HYDROGEOLOGICAL ASSESSMENT
of
PROPOSED SAND AND GRAVEL PIT

West 1/2 Lots 7,8,& 9,
Concession 7
Oro Township

REPORT
to
James Dick Construction Ltd.

Prepared by

Charlesworth & Associates

Job # 91-107

November 21, 1991

Copies:	1	James Dick Ltd
	1	Keewatin-Aski
	1	MacNaughton Ltd
	1	D. Hindson
	2	File

77 Mowat Avenue, Suite 101
Toronto, Ontario M6K 3E3
(416) 536-4916
Fax: (416) 536-9265

Charlesworth & Associates
CONSULTING HYDROGEOLOGISTS

James Dick Construction Limited
Box 470
Bolton
Ontario
L7E 5T4

November 21, 1991

Attention : Mr. G. Sweetnam

Re: Hydrogeological Assessment, Proposed Sand and Gravel Pit,
West 1/2 Lots 7,8, and 9, Concession 7, Oro Township,
November 21, 1991

Dear Mr. Sweetnam,

We are pleased to submit a copy of our revised report, Hydrogeological Assessment of a Proposed Sand and Gravel Pit, in support of the application for a Class A Aggregate License.

Our report has been prepared to reflect the intention of this application for the proposed excavation to stay a minimum of 1.5 metres above the water table. The report does not address any future requirements for washing aggregate at this site.

We understand that James Dick Limited may, in the future, consider applying for an amendment to the site plan to permit excavating below the water table. In recognition of this, we have commented on the additional hydrogeological investigation required to support such an application for amendment.

Yours truly,

Janet Haynes

Janet Haynes, M.E.Sc.
Senior Associate

cc: S. Denhoed; Keewatin-Aski Limited
J. Parkin; MacNaughton Hermsen Britton Clarkson Planning Limited
D. Hindson; Cattanach, Hindson, Sutton & Hall

TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

1.1 Purpose

Charlesworth & Associates were retained by James Dick Construction Limited on January 28, 1991 to carry out an hydrogeological investigation of the West 1/2 Lots 7,8,9, Concession 7, Oro Township. James Dick Construction Limited are applying for a license for the 125 ha site with the intention of developing a sand and gravel pit. The property is adjacent to another licensed property (E 1/2 Lot 8, Conc. 7) owned by the company. The proposed and licensed pits are shown in Figure 1.

In the current application, extraction is proposed to proceed to 1.5 metres above the water table. This report provides a hydrogeological assessment of the site and discusses the expected hydrogeological impacts of excavation to this depth. In the future, an application may be made for an amendment to the site plan, to permit excavation at this site to go below the water table. A brief discussion of the expected potential impacts of excavating below the water table and an outline of the additional hydrogeological work required to assess these expected impacts is included in this report.

This hydrogeological assessment forms part of the documentation required, under the Aggregate Resources Act, to apply for a Class A license for the West 1/2 Lots 7,8,9, Concession 7, Oro Township.

1.2 Scope

To evaluate the potential hydrogeological impact of the pit, it is necessary to determine the existing groundwater conditions. Hence, this study included collection and analysis of both field and office data. To understand the regional setting, the area within a 2 km radius from the site was used as the study area. For site specific discussions, the study area included the site, the adjacent licensed property and a 300 m zone around both.

In addition to reviewing existing regional and site data, water table monitors were installed on site to better determine the depth to the water table and its annual fluctuations. A house-to-house well survey was conducted in the surrounding 300 metre zone.

No assessment was made of the impact or groundwater resource requirements for washing the aggregate product.

1.3 Aggregate Extraction Operations

The site is located in the Bass Lake Moraine on the edge of an area designated as a granular resource of Primary Significance by the Ministry of Natural Resources (Ontario Geological Survey 1984). Several aggregate extraction operations either currently exist, or are proposed, in the immediate vicinity of the site. Adjacent to the property is the licensed pit owned by James Dick Construction. Alfa Aggregates is proposing to operate an aggregate pit (Roehner Pit) on the East 1/2 of Lot 9, and south of that Seeley and Arnill's Edgar pit is located in the East 1/2 of Lot 11. In Concession 8, to the east, Cook Construction and the Township of Oro operate pits on the West 1/2 of Lot 7 and the West 1/2 of Lot 11, respectively. A pit (Sarjeant) is proposed for the West 1/2 of Lot 8, Concession 8. All of the properties with proposed or existing aggregate extraction operations are shown in Figure 1.

At the subject property, the current operations plan is to excavate to approximately 1.5 metres above the water table or to the depth of suitable material, whichever occurs first. Activity in the expansion property will start after development of the existing licensed property, and will move generally from south to north. Access to the subject property will be from Concession 7 through the existing licensed property.

2. DATA ACQUISITION

2.1 Existing Data

A variety of existing data was compiled to assist in the impact assessment for this proposed site, including published geological reports and maps, unpublished reports on adjacent properties and the borehole data from the on-site aggregate exploration holes (Ingham, 1989). This information was used with the published and unpublished Ministry of the Environment (MOE) water well records to determine the regional geological and hydrogeological setting. Climate data was obtained for the nearby Midhurst station to determine precipitation and evapotranspiration. The 1:10000 scale aerial photographs were reviewed to examine topography and surface drainage conditions.

2.2 Drilling and Piezometer Installation

A total of 5 boreholes were drilled on site from March 25 to April 5, 1991. Four boreholes were drilled to water; the fifth borehole (DC-3) was terminated in boulders at 15.5 m.

The drilling was carried out by Longyear Canada using a CME 75 track-mounted rig under the supervision of Charlesworth and Associates. Hollow stem augers were used to advance the boreholes at all locations; 13.3 cm I.D. augers were used at DC-1 and 10.8 cm I.D. augers were used at the remaining locations.

In the first borehole, DC-1, split spoon samples were taken every 1.5 m throughout the depth of the borehole in order to obtain an understanding of the geology and familiarity with subsurface materials. In boreholes DC-2 to DC-4, the sampling interval was 3.0 m in the upper 26 metres, changing to 1.5 m as the expected water table elevation was approached. In borehole DC-5, the interval was increased to every 4.6 m in the upper 26 m, and then decreased to 1.5 metres.

Soil samples were described in the field, re-examined in the office, and saved for possible future examination. Descriptive borehole logs were prepared (Appendix A).

Piezometers were installed in 4 of the 5 boreholes and consist of a 51mm I.D. Sch 40 PVC riser pipe with a 3.1 metre long, threaded, machine-slotted (10-slot) PVC well screen. A piezometer was not installed in DC-3. Screens were installed with artificial and/or natural sand pack and the borehole backfilled with native material to within approximately one metre of the ground surface. Clay and cement grout were used to seal the holes to ground surface in order to prevent possible surface water infiltration. Upon completion, locking steel casings were installed.

Installation details are given in Appendix A.

Locations and elevations of the four piezometers and an existing groundwater monitor (M6; details in Appendix B) on the adjacent licensed property were surveyed in April, 1991. The elevations provided at that time were revised in November, 1991, by a survey to geodetic conducted by Young and Young Surveying Inc. This report has been revised to include these changes.

Water level data were taken on May 3 and May 13, 1991, and subsequently at approximately two month intervals. Water level data for May to October 1991 are provided in Table 1.

A water level was taken on July 31,1991 at the domestic well (MOE #19519) located on the licensed property. The well casing elevation was included in the November survey.

2.3 Well Survey

A well survey was conducted for homes along Concession Roads 6 and 7 from Lots 7 to 9 in order to acquire additional information on the private wells within 300 m of the site. During two field visits, on May 3 and 13, 1991, residents in nine of the ten homes within 300 m of the licensed and proposed properties were contacted for details of their wells. The tenth resident was not at home.

The well survey sheets are provided in Appendix C. All wells were matched to the MOE water well records. Well 3268, reported in the MOE well records, was not identified in the field, and is assumed to not be in service.

3. PHYSICAL SETTING

3.1 Physiography and Drainage

The study area is located within the Bass Lake Kame Moraine, an area of hummocky topography and considerable local relief (Figure 1). The moraine is a noticeable feature, rising above the rolling till plains which extend to the north and south. Local relief can reach 60 metres along the flanks of the moraine and in major valleys. The height of land created by the moraine is a watershed divide, with the northern slope draining toward Coldwater River and the southern slope to Hawkestone Creek.

The study property is located near the crest of the moraine, on the northwesterly facing slope. The southern third of the site is characterized by hummocky topography, with local relief of 12 metres and numerous dry depressions. The central and northwest portions of the site are gently rolling to sloping, with low relief. The northeast area is more rolling with moderate relief (6m).

The relatively high relief and sandy material found on-site allow rapid infiltration, and no water courses or wetlands are found on or around the site. No surface ponding was observed during the recent spring melt period. Intermittent streams occur to the south-southwest and the northeast of the site, draining towards Hawkestone Creek and Coldwater River respectively. Permanent streams to the north and south are fed by groundwater discharge along the margins of the Moraine.

3.2 Regional Geology

The Bass Lake Kame moraine is a complex geological area, composed predominantly of sands and is also known as the Oro sand hills. The moraine is believed to have formed as an interlobate moraine about 15,000 years ago. This type of environment, between the ice margins of two lobes of the continental glacier, would be an area of ice front fluctuation and major deposition of sorted or stratified sediments by meltwaters along the ice front. Unsorted glacial till would overlie and incorporate sorted deposits of sand, silt and gravels, and in turn be overlain and eroded. Hence, although predominantly sandy, the moraine also contains gravels, silts and extensive glacial till strata in a variable sequence. This complexity is apparent on the regional cross-section in Figure 3.

The surficial deposits in the moraine are over 150 metres deep (Burwasser and Ford, 1974a,b). Water wells in this area rarely penetrate through the sequence of till and granular deposits to the underlying limestone-dolostone bedrock.

Although the Bass Lake Moraine in this area is designated as a granular resource of Primary and Secondary Significance, the 1984 Aggregate Resources Report (Ontario Geological Survey, 1984) notes that locating good quality coarse aggregate is difficult due to the variable and unpredictable nature of the materials in the moraine. Figure 1 shows the extent of the Bass Lake Moraine and also the location of the sand and gravel resources deemed to be of Primary Significance and Secondary Significance by the Ministry of Natural Resources (Ontario Geological Survey, 1984). The majority of the proposed site is located within the area defined as being of Primary Significance.

3.3 Site Geology

On site, the surface deposits are predominantly clean fine to coarse sands with occasional thin silty beds. These strata range in thickness from greater than 30m in the south (DC-1) to less than 5 m in the northwest (DC-2). Beneath this, in part of the site, is a group of finer grained strata, including silty sands, silts and/or silt tills. This zone, identified as silty deposits on the east-west cross-section in Figure 4, was found in boreholes in the north part of the site at approximately 350 to 335 m elevation. However, this finer grained material was not encountered in the south of the site at DC-1.

Beneath the silty deposits, clean fine sand is generally encountered; the water table is located in this sand strata.

4. HYDROGEOLOGY

4.1 Hydrostratigraphy

The moraine is a groundwater recharge area, with downward vertical gradients. An unconfined aquifer occurs in the surficial granular deposits, and is underlain at depth by glacial till and other finer grained sediments. Water bearing sands and gravels within the tills form confined aquifers of varying extent.

Regional cross-section A-A' (Figure 3) is drawn from north to south along Concession Rd. 6 on the western edge of the site. The inferred regional water table, which marks the upper boundary of the unconfined aquifer, follows the topography in the region. The unconfined aquifer largely occurs within the variable granular deposits of the kame moraine at depths of greater than 25 metres (see Figure 3), and is underlain by tills (e.g. clay sand or hardpan in well records), silts and permeable sand and gravel zones. These deeper, more permeable zones are confined by the less permeable silts and tills. In some cases these zones appear to be reasonably extensive, supplying several wells. For example, to the south of the site a confined sand aquifer can be identified at an elevation of approximately 280 m elevation, (domestic wells 8728, 3269 and 11202). More precise identification of confined zones which can be correlated is difficult due to the sparse and often unreliable hydrostratigraphic data available on a regional scale.

Cross-section X - X' (Figure 4) illustrates the hydrostratigraphy in the central portion of the site. In this and the northern portion of the site, the unconfined aquifer is overlain by a zone of moist to saturated, interlayered fine sand, silty sand, silt, and silt till.

4.2 Water Table

The water level data obtained May 13, 1991 have been used in preparation of the drawings and are believed to adequately represent the water table elevation for purposes of discussion. Levels measured in July and October (Table 1) show that the magnitude of fluctuation over the summer has been about 1.2 metres or less.

Generally, the water table was encountered in the sand strata below the zone of finer grained, moist to saturated sediments (Figure 4). Seasonally, the water table rises and, at some locations, may encounter the base of the overlying less permeable deposits; this is observed at DC-5.

Beneath the site, the depth to water table measured in early May ranged from 26.5 to 34.3 m (Table 1). The water table elevation would appear to range from 335.6 m at DC-1 in the hummocky terrain of the southern part of the property to 320.3 m in DC-2 at the north end of the property.

However, at borehole DC-1, the water table elevation is somewhat anomalous and may represent a local perched condition. Water was encountered at 30.8 m in sand, 0.7 m above the contact with silty till. The borehole advanced 2.6 m into dense till and terminated. Water well log 8728 (Parke) indicated a possible thick till strata at this elevation and since, at the time of drilling DC-1, it was assumed that the water table had been encountered, a piezometer was installed. However, the piezometer was still dry a week later, and the static level in DC-1, unlike in the other piezometers, took several more weeks to reach equilibrium. This suggests that the piezometer had not encountered the main unconfined aquifer beneath the site, but that this saturated zone in which it is located, is a perched aquifer of relatively limited extent. This aquifer slowly drained into the borehole to finally reach the measured static level.

