Ex. M-437.

Review of Hydrogeological Report on Site F – Burlington, Proposed Landfill Region of Halton

Report to

David Estrin, Barristers and Solicitors for the Town of Milton

October 1987
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Geocon
Lavalin

Geocon

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1987 November 09

David Estrin
Barristers and Solicitors
22 Scollard Street
Toronto, Ontario

Attn: David Estrin

Dear Sir:

Review of Proposed Landfill Sites D and F, Region of Halton

We are pleased to submit this report on our review of the proposal by the Region of Halton to locate a landfill at Site F in the City of Burlington.

This document is to accompany the similar report which we recently submitted for Site D in the Town of Milton.

Yours sincerely,

David L. Charlesworth, Ph.D.
Consulting Hydrogeologist

Lavalin

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SUMMARY

what about surface water — ??

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Groundwater at Site F occurs within both a shallow, active system in the surficial deposits and the upper weathered zone of the Queenston Shale, and also as a deeper flow system within the shale. 2

The shallow system is of limited extent with water re-appearing at the surface within relatively short distances, as base flow to the streams or seepage to the limited wetlands.

The deeper water is part of a slow, sluggish flow system in which groundwater makes its way to Hamilton Harbour and in which the groundwater has been shown conclusively to be highly saline, with chloride concentrations frequently exceeding modern sea water. Indeed the groundwater in the Queenston shale, in this area, does not constitute a viable resource for domestic, municipal or industrial use. [In fact, it's greatest value may be in the area of waste disposal.] — use the environment as a disposal site philosophy.

The salinity of the groundwater in the shale is most probably derived from the sea in which the sediments were originally deposited hundreds of millions of years ago.

The proposed Site F is bounded on either side by landfills the oldest of which, the Bayview Park Landfill which lies to the east, first received

57 waste almost 30 years ago. That landfill is now closed but the other, the Burlington Landfill, located to the west of proposed Site F, is still in use.

A number of studies have been carried out in an attempt to define the extent of groundwater contamination at the two existing sites. After reviewing the results of these investigations we have concluded that there is no evidence of unacceptable off-site migration of contaminants from the sites through the groundwater regime.

Trow, in their study of Site F, placed considerable emphasis on their computer modelling and, in the light of the results obtained, concluded that there is a significant discharge zone from the shale to the surface, south of Highway 403. We are of the opinion that water which has moved to depth in the shale will not discharge here, but will flow south to Hamilton Harbour. Differs re flow

There is little use of groundwater south of the proposed site and municipal water is available. Where a limited shallow groundwater resource may exist in the surficial deposits it is not placed at risk by the existence of the present or proposed landfills on the south slope of the Niagara escarpment.

The very limited extent of poorly defined contaminant plumes from the existing landfills has been shown by the recent work of Dr. Rowe to be due to the better than expected attenuation capacity of the Queenston Shale. This conclusion is based on a more rigorous computer modelling of contaminant transport than that carried out by Trow.

With a gravity fed leachate collection system, greater slopes on the landfill base, naturally poor groundwater quality, no essential water supplies being placed at risk and a proven track record from existing landfills, it is our opinion that Site F is clearly preferable to Site D as the location for a regional landfill.

1. INTRODUCTION

Geocon were 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 Site D in the Town of Milton and Site F, in the City of Burlington, as both being suitable for the siting of a landfill.

The various reports which constitute the hydrogeological component of the above study were reviewed, along with numerous documents prepared by other consultants and research workers. A small amount of original field work was undertaken by Geocon.

For a hydrogeologist this area is interesting for a number of reasons. The groundwater is highly saline, the groundwater flow regime exists predominantly in a fractured medium, and two existing landfills serve as test cases for an examination of possible impacts of a proposed landfill.

The area in the vicinity of the proposed Site F has been extensively studied in recent years, due to the existence of the Burlington and Bayview Park landfills. Various study teams, from the consulting and academic worlds, have carried out drilling and water sampling programs in order to determine the geological and hydrogeological conditions in the area, and the extent of contamination from the existing sites.

predictability
monitoring
time factor

From the results of the various investigations a good understanding of the sub-surface conditions, in a general context, has been obtained. Although there are different interpretations of the details of the groundwater regime, the majority of reviewers have concluded that landfilling in this area does not pose a threat to the environment. We agree with that opinion. The fact that this is based primarily on observations of existing landfills lends particular weight to the conclusion that this site is safe for landfilling.

Our review of the Trow study of Site F has led us to the conclusion that their detailed interpretation of the hydrogeological regime is inaccurate. Nevertheless, it is our opinion that sufficient data exists for the vicinity of Site F, primarily from the studies of the existing sites, to conclude that a new landfill at this location will have little significant impact on the environment due to the treatment of contaminants in the groundwater regime.

2. PHYSIOGRAPHIC AND GEOLOGICAL SETTING

The site is located on the south slope of the Niagara escarpment and is marked by the extensive development of gullies and ravines. It is located on the deeply eroded edge of the Halton Till Plain and the surficial deposits consist of either Halton Till, which covers the northern and southern parts of the site, or lacustrine deposits which overlie the Halton Till to the south of Site F.

The till is predominantly silt to clayey silt and its occurrence is generally more continuous in the northern part of the site. The gully erosion which trends in a southerly direction has left generally linear outcrops of the till on the crests of the ridges.

Underlying the till, and extensively exposed on site, are argillaceous shales of the Queenston Formation which are predominantly brick red in colour, though greenish bands are reported to make up approximately 20% of the succession (Ref. 1).

The shales are fractured to varying degrees beneath the site and contain nodules and veins of gypsum, though Trow (Ref. 1) estimate that these make up less than 1 per cent of the rock mass.

Moving southward from the site the Queenston Shale dips beneath the surficial deposits which extend to Lake Ontario. These consist of Halton Till overlain by lacustrine sands.

Trow present a "Local Categorization of the Queenston Formation Based on Distribution of Fractures" in which they identify four zones within the shale, as shown on their Figure 2 (reproduced here as Figure 2) and described generally by the degree of fracturing or weathering. They subsequently define the succession on a hydrostratigraphic basis and present a summary on their Figure 4 (Figure 3).

What is particularly confusing for readers of the Trow report is that they maintain the same names for the hydrostratigraphic units within the Queenston shale as they used for the categorization based on fractures. However, as was revealed in cross-examination, they have redefined the contacts, so that they do not necessarily conform to the "Local Categorization" shown on their Figure 2. It should be noted that the surficial deposits within the vicinity of the site are considered by Trow as one hydrostratigraphic unit which they sub-divided into a "Till Unit" and a "Discharge Zone Till".

As will be discussed later, we are of the opinion that Trow have presented a hydrostratigraphic classification of the shale which is too rigorous to be supported by the available data.

FIGURE 2

LOCAL CATEGORIZATION OF THE
QUEENSTON FORMATION
BASED ON DISTRIBUTION OF FRACTURES
(after Trow,Ref.1)

