Natural Resources Canada/ Ressources naturelles Canada

GEOLOGICAL SURVEY OF CANADA · COMMISSION GÉOLOGIQUE DU CANADA

HYDROGEOLOGY OF THE OAK RIDGES MORAINE: PARTNERS IN GEOSCIENCE

Ministry of Northern Development and Mines · Ontario

Canada

INTRODUCTION

Objectives and Study Area

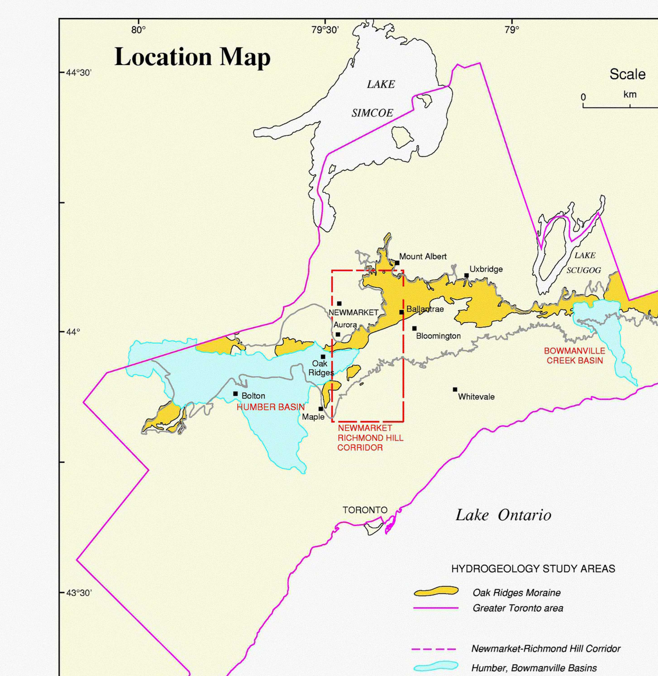
The Oak Ridges Moraine is recognized as a major aquifer complex and is one of the most heavily used groundwater sources in Canada. However, expanding the utilization of this resource and directing landuse planning is problematic because the extent of water-bearing sediments and distribution of recharge areas is poorly understood. In April, 1993, the Geological Survey of Canada began a 3 year, regional hydrogeology study of the moraine. The primary objective is to understand the moraine's interior structure in enough detail to identify the stratigraphic elements which control groundwater flow.

In an attempt to maintain a regional perspective, investigations have concentrated on three study areas and basins (Humber and Bowmanville basins, and the Newmarket/ Richmond Hill corridor -see map at right) which sample the full range of hydraulic gradients available on the moraine. The main study area (Newmarket/Richmond Hill corridor) and survey sites are shown on the large map.

Regional geological studies and geophysical surveys in particular, are crucial to identifying the stratigraphic elements which control groundwater flow.

METHODS

- Geological mapping
- Borehole drilling and sediment logging (Ontario Geological Survey)
- Downhole geophysical logging (gamma, conductivity, magnetic susceptibility
- Up-hole seismic velocity measurement
- Shallow reflection seismic
- EM 34, EM 47 electrical conductivity measurements (EM 47, OGS)
- Borehole database
- Borehole temperature logging
- Borehole and piezometer installation (April 1994)
- Ground probing radar
- Water chemistry
- Infiltration tests



