Appendix B1 - Hydrological Model Update (GAWSER)

Tier Three Water Budget and Local Area Stress Assessment:

Hydrological Model Update

Regional Municipality of Waterloo and City of Guelph

Draft Technical Memorandum

August 2009

Table of Contents

Table of Contents i
List of Tables i
List of Figures ii
Appendices ii

1.0 Introduction 1
1.1 GAWSER Background 1
1.2 Objective 2
1.3 Hydrology Routines 2
1.3.1 Climate 3
1.3.2 Hydrologic Response Units 4
1.3.3 Catchment 5
2.0 GAWSER Modifications 7
2.1 Climate Update 7
2.2 New Catchments 8
2.3 Hydrologic Response Unit Update 8
2.4 Infiltration Best Management Practices 9
3.0 Model Results 12
3.1 Hydrograph Comparison 12
3.1.1 Laurel Creek at Erbsville (02GAC15) 12
3.1.2 Clair Creek at Westmount 02GAC16 13
3.1.3 Schneider Creek at Kitchener (02GA037) 15
3.1.4 Hunsburger Creek (02GA043) 16
3.1.5 Alder Creek near New Dundee (02GA030) 17
3.1.6 Mill Creek (02GAC19) 18
3.1.7 Speed River near Armstrong Mills (02GA040) 20
3.1.8 Eramosa River above Guelph (02GA029) 21
3.1.9 Blue Springs Creek near Eden (02GA031) 23
3.2 Discussion 24
4.0 Conclusions 27
5.0 References 29

List of Tables

Table 2.1: GAWSER Climate Stations 8
Table 2.2: Impervious Percentages 9
Table 3.1: Evaluated Stream Gauges 12
Table 3.2: Approximate Groundwater Recharge Rates 25
Table 3.3: Typical Groundwater Recharge Rates (MOE, 1995) 26
Table 3.4: Groundwater Recharge (mm/yr) Summary 26

List of Figures

Figure 1.1: Spatial Scales Considered in GAWSER ... 3
Figure 3.1: Laurel Creek at Erbsville Monthly Mean Flow ... 13
Figure 3.2: Laurel at Erbsville Monthly Median Flow ... 13
Figure 3.3: Clair Creek Monthly Mean Flow ... 14
Figure 3.4: Clair Creek Monthly Median Flow ... 14
Figure 3.5: Schneiders Creek Monthly Mean Flow ... 15
Figure 3.6: Schneiders Creek Monthly Median Flow ... 16
Figure 3.7: Hunsburger Creek Monthly Mean Flow ... 17
Figure 3.8: Hunsburger Creek Monthly Median Flow ... 17
Figure 3.9: Alder Creek Monthly Mean Flow ... 18
Figure 3.10: Alder Creek Monthly Median Flow ... 18
Figure 3.11: Mill Creek Monthly Mean Flow ... 19
Figure 3.12: Mill Creek Monthly Median Flow ... 20
Figure 3.13: Speed at Armstrong Monthly Mean Flow ... 21
Figure 3.14: Speed at Armstrong Monthly Median Flow ... 21
Figure 3.15: Eramosa River above Guelph Monthly Mean Flow ... 22
Figure 3.16: Eramosa River above Guelph Monthly Median Flow ... 23
Figure 3.17: Blue Springs Creek Monthly Mean Flow ... 24
Figure 3.18: Blue Springs Creek Monthly Median Flow ... 24

Appendices

Appendix A: GAWSER Process Schematic
Appendix B: Maps
- Map 1: Revised ZUMs and Climate Stations
- Map 2: Refined GAWSER Catchments
- Map 3: Developments with Possible Infiltration BMPs (Stantec Interview)
- Map 4: Developments with Possible Infiltration BMPs (RMOW Registered Plans)
- Map 5a: Developments Assumed to have Infiltration BMPs (RMOW)
- Map 5b: Developments Assumed to have Infiltration BMPs (Guelph)
- Map 6a: Estimated Groundwater Recharge Rates (RMOW)
- Map 6b: Estimated Groundwater Recharge Rates (Guelph)

1.0 Introduction

This Technical Memorandum describes the process in which an existing continuous streamflow generation model is applied to refine estimates of groundwater recharge. Groundwater recharge is a major input to groundwater flow models, which will be used to characterize the groundwater flow system as part of the Regional Municipality of Waterloo and City of Guelph Tier 3 Water Budget and Local Area Risk Assessments.

The Grand River Conservation Authority (GRCA) developed and maintained a continuous streamflow generation model, utilizing the GAWSER code. The objective of the modelling exercise undertaken in this study is to refine and update the GRCA GAWSER model, and verify the model's performance on smaller, localized watercourses located within the urban areas.

1.1 GAWSER BACKGROUND

The Guelph All-Weather Sequential-Events Runoff (GAWSER) streamflow-generation model is a physically based deterministic hydrologic model used to predict the total stream flow resulting from inputs of rainfall and/or snowmelt. It can operate in both continuous or event based modes. It can be used to model recharge ponds and can predict pollutant accumulation, wash off, and transport. Climate input data required for continuous modelling includes daily maximum and minimum temperatures, daily total precipitation, and hourly rainfall.

The GRCA developed a continuous GAWSER model to simulate watershed hydrology. The hydrologic model was originally constructed for flood forecasting purposes in the late 1980s, and has been in a continual improvement process ever since. The event based model was converted to continuous model in the late 1990's at which time a substantial calibration/ verification exercise was carried out.

More recently, the GAWSER model was revisited based on initial feedback from a three-dimensional groundwater flow model developed for the GRCA Watershed, and applied as part of the Grand River Tier 2 Water Budget and Water Quantity Stress Assessment (AquaResource 2008). The GAWSER model refined in this study represents approximately 20 years of continuous improvement, and has been successfully tested in hundreds of real-time flood forecasting events.

GAWSER has been applied widely in Ontario for planning, design, real-time flood forecasting, and evaluating the effects of physical changes in the drainage basin (Schroeter and Associates, 2004). Precipitation inputs can be defined in terms of rainfall, snowmelt or a combination of the two. For model simulations, drainage basins can be divided into a series of linked elements representing watersheds, channels and reservoirs. The physical effects of each element are simulated using efficient numerical algorithms representing tested hydrologic models.

There are nine main hydrologic processes represented in the GAWSER continuous streamflow-generation model:

1. Accumulation and ablation of snow;
2. Filling and emptying of interception storage and depression storage;
3. Infiltration;

4. Filling and Depletion of Soil water Content;
5. Evapotranspiration;
6. Runoff and Overland Flow Routing;
7. Subsurface and Baseflow Generation and Routing;
8. Channel Routing; and,
9. Reservoir Routing.

The above processes are documented in the GAWSER Training Guide and Reference Manual (see Schroeter and Associates, 2004).

1.2 OBJECTIVE

The overall objective of this modelling exercise is to provide refined recharge estimates to the Regional Municipality of Waterloo (RMOW) and City of Guelph Tier 3 Water Budget and Local Area Risk Assessment investigations. Specific updates to the GAWSER model were as follows:

1. The simulation time period was extended from 1961-1999 to 1961-2005 to allow the model to consider the entire the late 90's-early 2000's drought.

2. Additional climate stations within the Central portion of the Grand River watershed were incorporated to better represent climate variability.

3. Additional stream gauges were considered to verify local response. Prior to this update, model performance was primarily evaluated within the larger river systems, whereas smaller watercourses (Alder, Clair, and Upper Laurel Creeks, etc.) were not investigated in detail.

4. Hydrologic response units within urban boundaries were refined. In previous models, the response units were based on 1992 land cover data, which was not reflective of current land use patterns.

5. The urban land area was subdivided into various urban land uses. Previously, all urban response units were modelled to have a similar imperviousness. Discretizing the urban response units by specific land use better represents the spatial distribution of imperviousness, and therefore recharge.

6. Recently developed lands designed to infiltrate the same volume of water as before development were identified and characterized as having infiltration characteristics similar to undeveloped lands.

1.3 HYDROLOGY ROUTINES

This section summarizes the hydrologic procedures within the GAWSER model, with a particular focus on procedures relevant to producing estimates of recharge. In addition to the procedures summarized here, the GAWSER model also included detailed reservoir and channel routing procedures. These routing procedures affect the shape of a storm hydrograph, but do not influence the partitioning of precipitation into evapotranspiration, overland runoff and groundwater recharge. Consequently, routing is not included in the detailed discussion below.

Estimates of groundwater recharge by GAWSER can be affected by processes calculated in three main areas; 1) climate, or Zones of Uniform Meteorology (ZUMs); 2) hydrologic response units; and 3) catchments. These three spatial units are presented in Figure 1.1.

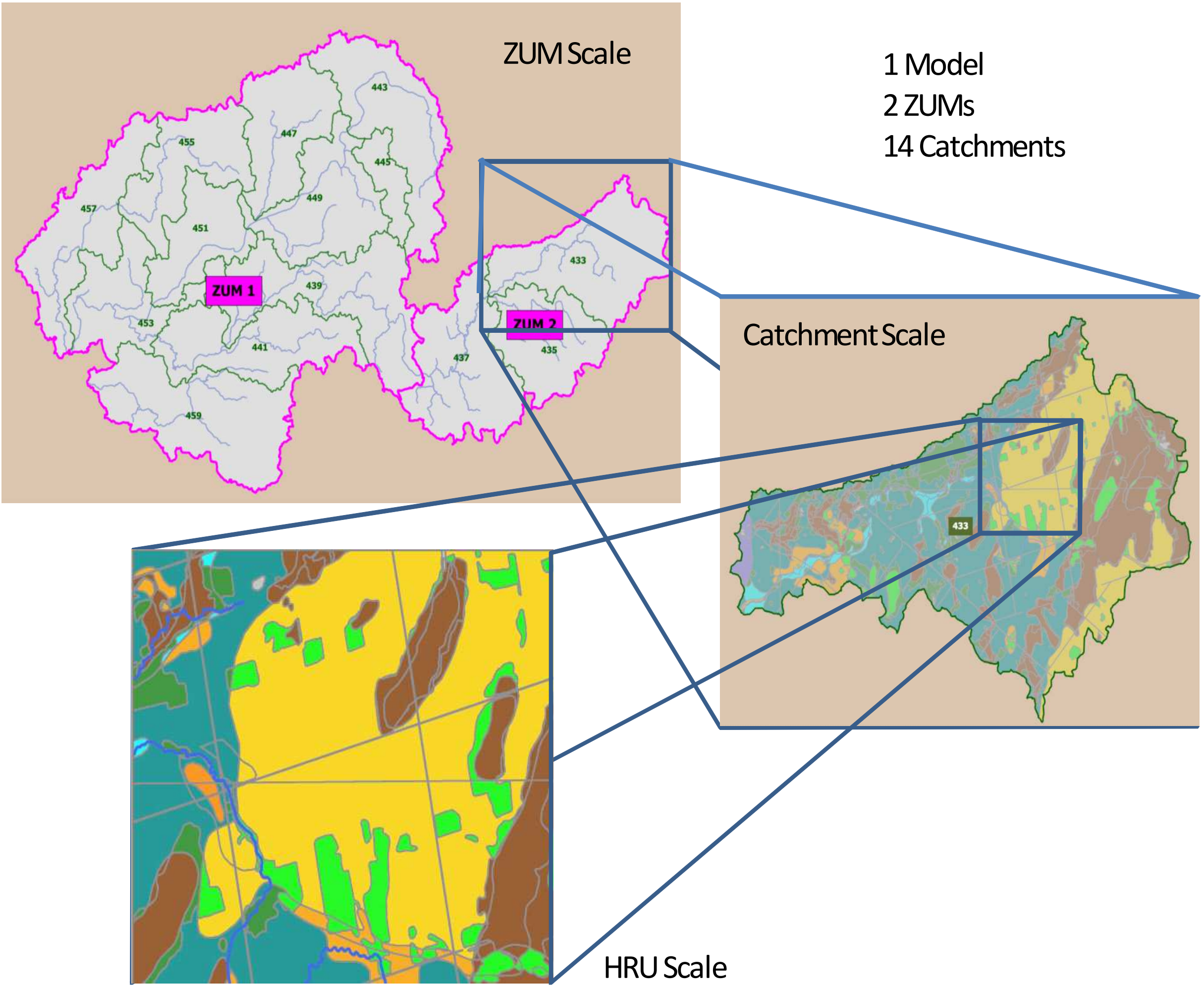

Figure 1.1: Spatial Scales Considered in GAWSER

The following three sections describe the major processes considered by GAWSER for each area.

1.3.1 Climate

Climate is the primary driver of a watershed's hydrologic response. In addition to the amount of precipitation received, the temporal distribution of precipitation (seasonal and hourly distributions) can dramatically affect a watershed's hydrologic response, and the amount of water that recharges the groundwater system.

Climate, and climate variability, is represented within GAWSER by assuming data captured at a particular climate station is representative of climate for a group of surface water catchments. These groups of surface water catchments are termed Zones of Uniform Meteorology (ZUM).

Ideally, a climate station would be present in each surface water catchment; however, due to the low density of long term climate stations this is not possible.

Within each ZUM, data from a particular climate station is used to represent hourly rainfall, snowfall and temperature for all surface water catchments within the ZUM. Snow processes are also calculated at the ZUM scale, where snow is accumulated within the snowpack when air temperatures are below zero. When air temperatures rise above zero, and the snowpack is unable to hold any additional liquid water, snowmelt is released from the snowpack and is supplied to the ground surface as precipitation. The effect of solar radiation on snowmelt processes is not considered.

Potential evapotranspiration is also specified at the ZUM scale. Potential evapotranspiration is the amount of water that can be evaporated or transpired by vegetation given an unlimited supply of water. Potential evapotranspiration effectively sets an upper bound on the amount of water that can be removed from the soil column. GAWSER can specify potential evapotranspiration either by calculating the term using a temperature based algorithm (Linacre, 1977), or by the modeller specifying monthly potential evapotranspiration rates.

1.3.2 Hydrologic Response Units

Hydrologic response units are combinations of surficial geology and land cover that respond similarly to precipitation events. Hydrologic parameters, such as infiltration rates, soil wilting point, field capacity, saturation, and depression storage are assigned to each response unit. These characteristics have been taken from published information (Watt et al., 1989), and have been applied in GAWSER applications across southern Ontario. As these are physical properties of surficial soils that should not vary from subwatershed to subwatershed, modification of the parameters is minimal.

Precipitation, in the form of rainfall or snowmelt, calculated at the ZUM scale, is the primary input to the hydrologic response unit calculations. Within each ZUM, nine different hydrologic response units can be simulated, each with different hydrologic properties. Each hydrologic response unit is represented as a two-layer soil column, with storage reservoirs to represent interception storage and depression storage. As precipitation occurs, interception storage is the first storage element that must be filled. Interception storage is the amount of water that is captured by vegetation above the ground surface, and is typically 1 to 2 mm. This water is removed through evapotranspiration.

Once interception storage is filled, precipitation reaches the ground surface, and is available to be infiltrated. Infiltration into the topmost soil layer is governed by the Green-Ampt infiltration equation, and considers the antecedent soil water content of the first soil layer. When precipitation falls at a rate that is greater than the calculated infiltration rate, water begins to fill depression storage. Depression storage is water retained in puddles, ditches, and other depressions in the surface of the ground, and is typically 5 to 12 mm. Following a precipitation event, water held in depression storage is available for both evapotranspiration and infiltration. When the rate of precipitation is greater than the rate of infiltration, and depression storage is filled, overland runoff is generated.

Water that enters the first soil layer via infiltration is stored as soil water content, until such a time where the soil water content of the first soil layer increases beyond than the specified field capacity of the first soil layer. At this time, soil water content is able to seep into the second soil layer from the first soil layer at a rate that is governed by the Holton et al. (1974) relationship, and is limited by the available soil water storage of the second soil layer. Once the soil water content in the second soil layer increases beyond field capacity, soil water percolates out of the second soil layer at a rate governed by a second application of the Holton et al. (1974) relationship. It is assumed that the second soil layer is free draining, and not impacted by a high water table. This assumption may lead to an over-estimation of percolated water, as high water tables will reduce the movement of water downward, and can promote overland runoff over infiltration.

Evapotranspiration is calculated by applying the potential evapotranspiration rates generated within the ZUM calculations to the hydrologic response units. Water is first removed from the interception and depression storage elements. Once both storage elements are empty, water is removed from the first soil layer. When the soil water content of the first soil layer is less than half of capacity, water is removed from the second soil layer. Once the soil water content for both soil layers has been depleted, evapotranspiration ceases until such a time where the soil water content is replenished by an infiltration event.

Water that percolates out of the second soil layer is the amount of water that passes through the evaporative root zone, and is often termed “infiltration, net of evapotranspiration”, and is assumed to be groundwater recharge. It should be noted that in many locations, there may still remain a significant depth of unsaturated materials that percolated water must traverse before reaching the water table.

Groundwater recharge is then provided to either a fast responding groundwater reservoir, or a slow responding groundwater reservoir, depending on the hydrologic response unit. The fast responding reservoir is intended to represent shallow groundwater flow systems (interflow or subsurface stormflow) that respond quickly to rainfall events, typically seen in less permeable materials. The slow responding reservoir represents the deeper groundwater flow systems typically associated with more pervious materials that sustain streamflows during dry periods.

The sum of groundwater reservoir discharge and overland runoff results in the streamflow response of the hydrologic response units for that time step. GAWSER utilizes an hourly time step, which allows the consideration of rainfall intensity’s effect on infiltration, at a level sufficient for water budget modelling.

Calculations completed at the hydrologic response unit scale also consider seasonal shifts in hydrologic parameters. These seasonal shifts are largely caused by the freeze/thaw cycle that occurs each year within southern Ontario, and can dramatically shift the infiltration capacity of soils. Monthly adjustment factors are used to continuously modify infiltration rates throughout the year, and have been applied throughout southern Ontario with minimal modification.

1.3.3 Catchment

To produce streamflow hydrographs from the hydrologic response unit calculations, watersheds are divided into catchments. Catchments are the smallest unit for which a simulated hydrograph can be output.

For a particular catchment, the simulated response from a hydrologic response unit found within the catchment is scaled up based on the proportion of area within that catchment that is classified as that specific response unit. Responses from other hydrologic response units found within the catchment are similarly scaled, and an aggregate hydrograph for the entire catchment is produced. While the total area that is comprised of a particular hydrologic response unit is considered, the location of the hydrologic response units within the catchment is not. This may affect the catchment hydrograph as the distance from the catchment outlet can affect overland runoff.

In addition to constructing hydrographs from the hydrologic response unit calculations, several other hydrologic processes are considered at this scale. These processes can include hummocky topography, groundwater recession constants, and deep groundwater recharge.

Hummocky topography is a topographic land form that consists of large scale depressions that have no surface water outlet. Runoff becomes trapped within these depressions and evaporates or infiltrates. Hummocky topography is simulated by constructing a hypothetical recharge pond at the catchment outlet. Based on the proportion of hummocky topography found within the catchment, a corresponding portion of the overland runoff is diverted into this hypothetical recharge pond, allowed to recharge, and is supplied to the slow groundwater reservoir. This volume of water added to the groundwater system by the recharge pond is also considered to be groundwater recharge.

Groundwater recession constants determine how quickly groundwater recharge re-enters the stream. While these constants are often regional in nature, GAWSER does allow them to be modified on a catchment-by-catchment basis. Watercourses with very steady baseflow that do not exhibit significant fluctuations, have larger recession constants than those which quickly drain following a precipitation event.

Within GAWSER, the modeller is able to specify the amount of groundwater recharge that does not return to the stream within the catchment that it recharges in. This allows the modeller to replicate regional groundwater flow systems, where groundwater flow crosses surface water boundaries. A specified proportion of all recharged water in the catchment is sent to a “deep groundwater reservoir”, effectively removing it from the catchment hydrograph. This deep recharge can then be brought back into the surface water flow system at any point downstream, replicating a regional groundwater discharge feature.

The individual catchment hydrographs are summed to produce river hydrographs. The river hydrograph is routed downstream to a stream gauge station, at which point modification of model properties is undertaken to minimize differences between simulated and observed streamflow.

For a detailed flow chart of the processes described above, please see Appendix A.

2.0 GAWSER Modifications

The following sections describe the modifications made to the Grand River GAWSER model to meet the modelling objectives outlined in Section 1.1. For a full description of the GAWSER model provided at the onset of this study, please refer to the Grand River Integrated Water Budget Report (AquaResource, 2008).

2.1 CLIMATE UPDATE

To represent the varying climate across the watershed, GAWSER uses “Zones of Uniform Meteorology” (ZUMs) to identify catchments with similar climate. Each ZUM is represented by a climate station in the GRCA to identify precipitation in that zone. In the previous Grand River Conservation Authority GAWSER model, nine climate stations were used in modeling the precipitation variability across the watershed.

For the purposes of Source Protection, the Ministry of Natural Resources contracted Dr. Harold Schroeter to consolidate and in-fill daily and hourly climate records for approximately 400 climate stations in the Province of Ontario. This process is described in Shroeter, et. al (2000). Additionally, Dr. Schroeter extended all climate datasets to a consistent time period; 1961-2005. With this updated dataset, the number of climate stations available for consideration in the Grand River GAWSER model was greatly increased. The new ZUMs and respective climate stations are illustrated on Map 1(Appendix B).

Given this new dataset, the number of climate stations represented in the Grand River GAWSER model increased from 9 to 21. The most significant change occurred in the Nith River area, where previously, data from the Woodstock climate station was used for the majority of the Nith and Whiteman’s Creek. Climate for the Lower Nith River, including the smaller watercourses draining the south flank of the Moraine (Alder Creek, Cedar Creek, etc.), is now represented by data collected at the Roseville climate station. The Roseville climate station is located south of the City of Kitchener, and is considered to be more representative of the climate on the south flank of the Waterloo Moraine than the Woodstock climate station. Other climate stations located within the Central portion of the Grand River watershed that are being considered in the updated GAWSER model include; Preston Sewage Treatment Plant (STP), Galt STP, Elmira, Valens, and the Elora Research Station.

Table 2.1 lists a comparison of the drainage areas associated with a particular climate station for the previous and updated Grand River GAWSER model. In the previous Grand River GAWSER model, each climate station was associated with 690km^2 of watershed area. Within the updated Grand River GAWSER model this average is lowered to approximately 320 km^2. This increased level of discretization should provide a better representation of climatic variability within the Grand River watershed.

Table 2.1: GAWSER Climate Stations

Climate Station	Associated Watershed Area (km^2)		Climate Station	Associated Watershed Area (km^2)	
	Tier 3	Tier 2		Tier 3	Tier 2
Arthur	-	571	Monticello	213	-
Brantford	199	695	Mount Forest	571	-
Cambridge Galt	233	-	Preston	115	-
Dunnville	179	-	Proton	201	791
Elmira	340	-	Roseville	583	-
Elora	147	-	Scotland	242	-
Glen Allan	491	515	Shand Dam	400	788
Grand Valley	377	-	Stratford	228	-
Guelph Turfgrass	440	599	Valens	247	-
Hagersville	545	724	Waterloo Wellington	405	353
Middleport	449	-	Woodstock	162	1186

With the new dataset produced by Dr. Schroeter, the modelling period considered was extended from 1961-1999 to 1961-2005. This allows the full extent of the late 90's early 2000's drought to be investigated.

2.2 NEW CATCHMENTS

Five new catchments were delineated in the Grand River model to gain a better understanding of the hydrologic response of the areas around the Region of Waterloo and the City of Guelph. These new catchments were delineated within GIS utilizing either high resolution elevation data from the Tri-City area within the RMOW, or the GRCA 10 m DEM for areas outside the Tri-City area. A total of 141 catchments make up the Grand River watershed in the continuous hydrologic model, including the newly delineated catchments. The average catchment size is 48 km^2, with the smallest being 3 km^2 and the largest being 154 km^2. Map 2 (Appendix B) shows the refined GAWSER catchments in the Central Grand River watershed.

The new catchments were delineated around streams of interest in the watershed, namely Upper Laurel Creek, Clair Creek, Upper Hunsburger Creek, Upper Alder Creek, and Upper Hanlon Creek. Catchments in the western reaches of the Cities of Waterloo and Kitchener were delineated to assess whether the GAWSER model was reasonably representing the hydrologic response of the Waterloo Moraine.

2.3 HYDROLOGIC RESPONSE UNIT UPDATE

Hydrologic Response Units (HRUs) are the elements used by the surface water model to determine how precipitation events affect the outflow hydrograph of each catchment. Response units for the model were delineated using an overlay of land cover and quaternary geology mapping. Quaternary geologic types were broadly assigned to one of five groupings: Impervious, Clay Tills, Silt Tills, Sand Tills, and Sand and Gravel. Land cover groupings included: Urban, Wetland, Low Vegetation, Medium Vegetation, and High Vegetation. A more detailed description of how these units were delineated is provided in the GRCA's Integrated Water Budget Report (January 2008). Land cover data used in the Grand River GAWSER model was based on 1992 imagery, and did not reflect the current land use practices, particularly within the urban areas.

Land use mapping from the cities of Kitchener, Waterloo, Cambridge and Guelph was obtained from the respective municipalities, and used to update the hydrologic response unit coverage within the urban boundaries. Municipal land use mapping was checked against 2006 orthoimagery to ensure lands flagged as developed urban areas were developed. Roads were buffered by 10 meters and assumed to be 100% impervious.

The previous Grand River GAWSER model assumed all urban response units had an impervious percentage of 50%. With the inclusion of municipal land use mapping, this impervious percentage was refined based on the specific urban land use type specified in the municipal mapping. Impervious percentages utilized for the variety of land uses are outlined on Table 2.2. These imperviousness estimates for the various land use designations were obtained from the Credit River Water Management Strategy Update (CVC, 2008).

Table 2.2: Impervious Percentages

Land Use Description	Imperviousness
Open Managed Space	3%
Low Density Residential	30%
Educational/Institutional	32%
Medium Density Residential	50%
High Rise Residential	50%
High Density Residential	65%
Prestige/Big Box Industrial	80%
Strip Mall/Big Box Commercial	96%

The percentage impervious values cited in Table 2.2 above are an estimate of the reduction in groundwater recharge that is expected when a parcel of land is developed. For example, if an undeveloped plot of land has 100 mm/yr of recharge, groundwater recharge will be reduced to 70 mm/yr after the construction of a low density residential subdivision (reduction of 30%). This groundwater recharge reduction is attributed to a decrease in infiltration (subsequently groundwater recharge), and an increase in runoff. Municipalities and Conservation Authorities are recognizing the importance of maintaining groundwater recharge post-development, and developers are being encouraged, or required, to implement infiltration best management practices in new developments. Section 2.4 outlines some of these infiltration best management practices implemented in the Grand River Conservation Authority jurisdiction.

2.4 INFILTRATION BEST MANAGEMENT PRACTICES

Many recent developments within the Grand River watershed have required the volume of infiltration post-development to equal the volume of infiltration that occurred prior to development. This requirement was first put into place during the 1992 Laurel Creek subwatershed plan, and has broadly been requested of developers by the GRCA since 1995 (Gus Rungis GRCA, pers. commun., July 2009).

Matching post-development infiltration volumes to pre-development volumes is typically done by implementing infiltration best management practices (BMPs). Examples of infiltration BMPs include the construction of large-scale infiltration ponds or the inclusion of lot-level controls (e.g.

directing downspouts into dry wells). This requirement is most often only applied to developments where the underlying soils are able to accept infiltration galleries or dry wells. Typically these are in areas with pervious surficial materials, or where the water table is at a sufficient depth below ground surface that it underlies the infiltration works. A search was conducted to identify a dataset that identifies developed lands that were designed to meet pre-infiltration targets; however, such a dataset was not found, and as such, two data sources were investigated. The first source of information was the Urban Land group at Stantec Consulting Ltd (Stantec) in Kitchener. Mr. Steve Brown, P.Eng., and Mr. Scott Robertson, P.Eng. were asked to identify developments that would like have been designed to meet pre-development infiltration targets. Mr. Brown has been involved with storm water design for urban development within the Grand River watershed since the mid-1990's, and Mr. Robertson, prior to joining Stantec's Urban Land group ,was the plan review engineer for the GRCA from 1999-2003. Together, Mr. Brown and Mr. Robertson have a wealth of knowledge regarding storm water practices within the Grand River watershed that dates back to the mid-1990s, and they were able to identify developments that did not implement infiltration controls due to local soil conditions. A map of developed areas identified by Mr. Brown and Mr. Robertson is included in Map 3.

The second source of information was the RMOW's spatial layer of Registered Subdivision Plans. The RMOW maintains this dataset of subdivision approvals which contains the year the Draft Plan was approved. The year of approval is an indication of whether the subdivision design would have been required to meet pre-development infiltration targets. Information on whether the underlying soils would be suitable for infiltration galleries was not provided. To determine which plans may have required post-development infiltration to equal pre-infiltration, the RMOW spatial layer was filtered. For the Laurel Creek watershed, all plans approved after 1992 were identified as having possible infiltration best-management practices. For the remainder of the RMOW, the threshold was selected to be 1995 (Gus Rungis, GRCA pers. comm.) The results of this filtering are illustrated on Map 4.

The map generated from interviewing Stantec Urban Land staff, and the map generated from the RMOW draft plan approvals were generally consistent. Stantec identified the large Mattamy development in the Townline Road/ Can-Amera Parkway area of Cambridge as having infiltration controls, whereas the RMOW dataset did not. In addition, the RMOW dataset identified developments on the west side of Kitchener as been approved subsequent to 1995; however, with the surficial geology being Maryhill Till, it is unlikely that infiltration controls were implemented, and this was confirmed during the Stantec interview. The RMOW dataset also identified smaller in-fill developments within the perimeter of the urban areas, where infiltration controls are probable.

Map 5a illustrates a combination of the map generated from the Stantec interviews, and the map generated from the RMOW approvals layer. This map is largely derived from the RMOW approvals layer, but with additional lands identified by Stantec . Subdivision plans approved after the 1995 threshold (1992 for Laurel Creek), but were located within low permeability surficial geology, and were positively identified by Stantec as not having infiltration controls, were removed from the RMOW Registered Subdivision dataset. Urban areas identified on this map were assumed to have infiltration characteristics, and thus groundwater recharge characteristics, similar to undeveloped lands.

Developed areas within the City of Guelph that were assumed to have infiltration BMPs, were those areas identified by Stantec Urban Land staff, and are illustrated on Map 5b.

3.0 Model Results

The following sections provide a comparison between simulated and observed streamflow using the Grand River GAWSER model modified as described above. In addition, groundwater recharge values estimated by the GAWSER model are presented at the hydrologic response unit scale.

3.1 HYDROGRAPH COMPARISON

The following section presents mean monthly and median monthly for the stream gauges within the Region of Waterloo and City of Guelph. These statistics are used to quantitatively evaluate the ability of the model to replicate observed hydrologic responses in the smaller watercourses within the study area. The investigated stream gauges, and their associated drainage areas are included in Table 3.1 and their location is illustrated on Maps 1 and 2.

Table 3.1: Evaluated Stream Gauges

Gauge Name	Gauge ID	Operating Agency	Drainage Area (km^2)
Laurel Creek at Erbsville	02GAC15	GRCA	18
Clair Creek at Westmount	02GAC16	GRCA	14
Schneider's Creek at Kitchener	02GA037	WSC/GRCA	32
Hunsburger Creek	02GA043	WSC	14
Alder Creek near New Dundee	02GA030	WSC	47
Mill Creek at Sd Rd 10	02GAC19	GRCA	82
Speed River near Armstrong Mills	02GA040	WSC/GRCA	174
Eramosa River above Guelph	02GA029	WSC	230
Blue Springs Creek	02GA031	WSC	45

3.1.1 Laurel Creek at Erbsville (02GAC15)

The Laurel Creek at Erbsville sub-catchment was newly delineated and modeled in the updated version of the GAWSER surface water model. Located in the headwaters of Laurel Creek, within the Waterloo Moraine, this catchment drains an area just under 18 km^2. The land use is generally agricultural with some unserviced residential, and the surficial deposits are dominated by pervious sands and gravels.

The simulated monthly mean (Figure 3.1) and median flows (Figure 3.2) match the observed flows at this gauge well and suggest that the modeled surface conditions and values for groundwater recharge and discharge are realistic and defensible. Flow is estimated to be significantly lower than observed during the months of January to March; however, the GRCA operates this gauge, and does not correct flow estimates for backwater due to ice effects. This often results in an overestimation of flow during months where ice is present.

For both mean and median, simulated streamflow matches observed streamflow very well. Median flow for the months of August and September deviate by less than 10 L/s. Monthly mean streamflow for the same months deviate by only 1-3 mm. As streamflow during these months are heavily influenced by baseflows and ultimately groundwater recharge, this increases the certainty associated to the groundwater recharge estimates generated by GAWSER.

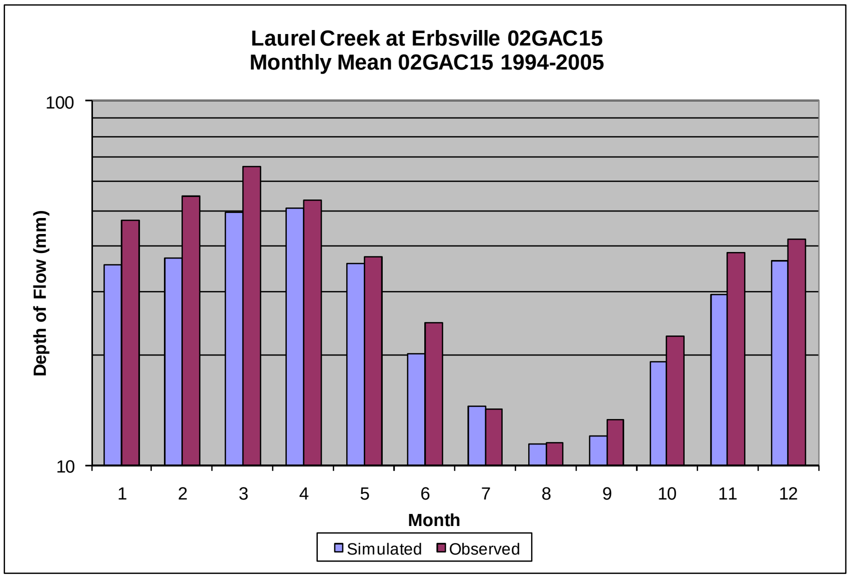

Figure 3.1: Laurel Creek at Erbsville Monthly Mean Flow

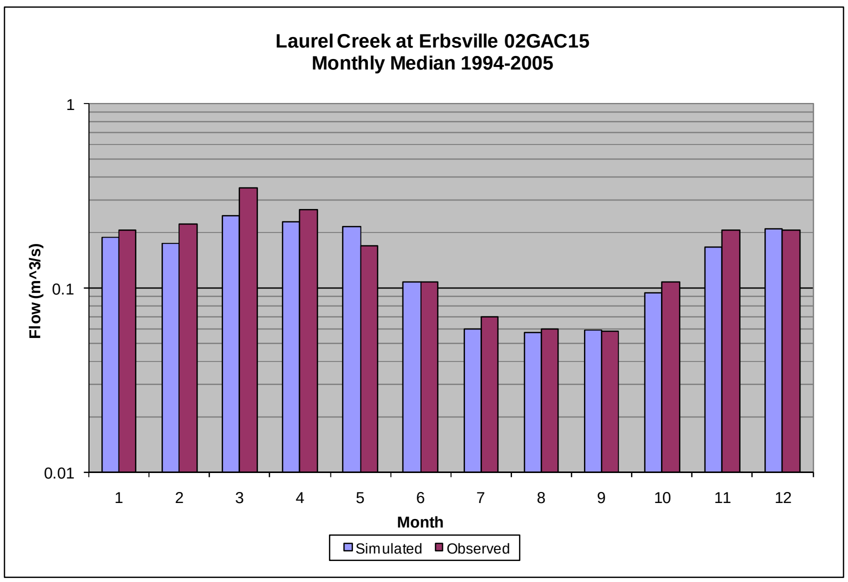

Figure 3.2: Laurel at Erbsville Monthly Median Flow

3.1.2 Clair Creek at Westmount 02GAC16

The Clair Creek at Westmount catchment is located in western Waterloo, and is a tributary to Laurel Creek. It is approximately 14 km^2, and drains an area that is almost entirely urbanized. Surficial geology is predominantly sand and gravel deposits, but also includes some Maryhill Till. The Clair Creek gauge is a GRCA operated station, and is therefore not corrected for ice effects.

Simulated monthly mean flows (Figure 3.3) closely replicate observed flow conditions. Summer months, where baseflow dominates the flow regime, are slightly over-predicted, with differences of 3-5 mm. Simulated monthly median flows are approximately 10 L/s higher than observed for July and August. While this is a small difference in flow rate, and within standard measurement error, it suggests the model may be over-estimating streamflow during the summer months. In addition, simulated median streamflow (Figure 3.4) is significantly lower than observed during the winter months of January and February. This difference again may be due to the observed streamflow data not being corrected for backwater due to ice.

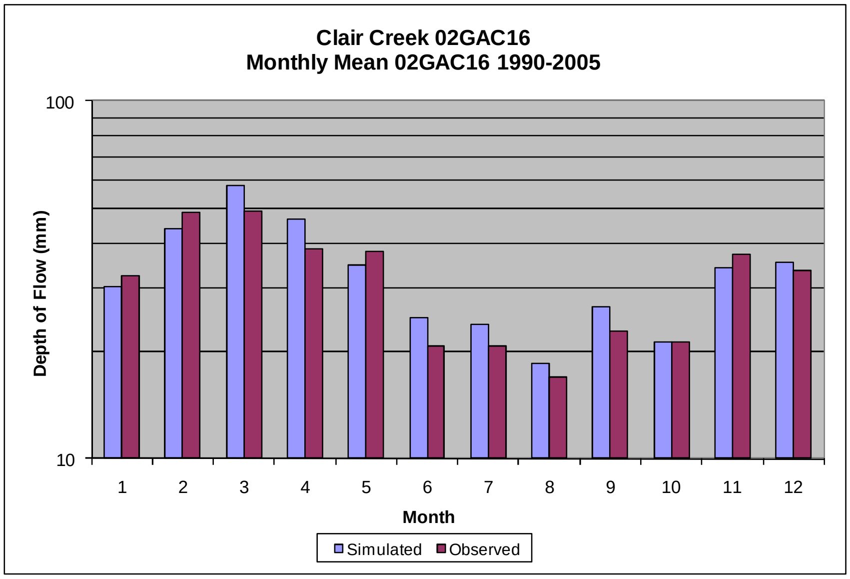

Figure 3.3: Clair Creek Monthly Mean Flow

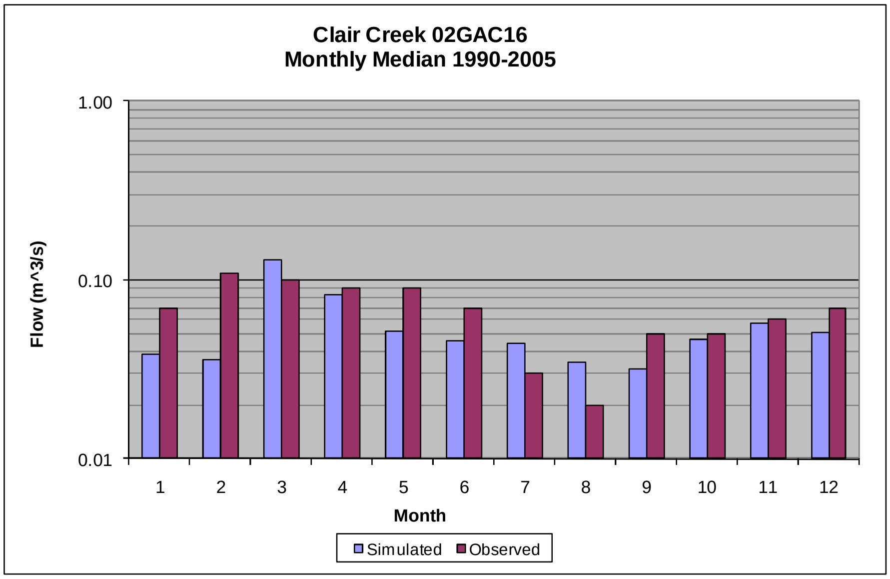

Figure 3.4: Clair Creek Monthly Median Flow

3.1.3 Schneider Creek at Kitchener (02GA037)

The Schneider Creek at Kitchener drains an area of approximately 25 km^2that is almost completely within the City of Kitchener. The geology is a mixture of coarse-grained sands and gravels and finer-grained Maryhill Till. The gauge was maintained by the Water Survey of Canada from 1971 to 1992, after which the GRCA maintained the gauge.