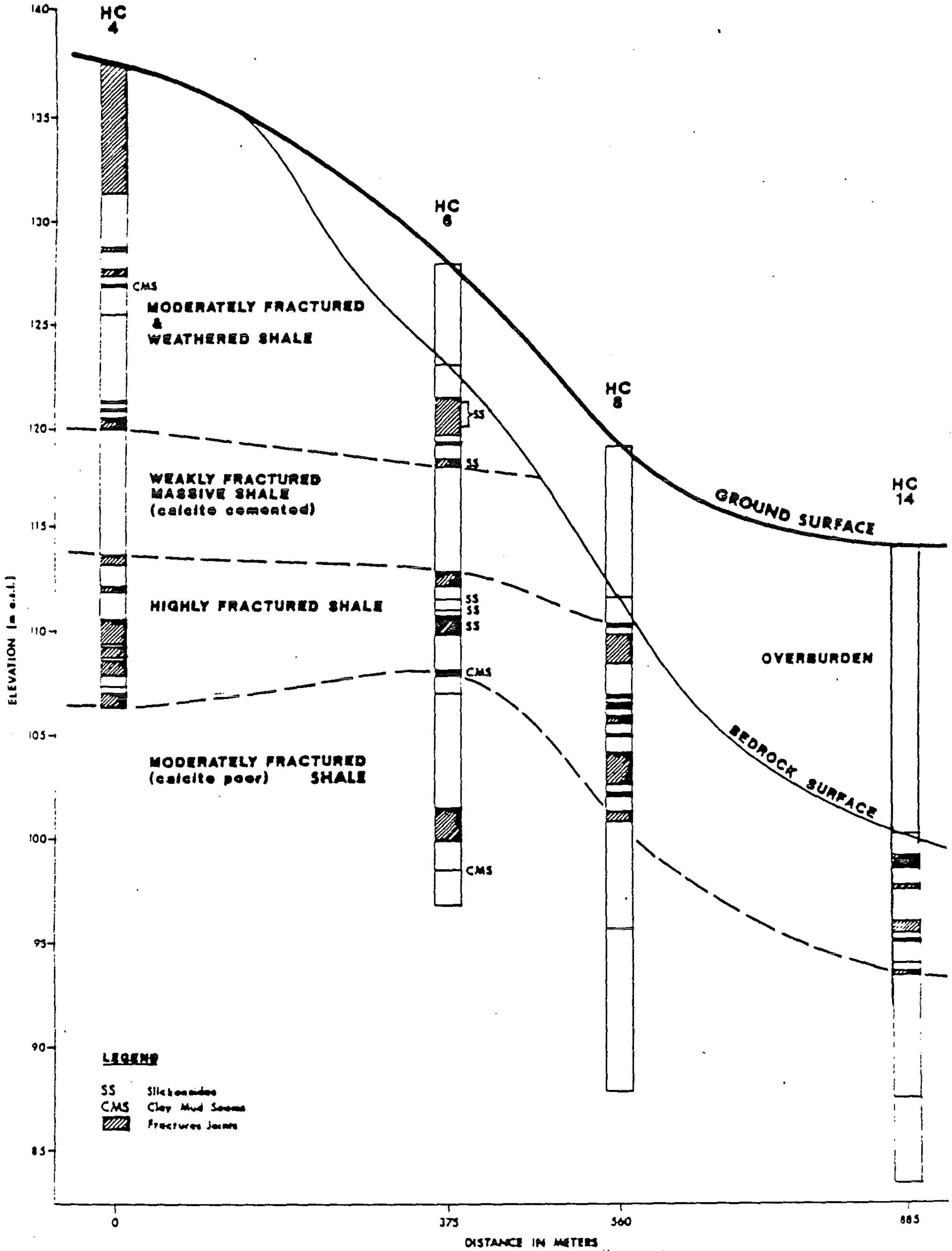
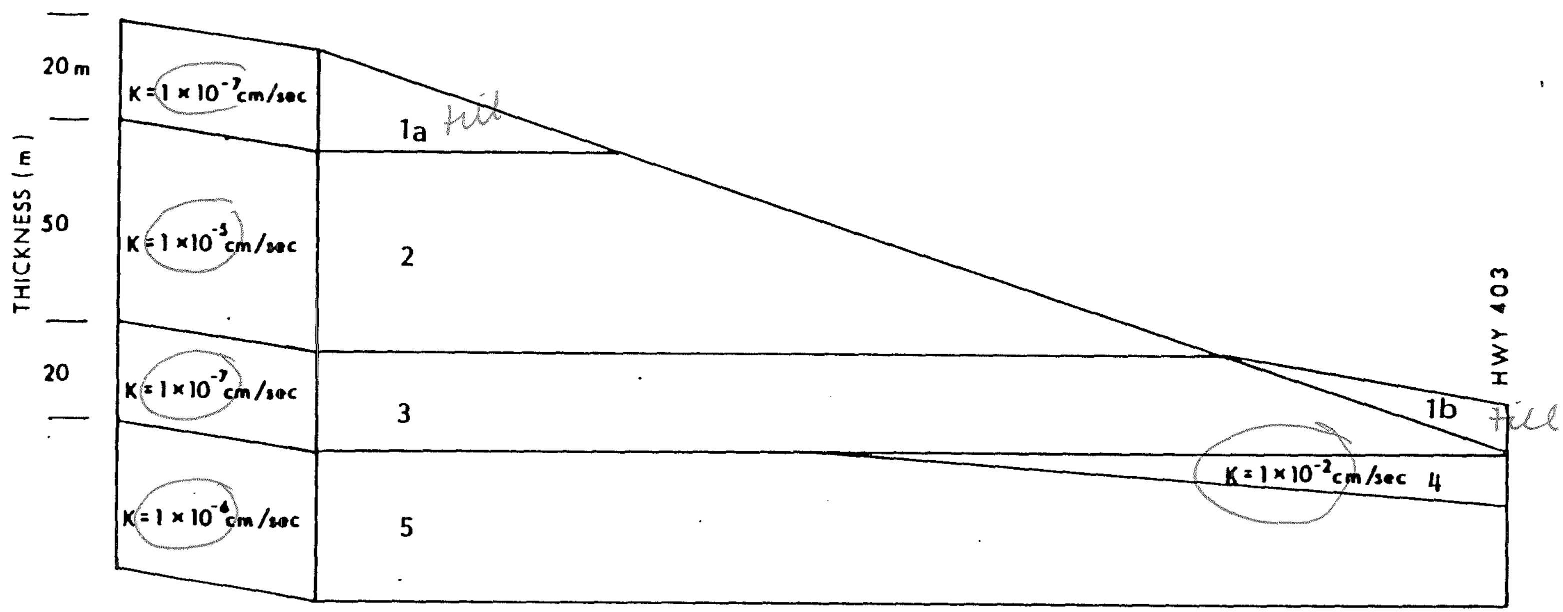


FIGURE 3

<u>SUMMARY OF HYDROSTRATIGRAPHIC UNITS</u>

(after Trow, Ref.1)



1) OVERBURDEN
   a) TILL UNIT
   b) DISCHARGE ZONE TILL
2) FRACTURED SHALE UNIT - HIGHLY WEATHERED AT SURFACE
3) WEAKLY FRACTURED MASSIVE SHALE UNIT
4) HIGHLY FRACTURED SHALE UNIT
5) MODERATELY FRACTURED BULK SHALE UNIT

3. GROUNDWATER OCCURRENCE AND USE

Groundwater occurs beneath the site in both the overlying till, where the till is present, and in the shale bedrock. The depth to the water table is reported by Trow as varying between 0.15 and 2.9 m, though it is probably deeper beneath the crests of the ridges.

On a regional scale the water table slopes generally in a southeasterly direction towards Hamilton Harbour but, on a local scale it slopes towards the streams which drain the area.

Just north of the site the elevation of the water table is 185 m and this drops to 115 m in the vicinity of Highway 403. From there it slopes more gently towards Hamilton Harbour where it is at an elevation of 75 m.

In the northern and southern parts of the site the water table, or top of the zone of saturation, is located within the surficial deposits, whereas in the central portion of the site, where the shale is exposed at the surface, the water table occurs within the rock.

Trow present a map showing the location of known water supply wells on the study area (Ref. 1, Drawing 2) and state that no residential users were identified downgradient of Site F. However a survey, following information from a local resident, led them to conclude that there were three wells currently being used for local consumption and two for limited outdoor use on a seasonal basis. They state that all these households are on municipal supply.

Assuming the results of a more recent survey, submitted by the Canadian Environmental Law Association, are proved accurate, they would not significantly change the situation with regard to groundwater use downgradient of the site.

The only source of acceptable groundwater in the downgradient area is a fresh water lens within the surficial deposits, which overlies the deeper more saline waters discussed below. Given the degree of urbanization it would be optimistic to consider this shallow fresh water lens as a future source of good quality water. In addition, any attempt to develop it on a large scale, even if yields and quality were adequate, would probably lead to the upwelling of deeper saline waters from the underlying shale thus rendering it unusable.

4. GROUNDWATER MOVEMENT

4.1 Hydraulic Gradients

In reviewing the results of the various investigations carried out in the study area it becomes apparent that there is some general agreement about groundwater movement, though there are differences with regard to detail.

not all MB-upward at one time

Most investigators agree that there are downward gradients beneath the site, indicating recharge conditions, and that a component of recharge goes to a deep flow system within the shale bedrock. There is also general agreement on the existence of a shallow active system within the overburden or shallow bedrock, with movement in the upper few metres, which discharges to the surface water drainage channels or swampy areas.

Estimates of the depth of the shallow flow system vary though Morrison Beatty suggest that 88% of the groundwater movement occurs within the upper 3 metres (Ref. 2) and that the shallow flow system in total is restricted to the upper 15 m (Ref. 3).

Within a rock such as the Queenston Shale the secondary permeability (i.e. the system of fractures and joints) will play a larger role in the movement of contaminants than the primary permeability (i.e. the pore space within the rock). Further, the main mechanism of transport for contaminants in the water, through the fracture system, will be the flow of the groundwater itself (i.e. advection).

Trow's interpretation is that there is a wedge of highly fractured shale (the" Highly Fractured Shale Unit") which acts as an underdrain to the flow system and which extends from about the mid-point of the proposed landfill site, beneath their Weakly Fractured Massive Unit, to about 500 m south of Highway 403. They postulate that south of the 403 there is a discharge zone where water from the Highly Fractured Shale Unit discharges upwards through the surficial deposits.

In describing the vertical gradients Trow say that there are strong downward vertical gradients beneath Site F and that the vertical gradients "are generally lateral to weakly upwards between the drilling sites HC-9-85 and HC-14-85 (south of the site) and (HC-13-85) near to Hamilton Harbour". An examination of the data presented on Trow's stratigraphic cross-sections in their report (Ref. 1) helps in assessing the validity of their interpretation.

It is our conclusion that downward gradients do indeed predominate within the vicinity of the site, but we also note that even downgradient, between Hwy. 403 and Hamilton Harbour, where lateral gradients are believed to predominate, downward gradients do still occur within the shale.

what about upward gradients

Looking at Trow's regional section A-A (Ref. 1, Drawing 6) and local cross-section A-a (Ref. 1, Drawing 8) it can be seen that the vertical gradients north of the site and in the centre of the site are downwards, whereas at the southern end of the site (HC-6) the gradients are downward in the upper and lower portions of the borehole, but are horizontal in the mid-portion. The downward gradient in the upper portion is between a standpipe in the till and a piezometer in the shale. The section of the borehole with horizontal gradients corresponds to their Weakly Fractured Shale and Highly Fractured Shale (as defined by their fracture logging, i.e. their Figure 2). Their hydrostratigraphic definition of the Highly Fractured Zone corresponds more closely to the lower section of the borehole, i.e. the portion with downward gradients.

?

If there is a highly fractured zone acting as an underdrain then it would be expected that vertical gradients would be less in that zone. This suggests that, at least in the vicinity of borehole HC-6, the zone definition based on the fractures is probably more realistic.

A short distance to the south the Waterloo borehole WAT-7 can be laterally projected onto the section and here the vertical gradients can be seen to be much more complex. They consist of downward gradients in the upper zones, with upward, downward and lateral gradients in the intermediate and deep zones. In this, and other Waterloo boreholes this complex pattern may be due to the detail afforded by the greater number of piezometers, or alternatively it may reflect leakage in the installations, which are all in one borehole.

The Morrison-Beatty hole MB-13, located further south, shows only downward gradients, although the instrumentation in this consists of only three piezometers and it is thus less likely to pick up subtle changes in gradient.

HC-9 located south of Highway 403, has horizontal gradients in the upper zone and downward gradients in the lower portion of the borehole.