Further in support that this static level may be perched, an exploration borehole drilled in August 1989, approximately 900 m north of DC-1, encountered 5 metres of fine grained material, possibly till, at a similar elevation (Ingham, 1989). In that borehole, the water table was reportedly found in underlying sands at an elevation similar to the water table in DC-4 and DC-5. (Elevations for the exploratory boreholes are estimated from the site topographic map (Keewatin-Aski 1991).)

Hence, the water table elevation ranges between 327 and 320 m, with a perched water table encountered at DC-1 at 335.6 m elevation.

4.3 Groundwater Flow

Inferred flow directions in the unconfined or water table aquifer are shown on Figure 5. Accurate elevations are available from the water table monitors on site; the data plotted are for May 13,1991, except for the static elevation at domestic well 19519, which was measured July 31,1991.

A groundwater divide appears to be present just south of or in the southern part of the proposed expansion site. Beneath most of the site, flow in the unconfined aquifer is northerly to northwesterly, eventually towards Coldwater River. South of the site and possibly in the southern portion of the site, flow is southerly towards Hawkestone Creek. The horizontal gradient is approximately 0.01.

The precise location of the groundwater divide is not known. Assuming that the water level in DC-1 is a perched condition, then in May there appears to be a component of flow from DC-4 southerly to DC-5, where the water level was slightly lower. However, in July and October, the water level at DC-4 was lower than at DC-5 (Table 1) and flow was northerly from DC-5. This apparent change in flow direction may be a seasonal phenomenon or simply an indication the static level in DC-5 was not at equilibrium by May of this year. Long term monitoring will determine if this change really occurs.

Because the majority of the water wells obtain water from confined zones at differing elevations, it is not possible to clearly define the direction in which the groundwater is moving at depth, below the unconfined aquifer. However, generally it appears that the overall pattern of flow is similar to the pattern in the unconfined aquifer.

4.4 Groundwater Use

Drilled wells are now the source of water for the residences and farms around the proposed site, though historically, many farms obtained water from cisterns because of the depth to the water table. No water wells were identified on the expansion site during this study. Eleven water wells were identified in the 300 m zone around the site and licensed properties (Table 2); of these, five active wells and one abandoned well (18749 - insufficient supply) are located along Concession 6 within 300 m of the site. Of the five wells reported in the MOE well records east of the site, well 3268 could not be located and is believed to not be in use. Well 19519 is located on the licensed James Dick property (East 1/2, Lot 8).

A summary of the water well information, extracted from Ministry of the Environment water well records for the 300 m zone and the general region, is found in Table 2. The data collected

The development of a pit on this site will increase the amount of groundwater recharge by increasing the amount of precipitation that infiltrates. The increase is a result of : 1) removal of surface vegetation and hence a reduction in evapotranspiration; 2) removal of most of the unsaturated soil thickness, and any related perched systems; and 3) capture of any surface runoff within the pit. This latter factor may not be significant, because currently most surface runoff infiltrates locally after collecting in depressions.

The average total annual precipitation for 1980 - 1989 is 950 mm at Midhurst, the nearest representative climate station (Environment Canada 1982). The average actual evapotranspiration, calculated for 1980-1989, is 537 mm or approximately 55% of precipitation. With the removal of vegetative cover, there would be more precipitation available to infiltrate through the unsaturated zone and recharge the water table aquifer. Evaporation loss from bare soil is considerably less than evapotranspiration loss from a vegetated surface.

The increased infiltration would, theoretically, create a slight mound or localized high point in the water table beneath the pit and slightly raise the water table in the surrounding area. The actual extent, both lateral and vertical, of the effect of the increased infiltration would depend on the increase in infiltration and the permeability of the deposits- i.e. more permeable deposits would see a wider area influenced with a lower rise in head than less permeable deposits.

Calculations to determine the approximate expected increase in the water table elevation are given in Appendix D. Using the Hantush method (1967), several different scenarios, using the expansion area only and the expansion plus licensed area, are presented. Evaporation from bare soil is assumed to be 20%, with the remaining precipitation infiltrating the soil and reaching the water table. The estimated maximum rise in the water table beneath the centre of the expansion site, assuming a third of the property is not vegetated for ten years, is 1.5 m (if the saturated zone is ten metres thick) to 2.5 m (if the saturated zone is 5 metres thick). Corresponding values for the combined licensed and expansion site areas are 1.7 m and 2.9 m for the maximum height of the mound. The increase at the site periphery ranges from 1.2 to 2.4 m.

It should be noted that these are estimates, derived from simplification of the subsurface conditions and assumptions about the average precipitation and evapotranspiration. They do not take into account the long term natural fluctuations in the water table. For example, since 1986, annual precipitation has declined from 1062 mm in 1986 to 808 mm in 1990. This natural trend has created a 20% drop in precipitation available to recharge the aquifer.

Long-term monitoring of the on-site observation wells will provide the best data on the water table fluctuations.

5.2 Impact on Surface Waters

No surface water was observed on site or immediately adjacent to the property during field work and, thus, the pit development should not adversely affect local surface waters. Excavation of the perched moist to saturated zone that underlies part of the site is not expected to have a significant impact on surface waters.

The mounding of the water table expected beneath the site would not significantly affect the volume of groundwater discharge to streams along the margin of the moraine.

5.3 Impact on Local Water Wells

No negative impacts are expected for the quantity of supply in local water wells. The increased infiltration expected to occur as a result of pit development would, if anything, slightly increase the local water supply available to users. Wells in the unconfined aquifer would have increased saturated thickness available and, for deeper wells, the increased water table elevation would increase the vertical gradient and, hence, the volume of recharge to the lower confined layers.

If washing is required to process the aggregate, lined ponds could be used to collect precipitation to provide some on-site water. For greater volumes of water, a drilled well would be required. At least part of the wash water would return to the water table, although some would be lost on aggregate leaving the site. The requirements for washing will be determined closer to development, when the expected granular product is defined. Additional drilling and a pumping test will likely be required to assess the available supply of water and the impact of taking washing water on surrounding wells.

5.4 Impact on Water Quality

Various operations in the pit have the potential to impact on groundwater quality. The potential for such impact increases as the overburden is removed and the path from ground surface to the water table is reduced. Fuels, greases, and dust control materials should be handled in such a way to minimize the risk of spills and to facilitate clean-up.

To minimize potential contamination, equipment servicing and refuelling should, where possible, occur in an area away from the pit floor, with a contoured impermeable base (i.e. an asphalt pad with a central drainage collection area). Procedures to prevent spills should be followed when activities have to occur in the pit.

Dust control will be accomplished primarily by water collected on-site in lined ponds (Keewatin-Aski 1991). Calcium chloride use is expected to be restricted to the entrance area on Concession 7. Part of this area will be paved, which will reduce dust control chemical requirements.

The majority of local wells obtain water from confined zones, and are somewhat protected, by the confining layer, from changes in water quality in the unconfined aquifer .

6. IMPACT OF DEVELOPMENT - *Excavation Below The Water Table*

6.1 Effect on the Water Table

If the pit is extended below the water table, then a number of additional factors would affect the water table elevation.

First, the aggregate removed from below the water table would be 'replaced' by water from the unconfined aquifer. Since a typical sandy soil is about 70% by volume solid material (the rest being space occupied by air or water), then the volume of water that would infill the pond would be equivalent to at least 70% of the volume of the soil excavated below the water table. This would represent a large volume of water for the entire excavation and, if the excavation occurred over a short period, would drawdown the water table considerably adjacent to the pond. The actual effect, both the amount of drawdown and the extent of the area affected away from the property, would depend on the aquifer characteristics around the site. At this property, the process would take place over several decades as the various phases of the pit development reached the base grade.

Any lowering of the water table is not expected to have a significant impact on surrounding surface vegetation, since the water table is currently more than 25 m below ground surface throughout the site. However, the impact on adjacent wells would need to be assessed.

With the development of a pond, there would be evaporation loss from the pond and, hence, from the unconfined aquifer. The estimated loss of water from the pond is equivalent to a decline in water level in the pond of 0.45 m per year (pan evaporation data, Lindsay-Frost and Guelph Stations; long term normal data, Environment Canada). However, this evaporation loss is offset by the proportion of precipitation no longer 'lost' by evapotranspiration but now reaching the pond area directly.

Development of a pond in the base of the pit would cause the slope of the water table to flatten in the area of the pond, slightly lowering the water table immediately upgradient of the pond and slightly increasing the elevation of the water table downgradient.

Finally, with excavation below the water table, care must be taken to prevent introduction of any contaminants into the pond and hence, the unconfined aquifer. This includes such standard techniques as design of surface runoff controls; care with the storage and use of dust suppressants, fuels and lubricants; and development of contingency plans to deal with accidental contamination of the pond.

At this time, there is not sufficient data to quantitatively assess the different effects that excavating below the water table would have on the water table elevation and to accurately predict the resultant pond level.

However, a preliminary design elevation of 329 m has been used for the pond level to develop the design drawings; this was derived from some basic calculations, using many simplifying assumptions and the earlier survey elevations. The new survey elevations would lower this estimate by a few metres, all other factors remaining constant. However, since the design drawings are for conceptual purposes only, and the preliminary value as initially calculated is known to be a very general estimate, the value has not been changed.

Prior to applying for an amendment to the license to allow extraction below the water table additional hydrogeological data will need to be acquired, using a program similar to the program outlined in the following section.

6.2 Future Hydrogeological Investigation

A hydrogeological investigation to assess the impact of excavation below the water table would include:

1. a series of boreholes with piezometers installed around the site perimeter, in order to identify the saturated thickness of and the soil materials in the unconfined aquifer.

2. hydraulic conductivity testing at selected boreholes.

3. analysis of the long-term monitoring data collected during pit development from piezometers on site and, if available, from adjacent operations.

4. test pumping of the aquifer at selected locations; the testing would include observations at adjacent piezometers and at off-site wells if possible.

This additional data on the unconfined aquifer characteristics, combined with data accumulated during pit operations, will provide the data base for assessing the impact of excavation below the water table.

7. CONCLUSIONS

The aggregate operation proposed for the west half of lots 7,8 and 9, Concession 8, Oro Township, Simcoe County , is located within the Bass Lake Kame Moraine. The pit is currently planned to be developed to 1.5 metres above the water table or the depth of suitable material, whichever is encountered first. The following are the conclusions of the hydrogeological study of the proposed site, prepared as part of the documentation required for a Class A license under the Aggregate Resources Act.

1. The proposed site is located in an area of groundwater recharge in the sandy deposits of the Bass Lake Moraine. No surface water was observed on site or immediately adjacent to the proposed site.

2. The depth to water table, measured in May, 1991 in four water table piezometers on site, and the monitor on the licensed property, is between 26 and 35 metres; a perched saturated zone occurs above the water table in parts of the site. The water table elevation ranges between 327 m in the south and 320 m in the northwest, with groundwater movement under most of the site in a northerly to northwesterly direction. If the elevation of 335.6 metres at DC-1 does not represent a perched condition, as concluded in this report, then the direction of flow is still northerly to northwesterly. There may be southerly component of groundwater flow beneath a southern portion of the site.

3. Development of the pit will cause an increase in the amount of precipitation reaching the water table within the pit area and a slight water table mound is expected to occur beneath the site. This is not expected to exceed 3 metres, and may be considerably less depending on long term precipitation, the area of bare soil, the length of time bare soil exists, and the thickness and lateral permeability of the unconfined aquifer.

4. Most water wells in the area obtain water from confined aquifers within the moraine. The wells within the 300 m zone apparently taking water from the unconfined aquifer are not expected to be negatively impacted.

5. Yields of local wells are not expected to be adversely affected by excavation of the pit to a maximum depth of 1.5 metres above the water table. If, however, groundwater is required for washing, an assessment of water needs will have to include impact on adjacent wells.

6. Removal of the overburden will increase the sensitivity of the unconfined aquifer beneath the pit to contamination. Hence all possible equipment refuelling, maintenance and servicing should be located away from the pit floor. When such activities have to occur in the pit, procedures to minimize accidental spills should be followed.

7. The application of calcium chloride for dust control should be kept to a minimum to reduce the increase in chloride in the groundwater.

8. Preliminary calculations, based on several simplifying assumptions, suggest that the impact of excavating below the water table will not have a significant net effect on the water table elevation. However, a more detailed hydrogeological investigation would be required to properly assess the impact.

8. RECOMMENDATIONS

1. The water table on site should be monitored bi-monthly to determine an annual fluctuation over one year. Subsequently, the water table should be measured quarterly or as required by the MOE. The data should be reviewed by a qualified hydrogeologist.

2. Prior to excavation at the pit, two water samples should be collected from the water table monitors and analyzed for the major ground water parameters (major ions, pH,

conductivity, alkalinity) and for phenols. This will provide baseline groundwater quality at the site.

3. Prior to excavation starting, water levels should be taken on all accessible domestic wells within 300 m of the proposed site, to determine the current water level in adjacent water wells. Although no negative impact is expected, this will provide baseline approximate static levels for adjacent wells.

4. Further work will be required to determine the source of and impact of obtaining washing water once water requirements are defined.

5. If an amendment to the site plan to extend pit operations below the water table is contemplated, an additional hydrogeological investigation, such as outlined in Section 6.2, will be required.

9. REFERENCES

Burwasser, G.J., and Ford, M.J. 1974a: Drift Thickness of the Orr Lake Area, Southern Ontario; Ontario Div. Mines, Prelim. Map P.977, Drift Thickness Ser., Scale 1:50,000. Geological Compilation.

Burwasser, G.J., and Ford, M.J. 1974b: Bedrock Topography of the Orr Lake Area, Southern Ontario; Ontario Div. Mines, Prelim. Map P.976, Bedrock Topography Ser., Scale 1:50,000. Geological Compilation, 1974.

Chapman, L.J., and Putnam, D.F. 1984: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey Special Volume 2.

