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September 8, 1966

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Department of Highways, Ontario,
Materials and Testing Division,
Highway 401 and Keele Street,
Downsview, Ontario.

Attention: Mr. A. G. Stermac, P. Eng.,
Principal Foundation Engineer.

Re: Settlement Study,
Burlington High Level Bridge,
Burlington, Ontario.

Dear Sirs:

This letter accompanies our factual report on the above study.

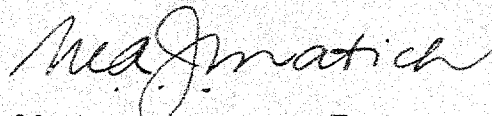
All available settlement data on the Burlington High Level Bridge including the results of the most recent settlement survey carried out in July, 1966, are presented herein in graphical form together with other pertinent information of a soil mechanics nature. A brief history of the structure outlining the factors significant to this study is given. The procedure adopted to arrive at the significant factual information is given together with a "Summary of Factual Information" which includes a list of the references which were drawn on to compile this report.

This report consolidates all available factual information of significance, and as arranged does not include interpretive comments relative to the possible increase in loading on the Bridge foundations, or the like. Depending on your requirements in this regard, we would propose that such interpretation would follow in the form of an addendum to this report, which would cover the specific future plans for the Bridge. For purposes of assessment of the factual information given herein in relation to specific design proposals, some supplementary site investigation work would be of considerable value and we would be pleased to discuss details of this aspect further with you.

We believe that this report presents all the factual information required from this study at this time. Should you have any questions regarding the information given herein or if we can be of further service to you otherwise, please do not hesitate to call us.

Yours very truly,

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A handwritten signature in dark ink, appearing to read "M. A. J. Matich". The signature is fluid and cursive, with the first name "M." and last name "Matich" being the most prominent parts.

M. A. J. Matich, P. Eng.,
President.

MAJM:bm

T7891
REPORT
TO
DEPARTMENT OF HIGHWAYS, ONTARIO
ON
SETTLEMENT STUDY
BURLINGTON HIGH LEVEL BRIDGE
BURLINGTON ONTARIO

Distribution:

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INTRODUCTION

Geocon Ltd has been retained by the Department of Highways, Ontario by letter dated June 14th, 1966, to carry out a Settlement Study on the Burlington High Level Bridge in Burlington, Ontario. The purpose of this present study is to examine and put on record available settlement data and other pertinent information. It is understood that the ultimate purpose of this study, together with the results of any further subsoil investigation, testing and analysis is to make recommendations from a soil mechanics standpoint relative to the ability of the existing Bridge foundations to carry additional load which would be involved should the superstructure of the Burlington High Level Bridge be widened to accomodate a greater flow of traffic. This study has been entirely based on available settlement records and design and construction information as taken from the list of references given in this report.

HISTORY OF STRUCTURE

Geocon Ltd carried out a detailed soil investigation at the site of the Burlington High Level Bridge between August and October of 1954. Prior to construction of the Burlington High Level Bridge most of the area under the line of the Bridge was covered with water up to 6 feet deep. In order to expedite and economize the construction of the Bridge substructure this area was reclaimed by filling to above water level whereby

foundation construction could be carried out in the "dry" utilizing well-points for dewatering excavations which extended below ground water level. Reclamation was carried out between March and July of 1955. The hydraulic fill used for reclamation was pumped from the bottom of Hamilton Bay using a "sand-sucker" dredge and was contained on the west side of the reclaimed area by a rock fill dyke located about 90 feet west of the Bridge centerline. The hydraulic fill was contained on the east side of the reclaimed area by the Hamilton Bar which essentially parallels the Bridge. The crest of the rock fill dyke was built to elevation 250 and the reclaimed area was raised to about elevation 249. Mean water level elevation in this area at the time of reclamation was about 246.

A series of dynamic penetration tests were carried out over the Bridge site by Foundation of Canada Engineering Corporation Limited, referred to herein as FENCO, after reclamation and prior to foundation construction. This work was done between June and August of 1955. From 2 to 4 penetration tests were put down at the location of each Pier and Abutment.

The Burlington High Level Bridge was constructed between August 1955 and October 1958. The substructure of the Bridge consists of 74 Piers and 2 Abutments. Piers N1 to N37 inclusive and the North Abutment are located north of the Burlington Canal and Piers S1 and S37

inclusive and the South Abutment are located south of the Burlington Canal.

The foundations for Piers N1 and S1 flanking the Burlington Canal consist of cellular type concrete caissons founded about 37 feet below ground level, that is at elevation 212. The caissons are founded on steel H piles extending about 50 feet below the bottom of the caissons. The foundations for Piers N2 and S2 also consist of cellular type concrete caissons which are founded at elevation 233. The foundations for piers N10 to N29 inclusive, consist of concrete pile caps founded on timber piles extending about 20 feet below the underside of pile caps. The elevation of the underside of pile caps is 240.75 for Piers N10 to N27 inclusive and 238 for Piers N28 and N29. The foundations for the remaining Piers and both Abutments consist of concrete spread footings. The bottom of spread footing elevation for the Pier and Abutment foundations north of the Burlington Canal varies between elevations 235 and 240 and similarly varies between elevations 238 and 240 for Pier and Abutment foundations south of the Burlington Canal. The Piers generally consist of a footing, pedestal and shafts and beam with the exception of north and south Piers 35, 36, 37 and 38 which do not have pedestals.

Settlements of all Piers and Abutments were observed frequently during construction of the substructure and superstructure as well as after completion of the Bridge at the following times; December, 1958; October, 1959; September, 1960; October, 1961; October, 1962; July, 1966. Settlement readings using a surveyor's level, were taken on at least 2 corners of the pedestal of each Pier with the exception of north and south Piers 35, 36, 37, and 38 where settlement readings were taken on the underside corners of the cantilevered portion of the pier. Settlement readings for the Abutments were taken on the corner pilasters on both sides of each Abutment. However, during construction of some Piers the initial elevation observation was taken on the footing, after construction of the footing only, but subsequent settlement observations of all Piers and Abutments were related to the reference points mentioned earlier.

Initial elevation observations to determine subsequent settlement were obtained at various stages of construction and at different times for individual Piers and Abutments. This information is summarized later in the report, that is for each Pier and both Abutments the stage of construction and the date when the initial elevation observation was obtained are given together with the date of the first settlement reading obtained after full dead load was acting and the time, computed to the nearest month, between the above readings.

All settlement readings up to and including the readings obtained in October, 1961, were determined with reference to construction bench marks. The elevations of the construction bench marks were established by reference to Geodetic Bench Mark No. MMCCCCXXVIII then at elevation 252.74 located on the south abutment of the existing bascule bridge over the Burlington Canal. A description of the construction Bench marks used to obtain the settlement readings up to and including the readings observed in October, 1961 is given later in the "Summary of Factual Information".

Prior to each settlement survey carried out by FENCO, the construction bench marks used were carefully compared against each other before commencing the settlement survey. However, during the October, 1961 settlement survey, it was noted that the Geodetic Bench Mark mentioned above had been releveled by the Geodetic Service at elevation 252.68, that is about 3/4 inches lower than the previous value. It is not known when this settlement took place although, during the three years previous to 1961, the effect of heavy pile driving on the foundations for the new lift bridge nearby must have had a considerable effect on all levels in the vicinity.