The data provided by the GRCAseems to exhibit a shift in the recorded data after 1995. After this date, streamflow decreases significantly, with flows exceeding 0.1 m^3/s only 10% of the time, whereas prior to 1995, streamflow exceeded 1 m^3/s almost 10% of the time. Furthermore, following 1995, streamflow reached zero approximately 15% of the time, whereas prior to 1995, the recorded streamflow never fell below 0.032 m^3/s. Based on this, it was felt the flow data following 1995 was inaccurate and likely impacted by shifting rating curves. Consequently, data collected after 1995 was not considered in the graphs presented below.

For the majority of months, the simulated and observed mean streamflows match very well (Figure 3.5). The month of January has the largest difference, with the simulated mean being 30 mm less than observed. This discrepancy is likely due to a mid-winter melt that the GAWSER model did not replicate well, or issues with the observed data. The months of May to October are replicated quite well, with maximum differences of approximately 5 mm (Figure 3.5). Observed and simulated monthly median flow compare favourably, with most months having a difference of 10 to 20 L/s. The match to observed flows during the months of November and December are the poorest, with simulated median flows being higher than observed by up to 90 L/s (Figure 3.6).

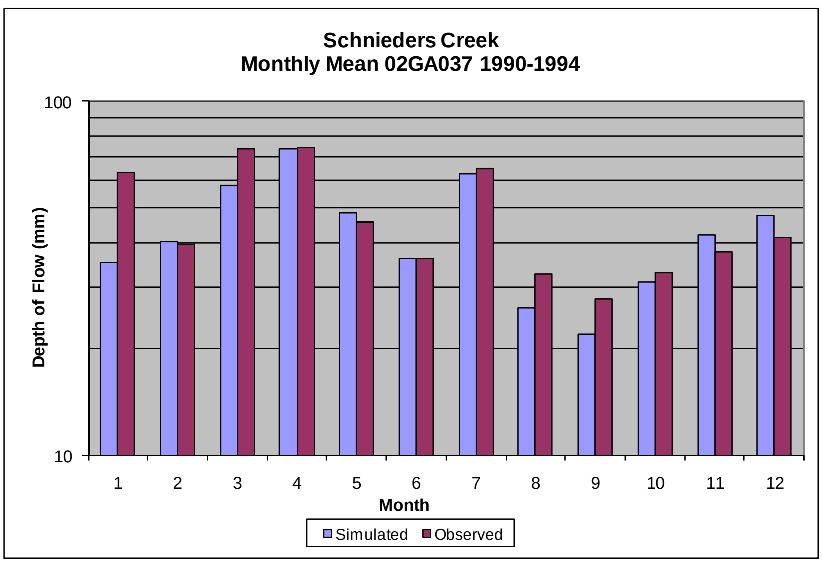

Figure 3.5: Schneiders Creek Monthly Mean Flow

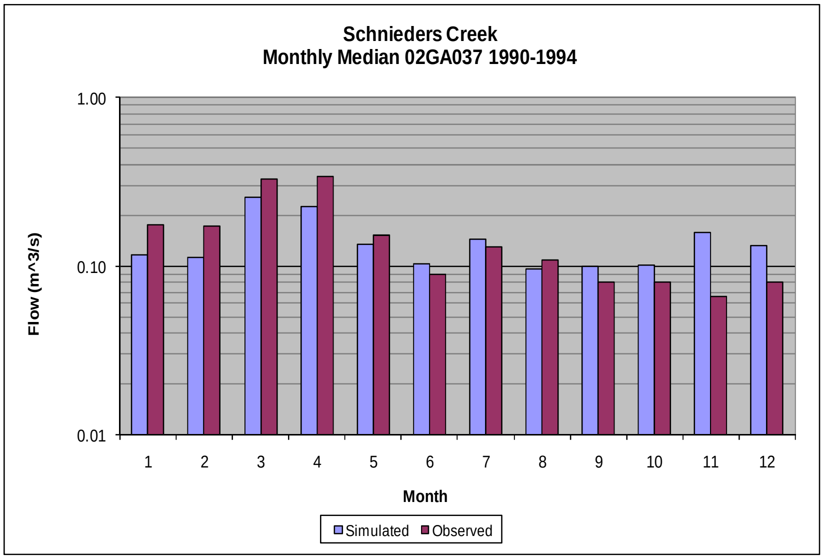

Figure 3.6: Schneiders Creek Monthly Median Flow

3.1.4 Hunsburger Creek (02GA043)

Hunsburger Creek is a small watershed located on the western flank of the Waterloo Moraine. Approximately 14 km^2 in size, the subwatershed is dominated by sand and gravel deposits with extensive hummocky topography. The streamflow response from this watercourse is extremely steady, with monthly median summer flows being more than half of April median flows.

The monthly mean (Figure 3.7) and median (Figure 3.8) streamflow predicted by the GAWSER model match observations quite well. Simulated monthly mean flows are approximately 10 mm lower during the months of February, March and April, which indicates spring snowmelt flows are too low (Figure 3.7). As spring flows are dominated by overland flow, rather than groundwater recharge, it raises the possibility of groundwater recharge estimates being too high, with insufficient overland runoff being generated. Another possible cause of this discrepancy could be that the groundwater flow system is responding quicker to recharge events during the spring season than is represented within the GAWSER model, and is producing discharge soon after the recharge event.

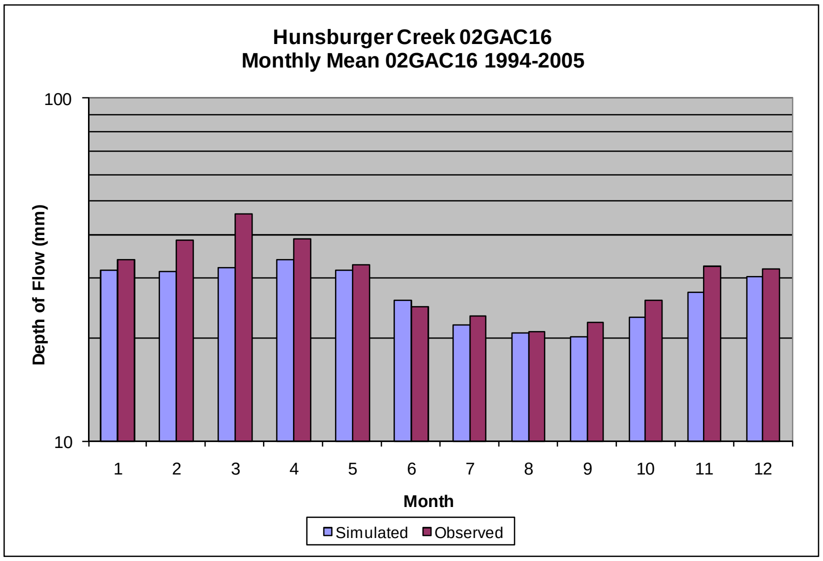

Figure 3.7: Hunsburger Creek Monthly Mean Flow

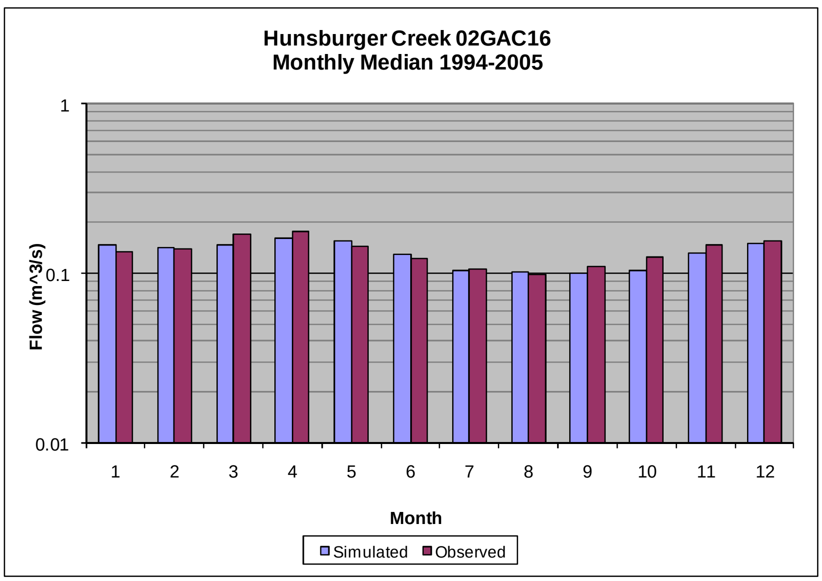

Figure 3.8: Hunsburger Creek Monthly Median Flow

3.1.5 Alder Creek near New Dundee (02GA030)

Alder Creek near New Dundee drains the south flank of the Waterloo Moraine and is a tributary of the Nith River. The drainage area is approximately 47 km^2, land use is predominantly agricultural, and surficial soils are comprised of sand and gravel deposits with lesser amounts of Maryhill Till. The majority of the catchment (80%) is mapped as hummocky topography and is assumed to be disconnected from the surface water drainage system.

Similar to Hunsburger Creek, spring mean flows (Figure 3.9) are under-represented, and this may mean there is insufficient overland runoff and too much groundwater recharge simulated during this season. The remaining simulated monthly means are within 1 mm of observed, with the exception of July. The month of July seems to be an outlier, as it is the only summer month were the mean observed flow increases from the month prior. Simulated monthly median flows (Figure 3.10) closely follow observed median flows, with the largest difference in summer months being less than 10 L/s.

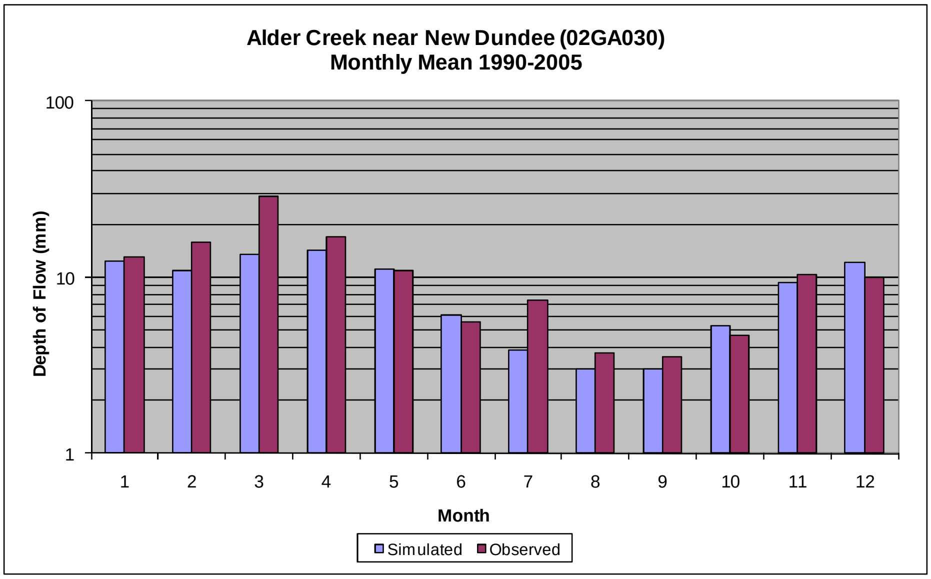

Figure 3.9: Alder Creek Monthly Mean Flow

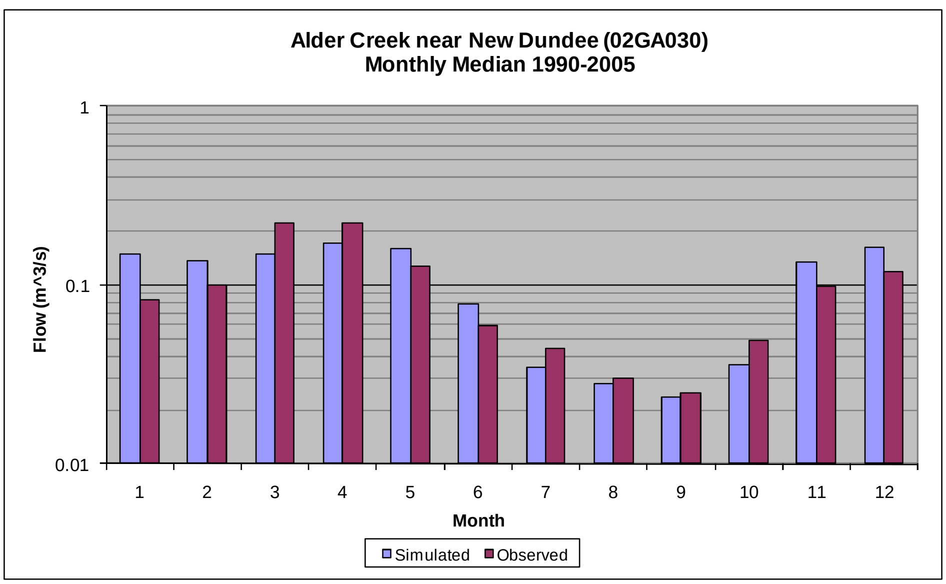

Figure 3.10: Alder Creek Monthly Median Flow

3.1.6 Mill Creek (02GAC19)

The Mill Creek catchment drains an area of approximately 82.3 km^2, located east of the City of Cambridge, south of the City of Guelph, and includes the area between the Galt and Paris

Moraines. The Moraines are comprised of complex interbeds of Wentworth Till and sand and gravel, and outwash deposits are located between the Moraines and underlie Mill Creek. Hummocky topography is associated with both of the Moraines. The gauge is operated and maintained by the GRCA, and therefore, is not corrected for backwater due to ice or aquatic vegetation.

The model performance at the Mill Creek gauge was greatly improved as part of this assessment. Previous model realizations utilized the Guelph Turfgrass climate station to represent temperature and precipitation within Mill Creek; however, data from the Cambridge/Galt climate station was utilized for Mill Creek in the recent model update leading to significantly higher summer flows and improvements in calibration.

Simulated monthly mean flows (Figure 3.11) closely follow observed conditions, with the largest discrepancy occurring during the month of March. Summer low flows are closely replicated, with maximum differences of 4 mm between simulated and observed. Simulated summer median flows (Figure 3.12) are lower than observed by approximately 0.2 m^3/s. Observed median flows do not seem to continue the traditional seasonal decline past the month of July, with similar flows for the months of July, August and September. This suggests a well buffered groundwater system that can sustain groundwater discharge during extended dry periods.

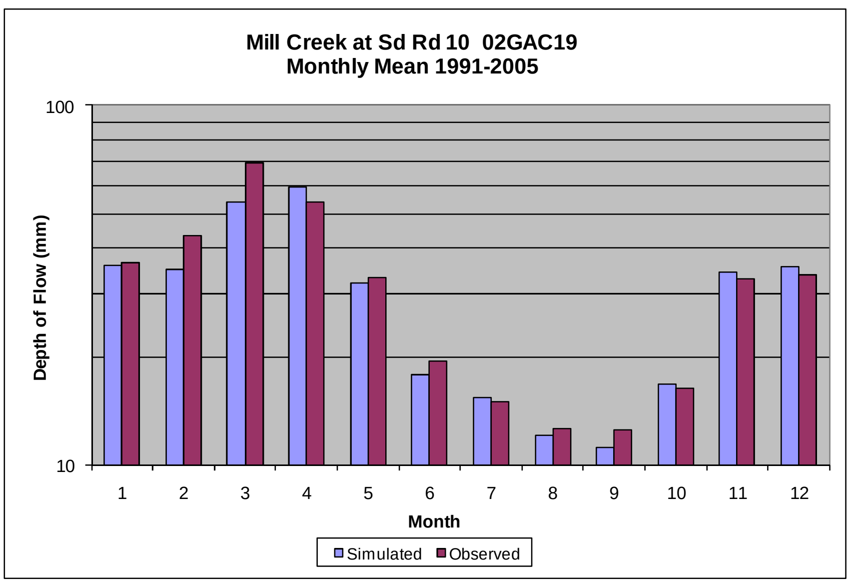

Figure 3.11: Mill Creek Monthly Mean Flow

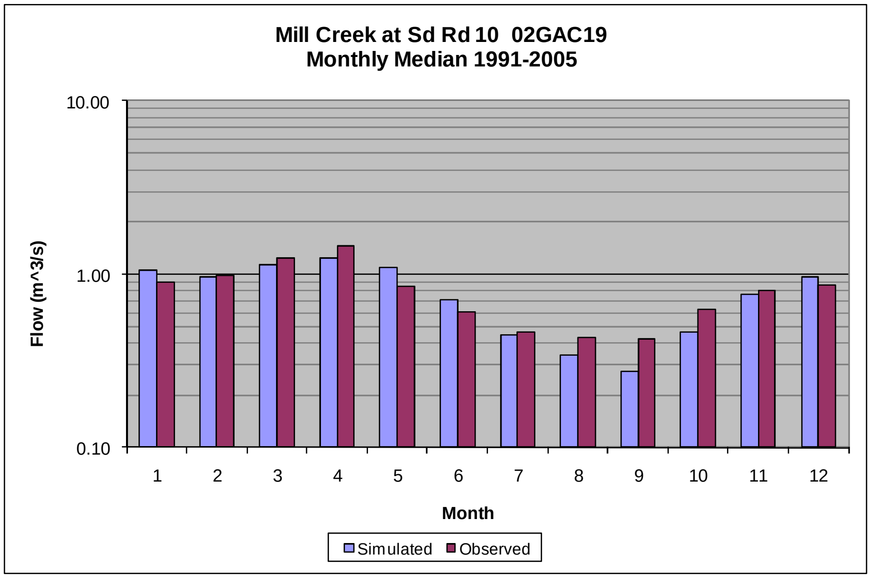

Figure 3.12: Mill Creek Monthly Median Flow

3.1.7 Speed River near Armstrong Mills (02GA040)

The Speed River near Armstrong Mills stream gauge drains an area of approximately 174 km^2, located in the Upper Speed River, upstream of Guelph Dam. The drainage area is predominantly agricultural with relatively large percentages of forest cover. Surficial geology varies within the drainage area, with extensive sand and gravel deposits associated with the Orangeville Moraine in the northern portion, transitioning to Port Stanley Till in the south. The Armstrong Mills stream gauge has transitioned between WSC and GRCA several times, and therefore, data associated with this gauge has not been corrected for backwater effects for a significant portion of the time.

Simulated and observed monthly mean flow match very well for the majority of months (Figure 3.13); in particular, simulated mean flow for the summer months deviate by less than 1 mm. A larger difference is seen during the months of January to March, which may be caused by measured streamflow being impacted by ice backwater. Monthly median streamflows are also well replicated (Figure 3.14), with the low flow month (September) having a simulated median flow only 4 L/s higher than observed. Median monthly flows are slightly lower than observed flows in the spring months and too high in the early summer months. This may suggest that the model is estimating too much groundwater recharge during spring snowmelt, with insufficient runoff, and subsequently discharging this excess water during the early summer.

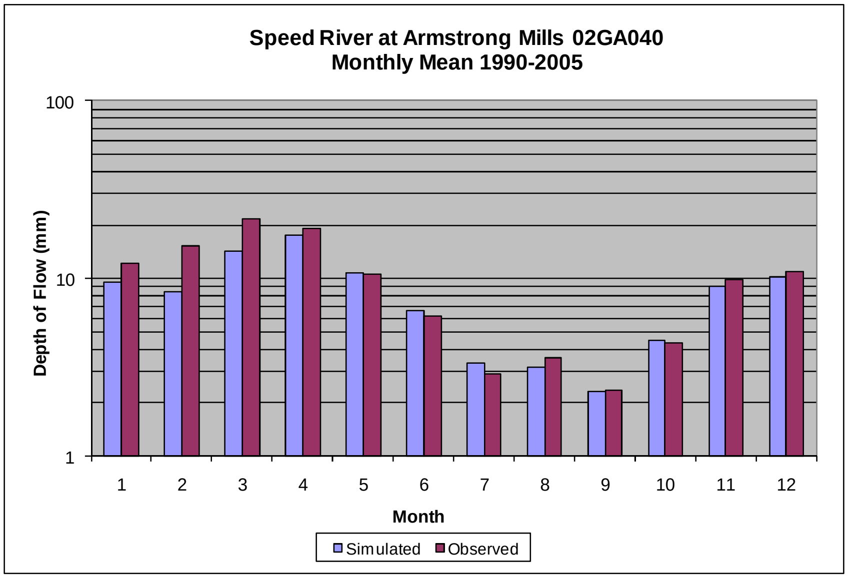

Figure 3.13: Speed at Armstrong Monthly Mean Flow

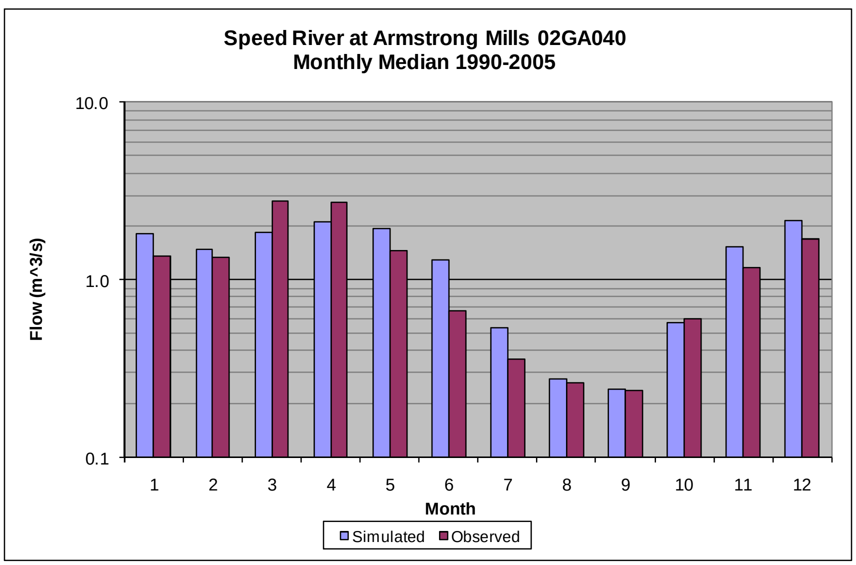

Figure 3.14: Speed at Armstrong Monthly Median Flow

3.1.8 Eramosa River above Guelph (02GA029)

The Eramosa River at Watson Road stream gauge drains an area of 230.4 km^2, and is located east of the City of Guelph. The drainage area is largely agricultural, but with significant forest and wetland cover. The uppermost portion of the drainage area is predominantly Port Stanley Till, but also contains some sand and gravel deposits associated with the Orangeville Moraine. The lower half of the drainage area is a mixture of Wentworth Till associated with the Galt and Paris Moraines, as well as extensive sand and gravel deposits. Hummocky topography is present within a large portion of the drainage area, predominantly associated with the Galt and Paris Moraines. The Eramosa River gauge is operated and maintained by WSC, and is therefore corrected for backwater effects.

The simulated and observed mean monthly flows (Figure 3.15) match quite well for most months, with summer flows deviating by a maximum of 3 mm. The seasonal response is well replicated, with the largest deviation occurring in the month of April (approximately 10 mm). Median monthly flows (Figure 3.16) match quite well, with the months of June to August having simulated flows within 50 L/s of observed flows. Flows in August and September are slightly lower than observed, and suggests a more resilient groundwater discharge feature exists than is being represented within the model.

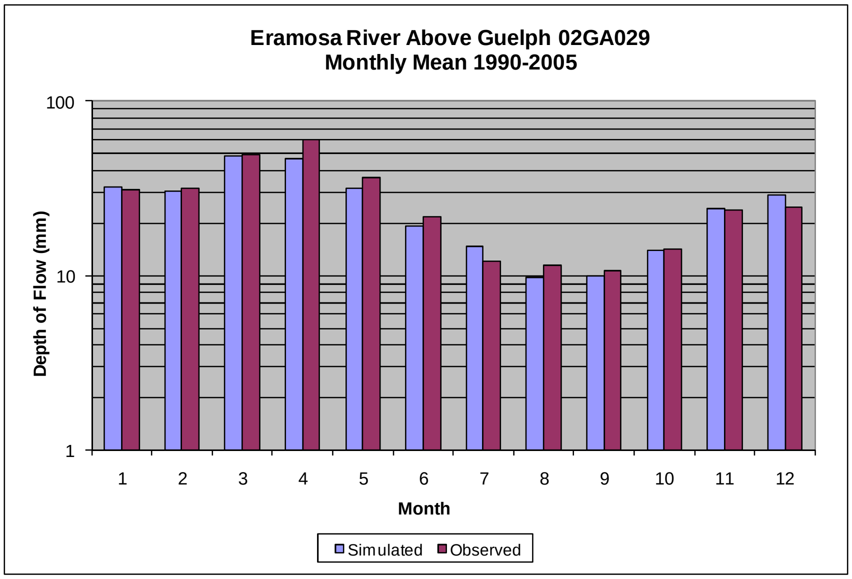

Figure 3.15: Eramosa River above Guelph Monthly Mean Flow

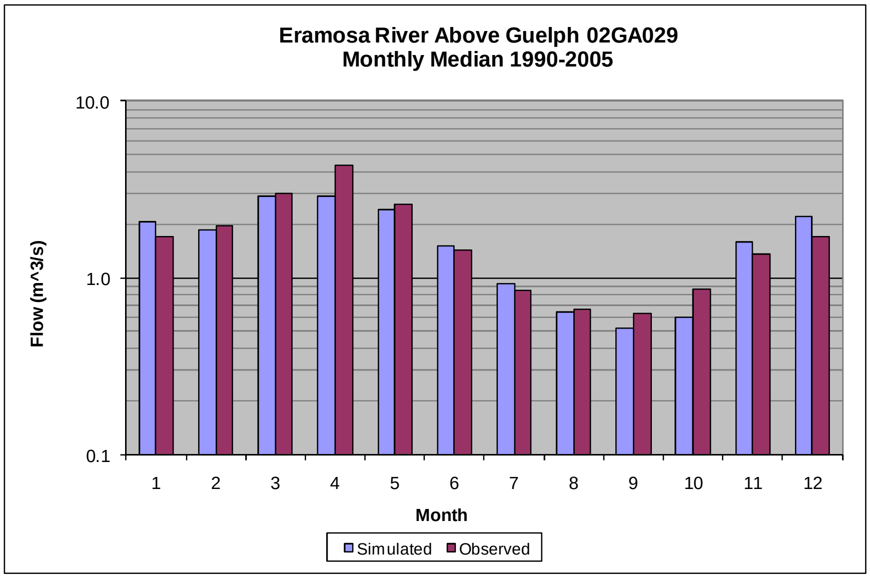

Figure 3.16: Eramosa River above Guelph Monthly Median Flow

3.1.9 Blue Springs Creek near Eden (02GA031)

Blue Springs Creek is located to the east of the City of Guelph, and enters the Eramosa River immediately downstream of Eden Mills. The drainage area is approximately 45 km^2, with the surficial geology largely dominated by Wentworth Till, with sand and gravel deposits associated with kames/eskers interspersed. Land cover is predominantly rural, with a high proportion of forest cover, and a large amount of hummocky topography.

Simulated summer mean flows (Figure 3.17) match well with observed summer mean flows, with differences of 1 mm for the months of August and September. Simulated mean flows during the spring period are lower than observed, and suggests either insufficient overland runoff is generated, or the groundwater system is responding faster during this period than is simulated within the model. Simulated and observed monthly median flow match very well for all months other than March and April, where observed flows are 0.2-0.3 m^3/s higher than simulated.

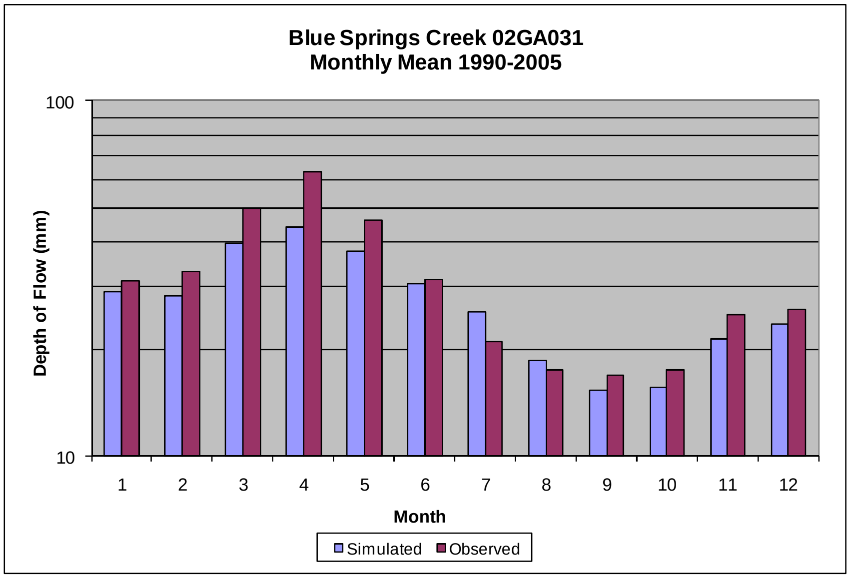

Figure 3.17: Blue Springs Creek Monthly Mean Flow

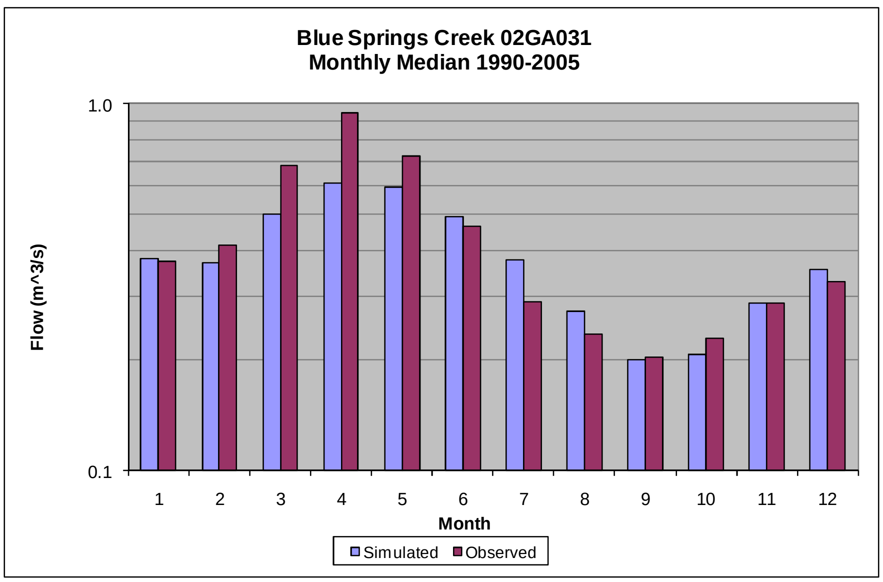

Figure 3.18: Blue Springs Creek Monthly Median Flow

3.2 DISCUSSION

For the purposes of the Tier 3 assessment, the GAWSER model is being used to partition precipitation into evapotranspiration, overland runoff and groundwater recharge. Groundwater recharge estimated from GAWSER is used as input into the groundwater flow model.

Matching simulated summer flow conditions to observed summer flow conditions, means the GAWSER model is meeting an important first step of ensuring the overall volume of estimated groundwater recharge reasonably matches the volume of baseflow observed at a stream gauge. The distribution of the recharge volume throughout the catchment is then assumed, based on delineation of the hydrologic response units used to determine the catchment response. The comparison of the observed and predicted monthly flow graphs presented in the preceding section, provide a level of certainty that the GAWSER model is closely replicating the observed hydrologic response, for a range of different land uses and geology types.

It is important to note that the hydrologic response unit delineation, and subsequently the catchment response, is dependent on the surficial geology mapped within the catchment. As this mapping is done at a scale of 1:50,000, there may be localized areas where the surficial geology is not representative of actual geologic conditions. While this should not affect hydrograph comparisons at the scale of a subcatchment, it may affect the volume of water recharging within a well's contributing area. Where local information suggests surficial geology differs from the mapped product, the estimates of groundwater recharge should be manually modified.

GAWSER estimates of groundwater recharge for the 1961-2005 time period are illustrated on Map 6a (RMOW) and 6b (City of Guelph).

Included in Table 3.2 are groundwater recharge estimates produced by the GAWSER model for major hydrologic response units. This should be considered to be approximate values, as climatic differences introduce variation into these values throughout the watershed. Values have been rounded to the nearest 10 mm.

Table 3.2: Approximate Groundwater Recharge Rates

Hydrologic Response Unit	**Approximate Recharge (mm/yr)**
Clay Till Low Vegetation	60
Clay Till High Vegetation	120
Silt Till Low Vegetation	100
Silt Till High Vegetation	150
Sand Till Low Vegetation	170
Sand Till High Vegetation	240
Sand and Gravel Low Vegetation	330
Sand and Gravel High Vegetation	350
Silt Till Low Density Residential	70
Sand and Gravel Low Density Residential	220
Sand and Gravel Developed with Infiltration BMPs	330
Sand Till - Hummocky	> 250
Sand and Gravel - Hummocky	> 400

While not as detailed as the values presented in Table 3.2, typical groundwater recharge rates, as reported within the "*Hydrogeological Technical Information Requirements for Land Development Applications"* (MOE, 1995), are included in Table 3.3 for comparison purposes. The GAWSER estimated values are generally in line with the MOE published values, with the exception of sand and gravels, for which the GAWSER values are significantly higher.

Table 3.3: Typical Groundwater Recharge Rates (MOE, 1995)

Soil Texture	Recharge Rate (mm/year)
Coarse sand and gravel	> 250
Fine to medium sand	200 – 250
Silty Sand to Sandy Silt	150 – 200
Silt	125 – 150
Clayey Silt	100 – 125
Clay	< 100

While there may be significant changes in local scale recharge from the Tier 2 estimate, Table 3.4 illustrates that at larger spatial scales, the difference is less than 10%. This difference is attributable to updated land cover within the urban areas, the incorporation of varying impervious percentages for specific land uses, and additional climate stations being considered.

Table 3.4: Groundwater Recharge (mm/yr) Summary

Spatial Area	Tier 2	Tier 3 (No Infiltration BMPs)	Tier 3 (Infiltration BMPs)
Region of Waterloo Municipal Boundary	211	196	197
Guelph Tier 3 Boundary	232	210	211

*Values are averages for the 1980-1999 period, in units of mm/yr

While the presence of infiltration BMPs have a minimal impact on groundwater recharge at larger scales, they will have a significant impact at the local scale.

4.0 Conclusions

The Grand River GAWSER model was updated to better reflect the current extent of urbanization, as well as the varying levels of impervious cover for specific urban land uses. Additionally, the number of climate stations considered within the model was more than doubled, and is therefore better able to represent the climatic variability that occurs within the Grand River watershed.

To evaluate the model's performance on smaller watercourses, several new catchments were delineated and added to the Grand River GAWSER model. This allowed simulated hydrographs to be output at locations which correspond to stream gauges not considered in previous exercises, and were compared to observed flow data. Simulated flows compare favourably to observed streamflow, and increased the level of confidence in the ability of the Grand River GAWSER model to represent the hydrologic processes found within the Grand River watershed.

In addition to streamflow hydrographs, GAWSER provided estimates of groundwater recharge at the hydrologic response unit scale. Groundwater recharge is assumed to be the amount of water that is able to percolate beyond the evaporative root zone. When utilizing these estimates of groundwater recharge within the Tier 3 Water Budget and Local Area Risk Assessment, several considerations should be made:

1. Estimates of groundwater recharge produced by the GAWSER model do not include water introduced to the subsurface through processes other than infiltration. Other processes may include leakage from the water distribution system or the storm water collection system. In older urban areas, the volume of water added to the subsurface from these sources may be significant.

2. GAWSER assumes that the water leaving the second soil layer can always be accepted by the underlying groundwater flow system. In actuality, a seasonally high water table may limit the volume of water that is able to percolate downward, and promote overland runoff rather than groundwater recharge. In such cases, GAWSER may be over-estimating the amount of groundwater recharge that occurs during seasons with high water tables (e.g. spring).

3. The hydrologic response units are based on 1:50,000 Quaternary geology mapping. While it is unlikely that errors associated with this scale of mapping are significant enough to affect a hydrograph produced from a moderately sized (10-20 km^2) catchment, there may be local areas were the Quaternary geology mapping, and therefore recharge, differs from real-world conditions. These errors may be significant when evaluating the volume of water recharging in a groundwater well's contributing area.

4. The impervious percentages applied to the urban land uses are generalized, and there is likely local or site variability. For example, industrial sites are assumed to be 80% impervious, with a corresponding decrease in groundwater recharge. While 80% is likely reasonable as a generalized percentage, there may be industrial sites with impervious percentages well below 80%, and sites with percentages well above 80%. As above,

this local scale variability may be significant when evaluating the volume of water recharging in a groundwater well's contributing area.

5.0 References

AquaResource Inc. 2008. Grand River Integrated Water Budget. A Report to the Grand River Conservation Authority.

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Schroeter and Associates. 1996. GAWSER: Guelph All-Weather Sequential-Events Runoff Model, Version 6.5, Training Guide and Reference Manual. Submitted to the Ontario Ministry of Natural Resources and the Grand River Conservation Authority. (Appendix A and B updated for Version 6.9.6, October 2004)

Schroeter, H.O., D.K. Boyd, and H.R. Whiteley. 2000a. Filling gaps in meteorological data sets used for long-term watershed modelling. Proceedings of the Ontario Water Conference 2000, April 26-27, 2000, Richmond Hill, Ontario.