Moving south towards Hamilton Harbour, HC-10 has upward gradients in the surficial deposits and horizontal in the upper portion of the shale.

how ignore this

HC-12 also has horizontal gradients in the upper part of the shale, but there is an apparent upward gradient in the lower part of the borehole. The lack of detail over the lower section precludes an accurate assessment of the vertical gradients.

Close to Hamilton Harbour HC-13 shows an upward gradient between the two upper piezometers and a downward gradient between the lower of these and the bottom piezometer.

As part of the present review two additional cross-sections were prepared, using data presented in the Trow report or data from other earlier studies. These sections have been designated G-G' and H-H' and their locations are shown on Figure 1.

Section G-G' (Figure 4) starts in the northern part of the existing Burlington Landfill and extends throughout the proposed Site F down to south of Highway 403 in the vicinity of borehole HC-14.

The two Gartner Lee boreholes, at the northern end of Section G-G', both show downward gradients and borehole HC-3, further south in the centre of the site, has generally downward gradients but with a more or less horizontal zone in the mid-portion, which roughly corresponds to a fractured zone in the borehole.

Borehole HC-8 just south of the proposed landfill has horizontal to slightly upward gradients in the upper part of the shale and downward gradients to the bottom, over the major portion of the borehole. The downward gradients appear to correspond to Trow's Highly Fractured Zone.

South of Highway 403, at borehole HC-14, the gradient in the upper part of the borehole (i.e. in Trow's Highly Fractured Unit) is downwards. In the deeper part of the borehole the gradient is more or less horizontal.

Cross-section H-H was prepared by Geocon in order to review the hydrogeology along a line extending downgradient through the Bayview Park Landfill. From this it can be seen that north of Bayview Park, at Morrison Beatty borehole MB-6, there is a downward gradient in the upper part of the borehole and an upward gradient in the lower part of the borehole.

In the Waterloo boreholes, located in a line downgradient of the site, the pattern is somewhat complex, with combinations of upward, downward and horizontal gradients.

During a field visit earlier this year it was observed that the intermediate piezometer in MB-11 was flowing, thus clearly demonstrating an upward gradient.

Trow's regional section B-B (Ref. 1, Drawing 7) extends from the northern limit of Site F to Hamilton Harbour and shows predominantly downward gradients in the vicinity of the site, with an upward gradient in the upper part of the shale at HC-8, located close to Indian Creek north of Highway 403. South of the 403, at HC-14, there appears to be a slight downward gradient at the overburden shale contact and a horizontal gradient below that. Moving south towards the Harbour there is an upward gradient in the vicinity of HC-11, from the shale to the overburden, and downward gradients at HC-16, close to the Harbour.

While reviewing the vertical gradients it is worth looking at Trow's section F-F (Ref. 1, Drawing 10), which runs perpendicular to the sections described above. It is located south of the 403, in area close to that identified by Trow as the discharge zone from their Highly Fractured Zone.

In borehole HC-15 it can be seen that the gradients are downward in the upper part of the shale and horizontal in the lower part of the borehole. The downward gradients appear to correspond to the Trow's Highly Fractured Zone.

In borehole HC-14 the vertical gradient in the upper part of the shale, in the Highly Fractured Zone, appears to be downwards, and horizontal at depth.

As discussed earlier, HC-9 has essentially horizontal or slightly downward gradients in the till and the upper part of shale and downward vertical gradients below that.

As part of the present study Geocon monitored water levels in the nests of piezometers installed at eight locations from August and October, 1987 and the results are plotted as hydrographs in Appendix A.

The pattern of vertical gradients recorded in boreholes HC-3, HC-5 and HC-8 during the present study were similar to those given by Trow. In the case of HC-6, the pattern was initially the same, although the last two readings saw the water level rise in the lowest piezometer to an elevation slightly above the water level in Piezometer No. 2. There is no obvious reason for this.

The water levels in borehole HC-9 showed a similar pattern to that depicted by Trow, with very small to non-existent gradients in the upper three piezometers and a stronger downward gradient between the two deepest piezometers. A close examination of the hydrographs for the upper three piezometers shows that the vertical gradients actually changed from being slightly downward to slightly upwards.

It can be seen from the hydrograph for the deepest piezometer (No. 4) that sometime in August someone (possibly as part of a monitoring program) removed water from the hole. After five weeks the water level had not fully recovered, indicating that this piezometer is set in a poorly permeable part of the shale.

In the case of HC-14 the vertical gradients, for most of the monitoring period, were consistently downwards without the near horizontal pattern exhibited in the Trow cross-sections. However, towards the end of the monitoring period, Piezometers 2 and 3 had water levels which were essentially the same.

HC-15, for the Geocon monitoring period, showed consistently downward gradients, rather than the horizontal gradient in the lower portion of the hole, as shown at the time that Trow collected the data on Section F-F. Here again the apparent effects of sampling are obvious in some of the piezometers.

The apparent pattern in WAT-7 is of downward gradients from the surface to Piezometer 4 and then upward gradients from Piezometers 4 to 7. Below this depth the gradient is again downwards to Piezometer 8, below which the picture is complicated by the question of how well the piezometers are actually working. Distilled water was introduced to Piezometers 9 and 10 in order to test them and it can be seen that the rate of recovery from that was extremely slow, suggesting that the piezometers may be blocked.

In summary, this review of the water level data suggests that downward gradients predominate at Site F, and even to the south of the site, though there are local complexities which probably vary on a seasonal basis in the case of the shallow flow system.

at that location

Close to the area in which Trow postulate that there is a discharge zone, i.e. south of the railroad tracks, their monitoring holes do not show upward gradients from the shale. Thus, unless there is a reversal of gradients within a relatively short distance, the idea of a discharge zone appears somewhat doubtful. at that location

Between the CN tracks and Hamilton Harbour there are, at a number of locations, upward gradients within or into the surficial deposits. However, based on the water quality data, there is no evidence of discharges at the surface from the regional (saline) flow system in the shale.

The vertical gradients do not appear to support Trow's contention that the zone which they have defined as the Highly Fractured Shale Unit is a significant underdrain to the system.

4.2 Hydraulic Conductivity

The work of Morrison Beatty (Refs. 2 and 3) indicated that there was a decrease in hydraulic conductivity with depth, from 10^{-3} cm/sec at the weathered surface, to 10^{-7} cm/sec at depth. Hewetson (Ref. 4) derived values which were generally lower that Morrison Beatty's and concluded that there was no decrease with depth. Her range of values was 1.8×10^{-4} to 2.3×10^{-10} cm/sec.

Gartner Lee in their early work in this area (Ref. 5) had a range of values from 2×10^{-5} to 7×10^{-7} cm/sec and their average value was 5×10^{-6} cm/sec. In their plume delineation study Gartner Lee (Ref. 10) obtained values in the range of 4×10^{-4} to 2×10^{-6} cm/sec. and in their study for the continued use of the Burlington Site (Ref. 7) they adopted a value of 5×10^{-6} cm/sec.

Trow, in their study of Site F, cite the largest range of values, namely 10^{-2} to 10^{-7} cm/sec. However the high value in that range, which is an order of magnitude greater than that obtained by other workers, was derived from a pumping test; at this point it should be noted that we have reservations about an assumption made in the derivation of this value and believe that it could be an order of magnitude less. but still high

In summary it can be said that there is doubtless a range of hydraulic conductivity values in the shale, and that it is controlled in the main by the degree of fracturing. In view of this, Morrison Beatty's conclusion that it tends to decrease with depth seems reasonable although later data has thrown some doubt on this conclusion. Our examination of the Trow data suggest that their argument for redefining their hydrostratigraphic units on the basis of the hydraulic conductivities is somewhat tenuous. In addition, the value which they derived from the pumping test for their highly fractured unit could be at least an order of magnitude too high because of the value they assumed for the saturated thickness of the water-bearing formation.

not address pumping tests as better tests

can you use just one value

In our opinion 4.5×10^{-6} cm/sec., as used by Dr. Rowe in his modelling, is a reasonable value, in the light of the data quoted above. Given that there is some evidence of decrease in k with depth, this value is particularly conservative for the deep system.

4.3 Porosity

The effective porosity of the Queenston Shale will be a function of the fractured nature of the rock, and this has generally been taken into account in the various studies of this general area. The range of values quoted by the different workers has varied.

faster smaller faster vel

Trow (Ref. 1) assumed a value of 0.001 for the fractured weathered shale, whereas Gartner Lee (Ref. 5) quote 5% or .05 for the porosity of the shale.

Hewetson (Rev. 4) obtained values for fracture porosity based on an estimate of the fracture aperture in the rock. Using the method described by Snow (1968) she derived a range for the porosity of 0.007% to 0.1%. The highest value (0.1%) was encountered in the shallow weathered rock and the lower values tended to be for the deeper horizons. The range of values for fracture porosity derived by Hewetson was based on fracture apertures from 1 to 50 µm. The geometric mean of Hewetson's values is 0.002%. Dr. Rowe, in his modelling of Site F for the Town of Milton performed a series of analyses for porosities ranging from 0.0001 to 0.01 and concluded that, essentially, the fracture porosity has little effect on the contaminant plume for a given flow per unit area through the fracture system.

4.4 Groundwater Velocity

A range of lateral groundwater velocities were given in the various studies of the area. Gartner Lee (Ref. 6) quote a range of 1 to 15 metres/year and in a later report (Ref. 7) they conclude that the flow is in the order of 15 m/year.