GEOPHYSICS

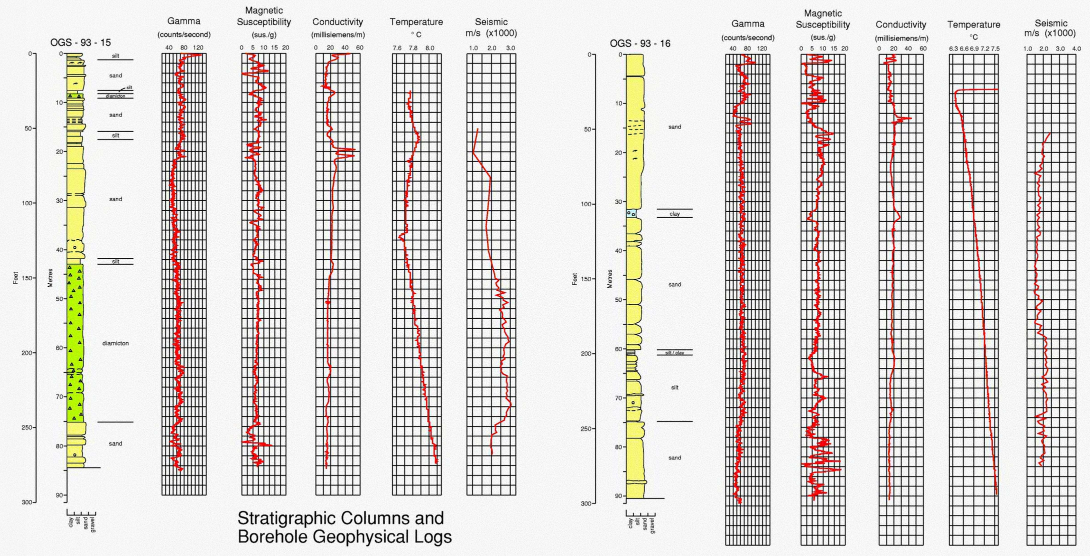
INTRODUCTION

High resolution seismic reflection profiling has proved instrumental in mapping the subsurface structure and stratigraphy. This, together with partial success in detecting bedrock, is providing a major advance in the understanding of moraine structure. Furthermore, ground penetrating radar reliably maps the watertable in glaciofluvial sediments and electromagnetic induction is being used to aid in determining the texture and infiltration capacity of the sediment column between the surface and the watertable.

GEOPHYSICAL HIGHLIGHTS

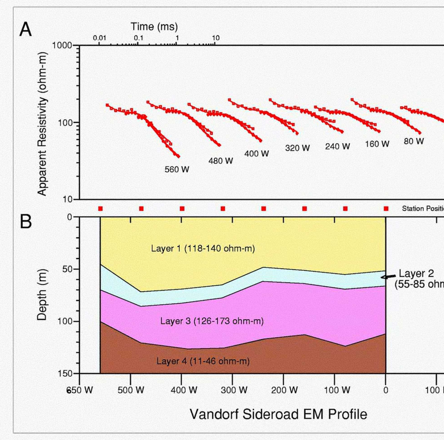
- Newmarket Till is characterized by high seismic velocities, making it a good target for seismic surveys
- Seismic reflection profiles have delineated possible tunnel channels
- Ground Penetrating Radar (GPR) can map very shallow subsurface structure and the top of the water table
- Electromagnetic soundings show potential for mapping depth to bedrock
- High resolution temperature logs may indicate groundwater flow

BOREHOLE RESULTS

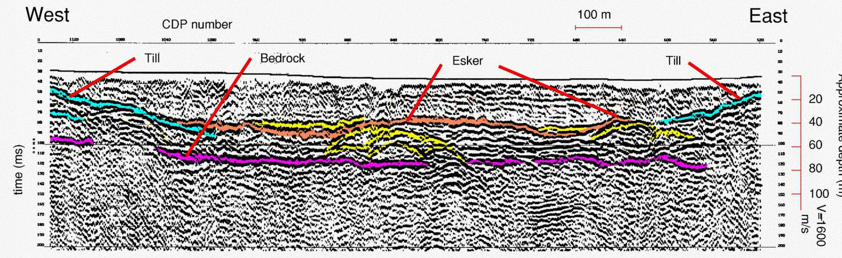


Stratigraphic Columns and Borehole Geophysical Logs

VANDORF SIDEROAD EM PROFILE

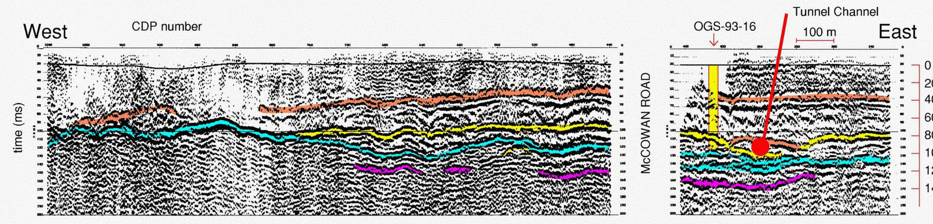


Data were collected along a 560 m east-west line located north of Vandorf Sideroad. Panel A shows apparent resistivity versus time for eight stations; panel B shows geoelectric interpretation. Bedrock (layer 4) lies between 100 and 125 m in depth. A thin (10-20 m) layer of relatively low resistivity (layer 2; 55-85 ohm-m) extends the length of the profile at 50-80 m. This may be a clay-rich layer in comparison to layers 1 and 3, which exhibit resistivities of 118-173 ohm-m.