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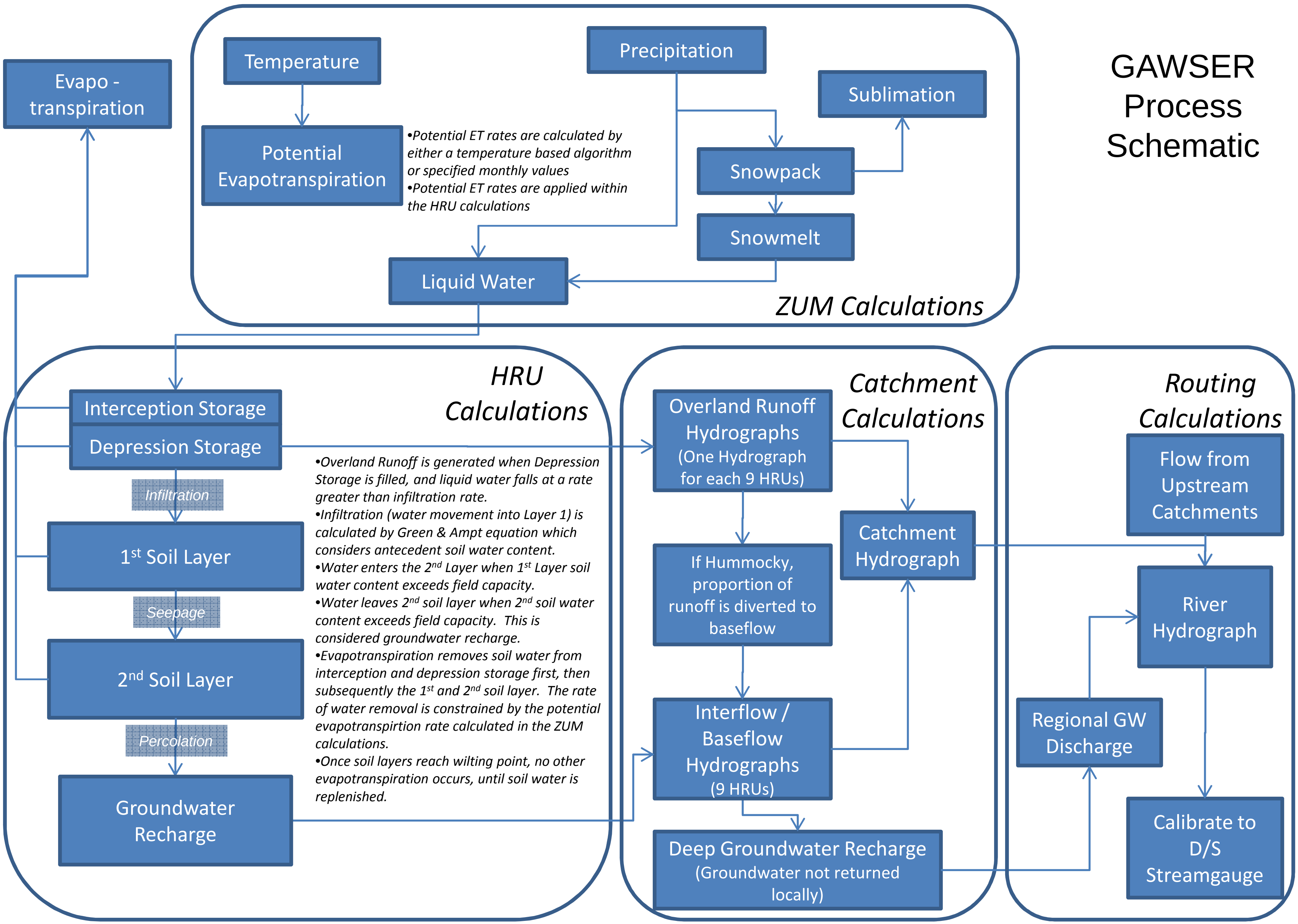
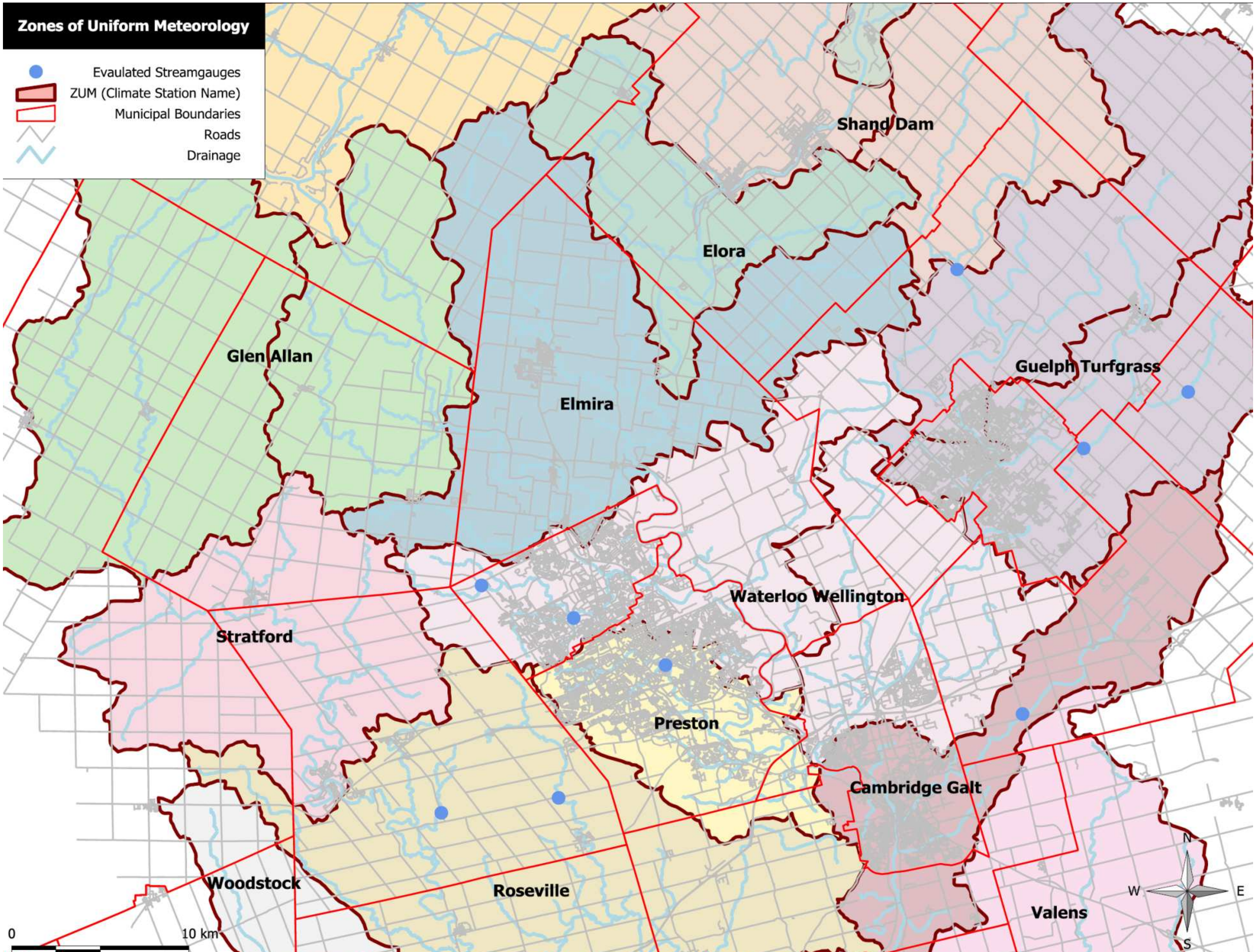
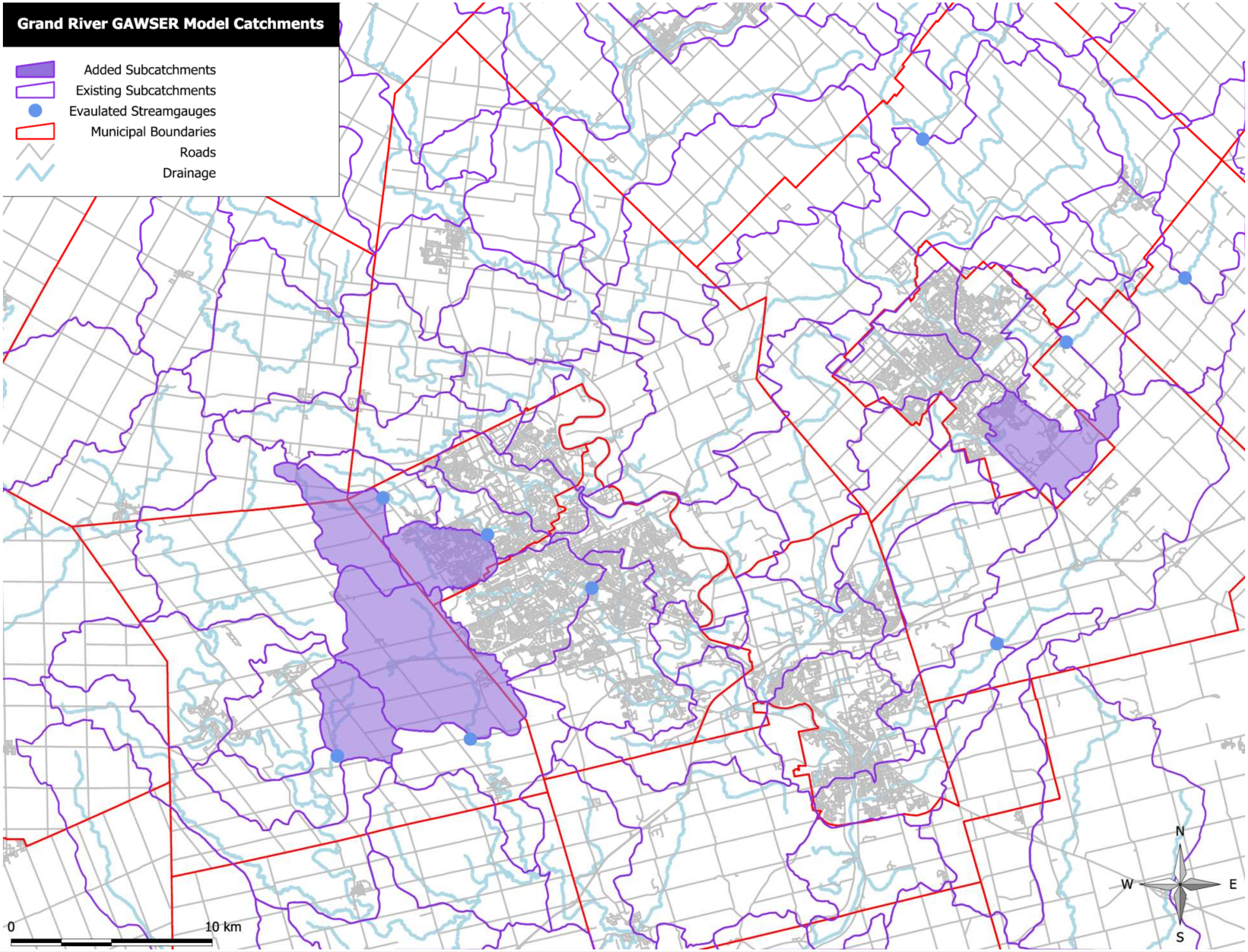
Appendix A


GAWSER Process Schematic
Evapo - transpiration
Temperature
Precipitation
Sublimation
Potential Evapotranspiration
•Potential ET rates are calculated by either a temperature based algorithm or specified monthly values
•Potential ET rates are applied within the HRU calculations
Snowpack
Snowmelt
Liquid Water
ZUM Calculations
HRU Calculations
Interception Storage
Depression Storage
Infiltration
1st Soil Layer
Seepage
2nd Soil Layer
Percolation
Groundwater Recharge
•Overland Runoff is generated when Depression Storage is filled, and liquid water falls at a rate greater than infiltration rate.
•Infiltration (water movement into Layer 1) is calculated by Green & Ampt equation which considers antecedent soil water content.
•Water enters the 2nd Layer when 1st Layer soil water content exceeds field capacity.
•Water leaves 2nd soil layer when 2nd soil water content exceeds field capacity. This is considered groundwater recharge.
•Evapotranspiration removes soil water from interception and depression storage first, then subsequently the 1st and 2nd soil layer. The rate of water removal is constrained by the potential evapotranspirtion rate calculated in the ZUM calculations.
•Once soil layers reach wilting point, no other evapotranspiration occurs, until soil water is replenished.
Catchment Calculations
Overland Runoff Hydrographs (One Hydrograph for each 9 HRUs)
Catchment Hydrograph
If Hummocky, proportion of runoff is diverted to baseflow
Interflow / Baseflow Hydrographs (9 HRUs)
Deep Groundwater Recharge (Groundwater not returned locally)
Routing Calculations
Flow from Upstream Catchments
River Hydrograph
Regional GW Discharge
Calibrate to D/S Streamgauge

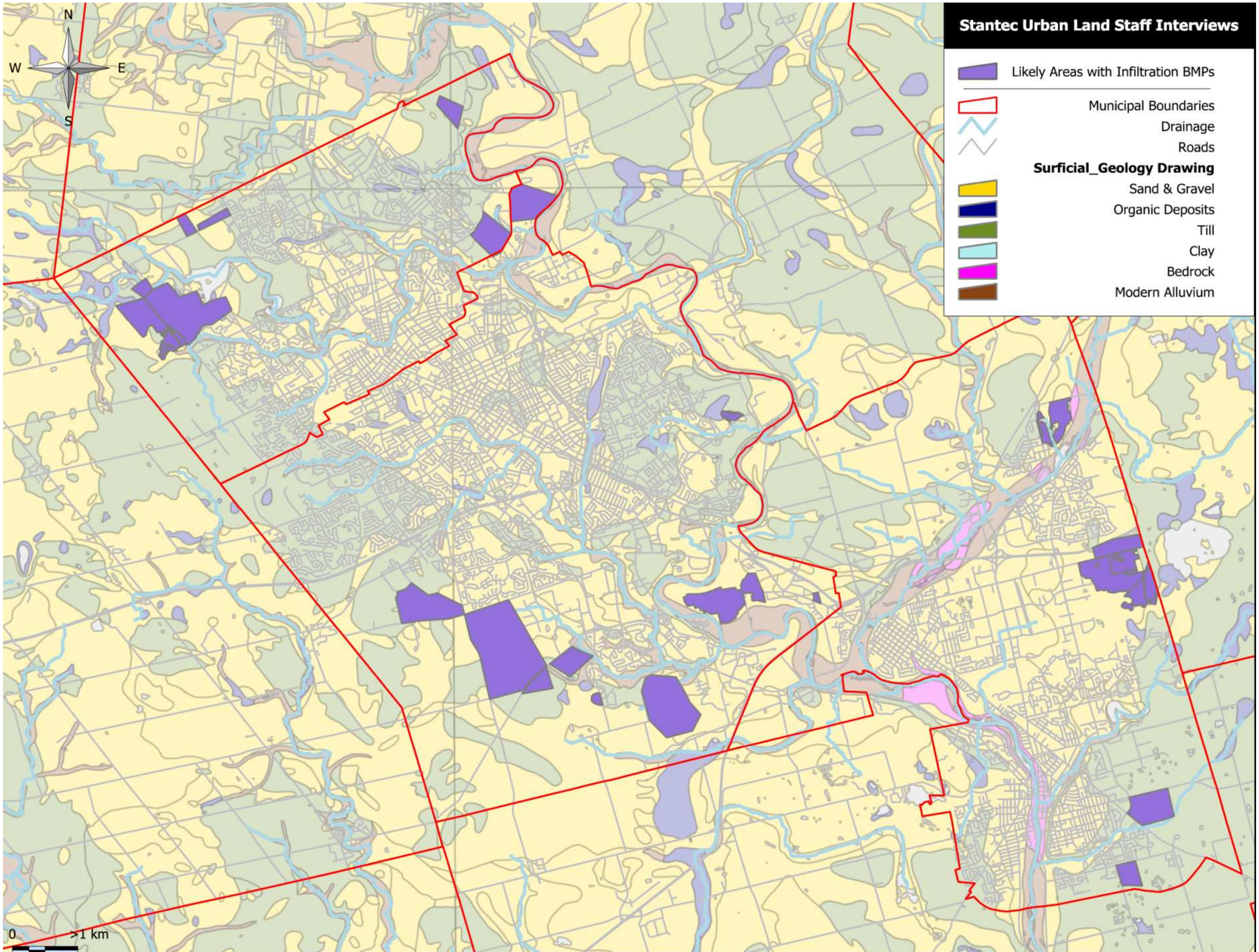
Appendix B



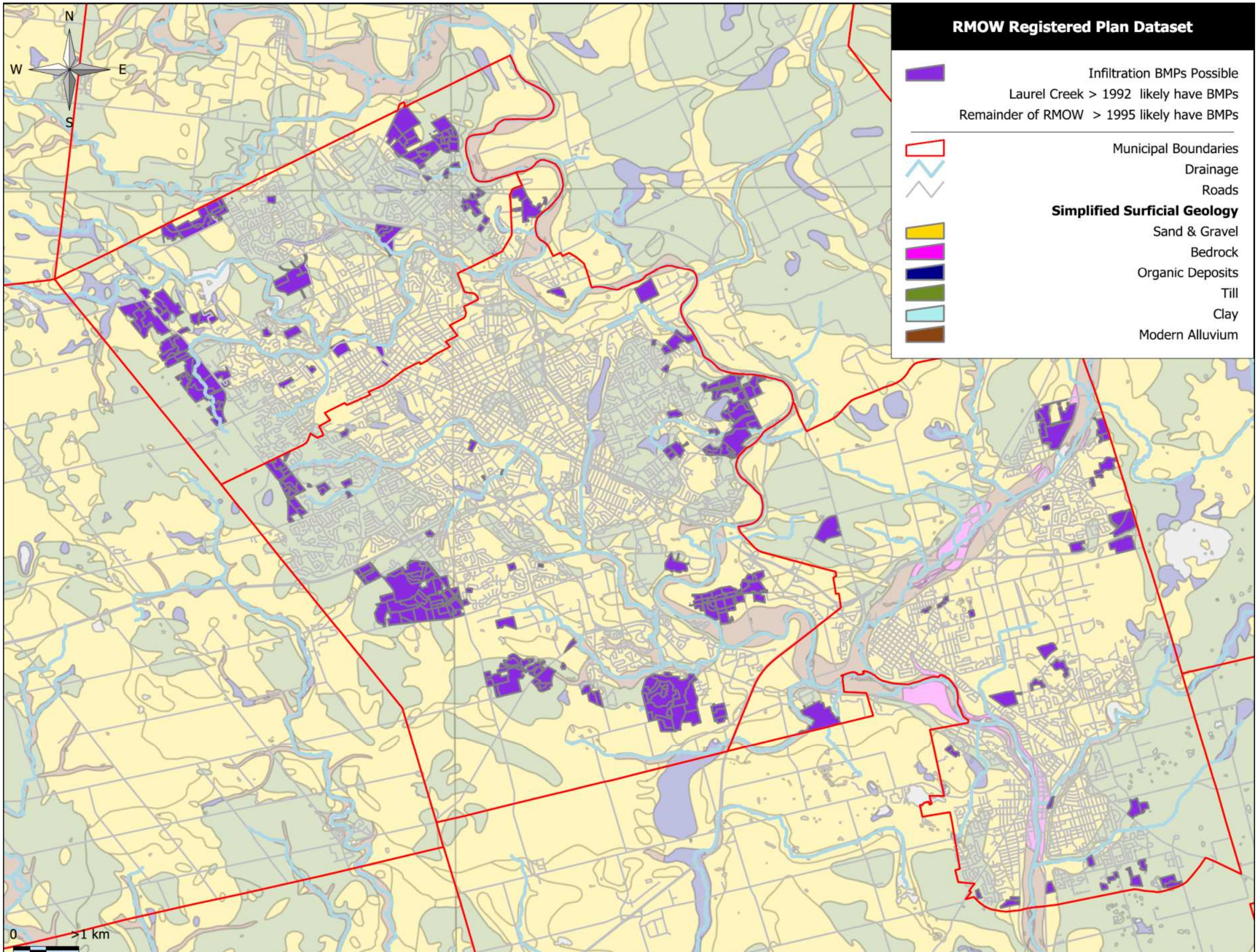
Map 1: Revised ZUMs and Climate Stations



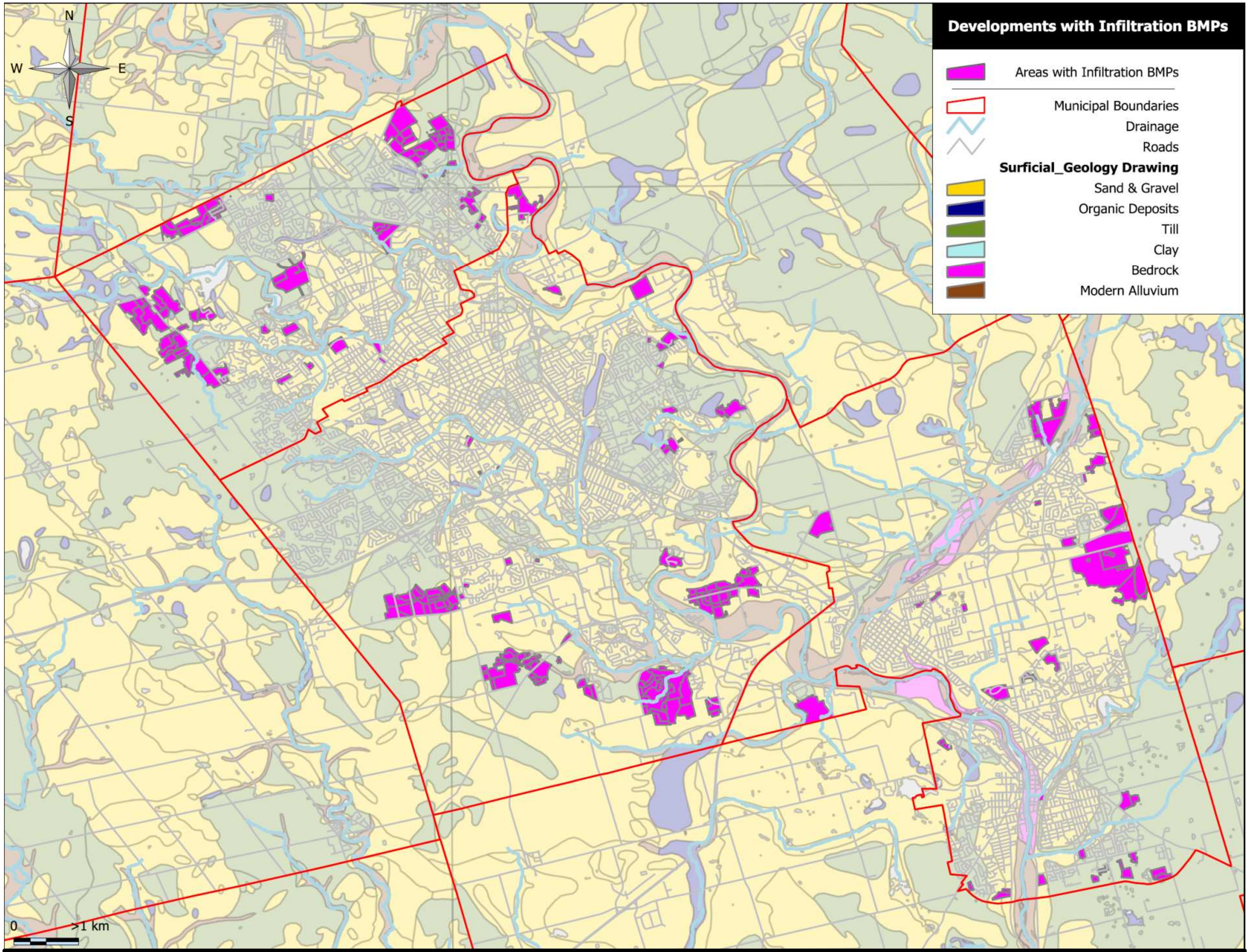
Map 2: Refined GAWSER Catchments



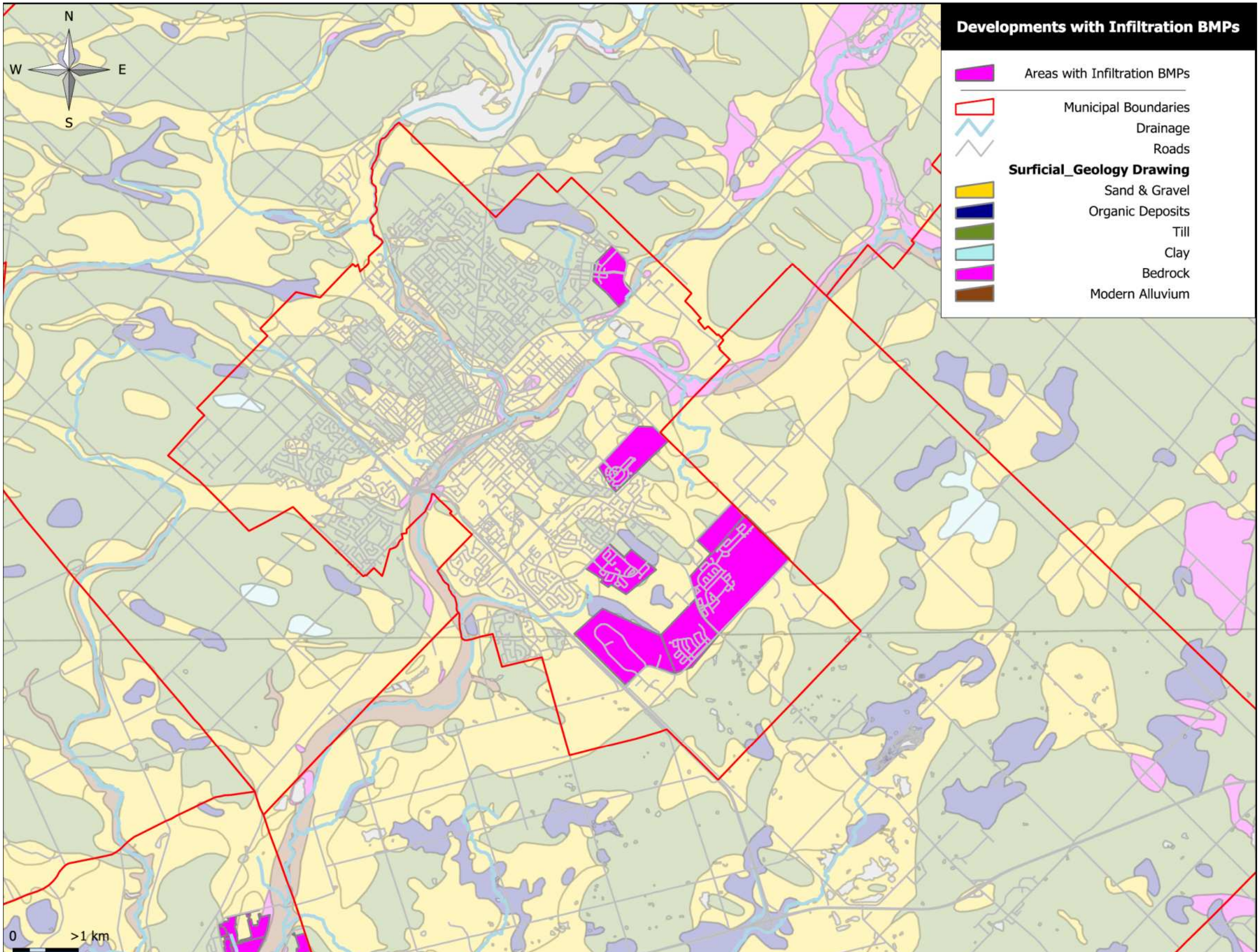
Map 3: Developments with Possible Infiltration BMPs (Stantec Interview)



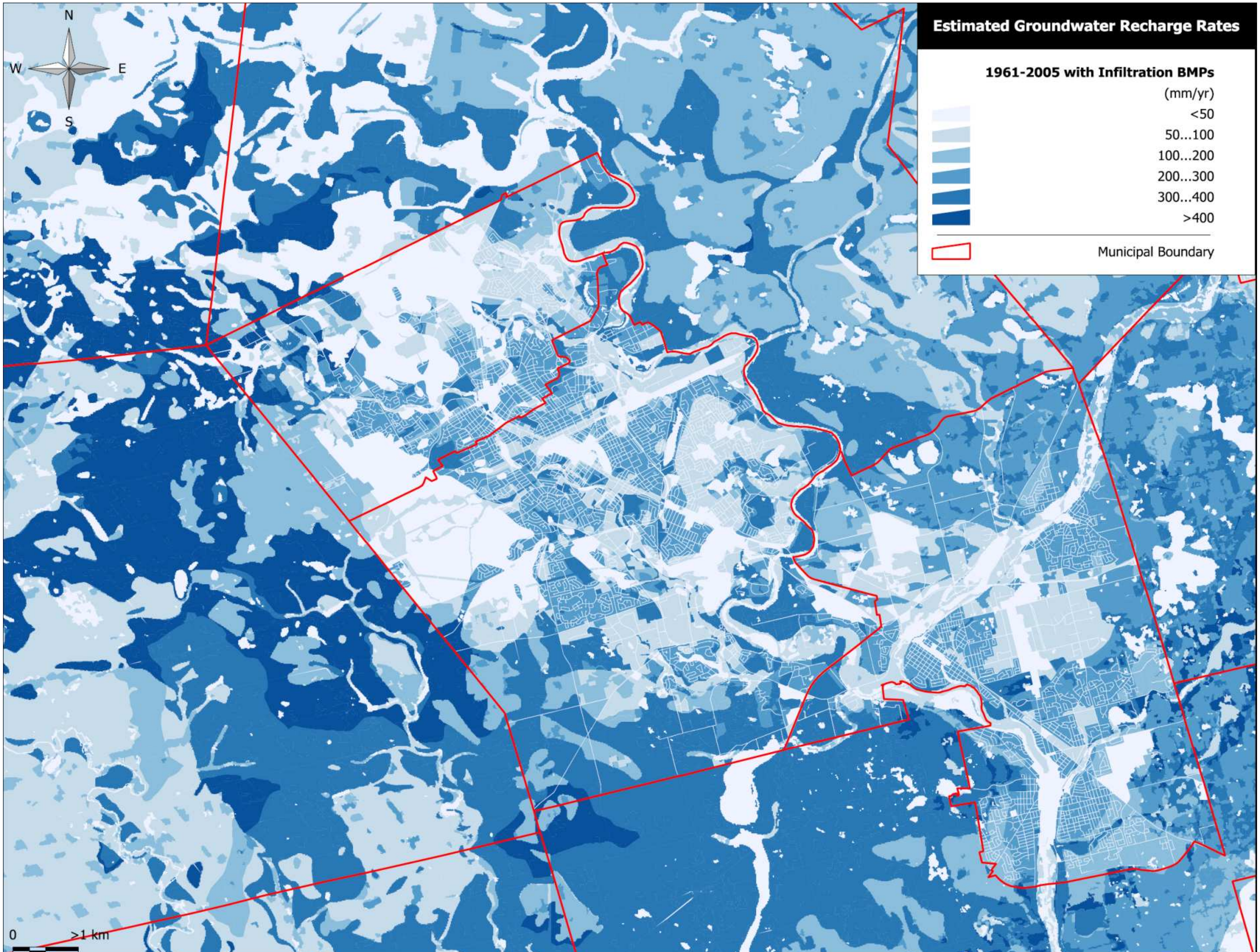
Map 4: Developments with Possible Infiltration BMPs (RMOW Registered Plans)



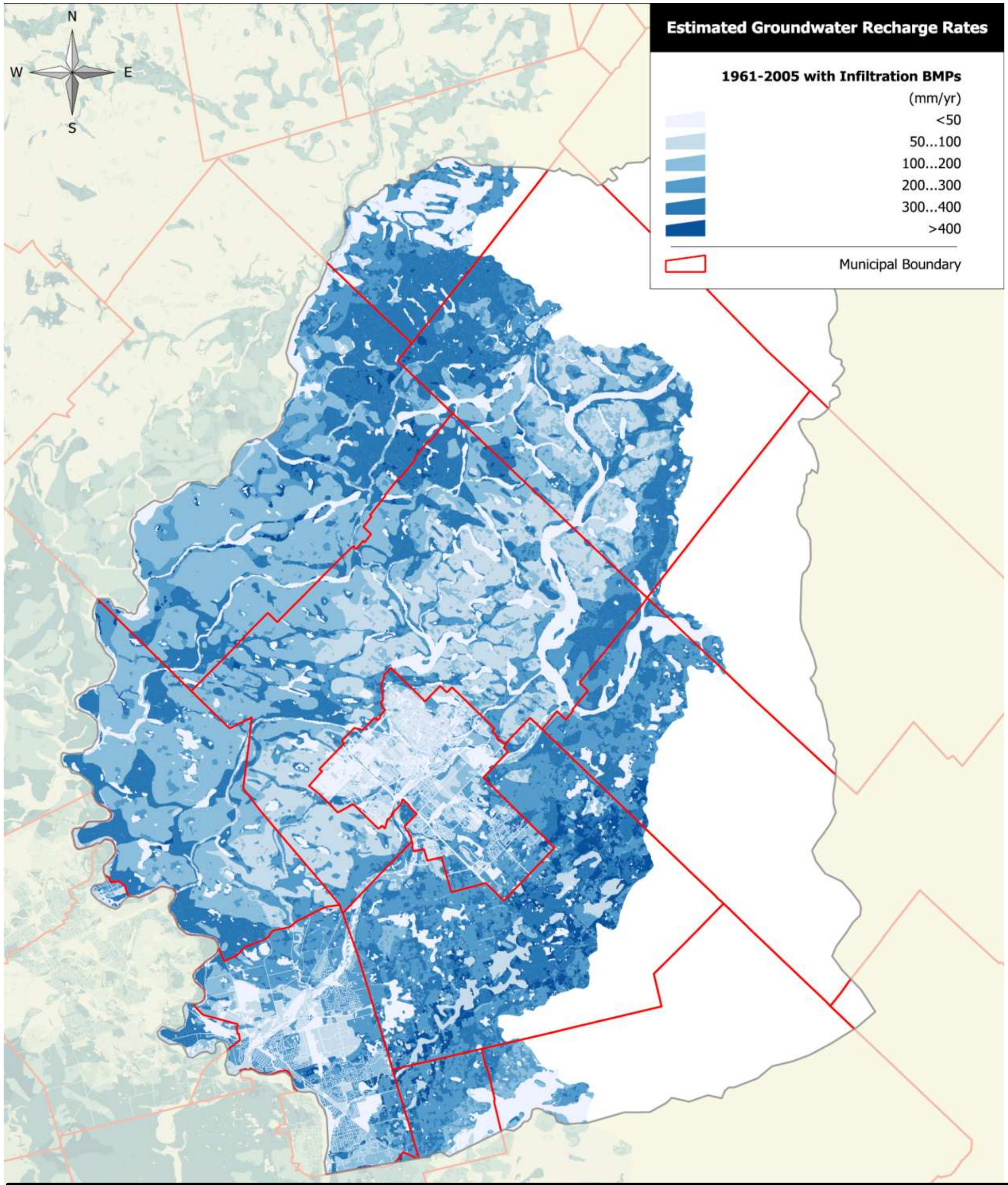
Map 5a: Developments Assumed to have Infiltration BMPs (RMOW)



Map 5b: Developments Assumed to have Infiltration BMPs (Guelph)



Map 6a: Estimated Groundwater Recharge Rates (RMOW)



Map 6b: Estimated Groundwater Recharge Rates (Guelph)

Appendix B2 – Consumptive Groundwater Demand

Consumptive Groundwater Demand

This section provides a summary of the permitted non-municipal consumptive groundwater demands for the assessment area as part of the City of Guelph Tier Three Assessment. Consumptive water demand refers to water that is taken and not returned to its original source (i.e., stream or aquifer) within a reasonable amount of time. Understanding this type of water demand is critical to the development of a water budget framework. An estimate of the extent and variability of water use throughout the Study Area is required to identify areas that may be under the highest degree of potential hydrologic stress.

The following section determines the total permitted non-municipal consumptive water demand by using reported pumping rates where applicable or estimated pumping rates. Estimated pumping rates were generated by combining the permitted rate with the months of expected active pumping and a consumptive factor. Consumptive factors are applied to determine the amount of pumped water that is not returned to the original source in a reasonable amount of time. While this section documents estimated consumptive water demand, it is recognized that there are a number of non-consumptive water uses (i.e., water for waste assimilation or for sustaining ecological health) that are not included. These water needs do not remove water from its source and as such are not considered to be water takings in this assessment.

A database of consumptive demand was developed that includes reported daily and monthly takings, as well as permitted rates where reported rates are lacking, for each non-municipal sources of groundwater taking in the City of Guelph numerical model domain. Numerous data sources were compiled in the creation of the reported and estimated consumptive demand database for non-municipal water takings, as listed below:

- Permit To Take Water (PTTW) Database (2008) – Ministry of the Environment (provided by the Grand River Conservation Authority (GRCA));
- Water Taking Reporting System (WTRS) (2008) – Ministry of the Environment (provided by the GRCA (Extraction Date: January 19, 2010));
- Monthly reported water takings (2002-2006) – Grand River Conservation Authority Integrated Water Budget Report (AquaResource, 2009a).

A total of 190 permitted sources are considered (**Table 1**). The supplied 2008 WTRS dataset contains permit and source names, period of water taking, and daily reported pumping rates, and lacks geographic information. As the 2008 PTTW is the most current dataset with available geographic data, co-ordinates of permits /sources were taken from this dataset.

Table 1. Permitted, non-municipal groundwater takings.

Permit Number	Source Name	Easting	Northing	Major Category	Specific Purpose	Max Permitted (L/d)	Max Permitted (m3/d)	Max Days/Year	In Model
00-P-2417	Well	567174	4837007	Agricultural	Other - Agricultural	654624	654.6	365	Yes
00-P-2417	Well	566898	4836647	Agricultural	Other - Agricultural	654624	654.6	365	Yes
00-P-2681	One well (PW1)	551316	4808472	Agricultural	Sod Farm	818280	818.3	365	Yes
00-P-2782	Well (WWR # 10911)	559540	4807988	Water Supply	Campgrounds	255000	255.0	365	Yes
00-P-2782	Well (WWR # 2273)	559451	4808040	Water Supply	Campgrounds	255000	255.0	365	Yes
00-P-2782	Well (WWR # 6096)	559838	4808018	Water Supply	Campgrounds	255000	255.0	365	Yes
00-P-2791	Dugout pond	558358	4808902	Commercial	Golf Course Irrigation	599636	599.6	365	Yes
00-P-2791	Well	558458	4808933	Commercial	Golf Course Irrigation	490968	491.0	365	Yes
0104-783FXW	Pond 1	551859	4824135	Commercial	Golf Course Irrigation	1091000	1091.0	150	Yes
0147-6K9RKS	EW10-92	562971	4822422	Remediation	Other - Remediation	23040	23.0	365	Yes
0147-6K9RKS	EW11-93	562968	4822422	Remediation	Other - Remediation	12960	13.0	365	No
0147-6K9RKS	EW12-93	562971	4822424	Remediation	Other - Remediation	12960	13.0	365	Yes
0147-6K9RKS	EW41-94	562963	4822429	Remediation	Other - Remediation	10080	10.1	365	No
0147-6K9RKS	OW45-04/RW45-04	563000	4821986	Remediation	Other - Remediation	7200	7.2	365	Yes
0147-6K9RKS	Well OW3-91/RW3-91	563024	4821986	Remediation	Other - Remediation	7200	7.2	365	Yes
01-P-2004	29 Wells	557025	4823001	Remediation	Groundwater	328000	328.0	365	Yes
01-P-2027	Dugout pond	576357	4844164	Commercial	Golf Course Irrigation	982000	982.0	122	Yes
01-P-2027	Well (WWR # 6710895)	576640	4844411	Commercial	Golf Course Irrigation	982000	982.0	122	Yes
01-P-2040	one well (WWR#9810606)	582790	4805120	Water Supply	Other - Water Supply	46000	46.0	365	Yes
01-P-2192	Well	571930	4849456	Institutional	Schools	100000	100.0	365	Yes
01-P-2207	Well L1	574846	4807052	Water Supply	Communal	36530	36.5	365	Yes
01-P-2207	Well U2	574985	4806782	Water Supply	Communal	13120	13.1	365	Yes
01-P-2236	well	557700	4835799	Commercial	Golf Course Irrigation	589000	589.0	183	Yes
01-P-2236	dugout	557700	4835800	Commercial	Golf Course Irrigation	2182000	2182.0	183	No
01-P-2245	well	570784	4815980	Miscellaneous	Irrigation	60000	60.0	365	Yes
01-P-2245	dugout pond	570901	4815964	Miscellaneous	Heat Pumps	69000	69.0	365	Yes
01-P-3025	Well No 1	580393	4816204	Water Supply	Communal	1309250	1309.3	90	Yes
01-P-3025	Well No 2	580393	4816204	Water Supply	Communal	1309250	1309.3	90	Yes
02-P-2002	Scalehouse Well	560055	4810875	Industrial	Aggregate Washing	122000	122.0	175	No
02-P-2002	Washplant Well	559836	4811222	Industrial	Aggregate Washing	548000	548.0	175	Yes
02-P-2060	Well #1	548754	4815632	Agricultural	Nursery	164000	164.0	180	Yes
02-P-2061	Well #1	548769	4815586	Agricultural	Nursery	164000	164.0	180	Yes
02-P-2064	Drilled Well #1	569356	4811814	Agricultural	Nursery	273000	273.0	220	Yes
02-P-3097	Pond	584900	4808800	Agricultural	Field and Pasture Crops	1000000	1000.0	150	Yes
0302-7CEL63	Well N1	560648	4809366	Commercial	Mall / Business	210000	210.0	365	Yes
0302-7CEL63	Well N2	560679	4809389	Commercial	Mall / Business	100000	100.0	365	Yes
0302-7CEL63	Well N3	560725	4809289	Commercial	Mall / Business	273000	273.0	365	Yes
0334-6ARJNR	Well PW1/89	557026	4804566	Commercial	Golf Course Irrigation	819000	819.0	153	Yes

