M438.

Review of Hydrogeological Report on Site D – Milton, Proposed Landfill Region of Halton

Report to

David Estrin, Barristers and Solicitors for the Town of Milton

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Geocon
Lavalin

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SUMMARY

With respect to the proposed landfill at Site D, in the Town of Milton, it is the opinion of Geocon that Trow's predictions of possible impacts of the landfill on the groundwater regime contain a significantly greater degree of uncertainty than is immediately obvious from their report. Thus, given that there are a number of residents in the area who are dependent on wells for their water supply, and for whom there is no readily available alternative source of water, we believe that Site D is less suitable than Site F as the location for the proposed Regional landfill.

In undertaking their assessment of the suitability of the proposed Site D, Trow have indicated that they have been conservative in their assumptions. An examination of the data shows that, in a number of instances, this was not the case.

The key conclusions derived from this review of the hydrogeological data for the proposed Site D in Milton, as stated in Section 8 of this report, are

- Trow's basic assumption that the vertical gradients are downward into the shale bedrock and that the rock thus functions as an underdrain to the system is largely incorrect. Thus Trow's assessment of the site is based on an incorrect conceptual model of the groundwater regime.

- Trow's value of 10^{-5} cm/sec for the hydraulic conductivity of the weathered Upper Till is not as conservative as they wish to imply. It can be considered to be a reasonable value but does not provide "a margin of safety in the impact assessment calculations".

- The geometric mean of the relevant Trow data for the hydraulic conductivity of the unweathered Upper Till is 2.4×10^{-7} cm/sec and thus they have not been conservative in assigning a value of 8.1×10^{-8} cm/sec.

- There is considerable uncertainty with regard to the lateral extent of the Upper Granular Unit and also some uncertainty with regard to groundwater flow directions within that unit.

- There is uncertainty with regard to the hydrogeological significance of the Lower Granular Unit, in view of the fact that flow appears to be upwards from the bedrock to that unit. It is not conservative to assume that contamination in this unit could be controlled by a purge well system.

- There is considerable variability in the chemistry of the groundwater at Site D with domestic wells around the area being at or close to MOE guidelines for chloride and sulphate. Thus it would be contrary to MOE policy for a landfill to add any additional loading of these parameters.

- The natural variation in the concentration of parameters such as chloride would make it difficult to detect the early onset of leachate contamination or to define the limits of that contamination within the groundwater regime.

- The proposed landfill could impact on existing or future groundwater users in the area by the off-site movement of contaminants, or by a decline in water levels brought about by the operation of the hydraulic trap or purge wells.

- There could be significant difficulties in monitoring the effectiveness of the hydraulic trap and the leachate collection system.

1. INTRODUCTION

Geocon Inc. was retained by the Town of Milton to review the work carried out by Trow Hydrology Consultants Limited as part of the study to select a new landfill site for the Regional Municipality of Halton. In carrying out that study Trow, as consultants to the Region, had recommended both Site D in the Town of Milton, and Site F in the City of Burlington, as being suitable for the siting of a landfill.

The report which constitutes the hydrogeological component of the above study (ref. 1) was reviewed, along with a number of documents prepared by other consultants and research workers. A small amount of original field work was undertaken by Geocon.

The review of the Trow reports, for both Sites D and F, posed some difficulties due to various inconsistencies in Trow's presentation and interpretation of the data.

2. PHYSIOGRAPHIC AND GEOLOGICAL SETTING

Site D is located in the Halton Till Plain in an area of gently rolling topography and exhibits only small topographic relief. It is situated on the water divide between Bronte Creek and Sixteen Mile Creek.

The bedrock beneath the site is the red shale of the Queenston Formation which is of Upper Ordovician age and which, based on an examination of the cores obtained from the site investigation, Trow describe as showing strong weathering with a sometimes poorly defined contact with the overlying surficial deposits.

In the vicinity of the site the surficial deposits vary in thickness from 12 to 29 metres and a bedrock depression runs in a generally east-west direction beneath the northern part. This may be part of a larger bedrock valley which extends to the west.

The surficial deposits are predominantly till with some interbedded stratified materials. The Upper Till, in which it is proposed to locate the landfill, is the Halton Till which is predominantly fine-grained varying from clayey silt to silt.

3. GEOLOGICAL HISTORY

The surficial deposits at Site D were deposited during the Late Wisconsinan glaciation, between approximately 15 000 and 12 000 years ago (Karrow, Ref. 2). At that time, a lobe of the continental glacier occupied the Lake Ontario Basin. This lobe advanced several times across this area, from the southeast, depositing unsorted (till) and stratified sediments, before the glaciation finally retreated north.

The fluctuating ice margin presented a variety of depositional environments. Materials entrained by the advancing ice were deposited either directly by the ice as glacial till or by melt waters as stratified deposits (i.e. sorted by particle size) either in front of the ice margin or below the ice. The stratified or sorted deposits could range from thick sequences, traceable over some distance, to thin scattered lenses representing a very short, local sedimentary event. Textures could vary within a deposit depending upon the depositional environment. Similarly till could vary from massive thick sheets to multiple thin layers, deposited in various subglacial environments. During each fluctuation of the ice margin, existing deposits could be partly or entirely eroded and new materials deposited on top.

At Site D Trow identified two main till units: the Upper Till and the Lower Till. The Lower Till is probably not a single till but, as noted by Trow, may be composed of several tills with matrix textures which vary from gravelly to clayey, but which are predominantly sandy silt to silty sand. Within the Lower Till are many stratified deposits, varying in texture from clay to gravel, but being predominantly sands and silts. Thicknesses vary from seams a few centimetres thick to layers several metres thick. The continuity, texture and extent of these deposits in the Lower Till will depend on the nature of the initial deposition and how subsequent ice sheet movement affected the deposits.

The Lower Till and associated sediments were probably deposited during one advance of the Lake Ontario Lobe out of the Basin (possibly depositing the Wentworth Till), with local fluctuations of the ice margin, during the advance and subsequent retreat, contributing to the more complex nature of this unit.

The Upper (or Halton) Till, deposited during a subsequent advance of the ice margin from the Lake Ontario basin, is more massive than the Lower Till. It has a predominantly clayey silt matrix, as noted by Trow, but does locally contain generally thin sand till to silt till layers and, again, thin lenses of stratified deposits. These sorted deposits do not appear to be as continuous between boreholes as the stratified deposits in the Lower Till.

On the surface of the Upper (or Halton) till, shallow (<1 m) silts, sands and clays were deposited in scattered pockets by a short-lived Lake Peel that formed north of the Trafalgar moraine (a slight rise of land found south of the Site D area), from meltwaters from the finally retreating ice.

Trow identifies a 'thin bed of silt' at the contact between the Upper and Lower Tills. The origin and distribution of this unit, where it occurs on top of the Lower Till, may be analogous to the origin and distribution of the Lake Peel sediments on the Halton Till, or these deposits may be the result of scattered depositional conditions on or near the previous surface of the Lower Till.

4. SITE STRATIGRAPHY

4.1 Interpretation by Trow

Trow identify six units within the surficial deposits as being worthy of note and describe them, in descending order from the ground surface, as follows:

- The Upper Till. This is the Halton Till and Trow describe it as predominantly a clayey silt till with minor silt and sand, and with the upper 4 metres or so usually being weathered.

- A Thin Silt Bed. Trow describe this as marking the contact between the Upper and Lower Tills. It should be noted that our review of the data indicates that this unit varies from silt to occasional sand and gravel and ranges in thickness from .04 m to .72 m. The unit is not present at all locations, and was not identified in the Gartner Lee Associates Limited study of the area around Site D (ref. 3).

- The Lower Till. This is predominantly sandy silt to silty sand till and contains the following two granular units:

  - The Upper Granular Unit. This consists predominantly of sand and gravel.

  - The Lower Granular Unit. This is described by Trow as being predominantly silt.

- A Basal Till. This is a gravelly till of limited extent.

In their report Trow present seven geological cross-sections of which three are described as "Regional" and the remaining four are referred to as "Local" (see Drawings 6 to 11 in Ref. 1). The regional cross-sections have generalized the stratigraphy and it is only in the four local cross-sections that the six units of the surficial deposits are delineated.

In preparing this review of Site D several cross-sections were re-drawn from basic data, including detailed Morrison Beatty and Comcor borehole logs which were not originally available to Trow, (Appendices A and B). The re-interpreted sections RB-RB, RD-RD and RG-RG, corresponding to Trow's sections B-B, D-D and G-G are included as Figures 2, 3 and 4. A new section RH-RH is also presented as Figure 5. The locations of these cross-sections are shown on the site plan (Figure 1).

4.2 Method of Re-interpretation

The actual extent of the various stratigraphic units and their continuity, both beneath and off the site, can only be inferred from the borehole data, though the results of the pumping tests also help to a limited degree in the case of the Upper Granular Unit.

Correlations can be made between boreholes at this site with varying degrees of confidence because of differences in distance between the holes and/or the amount of detail recorded in the borehole log. In addition, the stratified units do vary laterally in texture, thickness and to some extent in elevation. Thus it may be difficult to determine if a change in texture between two boreholes represents a facies change within the same unit or the pinching out of one unit and its lateral replacement with a different unit.

In preparing the revised cross-sections included in this report reasonable alternative interpretations were made, where applicable, which demonstrate that the approach taken by Trow has not always been conservative. For example, on section RD-RD (Figure 3) the extent of the Upper Granular Unit tends to correspond to that shown by Trow on their section E-E, on the assumption that the unit may have been missed in the intermittent sampling from their 1984 series of boreholes.

4.3 Upper Till

The Upper Till deposit, in which the landfill is proposed to be founded, is somewhat more variable than Trow seem to imply. In discussing values for hydraulic conductivity they state that the unit is devoid of features such as sand layers whereas an examination of the borehole logs, as discussed below in Section 5.3.2, shows this not to be the case.

An examination of the log for borehole HC1-85 (Vol. 2, ref. 1), and Trow's cross-section E-E, (Vol. 1, ref. 1) indicates that the lower two metres or so of the Upper Till at that location are actually silt and sand, with only traces of clay, rather than the clayey silt till that Trow describe elsewhere.

Under cross-examination by Mr. Estrin, Trow suggested that this could either mean that there was a zone of increased silt and sand content within the Upper Till, or alternatively that the contact between the Upper and Lower Tills should have been drawn "a couple of metres higher". Either way this suggests a further degree of uncertainty with regard to the stratigraphy.

Occasionally the Upper Till appears to thin slightly such as at GL 84-1 or MB OW-4. In the latter borehole the base of the upper clayey silt to silty clay till is at approximately 5.05 m depth (176.76 m elevation) where it overlies 2.27 m of a sandy silt till with numerous sand seams. In this area the base elevation of the landfill cell is at approximately 179.3 m giving only 2.54 m separation between the base of the landfill and the Lower Till.

4.4 Silt Layer

In the case of the unit described by Trow as a "thin bed of silt", Trow did not prepare a plan view of its extent but, from our Figure 7, it can be seen that the most conservative approach (in terms of assessing potential paths for leachate migration) could have it underlying virtually all of the site.

Alternatively it may be of much less significance. Thus, with the present data base, there is a fair degree of uncertainty about the extent of this unit.

With regard to the texture of this so called "thin bed of silt" it can be seen from the data plotted on Figure 7, which is derived from the borehole logs, that the nature and thickness of this deposit varies considerably. For example at HC4-85 the silt layer is represented by 22 cm of sandy silt whereas at nearby HC2-86 there are 16 cm of sand and gravel at a similar elevation. Thus, describing the unit as a silt layer may be somewhat misleading in that such a description can imply less variability than is actually found.

4.5 Upper Granular Unit

In the Trow report (Ref. 1) the type of uncertainty referred to above is highlighted by an examination of their cross-sections D-D and E-E (Drawings 8 and 9, Vol. 1, ref. 1) in the vicinity of borehole HC5-84, where the cross-sections intersect. On section D-D the Upper Granular Unit is shown as being absent in borehole HC5-84 whereas on section E-E presumably extrapolating from HC4-85, the Upper Granular Unit is shown as being present. As the sampling in the 1984 drilling program was not continuous, but only took place every 1.5 metres, it is possible that the Upper Granular unit was missed in borehole HC5-84 and that section E-E is the more accurate interpretation.

On their section G-G Trow do not show the Upper Granular Unit extending to the northern end of the section. However an examination of the detailed logs for the Comcor (CC-2) and Morrison-Beatty (OW-3) boreholes shows more granular material at an elevation of approximately 170 to 173m which roughly corresponds to the elevation of the Upper Granular Unit. Thus it seems reasonable, and certainly conservative at least from the perspective of potential contaminant migration, to assume that the Upper Granular Unit

5. HYDROGEOLOGY

5.1 Hydrostratigraphy

Trow identified five hydrostratigraphic units which generally correspond to the stratigraphic units described above in Section 4. Within the Upper Till, however, they note that there are weathered and unweathered portions with the weathering extending down to depths of 4 metres or so. They did not consider the Basal Till or the thin bed of silt at the base of the Upper Till as distinct hydrostratigraphic units.

However, as was demonstrated in Section 4, this "thin silt" unit could underlie most of the site and, where encountered, varies in thickness and texture from 4 cm of silt to 16 cm of sand and gravel and 72 cm of sand and silt. Thus, given its relative proximity to the bottom of the landfill ($\sim$4m), a conservative approach would consider its hydrostratigraphic significance.

