APPENDIX C
Characterization Update – Rockwood and Hamilton Drive

CITY OF GUELPH AND TOWNSHIP OF GUELPH/ERAMOSA
TIER THREE WATER BUDGET AND LOCAL AREA RISK ASSESSMENT

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CHARACTERIZATION UPDATE - ROCKWOOD AND HAMILTON DRIVE

Report Prepared for:
LAKE ERIE SOURCE PROTECTION REGION

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CHARACTERIZATION UPDATE - ROCKWOOD AND HAMILTON DRIVE

Report prepared for Lake Erie Source Protection Region, March 2017

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We certify that this report is accurate and complete and accords with the information available during the site investigation. Information obtained during the site investigation or provided by third parties is believed to be accurate but is not guaranteed. We have exercised reasonable skill, care and diligence in assessing the information obtained during the preparation of this report.

This report was prepared for the Lake Erie Source Protection Region under contract with the City of Guelph. The report may not be relied upon by any other person or entity without our written consent and that of the City of Guelph. Any uses of this report by a third party, or any reliance on decisions made based on it, are the responsibility of that party. We are not responsible for damages or injuries incurred by any third party, as a result of decisions made or actions taken based on this report.

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1 INTRODUCTION

The Lake Erie Source Protection Region is undertaking a Tier Three Water Budget and Local Area Risk Assessment (Tier Three Assessment) for the municipal drinking water supplies of the City of Guelph and the Township of Guelph/Eramosa (in Rockwood and Hamilton Drive). A Tier Two Water Quantity Stress Assessment (Tier Two Assessment) was completed for the Grand River Watershed (AquaResource 2009a) as part of the *Clean Water Act* Technical Assessment process (Government of Ontario 2017). The Upper Speed River and Eramosa River Subwatersheds were identified in the Tier Two Assessment as having a Moderate potential for groundwater and surface water quantity stress; thus, a Tier Three Assessment is required for all municipal drinking water supplied located within these subwatersheds, which includes those in the City of Guelph and the Township of Guelph/Eramosa (in Rockwood and Hamilton Drive).

This report provides a characterization update for the Rockwood and Hamilton Drive areas, as the characterization report for the City of Guelph municipal wells was completed separately (Appendix A).

1.1 Previous and Concurrent Studies

A number of regional- and local-scale groundwater studies have been carried out, or are currently underway, within the Study Area (Appendix C1, Figure 1-1). These studies provided information on the geology and hydrogeology of the area and are summarized below.

1.1.1 Existing Conceptual Geologic and Hydrogeologic Models

The following list outlines some of the conceptual models that have been developed at various scales within and surrounding the Study Area:

- Overburden and bedrock geology studies. Numerous studies describe the Quaternary and bedrock geology in the Study Area. These include Belanger et al. (2006), Brunton et al. (2005), Brunton et al. (2006), Brunton (2008, 2009), Burt and Webb (2013), Cole et al. (2009), Gao (2011), Greenhouse and Karrow (1994), Karrow (1967, 1987), Lee et al. (2011), and McKenzie (1990).

- Ontario Geologic Survey (OGS) Conceptual Model (Brunton and Brintnell 2011). This regional scale conceptual model interpreted the subsurface bedrock layers through interpretation of outcrop and corehole observations along the Niagara Escarpment and west through the City of Guelph and the Township of Guelph/Eramosa.

- Subwatershed-Scale Tier Two Water Budget Conceptual Model (AquaResource 2009a). This conceptual model was refined from that developed by Waterloo Hydrogeologic Inc. (WHI 2005) and comprises 13 primary hydrostratigraphic units (five overburden and eight bedrock).

- Hydrostratigraphic Model of the Regional Municipality of Waterloo (Bajc and Shirota 2007). This conceptual model was developed by the OGS in the neighbouring Regional Municipality of Waterloo and identified 19 overburden stratigraphic units, 10 of which were found to be regionally significant.

- Halton Hills Tier Three Water Budget Conceptual Model (AECOM and AquaResource 2012a). This conceptual model was developed in the neighbouring Halton Hills area within the Region of Halton. The conceptual model identified eight overburden units and eight bedrock units.

1.1.2 Watershed and Subwatershed Scale Water Resources Studies

The following list outlines some of the surface water and groundwater studies that have relevant input into the development of the conceptual hydrogeological model:

- *Guelph/Eramosa Township Regional Groundwater Characterization and Wellhead Protection Study* (Gartner Lee 2004). This study characterized the regional groundwater and aquifer systems, completed a groundwater susceptibility analysis, assessed groundwater use, identified contamination sources, and modelled and mapped Wellhead Protection Areas (WHPAs) in the Township of Guelph/Eramosa.

- *Guelph-Puslinch Groundwater Protection Study* (Golder 2006a). This study characterized the regional groundwater and aquifer systems, completed a groundwater susceptibility analysis, assessed groundwater use, identified contamination sources, and modelled and mapped WPHAs in the City of Guelph and Puslinch Township.

- *Wellington County Groundwater Protection Study* (Golder 2006b). This study characterized the regional groundwater and aquifer systems, completed a groundwater susceptibility analysis, assessed groundwater use, identified contamination sources, and modelled and mapped wellhead protection areas in Wellington County.

- *City of Guelph Source Protection Project Final Groundwater and Surface Water Vulnerability Report* (AquaResource 2010). This report described the watershed and further characterizes water quality, water quantity, vulnerable areas, and drinking water threats.

1.1.3 Local Scale Municipal Water Resources Studies

Various local studies have been commissioned to help manage groundwater supplies. These reports provide analyses and discussion on the local geology and hydrogeology and groundwater/surface water interactions:

- City of Guelph Quadrant Investigations (Jagger Hims 1995, 1998a, 1998b, 1998c). The quadrant studies examined available geologic and hydrogeologic information for each of the four quadrant areas and summarizes testing conducted at each municipal well to determine its capacity to yield water and water quality at each municipal well.

- *Engineers Report for the Township of Guelph-Eramosa, Rockwood Water Supply System* (Burnside 2001). This report provided a description of the Township of Guelph/Eramosa's municipal system located in Rockwood and included an assessment of operational procedures, as well as water quality and recommendations for a monitoring program.

- Groundwater Under Direct Influence (GUDI) of Surface Water Studies in Rockwood and Hamilton Drive (Burnside 2002a, 2002b). These studies characterized the local groundwater and aquifer systems of Rockwood and Hamilton Drive and examined potential connections of the groundwater system to surface water features.

- *Rockwood Environmental Assessment, Hydrogeologic Report, Construction and Testing of TW3/02, Proposed Rockwood Well 3* (Burnside 2002c). This study documented the exploration, well construction and testing of Rockwood Well 3 that was proposed as a new municipal water supply source as part of a Class Environmental Assessment. The report was submitted to support the Permit to Take Water (PTTW) application for the TW3/02 well site.

1.1.4 Numerical Groundwater Modelling Studies

Several groundwater models have been developed within the Study Area. Each model was designed to improve the understanding of different portions of the groundwater system and/or the interaction between the groundwater flow system and surface water features. The following list summarizes the groundwater flow models completed within the Study Area:

- *Guelph/Eramosa Township Regional Groundwater Characterization and Wellhead Protection Study* (Gartner Lee 2004). This study used FEFLOW and MODFLOW for WHPA modelling at municipal wells in the Township of Guelph/Eramosa.

- *Guelph-Puslinch Groundwater Protection Study* (Golder 2006a). This study used FEFLOW for WHPA modelling at municipal wells in the City of Guelph and Puslinch Township.

- *Wellington County Groundwater Protection Study* (Golder 2006b). This study used MODFLOW for WHPA modelling at municipal wells in the County of Wellington.

- *City of Guelph Source Protection Project Final Groundwater and Surface Water Vulnerability Report* (AquaResource 2010). This study involved mapping vulnerability in WHPA zones for municipal wells in the City of Guelph. A preliminary version of the numerical model constructed for the Tier Three Assessment (Appendix B) was used for this study.

- *Halton Hills Tier Three Water Budget and Water Quantity Risk Level Assessment Model Development and Calibration Report* (AECOM and AquaResource 2012b). This study used FEFLOW and MIKE SHE for completing Water Quantity Risk Assessments at municipal wells in the Town of Halton Hills.

1.2 Report Outline

This report is organized into the following sections:

Section 1: Introduction: The framework for this study is described. This includes a brief review of relevant studies that have been undertaken or are underway in the Study Area.

Section 2: Physical Setting: This section describes the Study Area and includes descriptions of each community and the surrounding topography, physiography, surface water features, bedrock and overburden geology, and conceptual hydrostratigraphy.

Section 3: Water Demands and Monitoring: The municipal water supply systems and non-municipal permitted groundwater demands within the Study Area are described. This section also outlines water level monitoring.

Section 4: Summary

Section 5: References

2 PHYSICAL SETTING

2.1 Study Area

The Study Area is located in southwestern Ontario, within the northeastern part of the Grand River Watershed and the southern part of Wellington County (Figure 1-1). Rockwood and Hamilton Drive are located within the Township of Guelph/Eramosa, which makes up part of Wellington County. The Township also includes the communities of Eden Mills, Everton, Oustic, Marden, and Ariss.

The Township of Guelph/Eramosa encompasses the west, north, and east sides of the City of Guelph. Other townships, towns, or cities surrounding the Township of Guelph/Eramosa include the City of Guelph, the Township of Centre-Wellington, the Town of Erin, the Town of Halton Hills, the Town of Milton, and the Township of Puslinch (Figure 1-1). The Township of Guelph/Eramosa is home to just over 12,300 residents (Statistics Canada 2012a) and land use is dominated by agriculture (Appendix A).

The areas of interest that were the focus for the characterization for both Rockwood and Hamilton Drive are illustrated on Figure 1-1. Each of these settlements is described in greater detail below.

2.1.1 Hamilton Drive

Hamilton Drive is a subdivision of approximately 825 residents (Gartner Lee 2004), located just outside of the City of Guelph boundary. It is bounded to the south by Highway 6, to the north by Victoria Street, to the east by the Speed River, and to the west by Conservation Road (Figure 2-1). It is located west of the Speed River but within the central portion of the Speed River basin. The Speed River flows along the east side of the community, from Guelph Lake, and ultimately drains south into the Grand River.

The Hamilton Drive water system consists of two municipal groundwater wells (Huntington Estates and Cross Creek wells), two pump houses, one water tower, and a distribution system (MOE 2012a). At each pump house, there is one well and an in-ground reservoir. This system is a demand/storage system; once the storage systems are at capacity, pumping ceases until the water level drops in the tower (MOE 2012a).

The Huntington and Cross Creek wells are completed in a deep, semi-confined, lower bedrock aquifer. The location of the municipal supply wells and the surrounding land use are illustrated on Figure 2-1. Land use in the Hamilton Drive is classified as “Built-up Impervious,” representing the residential subdivision. Land uses surrounding the community is dominated by “Undifferentiated” (i.e., agriculture) and wetland uses. The Huntington Well is located on the northern end of the subdivision, approximately 225 m from the Speed River. The Cross Creek Well is positioned approximately 760 m southwest of the Huntington Well, along Cross Creek Boulevard and located approximately 435 m from the Speed River.

2.1.2 Rockwood

Rockwood is located approximately 7.5 km northeast of the City of Guelph along the Eramosa River (Figures 1-1 and 2-2). Rockwood is more developed than Hamilton Drive with a population of approximately 3,870 people (Statistics Canada 2012b).

Rockwood is serviced by three municipal groundwater wells completed in the limestone bedrock, a water tower, and distribution system. A fourth municipal well (Rockwood Well 4) has been drilled and a PTTW has been received as part of a consolidated PTTW for the four wells; the well is expected to start production in 2017. The location of the municipal supply wells and the surrounding land use are illustrated on Figure 2-2. Land use within Rockwood is considered “Built-up Area Impervious,” with wetlands and forest features found along the Eramosa River and cross-cutting the village. Areas outside of Rockwood are primarily classified as “Undifferentiated” (i.e., agriculture). Rockwood Well 1 (TW1-67) and Well 2 (TW1-76) are located at the Station Street Pump House in the northwest part of the village, Rockwood Well 3 (TW3/02) is found at the Bernardi Pump House south of the village (MOE 2012b) and Rockwood Well 4 (TW2-14) is found approximately 1.4 km northeast of Rockwood Well 3. The two wells located within the Station Street Pump House are approved to supply water at a maximum daily flow of 1,965 m^3/day and the well located within the Bernardi Pump House is approved to supply water at a maximum daily flow of 1,310 m^3/day. Extracted groundwater is treated with sodium hypochlorite solution (chlorine) and iron sequestering (sodium silicate), which is injected during the pump cycle (MOE 2012b). Rockwood Well 4 has a recommended permitted rate of 1,310 m^3/day (Burnside 2015).

The wells are located in the urbanized portion of Rockwood within 1.5 km of the Eramosa River. Due to the proximity of significant surface water features and bedrock production aquifers outcropping at area watercourses, a significant hydraulic connection to the groundwater zone in the shallow bedrock is observed near Rockwood wells 1 and 2 (Burnside 2001); therefore, these wells are designated as GUDI wells (Burnside 2002a).

2.2 Ground Surface Topography

Ground surface elevation across the Study Area varies from a high of approximately 460 m above sea level (asl) northwest of Rockwood, to 320 m asl along the base of the Eramosa and Speed River valleys south of Rockwood and Hamilton Drive, respectively (Figure 2-3).

2.3 Physiography

The Hamilton Drive and Rockwood areas are located within the Guelph Drumlin Field and Horseshoe Moraines physiographic regions (Figure 2-4; Chapman and Putnam 1984).

Hamilton Drive and the western half of Rockwood are located within the Guelph Drumlin Field, which is characterized by a drumlinized till plain with swarms of drumlin and drumlinoid hills. Drumlins are streamlined hills of varying size and morphology that tend to taper on one end. The tapered end of a drumlin indicates the direction of flow during formation. Generally, the drumlins in the Guelph Drumlin Field indicate a southeast direction of flow. Eskers are also present along slightly elevated till plains. One such esker segment is present roughly 3.5 km north of the municipal wells located in Hamilton Drive (Figure 2-4). Near Hamilton Drive and Rockwood, the drumlinized surficial till sheet and overlying esker forms are dissected by a network of spillways and gravel terraces with wetland areas. These low-lying areas tend to be occupied by modern drainage channels.

The Horseshoe Moraines region is composed of a series of recessional moraines encircling the Great Lakes in southwestern Ontario. The Paris, Galt, and Moffat moraines found within the Horseshoe Moraines region near the City of Guelph trend southwest-northeast. The Paris Moraine overlies the eastern half of Rockwood. No recessional moraines are mapped near Hamilton Drive. The Paris Moraine is characterized by till that is dissected by spillways with broad gravel and sand terraces and swampy floors (Chapman and Putnam 1984). These are the same spillway features that dissect the drumlinized till plain of the Guelph Drumlin Field.

2.4 Surface Water Features

There are various smaller rivers, creeks, and other surface water features located within or adjacent to the populated areas of interest in the Study Area. Locating these features and their proximity to municipal water supply wells is an important consideration when identifying possible groundwater-surface water interactions and watercourses that may be sensitive to water takings.

2.4.1 Rivers and Creeks

The Speed and Eramosa rivers are the main drainage features in the Study Area. The Speed River flows southwest along the eastern boundary of Hamilton Drive (Figure 2-5), where it continues to flow south through the City of Guelph. The Eramosa River joins the Speed River some 5 km south of Hamilton Drive. The Speed River is dammed to form Guelph Lake, a small, shallow man-made lake that lies northeast of Hamilton Drive, outside the limits of the City of Guelph (Figure 2-5).

The Eramosa River flows south through Rockwood. Karrow (1967) and Armstrong and Dodge (2007) observed that limestone bedrock is exposed at surface within the Eramosa River valley in this portion of the Study Area. This river turns westward at the confluence with Blue Springs Creek, meanders across the drumlinized till plain between Rockwood and Guelph until joining the Speed River in the City of Guelph, and finally continuing to the Grand River in the City of Cambridge.

The positions of the rivers are thought to be the result of past glacial processes whereby glacial meltwater drained along, and in front of, the glacial ice margin (Karrow 1967). Various smaller rivers and creeks feed the Speed and Eramosa rivers within the Study Area. These include Lutteral Creek and Blue Springs Creek from the east (with gradients of 1.5 to 3.0 m/km) and Marden Creek, Clythe Creek, and Hadati Creek from the west (with gradients of 2.5 to 12.5 m/km; Figure 2-5).

Tributaries of the Eramosa River and Guelph Lake are classified as cold water and cool watercourses (Figure 2-5). Several open water bodies are found in the Study Area including Guelph Lake northeast of Hamilton Drive, ponded sections of the Eramosa River near Rockwood, and lesser water bodies along the Speed River.

2.4.2 Significant Wetland Complexes

Wetland complexes in the Study Area are variable and widespread (Figure 2-5). Surrounding Hamilton Drive and Rockwood are localized wetland complexes: Marden South Complex found north, west, and south of Hamilton Drive; Guelph North-East Complex and Clythe Creek Wetland located east of Hamilton Drive; Crewson's Corners Swamp east of Rockwood; and Eramosa River-Blue Springs Creek Wetland that runs through Rockwood along the Eramosa River and Blue Springs Creek. These complexes rest on fine-grained till complexes (of the Port Stanley and Tavistock Till) within topographic depressions (Karrow 1967).

2.5 Regional Geology and Hydrogeology

To examine groundwater flow conditions and the interaction between the surface water and groundwater flow systems, an understanding of the regional and local subsurface geologic environment is required. The subsurface bedrock geologic setting is described below, followed by a discussion of the distribution and thickness of Quaternary deposits within the Study Area.

2.5.1 Paleozoic Bedrock Geology

Bedrock geology beneath the Study Area consists of Paleozoic limestone, dolostone, and shale formations that overlie deeply buried Precambrian crystalline basement rocks (Armstrong and Carter 2006). Bedrock formations dip regionally to the southwest and record deposition related to sea level changes in a shallow subtropical sea during the Paleozoic Era (approximately 440 to 420 million years ago). The thickest Quaternary-aged overburden sediments are present north of Rockwood following a southwest-northeast trending bedrock channel (Burt and Webb 2013). Near Rockwood, Paleozoic bedrock is found exposed at the surface and forms the streambed along portions of the Eramosa River, where overburden sediment has been completely eroded (Karrow 1967).

Paleozoic bedrock formations that underlie the Study Area are listed in Table 2-1 (listed youngest to oldest) and illustrated on Figure 2-6. The stratigraphic subdivision of Paleozoic bedrock units has been revised by Brunton (2009) since subcrop mapping was released in 2007 (Armstrong and Dodge 2007). Revision focused on redefining the stratigraphic subdivisions within the previously termed Amabel Formation into distinct units (Table 2-1). The characteristics of each bedrock formation within the Study Area are discussed below.

TABLE 2-1 Paleozoic Geology beneath the Hamilton Drive - Rockwood Area

Revised Stratigraphic Subdivisions		Previous Stratigraphic Subdivisions	
Formation	**Member**	**Formation**	**Member**
Guelph Formation	Hanlon Member	Guelph Formation	N/A
	Wellington Member		
Eramosa Formation	Stone Road Member	Amabel Formation	Eramosa Member
	Reformatory Quarry Member		
	Vinemount Member		
Goat Island Formation	Ancaster / Niagara Falls Members		Wiarton / Colpoy / Lions Head Members
Gasport Formation	Gothic Hill Member		
Irondequoit / Rockway / Merritton Formations	N/A	Irondequoit / Reynales Formations	N/A
Cabot Head Formation	N/A	Cabot Head Formation	N/A

Note:
modified from Brunton (2009)

2.5.1.1 Cabot Head Formation

The Cabot Head Formation is characterized by grey-green or maroon stratified shale with lesser sandstone and limestone interbeds (Carter and Armstrong 2010). This formation is thought to record a gradual transition from offshore sea sedimentation to marginal marine environment deposition in response to lowering sea levels during the Early Silurian Period (Johnson et al. 1992). It has variable thickness and ranges from 10 to 39 m thick (Johnson et al. 1992). In the Study Area, the fine-grained Cabot Head shale acts as a regional aquitard on which the active dolostone groundwater system rests. The planar upper contact surface of the Cabot Head Formation appears to be eroded by a regional unconformable surface along the base of the Merritton Formation toward the Algonquin Arch (Carter and Armstrong 2010), which underlies the Study Area.

2.5.1.2 Merritton, Rockway, and Irondequoit Formations

The Merritton Formation (also known as the Fossil Hill Formation) is a lower dolostone bedrock formation resting on the Cabot Head Formation, which records sea level fluctuations and limited siliciclastic sediment availability in the Michigan Basin during the Early Silurian Period. The roughly 1 to 2 m thick Merritton Formation overlies the Cabot Head Formation. The Merritton Formation is a pinkish-brown, finely crystalline dolostone unit with dark shale-rich partings (Armstrong and Carter 2010; Brunton 2009). The greenish-grey coloured fine crystalline argillaceous dolostone of the Rockway Formation (Carter and Armstrong 2010; Brunton 2009) overlies the Merritton Formation. Shale-rich partings are common in the Rockway Formation (Carter and Armstrong 2010; Brunton 2009).

This unit tends to be 1 to 2 m thick across the Study Area. The Merritton and Rockway formations were formerly collectively known as the Reynales Formation (Johnston et al. 1992; Brett et al. 1990) and record the gradual transition from a subtidal to offshore depositional environments (Johnston et al. 1992). The Irondequoit Formation overlies the Rockway Formation and is described as a thickly to medium-bedded crinoidal grainstone (Brunton 2009) deposited in a shallow shoal environment (Johnston et al. 1992). It is approximately 3 m thick throughout the Study Area.

The Early Silurian-aged dolostones of the Merritton, Rockway, and Irondequoit formations have a total thickness of approximately 3 to 5 m in the Study Area. These formations have similar hydraulic properties to the lower portion of the overlying Gasport Formation and can be grouped with the lower Gasport hydrostratigraphic unit (Appendix B).

2.5.1.3 Gasport Formation

The Gasport Formation, previously termed the Amabel Formation (Table 2-1), is characterized by cross-bedded crinoidal grainstone-packstone with reef mound and coquina beds (shell beds; Brunton 2009). Fining-upward cycles have been identified in the Gasport Formation and overlying Goat Island Formation: coarse-grained, fossiliferous, grainstone shoal deposits transition upwards into fine-grained, less fossiliferous, lower energy deposits (Johnston et al. 1992). In the Study Area, the formation varies from approximately 25 m to greater than 70 m in thickness. Increased primary and secondary porosity related to the presence of reef mounds, crinoidal grainstones, coquina beds, and subsequent dissolution features create zones of increased transmissivity within the formation. As such, the Gasport Formation lithostratigraphic unit can be further subdivided into three hydrostratigraphic units based on geophysical response logs, flow logs, aquifer tests, and corehole data collected at borehole locations throughout the Guelph area: upper Gasport, middle Gasport, and lower Gasport zones. This subdivision is thought to best represent the vertical variations in hydraulic properties as related to the increased transmissivity of reef mounds and coquina beds (Appendix B). The three hydrostratigraphic units are described in the following sections.

Lower Gasport Hydrostratigraphic Unit

The lower Gasport Formation tends to consist of a fine-crystalline dolostone that extends across the Study Area and is up to 10 to 20 m in thickness. A lower permeability is interpreted for this unit as it typically does not contain reef mounds or coquina bed zones. For the purposes of this study, and to be consistent with previous hydrogeologic investigations in the region (e.g., Golder 2006a, 2006b; Appendices A and B), the underlying Early Silurian-aged Merritton, Rockway, and Irondequoit formations were grouped with this lower Gasport Formation into a single hydrostratigraphic unit, as they have similar hydrogeological characteristics.

Middle Gasport Hydrostratigraphic Unit

The middle Gasport Formation was previously termed the production zone of the Amabel Formation (or Production Amabel layer). It has an average thickness of 12 m in the City of Guelph and is represented in numerical groundwater flow models as a gently dipping unit of 12 m uniform thickness (Golder 2006b; Appendix B).

A portion of the Gasport Formation is characterized by increased dissolution features, karstic cavities (vugs), and fractures as observed in geophysical response logs, flow profiles, packer tests, and video surveys collected at 28 wells within the City of Guelph (Appendices A and B). A belt of composite reef mound sequences is also noted in the Gasport Formation. This reef complex can be traced from the Middleton Well Field in Cambridge (Jagger Hims 1995), through the former Dolime Quarry (CRA 2009) in the City of Guelph, and northeast of Guelph and in Fergus (Jagger Hims 1995). If the middle Gasport Formation tends to be composed of reef mound lithofacies, enhanced dissolution in the more porous rock of reef structures could account for the preferential development of secondary porosity features observed in this portion of the Gasport Formation.

Upper Gasport Hydrostratigraphic Unit

The upper Gasport Formation resembles the lower Gasport Formation and consists of mainly a fine-crystalline dolostone. It extends across the Study Area with thicknesses ranging from 3 to 40 m. Similar to the lower Gasport Formation, a lower permeability is interpreted for this unit as it typically does not contain reef mounds or coquina bed zones.

2.5.1.4 Goat Island Formation

The Goat Island Formation was not distinguished in previous conceptual models and was grouped with the Amabel Formation (Golder 2006a, 2006b; Brunton 2009). It is generally thin (< 5 m) and pinches out along the top of thick reef mounds preserved in the underlying Gasport Formation.

The Goat Island Formation can be subdivided into two members: the upper Ancaster Member and the underlying Niagara Falls Member (Brunton 2009). The members of the Goat Island Formation record the transition of a shoal depositional environment into a lower energy, deeper basinal environment (Johnston et al. 1992). The Niagara Falls Member is a finely crystalline and cross-laminated crinoidal grainstone with small reef mounds (Brunton 2009). The contact between members tends to be sharp and planar; however, near Cambridge and Guelph, these units are interbedded along their contact surface. The Ancaster Member is described as a grey, chert-rich, finely crystalline / argillaceous dolostone. The frequency of shale beds within the Ancaster Member occasionally increases and the character of the formation is similar to the overlying Vinemount Member of the Eramosa Formation and it may impede groundwater movement.

2.5.1.5 Eramosa Formation

The Eramosa Formation, previously grouped with the Amabel Formation, is characterized by crystalline and argillaceous dolostone. The Eramosa Formation can be further divided into three members (from oldest to youngest): 1) Vinemount Member, 2) Reformatory Quarry Member, and 3) Stone Road Member (Brunton 2009). Each of these members displays differing hydraulic properties. For the purposes of this study, the Vinemount and Reformatory Quarry members were discretely selected. The Stone Road Member has similar hydraulic properties to the Guelph Formation and, as such, was not represented as a separate conceptual model layer (Appendix B). The Vinemount and Reformatory Quarry Members of the Eramosa Formation are described in the following sections.

Vinemount Member

The Vinemount Member is described as a dark grey to black, thinly bedded, fine crystalline, argillaceous dolostone with a petroliferous odour (Brunton 2009). In previous studies in the Study Area, it was mapped as the Eramosa Member of the Amabel Formation (Table 2-1). It tends to be less than 10 m thick and pinches out west of the City of Guelph along the top of thick reef mounds preserved in the underlying Gasport Formation. It is also absent near Rockwood between the Eramosa River and Blue Springs Creek. Because of its distinctive colour, it is commonly identified in water well records as "black shale." This unit records deeper basinal deposition. This fine-grained unit represents an aquitard where present within the Study Area.

Reformatory Quarry Member

The Reformatory Quarry Member, previously grouped with the Eramosa Member of the Amabel Formation (**Table 2-1**), is described as light brown to cream-coloured, pseudonodular, thickly bedded, and coarsely crystalline dolostone that is susceptible to karstification due to uniform fine dolomite crystallinity (Brunton 2009). This unit also often contains mud-rich and microbial mat-bearing sediments that may reduce the vertical permeability across this unit. The thickness of the Reformatory Quarry Member is quite variable across the Study Area; it thins in response to preserved reef mounds in the underlying Gasport Formation.

2.5.1.6 Guelph Formation

The Guelph Formation consists of medium to thickly bedded crinoidal grainstones and wackestones and reef complexes (Brunton 2009). The Guelph Formation is a cream-coloured fossiliferous dolostone that represents an important aquifer in the Hamilton Drive area where it is most often the uppermost bedrock unit along the pre-Quaternary unconformity. In the Study Area, the contact between the Guelph Formation and the underlying Eramosa and/or Gasport formations extends from Guelph to the northeast toward Erin. The contact lies west of Rockwood; therefore, the Guelph Formation is absent in Rockwood. The thickness of the Guelph Formation in the Study Area is quite variable in response to post-depositional erosion. Thick sequences of Guelph Formation of 25 to 40 m are observed in northwest Guelph (Appendix A).

