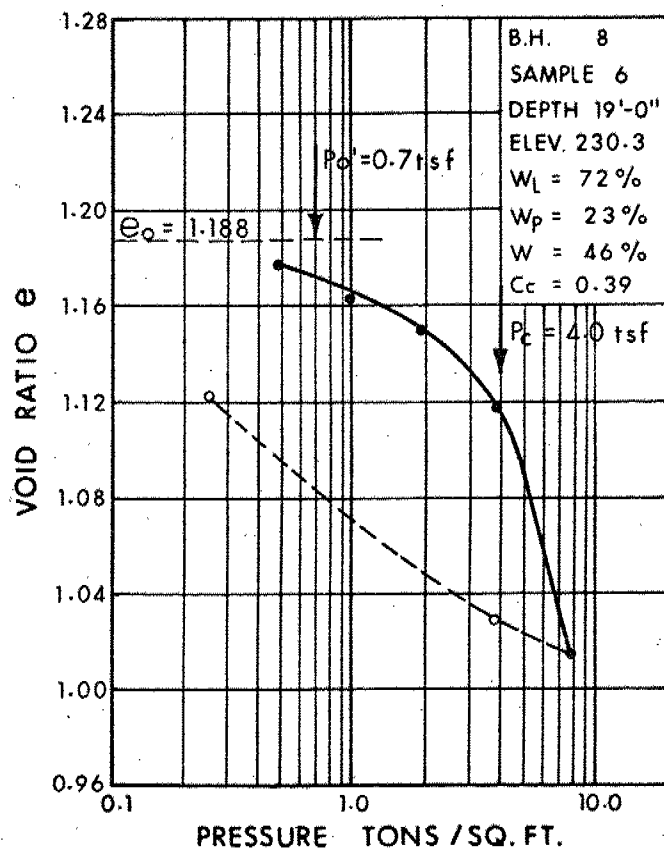
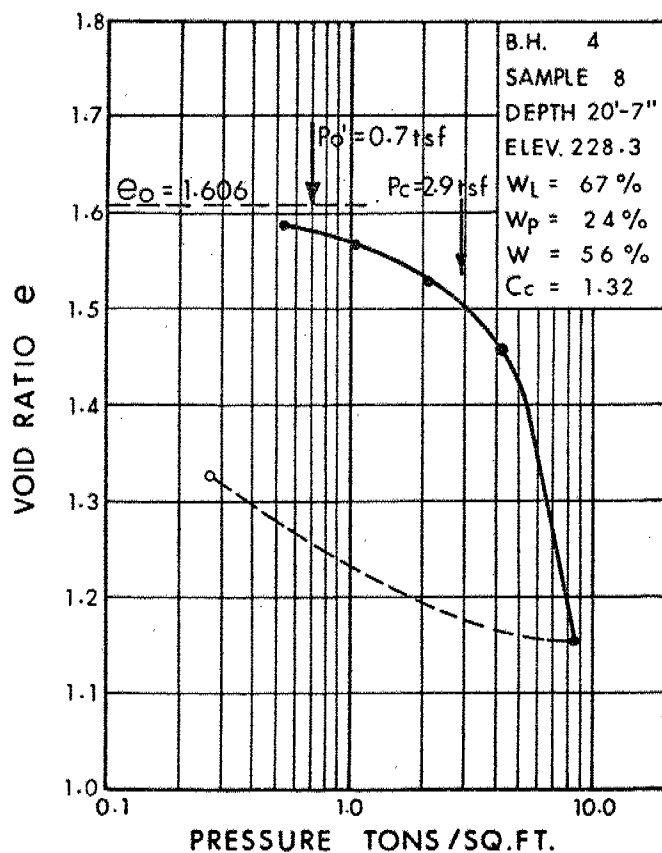