As no hard data on the hydraulic properties of this unit were collected by Trow it is not discussed further in this section. However it should be noted that the hydraulic conductivity could easily vary, depending on the lithology, from 10-4 to 10-6 cm/sec.

Beneath the site the water table, or top of the zone of saturation, occurs within the weathered zone of the Upper Till and, at the time that Trow took water level measurements in April 1986, the depth to water from the ground surface varied between 0.2 and 1.4 metres.

With a shallow water table such as this it may well be that the seasonal surface water drainage channels from the site are, during certain times of the year, in direct hydraulic continuity with the shallow groundwater system. Similarly the various surface water ponds may also be interconnected to the water table.

5.2 Hydraulic Gradients

5.2.1 Horizontal Gradients

Water Table

On Drawing 17 of their report (Ref. 1) Trow show a water table contour map which indicates that, within the shallow weathered till, lateral flow from beneath the site is predominantly in a westerly or southwesterly direction. There is a groundwater high located in the southeast part of the site and flow is towards a depression in the water table about mid-way along First Line.

In Section 6.4.3 of their report (Ref. 1) they state that the horizontal gradient of the shallow system varies between 0.001 and 0.009 but averages about 0.004. In the present study we were unable to reproduce these numbers and, under cross-examination, it was conceded by Trow that their method for calculating gradients was incorrect. Revised numbers submitted by Trow gave a geometric mean gradient of 0.005.

Although the concept of an average gradient, in this context, is of limited value we are of the opinion that a value of 0.008, as presented in Exhibit M-168, would be more realistic.

Granular Units

Trow presented a potentiometric contour map for the Upper Granular Unit on Drawing 18 (Ref. 1). However, this interpretation is based on very few data points and one of these (HC4-85) does not have a piezometer set in the Upper Granular Unit. In fact, the water level used is from a piezometer set in the Lower Granular Unit, some 4.5 metres below the bottom of the Upper Granular Unit.

If, as Trow stated in cross-examination, the piezometric heads in the Upper and Lower Granular Units are the same at this location then this throws even more doubt on statements made with regard to downward vertical gradients. In fact it would mean that, at this location, virtually all the loss in head between the standpipe in the Upper Till and the piezometer set in the Lower Granular Unit occurs in the interval between the standpipe and the Upper Granular Unit.

With regard to the potentiometric contour map presented in Drawing 18 it can be stated that it is based on limited and, in some cases, inappropriate data and that, combined with the uncertainties associated with the actual limits of the Upper Granular Unit itself, it can be regarded as only tentative.

The piezometric contours constructed on Drawing 18, (ref. 1), indicate groundwater flow is eastwards - apparently towards the end of the unit. Trow identifies an approximate gradient of .001 in this unit based on the limited data above. However, because of a lack of more conclusive data, it could reasonably be assumed that the flow direction in the Upper Granular Unit might show some similarities to the flow pattern in the Upper Till (Drawing 17, ref. 1), i.e. with a westerly component within part of the unit.

In cross-examination by Mr. Tidball, Trow were essentially asked to comment on where the groundwater was going in the Upper Granular Unit, given that their Drawing 18 showed the unit to be of limited extent. Their response was somewhat inconclusive but looked at scenarios such as the flow being extremely sluggish and possibly moving into the till or, alternatively, that the unit might extend further off-site than they had shown.

A third possibility suggested by Trow under cross-examination was that the main effect of the Upper Granular Unit might be to only create a deflection in the predominantly downward moving groundwater beneath the site. In our view this latter concept is unlikely to be the only effect that the unit has on groundwater flow, and certainly would not be a conservative approach to evaluating leachate migration.

Regardless of the present flow conditions, any leachate mounding above the water table will modify flow conditions below the landfill such that a radial flow pattern could develop.

No groundwater contour map was presented for the Lower Granular Unit, presumably due to the paucity of data.

5.2.2 Vertical Gradients

Trow state in their report that the dominant gradients at Site D are vertical and that, in the main, these are downwards. In fact they subsequently conclude that most groundwater flow is vertically downwards and that lateral movement off-site within the surficial deposits plays only a small role, although they concede that small upward gradients were measured at a few locations.

In reviewing the water level data presented in Appendix 5 to their main report (Ref. 1) and also in referring to the Trow Local Stratigraphic Cross-sections (Drawings 8 to 11) it can be seen that upward gradients were actually measured at five of the 21 borehole locations for which water level data is given and that a vertical gradient of zero was recorded between two piezometers at another location (HC1-86). What is important to note however, is that the incidence of upward or zero vertical gradients recorded appears to be directly related to the number of piezometers installed in the boreholes. For example, and again referring to Appendix 5 (Ref. 1), out of the 21 boreholes for which water level data was given nine have only two piezometers and, of these, none recorded upward gradients.

Eight of the boreholes had three piezometers and in two of these upward gradients were recorded. Only three boreholes with water levels in appendix 5 had four piezometers and all of these showed some upward or zero vertical gradients. One borehole installation had five piezometers and this also recorded an upward gradient in one horizon.

Thus it appears that the pattern of vertical gradients is more complex than suggested by Trow and that multiple nests containing at least four piezometers are necessary in order to obtain an understanding of the vertical flow system.

Of particular importance is a review of data which might support Trow's concept of the "underdraining of the overburden materials by the bedrock", as stated on Page 52 of their report (Ref. 1), a concept which appears to be fundamental to their modelling.

In fact an examination of the data in Appendix 5 reveals that there are no Trow boreholes actually showing a downward gradient from either the Lower Granular Unit or the underlying till into the bedrock. Borehole HC3-85, in which the Lower Granular Unit is absent, does show a downward gradient from the Upper Granular Unit, albeit it a very slight one, and Morrison Beatty MB-OW3 appears to show a downward gradient from the Lower Granular Unit.

Data from the five Trow boreholes which appear to show a downward gradient into the bedrock are actually being measured from some point above the Lower Granular Unit and could thus be misleading. In fact with four boreholes actually showing gradients up from the rock into the overlying surficial deposits (HC1-85, HC4-85, HC1-86 and HC2-86) the evidence to support the bedrock as an underdrain appears to be, at best, tenuous.

The statement on Page 51 that "..an upward gradient of about 0.01 was measured between the gravelly till and the Bedrock at well HC4-85" appears to minimize the significance of the water levels by implying that movement would only be upwards into the base of the till, on a localized scale. However this statement is obviously incorrect. The gradient is upwards from the bedrock into the Lower Granular Unit and hence this gradient is of potentially greater significance, suggesting that the Lower Granular Unit could be acting as the underdrain for the system.

In summarizing the groundwater gradients at the site it is concluded that the pattern is different from that suggested by Trow, who maintain that the main gradient and hence groundwater flux, is vertically downward from the shallow zone to the bedrock.

5.3 Hydraulic Conductivities

5.3.1 Weathered Upper Till

Trow estimate that the weathered or fractured zone of the Upper Till extends to a depth of 4 or 5 metres and in their report (Ref. 1) they state on Page 47 that "the weathered zone is estimated to have a hydraulic conductivity of about 1×10^{-5} cm/sec which is about two orders of magnitude greater than the unfractured Upper Till" (see below).

In Appendix 12 (Ref. 1), which presents the results of Trow's Hvorslev tests, and relating these to the borehole logs (Appendix 2, Ref. 1) and the well construction details (Appendix 4, Ref. 1) it is possible to assess which field value for hydraulic conductivity might apply to the weathered Upper Till.

Of the six piezometers or standpipes which intersect the weathered zone it appears as if only two are completely screened in that zone, and that the others are partially in the weathered and partly in the unweathered zone. The two installations which are completely within the weathered zone are HC1-85-4 and HC6-85-3 and these gave hydraulic conductivities of 1.8×10^{-6} and 1.9×10^{-7} cm/sec respectively.

A major concern with these values is that they may not be representative of the bulk of the unweathered zone because of the small size of the sample and because of possible smearing on the sides of the boreholes due to the drilling process. Smearing and disturbance of the material within the immediate vicinity of the borehole wall could lead to erroneously low values for the hydraulic conductivity.

In their report Trow used an alternative approach to calculating the hydraulic conductivity and appear to give some weight to the significance of the values which they obtained. This method, which is based on the results of their tritium analysis, is described on Page 62 of the report.

In setting up the calculation they make various assumptions, one of which is that molecular diffusion, in the case of tritium, is negligible. This statement is not supported by the literature. For example Foster (Ref. 5) and Gillham and Cherry (Ref. 6) have suggested that diffusion can be a significant factor in retarding the movement of tritium.

If diffusion has taken place and if no correction factor is applied, the velocity used in the calculation will be too low and this will lead to a hydraulic conductivity value which is too low. However, if the assumption that molecular diffusion is negligible is accepted then it is necessary to look at the vertical gradients at this location.

On Page 62 Trow have given a vertical hydraulic gradient of 0.38 and on exhibit H-181 they show how this calculation was derived. This appears to be based on the difference in water levels in tritium piezometers HT-T-86-6 and HC-T-86-5 which, according to their data was, 0.35 m.

For the distance between the the two piezometers they have used a value of 0.92 m and this appears to be the distance between the bottom of the upper piezometer and the top of the lower one. In our opinion this is not the correct way in which the gradient should be calculated and leads to an unnecessary error. If the same point on each piezometer is taken, and we have used the mid-points, then the distance is in the order of 1.57 metres.

Using Trow's water level and the recalculated distance gives a vertical gradient of 0.22 and if the water levels measured by Geocon are used then the gradient is 0.20. Substituting the new gradient in the equation on Page 62 would then give a hydraulic conductivity of 9.5×10^{-7} or roughly 1×10^{-6} cm/sec.

In our opinion, however, the most critical factor in this attempt to calculate the hydraulic conductivity from the tritium penetration is the possible effects of upward gradients at the base of the weathered or fractured unit.

Although the water level data presented in exhibit H-181 shows consistently downward gradients at this location the measurements taken by Geocon in October 1987 (see below) indicate that in the vicinity of the contact between the weathered and unweathered till the vertical gradient is in fact virtually ~~horizontal~~ zero, or even slightly upwards. Thus the limiting factor for the depth of penetration of the tritium-rich water is probably the vertical gradients rather than a low hydraulic conductivity.

Piezo No.	Water Level m. Below Ground Level	Ground Elevation m.GSD	Water Level Elevation m.GSD
HC-T-1	4.37	186.27	181.90
HC-T-2	2.82	186.29	183.47
HC-T-3	1.41	186.36	184.95
HC-T-4	1.09	186.36	185.27
HC-T-5	1.09	186.35	185.26
HC-T-6	0.76	186.35	185.59

Another point worth noting in reviewing the conclusions which Trow have drawn from their tritium data is a discrepancy relating to their water balance. Using the values given or calculated on Page 62 to calculate annual recharge by applying Darcy's law gives a value for downward flow through the weathered Upper Till of .675 l/sec compared to the value of 0.180 l/s given on Figure 3.

Alternatively, if compared with the water balance on Page 65, the numbers on Page 62 give an annual recharge value in the order of 36 mm/annum rather than 10 mm.

In summary it is our conclusion that no confidence can be placed in Trow's calculation of hydraulic conductivity of the weathered Upper Till from the tritium profiles. The value of 10^{-5} cm/sec used by Trow for the hydraulic conductivity of the weathered Upper Till does not provide a "margin of safety" in the impact assessment calculations (Page 63, Ref. 1). It is a reasonable but not a conservative value.

5.3.2 Unweathered Upper Till

On Page 46 of their report (Ref. 1) Trow state that the hydraulic conductivities of the unfractured (or unweathered) Upper Till varies from 5×10^{-8} to 1.7×10^{-7} cm/sec. and that the geometric mean is 8.1×10^{-8} cm/sec. In reviewing the various data given in the Trow Appendices (Ref. 1), the present study was unable to duplicate Trow's calculations and arrived at a somewhat higher value of 2.4×10^{-7} cm/sec. The relevant data are summarized below.

Borehole	k cm/sec
HC-1-86-3	5.0×10^{-8}
HC-2-86-4	1.7×10^{-7}
HC-3-86-3	6.3×10^{-8}
HC-1-85-3	7.9×10^{-6}
HC-6-85-2	2.0×10^{-7}

Geometric mean 2.4×10^{-7}

Furthermore, the data provided by Trow in Exhibit H-172A shows four values being used to determine the mean hydraulic conductivity of this unit. However, the geometric mean of the data presented is 1×10^{-7} cm/sec rather than 8×10^{-8} cm/sec as stated by Trow.

It is relevant to note that in Section 9.1 of their report (Page 119) Trow, after describing the hydraulic conductivity of the unweathered Upper Till as being 8 x 10^{-8} cm/s say that it is "...devoid of higher hydraulic conductivity features such as sand layers...". In reviewing the borehole logs it is clear that this statement is inaccurate, as noted below.

BOREHOLE	Sand Seams, etc.
2-85	3.95 - 4.14 m - medium sand and gravel
3-85	4.92 - 5.03 m - sand seam
4-84	between approximately 4 and 5 m, the Upper Till is interbedded with sand and gravel till
CC-3	6.5 to 9 m - sand seams .1, .2 and .3 m thick

In summary Trow have not been conservative with regard to the properties of the Upper Till, the unit into which the refuse is to be placed.