Permit Number	Source Name	Easting	Northing	Major Category	Specific Purpose	Max Permitted (L/d)	Max Permitted (m3/d)	Max Days/Year	In Model
03-P-2003	Dugout pond	561056	4814413	Industrial	Aggregate Washing	490000	490.0	229	No
03-P-2045	Well #3	577363	4807159	Water Supply	Campgrounds	200000	200.0	365	Yes
03-P-2045	Well #9	577587	4807179	Water Supply	Campgrounds	200000	200.0	365	Yes
03-P-2047	Well	560391	4798971	Industrial	Aggregate Washing	524000	524.0	270	No
03-P-2098	Well TW1	574748	4803749	Water Supply	Campgrounds	145000	145.0	365	Yes
03-P-2099	Well WS1	548102	4806061	Water Supply	Campgrounds	82100	82.1	180	Yes
03-P-2215	Pond	583025	4807261	Agricultural	Field and Pasture Crops	699000	699.0	4	Yes
03-P-2215	Pond	582634	4807565	Agricultural	Field and Pasture Crops	699000	699.0	4	Yes
03-P-2245	Pond	548975	4805598	Commercial	Golf Course Irrigation	1634000	1634.0	150	Yes
03-P-2249	Well (TW-2)	579651	4809964	Water Supply	Communal	1309000	1309.0	365	Yes
03-P-2265	Dugout Pond	579411	4805871	Agricultural	Field and Pasture Crops	1000000	1000.0	45	Yes
03-P-2266	Dugout Pond	582265	4808098	Agricultural	Field and Pasture Crops	1000000	1000.0	20	Yes
03-P-2267	Dugout Pond	580060	4809797	Agricultural	Field and Pasture Crops	540000	540.0	30	Yes
03-P-2408	Test Well 1	552053	4812678	Agricultural	Sod Farm	2160000	2160.0	180	Yes
0507-74TRLE	Trenches	544995	4824415	Dewatering Construction	Construction	100000	100.0	30	Yes
0700-6YTS5P	Well # OW22-89	557183	4801047	Remediation	Other - Remediation	72000	72.0	365	Yes
0700-6YTS5P	Well # PW5-97	557018	4801061	Remediation	Other - Remediation	14400	14.4	365	Yes
0700-6YTS5P	Well # PW6-02	557049	4801038	Remediation	Other - Remediation	14400	14.4	365	Yes
0704-6XGLMP	Clubhouse Well	573676	4846518	Commercial	Golf Course Irrigation	55000	55.0	365	Yes
0800-6XARHU	Clubhouse Well	575516	4820861	Commercial	Golf Course Irrigation	96480	96.5	365	Yes
0882-6FTHMA	Irrigation Well	566388	4816161	Water Supply	Other - Water Supply	656000	656.0	214	Yes
0882-6FTHMA	Maintenance Well	566425	4815893	Water Supply	Other - Water Supply	65000	65.0	365	Yes
0882-6FTHMA	Clubhouse Well	566318	4816054	Water Supply	Other - Water Supply	130000	130.0	365	Yes
1065-5VFQ9K	Admiral Well	564140	4815443	Industrial	Brewing and Soft Drinks	552900	552.9	365	No
1204-62XKAF	Well	562403	4822865	Industrial	Cooling Water	110000	110.0	227	Yes
1216-6SCL4W	Well No. PW-1	571022	4812087	Industrial	Food Processing	110000	110.0	365	Yes
1351-6D5LEK	Well TW1-89	549716	4817654	Water Supply	Other - Water Supply	142000	142.0	365	Yes
1528-6GTN6M	Well 26R	557917	4822988	Remediation	Other - Remediation	299000	299.0	365	Yes
1528-6GTN6M	Well 31	557809	4823006	Remediation	Other - Remediation	15000	15.0	365	Yes
1528-6GTN6M	Well 6	557836	4822990	Remediation	Other - Remediation	15000	15.0	365	Yes
1787-6C8RLU	Well #1 Central Utilities Plant	562478	4820358	Agricultural	Other - Agricultural	737000	737.0	365	Yes
1787-6C8RLU	Well #3 Athletics Centre	562551	4820377	Agricultural	Other - Agricultural	525000	525.0	365	Yes
1787-6C8RLU	Well #4 Building #250	561928	4819232	Agricultural	Other - Agricultural	1309000	1309.0	365	No
1833-6G7QVG	Artesian Well	577113	4840275	Commercial	Other - Commercial	64000	64.0	300	No
2042-6UWKST	PW1	574238	4802188	Water Supply	Other - Water Supply	87000	87.0	365	Yes
2042-6UWKST	PW3	574337	4802257	Water Supply	Other - Water Supply	708000	708.0	365	Yes
2202-6X9QTU	Spring	565845	4845183	Commercial	Aquaculture	2620000	2620.0	365	No
2202-6X9QTU	Well	566032	4845329	Commercial	Aquaculture	654000	654.0	365	No
2448-6FUKQ5	Mill Creek Pit	567290	4810630	Industrial	Aggregate Washing	8183000	8183.0	250	Yes

Permit Number	Source Name	Easting	Northing	Major Category	Specific Purpose	Max Permitted (L/d)	Max Permitted (m3/d)	Max Days/Year	In Model
2540-6PLKFX	PW1/00 (main well)	553898	4812349	Commercial	Golf Course Irrigation	1637000	1637.0	183	Yes
2540-6PLKFX	PW1/88 (standby well)	553771	4812203	Commercial	Golf Course Irrigation	655000	655.0	183	Yes
2563-6VKR7T	One Bedrock Well (A037447)	552019	4811557	Agricultural	Sod Farm	1718000	1718.0	184	Yes
2688-7BRKDG	PW1	557476	4801412	Remediation	Groundwater	213000	213.0	365	Yes
2688-7BRKDG	PW2	557425	4801474	Remediation	Groundwater	115000	115.0	365	Yes
2688-7BRKDG	PW3	557408	4801531	Remediation	Groundwater	38000	38.0	365	Yes
2768-6QXRCC	One Well #A017773	557427	4815114	Industrial	Manufacturing	79200	79.2	365	Yes
2856-6N7MQK	Well #2 WWR# 6811368	579692	4806474	Commercial	Bottled Water	118860	118.9	365	Yes
3024-6CQJZ5	Well MOE# 6709444	565174	4820242	Commercial	Golf Course Irrigation	882000	882.0	215	Yes
3036-6QPKHE	PW1	560000	4823000	Institutional	Other - Institutional	136800	136.8	365	Yes
3234-74ER7S	McNally Pit Wash Pond	568280	4810400	Industrial	Aggregate Washing	23568000	23568.0	365	Yes
3331-73RKYV	Well PW1	569534	4814390	Water Supply	Communal	132000	132.0	365	Yes
3331-73RKYV	Well PW2	569537	4814528	Water Supply	Communal	185000	185.0	365	Yes
3331-73RKYV	Well PW3	569499	4814701	Water Supply	Communal	323000	323.0	365	Yes
3331-73RKYV	Well PW4	569080	4814310	Water Supply	Communal	333000	333.0	365	Yes
3581-7CML9F	Calico Well	554681	4820016	Water Supply	Communal	5237000	5237.0	365	No
3617-74SPNH	Phase 2	580955	4829545	Dewatering	Pits and Quarries	12960000	12960.0	350	No
3617-74SPNH	Phase 3	580435	4829560	Dewatering	Pits and Quarries	12960000	12960.0	120	No
3830-6W6JHW	Source Pond	569250	4811950	Industrial	Aggregate Washing	23568000	23568.0	365	Yes
3878-6Z3JUU	MH-1155	551100	4807800	Dewatering	Other - Dewatering	49000	49.0	365	Yes
3878-6Z3JUU	MH-1161	551300	4807300	Dewatering	Other - Dewatering	117000	117.0	365	Yes
3878-6Z3JUU	MH-1164	551300	4807400	Dewatering	Other - Dewatering	117000	117.0	365	Yes
3878-6Z3JUU	MH-1184	550900	4807800	Dewatering	Other - Dewatering	117000	117.0	365	Yes
3878-6Z3JUU	MH-1809	551400	4807300	Dewatering	Other - Dewatering	117000	117.0	365	Yes
3878-6Z3JUU	MH-1819	551100	4807800	Dewatering	Other - Dewatering	13000	13.0	365	Yes
3878-6Z3JUU	MH-863	551000	4807300	Dewatering	Other - Dewatering	49000	49.0	365	No
4116-7CELMY	Well S1	560640	4809381	Commercial	Mall / Business	264000	264.0	365	Yes
4116-7CELMY	Well S2	560679	4809412	Commercial	Mall / Business	196000	196.0	365	Yes
4116-7CELMY	Well S3	560725	4809296	Commercial	Mall / Business	273000	273.0	365	Yes
4165-6M8LZE	Well 1 (A022033)	577005	4803664	Agricultural	Other - Agricultural	345600	345.6	120	No
4358-6NQLG6	Well P15	555754	4806616	Water Supply	Other - Water Supply	1638000	1638.0	365	No
4366-6BTRUX	Well	563512	4821997	Miscellaneous	Heat Pumps	816000	816.0	365	Yes
4845-6E8HA5	PW-1	549235	4813543	Industrial	Food Processing	550000	550.0	365	Yes
4845-6E8HA5	PW-2	549159	4813543	Industrial	Food Processing	550000	550.0	365	Yes
4845-6E8HA5	PW-3	549103	4813513	Industrial	Food Processing	550000	550.0	365	Yes
5081-6GEPMB	W1 (Standby) (MOE WWR - 67-07918)	560760	4827800	Water Supply	Other - Water Supply	130000	130.0	214	Yes
5081-6GEPMB	W2 (MOE WWR - 67-07917)	560520	4828020	Water Supply	Other - Water Supply	130000	130.0	214	Yes
5170-6X9H33	Well A017818	568312	4816988	Commercial	Golf Course Irrigation	657000	657.0	180	Yes
5201-6B7HDA	Well A - Office	567598	4812203	Industrial	Other - Industrial	114600	114.6	300	Yes

Permit Number	Source Name	Easting	Northing	Major Category	Specific Purpose	Max Permitted (L/d)	Max Permitted (m3/d)	Max Days/Year	In Model
5201-6B7HDA	Well B - Asphalt Plant	567476	4812030	Industrial	Other - Industrial	515600	515.6	300	Yes
5201-6B7HDA	Well C - Concrete Plant	567608	4811999	Industrial	Other - Industrial	802000	802.0	300	Yes
5336-6C8R2N	Arboretum Well	563398	4821157	Agricultural	Field and Pasture Crops	110000	110.0	200	Yes
5336-6C8R2N	Aviary Well	563010	4820588	Agricultural	Field and Pasture Crops	175000	175.0	200	Yes
5336-6C8R2N	Hilton Centre Well	563036	4821307	Agricultural	Field and Pasture Crops	252000	252.0	60	Yes
5675-6W9TDF	Auxilary Pond No 4	581600	4832100	Industrial	Aggregate Washing	2454840	2454.8	365	No
5675-6W9TDF	Source Pond No. 9	581800	4831900	Industrial	Aggregate Washing	5400000	5400.0	365	No
6031-7CVQ3X	Ground Water	555875	4809552	Dewatering	Other - Dewatering	320000	320.0	30	Yes
6046-6GNKQD	Spring #1	576039	4845619	Commercial	Aquaculture	1964000	1964.0	365	No
6046-6GNKQD	Spring #2	575888	4845528	Commercial	Aquaculture	7855500	7855.5	365	No
6046-6GNKQD	Springs - other	575915	4845457	Commercial	Aquaculture	196500	196.5	365	No
6046-6GNKQD	Two Dug Wells	575866	4845577	Commercial	Aquaculture	3273000	3273.0	365	No
6064-646HBU	PH#4	554212	4845252	Water Supply	Communal	425000	425.0	365	Yes
6064-646HBU	PW1-78	553905	4845247	Water Supply	Communal	327000	327.0	365	Yes
6064-646HBU	PW2-67	554167	4845115	Water Supply	Communal	1308000	1308.0	365	Yes
6064-646HBU	PW3-81	553930	4845624	Water Supply	Communal	654000	654.0	365	Yes
6066-6VXQU2	Maintenance Well	561196	4803854	Water Supply	Other - Water Supply	34000	34.0	365	Yes
6066-6VXQU2	Clubhouse Well	561060	4803785	Water Supply	Other - Water Supply	50000	50.0	365	Yes
6066-6VXQU2	Well PW1/2005	561189	4803847	Water Supply	Golf Course Irrigation	1965000	1965.0	184	Yes
6268-6QJLB3	Breslau Pit Extraction Pond	547580	4811942	Industrial	Other - Industrial	5942000	5942.0	360	No
6434-6VZHGY	GDCW1	574474	4847801	Remediation	Groundwater	322000	322.0	365	Yes
6434-6VZHGY	GDCW2	574451	4847978	Remediation	Groundwater	983000	983.0	365	Yes
6445-6QZMES	Main Quarry Discharge, Interim conditions	583110	4820430	Dewatering	Pits and Quarries	17280000	17280.0	365	No
6445-6QZMES	North Quarry Dewatering	582360	4822200	Dewatering	Pits and Quarries	31968000	31968.0	365	No
6445-6QZMES	Operations Water Use, Long-term conditions	583610	4821160	Dewatering	Pits and Quarries	17280000	17280.0	240	No
6445-6QZMES	Recharge System	583270	4820850	Dewatering	Pits and Quarries	25920000	25920.0	365	No
6445-6QZMES	Central Sump Dewatering, Long-term conditions	583610	4821160	Dewatering	Pits and Quarries	38880000	38880.0	365	No
6480-74BKR4	Drilled Well No. TW1-88	568384	4847833	Commercial	Bottled Water	1113000	1113.0	365	Yes
6560-6DYPGH	Well WSW 1	570188	4811581	Industrial	Manufacturing	250000	250.0	365	Yes
6560-6DYPGH	Well WSW 2	569847	4811446	Industrial	Manufacturing	200000	200.0	365	Yes
6661-65YPPD	Cambridge Landfill Well #CL-PW2	558706	4801766	Remediation	Other - Remediation	980000	980.0	365	No
6800-72CLQH	Well No. 3	558858	4823140	Industrial	Other - Industrial	1635000	1635.0	365	Yes
69-P-0241	Well (1)	547680	4813810	Water Supply	Communal	818280	818.3	365	Yes
69-P-0481	Well	584508	4807358	Agricultural	Other - Agricultural	229118	229.1	365	Yes
69-P-0481	Well	584556	4807311	Agricultural	Other - Agricultural	229118	229.1	365	Yes
7043-74BL3K	TW3-80	568935	4812721	Commercial	Bottled Water	3600000	3600.0	365	Yes
7134-6LJKT4	Pond	565889	4853747	Industrial	Aggregate Washing	73000	73.0	140	Yes
7175-6LCQ2M	Spring Fed Pond	574049	4832866	Commercial	Golf Course Irrigation	238000	238.0	184	Yes
7240-65YKTN	Sump 4	559873	4819122	Dewatering	Pits and Quarries	13750000	13750.0	365	No

Permit Number	Source Name	Easting	Northing	Major Category	Specific Purpose	Max Permitted (L/d)	Max Permitted (m3/d)	Max Days/Year	In Model
7240-65YKTN	Sump 3	559565	4818733	Dewatering	Pits and Quarries	13750000	13750.0	365	No
72-P-0453	Dugout Pond	568922	4812609	Industrial	Aggregate Washing	8182800	8182.8	250	Yes
73-P-0480	Well (WWR#6704723)	565997	4851754	Agricultural	Other - Agricultural	1210000	1210.0	365	Yes
7403-6HCMGT	Dugout Pond	563572	4802239	Recreational	Fish Ponds	654000	654.0	111	Yes
7403-6HCMGT	Dugout Pond	563566	4802151	Recreational	Fish Ponds	654000	654.0	111	Yes
7403-6HCMGT	Dugout Pond	563569	4802197	Recreational	Fish Ponds	654000	654.0	111	Yes
7646-6QJQR7	PW1	573938	4802156	Water Supply	Communal	318220	318.2	365	Yes
7646-6QJQR7	PW2	573892	4802122	Water Supply	Communal	318220	318.2	365	Yes
7825-6WLMDA	Well G8	558339	4802613	Water Supply	Other - Water Supply	2292000	2292.0	365	No
8228-76XLE2	PW2	569616	4813435	Water Supply	Communal	137000	137.0	85	No
8228-76XLE2	PW5	569536	4813137	Water Supply	Communal	67000	67.0	85	No
8228-76XLE2	PW6	569384	4813245	Water Supply	Communal	785000	785.0	365	Yes
8228-76XLE2	PW7	569389	4813250	Water Supply	Communal	785000	785.0	365	Yes
8664-75QJ2J	Hillsburgh Well	571834	4846628	Commercial	Bottled Water	225000	225.0	260	Yes
8708-6LLS2Z	Well #1 (WWR# 6508121)	549441	4817845	Commercial	Golf Course Irrigation	909000	909.0	120	Yes
8708-6LLS2Z	Well TW 2003-1	549354	4817908	Commercial	Golf Course Irrigation	909000	909.0	180	Yes
88-P-2069	Wells	558681	4816893	Industrial	Other - Industrial	654624	654.6	365	Yes
89-P-2014	Well	569462	4812611	Industrial	Other - Industrial	72800	72.8	365	Yes
92-P-2054	Pond	566972	4855604	Industrial	Aggregate Washing	5940000	5940.0	140	Yes
93-P-2103	Well	565004	4819478	Commercial	Golf Course Irrigation	540000	540.0	365	Yes
97-P-2048	Pond 1	576563	4848625	Industrial	Aggregate Washing	2288000	2288.0	365	Yes
97-P-2048	Pond 2	576719	4848625	Industrial	Aggregate Washing	982000	982.0	365	Yes
98-P-2064	Well	569203	4814403	Water Supply	Campgrounds	392774	392.8	365	Yes
98-P-2106	Well	577179	4846206	Industrial	Aggregate Washing	392774	392.8	210	No
98-P-3017	Quarry sump	583818	4819291	Dewatering	Pits and Quarries	20711520	20711.5	365	No
99-P-2012	Well SK3	547889	4812595	Industrial	Other - Industrial	33000	33.0	365	No
99-P-2012	Well SK4	547993	4812609	Industrial	Other - Industrial	33000	33.0	365	No
99-P-2012	Well SK5	547882	4812614	Industrial	Other - Industrial	410000	410.0	365	No
99-P-2012	Wells SK1	547973	4812619	Industrial	Other - Industrial	33000	33.0	365	No
99-P-2070	Well EW1-91	561092	4820909	Remediation	Groundwater	46080	46.1	365	Yes
99-P-2070	Well EW2-98	561018	4820862	Remediation	Groundwater	46080	46.1	365	Yes
99-P-2070	Well EW3-99	560985	4820923	Remediation	Groundwater	46080	46.1	365	Yes
99-P-2070	Well EW4-99	560982	4820975	Remediation	Groundwater	46080	46.1	365	Yes
99-P-2132	Well (1)	569100	4806163	Commercial	Aquaculture	1636560	1636.6	365	Yes
99-P-3017	Quarry Sump	583818	4819291	Dewatering	Pits and Quarries	20711520	20711.5	365	No

Data Verification

As data is sourced from numerous entities, each with inherent data issues, all data were inspected to ensure dataset are complete and correct. Data management and verification procedures are briefly described below.

The 2008 PTTW database has missing maximum pumping days per year, and pumping rate data for many records. The PTTW database also lacks information pertaining to the collective or individual nature of the permitted taking sources for a given permit. That is, for a permit with three sources, a maximum permitted rate of 25,000 L/day might apply concurrently to all three sources (total rate for permit = 25,000 L/day), or independently for each source (total rate for permit = 75,000 L/day). Establishing this relationship is imperative as the WTRS is self reported by PTTW holders, whereby a PTTW holder may report the pumping rates over multiple permitted sources at a single source if the permit stipulates a collective association.

Surface water and groundwater takings are captured in the PTTW database. As only groundwater takings are included in the groundwater flow model, all surface water takings were not considered. However, many permits contain a combination of surface water and groundwater takings. For example, many aggregate washing operations pump groundwater from a well to a redistribution pond. The water is then circulated through the washing system from the pond. Both of these sources will be recorded in the PTTW database, but only the well extracts groundwater in any significant amount. Thus, in the groundwater flow model, only the well is considered as a true taking, and included.

To resolve these data issues, every permit in the 2008 PTTW database located within the City of Guelph numerical model domain was referenced to the original permit, and the data therein verified. Missing data fields were populated, the relationship between multiple sources noted, and the true nature of takings examined. Originally issued permits were accessed using the Environmental Registry (www.ebr.gov.on.ca). Agricultural permits are not listed on the Environmental Registry. All agricultural permits were cross-referenced to a database independently maintained by GRCA to verify the pumping rate. Should an agricultural permit lack data pertaining to maximum pumping days per year, the days recorded in the database independently maintained by GRCA were used to populate the 2008 PTTW database. If those data were also absent in the GRCA database, it was assumed that the permit could be active 365 days/year.

Temporary permits (active for ≤ 1 year), such as pumping tests, or temporary construction permits, are not considered sustained water takings, and were not included. There are five groundwater takings that have an identified spring as a water source. These sources were included, as water is redistributed by anthropogenic practices.

Data issues are also present in the WTRS dataset (MOE, 2008) supplied by the GRCA. As the WTRS is self reported by PTTW holders, there are data entry errors stemming from permit holders entering data in the wrong units (e.g. gallons/day vs. L/day), inaccurate measurement practices, or number keying issues. Regardless, this leads to erroneous data inclusion. To identify permitted sources with erroneous data, the maximum daily reported rate was queried from the WTRS dataset, and compared to the maximum daily permitted rate. If the maximum daily reported rate was larger than the maximum daily permitted rate, the reported data for that source was manually inspected to correct data, if possible.

Reported Pumping Rates

Reported values were compiled from daily reported takings for each source recorded in the 2008 WTRS dataset, or, if that information was unavailable, the reported monthly takings (2002 - 2006) at each source recorded in the Grand River Conservation Authority Integrated Water Budget Report (AquaResource, 2009a). If no reported data were available for a source of water taking, the consumptive demand was estimated using the maximum permitted rates, and maximum allowable days of pumping recorded in the PTTW dataset (see below).

2008 WTRS Reported Data

Daily reported takings are recorded in the 2008 WTRS for 3468 permits (each permit may have numerous sources) throughout Ontario. In the ROW, 89 sources of water taking (of a possible 190 sources) have data recorded in the WTRS (**Table 2**). As the WTRS records daily pumping rates, and the groundwater flow model will input data on a monthly basis, the daily reported rates were averaged over the month to obtain monthly pumping rates. All pumping data was converted from L/day to m^3/day to be consistent with other data sources.

The WTRS dataset contains actual pumping rates on a daily basis; however, not all water withdrawn from a source is necessarily consumed. To establish a comprehensive understanding of water flow through a system, groundwater flow models examine the consumptive use of water takings. That is, how much of the water that is withdrawn and not returned to its original source, the pumped aquifer in this instance. To calculate the consumptive use of WTRS reported takings, a consumptive factor related to the specific purpose of the taking is applied (**Table 3**). As the WTRS dataset reports daily water takings, default monthly adjustments to account for seasonality of water takings were unnecessary. For a detailed description of applying consumptive use factors, see the Consumptive Use Estimates section below.

2002 – 2006 Monthly Reported Data

Monthly reported water takings reported in the Grand River Conservation Authority Integrated Water Budget Report (AquaResource, 2009a) were available for 45 sources of water taking in the Study Area (**Table 4**). Of those 45 sources, 23 sources also have WTRS data available. For sources with multiple sources of reported data, the WTRS data was chosen as it is more recent.

It was noted that there was frequently a discrepancy between the consumptive use rates in the WTRS and Grand River Conservation Authority Integrated Water Budget Report (AquaResource, 2009a) (GRCA T2) datasets at a given source, where both data were available. This discrepancy is likely related to the nature of the reported data: reported values capture only a year of data. Variations in annual amounts of precipitation, and other climatic factors could influence the amount of water needed for a given activity. **Figures 1 and 2** illustrate the difference between the WTRS and GRCA T2 reported rates for all sources of selected permits with different purposes: 1) other – water supply, associated with a golf course (**Figure 1**), and 2) aggregate washing (**Figure 2**). In each example, the WTRS reported rates are 100% consumptive, thus generalizations introduced by consumptive use factor estimations are not applicable.

Table 2. WTRS (2008) reported monthly groundwater takings.

Permit Number	Source Name	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
00-P-2417	Well	0.0	0.0	0.0	0.0	544.4	346.2	649.8	0.0	25.0	0.0	0.0	0.0	130.5	Yes
00-P-2417	Well	0.0	0.0	0.0	0.0	544.4	346.2	649.8	0.0	25.0	0.0	0.0	0.0	130.5	Yes
00-P-2791	Dugout pond	0.0	0.0	0.0	59.7	119.5	134.8	180.5	211.2	110.6	7.3	0.0	0.0	68.6	Yes
00-P-2791	Well	0.0	0.0	0.0	47.8	82.9	134.0	161.8	187.3	207.9	0.0	0.0	0.0	68.5	Yes
0104-783FXW	Pond 1	0.0	0.0	0.0	22.7	44.6	60.9	110.2	71.3	79.4	0.0	0.0	0.0	32.4	Yes
01-P-2004	29 Wells	163.3	162.6	206.9	189.0	173.7	147.1	150.1	128.8	97.3	130.3	138.6	132.9	151.7	Yes
01-P-3025	Well No 1	157.8	185.8	220.7	322.4	398.6	462.0	530.8	523.9	419.0	271.9	174.1	175.4	320.2	Yes
01-P-3025	Well No 2	13.1	12.8	15.0	15.4	29.0	38.6	38.4	36.8	55.1	18.9	17.1	18.0	25.7	Yes
02-P-2002	Scalehouse Well	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	No
02-P-2002	Washplant Well	0.0	0.0	0.0	0.0	148.5	145.7	164.1	151.1	164.8	174.6	90.8	0.0	86.6	Yes
0334-6ARJNR	Well PW1/89	0.0	0.0	0.0	0.0	116.0	248.9	456.8	90.7	0.0	0.0	0.0	0.0	76.0	Yes
03-P-2098	Well TW1	0.0	0.0	0.0	1.1	11.1	16.7	25.7	22.1	10.9	7.2	0.0	0.0	7.9	Yes
03-P-2245	Pond	0.0	0.0	0.0	0.0	14.8	74.0	107.3	75.9	46.2	0.0	0.0	0.0	31.8	Yes
03-P-2408	Test Well 1	0.0	0.0	0.0	0.0	0.0	0.0	61.7	0.0	0.0	0.0	0.0	0.0	5.1	Yes
0700-6YTS5P	Well # OW22-89	53.3	53.1	53.9	54.4	54.9	49.3	41.8	39.9	25.4	39.2	32.6	51.1	45.7	Yes
0700-6YTS5P	Well # PW5-97	1.3	12.0	12.1	8.0	5.6	5.2	7.9	8.2	13.1	14.9	6.0	11.5	8.8	Yes
0700-6YTS5P	Well # PW6-02	0.2	0.1	0.7	0.1	0.1	0.1	1.1	0.1	0.1	0.2	0.1	0.1	0.3	Yes
0704-6XGLMP	Clubhouse Well	0.0	0.0	0.0	9.1	22.7	12.5	48.9	35.9	38.5	0.0	0.0	0.0	14.0	Yes
0882-6FTHMA	Irrigation Well	0.0	0.0	0.0	0.0	0.0	0.0	85.2	32.5	0.0	0.0	0.0	0.0	9.8	Yes
0882-6FTHMA	Maintenance Well	0.1	0.1	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1	0.3	Yes
0882-6FTHMA	Clubhouse Well	6.5	4.7	4.4	7.3	11.0	12.3	15.2	13.9	12.6	10.1	7.2	8.2	9.5	Yes
1065-5VFQ9K	Admiral Well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
1204-62XKAF	Well	44.0	48.4	50.2	49.1	50.2	59.1	46.6	38.7	70.5	65.1	68.6	39.2	53.2	Yes
1216-6SCL4W	Well No. PW-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	41.4	46.3	42.2	35.3	16.2	Yes
1351-6D5LEK	Well TW1-89	10.9	10.0	6.8	13.3	14.6	9.8	2.1	4.3	10.8	10.4	9.0	8.2	9.2	Yes
1528-6GTN6M	Well 26R	31.7	53.8	82.3	99.5	93.9	112.6	140.6	125.0	103.8	75.5	82.6	53.1	87.9	Yes
1787-6C8RLU	Well #1 Central Utilities Plant	14.9	182.1	163.5	221.4	149.7	124.2	135.0	158.7	176.0	195.0	158.7	93.9	147.7	Yes
1787-6C8RLU	Well #3 Athletics Centre	9.5	32.9	32.8	32.8	32.8	32.8	32.8	31.7	32.8	32.8	32.8	32.8	30.7	Yes
1787-6C8RLU	Well #4 Building #250	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
2042-6UWKST	PW1	0.0	0.0	0.0	0.0	0.4	2.8	1.2	0.0	0.0	0.0	0.0	0.0	0.4	Yes
2042-6UWKST	PW3	77.9	70.6	76.9	87.0	108.9	108.7	178.6	128.2	123.4	91.6	91.4	97.4	103.4	Yes
2202-6X9QTU	Spring	1798.5	1897.8	2031.8	2086.3	1797.1	1676.4	1620.4	1695.7	1669.0	1689.8	1697.2	1735.2	1782.9	No
2202-6X9QTU	Well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
2448-6FUKQ5	Mill Creek Pit	0.0	0.0	0.0	3134.0	4796.7	4915.9	4116.8	3929.6	4508.6	4457.7	0.0	0.0	2488.3	Yes
2563-6VKR7T	One Bedrock Well (A037447)	0.0	0.0	0.0	0.0	0.0	0.0	29.0	0.0	12.9	0.5	0.0	0.0	3.5	Yes
3234-74ER7S	McNally Pit Wash Pond	0.0	0.0	0.0	0.0	6985.9	9518.6	9896.1	8763.2	5654.4	11070.5	5631.6	0.0	4793.4	Yes
3331-73RKYV	Well PW1	13.2	24.7	14.4	18.0	23.3	34.1	20.7	19.3	20.6	17.8	21.4	18.1	20.5	Yes

Permit Number	Source Name	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
3331-73RKYV	Well PW2	34.4	78.0	36.1	33.8	26.0	31.4	35.4	27.3	28.4	21.4	19.8	19.5	32.6	Yes
3331-73RKYV	Well PW3	67.3	69.1	78.9	66.7	93.5	107.8	83.7	93.4	63.0	57.7	48.1	55.8	73.7	Yes
3331-73RKYV	Well PW4	0.9	0.9	0.7	0.7	1.4	4.1	4.3	2.5	1.1	1.1	0.6	0.7	1.6	Yes
3581-7CML9F	Calico Well	0.0	0.0	0.0	672.7	805.1	763.5	738.4	819.5	780.4	768.1	767.4	770.6	688.6	No
3617-74SPNH	Phase 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
3617-74SPNH	Phase 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
3830-6W6JHW	Source Pond	0.0	0.0	0.0	4685.4	12021.1	9056.9	10357.4	9884.2	12203.7	12308.8	8900.5	0.0	6618.2	Yes
3878-6Z3JUU	MH-1155	48.9	48.9	48.9	48.9	48.9	48.9	43.4	36.9	36.0	34.2	34.0	36.1	42.8	Yes
3878-6Z3JUU	MH-1161	3.6	3.6	3.6	3.6	3.6	3.6	32.7	69.6	21.7	14.0	3.1	5.9	14.1	Yes
3878-6Z3JUU	MH-1164	3.6	3.6	3.6	3.6	3.6	3.6	2.5	1.3	0.8	0.6	0.6	1.1	2.4	Yes
3878-6Z3JUU	MH-1184	3.6	3.6	3.6	1217.0	3.6	3.6	3.0	2.7	3.0	2.4	2.9	4.0	104.4	Yes
3878-6Z3JUU	MH-1809	3.6	3.6	3.6	3.6	3.6	3.6	3.4	3.2	3.1	2.5	2.4	3.3	3.3	Yes
3878-6Z3JUU	MH-1819	12.8	12.8	12.8	12.8	12.8	12.8	20.6	30.4	28.0	25.4	25.8	30.3	19.8	Yes
3878-6Z3JUU	MH-863	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
4165-6M8LZE	Well 1 (A022033)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
4358-6NQLG6	Well P15	949.9	934.7	927.2	903.4	881.1	213.2	675.4	885.7	1363.6	1153.7	1264.0	1382.4	961.2	No
4845-6E8HA5	PW-1	43.2	39.9	37.6	41.6	34.9	47.1	77.1	78.2	81.5	90.5	81.3	55.8	59.1	Yes
4845-6E8HA5	PW-2	1.0	0.0	0.0	13.0	15.9	19.6	29.5	29.9	30.9	32.5	35.1	16.8	18.7	Yes
4845-6E8HA5	PW-3	266.0	278.7	250.7	248.3	207.6	193.9	187.0	171.0	178.4	192.4	205.7	220.3	216.7	Yes
5081-6GEPMB	W1 (Standby) (MOE WWR - 67-07918)	0.0	0.0	0.0	0.7	1.2	3.0	8.2	7.0	3.6	1.4	0.0	0.0	2.1	Yes
5081-6GEPMB	W2 (MOE WWR - 67-07917)	0.0	0.0	0.0	0.7	1.2	3.0	8.2	7.0	3.6	1.4	0.0	0.0	2.1	Yes
5201-6B7HDA	Well A - Office	0.7	1.4	0.9	2.3	4.8	3.9	3.3	1.7	1.3	1.1	1.1	0.6	1.9	Yes
5201-6B7HDA	Well B - Asphalt Plant	0.0	0.0	0.0	0.0	9.2	17.5	35.4	25.0	28.0	19.1	7.2	3.2	12.0	Yes
5201-6B7HDA	Well C - Concrete Plant	0.0	0.0	0.0	0.0	0.0	23.8	35.6	30.8	36.5	38.0	21.5	1.7	15.7	Yes
5675-6W9TDF	Auxilary Pond No 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
5675-6W9TDF	Source Pond No. 9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6268-6QJLB3	Breslau Pit Extraction Pond	3201.8	3226.2	2715.9	5176.9	3410.4	1685.7	3909.0	2942.5	3128.9	3318.2	3243.7	3224.8	3265.3	No
6445-6QZMES	Main Quarry Discharge, Interim conditions	1533.7	937.2	915.3	819.6	936.1	854.1	3892.6	6072.8	5872.7	1054.4	1174.2	5154.2	2434.8	No
6445-6QZMES	North Quarry Dewatering	159.3	527.9	635.9	530.7	559.5	591.3	1317.3	1826.7	1765.5	588.4	580.9	1566.4	887.5	No
6445-6QZMES	Operations Water Use, Long-term conditions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6445-6QZMES	Recharge System	984.6	1174.4	1628.1	1303.0	1302.0	1511.1	1376.6	1233.9	1189.1	1299.2	1149.6	1111.6	1271.9	No
6445-6QZMES	Central Sump Dewatering, Long-term conditions	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6661-65YPPD	Cambridge Landfill Well #CL-PW2	760.5	785.7	777.9	786.6	811.9	803.6	26644.6	769.5	793.9	795.6	749.3	788.7	2939.0	No
6800-72CLQH	Well No. 3	130.2	132.9	138.7	142.3	144.1	146.1	144.3	139.8	145.4	0.0	0.0	0.0	105.3	Yes
7175-6LCQ2M	Spring Fed Pond	0.0	0.0	0.0	11.4	13.1	15.0	36.9	21.1	22.1	0.0	0.0	0.0	10.0	Yes
72-P-0453	Dugout Pond	0.0	0.0	0.0	0.0	5338.6	5542.0	5610.8	4836.3	4777.5	5273.8	285.5	0.0	2638.7	Yes
7646-6QJQR7	PW1	50.2	48.3	46.2	41.3	34.6	24.9	35.5	7.3	0.3	0.0	7.4	38.5	27.9	Yes
7646-6QJQR7	PW2	39.5	22.0	87.6	51.0	90.6	95.3	113.5	145.5	152.4	138.0	131.7	136.0	100.3	Yes

Permit Number	Source Name	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
7825-6WLMDA	Well G8	779.2	1174.8	1253.9	1507.6	1244.6	1334.7	1313.2	1200.9	1142.4	1155.1	1162.3	1182.5	1204.3	No
8228-76XLE2	PW2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
8228-76XLE2	PW5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
8228-76XLE2	PW6	21.5	17.5	1.2	4.1	2.8	6.3	12.7	3.2	2.8	6.6	10.6	10.8	8.3	Yes
8228-76XLE2	PW7	3.0	20.5	1.1	4.0	3.3	5.4	11.9	15.4	15.6	16.3	10.2	11.7	9.8	Yes
8664-75QJ2J	Hillsburgh Well	86.8	81.5	73.9	84.9	78.6	89.7	91.5	77.4	73.9	71.6	69.1	68.0	78.9	Yes
89-P-2014	Well	0.1	0.3	0.2	3.8	20.2	18.1	5.6	0.1	0.2	10.2	0.1	0.1	4.9	Yes
93-P-2103	Well	0.0	0.0	0.0	0.0	0.0	0.0	36.6	0.0	73.7	0.2	0.0	0.0	9.2	Yes
98-P-2106	Well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
99-P-2070	Well EW1-91	10.0	6.8	5.5	2.0	5.2	4.1	3.7	2.9	0.2	8.2	12.0	9.3	5.8	Yes
99-P-2070	Well EW2-98	14.2	8.4	7.8	8.1	7.5	9.5	9.4	18.9	16.1	12.3	13.6	10.5	11.4	Yes
99-P-2070	Well EW3-99	3.0	7.0	8.9	11.7	5.0	2.3	6.9	5.7	3.4	5.1	2.6	5.7	5.6	Yes
99-P-2070	Well EW4-99	4.8	4.3	6.7	8.1	6.0	10.6	8.8	8.8	12.6	10.3	8.4	6.2	8.0	Yes
99-P-3017	Quarry Sump	1896.6	5491.7	8215.9	8701.4	4577.5	3868.8	5808.1	6997.1	5253.7	2822.3	3553.6	7237.5	5368.7	No

Table 3. WTRS (2008) monthly consumptive demand estimates for each groundwater taking.