2.5.1.7 Bedrock Surface Topography

A major unconformity separates the Paleozoic bedrock from overlying Quaternary overburden deposits across Ontario. This unconformity represents the period between the deposition of the Paleozoic bedrock and the deposition of overlying Quaternary sediment approximately 200 million years later. During this period, the Paleozoic bedrock surface was exposed and extensively eroded (Johnson et al. 1992). As such, the uppermost portion of bedrock (regardless of unit) is highly weathered and fractured. The bedrock topographic surface reflects the erosion and drainage patterns that were established during that time period.

The bedrock surface illustrated on Figure 2-7 was created using available local borehole logs that describe the depth (metres below ground surface [m bgs]) to the top of the uppermost bedrock strata. Deep overburden wells and some contouring along bedrock valleys were also used to further constrain the top of bedrock surface.

Bedrock topography within the Study Area slopes from north to south and ranges from approximately 420 m asl north of Rockwood, near Erin, to less than 295 m asl in bedrock valleys near Rockwood and Hamilton Drive (Figure 2-7). Significant buried bedrock valleys are present within the Study Area. A major northeast-southwest trending buried valley has been interpreted to extend from the Niagara Escarpment (in the northeast), through Rockwood, toward the City of Guelph (in the southwest). Other northeast-southwest trending valleys can be traced near Hamilton Drive under Guelph Lake and elsewhere in the Guelph area. Valleys tend to be deep (up to 70 m) and form branches of the dendritic Dundas Valley system as described by Eyles et al. (1997) and Gao (2011). Past borehole and geophysical response logging (Greenhouse and Karrow 1994) and recent core (Burt and Webb 2013) collected within the valley-fill sequence near Rockwood Valley indicate these features are infilled with coarse-grained sediment. Previous conceptualizations suggest till infilling the bedrock valleys in the Study Area (Gartner Lee 2004; Golder 2006b; Appendix A).

Based on the current interpretation, there are some inconsistencies between the location, depth, and continuity of buried bedrock valleys between this study and the neighbouring Halton Hills Tier Three study (AECOM and AquaResource 2012a). This should be reviewed in any future updates of the City of Guelph and Township of Guelph/Eramosa Tier Three Assessment and the Halton Hills Tier Three Assessment.

2.5.2 Overburden (Quaternary) Geology

Within the Study Area, overburden units deposited during the Quaternary Period (2 million years before present [ybp] to 10,000 ybp) detail a record of repeated ice advance and retreat of ice lobes that originated from the Erie-Ontario lake basin (Karrow 1967). Evidence of till units as old as Early Wisconsinan exist; however, the majority of the overburden sediments present are Late Wisconsinan fine- and coarse-textured tills and more recent floodplain deposits along the banks of the Speed and Eramosa rivers and their tributaries. **Figure 2-8** illustrates the surficial geology mapped within the Study

Area, and Table 2-2 lists the overburden deposits (from youngest to oldest) as summarized in Appendix A.

TABLE 2-2 Summary of Quaternary Deposits Identified near Hamilton Drive and Rockwood

Age (ybp)	Substage	Glacial Stade/ Interstade	Deposit	Lithology
5,000 to 13,200	Holocene	Holocene / Recent	Modern alluvium	Sand, gravel, silt, clay
			Organic deposits	Clay, silt, muck, marl, peat
13,200 to 14,000	Late Wisconsinan	Mackinaw Interstade	Grand River Outwash	Sand, gravel
			Wentworth Till	Sandy diamict
14,000 to 15,500		Port Bruce Stade	Lacustrine deposits	Silt, clay
			Outwash deposits	Sand, gravel
			Port Stanley Till	Sandy to silty till
15,500 to 18,000		Erie Interstade	Glaciolacustrine deposits, Subaquatic fan deposits (associated with the Orangeville Moraine)	Sand, silt, clay
18,000 to 25,000		Nissouri Stade	Catfish Creek Till	Sandy, stoney till

Identification and correlation of till sheets and their associated stratigraphic order have provided the basis for the reconstruction of the glacial history of the Study Area (Karrow 1967, 1987). Studies use both physical and chemical data from field and laboratory observations to identify and relate stratigraphic units from one location to another. In general, diamict in the Study Area tends to be coarse-grained (silty/sandy) and often represents weak aquitard units. Coarse-grained sand and gravel, deposited in modern alluvium, former shorelines, and glacial outwash material, may form overburden aquifers, especially where such material infills bedrock channel depressions. A summary of the Quaternary glacial history and sedimentary deposits of the Study Area presented by Karrow (1967, 1987) and Barnett (1992) is provided below.

2.5.2.1 Glacial History

During the Early Wisconsinan Period, the Laurentide Ice Sheet was expanding across Ontario following colder climatic conditions. This was followed by warming temperatures in the Middle Wisconsinan Period. In the Hamilton Drive and Rockwood areas, the glacial activity related to Early and Middle Wisconsinan sediments is poorly understood as more recent glacial processes have overprinted and, in most cases, have completely eroded evidence of this time period.

During the Nissouri Stade of the Late Wisconsinan Period, approximately 16,000 to 24,000 ybp, the Laurentide Ice Sheet advanced from the northeast throughout Ontario into the United States, reaching its glacial maximum (Dyke and Prest 1987). A regionally extensive till sheet (Catfish Creek Till) was deposited over much of southern Ontario at this time (Karrow 1988). Topography is interpreted to have had little effect on glacial ice dynamics during this Stade due to the thickness of the ice sheet and the rate of advance (Karrow and Paloschi 1996).

The climate warmed and this led to the onset of the Erie Interstade. During this time, numerous large glacial lakes formed along the margins of the Laurentide Ice Sheet in the Erie and Huron basins with smaller lakes forming on the topographic lows on the surface of the Catfish Creek Till (Karrow 1988). Discontinuous fine-grained lacustrine sediment (silt and clay) was deposited on the surface of the Catfish Creek Till in these smaller glacial lakes, and some of the Maryhill Till sediments record lacustrine conditions (Bajc and Karrow 2004). As the climate cooled, the Huron-Georgian Bay and Erie-Ontario lobes advanced into the region triggering the end of the Erie Interstade and beginning of the Port Bruce Stade.

The Erie-Ontario Lobe advanced into the Study Area and deposited the Port Stanley Till during the Port Bruce Stade. The climate warmed and the ice retreated, ushering in the Mackinaw Interstade, which was characterized by large volumes of glacial meltwater that laid down thick units of coarse-grained glaciofluvial and glaciolacustrine sediments. Subsequent glacial overriding erosion and deposition altered the morphology of these Mackinaw deposits in some areas.

During the late Mackinaw Interstade and early part of the Port Huron Stade, the Erie-Ontario Lobe advanced into the Study Area depositing the Wentworth Till (Karrow 1967). Following this period, the Earth’s climate gradually started to warm, ending the Wisconsinan ice age in the Guelph area. Glacial meltwaters ponded in front of ice margins forming large proglacial lakes. Following retreat of ice from the Study Area, fluvial processes continued to shape the landscape with ongoing erosion and deposition along the Speed and Eramosa rivers and their various tributaries.

2.5.2.2 Late Wisconsinan Period and Sedimentary Deposits

Nissouri Stade and Sedimentary Deposits

The Nissouri Stade (~23,000 ybp) marks the first glacial advance of the Late Wisconsinan when the Laurentide Ice Sheet advanced as far south as Wisconsin in the United States. In the Study Area, the Catfish Creek Till is the dominant layer represented by this time period. This till is widespread across Ontario and is characterized as an olive-buff colour. It has been described as a sandy, stony till, and is 3 to 6 m thick (Barnett 1992). The coarse-grained texture and hardness of the unit is diagnostic in the drilling community, where it is often referred to as “hardpan.”

Port Bruce Stade and Sedimentary Deposits

The colder climatic conditions of the Port Bruce Stade (~15,000 ybp) permitted the growth of glacial ice and the spreading and re-advance of the Huron-Georgian Bay and Erie-Ontario lobes of the Laurentide Ice Sheet from the Great Lake basins. This was a time period of active sediment deposition as the majority of the till units found across southwestern Ontario were laid down at this time. The number and variety of till units during this time period indicates that the advance was not as continuous as with the Nissouri Stade, but was more intermittent with smaller advances and recessions. Other glacial features, including eskers, kames, and outwash sediment, were deposited in response to fluctuating glacial margins during the Port Bruce Stade. Recession of glacial ice from the Study Area is noted in a series of recessional or end moraines on the surface of the till plains and associated glaciofluvial material.

Roughly concurrent with the deposition of the Tavistock Till by the Huron-Georgian Bay lobe, the Port Stanley Till was deposited by the Ontario-Erie Lobe. The Port Stanley Till is a buff, sandy-to-silty till. It is found at surface west of the Paris Moraine and spans much of the Rockwood Area of Interest and the entirety of the Hamilton Drive Area of Interest.

Mackinaw Interstade and Sedimentary Deposits

The Mackinaw Interstade (~14,000 ybp) is characterized by a warming climate and the further recession of the Laurentide Ice Sheet. The Mackinaw Interstade was characterized by: 1) the formation of the recessional Paris and Galt Moraines at the Erie-Ontario Lobe margin, 2) the formation of the Oak Ridges Moraine in the interlobate setting between the Ontario and Simcoe lobes, 3) the deposition of till sheets (e.g., Wentworth Till), 4) the deposition of glaciofluvial outwash, and 5) the lowering of lake levels in the Huron and Erie basins (Barnett 1992).

The Wentworth Till is a sandy silt till reflecting the incorporation of coarse-grained glaciofluvial sediment (Barnett 1992). Frequent lenses and discontinuous beds of stratified, coarse-grained sediment are found interbedded within the Wentworth Till, indicating the till was laid down at a similar time period as glaciofluvial activity. The Wentworth Till consists of ice-marginal debris flow deposits that were reworked by meltwater along the Paris and Galt moraines (Bajc 2009). Debris flows are defined as the movement of a mass of sediment down a slope and can be triggered by rapid sedimentation, earthquakes, and glacial ice. Debris flow deposits that result from glacial ice tend to 1) consist of poorly sorted sediment (clay, silt, sand, and gravel in varying amounts); 2) incorporate lenses of underlying sediment; and 3) lack structure; however, stratification can occur (Boulton 1972; King et al. 1998; Sverre Laberg and Vorren 2000).

The Wentworth Till reaches a maximum thickness of approximately 24 m on the Paris and Galt moraines, with clast content ranging from 35% to 65% (Bajc 2009). East of the moraines, clast content decreases, silt and clay content increase, and the Wentworth Till is a gently undulating till sheet reaching a maximum thickness of approximately 5 m (Bajc and Shirota 2007; Bajc 2009).

Grand River outwash and other surficial outwash deposits consist of sand and gravel deposits confined to the Conestogo, Grand, Nith, and Speed river valleys (Bajc and Shirota 2007). Outwash material was deposited by proglacial meltwater streams within a braided stream environment before the re-advance of Erie-Ontario ice to the Paris and Galt moraines (Bajc and Karrow 2004). Glaciofluvial deposits in low-lying areas in front (northwest) of the moraines are attributed to the release of subglacial meltwater from north of the Oak Ridges Moraine, located east of the Study Area, north of the Greater Toronto Area (Bajc and Karrow 2004).

Meltwater may have drained toward the southwest along the margins of the Paris and Galt moraines. Numerous coarsening-upward sequences were documented in boreholes in front (west) of the Paris Moraine (Bajc and Shirota 2007). This suggests repeated episodes of waning flow conditions from higher-energy flows (e.g., braided stream systems) to lower-energy flows (e.g., quiet water). Southward drainage down the Grand River valley was likely blocked several times by Erie-Ontario ice advancing from the southeast (Bajc and Karrow 2004). Blockage of the outlet would have led to localized ponding of meltwater and the deposition of lenses and discontinuous beds of quiet water, fine-grained silt, and clay within the coarse-grained sand and gravel outwash.

Recent Deposits

Glacial ice fully withdrew from the Study Area approximately 11,000 years ago. Vegetation patterns changed from those of a tundra environment, to coniferous forests, and finally to predominantly deciduous forests. Where the Late Wisconsinan was dominated by significant glacial depositional processes, the post-glacial era was dominated by fluvial erosional processes as the amount of glacial meltwater and associated suspended sediment loads declined. The sediment deposition that has occurred in the Study Area has been minor and has been limited to the floodplains adjacent to surface water systems, alluvium in drainage valleys, and organic deposition in wetlands and lakes.

2.6 Conceptual Hydrostratigraphy

2.6.1 Hydrostratigraphic Framework

Three dimensional (3D) hydrogeologic framework models of the Township of Guelph/Eramosa (Gartner Lee 2004), County of Wellington (Golder 2006b), City of Guelph and Puslinch Township (Golder 2006a), and City of Guelph and surrounding areas (Appendices A and B) have been constructed for the bedrock system and form the basis of the associated numerical groundwater flow models. The delineation of overburden and bedrock units described by Gartner Lee Limited (2004) and Golder Associates Ltd. (2006b; Appendix A) were considered for this current study alongside the OGS (Bajc and Shirota 2007; Brunton 2009) layer structures to develop revised conceptualizations for the Hamilton Drive and Rockwood areas.

In all, 14 conceptual hydrostratigraphic layers are interpreted across the Hamilton Drive and Rockwood areas as outlined in Table 2-3 and illustrated on Figure 2-9, following regional reconstructions of overburden and bedrock hydrostratigraphy. The upper soil layer was not included in the conceptual hydrostratigraphic model layers that were used for the numerical groundwater modelling efforts; however, it is recognized that the topsoil is present in the Study Area.

TABLE 2-3 Hydrostratigraphic Framework for the Hamilton Drive and Rockwood Areas

System	(Hydro)Geologic Unit	Character*	Description
Quaternary Sediment	Grand River Outwash	AQ	Coarse-grained glaciofluvial sediment
	Wentworth Till and Equivalents	AT/AQ	Surficial till along and east of the Paris Moraine near Rockwood (absent near Hamilton Drive)
	Glaciolacustrine / Glaciofluvial Sediment	AQ	Fine- and coarse-grained interstadial sediment
	Port Stanley Till / Glaciolacustrine Silt and Clay / Catfish Creek Till	AT	Surficial till west of the Paris Moraine, subsurface fine-grained glaciolacustrine sediment and till sheets across the Study Area
	Older (Glacio)Fluvial Sediment	AQ	Coarse-grained bedrock valley-fill sequences
Paleozoic Bedrock	Contact Aquifer	AQ	Weathered bedrock zone (regardless of bedrock unit); potential for increased weathering along base of bedrock valleys
	Guelph Formation / Stone Road Member of Eramosa Formation	AQ	Dolomitic rock, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Reformatory Quarry Member of Eramosa Formation	Poor AQ/ Poor AT	Dolomitic rock and shale, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Vinemount Member of Eramosa Formation	AT	Dolomitic rock and shale, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Goat Island Formation	Poor AQ	Dolomitic rock, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Upper Gasport Formation	AQ	Dolomitic rock, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Middle Gasport Formation (Production Zone)	High Permeability AQ	Dolomitic rock, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Lower Gasport Formation / Irondequoit Formation/ Rockway Formation / Merritton Formation	AQ	Dolomitic rock, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)
	Cabot Head Formation	AT	Shale, conceptualized as dipping toward the southwest (dip angle approximately 0.2^{o} or 0.3%)

Note:
* Describes the relative hydrogeologic nature of the sediment / rock, whereby AT denotes aquitard material and AQ denotes aquifer material.

Golder (Appendix A) conceptualized the overburden in the Guelph area as a two-layer system consisting of variable surficial material underlain by a thick Port Stanley and Catfish Creek Till succession extending to bedrock. In contrast, the overburden described by Bajc and Shirota (2007), and captured in core data presented by Burt and Webb (2013), detail a stacked system of laterally continuous fine-grained sedimentary packages of till and glaciolacustrine sediment with discontinuous intervening granular units. The latter representation of the overburden in the Hamilton Drive/Rockwood area was adopted to provide a better representation of possible interconnections between the surface, intermediate, and bedrock aquifers.

The bedrock units identified by Golder (Appendix A), which formed the initial hydrostratigraphic framework for the FEFLOW groundwater flow model (Appendix B) used in the Tier Three Assessment, accurately capture the hydraulics of the bedrock as observed in available hydrogeological data. This framework was adopted for the bedrock system in the Hamilton Drive and Rockwood areas. The distribution and hydrogeologic properties of the overburden and bedrock systems are described in the following sections.

2.6.2 Overburden Hydrostratigraphy

Overburden deposits in the areas near the municipal water supplies (according to water well logs) in the Study Area range in thickness from 10 to 30 m near Hamilton Drive (Figures 2-10 and 2-11) and <1 to 15 m in Rockwood (Figures 2-12 to 2-15). As discussed earlier, these overburden deposits are largely fine-grained till and glaciolacustrine deposits. Due to this predominance of a largely fine-grained overburden sedimentary package, unconsolidated sediments have not been targeted as a source of municipal water supply; all municipal supply wells in the Township of Guelph/Eramosa municipal systems are completed in bedrock.

Coarse-grained materials in the area may form shallow aquifers, as seen south of the City of Guelph, but these granular deposits are not laterally extensive. However, there is a potential connection between the surface and the deeper production zone of the middle Gasport Formation through overburden aquifers in buried bedrock valleys (Figures 2-13 and 2-15). Bedrock valley infill tends to be mainly sand with minor silt-rich beds and capped by a sandy diamict at surface near Rockwood (Burt and Webb 2013). Valley sand is interpreted to be overlain by glaciofluvial outwash that outcrops at surface southeast of Everton, just north of Rockwood (Figure 2-13).

2.6.3 Bedrock Hydrostratigraphy

The bedrock aquifers tend to be protected by the overlying finer-grained overburden sediment, with the exception of Rockwood, where fluvial activity has eroded the overlying sediment. Here, the bedrock is exposed at surface in the Eramosa River valley. As the municipal supply wells in Rockwood are located close to the watercourse, municipal supplies may be GUDI wells (Burnside 2002a).

The major bedrock units in the Study Area and their hydrogeologic character are outlined in Table 2-3. The spatial distribution and subsurface geometries of these units are important in understanding patterns in the groundwater flow system and potential hydraulic connections between aquifer units.

All bedrock units generally dip toward the southwest (Figures 2-10 and 2-15). The Guelph Formation is characterized as an aquifer and near Hamilton Drive ranges in thickness from 2 to 28 m. It generally thins toward the south (Figure 2-11). Near Rockwood, this unit is only present west of the Eramosa River west of Rockwood, and ranges in thickness from 2 to 15 m (Figure 2-12).

The Reformatory Quarry Member of the Eramosa Formation is characterized as a poor aquitard, and near Hamilton Drive ranges in thickness from 0 to 50 m. It is thickest in the west and near the municipal wells, thinning toward the east (Figure 2-10). In Rockwood, this unit is more prevalent in the vicinity and west of the municipal wells, and ranges in thickness from 0 to 19 m. The distribution of this unit is controlled by post depositional erosion; its absence is most visible near buried bedrock channels (Figures 2-12 to 2-15).

The Vinemount Member of the Eramosa Formation is characterized as a regional aquitard and near Hamilton Drive ranges in thickness from 1 to 9 m. It is thickest in the east, thins toward the west (Figures 2-10 and 2-11). It pinches out west of the Hamilton Drive area. This pinch out is visible near the Marden Tract Well on the western end of the cross-section on Figure 2-10. In Rockwood, the Vinemount Member ranges in thickness from 0 to 15 m (Figure 2-15). East of Rockwood and in the vicinity of Hidden Quarry, the Vinemount Member is interpreted to be absent based on borehole logs from test wells and mapped outcrops (Telford 1976). The Vinemount Member plays a significant role in the subsurface flow regime, separating upper and lower aquifer materials and potentially allowing communication of lower aquifer materials with upper units and ground surface. This is particularly important in Rockwood where the Vinemount Member is shown to be eroded by channels and infilled with overburden sediments, suggesting potential hydraulic interaction of deep aquifers (e.g., Gasport Formation) with either the near-surface aquifers (Figures 2-12 to 2-15) or surface water (e.g., Eramosa River) in topographic valleys (Figure 2-15).

The Goat Island Formation, which thickens and thins in response to the absence or presence of reef mounds in the upper Gasport Formation (Figure 2-11), ranges in thickness from 0 to 26 m near Hamilton Drive. This unit is thickest in the west and near the municipal wells, thinning toward the east (Figure 2-10). In Rockwood, this unit is prevalent and ranges in thickness from 0 to 17 m. The presence of this unit is controlled by post-depositional erosion; its absence is most visible near buried bedrock channels (Figures 2-12 to 2-15).

The Gasport Formation is one of the main source aquifers in the Study Area. The upper Gasport Formation ranges in thickness from 4 to 33 m in the Hamilton Drive area and 0 to 33 m in the Rockwood area. The middle Gasport Formation is conceptualized as a uniform 12 m thick layer across the Study Area except where incised by buried bedrock channels (Figures 2-12 to 2-15). Coarse-grained fill sequences in these valleys suggest a potential hydraulic connection between the middle Gasport Formation and the near surface aquifers (Figures 2-13 to 2-15). The lower Gasport Formation ranges in thickness from 4 to 13 m near Hamilton Drive and 0 to 26 m in Rockwood. The Gasport Formation thins eastward in response to the regional dip and erosion along the pre-Quaternary unconformable surface.

The Gasport Formation horizons appear relatively constant in thickness, except where eroded by bedrock valleys and built up as reef mounds. In areas where the Vinemount Member has been eroded, the Gasport Formation may be hydraulically connected to the near-surface aquifer units and/or surface water features.

The Cabot Head Formation acts as a regional aquitard and represents the bottom of the active groundwater flow system. In some locations, buried bedrock valleys are interpreted to incise through the Gasport Formation and into the underlying Cabot Head Formation (Figures 2-14 and 2-15).

2.6.4 Groundwater Flow

Water elevation surfaces for overburden and bedrock are illustrated on Figures 2-16 and 2-17, respectively. Static water levels reported in the Ontario Ministry of the Environment (MOE) Water Well Records and higher quality observation wells were interpolated across the Study Area (Golder 2006b) to create these maps.

The water levels in the MOE water well database were measured and recorded by water well drillers after drilling a well. These static water levels were collected over decades and may represent pre-pumping water-level conditions that are not indicative of present-day levels (which can be influenced by localized pumping). In addition, these water levels may have been taken soon after drilling when the well had not fully equilibrated. Local circular equipotentials, or bulls-eyes, may reflect local, temporally restricted conditions; efforts were made to remove outliers and preserve trends in the water level observations.

Additionally, the local features in the water level surfaces are likely relicts of the broad bedrock/ overburden distinction whereby multiple aquifer units, and their associated potentiometric surfaces, in both the overburden and bedrock system are represented by a single surface. Further subdivision of the potentiometric surfaces creates a data scarcity issue, necessitating the broader categorization. Despite the limitations, the data used to create the water level maps (Figures 2-16 and 2-17) are the best available, and the maps are considered a reasonable representation of groundwater flow conditions.

2.6.4.1 Groundwater Flow in Overburden

The water levels found in the overburden generally represent a subdued reflection of ground surface topography. Maximum elevations exceed 410 m asl in the northeastern portion of the Study Area beneath the Paris and Orangeville moraines (Figure 2-16). The Orangeville Moraine is thought to be an interlobate moraine, which serves as an area of recharge (AquaResource 2011a). Water levels decline regionally to less than 270 m asl northeast of Rockwood across and below the Niagara Escarpment. Groundwater flow is inferred to follow a regional hydraulic head decline from north to south between Everton and the City of Guelph.

2.6.4.2 Groundwater Flow in Bedrock

The water levels found in bedrock (Figure 2-17) are observed to follow a similar pattern as that of the shallow system. Maximum elevations (approximately 420 m asl) are located in the northeast portion of the Study Area, while minimum water level elevations (approximately 250 m asl) are found below the Niagara Escarpment. Regional groundwater flow is inferred to follow a hydraulic head decline from north to south. The deep hydraulic head contours show a potential for groundwater discharge along the Eramosa River near Rockwood. Equipotential lines deflect near buried bedrock valleys suggesting preferential flow through the coarse-grained valley infill sequences.

3 WATER DEMANDS AND MONITORING

3.1 Municipal Groundwater Demand

The Township of Guelph/Eramosa relies on groundwater to meet the municipal water demands of Hamilton Drive and Rockwood. Recognizing the importance of understanding and managing its groundwater resources, the Township has implemented groundwater monitoring programs to ensure the long-term sustainability of its water resources.

3.1.1 Hamilton Drive

Hamilton Drive relies solely on bedrock-derived groundwater for its municipal water supply demands. Water is extracted from two municipal supply wells (Cross Creek Well and Huntington Estates Well) located within the subdivision development (Table 3-1; MOE 2012a). A third well, the Blue Forest Well, was abandoned in 2004. Due to the accumulation of fine-grained material overlying the bedrock near the active production wells, there is assumed to be a lack of hydraulic connection between surface water features and bedrock aquifers units; therefore, both wells are classified as non-GUDI (Burnside 2002b).

TABLE 3-1 Hamilton Drive Water Supply Wells

Well Name	Easting (UTM NAD83)	Northing (UTM NAD83)	Permit Number (expiry)	Permitted Capacity (m^3/day)	Average Annual Reported Taking (2009-2010) (m^3/day)
Cross Creek Well	558038	4825840	5113-8K6MHC (31/05/2021)	812	87
Huntington Estates Well	558405	4826512	2010-95CQ5Q (31/05/2023)	916	92
TOTALS				1,728	179

Figure 2-1 illustrates the locations of the municipal supply wells listed in Table 3-1. Each of the municipal supply wells operate under separate PTTW. The total permitted rate of groundwater extraction is 1,728 m^3/day; however, the average reported daily taking (2009-2010) for the community is 179 m^3/day. PTTW locations, as recorded in the PTTW dataset, may not reflect the co-ordinates supplied by the municipality for the municipal supply wells. Typographic errors, differences in precision, etc. may influence the coordinate fields in the PTTW dataset. As such, co-ordinates in PTTW dataset were updated to reflect those supplied by the municipalities.

Chart 3-1 displays the monthly pumping at each municipal supply well within Hamilton Drive from 2004 to 2012. Summer season peaks in water demand have fluctuated over time with a change from higher demands (e.g., 200 m^3/day) before 2008, to lower demands (e.g., 125 m^3/day) from 2008 to 2010, and back to higher peak demands since 2011 (e.g., greater than 250 m^3/day). Water demand in the winter demands has remained relatively unchanged over the same time period at approximately 75 m^3/day (Chart 3-1).