Cherry and Hewetson (Ref. 11) suggest that the average linear groundwater velocity could vary from 6 to 130 metres/year depending on whether they use the earlier or later results from their response tests to calculate hydraulic conductivity. They suggest that the high value represents an upper limit to the rate of groundwater movement and that it represents fracture flow. Trow (Ref. 1) quote the range of values given by Cherry and Hewetson of 6 to 130 metres/year. Dr. Rowe after carrying out a range of calculations using different groundwater velocities, concludes that the result of the Burlington Landfill Plume Delineation Studies (Ref. 10) carried out by Gartner Lee are most consistent with calculations performed using an average lateral flow per unit area of 0.05 m/a which, assuming an effective porosity of 0.001, corresponds to an average linear groundwater velocity of 50 m/year.

5. GROUNDWATER CHEMISTRY

5.1 Background Patterns

what Halton art water generally

The distinctive feature of the groundwater chemistry in the vicinity of Site F is the high salinity of the water in the Queenston Shale. This is most probably connate water, which has been in the rock since the deposition of the sediments, and its presence is indicative of a slow sluggish groundwater regime.

There is a distinct pattern of increasing chloride with depth within the rock at this location, indicating that in the shallow zone, there has been some flushing of the original water by the recharge from modern precipitation. However, this effect does not seem to extend to any great depth.

Morrison Beatty (Ref. 2) reported dramatic increases in the concentration of sulphate, chloride, calcium, magnesium, sodium and potassium between depths of 3 and 20 metres. In the present study a somewhat arbitrary distinction was made between water which has more than 5,000 milligrams/litre of chloride and those waters with less. On this basis an upper and lower unit were assigned to the shale with reference to the groundwater regime. On this basis the upper zone seems to be less than 20 metres deep within the shale and can indeed be significantly less.

Borehole HC-1 located upgradient of the proposed site has relatively low chlorides even in the deepest piezometer (367 mg/l). However, looking at Trow's section A-a (Ref. 1, Drawing 9) it can be seen that this hole does not extend 20 metres into the shale and would thus be in the upper zone of the shale as defined by Geocon. Thus the chemistry of the water from this hole cannot be considered as background for the lower more saline zone of the shale.

Borehole HC-4 located within the proposed Site F, had low chloride values in the upper two piezometers (less than 50 mg/l) located within Trow's

"Moderately Fractured and Weathered Shale" and their "Weakly Fractured Massive Shale". In the deepest piezometer, however, within Trow's "Highly Fractured Zone" the chloride content had increased to 8970 mg/l.

At the lower end of Section A-a borehole HC-9 had 17,100 mg/l of chloride in Piezometer No. 2, which is located only a few metres into the shale. Suggesting that the active zone within the shale, at this location, is relatively shallow.

Looking at the tritium data presented by Morrison Beatty (Ref. 3), this indicates that water less than 30 years old has not migrated down to a depth of more than 20 metres.

The tritium data presented by Trow (Ref. 1) was collected at two locations, HC-5 and HC-8. These data show very little penetration of post-1952 water of HC-8, where even the sample from a depth of only 3 m in the till was pre-1952 in age. At HC-5 there had been somewhat deeper penetration but there was a pattern of decreasing tritium with depth.

are there?

It should be noted that there is a discrepancy between the results presented by Trow and ~~those presented~~ by Hewetson (Ref. 4). It is our opinion that Hewetson's tritium data is suspect, possibly due to problems with collection and sampling.

not so — no. of results

In summary it can be said that there is a pattern of increasing mineralization of the groundwater with depth in the shale and that the less mineralized water which occurs in the shallow zones represent the effects of recharge from precipitation in recent years.

5.2 Leachate Contamination

The topic on which there is most disagreement with regard to the existing landfill sites adjacent to proposed Site F, is the extent if any to which those landfills have created a contaminant plume within the groundwater regime. As indicated earlier, the problems facing those who are trying to determine the extent of such contamination is that the shale bedrock contains naturally elevated concentrations of many of the parameters, both organic and inorganic, which are typically used as indicators of contamination by leachate. Parameters such as chloride, sulphate, hardness, alkalinity, dissolved organic carbon and phenols are all at relatively high levels. Levels which are greater than those usually encountered in leachate. Thus the impact of leachate on the groundwater chemistry is masked by the naturally high concentrations of these various parameters.

At the Bayview Landfill, Hewetson (Ref. 4) attempted to define the levels of contamination by the use of various key organic parameters, principally 1,1,1-trichloroethane (TCA), chlorobenzene (CB) and paradichlorobenzene (PDCB). Generally Hewetson found TCA and PTCB throughout the sampling network. However, she also found significant levels of TCA and PDCB in her background hole, WAT-2. As discussed by Feenstra, in his witness statement, it seems likely that the volatile organic chemical concentrations detected by Hewetson are the result of other sources of contamination such as solvents used in the construction of a piezometer or inadequately cleaned pipes used in the borehole installation.

Conestoga Rovers and Associates, in their 1986 monitoring report on the Bayview Landfill (Ref. 12), attempted to use organic nitrogen concentrations in order to demonstrate that a contaminant plume exists downgradient of the site. Organic nitrogen is calculated by taking the difference of total Kjeldahl nitrogen and free ammonia. In our opinion there are problems associated with using this parameter to determine the existence of the contaminant plume. For example, the values of organic nitrogen as calculated by Conestoga Rovers, are relatively small, (i.e., less than 1 mg/l). However, these values are derived by taking the difference between Kjeldahl nitrogen and free ammonia which, in many cases are present in significantly greater concentrations than the resulting value calculated for the organic nitrogen.

Thus, the relatively small concentrations of organic nitrogen calculated by this method are less than the possible errors in the original analyses for Kjeldahl nitrogen and ammonia. Gartner Lee (Ref. 10) also point out that there are potential problems of the accuracy of the Kjehdahl nitrogen and ammonia analyses in highly mineralized waters.

In addition, Hewetson (Ref. 4), referring to phenol, DOC and organic nitrogen, states:-

> "....because there is a possibility that natural organic matter in the shale causes some of the higher phenol, dissolved organic carbon and organic nitrogen values, these parameters cannot be used to definitely delineate the full extent of the zone of contamination, particularly at considerable distance from the landfill."

A further problem with respect to the CRA study is their assumption of a background level of less than 0.3 mg/l, based on very sparse data.

In light of the above facts and given that little is known about the occurrence of organic nitrogen, either at this site in particular or with regards to groundwater in general, it seems unreasonable to use the organic nitrogen concentrations to conclude that a plume extends downgradient to the Bayview Landfill.

With reference to the existing Burlington Landfill, Gartner Lee and Associates have been monitoring the groundwater conditions for several years and have recently undertaken a plume delineation study (Ref. 10). The results of their plume delineation study, up to this time, have led them to conclude that the impact of the landfill to the south appears to be negligible though they concede there is some evidence of leachate having moved approximately 25 metres.

They have a program underway of sampling and analysis from a number of specially constructed piezometers downgradient of the site from which they are attempting to identify a suite of volatile organics which, they have concluded, offer the best opportunity of detecting a contaminant plume. The results to date indicate that only three volatile organic compounds were found in the groundwater and that some concentrations are less downgradient of the site than upgradient.

They also looked at the phenol concentrations and concluded that there was weak evidence of leachate possibly having moved 25 metres or so to the south at a depth of approximately 6 metres.

A considerable amount of effort has been expended on determining and examining the chemistry of the groundwater in the study area, and this has been extensively reported on by various other workers. In summary, it can be said that there is a wide divergence of opinion of the extent of contamination extending from the two existing landfill sites. At the Bayview site Cherry and Lush (Ref. 13) concluded in 1980 that a large plume of leachate contaminated groundwater had developed in the shale and that the zone at that time extended beneath and beyond Highway 403. In contrast, Morrison Beatty (Ref. 3) concluded in 1981 that the leachate plume in the shallow system had not migrated more than a few tens of metres from the landfill and in their earlier study (Ref. 2) they concluded that the leachate at Bayview Park had migrated down to 20 metres and only a few tens of metres laterally around the perimeter, though they did at that time conclude that leachate may have been transported up to 100 metres beneath the ravines in a southward direction and up to 50 metres beneath the ridges.

At the Burlington Landfill, as previously described, Gartner Lee have found little evidence of a contaminant plume moving from beneath the existing landfill site.

Even with uncertainties regarding the extent or even existence of a contaminant plume from either of the existing sites, the important fact is that the plumes, even if they exist, are extremely difficult to detect and are thus clearly not having a significant impact on groundwater quality.

6. OVERVIEW OF IMPACT ASSESSMENT

In reviewing the potential for an adverse impact on the environment for the proposed landfill at Site F, it is necessary to look at the pathways by which this may occur through the groundwater regime. Trow, primarily on the basis of their model, have postulated a discharge zone in the lowland south of Highway 403.

It is our opinion that this zone is not generally functioning as a discharge zone on the scale suggested by Trow. It possible that there is some localized discharge derived from water within the surficial deposits but the evidence for upward discharge from the shale bedrock does not exist. Key

In an attempt to obtain a better understanding of the discharge zones Geocon installed a number a mini-piezometers at the locations shown on Figure 1. Three of these locations were situated within the discharge area defined by Trow and the results from this (see Appendix B) did not indicate discharge conditions. Similarly, a review of site conditions in the late summer of 1987 at this site confirmed that at that time much of the wetland area had dried up and that the creek channel passing through was also dry, thus suggesting that this is not a major groundwater discharge zone. Did they work where discharge gradients were

The evidence from the mini-piezometer installation located just north of Highway 403 (Installation B) was somewhat inconclusive but did suggest that some localized discharge could be occurring at that location. This would be in keeping with the concept of shallow flow reappearing at the surface north of the 403, within the limits of the property boundaries.

It seems clear that any water moving to depth beneath Site F, or the Burlington or Bayview Landfills, will move slowly within the regional flow system towards Hamilton Harbour. As has been amply demonstrated by the various studies undertaken in the area, the water in this deep system is highly saline. This salinity serves as a tracer in detecting possible discharges to the surface. A review of downgradient conditions between the landfill areas and Hamilton Harbour has not produced any indication of the discharge of saline waters. For example, Trow undertook measurements of electrical conductivity of the waters in the Indian and Falcon Creeks and no saline discharges were encountered.