5.3.3 Upper Granular Unit

Trow state on page 44 of their report (Ref. 10) that the hydraulic conductivity of the Upper Granular Unit is 8.2 x 10^{-3} cm/sec, apparently based on the results of the pumping test. On page 46 they tabulate the results of the pumping test and indicate a geometric mean of 2.5 x 10^{-4} m^2/sec for the transmissivity of the Upper Granular Unit.

They then indicate that the hydraulic conductivity is 8.2 x 10^{-3} cm/sec, which was based on an aquifer thickness of 3 metres. An examination of the borehole log for HC-2-85, which in their interrogatory responses to Weir and Foulds (Exhibit H-84) Trow indicate contains the stratigraphic data for the pumping well, the aquifer thickness appears to be 2.1 metres.

In examining the driller's log for the actual pumping well (Exhibit M-163) the thickness of the aquifer appears to be confirmed as no greater than 2.1 metres and thus this would give a value for the hydraulic conductivity of 1.19 x 10^{-2} cm/ sec.

45%.

In reviewing Appendix 12 it can be seen that there are two piezometers which have Hvorslev values for the Upper Granular Unit and these are 1.1×10^{-6} and 4.0×10^{-5} cm/sec.

It should be noted that the transmissivity values presented on Page 46 of the Trow report (Table 6) were derived from various analyses of the time-drawdown data obtained from the pump test. However in their various calculations of impacts of the purge wells or hydraulic trap Trow use a transmissivity value which they derived from the distance drawdown data. If this is then used to calculate the hydraulic conductivity it gives a value of 3×10^{-3} cm/sec if the aquifer thickness is assumed to be 3 metres (Trow's figure) or 4.3×10^{-3} cm/sec if 2.1 metres is used (Geocon's figure). Thus it can be seen that using Trow's own data a range of values for hydraulic conductivity is obtained.

The difference in the value of the hydraulic conductivity obtained from the pumping test and those from the Hvorslev method requires some explanation. In cross-examination Trow said that smearing of the borehole was a probable cause and this has some validity, although in a loose sand and gravel deposit (see drillers log, Exhibit M-163) the range of difference between 10^{-2} and 10^{-6} cm/sec seems rather excessive. If this explanation is accepted, however, then it throws serious doubt on the values derived by the Hvorslev method for the various other units, and particularly for the weathered Upper Till.

5.3.4 Lower Granular Unit

In the case of the Lower Granular Unit Trow also conducted a pumping test and used this to arrive at a value for hydraulic conductivity of 3.3×10^{-4} cm/sec (Page 43, Vol. 1, Ref. 1). There were some difficulties in carrying out an effective pumping test as the yield from the pumping well was extremely low, with a large drawdown. The pumping rate of 1.59×10^{-5} cubic metres/sec is equivalent to only 0.21 gallons per minute and the drawdown in the pumped well, after some 15 hours, was more than 6 metres.

In the nearest observation hole, located only 3 metres from the pumped well, the drawdown approached 1 metres in the same time. The second observation hole, apparently located a little over 12 metres from the pumping well, actually exhibited a small rise in the water level during the time of the pump test. Thus the test cannot be considered to be representative of a large volume of this hydrostratigraphic unit.

Trow calculated a hydraulic conductivity of 3.3×10^{-4} cm/sec from the transmissivity of 9.7×10^{-6} m^2/sec, using an aquifer thickness of 3 metres.

However, an examination of the various different data given in the Trow report and its appendices shows that the thickness of the aquifer is by no means well defined at this location. The table presented below shows possible different values, all derived from the Trow data.

SOURCE	ITEM	DETAILS	AQUIFER THICKNESS
Borehole Log HC-4-85	Granular Unit	170.68 to 165.82 m	4.9 m
Appendix 4	Screen in HC-4-85	170.1 to 167.4 m	2.7 m
Driller's Log PW-1	Apparent Aquifer	60 to 65 ft	5 ft 1.52 m
"	Screen Setting	59 to 63 ft	4 ft 1.22 m

In our opinion, the least appropriate value to assume for the aquifer thickness would be the length of screen in borehole HC-4-85. Under cross examination Trow indicated that, in the case of the Upper Granular Unit, they would tend to be influenced by the position at which the driller set the screen. In this case that would suggest an aquifer thickness of 1.22 m. Alternatively the borehole log, and Trow's interpretation on cross-section D-D (ref. 1), indicate that the unit could be as much as 5 metres thick.

Using the two values given above would give hydraulic conductivities of 7.9 x 10^{-4} and 1.9 x 10^{-4} cm/sec. Thus, by simply using the results of the pumping test and critically examining only one parameter, an uncertainty of almost one order of magnitude can be introduced.

With regard to Hvorslev values it appears that only two are applicable to the Lower Granular Unit and these are for piezometers HC-4-85-2 and HC-1-86-2. The values obtained by Trow were 1.2 x 10^{-6} and 1.7 x 10^{-4} cm/sec respectively.

In summary, based on the Trow data, the possible range of values for the hydraulic conductivity of the Lower Granular Unit covers a range of almost three orders of magnitude (i.e. 10^{-3} to 10^{-6} cm/sec).

5.3.5 Refuse

Trow (Ref. 1) have assumed a value of 1 x 10^{-4} cm/sec for the hydraulic conductivity of the waste. Reported values in the literature range from 10^{-2} to 10^{-5} cm/sec (Refs. 7, 8) for hydraulic conductivity of refuse.

In view of the fact that Dr. Rowe's modelling indicates that the hydraulic trap is sensitive to the hydraulic conductivity of the waste, and that with a hydraulic conductivity of 10^{-5} cm/sec the trap will fail, it is important to assume a conservative value. Given that the two references cited above both quote values as low as 10^{-5} cm/sec in the refuse, it is realistic to model the proposed landfill assuming a refuse hydraulic conductivity of 10^{-5} cm/sec as one of the possible scenarios.

5.4 Porosity

In the Trow study one of the least well defined parameters is the effective porosity. Some effort went into trying to determine parameters such as hydraulic conductivity and hydraulic gradient but with respect to effective porosity a value was assumed.

When it is considered that this factor plays an equal role with the other two in determining the rate of movement of contaminants through a water bearing formation, it might be argued that more effort should have been directed towards determining an appropriate range of values. In fairness to Trow, however, it should be noted that most similar studies, at least in Ontario, have taken a similar approach, i.e. values for effective porosity were assumed.

In the case of the unweathered Upper Till they assumed a value of 0.25. With regard to the weathered zone, however, assuming that it would behave more like a fractured medium, they assigned a value of 0.001. This contrasts with the value of 0.0001 assumed by Gartner Lee in their earlier investigation in this area (Ref. 3).

Grisak (Ref. 9) derived a value of 0.00025 for a till in Manitoba and D'Astous et al. (Ref. 10), in their study of the Sarnia clays, calculated values of 0.00075, 0.00047 and 0.00023 for the effective porosity at depths of 2, 3 and 4 m respectively. Whilst recognizing that these values are derived for different locations, and for materials with different clay contents, it would seem that for Trow to have been conservative they should have assumed a lower value for the weathered Upper Till at Site D, for example 0.0005.

5.5 Groundwater Hydrographs

Trow took water levels in the various piezometers at ten borehole installations during the period from October 1985 to April 1986 and presented the results in the form of hydrographs in their Appendix 8 (Vol. 2, ref. 1).

On first examination many of these appear to be typical of a fairly active groundwater system, as indicated by noticeable fluctuations between some readings. However an examination of the diary of events presented in that appendix suggests that some of the more pronounced fluctuations in the 1985 series of boreholes were probably induced by the sampling or development process. Thus the hydrographs are of limited value in terms of assessing the groundwater system.

The five sets of hydrographs included for the 1984 boreholes are of more use because, in general, they were less directly affected by activities of the Trow study team. Strangely, for their 1984 boreholes Trow have only presented water level hydrographs for the period September 1985 to April 1986, though they had monthly measurements covering at least one complete year for those boreholes. (See Exhibit H-84, Addendum E.)

Reviewing the hydrographs presented in Appendix 8 (Vol. 2, ref. 8) it can be seen that the shallow piezometers, which appear to be set mainly in the weathered zone of the Upper Till, showed some response to the precipitation which occurred at the end of October and beginning of November.

In March, following smaller precipitation events than occurred in the Fall, there was again a rise in water levels in the shallow piezometers. HC7-84, the second deepest piezometer, also set in the Upper Till, showed a response similar to the one set in the weathered zone.

In reviewing the additional tabulated data provided by Trow in their response to the Weir and Foulds Interrogatory (Exhibit H-84, Addendum E), the range of fluctuations of the water table over a one year period can be determined. The maximum and minimum water levels for the various shallow piezometers are given below and it can be seen that the range of fluctuation is as much as 1.92 m.

Borehole	Lowest Depth (m)	Water Level Date	Highest Depth (m)	Water Level Date	Difference
1-845 S	0.9	07 Oct. 85	0.04	01 Apr. 85	0.86
3-845 S	1.74	15 July 85	0.82	01 Apr. 85	0.92
4-845 S	1.96	20 Aug. 85	0.23	01 Apr. 85	1.73
7-845 S	2.02	20 Aug. 85	0.10	12 Mar. 85	1.92
8-845 S	1.59	20 Aug. 85	0.17	24 Mar. 86	1.42

This range of fluctuations corresponds well with records from a shallow MOE observation hole located north of the site in Trafalger Township, Lot 14, Concession 3, which had annual water table fluctuations during the period 1975 to 1979 varying from 1.45 m in 1975 to 1.91 m in 1978 (ref. 13).

In looking at the fluctuations of the deeper piezometers, except for HC1-84 which does not have a long enough record, and HC3-84 which appears to have been disturbed in November, the hydrographs show subdued but similar responses to the shallow piezometers. This type of pattern is what would be expected from a deeper system, when compared to a shallower more active system.

As part of the present investigation, Geocon carried out weekly water level measurements in all of the piezometers at five borehole locations on Site D, for the two month period from August 7th to October 9th, 1987. The hydrographs for this period are presented in Appendix C of the present report. The rainfall records for the same period from the Hornby Station are included in the appendix.

In assessing response to recharge events this period was not ideal as it was relatively dry and, when rainfall did occur, a significant proportion probably went to satisfying the soil moisture deficit.

The hydrographs for HC1-85 fall into two distinct categories. The two shallow piezometers, which are set in the Upper Till (one in the weathered and one in the unweathered zone) both show more variation than the two deep piezometers (one in the bedrock and one in the Lower Granular Unit). In fact the lower two rose slightly over the monitoring period whereas the upper two showed an overall decline. The two shallow piezometers did show some response to the rainfall events.

In the case of HC2-85 there was not the same difference in water level elevations between the shallow and deep piezometers. Again, however, the shallow piezometer showed greater fluctuations, though the reading on Sept. 18th, for the bedrock piezometer seems somewhat unusual and may be erroneous.

HC4-85 showed a large difference in elevations between the shallow piezometer (in the Upper Till) and the two deeper ones (in the Lower Granular Unit and the bedrock). The fluctuations in the shallow piezometer were more subdued than the the boreholes already described and, in essence, the hydrograph shows no response to the rainfall. The water level in the Upper Till declined over the monitoring period.

HC2-86 generally showed the pattern of fluctuations in the shallow systems and considerably less fluctuation in the two deeper piezometers. The three shallow piezometers are located in the weathered Upper Till, the unweathered Upper Till and the upper part of the Lower Till. The response of the shallowest piezometer (or standpipe), set in the weathered Upper Till is probably due to prior damage to the piezometer as reported by Trow (pers. comm. 1987). Thus, it seems likely that this piezometer (standpipe) may not be functioning correctly. However, regardless of this, it is important to note that even the Lower Till appears to respond to rainfall events.

MB-OW-4 corresponded more closely to HC-4-85 in terms of the subdued response of all the piezometers.

In summary the results of the water level monitoring are not conclusive but do suggest that the groundwater system in the Upper Till, and even in the upper part of the Lower Till is reasonably active over part of the site.

5.6 Groundwater Chemistry

Trow present the results of their chemical analysis of water samples in Appendix 11 and they discuss their significance in Section 7.0 of their report (Ref. 1).

TABLE 1 ANALYSES OF WATER FROM DOMESTIC WELLS

Well Name/Number	June 1987					Sept. 1987
	pH	Alkanity (as $CaCO_3$)	Total Hardness (as Ca CO_3)	Sulphate	Chloride	Chloride
Martin (2476)	7.3	30	875**	630*	600*	85
Reed (14hc)	7.4	400	540**	72	16	Dry
Chlon (16hc)	7.6	68	470	290	345*	236
Pompa (5663)	7.4	50	765**	550*	410*	350*
Chaput (4074)	7.6	62	350	230	300*	330*

NOTE: For location see Figure 1

All values except pH in milligrams/litre

* Concentration in excess of MOE Drinking Water Objectives

** Concentrations considered unacceptable for most domestic purposes

At the bottom of Page 53 they refer to the analyses of water from shallow overburden wells "..to a depth of approximately 5 m below ground surface" and then discuss the major anions and cations.

The piezometers which are located within the upper 5 or so metres are HC-1-85-4, HC-5-85-3 and HC-6-85-3. Of these the last two have chlorides of 4.7 and 37.4 mg/l respectively, whereas HC-1-85-4 had a chloride concentration of 991 mg/l.