Dixon Hydrogeology Limited. 1991: Hydrogeological Study, Alfa Aggregates Limited, Roehner Pit, Part East Half Lot 9, Concession 7, Township of Oro.

Hantush, M.S. 1967: Growth and Decay of groundwater-Mounds in response to Uniform Percolation; Water Resources Research, Vol. 3, No.1, p.227-234.

Ingham,K.W. 1989: Preliminary Report, Exploratory Drilling Program, Oro Property; prepared for James Dick Aggregates

Keewatin-Aski Ltd. 1991: Application for Zoning Amendment for West 1/2 Lots 7,6, & 9, Concession 7, Township of Oro.

Ministry of the Environment. Water Well Records, Oro Township, Simcoe County, Ontario.

Ontario Geological Survey. 1984: Aggregate Resources Inventory of Oro Township Simcoe County Southern Ontario. Paper 65.

FIGURES

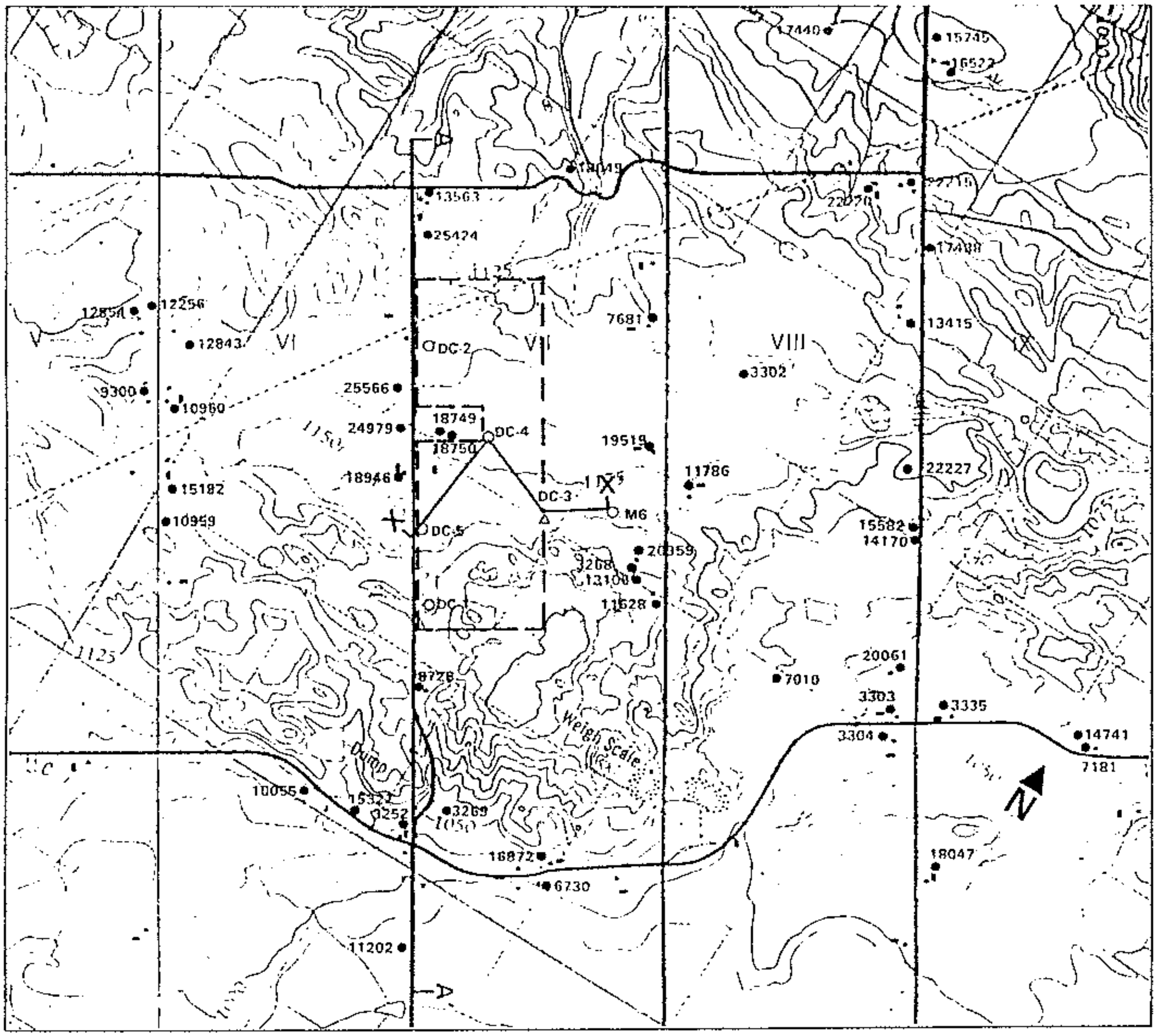


FIGURE 2

WATER WELL AND BOREHOLE LOCATIONS

LEGEND

- O Water Table Monitor
  - DC - installed by Charlesworth & Assoc.
  - M - previously installed
- Δ Borehole drilled; no monitor
- ● Water Well - MOE Number and Location
- — — Site Boundary
- A A' Cross-Section Location

November 1991

Scale 1:25000

Proposed Sand and Gravel Pit
West 1/2 Lots 7,8,9. Conc 7.
Oro Township, Simcoe County.
for
James Dick Construction Ltd.

DAVID L. CHARLESWORTH & ASSOCIATES INC

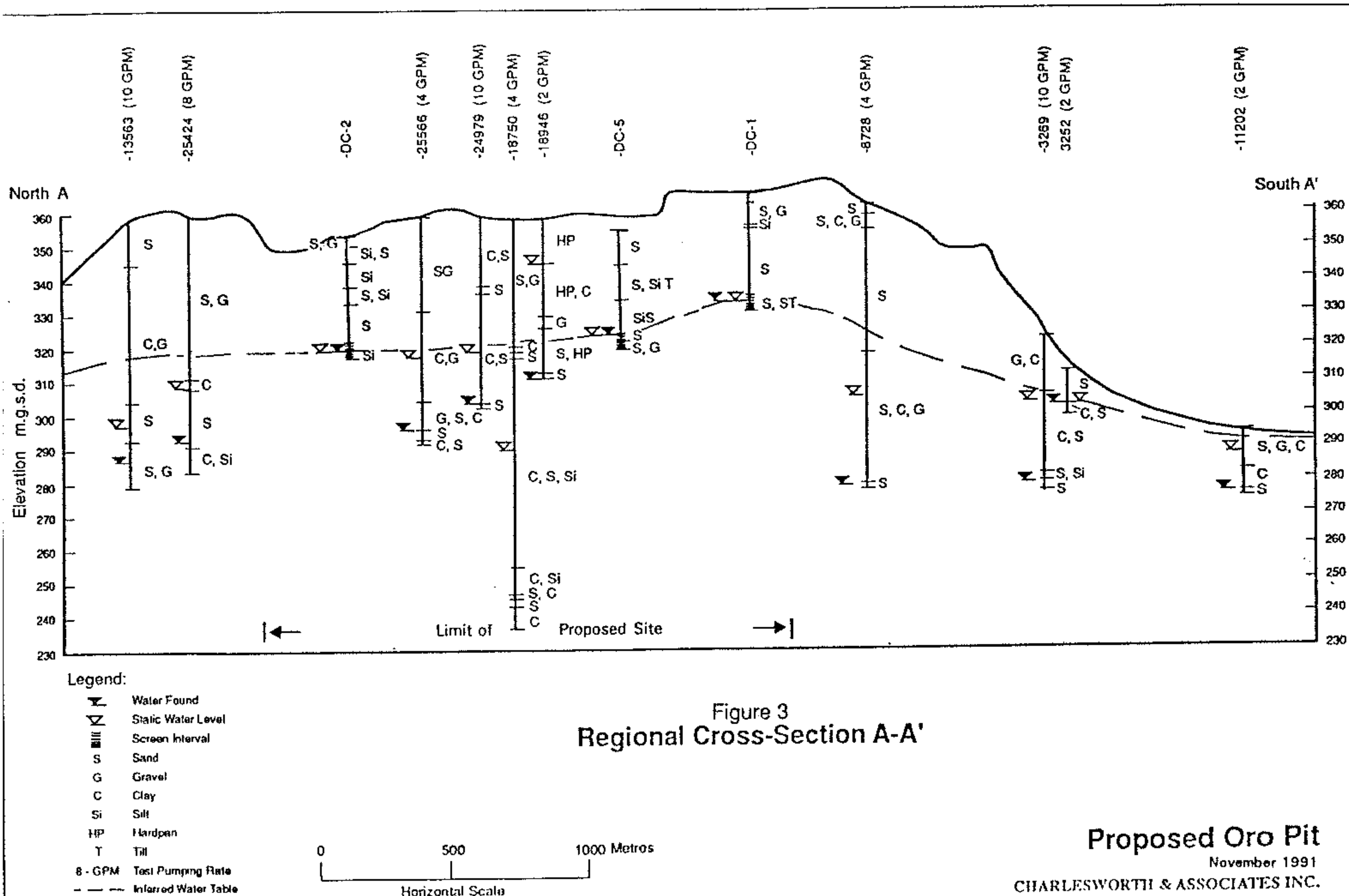


Figure 3
Regional Cross-Section A-A'

Proposed Oro Pit
November 1991
CHARLESWORTH & ASSOCIATES INC.

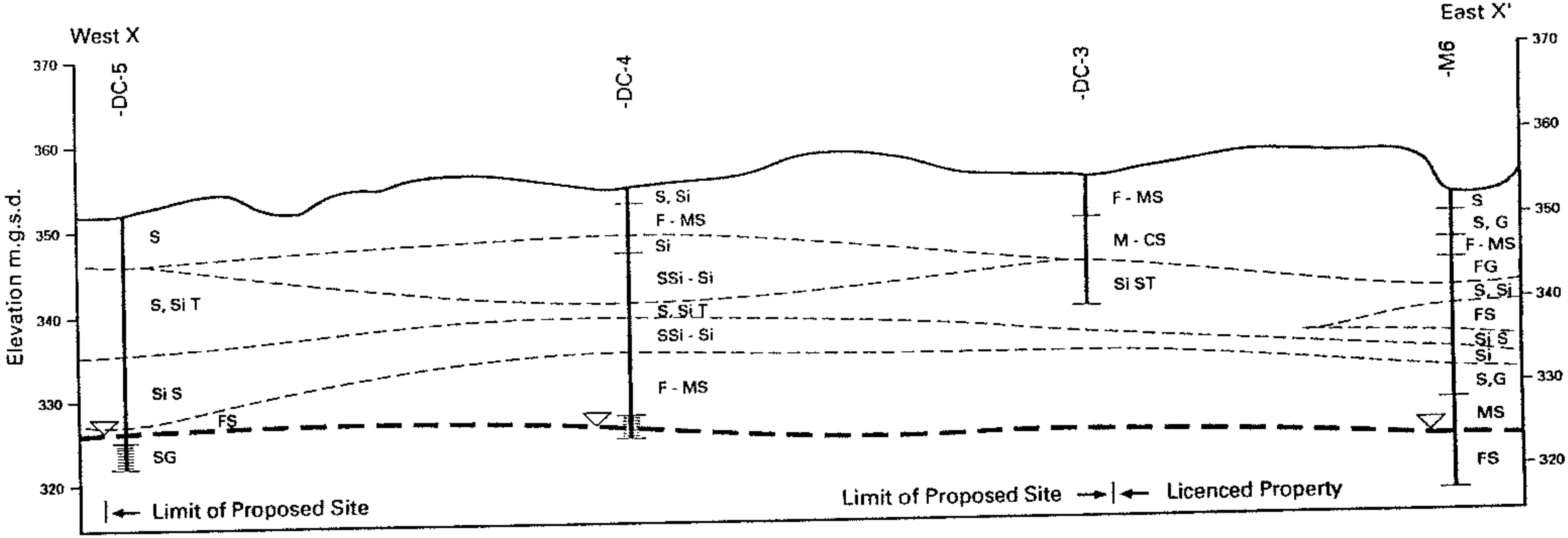


Figure 4
Cross–Section X-X'
Proposed Oro Pit

Legend:

(symbol)	Static Level May 13/91
(symbol)	Screened Interval
G	Gravel
C	Clay
Si	Silt
T	Till
S	Sand
F,M,C	Fine, Medium, Coarse Sand
	Silty Deposits
8 - GPM	Test Pumping Rate
— — —	Inferred Water Table (May 13, 1991)

0 200 400
Horizontal Scale (metres)