Trow's survey of homes in the area concluded that there was little or no groundwater use downgradient of the proposed site. However, they acknowledge that there is possibly a fresh water lens (rind) within the surficial deposits in that area. It is clear, however, that the amount of water available within this fresh water lens is extremely limited due to the presence of the highly saline water at depth. Any attempt to extract large quantities of groundwater from the fresh water lens would quickly lead to the upward movement of saline waters, assuming that in fact the surficial deposits were able to supply adequate yields. Can this argument go both ways

Given the degree of urbanization between Highway 403 and Hamilton Harbour it is obvious that with no large scale abstraction the greatest threat to the shallow groundwater resources in those areas is from pollution occurring at the ground surface, such as road salting. In the event of large scale pumping, which probably would not be possible, the natural salinity of the underlying water would be a greater hazard than leachate from the landfills, which might have moved in the deep groundwater zone.

It is clear that groundwater conditions beneath proposed site F are essentially similar to conditions beneath the Bayview and Burlington landfills. The proposed Site F landfill, however, will be equipped with underdrains feeding into a leachate collection system which neither of the other sites had initially. The more recent areas of expansion at Burlington were so equipped and a perimeter drain was installed.

At Bayview Park no underdrains exist but a perimeter collection system has subsequently been installed to intercept leachate seepages.

The proposed development for Site F will initially be in the north half and thus it will be possible to monitor impacts which might occur in the area to the south before such impacts would reach the lower site boundary and this is seen as a distinct advantage in terms of dealing with problems.

In comparing the proposed leachate collection system at Site F with that at Site D, it is important to note that the slope of 2% at Site F versus 0.25% at Site D, should help in preventing clogging of the collector pipes. In addition, the fact that the proposed Site F leachate collection system is gravity fed, whereas Site D will depend on pumping, makes it less susceptible to failure.

In our opinion the absence of a viable groundwater resource within the shale which has been clearly demonstrated by the work carried out over the years, makes Site F a good location for a waste disposal site. As far back as 1980, Cherry and Lush (Ref. 13) commenting on the proposal by National Sewer Pipes for a landfill on the property currently being recommended for Site F, noted:

> "Based on the low yield capability and poor quality of the natural groundwater, it is reasonable to conclude that the Queenston Shale, in the area that could be affected by a landfill on the NSPL site or by the Bayview and Burlington Landfills is not a groundwater reservoir of significant value in the context of regional supply of potable water or of an industrial water supply. Even if the relevant cost of desalting water diminishes greatly in future decades, it is unlikely that groundwater in the Queenston Shale in the area of potential leachate influence will acquire significant value.
>
> If the hydrogeological assessment of the NSPL site were to rest entirely on the question of potential for contamination of ground-

water resources, there would be no doubt that the site would be suitable for a landfill."

In 1982, Keros Cartwright, a consulting hydrogeologist from Illinois, reviewing various reports relating to the NSPL proposed landfill on this site stated (Ref. 14):

"based on the hydrogeology of the site... it is my opinion that the proposed landfill site is suitable for municipal waste."

He went on to state that the precise groundwater flow paths have not been defined and that each investigator has described the flow paths in slightly different terms. He further stated, however, that there was little significant difference between the descriptions. He concluded his review with the following comments:

"In conclusion, the site appears to be well suited for the disposal of municipal waste. The existence of two sanitary landfills on adjacent land provides a unique opportunity to assess the effects of a landfill in this environment. The old Bayview Landfill is especially instructive, since it has been in existence for a considerable period of time.

Leachate from the Bayview Landfill is traceable only a few tens of metres from the waste. Some leachate may have become mixed with the deeper brackish groundwaters; however, they are indistinguishable from the poor quality water already present in the aquifer. There is no indication of extensive migration of leachate from the old Bayview Landfill.

Considering the carefully engineered plans for the proposed landfill, the new landfill should have little or no impact on the groundwater in the area around the landfill."

only a toe drain

These opinions, expressed by earlier reviewers are in line with the Geocon conclusions and, given the higher degree of engineering involved in the current proposal for Site F, we are of the opinion that this is an excellent location. The poor quality groundwater of this area can be considered as a good resource for the disposal of waste.

- discharges to streams
- polluted areas -

7. CONCLUSIONS

The groundwater flow regime, though probably complex in detail, is reasonably simple on a regional scale and consists predominantly of fracture flow within the Queenston Shale.

Trow's hydrostratigraphic definition of various units within the shale is somewhat tenuous, as are the results of the computer modelling which was based on their conceptual model of the hydrostratigraphy.

The quality of the groundwater within the Queenston shale is, for the most part, extremely poor, and does not constitute a viable resource for either domestic, municipal or industrial use. In fact its greatest value may be in the area of waste disposal.

The large body of increasingly sophisticated work which has been carried out over the years has failed to clearly define leachate ~~plumes~~ emanating from the two existing landfills. In fact there is no evidence of unacceptable off-site migration of contaminants through the groundwater regime from either landfill.

Leachate contaminated groundwater which moves to depth in the shale will flow laterally, in a sluggish flow system, towards Hamilton Harbour, and is unlikely to appear at the ground surface, either as base flow to streams or as seepage into wetlands.

There are no downgradient groundwater users which are threatened by the existing or proposed landfills and, in addition, municipal water is already supplied to the area.

The gravity fed leachate collection system, with a slope of 2%, is potentially more reliable than that proposed at site D, which will have a slope of .25% and which will need to be pumped up to the collection point.

The proposed development of the northern end first will permit greater flexibility in the monitoring of the performance of the system, before landfilling moves southward towards the downgradient end of the site.

The work carried out by Dr. Rowe, as part of the review of the Trow proposal, indicates that the attenuation capabilities of the shale are somewhat better than might have been expected.

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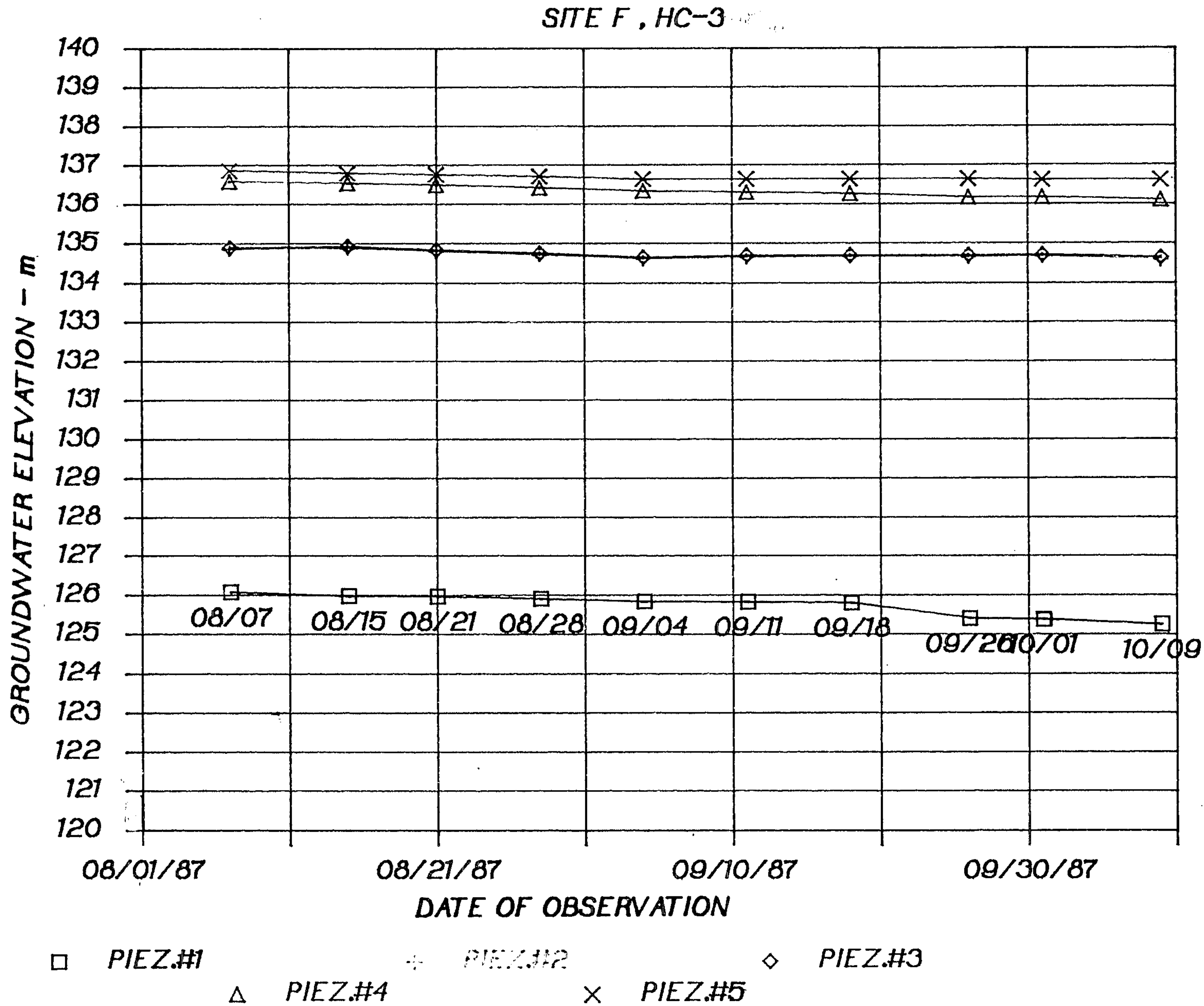
appendices