It is possible that this higher value is due to road salting, as suggested by Trow in cross-examination, in which case it could be indicative of a reasonably active flow system. However, referring back to the earlier discussion of vertical gradients it will be seen that borehole HC-1-85 exhibited an upward gradient within the Upper Till and thus this elevated chloride may be related to the upward movement of groundwater from a lower horizon within the surficial deposits. Either way, however, it cannot be considered as being indicative of a sluggish flow system within the weathered till.

A similar argument can be applied to the sulphate value recorded for HC-1-85-4, which is rather high at 1940 mg/l, though not as high as HC-6-85-3 in which a value of 4540 mg/l was recorded. In reviewing the chemical data presented by Trow in Appendix 11 and their discussion of the results in Section 7.0 (Ref. 1) it can be seen that the quality varies significantly across the site, and with depth, and that a number of parameters are frequently close to, and sometimes in excess of the MOE drinking water standards.

In an attempt to assess the quality of the water in the domestic wells along First Line, Geocon, in June 1987, initiated the sampling of five wells which were then analysed for the parameters shown in Table 1.

The wells were sampled again in September and analysed for chloride. From this it can be seen that the quality is such that it could not tolerate any additional loading and, in addition, there is some variation with time. This latter point would make it difficult for monitoring to detect the onset of leachate contamination as the natural fluctuations in the water quality would probably mask it in the early stages.

5.7 Groundwater Use

The residents in the vicinity of Site D depend on wells for their water supply as there is no piped municipal water available in the area.

The majority of the homes obtain their water from the bedrock (Figure 1). However, immediately west of the site, along First Line, several homes obtain water supplies from the overburden, probably from granular layers at least some of which may be contiguous with granular units beneath the site. In the Trow investigation the possible inter-relationship between these units has not been defined.

Figure 1 shows the location of domestic wells in the vicinity of the site. A distinction has been made between those wells which obtain their water from the surficial deposits and those which obtain their water from the bedrock.

6. IMPACT ASSESSMENT

6.1 General

There are two ways in which the proposed landfill could have an adverse impact on existing or future groundwater users in the area. The first is by off-site movement of contaminants affecting the groundwater quality and the second is by the operation of the site leading to a decline in water levels to the point where the yields of the domestic wells are impaired.

The decline in water levels could be brought about either by the operation of the hydraulic trap or by the implementation of contingency measures such as purge wells.

6.2 Impact on Groundwater Quality

In their report Trow attempt to assess the possible impact on off-site groundwater quality by applying groundwater modelling techniques. The appropriateness of the models and the validity of the results are addressed elsewhere by Dr. Kerry Rowe. The present reviewer, however, has concerns about the depth of understanding of the flow system which serves as basic input to the Trow model.

As the previous sections of this report have shown, there are a number of inconsistencies and inaccuracies in the conclusions presented by Trow. Their response, in cross-examination, has been that where there are uncertainties they have been conservative. That has not always been the case.

With regard to the modelling, their attempts to be conservative have led to the use of generalized assumptions with regard to certain parameters, and these are somewhat removed from reality. This might lead one to the conclusion that what they have ended up with is a generic solution rather than a site specific model.

If the hydraulic trap continues to operate satisfactorily and, using Trow's assumptions, then the landfill, as proposed, should not have an adverse impact on off-site groundwater quality. However if the leachate collection system, or a portion of it, and hence the hydraulic trap, should fail then there is a risk of off-site migration of contaminants.

Dr. Rowe, in his report, has shown that the effectiveness of the hydraulic trap is quite sensitive to the hydraulic conductivity of the waste. His modelling indicates that if the hydraulic conductivity of the waste should be one order of magnitude less than that assumed by Trow (i.e. 10^{-5} cm/sec rather than 10^{-4} cm/sec) then the trap would not work and unacceptable off-site contamination would occur.

Assuming that initially the hydraulic trap works but that a subsequent failure of a portion of the collection system occurs, but is not recognized, a build-up of leachate within the landfill would occur and hence an increase in the driving force behind the movement of contaminants into the groundwater regime would result.

Although the build-up of leachate within the refuse would not be uniform, due to localised perching and break-outs on the sides, it would be in keeping with the modelling already carried out to consider the simple or idealized case of such mounding. Thus the scenarios proposed by Dr. Rowe, of a partial failure of the collection system, are a reasonable modelling exercise and the extreme case of mounding up to an average height of 15 m, based on a complete failure of the under-drains, should be considered.

In considering the possible failure of the system it is necessary to consider over what time scale that would remain critical. In cross-examination Trow were asked to address this point and acknowledged that the site would generate leachate for decades, possibly up to a hundred years.

There is little reliable data on this topic, as comprehensively monitored landfills have not been around long enough. However a conservative approach must assume that, in a case such as Site D, the collection system will have to operate for many decades.

Freeze and Cherry (Ref. 11) state that although it is well established that landfills produce leachate for at least a few decades little is known about the capabilities for leachate production over much longer periods of time. They go on to say that leachate production may continue for many decades or even hundreds of years.

Finally, in considering possible impacts on groundwater quality in the event of systems failure it is relevant to review Trow's Figure 19 (Ref. 1, Vol. 1), which represents their best case for chlorides. This shows that, even with the declining chloride input, the concentration in the Granular Units at the site boundary would still eventually exceed the current MOE drinking water guidelines, without even considering the current background chloride levels in the water.

6.3 Impact on Groundwater Levels and Yields

6.3.1 The Hydraulic Trap

In Appendix 16 Trow address the issue of "Quantitative Impact of the Hydraulic Trap". In doing this they look only at the upward flow of water from the Upper Granular Unit, through the top part of the Lower Till and the lower part of the Upper Till, into the landfill.

Taking the above approach they arrive at a value of 3.6 l/min for flow and then use this to calculate the possible impact on domestic wells. This approach, however, ignores the effects of lateral inflow from the weathered zone of the Upper Till.

As the inter-relationships of the various units, and the relationship of those units to the domestic wells, is not fully understood it is possible that there could be an impact significantly greater than that described in Appendix 16.

In Appendix 16 it should be noted that Trow, in their calculations use a transmissivity value of 8.05 m^2/day which they ascribe to the distance-drawdown graph. On Page 46, Table 6, of the same report they calculated a mean transmissivity of 2.5×10^{-4} m^2/sec or 21.6 m^2/day. The discrepancy in these values is not explained in the report.

6.3.2 Purge Wells

Trow refer to natural attenuation as being the primary contingency method at Site D though, in reality, this is not a contingency measure. Thus, for the granular units, the proposed purge well systems are the primary and sole contingency measure proposed by Trow.

Lower Granular Unit

In the case of the Lower Granular Unit the results of the pumping test raise concerns about the viability of the proposed purge well system. The steep cone of depression, which was relatively deep for the low pumping rate used, and yet which extended for such a short distance, suggests that it would be difficult, in practical terms, to effectively intercept all the contaminant flow other than with a ring of closely spaced boreholes.

It was seen in an earlier section of this report that the flow system as described by Trow is not supported by the data and that, rather than the bedrock functioning as an underdrain, it may be the Lower Granular Unit and associated deposits which play that role. On Page 134 of their report Trow calculate that the amount of pumpage required from the Lower Granular Unit would be 7.8 l/min which is equal to the recharge rate from the landfill cells to that unit. If, in fact, there is upward flow from the bedrock, which Trow do not recognize, then this number would be higher. Thus given the uncertainties of the flow system within this unit it is quite possible that considerably more purge wells than calculated by Trow would be required in order to prevent off-site migration.

In summary, it would appear that there are important questions still to be answered about flow in the Lower Granular Unit, and about how representative are the pump test results. Based on this limited data it is difficult to to do more than speculate as to the necessary and appropriate design of the purge well system, and certainly premature to calculate what might be its off-site impact.

Upper Granular Unit

Trow (pg. 133, Vol. 1, ref. 1) estimate that the recharge from the landfill to the Upper Granular Unit, assuming a vertical gradient of 0.5, would be 12.6 l/min. In the event of higher mounding, as postulated by Dr. Rowe, this figure would of course, increase proportionally.

Trow state that to intercept all the contaminated water which recharges the unit it will be necessary to pump one or two wells at the rate at which the contaminated water is recharging the unit, i.e. 12.6 l/min. In fact, depending on the extent and configuration of the unit, which at this time have not been clearly defined, it may be necessary to pump at greater rates because the cones of capture which develop around the wells will probably extend beyond the limits of the cells.

The classical type of purge well system is located down-gradient of the landfill in order to intercept the plume. What is being proposed here does not conform to that pattern, probably because the extent of the unit and the hydraulic gradients within that unit have not been clearly defined.

In terms of impacts on domestic wells it can be said that pumping at greater rates than 12.6 l/min would have proportionally greater impacts on the water levels and hence the yields. In view of the fact that the Geocon investigations revealed that at least one domestic well went dry this summer (Table 1) this should be a matter for concern.

In discussing the impact of either purge wells or the hydraulic trap on water levels in the domestic wells it should be noted that a reverse situation could occur. Thus pumping from wells or boreholes on nearby properties could produce drawdowns in the Upper Granular Unit beneath the landfill.

Trow, on Page 133, calculate that purge wells in the Upper Granular Unit pumping at 2.8 gpm (12.6 l/m) would lower water levels in nearby domestic wells by 1.7 m. Assuming that this calculation is correct would mean that a well on nearby property, pumping at that rate for the same time period, would lower the head in the Upper Granular Unit below the landfill by a similar amount.

Such a well could be constructed for a dairy farm or similar operation. Whilst it is extremely unlikely that the well would operate continuously it is possible that it would pump at 2 to 3 gpm and, if this was sustained for only 24 hours, it would still draw the water level down beneath the landfill.

Such a drawdown would produce the same effect as the mounding of the leachate, as modelled by Dr. Rowe, and combined with mounding, could lead to the onset of off-site migration of leachate.

7. GROUNDWATER MONITORING

As discussed in the Section 5.6, there is considerable variability in the concentrations of the inorganic parameters in the groundwater in the vicinity of Site D, both with respect to space and time. This would make it extremely difficult to identify the on-set of leachate contamination or to define the limits of a plume which might have developed, other than when levels had become highly elevated.

Another factor which poses problems in monitoring the groundwater system is the uncertainty surrounding the extent of the granular units within the surficial deposits. As discussed above, the Trow investigations have failed to accurately define these and thus it will be difficult to design an adequate monitoring system. In this case the conservative approach would necessitate the construction of a large number of multi-level installations all around the perimeter of the site.

The configuration shown on Figure 24 (Ref. 1) and expanded during cross-examination, still leaves us with concerns about the degree of protection afforded to the domestic wells.

Freeze and Cherry (Ref. 11, Pages 397-399) discuss how heterogenieties in deposits can create difficulties in the prediction and detection of contaminant movement. Although the examples presented are, by necessity, somewhat idealized, they do serve to show how, in a system such as exists at Site D, the discontinuity of a bed such as either of the granular units, or indeed the "Thin Silt" unit, can lead to a large distortion in the flow path of the contaminants.

It is not clear from Trow's report how they would effectively monitor the performance of the leachate collection system. They refer to the monitoring of leachate build-up in the man-holes but this would not tell them if the system was blocked and hence if there was a build-up of leachate taking place within the cells.

With the proposed system they will not know with any degree of accuracy how much water is infiltrating the site and thus it will be virtually impossible for them to determine whether any of the leachate is by-passing the system and discharging into the groundwater regime. Even keeping records of the quantities collected will not be of much help as the seasonal and annual variations will be significant.

It should be noted that it would be possible to have downward gradients out of the landfill at some locations, due to failed collection tiles, even if the sub-headers are still working. In such a situation it might be argued that a failure would be suspected if leachate quantities collected were less than expected. However, in describing the difficulties of predicting the quantities of leachate generation, Bass (Ref. 12) states that:

> "... The state of the art for predicting leachate generation for short time intervals ... is very rudimentary."

and

> "... Because of the high degree of sensitivity of the various leachate prediction models, it would be impossible to determine whether production of leachate at lower-than-predicted levels is the result of a system failure or poor modeling. Therefore, caution should be exercised when using leachate prediction methods for on-going monitoring of leachate collection systems."

8. CONCLUSIONS

The key conclusions derived from this review of the hydrogeological data for the proposed Site D in Milton are set out below:

- Trow's basic assumption that the vertical gradients are downward into the shale bedrock and that the rock thus functions as an underdrain to the system is largely incorrect. Where adequate instrumentation exists the water levels indicate that, at most locations, the gradient is upwards from the rock. Thus Trow's water balance and the basic concept for their model at Site D appear to be based on an incorrect analysis of the groundwater regime.

- Trow's value of 10^{-5} cm/sec for the hydraulic conductivity of the weathered Upper Till is not as conservative as they wish to imply. It can be considered to be a reasonable value but does not provide "a margin of safety in the impact assessment calculations". Further, no confidence can be placed on the use of the tritium profiles to calculate or corroborate the hydraulic conductivity of this unit. In fact the hydrographs suggest that the groundwater regime in the Upper Till may be reasonably active.

- Trow have not been conservative in assigning a value of 8.1×10^{-8} cm/sec for the hydraulic conductivity of the unweathered Upper Till, as evidenced by the fact that the geometric mean of the relevant Trow data is actually 2.4×10^{-7} cm/sec.

- There is considerable uncertainty with regard to the lateral extent of the Upper Granular Unit and also some uncertainty with regard to groundwater flow directions within that unit.