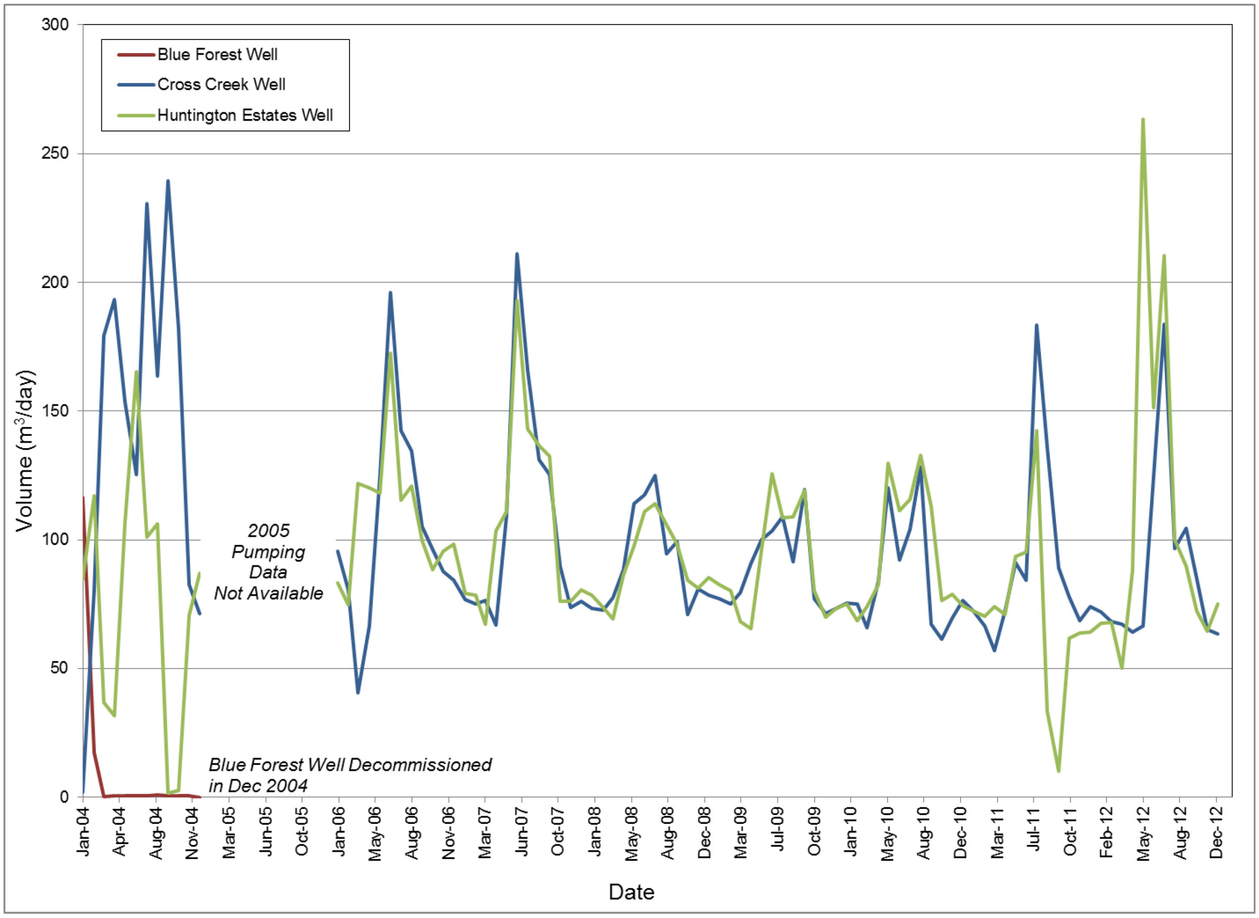

CHART 3-1 Hamilton Drive Monthly Total Pumping (2004-2012)

(Note: This chart includes pumping data from Blue Forest Well that was decommissioned in 2004.)

Well completion details for the municipal supply wells in Hamilton Drive are provided in previous reports (Gartner Lee 2004) and are summarized here. The Cross Creek Well is cased across the overburden and Guelph Formation into the Reformatory Quarry Member of the Eramosa Formation to a depth of 39.6 m bgs and open hole in bedrock to 99.1 m bgs. The Huntington Estates Well is cased into the shallow bedrock Guelph Formation to a depth of 12.5 m bgs and extends as an open hole in the bedrock to a total depth of 71.9 m bgs. In 2002, a PVC liner was installed to a depth of 35.1 m bgs within the Huntington Well to seal off the annular space of the well casing (Burnside 2002b). Well construction details and borehole logs for the Hamilton Drive wells are provided in Appendix C2.

3.1.2 Rockwood

Rockwood currently derives all of its potable water from three bedrock wells: Rockwood wells 1 (TW1-67) and 2 (TW1-76), and Rockwood Well 3 (TW3-02; Table 3-2). A fourth municipal well, Rockwood Well 4 (TW2-14), was constructed in 2014 and was permitted in 2015 as part of a consolidated PTTW for the four wells. It is planned to go into production in 2017. Wells 1 and 2 are designated as GUDI wells (Burnside 2002a).

TABLE 3-1 Rockwood Water Supply Wells

Well Name	Easting (UTM NAD83)	Northing (UTM NAD83)	Permit Number (expiry)	Permitted Capacity (m^3/day)	Average Annual Reported Taking (2009-2010) (m^3/day)
Rockwood Well 1 (TW 1-67)	568785	4830026	6477-9XRPCX (31/05/2025)	1,965	283
Rockwood Well 2 (TW 1-76)	568784	4830030		1,965	262
Rockwood Well 3 (TW3-02)	569800	4828135		1,310	422
Rockwood Well 4 (TW2-14)	570671	4829230		1,310	0
TOTALS				6,550	967

Rockwood wells 1 and 2 operated under one consolidated PTTW (4571-7FRLLE), which was to expire at the end of March 2018. Rockwood Well 3 operated under a separate PTTW (4473-8JALSX), which was to expire at the end of March 2021. A new consolidated PTTW (6477-9XRPCX) for all the Rockwood wells including the newest Rockwood Well 4 was obtained in 2015. The total permitted taking is 6,550 m^3/day. The total average reported daily taking (2009-2010) for the municipal wells in Rockwood was 967 m^3/day.

Monthly pumping at Rockwood wells 1, 2, and 3 is shown in Chart 3-2 for the 8-year period from 2004 to 2012. The pumping rates for each well generally vary between 200 and 600 m^3/day. Maximum and minimum extremes beyond this range appear to be the result of pumping operations at Station Street (wells 1 and 2) whereby pumping is decreased in one well and simultaneously increased in the other to compensate, except for the year 2011, which showed slightly elevated summer demands, seasonal trends in pumping have remained relatively steady over time.

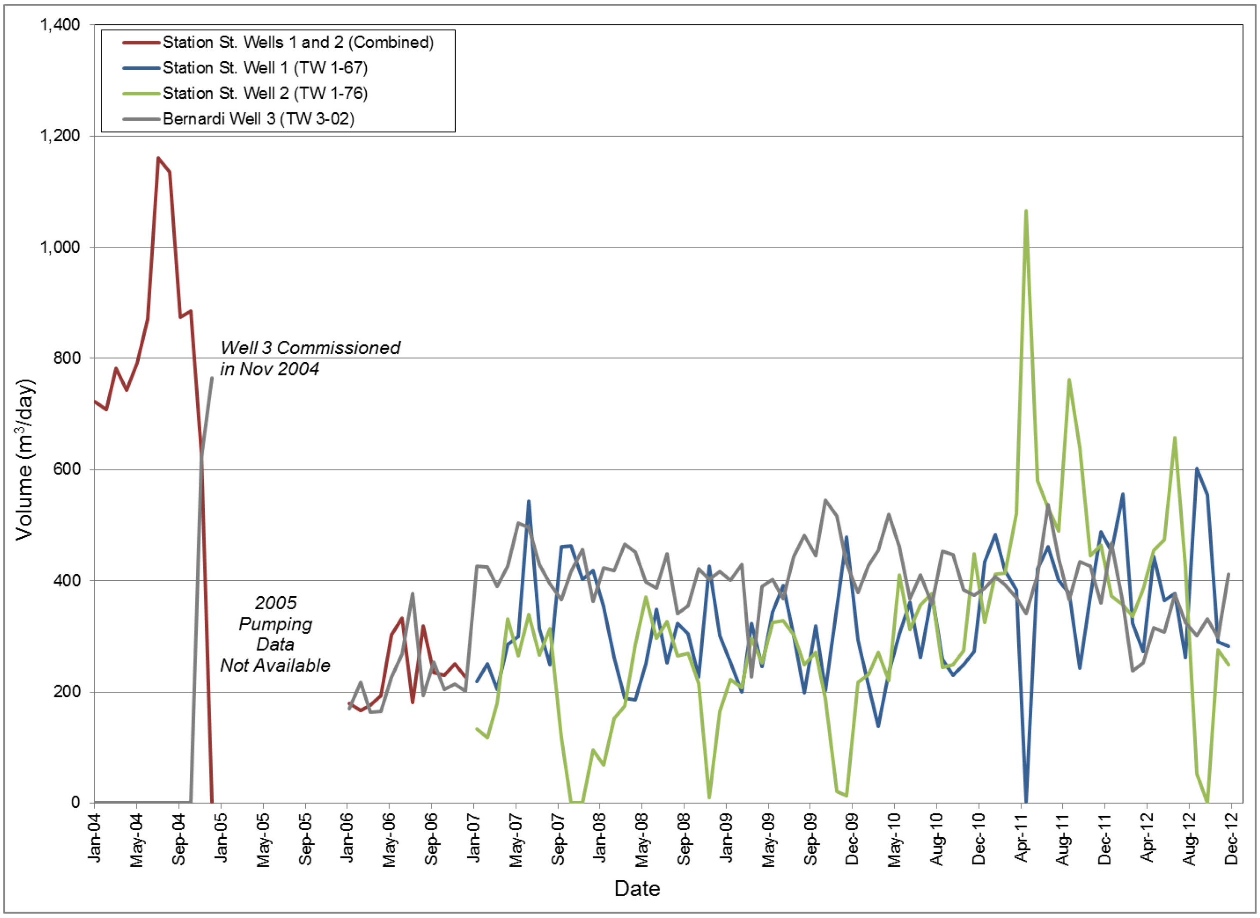

CHART 3-2 Rockwood Monthly Total Pumping (2004-2012)

Well completion details for the Rockwood municipal supply wells are provided in previous reports (Gartner Lee 2004; Burnside 2015) and summarized here. All wells are cased through the overburden sequence and open hole to the bedrock system. The production zone of the middle Gasport Formation is the target municipal supply aquifer in the Rockwood area. As part of a GUDI assessment (Burnside 2002a), steel liners were installed in wells 1 and 2 to a depth of 36.5 m bgs and 38.4 m bgs, respectively. These liners limit the groundwater withdrawal to the deeper portion of the middle Gasport Formation production zone. The bottom of each liner is more than 25 m below the static groundwater head near the supply wells. Following the installation of the liners, the significant hydraulic connection observed between the shallow bedrock (outcropping at surface in the Eramosa River valley) and deep middle Gasport Formation had substantially diminished (Gartner Lee 2004). Available well construction details and borehole logs for the Rockwood wells are provided in Appendix C2.

3.2 Non-municipal Permitted Groundwater Demands

In addition to the municipal water takers in the Study Area, there are also a number of large permitted water takers with PTTWs. Figure 3-1 illustrates the locations of these non-municipal PTTW holders (as obtained from the *Permit to Take Water Database* (MOE 2008). The following sections describe the method for estimating consumptive demand, as well as describing each of the non-municipal permitted water takings near each municipal system. The estimated consumptive volume for each water taking is also described.

3.2.1 Methodology

As each PTTW in the Study Area was used to assess the quantity of groundwater available to meet current and future municipal demand, ensuring the accuracy of the water taking, including the specified rate of withdrawal is critical. To ensure the water withdrawals are as accurate as possible, a structured, highly detailed process was employed to review and estimate the volume of water withdrawn from the Hamilton Drive and Rockwood areas. This process is outlined in the following steps:

- organize and link Provincial PTTW and Water Taking and Reporting System (WTRS) databases
    - Water use information in Ontario is predominantly found in one of two databases. The PTTW database primarily contains regulatory information, such as geographic coordinates; the maximum permitted rate of withdrawals; and the intended use of the withdrawn water. The WTRS database contains reported values of the actual amount of water withdrawn for each PTTW. The WTRS database has been in use since 2008; however, does not have a direct linkage to the PTTW. A significant level of effort was required to build a linkage between the two databases and to facilitate assigning reported withdrawal rates to each PTTW.
- manually inspect all PTTWs in the Hamilton Drive and Rockwood areas
    - This step included evaluating the information associated with each PTTW in the Hamilton Drive and Rockwood areas. This was necessary to identify and address issues in the PTTW database. This step also included downloading and inspecting the physical PTTWs from the online Environmental Registry (whenever available). By downloading each PTTW, it was possible to better characterize how water is withdrawn and used by each operation, resulting in more accurate estimates of consumptive water demand. This step was also useful in identifying those water withdrawals that were characterized as being sourced from “Surface and Groundwater,” which in reality, were predominantly sourced from surface water supplies.

- identify water withdrawals for consideration
  - When inspecting PTTWs, water withdrawals that were cancelled, temporary, or predominantly from sourced from surface water were excluded from further analysis.
- assign water withdrawal rates
  - When assigning withdrawal rates to the permitted water takings, consideration was first given to data contained in the WTRS database. WTRS data was considered to be more reflective of actual water withdrawals than estimates based on maximum permitted rates. For those permits where no WTRS data were available, withdrawal rates were estimated using a combination of maximum permitted rate; days permitted of pumping; and estimates of months where that permit would be active (based on the use of water).
- assign consumptive use factors
  - This study examined consumptive water demand (i.e., water that is consumed and not returned to the pumped aquifer within a reasonable amount of time). For the purposes of this study, if water is removed from a groundwater aquifer and not returned to the groundwater system, the taking is assumed to be 100% consumptive. Groundwater takings are typically 100% consumptive as wastewater is seldom returned to the groundwater flow system and often discharged to surface water systems. If, through review of the PTTW, it was found that withdrawn water is returned to the original source, an appropriate consumptive factor for the use of water was applied to the water withdrawal rates (AquaResource 2011b).

3.2.2 Hamilton Drive

There are several large water takers (>50,000 L/day) near Hamilton Drive. The total maximum permitted pumping rate for permitted water takers near Hamilton Drive is 2,689 m^3/day; however, the total calculated consumptive rate is only 486 m^3/day based on 2008 PTTW and WTRS information. Each of the permitted water takers near Hamilton Drive is discussed below.

In all, 29 remediation wells, operating under permit 01-P-2004, are located within the City of Guelph near the intersection of Arrow Road and Fair Road, north of Woodlawn Road (Highway 7). A collective consumptive rate of 152 m^3/day is calculated from reported rates (as captured in the WTRS). This is 54% less than the maximum permitted pumping rate of 328 m^3/day.

There are three wells within the City of Guelph boundary, just south of Woodlawn Road West, near Edinburgh Road North, operating under water-taking permit No. 528-6GTN6M. The permit is for a remediation system with a collective maximum permitted rate of 329 m^3/day and 365 days per year of active taking. The 2008 WTRS records and Grand River Conservation Authority (GRCA)-reported water takings (AquaResource 2009b) for this permit indicate that the average annual consumptive demand is 88 m^3/day collectively.

Another water-taking permit (No. 6800-72CLQH), located within the City of Guelph boundary just north of Speedvale Avenue West, near Woolwich Street, is for industrial use. Its maximum permitted rate is 1,635 m^3/day and 365 days per year of active taking. The 2008 WTRS records indicate that the average annual consumptive demand is 105 m^3/day.

A water-taking permit (No. 3036-6QPKHE) is also located within the City of Guelph boundary, south of Speedvale Avenue West, near Delhi Street. The permit is for institutional use and the maximum permitted rate at this location is 137 m^3/day and 365 days per year of active taking. No reported rates were available for this permit, and as such, an average annual consumptive rate of 137 m^3/day is estimated based on a 100% consumptive use factor.

Approximately 1.7 km northeast of the City of Guelph boundary, just north of Guelph Lake and south of Conservation Road near Watson Road, there is a water-taking permit (5081-6GEPMB) for two wells (MOE WWR - 67-07918 and MOE WWR - 67-07917). The permit is for water supply, with a collective maximum permitted rate of 260 m^3/day and 214 days per year of active taking for each well. The 2008 WTRS records for this permit indicate that the average annual consumptive demand is 4 m^3/day collectively.

3.2.3 Rockwood

There are several large water takers (>50,000 L/day) near Rockwood. The total maximum permitted pumping rate for permitted water takers near Rockwood is 3,575 m^3/day; however, the total calculated consumptive rate is only 561 m^3/day based on 2008 PTTW and WTRS information. Each of the permitted water takers near Rockwood is discussed below.

There are two wells 11.5 km northeast of the City of Guelph boundary, just north of Highway 124 and south of Side Road 15 near Wellington Road 26, operating under water-taking permit No. 00-P-2417. The permit is for agricultural use with a total maximum permitted rate of 1,309 m^3/day and 365 days per year of active taking for each well. The 2008 WTRS records for this permit indicate that the average annual consumptive demand is 222 m^3/day.

A water-taking permit (No. 7175-6LCQ2M) is located 13 km northeast of the City of Guelph boundary just north of Erin-Halton Hills Town Line near First Line. The permit is for commercial use with a maximum permitted rate of 238 m^3/day and 365 days per year of active taking. The 2008 WTRS records for this permit indicate that the average annual consumptive demand is 9 m^3/day.

A water-taking permit (No. 1833-6G7QVG) is located near the Town of Erin just south of Wellington Road 50 near Allan Path. The permit is an artesian well used for commercial use and has a maximum permitted rate of 64 m^3/day and 300 days per year. No reported rates were available for this permit, and as such an average annual consumptive rate of 52 m^3/day is estimated based on a 100% consumptive use factor and 300 days per year of permitted pumping.

A water-taking permit (No. 01-P-2027) is for two wells at a golf course and is located near Erin south of Side Road 10 near 8^{th} Line. The permit is for commercial use with a total maximum permitted rate of 1,964 m^3/day and 122 days per year of active taking for each well. No reported rates were available for this permit, and as such, an average annual consumptive rate of 278 m^3/day is estimated based on a 85% consumptive use factor for golf course irrigation and 122 days per year of permitted pumping.

3.3 Municipal Groundwater Monitoring

Under the MOE PTTW process, many municipal water systems are required to carry out groundwater monitoring programs. The collection and inspection of groundwater level monitoring data in and around municipal well fields aids in the understanding of the effects of municipal pumping both temporally (i.e., seasonally) and spatially (i.e., regionally across the well field). Often these monitoring efforts help to identify potential negative impacts to sensitive receptors such as other municipal supply wells, private wells, and groundwater-fed surface water features (e.g., rivers, ponds, and wetlands). In the Study Area, there are monitoring wells near both the Hamilton Drive and Rockwood well fields.

3.3.1 Hamilton Drive

Near Hamilton Drive, water levels are regularly monitored at both municipal supply wells and two monitoring wells (MW2S and MW2I; Figure 2-1). Chart 3-3 illustrates water level and pumping data for the Cross Creek municipal well from 2008 to 2012. The average monthly pumping maintained a fairly consistent pattern of high summer demand and low winter demand until 2011 and 2012 where summer seasonal demands noticeably increased. Water levels in the Cross Creek Well identified as “non-pumping” levels remain steady throughout the period of record, whereas levels identified as “pumping” show a greater degree of fluctuation. While there is some scatter in the pumped water levels relative to the pumping data, a trend of low levels during high demand and higher levels during low demand is still observable (e.g., 2010). In general, the pumped water levels varied between 317 and 327 m asl until the high demand period during the summer of 2012 when pumped levels declined to 312 m asl. The chart depicting municipal water levels and pumping data for the Huntington well is found in Appendix C3.

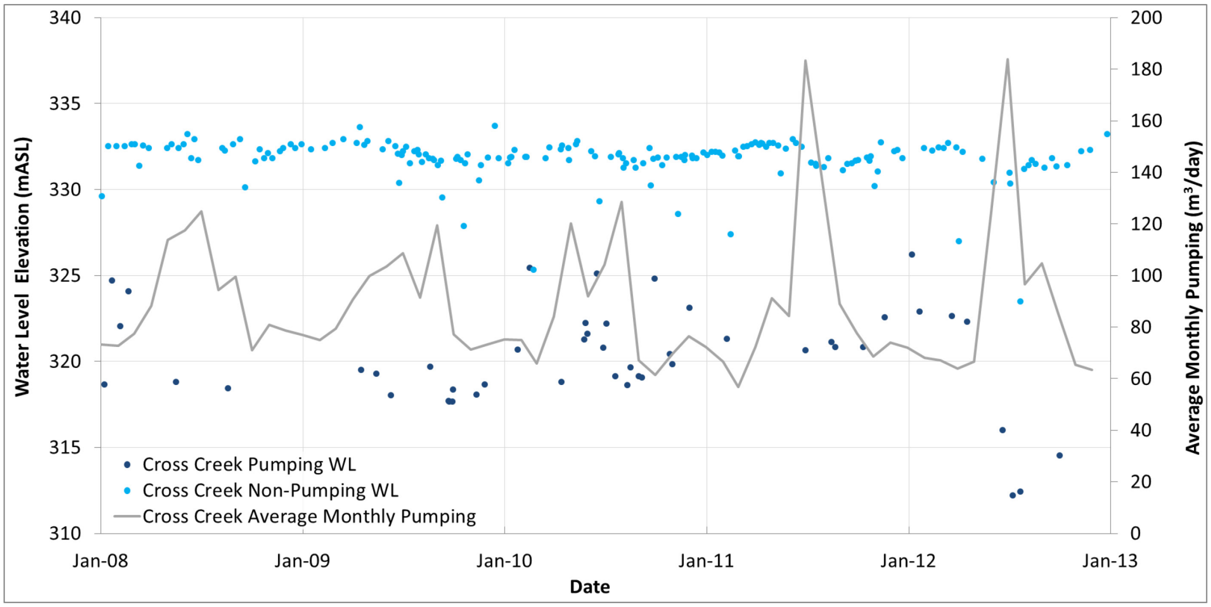

CHART 3-3 Water Level Monitoring at Cross Creek Well (2008-2012)

Chart 3-4 illustrates monitoring well water level changes in MW2S and MW2I (Figure 2-1 shows monitoring well locations). These wells are used to monitor the drawdown effects related to the pumping from the Huntington Well; therefore, monthly pumping from this well is also presented on Chart 3-4. As shown, water levels for these two wells show a strong influence from municipal pumping, with a water level rise following a decrease in pumping and water level fall with an increase in pumping. Overall, levels fluctuate fairly consistently between 2008 and 2012.

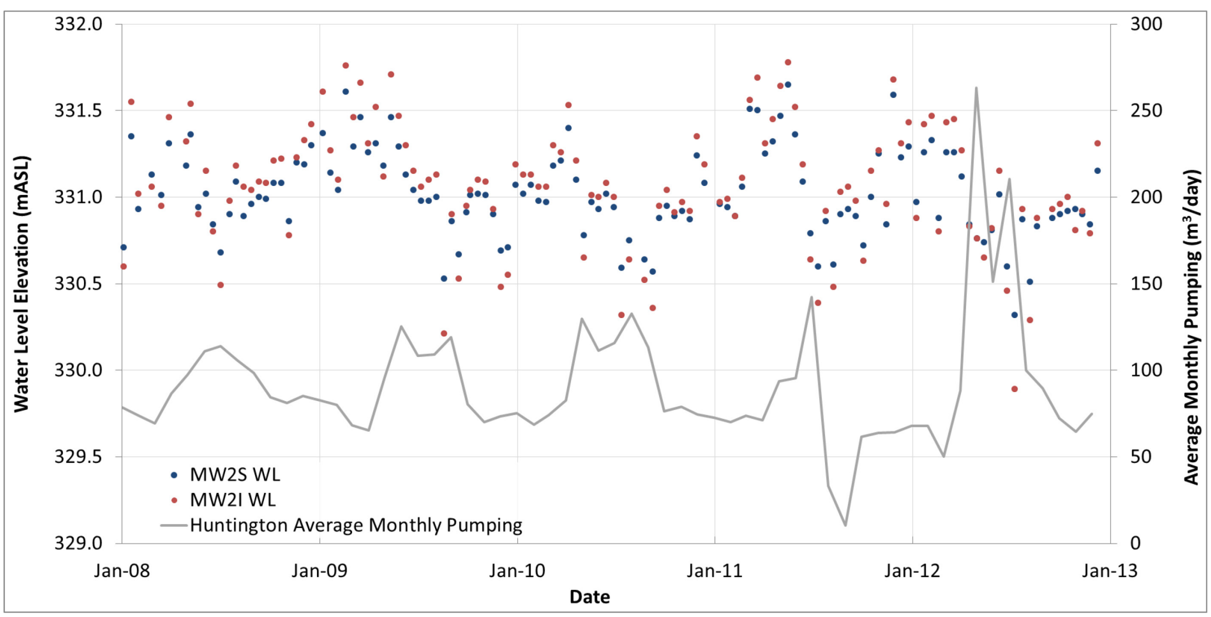

CHART 3-4 Water Level Monitoring at MW2S and MW2I (2008-2012)

3.3.2 Rockwood

In Rockwood, municipal well water levels are collected daily from Rockwood wells 1 and 2, and Rockwood Well 3, as well as monthly at two monitoring wells and two private domestic wells (i.e., OW3R-08-S and OW3R-08-D, Oelbaum well, and Perkes well; Figure 2-2). The daily water level trends of Rockwood Well 1, relative to the average monthly pumping rate, are shown below (Chart 3-5). During a 4-year period (2009 to 2012), both the non-pumping and pumping water levels at Well 1 have steadily declined as the pumping rate has increased slightly over that same period. The monthly variation in pumping related to seasonal water use is not always directly correlated to the monthly variation in water levels; likely due to the close proximity to Well 2 and the influence of Well 2 pumping on Well 1 water levels (and vice versa). Water level data for Rockwood wells 2 and 3 are provided in Appendix C3.

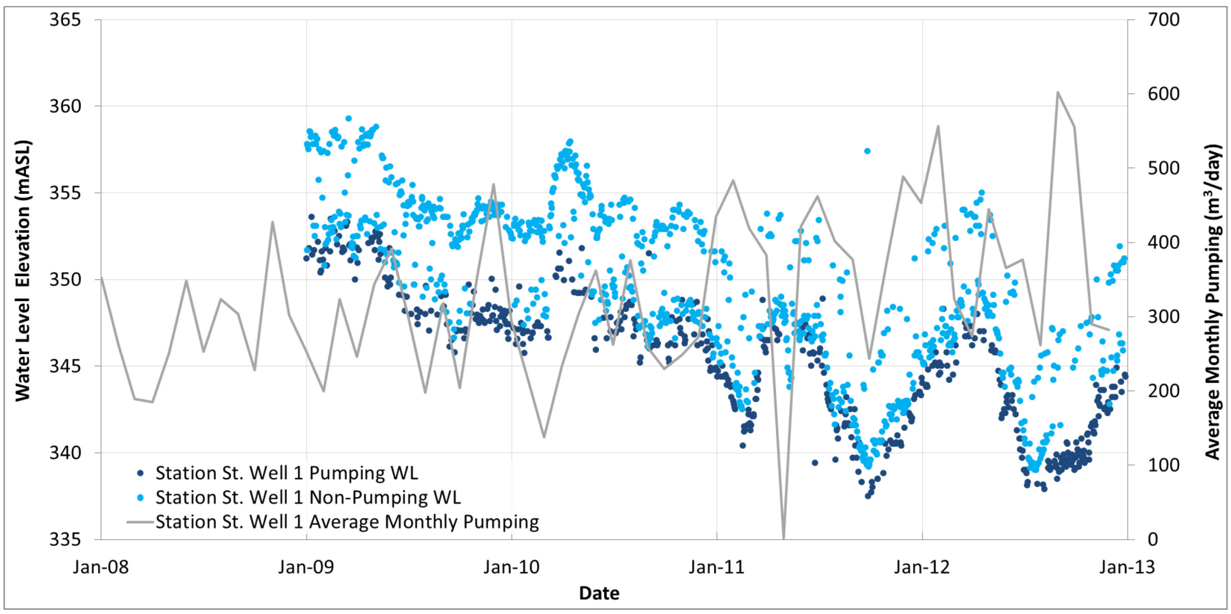

CHART 3-5 Water Level Monitoring at Rockwood Well 1 (2009-2012)

Chart 3-6 illustrates monitoring well water level changes in monitoring wells OW3R-08-S and OW3R-08-D and private wells Oelbaum and Perkes (Figure 2-2 provides well locations). These wells are used to monitor the drawdown effects related to the pumping from Rockwood Well 3; therefore, monthly pumping from Well 3 is also provided on **Chart 3-6**. As shown, the water level in the Oelbaum well is significantly deeper than the other well datasets, suggesting that a different flow system contributes water to this well. These water levels maintain a fairly consistent elevation and generally only vary between 331 and 332 m asl. The water levels of the remaining three monitoring wells are found at shallower depths, ranging from 348 to 354 m asl, and all display similar trends in variation over time. Water levels in these shallower wells generally fall during intervals of increased demand and rise during times of reduced demand in response to pumping at Rockwood Well 3. However, over the long-term, water levels appear to be relatively stable with no discernable trends toward declining or rising levels.

