THE OAK RIDGES MORaine:
EVALUATION OF GROUNDWATER RESOURCES IN THE UXBRIDGE AREA

by

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A thesis submitted to the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Ottawa-Carleton Geoscience Centre and Department of Earth Sciences
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THE OAK RIDGES MORaine:
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Submitted by Igor Egorov in partial fulfillment of the requirements for the degree of
Master of Earth Sciences

A handwritten signature in dark ink, appearing to read "Richard A. Hertz", is written over a horizontal line.

Thesis Supervisor

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ABSTRACT

Groundwater in the Uxbridge area is available from three sand and gravel aquifers found within fluvio-glacial deposits. Analyses of MOEE well records have proven that two aquifers, the upper and intermediate aquifers, are located within the Oak Ridges Moraine sediments and separated by a low permeability layer. This local aquitard has sporadic distribution. A 30-day pumping test, with an 18-day recovery monitoring period, was conducted to evaluate the lower aquifer and estimate its transmissivity, storativity and hydraulic conductivity. Average transmissivity and storativity values are $1.72 \times 10^{-3} \text{ m}^2/\text{s}$ and 1.91×10^{-3} , respectively. Bulk hydraulic conductivity of the Newmarket till aquitard was calculated as $1.32 \times 10^{-11} \text{ m/s}$ compared to a value of 2.46×10^{-5} for the lower aquifer. In the Uxbridge area, the lower aquifer is a nonleaky confined aquifer containing heterogeneities that appear in the aquifer test data as barriers. There are no direct hydraulic connections between the lower and intermediate aquifers in the study area.

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ORIGINAL CONTRIBUTION

- participation in the 30 day pumping/18 day recovery tests; analysis of pumping/recovery test data;

- calculation of hydrogeological parameters, such as transmissivity, storativity and hydraulic conductivity for the lower aquifer;

- estimation of hydraulic conductivity for the Newmarket till (confining layer);

- placement of hydrogeological info into the context of the Quaternary geology of the ORM and its applications requiring water supply, and potential interference for the lower aquifer in the Uxbridge area;

- potential applications for the engineering development in the Uxbridge area.

INTRODUCTION

GROUNDWATER RESOURCE ISSUES IN THE OAK RIDGES MORaine AREA

The Oak Ridges Moraine (ORM) area is a rich natural heritage area protected by several preservation acts (e.g., Bills 29, 42, 55 and 122, 2001). For the past ten years, scientists and other professionals have recognized that quantitative evaluations of available groundwater resources in the Oak Ridges Moraine (ORM) area are strongly needed. In addition, the groundwater hydraulic system in the Oak Ridges Moraine area is still poorly understood.

There was a proposal to build a new Gan Eden community in the Uxbridge area, which is part of the ORM. This proposal raised several concerns, such as the protection of ground water aquifers from exhaustion and the impact of water supply pumping on existing private domestic wells. In response to the concerns, Beatty & Associates Limited conducted an aquifer test at Gan Eden site. The pumping lasted 30 days and a recovery monitoring period lasted 18 days. In a standard test, the pumping lasts 1 to 14 days. The author participated personally in the aquifer test at Gan Eden site and performed the independent analyses of the pumping/recovery test data. Because of the time length of the test, results were abundant. Subsequently, they allowed the use of many data analyzing methods, both for unsteady and steady state water flows.

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

This thesis discusses the groundwater resources and hydrodynamics at the Gan Eden site, the Uxbridge area of the Oak Ridges Moraine. The results of the research are coordinated geographically. They characterize the specific groundwater conditions in the Gan Eden area of the Oak Ridges Moraine. Due to high variability of the hydrogeological conditions in the Oak Ridges Moraine the results are compared with published material describing groundwater flow on different scales.

Complexity of the multi-aquifer groundwater system of the ORM sediments required a comprehensive approach. In this research, appropriate evaluation of the groundwater resources of the Uxbridge area have been done based upon the testing and appraising of every unit of a complex hydrogeological system.

The first three chapters are devoted to background information on the Oak Ridges Moraine area already known from published research literature and open files. Terrain analysis and the stratigraphic-hydrogeological model of the area are accepted as key elements in the delineation of aquifers. This knowledge is necessary for assessment of the geometrical dimensions of hydrogeological units. It helps to understand the hydrogeological regime of water flow and clarified the interrelation between aquifers, and between surface water and groundwater.

Chapter 4 deals with hydrogeological analyses of the Uxbridge area aquifers as a case study based on borehole logs and water well records from the Ministry of Environment database (MOEE records).

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

A proper evaluation of groundwater resources requires knowledge related to water-level changes with reference to time and space as a result of water pumping from aquifers. The hydrogeologic properties and spatial relationships of the aquifers and aquitards are of utmost importance. Pump testing of the aquifers is an important step in prediction and hydrogeological mapping. Traditional pumping tests provide very reliable data for determining such aquifer properties as transmissivity, storativity and hydraulic conductivity. However, traditional pumping tests don't show the large-scale physical properties of aquifers. Therefore, a unique 30-day pumping test and 18 day monitoring recovery period were conducted in the lower aquifer at the Gan Eden study site near Uxbridge.

Chapter 5 presents different methods of data analysis and discusses the results and data interpretation of the aquifer test. Physical properties obtained from data analyses can be used for further groundwater estimations in the Uxbridge area of the Oak Ridges Moraine. The conclusions contain some practical recommendations for the usage of groundwater resources from the lower aquifer. Appendices contain tables of sorted data with water well records, borehole logs and pumping test data.

CHAPTER 1

TERRAIN ANALYSIS AND THE ORIGIN OF THE OAK RIDGES MORaine

Discussions on the origin of the ORM go back to the 19th century when an article entitled *A sketch of the topography and geology of Lake Ontario* by Bigsby was published in 1829. Since then, scientists and academics have not come to an agreement as to how the moraine was formed.

The concept accepted as a working model for the purpose of this thesis is based on the physiography-stratigraphic approach. This model has been advocated by a group of scientists from the Geological Survey of Canada (GSC) and Ontario Geological Survey (OGS). The scientists stress the importance of the physiographic units of the Greater Toronto Area, local landscape elements and landscape associations in understanding the processes that have taken place during the ORM development. However, at the same time, the proponents underline the fact that these approaches do not answer all questions related to the origin of the moraine as to what parts of this moraine were the products of glaciofluvial and glaciolacustrine processes as opposed to ice-dynamic processes; whether sedimentation was subglacial, ice supported and/or ice marginal; whether it was time transgressive or synchronous; whether sedimentation was rapid, sporadic, or slow and more continuous.

1.1 REGIONAL PHYSIOGRAPHY.

The location of the ORM relates to its regional physiographic position. The ORM was built within the southern part of the Laurentide Ice Sheet in southern Ontario (Shaw

The Oak Ridges Moraine: Evaluation of Groundwater Resources in the Uxbridge Area

et al., 1996). It divides the Lake Ontario and Georgian Bay drainage basins, forming relatively high altitude ridges (Figure 1.1). This large ice-aged deposition extends 160 km in length from the Niagara Escarpment to beyond Rice Lake (Figures 1.1, 1.2).

Figure 1.1 Hill-Shaded Digital Elevation Model showing a relief of the central ORM area (modified from Skinner and Moore, 1997).

The ORM is composed of the following four elevated wedge-shaped masses (from east to west): Rice Lake (R), Pontypool (P), Uxbridge (U) and Albion Hills (A). Narrower ridges join these bodies (Figure 1.3).

The ORM was built on a high-relief erosional surface. It is defined as drumlinized uplands (Figure 1.3) with wide flat-floored valleys (Figure 1.2). This erosional surface is composed mostly of Newmarket till whose surface marks a regional unconformity. The relicts of this surface are still found to the north and south of the ORM. The Peterborough drumlin field is an example of such a surface that allegedly extends under the ORM (Gwyn and Cowan, 1978). The Peterborough drumlins are elongate from northeast to southwest and are separated by up to 50 m deep steep sided valleys.

Figure 1.2 Colour Graded Digital Elevation Model (modified from Kenny et al., 1996; Skinner and Moore, 1997) with the following regional landscape elements: 1 - Niagara Escarpment, 2 - Drumlinized Uplands, 3 - Wide Flat-Floored Valleys, 4 - The ORM, 5 - Low-Relief Plains (south of the ORM). The study area is shown in the black rectangle.

According to another theory, the mechanism for the formation of the streamlined upland surface is erosion by subglacial deformation (Boyce and Eyles 1991). The flat-floored branched deep valleys, which are several kilometres wide (1-4 km) (Figures 1.2, 1.3), were formed by high-energy subglacial streams or meltwater flood events (Barnett, 1989, 1990).

Figure 1.3 Regional physiographic units of the Greater Toronto Area and ORM on the Digital Elevation Models. The ORM can be divided into four segment wedges: from east to west: R - Rice Lake, P - Pontypool, U - Uxbridge and A - Albion Hills (modified from Barnett et al., 1998).

The Oak Ridges Moraine: Evaluation of Groundwater Resources in the Uxbridge Area

Eskers and large bedforms may be found in some of the channel valleys.

The ORM has an abrupt western border formed by the Niagara Escarpment. This prominent bedrock cuesta has played a fundamental role in the ORM formation. The channel system eroded into the Niagara Escarpment controlled regional water levels in the ice-marginal lake (Figure 1.4).

Major lake basins, namely Lake Ontario and Georgian Bay, the Niagara Escarpment, and the retreating ice front controlled the system of ORM sedimentation. The erosion corridors in the Niagara Escarpment provided ice-marginal drainage of meltwater southwestward and northwestward during ORM deposition. During the period of ORM sedimentation, these corridors controlled water level and, thus, the environment of sedimentation within the system (Figure 1.5).

The oldest Caledon Outlet channel cuts through the Niagara Escarpment at an elevation of about 425 m a.s.l. The channel cuts through gravelly sediments of the Singhampton and Paris moraines deposited above the cuesta and located westward from the ORM (Figure 1.5). Other, lower elevation outlet re-entrants, such as Acton - about 350 m a.s.l., Campbellville - about 290 m a.s.l. and Kilbride - about 250 m a.s.l., have been found in the escarpment face to the south of the Caledon outlet (Figure 1.5). These outlets are floored with coarse gravel sediments. This fact points to the high-volume high-energy flows which occurred at elevations up to 425 m a.s.l. (Caledon channel). Thus, all channels acted as opening controls for the trapped meltwater in the ORM sedimentation basin (Chapman 1985).

Figure 1.4 Synoptic view from the southwest showing ice positions and depositional environment in the ORM area that is highlighted by the rectangle (modified from Barnett et al., 1998).

Figure 1.5 Outlet channels and water level control on ORM sedimentation along the Niagara Escarpment. Singhampton, Paris and Acton moraines are shown draping the Niagara Escarpment (modified from Chapman, 1985).

The channels provide a water-level datum for depositional settings that are presented as different stages of the ORM development. Stages of sedimentation (subglacial and ice-marginal sedimentation) were influenced by subglacial hydrology and ice dynamics. Later regional outlet channels (425 - 245 m a.s.l.) along the Niagara escarpment controlled such stages of sedimentation as subaqueous fan sedimentation and fan to delta sedimentation (Figure 1.6).

Water levels within the cavities of the expanding ice-walled lake promoted sedimentation so that subaqueous deposition has occurred prior to drainage through the Campbellville outlet, whereas subaerial and deltaic deposition occurred during and following the opening of the Campbellville outlet (Barnett et al., 1998).

Thus, the system of channels along the escarpment provided outlets for ice-marginal drainage and it controlled regional water levels during moraine building. Sedimentation of the ORM was within four main sedimentary environments: I) subglacial sedimentation - high-energy erosion and coarse sedimentation within a tunnel; II) subaqueous fan sedimentation - ice-confined, high energy to reduced energy sedimentation of gravelly sequences, transitional to large sandy sets; III) fan to delta sedimentation - distal fan deposition of silt-clay rhythmites and sandy subaerial braid-plain sedimentation; IV) ice-marginal sedimentation - debris flows, turbidity currents and sedimentation from suspension (Figure 1.6). These four stages highlight the moraine development that rapidly evolved from a glaciofluvial-dominated core to flanking glaciolacustrine-dominated sediments. The model reflects the transition from subglacial to proglacial conditions during moraine formation, with emphasis on the main processes of deposition (Barnett et al., 1998).

Figure 1.6 Developmental stages of the ORM. Note view is from the southwest. For the explanation of the symbols please refer to the text. (modified from Barnett et al., 1998).

1.2 UXBRIDGE WEDGE GEOMORPHOLOGY.

The landform architectural element approach is beneficial for understanding the distribution of aquifers, infiltration rates and flow directions within the ORM. By subdividing complex glacial landforms into smaller units (fan, delta, moraine, plain), it is easier to interpret them using knowledge of relationships between landform and sediments.

The ORM elements, such as subaqueous fan, fan-delta, and subaerially deposited sediments have been formed in different depositional environments with different levels of energy (from proximal-high energy to distal - low energy). Coarse sediments and fine sediments have been arranged in different fashions in every particular landscape (Barnett, 1997). Three major types, hummocks, plains, and ridges, are common within the ORM sediment wedges. Within these three areas, there are the following 8 landform elements in the Uxbridge sediment wedge: Bloomington fan, Holt fan, Goodwood plain, Ballantrae plain, Palgrave moraine, Uxbridge moraine, Utica delta, and Seville delta (Figures 1.7, 1.8).

The Bloomington fan (Bf on the Figure 1.8) is a broad feature that composes the core and the highest area of the Uxbridge sediment wedge. The fan extends toward the southwest. This is probably a subaqueous fan delta that formed at the mouth of a major conduit within the northern ice lobe. Ice walls formed a narrow lake that collected meltwater coming from a conduit in the ice.

Figure 1.7 Landform elements of the Uxbridge sediment wedge of the ORM shown overlying a hill-shaded DEM (Kenny, 1997).

Explanation of symbols: Bf, Bloomington fan; bBf, buried Bloomington fan; Bp, Balantrae plain; Gp, Goodwood plain; Hf, holt fan; Pm, Palgrave moraine; Ud, Utica delta; Um, Uxbridge moraines; III, Broad valleys; IV, Drumlinized uplands.

Figure 1.8 Schematic map of landform elements of the Uxbridge sediment wedge of the ORM (modified after Barnett, 1994). Section AA' shown in Figure 1.9

Figure 1.9 Schematic transverse section through the Uxbridge sediment wedge of the ORM (modified after Barnett, 1994). See Figure 1.8 for location of section.

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The southern wall of ice redirected meltwater flow to the southwest so that this landform and the distribution of sediment facies, structures and paleoflow were elongated in the same direction as the meltwater flow (Barnett, 1994).

The Ballantrae plain (Bp) is an extensive plain formed in a deeper part of the ice-supported lake. It consists of a series of plains that were developed close to the northern margin of the lake. These plains decrease in elevation to the north.

A steep depositional slope separates the Ballantrae plain from the western lower altitude Aurora basin. At present, this slope is heavily dissected and gullied. The surface of the plain has been altered by wind activity, which has remobilized sands of the plain to form dunes and blowouts on its surface. The Goodwood plain (Gp) delineates the glaciofluvial river and delta topset component of the Ballantrae plain. A thick unit of rhythmites, which is a product of an abrupt and rather short rise in the water level of a lake, occurs within the sand and gravel sediment areas of the Goodwood plain. Several distinguishable ridges of gravel and sand, interpreted as moraines, kames and subaqueous fan deposits represent the Uxbridge moraines (Um). These moraines disappear under sands of the Ballantrae plain towards the west. However, they can be traced by the lines of buried kettle holes or ice-contact slopes. Palgrave moraine (Pm) delineates the southern flank of the ORM (Figure 1.7) This area of hummocky topography with many closed depressions often contains wetlands. Different types of tills, such as flow tills, melt-out tills, lodgement tills, among others, are common for the area. All of these point to the fact that the Palgrave moraine formed in response to instability along the margin of the Ontario lobe. Northwest of the ORM Uxbridge wedge is a large fan-shaped body named

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the Holt fan (Hf). The sedimentation environment of the Holt fan is similar to the Bloomington fan, a subaqueous fan at the mouth of a channel coming from the margin of the northern ice. The Utica (Ud) and Roseville (Rd) deltas have fan shapes and were deposited by northward-flowing rivers that entered into glacial Lake Schomberg. Lake Schomberg was an ice marginal lake dammed between the northern flank of the moraine and the receding northern ice margin. All landform architectural elements are shown in Figure 1.7.

To obtain a detailed analysis of the terrain, geomorphology boundaries and the road layer of the study area have been located on a high resolution Digital Elevation Model map of the Uxbridge sediment wedge (Figure 1.10). Well surface elevations and descriptions of surficial sediments (Appendix A) from water well records (MOEE database) allowed drawing of a map of landform elements for the study area (Figure 1.11). According to Figure 1.11, five main landform elements are present on the study site:

- 1) Goodwood plain;
- 2) Roseville delta;
- 3) Uxbridge moraine;
- 4) Broad valleys;
- 5) Drumlinized uplands.

Figure 1.10 UTM coordinated location of the study area on high resolution Digital Elevation Model showing the elevations of the Uxbridge sediment wedge of the ORM.

Figure 1.11 The map showing main landform elements of the study area with road layer and location of water wells from the MOEE database.

CHAPTER 2

GEOLOGICAL SETTING OF UXBRIDGE WEDGE OF THE OAK RIDGES MORaine

A geological understanding of the Uxbridge wedge area has been accomplished with the help of the Greater Toronto Area (GTA) regional geoscience database created by the Terrain Science Division of the Geological Survey of Canada (GSC), the water well records maintained by the Ministry of Environment and Energy (MOEE), and other published data and open files (eg., Karrow, 1967, Gwyn et al., 1997, Sharpe et al., 1994, Russell et al., 1996).

The principal geological map which was used for this study was GSC Open File 3329. The Open File presents a 1:50 000 scale map of the Uxbridge and Newmarket area (NTS 31D/3) including digital elevation models, bedrock topography and drift thickness of the Uxbridge wedge area (Gwyn et al., 1997). Using UTM coordinates, the study area located within the Uxbridge wedge of ORM has been placed on the models as shown in Figures 2.1, 2.2.

2.1 BEDROCK GEOLOGY

Sedimentary rocks underlie the Uxbridge wedge area (unit 1, Table 2.1). Bedrock units in Uxbridge consist of Ordovician clastic and carbonate rocks found at elevations 100-260 m.a.s.l. (Figure 2.1). According to the regional geological map of Gwyn et al., (1997), bedrock is not exposed in the area. However, geological drilling indicates that Ordovician shale of the Whitby Formation, located in the southern area, overlies limestone and shale of the Middle Ordovician Simcoe Group (Figure 2.1).

Figure 2.1 Bedrock Topography of the Uxbridge wedge area. Study area is shown in the black rectangle (modified from Russell et. al., 1997).

Figure 2.2 Map showing thickness of the Quaternary sediments of the Uxbridge wedge area (modified from Russell et. al., 1997). Study area is shown in the black rectangle.

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Table 2.1 Stratigraphic elements of the Oak Ridges Moraine area
(modified from Gwyn et al., 1997)

Stratigraphic unit ¹ (youngest on top)	Map unit	Explanation/description ²
Quaternary	Period covering last 2 million years of glacial climates	
Recent		Last 10 000 years B.P. following glacial climates
Lake Ontario deposits	11	Deposits along shore of modern lake (75 m.a.s.l.)
Alluvium (river deposits)	10a	Sediment deposits by modern rivers in Recent time
Older alluvium	10b	Sediment deposited by rivers in modern valleys during glacier melt
Organic deposits	9	Plant and animal matter accumulating in wetlands
Pleistocene	Time of advance and retreat of the great ice sheets (~2 million to 10 000 years BP)	
Peel/Schomberg deposits	7,8	Series of lake beds deposited as melting ice blocked drainage (commonly >180 m.a.s.l.)
Lake Iroquois/ Algonquin deposits	7,8	Two of the largest postglacial lakes in Lake Ontario/Lake Huron basins
Glaciofluvial deposits	6	Deposits of high-energy streams or currents issuing from a glacier (may form core of ORM)
a. Wilfield/Kettleby ³ tills ⁴	4a	Interbedded with lake deposits and flanks the Oak Ridges Moraine (White, 1975)
b Halton / [Bouchette tills] ⁵	4b	Clay, silt till; few stones; thick in Humber Valley, thins rapidly to the east (Karrow, 1959)
c. Oak Ridges Moraine	5	Thick fine sand, silt and gravel, mainly glacial lake deposit, resting on eroded Newmarket till (Chapman and Putnam, 1943)
d. Wentworth/upper Leaside ⁶ tills	3d	Sandy, stony till: may grade upward into Halton Till (Karrow, 1959). Leaside till (Karrow, 1967)
e. Port Stanley/Tavistock tills	3e/4c	Port Stanley: Lake Ontario sandy stony till; c Tavistock: Lake Huron derived till
Unconformity⁷	Major erosional episode marked by drumlin formation channel cutting and scouring, produced by subglacial floods (Barnett et al., 1990)	
f. Newmarket /northern tills	3f	Sandy, stony till extending beneath the ORM (Gwyn and Dilabio, 1973; Sharpe et al, 1994)
g. Upper Thorncliffe Formation	2g	Sandy beds (deltaic?/ fan beds) found at Scarborough Bluffs (Karrow, 1967; Singer, 1974)
h. Seminary/ Meadowcliffe/Bondhead tills	2h	Thin mixed sediment separating thick Thorncliffe sands at lake bluffs (Karrow, 1967)
i. Lower Thorncliffe Formation	2i	Sandy to clayey beds found at Scarborough or Bowmanville bluffs ~30-50,000 years old (Terasmae, 1960)

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Stratigraphic unit ¹ (youngest on top)		Map unit	Explanation/description ²
	j. Sunnybrook tills /Port Hope	2j	Regional till sheet and marker beds (clay till with very few stones) (Karrow, 1967; Brookfield, 1982)
	k. Scarborough Formation	2k	Cool-climate (-5°C) raised lake beds (~122 m.a.s.l.) may be ~90000 years old (Karrow, 1967)
	l. Don Formation	2l	Warm-climate (+3°C), raised lake beds with interglacial fossils (Karrow, 1967)
	m. York till	2m	Dense, sandy till from glacial interval prior to last major warm period (Karrow, 1967)
	n. Older sand ⁸	2n	Undifferentiated stratified sediment, mainly sand, some pebbles
	o. Older clay, silt ⁸	2o	Undifferentiated stratified sediment, mainly silt and clay
Unconformity			Major interval or interval of time and erosion
Paleozoic			
	Bedrock	1	Ancient marine sand, silt, and limey mud rocks formed ~250-570 million years ago
	a. Bedrock-drift complex	1a	Map unit with thin 9 (<1 m) cover of glacial deposits on lime bedrock.
	b. Clastic (sandstone or shale)	1b	Rocks made from grains of sediment cemented together; Georgian Bay/Queenston shale
	c. Carbonate	1c	Limestone and dolostone rocks found respectively east and west of the Niagara Escarpment
<p>1. See Barnett et al., 1991, for stratigraphic scheme of southern Ontario;</p> <p>2. Lithology of older sediment is described;</p> <p>3. Wilfield occurs south of ORM; Kettleby occurs north of ORM;</p> <p>4. Tills are mixed sediment (sand, silt, clay, stone) deposited by glaciers; till, lower case, indicates local name;</p> <p>5. Units in square brackets [] refer to names for strata found east of Oshawa; (Brookfield et al., 1982);</p> <p>6. May correlate with Newmarket tills; Wentworth may have been deposited from retreat phase of "Newmarket ice";</p> <p>7. Erosional episodes may be present between and within other units e.g., boulder pavements;</p> <p>8. Uncertain age designation.</p>			

Whitby shale has been eroded in many places to elevations about 100 m.a.s.l., while the average relief of the bedrock surface is about 150 m.a.s.l. (Figure 2.1). The bedrock surface dips toward the southwest creating depressions in the southern and western margins of the area. The low eroded bedrock surface along the western margin of the map area in Figure 2.1 creates the eastern edge of the Laurentian valley, part of an ancient periglacial river system (Gwyn et al., 1997).

2.2 SURFICIAL GEOLOGY

The bedrock surface is covered by overburden of varying thickness consisting of glacial and non-glacial sediments. The thickest overburden is found in the vicinity of Utica where the bedrock is covered by 260m of the ORM (Figure 2.2). The thinnest area of overburden consists of Quaternary sediments in the northern part of the map area (Figure 2.2).

Relationships among bedrock and surficial geological units are shown in the three-dimensional block diagram of Figure 2.3. Table 2.1 (Gwyn et al., 1997) also explains age relationships of units and regional stratigraphic terminology. Table 2.2 (Gwyn et al., 1997) classifies sediments in the ORM area according to their grain size, thickness, landform type, and sediment origin.

Surficial geology can be divided, based on the variety of sediments, into four principle stratigraphic units (Figure 2.3).

Figure 2.3 Geological model of major strata in the Uxbridge wedge of the ORM area (after Sharp et al., 1996).

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Table 2.2 Glacial and recent sediments (modified from Gwyn et al., 1997)

Map unit	Name (origin)	Sediment	Thickness	Landform type
11	Recent deposits	sand, gravel and diamicton	1-3 m	dunes, lakeshores, slopes, lakeshore deposits and fill
10	River deposits	a. gravel, sand, silt, clay, muck b. gravel, sand, silt, clay	1-2 m 1-8 m	modern floodplains, river and delta terraces of early post-glacial age
9	Organic deposits	peat	1-7 m	wetlands
8	Glacial lake deposits ^{1,2}	a. sand and silty sand b. gravely sand and gravel	1->50 m 1-5 m	basins and near shore flats raised shorelines or bars
7	Glacial lake deposits ^{1,2}	a. silt, clay, diamicton b. silt and clay	1-10 m 1-5 m	basins basins
6	Glacial river deposits ³	a. sand b. gravel	1-15 m 1-15 m	eskers, fills and terraces eskers, fills and terraces
5	Moraine deposits	a. sand, silt, gravel, diamicton, b. sand and gravel	1-100 m 1-20 m	broad moraines channels, hills, depressions
4	Glacial deposits (till) ^{1,2}	clayey silt to silt, 1-2% stones (e.g., Halton and Wildfield/Kettleby ⁴ tills)	1-15 m	till or lake plains
~~~~erosional unconformity~~~~				
3	Glacial deposits (till) ^{1,2}	sandy silt, sand, >3-10% stones (e.g, Newmarket/northern ⁵ till)	1-50 m	plains and uplands
2	Lower sediments	sand, silt, clay and till	1-100 m	bluffs, buried plains
	g. Upper Thorncliffe Formation; h. Seminary/Meadowcliffe/ Bondhead tills i. Lower Thorncliffe Formation; j. Sunnybrook till; k. Scarborough Formation l. Don Formation; m. York till; n. Stratified sediment, sand o. Stratified sediment, silt and clay			
~~~~unconformity (long interval with no deposits and for major erosion)~~~~				
	Paleozoic			
1	Bedrock	limestone, sandstone, or shale	~50-500 m	Niagara Escarpment; buried valleys

1. Glacial lake deposits and glacial deposits (till) are grouped as coarse and fine textured
2. Peel/Schomberg ponds above, Lake Iroquois/Algonquin below raised shorelines
3. Subglacial and/or proglacial outwash
4. Wildfield south of ORM and Kettleby north of ORM
5. Northern till indicates a source area to the north; it may have several age assignments (White, 1975)

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From the youngest unit downwards, the following major units and unconformities are identified in the Uxbridge wedge area:

1. Glacial deposits;
2. Halton till;
3. Oak Ridges Moraine;

Regional unconformity

4. Newmarket till;
5. Lower Drift;

2.3 LOWER (DRIFT) DEPOSITS

Lower units consist of thick, layered sediment packages (units 2g, 2i, 2n and 2o, Table 2.2) that accumulated on the eroded surface of the Palaeozoic bedrock (Figures 2.3, 2.4).

In the Uxbridge wedge area, lower drift deposits also are not exposed at surface except at several scattered locations within valleys in Uxbridge Township. Outside of the Uxbridge wedge area, sequences of sand, silt and clay have been found along Lake Ontario bluffs and river valleys (Figure 2.4). Based on the results of geological mapping, drilling and seismic profiles, it has been established that these sediments extend as far north as Lake Simcoe (Eyles et. al., 1985). Being mostly sand and silt, the lower deposits can contain layers and lenses of clay (Karrow, 1967).

Lower deposits have been deposited in proglacial lakes. From the bottom up, they include York till, Don Formation, Scarborough Formation, Sunnybrook till and finally, the Thorncliffe Formation.

Figure 2.4 Generalized surficial geology map of the Oak Ridges Moraine region showing major geological units in the area (modified from Sharpe et. al., 1997).

Figure 2.5 Schematic cross section showing major elements of the geological/ hydrogeological model of the Uxbridge wedge of the ORM (modified from Sharpe et al., 1994).

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

The York till (unit 2m, Table 2.1) is made of clay-sand diamicton with 5-10% gravel. It is often difficult to distinguish from younger tills, such as the Newmarket till. The Don Formation (unit 2l, Table 2.1) consists of sand, silt and clay with fossils indicating lacustrine environment.

The Scarborough Formation (unit 2k, Table 2.1) comprises silt-clay rhythmites and silt. It can be observed in bluffs along Lake Ontario at 50-100 m.a.s.l. The lower part of the formation is characterized by a 20-30 m thick layer of sand covered by rhythmites and massive silt. The Sunnybrook till (unit 2j, Table 2.1) is a clayey-silt diamicton with a very low content of stones. However, stratified layers with some stones in the bottom of rhythmites and massive clay indicate that it may be a till. The Thorncliffe Formation (units 2g, 2h and 2i, Table 2.1) is made of silt-clay rhythmites and cross-laminated/cross-bedded sands. The thickness of sandy deposits can be up to 50 m. It has to be pointed out that the extent and thickness of this formation makes it a very important aquifer in the Uxbridge wedge area.

2.4 NEWMARKET/NORTHERN TILL

The Newmarket till is a thick regionally extensive till unit that can be traced across the Greater Toronto Area and below the Oak Ridges Moraine. The entire thickness of the till ranges between 5 and 60 meters (Boyce et al., 1995). This makes the till a regional marker and also a regional aquitard that confines several underlying overburden aquifer systems (Sibul et al., 1977, Boyce, 1995, Gerber and Howard, 1996, and Gerber, 1999). The till was deposited by southward-flowing ice during the last (Late Wisconsinian) glacial maximum (Boyce et al., 1995). It is an overconsolidated diamict

consisting of a mixture of granitic, gneissic and carbonate pebble and boulder-sized clasts suspended in a silt to silty-sand matrix. The Newmarket/Northern till has a planar lower contact on rippled sand of the Thorncliffe Formation. The planar contact may be observed on seismic profiles. The base typically occurs between 200 and 220 m.a.s.l. within the Uxbridge wedge (Boyce et al., 1995).

2.5 THE OAK RIDGES MORaine

Oak Ridges Moraine sediments form an extensive surface deposit 160 km long and 2 to 11 km wide. The ORM may be more extensive in the subsurface, particularly under the Halton till (Figure 2.5). Rhythmically interbedded fine sands and gravels are the dominant sediments, but coarse sands and gravels are prominent locally. Core logging indicates that areas of the moraine are composed of two or four fining upward packages (Barnett, 1993, also Appendix B). The lower contact of the moraine is an irregular eroded surface on the Newmarket/Northern till. ORM sediments may reach thicknesses of 150 m.

2.6 HALTON TILL

Halton till forms the highest stratigraphic unit, and occurs as a surficial till and lake sediment south of the ORM. It is dominantly clayey silt to silt till with interbedded sand and silt. The Halton till thins toward the north and east. As mentioned above, the Halton till overlaps the ORM along the southern flank of the moraine where it is characterized by a zone of hummocky terrain (Barnett and Henderson, 1995).

CHAPTER 3

HYDROGEOLOGICAL SETTING OF THE OAK RIDGES MORaine

3.1 MAJOR AQUIFERS AND AQUITARDS IN THE AREA

The ORM sediments and Lower Drift are two major hydraulic systems separated by Pleistocene tills. Pleistocene tills are the primary substrates of interest for hydrogeologic characterization since they are widely distributed and form regional low permeability aquitards. In the ORM area, thick tills, such as the Halton till and the Northern/Newmarket till, have long been regarded as very low permeability aquitards (Sibul et al., 1977). However, recent hydrogeological work by Boyce (1995), Gerber and Howard (1996) and Gerber (1999), contrary to the afore-mentioned view, have identified the presence of active groundwater flow systems and relatively rapid rates of flow (on the order of more than 1 m/year) within a thick (as much as 60m) regionally extensive till unit (Northern/Newmarket till). Moreover, leakage through the till may be substantial in places where it is incised and sometimes entirely eroded (Desbarats et al., 2001). It has to be pointed out, however, that the mechanisms of groundwater flow through the regional aquitard and the permeability of the tills are not well understood. Possibility of leakage through the Northern/Newmarket till in the Gan Eden area will be discussed in Chapter 5.

According to the regional stratigraphic model presented in the previous chapter, deposits of the ORM form an aquifer system that is confined southward from the center

of the ORM by the Halton till. The moraine comprises a sand and gravel-cored ridge that forms a major groundwater recharge area, as well as a regional groundwater and surface drainage divide in south-central Ontario. Sediments of the ORM are mainly rhythmically interbedded fine sands, silts and gravel, but also contain clayey silt and till. In high elevation localities, low permeability layers divide the ORM hydraulic system into two sub-aquifers (for a detailed discussion of low permeable layers within the ORM sediments please refer to Chapter 4). These upper aquifers have very high recharge potential and thus are likely to recharge underlying aquifers located within thick deltaic sands and silts of the Thorncliffe and Scarborough Formations. These aquifers are a primary source of groundwater for domestic and agricultural water supplies. Hydraulic parameters of the aquifers, such as transmissivity and storativity in the Uxbridge study area are discussed in Chapter 5.

The lower aquifer is confined and separated from the upper aquifer system by a regional aquitard formed by clayey sediments of the Lower Drift and the overlying Northern/Newmarket till (Sibul et al., 1977). The Northern/Newmarket till is an overconsolidated diamict comprising a mixture of pebble- and boulder-sized clasts suspended in a silt to silty-sand matrix. The presence of fractures, sandy layers, lenses, dikes and inclusions causes groundwater flow heterogeneity in the till aquitard. With a total thickness that ranges from 0 to 60m, the Northern/Newmarket till forms an extensive tabular aquitard that can be mapped from outcrops in bluffs on the shores of Lake Ontario to the south and beneath the ORM. Geometry of the Northern/Newmarket till is known from seismic profiles (Pugin et al., 1999) and from sediment and

geophysical logging of continuously cored boreholes (Boyce et al., 1995). The till's lower boundary is in most places planar, except in localities where it forms dome shapes draping (0-10m thick) over Lower Drift sediments. The upper boundary of the Northern/Newmarket till is irregular, outlined by drumlins and incised channels (Brennand and Shaw 1994). The channels that cut into Northern/Newmarket till are filled with sand and gravel sediments (Barnett et al., 1998). These channels could enhance productivity in the lower aquifer in areas where they exist.