- There is uncertainty with regard to the hydrogeological significance of the Lower Granular Unit, in view of the fact that flow appears to be upwards from the bedrock to that unit. Based on the evidence presented

appendix a

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IN - OW2
Elev 182.96 (HCL V)

CLIENT: TOWN OF MILTON FILE NO. 413-841
PROJECT: LOCATION: BOYNE
GEOLOGIST/ENGINEER: TH DATE COMPLETED: July 31, 1984

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
TOPSOIL, clayey silt, black, moist	.23						
Clayey silt with small stones (TILL), some sandier zones, highly weathered, mottled, many horiz. fractures, brown, buff and grey, moist	3.1						
Clay, Silt (Diamicton), some pockets of fine sand and silt, some minor stratification and minor banding, brown with some buff mottling, wet	3.4						
Clay, silty, with some fine sand pockets (streamers) and some minor stratification and colour banding, oxidation on sand in streamers, some v. minor mottling, olive brown to grey, wet	4.05						
Clayey silt with many [illegible], some cobbles (TILL) and some boulders, greyish, reddish, angular [illegible], wet - greyer with depth	7.4						
Clayey, sandy silt (Diamicton) with stones, 1 inch of interbedded silt and clay at bottom of [illegible], grey, wet	7.5						

PRELIMINARY

WL-040281

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

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IN-OW2
[illegible]

CLIENT ______________________ FILE NO. ________

PROJECT ______________ LOCATION ______________

GEOLOGIST/ENGINEER ______________ DATE COMPLETED ______________

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
Sandy Silt with some clay (TILL), some silty sand zones, angular stones, some cobbles, grey – reddish brown, moist	9.3						
Silty Sand with stones, angular to subangular stones (mostly grey shale) (TILL), may have good K, brown, moist	10.88						
Silt, clay and Sand, (Diamicton), banded deposits, sand streamers with some gravel, stones, greyish to reddish grey	11.58					PRELIMINARY	
Silty fine Sand, with stones (TILL), some cobbles, reddish brown-brown, moist	12.10						
SHALE, red, well fractured vertical and horizontal, fairly soft, dry, easy to drill	13.2						
E.O.H. 13.2							

WL-040281

GS - GRAB SAMPLE SS - SPLIT SPOON ST - SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

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IN - OW3
Elev. 183.07 (HCL ∇)

CLIENT TOWN OF MILTON FILE NO. 413-841
PROJECT ______ LOCATION Boyne
GEOLOGIST/ENGINEER TH DATE COMPLETED August 1, 1984

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
TOPSOIL, clayey silt, black, moist	.22						
Clayey Silt with some stones (angular to sub-angular), horizontal fractures, whitish grey, weathered with buff coloured mottling, becoming grey at 4.0m, some reddish brown stones, moist (TILL)	7.62						
Clayey Silt with high stone content (mostly grey shale), brown, wet (TILL)	8.07					PRELIMINARY	
Clayey Silt with stones, minor fractures, some cobbles, brown, moist (TILL)	8.92						
GRAVEL, silty with some clay, angular to sub-rounded gravel, brown, wet	8.99						
Clayey Silt with stones, some cobbles, brown, moist (TILL)	9.78						
SAND, fine with minor silt and minor gravel, brown, wet	9.91						
Clayey Silt with stones and some cobbles (TILL) reddish brown, wet	11.73						
SILT & CLAY, stratified, some pebbles (1-2mm Ø), colour banding, grey and reddish brown, moist	12.01						

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ∇

WL-040281

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IN - OW3
Page 2

CLIENT ______ FILE NO. ______
PROJECT ______ LOCATION ______
GEOLOGIST/ENGINEER ______ DATE COMPLETED ______

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
Clayey Silt with some sand, some small sand pockets, many angular to sub-ang. stones, reddish brown to brown, moist (TILL) -sandier at 13.26-15.09	15.09						
SILT & CLAY, stratified, colour banded, one minor sand layer at 15.24m, approx 1cm thick, moist	15.24						
SILT, stoney (TILL), gravel size cobbles, angular, some clay, reddish brown, moist	16.31						PRELIMINARY
SAND, with some gravel brown, wet	16.86						
SILTY sand with clay, ang. to sub. ang. stones (TILL), some pockets of silty gravel and sand, brown, wet	17.59						
Sandy, clayey, silt with stones (ang- subang.) some cobbles, reddish brown, (TILL), wet	17.83						
SAND & GRAVEL, silty, fine sand, gravel size stones - ang. to sub. ang. (possibly washed till), brown wet	18.14						
Clayey, Sandy Silt, with stones, some boulders (TILL), some sand & gravel pockets, wet	20.82						

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

WL-040281

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IN-OW3
Page 3

CLIENT ______ FILE NO. ______
PROJECT ______ LOCATION ______
GEOLOGIST/ENGINEER ______ DATE COMPLETED ______

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
SAND, med. to fine grained with some minor coarse zones, rounded to subrounded gravel, also some diamicton zones at 21.49-21.58 m, grey, wet	22.56						
SAND & GRAVEL, silty fine-med sand, some coarse zones, reddish brown, wet	23.16						
SAND, fine, grey, wet	23.32						
Silty sand with clay and stones (Diamicton), zone of silty sand and gravel at 23.41m-23.50m reddish brown to grey, wet	23.62						
SAND, med-fine grained with some minor gravel, reddish brown wet	23.80						
SHALE, red, thin beds, fractured, hard to drill	23.90						
E.O.H							

PRELIMINARY

WL-040281

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

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ELEV 181.81 (✓ by HCL)
IN-OW4
Page 1

CLIENT Town of Milton FILE NO. 413-841
PROJECT LOCATION Boyne
GEOLOGIST/ENGINEER AEC DATE COMPLETED Aug 17, 1984

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
Topsoil, silty sand, dark brown, organics	.46						
SILT, clayey, brown-grey with mottled brown patches, cohesive, moist, few stones	.99						
Clayey Silt with many sand pockets, many pebbles and cobbles (TILL) vert. and horz. fractures, crumbly texture	4.27						
Silty Clay, cohesive, boulders and a few pebbles (TILL), greyish brown with some reddish brown patches, some fine sand partings	5.05						
Sandy Silt with some clay, crumbly texture, numerous sand seams, reddish brown, numerous stones, cobbles, horiz. fractures (TILL)	7.32						
Clayey Silt with sand seams, grey brown with fine sand, many pebbles and cobbles some grey-green patches, cohesive (TILL)	7.92						
Clayey silt, some pebbles, some hor. fract. grey brown w/ mottled red patches, becoming sandier at 9.3m	9.30						

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

WL-040281

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IN - OW4
Page 2

CLIENT ______ FILE NO. 413-841
PROJECT ______ LOCATION ______
GEOLOGIST/ENGINEER ______ DATE COMPLETED ______

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
Sand, coarse with some gravel, with some silt, gravel and sand layers, grey, wet to saturated	10.67						
Clayey silt with some sand, stones and boulders, dense, some minor sand seams, horiz. fractures grey brown, reddish brown at 11.9 m (TILL)	13.4						
SILT and fine sand, laminated, some cobbles and pebbles, wet - saturated	14.63						PRELIMINARY
Silt and Sand, stones and pebbles, large sand seams, (Diamicton) saturated, reddish brown	15.39						
Silt, laminated, pebbles, brown, wet	15.70						
Sand, fine to med., silty, brown, wet	16.31						
Silt and Sand, med. to coarse, many pebbles and cobbles, brown, wet	17.04						
Sand and Gravel, coarse sand, cobble size gravel throughout, brown	17.32						
Silt and Sand with some stones (Diamicton) crumbly, wet	17.98						
Sand, coarse to med. few pebbles, some clay and							

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

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IN-OW 4
page 3

CLIENT ______ FILE NO. ______
PROJECT ______ LOCATION ______
GEOLOGIST/ENGINEER ______ DATE COMPLETED ______

DESCRIPTION	DEPTH metres	DEPTH feet	SAMPLE no.	SAMPLE type	SAMPLE "N"	WELL DETAIL	REMARKS
Silt layers, reddish brown - grey	18.67						
Sand and Silt, med-fine sand, coarse sand seam at 19.0m	19.08						
Clayey Silt with some stones (Diamicton), grey, cohesive	19.96						
SHALE, weathered with some clay, silt and sand, grey shale fragments	22.25						
E.O.H. 22.25m							

PRELIMINARY

WL-040281

GS- GRAB SAMPLE SS- SPLIT SPOON ST- SHELBY TUBE "N" BLOWS PER FOOT WATER LEVEL ▽

appendix b

APPENDIX B

COMCOR BOREHOLE LOGS

SITE D

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Tomosky Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-1-1
Completion Date: July 9,1985
Ground Elevation: 183.598
Top of Casing Elevation: 184.758
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
		184.758				
0.0		183.6				
	Topsoil					
	Fine sand					
1.0	Grey/brown silty clay till with some sand and pebbles, weathered and fractured					
2.0	Red/brown silty sandy clay till, with pebbles and occasional cobbles weathered and fractured					
3.0			50mmØ sch. 40 PVC pipe	1	CS	
4.0	Moist to wet medium to fine sand with some very fine sand			2	CS	
5.0	Red/brown silty sandy clay till with pebbles and occasional cobbles, weathered and fractured			3	CS	
6.0	Wet medium sand changing to very fine silty sand		bentonite cement grout			
7.0	Moist red/brown silty sandy clay till			4	CS	
8.0						
9.0	Silty clay till becoming dryer and redder					
10.0	Red/brown very silty clay till, with some fine sand, pebbles and cobbles, weathered and fractured					
11.0				5	CS	
12.0	Red very fine to fine sand					
	Red/brown very silty clay till with pebbles and cobbles					
13.0				6	CS	
14.0	Cobble, red/brown very silty clay till, slightly more silty and sandy					
	Grey silt with clay					
15.0	Interbedded silts and clays with some very fine sand					

CS - Continuous Sampler

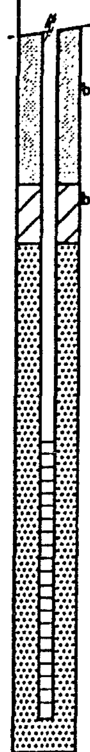
CONCOR

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Tomosky Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-1-1
Completion Date: July 9, 1985
Ground Elevation: 183.598
Top of Casing Elevation: 184.758
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
15.0	Wet sands and silts with cobbles					
16.0	Red/grey silty clay till with pebbles		bentonite cement grout	7	CS	
17.0	Red medium to fine sand, some coarse sand and gravel	166.8	bentonite seal			
	Red/grey silty clay till, pebbles, weathered	166.2				
18.0				8	CS	
19.0	Dry grey silt till and fine sand, some clay and pebbles, some grey shale particles	163.8	50mmØ sch. 40 PVC pipe			
20.0	Wet coarse sand and gravel, some fine sand		silica sand			
21.0	Lost core, assumed (by drill performance) to be fine sands, wet, very fine sands and silts No recovery - assumed (by drill performance) to be wet sands		8.1m x50mmØ 10 slot PVC well screen			
22.0						
	Poor recovery - contains sands/gravel/red shale					
23.0	Poor recovery	160.7		9	CS	
	Red shale bedrock	160.3				
	End of Hole					
24.0						
25.0						
26.0						
27.0						
28.0						
29.0						
30.0						



CS - Continuous Sampler

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Tomosky Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-1-2
Completion Date: July 9, 1985
Ground Elevation: 183.778
Top of Casing Elevation: 184.728
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
		184.728				
0.0		183.8				
	Refer to CC-1-1 for description of stratigraphy					
1.0			bentonite cement grout and cuttings			
2.0						
			50mmø sch. 40 PVC pipe			
3.0						
		180.1	bentonite seal			
4.0		179.8				
			silica sand			
5.0						
6.0		177.5	1 m x50mmø 10 slot PVC well screen			
7.0		176.6				
	End of Hole					
8.0						
9.0						
10.0						
11.0						
12.0						
13.0						
14.0						
15.0						

CS - Continuous Sampler

CONCOR

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Martin Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-2-1
Completion Date: July 10, 1985
Ground Elevation: 182.943
Top of Casing Elevation: 183.093
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
		183.093				
0.0		182.9				
	Topsoil					
1.0	Red/brown/grey silty clay till, some sand, pebbles, weathered & fractured		bentonite cement grout and cuttings			
2.0						
3.0						
4.0						
5.0			50mmØ sch. 40 PVC pipe			
6.0	Slightly moist greyer silty clay till, some sand, pebbles, weathered & fractured					
7.0	Dry red/brown silty clay till, pebbles & cobbles, weathered & fractured					
8.0	Wet red silt, very fine sand seam					
	Red/brown/grey silty clay till, some sand, pebbles, weathered & fractured			1	CS	
9.0	Wet red silt seam becoming brown/grey/red silty clay till, some sand, pebbles, weathered & fractured					
10.0				2	CS	
	Grey/blue silty clay till, pebbles and cobbles, very hard					
11.0						
	Cemented silt with fine to very fine sand & some gravel (dry)					
12.0						
	Grey/brown silty clay till with pebbles, evidence of cobbles					
	Wet red silt & very fine sand with coarse sand and gravel					
13.0						
	Red/brown silty clay till with pebbles					
14.0						
15.0						