Charlesworth & Associates
CONSULTING HYDROGEOLOGISTS

November 1991

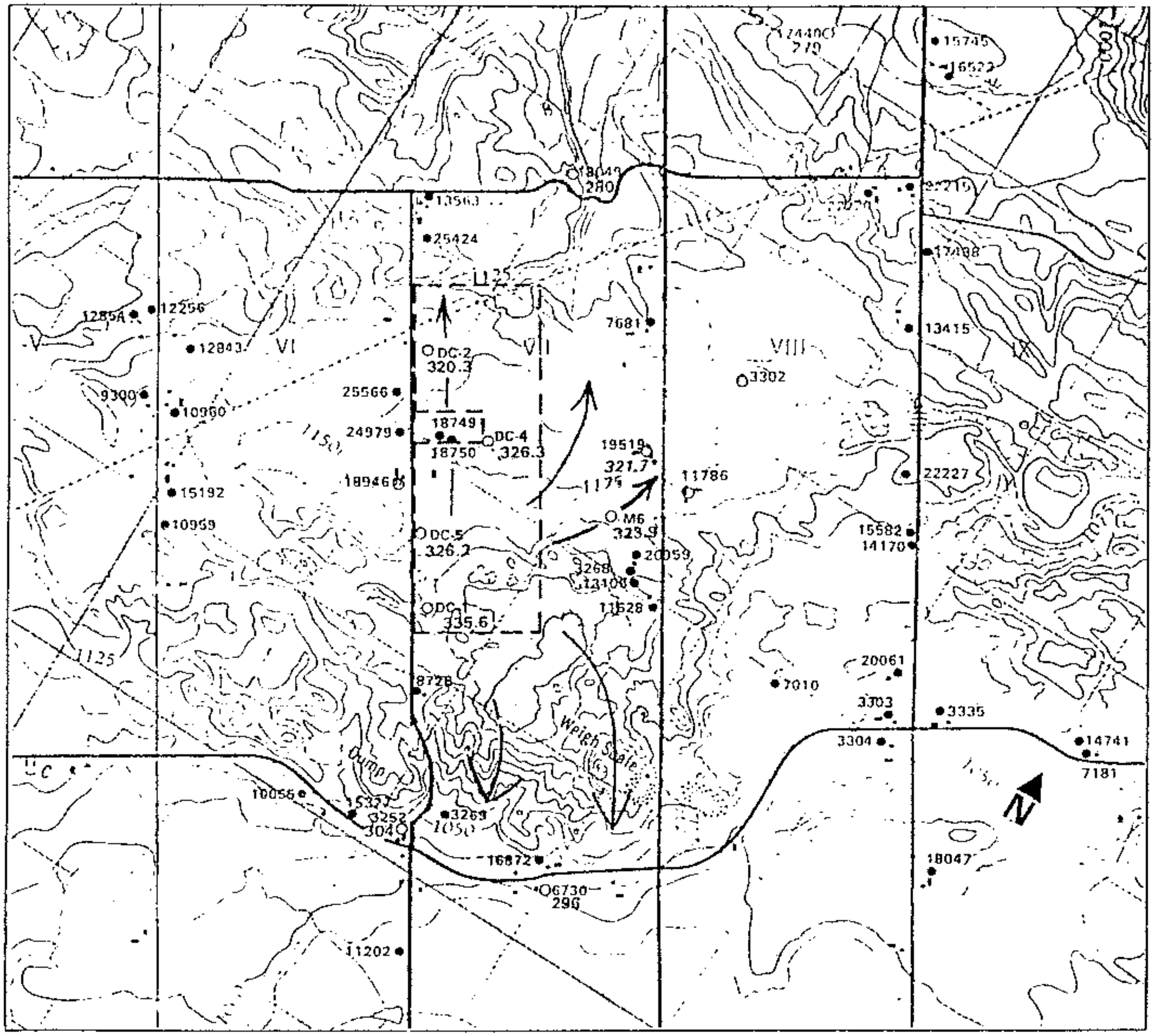


FIGURE 5

WATER TABLE ELEVATIONS

LEGEND

○	Water Table Well/Monitor
325.4	Static Water Elevation May 13, 1991
*321.7**	Static Water Elevation measured July 31, 1991
●	Other Water Wells
→	Inferred Flow Direction, Water Table Aquifer
— —	Site Boundary

November 1991 Scale 1:25000

Proposed Sand and Gravel Pit
West 1/2 Lots 7,8,9. Conc 7.
Oro Township, Simcoe County.
for
James Dick Construction Ltd.

CHARLESWORTH & ASSOCIATES INC.

TABLES

TABLE 1 WATER LEVEL MEASUREMENTS, ORO SITE

Date	DC-1	DC-2	DC-4	DC-5	M6
	Depth from Top of Pipe (metres)				
May 3, 1991	32.89	34.35	29.44	26.70	29.15
May 13, 1991	31.87	34.27	29.36	26.45	29.07
July 22,1991	31.73	34.31	29.20	25.42	28.74
Oct. 1,1991	32.06	34.05	28.75	25.47	28.51
	Static Level Elevation (metres above ground datum)				
May 3,1991	334.56	320.22	326.22	325.94	323.81
May 13 1991	335.58	320.30	326.30	326.19	323.89
July 22,1991	335.72	320.26	326.46	327.22	324.22
October 1,1991	335.39	320.52	326.91	327.17	324.45

Water level taken in domestic well, MOE # 19519; July 31,1991

Depth to water	42.19 m
Static water elevation	321.67 m

TABLE 2 SUMMARY OF MOE WATER WELL RECORD

MOE	Conc	Lot	Ground Elev. m	Owner	Water Source	Total Depth m	Test Rate GPM	Water Found mgsd	Static Level mgsd
Wells within 300 metres of the Site and Adjacent Property									
25666	6	7	358	Dover	fs	66.14	4	296	317
24979	6	8	358	Wilson	s	55.78	10	304	319
18946	6	8	358	Wagner	fs	47.24	2	311	346
19519	7	8	358	Alexander	s	46.94	8	311	316
18749	7	8	358	Garside		97.54			
18750	7	8	358	Garside	s	120.7	4		290
20959	7	9	360	Norman	s	72.54	7	290	313
3268	7	9	360	McNiven	s	45.42	1	315	320
13106	7	9	360	Roehner	s	65.95	6	275	298
8728	7	10	363	Parke	fs	84.12	4	280	306
11766	8	8	357	Middleton	s	45.72	4	313	317
Wells beyond 300 metres of the Site and Adjacent Property									
12854	5	7	372	Winger	cs	139	30	233	299
9300	5	7	358	Ross	f-ms	102.1	12	279	298
12256	5	7	372	King-Winger	Dry	100.58			
12843	6	7	357	Sutherland	cs	120.4	30	240	292
10960	6	8	358	Crittenden	c	68.58	5	291	299
15192	6	8	363	Hiltz	sgc	97.54	4	302.04	314
10959	6	9	363	Bolechowsky	ms	79.25	3	285	300
10055	6	11	335	Simek	ms	64.01	30	274	313
15327	6	11	323	Derks	sfg	30.48	10	293	311
3252	6	11	312	Eenhorn	cms	10.67	2	304	303
11202	6	12	295	Mallinson	fs	17.98	2	278	290
18049	7	5	328	Holmes	s	57.91	5	281	280
13563	7	6	358	H. Antiques	cs	79.25	10	287	296
25424	7	6	358	Ginn	csi	74.68	8	292	309
7681	7	7	343	Bolton	fs	68.88	6	277	331
11628	7	9	363	Porter	sg	50.9	2	313.01	316
3269	7	11	323	Nichols	ms	45.11	10	280	304
16872	7	11	320	Starr	cs	62.48	30	262	
6730	7	12	309	Starr	g	16.45	2	294	296
17440	8	4	290	Atwood	s	16.15	5	279	270
22220	8	6	312	Leach	s	46.94	5	268	305
22215	8	6	312	Cuthbertson	g	32.92	5	279	307
3302	8	7	360	Graves	ms	44.2	5	319	322
13415	8	7	335	Walsh	s	42.98	7	293	312
22227	8	8	343	Leach	s	13.72	7	332	339
14170	8	9	330	Clime	s	55.47	3	275	292

TABLE 2 SUMMARY of MOE WATER WELL RECORDS continued

MOE	Conc	Lot	Ground Elev. m	Owner	Water Source	Total Depth m	Test Rate GPM	Water Found mgsd	Static Level mgsd
Wells beyond 300 metres of the Site and Adjacent Property continued									
15582	8	9	335	Asmi	f-ms	93.57	15	260	306
20061	8	10	320	P.F.Group	cg	41.76	18	278	302
7010	8	10	320	Beaton	ms	42.67	25	277	306
3303	8	10	317	Woodron	msg	41.15	10	276	299
3304	8	11	317	Merkus	csg	31.39	7	286	303
15475	9	4	290	Young	sc	39.32	10	252	280
16522	9	4	290	Young	ms	42.67	40	250	277
17438	9	6	335	Wiedman	s	27.43	4	309	319
3335	9	10	317	Wilson	cs	46.63	15	270	299
14741	9	10	326	Jeremy	cg	53.34	5	275	
7181	9	11	328	Hollis	csst	54.25	10	274	298
16047	9	12	317	Kozak	s	29.87	12	290	300

Legend
s-sand
g-gravel
si-silt
st-stones
c-clay
f,m,c-fine, medium, coarse

APPENDICES

APPENDIX A

BOREHOLE LOGS AND INSTALLATION DETAILS
DC-1 to DC-5

Table A-1 Well Installation Details

Monitors	DC-1	DC-2	DC-4	DC-5
Top of Casing Elev.* mgsd	367.45	354.57	355.66	352.64
Ground Elevation * mgsd	366.70	354.07	354.62	352.05
Stick Up m *	0.75	0.50	1.04	0.59
Screen Interval				
Top metres	30.30	32.90	26.50	26.80
Bottom metres	33.40	36.00	29.60	29.90
Top mgsd	336.40	321.17	328.12	325.25
Bottom mgsd	333.30	318.07	325.02	322.15
Screened Material	Sand/Si Sand Till	Sand/Si	Sand	Sand/Sand & Gravel

* Taken from Young and Young, November, 1991
mgsd = Elevation metres, ground surface datum

Project: Proposed Oro Pit No.: 91-107

Date Drilled: March 25/91 to March 27/91 Driller: Longyear

Borehole Location: Southwest Corner, Conc.7, Lot 9.

Drilling Supervised by: K. Henderson

Drilling Method: CME 75, 5 1/4" ID HSA

Piezometer Details

Type of Pipe: 51mm ID Schedule 40 PVC

Type of Screen: 10 Slot PVC

Borehole No.: DC-1

Piezometers: DC-1

Sheet 1 of 2

SS Split Spoon Sample RX Rock Core
WA Wash Sample Piezometer Screen (water level elev. m, Y/M/D)
AU Auger Sample
CN Continuous Sample

Scale (ft) (m)	Elev (m GSD) / Depth (m)	Geological Log – Description	Static Level	Piezometer Details	Sample No	Sample Type	Blows 30 cm
		Ground Surface 366.70 mgsd					
	366.55 / .15	Topsoil - dark brown, rootlets, soft, moist		Cement	1	ss	9
1		GRAVELLY SAND - fine to medium		Holeplug			
5 / 2		- grey brown - pebbles - loose			2	ss	22
10 / 3		- dry to moist			3	ss	36
4		- grading into SAND (fine to medium) - trace to some gravel, pebbles - decreasing gravel and pebble content with depth - dry			4	ss	38
15 / 5							
20 / 6		- occasional silt pockets - some beds darker		Native Backfill	5	ss	39
7					6	ss	34
25 / 8							
30 / 9	357.5 / 9.2	SILT - to very fine sand - grey, compact, moist			7	ss	30
10	357.0 / 9.7	SAND - fine to medium					
35 / 11		- light brown - uniform			8	ss	36
40 / 12		- compact - dry - very fine sand zone at 12.3m, 15cm thick			9	ss	32
13							
45 / 14					10	ss	33
50 / 15		- trace very coarse sand at 15.2m			11	ss	44

Borehole Record

Kirsten Henderson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project: Proposed Oro Pit   No.: 91-107

Borehole Location: Southwest Corner, Conc. 7, Lot 9.

Borehole No.: DC-1
Piezometers: DC-1

Scale (ft.): 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110
Scale (m): 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34

Elev. (m GSD) / Depth (m)	Geological Log – Description	Static Level	Piezometer Details	Sample No.	Sample Type	Blows /0.3m
				12	ss	31
	- becoming finer at 17.3m			13	ss	32
349.0 / 17.7	SAND - very fine to fine - grey brown, compact, dry to moist - interbedded silt layers from 18.8-18.9m			14	ss	37
19.4	SAND - fine to medium - light brown - some beds darker - trace coarse sand, gravel, silt - occasional silt seams - compact			15	ss	45
			Native Backfill	16	ss	38
				17	ss	55
	- dry to moist			18	ss	50
	- slightly coarser below 24.9m					
				19	ss	45
				20	ss	53
	- very fine sand seams, 2.5 cm thick, at 29.1 and 29.5m - becoming finer at 30.5m - wet at 30.8m			21	ss	74
	(May 13, 1991)	▼	Artificial Pack			
335.20 / 31.5	SILTY SAND TILL - grey - trace gravel and cobbles - dense - moist to wet			22	ss	100 / 3"
				23	ss	150 / 3"
332.60 / 34.1	End of Borehole at 34.1m					

Borehole Record

Kirsten Henderson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project Proposed Oro Pit No.: 91-107	Borehole No. DC-2
Date Drilled March 28/91 to April 2/91 Driller: Longyear	Piezometers: DC-2
Borehole Location: Northwest Corner, Conc. 7, Lot 7.	
Drilling Supervised by: K. Henderson	Sheet 1 of 3
Drilling Method CME 75, 4 1/4" ID HSA	SS Split Spoon Sample; RX Rock Core; WA Wash Sample; AU Auger Sample; CN Continuous Sample; Piezometer Screen (water level elev. m, Y/M/D)
Piezometer Details Type of Pipe 51mm ID Schedule 40 PVC Type of Screen 10 Slot PVC	

Scale (ft)	Scale (m)	Elev (m GSD) / Depth (m)	Geological Log — Description	Static Level	Piezometer Details	Sample No.	Sample Type	Blows /0.3m
			Ground Surface 354.07 mgsd					
		353.84 / .23	Topsoil, dark brown, rootlets, soft, moist		Cement Holeplug	1	ss	4
5	1	352.87 / 1.2	SAND - fine to medium - light brown, uniform, loose, moist			2	ss	20
	2	351.47 / 2.6	coarse SAND & GRAVEL - brown grey, trace silt, loose, moist to wet			3	ss	25
10–25	3–8		SILTY SAND - very fine - grey brown - uniform - compact - moist		Native Backfill	4	ss	59
25	8	346.17 / 7.9	SILT - some very fine sand - grey brown - dense - moist to wet - dilatant			5	ss	146
35	11					6	ss	100 / 4"
40	12		- occasional pebbles					
45–50	13–15					7	ss	100 / 5"

Borehole Record

Kirsten Henderson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project: Proposed Oro Pit No.: 91-107

Borehole Location: Northwest Corner, Conc. 7, Lot 7

Borehole No.: DC - 2

Piezometers: DC - 2

Elev. (m GSD) / Depth (m)	Geological Log / Description	Static Level	Piezometer Details	Sample No	Sample Type	Blows
318.97 / 35.1				16	ss	148 / 11"
318.07 / 36.0	SILT - grey, some clay, wet - sand seams at 35.5 & 35.6 m, 1cm thick - occasional silty clay seams					
	End of Borehole at 36.0m					

Borehole Record

Kirsten Henderson /D.A.

Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.

Consulting Hydrogeologists

Project: Proposed Oro Pit — No.: 91-107

Date Drilled: April 13th 1991 — Driller: Longyear

Borehole Location: South Central Portion of Conc.7, Lot 8.

Drilling Supervised by: K. Henderson

Drilling Method: CME 75, 3 1/4" ID HSA

Piezometer Details

Type of Pipe: 51mm ID Schedule 40 PVC

Type of Screen: 10 Slot PVC

Borehole No.: DC-3

Piezometers: DC-3

Sheet 1 of 1

SS Split Spoon Sample — RX Rock Core
WA Wash Sample
AU Auger Sample
CN Continuous Sample
Piezometer Screen (water level elev. m, Y/M/D)

Scale (ft) (m)	Elev (m GSD) / Depth (m)	Geological Log — Description	Static Level	Piezometer Details	Sample No.	Sample Type	Blows per ft
		Ground Surface 355.0 mgsd **(estimated)**					
	354.92 / .08	Topsoil, dark brown, rootlets, moist			1	ss	4
1		SAND - fine to medium - light brown, uniform, loose, moist - dark bedding			2	ss	9
10 — 3		- becoming coarser with trace gravel at 3.0m			3	ss	21
15	350.4 / 4.6						
20 — 6		SAND - medium to coarse - grey brown - some gravel, pebbles and cobbles - dense - dry to moist			4	ss	102 / 7"
30 — 9					5	ss	105
10	344.9 / 10.1						
40 — 12		SILTY SAND TILL - grey - trace gravel and cobbles - moist to wet - sand seam at 11.9m, 7.5cm thick - dense - boulders from 13.7m to 15.5m			6	ss	87
50 — 15	339.5	End of Borehole at 15.5m			7	ss	70 / 2"

Borehole Record

Kirsten Henderson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project: Proposed Oro Pit — No.: 91-107

Date Drilled: April 3/91 to April 4/91 — Driller: Longyear

Borehole Location: Northwest Portion of Conc.7, Lot 8.

Drilling Supervised by: K. Henderson

Drilling Method: CME 75, 4 1/4" ID HSA

Piezometer Details

Type of Pipe: 51mm ID Schedule 40 PVC

Type of Screen: 10 Slot PVC

Borehole No.: DC-4

Piezometers: DC-4

Sheet 1 of 2

SS Split Spoon Sample — RX Rock Core
WA Wash Sample — Piezometer Screen (water level elev. m, Y/M/D)
AU Auger Sample
CN Continuous Sample

Scale (ft.)	Scale (m)	Elev (m GSD) / Depth (m)	Geological Log — Description	Piezometer Details	Sample No	Sample Type	Blows per 0.3m
			Ground Surface 354.62 mgsd				
		354.47 / .15	Topsoil - dark brown, moist	Cement	1	ss	5
5	1	352.82 / 1.8	SILTY SAND - brown, rootlets, loose, moist	Holeplug			
10	2–4		SAND - fine to medium - grey brown - trace fine gravel - compact, uniform, moist		2	ss	27
15	5		- sandy silt seam at 5.7m, 2.5cm thick		3	ss	33
20	6–7	348.72 / 5.9	SILT - grey, moist - sand seam at 6.0m	Native Backfill			
25–40	8–12	347.02 / 7.6	SANDY SILT TO SILT - grey - compact - wet		4	ss	100
			- increasing silt content with depth		5	ss	145
45–50	13–15	340.92 / 13.7	SANDY SILT TILL - grey - trace gravel - dense, moist		6	ss	100/4"

Borehole Record

Kirsten Henserson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project: Proposed Oro Pit No.: 91-107

Borehole Location: Northwest Portion of Conc.7, Lot 8

Borehole No.: DC-4

Piezometers: DC-4

Scale (ft.)	Scale (m)	Elev. (m GSD) / Depth (m)	Geological Log Description	Strat. Plot	Piezometer Details	Sample No.	Sample Type	Blows /0.3m
	16	339.02 / 15.6	SANDY SILT to SILT - grey - dense - dilatant - wet			7	ss	100 / 4"
55, 60	17, 18, 19		- moist, not dilatant at 18.5m - pebble at 18.6m					
65	20	334.82 / 19.8	SAND - fine to medium - brown, darker bedding - uniform - compact - dry to moist		Native Backfill	8	ss	105
70, 75, 80	21, 22, 23, 24, 25		- grading to SAND, very fine to fine - trace silt			9	ss	115
85, 90	26, 27, 28		SAND - fine to medium (May 13, 1991) - trace coarse sand and gravel - wet at 28.3m	▼	Artificial Pack	10	ss	141
95	29	324.72 / 29.9			Natural Pack Cave	11	ss	70 / 2"
100, 105, 110	30, 31, 32, 33, 34		End of Borehole at 29.9m					

Borehole Record

Kirsten Henderson /D.A.

Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.

Consulting Hydrogeologists

Project: Proposed Oro Pit	No.: 91-107
Date Drilled: April 4/91 to April 5/91	Driller: Longyear
Borehole Location: Southwest Corner of Conc.7, Lot 8.	
Drilling Supervised by: K. Henderson	
Drilling Method: CME 75, 5 1/4" ID HSA	

Borehole No.: DC-5
Piezometers: DC-5

SS Split Spoon Sample
WA Wash Sample
AU Auger Sample
CN Continuous Sample
RX Rock Core
Piezometer Screen (water level elev. m, Y/M/D)

Piezometer Details
Type of Pipe: 51mm ID Schedule 40 PVC
Type of Screen: 10 Slot PVC

Scale (ft) (m)	Elev (m GSD) / Depth (m)	Geological Log Description	Static Level	Piezometer Details	Sample No	Sample Type	Blows /0.3m
		Ground Surface 352.05 mgsd					
	351.82 / .23	Topsoil - dark brown, rootlets, soft, dry		Cement Holeplug	1	ss	5
		SAND - very fine to fine, some silt - brown, uniform, loose, dry					
		- becoming coarser, fine to medium SAND at 4.0m - pebbles and cobbles from 4.1m			2	ss	21
	346.25 / 5.8	SANDY SILT TILL - grey brown - trace gravel - compact to dense - moist, some wet zones		Native Backfill	3	ss	66/11"
		- becoming very dense - pebbles and cobbles			4	ss	152

Scale: ft 5, 10, 15, 20, 25, 30, 35, 40, 45, 50; m 1–15

Borehole Record

Kirsten Henderson /D.A.
Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.
Consulting Hydrogeologists

Project: Proposed Oro Pit No.: 91-107

Borehole Location: Southwest Corner of Conc.7, Lot 8.

Borehole No.: DC-5

Piezometers: DC-5

Scale (ft.)	Scale (m)	Elev. (m GSD) / Depth (m)	Geological Log Description	Static Level	Piezometer Details	Sample No.	Sample Type	Blows /0.3m
55, 60	16, 17, 18	335.85 / 16.2	SILTY SAND - fine to medium (Till) - grey - trace coarse sand and gravel - very dense - moist			5	ss	100 / 5"
65, 70, 75, 80, 85	19, 20, 21, 22, 23, 24, 25		- silt rich zones at 22.9 and 23.2m	(May 13, 1991) ▼	Native Backfill	6	ss	100 / 6"
90	26, 27, 28	325.95 / 26.1	SAND - very fine to fine - grey - some silt, trace coarse sand and gravel - dilatant - dense - wet		Artificial Pack	7 8	ss ss	105 / 6" 100 / 3"
95, 100	29, 30	323.75 / 28.3	SAND (medium to coarse) and GRAVEL - trace to some silt - grey brown - dense - wet		Natural Pack	9	ss	100 / 3"
105, 110	31, 32, 33, 34	322.15 / 29.9	Borehole Ends at 29.9m					

Borehole Record

Kirsten Henderson /D.A.

Prepared by

DAVID L. CHARLESWORTH & ASSOCIATES INC.

Consulting Hydrogeologists

APPENDIX B

BOREHOLE LOG AND MONITOR DETAILS

MONITOR M6

Table B-1 M6 Monitor Details

Top of Casing Elev. mgsd	352.955*
Ground Elevation mgsd	352.305*
Stick Up m	.65*
Screen Interval	
Top metres	Unknown
Bottom metres	31.85(Measured by DLC-May 13/91)
Top mgsd	Unknown
Bottom mgsd	320.455(Measured by DLC-May 13/91
Screened Material	Sand(Based on Borehole Log)

*Taken from Young and Young, November,1991
mgsd = Elevation metres, ground surface datum

BOREHOLE NO. 6

Section Feet	Description
0 – 1.0	SOIL PROFILE
1.0 – 6.0	SAND Fine
6.0 – 17.0	GRAVELLY SAND Medium and fine sand
17.0 – 22.0	SAND Fine
22.0 – 25.0	SAND Medium
25.0 – 35.0	GRAVEL Fine
35.0 – 44.0	SILTY SAND Grey with pebbles
44.0 – 48.0	SAND Fine thin silt seams
48.0 – 53.0	SAND Fine
53.0 – 60.0	SANDY SILT thin beds of fine sand
60.0 – 67.0	SILT
67.0 – 80.0	GRAVELLY SAND Medium sand
80.0 – 102.0	SAND Medium (97 ▼)
102.0 – 115.0	SAND Fine to very fine, medium grey uniform, compact

APPENDIX C

WATER WELL SURVEY SHEETS

Matches MOE #13106

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion Project # 91-107

FIELD LOCATION NUMBER O-2 DATE May 3/91

Resident Name Mr. Roehner

Address

Lot 9 Conc 7 Township Oro

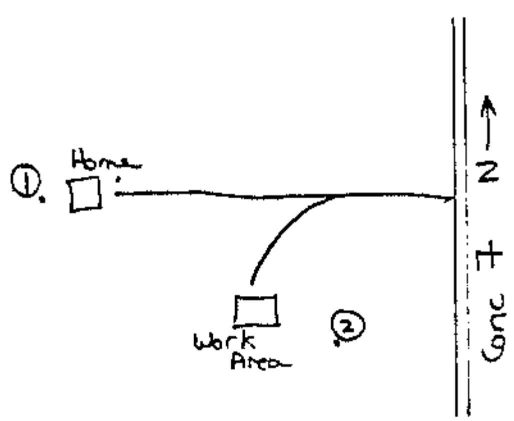
Description of Wells

Number wells - active 1
inactive 1 Why? Test Hole

Well # on Sketch	1	2	
In use	Y	N	
Depth (top of casing)	293'*	167'*	
Static (Top of cas.)	173' *		
Casing above ground	--------	--------	-----
Bedrock/OB?			
Casing Condition			
Quantity			
Quality			

Comments * Resident Report

Site Sketch



Matches MOE #117?

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion Project # 91-107

FIELD LOCATION NUMBER O-4 DATE May 3/91

Resident Name M Blake (renting from Sargent)

Address

Lot 8 Conc 8 Township Oro

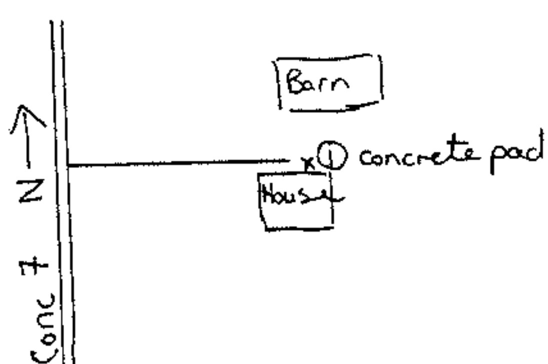
Description of Wells

Number wells - active 1
inactive Why?

Well # on Sketch	1		
In use			
Depth (top of casing)	No Acc.		
Static (Top of cas.)			
Casing above ground			
Bedrock/OB?			
Casing Condition			
Quantity	Plenty		
Quality	Good		

Comments

Site Sketch



Matches MOE #19519

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion   Project # 91-107

FIELD LOCATION NUMBER O-5   DATE May 3/91

Resident Name Mr. Sullivan (Alexander-Former Owner)

Address

Lot 8 Conc 7 Township Oro

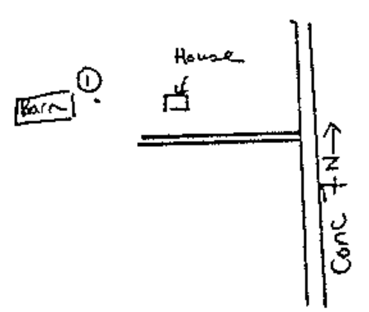
Description of Wells

Number wells - active 1
inactive ____ Why? ____

Well # on Sketch	1		
In use	Y	NOTE:	
Depth (top of casing)	>40m*	Depth to water 42.19 m July 31/91	
Static (Top of cas.)		Top of Casing 363.86 m elevation (surveyed Nov., 1991)	
Casing above ground	-------	-------	-----
Bedrock/OB?			
Casing Condition			
Quantity	Plenty		
Quality	Good		

Comments Drilled well - through old dug well, enough water for dishwasher and washing machine.

Site Sketch



Matches MOE #25566

WATER WELL SURVEY FIELD SHEET

David L. Charlesworth & Assoc.