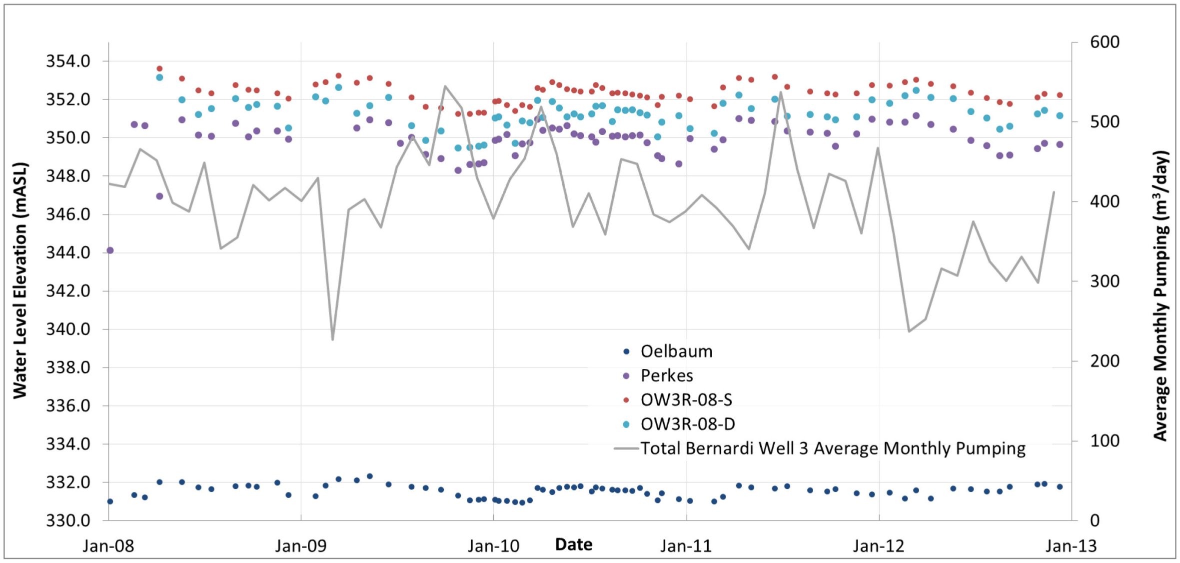

CHART 3-6 Water Level Monitoring near Rockwood Well 3 (2008-2012)

4 SUMMARY

The Study Area is covered by Quaternary-aged sediments deposited during the Late Wisconsinan as glacial ice lobes advanced and retreated across southern Ontario. These deposits range in thickness of up to 30 m near Hamilton Drive and up to 5 m in Rockwood where, in some areas of the Eramosa River valley, overburden sediments have been completely eroded, and bedrock is found at surface. Due to the predominantly fine-grained nature of the overburden, these sediments have not been targeted as a source of municipal water supply; therefore, all municipal potable water is derived from bedrock aquifers.

A 3D hydrostratigraphic model was constructed for the Hamilton Drive and Rockwood areas building on delineation work previously completed by Gartner Lee (2004) and Golder (2006a; Appendix A), as well as the layer structures previously developed by the OGS (Bajc and Shirota 2007; Brunton 2009). Ultimately, 14 conceptual hydrostratigraphic layers were interpreted across the Study Area, including 5 overburden and nine bedrock layers. This 3D hydrostratigraphic model was used to form the basis for a numerical groundwater flow model to evaluate the long-term reliability of water supplies in the Township of Guelph/Eramosa and the City of Guelph.

Characterization efforts completed as part of the Tier Three Assessment provide enhanced understanding of the regional and local geology and hydrostratigraphy. The surfaces that form the basis of the 3D geologic models represent the most current interpretation of the hydrostratigraphic units within Study Area and incorporate all of the field data and available glacial understanding of the area.

The refined surfaces have been used to update the Tier Three Assessment numerical model and to provide the enhanced hydrogeologic structure needed to support the detailed evaluations of the Tier Three Assessment.

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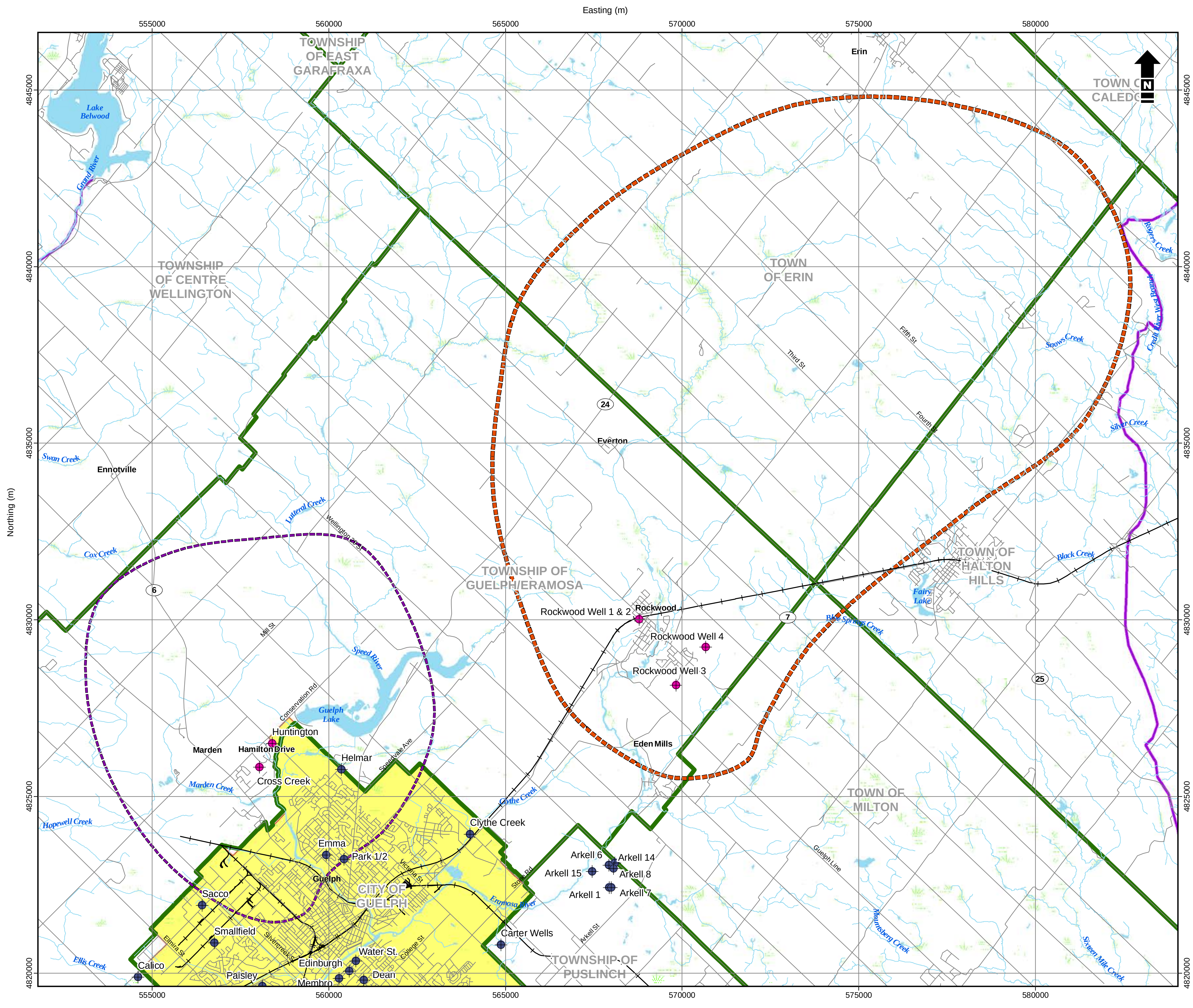
APPENDIX C1

FIGURES



- Area of Interest - Hamilton Drive
- Area of Interest - Rockwood
- Tier Three Model Boundary (Study Area)
- Grand River Watershed Boundary
- Municipal Boundary
- Wellington County
- Community
- Wetland
- Water Body
- Watercourse
- Road
- Railroad
- Municipal Well (City of Guelph)
- Municipal Well (Guelph/Eramosa Township)

Index Map

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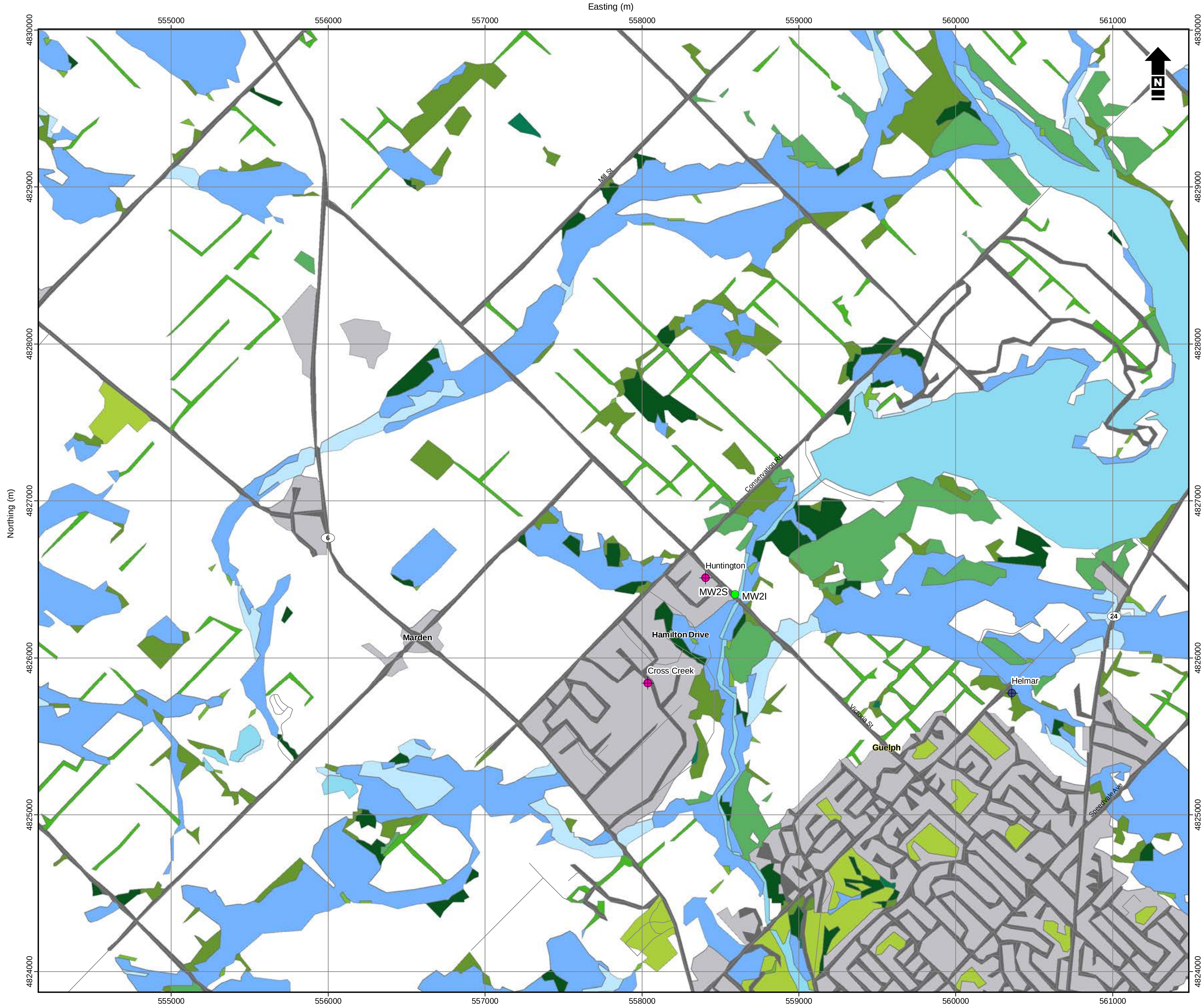
Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

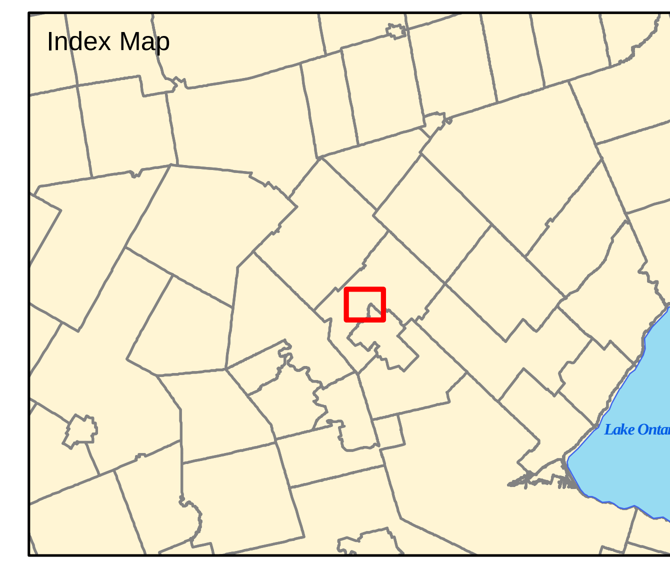
City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Study Area

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure 1-1





Water Body
Watercourse
Road
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)
Monitoring Well

Landuse

- Forest
- Coniferous Forest
- Mixed Forest
- Deciduous Forest
- Plantations - Tree Cultivated
- Hedge Row
- Transportation
- Extraction
- Built-up Area Pervious
- Built-up Area Impervious
- Swamp
- Fen
- Bog
- Marsh
- Open Water
- Undifferentiated

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250 0 250 500 m
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City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Hamilton Drive

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

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Figure
2-1

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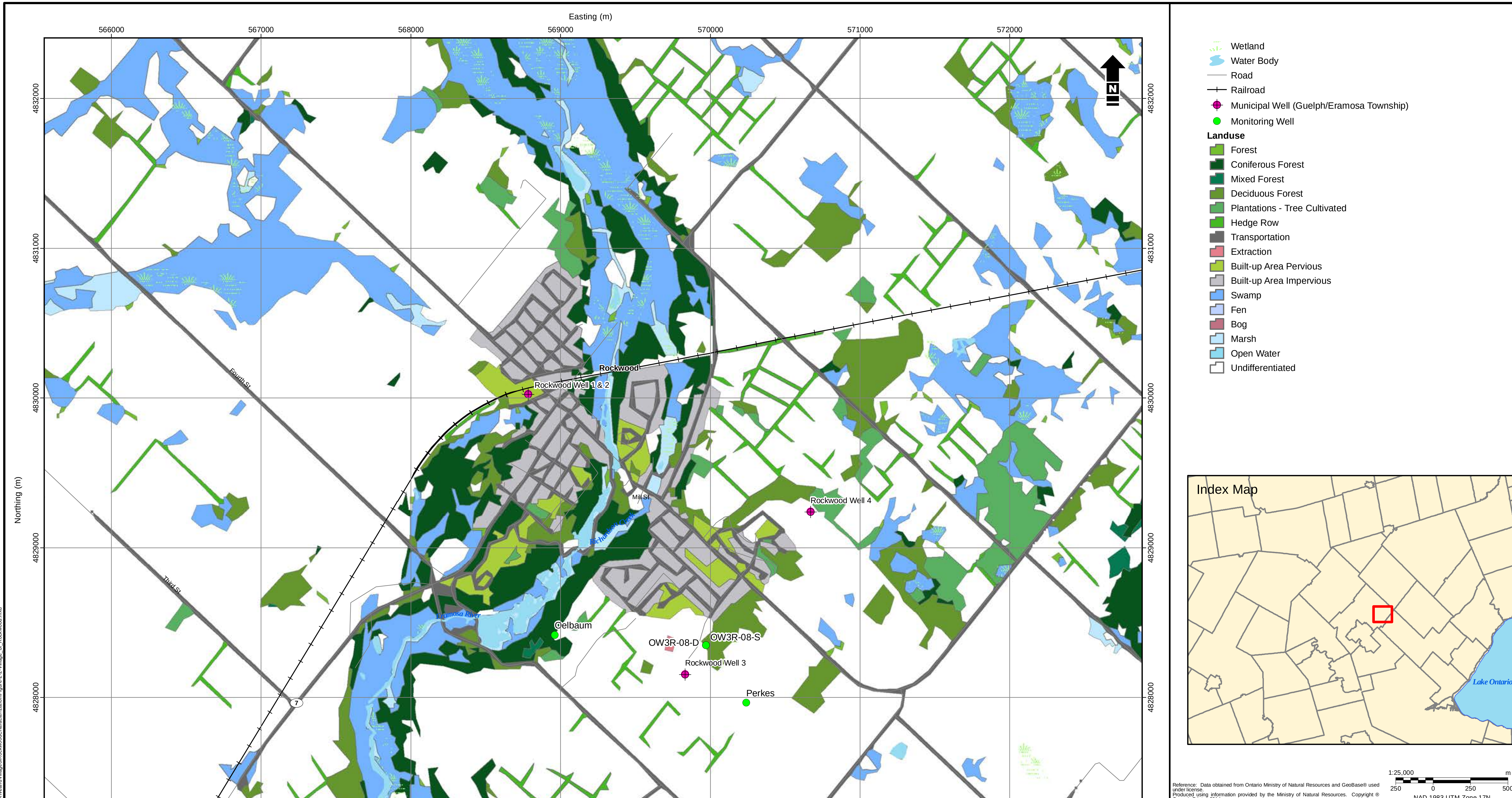

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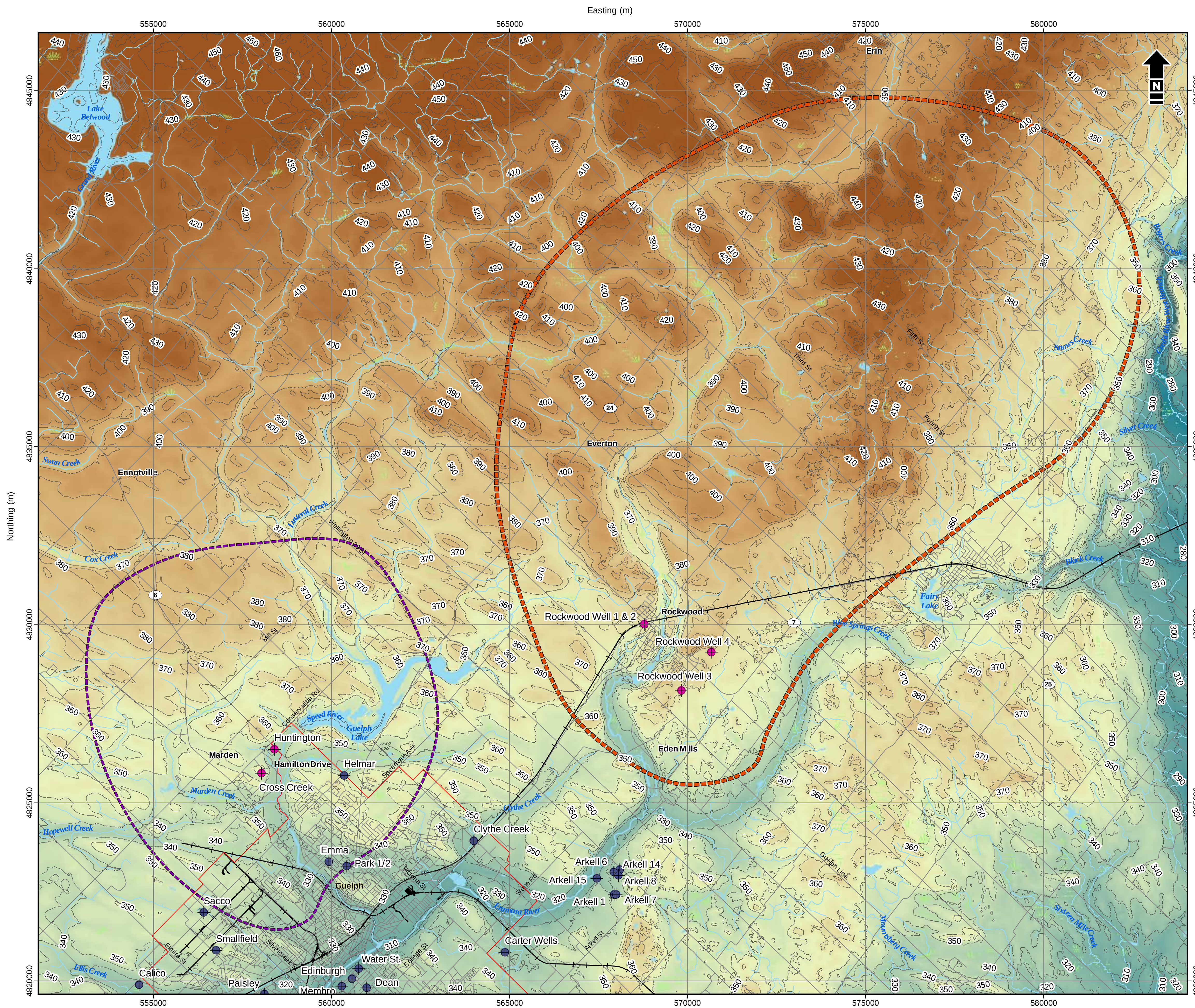
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

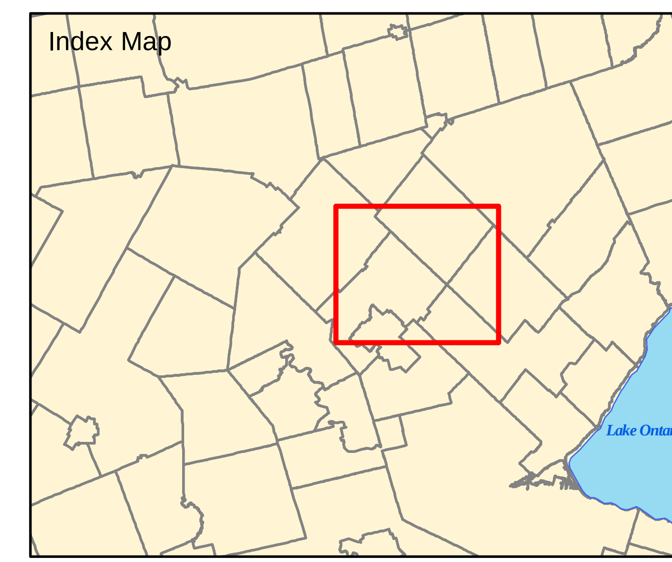
Rockwood

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-2

I:\City of Guelph\15072\Figures and Tables\QGIS\2014\Report\Appendix C_Hamilton Drive and Village of Rockwood\Rockwood Characterization\Figure-2-2-Village_of_Rockwood.mxd





Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Elevation Contour Interval 10m
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Elevation (masl)
High : 475
Low : 270

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NAD 1983 UTM Zone 17N

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Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Ground Surface Topography

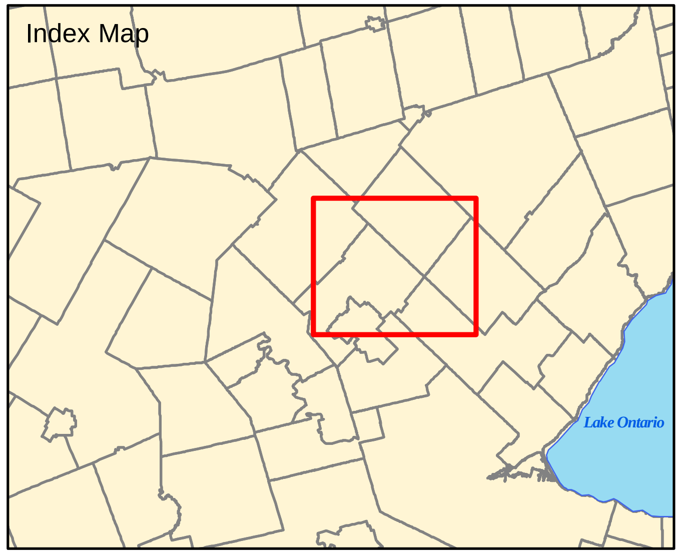
Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 2-3

Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Physiographic Region
1, Niagara Escarpment
5, Horseshoe Moraines
6, Flamborough Plain
9, Hillsburgh Sandhills
11, Guelph Drumlin Field

Physiography
1: Escarpments
2: Till Moraines
3: Spillways
4: Kame Moraines
6: Till Plains (Drumlinized)
7: Drumlins
9: Limestone Plains
13: Eskers



Reference: Data obtained from Ontario Ministry of Natural Resources and GeoBase® used under license.
Chapman, L.J. and Putnam, D.F. 2007. Physiography of Southern Ontario; Ontario Geological Survey, Miscellaneous Release-Data 228 ISBN 978-1-4249-5158-1
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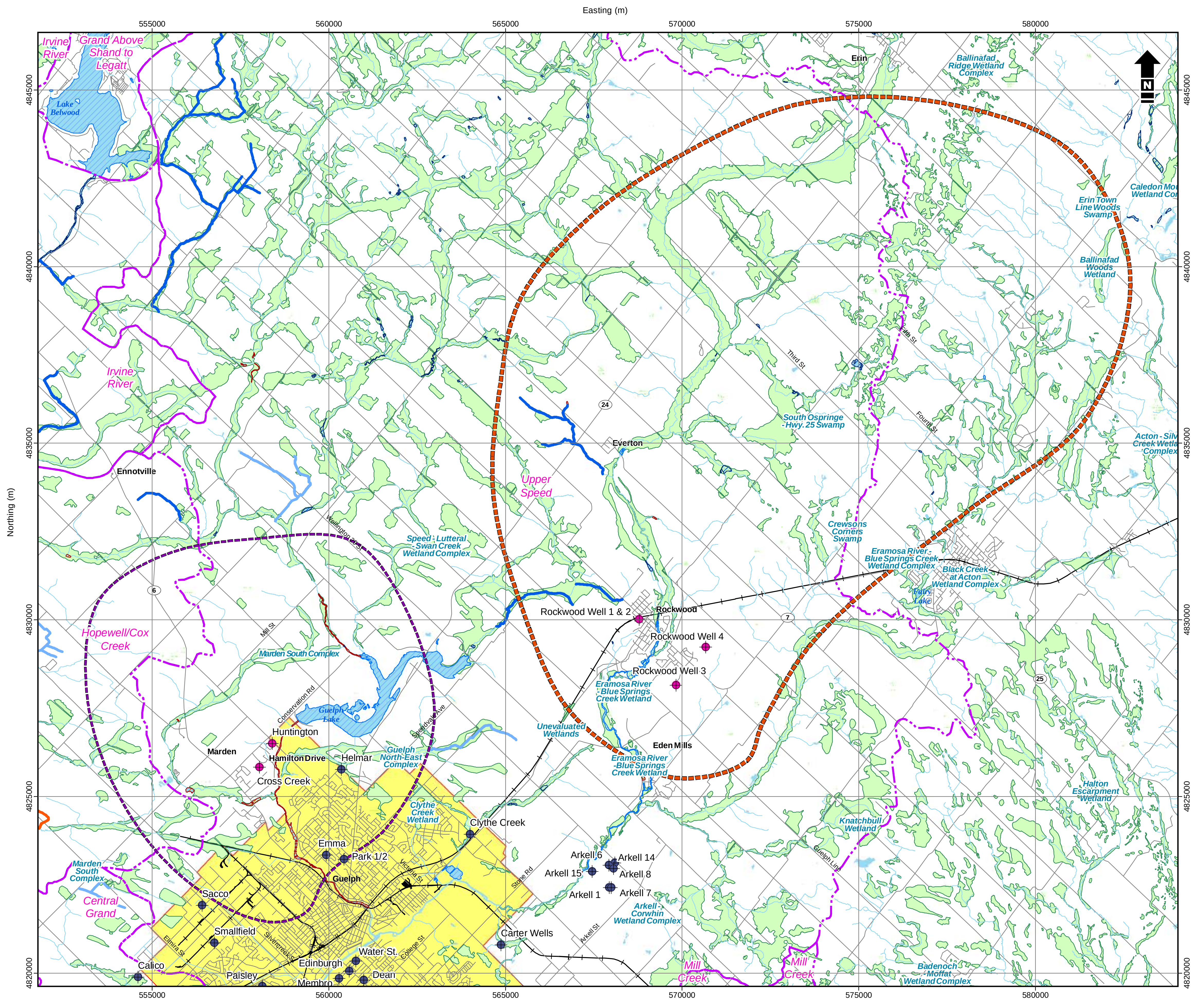
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