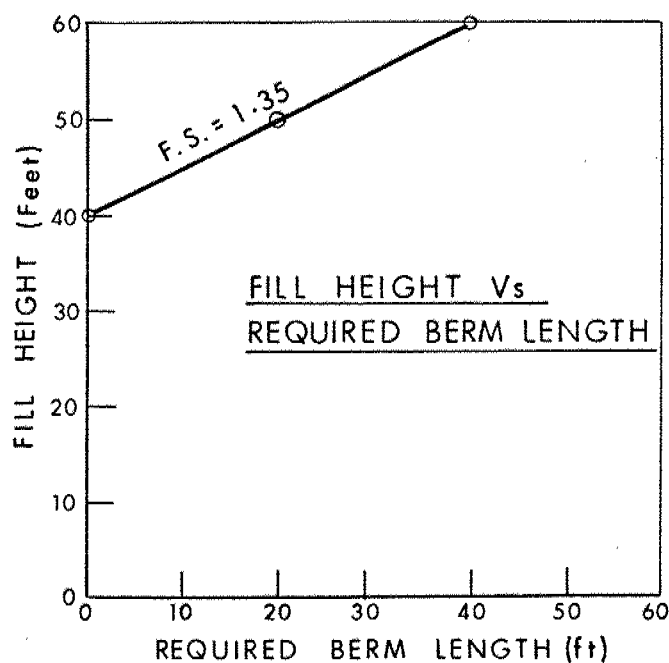
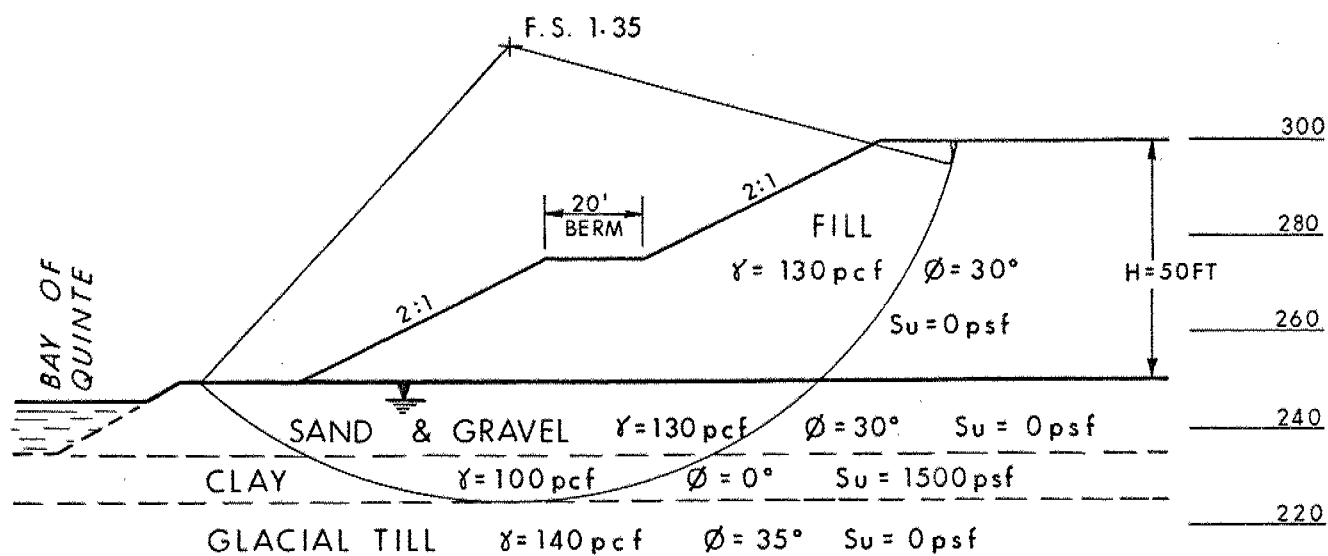
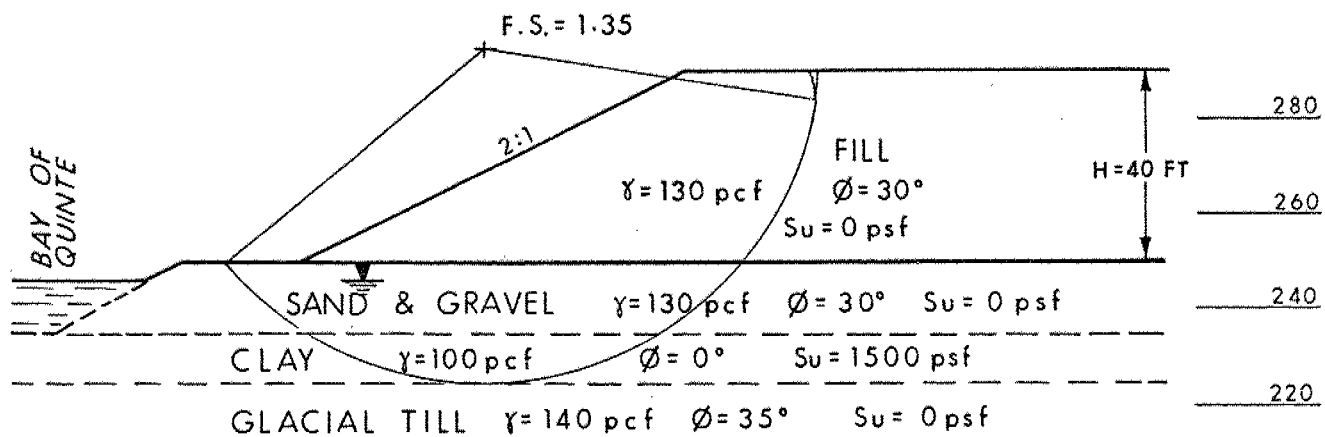