CS - Continuous Sampler

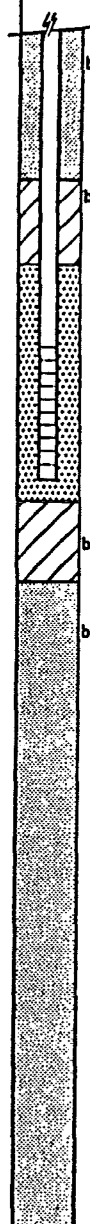
CONCOR

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Martin Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-2-1
Completion Date: July 10, 1985
Ground Elevation: 182.943
Top of Casing Elevation: 183.093
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
15.0						
	Red/brown silty clay till with pebbles		bentonite cement grout and cuttings			
16.0	Cemented grey silt/clay with evidence of gravel					
	Red silty clay till, some sand, pebbles, weathered & fractured	166.2				
17.0	Red silt, pebbles, very fine sand (moist)		bentonite seal			
	Coarse sand & gravel (approx. 5 cm)					
	Moist red silt	165.2	silica sand			
18.0	Varved red & grey clay, silty					
	Wet red silt, very fine sand occasional pebble	164.3	1.5 m x50mmø 10 slot PVC well screen			
19.0				3	CS	
20.0		162.8				
		162.5		4	CS	
21.0	Moist grey silt/clay till with pebbles, occasional cobble		bentonite seal			
		161.6				
22.0			bentonite cement grout			
23.0				5	CS	
24 0						
25.0						
	Moist varved red/grey clay, silty					
26.0	Wet varved red/grey silts			6	CS	
27.0	Wet red silt, very fine sand					
	Cobble, wet silty sand and gravel					
28.0				7	CS	
	Broken/weathered red shale, silts & clay till mixed	154.1				
29.0	End of Hole			8	CS	
30.0						



CS - Continuous Sampler

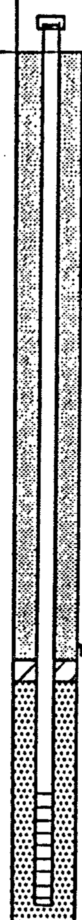
CONCOR

BOREHOLE LOG

Project Name: Boyne Site Investigation
Project No.: 9-004-85
Client: MEAC
Location: Martin Property
Drilling Method: Hollow Stem Auger

Borehole Number: CC-2-2
Completion Date: July 10, 1985
Ground Elevation: 182.968
Top of Casing Elevation: 183.103
Field Supervisor: T.J.F.

DEPTH metres	DESCRIPTION OF STRATIGRAPHY	ELEVATION metres AMSL	MONITORING INSTALLATION	SAMPLE No.	SAMPLE Type	SAMPLE N
		183.1				
0.0		183.0				
	Refer to CC-2-1 for description of stratigraphy					
1.0						
2.0			bentonite cement grout and cuttings			
3.0						
4.0			50mmØ sch. 40 PVC pipe			
5.0						
6.0						
7.0		176.0	bentonite seal			
		175.7				
8.0			silica sand			
		174.5				
9.0			1.25 m x50mmØ 10 slot PVC well screen			
		173.2				
10.0		173.0				
	End of Hole					
11.0						
12.0						
13.0						
14.0						
15.0						