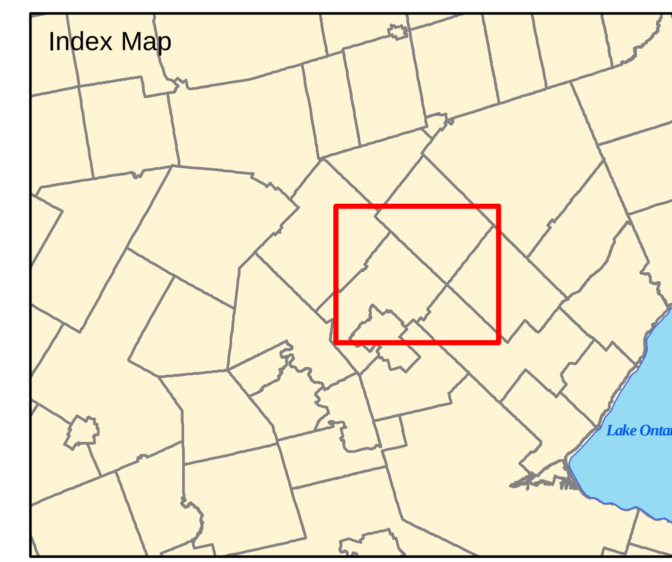
Physiography: Features and Regions

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 2-4



Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Subwatershed Boundary
Community
Wetland
Provincially Significant Wetland
Cool Water
Cold Water
Warm Water
Water Body
Watercourse
Cool Stream
Cold Stream
Warm Stream
Road
Railroad
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)



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Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Surface Water Features

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Figure
2-5

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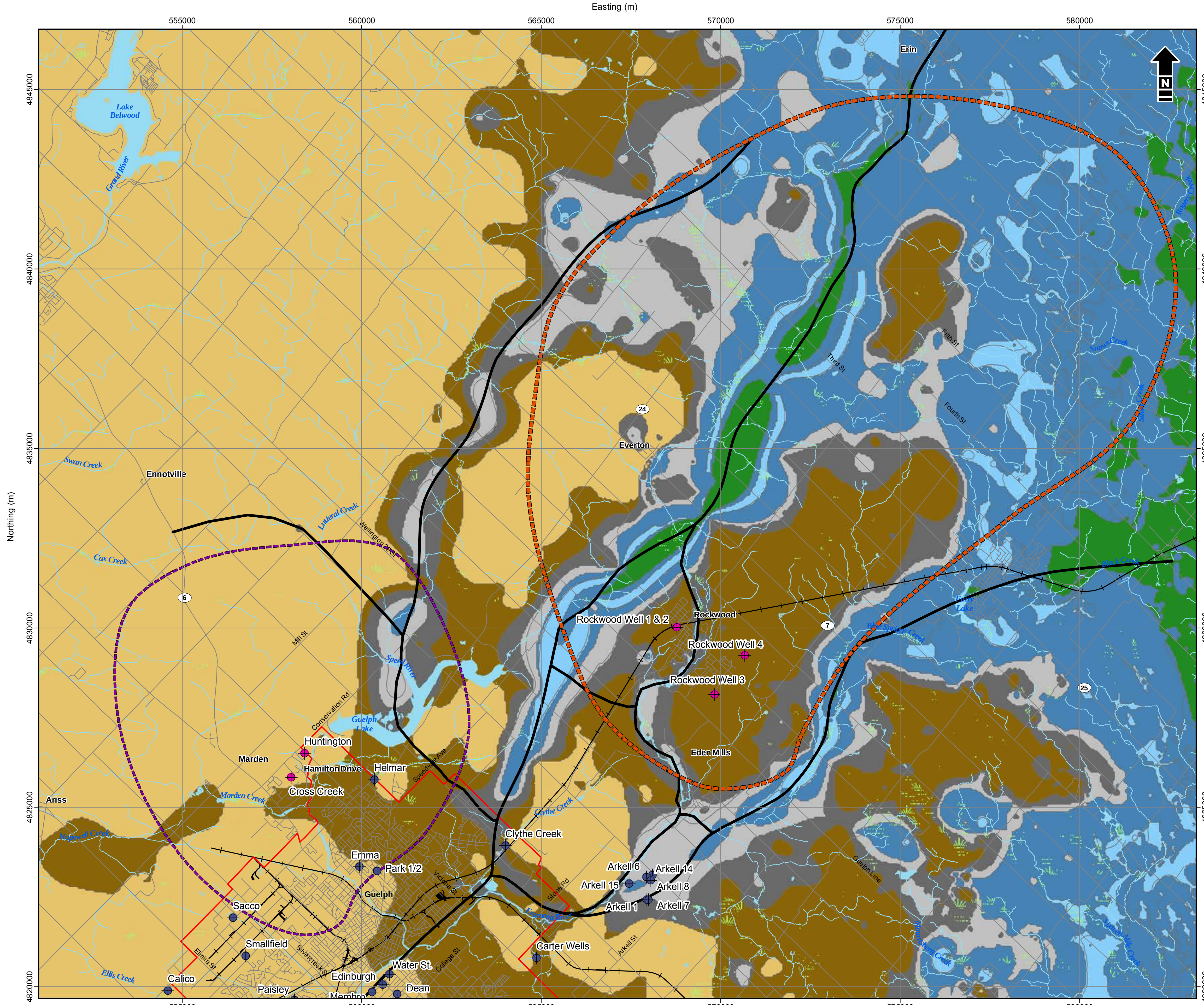
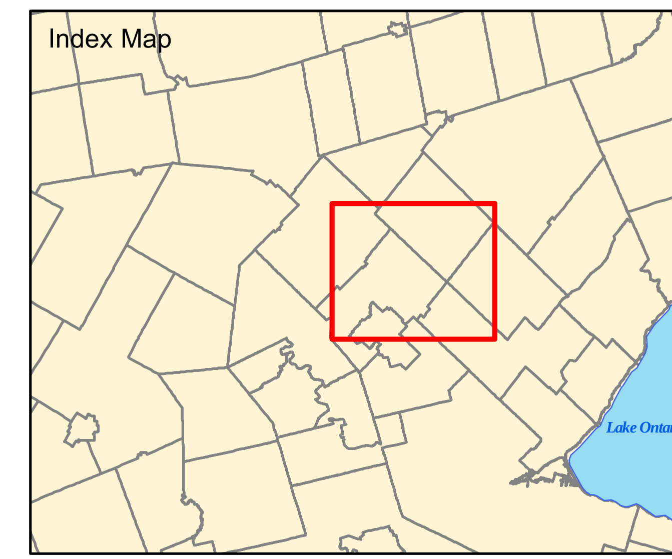


Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Bedrock Thalweg
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Bedrock Geology

Guelph Fm
Eramosa Fm - Reformatory Quarry
Eramosa Fm - Vinemount
Goat Island Fm
Gasport Fm (Upper Unit)
Gasport Fm (Middle Unit)
Gasport Fm (Lower Unit)
Cabot Head Fm



Reference: Data obtained from Ontario Ministry of Natural Resources and GeoBase® used under license.
Bedrock Geology: Armstrong, D.K. and Dodge, J.E.P. 2007. Paleozoic geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release—Data 219
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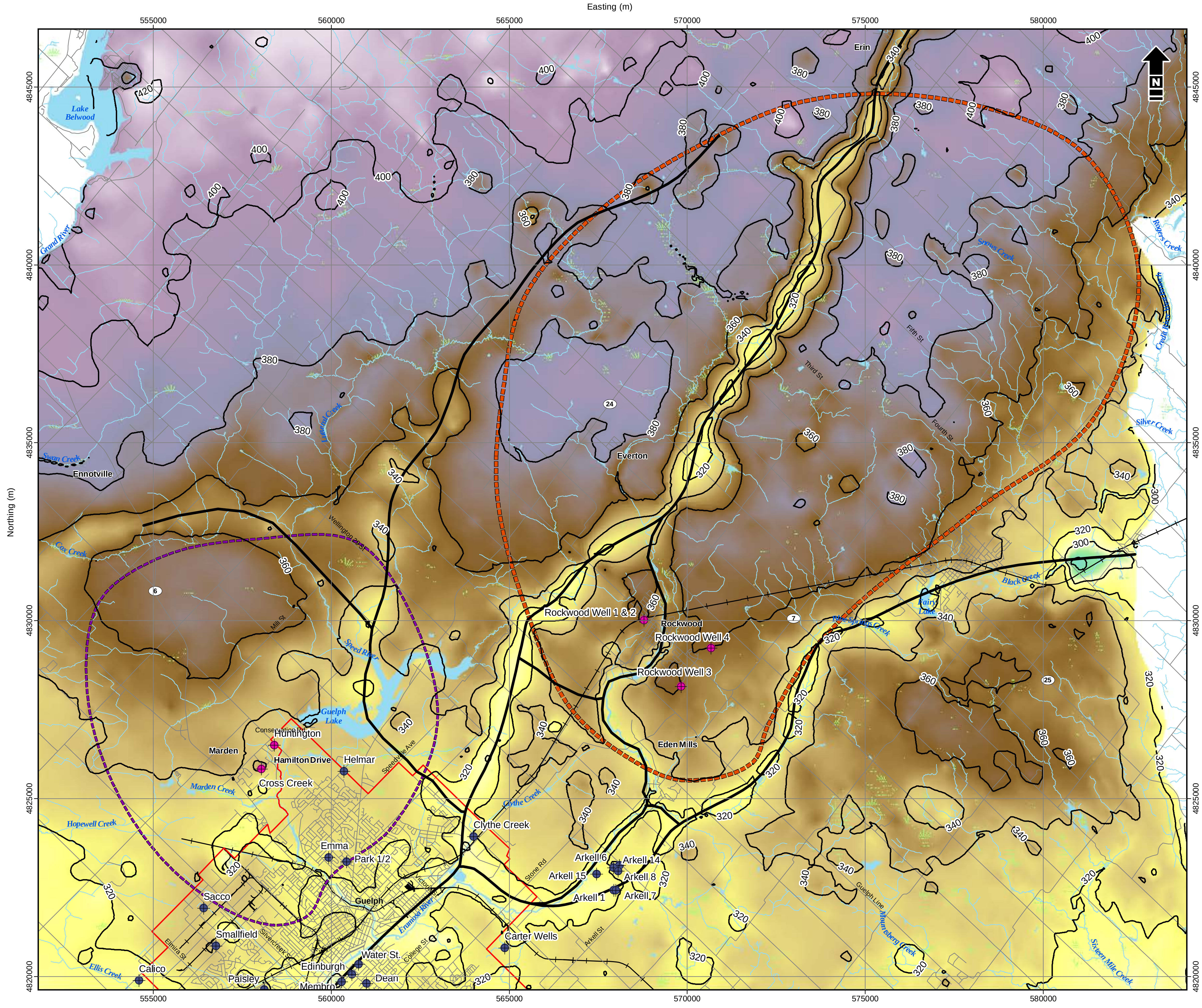
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Bedrock Geology

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure
2-6



Area of Interest - Hamilton Drive

Area of Interest - Rockwood

Community

Wetland

Water Body

Watercourse

Road

Railroad

Bedrock Thalweg

Bedrock Surface Contour (20m)

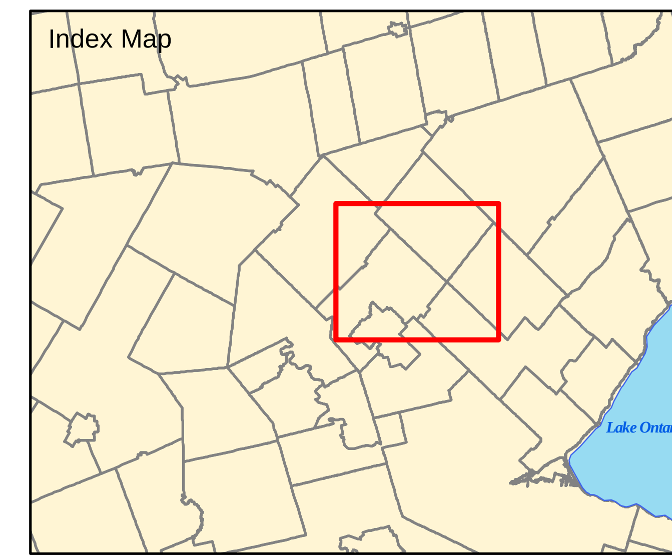
Municipal Well (City of Guelph)

Municipal Well (Guelph/Eramosa Township)

Bedrock Topography (masl)

High : 425

Low : 275



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Appendix C Characterization Update - Rockwood and Hamilton Drive

Bedrock Surface Topography

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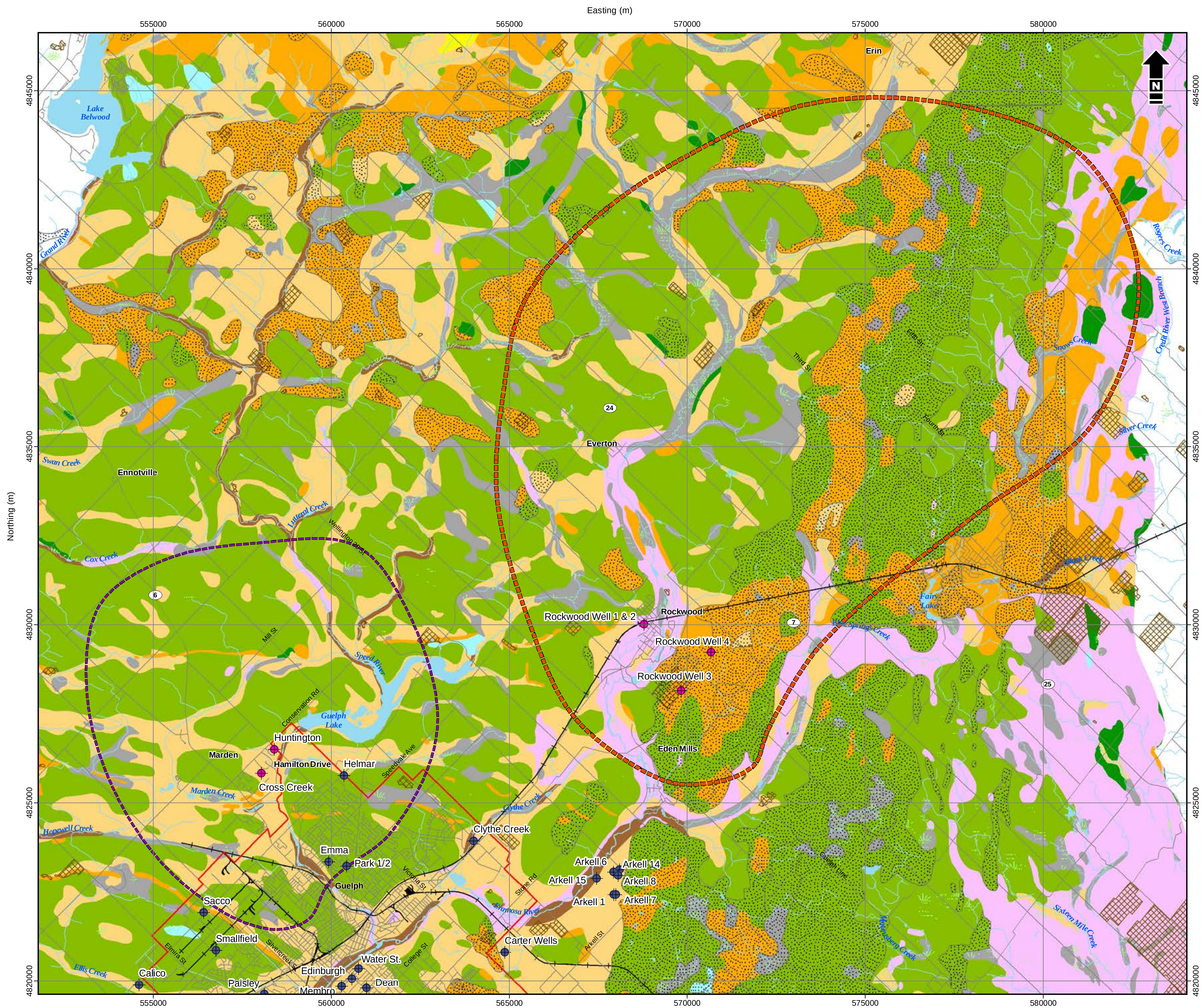
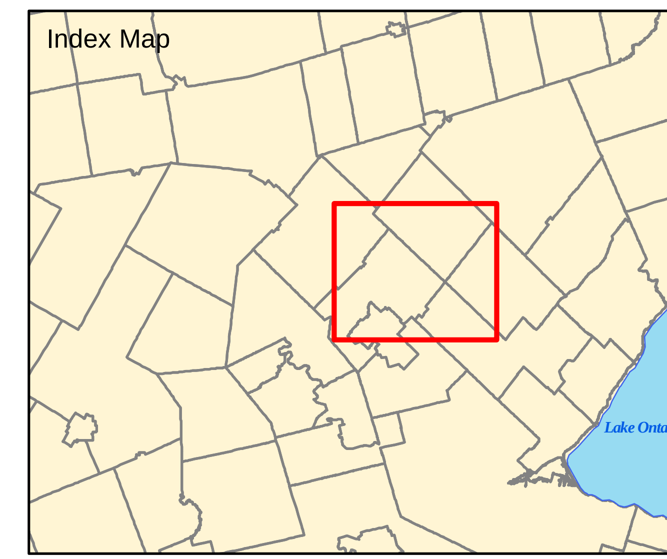
Figure 2-7



Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Moraine
Community
Pit and Quarry
Wetland
Water Body
Watercourse
Road
Railroad
Cross Section
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Surficial Geology

3: Paleozoic bedrock
4: Paleozoic bedrock-drift complex
4a: Mainly till veneer
5b: Stone-poor, carbonate-derived silty to sandy till
5d: Glaciolacustrine-derived silty to clayey till
6: Ice-contact stratified deposits
7: Glaciofluvial deposits
7a: Sandy deposits
7b: Gravelly deposits
8a: Massive-well laminated
8b: Interbedded flow till, rainout deposits and silt and clay
9c: Foreshore-basinal deposits
19: Modern alluvial deposits
20: Organic deposits



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Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Surficial Geology

Date:	Project:	Technical:	Reviewer:	Drawn:
08 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-8

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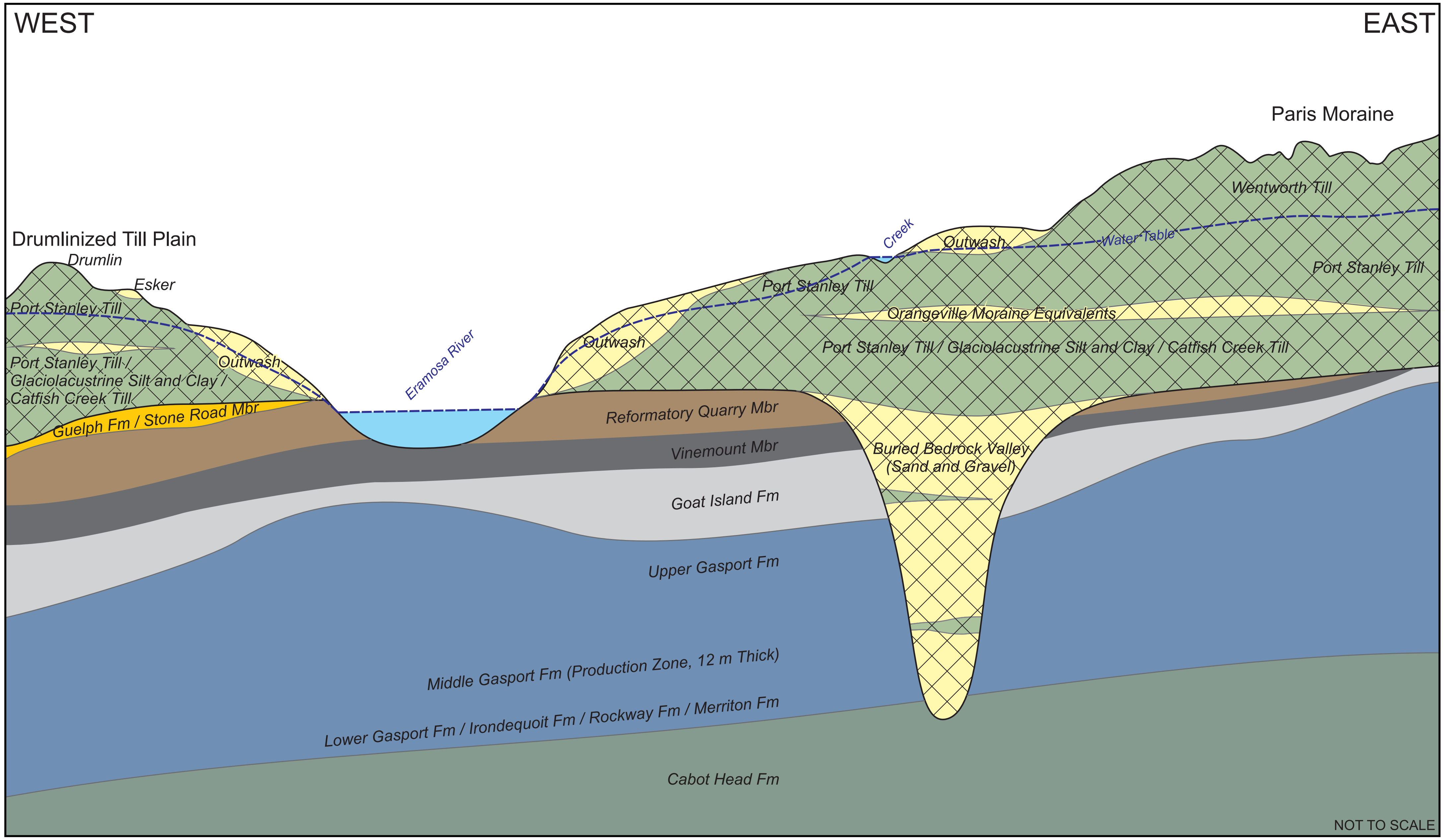

- Overburden material
- Fine-grained sediment (diamict/ till, silt, and clay)
- Coarse-grained sediment (sand and gravel)
- Guelph Formation / Stone Road Member of the Eramosa Formation
- Reformatory Quarry Member of the Eramosa Formation
- Vinemount Member of the Eramosa Formation
- Goat Island Formation
- Gasport Formation, Irondequoit Formation, Rockway Formation, and Merriton Formation
- Cabot Head Formation

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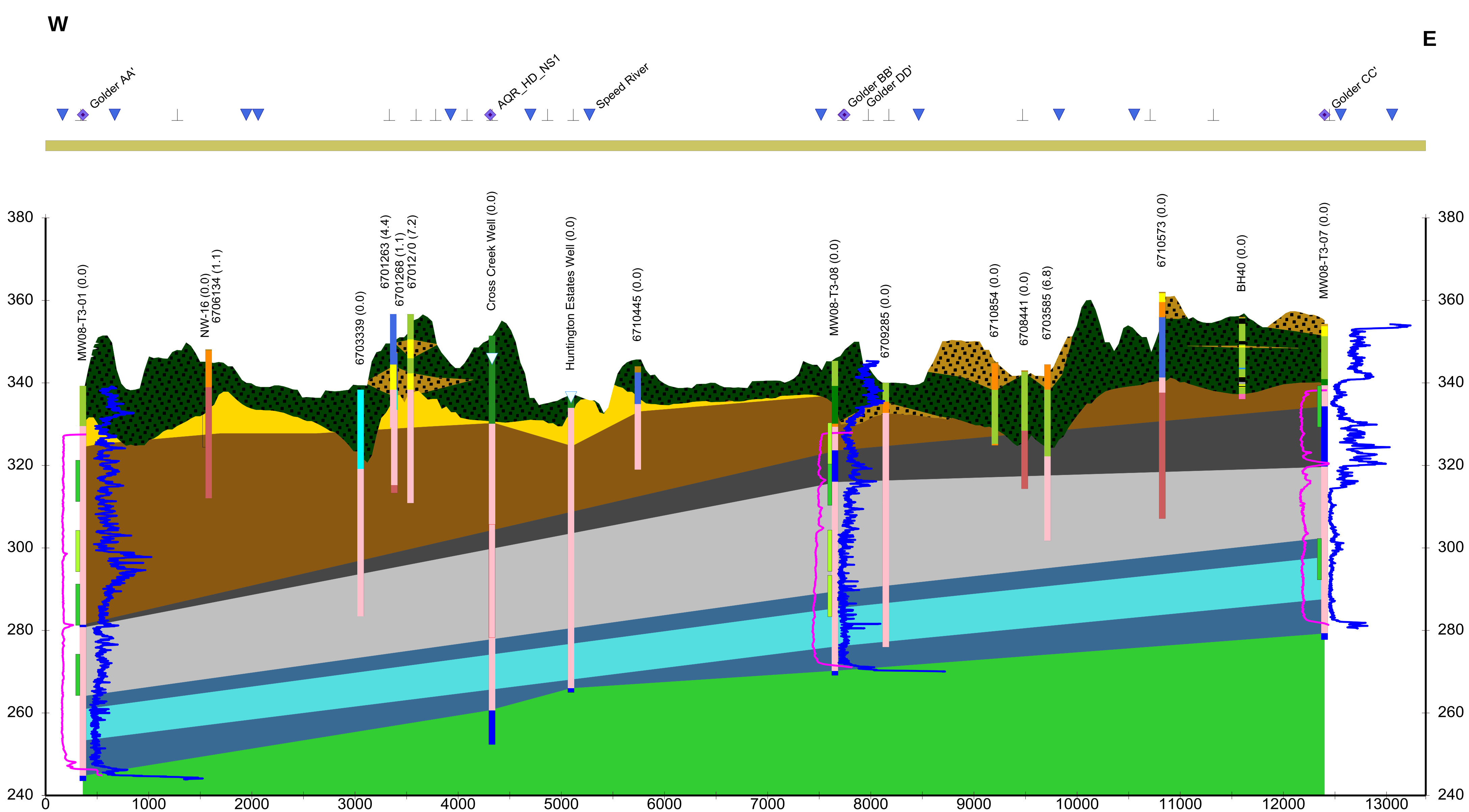
Appendix C Characterization Update - Rockwood and Hamilton Drive

Conceptual Hydrostratigraphic Model

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 2-9



LEGEND

Cross-Section Intersection
- Drainage
- Road
- Cross-Section

Response Log
- Conductivity Log (first log track)
- Gamma Log (fourth log track)

Previous Interpretation(s)
- Top of Guelph Fm
- Top of Eramosa Fm (Reformatory Quarry Mbr or Stone Road Member)
- Top of Eramosa Fm (Vinemount Member)
- Top of Goat Island Fm (Ancaster or Niagara Falls Mbrs)
- Top of Amabel Fm/Gasport Fm
- Top of Cabot Head Fm
- Top of Irondequot, Merriton, or Rockway Fms
- Top of Queenston Fm

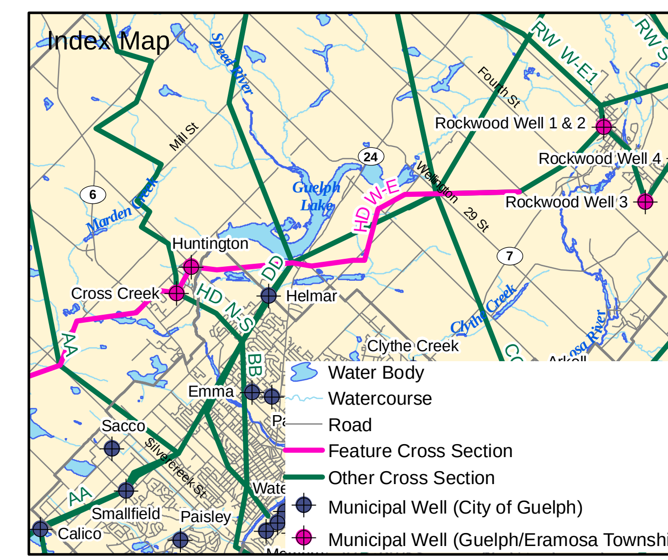
Ground Surface, Top of Bedrock Surface

Bedrock Supcrop (Armstrong and Dodge, 2007)
(along top of section)
- Amabel Fm/Gasport Fm
- Eramosa Fm
- Guelph Fm

Borehole Lithology
(third log track)
- Clay, silty clay
- Silt, clayey silt, sandy silt
- Diamict, cl/si matrix
- Diamict, si/sa matrix
- Sand, silty sand
- Gravel, gravelly sand
- Organic
- Fill, topsoil
- Limestone, dolostone
- Limestone, Shale
- Shale
- Undifferentiated bedrock
- Unknown