Due to the unreliability of construction bench marks because of possible settlement of the area as a whole, a new bench mark was established in 1961. The new bench mark was located on the north abutment of the Q.E.W. overpass over Highway No. 2 approximately 3/4 miles north of the north end of the Burlington High Level Bridge. This abutment is founded on rock and the new bench mark was used for the settlement surveys carried out in October, 1962 and July, 1966. The new bench mark was levelled at elevation 258.017 with reference to the most reliable of the construction bench marks.

A summary of the construction bench mark elevations used from the time of completion of construction of the piers up to October 1961 as well as the elevations of the construction bench marks in October 1962 which were determined with reference to the new bench mark established in 1961 is given in the "Summary of Factual Information". Also given in this section is a summary of the construction bench marks used to determine settlements of individual piers from the time of completion of construction of the piers up to October 1961 after which all settlements were determined with reference to the new bench established in 1961.

PROCEDURE

All available settlement data and other available information from a soil mechanics standpoint relative to the Burlington High

Level Bridge was obtained by Geocon Ltd for purposes mentioned earlier. From the collected data the time settlement relationship for each Pier and Abutment making up the substructure of the Burlington High Level Bridge was determined and examined in a number of graphical forms.

The time settlement curves were determined from settlement records maintained by FENCO during and after construction. The settlement records maintained during construction and up to about December, 1958 were given to us in the form of total settlements determined at various times during this period. The above total settlements were determined by computing the average settlement of four points on top of each pedestal and where no pedestals were involved the average settlement of four points at the underside corners of the cantilevered portion of each Pier was determined. The total settlement of the Abutments was determined by computing the average settlement of two points on each Abutment.

Settlement records after December, 1958 and up to July, 1966 were given to us in the form of elevations for the reference points on pedestals and cantilevers mentioned above. Increments of settlement were determined by computing the difference in average elevation between

settlement surveys. In some instances only 2 or 3 elevations for each Pier were given in which case the average elevations used to determine increments of settlement were computed using corresponding reference points. Total settlements were obtained by cumulative addition of the increments. In some cases the settlement observations indicated that a slight rise in elevation occurred between settlement surveys. This fact is probably due to the extreme accuracy (nearest 0.001 foot) to which the settlement surveys were carried out and due to possible variation in elevations of construction bench marks used for the surveys. The absence of permanent settlement observation points on each foundation may also have contributed to the observed rise in elevation mentioned above since present observation points are founded on rough concrete. Where an average elevation slightly greater than the one previous occurred, the corresponding increment of settlement was assumed to be zero and further increments were computed from the previous average elevation. However, the increment of settlement between the surveys of October, 1962 and July, 1966 was determined by the actual difference in average elevation since a reliable bench mark was used for these surveys. It is pointed out, however, that even in this instance a slight rise in average elevation of some Piers was observed in which case the increment of settlement was assumed to be zero.

Graphs of time versus net load over the construction period were determined for a number of selected Piers and both Abutments where the net footing load in tons per square foot at end of construction is the applied pressure on the base of the footing due to the dead weight of the structure and due to the effective weight of the soil overlying the footing minus the effective overburden pressure acting at the base of the footing, that is the effective overburden pressure due to soil between finished grade and bottom of excavation. In the case of piled foundations the net pressure has been considered to act at the two-thirds depth of the piles. However, the net pressure was determined on the basis of considering the effective overburden pressure between finished grade and bottom of pile cap elevation, since no excavation was carried out below pile cap elevation. In this respect, it was assumed that the net pressure without change in magnitude was transmitted by the piles to the two-thirds depth of the piles.

Graphs of time versus contact pressure over the construction period were determined for selected Piers and both Abutments. The contact pressure for the case of spread footings, at any given stage of construction is equal to the pressure actually imposed by the footing on the underlying soil at the particular time in question. For the case where backfilling is completed the contact pressure equals the net pressure as defined above plus the original overburden pressure at footing level. For the case of piled foundations the contact pressure at any given stage of construction is equal to the pressure actually imposed on the soil on a horizontal

plane intersecting the pile group at a depth equal to two-thirds of the length of the piles. This includes the weight of soil between underside of pile cap and the horizontal plane in question. For the case where backfilling is completed the contact pressure equals the net pressure as defined above plus the original overburden pressure at the horizontal plane in question.

The time-load curves were determined from information relative to net increase in soil pressure obtained from the results of FENCO calculations which were confirmed by independent calculations for typical Piers. In this respect, the net increase in soil pressure due to footing, pedestal, and shafts and beam was given together with the dead load of the superstructure acting at each Pier and Abutment. From this information, together with information from the settlement records maintained during construction relative to the time of settlement observations after construction of footing, pedestal, shafts and beam and superstructure, the time-load curves were constructed. It is pointed out that zero time for the time load curves corresponds to the time of initial elevation observation as shown in section 7 of the "Summary of Factual Information" and therefore the stage of construction corresponding to the load at zero time can be determined by reference to this section. In this respect, the load at zero time for a typical Pier where initial elevation observations commenced after construction of the footing only, is that due to the footing and the following three increments of load are due to the addition of pedestal, shafts and beam and superstructure respectively. Similarly, the load at zero time for a typical Pier where

initial elevation observations commenced after construction of the footing and pedestal, is that due to the footing and pedestal and the following two increments of load are due to the addition of shafts and beam and superstructure respectively. The final increment in load for the Abutments includes the surcharge due to the approach fill adjacent to the abutments. With the exception of Piers N1 and S1 it is noted that for some foundations the net pressure, as already defined, is negative after the footing only is poured in which case the effective overburden pressure exceeds the applied pressure due to the footing at this stage of construction. For Piers N1 and S1 no significant positive net pressure occurs until the increment of pressure due to the superstructure is applied since the foundations for those Piers are founded at a relatively low elevation involving a high effective overburden pressure at founding elevation.

The extent and geometry of the fill used for reclamation was examined. Elevations of ground level after reclamation were determined at the location of dynamic cone penetration tests carried out by FENCO. The above elevations were found to vary between 248.0 and 250.8 over the site and were generally between elevations 249 and 250. However, finished grade elevation over the site was specified as 249 except in the area of north and south Piers 1 and 2 where finished grade elevation was specified as 250. Therefore, for simplification of presentation all

finished grade elevations shown on all drawings are the specified ground levels as indicated above. The specified finished grade elevations were also used for computations where finished grade elevation was involved.

Computations were carried out to determine the relative significance of the net footing load and the surcharge as they affect the stress increase on top of the deep underlying compressible strata of compact sandy to clayey silt and stiff silty clay. The computations were carried out for 13 selected Piers assuming the net footing load to be distributed on the basis of a 2 vertical to 1 horizontal stress distribution under the loaded area and assuming the surcharge load due to the fill to be distributed on the basis of a 2 vertical to 1 horizontal stress distribution considering an equivalent uniformly loaded strip. The results of the above computations are presented later in the "Summary of Factual Information".

A number of dynamic cone penetration tests were carried out at the site during the initial site investigation by Geocon Ltd between August and October, 1954 and are referred to herein as Geocon penetration tests. The Geocon penetration tests were carried out before the inundated area under the Bridge line was reclaimed by filling. The series of dynamic cone penetration tests put down by FENCO were carried out after reclamation as mentioned earlier and are referred to herein as FENCO penetration tests. The dynamic penetration tests carried out before and after

reclamation were compared to determine the effect if any that the placement of the fill had on the relative density of the underlying natural sand strata.