CS - Continuous Sampler

COMCOR

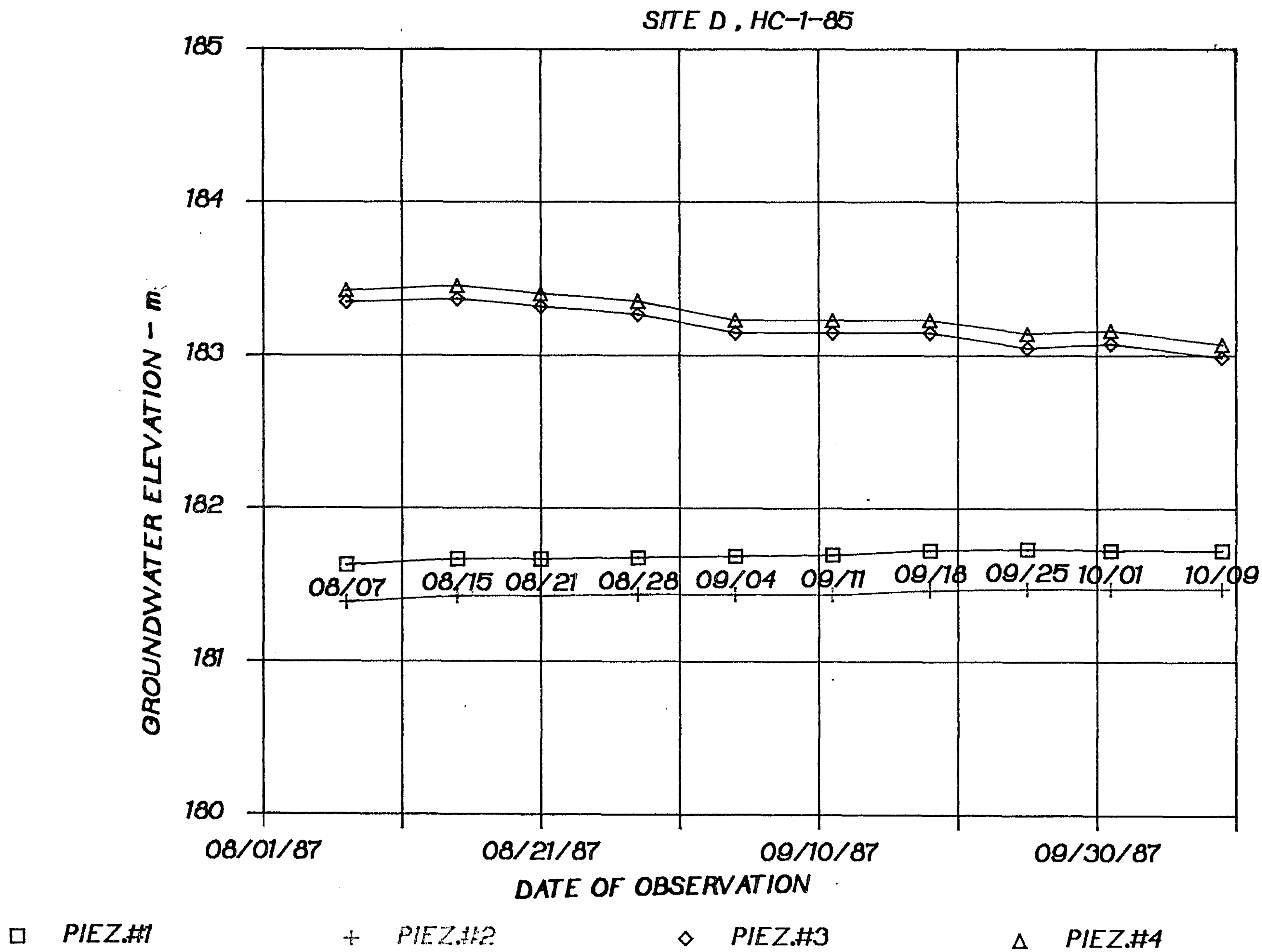
appendix c

APPENDIX C

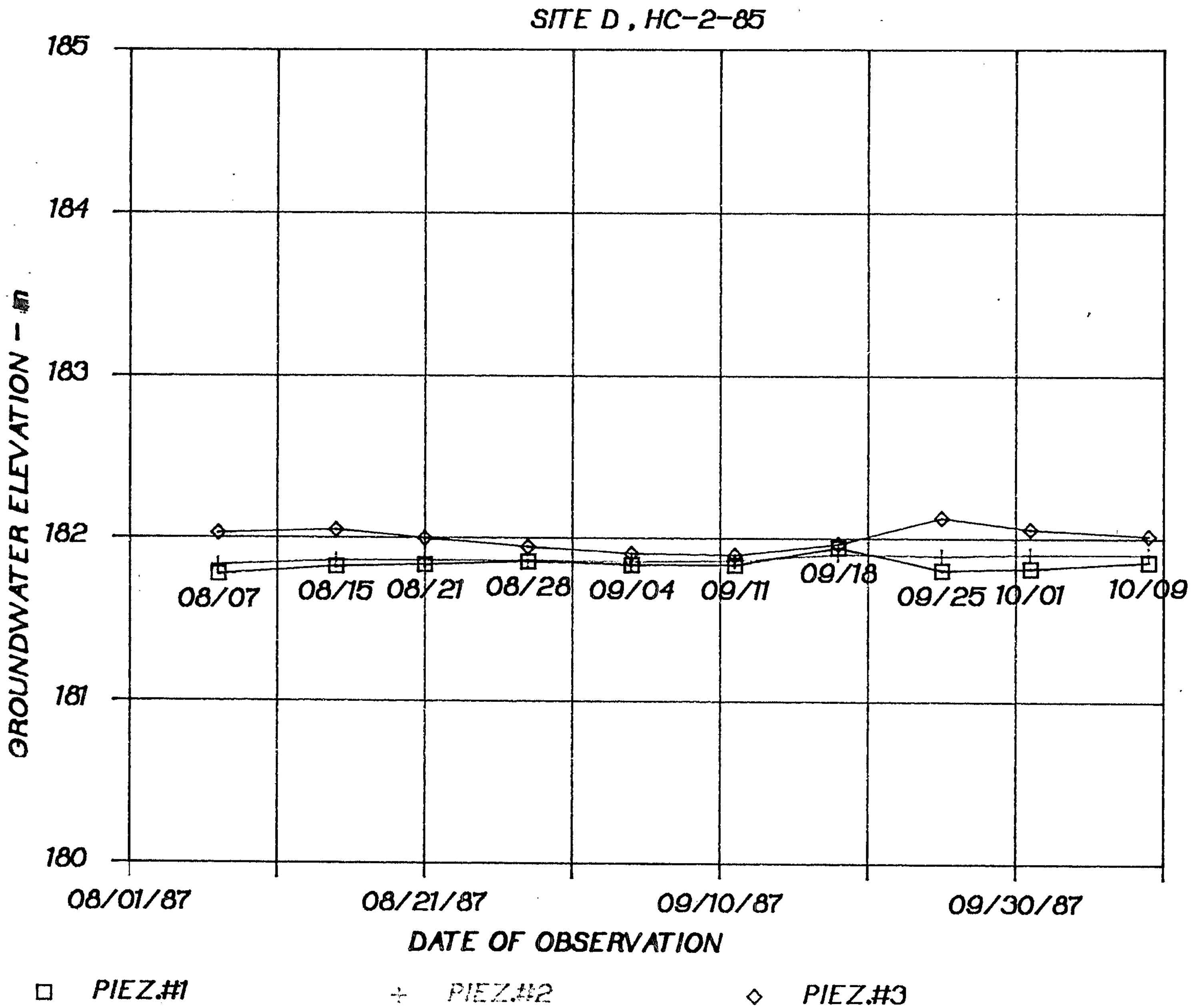
HYDROGRAPHS FOR

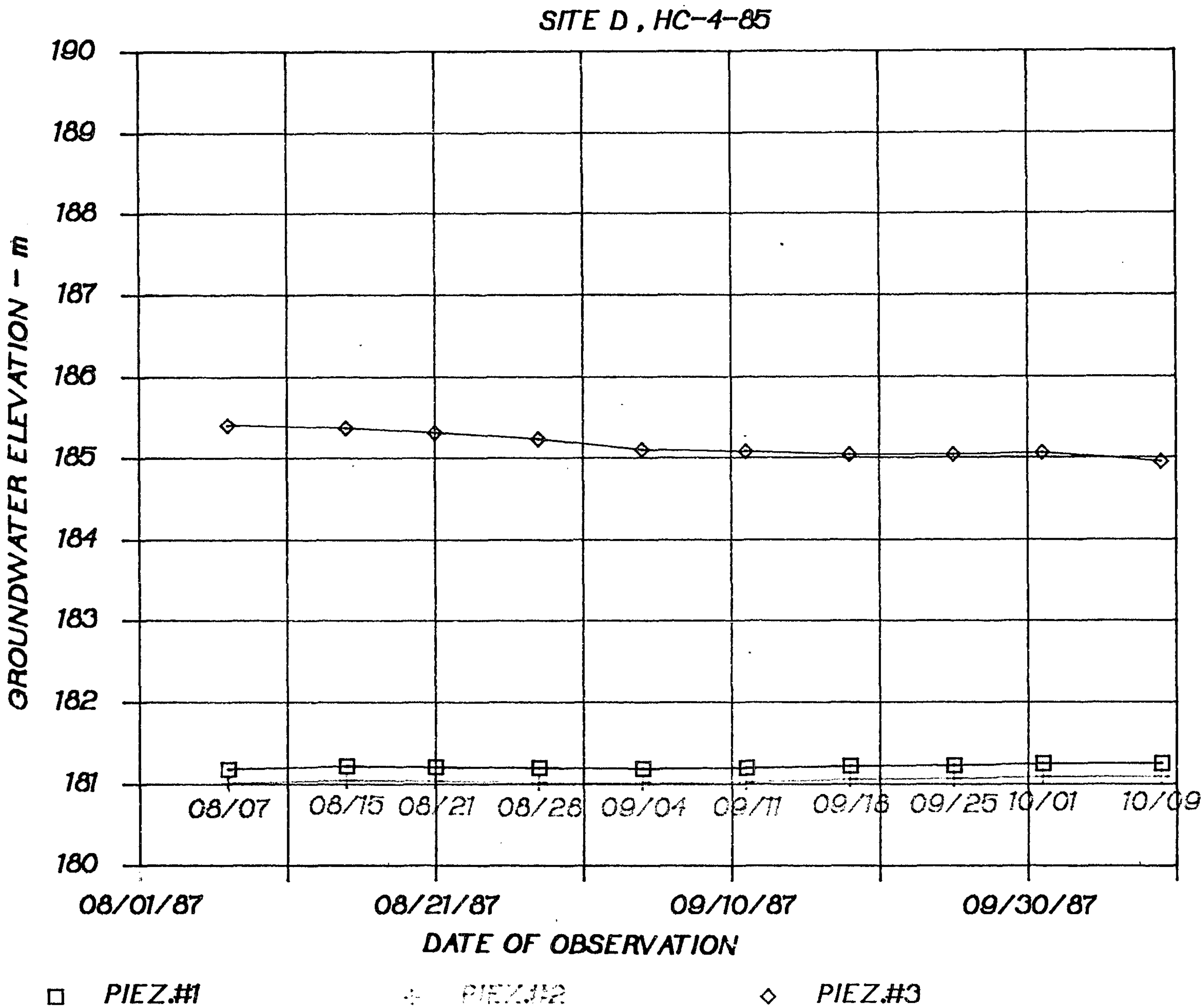
SELECTED BOREHOLES, 1987

SITE D, MILTON

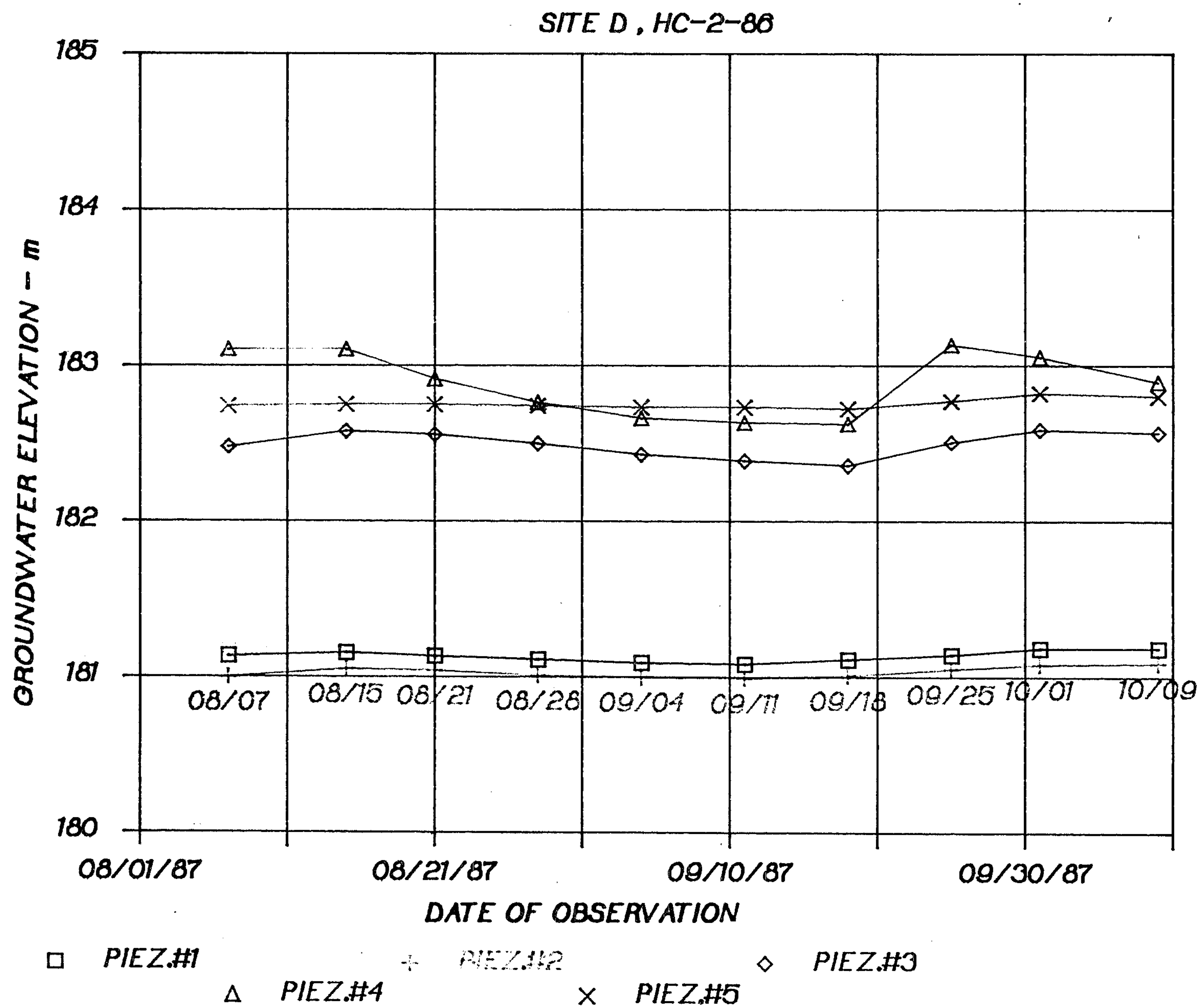


SITE D , HC-1-85
185
184
183
182
181
180
GROUNDWATER ELEVATION - m
08/07
08/15
08/21
08/28
09/04
09/11
09/18
09/25
10/01
10/09
08/01/87
08/21/87
09/10/87
09/30/87
DATE OF OBSERVATION
PIEZ.#1
PIEZ.#2
PIEZ.#3
PIEZ.#4

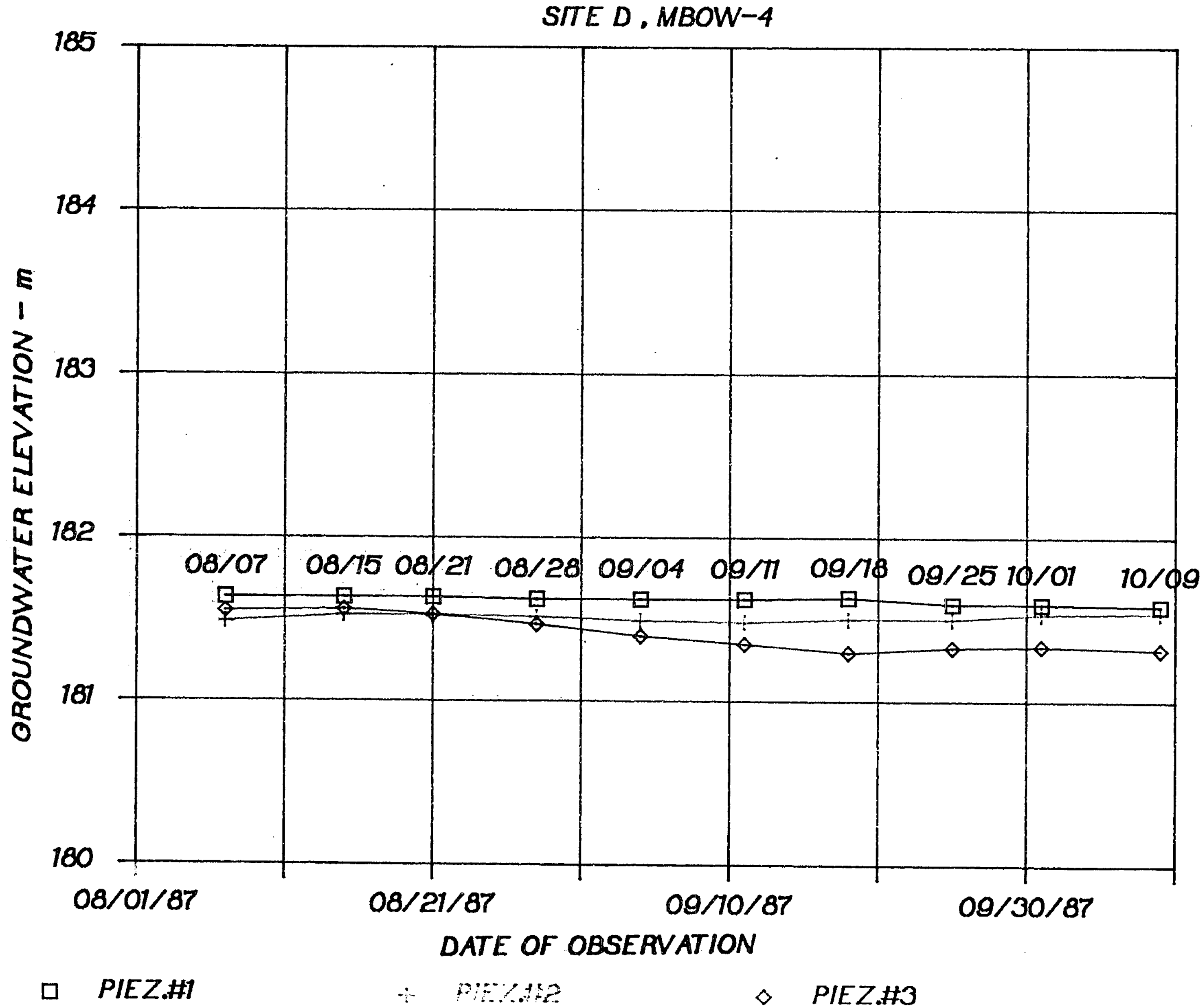

SITE D , HC-2-85
185
184
183
182
181
180
GROUNDWATER ELEVATION - m
08/07
08/15
08/21
08/28
09/04
09/11
09/18
09/25
10/01
10/09
08/01/87
08/21/87
09/10/87
09/30/87
DATE OF OBSERVATION
PIEZ.#1
PIEZ.#2
PIEZ.#3



SITE D , HC-4-85
GROUNDWATER ELEVATION – m
190
189
188
187
186
185
184
183
182
181
180
08/07
08/15
08/21
08/28
09/04
09/11
09/18
09/25
10/01
10/09
08/01/87
08/21/87
09/10/87
09/30/87
DATE OF OBSERVATION
PIEZ.#1
PIEZ.#2
PIEZ.#3

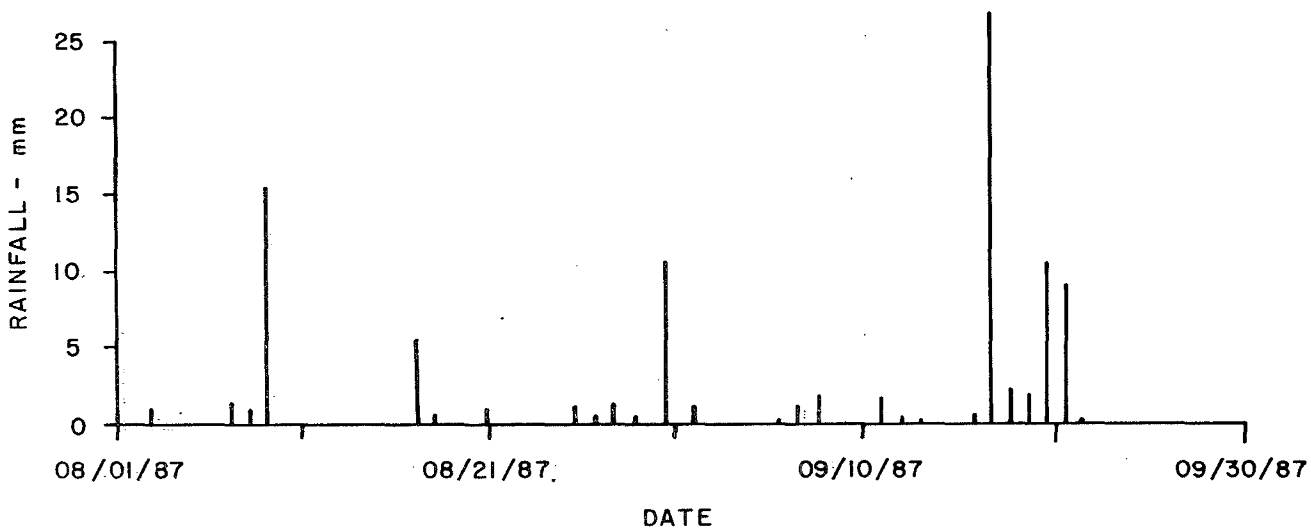


SITE D, HC-2-86
185
184
183
182
181
180
GROUNDWATER ELEVATION - m
08/07
08/15
08/21
08/28
09/04
09/11
09/18
09/25
10/01
10/09
08/01/87
08/21/87
09/10/87
09/30/87
DATE OF OBSERVATION
PIEZ.#1
PIEZ.#2
PIEZ.#3
PIEZ.#4
PIEZ.#5



SITE D , MBOW-4
185
184
183
182
181
180
GROUNDWATER ELEVATION – m
08/07
08/15
08/21
08/28
09/04
09/11
09/18
09/25
10/01
10/09
08/01/87
08/21/87
09/10/87
09/30/87
DATE OF OBSERVATION
PIEZ.#1
PIEZ.#2
PIEZ.#3