3.2 LOWER AQUITARD WINDOWS PROBABILITY

To identify possible windows a group of scientists from the Geological Survey of Canada built a model of "zero" aquitard thickness using data based on provincial water-well records (Desbarats et al., 2001). Measurements of Northern/Newmarket till thickness have been extracted from the MOEE water-well database and geological drilling records. Data were divided into two categories: hard thickness values obtained from wells fully intersecting the unit, and soft values obtained from wells that end in the unit. A histogram of non-zero aquitard thickness determined from fully penetrating wells is shown on Figure 3.1. 1609 zero-thickness values were eliminated from the histogram.

To calculate the probability of aquitard windows the following method described in Deutsch and Journel (1992) was used. This algorithm involves coding of aquitard thickness into a sequence of N binary "0" and "1" variables corresponding to a sequence of N threshold values. N equals 5 and threshold thicknesses are 0.0, 6.09, 12.18, 24.37, and 40.00 m. The last four threshold values correspond to the 25th, 50th, 75th and 90th percentiles of the distribution shown on Figure 3.1, respectively.

Figure 3.1 Histogram of non-zero aquitard thickness for shaded area (modified from Desbarats et al., 2001)

A hard thickness value $Z(x)$ at the point x in the horizontal plane is coded into a sequence of binary indicator variables $I(x; z_c)$ for the five threshold thicknesses z_c according to the following transform:

$$\begin{aligned} \text{If } Z(x) < z_c, \text{ then } I(x; z_c) &= \text{prob}\{Z(x) \leq z_c\} = 1, \\ \text{otherwise } I(x; z_c) &= \text{prob}\{Z(x) \leq z_c\} = 0. \end{aligned}$$

For soft thickness information, a minimum thickness $Z_p(x)$ determined from the partially penetrated well at the point x in the horizontal plain is coded into a sequence of binary indicator variables $I(x; z_c)$ for the five threshold thicknesses z_c according to:

$$I(x; z_c) = \text{prob}\{Z(x) \leq z_c \mid Z(x) > Z_p(x)\}.$$

The indicator value, $I(x; z_c)$, corresponding to a point x and a threshold z_c is given by the probability that true thickness $Z(x)$ is less or equal to z_c , given that $Z(x)$ must be greater than $Z_p(x)$. This conditional probability is estimated from the experimental histogram of thicknesses shown in Figure 3.1. An example of indicator coding is shown in Table 3.1. For example, hard thicknesses 0.0, 10.38 and 30.47m are coded into the sequences of indicators: (1.0, 1.0, 1.0, 1.0, 1.0), (0.0, 0.0, 1.0, 1.0, 1.0) and (0.0, 0.0, 0.0, 0.0, 1.0) respectively. Indicators derived from soft data are assumed fractional values between 0 and 1. For example, a lower-boundary thickness of 0.0 m from outcrop observation is coded into the sequence of indicators: (0.0, 0.266, 0.499, 0.755, 0.894), or a lower-boundary thickness of 4.69 m from a partially penetrating well is coded in the sequence of indicator values (0.0, 0.077, 0.370, 0.692, 0.866) (Table 3.1). Both indicator values derived from hard data and ones derived from soft data are treated the same.

Table 3.1 Examples of indicator coding of hard and soft data

Datum value (m)	$I(x: z_{c1})$ (0.00 m)	$I(x: z_{c2})$ (6.09 m)	$I(x: z_{c3})$ (12.18 m)	$I(x: z_{c4})$ (24.37 m)	$I(x: z_{c5})$ (40.00 m)
hard data					
0.00	1.0	1.0	1.0	1.0	1.0
10.38	0.0	0.0	1.0	1.0	1.0
30.47	0.0	0.0	0.0	0.0	1.0
soft data					
> 0.00	0.0	0.266	0.499	0.755	0.894
4.69	0.0	0.077	0.370	0.692	0.866
18.10	0.0	0.000	0.000	0.349	0.718

The map of probability for encountering an aquitard window on a 250 m² spacing, shown on Figure 3.2, is the result of 50 statistical simulation trials using Sequential Indicator Simulation software (Deutsch and Journel 1992). Large areas of the incised aquitard are proximal to Lake Simcoe and Oak Ridges Township. In contrast, the Uxbridge area is one of the regions with a low probability of encountering an aquitard window. However, there is a probability of encountering an aquitard window south-westward and north-westward from the study area (Figure 3.2). The importance and practical application of the fact that an aquitard window is possible in the proximity of the study area will be discussed in Chapter 5.

Figure 3.2 Map showing probability of encountering an aquitard window on 250 m² spacing in the study area (modified from Desbarats et al., 2001).

3.3 HETEROGENEITY OF GROUNDWATER REGIME IN NORTHERN/NEWMARKET TILL.

Groundwater flow between the ORM aquifer system and the lower aquifer is possible not only through windows in the regional aquitard but also by means of significant leakage through the Newmarket/Northern till aquitard.

There are several lines of evidence pointing to a large vertical heterogeneity in the Newmarket/Northern till for the Duffins Creek area (Gerber and Howard 1996; Gerber 1999). These structural properties of the Northern/Newmarket till could be extrapolated to the Uxbridge area. The following three lines are worth discussing for their contribution to the estimation of lower aquifer water resources.

Isotope analyses of till pore water show that tritiated waters are present at different depths within the till (Gerber and Howard 1996; Gerber 1999). They also report that there is little or no depletion in stable-isotope ratios with increasing depth. Earlier research (Remenda et al., 1996) documents that the isotope profiles $\delta^{18}\text{O}$ and $\delta^2\text{H}$ show depletion increasing smoothly with depth for a low-permeability, homogeneous aquitard.

The depletion rate depends on the dominant type of solute transport, which can involve diffusion or advection. When diffusion is the dominant process and advective transport is negligible, the depletion rate is very high. In contrast to that, isotope profiles for $\delta^{18}\text{O}$ and $\delta^2\text{H}$ (Figure 3.3) show the constant isotope concentration in the Northern/Newmarket till. This indicates the presence of permeability-enhancing sedimentary structures such as sand beds or fracture discontinuities within the till.

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The second line of evidence indicating a large vertical heterogeneity for the Northern/Newmarket till is deviation of hydraulic heads through the unit from an inclined line of the constant hydraulic gradient (Figure 3.3).

Figure 3.3 Representative composite profile for the Duffins Creek area showing core log, natural gamma log, hydraulic head, and stable-isotopes ($\delta^{18}\text{O} \pm 0.2\text{‰}$, $\delta^2\text{H} \pm 2.0\text{‰}$). HT Halton till; Nt Northern/Newmarket till; TF Thornccliffe formation; Su Sunnybrook diamict; DE3-DE6 Diamict elements (modified from Gerber and Howard 1996). Symbol explanation: C S S G - clay, silt, sand and gravel, respectively; symbols below the table mean methods of measuring, sampling and drilling.

Hydraulic heads at the top of the Northern/Newmarket till are higher than expected and hydraulic heads at the lower boundary of the till are lower than expected for a homogeneous aquitard (Figure 3.3). Gamma log also indicates geological heterogeneity of the Northern/Newmarket till (Figure 3.3).

The third line of evidence indicating a large heterogeneity is variability in hydraulic conductivity measured by the slug-test technique. Slug-test estimates of hydraulic conductivity (K) in wells for Northern/Newmarket till range over 7 orders of magnitude, from 10^{-12} to 10^{-5} m/s (Gerber and Howard, 2000).

All of the above mentioned evidence for heterogeneities or zones of higher hydraulic conductivity can be organized into architectural elements, which are distinct "pockets" of strata with internally consistent sedimentary characteristics or facies and usually correspond to hydrostratigraphic units (Boyce and Eyles 2000).

Architectural-element analysis is based on recognition of distinctive assemblages of sedimentary facies and the presence of bounding erosion surfaces in drill core logs, borehole geophysical data (gamma, EM conductivity, temperature), and outcrops (Boyce and Eyles 2000). This analysis indicates that the Northern/Newmarket till consists of the three following distinctive architectural-element types shown on Figure 3.4: diamict elements, interbed elements and deformed zones.

The first types of architectural elements, called diamict elements, are made of planar tabular till beds (unit DE in Table 3.2). Till beds have their boundaries composed of erosion surfaces that can vary from horizontal to dipping. The surfaces are usually covered by thin sand and gravel beds including discontinuous boulder concentrations (Figure 3.5).

Figure 3.4 Different scale of architectural element types A. Large scale composite elements of the Northern/Newmarket till aquitard; B. small-scale sedimentary heterogeneities identified in cores and outcrops (modified from Gerber 1999).

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Table 3.2 Architectural elements and sedimentary facies identified in the Northern/Newmarket till aquitard. Explanation of symbols: L length; T thickness; A area (after Boyce and Eyles 2000).

Architectural elements in Northern/Newmarket till		Code	Outcrop (2-D) geometry	Approx. scale	L/T	Inferred processes
Diamict element		DE	Tabular diamict beds, planar to gently undulating bounding contacts; boulder pavement often marking upper surface	>100 (L), <10 m (T), >10 ³ m (A)	>10	Subglacial aggradation of deformation till
Interbed	Coarse	I-c ₁	Laterally continuous, sheet-like sands and gravels separating diamict elements	>100 m (L), <5 m (T), 10 ³ m ² (A)	>25	Ice-bed separation; erosion and deposition by subglaciofluvial meltwater sheet flow
		I-c ₂	Laterally discontinuous sand and gravel body, with pinch and swell geometry	<10 m (L), <1 m (T), 10 ² m ² (A)	<10	Ice-bed separation; localized incision by subglaciofluvial meltwater sheet flow
	Fine	I-f	Laterally continuous tabular silt and mud units separating diamict elements	>10 m (L), <1 m (T), 10 ² m ² (A)	>10	Ice-bed separation, low-energy sedimentation in subglacial water body
Deformed zone		DZ	Undulatory zone of deformed till and thrust sediments at base of till sheet; variable thickness and spatial extent	Variable (L), <10 m (T), 10 ² m ² (A)	?	Subglacial deformation of pre-existing strata

Figure 3.5 Diamict element bounded by linear boulder concentration (after Boyce and Eyles 2000).

Individual diamict elements may have an areal extent of at least four km², as has been demonstrated by the correlation of bounding erosion surfaces in drill core and gamma logs at investigation sites located in the proximity of Whitevale township (Boyce and Eyles 2000).

Diamict elements are dominated by massive facies consisting of poorly sorted, clast-rich and heavily overconsolidated diamict with a sandy-silt to silty-sand matrix. Diamict laminae, silt and sand lenses are crudely stratified facies occupying 10% of the cumulative diamict thickness. Other small-scale heterogeneities within diamict elements include narrow (<2cm) sand-filled dikes, inclusion of sorted sediments, and localized clast concentrations (Boyce and Eyles 2000).

The second distinctive architectural type is called an interbed element. Such elements are composed of very thin sheet-like beds of glacio-fluvial sand and gravel (unit I-c in Table 3.2) or sand, silt and some clay (unit I-f in Table 3.2). Interbeds act as separating units between till elements. Interbeds may reach thicknesses of 2m. They are often hydraulically connected with each other (Boyce and Eyles 2000). Intensive seepage faces in outcrops (Figure 3.6) indicate active groundwater flow within these units.

Figure 3.6 Sand interbeds marked by seepage (after Boyce and Eyles 2000).

There are two such distinct subtypes of interbeds; coarse-grained and fine-grained interbeds. They can be identified on the basis of texture, composition and geometry.

Coarse-grained interbeds (unit I-c in Table 3.2) occur as sheet-like beds of crudely bedded sands and gravels. Usually, primary structures are destroyed by post-

depositional deformation. In contrast to fine-grained interbeds, coarse-grained interbeds are associated with zones of active groundwater flow in the Northern/Newmarket till. On geophysical logs coarse-grained interbeds correlate with localized inflections in EM conductivity and changes in borehole fluid temperature (Boyce and Eyles 2000).

Fine-grained interbeds (unit I-f in Table 3.2) consist of thin (less than 1m) tabular beds of sand, silt and mud. Occasional dropstones and clots of diamict are present. Laminated layers of silty clay have thicknesses less than 0.1 m. Fine-grained interbeds were formed in low-energy depositional environments in standing-water bodies ponded between the ice base and underlying diamict elements (Boyce and Eyles 2000).

The third distinctive architectural element type is called a deformed zone (Figure 3.7 and unit DZ in Table 3.2). It consists of lacustrine sand and silt deformed in the process of glacio-tectonics. These sediments are incorporated into till elements by folding and thrusting. Deformed zones are of limited extent and their thickness is usually less than 10 m (Table 3.2). These zones are mostly located at the base of the Newmarket/Northern till where the ice deformed underlying Thorncliffe Formation sediments. Within deformed zones at the base of Newmarket/Northern till, bulk hydraulic conductivity has an increased value in comparison with the middle part of the till (Gerber 1999). Due to these increased bulk values of hydraulic conductivity, hydraulic heads at the base of the till are less than expected for a homogeneous aquitard (Figure 3.3).

Figure 3.7 Basal deformation zone (*DZ*) showing thrusting and incorporation of Thorncliffe Formation (*TF*). Arrows pointing to lines of deformation (after Boyce and Eyles 2000).

CHAPTER 4

CASE STUDY OF AQUIFERS IN UXBRIDGE AREA

4.1 STUDY PROCEDURE OF THE AREA

The preliminary regional study presented in previous chapters, which involved a review of relevant literature and maps, is not enough to delineate aquifers in the study area. Water well records of the Ministry of the Environment (Appendix A) together with data from the Hydrogeology and Master Servicing Plan (Cosburn Patterson Mather Limited. et al., 1999) have been reviewed and analysed for the area shown in Figures 4.2 - 4.6 to detail watershed and shallow water flow directions, delineate surficial deposits of the study area, identify aquitard units within the ORM sediments, and approximate the elevations of the Newmarket till surface as well as piezometric surfaces of different aquifers.

4.2 SITE TOPOGRAPHY AND DRAINAGE

The study area is located within a rectangular block (Figure 4.1) with the following UTM boundaries (Canadian Universal Transverse Mercator): western - 647 900 m E, eastern - 650 000m E, southern - 4880 000m N, northern - 4884 000m N (within NTS 31D/3, Zone 17. The centre of the study area is surrounded by Highway 47, Brock Road, Old Stouffville Road, and 6th Concession Road (Figure 4.2).

Figure 4.1 Map showing location of the study area in Greater Toronto Area (modified from Barnett et al., 1998).

Figure 4.2 Diagram showing landform elements of the study area . Explanation of the symbols: Gp, Goodwood plain; Rd, Rosedale delta; Um, Uxbridge moraines; III, drumlinized upland, IV, broad valley.

Topography varies across the area from hummocky and undulating topography to flat lands. The elevation of the area ranges from a high of 375m.a.s.l. measured on the top of the ridge (Uxbridge moraines, unit Um in Figure 4.2) to a low of 297m.a.s.l. in the north-eastern Uxbridge valley region (unit IV in Figure 4.2). Thus, the maximum topographic relief over the study area is 78m. Most of the area lies within the Goodwood plain (unit Gp in Figure 4.2).

The study area drains from the relatively high ground of the Uxbridge moraine ridge, located in the southeastern corner of the area, to the north, north-west and south into Uxbridge Brook, Pefferlaw Brook and an internal draining wetland (Figure 4.3). Uxbridge Brook watershed covers approximately 85% of the study area. Within this area, a low-lying wetland locality (UTM 4881 600m N, 649 230m E, 309m.a.s.l. in Figure 4.3) containing a small headwater creek constitutes a sub-watershed which forms about 20 % of the Uxbridge Brook watershed within the study area. Drainage in the low-lying wetland of the area is imperfect with occasional ponding visible at the ground surface. Recent organic deposits of peat underlie this location. The interrupted drainage pattern is a factor in the presence of a lowered groundwater table in this location (Figure 4.3).

There is a groundwater mound in the southeastern section of the study area. This high groundwater elevation is associated with the natural topography and coincides with the hills of the Uxbridge moraines.

Figure 4.3 Map showing two sub-watersheds of the Pefferlaw Brook and Uxbridge Brook watershed pertaining to South Lake Simcoe watershed area and shallow groundwater contours with groundwater flow directions for the study area (data taken from Hydrogeology and Master Servicing Plan, 1999).

This physiographic unit creates a local divide for the shallow groundwater flow (Figure 4.3). The groundwater table in the of south eastern part of the site (intersection 6th Conc. Road and Wagg Road) reached an elevation of about 340m.a.s.l. during the summer of 1999. The difference between groundwater table elevations under this Uxbridge moraine hill and the above mentioned low-lying wetland section (310m.a.s.l) or Rosedale delta section located in the north western part of the area (315m.a.s.l.) creates hydraulic gradients of 0.05 and 0.02, respectively (Figure 4.3). Groundwater table elevations were mapped for the study area in July, 1999 (Hydrogeology and Master Servicing Plan, 1999).

4.3 GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The study area is located on the northern slope of the ORM. In this locality moraine deposits (unit 5 in Figure 4.4) are the dominant surficial geological units. Together with glacial deposits and recent deposits (units 6, 10 in Figure 4.4), moraine covers approximately 80% of the study site. These surficial sediments are represented on the site by mostly fine to medium grained sand. Recent organic deposits (unit 9 in Figure 4.4) cover less than 5 % of the area. The eroded relict surface of the drumlinized uplands is composed of Newmarket till sediments (unit 3 in Figure 4.4). Newmarket till occurs between 258 m.a.s.l. and 288 m.a.s.l (Table 4.1) and divides the Quaternary drift into two major hydraulic units; the lower drift and the ORM sediments. The approximate thickness of Northern till is 17.8 m (Table 4.1).

Figure 4.4 Surficial geology map showing major deposits in the study area. Unit numbers correspond to the unit numbers in Table 3.1, 3.2 in Chapter 3.

Table 4.1 Elevations and thickness of Newmarket till in the study area from well logs in Appendix B

Well	GLL-1	GLL-2	TW-1-88	OW00-39	Average
Well top elevation, m.a.s.l.	369	320	322	314	331.25
Top elevation of the unit, m.a.s.l.	288	279	283	275	281.25
Bottom elevation of the unit, m.a.s.l.	269	258	266	261	263.5
Thickness of the unit, m	19	21	17	14	17.8

The well records from the wells (Appendix B), along with published MOEE well records (Table 4.2 and Appendix A) show another low permeability layer within the study area. This layer plays the role of an aquitard, dividing the ORM deposits into an upper unconfined local aquifer and an intermediate confined aquifer. It consists of very dense fine silty sand with some clay and gravel (see borehole logs in Appendix B). The density and fine grained nature of these sediments significantly decrease the vertical hydraulic conductivity of the unit.

MOEE water well locations are shown in Figure 4.5. Two cross sections shown in Figure 4.6 represent a 3D model of the discontinuous local aquitard varying between 290 and 315 m.a.s.l. MOEE well logs for the sections are compiled in Table 4.2.

Figure 4.5 Map showing TW, MOEE water well and GLL borehole locations in the study area (data from personal communication and MOEE records). Pumping and observation wells are located within the black rectangular. Black circle outlines the depression cone boundary.

The upper aquifer exists only in elevated localities. Maximum thickness of the unconfined aquifer is 25 m as surveyed in the southeast part of the study area. It disappears northward from the centre of the study area (Figure 4.5) in drumlinized uplands and the Uxbridge flat valley (units III and IV in Figure 4.2). Since the area of the ORM sediments are limited to the north by drumlinized uplands and the Uxbridge flat valley, the boundary of the upper aquifer approximately coincides with the ORM deposition boundary. There is a northern extension of the intermediate aquifer in the form of sandy and gravelly fractions of an unconfined aquifer in glacial lake deposits (unit 8 in Figure 4.4).

Thickness of the intermediate aquifer within the study area is between 15 and 39 m. In order to find the piezometric surface of the intermediate aquifer two corridors of water wells on the site map have been chosen. One of them runs in a north easterly direction with Toronto Street coinciding with the centre line of the corridor. The width of the corridor is 625m. Another corridor the same width follows the 6th Concession Road. Elevations of well bottoms, static levels and composition of the sediments at the well bottoms are shown against well UTM coordinates along the X-axis (Figure 4.7, 4.8). Static levels in the wells show the hydraulic head at the point of screen installation. Figures 4.7 and 4.8 show there are at least 6 water wells in the upper aquifer and the static level reflects the water table (approximately 310 -330 m.a.s.l.). The piezometric surface of the intermediate aquifer varies between 318 and 310 m.a.s.l.

Figure 4.6 Generalized three dimensional isometric diagram showing two cross-sections across the study site through water supply wells (shown in Figure 4.5). The local aquitard within the ORM sediments, is shown in black. Newmarket till aquitard is shown in red.

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Table 4.2 Water well data (from MOEE water well Record) for section in Figure 4.6

Well Num	Elevation m	Well depth, m	Test Rate, gpm	Well Log, ft
A - A'				
9689	299.9	62.5	10	BRWN LOAM 0003 BRWN CLAY SNDY 0019 <i>BRWN CLAY BLDRHARD 0044 GREY CLAY STNS HARD 0048</i> ¹ GREY GRVL STNSLOOS 0065 GREY CLAY STNS HARD 0180 RED CLAY SOFT 0189 ² GREY SAND SILT LYRD 0205
6343	274.3	27.4	5	BRWN SAND DRY 0014 <i>BRWN CLAY PCKD 0048</i> BRWN FSND 0081 BRWN SAND LOOS 0090
868	306.0	23.5	10	BRWN SAND 0006 <i>YLLW CLAY 0018</i> BRWN SAND 0025 RRWNSILT 0051 GREY CLAY 0054 GREY SILT 0062 GREY CLAYGRVL 0076 BRWN GRVL SAND 0077
5869	327.7	34.1	15	BRWN SAND 0080 BLUE CLAY 0098 BRWN FSND 0112
4964	310.9	31.4	5	BRWN LOAM LOOS 0001 <i>BRWN SAND CLAY LOOS 0036</i> GREYCLAY SAND SOFT 0048 GREY CLAY GRVL HARD 0093 BRWNSAND GRVL MGRD 0103 GREY CLAY SAND 0103
6345	335.3	47.2	4	YLLW SAND 0025 <i>BRWN CLAY 0035</i> GREY SAND 0070 BRWNCLAY 0075 BRWN SAND CLAY 0080 GREY CLAY STNS 0122 GREY GRVL CLAY 0124 BLUE CLAY STNS 0155
6663	335.3	14.0	6	BRWN SAND 0027 <i>YLLW CLAY 0028</i> GREY SILT CLAY 0040BRWN SAND 0046
1600	338.0	33.2	10	BLCK LOAM 0002 <i>BRWN CLAY 0014 BRWN CLAY GRVL 0020</i> BRWN SAND 0036 BRWN CLAY SAND 0067 BRWN SAND FSND 0077 BRWN SILT CLAY 0089 GREY CLAY SILT 0104 GREYSAND FSND 0109
B - B'				
7267	312.4	33.5	15	BRWN SAND STNS 0021 GREY STNS 0024 BRWN SAND STNS 0027 BRWN CLAY SNDY 0082 BLUE CLAY STNS 0090 GREYSAND STNS 0097 WHIT CLAY STNS 0101 GREY SAND STNS 0110
9797	321.9	58.5	6	BRWN LOAM 0003 BRWN SAND SOFT 0052 GREY CLAY GRVLHARD 0088 GREY CLAY BLDR 0097 GREY CLAY GRVL 0103 BRWN SAND SOFT 0116 GREY CLAY STNS HARD 0148 GREYCLAY BLDR 0183 BLCK SAND SOFT 0188 GREY CLAY HARD 0192
3286 TW3	318.7	127.1	10	BLCK LOAM 0001 BRWN SAND 0029 BRWN CLAY SAND STNSSGREY SILT CLAY 0091 GREY CLAY SAND STNS 0122 GREY CLAY SILT 0164 GREY SILT SAND 0188 GREY CLAYSAND STNS 0286 GREY SAND SILT FGRD 0294 GREY CLAYCLN 0414 BLCK SHLE 0417
4547	297.2	24.7	9	BRWN MSND 0035 <i>BRWN MSND CLAY 0060</i> GREY MSND 0081
6727	320.0	53.0	3	BRWN SAND LOOS 0080 GREY FSND CLAY 0172 GREY GRVLLOOS 0174

¹ Italic underlined font indicates clay layer within ORM sediments

² Bold font indicates clay fractions of the Newmarket till

The lower aquifer is confined by the Newmarket till from the top and by shale of the Whitby Formation from the bottom. The elevation of the upper boundary of the lower aquifer ranges between 256 and 269 m.a.s.l. in the study area. Bedrock elevation on the site is approximately 190 m.a.s.l. The lower aquifer consists of thick sediment packages of mostly silt and sand with some layers and lenses of clayey sediments. The total thickness of all fractions of the lower aquifer in the boreholes OW00-39 and TW3 is approximately 70 and 76 m, respectively (Appendix B).

Vertical gradients in the study area are generally downward. According to Figures 4.7 and 4.8, the water table in the upper aquifer is higher than the piezometric surface for the intermediate and lower aquifers. The piezometric surface in the intermediate aquifer is higher than the piezometric surface in the lower aquifer. Therefore, a component of groundwater flow from the upper and intermediate aquifers moves downward to recharge the intermediate and the lower aquifers, respectively.

Figure 4.7 Diagram showing water well locations in corridor #1 going parallel to Toronto Street in the study area (Figure 4.5), static water levels in wells and piezometric surfaces of different aquifers.

Figure 4.8 Diagram showing water well locations in the corridor #2 following 6th Conc. Road in the study area (Figure 4.5), static water levels in wells and piezometric surfaces of different aquifer.

CHAPTER 5

PUMPING TEST OF THE LOWER AQUIFER

This chapter discusses the principle concepts relevant to a pumping test and deals with the analysis of pumping test data for the lower aquifer. The pumping test that included recovery monitoring was conducted by Beatty and Associates Limited at the Gan Eden site between August 18th and October 15th, 2000. The author participated in the collection of the data during the final phase of the pumping test (Figure 5.1) and also analysed the data.

Figure 5.1 Measuring water level in a well during recovery monitoring period (September 19th, 2000).

5.1 PUMPING TEST SETTINGS

The lower aquifer test consisted of pumping two wells installed at depths of 125 m, spaced 5.2 m apart. Pumping was at a constant combined rate of 2272 L/min and recording the drawdown in the pumping wells, and nearby observation wells at specific times. The water from each well was piped to discharge basins located more than 550m away.

The test had two purposes:

1) to determine the characteristics of the pumping wells. For the well-performance test, yield and drawdown were recorded to calculate specific capacity. Specific capacity gives a measure of the productive capacity of the completed well providing information needed for the selection of pumping equipment for water supply.

2) to obtain hydraulic parameters for the lower aquifer. This provides data from which principal factors of the aquifer performance, such as transmissivity and storativity, were calculated. These parameters may be used to predict the effect of new withdrawals on existing wells, the drawdowns in a well at future times and at different discharge rates. Also, they will be useful to determine the radius of the cone of depression for individual or multiple wells.

To produce more accurate data, several important procedures were undertaken. Firstly, a gasoline generator (Figure 5.2) supplying power for the pumps was operated with a speed less than 2/3 of the maximum capacity to maintain constant yield. Secondly, drawdown readings were taken at proper time intervals, shorter intervals at the beginning

Figure 5.2 Photograph showing gasoline power station supplying electric power for water pumps.

During the pump test, yield was measured for each pumping well with flow meters and orifice weirs. The orifice weirs were used to measure the pipeline discharge rates into the primary infiltration basin and a smaller secondary basin (Figure 5.3).

Figure 5. 3 Photographs showing main (above) and secondary (below) infiltration basins.

An orifice weir is a hole of precise dimensions through which discharged water is directed (Figure 5.4). The water pressure inside an orifice weir is measured in a manometer tube to determine a discharge rate.

Figure 5.4 Orifice weirs and manometer tubes operating during the pumping test.

The construction of an orifice weir consists of a discharge pipe, orifice plate and manometer (Figure 5.5). The discharge pipe is at least 6 feet (2 meters) long, oriented horizontally and cut squarely at the end (Figure 5.5).

Figure 5.5 Design of an orifice weir (after Driscoll, 1986).

An orifice plate with a known cross-sectional area confines the flow at the end of the discharge pipe. An orifice plate is a circular steel plate, 3/8-inch (9.5 mm) thick, fastened over the end of the discharge pipe. The diameter of the centered hole is less than 80% of the inside diameter of the discharge pipe. Water pressure at the orifice is measured by means of a manometer inserted into the discharge pipe 24 inches (61 cm) "upstream" from the orifice plate (Figure 5.5). More information on construction of an orifice weir may be found in Driscoll (1986).

To calculate the discharge, the ratio of orifice diameter to pipe diameter was found. The coefficient C was obtained using the relationship shown on Figure 5.6.

Figure 5.6 Value of the coefficient C for using an orifice weir (after Driscoll, 1986).

The following equation was then used to calculate the water discharge from the orifice weir:

$$Q = 8.025 CAh^{1/2}$$

Where Q - discharge, U.S. gallons per minute

C - coefficient from Figure 5.6

A - area of the orifice, square inches

h - height of the water in the manometer above the center line of the discharge tube, inches.

There were two methods used for measuring the water level in wells: 1) an electric water-level indicator tape (Figure 5.7, 5.8), and 2) a pressure transducer (Figure 5.8).

Figure 5.7 Measuring depth to water in observation well

OW00-39 using an electric water level tape.

The first method uses a weighted calibrated line with an electrode (Figure 5.7). An electric water-level tape (electric sounder) works on the principle that an electric current will pass through water fairly easily. The tape consists of a current source, two wires

attached to the source at one end and weighted at the other. When the weighted end enters the water, a buzzer sounds to indicate current completion (Figure 5.8).

Figure 5.8 Design of an electric sounder and pressure transducer for measuring water level in an observation well (modified from Driscoll, 1986).

The second method used the pressure transducer. This method measures the height of the water column situated above the transducer probe (Figure 5.8).

The design principle of the pressure transducer is that the pressure on the tip of the probe is related to the height of the water column covering the probe. An electric current passes through the tip of the probe, and the current is proportional to the pressure. A digital readout device attached to the transducer cable translates the current into head measurements. During the test, pressure transducer readings were stored digitally (in a data logger) and later downloaded into a computer. These data, corrected for barometric pressure, are shown on Figure 5.9.

This method was supposed to be particularly useful at the beginning of the pumping test when water levels changed rapidly. This advantage, however, was lost due to the long time setting (15 minutes) between measurements (Figure 5.9).

The pumping test consisted of two stages: pumping and recovery. Before the pumping stage began, the static water level in all pumping and observation wells was recorded (for the test data please refer to Appendix D). After the pumping stopped, recovery data were measured in all wells to verify the aquifer parameters calculated during the pumping stage of the test.

5.2 STAGE ONE: PUMPING

A schematic stratigraphic cross-section of the study site is shown in Figure 5.10.

Figure 5. 9 Graph showing correlation between recovery data measured by electric cable water-level tape and pressure transducer in observation well OW00-39.

Figure 5.10 Schematic cross-section of the lower aquifer pumping test. Symbols shown:

Q - constant pump rate, s - drawdown, h - hydraulic head, b - thickness of the lower aquifer, r -- distance from the pump wells.

The lower aquifer is confined above and below by aquitards. It is bounded by the Newmarket till above (marked as "Aquitard" between the intermediate and the lower aquifers on Figure 5.10) and below, by clayey fractions of the lower drift and shale bedrock. The pressure of the water in the lower confined aquifer is higher than that of the atmosphere. Therefore, the water level in wells is above the upper boundary of the aquifer. Measurements at pumping and observation wells before pumping showed that the piezometric surface of the lower aquifer (static level) is above the top of the aquifer about 42 m. The average thickness of the aquifer tested is about 74 m (Section 4.2).

The two pumping wells are 125m deep and completed in the lower aquifer. They were located 5.15 m apart within the Gan Eden test site (Figure 5.11). For modeling purposes, the two pumping wells were assumed as a combined well TW3&TW4 (Figure5.10). According to the principle of superposition, the total effect of the two pumping wells equals the effect of the combined well placed between the pumping wells. This total effect was measured in observation wells OW00-39 and TW-1-88 (Figure5.10). They were 117 m and 65 m deep, respectively. The observation well OW00-39 was located 82 m southwest of the pumping wells. The observation well TW-1-88 was located 1108 m west northwest of the pumping wells (Figure 5.11). The observation well TW3A was 50 m deep and screened in the intermediate aquifer (Figure5.10). It was located 7 m east of the pumping well TW4 (Figure 5.11). Additional private domestic wells were also monitored during the pumping test, but they are not discussed further because of the lack of response.

Figure 5. 11 Map showing location of pumping, observation and private wells.

5.2.1 Methods of Data Analyses

A detailed theoretical background of solution methods and basic concepts of hydraulic conductivity, porosity, hydraulic head, transmissivity and storativity may be found in several texts (e.g. Freeze and Cherry, 1979; Driscoll, 1986; Kruseman & deRidder, 1990; and Fetter, 1994).

The choice of theoretical solution methods is based on an understanding of the physics of the water flow toward a well during pumping. There are two principle water flow regimes during the pumping test: steady-state and unsteady-state. Steady state flow was achieved in the Gan Eden test after 20000 min or 13.9 days (Figure 5.12).

Methods for evaluating pumping tests in confined aquifers are available for both steady-state and unsteady state groundwater flows (Kruseman & deRidder, 1990). All of these methods are developed for an ideal flow system. The ideal flow system implies the following (Freeze and Cherry, 1979):

- (1) a constant thickness aquifer is confined, horizontal, infinite in horizontal extent, homogeneous and isotropic with respect to hydrogeological parameters,
- (2) there is a single pumping well in the aquifer, with constant pumping rate,
- (3) the well diameter is infinitesimally small,
- (4) the well penetrates the entire aquifer,
- (5) the hydraulic head in the aquifer prior to pumping is uniform throughout the aquifer.

Figure 5.12 Drawdown data from the pumping and observation wells. Unsteady-state and steady-state periods are shown.

Real flow systems are different from the ideal. As a result, interpretation of the pumping test data is attended by some difficulties (will be discussed in Section 5.2.2). In addition, most pumping tests are not continued for a long enough period of time to achieve steady-state conditions.

Two of the most common methods, Theis and Jacob&Cooper methods, were employed to analyse the unsteady-state flow.