Project Title ORO Expansion Project # 91-107

FIELD LOCATION NUMBER O-6 DATE May 3/91-May 13/91

Resident Name Mr. Dover

Address

Lot 7 Conc 6 Township Oro

Description of Wells

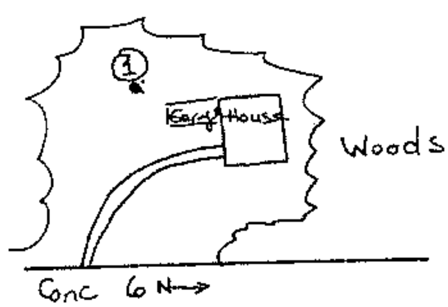
Number wells - active 1
inactive ____ Why? ____

Well # on Sketch	1		
In use	Y		
Depth (top of casing)	208'*		
Static (Top of cas.)			
Casing above ground	-------	--------	-----
Bedrock/OB?			
Casing Condition			
Quantity	Adequ.	8GPM	
Quality	Iron		

Comments Drilled in 1989 by Pete Marshall, steady flow

* Resident Report

Site Sketch



Matches MOE #24979

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion Project # 91-107

FIELD LOCATION NUMBER O-7 DATE May 3/91

Resident Name Mrs. Wilson

Address

Lot 8 Conc 6 Township Oro

Description of Wells

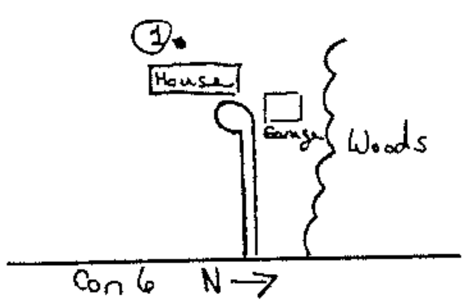
Number wells - active 1
inactive Why?

Well # on Sketch	1		
In use	Y		
Depth (top of casing)	150'*		
Static (Top of cas.)			
Casing above ground	-------	-------	-----
Bedrock/OB?			
Casing Condition			
Quantity	Plenty		
Quality	Hard		

Comments 20 gpm, drilled 3 years ago,

* Resident Report

Site Sketch



Matches MOE #18749 and 18750

WATER WELL SURVEY FIELD SHEET

David L. Charlesworth & Assoc.

Project Title ORO Expansion Project # 91-107

FIELD LOCATION NUMBER O-8 DATE May 3/91

Resident Name Mrs. Garside

Address

Lot 8 Conc 7 Township Oro

Description of Wells

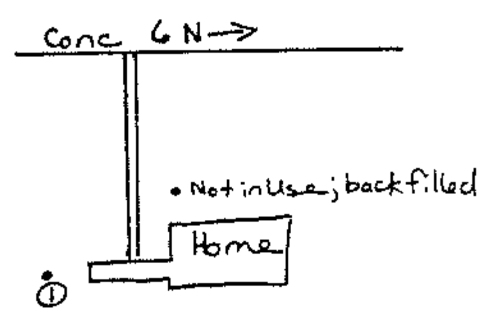
Number wells - active 1 (#18750)
inactive 1 Why? could not be developed

Well # on Sketch	1		
In use	Y		
Depth (top of casing)	400'*		
Static (Top of cas.)	Buried		
Casing above ground	-------	--------	-----
Bedrock/OB?			
Casing Condition			
Quantity	Adequ.		
Quality	Fe, Mn		

Comments Need water for domestic purposes inaddition to horses and dogs, water filtered. * Resident Report

---

Site Sketch



Matches MOE #189

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion   Project # 91-107

FIELD LOCATION NUMBER 0-9   DATE May 3/91

Resident Name Mrs. Wagner

Address

Lot 8   Conc 6   Township Oro

Description of Wells

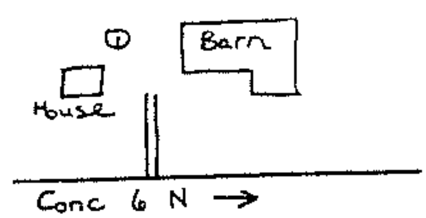
Number wells - active 1
inactive ____ Why? ____

Well # on Sketch	1		
In use	Y		
Depth (top of casing)	155'*		
Static (Top of cas.)			
Casing above ground	-------	-------	-----
Bedrock/OB?			
Casing Condition			
Quantity	2.5 gpm		
Quality	Good		

Comments Sufficent for livestock (sheep), drilled 8 years ago.

* Resident Report

Site Sketch



Matches MOE #8728

WATER WELL SURVEY FIELD SHEET
David L. Charlesworth & Assoc.

Project Title ORO Expansion   Project # 91-107

FIELD LOCATION NUMBER O-10   DATE May 3/91

Resident Name Mrs. Parke

Address

Lot 10   Conc 7   Township Oro

Description of Wells

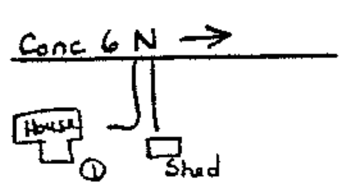
Number wells - active 1
inactive ______ Why? ______

Well # on Sketch	1		
In use	Y		
Depth (top of casing)	275'*		
Static (Top of cas.)	230'*		
Casing above ground	-------	-------	-----
Bedrock/OB?			
Casing Condition			
Quantity	Plenty		
Quality	Hard		

Comments Drilled around 1972.

* Resident Report

Site Sketch



APPENDIX D

SUMMARY OF RESULTS
HANTUSH GROUNDWATER MOUNDING CALCULATIONS

Estimation of Groundwater Mounding
Resulting From Increased Infiltration
Hantush Method

The possible height of the groundwater mound was calculated using the Hantush method (1967) and several scenarios.

Referring to the site plans, no more than 1/3 of the site will be will be bare of vegetation at one time; the remaining area will either have original vegetation or be rehabilitated. This assumption is used to determine the area experiencing increased infiltration in scenarios 1 to 4. Scenarios 5 to 8 assume that all vegetation is removed and the entire proposed site or proposed site and licensed site experience an increase in infiltration. This represents a 'worst case' with respect to the possible maximum infiltration increase.

The increase in infiltration is estimated assuming 20% evaporation from the bare soil and no evapotranspiration loss from the affected area.

Site Assumptions

1. Hydraulic conductivity of the aquifer (**k**) = 1 x 10 $^{-2}$ cm/sec.
   This value was based on a geometric mean of hydraulic conductivities calculated, using the Hazen method, from grain size curves of samples obtained near the unconfined aquifer elevation (Ingham 1989).

2. Increased infiltration (**w**) of 0.001 mm/day, due to the change from evapotranspiration from a vegetated surface to evaporation from bare soil.

3. Specific yield (**e**) = 0.1

4. Saturated aquifer thickness (**hi**) of 5 metres or 10 metres.

5. Dimensions given for the area of increased infiltration for scenarios of the licensed and the proposed site are for a rectangle of equivalent area.

SCENARIO 1

Expansion Property - vegetation removed from 1/3 of site

Area of increased infiltration = 500m x 750 m; assume entire expansion property has vegetation removed.
Assume 10 m of saturated aquifer;

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	10	11.1	10.65	911.52	730	250	0	375	0	11.12	1.1
0.001	8.64	0.1	10	10.9	10.45	902.88	730	250	250	375	0	10.91	0.9
0.001	8.64	0.1	10	11	10.5	907.2	730	250	0	375	375	10.82	0.8
Time = 10 years													
0.001	8.64	0.1	10	11.4	10.7	924.48	3650	250	0	375	0	11.46	1.5
0.001	8.64	0.1	10	11.3	10.65	920.16	3650	250	250	375	0	11.38	1.4
0.001	8.64	0.1	10	11.2	10.6	915.84	3650	250	0	375	375	11.17	1.2

SCENARIO 2

Licensed + Expansion Property ; vegetation cleared from 1/3 of property.

Dimensions of area of increased infiltration = 600m x 790 m
Assume aquifer has 10 m saturated thickness.

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	10	11.3	10.65	920.16	730	300	0	395	0	11.33	1.3
0.001	8.64	0.1	10	11	10.5	907.2	730	300	300	395	0	11.03	1.0
0.001	8.64	0.1	10	10.95	10.48	905.04	730	300	0	395	395	10.98	1.0
Time = 10 years													
0.001	8.64	0.1	10	11.7	10.85	937.44	3650	250	0	375	0	11.66	1.7
0.001	8.64	0.1	10	11.4	10.7	924.48	3650	250	250	375	0	11.42	1.4
0.001	8.64	0.1	10	11.3	10.65	920.16	3650	250	0	375	375	11.35	1.3
Time = 100 years													
0.001	8.64	0.1	10	12.1	11.05	954.72	36500	250	0	375	0	12.05	2.0

SCENARIO 3

Expansion Property - vegetation removed from 1/3 of site

Area of increased infiltration = 500m x 750 m; assume entire expansion property has vegetation removed.
Assume 5 m of saturated aquifer;

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	5	6.7	5.85	505.44	730	250	0	375	0	6.68	1.7
0.001	8.64	0.1	5	6.3	5.65	488.16	730	250	250	375	0	6.25	1.2
0.001	8.64	0.1	5	6.2	5.6	483.84	730	250	0	375	375	6.23	1.2
Time = 10 years													
0.001	8.64	0.1	5	7.5	6.25	540	3650	250	0	375	0	7.52	2.5
0.001	8.64	0.1	5	7.2	6.1	527.04	3650	250	250	375	0	7.19	2.2
0.001	8.64	0.1	5	7.1	6.05	522.72	3650	250	0	375	375	7.11	2.1
Time = 100 years													
0.001	8.64	0.1	5	8.5	6.75	583.2	36500	250	0	375	0	8.45	3.4

SCENARIO 4

Licensed + Expansion Property , vegetation cleared from 1/3 of property.

Dimensions of area of increased infiltration = 600m x 790 m
Assume aquifer has 5 m saturated thickness.

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	5	7	6	518.4	730	300	0	395	0	6.96	2.0
0.001	8.64	0.1	5	6.5	5.75	496.8	730	300	300	395	0	6.46	1.5
0.001	8.64	0.1	5	6.4	5.7	492.48	730	300	0	395	395	6.42	1.4
Time = 10 years													
0.001	8.64	0.1	5	7.9	6.45	557.28	3650	300	0	395	0	7.92	2.9
0.001	8.64	0.1	5	7.4	6.2	535.68	3650	300	300	395	0	7.36	2.4
0.001	8.64	0.1	5	7.3	6.15	531.36	3650	300	0	395	395	7.36	2.4
Time = 100 years													
0.001	8.64	0.1	5	9	7	604.8	36500	300	0	395	0	9.01	4.0

SCENARIO 5

Expansion Property - no vegetation on entire site

Area of increased infiltration = 626m x 1610 m;
Assume 10 m of saturated aquifer;

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	10	12	11	950.4	730	313	0	905	0	12.13	2.1
0.001	8.64	0.1	10	11.7	10.85	937.44	730	313	313	905	0	11.70	1.7
0.001	8.64	0.1	10	11.3	10.65	920.16	730	313	0	905	905	11.28	1.3
Time = 10 years													
0.001	8.64	0.1	10	13.5	11.75	1015.2	3650	313	0	905	0	13.44	3.4
0.001	8.64	0.1	10	13	11.5	993.6	3650	313	313	905	0	13.02	3.0
0.001	8.64	0.1	10	12.4	11.2	967.68	3650	313	0	905	905	12.41	2.4

SCENARIO 6

Licensed + Expansion Property ; no vegetation on entire site

Dimensions of total area = 790m x 1800 m
Assume aquifer has 10 m saturated thickness.

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	10	12.4	11.2	967.68	730	395	0	900	0	12.47	2.5
0.001	8.64	0.1	10	11.9	10.95	946.08	730	395	395	900	0	11.98	2.0
0.001	8.64	0.1	10	11.5	10.75	928.8	730	395	0	900	900	11.53	1.5
Time = 10 years													
0.001	8.64	0.1	10	14	12	1036.8	3650	395	0	900	0	14.01	4.0
0.001	8.64	0.1	10	13.5	11.75	1015.2	3650	395	395	900	0	13.42	3.4
0.001	8.64	0.1	10	12.9	11.45	989.28	3650	395	0	900	900	12.95	3.0

SCENARIO 7

Expansion Property - no vegetation on entire site

Area of increased infiltration = 626m x 1810 m;

Assume 5 m of saturated aquifer;

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	5	7.8	6.4	552.96	730	313	0	905	0	7.82	2.8
0.001	8.64	0.1	5	7.2	6.1	527.04	730	313	313	905	0	7.30	2.3
0.001	8.64	0.1	5	6.6	5.8	501.12	730	313	0	905	905	6.67	1.7
Time 10 Years													
0.001	8.64	0.1	5	9.6	7.3	630.72	3650	313	0	905	0	9.68	4.7
0.001	8.64	0.1	5	9.2	7.1	613.44	3650	313	313	905	0	9.25	4.3
0.001	8.64	0.1	5	8.4	6.7	578.88	3650	313	0	905	905	8.44	3.4

SCENARIO 8

Licensed + Expansion Property ; all vegetation removed;

Dimensions of total area = 790m x 1800 m

Assume aquifer has 5 m saturated thickness.

w m/d	k m/d	e	hi m	h est m	b	v	t days	l m	x	a m	y m	h calc. m	head increase
Time = 2 years													
0.001	8.64	0.1	5	8.3	6.65	574.56	730	395	0	900	0	8.32	3.3
0.001	8.64	0.1	5	7.6	6.3	544.32	730	395	395	900	0	7.55	2.6
0.001	8.64	0.1	5	7	6	518.4	730	395	0	900	900	6.97	2.0
Time 10 Years													
0.001	8.64	0.1	5	10.3	7.65	660.96	3650	395	0	900	0	10.27	5.3
0.001	8.64	0.1	5	9.8	7.4	639.36	3650	395	395	900	0	9.90	4.9
0.001	8.64	0.1	5	9	7	604.8	3650	395	0	900	900	9.06	4.1