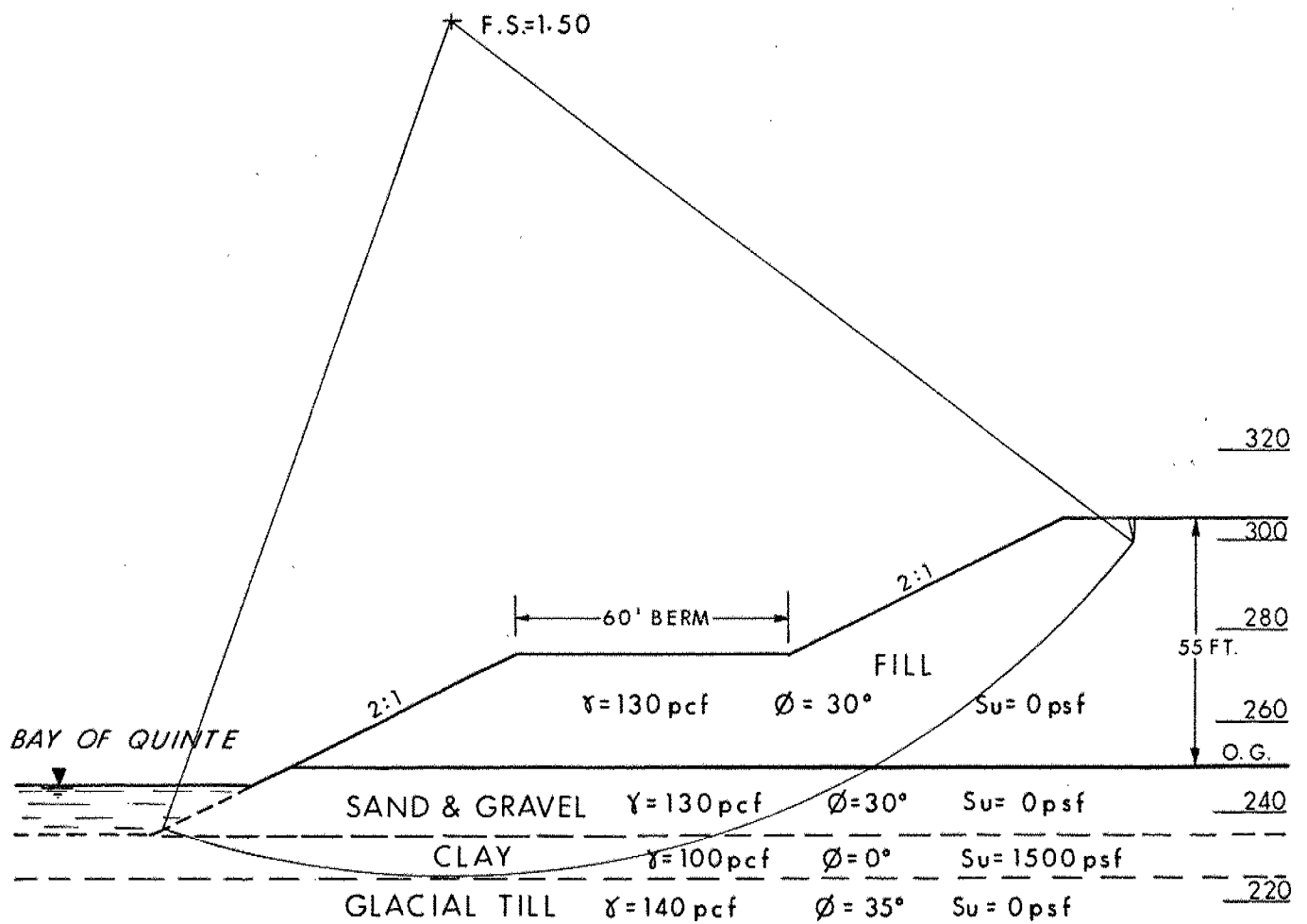
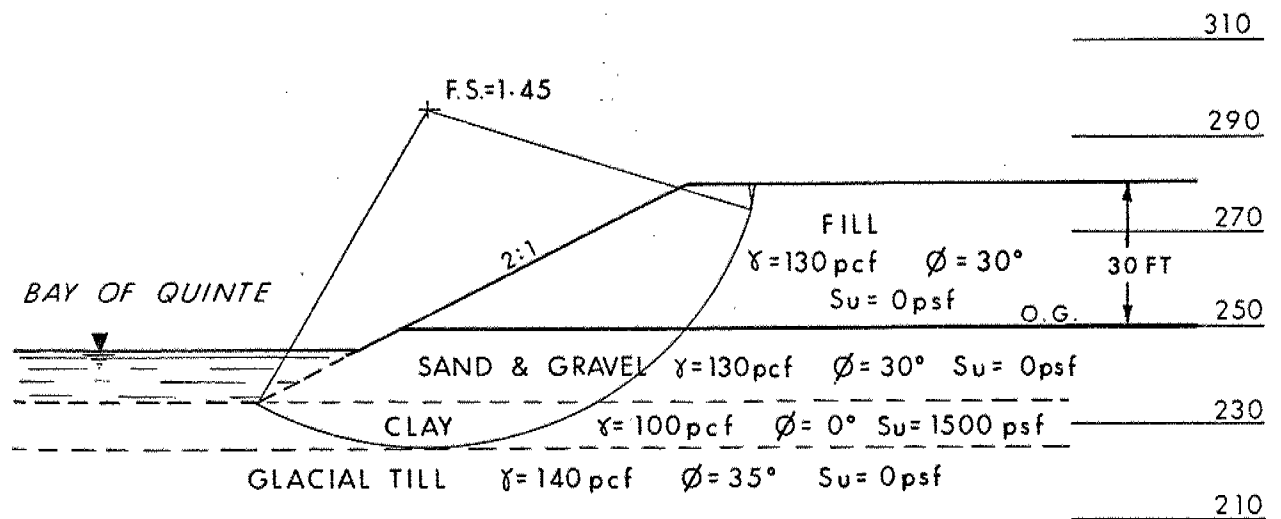