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The partial differential equation that describes saturated flow in two horizontal dimensions in the ideal confined system is:

$$\frac{\partial^2 h}{\partial r^2} + \frac{\partial h}{r \partial r} = \frac{S}{T} \frac{\partial h}{\partial t} \quad (5.1)$$

where h - hydraulic head, m

r - radius from pumping well to observation well, m

T - transmissivity, m²/s

S - storativity,

t - time since pumping began, s.

The mathematical region of flow, as illustrated on Figure 5.10, is a horizontal one-dimensional line through the aquifer, from $r = 0$ at the pumping well to $r = \infty$ at the infinite extremity.

The initial conditions are:

$$h(r, 0) = h_0 \quad \text{for all } r \text{ at time zero}$$

where h_0 is the initial hydraulic head, m.

The boundary conditions assume no drawdown occurs at an infinite radial distance:

$$h(\infty, t) = h_0 \quad \text{for all } t$$

and that a constant pumping rate, Q (m³/s) is used:

$$\lim_{r \rightarrow 0} \left(r \frac{\partial h}{\partial r} \right) = \frac{Q}{2\pi T} \quad \text{for } t > 0 \quad (5.2)$$

The solution of the above equation describes the hydraulic head at any radial distance, r , at any time after the start of pumping. One of the methods to solve equation (5.2) was proposed by Theis (1935). He developed an analytical solution as follows:

$$s(r, t) = \frac{Q}{4\pi T} \int_u^\infty \frac{e^{-u} du}{u}, \quad \text{where } u = \frac{r^2 S}{4Tt} \quad (5.3)$$

where $S = h_0 - h(r, t)$ is drawdown (Figure 5.10).

The integral in equation (5.3) is called an exponential integral. For the specific definition of u given by the equation (5.3), the integral is known as the well function, $W(u)$. The well function can be represented by an infinite Taylor series of the following form:

$$W(u) = -0.5772 - \ln(u) + u - \frac{u^2}{2 \cdot 2!} + \frac{u^3}{3 \cdot 3!} + \dots \quad (5.4)$$

Using this function, equation (5.3) becomes:

$$s = \frac{Q}{4\pi T} W(u) \quad (5.5)$$

The line on a log-log plot with $W(u)$ along the Y axis and $1/u$ along the X axis is commonly called the *Theis curve* (Figure 5.13).

Figure 5.13 Theoretical Theis curve of $W(u)$ versus $1/u$ used for the log-log matching procedure

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The field data measurements, time-drawdown values, are plotted at the same size and scale as a $W(u)$ versus $1/u$ curve. The data analysis is done by superimposing the two plots and matching observed data points to the Theis curve.

To calculate transmissivity and storativity (Equation 5.6), values $W(u)$, $1/u$, s , and t are found at a match point, and used with known values of Q and r with the following equation (5.6)

$$T = \frac{Q}{4\pi s} W(u) \text{ and } S = \frac{4Tt \cdot u}{r^2} \quad (5.6)$$

The second method used is the Jacob&Cooper technique (1946). This method involves truncation of the infinite Taylor series, which is used to estimate the well function $W(u)$. Therefore, this method is valid for greater time values and decreasing distance from the pumping well ($u < 0.05$) (Kruseman & deRidder, 1990). The resulting equation is:

$$s = \left(\frac{2.3Q}{4\pi T} \right) \log_{10} \left(\frac{2.25Tt}{Sr^2} \right) \quad (5.7)$$

Since Q , r , T , and S are constant, s versus $\log t$ should plot as a straight line on semi-logarithmic paper. Thus, straight-line plots of drawdown versus time can occur after sufficient time has elapsed. If Δs is the drawdown for one log cycle of time and t_0 is the time intercept where the drawdown line intercepts the zero drawdown axis, it

follows from further manipulation with equation (5.7) that values of T and S may be calculated as follows:

$$T = \frac{2.3 Q}{4\pi\Delta s} \quad \text{and} \quad S = \frac{2.25 T t_0}{r^2} \quad (5.8)$$

The most used method for steady-state flow is Thiem's method (1906). Thiem showed that the well discharge can be expressed as

$$Q = \frac{2\pi T(H_2 - H_1)}{\ln(r_2 / r_1)} \quad (5.9)$$

where

Q - well discharge, m³/s

T - transmissivity of the aquifer, m²/s

H_1 and H_2 - the respective steady-state elevations of the water levels in the observation wells, m

r_1 and r_2 - respective distances of the observation wells from the pumping well TW3&TW4, m

For calculation of the transmissivity, equation (5.9) is commonly written as

$$T = \frac{Q \cdot \ln(r_2 / r_1)}{2\pi \cdot (s_1 - s_2)} \quad (5.10)$$

where S_1 and S_2 are the respective steady-state drawdowns in the observation wells.

Storativity cannot be found with the Thiem method.

5.2.2 Data Analysis

Observation well OW00-39 (Theis method)

The flow rate for the 30-day performance test was $0.037867 \text{ m}^3/\text{s}$ (2272 L/min) from both pumping wells. During the test only wells OW00-39 and TW-1-88 responded. Observation well TW3A did not respond to the pumping (Figure 5.12). As a result, the analysis of the pumping test is based on data obtained from wells OW00-39 and TW-1-88.

As a first approach, Theis time-drawdown plots were used to interpret data from observation well OW00-39 (Figures 5.14). As shown on the graph, field data deviate from the theoretical curves several times. These deviations are explained by the fact that aquifer conditions are not ideal (Section 5.2.1). The degree and nature of the deviations are discussed in Section 5.4. To calculate transmissivity and storativity, the whole period of pumping has been divided into two groups: 1) three unsteady-state time intervals based on the best fit to theoretical curves and 2) one steady-state period after 13.9 days of pumping (Figure 5.14).

Figure 5.14 Determination of transmissivity and storativity using the Theis log-log curve-matching procedure and deviation from the theoretical Theis curve. p1, p2, p3 are match points during the different time periods. Data taken from observation well OW00-39.

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As shown in Figure 5.14, data taken after the first 12 min of pumping (*Early Time* in Figure 5.14) show *negative deviation* from the theoretical curve, meaning that drawdown is more than expected or drawdown is below the theoretical curve. During the early time period the match point of the Theis curve has the following coordinates:

- 1) time equals 1.2 min, and
- 2) drawdown equals 0.64 m (Figure 5.14). Using equation (5.6) to find transmissivity and storativity gives:

$$T_1 = \frac{0.037867 \cdot 1}{4\pi \cdot 0.64} = 4.71 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

$$S_1 = \frac{4 \cdot 4.71 \cdot 10^{-3} \cdot 1.2 \cdot 60}{82^2} = 2.02 \cdot 10^{-4}$$

After 400 min (*Mid Time* period in Figure 5.14), data have also deviated from the theoretical curve. The second Theis curve has a match point P2 with coordinates t_2 and s_2 equal to 49 min and 1.7 m, respectively. Transmissivity and storativity are calculated to be:

$$T_2 = \frac{0.037867 \cdot 1}{4\pi \cdot 1.70} = 1.77 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

$$S_2 = \frac{4 \cdot 1.77 \cdot 10^{-3} \cdot 49 \cdot 60}{82^2} = 3.10 \cdot 10^{-3}$$

Data taken after 8000 min (*Late Time* period in Figure 5.14) also deviate from the Theis curve. The match point for the *Late Time* period of pumping time is P3 with

coordinates t_3 and s_3 equal to 62 min and 3.75 m, respectively. Using equation (5.6) to find transmissivity and storativity gives:

$$T_3 = \frac{0.037867 \cdot 1}{4\pi \cdot 3.75} = 8.04 \cdot 10^{-4} \text{ m}^2 / \text{s}$$

$$S_3 = \frac{4 \cdot 8.04 \cdot 10^{-4} \cdot 62 \cdot 60}{82^2} = 1.78 \cdot 10^{-3}$$

Observation well OW00-39 (Jacob&Cooper method)

Figure 5.15 shows the drawdown in observation well OW00-39 against logarithmic time using the Jacob&Cooper semi-log method.

According to Jacob's assumptions (Kruseman & deRidder, 1990),

$$u = \frac{r^2 S}{4Tt} < 0.05$$

The error in the result is less than 2% (Kruseman & deRidder, 1990). The time when the Jacob&Cooper method becomes valid for OW00-39 equals:

$$t \geq \frac{r^2 S}{4Tu} = \frac{82^2 \cdot 2.02 \cdot 10^{-4}}{4 \cdot 4.71 \cdot 10^{-3} \cdot 0.05} = 1.44 \cdot 10^3 \text{ sec} = 24 \text{ min}$$

where estimative values T and S are taken from previous calculations for the *Early Time* period by the Theis method.

Figure 5.15 Graph showing determination of transmissivity and storativity using the semi-log Jacob&Cooper method. Data from observation well OW00-39.

Thus, data taken during the first 24 minutes are not reliable when using the Jacob&Cooper technique.

Data taken after 3 days of pumping (4320min) are also difficult to analyze when using the Jacob&Cooper method, because water flow is approaching steady-state (on the logarithmic scale, see Figure 5.15)

As shown on the Jacob&Cooper graph (Figure 5.15), the nature of the deviation is the same as on the Theis graph. There are several slopes on Figure 5.15 that correspond to different values of transmissivities. Using equation (5.8) gives:

$$T_1 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 3.77} = 1.84 \cdot 10^{-3} m^2 / s$$

$$S_1 = \frac{2.25 \cdot 1.838 \cdot 10^{-4} \cdot 8.91 \cdot 60}{82^2} = 3.29 \cdot 10^{-4}$$

From the second slope, transmissivity equals

$$T_2 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 6.85} = 1.01 \cdot 10^{-3} m^2 / s$$

and storativity is

$$S_2 = \frac{2.25 \cdot 1.012 \cdot 10^{-3} \cdot 56.70 \cdot 60}{82^2} = 1.15 \cdot 10^{-3}$$

Finally, slope#3 gives:

$$T_3 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 9.74} = 8.102 \cdot 10^{-4} \text{ m}^2 / \text{s}$$

$$S_3 = \frac{2.25 \cdot 8.102 \cdot 10^{-4} \cdot 143.68 \cdot 60}{82^2} = 2.337 \cdot 10^{-3}$$

Thiem's method for observation wells OW00-39 and TW-1-88

Thiem's method (equations 5.10) is applicable after steady-state conditions have been achieved.

Figure 5.16 Graph showing differences between three steady-state drawdowns.

From the difference between the steady-state drawdowns s_1 and s_2 for observation wells OW00-39 and TW-1-88, respectively, using equation (5.10) gives

$$T_{1-2} = \frac{0.037867 \cdot \ln(1108 / 82)}{2\pi \cdot (17 - 2.4)} = 1.08 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

Observation well TW-1-88 (Theis method)

As shown in Figure 5.17, data taken during the first 1000 min can not be interpreted because of measuring error.

During the time period between 1000 and 20000 minutes, data fit the Theis curve with match point P1. The match point has the following coordinates: 1) time equals 1950 min, and 2) drawdown equals 1.2 m (Figure 5.17). Using equation (5.6) to find transmissivity and storativity gives:

$$T_1 = \frac{0.037867 \cdot 1}{4\pi \cdot 1.2} = 2.51 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

$$S_1 = \frac{4 \cdot 4.71 \cdot 10^{-3} \cdot 1950 \cdot 60}{1108^2} = 1.80 \cdot 10^{-3}$$

Observation well TW-1-88 (Jacob & Cooper method)

According to Jacob's assumptions (Kruseman & deRidder, 1990),

$$u = \frac{r^2 S}{4Tt} < 0.05$$

Figure 5.17 Theis log-log graph showing matching procedure and deviation from the theoretical Theis curve. P1 is match point during middle time period. Data taken from the observation well TW-1-88

The time when the Jacob&Cooper method becomes valid equals:

$$t \geq \frac{r^2 S}{4Tu} = \frac{1108^2 \cdot 1.8 \cdot 10^{-3}}{4 \cdot 2.51 \cdot 10^{-3} \cdot 0.05} = 4.40 \cdot 10^6 \text{ sec} = 7.34 \cdot 10^4 \text{ min}$$

Since $t = 7.34 \cdot 10^4$ min exceeds the time of unsteady-state flow Jacob's assumption $u < 0.05$ cannot be fulfilled. Therefore, Jacob's method can not be used for this observation well with acceptable error.

5.2.3 Estimation of Hydraulic Conductivity of the Newmarket Till

Using Thiem's method gives a possibility to estimate the recharge flow through Newmarket till and average hydraulic conductivity of the aquitard in the study area.

After 20000 min (13.9 days) of pumping, the cone of depression spreads over R meters in radius (Figure 5.18). Radius can be calculated using Thiem's equation (5.10).

Setting $s_2=0$, $r_2=R$ and solving for R gives:

$$R = r_1 \cdot e^{\frac{2\pi T s_1}{Q}} \quad (5.12)$$

where

R - radius of steady-state cone depression, when drawdown equals zero, m;

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r_l - distance between the pumping well and the observation

well OW00-39 or TW-1-88;

s_l - steady-state drawdown in the observation well OW00-39

or TW-1-88, m

Using equation (5.12) for OW00-39 gives:

$$R = 82 \cdot e^{\frac{2\pi 1.08 \cdot 10^{-3} \cdot 17}{0.037867}} = 1725 m$$

Using equation (5.12) for TW-1-88 gives:

$$R = 1108 \cdot e^{\frac{2\pi 1.08 \cdot 10^{-3} \cdot 2.4}{0.037867}} = 1703 m$$

Since, TW-1-88 is much closer to the boundary of the depression cone, second radius $R=1703$ m is more reliable. Therefore, this value was accepted for further calculations.

Figure 5.18 Calculation of recharge through the Newmarket till and hydraulic conductivity of the till using Thiem's method. For symbols explanation refer to the text.

The surface area of the top of the depression cone during steady-state conditions is

$$A = \pi R^2 = \pi \cdot 1703^2 = 9.111 \cdot 10^6 \text{ m}^2$$

For steady-state conditions, the total well discharge equals recharge of the lower aquifer from area A and lateral flow through an imaginary cylindrical surface which has a radius R (Figure 5.18).

$$Q = V \cdot A + V_h \cdot A_{cyl} \quad (5.13)$$

where

Q - total well discharge ($0.037867 \text{ m}^3/\text{s}$);

A_{cyl} - imaginary cylindrical surface area, m^2 ;

$$A_{cyl} = 2\pi R \cdot b = 2\pi \cdot 1703 \cdot 70 = 7.49 \cdot 10^5 \text{ m}^2$$

where

b - average thickness of the lower aquifer in the study area, m.

$A = 9.111 \cdot 10^6 \text{ m}^2$ - surface area of the top of the depression cone

(Figure 5.18),

V - Darcy velocity through the Newmarket till, m/s,

$$V = K_{NM} \cdot I \quad (5.14)$$

where

K_{NM} - bulk hydraulic conductivity of the Newmarket till in the study area, m/s;

I - average steady-state hydraulic gradient through the Newmarket till in the study area,

$$I = \frac{H_{IA} - H_{LA}}{L_{NM}} \quad (5.15)$$

where

H_{IA} - hydraulic head in the intermediate aquifer, m;

$H_{IA} = 308.8$ m (data from the observation well TW3A);

H_{LA} - average hydraulic head in the lower aquifer within the depression cone (Figure 5.19), m.

Numerical approximation (Figure 5.19) gives:

$$H_{LA} = H_{TW3\&4} - s_{av} = 305.7 - 5.4 = 300.3m \quad (5.16)$$

where

$H_{TW3\&4}$ - average static hydraulic head in the pumping wells

TW3 and TW4 before pumping, m;

s_{av} - average steady-state drawdown within the imaginary cylindrical cone, m;

L_{NM} - average thickness of Newmarket till in the study area, m

$L_{NM} = 17.8$ m (Table 4.1).

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From equation (5.15)

$$I = \frac{308.8 - 300.3}{17.8} = 0.478$$

Figure 5.19 Calculation of the average drawdown and the average hydraulic head within the imaginary cylindrical cone. For symbols explanation refer to the text.

V_h - Darcy velocity through the imaginary cylindrical surface with the radius R

(Figure 5.18), m/s

$$V_h = K_{LA} \cdot I_h \quad (5.17)$$

where

K_{LA} - bulk hydraulic conductivity of the lower aquifer in the study

area, m/s

$$K_{LA} = \frac{T_{LA}}{b_{LA}} \quad (5.18)$$

where

T_{LA} - average transmissivity of the lower aquifer, m²/s (Section 5.4);

b_{LA} - average thickness of an aquifer in the study area, m.

$$K = \frac{T_{LA}}{b_{LA}} = \frac{1.08 \cdot 10^{-3}}{70} = 1.54 \cdot 10^{-5} \text{ m/s}$$

I_h - horizontal hydraulic gradient at the imaginary cylindrical surface with a radius R (Figure 5.18),

$$I_h = \frac{S_{(R-1)} - S_{(R)}}{1m} = S_{(R-1)} \quad (5.19)$$

where

$S_{(R-1)}$ and $S_{(R)}$ are the respective drawdown with distance

$R-1$ and R meters from the pumping wells (Figure 5.18), m

At the boundary of the depression cone $s_{(R)}=0$ and $s_{(R-1)}$ can be calculated using Theim's equation (5.10).

Setting $s_2=0$, $s_1=s$, $r_2=R$, $r_1=R-1$ and solving for s gives:

$$s_{(R-1)} = \frac{Q \cdot \ln(R / (R - 1))}{2\pi \cdot T} \quad (5.20)$$

or

$$s_{(1703)} = \frac{0.037867 \cdot \ln(1703 / (1703 - 1))}{2\pi \cdot 1.08 \cdot 10^{-3}} = 3.28 \cdot 10^{-3} m$$

From equation (5.19)

$$I_h = 3.28 \cdot 10^{-3}$$

From equation (5.17)

$$V_h = 1.54 \cdot 10^{-5} \cdot 3.28 \cdot 10^{-3} = 5.048 \cdot 10^{-8} m / s$$

Solving for K_{NM} and substitution for V , A , V_h and A_{cyl} in equation (5.13) gives

$$K_{NM} = \frac{Q - V_h \cdot A_{cyl}}{A \cdot I} \quad (5.21)$$

or

$$K_{NM} = \frac{0.037867 - 5.048 \cdot 10^{-8} \cdot 7.490 \cdot 10^5}{9.111 \cdot 10^6 \cdot 0.478} = 1.32 \cdot 10^{-11} m / s$$

This bulk aquitard vertical hydraulic conductivity is consistent with matrix hydraulic conductivity estimates from slug and laboratory triaxial permeability testing, which consistently range from 1×10^{-11} to 1×10^{-10} m/s (Richard et al., 2001). However, these estimates are as much as 2.5 orders of magnitude smaller than hydraulic conductivity estimates derived from isotopic data (Gerber and Howard, 1996) and regional groundwater flow modeling (Gerber and Howard, 2000).

Calculated bulk hydraulic conductivities of the lower aquifer and the Newmarket till are shown in Table 5.2 (p.108).

5.3 STAGE TWO: RECOVERY

Recovery-test measurements also allow transmissivity of the aquifer to be calculated, thereby providing an independent check on the results of the pumping test. Residual drawdown data collected during the recovery period is more reliable than drawdown data during the pumping period because constant discharge during pumping is difficult to achieve in the field (Figure 5.20).

When the pump was shut down on September 18, 2000, the water levels inside the pumping and observation wells started to rise. This rise in water level is known as recovery and the amount of recovery still to occur at any given time is the residual drawdown s' (Figure 5.20). Residual drawdown data were collected from both the pumping and observation wells for a period of 18 days.

5.3.1 Methods of Data Analyses

The first method used to calculate transmissivity from the recovery period of the test data is based on the calculation of residual drawdown. According to Theis (1935), the residual drawdown, after pumping stopped, is

$$s' = \frac{Q}{4\pi T} (W(u) - W(u')) \quad (5.22)$$

where

$$u = \frac{r^2 S}{4Tt} \quad \text{and} \quad u' = \frac{r^2 S'}{4Tt'} \quad (5.23)$$

s' - residual drawdown;

r - distance from pumping well to piezometer;

T - transmissivity,

S and S' - storativity values during pumping and recovery, respectively,

t and t' - elapsed times from the start and ending of pumping, respectively.

Using the approximation for the well function, $W(u)$, shown in the Jacob&Cooper method, this equation becomes:

$$s' = \frac{Q}{4\pi T} \left(\ln \frac{4Tt}{r^2 S} - \ln \frac{4Tt'}{r^2 S'} \right) \quad (5.24)$$

When S and S' are constant and equal and T is constant, equation (5.24) can be reduced to:

$$s' = \frac{2.3Q}{4\pi T} \log \left(\frac{t}{t'} \right) \quad (5.25)$$

Figure 5.20 Drawdown and recovery plots for the well OW00-39. Pumping period and recovery period

continued 31 days and 18 days, correspondingly.

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Using the semi-log method, transmissivity can be found based on equation (5.25) (Figure 5.21).

The second method is based on the assumption that when water flow had reached steady-state conditions, another imaginary well started reinjecting water in the lower aquifer with the same rate (e.g., reinjection rate equals $0.037867 \text{ m}^3/\text{s}$). Then, the Theis method can be used by substitution of drawdown (Figure 5.21) with recovery $s-s'$ (Figure 5.22). Transmissivity can be found from the time-recovery plot using equation 5.6.

5.3.2 Data Analysis.

Observation well OW00-39 (Semi-log method)

After reviewing the data shown on Figure 5.21, three slopes were identified on the semi -logarithmic plot.

Slope#1 relates to the time right after pumping ended. These data represent aquifer transmissivity proximal to the pumping wells. It should be noted that there is no limitation $u < 0.05$ (page 87) for the residual drawdown because equation 5.24 better approximates the difference of two well functions than equation 5.7 approximates the infinite Taylor series (see equation 5.4).

Thus, from slope#1 transmissivity equals:

$$T_1 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 3.178} = 2.18 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

Figure 5.21 Semi-log graph showing relationship between residual drawdown and time ratio (ratio between elapsed times from the start and end of pumping, respectively). Semi-log method used for transmissivity calculations.

Figure 5.22 Log-Log graph showing relationship between recovery and time since end of pumping using Theis method for transmissivity calculations.

From Slope#2

$$T_2 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 5.54} = 1.25 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

From Slope#3

$$T_3 = \frac{2.3 \cdot 0.037867}{4\pi \cdot 10.067} = 6.89 \cdot 10^{-4} \text{ m}^2 / \text{s}$$

Observation well OW00-39 (Theis method)

Theis analysis using a log-log plot shows two match points (Figure 5.22).

Between 10 min and 180 min of recovery (Early Time period), data fit well to the Theis curve.

Using match point P1 and equation (5.6) to find transmissivity gives:

$$T_1 = \frac{0.037867 \cdot 1}{4\pi \cdot 1.20} = 2.51 \cdot 10^{-3} \text{ m}^2 / \text{s}$$

The match point for the time interval between 600 min and 24000 min of recovery (Mid Time period) is P2. Using equation (5.8) to find transmissivity gives:

$$T_2 = \frac{0.037867 \cdot 1}{4\pi \cdot 3.20} = 9.42 \cdot 10^{-4} \text{ m}^2 / \text{s}$$

Transmissivity and storativity values calculated using Theis, Jacob&Cooper and Thiem's methods for the pair of observation wells are shown in Table 5.1.

By comparing transmissivity values from the pumping and recovery periods, it is inferred that transmissivity values calculated from the recovery period data correlate well with transmissivity calculated from the pumping period data analyses (Table 5.1).

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Table 5.1 Transmissivity and storativity of the lower aquifer

UNSTEADY-STATE FLOW (PUMPING)				Average value
Theis Method (OW00-39)	EARLY TIME	MID TIME	LATE TIME	
Transmissivity, m ² /s	4.71*10 ⁻³	1.77*10 ⁻³	8.04*10 ⁻⁴	2.43*10 ⁻³
Storativity	2.02*10 ⁻⁴	3.10*10 ⁻³	1.78*10 ⁻³	1.69*10 ⁻³
Jacob&Cooper Method (OW00-39)	SLOPE#1	SLOPE#2	SLOPE#3	
Transmissivity, m ² /s	1.84*10 ⁻³	1.01*10 ⁻³	8.10*10 ⁻⁴	1.22*10 ⁻³
Storativity	3.29*10 ⁻³	1.15*10 ⁻³	2.24*10 ⁻³	2.23*10 ⁻³
Theis Method (TW-1-88)				
Transmissivity, m ² /s	2.51*10 ⁻³			2.51*10 ⁻³
Storativity	1.80*10 ⁻³			1.8*10 ⁻³
STEADY-STATE FLOW				
Thiem's Method				
Transmissivity, m ² /s	1.08*10 ⁻³			1.08*10 ⁻³
UNSTEADY-STATE FLOW (RECOVERY)				
Semi-Log Method (OW00-39)	SLOPE#1	SLOPE#2	SLOPE#3	
Transmissivity, m ² /s	2.18*10 ⁻³	1.25*10 ⁻³	6.89*10 ⁻⁴	1.37*10 ⁻³
Theis Method (OW00-39)	EARLY TIME	MID TIME		
Transmissivity, m ² /s	2.51*10 ⁻³	9.42*10 ⁻⁴		1.73*10 ⁻³
Average transmissivity, m ² /s				1.72*10 ⁻³
Average storativity				1.91*10 ⁻³

Table 5.2 Bulk hydraulic conductivities and thickness of the lower aquifer and the Newmarket till in the study area.

	Bulk hydraulic conductivity, m/s	Average thickness, m
Lower aquifer	1.54*10 ⁻⁵	70
Newmarket till	1.32*10 ⁻¹¹	17.8

5.4 INTERPRETATION OF RESULTS

The nonleaky artesian, fully penetrating, constant-discharge, time-drawdown type curve generally matches to early time-drawdown data for OW00-39 and the middle part of data set for TW-1-88 (Figures 5.14 and 5.17). In addition, the drawdown in observation well OW00-39 is more than expected. It means that it is unlikely there are either hydraulic windows or channels in the Newmarket aquitard connecting the lower and intermediate aquifers at the Gan Eden site. Other evidence of no leakage is the zero response from the observation and domestic wells installed in the intermediate aquifer.

After the *Early Time* period (Figures 5.14), the time rate of drawdown in observation well OW00-39 increased and field data deviate downward from the type-curve traces, indicating the presence of a barrier boundary. After about 500 min of pumping (after *Mid Time* period), the time-rate of drawdown in observation well OW00-39 increased again (Figure 5.14), and field data deviated from the second Theis curve trace, indicating the presence of another barrier.

Deviation of field data from the Theis curve during the *Mid Time* and *Late Time* periods indicates that there is internal hydrogeological heterogeneity within the lower aquifer which is correlated with stratigraphic heterogeneity (Chapter 2). The continuously decreasing values of transmissivity with increasing time suggests that some water is coming from finer-grained sediments and appear as barriers. Thus the presence of barriers (fine-grained units) is a result of the complex relationship among fractions of fluvio-glacial deposits in the lower aquifer.

The log-log drawdown curve from observation well TW-1-88 shows less deviation from the Theis curve than in observation well OW00-39 (in the middle part of Figure 5.15). Observation well TW-1-88 is located farther from the pumping wells than observation well OW00-39. That fact determines the lower amplitude of the pumping effect in TW-1-88 than recorded in OW00-39. In addition, for that scale of pumping effect, internal aquifer heterogeneity does not have a significant impact on the amplitude of deviation from the Theis curve. In the log-log plot for observation well TW-1-88 (Figure 5.15), only one Theis curve can be applied to approximate field data. Therefore, transmissivity calculated from the drawdown in the observation well TW-1-88 ($2.51 \times 10^{-3} \text{ m}^2/\text{s}$) represents an approximate transmissivity on a regional scale.

The average value of transmissivity is $1.72 \times 10^{-3} \text{ m}^2/\text{s}$ (Table 5.1). The transmissivity value obtained when the Theis method was used for the recovery period is close to the average transmissivity (Table 5.1).

The Jacob & Cooper method (pumping period) gives a range of transmissivities from 8.1×10^{-4} to $1.84 \times 10^{-3} \text{ m}^2/\text{s}$. The nature of deviation is the same as that found when the Theis method was used.

Thiem's method gives a conservative (close to minimal) transmissivity of

$$T = 1.08 \times 10^{-3} \text{ m}^2/\text{s}.$$

The storativity S found by means of the Theis and Jacob & Cooper methods varies from 2.02×10^{-4} to 3.29×10^{-3} .

The average storativity corresponding to average transmissivity ($1.72 \cdot 10^{-3} \text{ m}^2/\text{s}$) is $S_{av} = 1.91 \cdot 10^{-3}$. It means that extracting $1.91 \cdot 10^3 \text{ m}^3$ from the every 1 km^2 of the lower aquifer will decreases the hydraulic head by 1m.

These average transmissivity and storativity values ($1.72 \cdot 10^{-3} \text{ m}^2/\text{s}$, $1.91 \cdot 10^{-3}$, respectively) can be recommended for practical use in the Gan Eden area.

Using the average transmissivity value ($1.72 \cdot 10^{-3} \text{ m}^2/\text{s}$), the bulk hydraulic conductivity of the lower aquifer:

$$K = \frac{T_{av}}{b_{av}} = \frac{1.72 \cdot 10^{-3}}{70} = 2.46 \cdot 10^{-5} \text{ m/s} \quad (5.14)$$

where K -average hydraulic conductivity, m/s;

T_{av} - average transmissivity of the lower aquifer, m^2/s ;

b_{av} - average thickness of an aquifer in the study area, m.

The calculated value of hydraulic conductivity corresponds to fine sand and agrees with the geological logs (Appendix B).

Bulk hydraulic conductivity of the Newmarket till ($1.32 \cdot 10^{-11} \text{ m/s}$, see Section 5.2.3), calculated by means of the modified Thiem's method corresponds to a range of hydraulic conductivities typical of glacial till deposits. This very low permeability aquitard restricts the movement of groundwater to the underlying lower aquifer. There is no hydraulic connection through the Newmarket aquitard in the study area as far as could be determined from analyses of the pumping test data.

6. CONCLUSIONS

The 30-day pumping test, with the 18-day recovery monitoring period revealed that the lower aquifer is a productive aquifer and groundwater resources in the Uxbridge area are far from exhaustion. The physical properties of the lower aquifer indicate that there is enough groundwater for the Gan Eden community. Since there are no hydraulic connections between the lower and intermediate aquifers, the community water supply pumping will not affect surrounding domestic private wells installed into the intermediate and upper aquifers.

Average transmissivity and storativity values of the lower aquifer are 1.72×10^{-3} m²/s and 1.91×10^{-3} , respectively. Bulk hydraulic conductivity of the lower aquifer equals 1.54×10^{-5} m/s, based on a conservative transmissivity value (see Chapter 5) and equals 2.46×10^{-5} m/s, based on the average transmissivity value. The steady state stage of the pumping test allowed an estimation of the size of the depression cone using Thiem's method. The radius of the steady-state depression cone equals approximately 1703 m.

The pumping test revealed internal heterogeneity of the lower aquifer causing hydraulic barrier effects during the pumping test (see Chapter 5).

In spite of a high probability of encountering an aquitard window on a regional scale (see Chapter 3), within the Uxbridge area there are neither hydraulic windows nor channels in the Newmarket till aquitard connecting the lower and intermediate aquifers (see Chapter 5). Bulk hydraulic conductivity of the Newmarket till within the radius of the steady-state depression cone is 1.32×10^{-11} m/s, and is consistent with previous studies (see Chapter 3).

Analyses of MOEE records and literature data (see Chapter 4) proved that the complex hydrogeological system in the Uxbridge area may be divided into three aquifers: 1) the upper unconfined aquifer, 2) the intermediate confined aquifer and 3) the lower confined aquifer. Integration of terrain analyses into hydrogeological studies increases our understanding of the origin of the hydrogeological units (see Chapter 1). The upper and intermediate aquifers exist within glaciofluvial and glaciolacustrine deposits of the ORM, built on a high-relief erosional surface of the Newmarket till. The areal extent and interrelation of the ORM and adjacent terrain are revealed in digital elevation models and aerial photographs (see Chapters 1,2).

In the study area, hydraulic heads decrease with increasing depth of aquifer. This indicates that a component of groundwater flow from the upper and intermediate aquifers moves downward to recharge the intermediate and the lower aquifers, respectively, but at a very slow rate. Along the northern edge of the ORM, where the 30-day aquifer test was conducted, the upper aquifer is absent and this permits direct recharge to the intermediate aquifer.

In the study area, the lower aquifer is a nonleaky confined aquifer. That fact indicates that groundwater in the lower aquifer is naturally protected from groundwater quality degradation in case of contamination of the upper and intermediate aquifer.