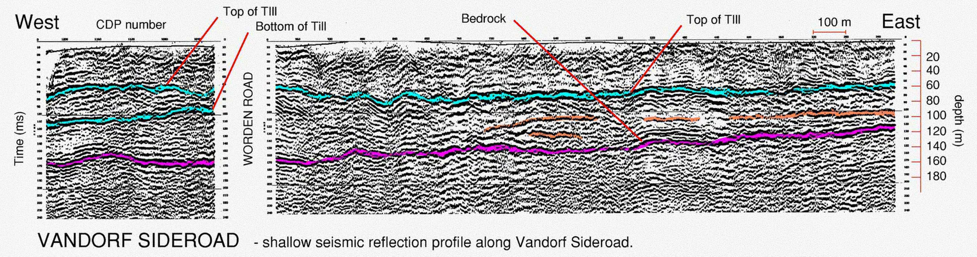
HERALD ROAD

Portion of shallow reflection profile (12-fold CDP) along Herald Road, showing a tunnel channel at least 40 m deep in the Newmarket Till surface. The section also shows buried "mounds", which could possibly be buried eskers.



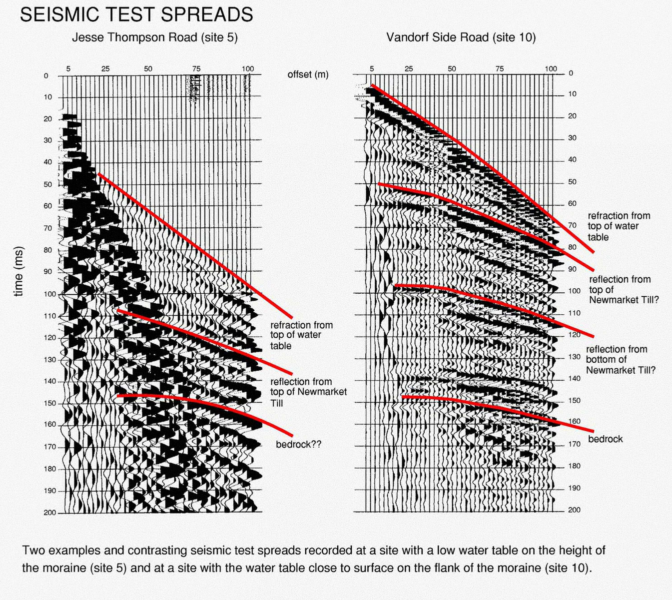
JESSE THOMPSON ROAD · YORK FOREST TRAIL

Portion of the shallow seismic profiles (12-fold CDP) along Jesse Thompson Road and the York Forest trail. The profile shows an in-filled depression that may be the subsurface representation of a buried tunnel channel beneath the moraine.

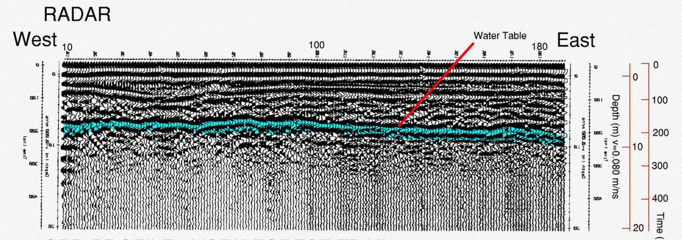


VANDORF SIDEROAD - shallow seismic reflection profile along Vandorf Sideroad.

High seismic velocities indicate the presence of a substantial thickness of Newmarket Till at a depth of approximately 50m. A well-defined reflection from bedrock is seen on the west portion of the line.