The Geocon penetration tests were put down using a hammer weight of 380 pounds dropping from $13\frac{1}{2}$ to 17 inches and the FENCO penetration tests were put down using a 225 pound hammer dropping $18\frac{1}{2}$ inches. It is known that for two dynamic penetration tests carried out using different hammer weights and lengths of hammer drop the results indicate different values of blows per foot at corresponding depths in soil of homogeneous relative density after all blows per foot have been converted to 4200 inch pounds of energy. Therefore, to properly compare Geocon and FENCO penetration tests consideration must be given to the effect of different hammer weights and lengths of drop between the two series of tests. To this end a comparison was made between adjacent Geocon and FENCO penetration tests which were put down in the area of north and south Piers 1 and 2 where no reclamation by filling was required. It is pointed out that the fill existing adjacent to the Burlington Canal is not representative of the hydraulic fill used for reclamation. The direct distance between adjacent penetration tests which were compared ranged from 17 feet to 28 feet and a substantial difference in relative density over this distance was not expected. The results of five comparisons, reflecting the effect of variable hammer weight and drop on number of blows per foot are shown on Drawing T7891-6 located at the rear of this report. Each comparison is presented

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in the form of a graph of adjacent Geocon and FENCO penetration tests where number of blows per foot, converted to 4200 inch pounds of energy, is plotted against elevation. A numerical comparison was obtained by determining the slope of the average line below about elevation 243 of each penetration test and determining the ratio of Geocon to FENCO slopes for adjacent penetration tests. The average of the above ratios was then determined.

The above adjustment for hammer weight and drop can now be applied to FENCO penetration tests to compare them with adjacent Geocon penetration tests for tests carried out in the area which was reclaimed by filling. Five such FENCO penetration tests are compared to the corresponding adjacent Geocon penetration tests on Drawing T7891-6 where blows per foot converted to 4200 inch pounds energy are plotted against elevation. The slopes of the average lines for the FENCO penetration tests were adjusted for hammer weight and drop for comparison with the average slopes of Geocon penetration tests. The slopes of the average lines below about elevation 243 of the above penetration tests are compared in the "Summary of Factual Information".

A. Drawings

The following is a summary of the factual information presented on the Drawings at the rear of this report as determined from available data.

1. Drawing T7891-1

The inferred soil stratigraphy as determined from the initial site investigation carried out by Geocon Ltd between August and October, 1954 is shown on this Drawing. This Drawing also shows a plan and section of the Burlington High Level Bridge together with total settlement of all Piers and Abutments, up to end of construction and July, 1966.

2. Drawings T7891-2 and 4

These drawings show data for sixteen representative Piers and both Abutments selected for detailed examination. The detailed examination included Piers N1, N4, N7, N13, N19, N29, N30, N34, N37 and the North Abutment located on the north side of the Burlington Canal and Piers S1, S4, S7, S13, S19, S20, S30 and the South Abutment located on the south side of the Burlington Canal. For each of the above mentioned Piers and Abutments the detailed examination includes the following information:

- a) A sketch of the plan and cross-section, taken perpendicular to the bridge centreline, showing the geometry of the footing, pedestal (where involved) and bottom portion of shafts. The

A. Drawings (continued)

2. Drawings T7891-2 and 4 (continued)

plan shows footing and pedestal dimensions and the cross-section shows the top of pedestal and footing elevations and bottom of footing elevation. The cross-section also shows the number and type of piles where they occur.

b) A graph of time versus settlement for all settlement observations to date where both time and settlement are plotted to an arithmetic scale.

c) A graph of time versus settlement for settlement observations over the period of construction where both time and settlement are plotted to an arithmetic scale. Together with the above graph is shown a corresponding graph of time versus load over the construction period giving both net and contact pressure in tons per square foot.

d) A graph of time versus settlement for all settlement observations to date where time is plotted to a logarithmic scale and settlement is plotted to an arithmetic scale.

e) A graph to time versus settlement for settlement observations over the period of construction where time is plotted to a logarithmic scale and settlement is plotted to an arithmetic scale. Together with the above graph is shown a corresponding graph of time

A. Drawings (continued)

2. Drawings T7891-2 and 4 (continued)

versus load over the construction period giving both net and contact pressure in tons per square foot.

f) A graph of two dynamic penetration tests carried out by FENCO between June and August of 1955 where blows per foot is plotted against elevation. Also shown on this graph is the corresponding inferred soil stratigraphy.

3. Drawings T7891-3 and 5

These drawings show for all Piers and Abutments graphs of time versus settlement for all settlement observations to date where both time and settlement are plotted to an arithmetic scale. Also shown below each time-settlement curve are the graphs of two corresponding dynamic penetration tests carried out by FENCO between June and August of 1955 where blows per foot is plotted against elevation. No penetration tests were carried out by FENCO at Piers S17 and S31. Also shown on these graphs are the corresponding inferred soil stratigraphies.

4. Drawing T7891-6

This Drawing shows a total of 18 representative cross-sections through reclaimed areas. The cross sections were drawn at the location of the Piers and Abutments selected for detailed examination.

A. Drawings (continued)

4. Drawing T7891-6 (continued)

This Drawing also shows a comparison of dynamic cone penetration test results in areas where no reclamation was carried out as well as a comparison of dynamic cone penetration test results in reclaimed areas before and after reclamation.

B. Data for Foundations During Construction

Pier No.	Stage of Construction at Initial Elevation Observation	Date of Initial Elevation Observation	Date of First Settlement Observation after Full Dead Load Acting	Time Between Observations (months)
N1	Pedestal poured	Mar. 4, 1957	July 31, 1958	16
N2	" "	Aug. 13, 1956	Aug. 1, 1958	24
N3	" "	Mar. 19, 1956	June 19, 1958	27
N4	" "	Mar. 27, 1956	June 9, 1958	27
N5	" "	Mar. 27, 1956	June 9, 1958	27
N6	Footing poured	Nov. 16, 1955	June 9, 1958	31
N7	" "	Nov. 24, 1955	June 9, 1958	31
N8	" "	Oct. 31, 1955	June 9, 1958	32
N9	" "	Oct. 19, 1955	June 11, 1958	32
N10	" "	Oct. 26, 1955	June 11, 1958	32
N11	" "	Nov. 1, 1955	June 11, 1958	31
N12	" "	Nov. 29, 1955	June 11, 1958	31
N13	" "	Dec. 6, 1955	June 9, 1958	30
N14	" "	Dec. 8, 1955	June 11, 1958	30
N15	" "	Dec. 12, 1955	June 11, 1958	30
N16	" "	Dec. 21, 1955	June 11, 1958	30
N17	Pier Complete	Jan. 16, 1956	June 11, 1958	30
N18	Pedestal poured	Jan. 16, 1956	June 11, 1958	29
N19	" "	Jan. 16, 1956	June 11, 1958	29