Permit Number	Source Name	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
00-P-2417	Well	Agricultural	Other - Agricultural	0.85	0.0	0.0	0.0	0.0	462.8	294.3	552.3	0.0	21.2	0.0	0.0	0.0	110.9	Yes
00-P-2417	Well	Agricultural	Other - Agricultural	0.85	0.0	0.0	0.0	0.0	462.8	294.3	552.3	0.0	21.2	0.0	0.0	0.0	110.9	Yes
00-P-2791	Dugout pond	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	50.7	101.6	114.6	153.4	179.5	94.1	6.2	0.0	0.0	58.3	Yes
00-P-2791	Well	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	40.6	70.4	113.9	137.5	159.2	176.7	0.0	0.0	0.0	58.2	Yes
0104-783FXW	Pond 1	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	19.3	37.9	51.8	93.7	60.6	67.5	0.0	0.0	0.0	27.6	Yes
01-P-2004	29 Wells	Remediation	Groundwater	1	163.3	162.6	206.9	189.0	173.7	147.1	150.1	128.8	97.3	130.3	138.6	132.9	151.7	Yes
01-P-3025	Well No 1	Water Supply	Communal	1	157.8	185.8	220.7	322.4	398.6	462.0	530.8	523.9	419.0	271.9	174.1	175.4	320.2	Yes
01-P-3025	Well No 2	Water Supply	Communal	1	13.1	12.8	15.0	15.4	29.0	38.6	38.4	36.8	55.1	18.9	17.1	18.0	25.7	Yes
02-P-2002	Scalehouse Well	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
02-P-2002	Washplant Well	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	22.3	21.9	24.6	22.7	24.7	26.2	13.6	0.0	13.0	Yes
0334-6ARJNR	Well PW1/89	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	0.0	98.6	211.5	388.3	77.1	0.0	0.0	0.0	0.0	64.6	Yes
03-P-2098	Well TW1	Water Supply	Campgrounds	1	0.0	0.0	0.0	1.1	11.1	16.7	25.7	22.1	10.9	7.2	0.0	0.0	7.9	Yes
03-P-2245	Pond	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	0.0	12.5	62.9	91.2	64.5	39.3	0.0	0.0	0.0	27.0	Yes
03-P-2408	Test Well 1	Agricultural	Sod Farm	0.85	0.0	0.0	0.0	0.0	0.0	0.0	52.4	0.0	0.0	0.0	0.0	0.0	4.4	Yes
0700-6YTS5P	Well # OW22-89	Remediation	Other - Remediation	1	53.3	53.1	53.9	54.4	54.9	49.3	41.8	39.9	25.4	39.2	32.6	51.1	45.7	Yes
0700-6YTS5P	Well # PW5-97	Remediation	Other - Remediation	1	1.3	12.0	12.1	8.0	5.6	5.2	7.9	8.2	13.1	14.9	6.0	11.5	8.8	Yes
0700-6YTS5P	Well # PW6-02	Remediation	Other - Remediation	1	0.2	0.1	0.7	0.1	0.1	0.1	1.1	0.1	0.1	0.2	0.1	0.1	0.3	Yes
0704-6XGLMP	Clubhouse Well	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	7.8	19.3	10.6	41.5	30.5	32.7	0.0	0.0	0.0	11.9	Yes
0882-6FTHMA	Irrigation Well	Water Supply	Other - Water Supply	1	0.0	0.0	0.0	0.0	0.0	0.0	85.2	32.5	0.0	0.0	0.0	0.0	9.8	Yes
0882-6FTHMA	Maintenance Well	Water Supply	Other - Water Supply	1	0.1	0.1	0.1	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1	0.3	Yes
0882-6FTHMA	Clubhouse Well	Water Supply	Other - Water Supply	1	6.5	4.7	4.4	7.3	11.0	12.3	15.2	13.9	12.6	10.1	7.2	8.2	9.5	Yes
1065-5VFQ9K	Admiral Well	Industrial	Brewing and Soft Drinks	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
1204-62XKAF	Well	Industrial	Cooling Water	1	44.0	48.4	50.2	49.1	50.2	59.1	46.6	38.7	70.5	65.1	68.6	39.2	53.2	Yes
1216-6SCL4W	Well No. PW-1	Industrial	Food Processing	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	41.4	46.3	42.2	35.3	16.2	Yes
1351-6D5LEK	Well TW1-89	Water Supply	Other - Water Supply	1	10.9	10.0	6.8	13.3	14.6	9.8	2.1	4.3	10.8	10.4	9.0	8.2	9.2	Yes
1528-6GTN6M	Well 26R	Remediation	Other - Remediation	1	31.7	53.8	82.3	99.5	93.9	112.6	140.6	125.0	103.8	75.5	82.6	53.1	87.9	Yes
1787-6C8RLU	Well #1 Central Utilities Plant	Agricultural	Other - Agricultural	0.85	12.6	154.8	138.9	188.2	127.3	105.5	114.7	134.9	149.6	165.7	134.9	79.8	125.6	Yes
1787-6C8RLU	Well #3 Athletics Centre	Agricultural	Other - Agricultural	0.85	8.1	28.0	27.8	27.8	27.8	27.8	27.8	26.9	27.8	27.8	27.8	27.8	26.1	Yes
1787-6C8RLU	Well #4 Building #250	Agricultural	Other - Agricultural	0.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
2042-6UWKST	PW1	Water Supply	Other - Water Supply	1	0.0	0.0	0.0	0.0	0.4	2.8	1.2	0.0	0.0	0.0	0.0	0.0	0.4	Yes
2042-6UWKST	PW3	Water Supply	Other - Water Supply	1	77.9	70.6	76.9	87.0	108.9	108.7	178.6	128.2	123.4	91.6	91.4	97.4	103.4	Yes
2202-6X9QTU	Spring	Commercial	Aquaculture	1	1798.5	1897.8	2031.8	2086.3	1797.1	1676.4	1620.4	1695.7	1669.0	1689.8	1697.2	1735.2	1782.9	No
2202-6X9QTU	Well	Commercial	Aquaculture	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
2448-6FUKQ5	Mill Creek Pit	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	470.1	719.5	737.4	617.5	589.4	676.3	668.7	0.0	0.0	373.2	Yes
2563-6VKR7T	One Bedrock Well (A037447)	Agricultural	Sod Farm	0.85	0.0	0.0	0.0	0.0	0.0	0.0	24.7	0.0	11.0	0.4	0.0	0.0	3.0	Yes
3234-74ER7S	McNally Pit Wash Pond	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	1047.9	1427.8	1484.4	1314.5	848.2	1660.6	844.7	0.0	719.0	Yes
3331-73RKYV	Well PW1	Water Supply	Communal	1	13.2	24.7	14.4	18.0	23.3	34.1	20.7	19.3	20.6	17.8	21.4	18.1	20.5	Yes

Permit Number	Source Name	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
3331-73RKYV	Well PW2	Water Supply	Communal	1	34.4	78.0	36.1	33.8	26.0	31.4	35.4	27.3	28.4	21.4	19.8	19.5	32.6	Yes
3331-73RKYV	Well PW3	Water Supply	Communal	1	67.3	69.1	78.9	66.7	93.5	107.8	83.7	93.4	63.0	57.7	48.1	55.8	73.7	Yes
3331-73RKYV	Well PW4	Water Supply	Communal	1	0.9	0.9	0.7	0.7	1.4	4.1	4.3	2.5	1.1	1.1	0.6	0.7	1.6	Yes
3581-7CML9F	Calico Well	Water Supply	Communal	1	0.0	0.0	0.0	672.7	805.1	763.5	738.4	819.5	780.4	768.1	767.4	770.6	688.6	No
3617-74SPNH	Phase 2	Dewatering	Pits and Quarries	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
3617-74SPNH	Phase 3	Dewatering	Pits and Quarries	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
3830-6W6JHW	Source Pond	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	702.8	1803.2	1358.5	1553.6	1482.6	1830.6	1846.3	1335.1	0.0	992.7	Yes
3878-6Z3JUU	MH-1155	Dewatering	Other - Dewatering	1	48.9	48.9	48.9	48.9	48.9	48.9	43.4	36.9	36.0	34.2	34.0	36.1	42.8	Yes
3878-6Z3JUU	MH-1161	Dewatering	Other - Dewatering	1	3.6	3.6	3.6	3.6	3.6	3.6	32.7	69.6	21.7	14.0	3.1	5.9	14.1	Yes
3878-6Z3JUU	MH-1164	Dewatering	Other - Dewatering	1	3.6	3.6	3.6	3.6	3.6	3.6	2.5	1.3	0.8	0.6	0.6	1.1	2.4	Yes
3878-6Z3JUU	MH-1184	Dewatering	Other - Dewatering	1	3.6	3.6	3.6	1217.0	3.6	3.6	3.0	2.7	3.0	2.4	2.9	4.0	104.4	Yes
3878-6Z3JUU	MH-1809	Dewatering	Other - Dewatering	1	3.6	3.6	3.6	3.6	3.6	3.6	3.4	3.2	3.1	2.5	2.4	3.3	3.3	Yes
3878-6Z3JUU	MH-1819	Dewatering	Other - Dewatering	1	12.8	12.8	12.8	12.8	12.8	12.8	20.6	30.4	28.0	25.4	25.8	30.3	19.8	Yes
3878-6Z3JUU	MH-863	Dewatering	Other - Dewatering	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
4165-6M8LZE	Well 1 (A022033)	Agricultural	Other - Agricultural	0.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
4358-6NQLG6	Well P15	Water Supply	Other - Water Supply	1	949.9	934.7	927.2	903.4	881.1	213.2	675.4	885.7	1363.6	1153.7	1264.0	1382.4	961.2	No
4845-6E8HA5	PW-1	Industrial	Food Processing	1	43.2	39.9	37.6	41.6	34.9	47.1	77.1	78.2	81.5	90.5	81.3	55.8	59.1	Yes
4845-6E8HA5	PW-2	Industrial	Food Processing	1	1.0	0.0	0.0	13.0	15.9	19.6	29.5	29.9	30.9	32.5	35.1	16.8	18.7	Yes
4845-6E8HA5	PW-3	Industrial	Food Processing	1	266.0	278.7	250.7	248.3	207.6	193.9	187.0	171.0	178.4	192.4	205.7	220.3	216.7	Yes
5081-6GEPMB	W1 (Standby) (MOE WWR - 67-07918)	Water Supply	Other - Water Supply	1	0.0	0.0	0.0	0.7	1.2	3.0	8.2	7.0	3.6	1.4	0.0	0.0	2.1	Yes
5081-6GEPMB	W2 (MOE WWR - 67-07917)	Water Supply	Other - Water Supply	1	0.0	0.0	0.0	0.7	1.2	3.0	8.2	7.0	3.6	1.4	0.0	0.0	2.1	Yes
5201-6B7HDA	Well A - Office	Industrial	Other - Industrial	1	0.7	1.4	0.9	2.3	4.8	3.9	3.3	1.7	1.3	1.1	1.1	0.6	1.9	Yes
5201-6B7HDA	Well B - Asphalt Plant	Industrial	Other - Industrial	1	0.0	0.0	0.0	0.0	9.2	17.5	35.4	25.0	28.0	19.1	7.2	3.2	12.0	Yes
5201-6B7HDA	Well C - Concrete Plant	Industrial	Other - Industrial	1	0.0	0.0	0.0	0.0	0.0	23.8	35.6	30.8	36.5	38.0	21.5	1.7	15.7	Yes
5675-6W9TDF	Auxilary Pond No 4	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
5675-6W9TDF	Source Pond No. 9	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6268-6QJLB3	Breslau Pit Extraction Pond	Industrial	Other - Industrial	1	3201.8	3226.2	2715.9	5176.9	3410.4	1685.7	3909.0	2942.5	3128.9	3318.2	3243.7	3224.8	3265.3	No
6445-6QZMES	Main Quarry Discharge, Interim conditions	Dewatering	Pits and Quarries	1	1533.7	937.2	915.3	819.6	936.1	854.1	3892.6	6072.8	5872.7	1054.4	1174.2	5154.2	2434.8	No
6445-6QZMES	North Quarry Dewatering	Dewatering	Pits and Quarries	1	159.3	527.9	635.9	530.7	559.5	591.3	1317.3	1826.7	1765.5	588.4	580.9	1566.4	887.5	No
6445-6QZMES	Operations Water Use, Long-term conditions	Dewatering	Pits and Quarries	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6445-6QZMES	Recharge System	Dewatering	Pits and Quarries	0.15	147.7	176.2	244.2	195.5	195.3	226.7	206.5	185.1	178.4	194.9	172.4	166.7	190.8	No
6445-6QZMES	Central Sump Dewatering, Long-term conditions	Dewatering	Pits and Quarries	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
6661-65YPPD	Cambridge Landfill Well #CL-PW2	Remediation	Other - Remediation	1	760.5	785.7	777.9	786.6	811.9	803.6	26644.6	769.5	793.9	795.6	749.3	788.7	2939.0	No
6800-72CLQH	Well No. 3	Industrial	Other - Industrial	1	130.2	132.9	138.7	142.3	144.1	146.1	144.3	139.8	145.4	0.0	0.0	0.0	105.3	Yes
7175-6LCQ2M	Spring Fed Pond	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	9.7	11.1	12.8	31.3	18.0	18.8	0.0	0.0	0.0	8.5	Yes
72-P-0453	Dugout Pond	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	800.8	831.3	841.6	725.5	716.6	791.1	42.8	0.0	395.8	Yes
7646-6QJQR7	PW1	Water Supply	Communal	1	50.2	48.3	46.2	41.3	34.6	24.9	35.5	7.3	0.3	0.0	7.4	38.5	27.9	Yes

Permit Number	Source Name	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	In Model
7646-6QJQR7	PW2	Water Supply	Communal	1	39.5	22.0	87.6	51.0	90.6	95.3	113.5	145.5	152.4	138.0	131.7	136.0	100.3	Yes
7825-6WLMDA	Well G8	Water Supply	Other - Water Supply	1	779.2	1174.8	1253.9	1507.6	1244.6	1334.7	1313.2	1200.9	1142.4	1155.1	1162.3	1182.5	1204.3	No
8228-76XLE2	PW2	Water Supply	Communal	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
8228-76XLE2	PW5	Water Supply	Communal	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
8228-76XLE2	PW6	Water Supply	Communal	1	21.5	17.5	1.2	4.1	2.8	6.3	12.7	3.2	2.8	6.6	10.6	10.8	8.3	Yes
8228-76XLE2	PW7	Water Supply	Communal	1	3.0	20.5	1.1	4.0	3.3	5.4	11.9	15.4	15.6	16.3	10.2	11.7	9.8	Yes
8664-75QJ2J	Hillsburgh Well	Commercial	Bottled Water	1	86.8	81.5	73.9	84.9	78.6	89.7	91.5	77.4	73.9	71.6	69.1	68.0	78.9	Yes
89-P-2014	Well	Industrial	Other - Industrial	1	0.1	0.3	0.2	3.8	20.2	18.1	5.6	0.1	0.2	10.2	0.1	0.1	4.9	Yes
93-P-2103	Well	Commercial	Golf Course Irrigation	0.85	0.0	0.0	0.0	0.0	0.0	0.0	31.1	0.0	62.6	0.2	0.0	0.0	7.8	Yes
98-P-2106	Well	Industrial	Aggregate Washing	0.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	No
99-P-2070	Well EW1-91	Remediation	Groundwater	1	10.0	6.8	5.5	2.0	5.2	4.1	3.7	2.9	0.2	8.2	12.0	9.3	5.8	Yes
99-P-2070	Well EW2-98	Remediation	Groundwater	1	14.2	8.4	7.8	8.1	7.5	9.5	9.4	18.9	16.1	12.3	13.6	10.5	11.4	Yes
99-P-2070	Well EW3-99	Remediation	Groundwater	1	3.0	7.0	8.9	11.7	5.0	2.3	6.9	5.7	3.4	5.1	2.6	5.7	5.6	Yes
99-P-2070	Well EW4-99	Remediation	Groundwater	1	4.8	4.3	6.7	8.1	6.0	10.6	8.8	8.8	12.6	10.3	8.4	6.2	8.0	Yes
99-P-3017	Quarry Sump	Dewatering	Pits and Quarries	0.15	284.5	823.8	1232.4	1305.2	686.6	580.3	871.2	1049.6	788.0	423.3	533.0	1085.6	805.3	No

Table 4. GRCA (2002 – 2006) reported monthly water takings (AquaResouce, 2009a).

Permit Number	Source Name	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	2008 WTRS Available	In Model
00-P-2791	Dugout pond	0	0	0	0	32.6	55.4	88.9	85.8	74.3	13.1	0	0	29.2	Yes	Yes
00-P-2791	Well	0	0	0	163.5	163.5	163.5	163.5	163.5	163.5	163.5	0	0	95.4	Yes	Yes
0147-6K9RKS	EW10-92	16	16	16	13.8	13.8	13.8	10.1	10.1	10.1	0	0	0	9.8	No	Yes
0147-6K9RKS	EW11-93	0	0	0	0	0	0	0	0	0	0	0	0	0	No	No
0147-6K9RKS	EW12-93	9	9	9	8.1	8.1	8.1	12.6	12.6	12.6	0	0	0	7.4	No	Yes
0147-6K9RKS	EW41-94	0	0	0	0.1	0.1	0.1	0	0	0	0.1	0.1	0.1	0	No	No
01-P-2004	29 Wells	169	203	205	170	162	161	142	137	116	92	129	159	153.8	Yes	Yes
01-P-2245	well	48	48	48	0	0	0	48.5	48.5	48.5	0	48.5	48.5	32.3	No	Yes
01-P-2245	dugout pond	0	0	0	0	0	19	19	19	0	0	0	0	4.8	No	Yes
02-P-2002	Washplant Well	0	0	0	31	158	335	266	280	237	208	113	7.1	136.3	Yes	Yes
03-P-2003	Dugout pond	0	0	0	0	0	0	0	0	0	0	0	0	0	No	No
03-P-2047	Well	0	0	0	0	0	0	0	0	0	0	0	0	0	No	No
03-P-2099	Well WS1	0	0	0	0	4.7	7.8	8.5	7.5	6.1	6.2	0	0	3.4	No	Yes
03-P-2245	Pond	0	0	0	66	66	66	66	66	66	66	0	0	38.5	Yes	Yes
0882-6FTHMA	Irrigation Well	0	0	0	0	0	340	490	490	171	0	0	0	124.3	Yes	Yes
0882-6FTHMA	Maintenance Well	3	1	3	6.6	14.5	13.3	12.2	11.8	12	10.3	5.3	2.9	8	Yes	Yes
0882-6FTHMA	Clubhouse Well	103	124	164	289.6	412.6	546.6	499.7	459.2	428.5	353.6	279.7	272.2	327.7	Yes	Yes
1204-62XKAF	Well	39	56	46	42.7	35.2	52.7	36.5	40	27.3	26.4	50.6	28.6	40.1	Yes	Yes
1528-6GTN6M	Well 26R	0	0	0	0	0	0	0	0	0	0	0	0	0	Yes	Yes
1528-6GTN6M	Well 31	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.1	No	Yes
1528-6GTN6M	Well 6	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0.1	No	Yes
2448-6FUKQ5	Mill Creek Pit	0	0	0	255.2	450.7	382.1	294.7	329.4	303.1	204.8	0	0	185	Yes	Yes
2540-6PLKFX	PW1/00 (main well)	0	0	0	0	46	620.5	641	623	331	0	0	0	188.5	No	Yes
2540-6PLKFX	PW1/88 (standby well)	0	0	0	0	0	0	12.7	0	0	0	0	0	1.1	No	Yes
3024-6CQJZ5	Well MOE# 6709444	0	0	0	0	107.8	326.4	166.4	319.3	0	0	0	0	76.7	No	Yes
3331-73RKYV	Well PW1	24	40	78	30.9	23.6	30.4	25.5	23.8	13.6	16.6	37	55.1	33.3	Yes	Yes
3331-73RKYV	Well PW2	29	30	44	33.8	35.9	52.2	47.3	45.6	36	45.5	61.1	83.5	45.3	Yes	Yes
3331-73RKYV	Well PW3	58	68	60	63.6	56.5	77.2	74.2	62.1	49.5	60.6	109.9	209.9	79.2	Yes	Yes
3331-73RKYV	Well PW4	0	0	0	0	0	0	0	0.1	0	0	0	0	0	Yes	Yes
3830-6W6JHW	Source Pond	0	0	26	425.7	422.6	618	587.2	580.8	662.1	635	693.8	95.5	395.6	Yes	Yes
4845-6E8HA5	PW-1	66	75	67	70	77	80	54	61	68.5	69	70	59	68	Yes	Yes
4845-6E8HA5	PW-2	29	32	31	30	32	35	26	27	29.5	30	30	26	29.8	Yes	Yes
4845-6E8HA5	PW-3	208	232	177	184	126.5	151	193	180	218	219.5	221	191	191.7	Yes	Yes
5201-6B7HDA	Well A - Office	2	2	2	2.3	3	4.3	3.9	4.3	4.3	3.7	3.7	2.2	3.1	Yes	Yes
5201-6B7HDA	Well B - Asphalt Plant	0	0	0	0	4.7	10.8	10.5	12.3	5.7	1.6	0.5	0.2	3.9	Yes	Yes
5201-6B7HDA	Well C - Concrete Plant	0	0	0	30.4	74.5	72.8	53.6	42.9	69.6	38.6	30.7	4.2	34.8	Yes	Yes
6480-74BKR4	Drilled Well No. TW1-88	558	453	480	387	661	482	702	429	817	753	154	115	499.3	No	Yes

Permit Number	Source Name	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	2008 WTRS Available	In Model
7043-74BL3K	TW3-80	2536	2188	2061	2217	2486	2728	2789	2589	2169	2065	2666	2261	2396.3	No	Yes
7240-65YKTN	Sump 4	5676	9169	7868	3524	7879	3885	6507	8082	9834	11122	11498	9613	7888.1	No	No
7240-65YKTN	Sump 3	4435	6553	5698	3304	6340	3508	3376	6044	7026	7975	8252	6863	5781.2	No	No
93-P-2103	Well	0	0	0	0	0	97.5	142	132	94.5	0	0	0	38.8	Yes	Yes
99-P-2012	Well SK3	160	400	540	190	410	570	350	270	200	240	240	280	320.8	No	No
99-P-2012	Well SK4	17	22	19	21.2	21.1	19.5	17.9	32.1	26.6	22.3	26.5	27.8	22.8	No	No
99-P-2012	Well SK5	5349	5885	6917	6831	6663	7252	6721	6509	6408	6690	6195	6542	6496.8	No	No
99-P-2012	Wells SK1	73	91	124	80	95	76	86	77	4	38	41	41	68.8	No	No

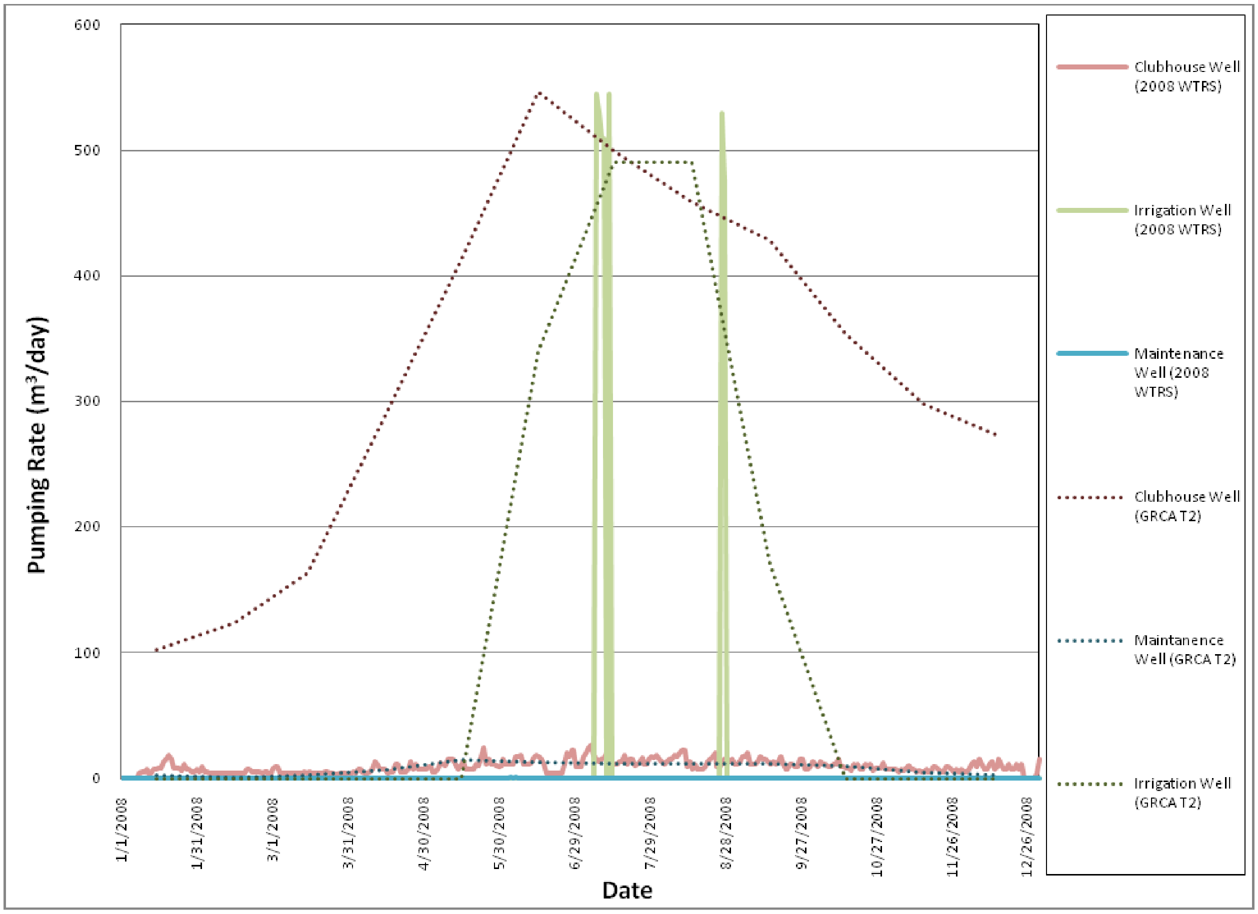


Figure 1. Reported pumping rates for permit 0882-6FTHMA (Other-Water Supply, 3 sources).

Consumptive Use Estimates

If reported pumping rates are not available, the consumptive demand was calculated using the maximum permitted rates, and maximum allowable days of pumping recorded in the PTTW database. As such, these estimates are subject to various levels of uncertainty. Demands are subject to uncertainty resulting from estimated water takings and seasonal and consumptive use factors (see below).

When using the PTTW database to estimate actual water demands, the following considerations are made:

- When specifying the amount of water required for their specific use, permit holders often request a volume of water that exceeds their requirements. This may be done to ensure compliance in dry years, or to secure sufficient water for possible future expansion of the operation;
- Permitted volume is often derived from the capacity of the pumping equipment rather than the requirements of the user, often significantly over-estimating the user's demand;
- The database does not maintain a record of seasonal water demand requirements;

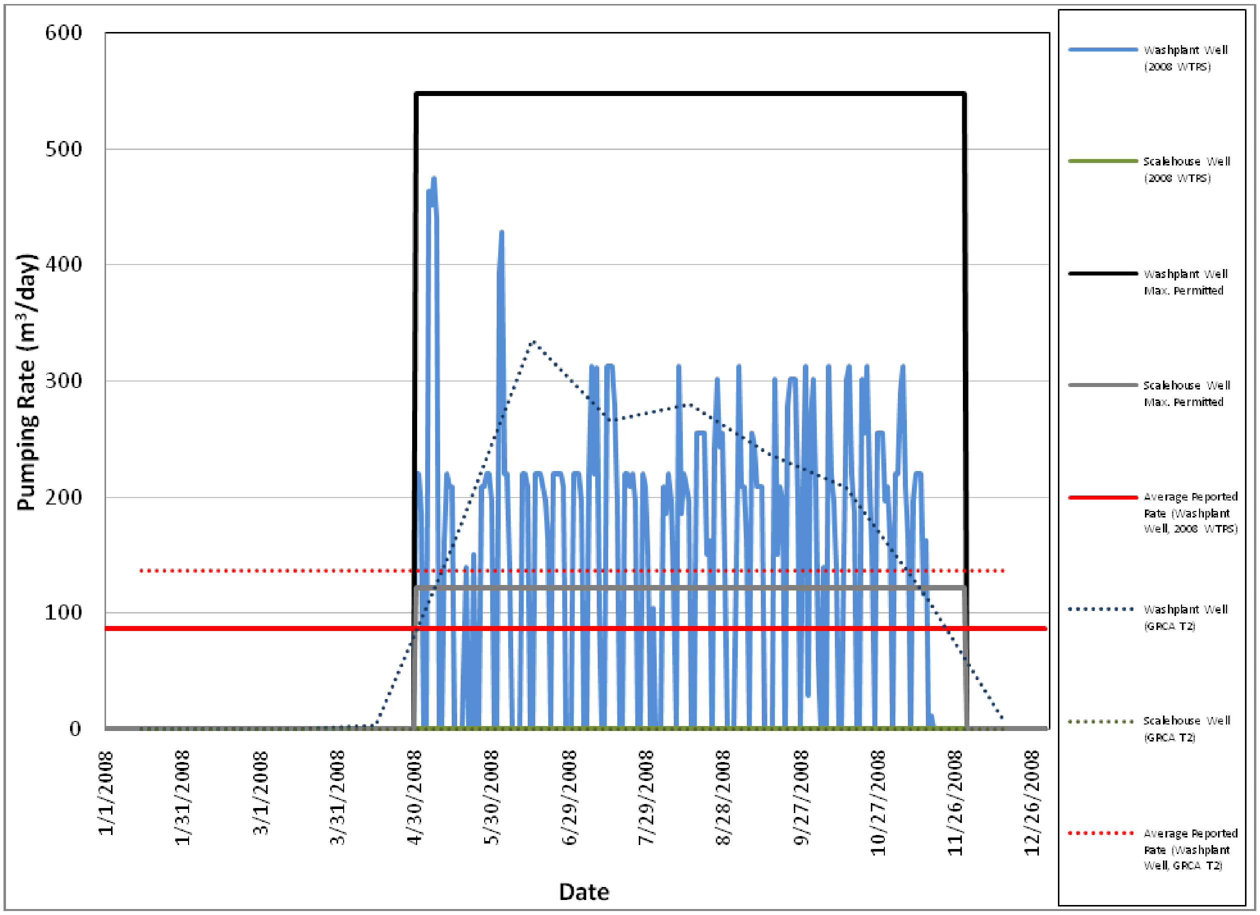


Figure 2. Reported pumping rates for permit 02-P-2002 (Aggregate washing, 2 sources).

- Multiple wells or sources may be included on a particular permit, and the permitted rate refers to the total for all sources associated with that permit. As an example, two nearby wells may operate under one permit, but the wells may never operate simultaneously. In this case, each well source could pump at the maximum permitted rate, but not at the same time. To estimate total demand, the total permitted rate should be logically divided amongst the active source locations;
- The spatial location of water taking sources is not always accurate;
- The PTTW database is not current with respect to the MOE's actual permitting activities (recent permit numbers may not be included within the database); and
- Historic water takings may be "grandfathered" and do not require a permit. As a result, there may be some significant water takings not reflected by the PTTW database.

Estimating consumptive demand from information contained within the PTTW database was completed by following the methodology included in Appendix D of Guidance Module 7 (MOE, 2007). This procedure is summarized below:

- Maximum permitted rates were combined with the number of days each permit is permitted to pump. The resultant volume was then evenly distributed through months in which it was assumed the PTTW would be active;

- The pumping rate was adjusted using a consumptive use factor. Consumptive use refers to the amount of water that is pumped, but not returned back to the original water source.

Monthly estimates of water use are required to accurately quantify the annual volume of water withdrawn, as well as to represent the seasonal changes in total water. The months where a water taking is expected to be active, based on the purpose of that water taking are shown on **Table 5,** where 1 designates when the permit is active, and 0 designates when it is inactive.

This facilitates the estimate of actual water used in an assessment area, as it recognizes that many types of water taking operations only take water during a specific time period each year. The demand adjustments shown in **Table 5** were combined with the maximum permitted days per year, and the maximum permitted withdrawal, both specified in the PTTW database, to obtain monthly water use estimates.

Estimating consumptive water demand requires a proper consideration of scale as well as the physical water taking operation. This study examines consumptive water demand respective to the source - estimate of water which is consumed and not returned to the pumped aquifer within a reasonable amount of time. Therefore, for a groundwater assessment, if water is removed from the groundwater system and not returned to the groundwater system, the taking is assumed to be 100% consumptive. Groundwater takings are typically 100% consumptive, since wastewater is seldom returned to the groundwater system, but rather discharged to surface water systems. Exceptions would include irrigation, where a portion of the applied irrigation water would saturate surficial soils and percolate beneath the evaporative root zone, returning to the groundwater system.

Table 6 provides a list of consumptive use factors (J. Kinkead Consulting and AquaResource, 2009) that were used in this study. These values correspond to the 'Specific Purpose' assigned by the MOE to each permit. Where water was not returned to the same source, a consumptive factor of 1 was used.

Table 5. Monthly PTTW Adjustments (Source: MOE, 2007).

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural	Field and Pasture Crops	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Fruit Orchards	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Nursery	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Other - Agricultural	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Sod Farm	0	0	0	0	0	1	1	1	1	0	0	0
Agricultural	Tobacco	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Bottled Water	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Golf Course Irrigation	0	0	0	0	0	1	1	1	1	0	0	0
Commercial	Mall / Business	1	1	1	1	1	1	1	1	1	1	1	1
Commercial	Other - Commercial	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Other - Construction	1	1	1	1	1	1	1	1	1	1	1	1
Construction	Road Building	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Construction	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Other - Dewatering	1	1	1	1	1	1	1	1	1	1	1	1
Dewatering	Pits and Quarries	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Aggregate Washing	0	0	0	0	1	1	1	1	1	1	1	0

General Purpose	Specific Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Industrial	Cooling Water	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Food Processing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1
Industrial	Other - Industrial	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Other - Institutional	1	1	1	1	1	1	1	1	1	1	1	1
Institutional	Schools	1	1	1	1	1	1	0	0	1	1	1	1
Miscellaneous	Heat Pumps	1	1	1	1	1	1	1	1	1	1	1	1
Miscellaneous	Other - Miscellaneous	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Other - Recreational	1	1	1	1	1	1	1	1	1	1	1	1
Recreational	Wetlands	1	1	1	1	1	1	1	1	1	1	1	1
Remediation	Other - Remediation	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Campgrounds	0	0	0	0	1	1	1	1	1	0	0	0
Water Supply	Communal	1	1	1	1	1	1	1	1	1	1	1	1
Water Supply	Other - Water Supply	1	1	1	1	1	1	1	1	1	1	1	1

The methodology outlined above was applied to estimate the consumptive water demand each permitted water taking lacking reported pumping rates. Consumptive demand was estimated from PTTW values for 79 sources of groundwater taking in the City of Guelph numerical model domain (**Table 7**).

Table 6. Consumptive use factors (J. Kinkead Consulting and AquaResource, 2009).

Major Category	Specific Purpose	Consumptive Factor	Major Category	Specific Purpose	Consumptive Factor
Agricultural	Field and Pasture Crops	0.85	Industrial	Cooling Water	1
Agricultural	Nursery	0.85	Industrial	Food Processing	1
Agricultural	Other - Agricultural	0.85	Industrial	Manufacturing	1
Agricultural	Sod Farm	0.85	Industrial	Other - Industrial	1
Agricultural	Tobacco	0.85	Institutional	Other - Institutional	1
Commercial	Aquaculture	1	Institutional	Schools	1
Commercial	Bottled Water	1	Miscellaneous	Heat Pumps	1
Commercial	Golf Course Irrigation	0.85	Recreational	Fish Ponds	0.008
Commercial	Mall / Business	1	Recreational	Other - Recreational	1
Commercial	Other - Commercial	1	Remediation	Groundwater	1
Dewatering	Construction	1	Remediation	Other - Remediation	1

Dewatering	Other - Dewatering	1	Water Supply	Campgrounds	1
Dewatering	Pits and Quarries	0.15	Water Supply	Communal	1
Industrial	Aggregate Washing	0.15*	Water Supply	Other - Water Supply	1
Industrial	Brewing and Soft Drinks	1			

* Well sources in aggregate washing permits with redistribution ponds are considered 100% consumptive (consumptive factor of 1), if the pond is considered to pump water taken from well.

Compiled Consumptive Demand Data

Within the City of Guelph model domain, there are 190 sources of permitted, non-municipal, groundwater taking. There are 10 sources located within 1 km of municipal wells in the numerical model domain. **Map 1** illustrates the location of all sources of sources of permitted, non-municipal, groundwater taking to be considered in the numerical model in relation to municipal pumping wells.

Table 8 summarizes the maximum permitted rate, percentage of total permitted takings, and consumptive demand for each water use sector ('Specific Purpose'). It should be noted that this summary incorporates values from the WTRS, monthly reported water takings reported in the Grand River Conservation Authority Integrated 22Water Budget Report (AquaResource, 2009a), and consumptive use estimates derived from maximum permitted pumping rates recorded in the PTTW database where reported rates are lacking.

Consumptive use estimates tend to be lower than the reported maximum permitted pumping rate documented in the PTTW database, representing more realistic estimates than what would be estimated by simply summing the permitted volumes. This highlights the need for effective understanding and assessment of demand volumes.

Table 7. Estimated consumptive demand derived from the PTTW database (MOE, 2008).

Permit Number	Source Name	Max Permitted (m3/d)	Max Days/Year	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	Max Monthly (m3/d)	In Model
00-P-2681	One well (PW1)	818.28	365	Agricultural	Sod Farm	0.85	0	0	0	0	0	696	696	696	696	0	0	0	232	696	Yes
00-P-2782	Well (WWR # 10911)	255	365	Water Supply	Campgrounds	1	0	0	0	0	85	85	85	85	85	0	0	0	35	85	Yes
00-P-2782	Well (WWR # 2273)	255	365	Water Supply	Campgrounds	1	0	0	0	0	85	85	85	85	85	0	0	0	35	85	Yes
00-P-2782	Well (WWR # 6096)	255	365	Water Supply	Campgrounds	1	0	0	0	0	85	85	85	85	85	0	0	0	35	85	Yes
0147-6K9RKS	OW45-04/RW45-04	7.2	365	Remediation	Other - Remediation	1	7	7	7	7	7	7	7	7	7	7	7	7	7	7	Yes
0147-6K9RKS	Well OW3-91/RW3-91	7.2	365	Remediation	Other - Remediation	1	7	7	7	7	7	7	7	7	7	7	7	7	7	7	Yes
01-P-2027	Dugout pond	982	122	Commercial	Golf Course Irrigation	0.85	0	0	0	0	0	417	417	417	417	0	0	0	139	417	Yes
01-P-2027	Well (WWR # 6710895)	982	122	Commercial	Golf Course Irrigation	0.85	0	0	0	0	0	417	417	417	417	0	0	0	139	417	Yes
01-P-2040	one well (WWR#9810606)	46	365	Water Supply	Other - Water Supply	1	46	46	46	46	46	46	46	46	46	46	46	46	46	46	Yes
01-P-2192	Well	100	365	Institutional	Schools	1	100	100	100	100	100	100	0	0	100	100	100	100	83	100	Yes
01-P-2207	Well L1	36.53	365	Water Supply	Communal	1	37	37	37	37	37	37	37	37	37	37	37	37	37	37	Yes
01-P-2207	Well U2	13.12	365	Water Supply	Communal	1	13	13	13	13	13	13	13	13	13	13	13	13	13	13	Yes
01-P-2236	well	589	183	Commercial	Golf Course Irrigation	0.85	0	0	0	0	0	501	501	501	501	0	0	0	167	501	Yes
01-P-2236	dugout	2182	183	Commercial	Golf Course Irrigation	0.85	0	0	0	0	0	1855	1855	1855	1855	0	0	0	618	1855	No
02-P-2060	Well #1	164	180	Agricultural	Nursery	0.85	0	0	0	0	0	0	139	139	0	0	0	0	23	139	Yes
02-P-2061	Well #1	164	180	Agricultural	Nursery	0.85	0	0	0	0	0	0	139	139	0	0	0	0	23	139	Yes
02-P-2064	Drilled Well #1	273	220	Agricultural	Nursery	0.85	0	0	0	0	0	0	232	232	0	0	0	0	39	232	Yes
02-P-3097	Pond	1000	150	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	850	850	0	0	0	0	142	850	Yes
0302-7CEL63	Well N1	210	365	Commercial	Mall / Business	1	210	210	210	210	210	210	210	210	210	210	210	210	210	210	Yes
0302-7CEL63	Well N2	100	365	Commercial	Mall / Business	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	Yes
0302-7CEL63	Well N3	273	365	Commercial	Mall / Business	1	273	273	273	273	273	273	273	273	273	273	273	273	273	273	Yes
03-P-2045	Well #3	200	365	Water Supply	Campgrounds	1	0	0	0	0	200	200	200	200	200	0	0	0	83	200	Yes
03-P-2045	Well #9	200	365	Water Supply	Campgrounds	1	0	0	0	0	200	200	200	200	200	0	0	0	83	200	Yes
03-P-2215	Pond	699	4	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	38	38	0	0	0	0	6	38	Yes
03-P-2215	Pond	699	4	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	38	38	0	0	0	0	6	38	Yes
03-P-2249	Well (TW-2)	1309	365	Water Supply	Communal	1	1309	1309	1309	1309	1309	1309	1309	1309	1309	1309	1309	1309	1309	1309	Yes
03-P-2265	Dugout Pond	1000	45	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	617	617	0	0	0	0	103	61694	Yes
03-P-2266	Dugout Pond	1000	20	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	274	274	0	0	0	0	46	274	Yes
03-P-2267	Dugout Pond	540	30	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	222	222	0	0	0	0	37	222	Yes
0507-74TRLE	Trenches	100	30	Dewatering Construction	Construction	1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	Yes

Permit Number	Source Name	Max Permitted (m3/d)	Max Days/Year	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	Max Monthly (m3/d)	In Model
0800-6XARHU	Clubhouse Well	96.48	365	Commercial	Golf Course Irrigation	1	0	0	0	0	0	96	96	96	96	0	0	0	32	96	Yes
1833-6G7QVG	Artesian Well	64	300	Commercial	Other - Commercial	1	52	52	52	52	52	52	52	52	52	52	52	52	52	52	No
2688-7BRKDG	PW1	213	365	Remediation	Groundwater	1	213	213	213	213	213	213	213	213	213	213	213	213	213	213	Yes
2688-7BRKDG	PW2	115	365	Remediation	Groundwater	1	115	115	115	115	115	115	115	115	115	115	115	115	115	115	Yes
2688-7BRKDG	PW3	38	365	Remediation	Groundwater	1	38	38	38	38	38	38	38	38	38	38	38	38	38	38	Yes
2768-6QXRCC	One Well #A017773	79.2	365	Industrial	Manufacturing	1	79	79	79	79	79	79	79	79	79	79	79	79	79	79	Yes
2856-6N7MQK	Well #2 WWR# 6811368	118.86	365	Commercial	Bottled Water	1	119	119	119	119	119	119	119	119	119	119	119	119	119	119	Yes
3036-6QPKHE	PW1	136.8	365	Institutional	Other - Institutional	1	137	137	137	137	137	137	137	137	137	137	137	137	137	137	Yes
4116-7CELMY	Well S1	264	365	Commercial	Mall / Business	1	264	264	264	264	264	264	264	264	264	264	264	264	264	264	Yes
4116-7CELMY	Well S2	196	365	Commercial	Mall / Business	1	196	196	196	196	196	196	196	196	196	196	196	196	196	196	Yes
4116-7CELMY	Well S3	273	365	Commercial	Mall / Business	1	273	273	273	273	273	273	273	273	273	273	273	273	273	273	Yes
4366-6BTRUX	Well	816	365	Miscellaneous	Heat Pumps	1	816	816	816	816	816	816	816	816	816	816	816	816	816	816	Yes
5170-6X9H33	Well A017818	657	180	Commercial	Golf Course Irrigation	0.85	0	0	0	0	0	558	558	558	558	0	0	0	186	558	Yes
5336-6C8R2N	Arboretum Well	110	200	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	94	94	0	0	0	0	16	94	Yes
5336-6C8R2N	Aviary Well	175	200	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	149	149	0	0	0	0	25	149	Yes
5336-6C8R2N	Hilton Centre Well	252	60	Agricultural	Field and Pasture Crops	0.85	0	0	0	0	0	0	207	207	0	0	0	0	35	207	Yes
6031-7CVQ3X	Ground Water	320	30	Dewatering	Other - Dewatering	1	26	26	26	26	26	26	26	26	26	26	26	26	26	26	Yes
6046-6GNKQD	Spring #1	1964	365	Commercial	Aquaculture	1	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964	1964	No
6046-6GNKQD	Spring #2	7856	365	Commercial	Aquaculture	1	7856	7856	7856	7856	7856	7856	7856	7856	7856	7856	7856	7856	7856	7856	No
6046-6GNKQD	Springs - other	196	365	Commercial	Aquaculture	1	197	197	197	197	197	197	197	197	197	197	197	197	197	197	No
6046-6GNKQD	Two Dug Wells	3273	365	Commercial	Aquaculture	1	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	3273	No
6064-646HBU	PH#4	425	365	Water Supply	Communal	1	425	425	425	425	425	425	425	425	425	425	425	425	425	425	Yes
6064-646HBU	PW1-78	327	365	Water Supply	Communal	1	327	327	327	327	327	327	327	327	327	327	327	327	327	327	Yes
6064-646HBU	PW2-67	1308	365	Water Supply	Communal	1	1308	1308	1308	1308	1308	1308	1308	1308	1308	1308	1308	1308	1308	1308	Yes
6064-646HBU	PW3-81	654	365	Water Supply	Communal	1	654	654	654	654	654	654	654	654	654	654	654	654	654	654	Yes
6066-6VXQU2	Maintenance Well	34	365	Water Supply	Other - Water Supply	1	34	34	34	34	34	34	34	34	34	34	34	34	34	34	Yes
6066-6VXQU2	Clubhouse Well	50	365	Water Supply	Other - Water Supply	1	50	50	50	50	50	50	50	50	50	50	50	50	50	50	Yes
6066-6VXQU2	Well PW1/2005	1965	184	Commercial	Golf Course Irrigation	1	0	0	0	0	0	1965	1965	1965	1965	0	0	0	655	1965	Yes
6434-6VZHGY	GDCW1	322	365	Remediation	Groundwater	1	322	322	322	322	322	322	322	322	322	322	322	322	322	322	Yes
6434-6VZHGY	GDCW2	983	365	Remediation	Groundwater	1	983	983	983	983	983	983	983	983	983	983	983	983	983	983	Yes
6560-6DYPGH	Well WSW 1	250	365	Industrial	Manufacturing	1	250	250	250	250	250	250	250	250	250	250	250	250	250	250	Yes
6560-6DYPGH	Well WSW 2	200	365	Industrial	Manufacturing	1	200	200	200	200	200	200	200	200	200	200	200	200	200	200	Yes
69-P-0241	Well (1)	818.28	365	Water Supply	Communal	1	818	818	818	818	818	818	818	818	818	818	818	818	818	818	Yes

Permit Number	Source Name	Max Permitted (m3/d)	Max Days/Year	Major Category	Specific Purpose	Consumptive Factor	Jan (m3/d)	Feb (m3/d)	Mar (m3/d)	Apr (m3/d)	May (m3/d)	Jun (m3/d)	Jul (m3/d)	Aug (m3/d)	Sep (m3/d)	Oct (m3/d)	Nov (m3/d)	Dec (m3/d)	Avg (m3/d)	Max Monthly (m3/d)	In Model
69-P-0481	Well	229.118	365	Agricultural	Other - Agricultural	0.85	0	0	0	0	0	0	195	195	0	0	0	0	32	195	Yes
69-P-0481	Well	229.118	365	Agricultural	Other - Agricultural	0.85	0	0	0	0	0	0	195	195	0	0	0	0	32	195	Yes
7134-6LJKT4	Pond	73	140	Industrial	Aggregate Washing	0.15	0	0	0	0	7	7	7	7	7	7	7	0	4	7	Yes
73-P-0480	Well (WWR#6704723)	1210	365	Agricultural	Other - Agricultural	0.85	0	0	0	0	0	0	1029	1029	0	0	0	0	171	1029	Yes
7403-6HCMGT	Dugout Pond	654	111	Recreational	Fish Ponds	0.008	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Yes
7403-6HCMGT	Dugout Pond	654	111	Recreational	Fish Ponds	0.008	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Yes
7403-6HCMGT	Dugout Pond	654	111	Recreational	Fish Ponds	0.008	1	1	1	1	1	1	1	1	1	1	1	1	1	1	Yes
8708-6LLS2Z	Well #1 (WWR# 6508121)	909	120	Commercial	Golf Course Irrigation	1	0	0	0	0	0	894	894	894	894	0	0	0	298	894	Yes
8708-6LLS2Z	Well TW 2003-1	909	180	Commercial	Golf Course Irrigation	1	0	0	0	0	0	909	909	909	909	0	0	0	303	909	Yes
88-P-2069	Wells	654.624	365	Industrial	Other - Industrial	1	655	655	655	655	655	655	655	655	655	655	655	655	655	655	Yes
92-P-2054	Pond	5940	140	Industrial	Aggregate Washing	0.15	0	0	0	0	583	583	583	583	583	583	583	0	340	583	Yes
97-P-2048	Pond 1	2288	365	Industrial	Aggregate Washing	0.15	0	0	0	0	343	343	343	343	343	343	343	0	200	343	Yes
97-P-2048	Pond 2	982	365	Industrial	Aggregate Washing	0.15	0	0	0	0	147	147	147	147	147	147	147	0	86	147	Yes
98-P-2064	Well	392.774	365	Water Supply	Campgrounds	1	0	0	0	0	393	393	393	393	393	0	0	0	164	393	Yes
98-P-3017	Quarry sump	20712	365	Dewatering	Pits and Quarries	0.15	3107	3107	3107	3107	3107	3107	3107	3107	3107	3107	3107	3107	3107	3107	No
99-P-2132	Well (1)	1636.56	365	Commercial	Aquaculture	1	1637	1637	1637	1637	1637	1637	1637	1637	1637	1637	1637	1637	1637	1637	Yes

Table 8. Summary of permitted rates and consumptive demands by water use sector.