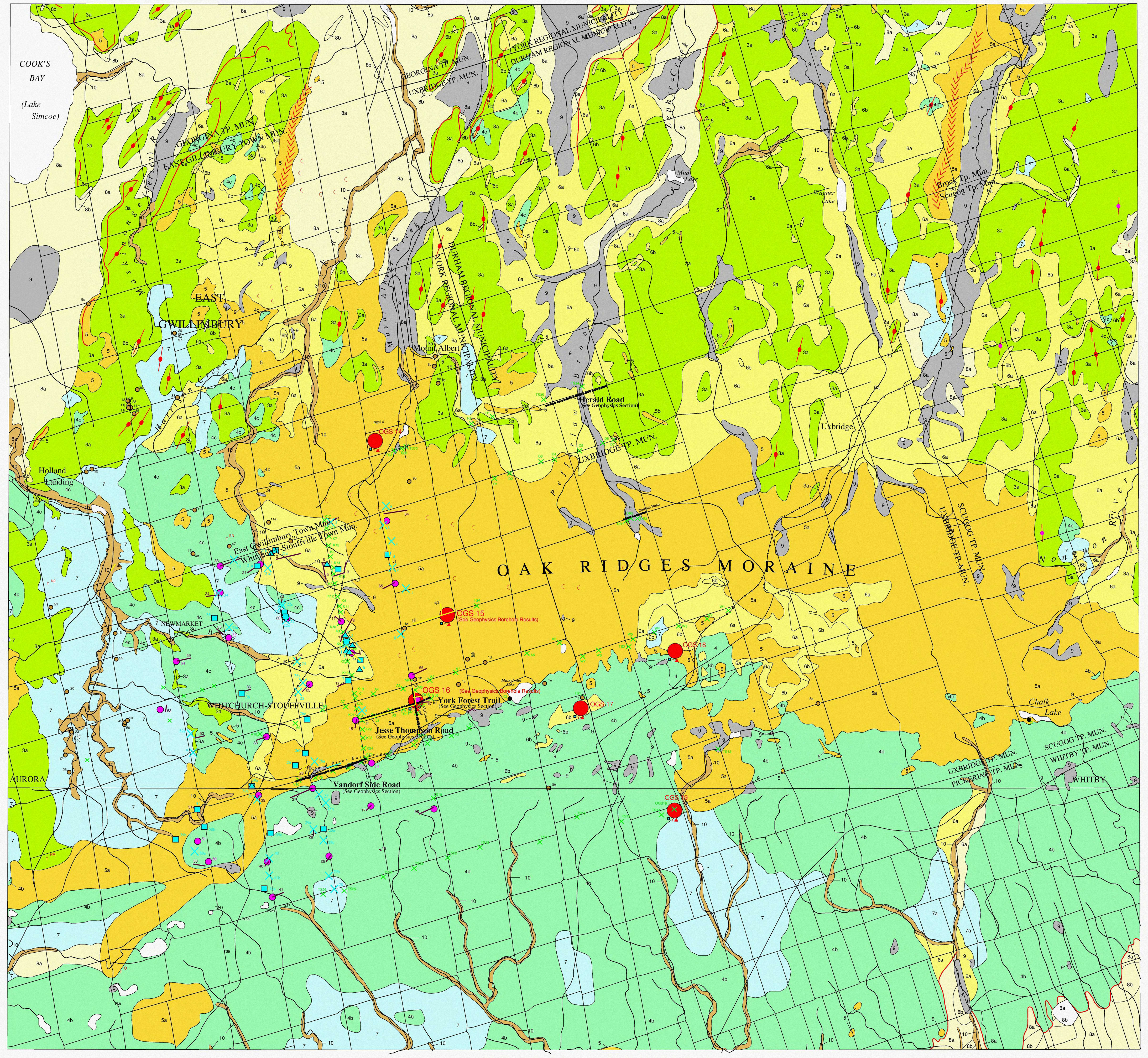


Two examples and contrasting seismic test spreads recorded at a site with a low water table on the height of the moraine (site 5) and at a site with the water table close to surface on the flank of the moraine (site 10).



GPR PROFILE - YORK FOREST TRAIL

Ground probing radar profile east of OGS-93-16. Data were recorded at 1m spacing. The reflection event at 180 ns (~7m below surface) is the water table.