B. Data for Foundations During Construction (continued)

Pier No.	Stage of Construction at Initial Elevation Observation	Date of Initial Elevation Observation	Date of First Settlement Observation after Full Dead Load Acting	Time Between Observations (months)
N20	Pier Complete	Feb. 22, 1956	June 11, 1958	28
N21	Pedestal poured	Feb. 22, 1956	June 11, 1958	28
N22	Footing poured	Feb. 1, 1956	June 11, 1958	28
N23	Pedestal poured	Feb. 22, 1956	June 13, 1958	28
N24	Footing poured	Feb. 8, 1956	June 13, 1958	28
N25	" "	Feb. 9, 1956	June 13, 1958	28
N26	" "	Feb. 1, 1956	June 13, 1958	28
N27	" "	Dec. 21, 1955	June 7, 1957	18
N28	" "	Dec. 27, 1955	June 7, 1957	18
N29	" "	Jan. 11, 1956	June 7, 1957	17
N30	" "	Dec. 12, 1955	June 7, 1957	18
N31	" "	Jan. 4, 1956	Aug. 9, 1957	19
N32	" "	Jan. 24, 1956	June 7, 1957	17
N33	" "	Jan. 24, 1956	Aug. 9, 1957	19
N34	" "	Dec. 31, 1955	Aug. 9, 1957	20
N35	" "	Jan. 9, 1956	Aug. 9, 1957	19
N36	" "	Jan. 16, 1956	Aug. 9, 1957	19
N37	" "	Jan. 16, 1956	Aug. 9, 1957	19
N. Abut.	" "	Feb. 15, 1956	Aug. 9, 1957	18

B. Data for Foundations During Construction (continued)

Pier No.	Stage of Construction at Initial Elevation Observation	Date of Initial Elevation Observation	Date of First Settlement Observation after Full Dead Load Acting	Time Between Observations (months)
S1	Tremie Seal Poured	Jan. 8, 1956	Aug. 1, 1958	31
S2	Pedestal poured	Aug. 29, 1956	Aug. 1, 1958	24
S3	" "	April 30, 1956	July 24, 1958	27
S4	" "	April 30, 1956	June 19, 1958	26
S5	" "	April 30, 1956	June 19, 1958	26
S6	" "	April 30, 1956	June 20, 1958	26
S7	" "	June 22, 1956	June 23, 1958	24
S8	" "	June 22, 1956	June 23, 1958	24
S9	" "	June 22, 1956	July 8, 1958	25
S10	" "	June 22, 1956	July 8, 1958	25
S11	" "	June 22, 1956	July 8, 1958	25
S12	" "	July 12, 1956	July 8, 1958	24
S13	" "	July 12, 1956	July 8, 1958	24
S14	" "	Mar. 27, 1956	July 8, 1958	28
S15	" "	Mar. 27, 1956	July 9, 1958	28
S16	" "	Mar. 27, 1956	July 10, 1958	28
S17	" "	Mar. 27, 1956	July 10, 1958	28
S18	" "	Mar. 27, 1956	July 10, 1958	28
S19	" "	Mar. 27, 1956	July 10, 1958	28

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B. Data for Foundations During Construction (continued)

Pier No.	Stage of Construction at Initial Elevation Observation	Date of Initial Elevation Observation	Date of First Settlement Observation after Full Dead Load Acting	Time Between Observations (months)
S20	Footing poured	Dec. 5, 1955	July 11, 1958	31
S21	" "	Nov. 30, 1955	July 11, 1958	32
S22	Pedestal poured	May 8, 1956	July 11, 1958	26
S23	" "	Dec. 13, 1955	July 15, 1958	31
S24	Footing poured	Nov. 21, 1955	July 15, 1958	32
S25	" "	Nov. 18, 1955	July 15, 1958	32
S26	Pedestal poured	Mar. 27, 1956	July 15, 1958	28
S27	Footing poured	Nov. 15, 1955	July 17, 1958	32
S28	" "	Nov. 7, 1955	July 17, 1958	32
S29	" "	Nov. 2, 1955	July 17, 1958	32
S30	" "	Feb. 21, 1956	July 22, 1958	29
S31	Pedestal poured	Feb. 21, 1956	July 22, 1958	29
S32	Footing poured	Jan. 16, 1956	July 22, 1958	30
S33	" "	Jan. 16, 1956	July 22, 1958	30
S34	" "	Jan. 27, 1956	July 23, 1958	30
S35	" "	Feb. 7, 1956	July 23, 1958	29
S36	" "	Jan. 27, 1956	July 23, 1958	30
S37	" "	Feb. 7, 1956	July 18, 1958	29
S. Abut	" "	Feb. 7, 1956	July 18, 1958	29

C. Description of Construction Bench Marks

BM No. N2	<u>EL 252.042</u> - Steel pin set with lead on top of concrete base of hydro tower north of Burlington Canal, northwest base, northwest corner.
BM No. N3	<u>EL 252.332</u> - Steel pin set with concrete on steel "H" pile east of bridge between piers N2 and N3.
BM No. N9A	<u>EL 250.573</u> - Steel pin set with lead on top of concrete base of hydro tower west of pier N16, southeast base, southeast corner.
BM No. S2B	<u>EL 251.970</u> - Steel pin set with lead on top of concrete base of hydro tower east of Pier S1, northwest base, northwest corner.
BM No. S4	<u>EL 251.192</u> - Steel pin set with lead on top of concrete base of hydro tower east of Pier S5, southwest base, southwest corner.
BM No. S8	<u>EL 250.549</u> - Steel pin set with lead on top of concrete base of hydro tower east of pier S10, southwest base, southwest corner.
BM No. S12	<u>EL 250.742</u> - Steel pin set with lead on top of concrete retaining wall, west of property Beach Blvd No 1000, east of Pier S21, 10' - 0" from north end of retaining wall.

D. Construction Bench Mark Elevations

Bench Mark	1956-57 Pier Completed	1958 Full D.L.	Dec. 1958 Traffic	Oct. 1959 Traffic	Sept. 1960 Traffic	Oct. 1961 Traffic	Oct. 1962 Traffic
N2	252.056	252.056	252.056	252.056	252.056	252.056	252.042
N3	252.355	252.355	252.355	252.355	252.351	252.351	252.332
N9A	250.595	250.593	250.595	250.597	259.574	250.583	250.573
S2B	251.986	251.986	251.986	251.986	251.973	251.965	251.970
S4	251.183	251.186	251.186	251.186	251.183	251.183	251.192
S8	250.535	250.535	250.535	250.535	250.538	250.538	250.549
S12	250.748	250.744	250.744	250.743	250.736	250.730	250.742

E. Construction Bench Marks used to Determine Settlements of Individual Piers

Piers	1956-57 Pier Completed	1958 Full D.L.	Dec. 1958 Traffic	Oct. 1959 Traffic	Sept. 1960 Traffic	Oct. 1961 Traffic
N1-N13	N2	N2	N2	N2	N2	N2
N14-N26	N3	N3	N3	N3	N3	N3
N27-N Abt.	N9A	N9A	N9A	N9A	N9A	N3
S1-S4	S2B	S2B	S2B	S2B	S2B	S4
S5-S12	S4	S4	S4	S4	S4	S4
S13-S26	S8	S8	S8	S8	S8	S8
S26-S Abt.	S12	S12	S12	S12	S12	S8