GLOSSARY

A SELECTED GLOSSARY OF HYDROGEOLOGICAL TERMS

Aquiclude	A layer of low permeability natural material (such as clay or shale) through which virtually no water moves. In reality most aquicludes are more accurately defined as aquitards
Aquifer	A saturated permeable geologic unit (soil or rock) that can transmit significant and accessible quantities of water.
Aquitard	A layer of low permeability natural material which can store water but does not transmit significant and accessible quantities of water. An aquitard acts as a confining layer to an aquifer.
Artesian Well	A well in a confined aquifer with a water level above the top of the aquifer; if the water level rises above the ground surface it is known as a flowing artesian well
Evapotranspiration	That portion of the precipitation returned to the air through direct evaporation and transpiration of vegetation
Glacial Drift	Sediment deposited by glaciers or predominantly of glacial origin
Ground Moraine	The material deposited from a glacier on the ground surface over which the glacier has moved
Groundwater	Subsurface water that occurs in soils and geologic formations that are fully saturated (ie. below the water table)
Hydraulic Conductivity	The constant of proportionality in the equation governing the movement of fluid through porous material. The higher the hydraulic conductivity the more readily the water will pass through the material. It is sometimes referred to as permeability, though the two are not strictly the same.
Hydraulic Gradient	The rate of change of pressure head per unit of distance, in a given direction
Hydraulic Head	The elevation of the water surface in the piezometer
Ice-Contact Deposits	Stratified sediments such as kames, deposited in contact with melting glacier ice

Kame	A conical hill or short irregular ridge of gravel or sand deposited in contact with glacier ice
Outwash	Drift deposited by meltwater streams beyond active glacier ice
Overburden	Commonly used to describe surficial deposits or any loose unconsolidated material which rests upon solid rock
Permeability	The permeability of a material is its capacity for transmitting a fluid. It is often used interchangeably with hydraulic conductivity, though the two terms are not strictly synonymous
Potentiometric Head	The same as the hydraulic head, but measured in piezometers in confined aquifers
Recharge	The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone
Surficial Deposits	Unconsolidated deposits, often glacial in origin, lying on top of the bedrock surface
Till	A non-stratified, unsorted sediment carried and deposited by a glacier
Water Table	The upper surface of the zone of saturation, which is at atmospheric pressure (i.e. not confined by a low permeability unit)
Well Yield	The maximum pumping rate that can be supplied by a well without lowering the water level in the well below the pump intake.

ADDENDUM REPORT
HYDROGEOLOGICAL ASSESSMENT
of
PROPOSED ORO
SAND AND GRAVEL PIT

West 1/2 Lots 7,8,9
Concession 7
Oro Township

prepared for

James Dick Construction Limited

by

Charlesworth & Associates

Job # 91-107 **August 1991**

Distribution: 1 Copy - Client
1 Copy - Keewatin-Aski
1 Copy - File

David L. Charlesworth & Associates Inc.

James Dick Construction,
P.O.Box 470,
Bolton, Ontario
L7E 5T4

August 22,1991

Attention: Mr. G. Sweetnam

RE: Addendum Report to Hydrogeological Assessment,
Proposed Oro Sand and Gravel Pit

Dear Mr. Sweetnam,

At your request, we have reviewed the hydrogeological data to consider the effects of excavating material below the water table, as is now proposed in the application to license the James Dick Construction property at Lots 7,8,9 (W1/2), Concession 7, Oro Township, Simcoe County. The following report presents our analysis and conclusions with regard to excavation in both the licensed property (East half Lot 8) and the proposed expansion property. This report forms an addendum to our original report 'Hydrogeological Assessment of Proposed Sand and Gravel Pit', June, 1991.

The development of the pit, and the removal of material below the water table has the potential to affect the elevation of the water table and the quality of water in the unconfined aquifer. At this site, we consider that many of the factors affecting water table elevation will counterbalance one another, leaving a relatively minor net effect. Off-site impact will be related more to the few nearby wells that may draw water from the unconfined aquifer, and not to surface vegetation. However, monitoring data during excavation will be the most effective means of determining the impact on water levels.

Exposing the unconfined aquifer, by excavating below the water table and forming a pond, increases the potential for contaminants to enter the aquifer, and caution should be exercised in the handling and storage of materials such as fuels.

Effective April 15th 1991 - We have relocated to Suite 101
77 Mowat Avenue, Suite 110, Toronto, Ontario, M6K 3E3
Tel (416) 536-4916 Fax 536-9265

We trust that this addendum report will satisfy your requirements. If you have any questions, please do not hesitate to contact us.

Yours sincerely,

Janet Haynes M.E.Sc.
Senior Associate

TABLE OF CONTENTS

1. INTRODUCTION

The application to license the west half Lot 7,8,9, Concession 7, Oro Township initially proposed that the excavation would remain above the water table. However, site plans have now been modified to include excavating below the water table in the expansion area and the existing licensed pit (E1/2 Lot 8). At this time it is proposed that the base of the pit will be excavated, by drag-line methods, up to 12.2 m below the water table, forming a pond of approximately 90 hectares and occupying most of the base of the pit. The pond surface will be about 30 m below original grade. The depth of the pit will depend on the thickness of granular material overlying glacial till at greater depth.

As presented in our June 1991 report (Hydrogeological Assessment of Proposed Sand and Gravel Pit, Oro Township; David L. Charlesworth & Associates), there are four piezometers located on the property undergoing application for a license and one piezometer on the licensed property. Table 1 is an update of Table 2 from the June report, and includes water level data from July 1991.

The purpose of this report, which forms an addendum to our June 1991 report, is to assess the effects of the proposed excavation on the groundwater regime.

2. ANALYSIS

2.1 *Unconfined Aquifer*

The unconfined aquifer is not well defined beneath the site. Textures observed around the depth of the piezometer screens, range from silt and very fine sand to sand and gravel. The boreholes that have penetrated to the aquifer were stopped after extending a few metres into the formation, having achieved the objective of identifying the water table. Hence the depth of saturated granular material comprising the unconfined aquifer is not known. Well records suggest that the aquifer extends off-site, but since it is not widely used as a groundwater source around the property, it is difficult to define off-site.

Some aquifer properties can be determined from the limited data available. Hydraulic conductivity values of 10^{-2} to 10^{-4} cm/s were calculated as probably representative of the aquifer, using the Hazen formula and grain size analysis of samples obtained from exploratory boreholes drilled in August 1989. A step test (Appendix 1) was performed on the domestic well on the licensed property (MOE 19519); this well is believed to be obtaining water from the unconfined zone. The aquifer rapidly reached an equilibrium drawdown level during pumping and recovered quickly after each step. Analysis of the data suggested that the formation at that location may have a specific capacity of 0.7 L/s per metre of drawdown. However, the calculated hydraulic conductivities are only representative of the upper part of the aquifer; the data produced by the step test is representative of only one location.

Variation in aquifer thickness and hydraulic conductivity are to be expected within this type of geologic environment. It is not likely that the aquifer is present as a continuous homogenous unit extending considerable distance all around this site. However, although potential impacts can not be accurately quantified from the available data, they can be qualitatively assessed.

2.2 *Impact on Water Table from Recharge and Evaporation*

In the June 1991 report, it was concluded that the excavation of a pit above the water table would lead to an increase in the water table beneath the site. The range of the rise in the water table would be similar to that calculated for the adjacent Roehner pit, (i.e. 0.02 to 3 m). Calculations for the proposed area to be licensed indicated a possible rise in the water table, beneath the site, of 0.1 to 0.9m using the modified Hantush method and 1.3 to 4.4 metres using MODFLOW (a finite difference, numerical model). (See Appendix 2.)

If the site is excavated beneath the water table, there will be loss of water from the unconfined aquifer as a result of evaporation from the pond surface which will tend to partially off-set the mounding described above. The estimated loss of water from the pond is equivalent to a decline in water level in the pond of 0.45 m per year (pan evaporation data, Lindsay-Frost and Guelph Stations; long term normal data, Environment Canada). However, this loss by evaporation is less than the long term average annual precipitation that will fall on the pond area.

The net effect of the above calculations suggests that there will probably still be some rise in the water table as a result of the excavation.

2.3 *Impact on Water Table Due to Excavation Below Water Table*

Excavation below the water table will remove the granular soil, and the resulting 'void' will be filled by water from the unconfined aquifer. Since a typical sandy soil is about 70% by volume solid material (the rest being space occupied by air or water), then the volume of water that will infill the pond will be equivalent to at least 70% of the volume of the soil excavated below the water table. This represents a large volume of water for the entire excavation. However, the process will take place over several decades as the various phases of the pit development reach the base grade. In addition, the depth of granular deposits may not reach 12 m below the water table and the depth of excavation may be much less than 12 m over parts of the site.

There will be some transient lowering of the water table adjacent to the areas excavated below the water table, and this will vary as the excavation progresses. Variation will result from differences in the depth of excavation, the hydraulic conductivity of the adjacent aquifer and the size of the adjacent pond. Given the nature and number of variables it is not possible to quantify the impact at this time. Though, as the excavation proceeds, an appreciation of the specific impacts will be obtained.

The lowering of the water table is not expected to have impacts on surrounding surface vegetation, since the water table is currently in excess of 25m depth throughout the site.

2.4 *Implications of the Sloping Water Table*

The water table beneath the site slopes toward the north-northwest. Table 1 provides the water level data available to date. As indicated in the June 1991 report, the water level at DC-1 is believed to represent a perched condition (Section 4.2).

The effect of the pond on the water table will be to flatten the water table around the area of the pond, slightly lowering the water table immediately upgradient of the pond and slightly increasing the elevation of the water table downgradient.

Through the central part of the site, the water table is between 328 and 330 m elevation (July 1991). The water table appears to slope toward the north-northwest at DC-2, where the static elevation is 322.38 m (July 1991). Assuming that the static elevation at DC-1 is not representative of conditions beneath most of the site (see below), then a pond constructed into this water table would have a water level near the midpoint elevation of 326 m, ignoring the effects of mounding and evaporation and assuming a fairly continuous, homogenous aquifer. This is part of the basis for deriving the suggested design water table elevation, for use in preparing the site plans.

The static level at DC-1 appears to represent a perched condition as stated previously. There are several reasons for arriving at this conclusion. Borehole DC-1 encountered saturated sand at a depth of 30.8m and passed into till at 31.5m. The borehole was terminated at 34.1 m (Appendix A, June 1991). At the time of drilling, it was assumed that the water table had been encountered and a piezometer was installed. However, the piezometer was still dry a week later, and the static level in DC-1, unlike in the other piezometers, took several more weeks to reach equilibrium. This suggested that the piezometer had not encountered the aquifer but that the saturated zone, in which it is located, is a perched aquifer, of relatively limited extent, that slowly drained into the borehole to finally reach the measured static. [In July, the depth of saturated sand had increased to 1 m above the till, the increase following the similar rise in static levels at most other piezometers on site.]

Review of the log from an exploratory borehole located east of DC-1 appears to support this. At that location, a layer of till overlies the main aquifer at a similar elevation.

Furthermore, looking at Cross-section A-A' (Figure A), the suggested stratigraphy also supports the conclusion that this is a perched condition, sitting on top of a till layer or wedge that appears to occur along this southwest perimeter of the property. An additional borehole may prove that the unconfined aquifer underlies this location, at greater depth.

If the static water level in DC-1 represents a limited perched condition, then this static value is not relevant to the water table beneath the site, or in the design considerations for the pond. However, when the excavation reaches this depth, there will be some drainage of the perched condition. The extent of this till layer and the perched water table on site will be determined clearly at the time of excavation. At that time, the depth and design of the excavation can be modified if necessary.

2.5 *Impact on Water Quality*

Excavation below the water table will remove the slight protection afforded to the unconfined aquifer by the metre of granular soils, which would have remained under the previously proposed plan. As a result, care must be taken to prevent introduction of any contaminants into the pond. This will include surface runoff controls, and care with the storage and use of dust suppressants, fuels and lubricants. A contingency plan must be developed prior to any excavation below the water table, to deal with accidental contamination of the pond.

As recommended in the June 1991 report, two water samples should be analyzed for major ground water quality parameters, prior to excavation to provide baseline data. In addition, water samples should be obtained again shortly before excavation below the water table commences on site. Subsequently, water samples should be taken periodically from the most appropriate monitors as excavation below the water table progresses. All analyses should be reviewed by a hydrogeologist to determine if any adverse impacts have occurred.

In addition, the excavation should avoid removing the underlying finer grained strata that protect the confined aquifers in this area.

2.6 *Impact Off-Site*

The potential changes in the water table are not expected to have an impact on the surface water or surface vegetation in the surrounding area. However, there may be some effect on MOE wells #18946 and #11786, which may be taking water from the unconfined aquifer. Well #11786 is located on a site proposed for sand and gravel development (Sargents); the well is expected to be affected by the pit activities; it is not known if this well will remain in service. However, the water level in well #18946 (Wager) should be monitored prior to initial excavation and again prior to excavation below the water table commencing in the western side of the proposed property. This will provide some baseline data for the water table fluctuations at this well.

If changes in water quality are detected in the site monitors, water quality in well 18946 should also be determined. This would be in addition to water quality data obtained from the well prior to excavation.

3. CONCLUSIONS

Given the overall geological complexity of the Bass Lake moraine, and the current data base relating to the continuity and thickness of the unconfined aquifer, it is difficult to quantitatively predict the impact of excavating below the water table. However, a qualitative estimate suggests that the impacts will be acceptable.

The removal of surface vegetation and most of the overlying materials will probably result in increased recharge and mounding of the water table in the pit area. However, the effects of excavating below the water table will go some way towards off-setting this by tending to lower the water table due to increased evaporation and removal of material.

As the development of the pit will extend over approximately 50 years, this will allow ample opportunity to monitor the actual impacts of the changing excavation and to develop strategies to mitigate any adverse effects on the unconfined aquifer.