Index to Map Symbols

- Infiltration Testing and Site Number
- Water Well Survey - Water Sample Taken and Site Number
- Water Well Survey - Water Level Test and Site Number
- Water Well Survey - Both Level and Sample Taken and Site Number
- Radar Profiles and Site Number
- Paleoecological Sites
- Municipal Well Locations
- EM-34 Survey and Site Number
- Seismic Profiles
- Seismic Test Spreads
- OGS Boreholes
  - EM-39 Logs
  - Temperature Probes
  - EM-47 Survey
- EM- 47 Profile

Scale · Échelle — Miles 1 0 1 2 3 Milles — Metres 1000 0 1000 2000 3000 4000 Mètres

LEGEND

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT

Unit	Description
11	**Recent Deposits: includes colluvium, shoreline and man-made features.**
10	**Alluvium:** gravel, sand, silt, clay, muck 10a) (includes Pleistocene alluvium)
9	**Organic deposits:** peat, muck

PLEISTOCENE

Unit	Description
8	**Glaciolacustrine Deposits: (Peel/Schomberg Ponds above, Lake Iroquois/Algonquin below raised shoreline).** a) sand and silty sand b) gravelly sand and gravel
7	**Glaciolacustrine Deposits:** massive to laminated silt and clay. **(Peel/Schomberg Ponds above, Lake Iroquois/Algonquin below raised shoreline).** a) includes interbedded diamicton
6	**Glaciofluvial Deposits:** a) mainly sand b) mainly gravel
5	**Ice Contact Stratified Drift Deposits:** a) mainly sand b) mainly gravel
4	**Till:** silt to clayey silt c) Wildfield/Kettleby b) Halton a) Tavistock
3	**Till:** sandy silt to sand c) Wentworth b) Port Stanley a) Newmarket
2	**Older Glacial and Interglacial Drift** b) Meadowcliffe till a) Sunnybrook drift

PALEOZOIC

Unit	Description
1	**Bedrock: carbonate rock** 1a) bedrock drift complex 1b) sandstone or shale

SYMBOLS

- Geological contact (approximate)
- Esker
- Drumlin or fluting
- Trend of moraine crest
- Raised shoreline (Lake Iroquois)
- Aeolian dunes
- Thin till over sand and gravel

User Notes

A variety of map scales was used to compile this map, leading to uneven coverage. Data are not valid at larger (more detailed) scales than 1:50,000 for areas except Legend is a composite for the Greater Toronto Area. Base neatlines are registered to the EMR base (1985). Some alluvial units have been adjusted to fit the 1985 base. Till sub units are arranged in stratigraphic order.

Sources of Information

Barnett, P.J., 1992: Quaternary geology, Markham area, unpublished data.

Gwyn, Q.H.J. and DiLabio, R.N.W., 1973: Quaternary Geology of the Newmarket area, southern Ontario; Ontario Division of Mines, Map 836, scale 1:50,000.

Hewitt, D.F., 1969: Industrial mineral resources of the Markham-Newmarket area; Ontario Department of Mines, Industrial Minerals Report 24, 41 p. Map 2124, scale 1 inch to 1 mile.

Karrow, P.F., 1968: Pleistocene geology of the Scarborough area; Ontario Department of Mines, Maps 2076, 2077, scale 1:50,000.

Sharpe, D.R., 1993: Quaternary geology of the Markham/Newmarket areas; unpublished data.

Watt, A.K., 1957: Pleistocene geology and groundwater resources of the Township of North York, York County; Ontario Department of Mines, Annual Report 1955, v. 64 pt. 7, 64 p., scale 1:31,180.

Westgate, J., 1978, 1979: Quaternary geology of the Markham area; unpublished data.

Map Credits

Compilation and editing by D.R. Sharpe and W.D. Finley.
Digital cartographic production and plotting by Northwood Geoscience Ltd. Ottawa.

Open File
Dossier Publique
2869
Geological Survey of Canada
Commission Géologique Du Canada
Ottawa

Sheet 1 of 1

Contribution to Geological Survey of Canada / Ontario Geological Survey collaboration on Oak Ridges Moraine Hydrogeology and NATMAP programs.

Publication credit; D.R. Sharpe, L.D. Dyke and S.E. Pullan.