FIG. 8



CASE A: Toe of Fill Slopes Not Closer than 20 ft. from Shoreline



CASE B: Toe of Fill Slopes at Edge of Shoreline



PHOTO 1 (LOOKING SOUTHWEST FROM ZWICK'S PARK)
OVERALL VIEW OF EXISTING HWY. 14
CROSSING OF BAY OF QUINTE



PHOTO 2 (LOOKING NORTH FROM ZWICK'S PARK PUMP HOUSE)
PROPOSED HWY. 14 APPROACH ON ZWICK'S PARK

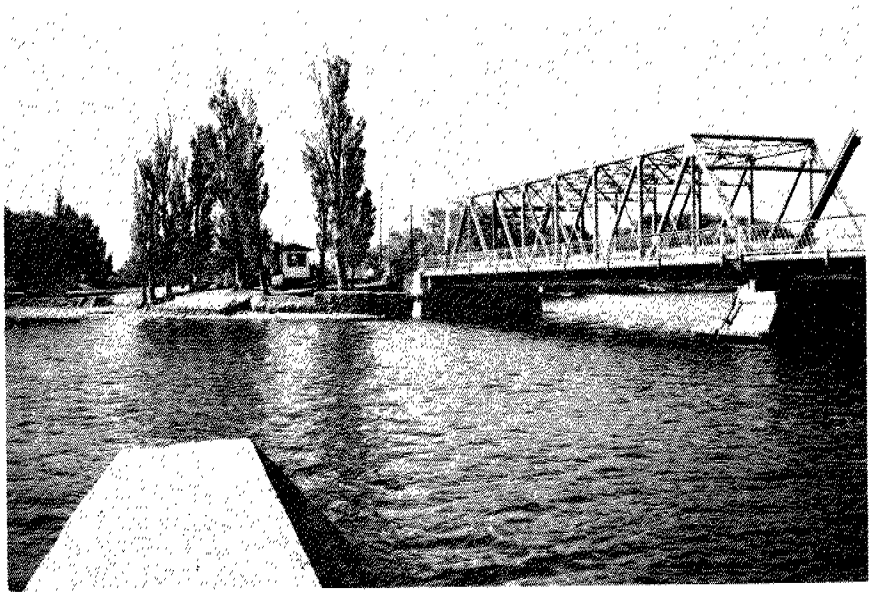


PHOTO 3 (LOOKING SOUTH FROM EAST SWING STOP PIER)
PROPOSED HWY. 14 APPROACH ON ROSSMORE

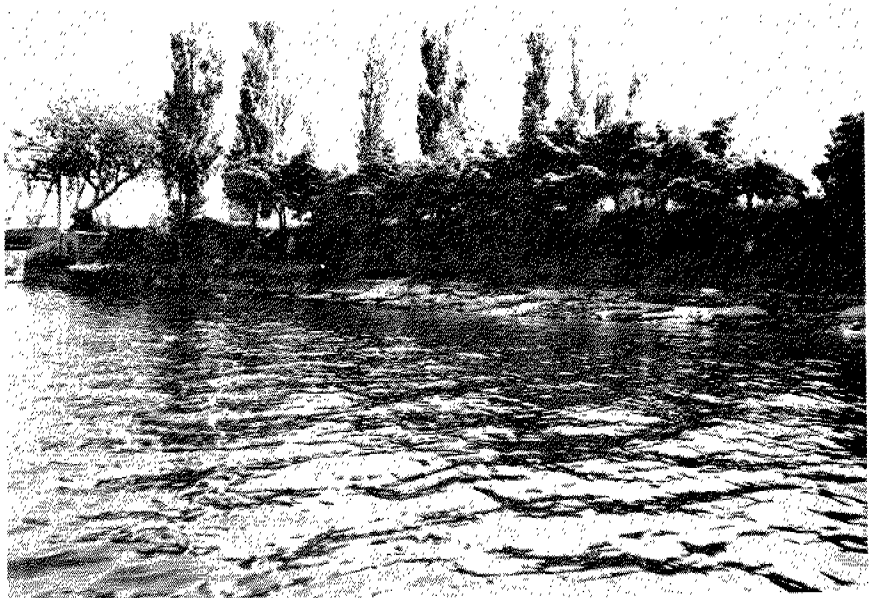


PHOTO 4 (LOOKING EAST AT PRINCE EDWARD COUNTY SHORELINE)
BEDROCK OUTCROPS

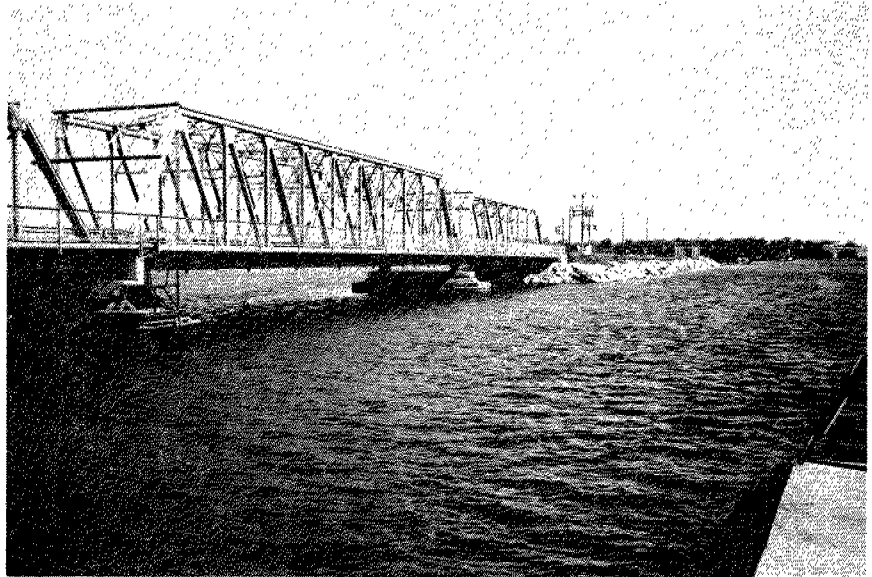


PHOTO 5 (LOOKING NORTHWEST)

NOTE: ROCK ARMOUR SLOPE PROTECTION

EXPLANATION OF TERMS USED IN REPORT

'N' VALUE: AN INDICATOR OF SUBSOIL QUALITY. IT IS OBTAINED FROM THE STANDARD PENETRATION TEST (CSA STD. A119.1). SPT 'N' VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 2 INCH O.D. SPLIT-BARREL SAMPLER TO PENETRATE 12 INCHES INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WEIGHING 140 POUNDS, FALLING FREELY A DISTANCE OF 30 INCHES. FOR PENETRATIONS OF LESS THAN 12 INCHES 'N' VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. 'N' VALUES CORRECTED FOR OVERBURDEN PRESSURE ARE DENOTED THUS N_c .

DYNAMIC CONE PENETRATION TEST (CSA STD. A119.3): CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (2" O.D. 60 CONE ANGLE) DRIVEN BY 350 FT-LB IMPACTS ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 12 INCH ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOIL QUALITY: SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSITY.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH AS FOLLOWS:

S_u (PSF)	0 - 250	250 - 500	500 - 1000	1000 - 2000	2000 - 4000	> 4000
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF SPT 'N' VALUES AS FOLLOWS:

'N' (BLOW/FT)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCK QUALITY: ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH DRILLED IN THAT CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE NATURALLY FRACTURED CORE PIECES, 4" IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	2"	2" - 12"	1' - 3'	3' - 10'	> 10'
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS & SYMBOLS

LABORATORY TESTING

TRIAXIAL TESTS ARE DESCRIBED IN TERMS OF WHETHER THEY ARE CONSOLIDATED (C) OR NOT (U) ISOTROPICALLY (I) OR NOT (A) AND SHEARED DRAINED (D) OR UNDRAINED (U) WITH PORE PRESSURE MEASUREMENTS (BAR OVER SYMBOLS) EG. $\bar{C}U$ = CONSOLIDATED ISOTROPIC UNDRAINED TRIAXIAL WITH PORE PRESSURE MEASUREMENT UNLESS OTHERWISE SPECIFIED IN REPORT ALL TESTS ARE IN COMPRESSION