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APPENDIX A

MINISTRY OF THE ENVIRONMENT WATER WELL RECORDS

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Municipality Concession	Lot	Well No	UTM, Easting	UTM, Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
4	18	5565	646350	4878800	342.9	34.14	1973.07	4743	15.24	28.96	26.82	32.92	3	RAFFAELIA	PRDG 0008 YLLW SAND CLAY 0060 BRWN SAND 0073 YLLWGRVL 0075 BRWN SAND SILT 0112
4	18	5709	646170	4878850	350.5	32.92	1973.06	1350	15.24	31.09	26.52	30.48	5	KOOGJE J	BRWN SAND GRVL 0042 GREY CLAY GRVL 0065 GREY GRVLCCLAY 0102 BRWN FSND 0108
4	18	6082	648000	4879400	335.3	36.88	1981.07	4738	15.24	36.88	24.38	33.53	3	COOK R	BRWN SAND CLAY 0012 BRWN GRVL SAND LOOS 0042 BRWNSAND STNS LOOS 0098 BRWN FSND VERY 0121
4	18	9255	646150	4878773	352	35.36	1988.06	4743	15.24	33.53	26.52	32	5	JEHOVAH WITNESS CH.	BRWN SAND 0018 BRWN GRVL SAND CMTD 0051 BRWN GRVLSTNS DRY 0070 BRWN SAND PCKD 0110 BRWN SAND CLN 0116
4	19	1722	646825	4879233	342.9	39.01	1993.05	1413	15.24	39.01	22.86	34.14	10	BROWN, RANDY	BLCK LOAM PCKD 0001 BRWN SAND PCKD DRY 0026 BRWNCCLAY BLDR HARD 0042 BRWN SAND CLAY PCKD 0112 BRWNSAND FSND LOOS 0128
4	19	2903	646125	4879070	345.9	28.04	1955.07	2531	5.08	27.43	18.29	0	0	WAGG W	PRDG 0038 GRVL 0058 CLAY 0088 GRVL 0092
4	19	2904	646545	4879130	344.4	33.53	1959.05	2204	5.08	28.04	22.56	27.43	0	CAIRNS L	GRVL 0030 CLAY 0050 GRVL CLAY 0100 FSND CSND 0110
4	19	2905	646082	4879164	345	35.05	1962.02	1413	15.24	35.05	8.23	33.53	5	YAKELEY LLOYD G	PRDG 0032 CLAY GRVL 0042 GRVL BLDR 0080 CLAY GRVL0090 FSND 0115
4	19	4947	646920	4879500	342.9	47.55	1971.05	5459	12.7	46.33	24.38	36.58	8	STEWART C	PRDG 0028 GRVL MSND 0035 MSND GRVL 0060 BRWN MSND 0115 BRWN FSND 0137 BLUE CLAY MSND 0152 CSND 0156
4	19	5297	646150	4878900	350.5	35.97	1972.11	4743	15.24	35.97	26.82	30.48	9	AUDET A	BLCK LOAM 0002 BRWN SAND CLAY 0029 BRWN GRVL 0096YLLW CLAY 0110 BRWN FSND 0118
4	19	6924	646950	4879500	342.9	33.53	1983.09	5459	15.24	32.31	21.34	30.48	12	CHUHAY W	BRWN GRVL 0007 BRWN SAND CLAY 0029 BRWN CLAY SOFT 0054 BRWN CLAY SAND 0065 BRWN GRVL LOOS 0087 BRWNCCLAY SAND 0095 BRWN CLAY SOFT 0106 BRWN CSND 0110
4	19	6925	647050	4879550	342.9	41.76	1983.09	5459	15.24	39.32	28.04	35.05	15	STOUFFVILLE IRON & M	BRWN LOAM 0004 BRWN GRVL LOOS 0032 BRWN SAND CLAY 0060 BRWN CLAY SOFT 0085 BRWN GRVL SAND 0094 BRWNGRVL SOFT 0115 BRWN GRVL SAND 0129 BRWN SAND 0137
4	19	7001	647100	4879550	342.9	26.82	1984.07	1413	12.7	26.82	21.34	22.86	0	FERGUSON D	BRWN SAND GRVL LOOS 0050 BRWN GRVL 0060 BRWN SANDCLAY PCKD 0075 BRWN SAND CLN LOOS 0088
4	19	7085	647100	4879700	342.9	25.3	1984.09	1413	15.24	25.3	19.2	19.81	0	ORTON HOMES	BRWN SAND GRVL LOOS 0015 BRWN SAND CLAY SILT 0045GREY GRVL SAND LOOS 0055 BRWN SAND CLAY SILT 0073BRWN SAND SHRP 0083

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Municipality Concession	Lot	Well No	UTM, Easting	UTM, Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
4	19	7212	646150	4878900	342.9	49.07	1985-01	1413	12.7	49.07	25.3	38.1	5	SYMES J	BRWN SAND PCKD 0012 GREY CLAY STN'S HARD 0050 GREY CGVL LOOS 0065 GREY CLAY LOOS 0087 BRWN CLAY SNDY SOFT 0100 GREY CLAY DNSE 0153 BLCK CGVL 0161
4	19	111	646818	4879182	341.1	26.52	1989-06	2218	5.08	21.34	21.34	0	0	WAKO, DANIEL	BLCK LOAM 0002 BRWN GRVL STNS 0005 BRWN FSND 0030 GREY STNS 0037 BLUE CLAY 0044 GRVL STNS 0070 BRWN FSND 0087
4	19	5474	646830	4879320	342.9	51.82	1973-06	4743	15.24	50.29	22.86	28.96	12	HOLMES M	YLLW CLAY SAND 0016 BRWN GRVL CLAY 0038 BRWN SAND 0080 BRWN SAND SILT 0120 BLUE CLAY SILT 0165 GREYSAND GRVL 0170
4	19	8563	999999	9999999	0	43.59	1987-09	4738	15.24	40.84	21.95	32	15	PARRATT, A.J.	BRWN SAND LOOS 0014 GREY CLAY SAND SOFT 0018 BRWN SAND LOOS 0033 GREY GRVL SAND LOOS 0085 BRWN SAND LOOS 0095 BRWN FSND VERY 0118 GREY CLAY SAND SOFT 0134 GREY GRVL SAND LOOS 0143
4	20	843	647167	4879688	338.9	115.8	1990-09	4743	15.24	114.6	3.7	6.706	0	MARK, M. V INC.	BRWN CLAY STNS 0018 BRWN SAND GRVL LOOS 0090 BLUE CLAY SAND LYRD 0138 GREY CLAY BLDR HARD 0161 GREYSAND CLAY MGRD 0162 GREY CLAY STNS HARD 0320 RED CLAY SOFT 0345 BLUE CLAY STKY 0376 BLCK GRVL SAND CLN 0380
4	20	2906	647129	4879769	342.9	12.19	1960-05	5420	76.2	0	0	0	0	GARRET D	GRVL 0018 YLLW CLAY 0023 GRVL 0040
4	20	2907	645944	4879641	350.5	32.61	1963-10	1413	12.7	32.61	26.52	27.43	0	ANDERSON W	CLAY STNS 0018 GRVL 0038 CSND 0080 GRVL 0087 YLLW CLAY GRVL 0095 CSND GRVL 0107
4	20	2908	647082	4879803	342.9	36.58	1966-08	3519	10.16	35.36	27.43	33.53	5	PUGH	LOAM 0002 BRWN MSND 0116 BRWN CSND 0120
4	20	2985	999999	9999999	0	34.14	1996-09	4743	15.24	24.38	24.38	28.96	0	MORTON, DALE	BLCK LOAM 0001 BRWN LOAM SNDY LOOS 0022 BRWN GRVL CLAY LOOS 0048 BRWN CLAY SAND LYRD 0080 BRWN SAND WBRG PCKD 0105 BRWN SAND CLN FSND 0112
4	20	5096	646050	4879300	345.9	30.48	1978-08	2218	5.08	26.52	25.91	0	0	LEMAN PAUL D	PRDG 0016 BRWN CLAY 0040 BRWN GRVL CLAY 0087 BRWNSAND 0100
4	20	5491	646000	4879420	342.9	33.22	1973-05	5459	15.24	32	18.9	30.48	8	MARCELLI CONST	LOAM 0001 FSND 0009 GRVL SAND 0045 FSND 0056 GRVLSAND 0080 FSND 0092 GRVL 0096 FSND 0109
4	20	5908	647776	4680120	329.2	17.68	1974-07	2218	5.08	12.19	12.19	0	0	VAN VEEN G	BRWN GRVL STNS 0016 BRWN FSND CLAY 0040 BRWN SAND 0058
4	21	1850	999999	9999999	0	52.12	1993-05	5459	15.24	50.9	12.8	45.72	15	GRIGSLY, TERRY	BRWN SAND 0019 BRWN SAND CLAY SILT 0035 BRWN SAND FSND 0042 BRWN FSND SILT 0070 BRWN CLAY SILT 0079 GREY CLAY SOFT 0088 GREY CLAY GRVL HARD 0140 GREY CLAY HARD 0152 GREY CLAY SAND 0167 GREY SAND

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Municipality Concession	Lot	Well No	UTM. Easting	UTM. Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
															MSND 0171
4	21	2909	647618	4880661	335.3	77.11	1953.06	4619	10.16	0	0	0	0	WATT STEUART A	BRWN CLAY 0020 BRWN MSND 0050 BLUE MSND 0125 HPAN0167 BLUE MSND CLAY 0213 HPAN STNS 0253
4	21	3775	647600	4880630	335.3	27.43	1968.11	1413	12.7	27.43	15.24	25.91	0	COOK REAL ESTATE	SMND 0050 FSND CLAY 0082 RED FSND 0090
4	21	4880	647260	4880330	324.6	21.34	1971.10	4743	15.24	18.59	7.62	16.76	0	BARTON DAN	YLLW CLAY MSND 0018 BRWN CLAY 0045 BRWN SILT CLAY0061 BRWN FSND 0070
4	21	644	646498	4879966	339.9	38.4	1990.06	5459	15.24	35.97	35.97	21.34	80	GARRO, G	BRWN SAND CLAY 0017 BLUE CLAY SOFT 0024 BRWN SAND0041 BRWN GRVL 006B BRWN SAND CSND 0077 BRWN SANDMSND 0094 BRWN SAND FSND 0108 BRWN CLAY SAND 0114BRWN CLAY 0118 BRWN SAND CSND 0126
4	21	1262	647329	4880174	328	43.28	1991.108	4743	15.24	41.45	41.45	8.23	40	BENNS, ERIC	BRWN LOAM SOFT 0002 RRWN SAND BLDR HARD 0050 BRWNSAND FSND 0057 GREY CLAY SAND HARD 0136 BLCK SANDCSND 0142
4	21	4519	646450	4880040	335.3	28.65	1976.09	2407	15.24	27.43	27.43	7.925	90	CRAIG	BRWN SAND 0038 BRWN CLAY SANDY 0074 BRWN SAND 0094
4	21	4542	647180	4880220	326.1	16.76	1970.09	1413	12.7	16.76	16.76	9.144	33	GIALLOMAR RO J	BRWN MSVD 0030 RED MSND 0055
4	21	5858	646878	4880115	330.7	23.77	1974.05	1413	12.7	23.77	23.77	9.144	45	CLIPPERFIE LD ROBERT	BRWN SAND STNS 0030 RED SAND 0078
4	21	6210	645650	4679950	342.9	32.61	1981.09	5459	15.24	27.74	27.74	21.34	95	MORANA P	BLCK LOAM 0001 BRWN SAND CLAY SOFT 0020 BRWN FSND0053 BRWN CSND 0080 BRWN CLAY SOFT 0091 BRWN SAND 0107
4	21	6218	646850	4880400	320	23.16	1981.06	5459	15.24	21.34	21.34	13.72	65	ARENDS R	BRWN SAND 0016 BRWN SAND CLAY 0023 BRWN SAND 0076
4	21	6422	646940	4880100	335.3	20.12	1975.10	2407	12.7	19.2	19.2	5.182	64	BAKER S	BLCK LOAM 0001 BRWN SAND WBRG 0066
4	21	6539	647500	4880310	327.7	25.91	1976.06	1413	15.24	25.91	25.91	10.97	55	KIELY ROY	BRWN SAND DRY 0005 BRWN GRVL DRY 0020 BRWN SANDCLAY PKD 0065 BRWN SAND LOOS 0085
4	21	7479	647300	4880250	320	19.81	1985.07	4743	15.24	10.67	10.67	7.62	48	BISHOP T	BRWN GRVL LOOS 0035 BRWN SAND CLN 0061 GREY SANDCLAY DRTY 0065
4	21	9189	645806	4879956	342.9	32	1988.07	5459	15.24	24.08	24.08	21.34	85	MASSA, M	BLCK LOAM 0002 BRWN SAND CLAY 0003 BRWN GRVL LOOS 0034 BRWN SAND SILT FSND 0079 BRWN SAND MSND 0105
4	22	2530	9999999	9999999	0	27.74	1995.07	4743	15.24	24.99	24.99	16.76	75	WRIGHT, KEN	BLCK LOAM 0002 BRWN CLAY SAND LYRD 0017 BRWN SANDLOOS 0055 BRWN SAND WBRG PKD 0082 BRWN FSND CLN 0091
4	22	5320	647300	4880950	327.7	25.3	1972.09	5459	15.24	25.3	25.3	11.89	55	GUTHRIE D	YLLW SAND 0005 GRVL 0022 CSND 0045 BLUE CLAY SAND0076 SAND 0083

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Municipality Concession	Lot	Well No	UTM, Easting	UTM, Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
4	22	6456	647300	4880750	327.7	19.2	1982.05	5459	15.24	17.98	17.98	6.096	50	RAMSEY C	BRWN CLAY SAND 0014 BRWN GRVL 0021 BRWN SAND CLAY 0059 BRWN SAND 0063
4	23	4691	646860	4881150	313.9	4.572	1970.09	5459	86.36	3.353	3.353	3.048	0	LAGARDE H	LOAM 0001 BRWN FSND 0010 BRWN CSND 0012 BRWN CLAY 0015
4	23	5328	647400	4881100	335.3	28.65	1972.12	1350	15.24	28.65	28.65	15.85	80	COLLIER R	GREY CLAY GRVL 0027 BRWN SAND 0073 GREY CLAY 0077BRWN SAND 0094
4	26	2913	645261	4881840	326.1	38.4	1963.05	1413	15.24	38.4	27.74	32.31	10	MCDERMOT Ti	RED MSND CLAY 0105 FSND CSND GRVL 0126
4	26	2914	646259	4882132	326.1	37.8	1966.08	1413	12.7	37.8	20.12	35.66	11	DALY J A	MSND 0066 FSND CLAY 0090 GRVL 0114 GRVL CLAY 0124
4	26	5218	646950	4882300	317	13.11	1978.12	4743	15.24	8.534	2.134	7.01	23	CROFT R	BLCK LOAM 0002 BRWN SAND CLAY LOOS 0028 BRWN SANDCLN 0035 UNKN 0043
4	26	6328	645501	4881811	335.3	42.67	1975.06	5459	15.24	39.62	27.43	38.1	12	RABB A	BRWN CSND 0045 BRWN MSND 0100 BRWN CLAY 0130 BRWNFSND 0140
4	26	10147	646760	4882273	331.9	37.19	1989.09	5459	15.24	35.36	18.29	33.53	11	RAAB, DAVE	BRWN SAND CLAY 0040 BRWN SAND CLAY 0103 GREY CLAYSTNY HARD 0116 GREY SAND GRVL CLAY 0122
4	26	11350	647109	4882280	317	32.31	1991.11	4743	15.24	31.7	15.24	21.34	70	PRATT, H	BRWN LOAM 0002 BRWN SAND 0034 GREY CLAY SAND LYRD 0059 GREY GRVL CLAY LOOS 0104 GREY GRVL SAND CLN 0106
4	27	2915	646774	4882763	327.7	42.67	1955.05	1413	15.24	42.67	21.34	24.38	80	BOYINGTON DON	GRVL 0020 CLAY MSND 0035 CLAY SILT 0065 BLUE CLAY0130 MSND GRVL 0140
4	27	5806	645150	4882150	312.4	33.53	1980.07	5459	20.32	24.99	6.096	24.99	82	WHITE ROSE NURSERIES	BRWN SAND 0037 BRWN CLAY SAND 0046 BLUE CLAY STNS 0049 GREY STNS SAND CLN 0050 BLUE CLAY STNS 0055 GREY SAND SILT 0070 GREY SAND STNS CLN 0078 BLUECLAY STNS 0079 GREY SAND STNS CLN 0094 BLUE CLAYSTNS 0106 BLUE CLAY SAND 0110
4	27	8246	645098	4882257	306.9	23.16	1986.06	5459	20.32	17.98	1.829	4.572	15	WHITE ROSE NURSERIES	BRWN SAND 0022 BRWN- CLAY 0023 BRWN SAND 0048 GREYSAND MSND 0059 GREY GRVL CGVL 0070 GREY SAND CSND 0072 GREY GRVL 0076
4	28	2916	646744	4883154	324.6	53.34	1958.04	1413	15.24	53.34	24.38	27.43	90	SPENCER A	MSND GRVL 0036 BLUE CLAY STNS 0070 HPAN 0080 BLUECLAY 0136 FSND SILT 0146 BLUE CLAY SILT 0160 GREYCLAY 0172 CSND GRVL 0175
4	28	6220	645000	4882600	312.4	35.36	1981.05	5459	15.24	33.53	7.62	33.53	11	DAVEY W	BLCK LOAM 0001 BRWN SAND 0028 BRWN CLAY 0030 BLUESAND SOFT 0050 BLUE CLAY SOFT 0071 BLUE SAND 0072BLUE CLAY STNS 0110 UNKH 0116
4	29	2917	646452	4883454	321.6	6.401	1963.04	5420	86.36	6.401	0	0	0	NIGHSWAN DER H G	LOAM MSND 0002 YLLW CLAY MSND 0008 BLUE CLAY 0021
4	29	5861	644924	4882985	309.4	23.77	1974.05	1413	12.7	23.77	16.46	19.51	64	FARBUHARS ON DAN	BRWN SAND 0050 BRWN CLAY 0054 BRWN SAND 0074 BRWNSAND STNS 0078

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4	29	6397	644870	4883100	300.2	18.59	1975.12	1413	15.24	18.59	10.06	10.67	35	BAIRD JOHN	BRWN SAND DRY 0033 RED SAND GRVL LOOS 0061
4	29	8789	999999	9999999	0	13.11	1987.04	5459	15.24	12.5	6.096	10.67	35	ROTUMDA, T.	BRWN SAND 0010 BRWN CLAY SNDY 0025 GREY CLAY STNS 0041 CSND CGVL 0043 CLAY 0043
4	30	8227	645222	4883493	305.1	31.09	1986.05	5459	15.24	30.18	7.62	24.38	80	HOCEVAR, FRANK	BRWN SAND 0053 GREY CLAY SNDY 0070 GREY CLAY SNDY 0096 SAND CSND CLN 0102
5	16	6667	649890	4879050	335.3	39.32	1976.10	1413	15.24	39.32	21.34	27.43	8	ALBERS H	BRWN SAND DRY 0065 BRWN CLAY SNDY PCKD 0096 GREYSAND SILT SOFT 0120 RED FSND CLN 0129
5	16	9785	999999	9999999	0	102.1	1989.03	5459	0	0	0	0	0	DASH, SAND & GRAVEL	BRWN SAND STNS 0037 BRWN CLAY SAND 0146 GREY CLAYSAND STNS 0199 WHIT CLAY STNS 0204 GREY CLAY STNS 0221 WHIT CLAY STNS 0239 GREY CLAY STNS 0270 GREYSILT SAND 0281 GREY CLAY STNS SAND 0287 GREY CLAYSILT 0312 GREY CLAY STNS 0335
5	16	9786	999999	9999999	0	60.96	1989.03	5459	0	0	0	0	0	DASH, SAND & GRAVEL	BRWN SAND STNS 0087 BRWN SAND CLAY 0106 BRWN SANDSILT 0118 BRWN CLAY SLTY 0123 BRWN SAND SILT 0129 BRWN CLAY SAND 0157 GREY CLAY STNS SAND 0200
5	18	1415	649978	4880110	331	25.91	1991.07	4743	15.24	24.38	9.144	16.76	6	SMITH, TOM	BRWN LOAM 0003 BRWN SAND LOOS 0037 BRWN CLAY SANDPCKD 0080 BLCK SAND CLN FSND 0085
5	18	1522	650027	4880162	328.9	34.75	1992.07	4738	15.24	33.22	16.76	3.353	18	BRUCE, GEORGE	BRWN SAND LOOS 0035 BLUE SAND CLAY 0045 BRWN SANDCLAY FGRD 0072 GREY SAND CLAY FGRD 0109 GREY SANDLOOS 0114
5	18	2948	648140	4879445	342.9	29.87	1959.06	3414	10.16	28.04	18.29	21.34	10	ELSON GEORGE	PRDG 0022 BRWN CLAY 0092 BRWN CSND 0098
5	18	2949	648092	4879508	339.9	27.43	1960.06	3414	10.16	27.43	16.15	16.46	10	PEW ROSS	GRVL 0018 GRVL MSND 0053 CSND 0090
5	18	2950	649662	4880088	333.8	33.53	1965.10	1413	12.7	33.53	20.73	22.86	8	SMITH GEORGE	MSND 0068 YLLW CLAY 0082 MSND SILT 0097 MSND 0110
5	18	2951	650021	4880156	333.8	12.8	1967.06	5420	86.36	8.534	8.534	0	0	SMITH G	LOAM 0001 CLAY MSND 0012 FSND 0025 CSND 0042
5	19	2952	648015	4879837	342	28.04	1967.12	2407	10.16	23.16	20.73	26.21	6	HOCKLEY K	PRDG 0005 BRWN CLAY 0026 GRVL 0086 BRWN MSND 0092
5	20	1600	648398	4880471	338	33.22	1992.08	5459	15.24	31.7	14.94	3.048	10	BARR,	BLCK LOAM 0002 BRWN CLAY 0014 BRWN CLAY GRVL 0020 BRWN SAND 0036 BRWN CLAY SAND 0067 BRWN SAND FSND 0077 BRWN SILT CLAY 0089 GREY CLAY SILT 0104 GREYSAND FSND 0109
5	20	2223	999999	9999999	0	29.57	1994.11	1413	15.24	29.57	12.19	22.25	50	WOOD, BARRY	BRWN SAND GRVL CGVL 0035 BRWN SAND MSND 0097
5	20	2953	647841	4880327	324.6	22.25	1962.11	2204	5.08	18.29	7.62	18.9	4	PARRATT D H	MSND 0010 GRVL 0012 RED CLAY 0030 MSND 0040 REDCLAY 0060 QSND 0066 FSND 0073
5	20	2955	648079	4880421	332.8	19.81	1964.05	5419	5.08	15.24	15.24	1.219	3	HEGGIE JD	BRWN CLAY 0010 RRWN MSND 0050 FSND 0065

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5	20	2956	648323	4880460	335.3	21.34	1965-06	3414	10.16	6.096	17.68	20.42	10	BROOKHUIS H.	BRWN MSND 0022 SILT 0041 MSND 0070
5	20	4167	648030	4880370	327.7	33.53	1969-09	3903	10.16	32	15.24	24.38	5	WATSON	CLAY MSND STNS 0002 BLUE CLAY MSND 0078 BRWN FSND 0110
5	21	3908	649700	4881075	353.6	21.03	1968-06	3414	15.24	0	61	67	3	BUNGER J	BRWN FSND 0006 CSND GRVL 0027 FSND 0063 MSND 0069
5	21	4642	648900	4880610	342.9	48.77	1977-06	4743	15.24	47.24	110	125	15	CLARKE D & B	YLLW SAND 0085 YLLW CLAY SAND 0110 BRWN SAND 0155BRWN SAND CLN 0160
5	21	5104	647750	4880750	332.2	20.12	1978-06	4743	0	18.9	28	46	8	ORTOM HOMES LTD	YLLW SAND CLAY 0017 BRWN CLAY SNDY 0035 BRWN SANDLOOS SLTY 0062 BRWN SAND CLN 0066
5	21	5710	648200	4880670	335.3	24.08	1973-06	1350	15.24	21.95	57	65	10	COLLICIA G	BRWN SAND CLAY 0060 BRWN GRVL 0072 BRWN SAND 0079
5	21	6436	649600	4881150	342.9	32	1982-10	1413	15.24	32	30	80	5	RAYMOND P	BRWN SAND DRY 0005 BRWN CLAY DNSE 0045 BRWN GRVLDRY 0055 BRWN CLAY DNSE 0080 BRWN FSND 0105
5	21	6663	648550	4880700	335.3	14.02	1976-09	1350	15.24	12.19	20	35	6	SAN ROQUE INVT	BRWN SAND 0027 YLLW CLAY 0028 GREY SILT CLAY 0040BRWN SAND 0046
5	22	2129	999999	9999999	0	46.94	1994-10	4738	15.24	44.81	34	150	30	BENSON, GLORIA	BRWN SAND 0041 GREY CLAY SAND 0054 GREY FSND VERY 0094 GREY CLAY SAND 0108 GREY CLAY SAND VERY 0117GREY CLAY GRVL HARD 0147 GREY GRVL SAND LOOS 0154
5	22	2603	999999	9999999	0	24.38	1995-10	4743	15.24	21.34	38	60	12	HOPTON, RAY	BLCK LOAM 0001 BRWN CLAY SAND LYRD 0038 BRWN SANDCLAY 0070 BRWN FSND 0083 BRWN MSND 0080 FSND 0050
5	22	2957	648386	4881371	332.2	15.24	1959-08	4102	76.2	6.096	20	2	2	MCCLINTOC K	YLLW FSND 0005 BRWN CLAY 0020 FSND 0030 CSND 0040GRVL 0045 MSND 0048
5	22	2958	647864	4881071	327.7	14.63	1962-08	5412	76.2	12.19	39	0	0	TUCK C H	BRWN CLAY 0006 MSND 0035 FSND 0045
5	22	2959	648063	4881274	327.7	13.72	1967-06	2610	76.2	10.67	36	2	2	MCLWORD	MSND 0039 FSND 0047
5	22	2960	648283	4881297	327.7	14.33	1967-06	2610	76.2	11.89	39	2	2	LADOUX M	FSND 0008 CSND 0013 FSND 0024 CSND 0030 CLAY 0031
5	22	2961	648390	4881382	327.7	9.449	1967-09	2610	76.2	7.315	25	0	0	NASH W	PRDG 0046 BRWN MSND 0078 MSND 0083
5	22	2962	648277	4881307	327.7	25.3	1967-11	2104	15.24	24.08	41	74	5	LEDoux M.	LOAM 0002 MSND 0052
5	22	3889	647650	4881040	327.7	15.85	1968-04	3102	76.2	12.19	40	0	0	BURROWS H	PRDG 0039 BRWN CLAY MSND 0052 GREY CLAY MSND 0070BRWN CSND GRVL CLAY 0074 BRWN GRVL CSND 0078
5	22	3983	648070	4891190	327.7	23.77	1968-05	2104	15.24	22.56	35	68	7	MILWARD FRED	BRWN LOAM SOFT 0003 BRWN SAND SOFT 0013 BRWN CLAYHARD 0027 BRWN SAND LOOS 0049 BLCK SAND WBRG 0076GREY CLAY HARD 0079
5	22	10055	647809	4881077	330.1	24.08	1989-06	4743	15.24	22.25	30	35	10	MILLAGE, BRIAN	YLLW SAND 0025 BRWN CLAY 0035 GREY SAND 0070 BRWNCLAY 0075 BRWN SAND CLAY 0080 GREY CLAY STNS 0122GREY GRVL CLAY 0124 BLUE CLAY STNS 0155

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5	22	9454	9999999	9999999	0	79.25	1988 11	5459	15.24	73.15	24	25	6	MARCELLI CONST.	BRWN SAND SILT 0058 BRWN SANDCLAY 0129 GREY CLAYSTNS SAND 0177 WHIT CLAY STNS SAND 0252 GREY CLAYSTNS SILT 0260
5	23	2656	9999999	9999999	0	49.38	1995 10	4645	162.6	47.24	49	150	30	JAY.M HOLDINGS LTD.	BRWN SAND LOOS 0018 BRWN SILT SAND SOFT 0030 BRWNCCLAY SILT 0043 BRWN SILT VERY FSND 0080 BRWN SILTVERY FSND 0085 BRWN SILT VERY FSND 0090 BRWN SILTSAND STNS 0100 BRWN SILT MSND 0120 BRWN SILT MSNDFSND 0150 BRWN SILT FSND LOOS 0160 GREY CLAY DNSE 0162
5	23	2657	9999999	9999999	0	51.82	1995 10	4645	15.24	47.24	60	150	7	JAY.M HOLDINGS LTD.	BRWN CSND CLN LOOS 0045 BRWN SILT CSND 0055 BRWNSILT VERY FSND 0090 BRWN SILT FSND HARD 0105 BRWNSILT MSND 0140 BRWN SAND SILT LOOS 0155 BRWN SILTFSDN LOOS 0165 BRWN SILT CSND 0170
5	23	2922	9999999	9999999	0	4.572	1996 07	6874	7.62	11.89	39	42	25	HURLEY CLARANCE	BRWN SAND 0043 UNKN CMTD 0015
5	23	4937	647530	4881220	326.1	13.72	1994 10	5459	76.2	12.19	35	0	0	MANCINI CONST	LOAM 0001 BRWN MSND CLAY 0040 BRWN CLAY FSND 0045
5	23	4938	647550	4881200	326.1	10.67	1995 10	5459	76.2	9.144	20	0	0	MANCINI CONST	LOAM 0001 BRWN FSND CLAY 0030 BRWN MSND 0035
5	23	4964	648600	4881550	310.9	31.39	1977 08	2651	15.24	28.35	46	0	5	TAYLOR LAN	BRWN LOAM LOOS 0001 BRWN SAND CLAY LOOS 0036 GREYCLAY SAND SOFT 0048 GREY CLAY GRVL HARD 0093 BRWNSAND GRVL MGRD 0103 GREY CLAY SAND 0103
5	23	5837	647497	4881395	320	16.46	1974 05	1413	12.7	16.46	1	45	6	ROHWER NICK CONST	BRWN SAND 0003 BRWN SAND CLAY 0040 RED SAND 0054
5	23	5853	647533	4881254	323.1	19.81	1974 05	1413	12.7	19.81	8	30	10	JACOBSEN J CONST	BRWN SAND 0008 BRWN CLAY 0050 GREY FSND 0065
5	23	6541	648200	4881300	327.7	15.85	1983 01	4743	15.24	11.89	11	30	10	ORTOM HOMES LTD	BRWN SAND LOOS 0039 BRWN SAND CLN 0042 BRWN CLAYSOFT 0052
5	23	7415	648650	4881500	304.8	70.1	1977 08	2651	0	0	0	0	0	TAYLOR LAN	BRWN LOAM 0001 BRWN SAND CLAY 0042 GREY CLAY SANDBLDR 0050 GREY CLAY GRVL 0085 GREY CLAY SAND GRVL 0230
5	23	4548	647650	4881200	323.1	12.19	1970 09	2215	5.08	6.706	22	0	5	HENDY S	BRWN CLAY 0005 BRWN MSND CLAY 0018 BRWN MSND 0040
5	24	5552	649230	4882260	304.8	59.13	1973 08	1413	12.7	52.43	48	58	10	MICHENER CE	BRWN SAND 0047 BRWN CLAY 0051 BRWN FSND SILT 0104BLUE FSND SILT 0128 BLUE CLAY 0151 GREY CLAY STNSBLDR 0160 BLUE CLAY 0172 RED SAND GRVL 0177 GREYCLAY STNS 0194
5	24	5869	649030	4882181	327.7	34.14	1974 04	4743	15.24	29.87	45	60	15	TAUNENBA UM J	BRWN SAND 0080 BLUE CLAY 0098 BRWN FSND 0112
5	25	2963	648052	4882544	324.6	30.48	1961 08	3414	10.16	30.48	45	90	2	LANGDON N	LOAM 0001 CLAY MSND STNS 0099 MSND GRVL 0100

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5	25	2985	649017	4882775	309.4	67.97	1964 10	2306	15.24	54.86	25	200	5	GOLDBERG HAROLD,	LOAM 0010 MSND 0120 MSND CLAY GRVL 0220 GRVL 0223
5	25	3286	999999	9999999	318.7	127.1	1997 05	5459	15.24	89.61	44	49	10	JAY, M HOLDINGS	BLCK LOAM 0001 BRWN SAND 0029 BRWN CLAY SAND STNSSGREY SILT CLAY 0091 GREY CLAY SAND STNS 0122GREY CLAY SILT 0164 GREY SILT SAND 0188 GREY CLAYSAND STNS 0286 GREY SAND SILT FGRD 0294 GREY CLAYCLN 0414 BLCK SHLE 0417
5	25	3287	999999	9999999	318.7	126.2	1997 05	5459	5.08	87.17	30	0	0	JAY, M HOLDINGS	BLCK LOAM 0001 BRWN SAND SILT 0029 BRWN CLAY SAND 0078 GREY SAND STNS SILT 0091 GREY CLAY SILTY 0122 GREY CLAY STNS 0164 GREY SILT SAND 0188 GREY CLAYSTNS 0286 GREY FSND DRTY 0294 GREY SAND CLN 0414
5	25	4685	648200	4882600	323.1	38.71	1994 10	4743	15.24	37.19	35	65	10	MOORE PETER	BRWN SAND 0045 BLUE CLAY SAND 0122 GREY SAND CLN 0127
5	25	4797	647600	4882400	321.6	39.62	1995 10	4743	15.24	38.4	33	65	10	ANCHOR P	BRWN SAND LOOS 0045 GREY SAND CLAY 0065 GREY SANDVERY SILTY 0080 GREY SAND CLAY 0126 GREY SAND PCKDWBRG 0130
5	25	6297	647784	4882429	320	63.4	1975 08	1413	12.7	63.4	60	70	10	HEIDI JOSEPH	RED SAND 0030 BRWN SAND CLAY 0050 GREYCLAY SILTSTNS 0200 GREY SAND 0208
5	25	7267	647150	4882250	312.4	33.53	1984 06	5459	15.24	32.31	6	106	15	LEWIS T	BRWN SAND STNS 0021 GREY STNS 0024 BRWN SAND STNS 0027 BRWN CLAY SANDY 0082 BLUE CLAY STNS 0090 GREYSAND STNS 0097 WHIT CLAY STNS 0101 GREY SAND STNS 0110
5	25	7481	649000	4882500	304.8	16.76	1985 09	1413	15.24	16.76	16	35	10	WILLIAMSON A	BRWN SAND DRY 0011 BRWN CLAY DNSE 0036 BRWN MSNDLOOS 0055
5	25	9797	648200	4882568	321.9	58.52	1989 03	4743	15.24	55.78	58	180	6	RAYMOND, PAT	BRWN LOAM 0003 BRWN SAND SOFT 0052 GREY CLAY GRVLHARD 0088 GREY CLAY BLDR 0097 GREY CLAY GRVL 0103BRWN SAND SOFT 0116 GREY CLAY STNS HARD 0148 GREYCLAY BLDR 0183 BLCK SAND SOFT 0188 GREY CLAY HARD 0192
5	26	868	648876	4882933	306	23.47	1990 11	1350	15.24	23.16	21	50	10	HUNTINGTON N. B	BRWN SAND 0006 YLLW CLAY 0018 BRWN SAND 0025 RRWNSILT 0051 GREY CLAY 0054 GREY SILT 0062 GREY CLAYGRVL 0076 BRWN GRVL SAND 0077
5	26	5825	647200	4882400	320	7.62	1980 06	3109	76.2	4.572	15	0	0	KUEHL F	LOAM 0001 BRWN CLAY 0014 CSND 0025
6	20	5553	651740	4881400	342.9	64.31	1973 10	1413	12.7	64.31	127	140	8	CORNWALL E	BRWN SAND 0127 BRWN SAND CLAY 0150 BLUE SILT 0180GREY SILT 0203 BLCK CSND 0211