F. Increase in Pressure on Top of Silt and Clay Strata Due to Net Footing Load and Hydraulic Fill Surcharge

Pier	Increase in Pressure on Top Silt Stratum (TSF)			Increase in Pressure on Top Clay Stratum (TSF)		
	Due to Net Footing Load	Due to Fill Surcharge	Total	Due to Net Footing Load	Due to Fill Surcharge	Total
N1	0.16	0.00	0.16	0.11	0.00	0.11
N4	0.10	0.00	0.10	0.06	0.00	0.06
N7	0.12	0.13	0.25	0.07	0.10	0.17
N13	0.08	0.09	0.17	0.05	0.08	0.13
N19	0.06	0.14	0.20	0.04	0.13	0.17
N29	0.02	0.14	0.16	0.01	0.14	0.15
N30	0.03	0.15	0.18	0.03	0.14	0.17
N34	0.03	0.14	0.17	0.02	0.13	0.15
S1	0.18	0.00	0.18	----	----	No clay
S4	0.09	0.13	0.22	0.08	0.12	0.20
S7	0.15	0.20	0.35	0.14	0.20	0.34
S19	----	----	No silt	0.05	0.19	0.24
S20	----	----	No silt	0.03	0.19	0.22

G. Comparison of Dynamic Cone Penetration Test Results

Adjacent Geocon and FENCO dynamic cone penetration tests put down where no reclamation was carried out were compared as discussed earlier. The results of this comparison indicate that the Geocon penetration tests gave values of blows per foot which were about one-half of the corresponding value of blows per foot as determined by the FENCO penetration tests with all values of blows per foot converted to 4200 inch pounds energy. That is, the average ratio of Geocon to FENCO corresponding slopes of average lines was 0.5 and ranged from 0.48 to 0.52 for the comparisons made. This difference is attributed to the difference in hammer weight and drop used in the Geocon and FENCO series of penetration tests since soil conditions at adjacent penetration tests were essentially the same. The FENCO penetration tests may now be adjusted to correct for difference in hammer weight and drop to correspond to the Geocon penetration tests and any future reference to adjusted FENCO penetration tests refers to FENCO penetration tests where values of blows per foot have been reduced by one-half.

Comparison of adjacent Geocon and adjusted FENCO penetration tests carried out in the area reclaimed by filling indicates that the values of blows per foot for the Geocon penetration tests are

G. Comparison of Dynamic Cone Penetration Test Results (continued)

generally less than the values of blows per foot for the FENCO penetration tests. This is especially obvious where the Geocon penetration tests show very low values of blows per foot in the natural surficial stratum of loose sand. It is therefore apparent that corresponding values of blows per foot in the natural sand strata are higher after reclamation than before.

H. References

1. Drawings

The following FENCO Drawings on the Burlington High Level Bridge dated April 13, 1955, except where noted, were used for reference

1126-A-1	Earthwork
1126-E-1	General Arrangement
1126-4J-1	Piers N1 and S1 General Arrangement
1126-4J-3	Piers N2 and S2 General Arrangement
1126-4J-5	Piers N3 and S3
1126-4J-6	Piers N4 and S4
1126-4J-7	Piers N5 and S5
1126-4J-8	Piers N6 and S6
1126-4J-9	Piers N7 and S7 General Arrangement

H. References (continued)

1. Drawings (continued)

1126-4J-11	Piers N8 and S8
1126-4J-12	Piers N9 and S9
1126-4J-13	Piers N10 and S10
1126-4J-14	Piers N11 and S11
1126-4J-15	Piers N12 and S12
1126-4J-16	Piers N13 and S13 General Arrangement
1126-4J-18	Foundations for Rocker Bents
1126-4J-19	Piers N16 and S16
1126-4J-20	Piers N19 and S19
1126-4J-21	Piers N22 and S22 General Arrangement
1126-4J-23	Piers N26 and S26
1126-4J-24	Piers N30 and S30
1126-4J-25	Piers N34 and S34
1126-4J-26	Piers N35, N36, N37
1126-4J-27	Abutments
1126-4J-39	Rolled Beam Spans Foundations for Rocker Bents, dated November 11, 1955
J1126-8	Table for Pier Settlement dated March 1, 1957
1126-X-1A to 4A	Record of Pier Elevations, dated July 19, 1966

H. References (continued)

2. Reports

- (a) Geocon Ltd Report OS6014, Site Investigation, Burlington High Level Bridge, dated November 18, 1954.
- (b) FENCO Report, Burlington Bay Skyway, 1959 Annual Inspection, dated November 16, 1959.
- (c) FENCO Report, Burlington Bay Skyway, 1960 Annual Inspection, dated October 19, 1960.
- (d) FENCO Report, Burlington Bay Skyway, 1961 Annual Inspection, dated November 23, 1961.
- (e) FENCO Report, Burlington Bay Skyway, 1962 Annual Inspection, dated December 6, 1962.

3. Articles

- (a) "The Burlington Skyway, Ontario's Largest Highway Bridge", Roads and Engineering Construction, January, 1956.
- (b) "The Burlington Skyway, Progress Report on Pier Construction Methods", Roads and Engineering Construction, August, 1956.

4. Records

- (a) FENCO, Settlement Records, Burlington High Level Bridge.

H. References (continued)

4. Records (continued)

(b) FENCO, Penetration Test Records, Burlington High Level Bridge.

(c) Record of telephone conversation between Mr. H. L. MacPhie of Geocon Ltd and Mr. Uesson of FENCO on August 11, 1966.