FIELD SAMPLING

S S SPLIT SPOON
W S WASH SAMPLE
S T SLOTTED TUBE SAMPLE
B S BLOCK SAMPLE
C S CHUNK SAMPLE
T W THINWALL OPEN
T P THINWALL PISTON
O S OSTERBERG SAMPLE
F S FOIL SAMPLE
R C ROCK CORE
P H T.W. ADVANCED HYDRAULICALLY
P M T.W. ADVANCED MANUALLY

EARTH PRESSURE TERMS

μ COEFFICIENT OF FRICTION
 δ ANGLE OF WALL FRICTION
 k_o COEFFICIENT OF EARTH PRESSURE AT REST
 k_A COEFFICIENT OF ACTIVE EARTH PRESSURE
 k_P COEFFICIENT OF PASSIVE EARTH PRESSURE
 i ANGLE OF INCLINATION OF SURCHARGE
 w SLOPE ANGLE-BACKFACE OF WALL
 β ANGLE OF SLOPE
 N_c, N_q, N_γ BEARING CAPACITY FACTORS
 D_f DEPTH OF FOOTING
 B, L FOOTING DIMENSIONS

INDEX PROPERTIES

γ UNIT WEIGHT OF SOIL (BULK DENSITY)
 γ_w UNIT WEIGHT OF WATER
 γ_d UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
 γ' UNIT WEIGHT OF SUBMERGED SOIL
 G_s SPECIFIC GRAVITY OF SOLIDS
 e VOIDS RATIO
 e_o INITIAL VOIDS RATIO
 e_{max} e IN LOOSEST STATE
 e_{min} e IN DENSEST STATE
 D_r RELATIVE DENSITY = $\frac{e_{max} - e}{e_{max} - e_{min}}$
 n POROSITY
 w WATER CONTENT
 w_L LIQUID LIMIT
 w_p PLASTIC LIMIT
 w_s SHRINKAGE LIMIT
 I_p PLASTICITY INDEX = $w_L - w_p$
 I_L LIQUIDITY INDEX = $\frac{w - w_p}{w_L - w_p}$
 I_c CONSISTENCY INDEX = $\frac{w_L - w}{w_L - w_p}$
 A_c ACTIVITY = $\frac{I_p \text{ of soil}}{I_p \text{ of } 2\mu m \text{ Soil Fraction}}$
 Om ORGANIC MATTER CONTENT
 S_r DEGREE OF SATURATION
 S SENSITIVITY = $\frac{S_u \text{ (undisturbed)}}{S_u \text{ (remoulded)}}$

STRENGTH PARAMETERS

ϕ ANGLE OF SHEARING RESISTANCE
 τ_f PEAK SHEAR STRENGTH
 τ_R RESIDUAL SHEAR STRENGTH
 c COHESION INTERCEPT
 $\sigma_1, \sigma_2, \sigma_3$ NORMAL PRINCIPAL STRESSES
 u PORE WATER PRESSURE
 u_e EXCESS u
 r_u PORE PRESSURE RATIO
 q_u UNCONFINED COMPRESSIVE STRENGTH
 s_u UNDRAINED SHEAR STRENGTH
 ϵ LINEAR STRAIN
 γ SHEAR STRAIN
 ν POISSON'S RATIO
 E MODULUS OF ELASTICITY
 G MODULUS OF SHEAR DEFORMATION
 k_s MODULUS OF SUBGRADE REACTION
 m, n STABILITY COEFFICIENTS
 A, B PORE PRESSURE COEFFICIENTS

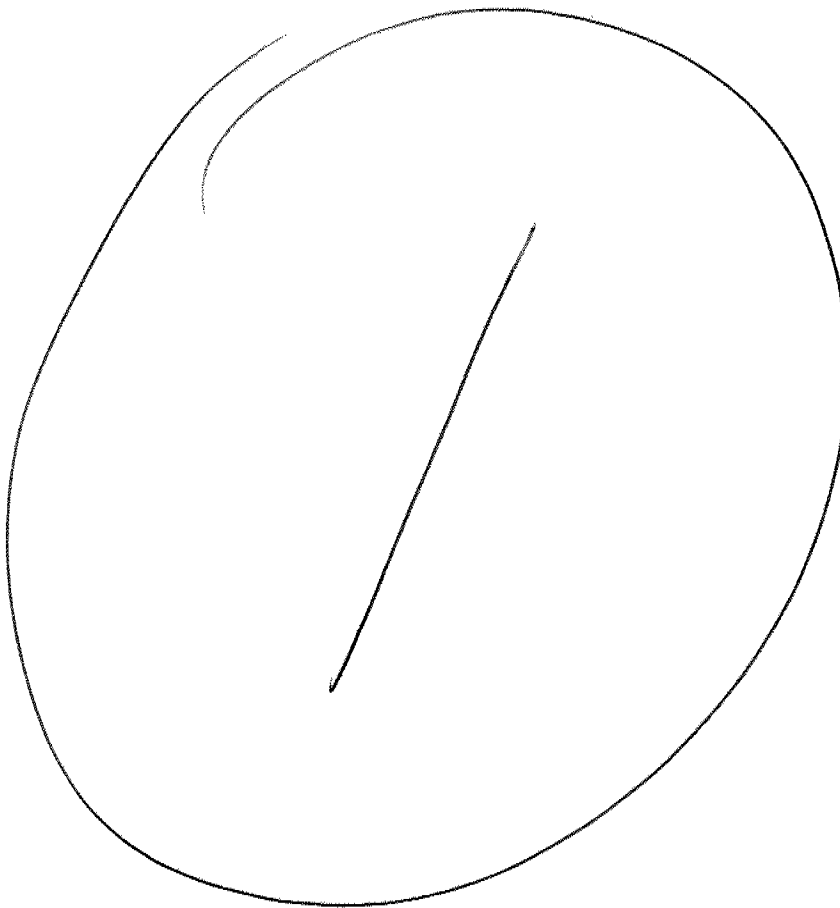
HYDRAULIC TERMS

h HYDRAULIC HEAD OR POTENTIAL
 q RATE OF DISCHARGE
 v VELOCITY OF FLOW
 i HYDRAULIC GRADIENT
 j SEEPAGE FORCE PER UNIT VOLUME
 η COEFFICIENT OF VISCOSITY
 k COEFFICIENT OF HYDRAULIC CONDUCTIVITY
 k_h k IN HORIZONTAL DIRECTION
 k_v k IN VERTICAL DIRECTION
 m_v COEFFICIENT OF VOLUME CHANGE
 c_v COEFFICIENT OF CONSOLIDATION
 C_c COMPRESSION INDEX
 C_r RECOMPRESSION INDEX
 d DRAINAGE PATH DISTANCE
 T_v TIME FACTOR
 U DEGREE OF CONSOLIDATION
 O_c OVERCONSOLIDATION RATIO (OCR)