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6	20	5557	649966	4880813	365.8	73.15	1973-09	1413	12.7	73.15	200	215	7	SPADEMAN R	BRWN SAND GRVL 0028 BRWN SAND 0196 BLUE CLAY 0228BLCK FSND 0240
6	20	6426	651600	4881580	342.9	46.63	1976-01	1413	15.24	46.63	112	125	8	GLOBAN DANIEL BLDR	BRWN SAND DRY 0012 BRWN GRVL DRY 0025 BRWN SAND DRY 0112 RED FSND LOOS 0153
6	21	2982	650942	4881610	335.3	36.88	1964-08	2113	15.24	35.36	87	116	2	ALSOP J A	LOAM 0001 BRWN GRVL 0003 GREY FSND 0116 GREY M8ND 0121
6	21	5093	650600	4881400	342.9	45.11	1978-07	4743	15.24	42.67	95	120	12	J E ALSOK LTD	BRWN SAND CLAY LTCL 0018 YLLW CLAY 0028 BRWN SAND LOOS 0105 BRWN SAND PCKD 0140 BRWN SAND CLN 0148
6	21	6763	651400	4881950	327.7	52.12	1903-11	1413	15.24	51.82	111	120	12	SIMMONS D	BLCK LOAM SOFT 0001 BRWN SAND GRVL LYRD 0105 BRWN FSND 0150 BRWN MSND CLN 0170 GREY CLAY STNS HARD 0171
6	22	6920	649750	4861850	327.7	74.07	1994-10	5459	15.24	70.71	35	232	7	SCOTT J	BRWN SAND 0038 BRWN CLAY SNDY 0157 BLUE CLAY SNDY 0204 WHIT CLAY STNS 0208 BLUE CLAY SILT 0219 GREY SAND SILT 0221 WHIT CLAY STNS 0229 GREY SAND STNS 0236 WHIT CLAY STNS 0243
6	22	6921	649850	4881850	327.7	64.62	1995-10	5459	15.24	63.09	30	207	40	HOMSMAP	BRWN SAND SILT 0048 BRWN CLAY SILT 0146 BLUE CLAY SILT 0206 GREY SAND STNS 0212
6	22	6927	649750	4881800	327.7	39.93	1983-07	5459	15.24	38.4	80	125	8	PORTER M	BRWN CSND 0017 BRWN FSND 0090 BRWN SAND CLAY 0093 BRWN FSND 0120 BRWN SAND CLAY SOFT 0126 BRWN FSND 0131
6	22	7005	649750	4881850	327.7	46.02	1984-06	4738	15.24	39.62	0	0	0	KASIM M	BRWN SAND LOOS 0040 BRWN CLAY SAND SOFT 0100 BRWN FSND VERY 0145 BRWN FSND 0151
6	22	7268	649800	4881750	327.7	65.53	1984-05	5459	15.24	64.62	212	15	15	SISCHEEK E	BRWN CLAY SAND 0009 BRWN SAND STNS 0033 BRWN CLAY SNDY 0118 BLUE CLAY SNDY 0177 GREY SAND SILT 0181 GREY CLAY SNDY 0203 GREY SAND SILT 0211 GREY SAND STNS 0215
6	22	7272	649700	4881800	327.7	65.53	1984-08	5459	15.24	62.79	80	206	15	FURNAS B	BRWN CLAY SNDY 0129 BLUE CLAY SNDY 0181 GREY SAND SILT 0191 GREY CLAY SNDY 0202 GREY SAND STNS 0215
6	22	7890	649593	4881399	334.1	36.58	1986-08	1413	15.24	36.58	82	108	7	GOURLY, STEWART M	BRWN SAND PCKD 0015 BRWN CLAY PCKD 0072 BRWN SILT SAND SOFT 0114 BRWN SAND FSND CLN 0120
6	22	8240	649942	4881593	331.9	49.68	1986-09	5459	15.24	46.02	65	155	10	BIRD, R	BRWN SAND 0048 BRWN SAND CLAY 0078 BRWN SAND FSND 0130 BLUE CLAY SOFT 0151 BLUE SAND FSND 0163
6	22	8241	649668	4881610	335	48.77	1986-12	5459	15.24	46.33	65	150	10	BOND, W	BRWN SAND 0029 BRWN CLAY 0034 BRWN GRVL 0046 BRWN SAND 0060 BRWN CLAY 0079 BRWN CLAY SAND 0095

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Municipality Concession	Lot	Well No	UTM, Easting	UTM, Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
															BRWNSAND FSND 0107 BRWN SAND CLAY 0152 BRWN SAND FSND 0160
6	22	8805	649781	4881909	335	66.75	1987/04	5459	15.24	65.53	28.96	54.86	5	TOMMEY, M	BRWN SAND CLAY 0004 BRWN SAND MSND 0039 BRWN SANDCLAY 0047 BRWN SAND MSND 0071 BRWN GRVL 0076 BRWNSAND 0083 BRWN CLAY SAND 0132 BLUE CLAY SAND FSND 0167 BLUE CLAY SOFT 0203 BLUE CLAY SAND FSND 0215 BLUE SAND FSND 0219
6	22	8847	649588	4881799	333.1	59.44	1987/12	1413	12.7	59.44	22.86	24.38	1	LEGER, L	BRWN SAND CLAY PCKD 0100 GREY SAND SILT LYRD 0170GREY SAND FSND 0185 GREY GRVL CGVL CLN 0195
6	22	8850	649774	4884541	331.9	68.58	1987/12	1413	12.7	68.58	24.38	27.43	2	WHITE	BRWN SAND PCKD 0020 BRWN CLAY HARD 0000 BRWN SAND/CLAY LYRD 0100 GREY CLAY HARD 0200 GREY GRVL SANDCLN 0225
6	22	8894	649750	4881622	334.1	68.58	1988/01	1413	12.7	68.58	30.48	48.77	12	STEWART, J	BRWN SAND PCKD FSND 0100 GREY SAND CLAY LYRD 0215BLCK SAND CSND CLN 0225
6	22	8923	649940	4881652	333.1	68.58	1987/12	4743	15.24	67.36	27.43	38.1	5	POTTER, DAVE	BRWN SAND LOOS 0050 BRWN SAND GRVL LOOS 0140 GREYCLAY STNS HARD 0160 GREY CLAY FILL 0221 BRWN SANDCSND CLN 0225
6	22	8849	649650	4881678	334.1	70.71	1987/12	1413	12.7	70.71	25.91	48.77	2	JONES, CLIVE	BRWN SAND CLAY PCKD 0100 GREY SAND SLTY FSND 0150GREY CLAY HARD 0215 GREY GRVL CGVL CLN 0232
6	23	2964	649497	4881999	304.8	38.1	1994/10	5420	12.7	0	0	0	0	PITTFIELD J	BRWN MSND 0018 BRWN CLAY MSND 0045 BLUE SILT CLAY 0080 QSDN SILT 0110 BLUE SILT CLAY 0125
6	23	2983	649497	4881999	304.8	89.92	1995/10	5420	12.7	0	0	0	0	PITTFIELD J	BRWN MSND 0008 QSDN 0112 MSND 0172 CLAY SILT FSND 0195 RED CLAY MSND 0245 MSND SILT GRVL 0257 MSNDSILT 0295
6	23	3758	651400	4882550	317	52.12	1968/07	5420	12.7	48.77	32.31	48.77	5	WINGERT J	PRDG 0045 BRWN MSND 0132 BLUE CLAY 0136 BLUE FSND0160 MSND 0171
6	23	4001	651390	4682550	320	30.78	1969/02	1413	12.7	30.78	20.12	27.43	2	HARRIS P	PRDG 0008 MSND 0073 RED FSND 0101
6	23	4040	651340	4882525	320	39.62	1969/05	1413	12.7	39.62	25.91	33.53	2	HARRIS PETER	MSND 0028 GRVL 0038 MSND 0062 GRVL 0071 MSND 0085RED FSND 0130
6	23	5498	651150	4882550	320	88.09	1979/08	1413	12.7	88.09	27.74	33.53	2	HARRIS P	BRWN SAND DRY 0091 BRWN FSND 0122 GREY QSDN CLAYSOFT 0271 GREY SAND LOOS 0279 GREY SAND GRVL PORS 0289
6	23	6505	650000	4882200	320	45.11	1982/12	1413	12.7	34.14	26.82	31.09	2	PARKER, L	BRWN SAND DRY 0088 BRWN SAND 0112 BRWN FSND SOFT0140 BLUE CLAY SOFT 0144 BLUE SILT SOFT 0148
6	23	6727	649900	4882300	320	53.04	1983/06	4738	15.24	52.43	18.29	24.38	3	HICKMAN W	BRWN SAND LOOS 0080 GREY FSND CLAY 0172 GREY GRVLLOOS 0174

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Municipality Concession	Lot	Well No	UTM, Easting	UTM, Northing	Elevation, m	Well Depth, m	Date	Driller	Well Diameter, cm	Water found	Static Level	Pump Level	Test Rate, gpm	Owner	Well Log
6	23	7889	649710	4881844	333.1	49.38	1986/08	4743	15.24	46.33	25.91	38.1	0	CAMPBELL	BRWN SAND LOOS 0040 BRWN GRVL SAND 0065 BRWN SAND LOOS 0090 BRWN SAND CLAY PCKD 0152 BRWN SAND CLNFSND 0162
6	23	1183	649812	4881985	335.9	71.32	1991/06	4738	15.24	70.1	27.13	3.048	10	FORBES, GEORGE	BRWN SAND 0051 BRWN SAND 0150 BRWN SAND VERY FSND 0170 GREY CLAY SAND 0220 GREY GRVL SAND PCKD 0230 GREY GRVL SAND LOOS 0234
6	23	6864	649750	4881950	327.7	29.26	1983/09	1350	15.24	28.04	19.81	28.35	4	MELKO R	BRWN SAND 0030 BRWN SAND CLAY 0034 BRWN SAND 0060 BRWN SAND GRVL 0075 BRWN SAND PCKD 0085 BRWN SAND DRY 0092 BRWN SAND 0095 UNKN 0096
6	23	6982	649850	4881900	327.7	32	1984/06	1413	15.24	32	24.99	28.96	4	WASYLENS KYD	BRWN SAND DRY 0028 BRWN CLAY DNSE 0067 BRWN FSND 0090 BRWN FSND LOOS 0105
6	23	7311	649650	4882100	327.7	52.73	1985/05	1413	15.24	52.73	21.34	27.43	12	LODGE B	BRWN SAND DRY 0080 GREY SILT SOFT 0115 GREY FSNDSILT 0125 GREY SILT CLAY LYRD 0168 GREY GRVL SAND-PORS 0173
6	23	7512	999999	9999999	0	73.15	1984/05	3903	15.24	70.1	32.31	6.706	10	BRODIE, ROBERT	BRWN CLAY STNS LYRD 0011 BRWN SAND GRVL 0098 BRWN CLAY STNS HARD 0112 GREY CLAY SAND LYRD 0149 GREY CLAY SILT LYRD 0223 BRWN SAND GRVL CMTD 0238 GREY CLAY STNS DNSE 0240
6	23	7568	999999	9999999	0	68.88	1985/12	1413	15.24	67.67	27.43	40.54	12	ZAPP, UDO	BRWN SAND DRY 0090 BRWN CLAY SAND PCKD 0126 GREY SAND SILT PCKD 0193 GREY CLAY SAND LYRD 0216 GREY GRVL SAND PORS 0222 GREY GRVL CMTD 0226
6	23	8521	649755	4882157	326.1	57.3	1994/10	1413	12.7	57.3	21.03	33.53	12	KOSAROW, ALEX	BRWN SAND DRY 0070 BRWN CLAY SLTY SOFT 0120 GREY CLAY SLTY SOFT 0175 GREY GRVL LOOS CLN 0188
6	23	8801	649793	4882144	330.1	58.52	1995/10	5459	15.24	57.3	28.96	56.39	6	MEYERSFEG	BRWN SAND CLAY 0017 BRWN SAND 0038 BRWN SAND CLAY 0048 BRWN GRVL 0059 BRWN SAND CLAY 0114 BLUE CLAY SOFT 0188 GREY SAND GRVL 0192
6	23	8802	649803	4882013	335	62.18	1987/07	5459	15.24	61.57	27.43	57.91	10	COLLINSFG	BLCK LOAM 0002 BRWN SAND 0015 BRWN SAND CLAY 0019 BRWN SAND 0048 BRWN SAND CLAY 0065 BRWN GRVL 0080 BRWN SAND FSND 0118 BLUE CLAY 0161 BLUE CLAY SAND 0170 BLUE CLAY SOFT 0202 BLUE SAND FSND 0204
6	23	9133	649514	4881150	324	58.52	1988/06	5459	15.24	56.39	24.38	56.39	10	ROBERTSON D	BRWN SAND CLAY 0010 BRWN SAND MSND 0028 BRWN GRVL 0036 BRWN SAND MSND 0055 BRWN SAND SILT 0112 BLUESILT SAND FSND 0118 GREY CLAY SILT 0185 GREY SANDSILT CSND 0192

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6	23	9343	649847	4882217	324	71.02	1988.08	5459	15.24	70.1	25.91	67.06	10	MENDERS. R	BRWN SAND 0012 BRWN SAND STNY 0016 BRWN SAND 0035 BRWN GRVL 0064 BRWN SAND CLAY 0108 GREY CLAY SAND 0141 GREY CLAY 0183 GREY GRVL SILT 0185 GREY GRVLCCLAY SILT 0198 GREY CLAY SAND SILT 0230 GREY SANDCSND 0233
6	24	5824	649400	4882300	304.8	4.267	1980.06	3109	0	0	0	0	3	HARTRICK B	LOAM 0001 BRWN CLAY SLTY 0006 FSND 0014
6	24	8624	649911	4881801	335	69.19	1987.10	2104	15.24	68.28	27.43	60.96	10	URECH, ALBERT	BRWN SAND DRY MSND 0100 GREY SILT WBRG MSND 0224GREY SAND WBRG MSND 0227
6	24	1002	999999	9999999	0	60.05	1991.02	1413	15.24	60.05	4.572	0	20	FOXBRIDGE W. GROUP	BRWN SAND PCKD 0017 BRWN FSND WBRG 0073 GREY FSNDWBRG 0137 BRWN SAND 0157 BLCK GRVL CGVL CLN 0197
6	24	1151	999999	9999999	0	60.96	1991.07	1413	5.08	0	0	0	0	FOXBRIDGE W. GROUP	BRWN SAND FSND 0135 BRWN SAND CSND 0156 BLCK GRVLCGVL 0200
6	24	1150	999999	9999999	0	60.96	1991.07	1413	5.08	0	0	0	0	FOXBRIDGE W. GROUP	BRWN SAND FSND 0137 BRWN SAND CSND 0156 BLCK GRVLCGVL 0200
6	25	4547	649450	4882750	297.2	24.69	1970.09	1413	12.7	24.69	10.67	15.24	9	HAYDEN JERROLD	BRWN MSND 0035 BRWN MSND CLAY 0060 GREY MSND 0081
6	25	4772	649190	4062950	304.8	6.706	1971.07	3413	76.2	3.962	4.572	4.572	10	PRENTICE J	BRWN FSND 0013 BRWN CSND 0022
6	25	7214	649100	4882800	304.8	26.52	1985.01	1413	12.7	26.52	12.19	21.95	5	LEESON D.	BRWN SAND LOOS 0038 GREY CLAY SILT SAND 0058 GREYSAND CLAY LYRD 0087
6	25	5631	649300	4882720	297.2	10.97	1973.10	1413	12.7	10.97	1.829	6.706	6	HAYDEN G	BRWN SAND CLAY 0006 BRWN SAND CLAY 0024 RED FSND 0036
6	25	5560	650920	4883250	283.5	41.45	1973.09	1413	12.7	41.45	11.28	18.29	12	CLELAND R	BRWN SAND 0025 BRWN GRVL 0046 BLUE CLAY SILT 0125GREY SAND SILT STNS 0136
6	25	5520	649200	4882920	304.8	39.01	1973.08	1413	12.7	25.91	12.19	24.38	3	SPLONICK W	BRWN SAND 0040 BRWN FSND 0085 BLUE SAND SILT 0125GREY CLAY STNS 0128
6	26	2966	650659	4883756	272.8	17.37	1962.11	3414	10.16	12.5	3.962	13.41	7	MCTAVISH J A	LOAM 0001 BRWN FSND 0041 GRVL 0057
6	26	4739	649130	4883170	297.2	25.3	1971.05	1413	12.7	25.3	4.572	23.47	9	DELIC M	BRWN MSND 0015 BRWN CLAY MSND 0046 BRWN SILT CLAYMSND 0074 RED FSND 0083
6	26	4819	649450	4883200	295.7	19.81	1977.09	4743	15.24	16.76	4.572	10.67	15	CANADIAN TAX COCK	YLLW SAND FILL 0004 BRWN SAND GRVL LOOS 0020 BRWNSAND CLAY DRTY 0055 GREY SAND CLN 0065
6	26	6454	651000	4683600	281.9	18.9	1982.05	5459	15.24	16.46	0.914	15.24	15	JOSEPH P	BRWN CLAY 0005 BRWN GRVL 0009 BRWN SAND CLAY 0020BLUE SAND 0034 BLUE SAND CLAY 0054 BRWN SAND 0062
6	26	5765	649500	4884200	320	14.02	1980.06	1413	0	0	0	0	0	BRUHEAU S	BRWN SAND DRY 0008 BRWN CLAY DNSE 0023 GREY CLAYDNSE 0040 GREY SILT SOFT 0046

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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6	26	5749	649600	4883550	320	21.34	1980/07	4743	15.24	17.07	3.658	8.534	20	WILLIAMSON BUICK	YLLW SAND CLAY LOAM 0030 SRWN SAND CLAY 0042 SRWNFSND 0056 BRWN CLAY SAND 0068 GREY CLAY STNS HPAN 0070
6	26	5922	649700	4883550	320	19.2	1980/11	4743	15.24	14.63	4.572	13.11	8	TATOA GO- TRANSIT	WHIT SAND CLAY 0016 BRWN CLAY SAND 0030 BRWN SAND 0048 BRWN SAND CLAY LYRD 0063
6	26	5027	649800	4883550	280.4	16.46	1978/05	4743	15.24	14.63	3.658	14.02	8	NOBLE TRANSPORT CO L	BRWN SAND CLAY LOOS 0017 YLLW CLAY SNDY 0035 BRWNFSND 0054
6	26	5634	649505	4683383	289.6	17.68	1974/04	1413	12.7	17.68	5.486	7.01	9	THOMPSON P A	BLCK LOAM 0003 BRWN SAND 0033 BRWN FSND 0044 REDSAND 0058
6	26	6378	649446	4883244	297.2	25.91	1975/11	1413	12.7	25.91	8.534	18.29	9	WOOD DOUG	RED SAND 0030 BRWN SAND SILT 0078 GREY FSND 0085
6	26	6384	650724	4883754	277.4	15.24	1975/11	4743	15.24	12.19	2.134	9.144	12	DEACON H A	BRWN SAND 0007 YLLW CLAY 0040 BRWN SAND 0050
6	26	9539	650982	4883672	274.9	24.38	1988/09	4743	15.24	21.34	2.134	21.34	7	SMITH, D	BRWN LOAM 0002 BRWN SAND WBRG LOOS 0027 GREY CLAYSAND LYRD 0051 BRWN CLAY SAND MUCK 0060 BRWN SANDCLN 0075 BRWN CLAY SNDY MGRD 0080
6	27	2654	999999	9999999	0	16.76	1995/11	3136	20.32	8.534	0	13.11	10	R.M. OF D. G. VLCKO	BRWN LOAM 0001 BRWN CLAY SNDY PCKD 0018 BRWN SANDSLTY 0028 BRWN FSND 0055
6	27	2987	649294	4883297	289.6	137.2	1961/08	3414	10.16	32	12.19	0	0	BERNHARD T P T	LOAM 0001 CLAY MSND 0047 SILT 0105 GREY CLAY GRVL 0380 BLCK SHLE 0450
6	27	4305	650600	4884100	281.9	16.76	1969/04	2104	15.24	15.54	3.048	12.19	7	FOSTER C W	PRDG 0012 GREY CLAY STNS 0015 BRWN MSND GRVL 0025BRWN CLAY MSND 0045 BRWN CSND 0055
6	27	4316	650830	4884170	272.8	6.096	1969/04	2104	15.24	5.791	0.914	5.486	22	FOSTER C W	LOAM 0002 BRWN CLAY MSND 0008 BRWN MSND GRVL 0019CSND GRVL 0020
6	27	4795	649400	4883700	295.7	21.34	1977/06	4743	15.24	16.76	5.182	12.8	20	WILLIAMSON ALEX	BRWN SAND FILL 0008 BRWN SAND LOOS 0016 BRWN GRVLSAND 0019 BRWN SAND DRY 0055 BRWN SAND PCKD 0062GREY FSND 0070
6	27	5747	649600	4883600	320	19.81	1980/07	4743	15.24	14.63	5.182	7.315	25	TRAUGOTT CONST LTD	WHIT SAND CLAY LYRD 0018 BRWN CLAY SAND 0032 BRWNFSND 0040 GREY FSND 0048 GREY CLAY SAND DRTY 0061GREY CLAY 0065
6	27	5867	649600	4883700	320	20.12	1980/09	4743	15.24	12.8	6.401	9.144	20	WILLIAMSON ESSO CTR	YLLW SAND CLAY 0020 BRWN SAND PCKD 0042 BRWN FSND 0053 BLUE CLAY SILT SOFT 0065 GREY CLAY 0066
6	27	6343	649250	4883800	274.3	27.43	1982/04	1413	15.24	27.43	14.33	23.16	5	CRAMM D	BRWN SAND DRY 0014 BRWN CLAY PCKD 0048 BRWN FSND 0081 BRWN SAND LOOS 0090
6	27	6752	649700	4883600	289.6	17.98	1983/10	1413	12.7	17.98	4.572	15.24	4	WILLIAMSON MOTORS	BRWN SAND PCKD 0008 GREY SAND PCKD 0050 BRWN MSNDLOOS 0059
6	27	7292	649250	4883550	289.6	15.24	1985/04	1413	12.7	15.24	4.572	12.8	4	MEHARG G	BRWN SAND LOOS 0010 BRWN CLAY SAND SOFT 0018 BRWNGRVL SAND LOOS 0020 BRWN CLAY SOFT 0035 BRWN FSND 0050

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6	27	7511	999999	9999999	0	13.72	1985-10	1413	12.7	13.72	3.048	9.144	6	HICKLING, SCOTT	BRWN SAND SILT LOOS 0036 GREY CLAY SILT SOFT 0037 RED SAND LOOS 0045
6	27	7592	999999	9999999	0	18.29	1985-11	1672	15.24	18.29	5.486	13.41	10	AKERS AUTO GLASS	LOAM 0002 SAND GRVL 0010 SAND 0056 SAND FGVL 0060
6	27	7599	999999	9999999	0	16.76	1985-12	1672	15.24	16.76	5.486	14.94	5	IMAGE GLASS & CONST.	LOAM 0001 SAND GRVL 0014 CLAY 0036 SAND FGVL 0055
6	27	7940	649384	4883706	295	24.69	1986-10	1	15.24	21.95	13.72	18.29	10	ACTON, BONNIE	BRWN SAND 0004 BLCK BLDR HARD 0007 BRWN SAND LOOS 0072 GREY SAND FSND 0078 GREY SAND CLAY MUCK 0081
6	29	2672	999999	9999999	0	22.25	1995-12	3136	15.24	11.28	0	0	6	R.M. OF D. D. WEBB	BRWN LOAM 0002 BRWN CLAY SNDY 0019 BRWN SAND 0073 GREY CLAY 0073
6	29	2974	999999	9999999	0	26.52	1996-09	1910	20.32	26.52	3.048	4.877	25	LARDNER, KENEVA	BLCK LOAM 0001 BRWN CLAY GVLY 0004 BRWN CLAY SNDY 0084 BRWN FGVL 0087
6	29	4901	650400	4884900	272.8	98.45	1977-02	2801	5.08	0	5.182	0	0	REGION OF DURHAM	BLCK LOAM 0001 BRWN CLAY GRVL SOFT 0009 GREY CLAY FSND SLTY 0018 BRWN FSND LOOS 0050 GREY CLAY SNDY SOFT 0067 FGVL CGVL LOOS 0086 GREY CSND CLAY LOOS 0089 GREY CLAY GRVL SNDY 0097 GREY CLAY GRVL HARD 0103 GREY CLAY GRVL SNDY 0130 GREY CLAY VERY HARD FSND LOOS 0235 BRWN CLAY FGVL SNDY 0260 BRWN CLAY VERY HARD 0263 BRWN CLAY FGVL SNDY 0292 GREY CLAY VERY HARD 0323
6	29	4903	650300	4884900	274.3	57.3	1977-02	2801	0	0	0	0	0	REGION OF DURHAM	BLCK LOAM 0001 BRWN CLAY GRVL SNDY 0008 GREY CLAY GRVL SLTY 0022 BRWN FSND LOOS 0052 GREY CLAY SNDY SLTY 0060 BLDR VERY HARD 0062 GREY CLAY GRVL SNDY 0068 FGVL MGVL CGVL 0079 GREY CLAY GRVL SNDY 0159 BRWN CLAY GRVL SNDY 0188
6	29	4904	650450	4884950	269.7	72.54	1977-02	2801	5.08	18.29	0	0	0	REGION OF DURHAM	BLCK LOAM 0001 BRWN CLAY GRVL SOFT 0012 GREY CLAY GRVL SLTY 0027 BRWN FSND LOOS 0052 GREY CLAY SLTY SOFT 0061 GREY CLAY GRVL SNDY 0070 FGVL CGVL SAND 0084 GRVL CSND LOOS 0092 GREY GRVL SAND CLAY 0104 GREY CLAY GRVL SNDY 0131 GREY CLAY GRVL SNDY 0144 BRWN CLAY GRVL SNDY 0238
6	29	5440	649700	4884700	262.1	65.53	1979-08	2801	5.08	49.68	0	0	0	UXBRIDGE	BRWN CLAY GRVL LOOS 0007 BRWN CLAY SAND SOFT 0019 GREY CLAY SOFT 0029 GREY SAND SILT CLAY 0052 GREY SILT SAND CLAY 0062 BRWN SAND GRVL CLAY 0070 BRWN SAND FGVL CGVL 0096 GREY CLAY GRVL 0163 GREY SAND GRVL PCKD 0195 GREY

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															SAND GRVL CLAY 0215
6	29	5465	648850	4884200	297.2	26.21	1973 05	1413	12.7	26.21	8.534	16.76	7	ANDERSON D	GREY SAND 0040 GREY SAND SILT GRVL 0080 GREY GRVLSAND 0086
6	29	4902	650250	4884850	275.8	98.45	1977 02	2801	0	0	0	0	0	REGION OF DURHAM	BLCK LOAM 0001 BRWN CLAY GRVL SNDY 0023 FSND LOOS 0040 GREY CLAY SNDY SLTY 0050 GREY CLAY SNDY HARD 0057 GREY CLAY GRVL HARD 0065 GREY CLAY GRVL SNDY 0106 GREY CLAY GRVL FSND 0142 BLDR VERY HARD 0144 GREY CLAY GRVL HARD 0166 GREY CLAY SLTY SNDY 0238 GREY CLAY GRVL SLTY 0307 GREY CLAY GRVL HARD 0323
6	29	1055	999999	9999999	0	58.83	1990 10	2801	60.96	0	2.743	8.839	60 0	REGION OF DURHAM	CLAY GRVL 0022 GRVL CLAY 0030 SAND GRVL 0064 GRVLCLAY SAND 0074 GRVL CLAY 0080 CGVL BLDR 0091 CGVLCLAY 0092 FGVL BLDR 0101 CLAY CGVL HARD 0116 GRVLCLAY 0121 CLAY GRVL HARD 0126 GRVL CLAY SOFT 0147CLAY GRVL HARD 0156 FGVL CGVL SAND 0171 FGVL CGVLCLAY 0173 FGVL CGVL BLDR 0188 FGVL CGVL BLDR 0193
6	29	5526	649800	4884500	281.9	65.23	1973 07	5459	15.24	63.4	16.76	38.1	6	STADE A	BRWN SAND 0045 GRVL CLAY 0070 BLUE CLAY STNS 0170CLAY GRVL 0208 SAND GRVL 0214
6	29	5641	649710	4884450	281.9	17.98	1973 11	4743	15.24	15.24	5.486	15.24	8	BAKELAAR J	BRWN CLAY 0013 YLLW SAND CLAY 0030 YLLW FSND 0038YLLW CLAY SAND MUCK 0050 BRWN FSND 0056 GREY SILT 0059
6	29	9176	999999	9999999	0	62.79	1988 07	5459	15.24	60.96	9.144	62.79	2	TESTA, G.	BRWN SAND 0010 BLUE CLAY STNS 0080 BLUE CLAY SOFT 0140 BLUE CLAY STNS 0200 GREY GRVL CMTD 0206
6	29	9625	999999	9999999	0	63.7	1989 02	5459	15.24	62.79	62.79	4.572	15	TREADWAY, K	BRWN CLAY SNDY 0021 BRWN SAND 0026 GREY CLAY SNDY 0127 GREY SAND STNS 0147 GREY CLAY SAND 0181 GREYCLAY SILT 0198 GREY SAND STNS 0209
6	29	9689	648796	4884464	299.9	62.48	1989 01	4743	15.24	57.61	18.29	56.39	10	SWART, H	BRWN LOAM 0003 BRWN CLAY SNDY 0019 BRWN CLAY BLDRHARD 0044 GREY CLAY STNS HARD 0048 GREY GRVL STNSLOOS 0065 GREY CLAY STNS HARD 0180 RED CLAY SOFT 0189 GREY SAND SILT LYRD 0205
6	30	4553	649340	4885650	288	32	1970 10	1413	12.7	32	10.97	28.96	7	GANTON E	BRWN CLAY STNS 0016 BLUE GRNT BLDR 0020 BRWN CLAYSTNS 0080 BLUE CLAY 0095 BLCK MSND 0105

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Municipality Concession	Lot	Well No	UTM. Easting	UTM. Northing	Elevation. m	Well Depth. m	Date	Driller	Well Diameter.cm	Water found	Static Level	Pump Level	Test Rate.gpm	Owner	Well Log
6	30	6569	648622	4885148	299.9	59.44	1987-08	1413	12.7	59.44	18.29	24.38	12	PATTISON, TOM	BRWN CLAY SOFT 0020 BRWN GRVL LOOS 0023 BRWN CLAYSOFT 0030 GREY CLAY HARD 0160 GREY SAND FSND 0166GREY CLAY DNSE 0186 BLCK SAND CSND CLN 0195
6	31	4879	649870	4885790	266.7	21.34	1971-08	4743	15.24	19.2	5.486	15.24	10	LAMB JAMES	YLLW CLAY 0023 BLUE CLAY STNS 0059 GREY CLAY GRVLSND 0063 GREY MSND GRVL 0070
6	31	5304	649150	4885250	292.6	24.38	1979-03	4743	15.24	23.47	5.791	15.24	20	PYKE BRIAN	BRWN CLAY FILL 0002 BLCK LOAM 0003 BRWN CLAY 0009YLLW CLAY SAND 0026 BLUE CLAY SOFT 0042 YLLW SANDGRVL LOOS 0049 BLUE CLAY STNS 0070 GREY GRVL LOOSDRY 0077 BRWN SAND GRVL 0080
6	31	6636	649900	4865500	266.7	22.56	1983-04	4743	15.24	21.34	1.219	9.144	15	NEWMARKE T PRE-CAST	BLCK LOAM 0002 YLLW CLAY SAND 0018 BLUE CLAY STKY 0055 BRWN CLAY SAND LYRD 0065 GREY SILT 0070 GREYSAND STNS CLN 0074
6	32	1609	649722	4886128	273.1	18.9	1992-07	5459	15.24	15.54	7.62	15.24	20	BEVERIDGE, BD	LOAM 0002 BRWN CLAY SNDY 0018 BRWN CLAY SAND GRVL 0051 BRWN SAND GRVL 0062
6	32	1869	999999	9999999	0	26.52	1993-12	4743	15.24	25.3	12.19	21.34	7	LOBBEZOO, R.	BLCK LOAM 0001 BRWN CLAY VERY HARD 0032 BLUE CLAYSTNS VERY 0045 GREY CLAY HARD 0066 BRWN GRVL SANDDRY 0079 BRWN CLAY SOFT 0083 BRWN SAND CLN 0087

APPENDIX B

BOREHOLE LOGS

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

BOREHOLE: GGL - 1
ELEVATION: 369 m a.s.l.
SOURCE: D. Sharpe (GSC),
(personal contact).

Symbol explanation:

→ - assumed hydrogeological unit boundary

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

DEPTH	LITHOLOGY	DESCRIPTION
0		TOPSOIL
		SILTY SAND: Brown silty fine to medium sand, trace clay.
-10		SAND AND SILT: Interbedded sand, silt and clay below 5.7
		SAND AND GRAVEL: Grey silty fine sand, trace clay and fine gravel. Increased clay content below 19.8m.
-20		
	Intermediate Aquifer	SAND AND SILT: Sand and silt layers with some clay. Higher clay content between 27.4 and 29.2m.
-30		SAND AND GRAVEL
		SAND AND SILT: Decreasing clay content below 47m
-40		SANDY SILT TILL: Some clay
-50		
	Newmarket Till	
-60		SILTY SAND
		SILT AND GRAVEL
-70		SILTY SAND TILL: Sand and gravel evident layering below 73.2m.
	Lower Aquifer	CLAYEY SILT: Grey clayey silt till, trace to some fine sand, trace subangular gravel.
-80		SILTY SAND TILL: Grey silty fine sand, some clay, trace to gravel, very dense.
-90		SAND AND GRAVEL: Grey medium to coarse sand and fine subangular gravel, with silt and clay.
m		CLAYEY SILT: Grey clayey silt till, trace to some gravel.

BOREHOLE: GGL - 2
ELEVATION: 320 m a.s.l.
SOURCE: D.Sharpe (GSC),
(personal contact).

Symbol explanation:

➡ - assumed hydrogeological unit boundary

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

DEPTH	LITHOLOGY	DESCRIPTION
0		SAND: Packed
		CLAY: Soft
		SAND: Layered, packed
-10	Intermediate Aquifer	
		CLAY: Layered, hard
-20		CLAY: Hard
		CLAY: Layered, some gravel
-30		SAND: Packed
		CLAY: Hard, cemented, some gravel
-40	Newmarket Till	TILL
-50		CLAY: Hard
		SAND: Medium Uniform
-60 m	Lower Aquifer	GRAVEL: Coarse Uniform

BOREHOLE: TW-1-88
ELEVATION: 322 m a.s.l.
SOURCE: MOEE RECORDS

Symbol explanation:
 —▶ - assumed hydrogeological unit boundary

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

BOREHOLE: OW00-39
ELEVATION: 314 m.a.s.l.
SOURCE: Beatty & Assoc. Ltd.
(personal contact).