Specific Purpose	Max Permitted Rate (m3/d)	Percentage of Total Permitted Takings	Consumptive Demand (m3/d)	Difference (Max Permitted - Consumptive) (m3/d)
Pits and Quarries	226,171.0	54.75	8,298.3	217,872.7
Aggregate Washing	82,716.4	20.02	1,225.6	81,490.8
Aquaculture	18,199.6	4.41	6,577.1	11,622.4
Golf Course Irrigation	17,913.1	4.34	1,204.9	16,708.2
Communal	16,129.9	3.90	2,394.6	13,735.3
Other - Industrial	10,245.6	2.48	4,317.2	5,928.4
Other - Water Supply	6,108.0	1.48	957.3	5,150.7
Other - Agricultural	5,894.1	1.43	237.9	5,656.2
Field and Pasture Crops	5,475.0	1.33	160.6	5,314.4
Bottled Water	5,056.9	1.22	1,217.1	3,839.8
Sod Farm	4,696.3	1.14	94.1	4,602.2
Groundwater	2,183.3	0.53	729.5	1,453.8
Fish Ponds	1,962.0	0.47	0.6	1,961.4
Campgrounds	1,784.9	0.43	175.7	1,609.2
Food Processing	1,760.0	0.43	122.3	1,637.7
Other - Remediation	1,483.2	0.36	1,211.6	271.7
Mall / Business	1,316.0	0.32	518.0	798.0
Other - Dewatering	899.0	0.22	84.4	814.6
Heat Pumps	885.0	0.21	323.1	561.9
Nursery	601.0	0.15	33.0	568.0
Brewing and Soft Drinks	552.9	0.13	0.0	552.9
Manufacturing	529.2	0.13	208.3	320.9
Other - Institutional	136.8	0.03	53.8	83.0
Cooling Water	110.0	0.03	20.7	89.3
Construction	100.0	0.02	3.2	96.8
Schools	100.0	0.02	32.9	67.1
Other - Commercial	64.0	0.02	20.6	43.4
Irrigation	60.0	0.01	12.7	47.3
Total	**413,133.2**	**100**	**30,235.1**	**382,898.1**

Screen Intervals

Data Sources

Numerous data sources were used to determine the screened interval of PTTWs in the City of Guelph model domain, as listed below:

- Water Well Information System (WWIS) modified by AquaResource (based on WWIS 2006 issued by the Grand River Conservation Authority)
- Water Resources Analysis System (WRAS+) – Region of Waterloo (2009)
- WWIS – Ministry of the Environment (Provided by the Grand River Conservation Authority (2009))
- Screened Intervals used in the Region of Waterloo Capture Zone Delineation Study (AquaResource, 2009b)

Map 2 illustrates the location of all PTTW sources within the numerical model domain, symbolized based on the source of screen data.

The sequence of data sources used to assign screen intervals to all PTTWs considered in this task was determined based on reliability, in reference to both data and location confidence (if related through data fields or spatially, respectively).

The WWIS dataset modified by AquaResource contains screen intervals for every PTTW captured in the 2006 database within the GRCA. As these data have been used in previous Source Water Protection studies (e.g. Grand River Conservation Authority Integrated Water Budget Report (AquaResource, 2009a)), screen intervals captured in this dataset were then applied to the PTTWs. Coincident Permit Number and Source Name fields were used to apply screen characteristics to PTTWs from the 2006 WWIS dataset. As source names are not consistent across the both datasets, PTTW records were manually inspected to ensure records with slight variations in source names were assigned screen depth data assigned to the same permit / source in the 2006 WWIS dataset. A total of 44 PTTW sources (23%) were assigned screen depth characteristics from this data source.

Screen information found within the WRAS+ database was joined to location data on the to create a spatial dataset containing screen depth data. PTTWs lacking screen data were assigned WRAS+ screen characteristics of the nearest WRAS+ well location within 100 m. It is thought the lateral and vertical distribution hydrostratigraphic units can be quite variable, thus application of screen data across distances >100 m from a PTTW might not accurately capture the correct extraction aquifer. Screen depth characteristics taken from the WRAS+ were applied to 5 PTTW sources (3%).

WWIS screen data issued by the MOE (2009) was applied to the remaining PTTW sources lacking screen data using the same methodology utilized in the application of WRAS+ screen data. A total of 40 PTTW sources (21%) were assigned screen depth characteristics from MOE WWIS data source.

Screen intervals used in the Region of Waterloo Capture Zone Delineation Study (AquaResource, 2009b) were then assigned to remaining PTTW sources lacking screen data, were applicable. A spatial relationship was established akin to that used in assigning WRAS+ screen data. The screen intervals was applied across PTTW sources using the closest PTTW location used in the Screened Intervals used in the Region of Waterloo Capture Zone Delineation Study (AquaResource, 2009b), within a buffer distance of 100 m around PTTW sources considered in this task. Twenty-five PTTW sources (13%) were assigned screen depth characteristics from this data source.

Should any of the remaining 76 PTTW sources without screen data have a source name that describes a pond, dugout pit or trench is assumed to extract water from the uppermost, modeled aquifer unit. A total of 26 PTTW sources (14%) were assigned screen depth information using this technique.

Fifty PTTW sources (26%) could not be matched to screen data. As reported screen data for these takings is absent, groundwater is assumed to be extracted from uppermost aquifer unit of sufficient thickness.

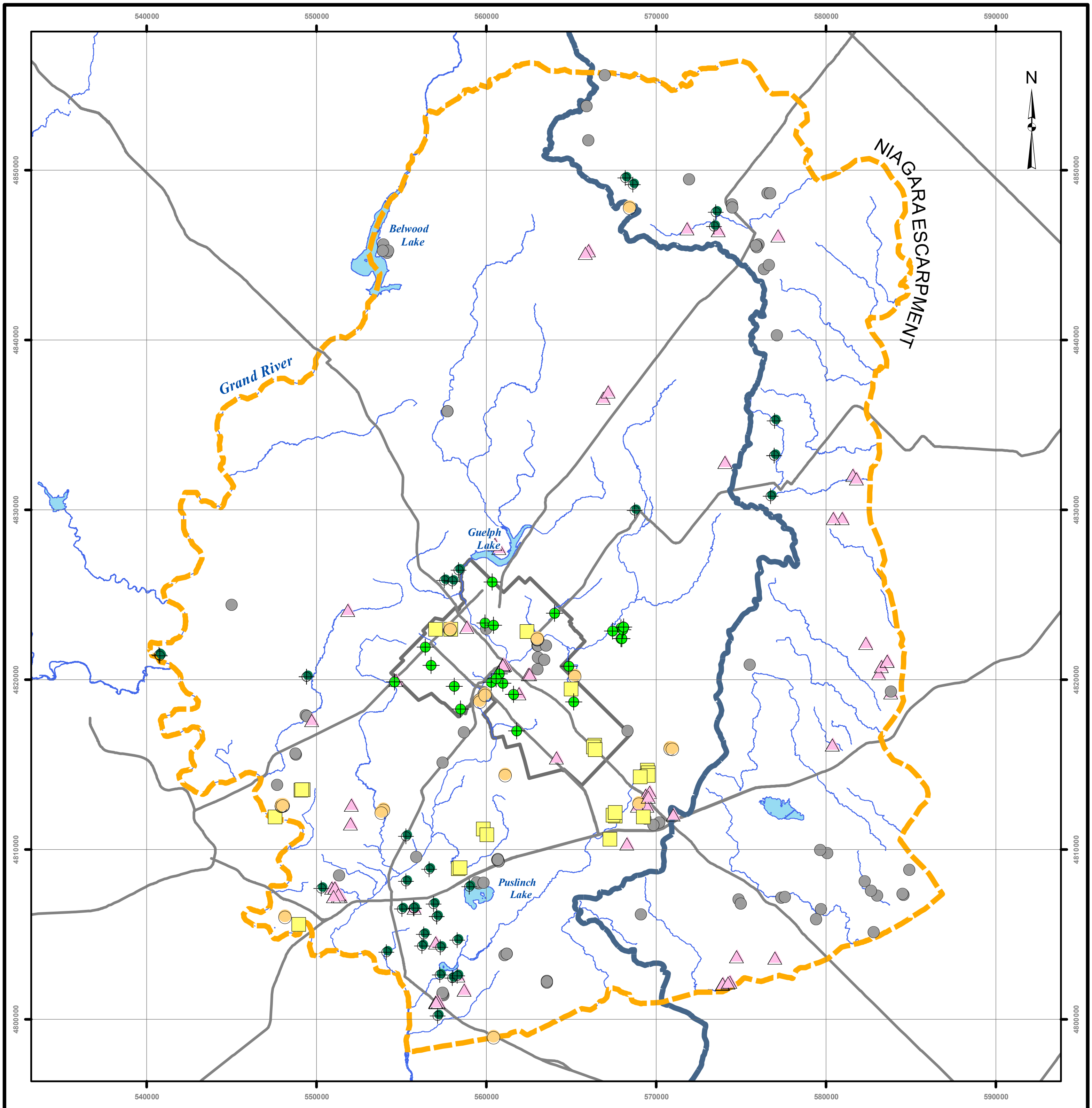
References

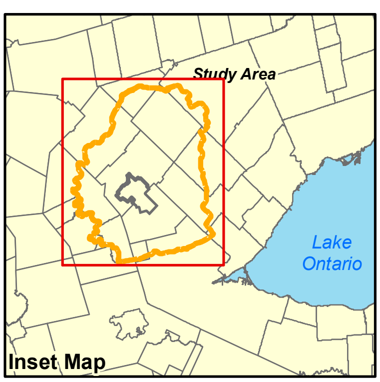
AquaResource. 2009a. Grand River Conservation Authority Integrated Water Budget Report. Report to the Grand River Conservation Authority. 194p.

AquaResource. 2009b. Region of Waterloo Capture Zone Delineation Study. Report to the Regional Municipality of Waterloo. 55p.

Kinkead Consulting and AquaResource. 2009. Methodology for Identifying Large Consumptive Water Users: Great Lakes – St. Lawrence River Basin Sustainable Water Resource Agreement. Report to the Ontario Ministry of Natural Resources. p. 28-32.

Ontario Ministry of the Environment, 2007. *DRAFT Assessment Report: Guidance Module 7. Water Budget and Water Quantity Risk Assessment.*





LEGEND

Reported Pumping Rates: Data Source(s)

- 2008 WTRS
- 2008 WTRS, GRCA Tier Two
- GRCA Tier Two
- No Reported Rates Available
- Guelph Water Supply Wells
- Other Municipal Water Supply Wells
- Major Road / Highways
- Rivers / Streams
- Open Water
- Model Boundary
- Grand River Watershed Boundary
- City of Guelph Boundary

Scale 1:310,000

0 2.5 5 10 15 20

Kilometres

REFERENCES:
Base Data - City of Guelph, 2009; GRCA, 2008, CVC, 2008, Ministry of Natural Resources, 2008
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Projection: UTM Zone 17N, NAD 83
Map Version: 1; Map Date: 2-June-2010; Created By: LW

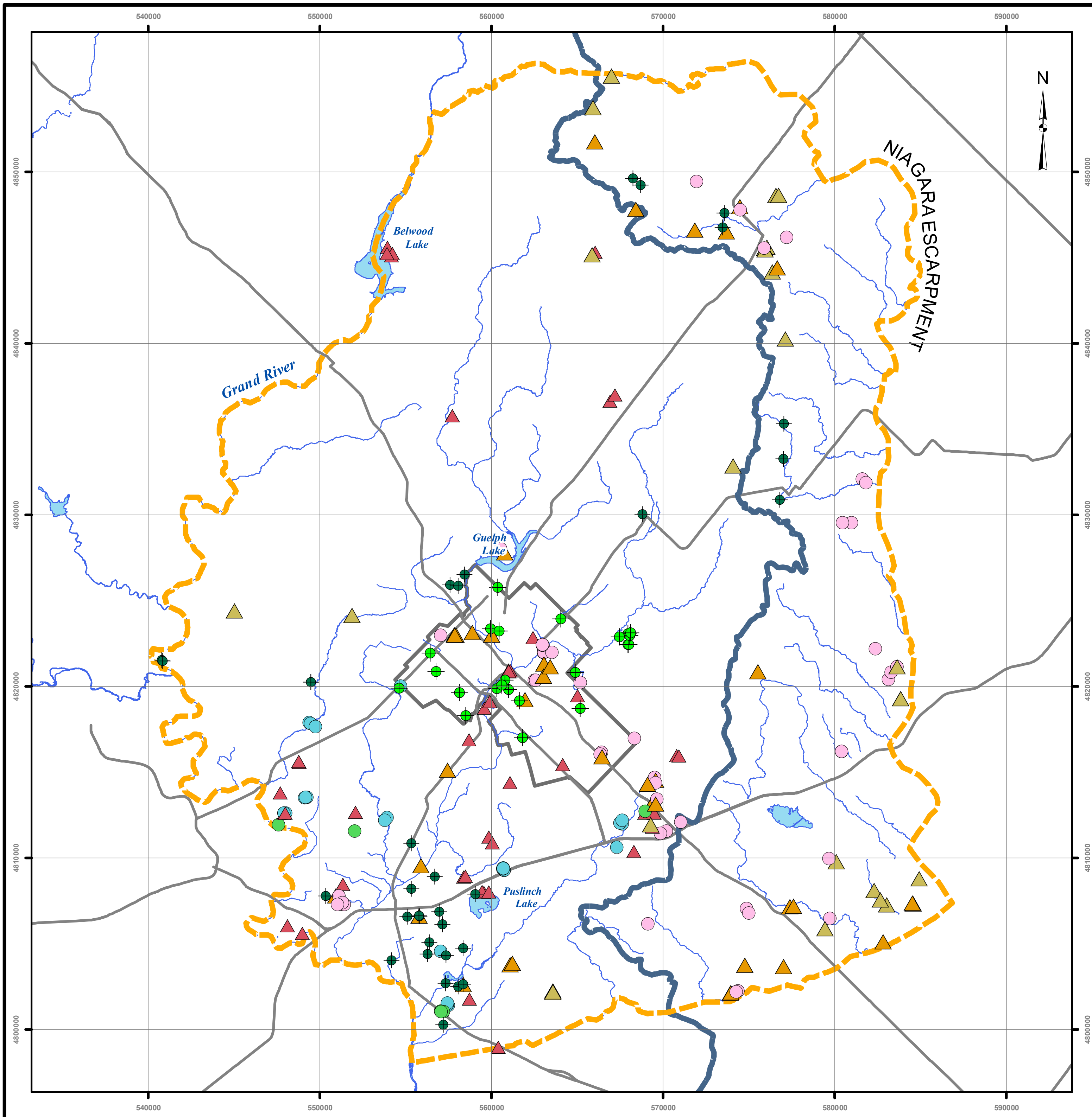
Tier Three Local Area Risk Assessment

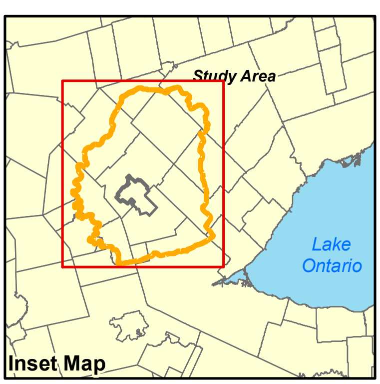
City of Guelph Making a Difference

Produced by Aquaresource Inc. and Golder Associates Ltd.

Map 1

Location of Non-municipal PTTWs in the Study Area





LEGEND

Screen Depth Data Source

- Modified 2006 WWIS Dataset
- WWIS (WRAS)
- WWIS (MOE)
- Region of Waterloo Capture Zone Delineation Study
- PTTW Source Name (Pond, Trench, etc)
- FEFLOW Numerical Model
- Guelph Water Supply Wells
- Other Municipal Water Supply Wells
- Major Road / Highways
- Rivers / Streams
- Open Water
- Model Boundary
- Grand River Watershed Boundary
- City of Guelph Boundary

Scale 1:310,000

0 2.5 5 10 15 20

Kilometres

REFERENCES:

Base Data - City of Guelph, 2009; GRCA, 2008, CVC, 2008, Ministry of Natural Resources, 2008

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Projection: UTM Zone 17N, NAD 83

Map Version: 1; Map Date: 2-June-2010; Created By: LW

Tier Three Local Area Risk Assessment

City of Guelph

Making a Difference

Produced by Aquaresource Inc. and Golder Associates Ltd.

Map 2

Non-municipal PTTW Screen Data Sources

Appendix B3 – High-Quality Calibration Targets

City of Guelph High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
500StoneRoad	561338	4818174	313.5	311.8	314.3	Guelph Fm.
ADMIRAL	564142	4815426	320.9	320.0	327.0	Middle Gasport
Arkell15-PW15A/00	567443	4822881	314.9	310.0	317.3	Middle Gasport
Arkell6-PW6/63	567939	4823073	314.8	310.0	318.0	Middle Gasport
Arkell7-PW7/63	567989	4822433	314.4	310.0	318.0	Middle Gasport
Arkell8-PW8/63	568074	4822973	315.1	310.0	318.0	Middle Gasport
BH1-3	563554	4817513	322.6	-	-	Overburden
BH3-1	562546	4816865	317.6	316.5	318.6	Guelph Fm.
BH4-3	564849	4815936	330.0	-	-	Overburden
BH5-1	563935	4817179	323.2	322.5	323.8	Guelph Fm.
BH6-1	562342	4818144	318.7	315.0	320.7	Guelph Fm.
BURKE_OBS	565149	4818696	327.3	-	-	Goat Island
Carter1-PW2/62	564872	4820592	321.4	318.0	325.0	Guelph Fm.
Carter2-PW1/89	564870	4820808	321.4	318.0	325.0	Guelph Fm.
CLAIRA	564875	4815909	328.4	327.3	329.5	Middle Gasport
CLAIRC	564875	4815909	329.9	328.9	330.3	Guelph Fm.
DOWNEYOBS	561794	4817026	294.4	293.0	295.0	Upper Gasport
EASTVIEWA	561281	4823857	317.0	313.0	320.0	Middle Gasport
EASTVIEWC	561281	4823857	331.6	329.9	332.8	Guelph Fm.
Edinburgh-PW2/53	560594	4820066	299.0	298.0	304.0	Middle Gasport
FLEMINGA	563298	4826047	343.8	341.5	344.9	Middle Gasport
FLEMINGC	563298	4826047	343.9	341.9	344.5	Contact Zone
GSTW1-08	562996	4814664	306.4	-	-	Middle Gasport
GSTW2-08	562286	4816097	312.8	-	-	Middle Gasport
GSTW3-08	565403	4815503	330.5	-	-	Upper Gasport
HAUSERA	555554	4819528	322.1	320.5	323.9	Middle Gasport
HAUSERC	555554	4819528	322.2	320.7	323.8	Guelph Fm.
HCMW08-01	562046	4817295	315.6	-	-	Overburden
HCP08-01	562228	4817087	316.7	-	-	Overburden
HCP08-02	562479	4817095	317.6	-	-	Overburden
HCP08-03	562899	4817371	319.3	-	-	Overburden
HCP08-04	562773	4817668	320.5	-	-	Overburden
HCP08-05	562509	4818198	322.4	-	-	Overburden
HCP08-06	562614	4817108	317.9	-	-	Overburden
HCP08-07	562197	4818322	322.8	-	-	Overburden
Logan4-OW4/66	563989	4826623	344.0	343.1	344.8	Middle Gasport
MCCURDYA	563539	4817510	321.3	320.5	322.8	Middle Gasport

City of Guelph High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MCCURDYC	563539	4817510	321.8	320.4	322.6	Guelph Fm.
MCW01-13	563816	4817724	326.7	-	-	Overburden
MCW01-5	563816	4817724	324.3	-	-	Overburden
MEMBROA	560273	4819870	287.4	283.5	290.0	Upper Gasport
MEMBROB	560273	4819870	309.7	309.4	310.2	Overburden
MW001	563019	4815738	324.0	-	-	Overburden
MW002	563116	4815264	325.8	-	-	Overburden
MW003	562436	4814814	325.9	-	-	Overburden
MW004	562532	4814286	326.0	-	-	Overburden
MW005_I	564015	4814708	327.7	-	-	Overburden
MW006	563955	4815051	327.6	-	-	Overburden
MW04-01A	560932	4818359	298.3	297.0	300.0	Middle Gasport
MW04-01B	560932	4818359	310.4	309.0	311.2	Guelph Fm.
MW06-01-10	563573	4818172	338.1	-	-	Overburden
MW06-01A	555405	4821496	335.4	334.0	336.4	Upper Gasport
MW06-01C	555405	4821496	341.3	340.3	341.9	Guelph Fm.
MW06-02A	558091	4821806	331.3	330.7	332.1	Middle Gasport
MW06-02C	558091	4821806	331.5	331.0	332.3	Guelph Fm.
MW06-03A	559683	4824622	306.2	301.8	308.1	Middle Gasport
MW06-03C	559683	4824622	337.8	336.1	338.3	Guelph Fm.
MW06-04A	559519	4819464	293.5	292.1	296.7	Middle Gasport
MW06-04C	559519	4819464	301.4	300.3	302.9	Guelph Fm.
MW06-05A	559860	4820988	307.9	304.0	310.2	Middle Gasport
MW06-05C	559860	4820988	318.0	316.9	318.5	Guelph Fm.
MW06-06A	563129	4819827	321.6	319.0	323.0	Middle Gasport
MW06-06C	563129	4819827	332.3	331.0	333.0	Guelph Fm.
MW06-07A	565683	4813871	317.4	316.3	319.1	Middle Gasport
MW06-07B	565683	4813871	316.8	316.1	317.1	Guelph Fm.
MW06-07D	565685	4813872	326.1	-	-	Overburden
MW06-08A	565944	4817135	331.5	330.0	332.2	Middle Gasport
MW06-08C	565944	4817135	333.7	331.4	334.5	Guelph Fm.
MW06-09A	566131	4818506	328.6	327.0	330.1	Middle Gasport
MW06-09D	566131	4818506	332.4	330.5	333.0	Overburden
MW06-10A	567678	4817485	332.7	331.2	333.4	Middle Gasport
MW06-10C	567678	4817485	332.8	331.2	333.4	Guelph Fm.
MW08-01A	560990	4817482	299.0	297.0	300.0	Middle Gasport
MW08-01B	560988	4817483	310.7	310.4	311.6	Overburden

City of Guelph High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MW08-02A	560096	4819483	293.2	292.0	295.0	Middle Gasport
MW08-02B	560096	4819483	312.8	312.5	313.2	Guelph Fm.
MW08-T3-01-Test1	555088	4824033	339.8	-	-	Goat Island
MW08-T3-01-Test4	555088	4824033	339.0	-	-	Guelph Fm.
MW08-T3-02-Test1	559364	4830635	358.4	-	-	Middle Gasport
MW08-T3-02-Test5	559364	4830635	360.0	-	-	Guelph Fm.
MW08-T3-04-Test1	552656	4836469	402.8	-	-	Middle Gasport
MW08-T3-04-Test3	552656	4836469	402.9	-	-	Guelph Fm.
MW08-T3-05-Test2	562217	4845821	431.0	-	-	Upper Gasport
MW08-T3-05-Test8	562217	4845821	430.8	-	-	Guelph Fm.
MW08-T3-06-Test1	568275	4834621	365.7	-	-	Middle Gasport
MW08-T3-06-Test6	568275	4834621	363.4	-	-	Upper Gasport
MW08-T3-07-Test1	564580	4828358	342.8	-	-	Middle Gasport
MW08-T3-07-Test4	564580	4828358	348.1	-	-	Guelph Fm.
MW08-T3-08-Test1	560944	4826609	336.5	-	-	Middle Gasport
MW08-T3-08-Test4	560944	4826609	342.9	-	-	Guelph Fm.
MW08-T3-09-Test1	570648	4820064	330.3	-	-	Middle Gasport
MW08-T3-09-Test4	570648	4820064	341.0	-	-	Goat Island
MW08-T3-10-Test1	563190	4812531	302.7	-	-	Middle Gasport
MW08-T3-10-Test3	563190	4812531	320.9	-	-	Guelph Fm.
MW09-TW3-01	560940	4810662	303.4	-	-	Middle Gasport
MW101	562590	4816126	317.8	-	-	Overburden
MW102	562163	4815860	319.1	-	-	Overburden
MW103	562895	4815933	322.8	-	-	Overburden
MW104	562401	4815648	321.1	-	-	Overburden
MW105	562700	4815489	322.7	-	-	Overburden
MW106	563458	4815478	326.2	-	-	Overburden
MW107	563540	4815143	326.7	-	-	Overburden
MW108	562867	4814607	327.3	-	-	Overburden
MW109	563116	4814444	326.7	-	-	Overburden
MW110	563532	4814502	327.1	-	-	Overburden
MW111	562710	4815365	324.9	-	-	Guelph Fm.
MW112	562531	4814288	325.8	-	-	Guelph Fm.
MW113	563532	4814478	325.9	-	-	Overburden
MW114	564115	4814640	326.5	-	-	Guelph Fm.
MW115	562313	4815311	323.5	-	-	Overburden
MW115A	562312	4815309	322.7	-	-	Overburden

City of Guelph High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MW116	562305	4816139	314.7	314.5	315.0	Contact Zone
MW117	562525	4815889	318.1	317.6	318.4	Overburden
MW118	562921	4815685	323.6	323.3	324.0	Overburden
MW119	562960	4815279	325.2	-	-	Overburden
MW120	563249	4814948	327.6	-	-	Overburden
MW121	563395	4814817	326.3	-	-	Overburden
MW121A	563396	4814817	326.9	-	-	Overburden
MW122	562960	4814929	326.1	-	-	Overburden
MW123	562723	4815369	307.7	305.0	313.0	Upper Gasport
MWB-D	565144	4818690	328.1	325.3	330.0	Contact Zone
MWB-I	565144	4818690	331.8	-	-	Overburden
MWB-S	565144	4818690	332.1	-	-	Overburden
MWD-D	561794	4817031	314.0	313.0	315.0	Guelph Fm.
OW01-92	559317	4818440	301.6	300.5	303.5	Upper Gasport
OW03-92	560172	4818351	300.8	299.0	302.0	Vinemount Member
OW04-92	560451	4818648	302.1	300.0	303.0	Vinemount Member
OW05-92A	560223	4819045	296.5	295.0	297.8	Upper Gasport
OW05-92B	560223	4819045	308.7	308.0	310.0	Guelph Fm.
OW10D-06	568680	4826606	323.0	321.0	324.0	Middle Gasport
OW10I	568680	4826606	323.3	-	-	Upper Gasport
OW11/00-D	568611	4822275	319.2	315.8	319.7	Middle Gasport
OW11/00-S	568612	4822272	328.2	325.9	328.8	Contact Zone
OW11D-06	563769	4823687	321.1	319.8	321.8	Middle Gasport
OW11S	563769	4823685	319.9	316.9	321.2	Overburden
OW12/00	567644	4821533	317.7	314.7	324.6	Middle Gasport
OW13/00	566977	4822128	319.4	316.3	320.0	Guelph Fm.
OW14/00-D	568104	4823140	317.8	312.6	318.0	Middle Gasport
OW14/00-S	568103	4823137	326.2	322.0	328.0	Guelph Fm.
OW15/00	567438	4822880	318.1	315.2	319.8	Middle Gasport
OW16/00	566841	4822217	315.7	-	-	Middle Gasport
OW18/00	567543	4822126	318.2	314.5	319.0	Middle Gasport
OW19A/00	567065	4822988	316.5	315.4	317.4	Middle Gasport
OW19B/00	567064	4822987	317.4	315.8	316.8	Guelph Fm.
OW1D-06	566772	4821308	319.7	318.0	321.5	Middle Gasport
OW1S	566772	4821306	339.8	337.0	341.0	Overburden
OW20A/00-I-OW20/01	567459	4823439	316.9	315.2	317.5	Middle Gasport
OW20B/00-II-OW20/01	567410	4823412	317.3	315.0	317.5	Vinemount Member

City of Guelph High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
OW2D-06	569990	4821372	323.0	321.8	325.5	Middle Gasport
OW2S	569988	4821373	339.9	338.2	340.8	Overburden
OW3D-06	569593	4823593	323.9	322.0	326.0	Middle Gasport
OW3S	569595	4823592	327.2	325.0	328.1	Contact Zone
OW4D-06	568632	4824518	319.0	318.0	321.0	Middle Gasport
OW5D-06	566441	4823588	318.4	316.0	320.0	Middle Gasport
OW5S	566442	4823587	343.8	338.0	346.0	Contact Zone
OW6D-06	566302	4821825	317.3	316.0	318.0	Upper Gasport
OW7D-06	569191	4822879	320.5	320.0	321.0	Middle Gasport
OW7S	569192	4824881	320.4	-	-	Upper Gasport
OW8D-06	571011	4823050	331.2	329.8	332.0	Middle Gasport
OW8S	571014	4823049	333.5	332.9	334.6	Overburden
OW9D-06	570515	4824670	322.8	322.0	323.5	Middle Gasport
OW9S	570516	4824660	323.2	-	-	Contact Zone
Sacco	556416	4821929	337.9	336.0	338.5	Middle Gasport
SC95-08-6	563979	4818259	331.2	330.0	332.5	Overburden
Smallfield	556716	4820859	334.2	330.0	336.0	Middle Gasport
SUMP3	560020	4819025	288.3	-	-	Upper Gasport
TW04-01A	561360	4818045	298.0	294.0	299.0	Middle Gasport
TW04-01C	561360	4818045	313.5	311.9	314.5	Guelph Fm.
TW04-02A	560339	4818016	296.4	294.0	297.0	Middle Gasport
TW04-02C	560339	4818016	308.6	306.0	309.3	Guelph Fm.
TW08-01A	561755	4817896	298.5	295.0	300.0	Middle Gasport
TW08-01B	561755	4817896	314.6	313.0	315.6	Guelph Fm.
TW08-02A	562101	4818417	298.1	295.0	300.0	Middle Gasport
TW08-02B	562101	4818417	318.8	314.0	319.8	Guelph Fm.
UG-3	562584	4820326	308.6	290.0	295.0	Upper Gasport
UG-4	562024	4819077	301.2	294.0	306.0	Middle Gasport
UG-7	561331	4819442	302.8	300.0	306.0	Middle Gasport