PERSONNEL

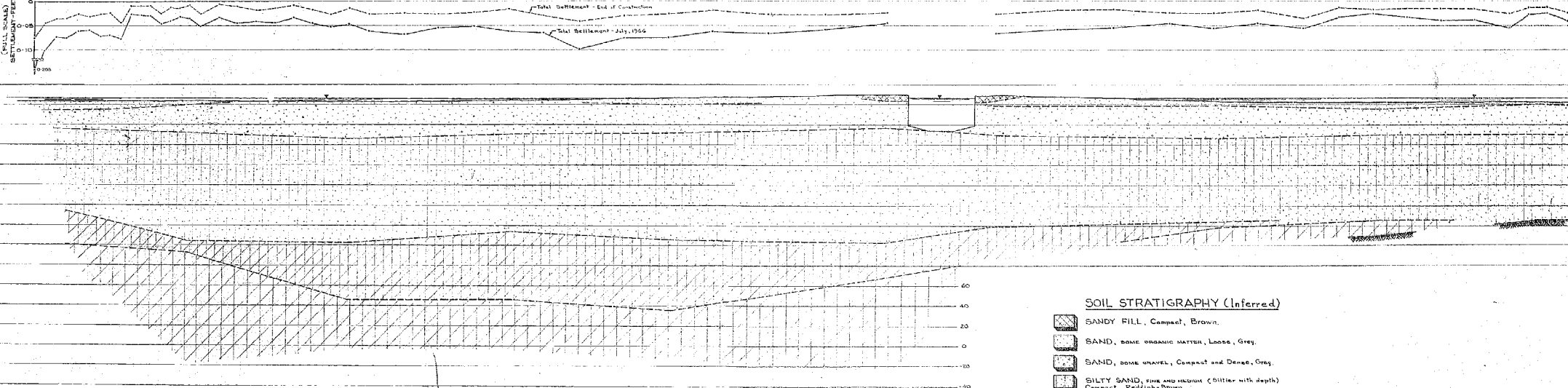
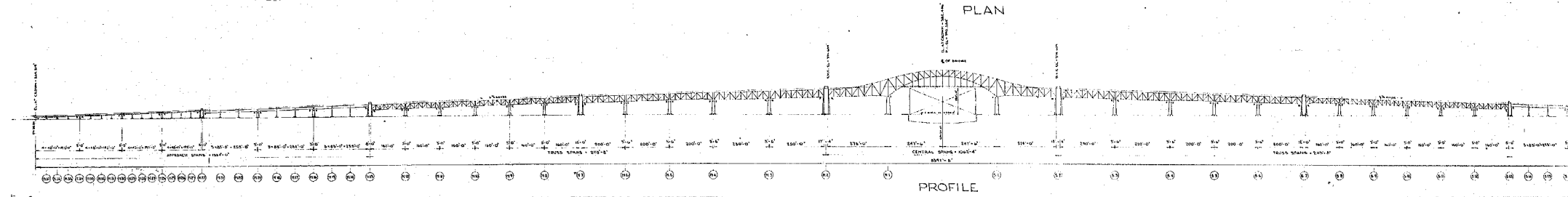
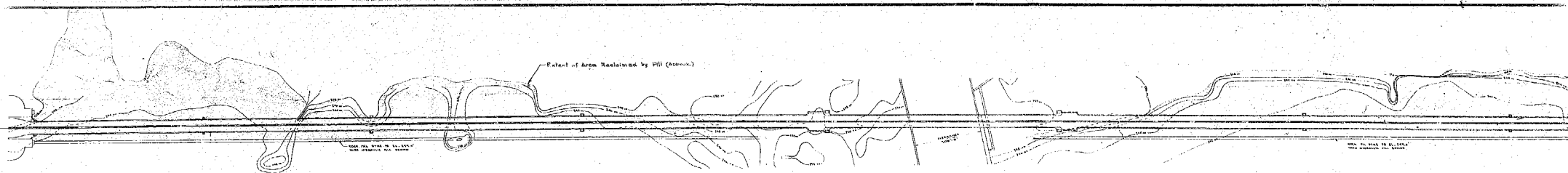
This report was written by Mr. H. L. MacPhie and reviewed by Mr. M. A. J. Matich, P. Eng.

H. L. MacPhie

H. L. MacPhie, P. Eng.,
Senior Soils Engineer.

M. A. J. Matich

M. A. J. Matich, P. Eng.,
President.



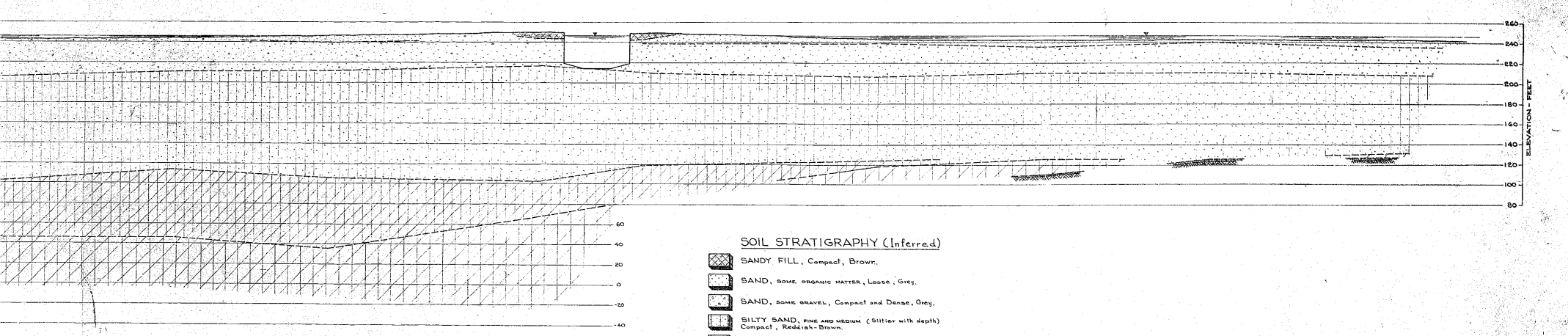
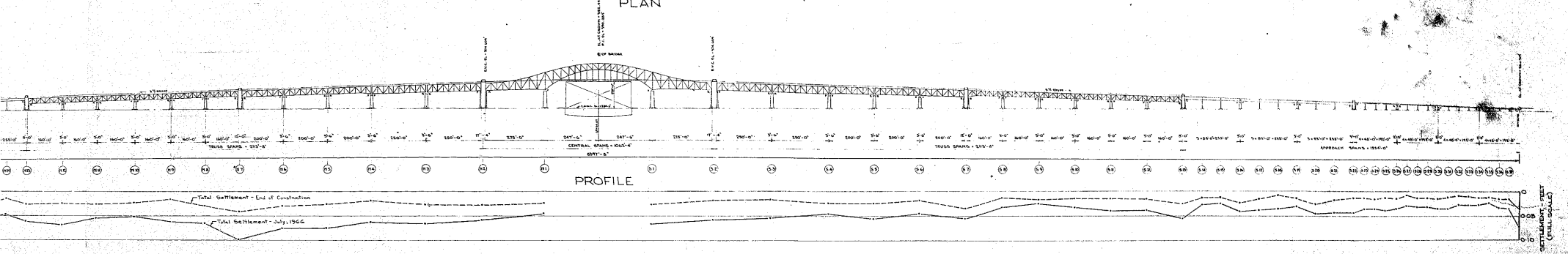
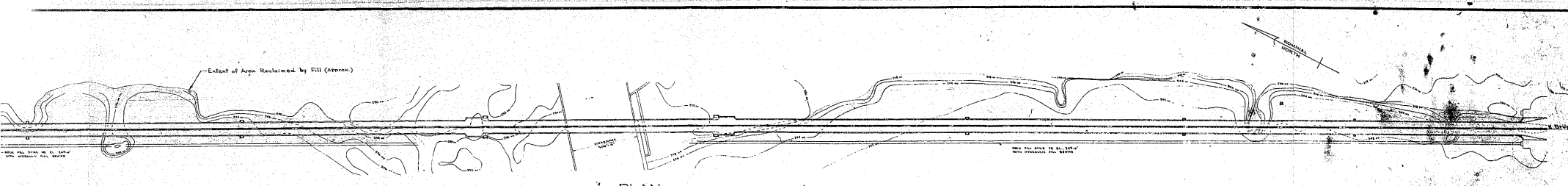
SECTION ALONG THE BRIDGE

SCALE
 0 100 200 300 400 500 FT.
 HORIZONTAL
 0 10 20 30 40 50 FT.
 VERTICAL

SOIL STRATIGRAPHY (Inferred)

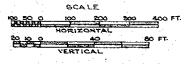
- SANDY FILL, Compact, Brown.
- SAND, some organic matter, Loose, Grey.
- SAND, some gravel, Compact and Dense, Grey.
- SILTY SAND, fine and medium (Siltier with depth) Compact, Reddish-Brown.
- SILTY TO CLAYEY SILT, Compact, Reddish-Brown.
- SILTY CLAY, Stiff, Grey.
- SHALE, Weathered.
- SHALE BEDROCK, Red.