Symbol explanation:
 → - assumed hydrogeological unit boundary

APPENDIX C

MANUAL DATA FROM OBSERVATION WELL OW00-39

PUMPING PERIOD

The Oak Ridges Moraine: Estimation of groundwater resources in the Uxbridge area

Date Time	Elapsed Time, min	Elapsed Time, s	Drawdown, m	Depth to Water, m
8/18/2000 10:00	0	0	0	8.627
8/18/2000 10:01	1	60	0.213	8.840
8/18/2000 10:02	2	120	0.345	8.972
8/18/2000 10:03	3	180	0.488	9.115
8/18/2000 10:04	4	240	0.583	9.210
8/18/2000 10:05	5	300	0.663	9.290
8/18/2000 10:06	6	360	0.766	9.393
8/18/2000 10:07	7	420	0.832	9.459
8/18/2000 10:08	8	480	0.912	9.539
8/18/2000 10:09	9	540	0.993	9.620
8/18/2000 10:10	10	600	1.045	9.672
8/18/2000 10:12	12	720	1.168	9.795
8/18/2000 10:14	14	840	1.294	9.921
8/18/2000 10:16	16	960	1.409	10.036
8/18/2000 10:18	18	1080	1.523	10.150
8/18/2000 10:20	20	1200	1.629	10.256
8/18/2000 10:22	22	1320	1.723	10.350
8/18/2000 10:25	25	1500	1.868	10.495
8/18/2000 10:30	30	1800	2.103	10.730
8/18/2000 10:35	35	2100	2.353	10.980
8/18/2000 10:40	40	2400	2.543	11.170
8/18/2000 10:45	45	2700	2.828	11.455
8/18/2000 10:50	50	3000	2.926	11.553
8/18/2000 10:55	55	3300	3.023	11.650
8/18/2000 11:00	60	3600	3.164	11.791
8/18/2000 11:10	70	4200	3.374	12.001
8/18/2000 11:20	80	4800	3.6	12.227
8/18/2000 11:30	90	5400	3.759	12.386
8/18/2000 11:40	100	6000	3.956	12.583
8/18/2000 12:00	120	7200	4.235	12.862
8/18/2000 12:10	130	7800	4.361	12.988
8/18/2000 12:22	142	8520	4.505	13.132
8/18/2000 12:40	160	9600	4.679	13.306
8/18/2000 13:00	180	10800	4.864	13.491
8/18/2000 13:30	210	12600	5.103	13.730
8/18/2000 14:00	240	14400	5.31	13.937
8/18/2000 14:30	270	16200	5.515	14.142
8/18/2000 15:00	300	18000	5.686	14.313
8/18/2000 15:30	330	19800	5.849	14.476
8/18/2000 16:00	360	21600	6.03	14.657

The Oak Ridges Moraine: Estimation of groundwater resources in the Uxbridge area

Date Time	Elapsed Time, min	Elapsed Time, s	Drawdown, m	Depth to Water, m
8/18/2000 16:30	390	23400	6.193	14.820
8/18/2000 17:00	420	25200	6.339	14.966
8/18/2000 17:30	450	27000	6.474	15.101
8/18/2000 18:00	480	28800	6.615	15.242
8/18/2000 18:54	534	32040	6.848	15.475
8/18/2000 20:00	600	36000	7.15	15.777
8/18/2000 21:00	660	39600	7.309	15.936
8/18/2000 22:00	720	43200	7.57	16.197
8/18/2000 23:00	780	46800	7.814	16.441
8/19/2000 0:00	840	50400	7.986	16.613
8/19/2000 1:00	900	54000	8.254	16.881
8/19/2000 3:20	1040	62400	8.623	17.250
8/19/2000 4:20	1100	66000	8.769	17.396
8/19/2000 5:20	1160	69600	8.931	17.558
8/19/2000 6:20	1220	73200	9.09	17.717
8/19/2000 8:00	1320	79200	9.353	17.980
8/19/2000 9:00	1380	82800	9.593	18.220
8/19/2000 13:00	1620	97200	10.26	18.887
8/19/2000 16:00	1800	108000	10.62	19.247
8/20/2000 9:45	2865	171900	12.67	21.297
8/20/2000 12:30	3030	181800	12.9	21.527
8/20/2000 13:00	3060	183600	12.93	21.557
8/20/2000 20:00	3480	208800	13.47	22.097
8/22/2000 9:58	5757	345420	14.373	23.000
8/22/2000 15:33	6092	365520	14.683	23.310
8/23/2000 9:00	7139	428340	15.363	23.990
8/23/2000 10:13	7212	432720	15.393	24.020
8/23/2000 15:20	7519	451140	15.503	24.130
8/24/2000 8:27	8546	512760	15.878	24.505
8/24/2000 12:00	8759	525540	15.913	24.540
8/24/2000 15:52	8991	539460	15.983	24.610
8/25/2000 8:22	9981	598860	16.218	24.845
8/25/2000 10:55	10134	608040	16.233	24.860
8/25/2000 14:37	10356	621360	16.273	24.900
8/28/2000 8:35	14314	858840	16.583	25.210
8/28/2000 9:40	14379	862740	16.563	25.190
8/28/2000 12:38	14557	873420	16.583	25.210
8/29/2000 8:37	15756	945360	16.673	25.300
8/29/2000 10:05	15844	950640	16.643	25.270
8/29/2000 12:54	16013	960780	16.643	25.270

The Oak Ridges Moraine: Estimation of groundwater resources in the Uxbridge area

Date Time	Elapsed Time, min	Elapsed Time, s	Drawdown, m	Depth to Water, m
8/30/2000 8:32	17191	1031460	16.843	25.470
8/30/2000 9:42	17261	1035660	16.828	25.455
8/31/2000 9:42	18701	1122060	16.953	25.580
8/31/2000 12:14	18853	1131180	16.938	25.565
9/1/2000 8:30	20069	1204140	17.023	25.650
9/1/2000 9:52	20151	1209060	16.973	25.600
9/2/2000 11:20	21679	1300740	16.828	25.455
9/3/2000 15:00	23339	1400340	16.868	25.495
9/4/2000 12:40	24639	1478340	16.808	25.435
9/5/2000 9:17	25876	1552560	16.843	25.470
9/5/2000 12:31	26070	1564200	16.813	25.440
9/6/2000 9:31	27330	1639800	16.893	25.520
9/6/2000 10:19	27378	1642680	16.888	25.515
9/7/2000 11:55	28914	1734840	16.83	25.457
9/8/2000 10:51	30290	1817400	17.118	25.745
9/9/2000 8:42	31601	1896060	17.243	25.870
9/10/2000 11:32	33211	1992660	17.183	25.810
9/11/2000 8:40	34479	2068740	17.093	25.720
9/11/2000 15:10	34869	2092140	17.073	25.700
9/12/2000 8:42	35921	2155260	17.043	25.670
9/13/2000 10:07	37446	2246760	16.953	25.580
9/14/2000 9:40	38859	2331540	16.703	25.330
9/15/2000 10:28	40347	2420820	16.458	23.945
9/16/2000 16:55	42174	2530440	16.213	24.840
9/17/2000 11:03	43262	2595720	16.423	25.050
9/18/2000 9:32	44611	2676660	16.573	25.200
9/18/2000 10:00	44639	2678340	16.583	25.210

APPENDIX D

MANUAL DATA FROM OBSERVATION WELL OW00-39

RECOVERY PERIOD

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
0	0	2678400	25.15	0.00	16.52	
1	60	2678460	25.18	0.03	16.55	44641
2	120	2678520	25.10	0.11	16.47	22321.00
3	150	2678550	25.05	0.16	16.42	17857.00
3	180	2678580	25.03	0.18	16.40	14881.00
3	210	2678610	24.99	0.22	16.36	12755.29
4	240	2678640	24.95	0.26	16.32	11161.00
4	270	2678670	24.90	0.31	16.27	9921.00
5	300	2678700	24.85	0.36	16.22	8929.00
5	330	2678730	24.82	0.39	16.19	8117.36
6	360	2678760	24.77	0.44	16.14	7441.00
6	390	2678790	24.74	0.47	16.11	6868.69
7	420	2678820	24.70	0.51	16.07	6378.14
7	450	2678850	24.66	0.55	16.03	5953.00
8	480	2678880	24.62	0.59	15.99	5581.00
8	510	2678910	24.58	0.63	15.95	5252.76
9	540	2678940	24.54	0.67	15.91	4961.00
9	570	2678970	24.52	0.69	15.89	4699.95
10	600	2679000	24.48	0.73	15.85	4465.00
10	630	2679030	24.45	0.76	15.82	4252.43
11	660	2679060	24.42	0.79	15.79	4059.18
11	690	2679090	24.39	0.82	15.76	3882.74
12	720	2679120	24.36	0.85	15.73	3721.00
12	750	2679150	24.33	0.88	15.70	3572.20
13	780	2679180	24.30	0.91	15.67	3434.85
13	810	2679210	24.28	0.93	15.65	3307.67
14	840	2679240	24.25	0.96	15.62	3189.57
14	870	2679270	24.22	0.99	15.59	3079.62
15	900	2679300	24.13	1.02	15.50	2977.00
15	930	2679330	24.17	1.04	15.54	2881.00
16	960	2679360	24.14	1.07	15.51	2791.00
16	990	2679390	24.12	1.09	15.49	2706.45
17	1020	2679420	24.09	1.12	15.46	2626.88
17	1050	2679450	24.07	1.14	15.44	2551.86
18	1080	2679480	24.05	1.16	15.42	2481.00
18	1110	2679510	24.03	1.18	15.40	2413.97
19	1140	2679540	24.01	1.20	15.38	2350.47
19	1170	2679570	23.99	1.22	15.36	2290.23
20	1200	2679600	23.96	1.25	15.33	2233.00
20	1230	2679630	23.94	1.27	15.31	2178.56
21	1260	2679660	23.92	1.29	15.29	2126.71
21	1290	2679690	23.90	1.31	15.27	2077.28
22	1320	2679720	23.88	1.33	15.25	2030.09
22	1350	2679750	23.86	1.35	15.23	1985.00
23	1380	2679780	23.84	1.37	15.21	1941.87
23	1410	2679810	23.83	1.38	15.20	1900.57
24	1440	2679840	23.81	1.40	15.18	1861.00
24	1470	2679870	23.79	1.42	15.16	1823.04

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
25	1500	2679900	23.77	1.44	15.14	1786.60
25	1530	2679930	23.75	1.46	15.12	1751.59
26	1560	2679960	23.74	1.47	15.11	1717.92
26	1590	2679990	23.72	1.49	15.09	1685.53
27	1620	2680020	23.71	1.50	15.08	1654.33
27	1650	2680050	23.69	1.52	15.06	1624.27
28	1680	2680080	23.67	1.54	15.04	1595.29
28	1710	2680110	23.66	1.55	15.03	1567.32
29	1740	2680140	23.64	1.57	15.01	1540.31
29	1770	2680170	23.62	1.59	14.99	1514.22
30	1800	2680200	23.61	1.60	14.98	1489.00
30	1830	2680230	23.60	1.61	14.97	1464.61
31	1860	2680260	23.58	1.63	14.95	1441.00
31	1890	2680290	23.56	1.65	14.93	1418.14
32	1920	2680320	23.55	1.66	14.92	1396.00
32	1950	2680350	23.53	1.68	14.90	1374.54
33	1980	2680380	23.53	1.68	14.90	1353.73
33	2010	2680410	23.51	1.70	14.88	1333.54
34	2040	2680440	23.50	1.71	14.87	1313.94
34	2070	2680470	23.48	1.73	14.85	1294.91
35	2100	2680500	23.47	1.74	14.84	1276.43
35	2130	2680530	23.46	1.75	14.83	1258.46
36	2160	2680560	23.45	1.76	14.82	1241.00
36	2190	2680590	23.43	1.78	14.80	1224.01
37	2220	2680620	23.42	1.79	14.79	1207.49
37	2250	2680650	23.40	1.81	14.77	1191.40
38	2280	2680680	23.39	1.82	14.76	1175.74
38	2310	2680710	23.38	1.83	14.75	1160.48
39	2340	2680740	23.37	1.84	14.74	1145.62
39	2370	2680770	23.35	1.86	14.72	1131.13
40	2400	2680800	23.34	1.87	14.71	1117.00
40	2430	2680830	23.33	1.88	14.70	1103.22
41	2460	2680860	23.32	1.89	14.69	1089.78
41	2490	2680890	23.31	1.90	14.68	1076.66
42	2520	2680920	23.30	1.91	14.67	1063.86
42	2550	2680950	23.28	1.93	14.65	1051.35
43	2580	2680980	23.27	1.94	14.64	1039.14
43	2610	2681010	23.26	1.95	14.63	1027.21
44	2640	2681040	23.25	1.96	14.62	1015.55
44	2670	2681070	23.24	1.97	14.61	1004.15
45	2700	2681100	23.23	1.98	14.60	993.00
45	2730	2681130	23.21	2.00	14.58	982.10
46	2760	2681160	23.20	2.01	14.57	971.43
46	2790	2681190	23.19	2.02	14.56	961.00
47	2820	2681220	23.18	2.03	14.55	950.79
47	2850	2681250	23.17	2.04	14.54	940.79
48	2880	2681280	23.16	2.05	14.53	931.00
48	2910	2681310	23.15	2.06	14.52	921.41
49	2940	2681340	23.15	2.06	14.52	912.02

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
49	2970	2681370	23.13	2.08	14.50	902.82
50	3000	2681400	23.12	2.09	14.49	893.80
51	3060	2681460	23.10	2.11	14.47	876.29
52	3120	2681520	23.08	2.13	14.45	859.46
53	3180	2681580	23.06	2.15	14.43	843.26
54	3240	2681640	23.05	2.16	14.42	827.67
55	3300	2681700	23.03	2.18	14.40	812.64
56	3360	2681760	23.01	2.20	14.38	798.14
57	3420	2681820	22.99	2.22	14.36	784.16
58	3480	2681880	22.97	2.24	14.34	770.66
59	3540	2681940	22.96	2.25	14.33	757.61
60	3600	2682000	22.94	2.27	14.31	745.00
65	3900	2682300	22.86	2.35	14.23	687.77
70	4200	2682600	22.78	2.43	14.15	638.71
75	4500	2682900	22.71	2.50	14.08	596.20
80	4800	2683200	22.64	2.57	14.01	559.00
85	5100	2683500	22.58	2.63	13.95	526.18
90	5400	2683800	22.45	2.70	13.83	497.00
105	6300	2684700	22.32	2.83	13.69	426.14
120	7200	2685600	22.18	2.97	13.55	373.00
135	8100	2686500	22.03	3.12	13.40	331.67
150	9000	2687400	21.90	3.25	13.28	298.60
165	9900	2688300	21.78	3.37	13.15	271.55
180	10800	2689200	21.68	3.47	13.05	249.00
195	11700	2690100	21.57	3.58	12.94	229.92
210	12600	2691000	21.46	3.69	12.83	213.57
225	13500	2691900	21.37	3.78	12.74	199.40
240	14400	2692800	21.27	3.88	12.64	187.00
255	15300	2693700	21.17	3.98	12.55	176.06
270	16200	2694600	21.09	4.06	12.47	166.33
285	17100	2695500	21.00	4.15	12.38	157.63
300	18000	2696400	20.92	4.23	12.30	149.80
315	18900	2697300	20.85	4.30	12.22	142.71
330	19800	2698200	20.76	4.39	12.14	136.27
345	20700	2699100	20.69	4.46	12.07	130.39
360	21600	2700000	20.63	4.52	12.00	125.00
375	22500	2700900	20.56	4.59	11.93	120.04
390	23400	2701800	20.48	4.67	11.86	115.46
405	24300	2702700	20.42	4.73	11.80	111.22
420	25200	2703600	20.34	4.81	11.71	107.29
435	26100	2704500	20.28	4.87	11.66	103.62
450	27000	2705400	20.21	4.94	11.58	100.20
465	27900	2706300	20.15	5.00	11.52	97.00
480	28800	2707200	20.09	5.06	11.46	94.00
495	29700	2708100	20.03	5.12	11.40	91.18
510	30600	2709000	19.97	5.18	11.34	88.53
525	31500	2709900	19.91	5.24	11.29	86.03
540	32400	2710800	19.85	5.30	11.23	83.67
555	33300	2711700	19.79	5.36	11.17	81.43

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
570	34200	2712600	19.74	5.41	11.11	79.32
585	35100	2713500	19.69	5.46	11.06	77.31
600	36000	2714400	19.64	5.51	11.02	75.40
615	36900	2715300	19.58	5.57	10.95	73.59
630	37800	2716200	19.53	5.62	10.90	71.86
645	38700	2717100	19.48	5.67	10.85	70.21
660	39600	2718000	19.42	5.73	10.80	68.64
675	40500	2718900	19.37	5.78	10.74	67.13
690	41400	2719800	19.32	5.83	10.70	65.70
705	42300	2720700	19.27	5.88	10.64	64.32
720	43200	2721600	19.23	5.92	10.60	63.00
735	44100	2722500	19.17	5.98	10.54	61.73
750	45000	2723400	19.13	6.02	10.50	60.52
765	45900	2724300	19.08	6.07	10.46	59.35
780	46800	2725200	19.04	6.11	10.42	58.23
795	47700	2726100	18.99	6.16	10.37	57.15
810	48600	2727000	18.94	6.21	10.32	56.11
825	49500	2727900	18.90	6.25	10.27	55.11
840	50400	2728800	18.86	6.29	10.23	54.14
855	51300	2729700	18.82	6.33	10.19	53.21
870	52200	2730600	18.78	6.37	10.15	52.31
885	53100	2731500	18.73	6.42	10.10	51.44
900	54000	2732400	18.68	6.47	10.06	50.60
915	54900	2733300	18.65	6.50	10.02	49.79
930	55800	2734200	18.59	6.56	9.97	49.00
945	56700	2735100	18.56	6.59	9.94	48.24
960	57600	2736000	18.52	6.63	9.90	47.50
975	58500	2736900	18.48	6.67	9.86	46.78
990	59400	2737800	18.44	6.71	9.82	46.09
1005	60300	2738700	18.41	6.74	9.78	45.42
1020	61200	2739600	18.36	6.79	9.73	44.76
1035	62100	2740500	18.32	6.83	9.69	44.13
1050	63000	2741400	18.28	6.87	9.65	43.51
1065	63900	2742300	18.25	6.90	9.62	42.92
1080	64800	2743200	18.22	6.93	9.59	42.33
1140	68400	2746800	18.03	7.18	9.40	40.16
1200	72000	2750400	17.90	7.31	9.27	38.20
1260	75600	2754000	17.76	7.46	9.13	36.43
1320	79200	2757600	17.64	7.58	9.01	34.82
1380	82800	2761200	17.49	7.72	8.86	33.35
1440	86400	2764800	17.37	7.85	8.74	32.00
1500	90000	2768400	17.24	7.97	8.61	30.76
1560	93600	2772000	17.11	8.10	8.48	29.62
1620	97200	2775600	17.00	8.21	8.37	28.56
1680	100800	2779200	16.92	8.30	8.29	27.57
3195	191700	2870100	14.66	10.49	6.03	14.97
3210	192600	2871000	14.66	10.49	6.03	14.91
3225	193500	2871900	14.69	10.46	6.06	14.84
3240	194400	2872800	14.69	10.46	6.06	14.78

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Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
3255	195300	2873700	14.69	10.46	6.06	14.71
3270	196200	2874600	14.67	10.48	6.04	14.65
3285	197100	2875500	14.65	10.50	6.02	14.59
3300	198000	2876400	14.63	10.52	6.00	14.53
3315	198900	2877300	14.62	10.53	5.99	14.47
3330	199800	2878200	14.67	10.48	6.04	14.41
3345	200700	2879100	14.57	10.58	5.94	14.35
3360	201600	2880000	14.56	10.59	5.93	14.29
3375	202500	2880900	14.55	10.60	5.92	14.23
3390	203400	2881800	14.53	10.62	5.90	14.17
3405	204300	2882700	14.52	10.63	5.89	14.11
3420	205200	2883600	14.49	10.66	5.86	14.05
3435	206100	2884500	14.48	10.67	5.85	14.00
3450	207000	2885400	14.46	10.69	5.83	13.94
3465	207900	2886300	14.44	10.71	5.81	13.88
3480	208800	2887200	14.43	10.72	5.80	13.83
3495	209700	2888100	14.41	10.74	5.78	13.77
3510	210600	2889000	14.40	10.75	5.77	13.72
3525	211500	2889900	14.38	10.77	5.75	13.66
3540	212400	2890800	14.37	10.78	5.74	13.61
3555	213300	2891700	14.34	10.81	5.71	13.56
3570	214200	2892600	14.34	10.81	5.71	13.50
3585	215100	2893500	14.32	10.83	5.69	13.45
3600	216000	2894400	14.30	10.85	5.67	13.40
3615	216900	2895300	14.28	10.87	5.65	13.35
3630	217800	2896200	14.26	10.89	5.63	13.30
3645	218700	2897100	14.24	10.91	5.61	13.25
3660	219600	2898000	14.24	10.91	5.61	13.20
3675	220500	2898900	14.20	10.95	5.57	13.15
3690	221400	2899800	14.20	10.95	5.57	13.10
3705	222300	2900700	14.18	10.97	5.55	13.05
3720	223200	2901600	14.17	10.98	5.54	13.00
3735	224100	2902500	14.17	10.98	5.54	12.95
3750	225000	2903400	14.15	11.00	5.52	12.90
3765	225900	2904300	14.14	11.01	5.51	12.86
3780	226800	2905200	14.12	11.03	5.49	12.81
3795	227700	2906100	14.10	11.05	5.47	12.76
3810	228600	2907000	14.09	11.06	5.46	12.72
3825	229500	2907900	14.08	11.07	5.45	12.67
3840	230400	2908800	14.06	11.09	5.43	12.62
3855	231300	2909700	14.05	11.10	5.42	12.58
3870	232200	2910600	14.05	11.10	5.42	12.53
3885	233100	2911500	14.03	11.12	5.40	12.49
3900	234000	2912400	14.01	11.14	5.38	12.45
3915	234900	2913300	14.00	11.15	5.37	12.40
3930	235800	2914200	13.99	11.16	5.36	12.36
3945	236700	2915100	13.97	11.18	5.34	12.32
3960	237600	2916000	13.96	11.19	5.33	12.27
3975	238500	2916900	13.95	11.20	5.32	12.23

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3990	239400	2917800	13.94	11.21	5.31	12.19
4005	240300	2918700	13.93	11.22	5.30	12.15
4020	241200	2919600	13.91	11.24	5.28	12.10
4035	242100	2920500	13.90	11.25	5.27	12.06
4050	243000	2921400	13.89	11.26	5.26	12.02
4065	243900	2922300	13.86	11.29	5.23	11.98
4080	244800	2923200	13.86	11.29	5.23	11.94
4095	245700	2924100	13.84	11.31	5.21	11.90
4110	246600	2925000	13.84	11.31	5.21	11.86
4125	247500	2925900	13.82	11.33	5.19	11.82
4140	248400	2926800	13.81	11.34	5.18	11.78
4155	249300	2927700	13.80	11.35	5.17	11.74
4170	250200	2928600	13.79	11.36	5.16	11.71
4185	251100	2929500	13.78	11.37	5.15	11.67
4200	252000	2930400	13.76	11.39	5.13	11.63
4215	252900	2931300	13.75	11.40	5.12	11.59
4230	253800	2932200	13.73	11.42	5.10	11.55
4245	254700	2933100	13.72	11.43	5.09	11.52
4260	255600	2934000	13.71	11.44	5.08	11.48
4275	256500	2934900	13.69	11.46	5.06	11.44
4290	257400	2935800	13.69	11.46	5.06	11.41
4305	258300	2936700	13.68	11.47	5.05	11.37
4320	259200	2937600	13.66	11.49	5.03	11.33
4335	260100	2938500	13.65	11.50	5.02	11.30
4350	261000	2939400	13.63	11.52	5.00	11.26
4365	261900	2940300	13.63	11.52	5.00	11.23
4380	262800	2941200	13.62	11.53	4.99	11.19
4395	263700	2942100	13.60	11.55	4.97	11.16
4410	264600	2943000	13.60	11.55	4.97	11.12
4425	265500	2943900	13.58	11.57	4.95	11.09
4440	266400	2944800	13.57	11.58	4.94	11.05
4455	267300	2945700	13.55	11.60	4.92	11.02
4470	268200	2946600	13.54	11.61	4.91	10.99
4485	269100	2947500	13.53	11.62	4.90	10.95
4500	270000	2948400	13.52	11.63	4.89	10.92
4515	270900	2949300	13.51	11.64	4.88	10.89
4530	271800	2950200	13.49	11.66	4.86	10.85
4545	272700	2951100	13.48	11.67	4.85	10.82
4560	273600	2952000	13.47	11.68	4.84	10.79
4575	274500	2952900	13.45	11.70	4.82	10.76
4590	275400	2953800	13.45	11.70	4.82	10.73
4605	276300	2954700	13.44	11.71	4.81	10.69
4620	277200	2955600	13.42	11.73	4.79	10.66
4635	278100	2956500	13.41	11.74	4.78	10.63
4650	279000	2957400	13.40	11.75	4.77	10.60
4665	279900	2958300	13.40	11.75	4.77	10.57
4680	280800	2959200	13.39	11.76	4.76	10.54
4695	281700	2960100	13.38	11.77	4.75	10.51
4710	282600	2961000	13.36	11.79	4.73	10.48

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4725	283500	2961900	13.35	11.80	4.72	10.45
4740	284400	2962800	13.34	11.81	4.71	10.42
4755	285300	2963700	13.34	11.81	4.71	10.39
4770	286200	2964600	13.32	11.83	4.69	10.36
4785	287100	2965500	13.30	11.85	4.67	10.33
4800	288000	2966400	13.30	11.85	4.67	10.30
4815	288900	2967300	13.29	11.86	4.66	10.27
4830	289800	2968200	13.28	11.87	4.65	10.24
4845	290700	2969100	13.26	11.89	4.63	10.21
4860	291600	2970000	13.25	11.90	4.62	10.19
4875	292500	2970900	13.24	11.91	4.61	10.16
4890	293400	2971800	13.24	11.91	4.61	10.13
4905	294300	2972700	13.22	11.93	4.59	10.10
4920	295200	2973600	13.21	11.94	4.58	10.07
4935	296100	2974500	13.20	11.95	4.57	10.05
4950	297000	2975400	13.19	11.96	4.56	10.02
4965	297900	2976300	13.17	11.98	4.54	9.99
4980	298800	2977200	13.17	11.98	4.54	9.96
4995	299700	2978100	13.16	11.99	4.53	9.94
5010	300600	2979000	13.15	12.00	4.52	9.91
5025	301500	2979900	13.14	12.01	4.51	9.88
5040	302400	2980800	13.13	12.02	4.50	9.86
5055	303300	2981700	13.12	12.03	4.49	9.83
5070	304200	2982600	13.11	12.04	4.48	9.80
5085	305100	2983500	13.10	12.05	4.47	9.78
5100	306000	2984400	13.10	12.05	4.47	9.75
5115	306900	2985300	13.08	12.07	4.45	9.73
5130	307800	2986200	13.07	12.08	4.44	9.70
5145	308700	2987100	13.06	12.09	4.43	9.68
5160	309600	2988000	13.05	12.10	4.42	9.65
5175	310500	2988900	13.04	12.11	4.41	9.63
5190	311400	2989800	13.03	12.12	4.40	9.60
5205	312300	2990700	13.02	12.13	4.39	9.58
5220	313200	2991600	13.00	12.15	4.37	9.55
5235	314100	2992500	12.99	12.16	4.36	9.53
5250	315000	2993400	12.99	12.16	4.36	9.50
5265	315900	2994300	12.98	12.17	4.35	9.48
5280	316800	2995200	12.97	12.18	4.34	9.45
5295	317700	2996100	12.96	12.19	4.33	9.43
5310	318600	2997000	12.94	12.21	4.31	9.41
5325	319500	2997900	12.95	12.20	4.32	9.38
5340	320400	2998800	12.94	12.21	4.31	9.36
5355	321300	2999700	12.92	12.23	4.29	9.34
5370	322200	3000600	12.91	12.24	4.28	9.31
5385	323100	3001500	12.90	12.25	4.27	9.29
5400	324000	3002400	12.90	12.25	4.27	9.27
5415	324900	3003300	12.89	12.26	4.26	9.24
5430	325800	3004200	12.88	12.27	4.25	9.22
5445	326700	3005100	12.86	12.29	4.23	9.20

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5460	327600	3006000	12.86	12.29	4.23	9.18
5475	328500	3006900	12.85	12.30	4.22	9.15
5490	329400	3007800	12.84	12.31	4.21	9.13
5505	330300	3008700	12.83	12.32	4.20	9.11
5520	331200	3009600	12.82	12.33	4.19	9.09
5535	332100	3010500	12.82	12.33	4.19	9.07
5550	333000	3011400	12.80	12.35	4.17	9.04
5565	333900	3012300	12.80	12.35	4.17	9.02
5580	334800	3013200	12.79	12.36	4.16	9.00
5595	335700	3014100	12.77	12.38	4.14	8.98
5610	336600	3015000	12.76	12.39	4.13	8.96
5625	337500	3015900	12.76	12.39	4.13	8.94
5640	338400	3016800	12.76	12.39	4.13	8.91
5655	339300	3017700	12.75	12.40	4.12	8.89
5670	340200	3018600	12.73	12.42	4.10	8.87
5685	341100	3019500	12.72	12.43	4.09	8.85
5700	342000	3020400	12.71	12.44	4.08	8.83
5715	342900	3021300	12.71	12.44	4.08	8.81
5730	343800	3022200	12.70	12.45	4.07	8.79
5745	344700	3023100	12.68	12.47	4.05	8.77
5760	345600	3024000	12.68	12.47	4.05	8.75
5775	346500	3024900	12.66	12.49	4.03	8.73
5790	347400	3025800	12.66	12.49	4.03	8.71
5805	348300	3026700	12.65	12.50	4.02	8.69
5820	349200	3027600	12.64	12.51	4.01	8.67
5835	350100	3028500	12.63	12.52	4.00	8.65
5850	351000	3029400	12.62	12.53	3.99	8.63
5865	351900	3030300	12.60	12.55	3.97	8.61
5880	352800	3031200	12.60	12.55	3.97	8.59
5895	353700	3032100	12.59	12.56	3.96	8.57
5910	354600	3033000	12.57	12.58	3.94	8.55
5925	355500	3033900	12.57	12.58	3.94	8.53
5940	356400	3034800	12.55	12.60	3.92	8.52
5955	357300	3035700	12.55	12.60	3.92	8.50
5970	358200	3036600	12.53	12.62	3.90	8.48
5985	359100	3037500	12.52	12.63	3.89	8.46
6000	360000	3038400	12.52	12.63	3.89	8.44
6015	360900	3039300	12.50	12.65	3.87	8.42
6030	361800	3040200	12.49	12.66	3.86	8.40
6045	362700	3041100	12.49	12.66	3.86	8.38
6060	363600	3042000	12.48	12.67	3.85	8.37
6075	364500	3042900	12.47	12.68	3.84	8.35
6090	365400	3043800	12.46	12.69	3.83	8.33
6105	366300	3044700	12.45	12.70	3.82	8.31
6120	367200	3045600	12.44	12.71	3.81	8.29
6135	368100	3046500	12.43	12.72	3.80	8.28
6150	369000	3047400	12.42	12.73	3.79	8.26
6165	369900	3048300	12.41	12.74	3.78	8.24
6180	370800	3049200	12.41	12.74	3.78	8.22

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
6195	371700	3050100	12.41	12.74	3.78	8.21
6210	372600	3051000	12.40	12.75	3.77	8.19
6225	373500	3051900	12.39	12.76	3.76	8.17
6240	374400	3052800	12.38	12.77	3.75	8.15
6255	375300	3053700	12.37	12.78	3.74	8.14
6270	376200	3054600	12.36	12.79	3.73	8.12
6285	377100	3055500	12.35	12.80	3.72	8.10
6300	378000	3056400	12.33	12.82	3.70	8.09
6315	378900	3057300	12.33	12.82	3.70	8.07
6330	379800	3058200	12.32	12.83	3.69	8.05
6345	380700	3059100	12.31	12.84	3.68	8.04
6360	381600	3060000	12.31	12.84	3.68	8.02
6375	382500	3060900	12.29	12.86	3.66	8.00
6390	383400	3061800	12.28	12.87	3.65	7.99
6405	384300	3062700	12.28	12.87	3.65	7.97
6420	385200	3063600	12.27	12.88	3.64	7.95
6435	386100	3064500	12.25	12.90	3.62	7.94
6450	387000	3065400	12.26	12.89	3.63	7.92
6465	387900	3066300	12.24	12.91	3.61	7.90
6480	388800	3067200	12.24	12.91	3.61	7.89
6495	389700	3068100	12.24	12.91	3.61	7.87
6510	390600	3069000	12.22	12.93	3.59	7.86
6525	391500	3069900	12.22	12.93	3.59	7.84
6540	392400	3070800	12.21	12.94	3.58	7.83
6555	393300	3071700	12.20	12.95	3.57	7.81
6570	394200	3072600	12.19	12.96	3.56	7.79
6585	395100	3073500	12.18	12.97	3.55	7.78
6600	396000	3074400	12.18	12.97	3.55	7.76
6615	396900	3075300	12.17	12.98	3.54	7.75
6630	397800	3076200	12.16	12.99	3.53	7.73
6645	398700	3077100	12.15	13.00	3.52	7.72
6660	399600	3078000	12.15	13.00	3.52	7.70
6675	400500	3078900	12.14	13.01	3.51	7.69
6690	401400	3079800	12.13	13.02	3.50	7.67
6705	402300	3080700	12.13	13.02	3.50	7.66
6720	403200	3081600	12.11	13.04	3.48	7.64
6735	404100	3082500	12.11	13.04	3.48	7.63
6750	405000	3083400	12.09	13.06	3.46	7.61
6765	405900	3084300	12.08	13.07	3.45	7.60
6780	406800	3085200	12.07	13.08	3.44	7.58
6795	407700	3086100	12.07	13.08	3.44	7.57
6810	408600	3087000	12.07	13.08	3.44	7.56
6825	409500	3087900	12.05	13.10	3.42	7.54
6840	410400	3088800	12.04	13.11	3.41	7.53
6855	411300	3089700	12.03	13.12	3.40	7.51
6870	412200	3090600	12.03	13.12	3.40	7.50
6885	413100	3091500	12.02	13.13	3.39	7.48
6900	414000	3092400	12.01	13.14	3.38	7.47
6915	414900	3093300	12.00	13.15	3.37	7.46