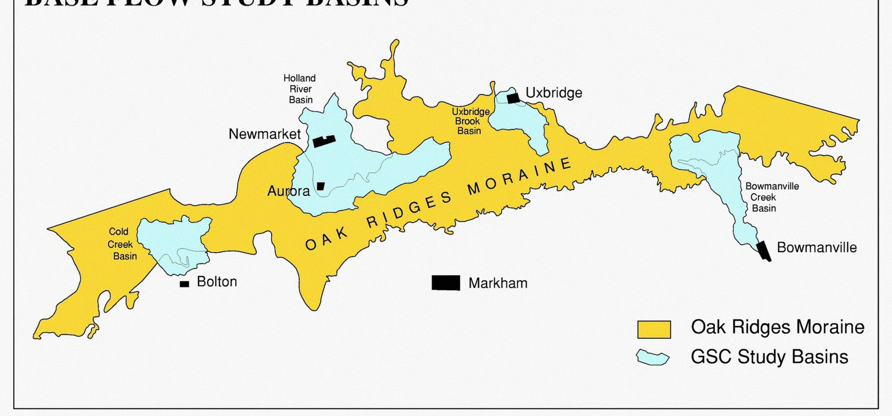
HYDROGEOLOGY

Glaciofluvial sediments increase in prominence moving from west to east along the moraine, accompanied by a tendancy toward steeper hydraulic gradients. These attributes are important in delineating recharge areas and determining the importance of local vs. regional groundwater flow. Study areas have been selected on this basis and the need to understand the relationship of well field aquifers to adjacent parts of the moraine. The base flows from the stream basins below have been compared to determine whether or not groundwater flow is restricted to basin boundaries.

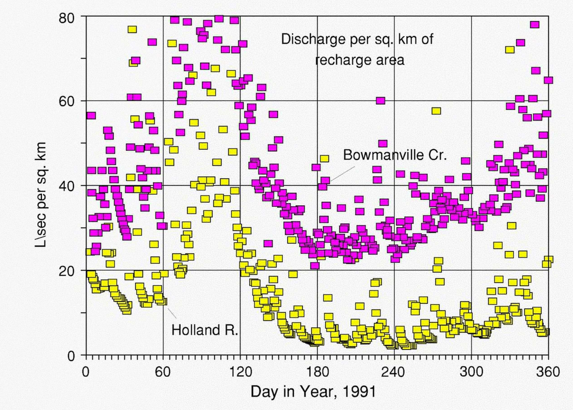
HYDROGEOLOGY HIGHLIGHTS

- Differences in base flow of streams indicate that groundwater flow crosses basin boundaries
- Breaches in the Newmarket (northern) Till provide a hydraulic connection between lower and upper aquifer levels
- Flow models show that breaches will control the location of recharge areas
- Aquifer complexes below the Newmarket Till are a regional groundwater resource

BASE FLOW STUDY BASINS

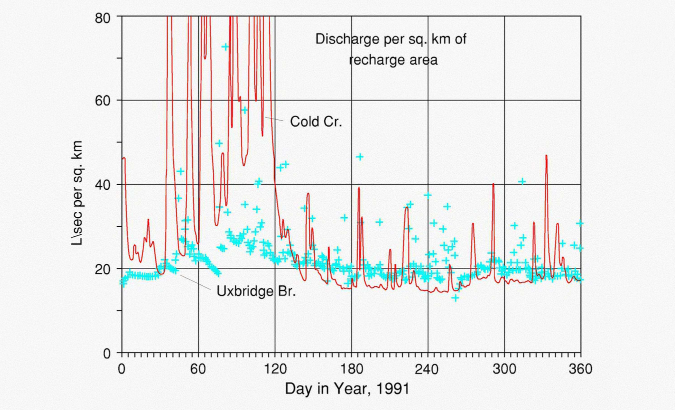


STREAM HYDROGRAPHS
HOLLAND R. / BOWMANVILLE CR.