NOTE: EFFECTIVE STRESS PARAMETERS ARE DENOTED BY USE OF APOSTROPHE ABOVE THE SYMBOL, THUS:
 ϕ' = EFFECTIVE ANGLE OF SHEARING RESISTANCE;
 σ' = EFFECTIVE NORMAL STRESS

35MM

DRAWING



memorandum



To: Mr. L.G. Timson
Sr. Project Manager
Planning and Design Section
Kingston Region

Date: 1980-12-04

From: Pavement & Foundation Design Section
Room 313, Central Building
Downsview

Re: The Norris Whitney Bridge (Bay of Quinte)
W.P. 134-74-01, Contract 80-34, Hwy. 14

Further to your recent memo, we have reviewed the revised geometry incorporating a modified upper berm width ranging from 6 m to 8 m between Sta. 21+170 and Sta. 21+185 for the north approach. This memo confirms our telephone conversation with you indicating that the proposed modification will be satisfactory from the stability point of view.

A handwritten signature in cursive script, appearing to read "M. Devata".

M. Devata
Senior Foundations Engineer

MD:ea

cc: R.W. Franks

memorandum



To: M. Devata
Pavement and Foundation Design Section
Central Building
Downsview

Date: 1980 11 14

FROM: Planning and Design Section
Kingston, Ontario

RE: W.P. 134-74-01, Contract 80-34
Highway 14, The Norris Whitney Bridge

Further to our telephone conversation on Thursday, November 13th, we enclose a sketch showing proposed modifications to the upper berm of the north approach. Considering the fact that there must be a sufficient depth of earth on the approach to support tree and shrub growth, the side slope should be constructed at a 2:1 slope rather than at the 1½:1 slope recommended by the Construction Office.

It would be appreciated if you provide us with comments on this proposal at your earliest convenience.

A handwritten signature in dark ink, appearing to read "L. G. Timson".

L. G. Timson
Sr. Project Manager

LFT/eb

c.c. R. W. Franks

Enclosure

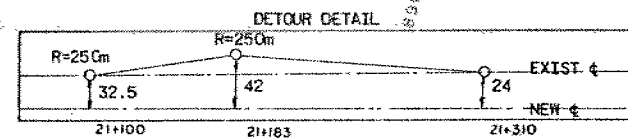




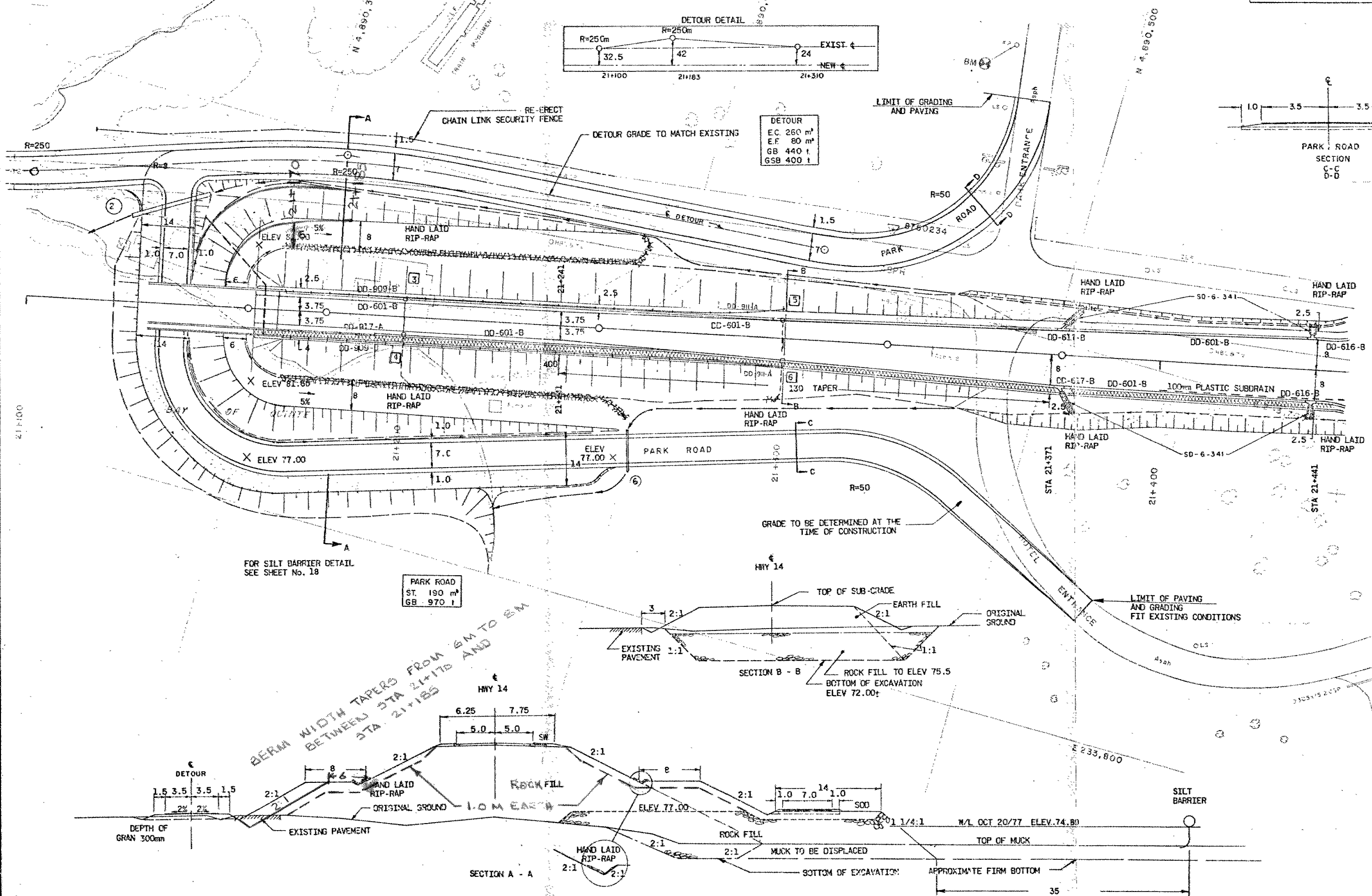
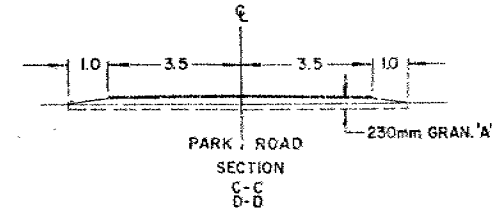
METRIC