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
6930	415800	3094200	12.00	13.15	3.37	7.44
6945	416700	3095100	12.00	13.15	3.37	7.43
6960	417600	3096000	11.98	13.17	3.35	7.41
6975	418500	3096900	11.98	13.17	3.35	7.40
6990	419400	3097800	11.97	13.18	3.34	7.39
7005	420300	3098700	11.97	13.18	3.34	7.37
7020	421200	3099600	11.96	13.19	3.33	7.36
7035	422100	3100500	11.95	13.20	3.32	7.35
7050	423000	3101400	11.94	13.21	3.31	7.33
7065	423900	3102300	11.93	13.22	3.30	7.32
7080	424800	3103200	11.93	13.22	3.30	7.31
7095	425700	3104100	11.91	13.24	3.28	7.29
7110	426600	3105000	11.91	13.24	3.28	7.28
7125	427500	3105900	11.90	13.25	3.27	7.27
7140	428400	3106800	11.89	13.26	3.26	7.25
7155	429300	3107700	11.88	13.27	3.25	7.24
7170	430200	3108600	11.88	13.27	3.25	7.23
7185	431100	3109500	11.88	13.27	3.25	7.21
7200	432000	3110400	11.87	13.28	3.24	7.20
7215	432900	3111300	11.85	13.30	3.22	7.19
7230	433800	3112200	11.85	13.30	3.22	7.17
7245	434700	3113100	11.84	13.31	3.21	7.16
7260	435600	3114000	11.84	13.31	3.21	7.15
7275	436500	3114900	11.82	13.33	3.19	7.14
7290	437400	3115800	11.82	13.33	3.19	7.12
7305	438300	3116700	11.81	13.34	3.18	7.11
7320	439200	3117600	11.80	13.35	3.17	7.10
7335	440100	3118500	11.79	13.36	3.16	7.09
7350	441000	3119400	11.79	13.36	3.16	7.07
7365	441900	3120300	11.78	13.37	3.15	7.06
7380	442800	3121200	11.78	13.37	3.15	7.05
7395	443700	3122100	11.76	13.39	3.13	7.04
7410	444600	3123000	11.76	13.39	3.13	7.02
7425	445500	3123900	11.75	13.40	3.12	7.01
7440	446400	3124800	11.74	13.41	3.11	7.00
7455	447300	3125700	11.74	13.41	3.11	6.99
7470	448200	3126600	11.73	13.42	3.10	6.98
7485	449100	3127500	11.72	13.43	3.09	6.96
7500	450000	3128400	11.72	13.43	3.09	6.95
7515	450900	3129300	11.71	13.44	3.08	6.94
7530	451800	3130200	11.70	13.45	3.07	6.93
7545	452700	3131100	11.70	13.45	3.07	6.92
7560	453600	3132000	11.69	13.46	3.06	6.90
7575	454500	3132900	11.69	13.46	3.06	6.89
7590	455400	3133800	11.68	13.47	3.05	6.88
7605	456300	3134700	11.68	13.47	3.05	6.87
7620	457200	3135600	11.65	13.50	3.02	6.86
7635	458100	3136500	11.65	13.50	3.02	6.85
7650	459000	3137400	11.64	13.51	3.01	6.84

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
7665	459900	3138300	11.64	13.51	3.01	6.82
7680	460800	3139200	11.64	13.51	3.01	6.81
7695	461700	3140100	11.62	13.53	2.99	6.80
7710	462600	3141000	11.63	13.52	3.00	6.79
7725	463500	3141900	11.61	13.54	2.98	6.78
7740	464400	3142800	11.61	13.54	2.98	6.77
7755	465300	3143700	11.60	13.55	2.97	6.76
7770	466200	3144600	11.60	13.55	2.97	6.75
7785	467100	3145500	11.59	13.56	2.96	6.73
7800	468000	3146400	11.59	13.56	2.96	6.72
7815	468900	3147300	11.59	13.56	2.96	6.71
7830	469800	3148200	11.57	13.58	2.94	6.70
7845	470700	3149100	11.57	13.58	2.94	6.69
7860	471600	3150000	11.56	13.59	2.93	6.68
7875	472500	3150900	11.56	13.59	2.93	6.67
7890	473400	3151800	11.55	13.60	2.92	6.66
7905	474300	3152700	11.54	13.61	2.91	6.65
7920	475200	3153600	11.54	13.61	2.91	6.64
7935	476100	3154500	11.53	13.62	2.90	6.63
7950	477000	3155400	11.52	13.63	2.89	6.62
7965	477900	3156300	11.52	13.63	2.89	6.60
7980	478800	3157200	11.51	13.64	2.88	6.59
7995	479700	3158100	11.52	13.63	2.89	6.58
8010	480600	3159000	11.50	13.65	2.87	6.57
8025	481500	3159900	11.49	13.66	2.86	6.56
8040	482400	3160800	11.49	13.66	2.86	6.55
8055	483300	3161700	11.48	13.67	2.85	6.54
8070	484200	3162600	11.48	13.67	2.85	6.53
8085	485100	3163500	11.47	13.68	2.84	6.52
8100	486000	3164400	11.47	13.68	2.84	6.51
8115	486900	3165300	11.46	13.69	2.83	6.50
8130	487800	3166200	11.45	13.70	2.82	6.49
8145	488700	3167100	11.45	13.70	2.82	6.48
8160	489600	3168000	11.45	13.70	2.82	6.47
8175	490500	3168900	11.43	13.72	2.80	6.46
8190	491400	3169800	11.43	13.72	2.80	6.45
8205	492300	3170700	11.43	13.72	2.80	6.44
8220	493200	3171600	11.42	13.73	2.79	6.43
8235	494100	3172500	11.41	13.74	2.78	6.42
8250	495000	3173400	11.41	13.74	2.78	6.41
8265	495900	3174300	11.41	13.74	2.78	6.40
8280	496800	3175200	11.40	13.75	2.77	6.39
8295	497700	3176100	11.39	13.76	2.76	6.38
8310	498600	3177000	11.39	13.76	2.76	6.37
8325	499500	3177900	11.38	13.77	2.75	6.36
8340	500400	3178800	11.38	13.77	2.75	6.35
8355	501300	3179700	11.36	13.79	2.73	6.34
8370	502200	3180600	11.37	13.78	2.74	6.33
8385	503100	3181500	11.36	13.79	2.73	6.32

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
8400	504000	3182400	11.36	13.79	2.73	6.31
8415	504900	3183300	11.35	13.80	2.72	6.30
8430	505800	3184200	11.35	13.80	2.72	6.30
8445	506700	3185100	11.34	13.81	2.71	6.29
8460	507600	3186000	11.34	13.81	2.71	6.28
8475	508500	3186900	11.33	13.82	2.70	6.27
8490	509400	3187800	11.33	13.82	2.70	6.26
8505	510300	3188700	11.32	13.83	2.69	6.25
8520	511200	3189600	11.32	13.83	2.69	6.24
8535	512100	3190500	11.32	13.83	2.69	6.23
8550	513000	3191400	11.31	13.84	2.68	6.22
8565	513900	3192300	11.30	13.85	2.67	6.21
8580	514800	3193200	11.29	13.86	2.66	6.20
8595	515700	3194100	11.29	13.86	2.66	6.19
8610	516600	3195000	11.29	13.86	2.66	6.18
8625	517500	3195900	11.29	13.86	2.66	6.18
8640	518400	3196800	11.28	13.87	2.65	6.17
8655	519300	3197700	11.27	13.88	2.64	6.16
8670	520200	3198600	11.27	13.88	2.64	6.15
8685	521100	3199500	11.26	13.89	2.63	6.14
8700	522000	3200400	11.25	13.90	2.62	6.13
8715	522900	3201300	11.24	13.91	2.61	6.12
8730	523800	3202200	11.24	13.91	2.61	6.11
8745	524700	3203100	11.24	13.91	2.61	6.10
8760	525600	3204000	11.23	13.92	2.60	6.10
8775	526500	3204900	11.22	13.93	2.59	6.09
8790	527400	3205800	11.22	13.93	2.59	6.08
8805	528300	3206700	11.22	13.93	2.59	6.07
8820	529200	3207600	11.20	13.95	2.57	6.06
8835	530100	3208500	11.20	13.95	2.57	6.05
8850	531000	3209400	11.19	13.96	2.56	6.04
8865	531900	3210300	11.19	13.96	2.56	6.04
8880	532800	3211200	11.19	13.96	2.56	6.03
8895	533700	3212100	11.17	13.98	2.54	6.02
8910	534600	3213000	11.17	13.98	2.54	6.01
8925	535500	3213900	11.17	13.98	2.54	6.00
8940	536400	3214800	11.15	14.00	2.52	5.99
8955	537300	3215700	11.16	13.99	2.53	5.98
8970	538200	3216600	11.14	14.01	2.51	5.98
8985	539100	3217500	11.14	14.01	2.51	5.97
9000	540000	3218400	11.13	14.02	2.50	5.96
9015	540900	3219300	11.13	14.02	2.50	5.95
9030	541800	3220200	11.11	14.04	2.48	5.94
9045	542700	3221100	11.11	14.04	2.48	5.94
9060	543600	3222000	11.12	14.03	2.49	5.93
9075	544500	3222900	11.10	14.05	2.47	5.92
9090	545400	3223800	11.10	14.05	2.47	5.91
9105	546300	3224700	11.09	14.06	2.46	5.90
9120	547200	3225600	11.09	14.06	2.46	5.89

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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9135	548100	3226500	11.08	14.07	2.45	5.89
9150	549000	3227400	11.08	14.07	2.45	5.88
9165	549900	3228300	11.07	14.08	2.44	5.87
9180	550800	3229200	11.07	14.08	2.44	5.86
9195	551700	3230100	11.07	14.08	2.44	5.85
9210	552600	3231000	11.07	14.08	2.44	5.85
9225	553500	3231900	11.06	14.09	2.43	5.84
9240	554400	3232800	11.06	14.09	2.43	5.83
9255	555300	3233700	11.05	14.10	2.42	5.82
9270	556200	3234600	11.05	14.10	2.42	5.82
9285	557100	3235500	11.04	14.11	2.41	5.81
9300	558000	3236400	11.04	14.11	2.41	5.80
9315	558900	3237300	11.04	14.11	2.41	5.79
9330	559800	3238200	11.03	14.12	2.40	5.78
9345	560700	3239100	11.03	14.12	2.40	5.78
9360	561600	3240000	11.03	14.12	2.40	5.77
9375	562500	3240900	11.01	14.14	2.38	5.76
9390	563400	3241800	11.01	14.14	2.38	5.75
9405	564300	3242700	11.01	14.14	2.38	5.75
9420	565200	3243600	10.99	14.16	2.36	5.74
9435	566100	3244500	10.99	14.16	2.36	5.73
9450	567000	3245400	10.99	14.16	2.36	5.72
9465	567900	3246300	10.99	14.16	2.36	5.72
9480	568800	3247200	10.98	14.17	2.35	5.71
9495	569700	3248100	10.97	14.18	2.34	5.70
9510	570600	3249000	10.97	14.18	2.34	5.69
9525	571500	3249900	10.97	14.18	2.34	5.69
9540	572400	3250800	10.97	14.18	2.34	5.68
9555	573300	3251700	10.96	14.19	2.33	5.67
9570	574200	3252600	10.95	14.20	2.32	5.66
9585	575100	3253500	10.94	14.21	2.31	5.66
9600	576000	3254400	10.94	14.21	2.31	5.65
9615	576900	3255300	10.94	14.21	2.31	5.64
9630	577800	3256200	10.93	14.22	2.30	5.64
9645	578700	3257100	10.92	14.23	2.29	5.63
9660	579600	3258000	10.92	14.23	2.29	5.62
9675	580500	3258900	10.92	14.23	2.29	5.61
9690	581400	3259800	10.91	14.24	2.28	5.61
9705	582300	3260700	10.90	14.25	2.27	5.60
9720	583200	3261600	10.90	14.25	2.27	5.59
9735	584100	3262500	10.90	14.25	2.27	5.59
9750	585000	3263400	10.89	14.26	2.26	5.58
9765	585900	3264300	10.88	14.27	2.25	5.57
9780	586800	3265200	10.87	14.28	2.24	5.56
9795	587700	3266100	10.87	14.28	2.24	5.56
9810	588600	3267000	10.88	14.27	2.25	5.55
9825	589500	3267900	10.87	14.28	2.24	5.54
9840	590400	3268800	10.86	14.29	2.23	5.54
9855	591300	3269700	10.86	14.29	2.23	5.53

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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9870	592200	3270600	10.85	14.30	2.22	5.52
9885	593100	3271500	10.85	14.30	2.22	5.52
9900	594000	3272400	10.85	14.30	2.22	5.51
9915	594900	3273300	10.85	14.30	2.22	5.50
9930	595800	3274200	10.84	14.31	2.21	5.50
9945	596700	3275100	10.83	14.32	2.20	5.49
9960	597600	3276000	10.83	14.32	2.20	5.48
9975	598500	3276900	10.83	14.32	2.20	5.48
9990	599400	3277800	10.82	14.33	2.19	5.47
10005	600300	3278700	10.82	14.33	2.19	5.46
10020	601200	3279600	10.82	14.33	2.19	5.46
10035	602100	3280500	10.82	14.33	2.19	5.45
10050	603000	3281400	10.82	14.33	2.19	5.44
10065	603900	3282300	10.82	14.33	2.19	5.44
10080	604800	3283200	10.82	14.33	2.19	5.43
10095	605700	3284100	10.82	14.33	2.19	5.42
10110	606600	3285000	10.81	14.34	2.18	5.42
10125	607500	3285900	10.81	14.34	2.18	5.41
10140	608400	3286800	10.80	14.35	2.17	5.40
10155	609300	3287700	10.80	14.35	2.17	5.40
10170	610200	3288600	10.80	14.35	2.17	5.39
10185	611100	3289500	10.79	14.36	2.16	5.38
10200	612000	3290400	10.79	14.36	2.16	5.38
10215	612900	3291300	10.78	14.37	2.15	5.37
10230	613800	3292200	10.78	14.37	2.15	5.36
10245	614700	3293100	10.77	14.38	2.14	5.36
10260	615600	3294000	10.76	14.39	2.13	5.35
10275	616500	3294900	10.76	14.39	2.13	5.34
10290	617400	3295800	10.76	14.39	2.13	5.34
10305	618300	3296700	10.75	14.40	2.12	5.33
10320	619200	3297600	10.75	14.40	2.12	5.33
10335	620100	3298500	10.74	14.41	2.11	5.32
10350	621000	3299400	10.73	14.42	2.10	5.31
10365	621900	3300300	10.73	14.42	2.10	5.31
10380	622800	3301200	10.72	14.43	2.09	5.30
10395	623700	3302100	10.72	14.43	2.09	5.29
10410	624600	3303000	10.71	14.44	2.08	5.29
10425	625500	3303900	10.71	14.44	2.08	5.28
10440	626400	3304800	10.71	14.44	2.08	5.28
10455	627300	3305700	10.70	14.45	2.07	5.27
10470	628200	3306600	10.69	14.46	2.06	5.26
10485	629100	3307500	10.69	14.46	2.06	5.26
10500	630000	3308400	10.68	14.47	2.05	5.25
10515	630900	3309300	10.68	14.47	2.05	5.25
10530	631800	3310200	10.66	14.49	2.03	5.24
10545	632700	3311100	10.67	14.48	2.04	5.23
10560	633600	3312000	10.67	14.48	2.04	5.23
10575	634500	3312900	10.67	14.48	2.04	5.22
10590	635400	3313800	10.65	14.50	2.02	5.22

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
10605	636300	3314700	10.65	14.50	2.02	5.21
10620	637200	3315600	10.65	14.50	2.02	5.20
10635	638100	3316500	10.65	14.50	2.02	5.20
10650	639000	3317400	10.64	14.51	2.01	5.19
10665	639900	3318300	10.64	14.51	2.01	5.19
10680	640800	3319200	10.64	14.51	2.01	5.18
10695	641700	3320100	10.63	14.52	2.00	5.17
10710	642600	3321000	10.62	14.53	1.99	5.17
10725	643500	3321900	10.62	14.53	1.99	5.16
10740	644400	3322800	10.61	14.54	1.98	5.16
10755	645300	3323700	10.61	14.54	1.98	5.15
10770	646200	3324600	10.61	14.54	1.98	5.14
10785	647100	3325500	10.60	14.55	1.97	5.14
10800	648000	3326400	10.60	14.55	1.97	5.13
10815	648900	3327300	10.60	14.55	1.97	5.13
10830	649800	3328200	10.60	14.55	1.97	5.12
10845	650700	3329100	10.59	14.56	1.96	5.12
10860	651600	3330000	10.59	14.56	1.96	5.11
10875	652500	3330900	10.58	14.57	1.95	5.10
10890	653400	3331800	10.58	14.57	1.95	5.10
10905	654300	3332700	10.57	14.58	1.94	5.09
10920	655200	3333600	10.57	14.58	1.94	5.09
10935	656100	3334500	10.57	14.58	1.94	5.08
10950	657000	3335400	10.56	14.59	1.93	5.08
10965	657900	3336300	10.56	14.59	1.93	5.07
10980	658800	3337200	10.55	14.60	1.92	5.07
10995	659700	3338100	10.55	14.60	1.92	5.06
11010	660600	3339000	10.55	14.60	1.92	5.05
11025	661500	3339900	10.55	14.60	1.92	5.05
11040	662400	3340800	10.54	14.61	1.91	5.04
11055	663300	3341700	10.53	14.62	1.90	5.04
11070	664200	3342600	10.53	14.62	1.90	5.03
11085	665100	3343500	10.52	14.63	1.89	5.03
11100	666000	3344400	10.52	14.63	1.89	5.02
11115	666900	3345300	10.52	14.63	1.89	5.02
11130	667800	3346200	10.51	14.64	1.88	5.01
11145	668700	3347100	10.50	14.65	1.87	5.01
11160	669600	3348000	10.51	14.64	1.88	5.00
11175	670500	3348900	10.50	14.65	1.87	4.99
11190	671400	3349800	10.50	14.65	1.87	4.99
11205	672300	3350700	10.49	14.66	1.86	4.98
11220	673200	3351600	10.49	14.66	1.86	4.98
11235	674100	3352500	10.48	14.67	1.85	4.97
11250	675000	3353400	10.47	14.68	1.84	4.97
11265	675900	3354300	10.47	14.68	1.84	4.96
11280	676800	3355200	10.47	14.68	1.84	4.96
11295	677700	3356100	10.46	14.69	1.83	4.95
11310	678600	3357000	10.46	14.69	1.83	4.95
11325	679500	3357900	10.45	14.70	1.82	4.94

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
11340	680400	3358800	10.45	14.70	1.82	4.94
11355	681300	3359700	10.45	14.70	1.82	4.93
11370	682200	3360600	10.46	14.69	1.83	4.93
11385	683100	3361500	10.45	14.70	1.82	4.92
11400	684000	3362400	10.45	14.70	1.82	4.92
11415	684900	3363300	10.44	14.71	1.81	4.91
11430	685800	3364200	10.44	14.71	1.81	4.91
11445	686700	3365100	10.43	14.72	1.80	4.90
11460	687600	3366000	10.42	14.73	1.79	4.90
11475	688500	3366900	10.43	14.72	1.80	4.89
11490	689400	3367800	10.43	14.72	1.80	4.89
11505	690300	3368700	10.42	14.73	1.79	4.88
11520	691200	3369600	10.42	14.73	1.79	4.88
11535	692100	3370500	10.41	14.74	1.78	4.87
11550	693000	3371400	10.41	14.74	1.78	4.86
11565	693900	3372300	10.41	14.74	1.78	4.86
11580	694800	3373200	10.41	14.74	1.78	4.85
11595	695700	3374100	10.40	14.75	1.77	4.85
11610	696600	3375000	10.40	14.75	1.77	4.84
11625	697500	3375900	10.40	14.75	1.77	4.84
11640	698400	3376800	10.40	14.75	1.77	4.84
11655	699300	3377700	10.38	14.77	1.75	4.83
11670	700200	3378600	10.38	14.77	1.75	4.83
11685	701100	3379500	10.38	14.77	1.75	4.82
11700	702000	3380400	10.38	14.77	1.75	4.82
11715	702900	3381300	10.38	14.77	1.75	4.81
11730	703800	3382200	10.37	14.78	1.74	4.81
11745	704700	3383100	10.37	14.78	1.74	4.80
11760	705600	3384000	10.36	14.79	1.73	4.80
11775	706500	3384900	10.35	14.80	1.72	4.79
11790	707400	3385800	10.35	14.80	1.72	4.79
11805	708300	3386700	10.35	14.80	1.72	4.78
11820	709200	3387600	10.35	14.80	1.72	4.78
11835	710100	3388500	10.34	14.81	1.71	4.77
11850	711000	3389400	10.34	14.81	1.71	4.77
11865	711900	3390300	10.32	14.83	1.69	4.76
11880	712800	3391200	10.32	14.83	1.69	4.76
11895	713700	3392100	10.32	14.83	1.69	4.75
11910	714600	3393000	10.32	14.83	1.69	4.75
11925	715500	3393900	10.32	14.83	1.69	4.74
11940	716400	3394800	10.31	14.84	1.68	4.74
11955	717300	3395700	10.31	14.84	1.68	4.73
11970	718200	3396600	10.31	14.84	1.68	4.73
11985	719100	3397500	10.30	14.85	1.67	4.72
12000	720000	3398400	10.30	14.85	1.67	4.72
12015	720900	3399300	10.30	14.85	1.67	4.72
12030	721800	3400200	10.29	14.86	1.66	4.71
12045	722700	3401100	10.29	14.86	1.66	4.71
12060	723600	3402000	10.28	14.87	1.65	4.70

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12075	724500	3402900	10.28	14.87	1.65	4.70
12090	725400	3403800	10.27	14.88	1.64	4.69
12105	726300	3404700	10.27	14.88	1.64	4.69
12120	727200	3405600	10.27	14.88	1.64	4.68
12135	728100	3406500	10.26	14.89	1.63	4.68
12150	729000	3407400	10.26	14.89	1.63	4.67
12165	729900	3408300	10.26	14.89	1.63	4.67
12180	730800	3409200	10.26	14.89	1.63	4.67
12195	731700	3410100	10.25	14.90	1.62	4.66
12210	732600	3411000	10.25	14.90	1.62	4.66
12225	733500	3411900	10.25	14.90	1.62	4.65
12240	734400	3412800	10.25	14.90	1.62	4.65
12255	735300	3413700	10.24	14.91	1.61	4.64
12270	736200	3414600	10.24	14.91	1.61	4.64
12285	737100	3415500	10.24	14.91	1.61	4.63
12300	738000	3416400	10.24	14.91	1.61	4.63
12315	738900	3417300	10.24	14.91	1.61	4.62
12330	739800	3418200	10.23	14.92	1.60	4.62
12345	740700	3419100	10.23	14.92	1.60	4.62
12360	741600	3420000	10.22	14.93	1.59	4.61
12375	742500	3420900	10.22	14.93	1.59	4.61
12390	743400	3421800	10.22	14.93	1.59	4.60
12405	744300	3422700	10.21	14.94	1.58	4.60
12420	745200	3423600	10.21	14.94	1.58	4.59
12435	746100	3424500	10.21	14.94	1.58	4.59
12450	747000	3425400	10.20	14.95	1.57	4.59
12465	747900	3426300	10.19	14.96	1.56	4.58
12480	748800	3427200	10.19	14.96	1.56	4.58
12495	749700	3428100	10.19	14.96	1.56	4.57
12510	750600	3429000	10.19	14.96	1.56	4.57
12525	751500	3429900	10.18	14.97	1.55	4.56
12540	752400	3430800	10.18	14.97	1.55	4.56
12555	753300	3431700	10.18	14.97	1.55	4.56
12570	754200	3432600	10.17	14.98	1.54	4.55
12585	755100	3433500	10.16	14.99	1.53	4.55
12600	756000	3434400	10.16	14.99	1.53	4.54
12615	756900	3435300	10.16	14.99	1.53	4.54
12630	757800	3436200	10.16	14.99	1.53	4.53
12645	758700	3437100	10.14	15.01	1.51	4.53
12660	759600	3438000	10.14	15.01	1.51	4.53
12675	760500	3438900	10.13	15.02	1.50	4.52
12690	761400	3439800	10.13	15.02	1.50	4.52
12705	762300	3440700	10.12	15.03	1.49	4.51
12720	763200	3441600	10.13	15.02	1.50	4.51
12735	764100	3442500	10.13	15.02	1.50	4.51
12750	765000	3443400	10.12	15.03	1.49	4.50
12765	765900	3444300	10.12	15.03	1.49	4.50
12780	766800	3445200	10.12	15.03	1.49	4.49
12795	767700	3446100	10.11	15.04	1.48	4.49

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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12810	768600	3447000	10.11	15.04	1.48	4.48
12825	769500	3447900	10.11	15.04	1.48	4.48
12840	770400	3448800	10.11	15.04	1.48	4.48
12855	771300	3449700	10.11	15.04	1.48	4.47
12870	772200	3450600	10.10	15.05	1.47	4.47
12885	773100	3451500	10.10	15.05	1.47	4.46
12900	774000	3452400	10.10	15.05	1.47	4.46
12915	774900	3453300	10.09	15.06	1.46	4.46
12930	775800	3454200	10.09	15.06	1.46	4.45
12945	776700	3455100	10.09	15.06	1.46	4.45
12960	777600	3456000	10.09	15.06	1.46	4.44
12975	778500	3456900	10.08	15.07	1.45	4.44
12990	779400	3457800	10.08	15.07	1.45	4.44
13005	780300	3458700	10.09	15.06	1.46	4.43
13020	781200	3459600	10.09	15.06	1.46	4.43
13035	782100	3460500	10.08	15.07	1.45	4.42
13050	783000	3461400	10.08	15.07	1.45	4.42
13065	783900	3462300	10.07	15.08	1.44	4.42
13080	784800	3463200	10.07	15.08	1.44	4.41
13095	785700	3464100	10.07	15.08	1.44	4.41
13110	786600	3465000	10.07	15.08	1.44	4.41
13125	787500	3465900	10.07	15.08	1.44	4.40
13140	788400	3466800	10.06	15.09	1.43	4.40
13155	789300	3467700	10.06	15.09	1.43	4.39
13170	790200	3468600	10.06	15.09	1.43	4.39
13185	791100	3469500	10.06	15.09	1.43	4.39
13200	792000	3470400	10.06	15.09	1.43	4.38
13215	792900	3471300	10.05	15.10	1.42	4.38
13230	793800	3472200	10.04	15.11	1.41	4.37
13245	794700	3473100	10.04	15.11	1.41	4.37
13260	795600	3474000	10.04	15.11	1.41	4.37
13275	796500	3474900	10.04	15.11	1.41	4.36
13290	797400	3475800	10.04	15.11	1.41	4.36
13305	798300	3476700	10.03	15.12	1.40	4.36
13320	799200	3477600	10.03	15.12	1.40	4.35
13335	800100	3478500	10.02	15.13	1.39	4.35
13350	801000	3479400	10.01	15.14	1.38	4.34
13365	801900	3480300	10.01	15.14	1.38	4.34
13380	802800	3481200	10.02	15.13	1.39	4.34
13395	803700	3482100	10.00	15.15	1.37	4.33
13410	804600	3483000	10.01	15.14	1.38	4.33
13425	805500	3483900	10.00	15.15	1.37	4.33
13440	806400	3484800	10.00	15.15	1.37	4.32
13455	807300	3485700	10.00	15.15	1.37	4.32
13470	808200	3486600	9.99	15.16	1.36	4.31
13485	809100	3487500	9.98	15.17	1.35	4.31
13500	810000	3488400	9.99	15.16	1.36	4.31
13515	810900	3489300	9.99	15.16	1.36	4.30
13530	811800	3490200	9.98	15.17	1.35	4.30

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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13545	812700	3491100	9.98	15.17	1.35	4.30
13560	813600	3492000	9.97	15.18	1.34	4.29
13575	814500	3492900	9.98	15.17	1.35	4.29
13590	815400	3493800	9.98	15.17	1.35	4.28
13605	816300	3494700	9.97	15.18	1.34	4.28
13620	817200	3495600	9.96	15.18	1.34	4.28
13635	818100	3496500	9.96	15.18	1.34	4.27
13650	819000	3497400	9.97	15.18	1.34	4.27
13665	819900	3498300	9.96	15.18	1.34	4.27
13680	820800	3499200	9.96	15.18	1.34	4.26
13695	821700	3500100	9.96	15.18	1.34	4.26
13710	822600	3501000	9.96	15.18	1.34	4.26
13725	823500	3501900	9.95	15.19	1.33	4.25
13740	824400	3502800	9.95	15.19	1.33	4.25
13755	825300	3503700	9.96	15.19	1.33	4.25
13770	826200	3504600	9.95	15.19	1.33	4.24
13785	827100	3505500	9.95	15.20	1.32	4.24
13800	828000	3506400	9.95	15.20	1.32	4.23
13815	828900	3507300	9.95	15.20	1.32	4.23
13830	829800	3508200	9.94	15.21	1.31	4.23
13845	830700	3509100	9.94	15.21	1.31	4.22
13860	831600	3510000	9.95	15.20	1.32	4.22
13875	832500	3510900	9.94	15.21	1.31	4.22
13890	833400	3511800	9.94	15.21	1.31	4.21
13905	834300	3512700	9.94	15.21	1.31	4.21
13920	835200	3513600	9.93	15.22	1.30	4.21
13935	836100	3514500	9.93	15.22	1.30	4.20
13950	837000	3515400	9.94	15.21	1.31	4.20
13965	837900	3516300	9.93	15.22	1.30	4.20
13980	838800	3517200	9.92	15.23	1.29	4.19
13995	839700	3518100	9.92	15.23	1.29	4.19
14010	840600	3519000	9.92	15.23	1.29	4.19
14025	841500	3519900	9.91	15.24	1.28	4.18
14040	842400	3520800	9.91	15.24	1.28	4.18
14055	843300	3521700	9.90	15.24	1.28	4.18
14070	844200	3522600	9.89	15.25	1.27	4.17
14085	845100	3523500	9.91	15.24	1.28	4.17
14100	846000	3524400	9.90	15.24	1.28	4.17
14115	846900	3525300	9.90	15.25	1.27	4.16
14130	847800	3526200	9.89	15.26	1.26	4.16
14145	848700	3527100	9.88	15.26	1.26	4.16
14160	849600	3528000	9.88	15.26	1.26	4.15
14175	850500	3528900	9.88	15.26	1.26	4.15
14190	851400	3529800	9.88	15.27	1.25	4.15
14205	852300	3530700	9.88	15.26	1.26	4.14
14220	853200	3531600	9.88	15.26	1.26	4.14
14235	854100	3532500	9.88	15.27	1.25	4.14
14250	855000	3533400	9.88	15.27	1.25	4.13
14265	855900	3534300	9.87	15.28	1.24	4.13

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14280	856800	3535200	9.87	15.28	1.24	4.13
14295	857700	3536100	9.87	15.28	1.24	4.12
14310	858600	3537000	9.87	15.28	1.24	4.12
14325	859500	3537900	9.87	15.28	1.24	4.12
14340	860400	3538800	9.86	15.29	1.23	4.11
14355	861300	3539700	9.86	15.29	1.23	4.11
14370	862200	3540600	9.86	15.29	1.23	4.11
14385	863100	3541500	9.86	15.29	1.23	4.10
14400	864000	3542400	9.85	15.30	1.22	4.10
14415	864900	3543300	9.85	15.30	1.22	4.10
14430	865800	3544200	9.86	15.29	1.23	4.09
14445	866700	3545100	9.86	15.29	1.23	4.09
14460	867600	3546000	9.85	15.30	1.22	4.09
14475	868500	3546900	9.85	15.30	1.22	4.08
14490	869400	3547800	9.85	15.30	1.22	4.08
14505	870300	3548700	9.84	15.31	1.21	4.08
14520	871200	3549600	9.84	15.31	1.21	4.07
14535	872100	3550500	9.84	15.31	1.21	4.07
14550	873000	3551400	9.84	15.31	1.21	4.07
14565	873900	3552300	9.84	15.31	1.21	4.06
14580	874800	3553200	9.83	15.31	1.21	4.06
14595	875700	3554100	9.83	15.32	1.20	4.06
14610	876600	3555000	9.83	15.32	1.20	4.06
14625	877500	3555900	9.82	15.32	1.20	4.05
14640	878400	3556800	9.82	15.33	1.19	4.05
14655	879300	3557700	9.82	15.33	1.19	4.05
14670	880200	3558600	9.82	15.33	1.19	4.04
14685	881100	3559500	9.82	15.33	1.19	4.04
14700	882000	3560400	9.82	15.33	1.19	4.04
14715	882900	3561300	9.82	15.33	1.19	4.03
14730	883800	3562200	9.81	15.34	1.18	4.03
14745	884700	3563100	9.80	15.35	1.17	4.03
14760	885600	3564000	9.80	15.35	1.17	4.02
14775	886500	3564900	9.80	15.35	1.17	4.02
14790	887400	3565800	9.80	15.35	1.17	4.02
14805	888300	3566700	9.79	15.36	1.16	4.02
14820	889200	3567600	9.79	15.36	1.16	4.01
14835	890100	3568500	9.78	15.37	1.15	4.01
14850	891000	3569400	9.77	15.38	1.14	4.01
14865	891900	3570300	9.77	15.38	1.14	4.00
14880	892800	3571200	9.77	15.38	1.14	4.00
14895	893700	3572100	9.77	15.38	1.14	4.00
14910	894600	3573000	9.77	15.38	1.14	3.99
14925	895500	3573900	9.76	15.38	1.14	3.99
14940	896400	3574800	9.76	15.39	1.13	3.99
14955	897300	3575700	9.76	15.39	1.13	3.98
14970	898200	3576600	9.76	15.38	1.14	3.98
14985	899100	3577500	9.76	15.39	1.13	3.98
15000	900000	3578400	9.76	15.39	1.13	3.98

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
15015	900900	3579300	9.76	15.39	1.13	3.97
15030	901800	3580200	9.76	15.39	1.13	3.97
15045	902700	3581100	9.75	15.40	1.12	3.97
15060	903600	3582000	9.75	15.40	1.12	3.96
15075	904500	3582900	9.75	15.40	1.12	3.96
15090	905400	3583800	9.75	15.40	1.12	3.96
15105	906300	3584700	9.75	15.40	1.12	3.96
15120	907200	3585600	9.75	15.40	1.12	3.95
15135	908100	3586500	9.75	15.40	1.12	3.95
15150	909000	3587400	9.75	15.40	1.12	3.95
15165	909900	3588300	9.75	15.40	1.12	3.94
15180	910800	3589200	9.74	15.41	1.11	3.94
15195	911700	3590100	9.73	15.42	1.10	3.94
15210	912600	3591000	9.74	15.41	1.11	3.93
15225	913500	3591900	9.74	15.41	1.11	3.93
15240	914400	3592800	9.73	15.42	1.10	3.93
15255	915300	3593700	9.72	15.43	1.09	3.93
15270	916200	3594600	9.72	15.43	1.09	3.92
15285	917100	3595500	9.72	15.43	1.09	3.92
15300	918000	3596400	9.72	15.43	1.09	3.92
15315	918900	3597300	9.72	15.43	1.09	3.91
15330	919800	3598200	9.71	15.44	1.08	3.91
15345	920700	3599100	9.70	15.44	1.08	3.91
15360	921600	3600000	9.70	15.44	1.08	3.91
15375	922500	3600900	9.70	15.44	1.08	3.90
15390	923400	3601800	9.70	15.44	1.08	3.90
15405	924300	3602700	9.70	15.45	1.07	3.90
15420	925200	3603600	9.69	15.45	1.07	3.89
15435	926100	3604500	9.69	15.45	1.07	3.89
15450	927000	3605400	9.69	15.46	1.06	3.89
15465	927900	3606300	9.69	15.46	1.06	3.89
15480	928800	3607200	9.68	15.47	1.05	3.88
15495	929700	3608100	9.68	15.47	1.05	3.88
15510	930600	3609000	9.68	15.47	1.05	3.88
15525	931500	3609900	9.68	15.47	1.05	3.88
15540	932400	3610800	9.68	15.47	1.05	3.87
15555	933300	3611700	9.67	15.48	1.04	3.87
15570	934200	3612600	9.67	15.48	1.04	3.87
15585	935100	3613500	9.67	15.48	1.04	3.86
15600	936000	3614400	9.65	15.49	1.03	3.86
15615	936900	3615300	9.65	15.49	1.03	3.86
15630	937800	3616200	9.65	15.49	1.03	3.86
15645	938700	3617100	9.65	15.49	1.03	3.85
15660	939600	3618000	9.65	15.50	1.02	3.85
15675	940500	3618900	9.64	15.50	1.02	3.85
15690	941400	3619800	9.64	15.50	1.02	3.85
15705	942300	3620700	9.63	15.51	1.01	3.84
15720	943200	3621600	9.63	15.52	1.00	3.84
15735	944100	3622500	9.64	15.51	1.01	3.84