appendix a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139
138
137
136
135
134
133
132
131
130
129
128
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125
124
123
122
121
120
08/07
08/15
08/21
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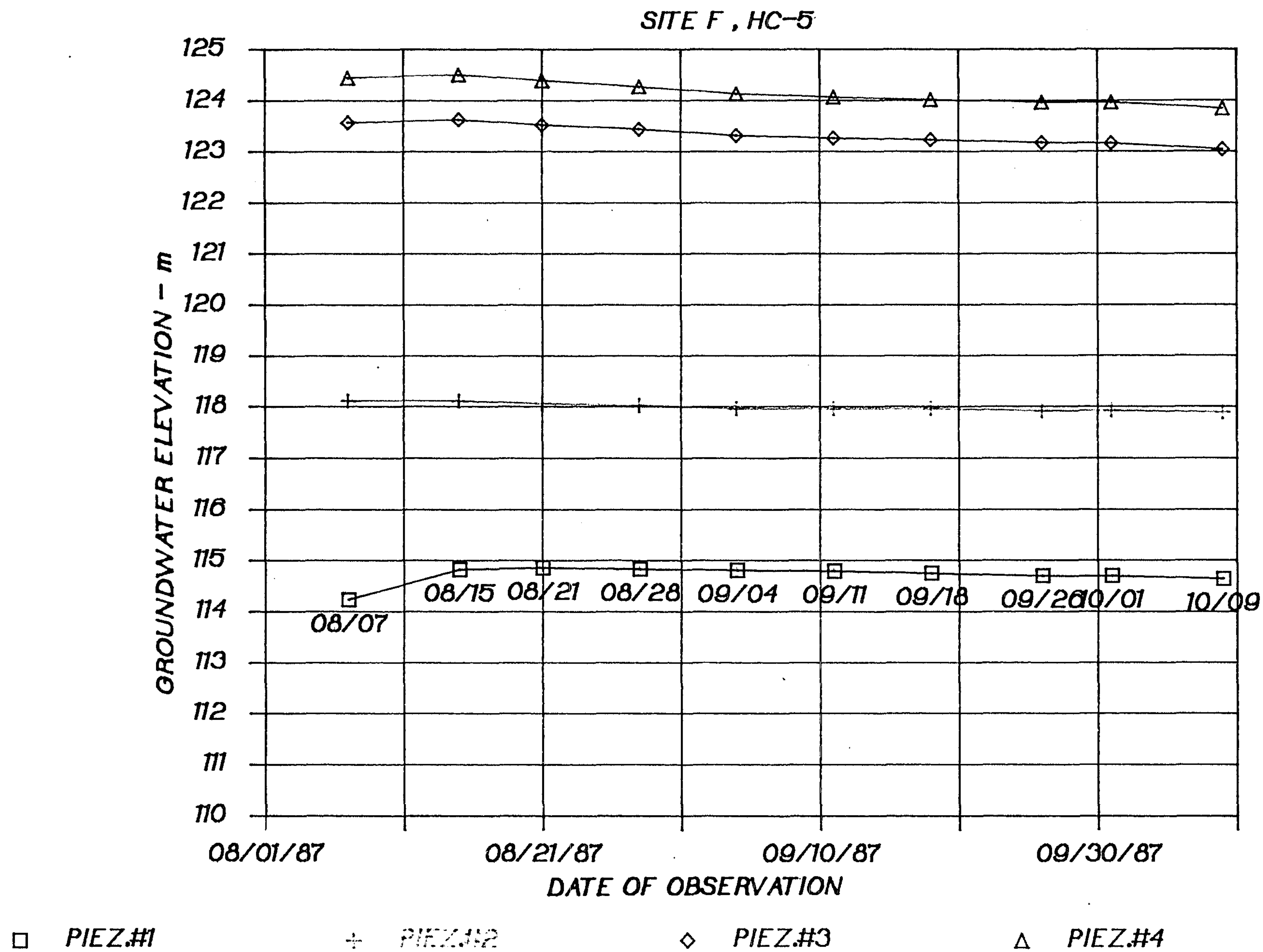
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123
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121
120
119
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117
116
115
114
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110
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08/15
08/21
08/28
09/04
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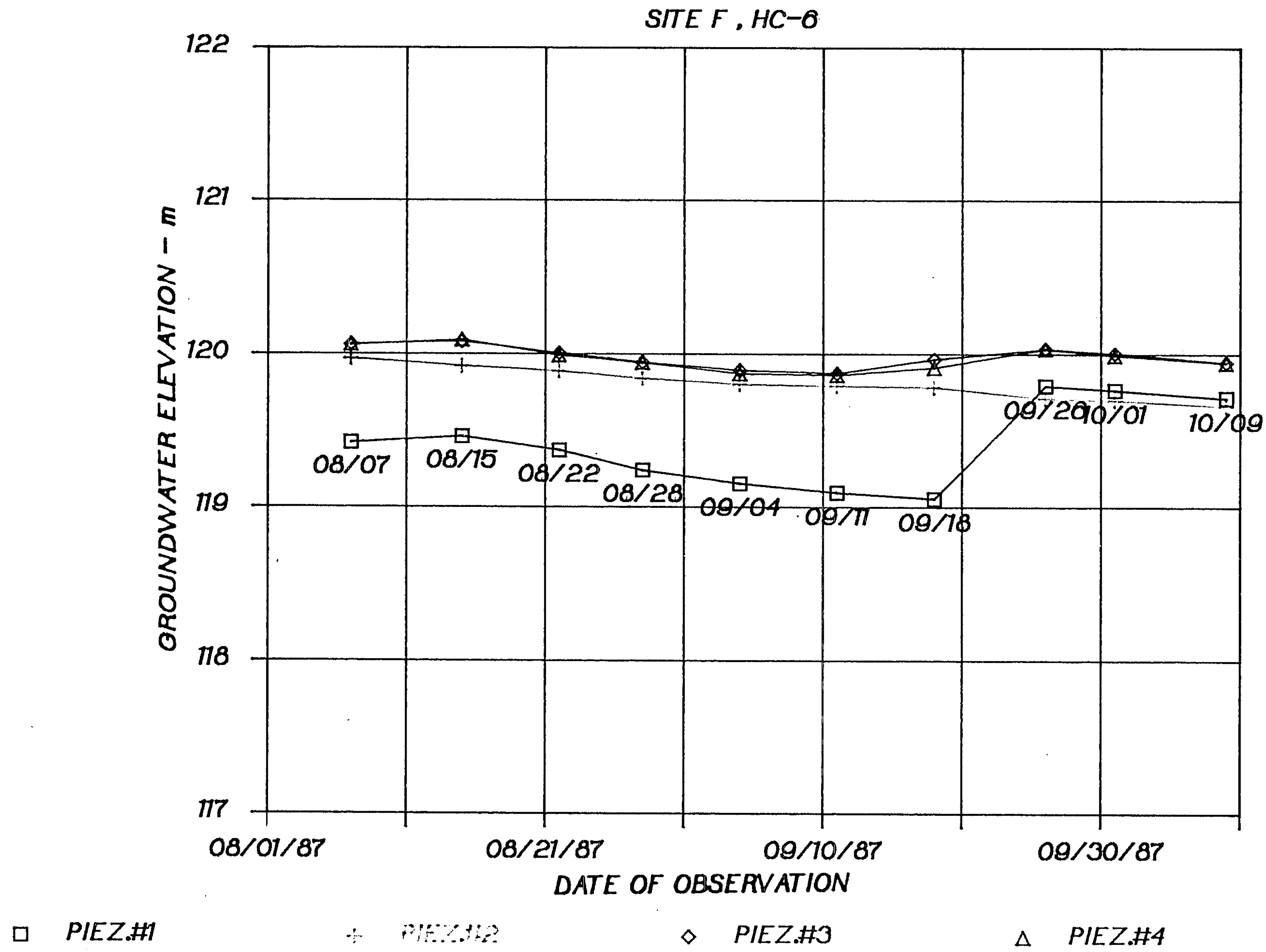
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08/07
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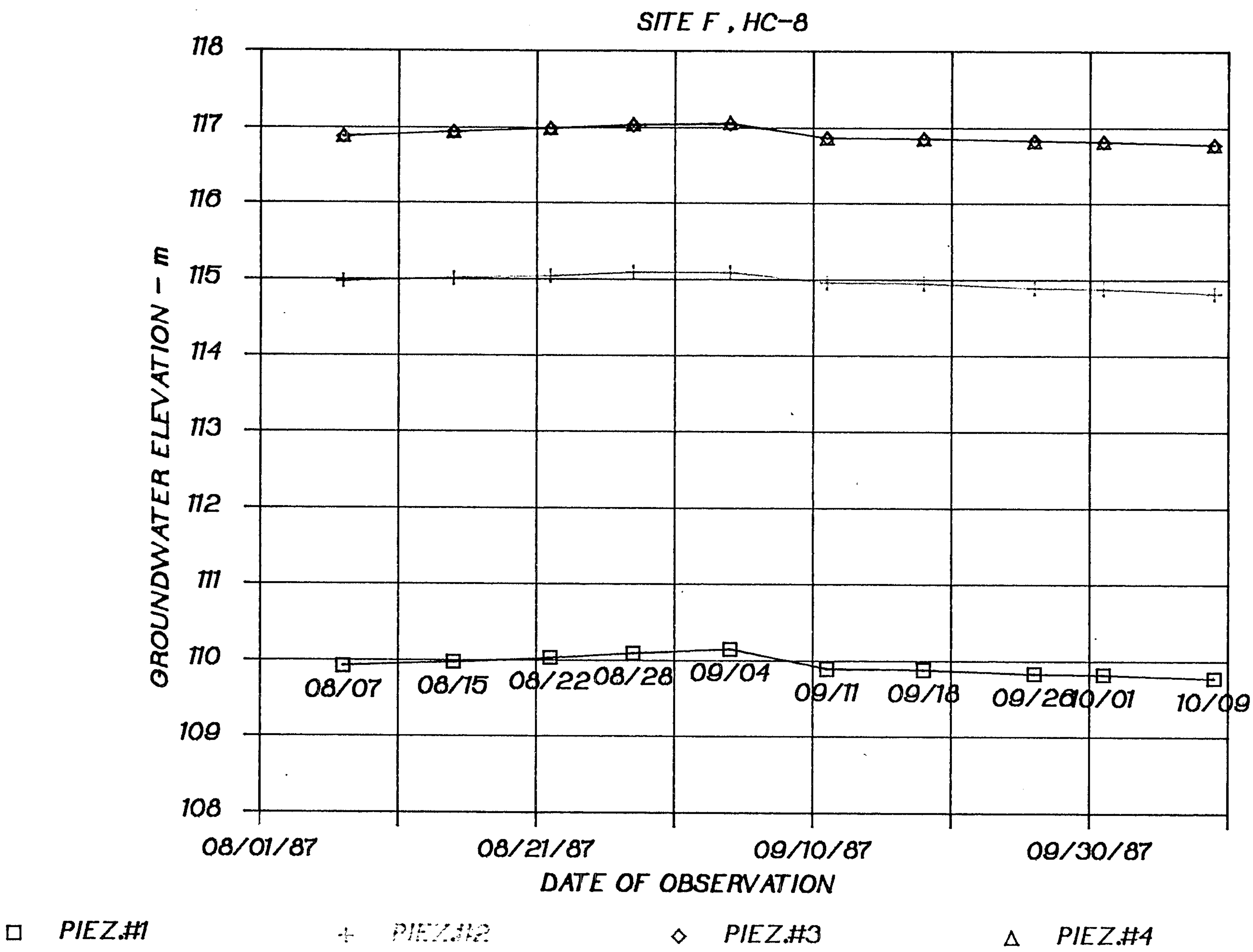
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113
112
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108
08/07
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09/11
09/18
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10/09
08/01/87
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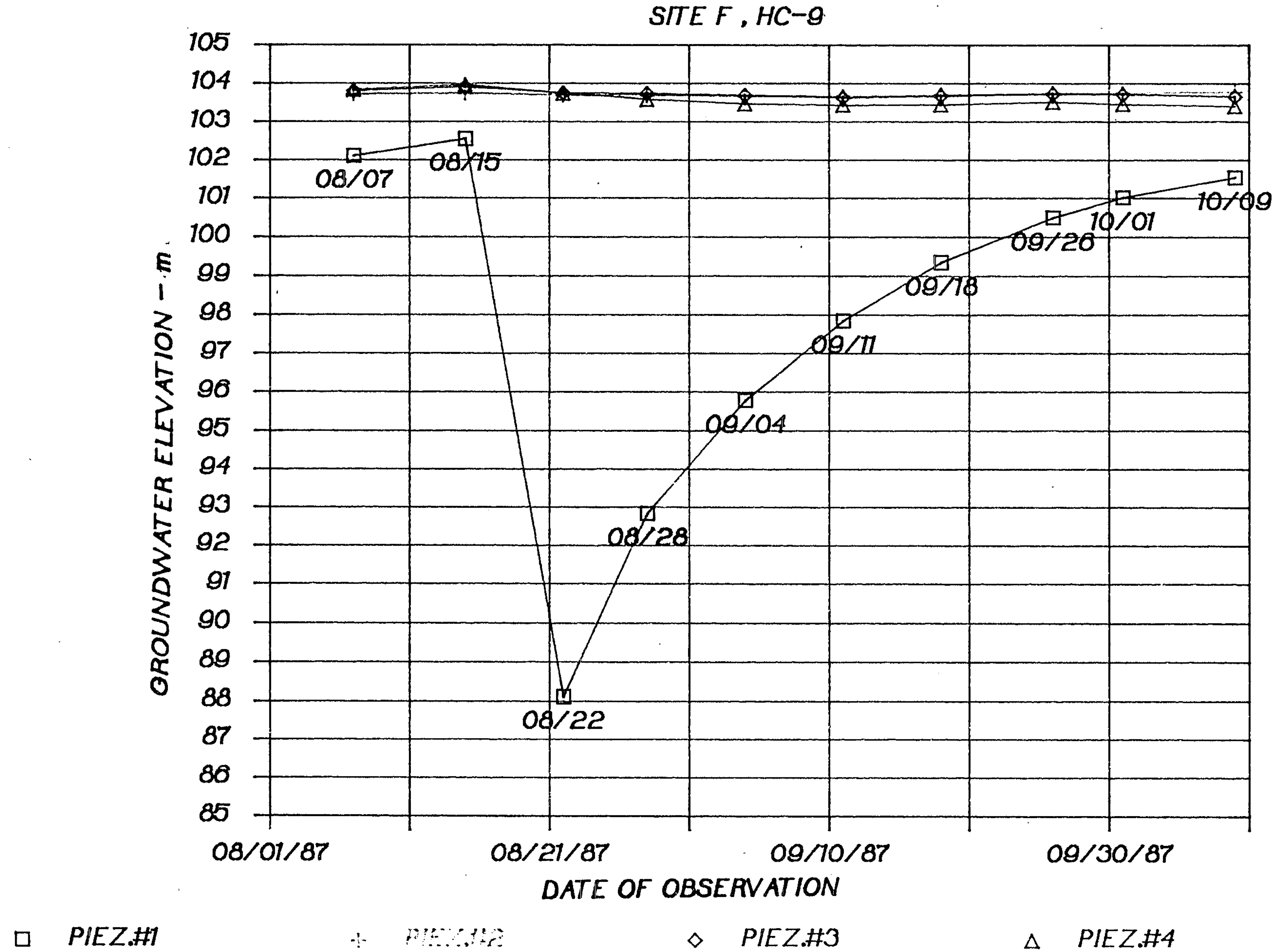