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-TW3-80	569037	4812797	315.6			Upper Gasport
MC-RockwoodTW#1-67	568785	4830023	357.3			Lower Gasport
MC-DP4a	561424	4813460	330.5			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-MW2	566461	4820071	324.2			Guelph Fm.
MC-BH6a	568738	4814705	331.3			Overburden
MC-MW3a	566301	4820107	323.4			Contact Zone
MC-MW1a	566364	4820061	324.0			Contact Zone
MC-TW4-80	568860	4812797	311.6			Upper Gasport
MC-TW2-80	568870	4812485	312.9			Middle Gasport
MC-TW1-80	569002	4812639	303.3			Reformatory Quarry
MC-BH2d	561460	4813625	326.9			Overburden
MC-DP1a	561467	4813601	326.9			Overburden
MC-BH22	561434	4814716	324.2			Overburden
MC-DP2b	561500	4813568	326.9			Overburden
MC-BH3c	561111	4813859	323.9			Overburden
MC-BH1d	561668	4813994	325.2			Overburden
MC-BH25	561586	4814140	324.8			Overburden
MC-TW1-99	571457	4817622	336.3			Middle Gasport
MC-DP3a	561579	4813460	326.9			Overburden
MC-DW1-DugWellonRd12	561343	4813899	323.9			Overburden
MC-BH214	560448	4811111	316.0			Overburden
MC-D-31	572358	4817850	333.7			Contact Zone
MC-D-55-67-07511	570740	4817154	328.6			Guelph Fm.
MC-BH219	560255	4811723	316.5			Overburden
MC-BH5a	560619	4813483	322.2			Overburden
MC-BH213	560378	4811309	315.8			Overburden
MC-D-36-67-02793	571986	4817294	324.7			Middle Gasport
MC-BH2c	568817	4809877	307.4			Contact Zone
MC-BH1c	568803	4809727	307.1			Contact Zone
MC-BH3b	568769	4809970	307.5			Contact Zone
MC-TW2-99	571931	4818172	337.7			Middle Gasport
MC-BH4a	560754	4813773	322.0			Overburden
MC-D-41-67-02754	571292	4816740	327.8			Overburden
MC-MP4	568610	4809499	307.1			Contact Zone
MC-MP2	568212	4809843	307.3			Overburden
MC-MW3	571139	4811499	311.6			Contact Zone
MC-MP3	568340	4809542	307.1			Overburden
MC-BH2	570434	4815297	323.3			Contact Zone
MC-MW10-99	571399	4816985	329.8			Overburden
MC-MW2-99	571647	4817292	332.0			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-MW11-99	571235	4818443	337.6			Overburden
MC-D-14-67-03761	571448	4819010	333.9			Vinemount Member
MC-DP6a	561767	4813499	325.3			Overburden
MC-9-78	560291	4804193	296.4			Reformatory Quarry
MC-MP1	568222	4810233	307.6			Overburden
MC-MW12-99	571542	4817282	338.2			Overburden
MC-BH103	570622	4815502	324.6			Overburden
MC-OW5-90	570861	4815146	325.1			Guelph Fm.
MC-MW-3825-67-03825	571118	4817527	332.0			Contact Zone
MC-TW4-62	565462	4820650	313.5			Goat Island
MC-MW2a	568445	4813462	314.3			Contact Zone
MC-OW6-90	570861	4815176	325.5			Contact Zone
MC-RockwoodGE-OW1/2	568792	4830030	349.4			Goat Island
MC-92-1	567639	4810138	307.5			Overburden
MC-D-37-67-04423	571836	4817520	328.3			Goat Island
MC-BH6-prop	567381	4809310	306.0			Overburden
MC-OW1	566720	4811756	311.7			Overburden
MC-DW2-DugWellonRd10	560728	4813417	320.0			Overburden
MC-MW1b	559032	4807918	305.1			Overburden
MC-OW1A-90	570825	4815656	326.2			Contact Zone
MC-DP12-99	571216	4817360	331.3			Overburden
MC-MW6-99	571533	4817912	335.2			Overburden
MC-BH2a	567817	4809323	307.4			Overburden
MC-BH3d	568416	4814494	319.4			Overburden
MC-MW1D-99	571357	4817463	332.2			Middle Gasport
MC-DP102	567102	4811878	307.3			Overburden
MC-DP6-99	571203	4817518	336.7			Overburden
MC-MW8-99	571726	4818087	337.4			Overburden
MC-DP8-99	571442	4817969	339.0			Overburden
MC-10-78	562795	4806775	298.4			Goat Island
MC-BH2e	568332	4814434	319.4			Overburden
MC-BH1e	568416	4814373	318.2			Overburden
MC-MW5	568802	4819262	338.6			Overburden
MC-MW7-99	571709	4817828	336.0			Overburden
MC-MW4	572962	4815225	325.9			Overburden
MC-DP7-99	571470	4817584	337.8			Overburden
MC-BH204	559676	4810903	307.7			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-DP5-99	571188	4817383	332.0			Overburden
MC-DP5a	560619	4813338	318.6			Overburden
MC-MW7	563413	4811246	314.7			Guelph Fm.
MC-BH5-prop	566946	4809469	305.4			Overburden
MC-DP4-99	571349	4817341	332.6			Overburden
MC-OW3-90	570524	4814845	327.7			Overburden
MC-DP115	567775	4811181	307.1			Overburden
MC-BH2b	567290	4808976	309.0			Overburden
MC-DP1-99	571250	4817123	331.1			Overburden
MC-D-28-67-05186	573039	4817853	329.9			Upper Gasport
MC-OW1B-90	570825	4815022	326.1			Overburden
MC-MW4a	558937	4807967	304.1			Overburden
MC-OW1234516A	566048	4809540	304.3			Overburden
MC-DP10-99	571474	4817607	337.5			Overburden
MC-BH3	567500	4809080	306.8			Overburden
MC-MP3c	558927	4807973	303.9			Overburden
MC-OW2-90	570334	4815022	324.5			Overburden
MC-DP13-99	571239	4817459	332.9			Overburden
MC-D-68-67-10983	570031	4817544	329.8			Lower Gasport
MC-BH1	569996	4815301	323.8			Overburden
MC-MW4-99	571167	4817231	332.3			Overburden
MC-DP7	566879	4810152	306.0			Overburden
MC-DP14-99	571258	4817112	331.2			Overburden
MC-BHC	567160	4811324	306.2			Overburden
MC-MW9-99	571840	4817662	336.4			Overburden
MC-BH1b	567230	4808807	307.7			Overburden
MC-BH3a	567182	4809371	306.7			Overburden
MC-TW16-79	566050	4809534	304.0			Overburden
MC-DP16	565953	4809865	304.5			Overburden
MC-BH205	559788	4810556	307.5			Contact Zone
MC-OW3	566756	4811894	310.9			Overburden
MC-92-13	567260	4810328	307.3			Overburden
MC-DP6	566850	4810320	305.8			Overburden
MC-MW2b	559095	4807834	304.0			Overburden
MC-BMW2	566690	4811747	308.1			Overburden
MC-MW3b	559130	4808021	303.6			Overburden
MC-MW-8956-67-08956	571347	4817597	336.5			Guelph Fm.
MC-TW10	566640	4811326	308.7			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-MW1-99	571360	4817463	336.0			Overburden
MC-BH4	567058	4809760	307.0			Overburden
MC-BH1-I	563389	4813634	326.4			Overburden
MC-BHB	567435	4811260	306.3			Overburden
MC-DP114	566912	4811652	307.8			Overburden
MC-D-58-67-03879	570740	4817620	330.6			Middle Gasport
MC-DP113	567311	4811129	306.5			Overburden
MC-BH1a	567429	4810589	307.4			Overburden
MC-MP2b	559147	4808056	303.5			Overburden
MC-DP116	567710	4811492	307.3			Overburden
MC-TW6	566556	4811410	308.9			Overburden
MC-92-25	566030	4809890	304.6			Overburden
MC-92-14	567200	4810080	307.5			Contact Zone
MC-DP117	567680	4811443	307.1			Overburden
MC-HA3	566733	4811440	307.2			Overburden
MC-92-15	567098	4810050	307.2			Guelph Fm.
MC-MW1	562785	4806823	299.6			Contact Zone
MC-DP10	566585	4810364	305.1			Overburden
MC-92-32	565916	4809982	304.6			Contact Zone
MC-BMW4	567497	4811427	307.0			Overburden
MC-DP15-99	571831	4818106	340.9			Overburden
MC-MW5-99	571260	4817810	337.2			Overburden
MC-DP2-99	571537	4817455	335.0			Overburden
MC-DP8	566750	4810142	306.0			Overburden
MC-92-26	565982	4809943	304.5			Overburden
MC-BMW1	566667	4811757	308.5			Overburden
MC-BH102	570162	4815309	325.1			Overburden
MC-TW11	567000	4811024	307.5			Contact Zone
MC-TW3	566410	4811537	308.8			Overburden
MC-MP1a	559119	4807826	303.3			Overburden
MC-DP101	567605	4811440	307.2			Overburden
MC-BH7	567000	4810090	307.0			Contact Zone
MC-OW4	566745	4811450	308.9			Overburden
MC-DP17	566720	4810470	305.6			Overburden
MC-DP5	566026	4809507	303.5			Overburden
MC-TW2	566994	4811020	306.1			Overburden
MC-DP100	567262	4811312	306.8			Overburden
MC-DP18	567726	4811623	307.7			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-BH101	570205	4814901	325.6			Overburden
MC-DP-18	567726	4811623	307.7			Overburden
MC-DP3	566553	4810406	305.3			Overburden
MC-BH8	566120	4809914	304.7			Overburden
MC-DP2	565882	4810035	304.4			Overburden
MC-92-31	566100	4810080	305.1			Overburden
MC-TW4	566408	4811545	308.7			Overburden
MC-92-8	567068	4810315	307.1			Overburden
MC-DP106	567318	4811201	306.8			Overburden
MC-DP-5A	566049	4809735	303.6			Overburden
MC-16-79	566068	4809743	303.7			Overburden
MC-TW17	566723	4811100	306.4			Overburden
MC-TW20	567599	4811606	307.8			Overburden
MC-DP112	567314	4811221	306.8			Overburden
MC-DP110	567017	4811031	306.3			Overburden
MC-DP9	566640	4810110	305.8			Overburden
MC-TW9	566571	4811515	308.8			Overburden
MC-DP111	567128	4811064	306.6			Overburden
MC-92-5	567379	4810979	307.4			Overburden
MC-DP4	566804	4810572	305.9			Overburden
MC-TW16	566742	4811279	307.1			Overburden
MC-92-33	566009	4810122	304.7			Contact Zone
MC-DP22	566744	4810530	305.9			Overburden
MC-MW10D-99	571401	4816983	329.1			Middle Gasport
MC-92-27	566059	4810104	304.8			Overburden
MC-DP1	565958	4810110	304.5			Overburden
MC-BH6	566940	4810390	306.7			Overburden
MC-DP103	566716	4811603	308.3			Overburden
MC-DP11	566436	4810390	305.2			Overburden
MC-DP3-99	571664	4817455	335.9			Overburden
MC-BH5b	568617	4814742	323.4			Overburden
MC-TW15	566765	4811309	307.3			Overburden
MC-TW18	566703	4811002	306.2			Overburden
MC-DP105	567308	4811244	307.0			Overburden
MC-DP108	566991	4811145	306.4			Overburden
MC-MW6	569561	4814976	322.3			Contact Zone
MC-DP107	566984	4811178	306.5			Overburden
MC-TW19	567510	4811567	307.9			Overburden

Other High-Quality Calibration Targets

Observation Name	Northing	Easting	Observed Head Target (masl)	Min. Obs. Level (masl)	Max. Obs. Level (masl)	Formation Screened
MC-TW14	566856	4810865	306.6			Overburden
MC-BH4-prop	567088	4808990	306.8			Overburden
MC-BH5	567158	4810745	307.0			Overburden
MC-DP-20	566987	4811162	307.1			Overburden
MC-TW13	566483	4811776	308.9			Overburden
MC-BHA	566866	4811330	307.9			Overburden
MC-92-30	566190	4810185	305.1			Overburden
MC-MOEEAberfoyleWe	566957	4812381	310.4			Overburden
MC-DP109	566987	4811162	306.5			Overburden
MC-TW1	566985	4811023	307.0			Overburden
MC-TW2-63	568325	4821888	336.5			Overburden
MC-DP9-99	571645	4818168	339.6			Overburden
MC-DP20	566987	4811162	306.6			Overburden
MC-DP21	566823	4810603	306.2			Overburden
MC-DP15	566080	4810109	304.6			Overburden
MC-TW5	566788	4811094	307.0			Overburden
MC-DP19	567314	4811221	307.1			Overburden
MC-DP-19	567314	4811221	307.4			Overburden
MC-92-29	566163	4810210	305.0			Overburden
MC-OW2	566910	4811750	309.1			Overburden
MC-DP104	566693	4811583	308.5			Overburden
MC-16-78	566062	4809750	303.9			Vinemount Member
MC-BH9	566570	4809940	306.1			Contact Zone
MC-BH4b	568607	4814561	321.1			Overburden
MC-BH3e	570387	4815749	326.2			Overburden
MC-92-28	566127	4810237	304.8			Overburden
MC-BHD	566945	4811112	306.6			Overburden
MC-DP12	566400	4810177	305.6			Overburden
MC-TW8	567460	4811180	307.7			Contact Zone
MC-TW7	567612	4811354	307.8			Overburden

Appendix B4 – Summer/Fall 2008 Baseflow Monitoring Program Summary Memo

30 Beacon Point Court
Breslau, Ontario N0B 1M0
Tel: 519-772-3777
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Memo

To: City of Guelph Tier 3 Project Team

From: AquaResource Inc.

Date: December 2008

Re: Summer/Fall 2008 Baseflow Monitoring Program Summary

The purpose of this memorandum is to summarize the summer/fall 2008 baseflow monitoring field program for the City of Guelph. The summary includes:

- Summer/fall 2008 climate and streamflow conditions;
- Locations of spot flow measurements;
- Operating procedures for measuring streamflow;
- Baseflow monitoring results; and
- Summary of the results.

Existing climate and streamflow conditions

Baseflow is the sustained flow of a water course after receding from a storm event. To measure baseflow, sufficient time must pass after a rainfall event, thus allowing the stream to recede to baseflow levels. Typically, a period of 5 to 7 days without rainfall is sufficient to ensure baseflow conditions are present. As such, the rainfall events and corresponding streamflow conditions were taken into account when selecting dates for baseflow monitoring. These conditions are summarized below.

According to the GRCA monthly condition report for July 2008, monthly average precipitation for Guelph reservoir was 224% higher than the long term average. Similarly, monthly average precipitation in August and September were 123% and 138% higher than the long-term average, respectively. In October, monthly average precipitation returned to below normal at 77% of the long-term average.

These wet climatic conditions made it difficult to select optimal dates to perform stream baseflow measurements. When large and frequent rainfall events occur, streamflow may not recede to baseflow levels between events; thus timing of monitoring events can be challenging. The dates selected for baseflow monitoring are shown on Figure 1 along with the hydrographs at the Speed River and Eramosa River GRCA streamflow monitoring stations from June 28th to October 22nd, 2008. It should be noted that the streamflow data are provisional and are not adjusted for backwater effects; however, the data can be considered as additional spot flow measurements in the Tier 3 analysis.

Baseflow was measured during three periods: early July, late August and late October. The dotted grey lines in Figure 1 indicate the dates AquaResource / Golder Associates measured spot flows. In July, spot flows were measured on July 7th; however due to frequent rainfall events in the month of July, spot flows were not taken at all locations. In August, spot flow locations were gauged during the period from August 22nd to 28th. In October, locations were measured on the 21st or 22nd.

As is evident in Figure 1, spot flows measured in July may be more representative of streamflow recession than baseflow conditions. Spot flows measured in August are generally representative of baseflow conditions; however, spot flows on August 22nd may be capturing receding streamflows. Spot flows measured in late October are considered to be representative of baseflow conditions.

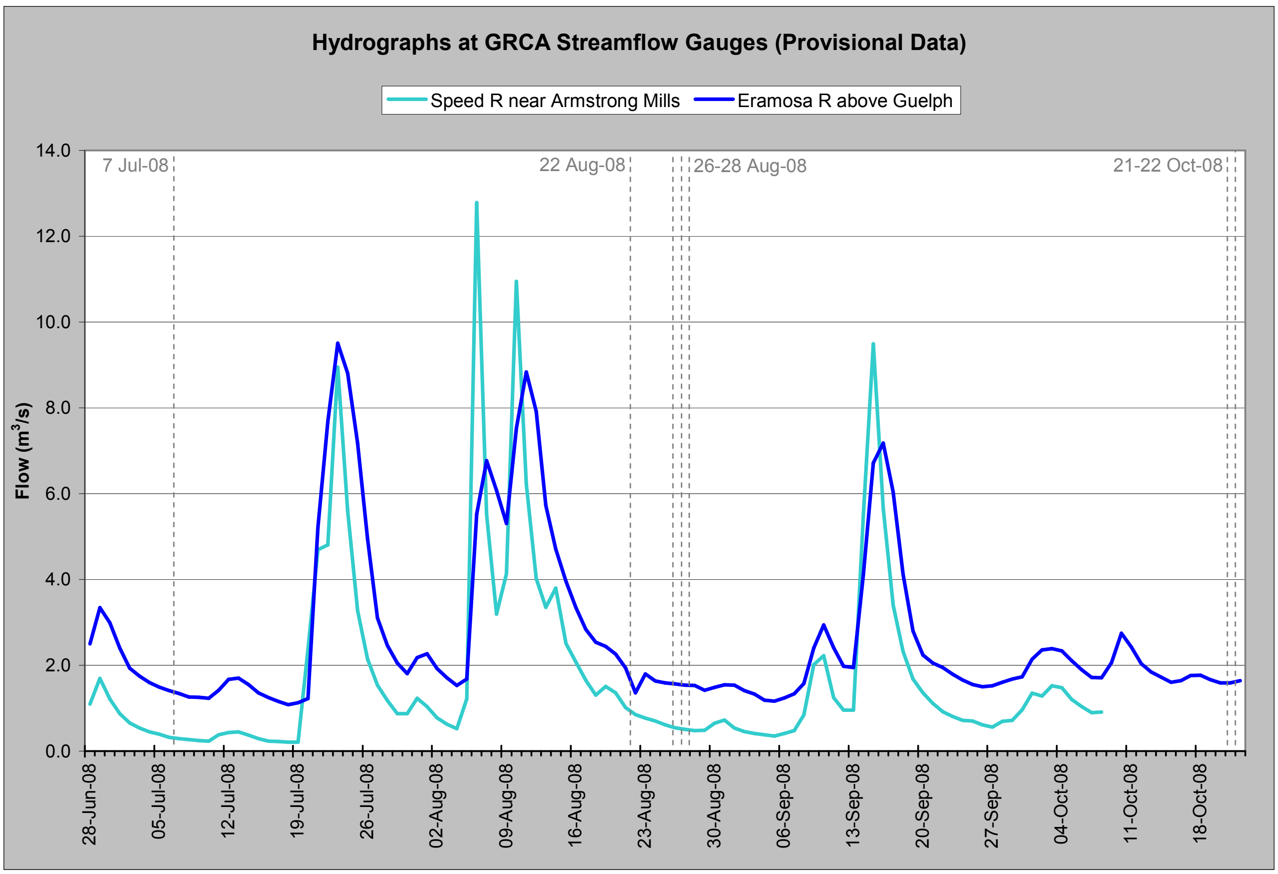


Figure 1: Flow Conditions at GRCA Gauges During the Summer/Fall 2008 Baseflow Monitoring Program

Spot Flow Locations

The purpose of the City of Guelph Tier 3 baseflow monitoring program is to validate the Tier 3 Water Budget results, as well as to provide additional calibration targets for the GAWSER surface water model. Locations of spot flows were chosen with this purpose in mind. Table 1 lists the spot flows by stream course, and includes the station code name and the nearest road intersection. A map of the spot flow locations, drainage areas and observe flow rates is shown in Figure 2. The GRCA streamflow monitoring stations and corresponding flow observations are included in this analysis and are identified with a “XX_GRCA” code.

Table 1: Spot Flow Locations

No.	Stream Course	Code	Station Name
1		SR_10	Speed R @ Wellington Rd 26
2		SR_20	Speed R @ 6th Line
3	Speed River	SR_30	Speed R @ 3rd Line
4		SR_40	Speed R @ Jones Baseline
5		SR_GRCA	Speed R near Armstrong Mills
6		LC_10	Lutteral Ck @ Sideroad 20
7	Lutteral Creek	LCT_20	Lutteral Ck Trib @ 6th Line
8		LC_30	Lutteral Ck @ 3rd Line
9	Guelph Lake	GLT_10	Guelph Lk Cold Trib @ 3rd Line
10		GLT_20	Guelph Lk Trib @ Jones Baseline
11	Marden Creek	MDC_10	Marden Ck @ Wellington Rd 30
12		ER_10	Eramosa R @ 3rd Line
13		ER_20	Eramosa R @ Wellington Rd 125
14	Eramosa River	ER_30	Eramosa R @ Evert St
15		ER_40	Eramosa R @ Wellington Rd 29
16		ER_GRCA	Eramosa R above Guelph
17		BSC_10	Blue Springs Ck @ 5th Line
18	Blue Springs Creek	BSC_20	Blue Springs Ck @ 28th SDRD
19		BSC_30	Blue Springs Ck @ 1st Line
20	Torrance Creek	TC_10	Torrance Ck @ Stone Rd
21	Hanlon Creek	HC_10	Hanlon Ck @ Hwy 6
22		HCT_20	Hanlon Ck South Trib @ Hwy 6
23	Irish Creek	IC_10	Irish Ck @ Wellington Rd 32
24		IC_20	Irish Ck @ Townline
25	Mill Creek	MC_10	Mill Ck @ Victoria Rd
26		MC_20	Mill Ck @ Wellington Rd 35
27		EC_10	Ellis Ck @ Wellington Rd 32
28	Ellis Creek	CGC_10	Ellis (Chilligo) Ck @ Kossuth Rd
29		EC_20	Ellis Ck @ Maple Grove Road
30	East Creek	ESTC_10	East Ck at Beaverdale
31	Swan Creek	SC_10	Swan Ck @ SDRD 4 at HWY 23
32		CC_10	Cox Ck @ 6th Line E
33	Cox Creek	CCT_20	Cox Ck south Trib @ 6th Line E
34		CC_30	Cox Ck @ Cox Creek Rd
35		HWC_10	Hopewell Ck @ Wellington Rd 32
36		HWC_20	Hopewell Ck @ Greenhouse Rd
37	Hopewell Creek	HWC_30	Hopewell Ck West @ Hopewell Creek Rd.
38		HWC_50	Hopewell Ck Downstream of Hwy 7
39		HWC_60	Hopewell Ck @ Breslau Dam
40	Airport Creek	AC_10	Airport Ck @ Grand River
41	Freeport Creek	FC_10	Freeport Ck @ King St
42	West Creek	WC_10	West Ck @ Cherry Blossom Rd.

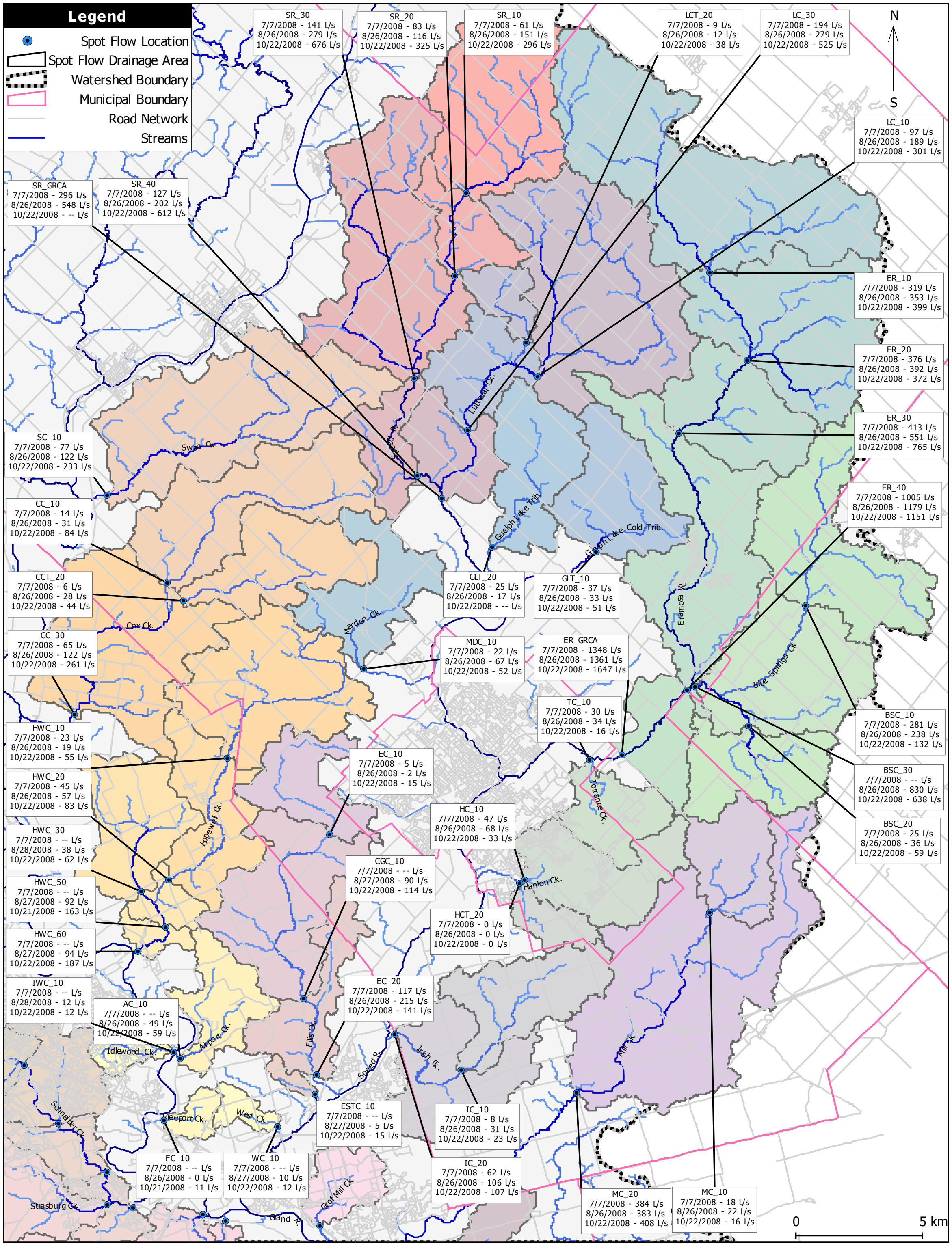


Figure 2: Summer/Fall 2008 Spot Flow Locations, Drainage Areas and Measured Flow Rates around the City of Guelph

Operating Procedures

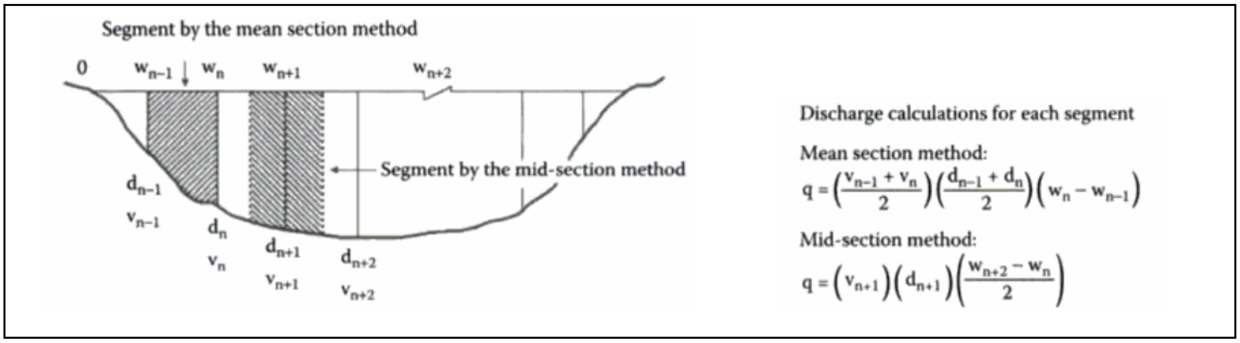
All streamflow measurements for the locations listed in Table 1 were completed by Golder Associates using Golder-owned Valeport Electromagnetic Flow Meters (Model 801) with the following exceptions:

- The following locations were measured on July 7th using a Golder-owned Impeller Flow Meter (Valeport Model BFM002):
  - Swan Creek (SC_10);
  - Cox Creek (CC_10, CCT_20, CC_30);
  - Speed River (SR_10, SR_20, SR_30, SR_40); and
  - Lutteral Creek (LC_10, LCT_20, LC_30).
- The following locations were measured on August 26th using a Valeport Electromagnetic Flow Meter (Model 801) from McQuest Marine Sciences Limited:
  - Torrance Creek (TC_10);
  - Eramosa River (ER_10, ER_20, ER_30, ER_40); and
  - Blue Springs Creek (BSC_10, BSC_20, BSC_30).
- All spot flows at Ellis Creek (EC_10) were measured using a bucket and stopwatch.
- The following locations were measured by AquaResource using a SonTek/YSI FlowTracker Handheld Acoustic Doppler Velocimeter (ADV) supplied by Hoskin Scientic:
  - Ellis Creek (CGC_10),
  - East Creek (ESTC_10);
  - Hopewell Creek (HWC_30, HWC_50, HWC_60);
  - Airport Creek (AC_10);
  - Freeport Creek (FC_10); and
  - West Creek (WC_10).

Reach sections for baseflow monitoring were selected where flow conditions were uniform and free of eddies, dead water near banks and excessive turbulence. Any vegetation, large rocks and/or obstructions were removed from the reach as best as possible.

To account for vertical velocity gradients, Golder measured streamflow velocities at 60% of the stream depth (from the surface) where total stream depths were less than 0.5 m and at 20% and 80% of the stream depth where depths were greater or equal to 0.5 m. Similarly, AquaResource measured streamflow velocities at 60% of the depth where total stream depths were less than 0.8 m and at 20% and 80% of the depth where total depths were greater than or equal to 0.8 m (Note: all stream depths were less than 0.8 m during baseflow monitoring).

Golder reported flow rates for each spot flow measurement using an average of the mid-section method and the mean-section method for discharge calculation. AquaResource reported flow rates for each spot flow measurement using the mid-section method for discharge calculation. A definition sketch of these two methods is shown in Figure 3. These methods assume that the velocity sample at each vertical depth represents the mean velocity for each individual section. The results from these two methods are typically within 1% of each other.



(Source: Mingteh Chang, 2006, Forest Hydrology: An Introduction to Water and Forests, Second Edition, pg. 399.)

Figure 3: Example of Streamflow Measurement Using the Mid-Section Method and the Mean-Section Method

Results of Baseflow Monitoring Program

The results from the summer/fall 2008 baseflow monitoring program have been organized in two tables and four figures which are included at the end of this memo.

Table 2 lists the observed streamflow in L/s at each spot flow location for the three monitoring sessions. It also presents the streamflow as an annual depth in mm/year over the total upstream drainage area, shown in km^2. Calculating the streamflow as a representative depth for the drainage area normalizes that value and facilitates direct comparison of baseflow discharge conditions from one area to the next.

Similarly, Table 3 also lists the observed streamflow in L/s for the three monitoring sessions as well as the “catchment yield” in L/s. The catchment yield represents the baseflow derived from each individual catchment, as opposed to the entire upstream area. The catchment yield is calculated by subtracting the spot flow measurements on upstream tributaries. It should be noted that these yield estimates have more uncertainty and error associated with them than the observed spot flows, as any errors from upstream measurements are accumulated at downstream locations. The catchment yields were converted to annual depths over the catchment area in mm/year, as shown in Table 3. These annual depths are illustrated in Figure 4 for July spot flows, in Figure 5 for August spot flows and in Figure 6 for October spot flows. Catchments with highly negative baseflow yields or depths are likely indicative of a losing stream reach, and could be contributing to deeper groundwater recharge.

Figure 7 is a graphical representation of the observed spot flows and allows the reader to visualize the range of baseflow measurements at each location.

It should be noted that streamflow measurements from both the GRCA gauge data and the AquaResource / Golder spot flow monitoring stations were omitted from all tables and figures where data were suspect or where conditions were obviously not representative of baseflow.

Summary of Results

Based on the information presented above, the following can be concluded from the summer/fall 2008 baseflow monitoring program for the City of Guelph area:

- Streamflow in late August and late October appear to be representative of baseflow conditions based on recorded hydrographs at GRCA streamflow monitoring locations;
- Stream baseflow is expected to be higher than the long-term average, due to higher than average precipitation;

- Relative flow depths and yield values provide a means of distinguishing the baseflow derived from each catchment in July, August and October. These values indicate areas that result in groundwater discharge and/or potential recharge conditions and provide insight into hydrogeologic characteristics and/or pumping impacts. This information should be considered in concert with other monitoring observations.
- Catchments in Figures 4 to 6 shown in dark blue, receive more than 300 mm/yr equivalent depth of discharge, which may in many cases exceeds local recharge. Such catchments likely collect groundwater discharge from recharge areas that extend beyond their bounds and indicate a convergent groundwater flow system.
- Catchments shown in yellow and light green receive little baseflow discharge and indicate that the local flow system contributes recharge to deeper groundwater flow systems which discharge in downstream catchments.
- Stream baseflow measurements represent a snapshot of the flow regime and error is typically on the order of 15% (Winter, 1981). Therefore the data presented in this memo should be viewed as providing insight into groundwater / surface water interaction for the conditions that occurred in 2008. The reader is cautioned against inferring long-term conditions from this limited data set.
- Seasonal fluctuations in baseflow conditions can be as high as a factor of 2 in some locations. The change in baseflow conditions typically reflects a slow change in storage from lower permeability materials.
- Negative incremental baseflow along Hopewell Creek in Breslau may be caused by low hydraulic conductivity of the local geologic materials, an under-draining of the local stream by high permeability materials, and/or the impact of local urban drainage. The results may also be impacted by measurement error and uncertainty. Cross-sections through the area should be used in concert with this data to better understand the local flow system.

The data presented in this memo will be used to validate the Tier 3 Water Budget results, as well as to provide additional calibration targets for the GAWSER surface water model for the City of Guelph.

References

Winter, T.C. 1981. *Uncertainties in estimating the water balance of lakes*. Water Resources Bulletin 17: 82-115.

Table 2: Summary of Summer/Fall 2008 Spot Flows Measurements and Depths over Total Drainage Area

					July			August			October		
No	Stream	Code	Name	Drainage Area (km^2)	Date	Flow (L/s)	Depth (mm/y)	Date	Flow (L/s)	Depth (mm/y)	Date	Flow (L/s)	Depth (mm/y)
1	Speed River	SR_10	Speed R @ Wellington Rd 26	30.0	7/7/08	61	64	8/26/08	151	159	10/22/08	296	312
2		SR_20	Speed R @ 6th Line	39.2	7/7/08	83	67	8/26/08	116	93	10/22/08	325	261
3		SR_30	Speed R @ 3rd Line	81.9	7/7/08	141	55	8/26/08	279	107	10/22/08	676	261
4		SR_40	Speed R @ Jones Baseline	91.2	7/7/08	127	44	8/26/08	202	70	10/22/08	612	212
5		SR_GRCA	Speed R near Armstrong Mills	169.5	7/7/08	296	55	8/26/08	548	102	10/22/08	--	--
6	Lutteral Creek	LC_10	Lutteral Ck @ Sideroad 20	49.1	7/7/08	97	63	8/26/08	189	121	10/22/08	301	194
7		LCT_20	Lutteral Ck Trib @ 6th Line	5.5	7/7/08	9	52	8/26/08	12	68	10/22/08	38	218
8		LC_30	Lutteral Ck @ 3rd Line	67.0	7/7/08	194	91	8/26/08	279	131	10/22/08	525	247
9	Guelph Lake	GLT_10	Guelph Lk Cold Trib @ 3rd Line	19.0	7/7/08	37	61	8/26/08	33	55	10/22/08	51	85
10		GLT_20	Guelph Lk Trib @ Jones Baseline	17.8	7/7/08	25	44	8/26/08	17	31	10/22/08	--	--
11	Marden Creek	MDC_10	Marden Ck @ Wellington Rd 30	16.2	7/7/08	22	43	8/26/08	67	131	10/22/08	52	102
12	Eramosa River	ER_10	Eramosa R @ 3rd Line	58.4	7/7/08	319	172	8/26/08	353	191	10/22/08	399	215
13		ER_20	Eramosa R @ Wellington Rd 125	93.7	7/7/08	376	127	8/26/08	392	132	10/22/08	372	125
14		ER_30	Eramosa R @ Evert St	113.5	7/7/08	413	115	8/26/08	551	153	10/22/08	765	213
15		ER_40	Eramosa R @ Wellington Rd 29	227.9	7/7/08	1005	139	8/26/08	1179	163	10/22/08	1151	159
16		ER_GRCA	Eramosa R above Guelph	238.9	7/7/08	1348	178	8/26/08	1361	180	10/22/08	1647	218
17	Blue Springs Creek	BSC_10	Blue Springs Ck @ 5th Line	30.6	7/7/08	281	290	8/26/08	238	245	10/22/08	132	136
18		BSC_20	Blue Springs Ck @ 28th SDRD	17.1	7/7/08	25	46	8/26/08	36	66	10/22/08	59	109
19		BSC_30	Blue Springs Ck @ 1st Line	75.9	7/7/08	--	--	8/26/08	830	345	10/22/08	638	266
20	Torrance Creek	TC_10	Torrance Ck @ Stone Rd	10.7	7/7/08	30	88	8/26/08	34	99	10/22/08	16	46
21	Hanlon Creek	HC_10	Hanlon Ck @ Hwy 6	17.8	7/7/08	47	83	8/26/08	68	121	10/22/08	33	59
22		HCT_20	Hanlon Ck South Trib @ Hwy 6	5.1	7/7/08	0	0	8/26/08	0	0	10/22/08	0	0
23	Irish Creek	IC_10	Irish Ck @ Wellington Rd 32	17.8	7/7/08	8	14	8/26/08	31	55	10/22/08	23	41
24		IC_20	Irish Ck @ Townline	38.3	7/7/08	62	51	8/26/08	106	87	10/22/08	107	88
25	Mill Creek	MC_10	Mill Ck @ Victoria Rd	13.3	7/7/08	18	43	8/26/08	22	51	10/22/08	16	38
26		MC_20	Mill Ck @ Wellington Rd 35	71.2	7/7/08	384	170	8/26/08	383	170	10/22/08	408	181
27	Ellis Creek	EC_10	Ellis Ck @ Wellington Rd 32	12.5	7/7/08	5	13	8/26/08	2	5	10/22/08	15	39
28		CGC_10	Ellis (Chilligo) Ck @ Kossuth Rd	40.3	7/7/08	--	--	8/27/08	90	71	10/22/08	114	90
29		EC_20	Ellis Ck @ Maple Grove Rd	53.8	7/7/08	117	69	8/26/08	215	126	10/22/08	141	83
30	East Creek	ESTC_10	East Ck at Beaverdale	1.4	7/7/08	--	--	8/27/08	5	114	10/22/08	15	330
31	Swan Creek	SC_10	Swan Ck @ SDRD 4 at HWY 23	43.0	7/7/08	77	56	8/26/08	122	89	10/22/08	233	171
32	Cox Creek	CC_10	Cox Ck @ 6th Line E	29.2	7/7/08	14	15	8/26/08	31	33	10/22/08	84	91
33		CCT_20	Cox Ck south Trib @ 6th Line E	19.0	7/7/08	6	10	8/26/08	28	47	10/22/08	44	73
34		CC_30	Cox Ck @ Cox Creek Rd	85.2	7/7/08	65	24	8/26/08	122	45	10/22/08	261	97
35	Hopewell Creek	HWC_10	Hopewell Ck @ Wellington Rd 32	30.7	7/7/08	23	24	8/26/08	19	19	10/22/08	55	56
36		HWC_20	Hopewell Ck @ Greenhouse Rd	48.3	7/7/08	45	29	8/26/08	57	37	10/22/08	83	54
37		HWC_30	Hopewell Ck West @ Hopewell Ck Rd	18.3	7/7/08	--	--	8/28/08	38	66	10/22/08	62	106
38		HWC_50	Hopewell Ck Downstream of Hwy 7	70.8	7/7/08	--	--	8/27/08	92	41	10/21/08	163	72
39		HWC_60	Hopewell Ck @ Breslau Dam	73.8	7/7/08	--	--	8/27/08	94	40	10/22/08	187	80
40	Airport Creek	AC_10	Airport Ck @ Grand River	11.4	7/7/08	--	--	8/26/08	49	136	10/22/08	59	163
41	Freeport Creek	FC_10	Freeport Ck @ King St	3.0	7/7/08	--	--	8/26/08	--	--	10/21/08	11	112
42	West Creek	WC_10	West Ck @ Cherry Blossom Rd	2.8	7/7/08	--	--	8/27/08	10	112	10/22/08	12	137

Table 3: Summary of Summer/Fall 2008 Spot Flows Measurements, Catchment Yields and Depths over Catchment Area

					July				August				October			
No	Stream	Code	Name	Catchment Area (km^2)	Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)	Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)	Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)
1	Speed River	SR_10	Speed R @ Wellington Rd 26	30.0	7/7/08	61	61	64	8/26/08	151	151	159	10/22/08	296	296	312
2		SR_20	Speed R @ 6th Line	9.2	7/7/08	83	22	76	8/26/08	116	-35	-119	10/22/08	325	29	98
3		SR_30	Speed R @ 3rd Line	42.7	7/7/08	141	59	43	8/26/08	279	163	120	10/22/08	676	351	260
4		SR_40	Speed R @ Jones Baseline	9.3	7/7/08	127	-14	-48	8/26/08	202	-77	-263	10/22/08	612	-64	-216
5		SR_GRCA	Speed R near Armstrong Mills	11.3	7/7/08	296	-25	-70	8/26/08	548	67	187	10/22/08	--	--	--
6	Lutteral Creek	LC_10	Lutteral Ck @ Sideroad 20	49.1	7/7/08	97	97	63	8/26/08	189	189	121	10/22/08	301	301	194
7		LCT_20	Lutteral Ck Trib @ 6th Line	5.5	7/7/08	9	9	52	8/26/08	12	12	68	10/22/08	38	38	218
8		LC_30	Lutteral Ck @ 3rd Line	12.4	7/7/08	194	87	222	8/26/08	279	79	199	10/22/08	525	186	472
9	Guelph Lake	GLT_10	Guelph Lk Cold Trib @ 3rd Line	19.0	7/7/08	37	37	61	8/26/08	33	33	55	10/22/08	51	51	85
10		GLT_20	Guelph Lk Trib @ Jones Baseline	17.8	7/7/08	25	25	44	8/26/08	17	17	31	10/22/08	--	--	--
11	Marden Creek	MDC_10	Marden Ck @ Wellington Rd 30	16.2	7/7/08	22	22	43	8/26/08	67	67	131	10/22/08	52	52	102
12	Eramosa River	ER_10	Eramosa R @ 3rd Line	58.4	7/7/08	319	319	172	8/26/08	353	353	191	10/22/08	399	399	215
13		ER_20	Eramosa R @ Wellington Rd 125	35.3	7/7/08	376	57	51	8/26/08	392	39	35	10/22/08	372	-27	-24
14		ER_30	Eramosa R @ Evert St	19.8	7/7/08	413	37	59	8/26/08	551	159	254	10/22/08	765	392	626
15		ER_40	Eramosa R @ Wellington Rd 29	38.5	7/7/08	1005	--	--	8/26/08	1179	-202	-166	10/22/08	1151	-252	-206
16		ER_GRCA	Eramosa R above Guelph	11.0	7/7/08	1348	343	984	8/26/08	1361	182	523	10/22/08	1647	495	1421
17	Blue Springs Creek	BSC_10	Blue Springs Ck @ 5th Line	30.6	7/7/08	281	281	290	8/26/08	238	238	245	10/22/08	132	132	136
18		BSC_20	Blue Springs Ck @ 28th SDRD	17.1	7/7/08	25	25	46	8/26/08	36	36	66	10/22/08	59	59	109
19		BSC_30	Blue Springs Ck @ 1st Line	28.1	7/7/08	--	--	--	8/26/08	830	556	624	10/22/08	638	448	502
20	Torrance Creek	TC_10	Torrance Ck @ Stone Rd	10.7	7/7/08	30	30	88	8/26/08	34	34	99	10/22/08	16	16	46
21	Hanlon Creek	HC_10	Hanlon Ck @ Hwy 6	17.8	7/7/08	47	47	83	8/26/08	68	68	121	10/22/08	33	33	59
22		HCT_20	Hanlon Ck South Trib @ Hwy 6	5.1	7/7/08	0	0	0	8/26/08	0	0	0	10/22/08	0	0	0
23	Irish Creek	IC_10	Irish Ck @ Wellington Rd 32	17.8	7/7/08	8	8	14	8/26/08	31	31	55	10/22/08	23	23	41