"ZWICK ISLAND PARK"

BAY OF QUINTE



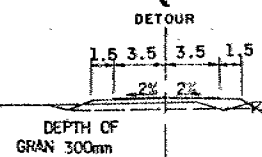
DETOUR
E.C. 260 m³
E.F. 80 m³
G.B. 440 t
G.S.B. 400 t



FOR SILT BARRIER DETAIL
SEE SHEET No. 18

PARK ROAD
ST. 190 m³
GB 970 t

BERM WIDTH TAPERS FROM 6M TO 5M
BETWEEN STA 21+175 AND
STA 21+185



SECTION A - A

SECTION B - B

SCALE

L. Timson

MINUTES OF DESIGN PACKAGE REVIEW MEETING

Held 1980-11-05 at Field Office for Contract 80-34

In Attendance

L. Timson - Project Manager, Planning and Design
J. Drope - Technician, Planning and Design
A. J. Yorke - Project Supervisor, Construction Office
C. H. Quick - Construction Supervisor, Construction Office
(unable to attend)

The following items were discussed and appropriate action will result.

Drainage - North Approach

Due to restricted area on the left side at Stations 21+160 and 21+175 the theoretical cross-section as shown on Sheet #10 requires revision.

These revisions are as follows.

1. Replace Culvert 2 with 600 mm CSP instead of 900 mm.
2. Place 20 m of 600 mm CSP under new entrance to West Zwick's Park.
3. Because of 1 and 2 above the drainage pattern will be split at Station 21+360.
4. Because of 1, 2 and 3 the low invert of culvert can be raised .3 m and the ditch to the north by corresponding depths.
5. Steepening of Berm side slopes Station 21+160 and 21+175 to $1\frac{1}{2}:1$ are still a requirement.

Mr. Timson will be contacting the Foundation and Landscaping Sections for comments re Item #5. On receipt of this information the necessary arrangements with the contractor will be made.

Construction North Approach

The approach fill is being changed to all rock borrow with a one metre cap of earth on the side slopes and berms. This cap depth will not be attainable at subgrade limits and will be somewhat less due to the need for consistent grade under curbs and sidewalks. Therefore, cap on fill slopes will vary for one metre at the bottom to one-third of a metre at subgrade. Mr. Timson felt that this depth would be sufficient to maintain vegetation.

Superelevation Control Data

Requested that this information be forwarded for alignment on Rossmore end.

Construction Operations

Mr. Timson queried what operations the contractor was going to proceed with this fall. This item was broached due to the sign advertising the Four Seasons Hotel not being lighted for sometime. The hotel management is agreeable to live with the sign not being lighted for a short time, but felt that the sign should be lighted for the winter season at whatever access was being used. This follows the conversations that I have had with the hotel maintenance supervisor - Mr. Milton McTaggart.

Silt Barrier Installation

Item was discussed re installation time and method. Mr. Timson stated that barrier should be anchored and set in place before barrier is dropped in water.

Standard DD917A

This standard was shown on Sheet #'s 7 and 10, but was not included in contract standards. Necessity of this could not be ascertained at this line.


Detour Construction

The discussion on this item was limited to the completion of the contract. Mr. Timson felt it would not be out of order to resurface with a 40 mm lift of HL4 prior to acceptance by the City of Belleville.

Special Provision - Clay Seal

The requirements for this item were discussed. The Ministry specification for clay seal would cause an unrealistic cost for the intent of the material required to line the pit. A good impermeable material would be satisfactory for this operation.

As the contract progresses, further meetings on the Design Package may be necessary.


for A. J. YORKE
Project Supervisor

AJY/dj

c.c. R. W. Franks	G. A. Wrong
✓ L. Timson	D. McFarlane
J. Drope	A. G. Kelly
A. J. Yorke	R. M. Dell
C. H. Quick	W. G. Wigle
E. J. Orr	S. C. J. Radbone
P. J. Harvey	J. W. Reid
B. J. Giroux	G.. Luyt

memorandum



To: Mr. K. Bassi
Head, Structural Design Office
Eastern Region

Date: 1980-03-03

Attention: Mr. C. Farrel

From: Pavement & Foundation Design Section
Room 313, Central Building
Downsview

Re: Bay of Quinte Crossing
at Belleville
W.P. 134-74-01, Site 28-28
Hwy. 14, District 8, Kingston

Further to our discussion of 80 02 14 we hereby confirm our verbal recommendations made to you at that time.