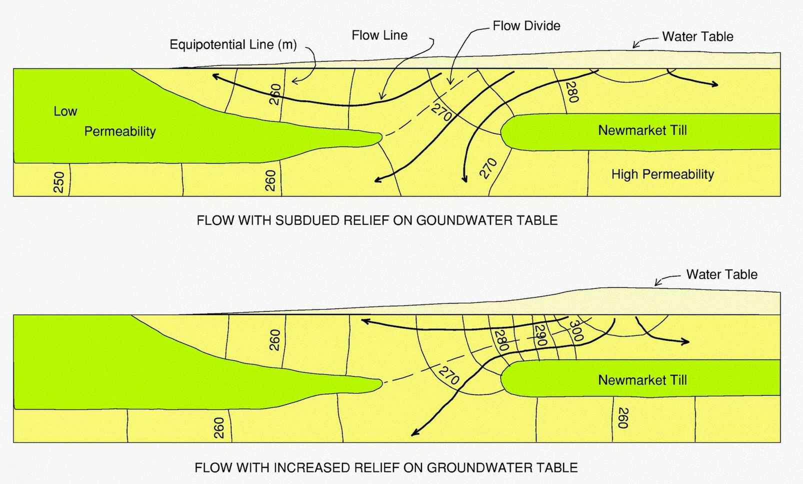
The hydrographs above compare Holland River with Bowmanville Creek. The discharges are given per square km of recharge area to account for the fact that groundwater only recharges over part of each basin. The relatively low flow for the Holland basin may mean that ground-water is finding a major routing beyond the outlet of the surface basin.

STREAM HYDROGRAPHS
UXBRIDGE BR. / COLD CR.



As a further comparison, Uxbridge Brook basin is entirely within the sandy core of the moraine and maintains a relatively high flow. Cold Creek Basin also exhibits a high flow despite the clay-rich till cover on the lower half of the basin. The high discharges suggests no loss of groundwater flow beyond basin-defined flow systems. A fundamental difference in moraine structure may be responsible for the apparent discharge shortfall of Holland River compared to other basins.

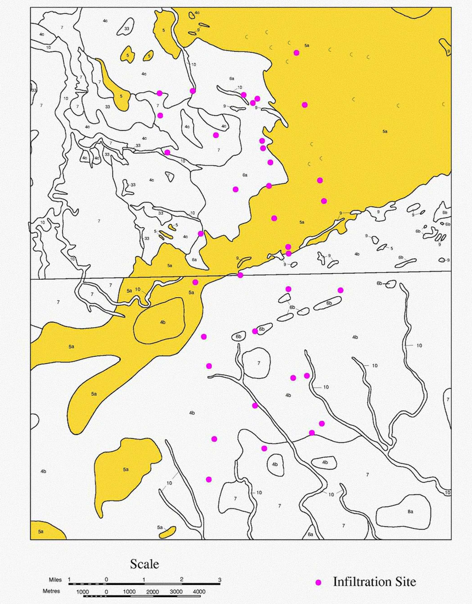
CONCEPTUAL FLOW MODEL



Breaches in the Newmarket Till provide a hydraulic connection between upper and lower aquifer levels and may permit regionalization of groundwater flow. However, the role of breaches as recharge areas will depend on such factors as hydraulic conductivity distribution in the aquifers and the topography of the water table.

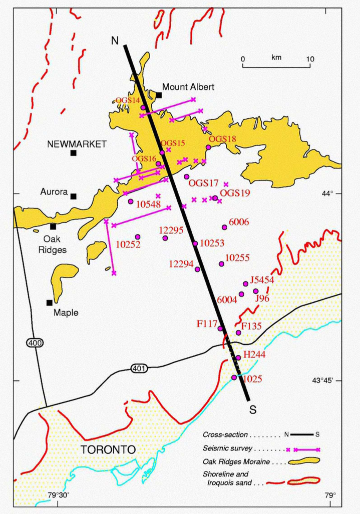
The above flow patterns would be markedly changed if groundwater withdrawal for municipal use were included in the model. Recharge through the breach in the impermeable horizon would be increased but determining the ultimate effect on the water table would also require knowing the infiltration (map at right).

INFILTRATION SITES



The map above plots the location of infiltration tests and high-lights the distribution of pervious moraine sands immediately east of the Newmarket-Aurora study area. Subsequent research will highlight the role of the sands and Newmarket Till in controlling recharge.