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103
102
101
100
99
98
97
96
95
94
93
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90
89
88
87
86
85
08/07
08/15
08/22
08/28
09/04
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10/09
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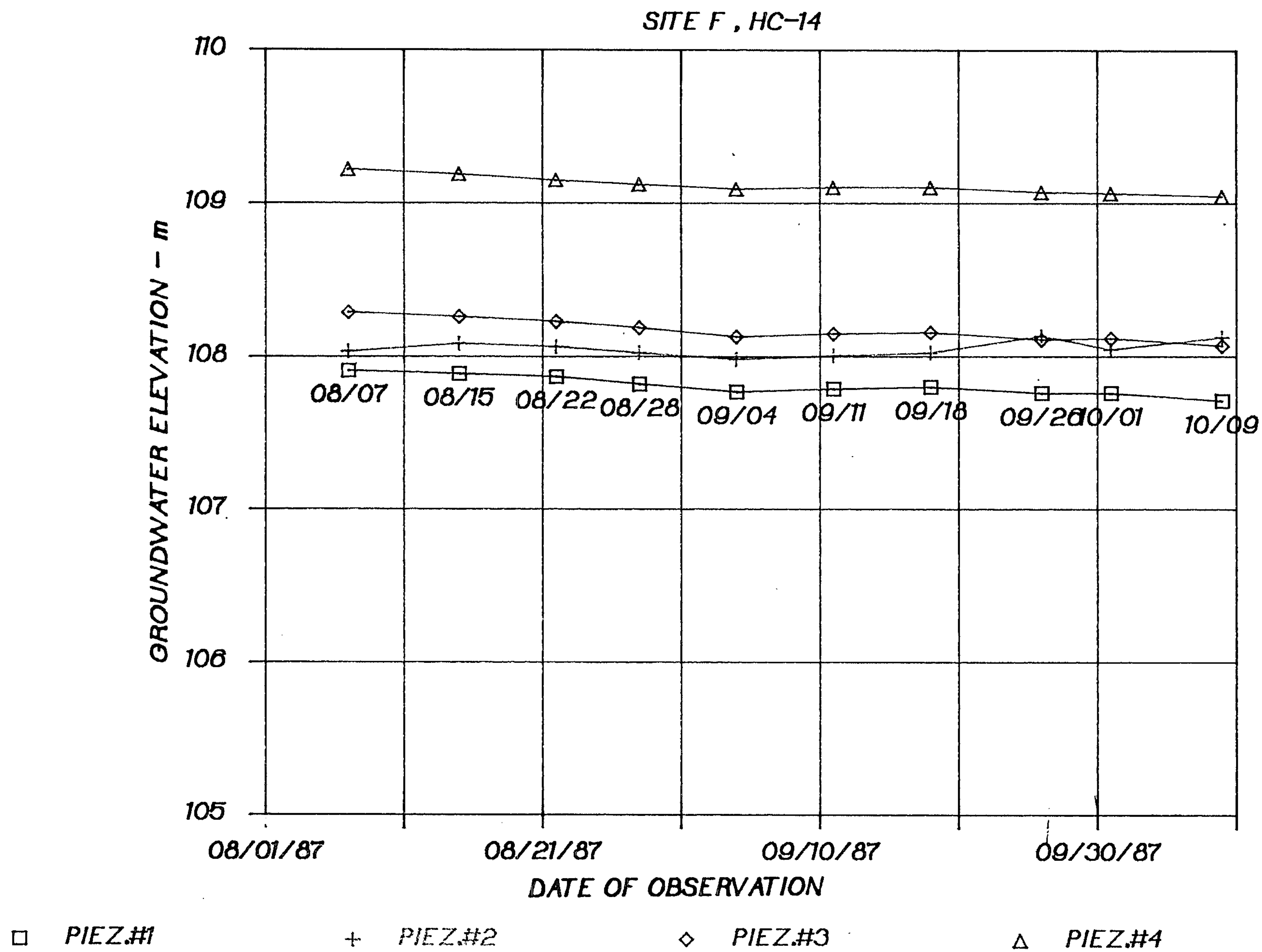
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107
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08/07
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08/22
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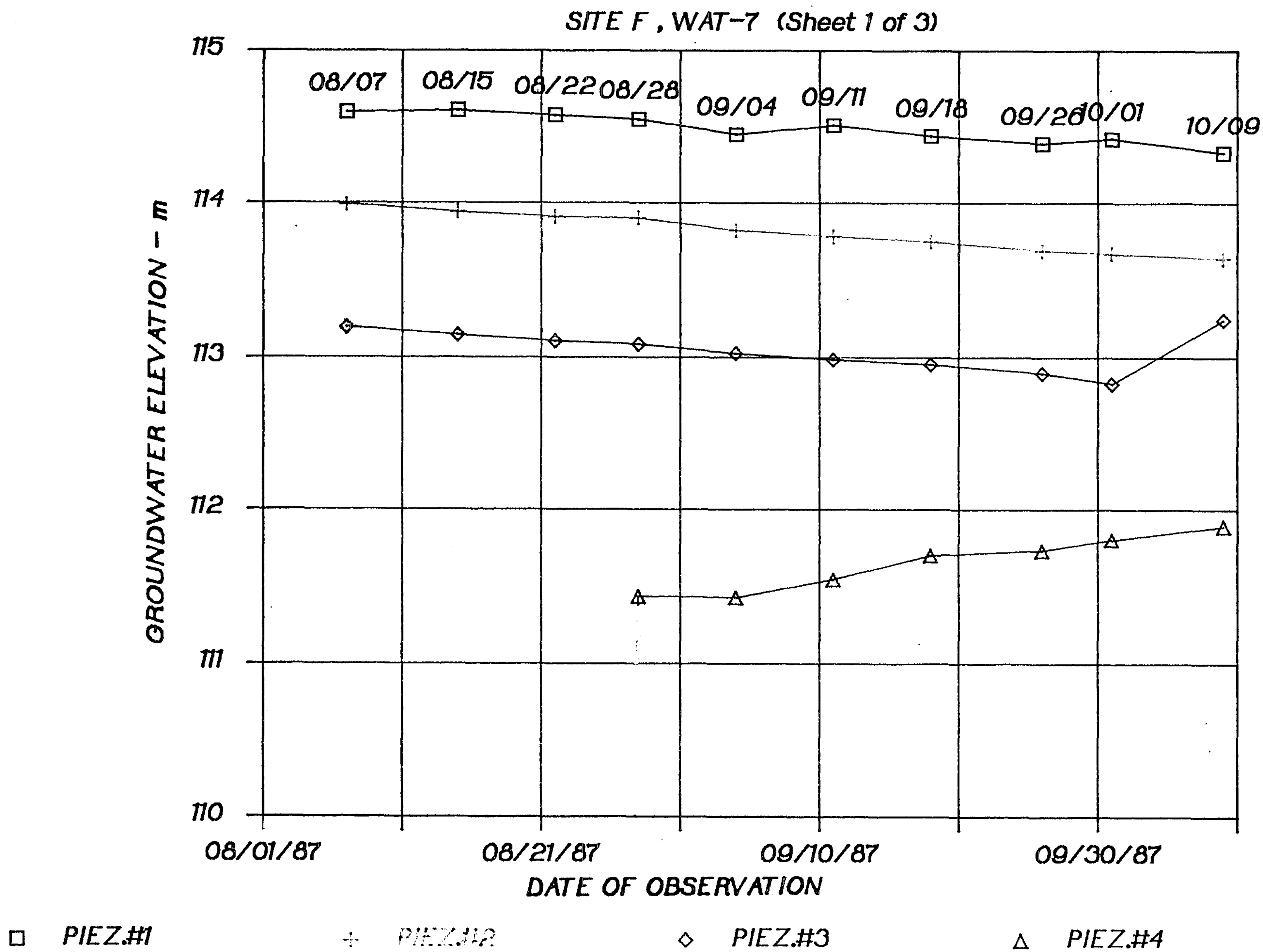
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112
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110
GROUNDWATER ELEVATION - m
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08/15
08/22
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09/18
09/26
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10/09
08/01/87
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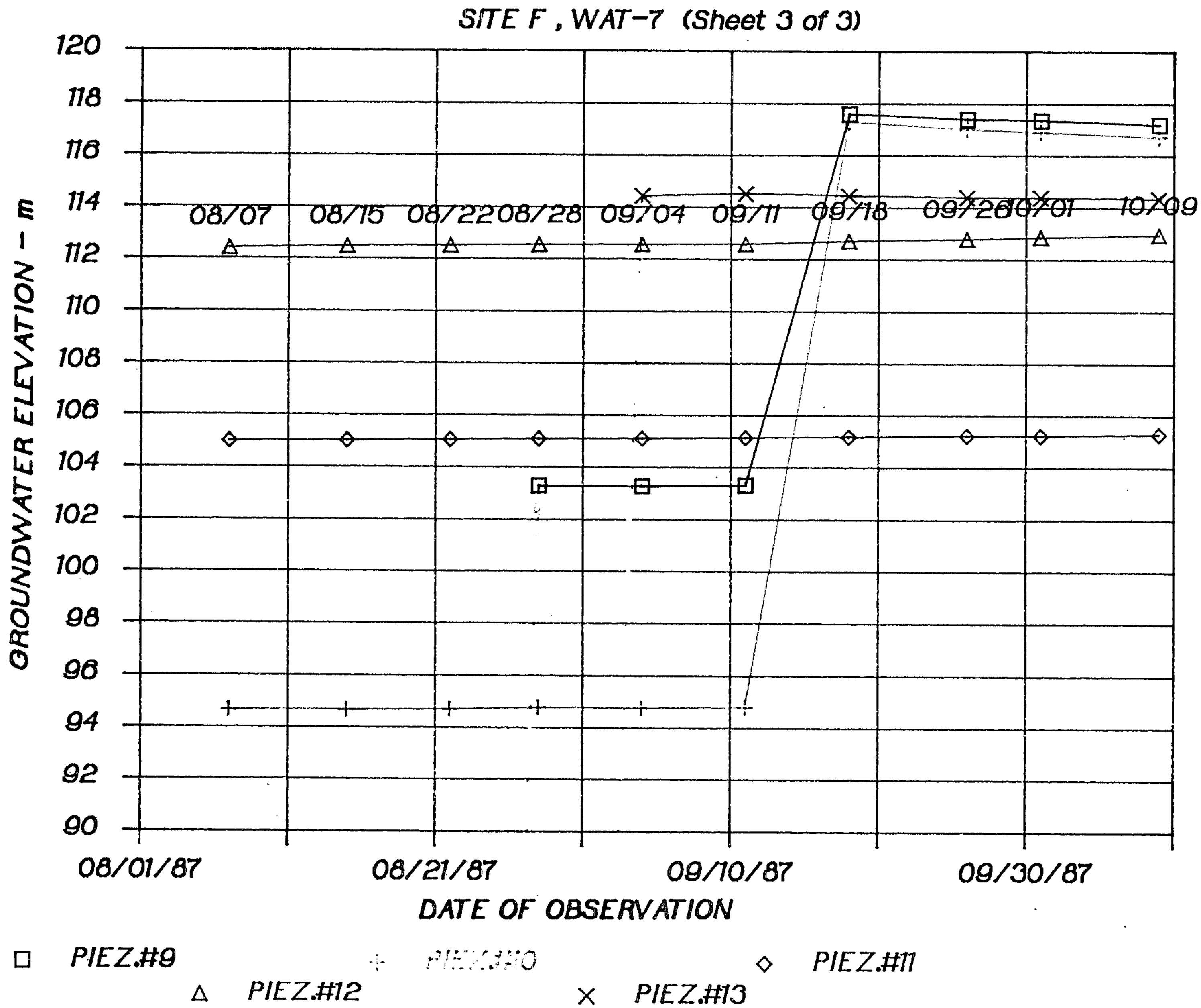
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114
112
110
108
106
104
102
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94
92
90
08/07
08/15
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appendix b