Hydraulic Conductivity (Kh) Estimate from Field Test (m/s)
(second log track)
- <1E-8
- 1E-8...1E-7
- 1E-7...1E-6
- 1E-6...1E-5
- 1E-5...1E-4
- 1E-4...1E-3
- >1E-3

Hydrostratgraphic Unit
- Overburden, Coarse
- Overburden, Fine
- Contact Aquifer
- Guelph Fm (including Stone Road Mbr of Eramosa Fm)
- Reformatory Quarry
- Eramosa Fm, Vinemount Mbr
- Goat Island Fm
- upper/lower Gasport Fm, Irondequit Fm, Rockway Fm, and Merriton Fm
- middle Gasport Fm
- Cabot Head Fm



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Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Hamilton Drive Cross-Section: West-East

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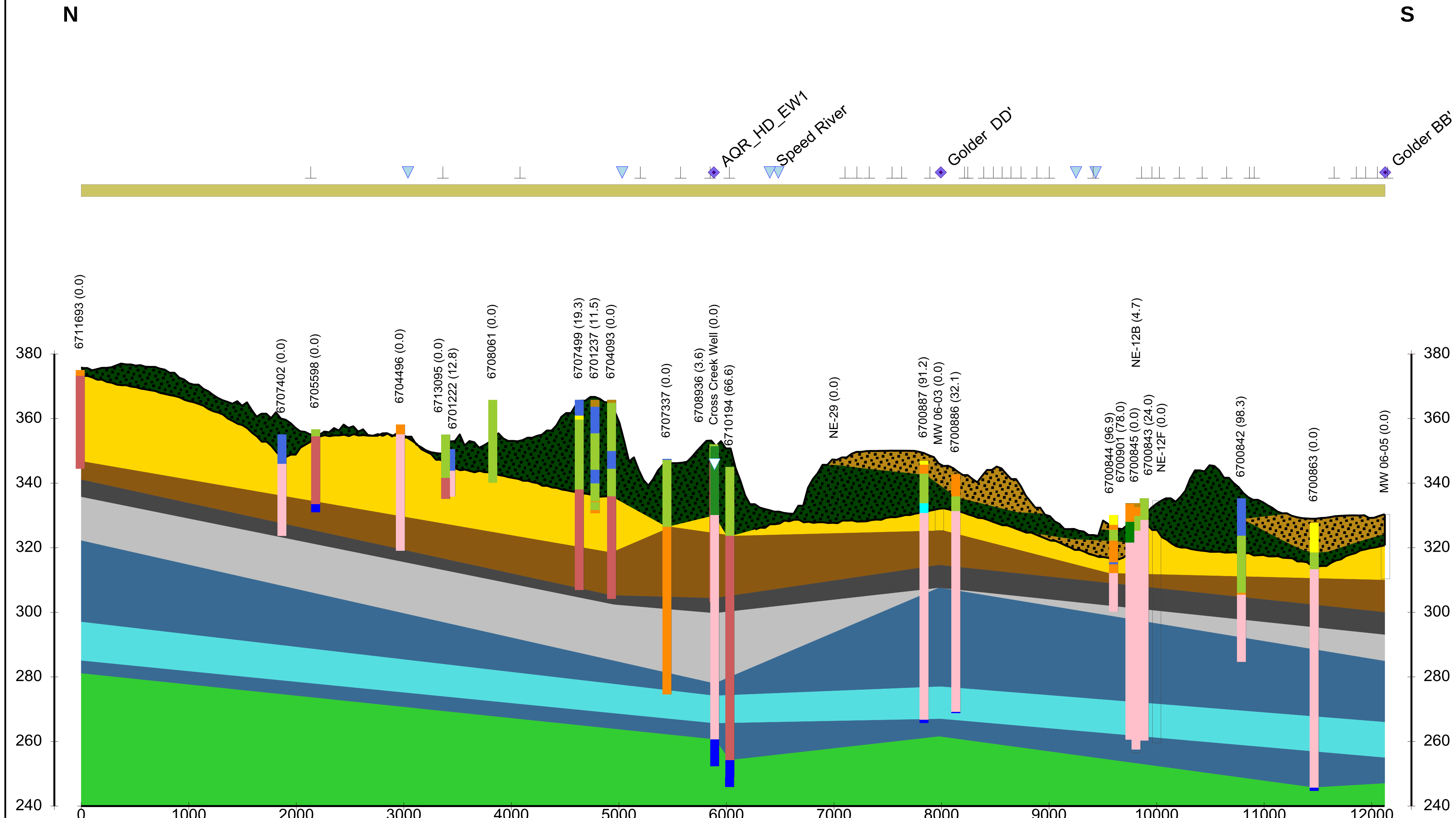
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-10



LEGEND

Cross-Section Intersection
Drainage
Road
Cross-Section

Response Log
Conductivity Log (first log track)
Gamma Log (fourth log track)

Previous Interpretation(s)
Top of Guelph Fm
Top of Eramosa Fm (Reformatory Quarry Mbr or Stone Road Member)
Top of Eramosa Fm (Vinemount Member)
Top of Goat Island Fm (Ancaster or Niagara Falls Mbrs)
Top of Amabel Fm/Gasport Fm
Top of Cabot Head Fm
Top of Irondequot, Merriton, or Rockway Fms
Top of Queenston Fm

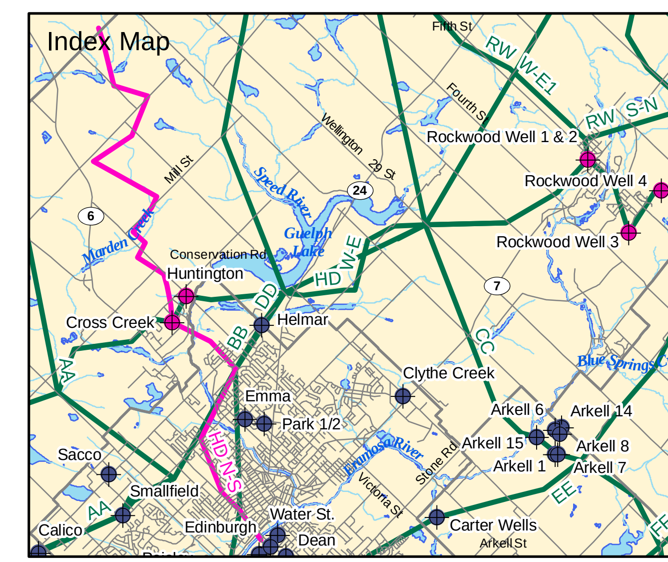
Ground Surface, Top of Bedrock Surface

Bedrock Supcrop (Armstrong and Dodge, 2007)
(along top of section)
Amabel Fm/Gasport Fm
Eramosa Fm
Guelph Fm

Borehole Lithology
(third log track)
Clay, silty clay
Silt, clayey silt, sandy silt
Diamict, cl/si matrix
Diamict, si/sa matrix
Sand, silty sand
Gravel, gravelly sand
Organic
Fill, topsoil
Limestone, dolostone
Limestone, Shale
Shale
Undifferentiated bedrock
Unknown

Hydraulic Conductivity (Kh) Estimate from Field Test (m/s)
(second log track)
<1E-8
1E-8...1E-7
1E-7...1E-6
1E-6...1E-5
1E-5...1E-4
1E-4...1E-3
>1E-3

Hydrostratgraphic Unit
Overburden, Coarse
Overburden, Fine
Contact Aquifer
Guelph Fm (including Stone Road Mbr of Eramosa Fm)
Reformatory Quarry
Eramosa Fm, Vinemount Mbr
Goat Island Fm
upper/lower Gasport Fm, Irondequit Fm, Rockway Fm, and Merriton Fm
middle Gasport Fm
Cabot Head Fm



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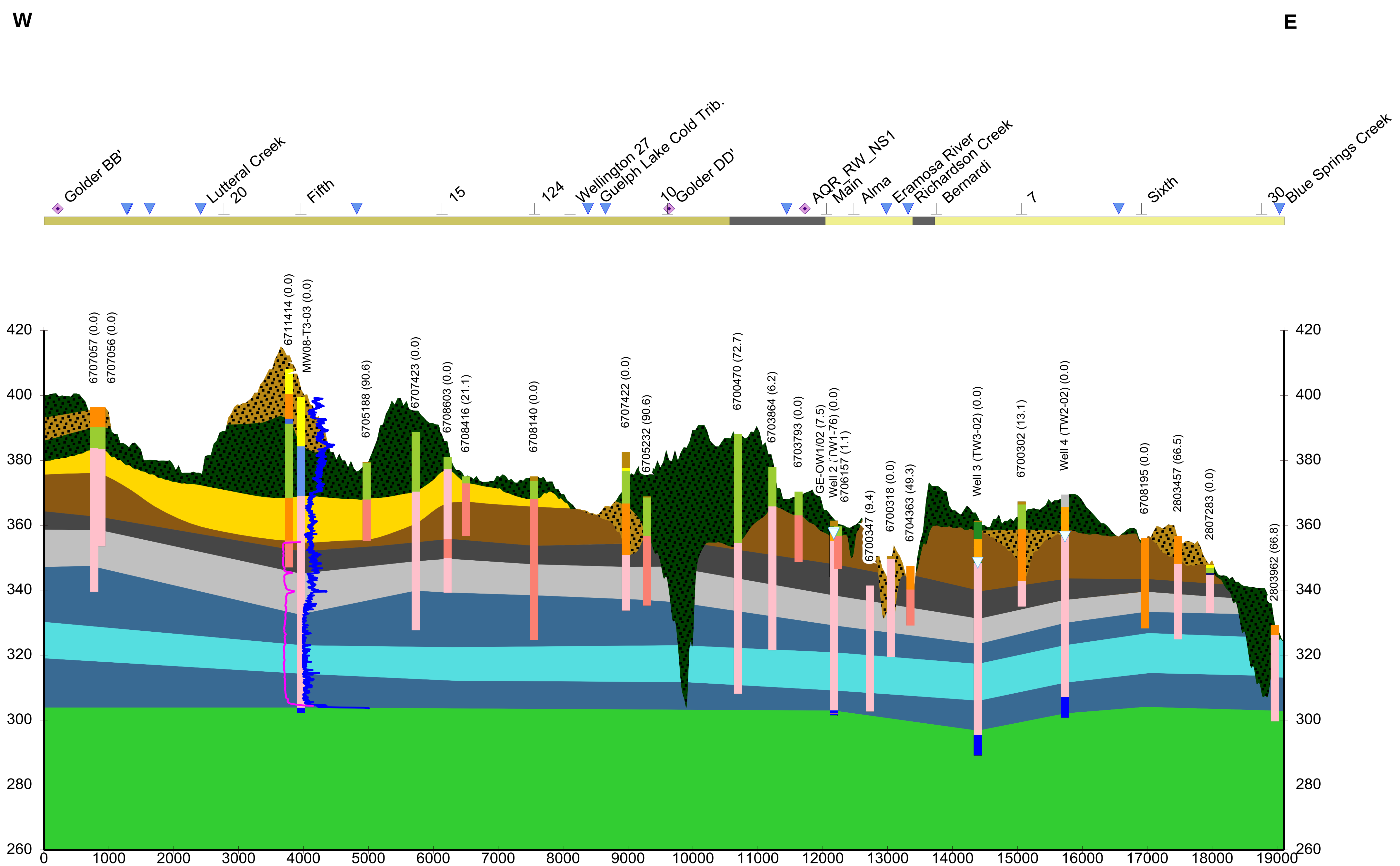
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Hamilton Drive Cross-Section: North-South

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-11



LEGEND

Cross-Section Intersection
- Drainage
- Road
- Cross-Section

Response Log
- Conductivity Log (first log track)
- Gamma Log (fourth log track)

Previous Interpretation(s)
- Top of Guelph Fm
- Top of Eramosa Fm (Reformatory Quarry Mbr or Stone Road Member)
- Top of Eramosa Fm (Vinemount Member)
- Top of Goat Island Fm (Ancaster or Niagara Falls Mbrs)
- Top of Amabel Fm/Gasport Fm
- Top of Cabot Head Fm
- Top of Irondequot, Merriton, or Rockway Fms
- Top of Queenston Fm

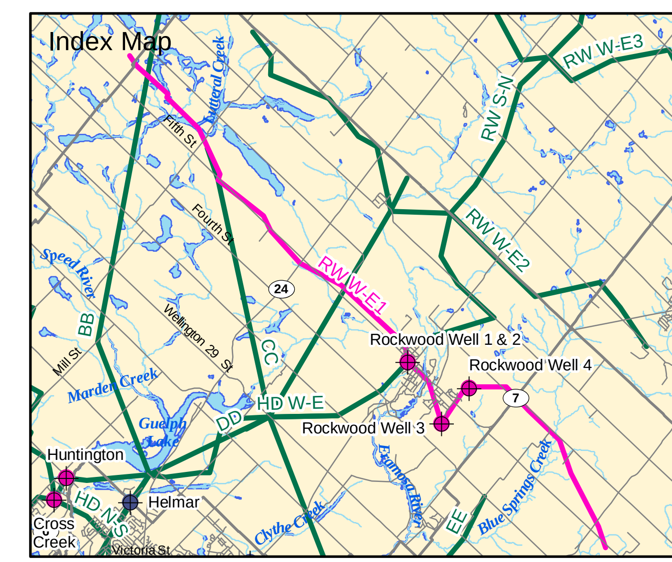
Ground Surface, Top of Bedrock Surface

Bedrock Supcrop (Armstrong and Dodge, 2007)
(along top of section)
- Amabel Fm/Gasport Fm
- Eramosa Fm
- Guelph Fm

Borehole Lithology
(third log track)
- Clay, silty clay
- Silt, clayey silt, sandy silt
- Diamict, cl/si matrix
- Diamict, si/sa matrix
- Sand, silty sand
- Gravel, gravelly sand
- Organic
- Fill, topsoil
- Limestone, dolostone
- Limestone, Shale
- Shale
- Undifferentiated bedrock
- Unknown

Hydraulic Conductivity (Kh) Estimate from Field Test (m/s)
(second log track)
- <1E-8
- 1E-8...1E-7
- 1E-7...1E-6
- 1E-6...1E-5
- 1E-5...1E-4
- 1E-4...1E-3
- >1E-3

Hydrostratgraphic Unit
- Overburden, Coarse
- Overburden, Fine
- Contact Aquifer
- Guelph Fm (including Stone Road Mbr of Eramosa Fm)
- Reformatory Quarry
- Eramosa Fm, Vinemount Mbr
- Goat Island Fm
- upper/lower Gasport Fm, Irondequit Fm, Rockway Fm, and Merriton Fm
- middle Gasport Fm
- Cabot Head Fm



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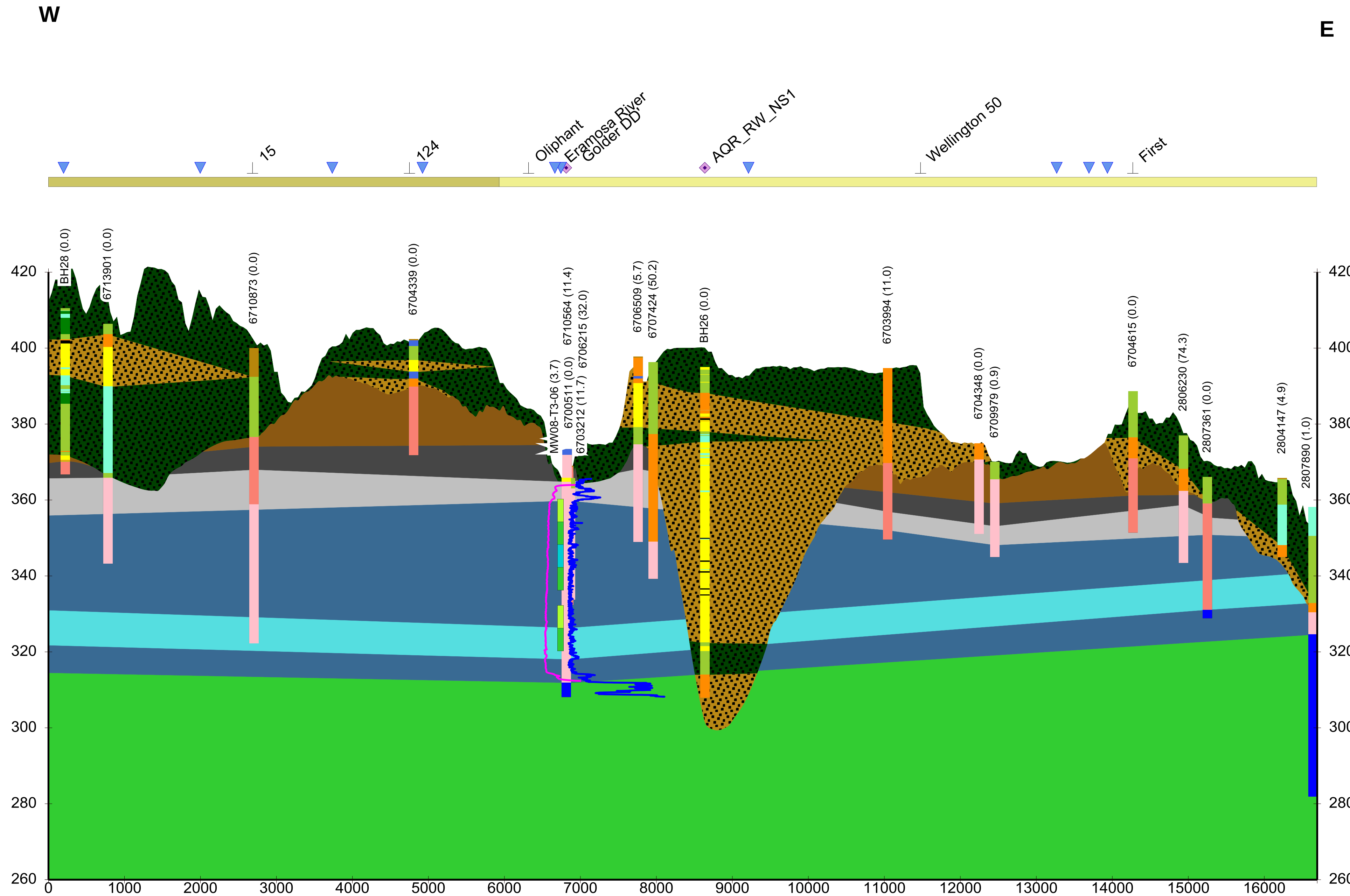
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Rockwood Cross-Section: West-East 1

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-12



LEGEND

Cross-Section Intersection
- Drainage
- Road
- Cross-Section

Response Log
- Conductivity Log (first log track)
- Gamma Log (fourth log track)

Previous Interpretation(s)
- Top of Guelph Fm
- Top of Eramosa Fm (Reformatory Quarry Mbr or Stone Road Member)
- Top of Eramosa Fm (Vinemount Member)
- Top of Goat Island Fm (Ancaster or Niagara Falls Mbrs)
- Top of Amabel Fm/Gasport Fm
- Top of Cabot Head Fm
- Top of Irondequot, Merriton, or Rockway Fms
- Top of Queenston Fm

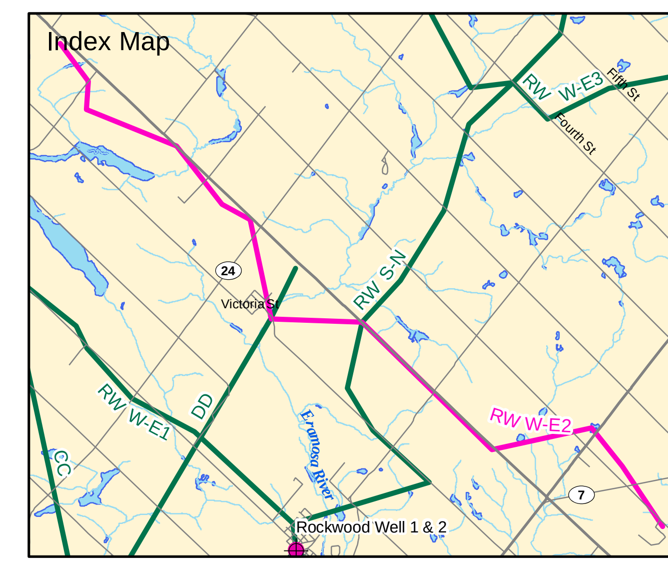
Ground Surface, Top of Bedrock Surface

Bedrock Supcrop (Armstrong and Dodge, 2007)
(along top of section)
- Amabel Fm/Gasport Fm
- Eramosa Fm
- Guelph Fm

Borehole Lithology
(third log track)
- Clay, silty clay
- Silt, clayey silt, sandy silt
- Diamict, cl/si matrix
- Diamict, si/sa matrix
- Sand, silty sand
- Gravel, gravelly sand
- Organic
- Fill, topsoil
- Limestone, dolostone
- Limestone, Shale
- Shale
- Undifferentiated bedrock
- Unknown

Hydraulic Conductivity (Kh) Estimate from Field Test (m/s)
(second log track)
- <1E-8
- 1E-8...1E-7
- 1E-7...1E-6
- 1E-6...1E-5
- 1E-5...1E-4
- 1E-4...1E-3
- >1E-3

Hydrostratgraphic Unit
- Overburden, Coarse
- Overburden, Fine
- Contact Aquifer
- Guelph Fm (including Stone Road Mbr of Eramosa Fm)
- Reformatory Quarry
- Eramosa Fm, Vinemount Mbr
- Goat Island Fm
- upper/lower Gasport Fm, Irondequit Fm, Rockway Fm, and Merriton Fm
- middle Gasport Fm
- Cabot Head Fm



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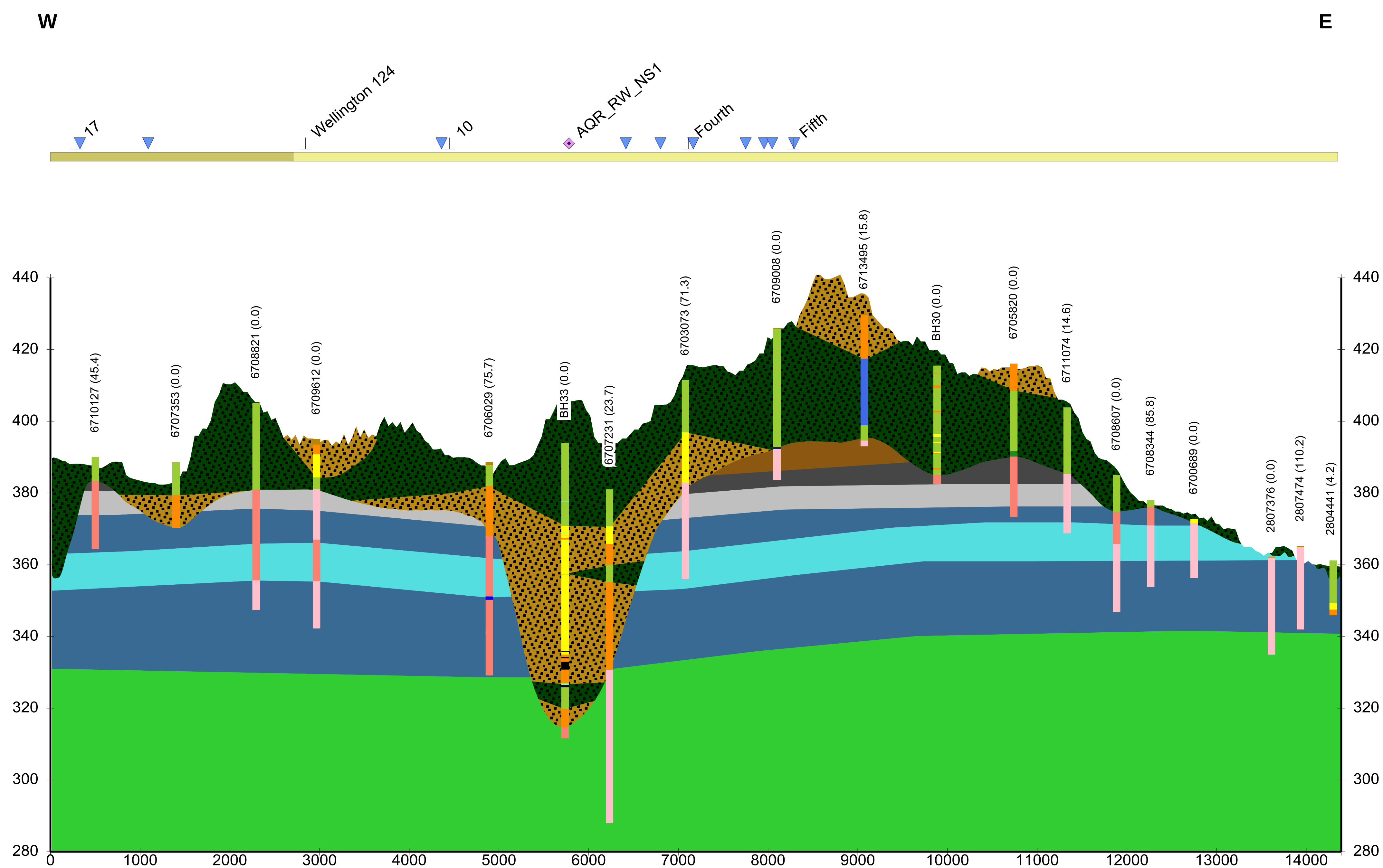
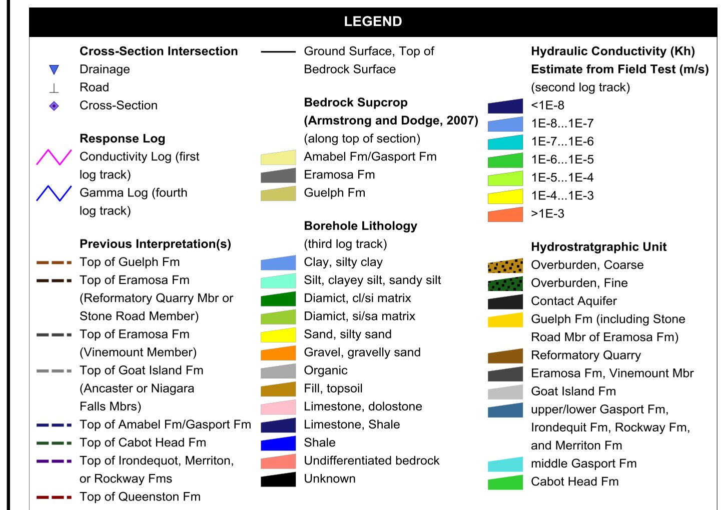
City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