For purposes of design, an elevation of 329 m is suggested for the water level in the pond. However, this value is for use only in preparation of the initial site plans. The long term monitoring data collected at the site should take precedence over this estimated value.

The changes in the water table are not expected to impact significantly on surface water conditions. Negative impacts on the quantity of water available in adjacent wells in the unconfined aquifer will occur only if there is a drop in the water table downgradient of the site. Given the current gradient, this is not expected. A significant drop in the water table would be identified during monitoring, and at that time it would be possible to determine how far this effect extended off-site.

There is not expected to be significant negative impact on water quality from standard operating activities, when proper material handling and storage procedures are followed. However, any negative impact on water quality should be determined from the periodic water quality data collected at site and if impacts approach the limits defined by the MOE Reasonable Use Guidelines policy, it will be necessary to undertake mitigative measures at that time.

If water is required for washing purposes, the source and impact of obtaining water will have to be determined when the water requirements are known.

4. RECOMMENDATIONS

The monitoring program outlined in the June 1991 report, should be enlarged as follows:

1. Water levels should be collected quarterly in monitors adjacent to excavations below the water table; data collection should start at least one year before the excavation goes below the water table and continue for one year after the excavation is completed. The data should be reviewed, with the other historical data, by a qualified hydrogeologist.

2. The water quality sampling carried out prior to excavation should be expanded to include a sample from MOE well #18946 (Wagner). The same parameters (major ions, pH, conductivity and alkalinity) and phenols should be obtained for all samples.

3. Periodic water samples should be collected from piezometers near the excavation, once the water table is reached. The actual timing and frequency of these samples will have to be determined based on the pit development.

4. All water level and quality data should be collated in a form that can be readily reviewed to determine trends in the groundwater level or quality.

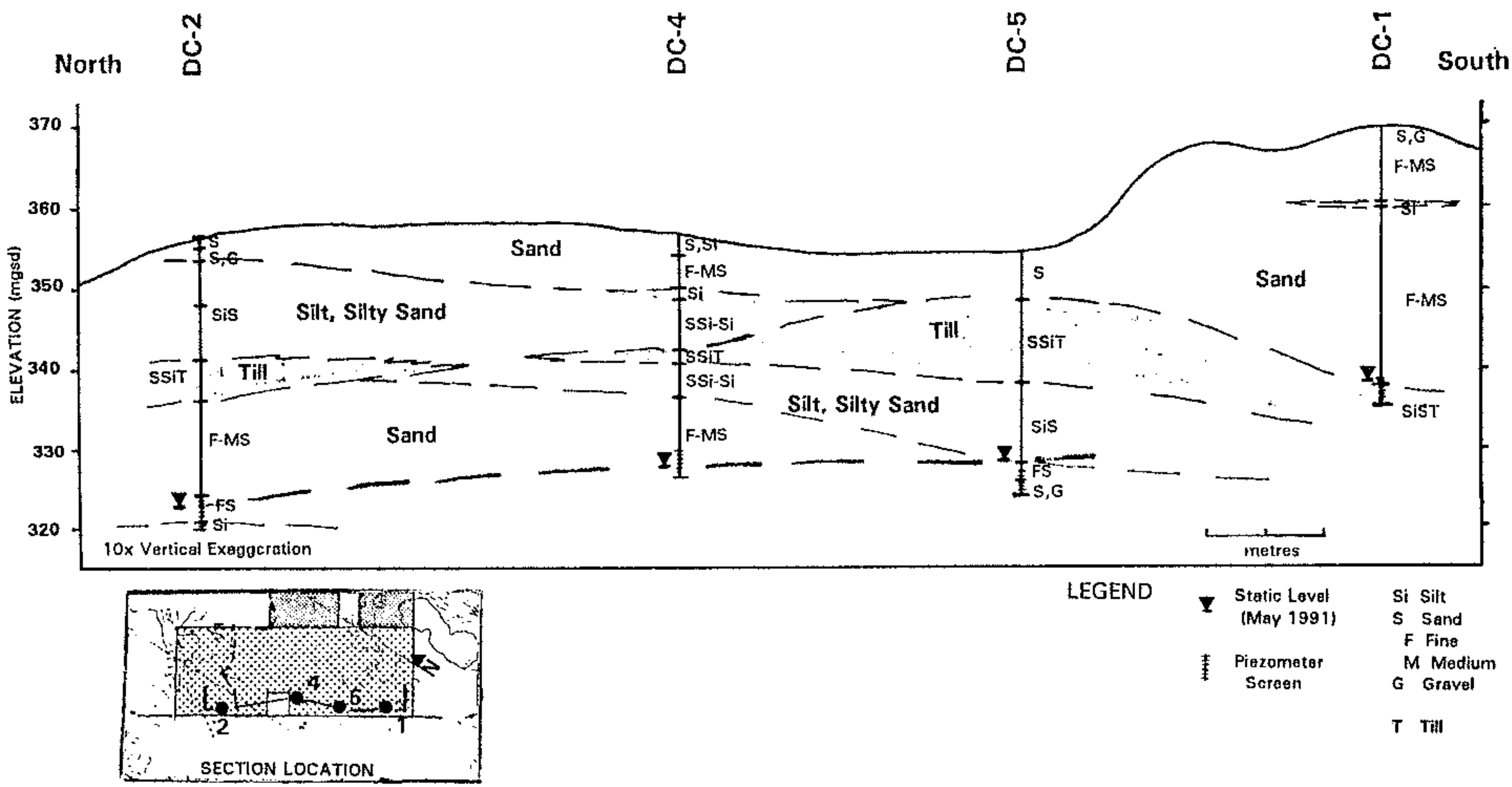
TABLES AND FIGURES

TABLE 1 Water Level Measurements,
Proposed Oro Sand and Gravel Pit

Static Elevation mgsd

Piezometer	DC-1	DC-2	DC-4	DC-5	MONITOR 6
May 3/91	337.28	322.42	327.83	328.23	329.36
May 13/91	338.30	322.42	327.94	328.49	329.44
July 22/91	338.90	322.38	328.07	329.51	329.77

Figure A Cross-Section, West Side of Proposed Oro Sand and Gravel Pit



APPENDIX 1

SUMMARY OF STEP TEST DATA
DOMESTIC WELL MOE 19519

SUMMARY OF STEP TEST DATA
DOMESTIC WELL MOE 19519

A step test was run on the domestic well on the Dick licensed property, identified as MOE well # 19519, only July 31, 1991. The well was drilled in 1984, and at that time pumped at 8 gpm for 2 hours. The recommended pump rate was 5 gpm.

TEST
After removing the domestic pump, steps were run at 5, 12, 20, and 23 gpm for one half-hour each. The highest test rate limited by drawdown at pump intake. At least 95% recovery occurred between steps, except for step 20 to 23 gpm.

RESULTS
1.The step test data is plotted on Figure A-1.
2.Drawdown occurred in first 3 - 5 min, then water levels stabilized or experienced only minor drawdown (<2cm);
2. >95% recovery in 3 minutes for drawdown 1.2 and 2.5 m (5 and 12 gpm).
3. Specific Capacity calculated as 9 - 9.3 gpm/m for steps;
4. The last step ran at a constant 23 gpm at constant head for 29 min.

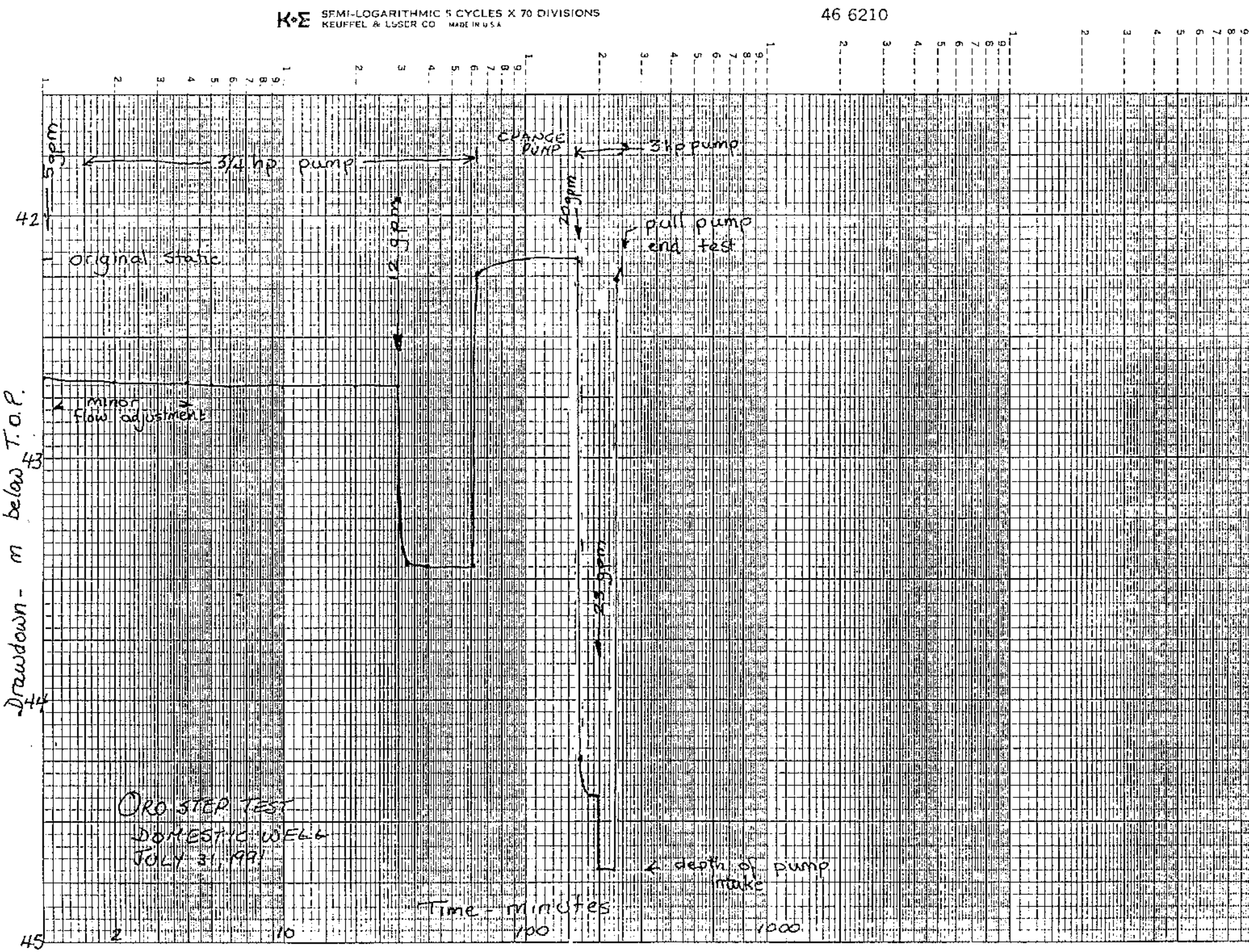


FIGURE A-1 STEP TEST, ORO SAND AND GRAVEL

APPENDIX 2

SUMMARY OF RESULTS
HANTUSH AND MODFLOW
GROUNDWATER MOUNDING CALCULATIONS

PROPOSED ORO PIT

GROUNDWATER MOUNDING CALCULATIONS

Groundwater mounding calculations were done for the proposed Oro aggregate pit given the following aquifer parameters:

Hydraulic conductivity	1 x 10^{-5} m/sec = 1×10^{-3} cm/s
Specific Yield	0.1
Aquifer type	unconfined
Aquifer thickness	5 m and 10 m
Recharge increase	5 % and 10 %
Yearly recharge	413 mm
Pit size	425 m x 1070 m

Four scenarios were modelled. This included a recharge increase of 5 % and 10 % and an aquifer thickness of 5 m and 10 m.

Two types of models were used. All four scenarios were modelled using Modflow-a 3 dimensional finite difference groundwater model run on an IBM 386. Two of the scenarios were run on a HP41-C programmable calculator running a programme based on the Hantush method for calculating groundwater mounding.

Modflow output is included but has been shortened to essential details for the scenario of 5 % recharge increase and a 5 m aquifer thickness. The output for the other scenarios is only groundwater levels after 10 years of operation.

A grid with 11 rows and 15 columns was set up with the pit placed at rows 5 and 6 column 6. Row spacing was 535 m which is half the pit length; column spacing is 425 m. The boundaries of the model were set as constant head nodes as a control on the model. Rows 2 and 10 and columns 2 and 14 were set at a spacing of 5000 m (ie the cells were set as 5000 m across). This was to give adequate spacing between the variable head nodes which make up the bulk of the grid and the constant head nodes on the boundaries.

For modelling purposes, the elevation of the water table was set as 100 m. Thus, for the 10 m aquifer the bottom was set at elevation 90.0 m.

Output for two scenarios was directed to a contouring programme and the results are given showing the extent of the mounding.

Results

1) 5 % Increase in Recharge 5 m Aquifer Thickness

The maximum mound growth is 2.35 m using Modflow. Using Hantush the maximum growth is 1.63 m.

2) 5 % Increase in Recharge 10 m Aquifer Thickness

The maximum mound growth is 1.28 m using Modflow. With the Hantush method, the maximum mound growth is 1.04 m.

3) 10 % Increase in Recharge 5 m Aquifer Thickness

The maximum mound growth is 4.36 m using Modflow. With the Hantush method, the maximum mound growth is 2.92 m.

4) 10 % Increase in Recharge 10 m Aquifer Thickness

The maximum mound growth is 2.59 m using Modflow. The Hantush method gives a maximum mound growth of 1.98 m.

Modflow consistently gives higher results than the modified Hantush method. The approximation to the Hantush method biases the resultant mound on the low side because of some simplifying assumption necessary for computational efficiency. Thus, the Modflow results probably are reasonably accurate.