APPENDIX B - DETAILS OF MINI-PIEZOMETERS

One of two mini-piezometers were installed at several locations where the water table was believed to be at or close to the ground surface. They were driven in by hand, to a shallow depth, in order to determine vertical gradients in what were thought to be possible discharge zones. They were installed on 29th April 1987 and water level measurement were subsequently taken on several occasions. The locations of these installations are shown in Figure 1 and construction details are given below.

Location	Piezometer	Location of Pipe Above Ground (ins)	Depth of Tip Below Ground Surface (ins)
A	Deep	16.0	32
	Shallow	24.5	11
B	(only one piezometer)	7.0	29
C	Deep	4.75	43
	Shallow	25.6	10
D	Deep	3.25	45
	Shallow	35.0	13
E	Deep	4.75	43
	Shallow	34.0	14

WATER LEVEL MEASUREMENTS
(ins. above or below ground surface)

Piezometer	May 01/87	Jun 05/87	June 26/87	Sept. 27/87
A - Deep	+15.25	+ 1.00	-17.50	
- Shallow	+19.50	- 7.00	+ 2.10	
B - Piezometer	+ 6.87	+ 5.90	+ 6.20	+ 3.65
- Stream	+ 6.75	+ 6.35	+ 6.34	moist but not flowing
C - Deep	+ 4.00	- 1.95	- 8.85	could not open
- Shallow	+22.00	+ 1.62	+ 3.22	dry
D - Deep	+ 1.37	- 4.15	-10.95	-36.60
- Shallow	+32.37	+ 9.00	- 5.20	dry
E - Deep	+ 3.75	+ 1.05	+ 2.95	-10.05
- Shallow	- 0.25	+ 4.1	+12.70	-13.80
- Stream	+ 1.75	dry	dry	dry

figures