The extreme ends of the north abutment wing wall should be provided with additional support comprised of steel 'H' piles driven to the bedrock surface. These piles are intended to prevent rotation of the abutment due to lateral forces on the abutment piles resulting from shear flow of the underlying clay deposits.

If you have any further queries please do not hesitate to contact us.

M. MacLean

MM:MD:ea

M. MacLean
For:
M. Devata
Senior Foundations Engineer

cc: T.C. Kingsland

memorandum



To: Mr. G. Wrong,
Head,
Pavement Design & Foundations Section,
Central Building, Downsview.

Date: 79 08 31

Attention: Mr. M. MacLean.

Subject: Bay of Quinte Crossing at Belleville,
W.P. 134-74-01, Site 28-28,
District #8.


I refer to our recent discussion regarding allowable pile loads on the above structure.

It was agreed that using 3 - HP 310 x 110 piles per caisson, the maximum working load per caisson could be 3500 KN rather than the 2700 KN value shown on page 24 of the foundation report. This value represents a tip pressure of 82.74 MPa (12,000 psi).

This bridge is being designed to the requirements of the Ontario Highway Bridge Design Code using ultimate limit state considerations. According to Cl. 6.8.4.3.2, the factored capacity of a caisson = $F_p R_s$, where $F_p = 0.4$ for steel H sections, R_s can be taken from Cl. 10.8.3 as $\phi A F_y$ (the λ values for these installations relatively small). Using 260 MPa yield steel, we obtain a factored capacity = $0.4 \times 0.9 \times 42.3 \times 260 = 3959$ KN. This represents a value of 1.13 x the working capacity. It is the thinking of this Section that this value is unduly conservative and would result in more piles than if the structure had been designed using working stress methods with an allowable tip pressure of 12,000 psi.

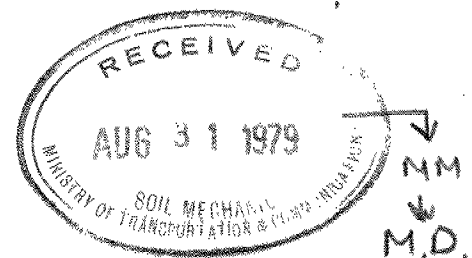
Using an F_p value of 0.45, we would obtain a factored capacity of 4454 KN which represents a value of 1.27 x the working capacity. This value more accurately represents the typical values of the applied load factors, and it was agreed that a factored capacity of 4454 KN should be used for the design of the caissons.

CFF/cf


C. F. Farrell,
Design Engineer,
Eastern Section.

*This in reference
to conversation
with C. Farrell & M.M.
I am in agreement
with the structural
office conclusions
M.M.*

c.c. K. Bassi
W. McFarlane



Mr. T.C. Kingsland
Head, Structural Section
Eastern Region

1979-11-27

From: Pavement & Foundation Design Section
Room 313, Central Building
Downsview

Re: Bay of Quinte Bridge at Belleville
W.P. 134-74-01, Site 28-28
Hwy. 14, District 8, Kingston

In response to your written request of 1979-11-14 concerning the foundations for the barrier wall for the above structure, we have the following comments to make.

We feel that adequate performance can be obtained from the barrier wall without supporting it on timber piles. The base width of the footing and depth below ground surface should be sized in view of the imposed loads according to the following soil parameters:

Maximum Allowable Bearing Capacity 100 kPA
Coefficient of Passive Earth Pressure $k_p = 3.0$

Because of anticipated settlements of the approach fill due to consolidation of the underlying subsoil as well as the settlements within the approach fill, the construction of the barrier wall should be delayed as long as possible after completion of the embankment.

MM:MD:ea

M. MacLean
Project Foundations Engineer
For: M. Devata
Senior Foundations Engineer

cc: C. Bassi - Att: C. Farrel
L. Timson

memorandum



To: Mr. T.C. Kingsland
Head, Structural Section
Eastern Region

Date: 1979-11-27

From: Pavement & Foundation Design Section
Room 313, Central Building
Downsview

Re: Bay of Quinte Bridge at Belleville
W.P. 134-74-01, Site 28-28
Hwy. 14, District 8, Kingston

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M MacLean

MM:MD:ea

M. MacLean
Project Foundations Engineer
For: M. Devata
Senior Foundations Engineer

cc: C. Bassi
Att: C. Farrel
L. Timson



Memorandum

To: Mr. L. G. Timson,
Planning & Design Office,
Eastern Region.

From: Pav't. & Foundation Design Section,
Engineering Materials Office,
Room 315, Central Building,
Downsview, Ontario.

Attention:

Date: 79 11 09

Our File Ref.

In Reply to

Subject:

Re: Bay of Quinte Crossing at Belleville,
Hwy. 14, District 8, Kingston,
W.P. 134-74-01, Site 28-28.

It is understood from recent discussions with you that the City of Belleville requires that the lower berm for the north approach fill be 16 metres wide to accommodate their needs. As discussed in our Foundation Investigation Report, an 8 metre wide upper berm and 12 metre wide lower berm is required for stability purposes. As you requested, we have reassessed the stability of the approaches based on the new requirements for the City of Belleville. Our recommendations are as follows.

Behind the centreline of the north abutment bearings, in the transverse direction, an 8 metre wide upper berm and a 12 metre wide lower berm are required for stability purposes. Further, our analysis indicates that an 8 metre wide upper berm with a lower berm of 16 metres wide would also be stable.

Ahead of the north abutment bearings, in the direction of the forward slope, a 6 metre wide upper berm and a minimum of 14 metre wide lower berm are required for stability purposes. Hence, a 6 metre wide upper berm and a 16 metre wide lower berm as required by the city would be stable also in the longitudinal direction.

A smooth transition should be incorporated between the transverse and longitudinal geometry.

If you have any further questions, please do not hesitate to call this office.

MM/MD/cy

c.c. T. C. Kingsland
K. Bassi
W. Blum
Files ✓

M MacLean
M. MacLean,
Project Foundations Engineer.
For: M. Devata,
Senior Foundations Engineer.