REFERENCE		DEPART MENT S BURLINGTON
DATE	See Report for Reference	



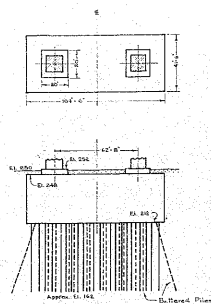
- SOIL STRATIGRAPHY (Inferred)**
- SANDY FILL, Compact, Brown.
 - SAND, SOME ORGANIC MATTER, Loose, Grey.
 - SAND, SOME GRAVEL, Compact and Dense, Grey.
 - SILTY SAND, FINE AND MEDIUM (Siltier with depth) Compact, Reddish-Brown.
 - SANDY TO CLAYEY SILT, Compact, Reddish-Brown.
 - SILTY CLAY, Stiff, Grey.
 - SHALE, Weathered.
 - SHALE BEDROCK, Red.

SECTION ALONG & BRIDGE



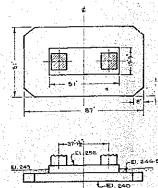
REFERENCE		DEPARTMENT OF HIGHWAYS, ONTARIO DOWNVIEW SETTLEMENT STUDY BURLINGTON HIGH LEVEL BRIDGE GENERAL ARRANGEMENT	GEOCON LTD DATE AUG 29, 1966 SCALE AS SHOWN MADE CHRG APPD REL. HEN. MAJIN No. T7891-1
BRIDGE	See Report for References		

PIER N.1

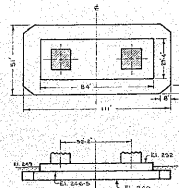


NOTE: 173 Steel H Piles
Set at 10' on center
around perimeter of footing

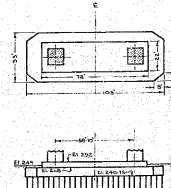
PIER N.4



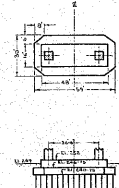
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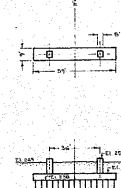
PIER N.13



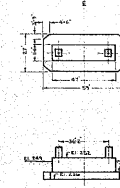
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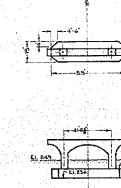
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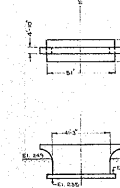
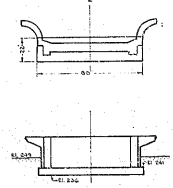
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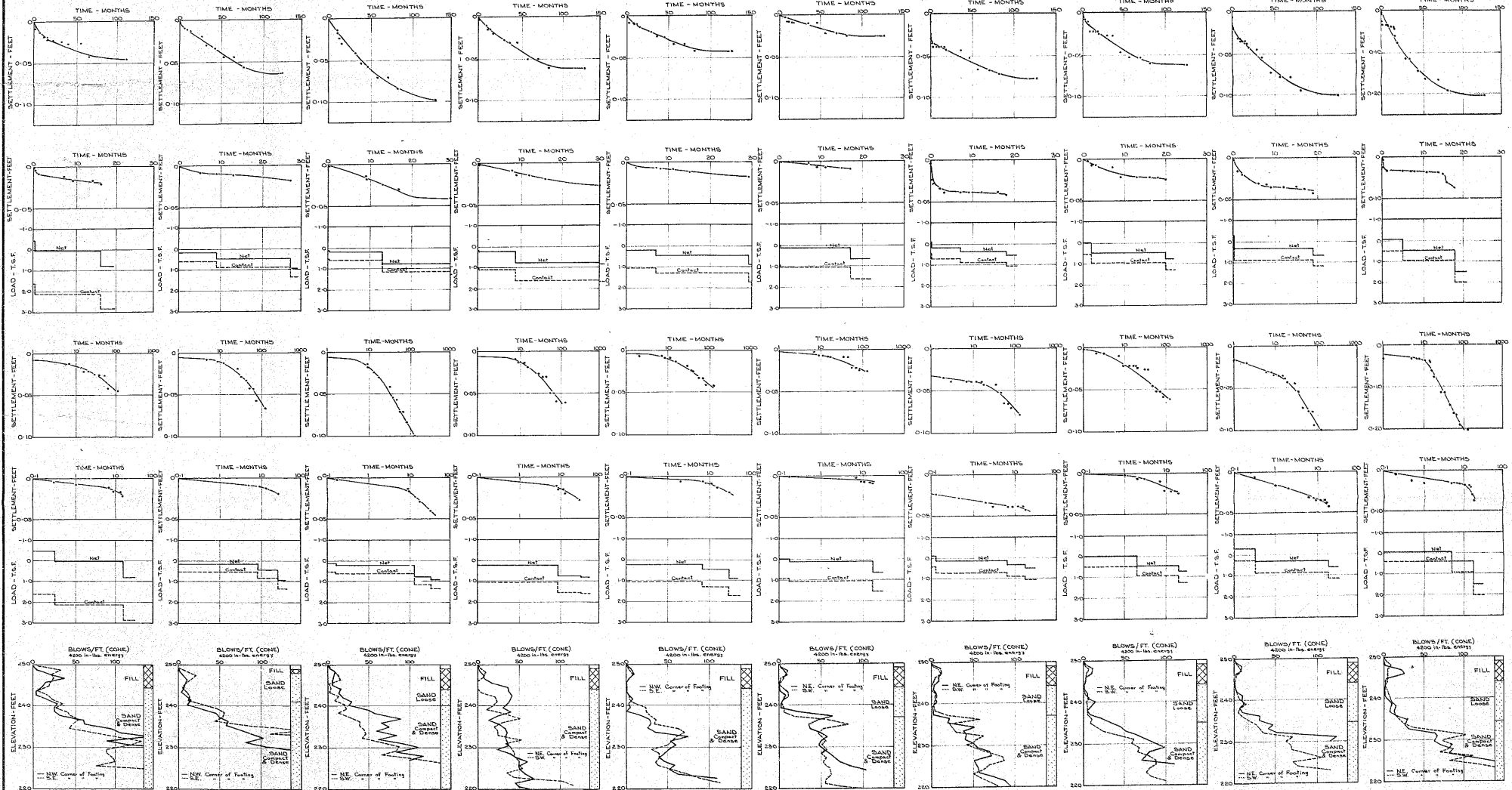
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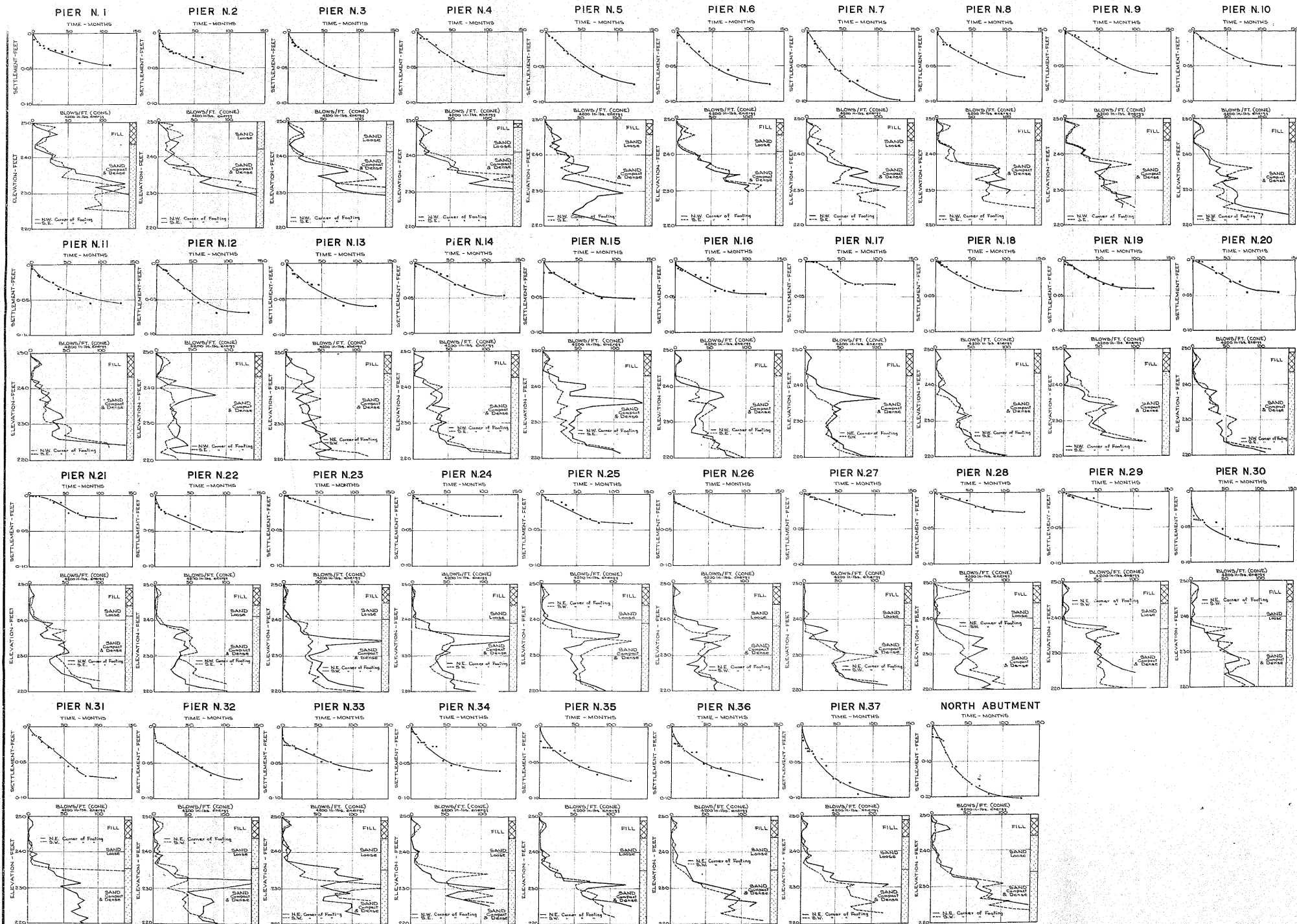