REGIONAL GEOLOGY



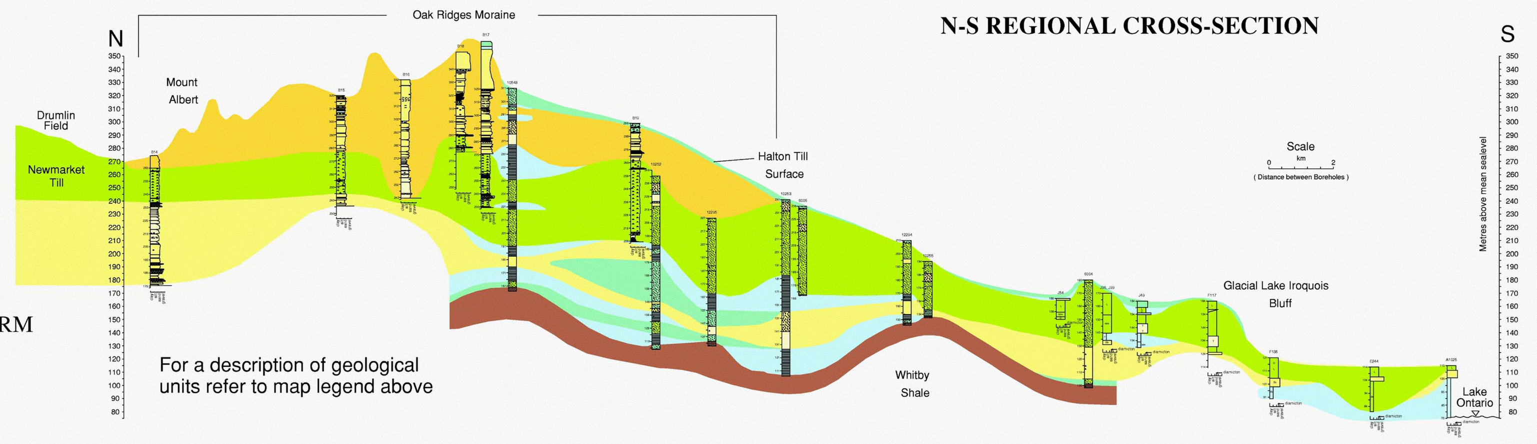
CROSS SECTION

The interaction of ice advances and meltwater episodes appear to be the dominant processes controlling the structure of the moraine. Tills representing ice advances from the north (older) (Newmarket) and south (Halton) flank the moraine. The older of the two is pervasive across the area and underlies the Oak Ridges Moraine. These tills enclose glaciofluvial sediments that were the late products of meltwater events which partly or totally removed the lower (Newmarket) till in some areas (south of Mount Albert - OGS B15). The resulting connection of upper with lower aquifers may be an important structural feature affecting groundwater flow within the moraine.

NEW MAPPING HIGHLIGHTS

- The coarse Newmarket (northern) Till is a thick regional sheet that is continuous beneath the ORM
- Erosional channels below the ORM truncate stratigraphic units, and relate to tunnel channels traced from north of the ORM
- The Oak Ridges Moraine (ORM) proper, has a restricted thickness in comparison to the total stratigraphic package
- The ORM extends below the Halton drift in the subsurface
- Halton drift forms a significant surface cover but is thin compared to older drift packages

N-S REGIONAL CROSS-SECTION



For a description of geological units refer to map legend above

CREDITS

PARTICIPANTS

Vic Allen, Thane Anderson, Peter Barnett, Mel Best, Andrée Bolduc, Tracy Brennand, Robbie Burns, Larry Dyke, R-A Daigneault, Michel Garneau, Ron Good, Vinod Guptu, Bill Hyatt, Jim Hunter, Frank Kenny, Jonathan Mwenifumbo, Jean Pilon, Susan Pullan, André Pugin, Viki Remenda, Hazen Russell, David Sharpe, Vern Singhroy, Brian Todd.

ASSISTANTS

Jason Bjornson, Steve Grant, Alain Grignon, Jim Hazzard, Catherine Kelly, Heather Maclean, Simone Mercier, Cheryl Miller, Peter Neff, Trevor Shaw, Ruedi Schwarzenbach, Paul White.

COLLABORATORS / ASSOCIATED PROGRAMS

The study is relying heavily on accumulating stratigraphic data from provincial government ministries, planning and engineering departments of all the Greater Toronto Area regional municipalities and several consulting engineering firms. Furthermore, consultation and coopreration with the synthesizing efforts of these agencies as well as university investigators is being sought. Included are the following - NATMAP, Ontario Geological Survey, Ontario Ministry of Environment and Energy, Regional Municipalities of Waterloo and York, Brock University, University of Ottawa, Queen's University, University of Geneva, University of Toronto, Gartner-Lee Associates, Golder Associates, Hunter Associates - MNR ORM Hydrogeology study, Terraqua Investigation Ltd., and Northwood Geoscience Ltd., Ottawa.