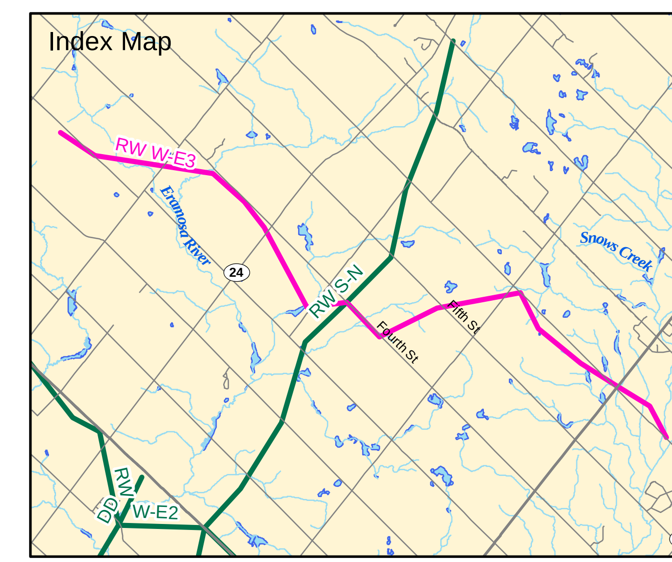
Rockwood Cross-Section: West-East 2

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 2-13







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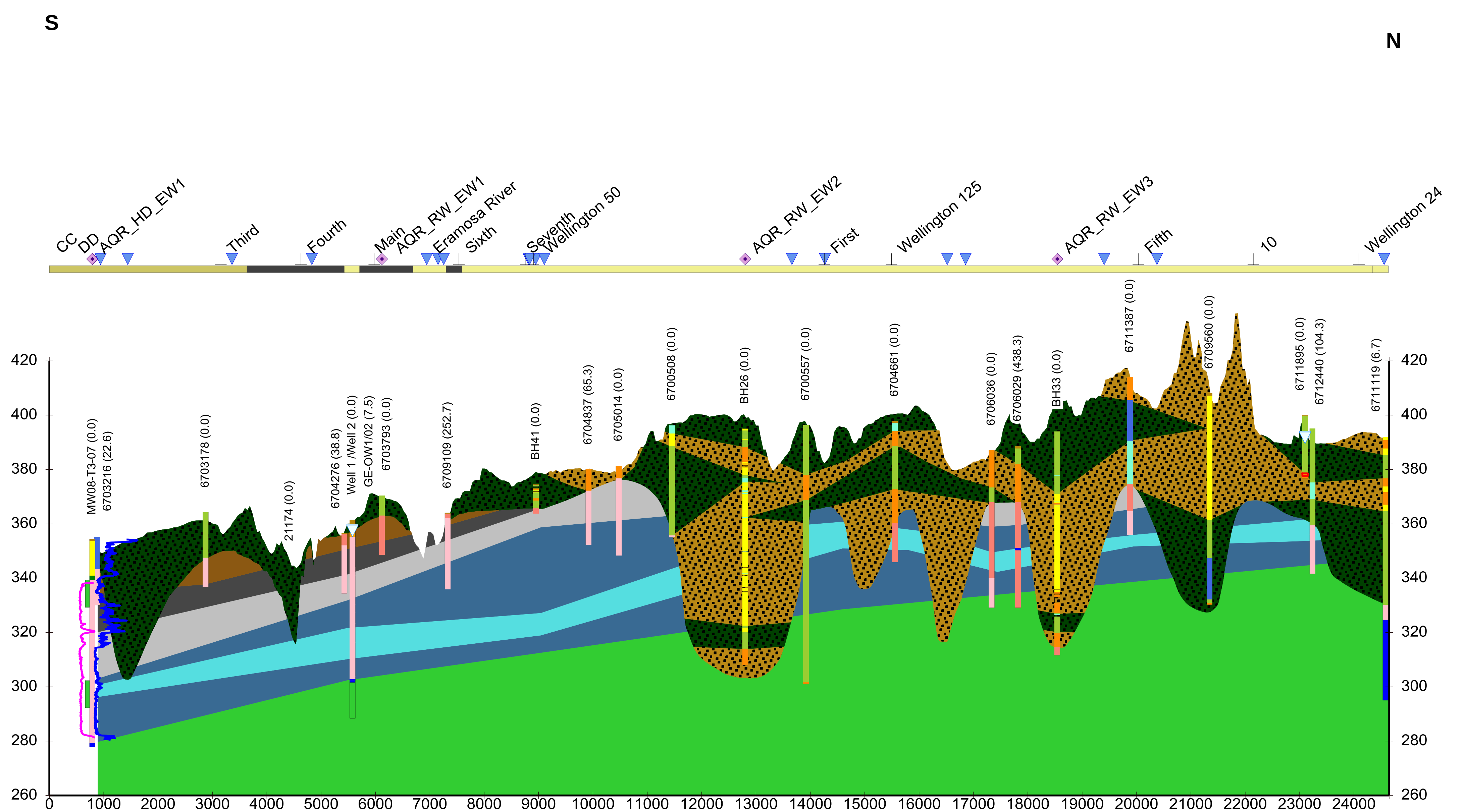
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Rockwood Cross-Section: West-East 3

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 2-14



LEGEND

Cross-Section Intersection
- Drainage
- Road
- Cross-Section

Response Log
- Conductivity Log (first log track)
- Gamma Log (fourth log track)

Previous Interpretation(s)
- Top of Guelph Fm
- Top of Eramosa Fm (Reformatory Quarry Mbr or Stone Road Member)
- Top of Eramosa Fm (Vinemount Member)
- Top of Goat Island Fm (Ancaster or Niagara Falls Mbrs)
- Top of Amabel Fm/Gasport Fm
- Top of Cabot Head Fm
- Top of Irondequot, Merriton, or Rockway Fms
- Top of Queenston Fm

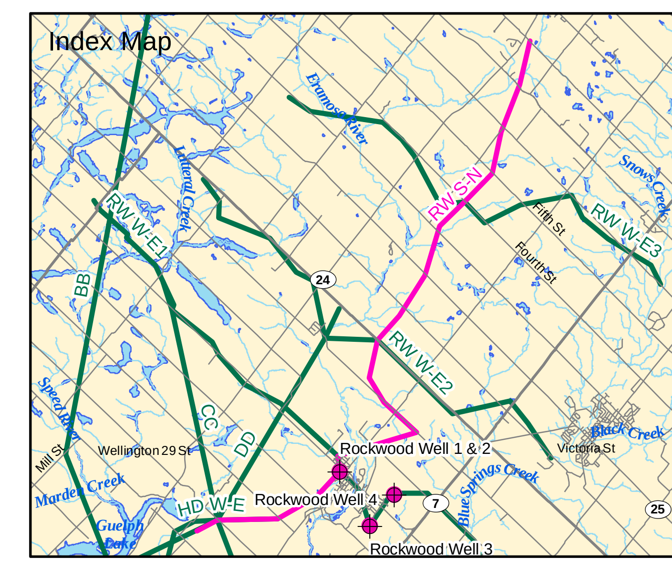
Ground Surface, Top of Bedrock Surface

Bedrock Supcrop (Armstrong and Dodge, 2007)
(along top of section)
- Amabel Fm/Gasport Fm
- Eramosa Fm
- Guelph Fm

Borehole Lithology
(third log track)
- Clay, silty clay
- Silt, clayey silt, sandy silt
- Diamict, cl/si matrix
- Diamict, si/sa matrix
- Sand, silty sand
- Gravel, gravelly sand
- Organic
- Fill, topsoil
- Limestone, dolostone
- Limestone, Shale
- Shale
- Undifferentiated bedrock
- Unknown

Hydraulic Conductivity (Kh) Estimate from Field Test (m/s)
(second log track)
- <1E-8
- 1E-8...1E-7
- 1E-7...1E-6
- 1E-6...1E-5
- 1E-5...1E-4
- 1E-4...1E-3
- >1E-3

Hydrostratgraphic Unit
- Overburden, Coarse
- Overburden, Fine
- Contact Aquifer
- Guelph Fm (including Stone Road Mbr of Eramosa Fm)
- Reformatory Quarry
- Eramosa Fm, Vinemount Mbr
- Goat Island Fm
- upper/lower Gasport Fm, Irondequit Fm, Rockway Fm, and Merriton Fm
- middle Gasport Fm
- Cabot Head Fm



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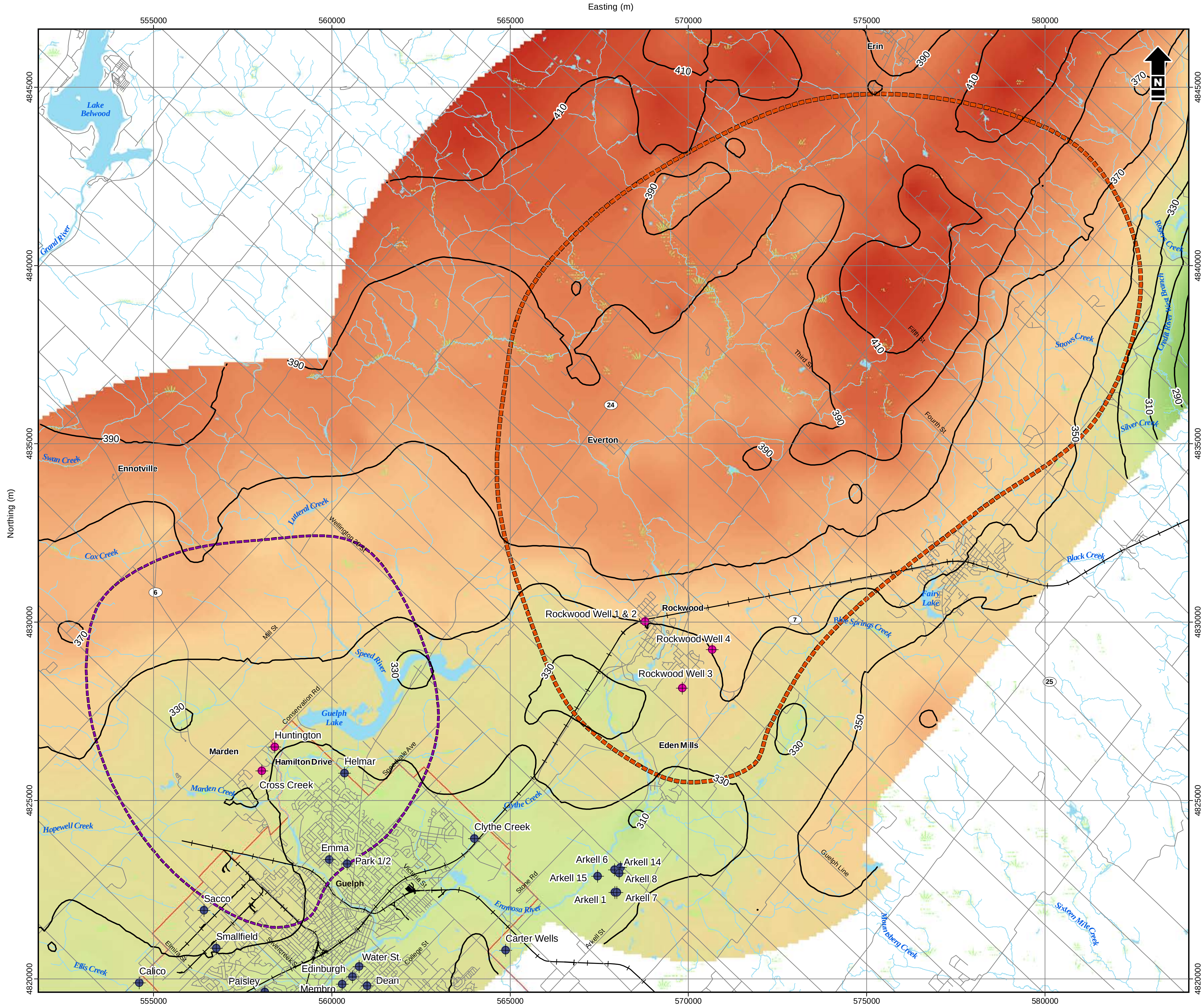
City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Rockwood Cross-Section: South-North

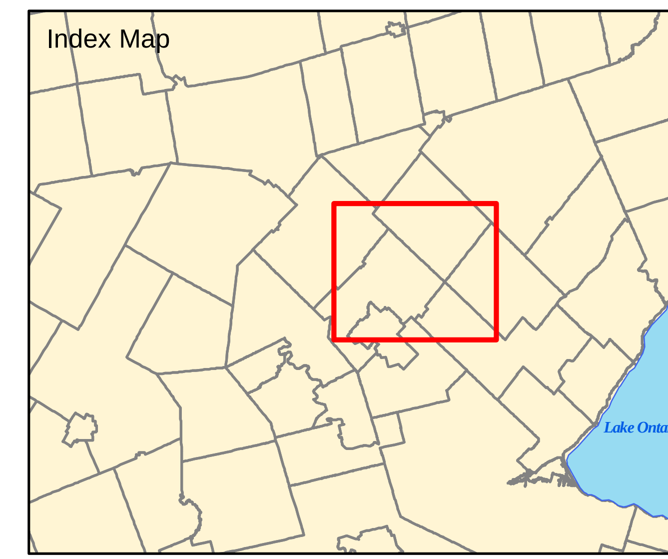
Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-15



Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Shallow Water Elevation Contour (20m)
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Shallow Water Level Elevation (masl)
High : 43!
Low : 240



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NAD 1983 UTM Zone 17N

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City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Shallow Water Level Elevation Surface

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

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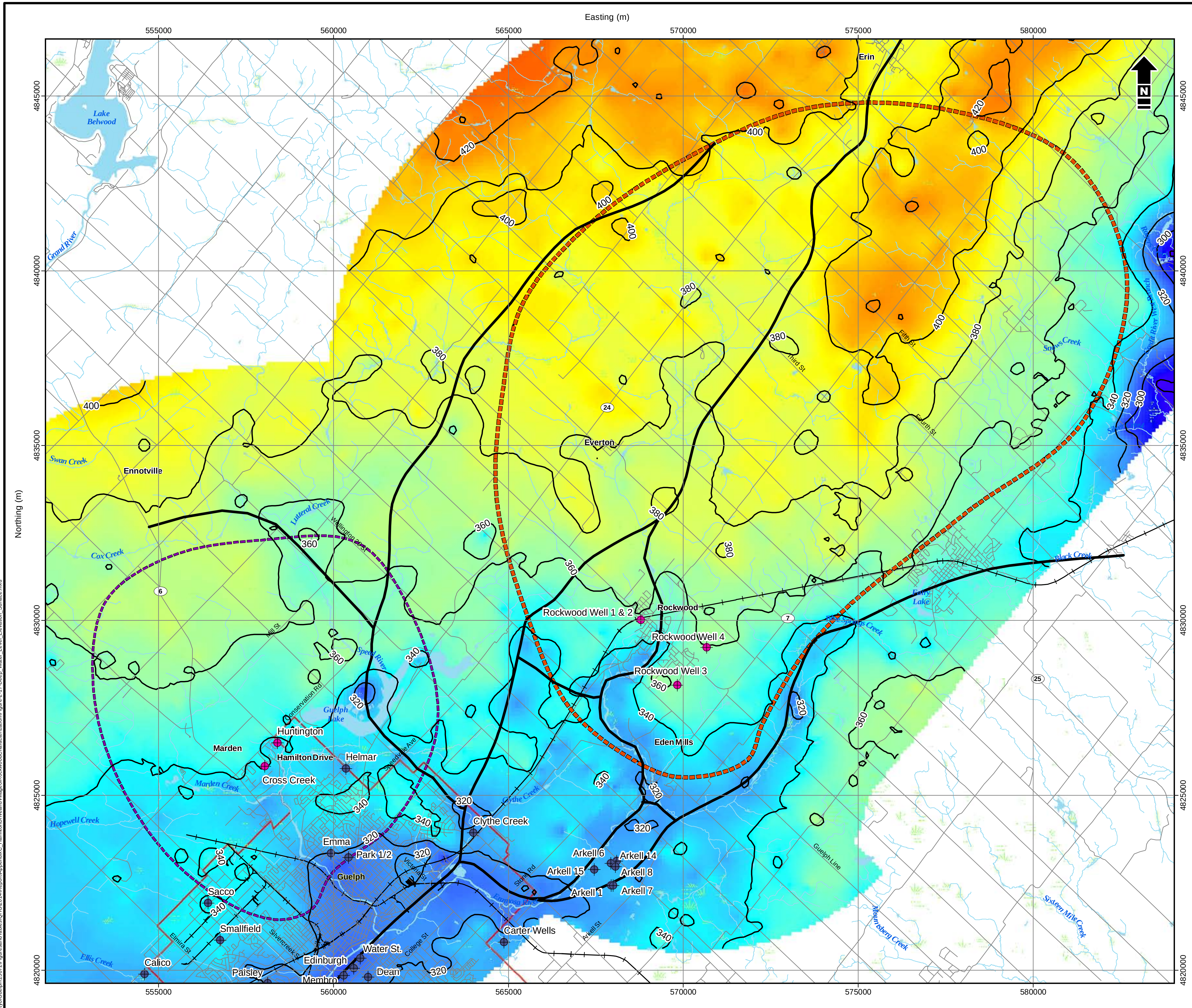
Figure
2-16

I:\City\Guelph\15072\Figures and Tables\GIS\2014\Report\AppendixC_HamiltonDriveandVillageofRockwood\Characterization\Figure-2-16-Shallow_Water_Level_Elevation_Surface.mxd



Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

Deep Water Level Elevation Surface (masl)

High : 445

Low : 235

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NAD 1983 UTM Zone 17N

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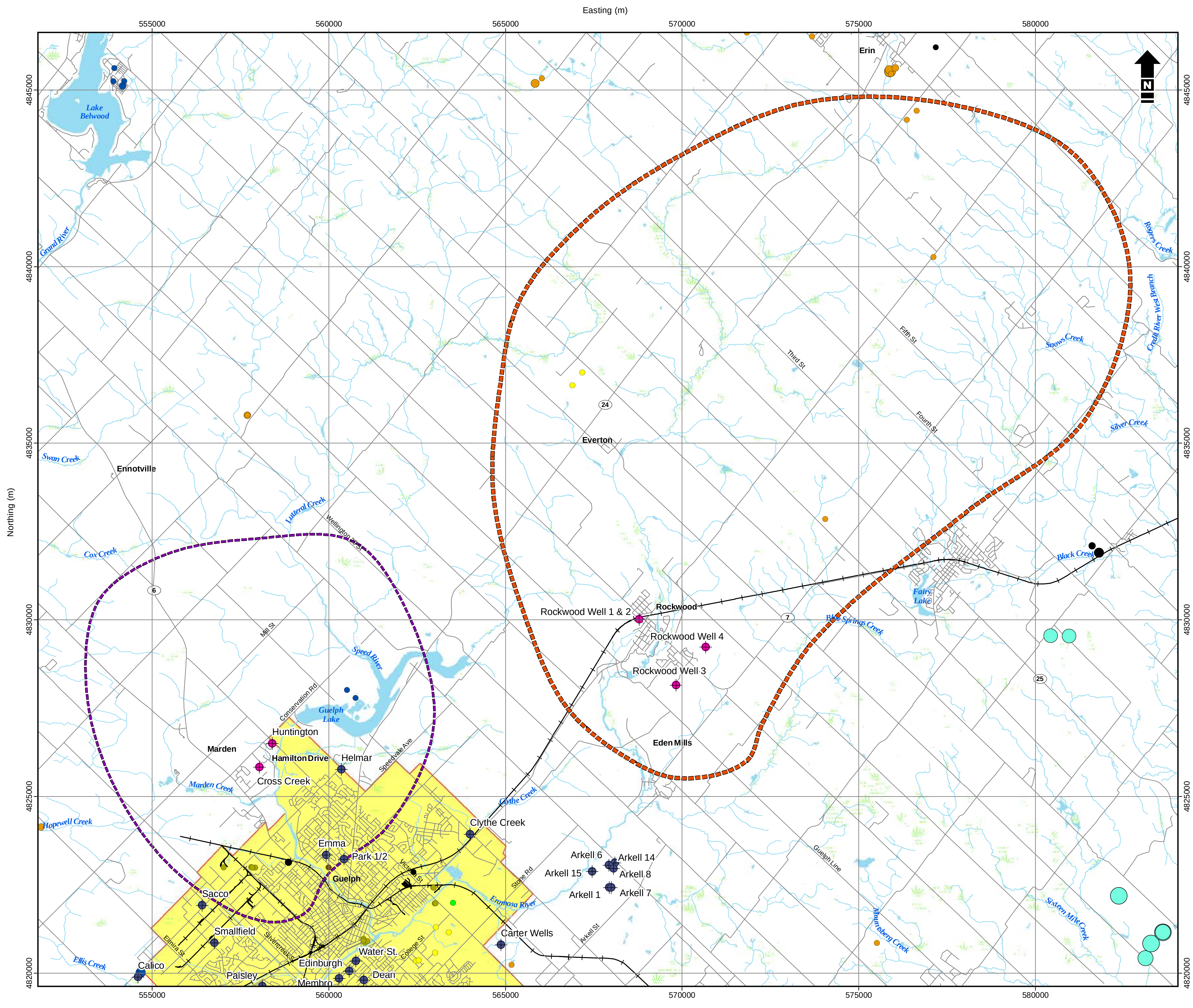
City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Deep Water Level Elevation Surface

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
2-17



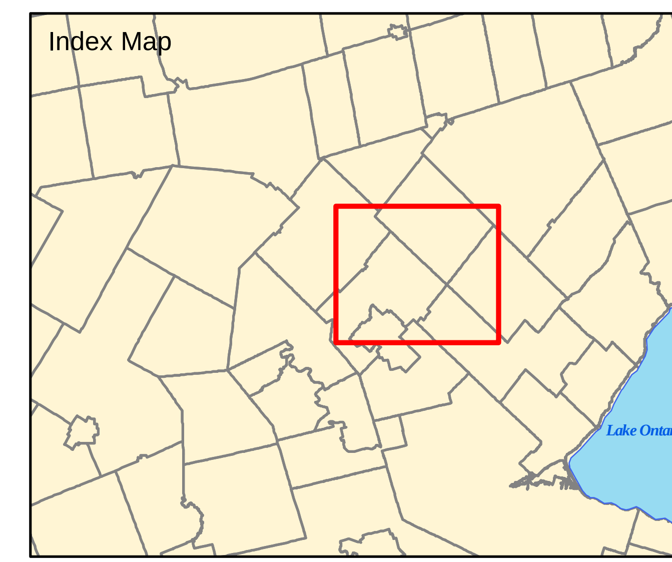
Area of Interest - Hamilton Drive
Area of Interest - Rockwood
Community
Wetland
Water Body
Watercourse
Road
Railroad
Municipal Well (City of Guelph)
Municipal Well (Guelph/Eramosa Township)

PTTW - Major Category

Agricultural
Commercial
Dewatering
Dewatering Construction
Industrial
Institutional
Miscellaneous
Recreational
Remediation
Water Supply

PTTW - Maximum Litres/Day

< 1,000,000
1,000,000 - 2,500,000
2,500,000 - 5,00,0000
5,000,000 - 7,500,000
7,500,000 - 10,000,000
10,000,000 - 12,500,000
12,500,000 - 15,000,000
15,000,000 - 20,000,000
> 20,000,000



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NAD 1983 UTM Zone 17N

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City of Guelph and Township of Guelph/Eramosa
Tier Three Water Budget and Local Area Risk Assessment
Appendix C Characterization Update - Rockwood and Hamilton Drive

Municipal and Non-Municipal Large Permitted Water Takers

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure 3-1

Appendix C2

Well Construction Details and Borehole Logs

FEB 5 '90 9:46 FROM GAMSBY MANNEROW GUELP TO G-M O.S. PAGE.002

Ministry of the Environment

Ontario

The Ontario Water Resources Act

WATER WELL RECORD

1-90

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

County or District	Township, Borough, City, Town, Village		Con., Block, Tract, Survey, etc.	Lot
WELLINGTON	Guelph Twsp	DIV. D.	2	PT. 7+8

Owner (surname first)	Address		Date completed
Cross Creek Sub. (BMW Properties)	MISSISSAUGA, ONT.	L5K-2J1	day 023 mo 01 yr 90

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

General colour	Most common material	Other materials	General description	Depth – feet From	To
BROWN	CLAY	STONES		0	15
BROWN	CLAY	GRAVEL		15	55
BROWN	CLAY	SAND, GRAVEL		55	70
BROWN	ROCK			70	100
BROWN	ROCK			100	110
BROWN GREY	ROCK			110	125
BROWN	ROCK			125	140
GREY	ROCK			140	150
D. BROWN	ROCK			150	240
GREY BROWN	ROCK			240	298
GREY	ROCK			298	315
Blue	Shale			315	325
ReD	Shale				

WATER RECORD

Water found at – feet	Kind of water
215	☑ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
298	☑ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas
	☐ Fresh ☐ Salty ☐ Sulphur ☐ Minerals ☐ Gas

CASING & OPEN HOLE RECORD

Inside diam. inches	Material	Wall thickness inches	Depth – feet From	To
10	☑ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic	.240	0	70
8	☑ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic	.240	0	130
8	☐ Steel ☐ Galvanized ☐ Concrete ☑ Open hole ☐ Plastic		130	325

SCREEN

Sizes of opening (slot no.) — Diameter — Length

Material and type — Depth to top of screen

PLUGGING & SEALING RECORD

Depth set at – feet From	To	Material and type (cement grout, lead packer, etc.)

PUMPING TEST

Pumping test method	Pumping rate	Duration of pumping
☑ Pump ☐ Bailer	124 GPM	48 hours 0 mins

Static level	Water level end of pumping	15 minutes	30 minutes	45 minutes	60 minutes
18.30 feet	40.50 feet	32.62	34.45	35.74	36.41

☑ Pumping ☐ Recovery

If flowing give rate — GPM; Pump intake set at — feet; Water at end of test: ☑ Clear ☐ Cloudy

Recommended pump type: ☐ Shallow ☑ Deep; Recommended pump setting — feet; Recommended pumping rate — GPM

FINAL STATUS OF WELL

☑ Water supply ☐ Observation well ☐ Test hole ☐ Recharge well ☐ Abandoned, insufficient supply ☐ Abandoned, poor quality ☐ Unfinished ☐ Dewatering

WATER USE

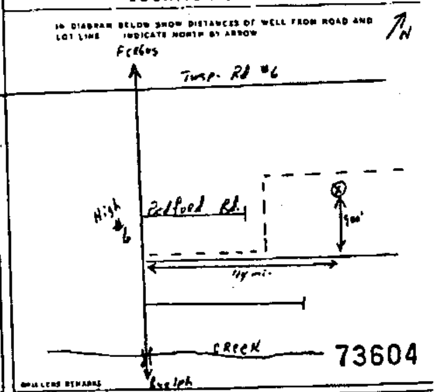
☑ Domestic ☐ Stock ☐ Irrigation ☐ Industrial ☐ Other ☐ Commercial ☐ Municipal ☐ Public supply ☐ Cooling or air conditioning ☐ Not used

METHOD OF CONSTRUCTION

☐ Cable tool ☐ Rotary (conventional) ☐ Rotary (reverse) ☑ Rotary (air) ☐ Air percussion ☐ Boring ☐ Diamond ☐ Jetting ☐ Driving ☐ Digging ☐ Other

LOCATION OF WELL

In diagram below show distances of well from road and lot line. Indicate north by arrow.



Drillers remarks

73604

CONTRACTOR

Name of well contractor	Well contractor's licence number
GRAHAM WELL DRILLING LTD.	2336

Address: RR # 5 Rockwood, ONT. N0B-2K0

Name of well technician	Well technician's licence number
J. HAWKINS	T-0427

Signature of technician/contractor: R. Graham — Submission date: day 031 mo 01 yr 90

OFFICE USE ONLY

OWNER'S COPY

FORM NO. 0506 (11/86) FORM

Figure C2-1: Cross Creek Well

Ministry of the Environment
Ontario

The Ontario Water Resources Act

WATER WELL RECORD

10/86 1. PRINT ONLY IN SPACES PROVIDED 2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON BLOCK, TRACT, SURVEY ETC.	LOT
Wellington	Guelph	1 DIV. D.	10 9

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
Huntington Est.	Guelph, ONT.	DAY 023 MO. 04 YR. 86

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
	Top Soil			0	1
Brown	Clay	Sand, Stones		1	10
"	Rock			10	60
Brown Gray	"			60	233
Blue	Shale			233	236
			TOTAL Depth 236 ft.		