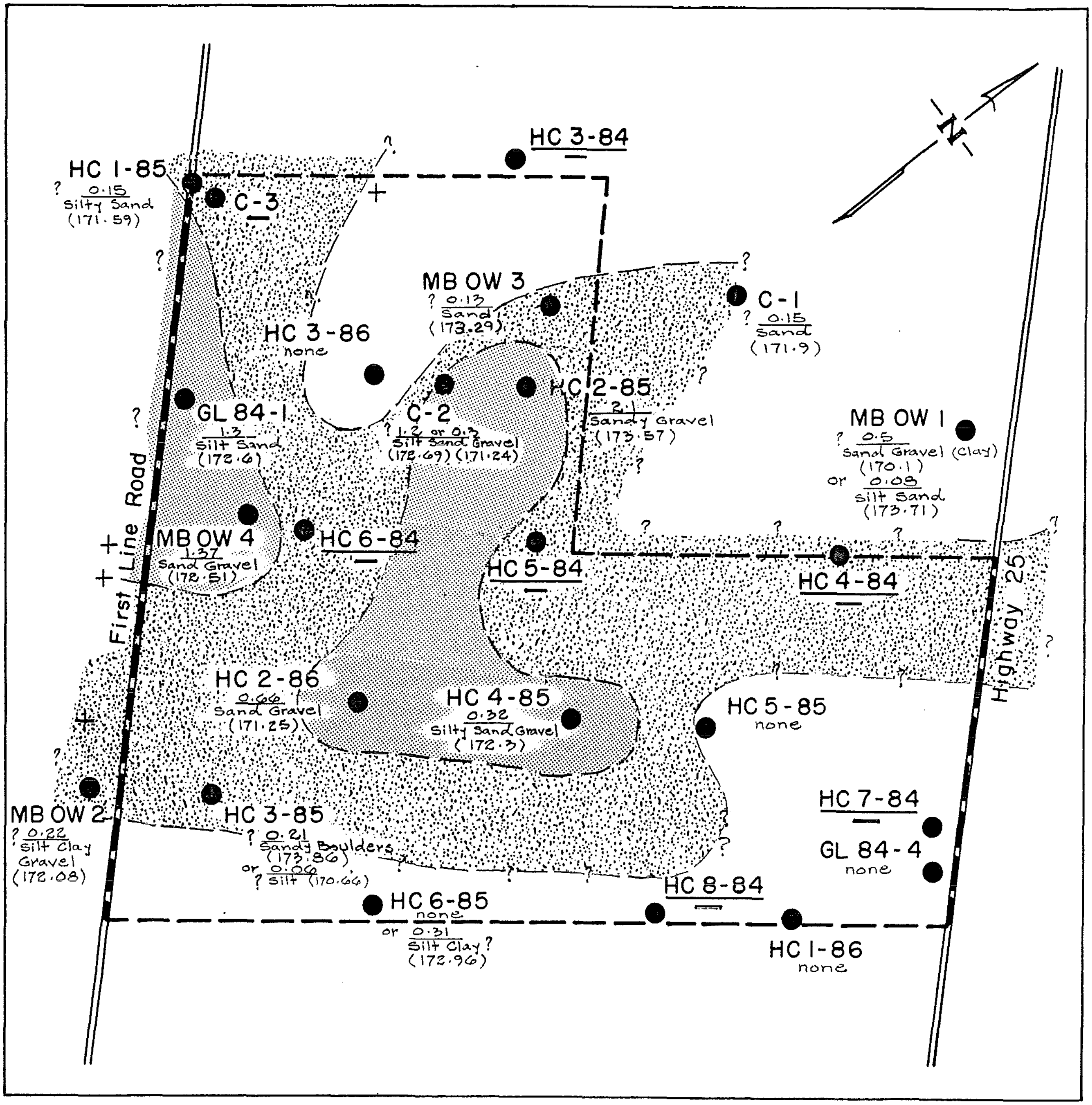
lower piez.



TOTAL DAILY RAINFALL, HORNBY ONTARIO

August and September, 1987

figures



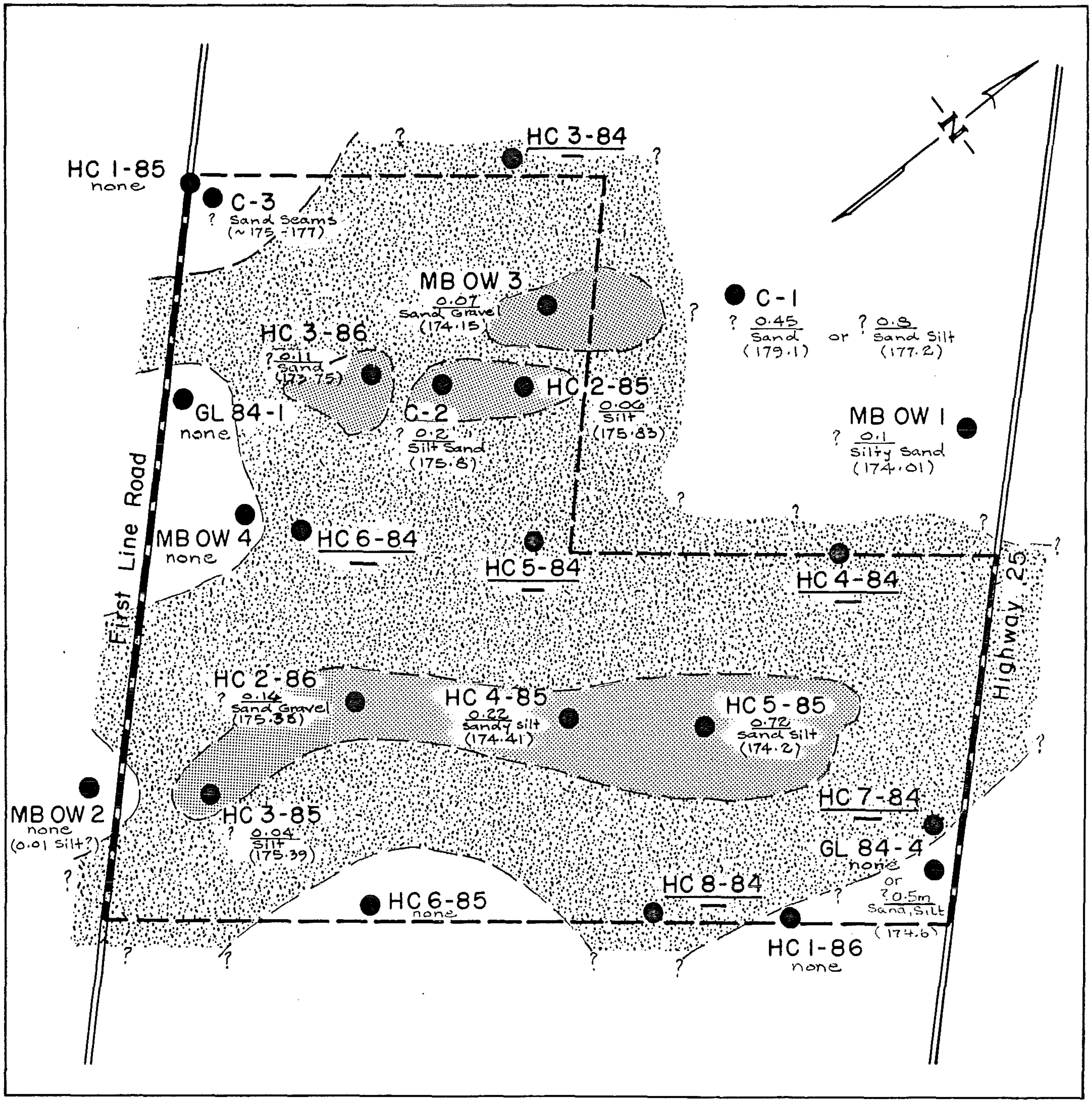
LEGEND

● Boreholes

HC	Hydrology Consultants Ltd.	.1	Thickness in metres
GL	Gartner Lee Assoc. Ltd.	Sand	Texture
MB	Morrison Beatty Ltd.	(174.5)	Elevation in metres of top of contact (estimated for GL Boreholes)
C	Comcor Ltd.	——	No data
HC-84	1.5 m sampling interval	?	Questionable data/interpretation
+	water well; possibly in granular unit	(light stipple)	Inferred minimum extent of unit
		(dense stipple)	Inferred maximum extent of unit

FIGURE 6 : EXTENT OF UPPER GRANULAR UNIT
SITE D, MILTON

Scale 1:10 000 approx. Borehole Locations from HCL Dwgs 2, 5

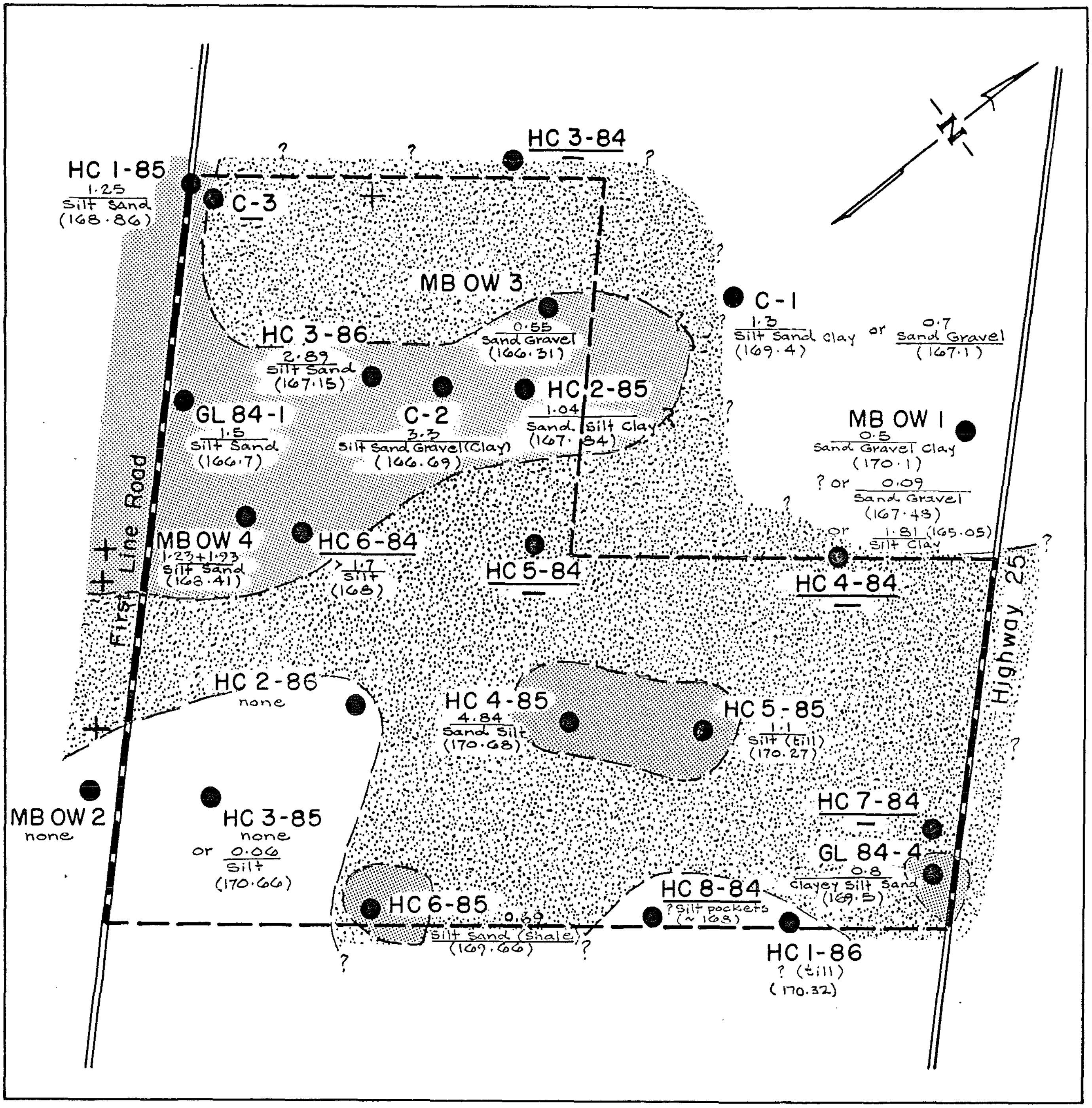


LEGEND

●	Boreholes	.1	Thickness in metres
HC	Hydrology Consultants Ltd.	Sand	Texture
GL	Gartner Lee Assoc. Ltd.	(174.5)	Elevation in metres of top of contact (estimated for GL Boreholes)
MB	Morrison Beatty Ltd.	—	No data
C	Comcor Ltd.	?	Questionable data/interpretation
HC-84	1.5 m sampling interval		Inferred minimum extent of unit
			Inferred maximum extent of unit

FIGURE 7 : EXTENT OF 'SILT' LAYER
SITE D, MILTON

Scale 1:10 000 approx. Borehole Locations from HCL Dwgs 2,5



LEGEND

●	Boreholes	.1	Thickness in metres
HC	Hydrology Consultants Ltd.	Sand	Texture
GL	Gartner Lee Assoc. Ltd.	(174.5)	Elevation in metres of top of contact (estimated for GL Boreholes)
MB	Morrison Beatty Ltd.	—	No data
C	Comcor Ltd.	?	Questionable data/interpretation
HC-84	1.5 m sampling interval	(light shading)	Inferred minimum extent of unit
+	water well; possibly in granular unit	(stippling)	Inferred maximum extent of unit

FIGURE 8 : EXTENT OF LOWER GRANULAR UNIT
SITE D, MILTON

Scale 1:10 000 approx. Borehole Locations from HCL Dwgs 2,5