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
15750	945000	3623400	9.63	15.51	1.01	3.83
15765	945900	3624300	9.63	15.51	1.01	3.83
15780	946800	3625200	9.63	15.51	1.01	3.83
15795	947700	3626100	9.63	15.52	1.00	3.83
15810	948600	3627000	9.63	15.52	1.00	3.82
15825	949500	3627900	9.63	15.52	1.00	3.82
15840	950400	3628800	9.63	15.52	1.00	3.82
15855	951300	3629700	9.62	15.53	0.99	3.82
15870	952200	3630600	9.62	15.53	0.99	3.81
15885	953100	3631500	9.63	15.52	1.00	3.81
15900	954000	3632400	9.62	15.53	0.99	3.81
15915	954900	3633300	9.61	15.54	0.98	3.80
15930	955800	3634200	9.61	15.54	0.98	3.80
15945	956700	3635100	9.62	15.53	0.99	3.80
15960	957600	3636000	9.61	15.54	0.98	3.80
15975	958500	3636900	9.61	15.54	0.98	3.79
15990	959400	3637800	9.61	15.54	0.98	3.79
16005	960300	3638700	9.61	15.54	0.98	3.79
16020	961200	3639600	9.60	15.55	0.97	3.79
16035	962100	3640500	9.60	15.55	0.97	3.78
16050	963000	3641400	9.60	15.55	0.97	3.78
16065	963900	3642300	9.58	15.56	0.96	3.78
16080	964800	3643200	9.58	15.56	0.96	3.78
16095	965700	3644100	9.58	15.56	0.96	3.77
16110	966600	3645000	9.58	15.56	0.96	3.77
16125	967500	3645900	9.58	15.56	0.96	3.77
16140	968400	3646800	9.58	15.56	0.96	3.77
16155	969300	3647700	9.58	15.57	0.95	3.76
16170	970200	3648600	9.57	15.57	0.95	3.76
16185	971100	3649500	9.57	15.58	0.94	3.76
16200	972000	3650400	9.56	15.59	0.93	3.76
16215	972900	3651300	9.57	15.58	0.94	3.75
16230	973800	3652200	9.55	15.60	0.92	3.75
16245	974700	3653100	9.56	15.59	0.93	3.75
16260	975600	3654000	9.56	15.59	0.93	3.75
16275	976500	3654900	9.55	15.60	0.92	3.74
16290	977400	3655800	9.54	15.61	0.91	3.74
16305	978300	3656700	9.54	15.61	0.91	3.74
16320	979200	3657600	9.54	15.61	0.91	3.74
16335	980100	3658500	9.54	15.61	0.91	3.73
16350	981000	3659400	9.54	15.61	0.91	3.73
16365	981900	3660300	9.53	15.62	0.90	3.73
16380	982800	3661200	9.54	15.61	0.91	3.73
16395	983700	3662100	9.52	15.63	0.89	3.72
16410	984600	3663000	9.52	15.63	0.89	3.72
16425	985500	3663900	9.52	15.63	0.89	3.72
16440	986400	3664800	9.52	15.63	0.89	3.72
16455	987300	3665700	9.52	15.63	0.89	3.71
16470	988200	3666600	9.52	15.63	0.89	3.71

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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16485	989100	3667500	9.51	15.63	0.89	3.71
16500	990000	3668400	9.51	15.63	0.89	3.71
16515	990900	3669300	9.51	15.64	0.88	3.70
16530	991800	3670200	9.51	15.64	0.88	3.70
16545	992700	3671100	9.51	15.64	0.88	3.70
16560	993600	3672000	9.51	15.64	0.88	3.70
16575	994500	3672900	9.51	15.64	0.88	3.69
16590	995400	3673800	9.51	15.64	0.88	3.69
16605	996300	3674700	9.50	15.65	0.87	3.69
16620	997200	3675600	9.50	15.65	0.87	3.69
16635	998100	3676500	9.50	15.65	0.87	3.68
16650	999000	3677400	9.50	15.65	0.87	3.68
16665	999900	3678300	9.50	15.65	0.87	3.68
16680	1000800	3679200	9.49	15.66	0.86	3.68
16695	1001700	3680100	9.49	15.66	0.86	3.67
16710	1002600	3681000	9.49	15.66	0.86	3.67
16725	1003500	3681900	9.49	15.66	0.86	3.67
16740	1004400	3682800	9.49	15.66	0.86	3.67
16755	1005300	3683700	9.49	15.66	0.86	3.66
16770	1006200	3684600	9.49	15.66	0.86	3.66
16785	1007100	3685500	9.49	15.66	0.86	3.66
16800	1008000	3686400	9.49	15.66	0.86	3.66
16815	1008900	3687300	9.48	15.67	0.85	3.65
16830	1009800	3688200	9.49	15.66	0.86	3.65
16845	1010700	3689100	9.48	15.67	0.85	3.65
16860	1011600	3690000	9.46	15.68	0.84	3.65
16875	1012500	3690900	9.46	15.68	0.84	3.65
16890	1013400	3691800	9.46	15.68	0.84	3.64
16905	1014300	3692700	9.46	15.68	0.84	3.64
16920	1015200	3693600	9.46	15.68	0.84	3.64
16935	1016100	3694500	9.45	15.69	0.83	3.64
16950	1017000	3695400	9.45	15.70	0.82	3.63
16965	1017900	3696300	9.45	15.70	0.82	3.63
16980	1018800	3697200	9.45	15.70	0.82	3.63
16995	1019700	3698100	9.44	15.70	0.82	3.63
17010	1020600	3699000	9.44	15.71	0.81	3.62
17025	1021500	3699900	9.44	15.71	0.81	3.62
17040	1022400	3700800	9.44	15.71	0.81	3.62
17055	1023300	3701700	9.43	15.72	0.80	3.62
17070	1024200	3702600	9.43	15.72	0.80	3.62
17085	1025100	3703500	9.43	15.72	0.80	3.61
17100	1026000	3704400	9.42	15.73	0.79	3.61
17115	1026900	3705300	9.42	15.73	0.79	3.61
17130	1027800	3706200	9.42	15.73	0.79	3.61
17145	1028700	3707100	9.42	15.73	0.79	3.60
17160	1029600	3708000	9.42	15.73	0.79	3.60
17175	1030500	3708900	9.42	15.73	0.79	3.60
17190	1031400	3709800	9.41	15.74	0.78	3.60
17205	1032300	3710700	9.40	15.74	0.78	3.59

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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17220	1033200	3711600	9.40	15.74	0.78	3.59
17235	1034100	3712500	9.40	15.74	0.78	3.59
17250	1035000	3713400	9.40	15.74	0.78	3.59
17265	1035900	3714300	9.40	15.74	0.78	3.59
17280	1036800	3715200	9.39	15.75	0.77	3.58
17295	1037700	3716100	9.39	15.75	0.77	3.58
17310	1038600	3717000	9.39	15.75	0.77	3.58
17325	1039500	3717900	9.39	15.75	0.77	3.58
17340	1040400	3718800	9.39	15.76	0.76	3.57
17355	1041300	3719700	9.39	15.76	0.76	3.57
17370	1042200	3720600	9.39	15.76	0.76	3.57
17385	1043100	3721500	9.38	15.76	0.76	3.57
17400	1044000	3722400	9.39	15.76	0.76	3.57
17415	1044900	3723300	9.38	15.76	0.76	3.56
17430	1045800	3724200	9.38	15.77	0.75	3.56
17445	1046700	3725100	9.38	15.77	0.75	3.56
17460	1047600	3726000	9.38	15.77	0.75	3.56
17475	1048500	3726900	9.38	15.77	0.75	3.55
17490	1049400	3727800	9.38	15.77	0.75	3.55
17505	1050300	3728700	9.37	15.78	0.74	3.55
17520	1051200	3729600	9.37	15.78	0.74	3.55
17535	1052100	3730500	9.37	15.78	0.74	3.55
17550	1053000	3731400	9.36	15.79	0.73	3.54
17565	1053900	3732300	9.36	15.79	0.73	3.54
17580	1054800	3733200	9.36	15.79	0.73	3.54
17595	1055700	3734100	9.36	15.79	0.73	3.54
17610	1056600	3735000	9.36	15.79	0.73	3.53
17625	1057500	3735900	9.35	15.80	0.72	3.53
17640	1058400	3736800	9.35	15.80	0.72	3.53
17655	1059300	3737700	9.36	15.79	0.73	3.53
17670	1060200	3738600	9.35	15.80	0.72	3.53
17685	1061100	3739500	9.35	15.80	0.72	3.52
17700	1062000	3740400	9.35	15.80	0.72	3.52
17715	1062900	3741300	9.33	15.81	0.71	3.52
17730	1063800	3742200	9.34	15.81	0.71	3.52
17745	1064700	3743100	9.34	15.81	0.71	3.52
17760	1065600	3744000	9.34	15.81	0.71	3.51
17775	1066500	3744900	9.33	15.81	0.71	3.51
17790	1067400	3745800	9.34	15.81	0.71	3.51
17805	1068300	3746700	9.33	15.81	0.71	3.51
17820	1069200	3747600	9.32	15.82	0.70	3.51
17835	1070100	3748500	9.32	15.82	0.70	3.50
17850	1071000	3749400	9.33	15.82	0.70	3.50
17865	1071900	3750300	9.32	15.83	0.69	3.50
17880	1072800	3751200	9.32	15.82	0.70	3.50
17895	1073700	3752100	9.31	15.84	0.68	3.49
17910	1074600	3753000	9.32	15.83	0.69	3.49
17925	1075500	3753900	9.32	15.83	0.69	3.49
17940	1076400	3754800	9.32	15.83	0.69	3.49

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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17955	1077300	3755700	9.31	15.84	0.68	3.49
17970	1078200	3756600	9.32	15.83	0.69	3.48
17985	1079100	3757500	9.31	15.84	0.68	3.48
18000	1080000	3758400	9.31	15.84	0.68	3.48
18015	1080900	3759300	9.31	15.84	0.68	3.48
18030	1081800	3760200	9.31	15.84	0.68	3.48
18045	1082700	3761100	9.31	15.84	0.68	3.47
18060	1083600	3762000	9.31	15.84	0.68	3.47
18075	1084500	3762900	9.30	15.85	0.67	3.47
18090	1085400	3763800	9.30	15.85	0.67	3.47
18105	1086300	3764700	9.30	15.85	0.67	3.47
18120	1087200	3765600	9.30	15.85	0.67	3.46
18135	1088100	3766500	9.29	15.86	0.66	3.46
18150	1089000	3767400	9.29	15.86	0.66	3.46
18165	1089900	3768300	9.29	15.86	0.66	3.46
18180	1090800	3769200	9.29	15.86	0.66	3.46
18195	1091700	3770100	9.29	15.86	0.66	3.45
18210	1092600	3771000	9.29	15.86	0.66	3.45
18225	1093500	3771900	9.29	15.86	0.66	3.45
18240	1094400	3772800	9.29	15.86	0.66	3.45
18255	1095300	3773700	9.29	15.86	0.66	3.45
18270	1096200	3774600	9.29	15.86	0.66	3.44
18285	1097100	3775500	9.28	15.87	0.65	3.44
18300	1098000	3776400	9.28	15.87	0.65	3.44
18315	1098900	3777300	9.28	15.87	0.65	3.44
18330	1099800	3778200	9.28	15.87	0.65	3.44
18345	1100700	3779100	9.27	15.87	0.65	3.43
18360	1101600	3780000	9.27	15.88	0.64	3.43
18375	1102500	3780900	9.26	15.88	0.64	3.43
18390	1103400	3781800	9.27	15.88	0.64	3.43
18405	1104300	3782700	9.26	15.89	0.63	3.43
18420	1105200	3783600	9.26	15.89	0.63	3.42
18435	1106100	3784500	9.26	15.88	0.64	3.42
18450	1107000	3785400	9.26	15.89	0.63	3.42
18465	1107900	3786300	9.25	15.90	0.62	3.42
18480	1108800	3787200	9.25	15.90	0.62	3.42
18495	1109700	3788100	9.25	15.90	0.62	3.41
18510	1110600	3789000	9.25	15.90	0.62	3.41
18525	1111500	3789900	9.25	15.90	0.62	3.41
18540	1112400	3790800	9.25	15.90	0.62	3.41
18555	1113300	3791700	9.25	15.90	0.62	3.41
18570	1114200	3792600	9.25	15.90	0.62	3.40
18585	1115100	3793500	9.24	15.91	0.61	3.40
18600	1116000	3794400	9.24	15.91	0.61	3.40
18615	1116900	3795300	9.24	15.91	0.61	3.40
18630	1117800	3796200	9.24	15.91	0.61	3.40
18645	1118700	3797100	9.23	15.92	0.60	3.39
18660	1119600	3798000	9.23	15.92	0.60	3.39
18675	1120500	3798900	9.23	15.92	0.60	3.39

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18690	1121400	3799800	9.23	15.92	0.60	3.39
18705	1122300	3800700	9.22	15.93	0.59	3.39
18720	1123200	3801600	9.23	15.92	0.60	3.38
18735	1124100	3802500	9.23	15.92	0.60	3.38
18750	1125000	3803400	9.23	15.92	0.60	3.38
18765	1125900	3804300	9.22	15.93	0.59	3.38
18780	1126800	3805200	9.21	15.93	0.59	3.38
18795	1127700	3806100	9.20	15.94	0.58	3.38
18810	1128600	3807000	9.21	15.93	0.59	3.37
18825	1129500	3807900	9.20	15.94	0.58	3.37
18840	1130400	3808800	9.20	15.94	0.58	3.37
18855	1131300	3809700	9.20	15.94	0.58	3.37
18870	1132200	3810600	9.20	15.95	0.57	3.37
18885	1133100	3811500	9.19	15.95	0.57	3.36
18900	1134000	3812400	9.19	15.95	0.57	3.36
18915	1134900	3813300	9.19	15.95	0.57	3.36
18930	1135800	3814200	9.19	15.95	0.57	3.36
18945	1136700	3815100	9.19	15.95	0.57	3.36
18960	1137600	3816000	9.19	15.95	0.57	3.35
18975	1138500	3816900	9.19	15.95	0.57	3.35
18990	1139400	3817800	9.19	15.96	0.56	3.35
19005	1140300	3818700	9.19	15.96	0.56	3.35
19020	1141200	3819600	9.19	15.96	0.56	3.35
19035	1142100	3820500	9.19	15.96	0.56	3.35
19050	1143000	3821400	9.19	15.96	0.56	3.34
19065	1143900	3822300	9.19	15.96	0.56	3.34
19080	1144800	3823200	9.19	15.96	0.56	3.34
19095	1145700	3824100	9.19	15.96	0.56	3.34
19110	1146600	3825000	9.19	15.96	0.56	3.34
19125	1147500	3825900	9.18	15.97	0.55	3.33
19140	1148400	3826800	9.17	15.98	0.54	3.33
19155	1149300	3827700	9.17	15.98	0.54	3.33
19170	1150200	3828600	9.17	15.98	0.54	3.33
19185	1151100	3829500	9.17	15.98	0.54	3.33
19200	1152000	3830400	9.17	15.98	0.54	3.32
19215	1152900	3831300	9.16	15.99	0.53	3.32
19230	1153800	3832200	9.15	16.00	0.52	3.32
19245	1154700	3833100	9.15	15.99	0.53	3.32
19260	1155600	3834000	9.15	15.99	0.53	3.32
19275	1156500	3834900	9.15	16.00	0.52	3.32
19290	1157400	3835800	9.16	15.99	0.53	3.31
19305	1158300	3836700	9.14	16.00	0.52	3.31
19320	1159200	3837600	9.15	16.00	0.52	3.31
19335	1160100	3838500	9.15	15.99	0.53	3.31
19350	1161000	3839400	9.15	16.00	0.52	3.31
19365	1161900	3840300	9.13	16.01	0.51	3.31
19380	1162800	3841200	9.14	16.00	0.52	3.30
19395	1163700	3842100	9.13	16.01	0.51	3.30
19410	1164600	3843000	9.13	16.01	0.51	3.30

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Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
19425	1165500	3843900	9.13	16.01	0.51	3.30
19440	1166400	3844800	9.13	16.01	0.51	3.30
19455	1167300	3845700	9.13	16.01	0.51	3.29
19470	1168200	3846600	9.13	16.01	0.51	3.29
19485	1169100	3847500	9.13	16.01	0.51	3.29
19500	1170000	3848400	9.13	16.02	0.50	3.29
19515	1170900	3849300	9.13	16.01	0.51	3.29
19530	1171800	3850200	9.13	16.02	0.50	3.29
19545	1172700	3851100	9.13	16.02	0.50	3.28
19560	1173600	3852000	9.13	16.02	0.50	3.28
19575	1174500	3852900	9.12	16.03	0.49	3.28
19590	1175400	3853800	9.13	16.02	0.50	3.28
19605	1176300	3854700	9.13	16.02	0.50	3.28
19620	1177200	3855600	9.11	16.04	0.48	3.28
19635	1178100	3856500	9.11	16.04	0.48	3.27
19650	1179000	3857400	9.12	16.03	0.49	3.27
19665	1179900	3858300	9.11	16.04	0.48	3.27
19680	1180800	3859200	9.11	16.04	0.48	3.27
19695	1181700	3860100	9.11	16.04	0.48	3.27
19710	1182600	3861000	9.11	16.04	0.48	3.26
19725	1183500	3861900	9.11	16.04	0.48	3.26
19740	1184400	3862800	9.11	16.04	0.48	3.26
19755	1185300	3863700	9.11	16.04	0.48	3.26
19770	1186200	3864600	9.11	16.04	0.48	3.26
19785	1187100	3865500	9.10	16.05	0.47	3.26
19800	1188000	3866400	9.11	16.04	0.48	3.25
19815	1188900	3867300	9.10	16.05	0.47	3.25
19830	1189800	3868200	9.10	16.05	0.47	3.25
19845	1190700	3869100	9.09	16.06	0.46	3.25
19860	1191600	3870000	9.10	16.05	0.47	3.25
19875	1192500	3870900	9.10	16.05	0.47	3.25
19890	1193400	3871800	9.09	16.06	0.46	3.24
19905	1194300	3872700	9.09	16.06	0.46	3.24
19920	1195200	3873600	9.09	16.06	0.46	3.24
19935	1196100	3874500	9.08	16.07	0.45	3.24
19950	1197000	3875400	9.08	16.06	0.46	3.24
19965	1197900	3876300	9.07	16.07	0.45	3.24
19980	1198800	3877200	9.08	16.07	0.45	3.23
19995	1199700	3878100	9.07	16.07	0.45	3.23
20010	1200600	3879000	9.07	16.07	0.45	3.23
20025	1201500	3879900	9.07	16.08	0.44	3.23
20040	1202400	3880800	9.07	16.08	0.44	3.23
20055	1203300	3881700	9.07	16.08	0.44	3.23
20070	1204200	3882600	9.07	16.08	0.44	3.22
20085	1205100	3883500	9.06	16.09	0.43	3.22
20100	1206000	3884400	9.06	16.09	0.43	3.22
20115	1206900	3885300	9.06	16.09	0.43	3.22
20130	1207800	3886200	9.07	16.08	0.44	3.22
20145	1208700	3887100	9.06	16.09	0.43	3.22

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Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
20160	1209600	3888000	9.06	16.09	0.43	3.21
20175	1210500	3888900	9.06	16.09	0.43	3.21
20190	1211400	3889800	9.06	16.09	0.43	3.21
20205	1212300	3890700	9.05	16.10	0.42	3.21
20220	1213200	3891600	9.05	16.10	0.42	3.21
20235	1214100	3892500	9.04	16.11	0.41	3.21
20250	1215000	3893400	9.04	16.11	0.41	3.20
20265	1215900	3894300	9.04	16.11	0.41	3.20
20280	1216800	3895200	9.04	16.11	0.41	3.20
20295	1217700	3896100	9.04	16.11	0.41	3.20
20310	1218600	3897000	9.04	16.11	0.41	3.20
20325	1219500	3897900	9.04	16.11	0.41	3.20
20340	1220400	3898800	9.04	16.11	0.41	3.19
20355	1221300	3899700	9.03	16.12	0.40	3.19
20370	1222200	3900600	9.03	16.12	0.40	3.19
20385	1223100	3901500	9.03	16.12	0.40	3.19
20400	1224000	3902400	9.02	16.12	0.40	3.19
20415	1224900	3903300	9.02	16.13	0.39	3.19
20430	1225800	3904200	9.02	16.12	0.40	3.19
20445	1226700	3905100	9.01	16.13	0.39	3.18
20460	1227600	3906000	9.01	16.14	0.38	3.18
20475	1228500	3906900	9.01	16.13	0.39	3.18
20490	1229400	3907800	9.01	16.14	0.38	3.18
20505	1230300	3908700	9.01	16.14	0.38	3.18
20520	1231200	3909600	9.00	16.15	0.37	3.18
20535	1232100	3910500	9.01	16.14	0.38	3.17
20550	1233000	3911400	9.01	16.14	0.38	3.17
20565	1233900	3912300	9.01	16.14	0.38	3.17
20580	1234800	3913200	9.01	16.14	0.38	3.17
20595	1235700	3914100	9.01	16.14	0.38	3.17
20610	1236600	3915000	9.00	16.15	0.37	3.17
20625	1237500	3915900	9.00	16.15	0.37	3.16
20640	1238400	3916800	8.99	16.16	0.36	3.16
20655	1239300	3917700	8.99	16.16	0.36	3.16
20670	1240200	3918600	8.98	16.17	0.35	3.16
20685	1241100	3919500	8.99	16.16	0.36	3.16
20700	1242000	3920400	8.98	16.17	0.35	3.16
20715	1242900	3921300	8.98	16.17	0.35	3.15
20730	1243800	3922200	8.98	16.17	0.35	3.15
20745	1244700	3923100	8.98	16.17	0.35	3.15
20760	1245600	3924000	8.98	16.17	0.35	3.15
20775	1246500	3924900	8.98	16.17	0.35	3.15
20790	1247400	3925800	8.98	16.17	0.35	3.15
20805	1248300	3926700	8.98	16.17	0.35	3.15
20820	1249200	3927600	8.99	16.16	0.36	3.14
20835	1250100	3928500	8.98	16.17	0.35	3.14
20850	1251000	3929400	8.97	16.18	0.34	3.14
20865	1251900	3930300	8.98	16.17	0.35	3.14
20880	1252800	3931200	8.97	16.18	0.34	3.14

The Oak Ridges Moraine: Evaluation of groundwater resources in the Uxbridge area

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20895	1253700	3932100	8.97	16.18	0.34	3.14
20910	1254600	3933000	8.97	16.18	0.34	3.13
20925	1255500	3933900	8.97	16.18	0.34	3.13
20940	1256400	3934800	8.97	16.18	0.34	3.13
20955	1257300	3935700	8.97	16.18	0.34	3.13
20970	1258200	3936600	8.97	16.18	0.34	3.13
20985	1259100	3937500	8.97	16.18	0.34	3.13
21000	1260000	3938400	8.97	16.18	0.34	3.13
21015	1260900	3939300	8.97	16.18	0.34	3.12
21030	1261800	3940200	8.97	16.18	0.34	3.12
21045	1262700	3941100	8.97	16.18	0.34	3.12
21060	1263600	3942000	8.97	16.18	0.34	3.12
21075	1264500	3942900	8.96	16.19	0.33	3.12
21090	1265400	3943800	8.96	16.18	0.34	3.12
21105	1266300	3944700	8.96	16.19	0.33	3.12
21120	1267200	3945600	8.96	16.19	0.33	3.11
21135	1268100	3946500	8.96	16.19	0.33	3.11
21150	1269000	3947400	8.96	16.19	0.33	3.11
21165	1269900	3948300	8.96	16.19	0.33	3.11
21180	1270800	3949200	8.96	16.19	0.33	3.11
21195	1271700	3950100	8.94	16.20	0.32	3.11
21210	1272600	3951000	8.95	16.19	0.33	3.10
21225	1273500	3951900	8.95	16.20	0.32	3.10
21240	1274400	3952800	8.94	16.20	0.32	3.10
21255	1275300	3953700	8.95	16.19	0.33	3.10
21270	1276200	3954600	8.95	16.19	0.33	3.10
21285	1277100	3955500	8.95	16.20	0.32	3.10
21300	1278000	3956400	8.95	16.19	0.33	3.10
21315	1278900	3957300	8.94	16.20	0.32	3.09
21330	1279800	3958200	8.95	16.20	0.32	3.09
21345	1280700	3959100	8.95	16.20	0.32	3.09
21360	1281600	3960000	8.94	16.20	0.32	3.09
21375	1282500	3960900	8.95	16.20	0.32	3.09
21390	1283400	3961800	8.94	16.20	0.32	3.09
21405	1284300	3962700	8.94	16.21	0.31	3.09
21420	1285200	3963600	8.95	16.20	0.32	3.08
21435	1286100	3964500	8.95	16.20	0.32	3.08
21450	1287000	3965400	8.94	16.21	0.31	3.08
21465	1287900	3966300	8.94	16.21	0.31	3.08
21480	1288800	3967200	8.94	16.21	0.31	3.08
21495	1289700	3968100	8.94	16.20	0.32	3.08
21510	1290600	3969000	8.94	16.21	0.31	3.08
21525	1291500	3969900	8.94	16.21	0.31	3.07
21540	1292400	3970800	8.94	16.21	0.31	3.07
21555	1293300	3971700	8.94	16.21	0.31	3.07
21570	1294200	3972600	8.94	16.21	0.31	3.07
21585	1295100	3973500	8.94	16.21	0.31	3.07
21600	1296000	3974400	8.94	16.21	0.31	3.07
21615	1296900	3975300	8.94	16.21	0.31	3.07

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21630	1297800	3976200	8.93	16.22	0.30	3.06
21645	1298700	3977100	8.94	16.21	0.31	3.06
21660	1299600	3978000	8.93	16.22	0.30	3.06
21675	1300500	3978900	8.94	16.21	0.31	3.06
21690	1301400	3979800	8.93	16.22	0.30	3.06
21705	1302300	3980700	8.92	16.23	0.29	3.06
21720	1303200	3981600	8.92	16.23	0.29	3.06
21735	1304100	3982500	8.93	16.22	0.30	3.05
21750	1305000	3983400	8.93	16.22	0.30	3.05
21765	1305900	3984300	8.93	16.22	0.30	3.05
21780	1306800	3985200	8.93	16.22	0.30	3.05
21795	1307700	3986100	8.93	16.22	0.30	3.05
21810	1308600	3987000	8.93	16.22	0.30	3.05
21825	1309500	3987900	8.92	16.23	0.29	3.05
21840	1310400	3988800	8.92	16.23	0.29	3.04
21855	1311300	3989700	8.91	16.24	0.28	3.04
21870	1312200	3990600	8.92	16.23	0.29	3.04
21885	1313100	3991500	8.92	16.23	0.29	3.04
21900	1314000	3992400	8.92	16.23	0.29	3.04
21915	1314900	3993300	8.92	16.23	0.29	3.04
21930	1315800	3994200	8.92	16.23	0.29	3.04
21945	1316700	3995100	8.92	16.23	0.29	3.03
21960	1317600	3996000	8.91	16.24	0.28	3.03
21975	1318500	3996900	8.91	16.24	0.28	3.03
21990	1319400	3997800	8.91	16.24	0.28	3.03
22005	1320300	3998700	8.91	16.24	0.28	3.03
22020	1321200	3999600	8.90	16.25	0.27	3.03
22035	1322100	4000500	8.90	16.24	0.28	3.03
22050	1323000	4001400	8.90	16.24	0.28	3.02
22065	1323900	4002300	8.90	16.24	0.28	3.02
22080	1324800	4003200	8.90	16.24	0.28	3.02
22095	1325700	4004100	8.90	16.24	0.28	3.02
22110	1326600	4005000	8.89	16.25	0.27	3.02
22125	1327500	4005900	8.89	16.25	0.27	3.02
22140	1328400	4006800	8.89	16.25	0.27	3.02
22155	1329300	4007700	8.90	16.24	0.28	3.01
22170	1330200	4008600	8.91	16.24	0.28	3.01
22185	1331100	4009500	8.90	16.24	0.28	3.01
22200	1332000	4010400	8.89	16.25	0.27	3.01
22215	1332900	4011300	8.89	16.25	0.27	3.01
22230	1333800	4012200	8.90	16.24	0.28	3.01
22245	1334700	4013100	8.90	16.25	0.27	3.01
22260	1335600	4014000	8.90	16.25	0.27	3.01
22275	1336500	4014900	8.89	16.25	0.27	3.00
22290	1337400	4015800	8.89	16.25	0.27	3.00
22305	1338300	4016700	8.89	16.25	0.27	3.00
22320	1339200	4017600	8.89	16.25	0.27	3.00
22335	1340100	4018500	8.89	16.26	0.26	3.00
22350	1341000	4019400	8.88	16.26	0.26	3.00

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22365	1341900	4020300	8.88	16.26	0.26	3.00
22380	1342800	4021200	8.88	16.26	0.26	2.99
22395	1343700	4022100	8.88	16.26	0.26	2.99
22410	1344600	4023000	8.88	16.26	0.26	2.99
22425	1345500	4023900	8.88	16.26	0.26	2.99
22440	1346400	4024800	8.88	16.27	0.25	2.99
22455	1347300	4025700	8.88	16.26	0.26	2.99
22470	1348200	4026600	8.88	16.26	0.26	2.99
22485	1349100	4027500	8.88	16.26	0.26	2.99
22500	1350000	4028400	8.88	16.26	0.26	2.98
22515	1350900	4029300	8.88	16.26	0.26	2.98
22530	1351800	4030200	8.88	16.27	0.25	2.98
22545	1352700	4031100	8.88	16.27	0.25	2.98
22560	1353600	4032000	8.87	16.28	0.24	2.98
22575	1354500	4032900	8.87	16.28	0.24	2.98
22590	1355400	4033800	8.88	16.27	0.25	2.98
22605	1356300	4034700	8.86	16.29	0.23	2.97
22620	1357200	4035600	8.87	16.28	0.24	2.97
22635	1358100	4036500	8.87	16.28	0.24	2.97
22650	1359000	4037400	8.86	16.29	0.23	2.97
22665	1359900	4038300	8.86	16.29	0.23	2.97
22680	1360800	4039200	8.86	16.29	0.23	2.97
22695	1361700	4040100	8.87	16.28	0.24	2.97
22710	1362600	4041000	8.87	16.28	0.24	2.97
22725	1363500	4041900	8.86	16.29	0.23	2.96
22740	1364400	4042800	8.86	16.29	0.23	2.96
22755	1365300	4043700	8.86	16.29	0.23	2.96
22770	1366200	4044600	8.86	16.29	0.23	2.96
22785	1367100	4045500	8.86	16.29	0.23	2.96
22800	1368000	4046400	8.86	16.29	0.23	2.96
22815	1368900	4047300	8.86	16.29	0.23	2.96
22830	1369800	4048200	8.86	16.29	0.23	2.96
22845	1370700	4049100	8.86	16.29	0.23	2.95
22860	1371600	4050000	8.85	16.30	0.22	2.95
22875	1372500	4050900	8.85	16.30	0.22	2.95
22890	1373400	4051800	8.85	16.30	0.22	2.95
22905	1374300	4052700	8.85	16.30	0.22	2.95
22920	1375200	4053600	8.85	16.30	0.22	2.95
22935	1376100	4054500	8.84	16.31	0.21	2.95
22950	1377000	4055400	8.84	16.31	0.21	2.95
22965	1377900	4056300	8.84	16.31	0.21	2.94
22980	1378800	4057200	8.85	16.30	0.22	2.94
22995	1379700	4058100	8.84	16.31	0.21	2.94
23010	1380600	4059000	8.83	16.31	0.21	2.94
23025	1381500	4059900	8.84	16.31	0.21	2.94
23040	1382400	4060800	8.83	16.31	0.21	2.94
23055	1383300	4061700	8.83	16.31	0.21	2.94
23070	1384200	4062600	8.83	16.31	0.21	2.93
23085	1385100	4063500	8.82	16.32	0.20	2.93

The Oak Ridges Moraine: Estimation of groundwater resources in the Uxbridge area

Elapsed Time, min	Elapsed Time, t', s	Time since Pumping Started, t, s	Depth to Water, m	Recovery, m	Residual Drawdown, m	Ratio, t/t'
23100	1386000	4064400	8.82	16.33	0.19	2.93
23115	1386900	4065300	8.82	16.33	0.19	2.93
23130	1387800	4066200	8.82	16.32	0.20	2.93
23145	1388700	4067100	8.82	16.32	0.20	2.93
23160	1389600	4068000	8.82	16.32	0.20	2.93
23175	1390500	4068900	8.81	16.34	0.18	2.93
23190	1391400	4069800	8.82	16.33	0.19	2.92
23205	1392300	4070700	8.82	16.33	0.19	2.92
23220	1393200	4071600	8.82	16.33	0.19	2.92
23235	1394100	4072500	8.82	16.33	0.19	2.92
23250	1395000	4073400	8.82	16.33	0.19	2.92
23265	1395900	4074300	8.81	16.34	0.18	2.92
23280	1396800	4075200	8.81	16.34	0.18	2.92
23295	1397700	4076100	8.81	16.34	0.18	2.92
23310	1398600	4077000	8.81	16.34	0.18	2.92
23325	1399500	4077900	8.80	16.35	0.17	2.91
23340	1400400	4078800	8.81	16.34	0.18	2.91
23355	1401300	4079700	8.81	16.34	0.18	2.91
23370	1402200	4080600	8.82	16.33	0.19	2.91
23385	1403100	4081500	8.81	16.34	0.18	2.91
23400	1404000	4082400	8.80	16.35	0.17	2.91