PIER N.37

NORTH
ABUTMENT

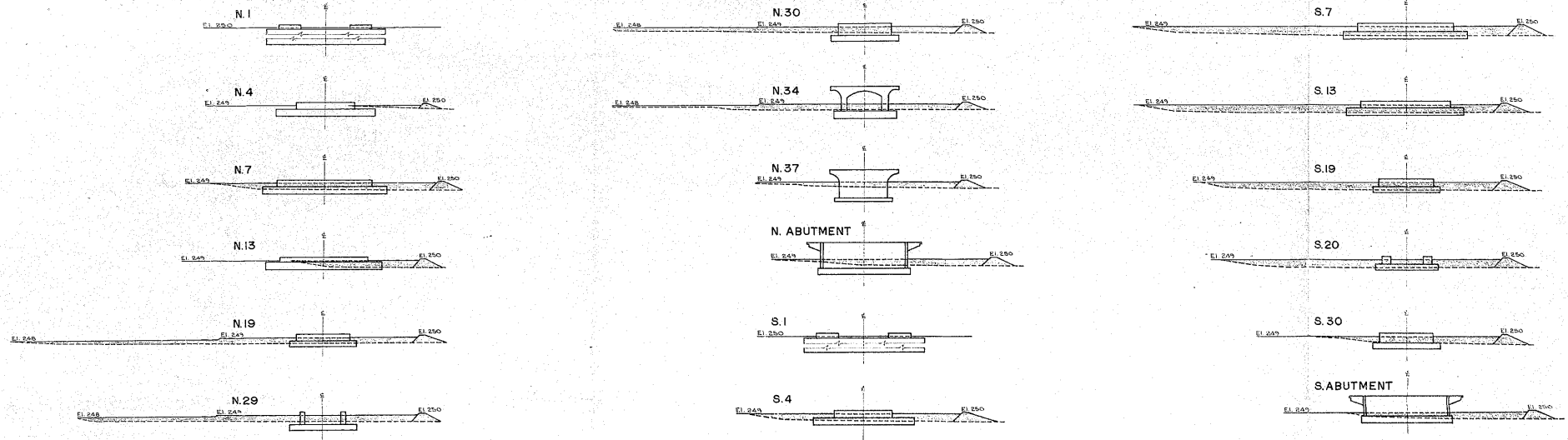
Note change in
Settlement Scale



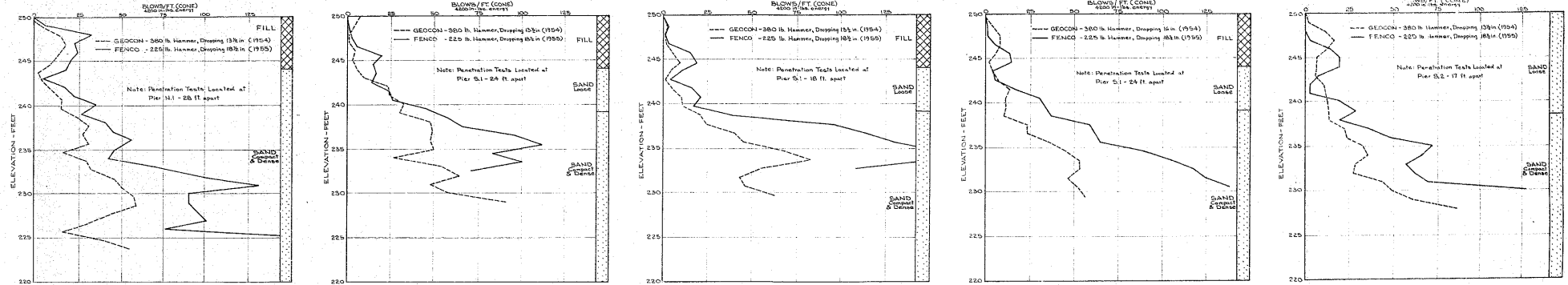




REPRESENTATIVE CROSS-SECTIONS THROUGH RECLAIMED AREAS



COMPARISON OF DYNAMIC CONE PENETRATION TEST RESULTS IN AREA WHERE NO RECLAMATION WAS CARRIED OUT (See Report for Analysis and Discussion)



COMPARISON OF DYNAMIC CONE PENETRATION TEST RESULTS IN RECLAIMED AREAS, BEFORE AND AFTER RECLAMATION (See Report for Analysis and Discussion)