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
60	☒ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
170	☐ FRESH ☒ SALTY ☐ SULPHUR ☐ MINERAL
228	☐ FRESH ☒ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL
	☐ FRESH ☐ SALTY ☐ SULPHUR ☐ MINERAL

CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
8"	☒ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE	.214	0	41
8"	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☒ OPEN HOLE		41	236
	☐ STEEL ☐ GALVANIZED ☐ CONCRETE ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.)	DIAMETER INCHES	LENGTH FEET
—	—	—

MATERIAL AND TYPE	DEPTH TO TOP OF SCREEN FEET
—	—

PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)
—		

PUMPING TEST

PUMPING TEST METHOD	PUMPING RATE	DURATION OF PUMPING
☒ PUMP ☐ BAILER	140 GPM	24 HOURS ___ MINS

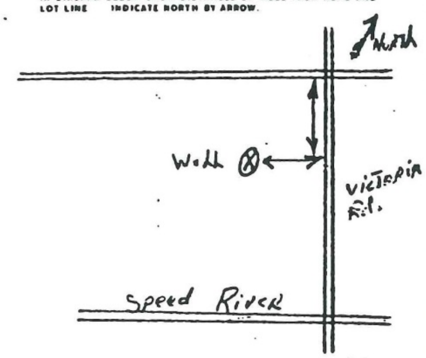
STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING ☒ PUMPING ☐ RECOVERY 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
1.5 FEET	85.6 FEET	52 FEET	57 FEET	60 FEET	62 FEET

IF FLOWING, GIVE RATE: — GPM; PUMP INTAKE SET AT: 153' FEET; WATER AT END OF TEST: ☒ CLEAR ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☒ DEEP; RECOMMENDED PUMP SETTING: 200' FEET; RECOMMENDED PUMPING RATE: ~~200~~ 140

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



DRILLERS REMARKS:

FINAL STATUS OF WELL	☒ WATER SUPPLY ☐ OBSERVATION WELL ☐ TEST HOLE ☐ RECHARGE WELL ☐ ABANDONED, INSUFFICIENT SUPPLY ☐ ABANDONED POOR QUALITY ☐ UNFINISHED
WATER USE	☐ DOMESTIC ☐ STOCK ☐ IRRIGATION ☐ INDUSTRIAL ☐ OTHER ☐ COMMERCIAL ☐ MUNICIPAL ☐ PUBLIC SUPPLY ☐ COOLING OR AIR CONDITIONING ☐ NOT USED
METHOD OF DRILLING	☒ CABLE TOOL ☐ ROTARY (CONVENTIONAL) ☐ ROTARY (REVERSE) ☒ ROTARY (AIR) ☐ AIR PERCUSSION ☐ BORING ☐ DIAMOND ☐ JETTING ☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: Graham Well Drilling LTD. LICENCE NUMBER: 2336
ADDRESS: Guelph, ONT
NAME OF DRILLER OR BORER: R. Graham LICENCE NUMBER:
SIGNATURE OF CONTRACTOR: [signature] SUBMISSION DATE: DAY 030 MO. 04 YR. 86

OFFICE USE ONLY: ORIGINAL WELL RECORD HUNTINGTON WELL

OWNER'S COPY

FORM NO. 0506—4—77 FORM 7

Figure C2-2: Huntington Estates Well

Well 1

UTM 5 | Z | E
5 | R | N

Elev. 5 | R | 1170

Basin 213

67 №. 371

The Ontario Water Resources Commission Act

WATER WELL RECORD

County or District WELLINGTON ~~Eramosa~~ Township, Village, Town or City ERAMOSA (Rockwood)

Con. IV Lot 6 Date completed 1 (day) December (month) 1967 (year)

Owner [redacted] Address 801 Bay Street, Toronto 5, Ontario
(print in block letters)

Casing and Screen Record		Pumping Test	
Inside diameter of casing	10 inch	Static level	12 feet
Total length of casing	31 feet 8 inches	Test-pumping rate	(approx.) 200 G.P.M.
Type of screen	None	Pumping level	40 feet
Length of screen	None	Duration of test pumping	24 hours
Depth to top of screen	None	Water clear or cloudy at end of test	Clear
Diameter of finished hole	10 inches	Recommended pumping rate	200 G.P.M.
		with pump setting of	160 feet below ground surface

Well Log / **Water Record**

Overburden and Bedrock Record	From ft.	To ft.	Depth(s) at which water(s) found	Kind of water (fresh, salty, sulphur)
Top Brown Soil	0	3		
Coarse stoney gravel with layers of clay	3	11		
Gravel becoming finer with less stones	11	20		
Pea Gravel	20	22½		
Limestone Rock (Dolmite)	22	198	? 44'	FRESH
			or between 96	& 180

For what purpose(s) is the water to be used? Town

Is well on upland, in valley, or on hillside? Upland

Drilling or Boring Firm G. Hart and Sons

R. R. 1

Address Fenelon Falls, Ontario.

Licence Number 2455

Name of Driller or Borer Kenneth H. Hart

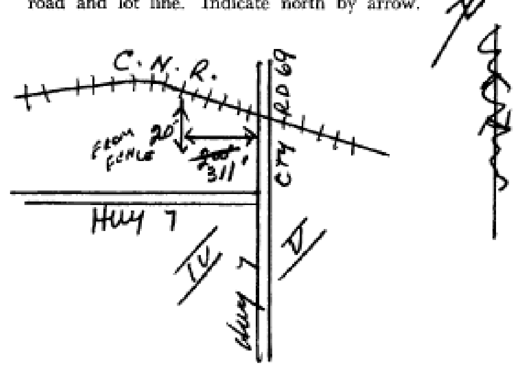
Address R. R. 1, Fenelon Falls, Ontario.

Date December 1, 1967.

Kenneth Hart
(Signature of Licensed Drilling or Boring Contractor)

Location of Well

In diagram below show distances of well from road and lot line. Indicate north by arrow.



Form 7 15M-60-4138

CSS.S8

OWRC COPY

Figure C2-3: Rockwood Well 1 (Burnside 2015)

Well 2

MINISTRY OF THE ENVIRONMENT
The Ontario Water Resources Act

WATER WELL RECORD

Ontario

-40P19C

1. PRINT ONLY IN SPACES PROVIDED
2. CHECK ☒ CORRECT BOX WHERE APPLICABLE

11 | 6706314 | MUNICIP. 67002 | CON. CON. 04

COUNTY OR DISTRICT	TOWNSHIP, BOROUGH, CITY, TOWN, VILLAGE	CON., BLOCK, TRACT, SURVEY, ETC.	LOT
WELLINGTON	TWP OF ERAMOSA / POLICE VILLAGE OF ROCKWOOD		006

OWNER (SURNAME FIRST)	ADDRESS	DATE COMPLETED
[redacted]	135 ST. CLAIR AVENUE WEST SUITE 100 TORONTO, ONTARIO	DAY 30 MO 8 YR 76

21 | ZONE 17 | EASTING 568780 | NORTHING 4829820 | 4 | 1184 | 4 | 23

LOG OF OVERBURDEN AND BEDROCK MATERIALS (SEE INSTRUCTIONS)

GENERAL COLOUR	MOST COMMON MATERIAL	OTHER MATERIALS	GENERAL DESCRIPTION	DEPTH - FEET FROM	TO
BROWN	FILL		LOOSE	0	6
BROWN	CLAY	STONES	PACKED	6	11
GREY	GRAVEL	STONES	LOOSE	11	20½
GREY	LIMESTONE			20½	30½
GREY BUFFED	LIMESTONE	GREY STREAKS	CODED	30½	63
BUFFED	LIMESTONE	GREY STREAKS		63	67
GREY	LIMESTONE		FINE IN GRAIN	67	70
GREY	LIMSTONE			70	102
DARK GREY	LIMESTONE			102	112
GREY	LIMESTONE	FINE IN GRAIN		112	125
DARK	LIMESTONE		~~MEDIUM H~~	125	130
DARK GREY	LIMESTONE		MEDIUM HARD	130	140
DARK GREY	LIMSTONE			140	148
GREY	LIMESTONE		LIMESTONE WATER 155 ? 160	148	189
GREY	BUFFED LIMESTONE			189	195

WATER RECORD

WATER FOUND AT - FEET	KIND OF WATER
	1 ☒ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL
	1 ☐ FRESH 3 ☐ SULPHUR 2 ☐ SALTY 4 ☐ MINERAL

51 CASING & OPEN HOLE RECORD

INSIDE DIAM INCHES	MATERIAL	WALL THICKNESS INCHES	DEPTH - FEET FROM	TO
12"	1 ☒ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	.219	20½ FEET OF WELL CASING	
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE	GROUT 10' AROUND CASING IN DEPTH		
	1 ☐ STEEL 2 ☐ GALVANIZED 3 ☐ CONCRETE 4 ☐ OPEN HOLE			

SCREEN

SIZE(S) OF OPENING (SLOT NO.) | DIAMETER INCHES | LENGTH FEET
MATERIAL AND TYPE | DEPTH TO TOP OF SCREEN FEET

61 PLUGGING & SEALING RECORD

DEPTH SET AT - FEET FROM	TO	MATERIAL AND TYPE (CEMENT GROUT, LEAD PACKER, ETC.)

71 PUMPING TEST

PUMPING TEST METHOD: 1 ☒ PUMP 2 ☐ BAILER | PUMPING RATE 300 GPM | DURATION OF PUMPING 27 HOURS

STATIC LEVEL	WATER LEVEL END OF PUMPING	WATER LEVELS DURING 15 MINUTES	30 MINUTES	45 MINUTES	60 MINUTES
13.9 FEET	30.7 FEET	13.1 FEET	16.0 FEET	17.9 FEET	19.5 FEET

1 ☐ PUMPING 2 ☐ RECOVERY

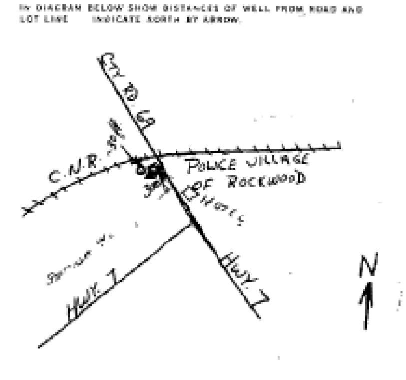
IF FLOWING, GIVE RATE: GPM | PUMP INTAKE SET AT 105 FEET | WATER AT END OF TEST: 1 ☒ CLEAR 2 ☐ CLOUDY

RECOMMENDED PUMP TYPE: ☐ SHALLOW ☒ DEEP | RECOMMENDED PUMP SETTING FEET | RECOMMENDED PUMPING RATE GPM

GPM/FT. SPECIFIC CAPACITY

LOCATION OF WELL

IN DIAGRAM BELOW SHOW DISTANCES OF WELL FROM ROAD AND LOT LINE. INDICATE NORTH BY ARROW.



DRILLERS REMARKS:

FINAL STATUS OF WELL: 1 ☒ WATER SUPPLY 2 ☐ OBSERVATION WELL 3 ☐ TEST HOLE 4 ☐ RECHARGE WELL 5 ☐ ABANDONED, INSUFFICIENT SUPPLY 6 ☐ ABANDONED, POOR QUALITY 7 ☐ UNFINISHED

WATER USE: 1 ☐ DOMESTIC 2 ☐ STOCK 3 ☐ IRRIGATION 4 ☐ INDUSTRIAL ☐ OTHER 5 ☐ COMMERCIAL 6 ☐ MUNICIPAL 7 ☒ PUBLIC SUPPLY 8 ☐ COOLING OR AIR CONDITIONING 9 ☐ NOT USED

METHOD OF DRILLING: 1 ☒ CABLE TOOL 2 ☐ ROTARY (CONVENTIONAL) 3 ☐ ROTARY (REVERSE) 4 ☐ ROTARY (AIR) 5 ☐ AIR PERCUSSION 6 ☐ BORING 7 ☐ DIAMOND 8 ☐ JETTING 9 ☐ DRIVING

CONTRACTOR

NAME OF WELL CONTRACTOR: LONGSTREET DRILLING CO. LTD | LICENCE NUMBER 3424
ADDRESS: P.O. BOX 510 MATHESON, ONT.
NAME OF DRILLER OR BORER: RONALD LONGSTREET | LICENCE NUMBER 3404
SIGNATURE OF CONTRACTOR | SUBMISSION DATE DAY MO. YR.

OFFICE USE ONLY

DATA SOURCE | CONTRACTOR | DATE RECEIVED 2 2027
DATE OF INSPECTION May 13/77 | INSPECTOR
REMARKS: CSS.S3 | P | WI

MINISTRY OF THE ENVIRONMENT COPY

FORM 7 MOE 07-091

Figure C2-4: Rockwood Well 2 (Burnside 2015)

Well 3

Ontario Ministry of the Environment

The Ontario Water Resources Act
WATER WELL RECORD

Print only in spaces provided.
Mark correct box with a checkmark, where applicable.

11 | 6714401 | Municipality 67002 | Con CON | 04

County or District: Wellington
Township/Borough/City/Town/Village: Rockwood
Con block tract survey, etc.: 4
Lot: 3

[redacted]

Address: COUNTY RD 124 PO BOX 2000 ROCKWOOD ONT
Date completed: 15 day 02 month 02 year

21 | Northing | RC | Elevation | RC | Basin Code

LOG OF OVERBURDEN AND BEDROCK MATERIALS (see instructions)

General colour	Most common material	Other materials	General description	Depth - feet From	Depth - feet To
Black	Top Soil			Ø	1½
Brown	Gravel	Clay		1½	6
Brown	Gravel	Cobbles Boulders	clay	6	19
Brown	Sand	Gravel cobbles		19	27
Brown	gravel	Sand		27	41½
Brown	Limestone	Brown Sand Clay	Broken	41½	43
Brown	Limestone		soft	43	46½
Grey/Brown	Limestone			46½	49
Grey	Limestone		Med Hard	49	217
Grey	Shale	Red Shale	Layers	217	238½

31

32

WATER RECORD

Water found at - feet	Kind of water
57 to 134 = 152 ft	☐ Fresh ☐ Sulphur ☐ Minerals ☐ Salty ☐ Gas
146½ to 158	☐ Fresh ☐ Sulphur ☐ Minerals ☐ Salty ☐ Gas — major frac
162½ to 212	☐ Fresh ☐ Sulphur ☐ Minerals ☐ Salty ☐ Gas — small frac
	☐ Fresh ☐ Sulphur ☐ Minerals ☐ Salty ☐ Gas

NOT TESTED

CASING & OPEN HOLE RECORD

Inside diam inches	Material	Wall thickness inches	Depth - feet From	Depth - feet To
008	☑ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic	.219	+3'8"	47
006	☑ Steel ☐ Galvanized ☐ Concrete ☐ Open hole ☐ Plastic	.188	+4	114½
006	☐ Steel ☐ Galvanized ☐ Concrete ☑ Open hole ☐ Plastic		114½	238½

SCREEN: Sizes of opening (Slot No.) | Diameter inches | Length feet | Material and type | Depth at top of screen feet

PLUGGING & SEALING RECORD

☐ Annular space ☐ Abandonment

Depth set at - feet From	To	Material and type (Cement grout, bentonite, etc.)
0	20	Bentonite
	114	drive shoe

PUMPING TEST

71 Pumping test method ☐ Pump ☐ Bailer | Pumping rate GPM | Duration of pumping Hours Mins

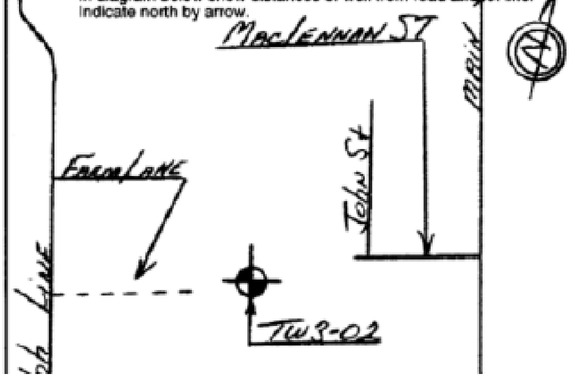
Static level | Water level end of pumping | Water levels during ☐ Pumping ☐ Recovery: 15 minutes, 30 minutes, 45 minutes, 60 minutes (feet)

If flowing give rate GPM | Pump intake set at feet | Water at end of test ☐ Clear ☐ Cloudy

Recommended pump type ☐ Shallow ☐ Deep | Recommended pump setting feet | Recommended pump rate GPM

LOCATION OF WELL

In diagram below show distances of well from road and lot line. Indicate north by arrow.



FINAL STATUS OF WELL

☐ Water supply ☐ Observation well ☐ Test hole ☐ Recharge well ☐ Abandoned, insufficient supply ☐ Abandoned, poor quality ☐ Abandoned (Other) ☐ Dewatering ☐ Unfinished ☐ Replacement well

WATER USE

☐ Domestic ☐ Stock ☐ Irrigation ☐ Industrial ☐ Commercial ☐ Municipal ☐ Public supply ☐ Cooling & air conditioning ☐ Not use ☐ Other

Figure C2-5: Rockwood Well 3 (Burnside 2015)

Ontario Ministry of the Environment

Well Tag No. (Place Sticker and/or Print Below) **Tag#: A152140**

Well 4

Well Record

Regulation 903 Ontario Water Resources Act

Page 1 of 1

Measurements recorded in: ☒ Metric ☐ Imperial

Well Owner's Information

First Name	Last Name / Organization	E-mail Address	☐ Well Constructed by Well Owner
	Township of Guelph / Eramosa		

Mailing Address (Street Number/Name)	Municipality	Province	Postal Code	Telephone No. (inc. area code)
8348 Wellington Rd 124 P.O Box 700	Wellington	ON	N0B2K0	

Well Location

Address of Well Location (Street Number/Name)	Township	Lot	Concession
154 Milne Place	Guelph / Eramosa	3	5

County/District/Municipality	City/Town/Village	Province	Postal Code
Wellington	Rockwood	Ontario	N0B2K0

UTM Coordinates Zone	Easting	Northing	Municipal Plan and Sublot Number	Other
NAD 83 17	570669	4829238		

Overburden and Bedrock Materials/Abandonment Sealing Record (see instructions on the back of this form)

General Colour	Most Common Material	Other Materials	General Description	Depth (m/ft) From	To
Black	Top soil			0	.60
Brown	Clay + stones			.60	9.44
Gray	Clay			9.44	14.93
Brown	Limestone Dark			14.93	21.03
Brown	limestone light			21.03	22.85
White	limestone			22.85	24.68
Gray	limestone			24.68	56.69
Brown	limestone			56.69	60.95
Blue	Shale			60.95	62.78

Annular Space

Depth Set at (m/ft) From	To	Type of Sealant Used (Material and Type)	Volume Placed (m³/ft³)
0	1.21	Bentonite	.30
1.21	47.24	Neet Cement	1.82

Method of Construction

☐ Cable Tool ☐ Diamond ☒ Rotary (Conventional) ☐ Jetting ☐ Rotary (Reverse) ☐ Driving ☐ Boring ☐ Digging ☐ Air percussion ☐ Other, specify

Well Use

☐ Public ☐ Commercial ☐ Not used ☐ Domestic ☒ Municipal ☐ Dewatering ☐ Livestock ☐ Test Hole ☐ Monitoring ☐ Irrigation ☐ Cooling & Air Conditioning ☐ Industrial ☐ Other, specify

Construction Record - Casing

Inside Diameter (cm/in)	Open Hole OR Material (Galvanized, Fibreglass, Concrete, Plastic, Steel)	Wall Thickness (cm/in)	Depth (m/ft) From	To
20.8	steel	.95	+.40	47.24
20	open hole		47.24	62.78

Status of Well

☒ Water Supply ☐ Replacement Well ☐ Test Hole ☐ Recharge Well ☐ Dewatering Well ☐ Observation and/or Monitoring Hole ☐ Alteration (Construction) ☐ Abandoned, Insufficient Supply ☐ Abandoned, Poor Water Quality ☐ Abandoned, other, specify ☐ Other, specify

Construction Record - Screen

Outside Diameter (cm/in)	Material (Plastic, Galvanized, Steel)	Slot No.	Depth (m/ft) From	To

Water Details

Water found at Depth 49.68 (m/ft) Kind of Water: ☐ Fresh ☒ Untested ☐ Gas ☐ Other, specify

Water found at Depth 59.13 (m/ft) Kind of Water: ☐ Fresh ☒ Untested ☐ Gas ☐ Other, specify

Water found at Depth (m/ft) Kind of Water: ☐ Fresh ☐ Untested ☐ Gas ☐ Other, specify

Hole Diameter

Depth (m/ft) From	To	Diameter (cm/in)
0	47.24	31.11
47.24	62.78	20

Well Contractor and Well Technician Information

Business Name of Well Contractor: Well Initiatives — Well Contractor's Licence No.: 7221

Business Address (Street Number/Name): 15 Town line — Municipality: Orangeville

Province: ON — Postal Code: L9W3R4 — Business E-mail Address: info@wellinitiatives.com

Bus. Telephone No. (inc. area code): 5199416829 — Name of Well Technician (Last Name, First Name): Losch Kim

Well Technician's Licence No.: T1927 — Signature of Technician and/or Contractor — Date Submitted: 20150208

Results of Well Yield Testing

After test of well yield, water was: ☒ Clear and sand free ☐ Other, specify

If pumping discontinued, give reason:

Pump intake set at (m/ft): 46.0

Pumping rate (l/min / GPM): 818

Duration of pumping: 72 hrs + 0 min

Final water level end of pumping (m/ft): 38.74

If flowing give rate (l/min / GPM):

Recommended pump depth (m/ft): 46.0

Recommended pump rate (l/min / GPM): 818

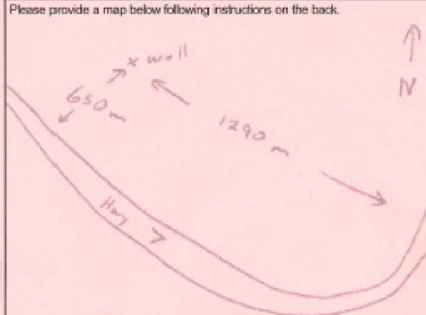
Well production (l/min / GPM):

Disinfected? ☒ Yes ☐ No

Draw Down Time (min)	Water Level (m/ft)	Recovery Time (min)	Water Level (m/ft)
Static Level	3.93		38.74
1	26.50	1	23.78
2	28.70	2	22.89
3	30.78	3	22.07
4	30.53	4	21.50
5	31.06	5	21.07
10	32.47	10	19.95
15	33.09	15	19.38
20	33.73	20	19.03
25	34.53	25	18.78
30	34.77	30	18.57
40	35.15	40	18.26
50	35.50	50	18.00
60	35.74	60	17.85

Map of Well Location

Please provide a map below following instructions on the back.



Comments: See attached map

Well owner's information package delivered ☐ Yes ☐ No — Date Package Delivered: YYYYMMDD — Date Work Completed: 20150210

Ministry Use Only — Audit No. Z197948 — Received

0506E (2007/12) © Queen's Printer for Ontario, 2007 — **Well Owner's Copy**

Figure C2-6: Rockwood Well 4

Appendix C3

Additional Water Level and Pumping Rate Data

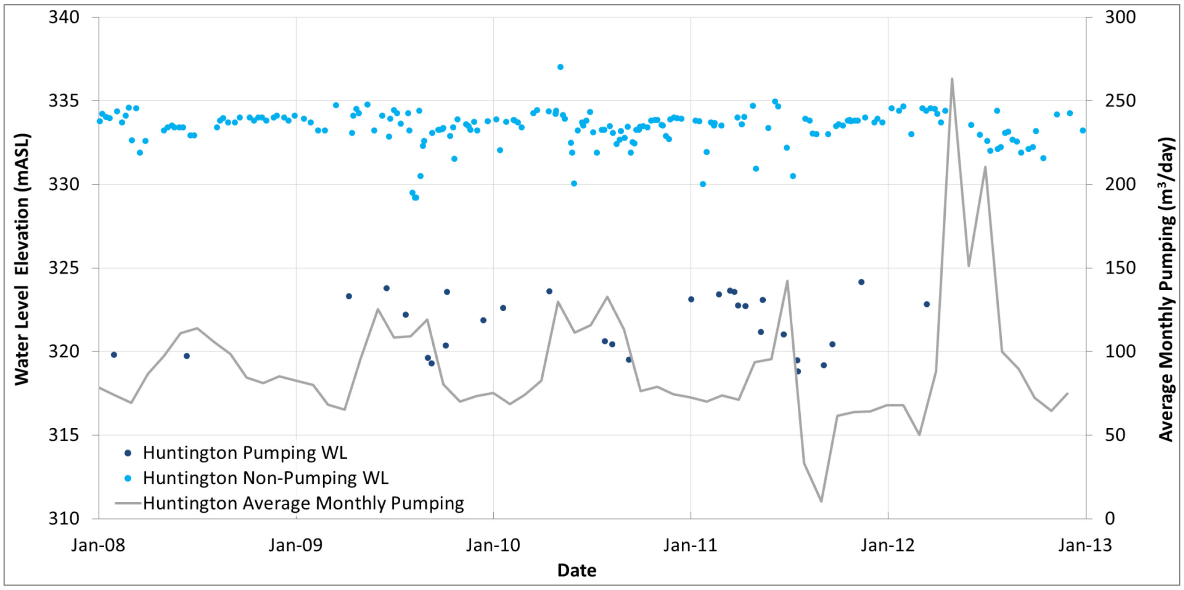


CHART C3-1 Water Level Monitoring at Huntington Well (2008-2012)

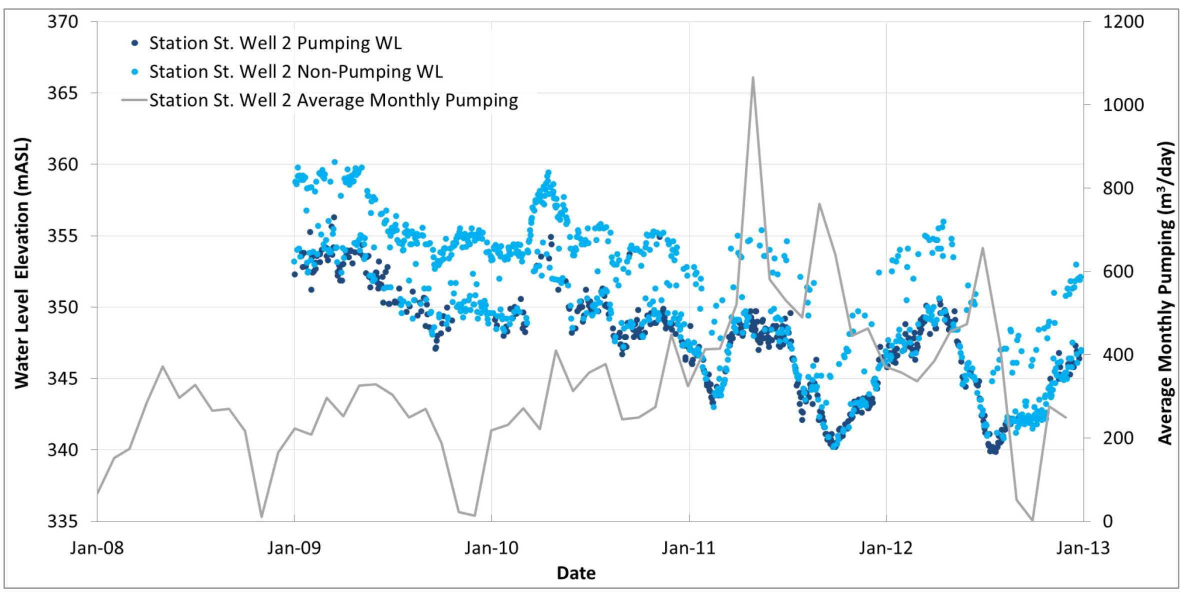


CHART C3-2 Water Level Monitoring at Rockwood Well 2 (2009-2012)

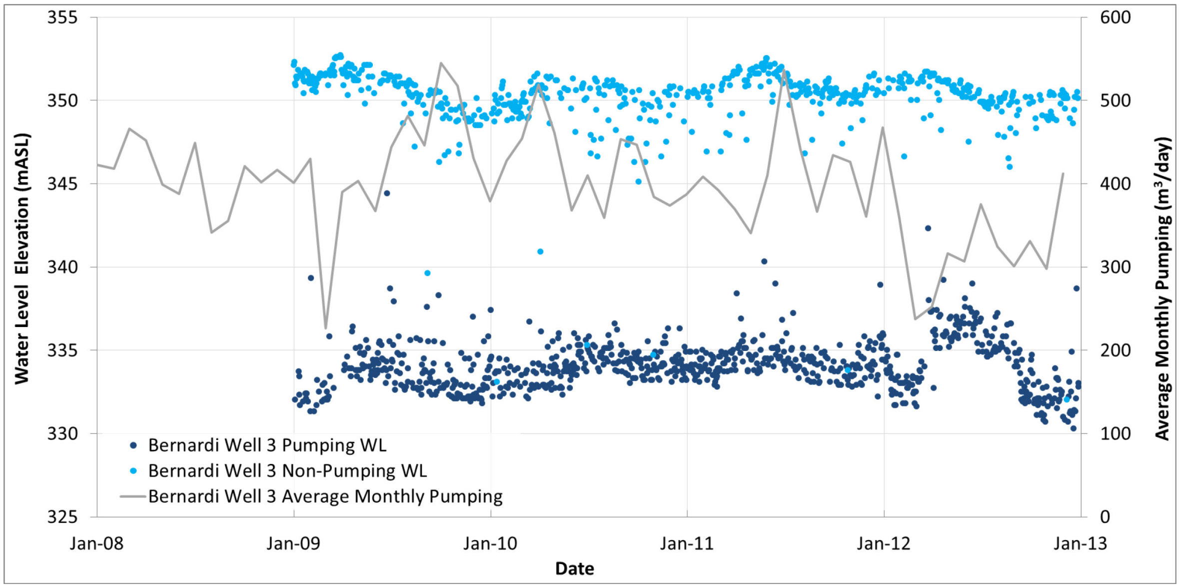


CHART C3-3 Water Level Monitoring at Rockwood Well 3 (2009-2012)