No	Stream	Code	Name	Catchment Area (km^2)	July				August				October			
					Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)	Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)	Date	Flow (L/s)	Yield (L/s)	Depth (mm/y)
24		IC_20	Irish Ck @ Townline	20.6	7/7/08	62	54	83	8/26/08	106	75	115	10/22/08	107	84	128
25	Mill Creek	MC_10	Mill Ck @ Victoria Rd	13.3	7/7/08	18	18	43	8/26/08	22	22	51	10/22/08	16	16	38
26		MC_20	Mill Ck @ Wellington Rd 35	57.8	7/7/08	384	366	200	8/26/08	383	362	197	10/22/08	408	392	214
27	Ellis Creek	EC_10	Ellis Ck @ Wellington Rd 32	12.5	7/7/08	5	5	13	8/26/08	2	2	5	10/22/08	15	15	39
28		CGC_10	Ellis (Chilligo) Ck @ Kossuth Rd	27.8	7/7/08	--	--	--	8/27/08	90	88	100	10/22/08	114	99	112
29		EC_20	Ellis Ck @ Maple Grove Rd	13.5	7/7/08	117	--	--	8/26/08	215	125	291	10/22/08	141	27	63
30	East Creek	ESTC_10	East Ck at Beaverdale	1.4	7/7/08	--	--	--	8/27/08	5	5	114	10/22/08	15	15	330
31	Swan Creek	SC_10	Swan Ck @ SDRD 4 at HWY 23	43.0	7/7/08	77	77	56	8/26/08	122	122	89	10/22/08	233	233	171
32	Cox Creek	CC_10	Cox Ck @ 6th Line E	29.2	7/7/08	14	14	15	8/26/08	31	31	33	10/22/08	84	84	91
33		CCT_20	Cox Ck south Trib @ 6th Line E	19.0	7/7/08	6	6	10	8/26/08	28	28	47	10/22/08	44	44	73
34		CC_30	Cox Ck @ Cox Creek Rd	37.1	7/7/08	65	46	39	8/26/08	122	64	54	10/22/08	261	133	113
35	Hopewell Creek	HWC_10	Hopewell Ck @ Wellington Rd 32	30.7	7/7/08	23	23	24	8/26/08	19	19	19	10/22/08	55	55	56
36		HWC_20	Hopewell Ck @ Greenhouse Rd	17.6	7/7/08	45	22	39	8/26/08	57	39	70	10/22/08	83	28	51
37		HWC_30	Hopewell Ck West @ Hopewell Ck Rd	18.3	7/7/08	--	--	--	8/28/08	38	38	66	10/22/08	62	62	106
38		HWC_50	Hopewell Ck Downstream of Hwy 7	4.3	7/7/08	--	--	--	8/27/08	92	-3	-24	10/21/08	163	18	133
39		HWC_60	Hopewell Ck @ Breslau Dam	2.9	7/7/08	--	--	--	8/27/08	94	2	21	10/22/08	187	24	257
40	Airport Creek	AC_10	Airport Ck @ Grand River	11.4	7/7/08	--	--	--	8/26/08	49	49	136	10/22/08	59	59	163
41	Freeport Creek	FC_10	Freeport Ck @ King St	3.0	7/7/08	--	--	--	8/26/08	--	--	--	10/21/08	11	11	112
42	West Creek	WC_10	West Ck @ Cherry Blossom Rd	2.8	7/7/08	--	--	--	8/27/08	10	10	112	10/22/08	12	12	137

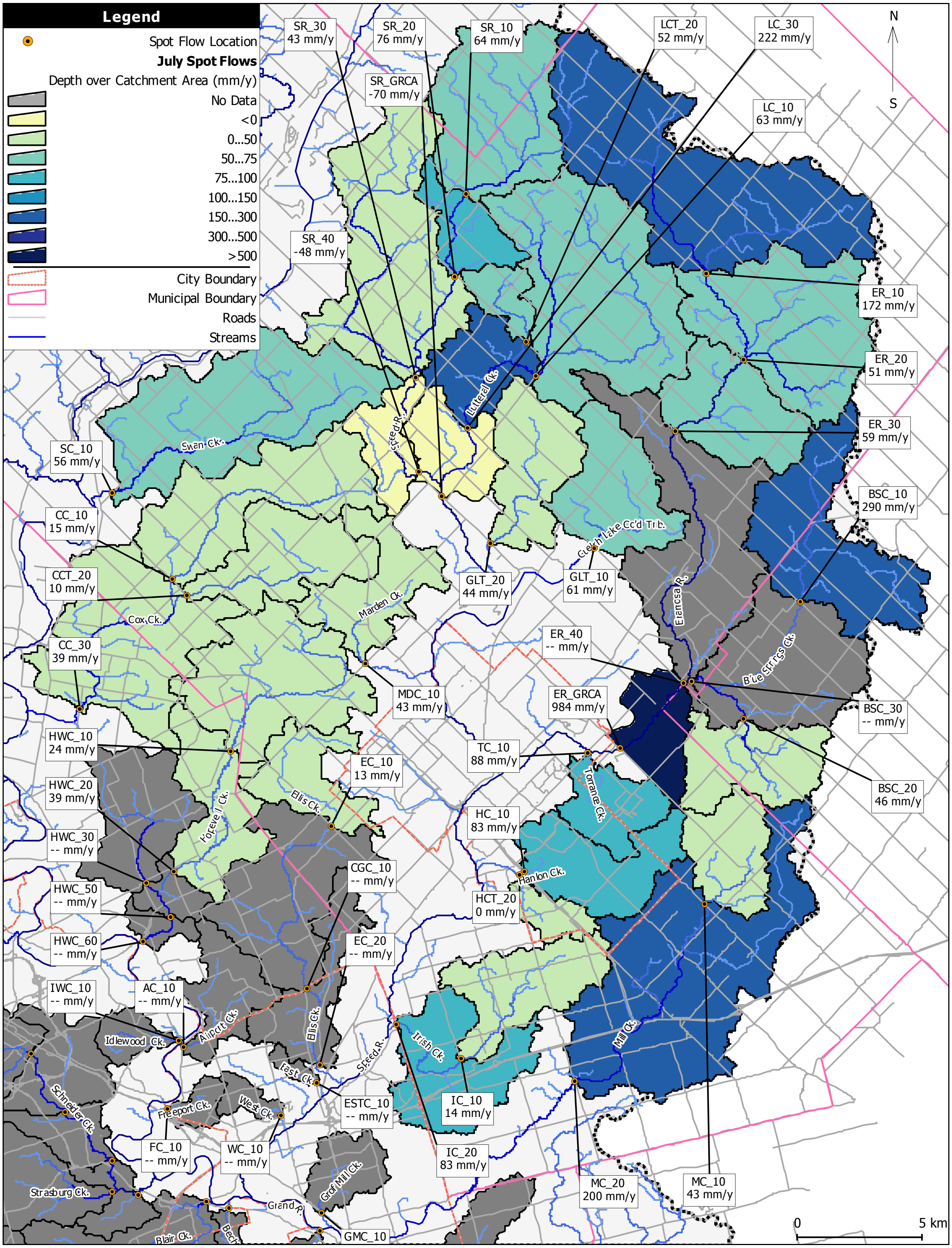


Figure 4: July Spot Flows as Relative Depths over Catchment Areas

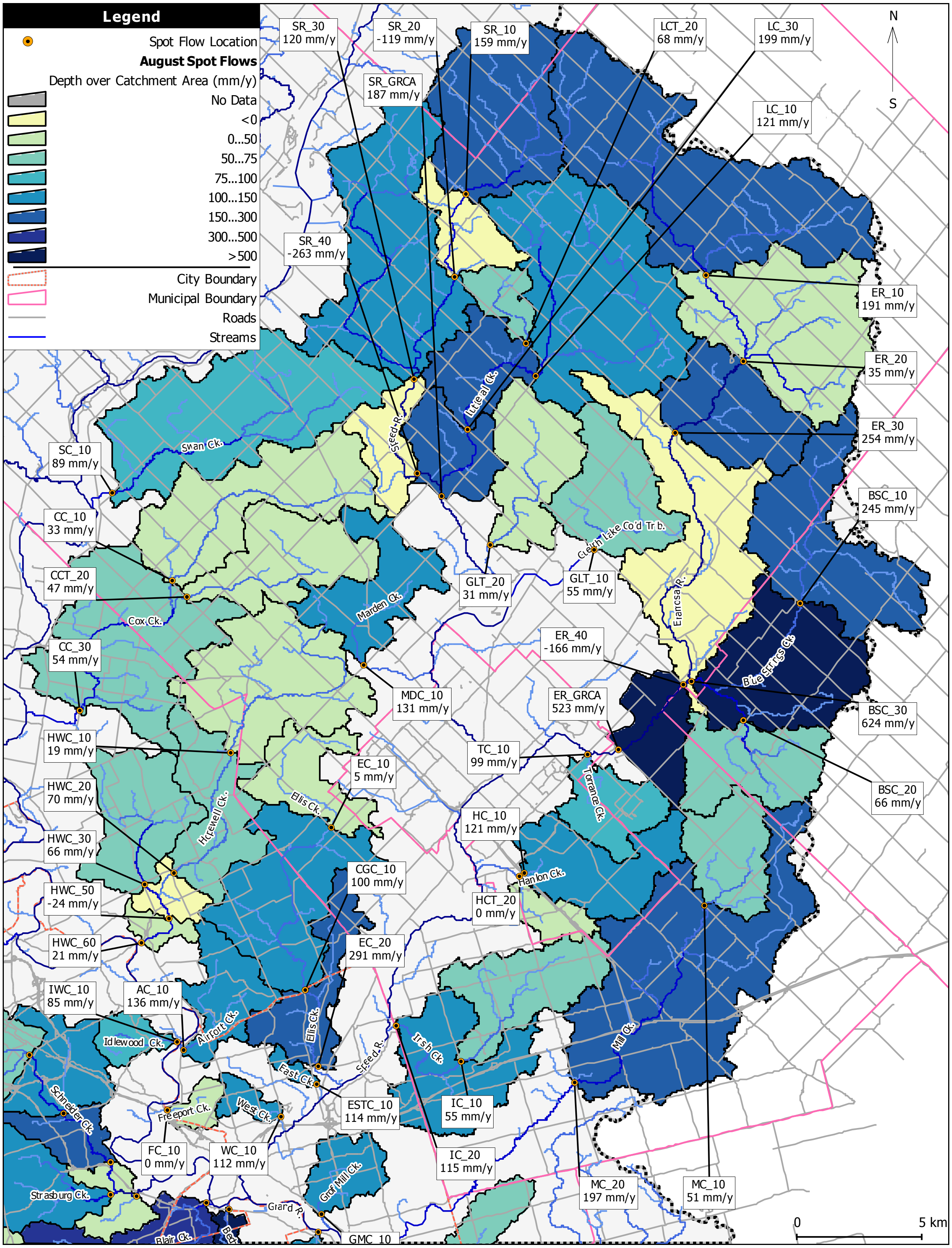


Figure 5: August Spot Flows as Relative Depths over Catchment Areas

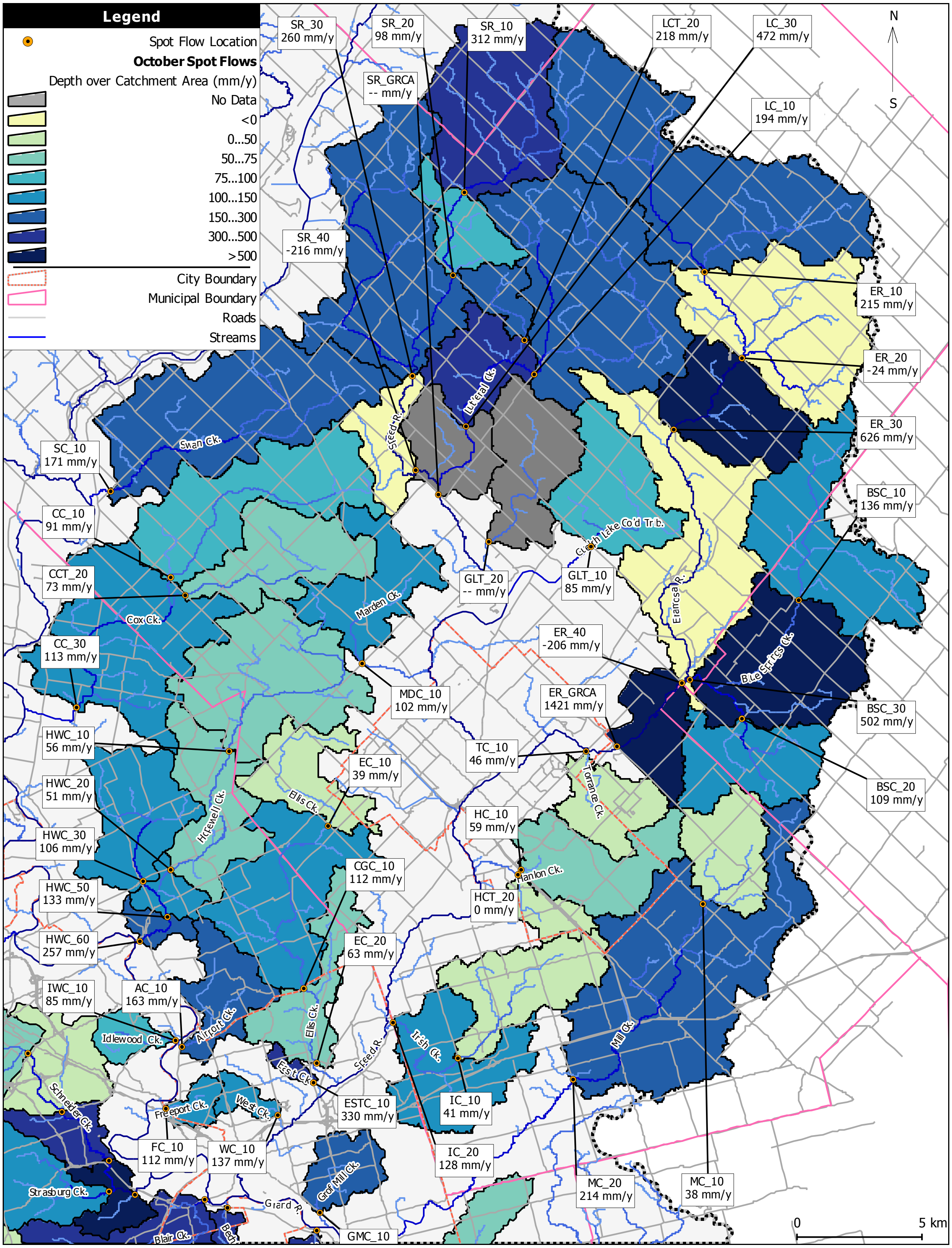


Figure 6: October Spot Flows as Relative Depths over Catchment Areas

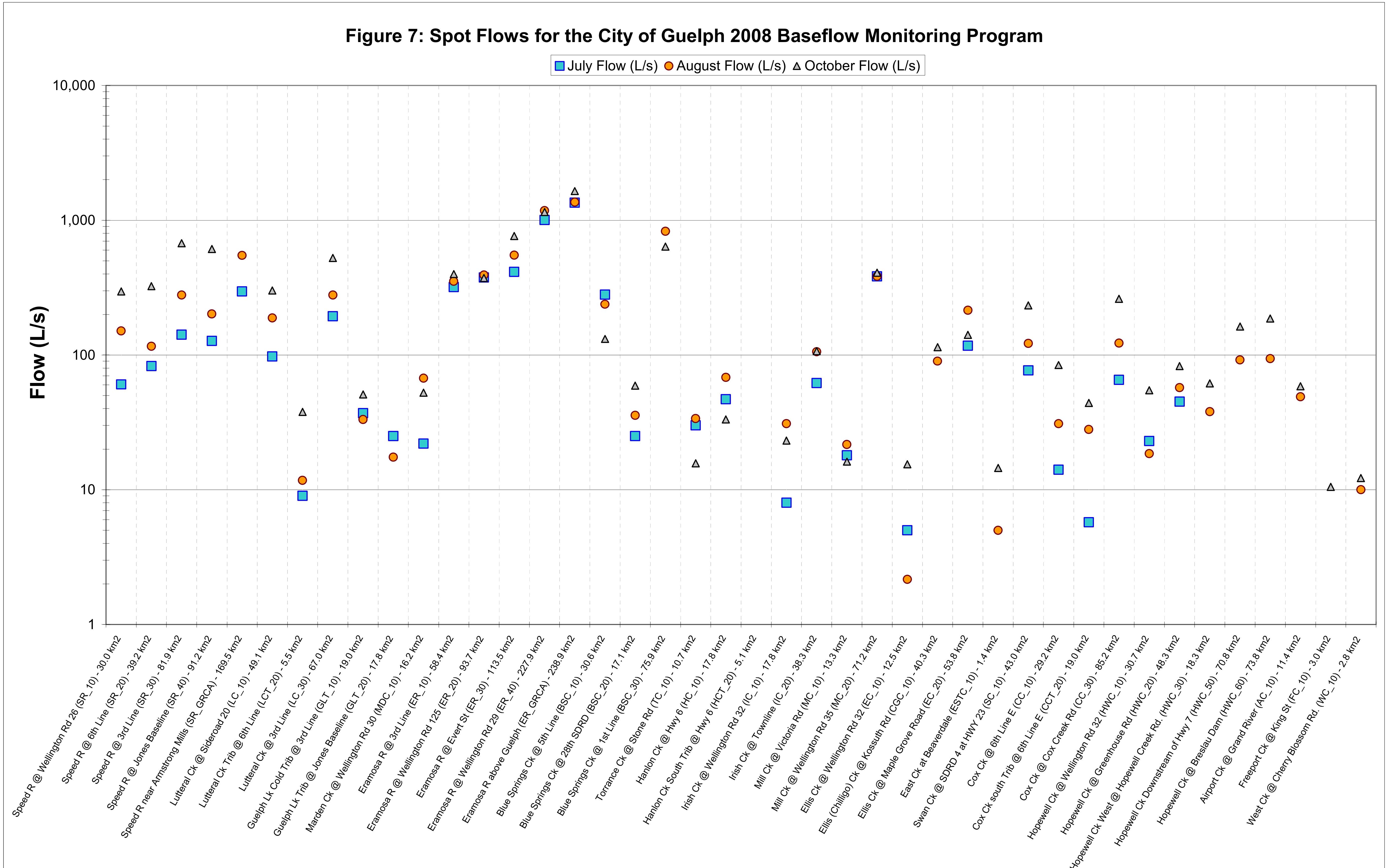
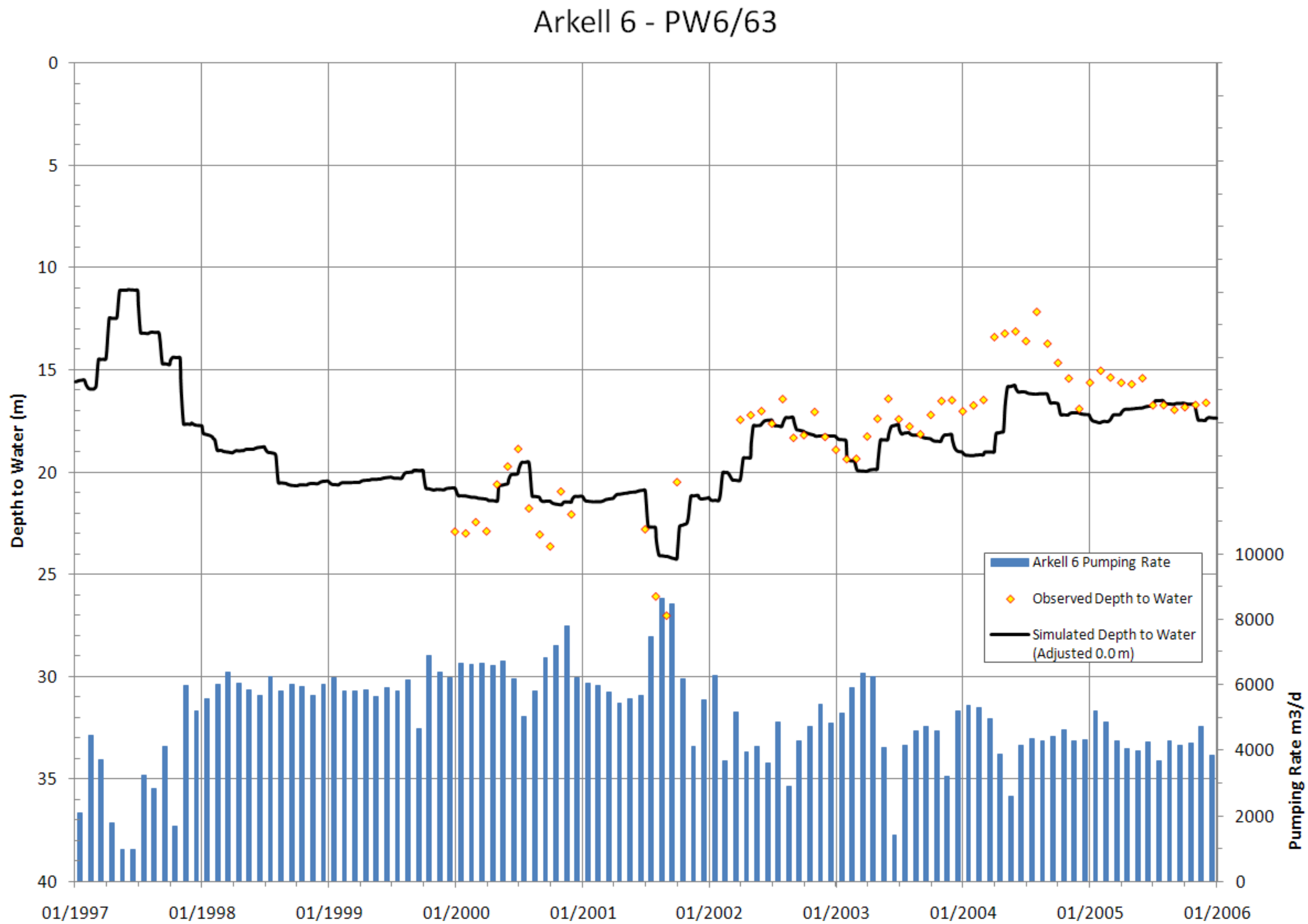


Figure 7: Spot Flows for the City of Guelph 2008 Baseflow Monitoring Program
July Flow (L/s)
August Flow (L/s)
October Flow (L/s)
Flow (L/s)
10,000
1,000
100
10
1
Speed R @ Wellington Rd 26 (SR_10) - 30.0 km2
Speed R @ 6th Line (SR_20) - 39.2 km2
Speed R @ 3rd Line (SR_30) - 81.9 km2
Speed R @ Jones Baseline (SR_40) - 91.2 km2
Speed R near Armstrong Mills (SR_GRCA) - 169.5 km2
Lutteral Ck @ Sideroad 20 (LC_10) - 49.1 km2
Lutteral Ck Trib @ 6th Line (LCT_20) - 5.5 km2
Lutteral Ck @ 3rd Line (LC_30) - 67.0 km2
Guelph Lk Cold Trib @ 3rd Line (GLT_10) - 19.0 km2
Guelph Lk Trib @ Jones Baseline (GLT_20) - 17.8 km2
Marden Ck @ Wellington Rd 30 (MDC_10) - 16.2 km2
Eramosa R @ 3rd Line (ER_10) - 58.4 km2
Eramosa R @ Wellington Rd 125 (ER_20) - 93.7 km2
Eramosa R @ Evert St (ER_30) - 113.5 km2
Eramosa R @ Wellington Rd 29 (ER_40) - 227.9 km2
Eramosa R above Guelph (ER_GRCA) - 238.9 km2
Blue Springs Ck @ 5th Line (BSC_10) - 30.6 km2
Blue Springs Ck @ 28th SDRD (BSC_20) - 17.1 km2
Blue Springs Ck @ 1st Line (BSC_30) - 75.9 km2
Torrance Ck @ Stone Rd (TC_10) - 10.7 km2
Hanlon Ck @ Hwy 6 (HC_10) - 17.8 km2
Hanlon Ck South Trib @ Hwy 6 (HCT_20) - 5.1 km2
Irish Ck @ Wellington Rd 32 (IC_10) - 17.8 km2
Irish Ck @ Townline (IC_20) - 38.3 km2
Mill Ck @ Victoria Rd (MC_10) - 13.3 km2
Mill Ck @ Wellington Rd 35 (MC_20) - 71.2 km2
Ellis Ck @ Wellington Rd 32 (EC_10) - 12.5 km2
Ellis (Chilligo) Ck @ Kossuth Rd (CGC_10) - 40.3 km2
Ellis Ck @ Maple Grove Road (EC_20) - 53.8 km2
East Ck at Beaverdale (ESTC_10) - 1.4 km2
Swan Ck @ SDRD 4 at HWY 23 (SC_10) - 43.0 km2
Cox Ck @ 6th Line E (CC_10) - 29.2 km2
Cox Ck south Trib @ 6th Line E (CCT_20) - 19.0 km2
Cox Ck @ Cox Creek Rd (CC_30) - 85.2 km2
Hopewell Ck @ Wellington Rd 32 (HWC_10) - 30.7 km2
Hopewell Ck @ Greenhouse Rd (HWC_20) - 48.3 km2
Hopewell Ck West @ Hopewell Creek Rd. (HWC_30) - 18.3 km2
Hopewell Ck Downstream of Hwy 7 (HWC_50) - 70.8 km2
Hopewell Ck @ Breslau Dam (HWC_60) - 73.8 km2
Airport Ck @ Grand River (AC_10) - 11.4 km2
Freeport Ck @ King St (FC_10) - 3.0 km2
West Ck @ Cherry Blossom Rd. (WC_10) - 2.8 km2

Appendix B5 – Transient Verification Results
Hydraulic Head - Municipal Wells



Tier Three Local Area Risk Assessment

Guelph

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Figure B5-1

Transient Verification Results – Arkell 6

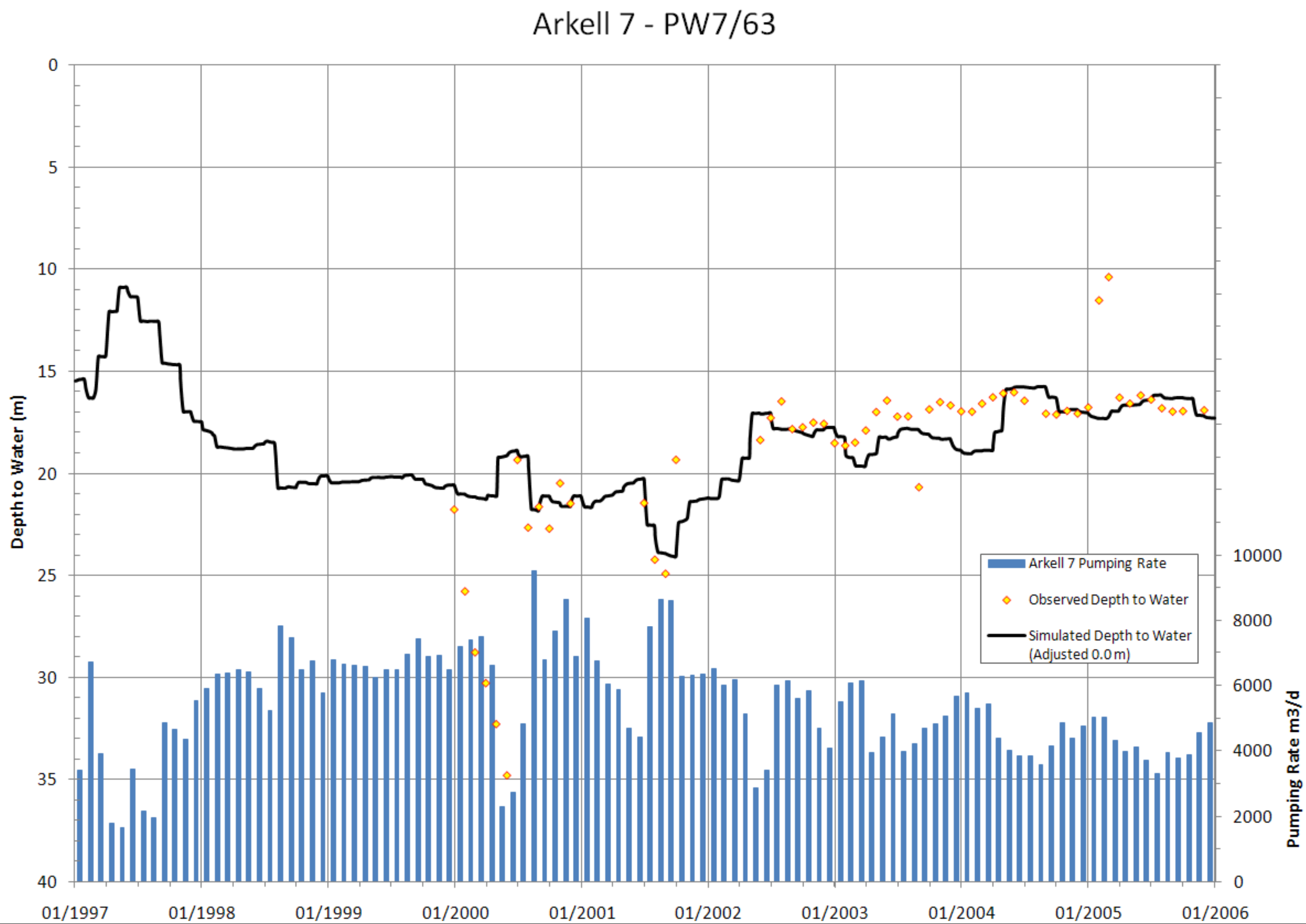

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Figure B5-2
Transient Verification Results – Arkell 7

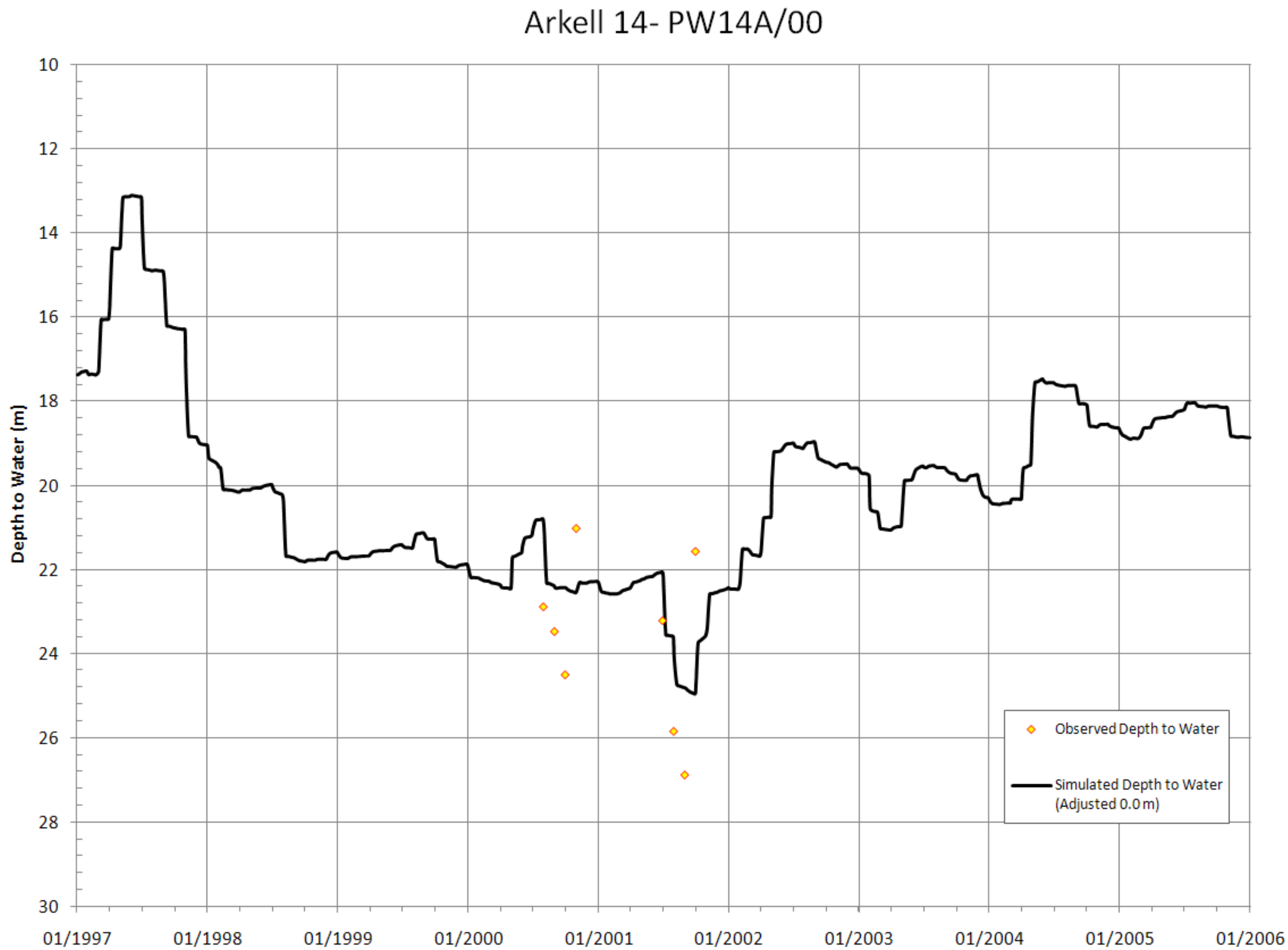

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Figure B5-3

Transient Verification Results – Arkell 14

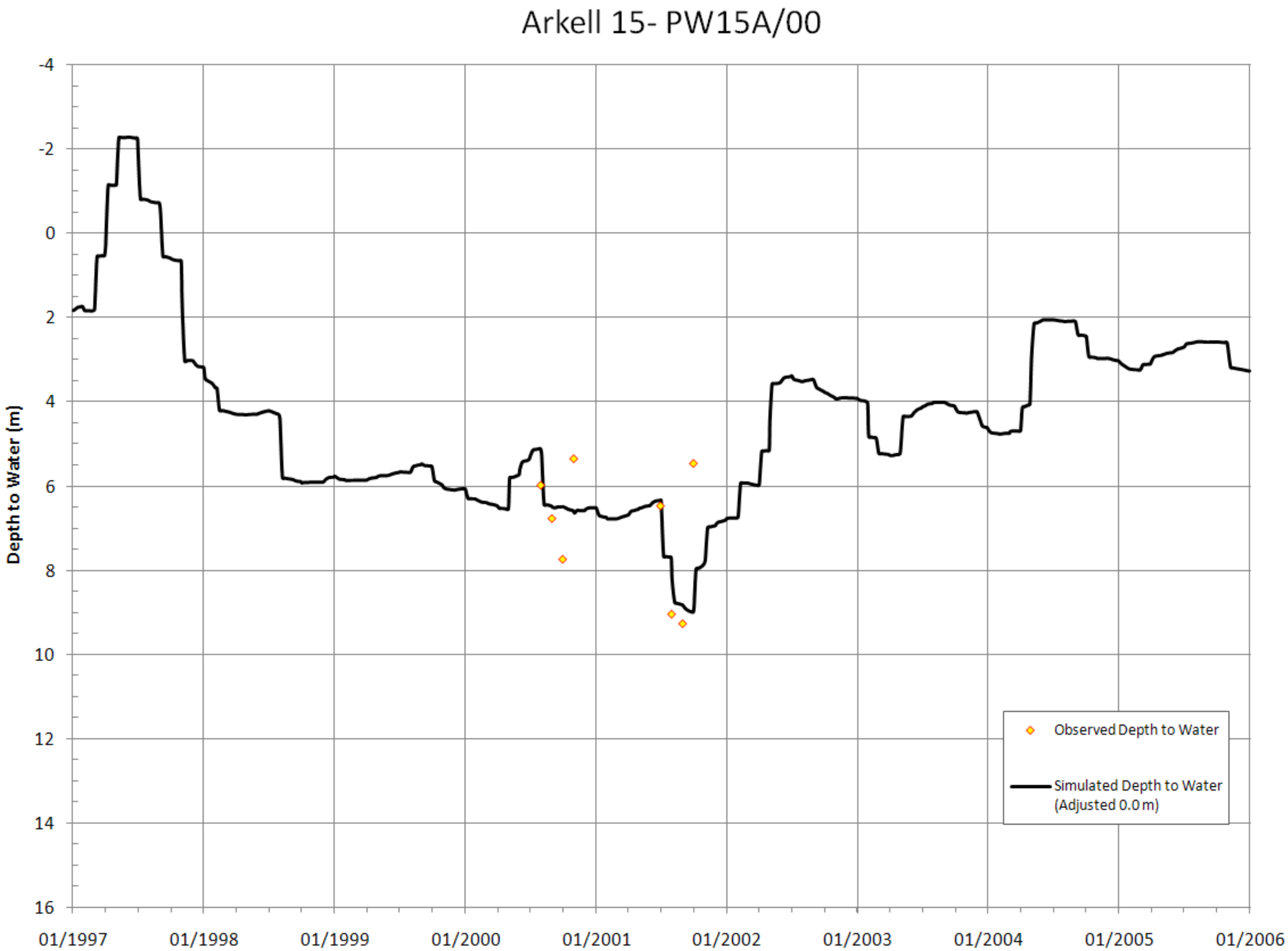

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Figure B5-4

Transient Verification Results – Arkell 15

Project: 2008003_Guelph_Tier3

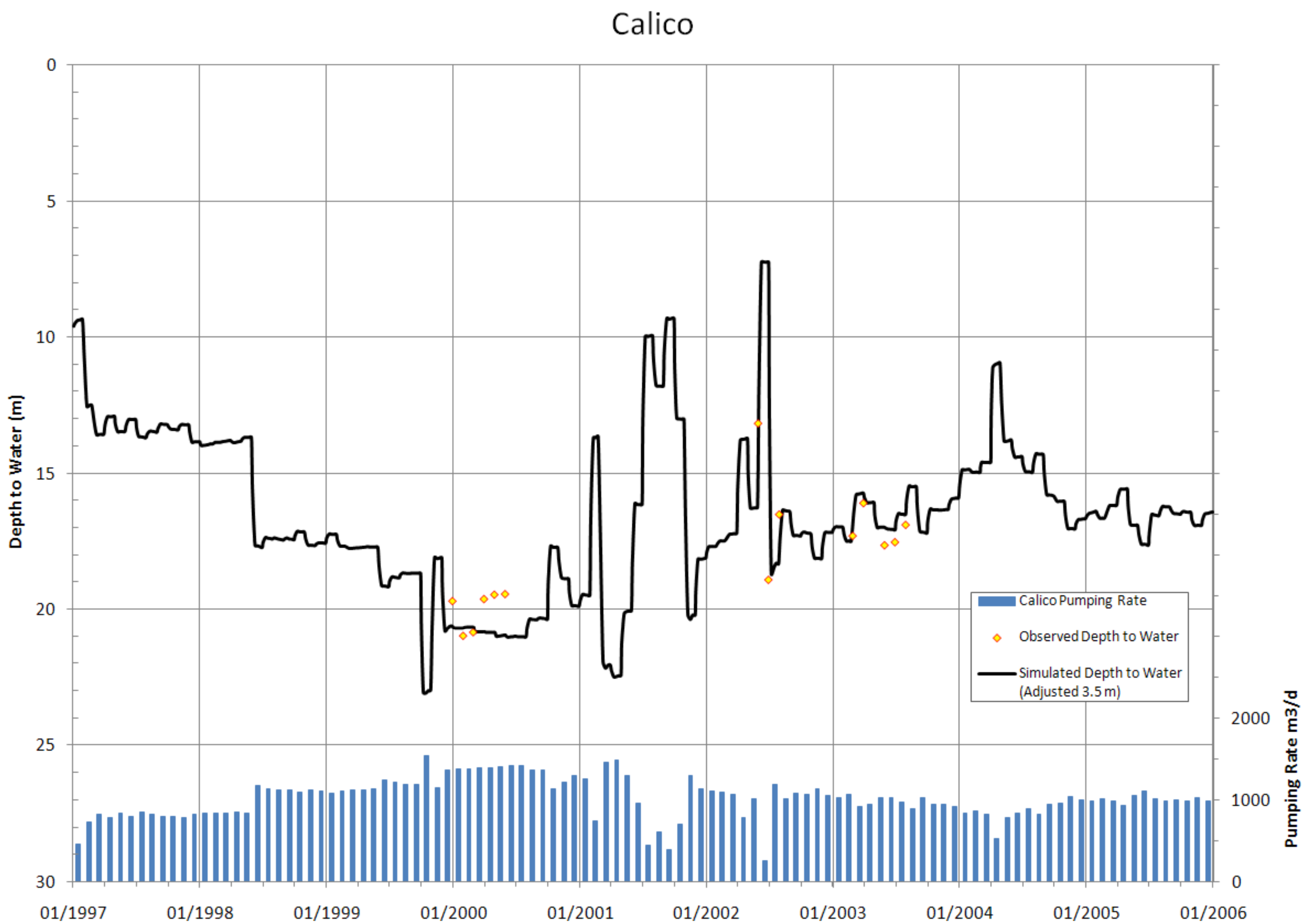

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Figure B5-5

Transient Verification Results – Calico

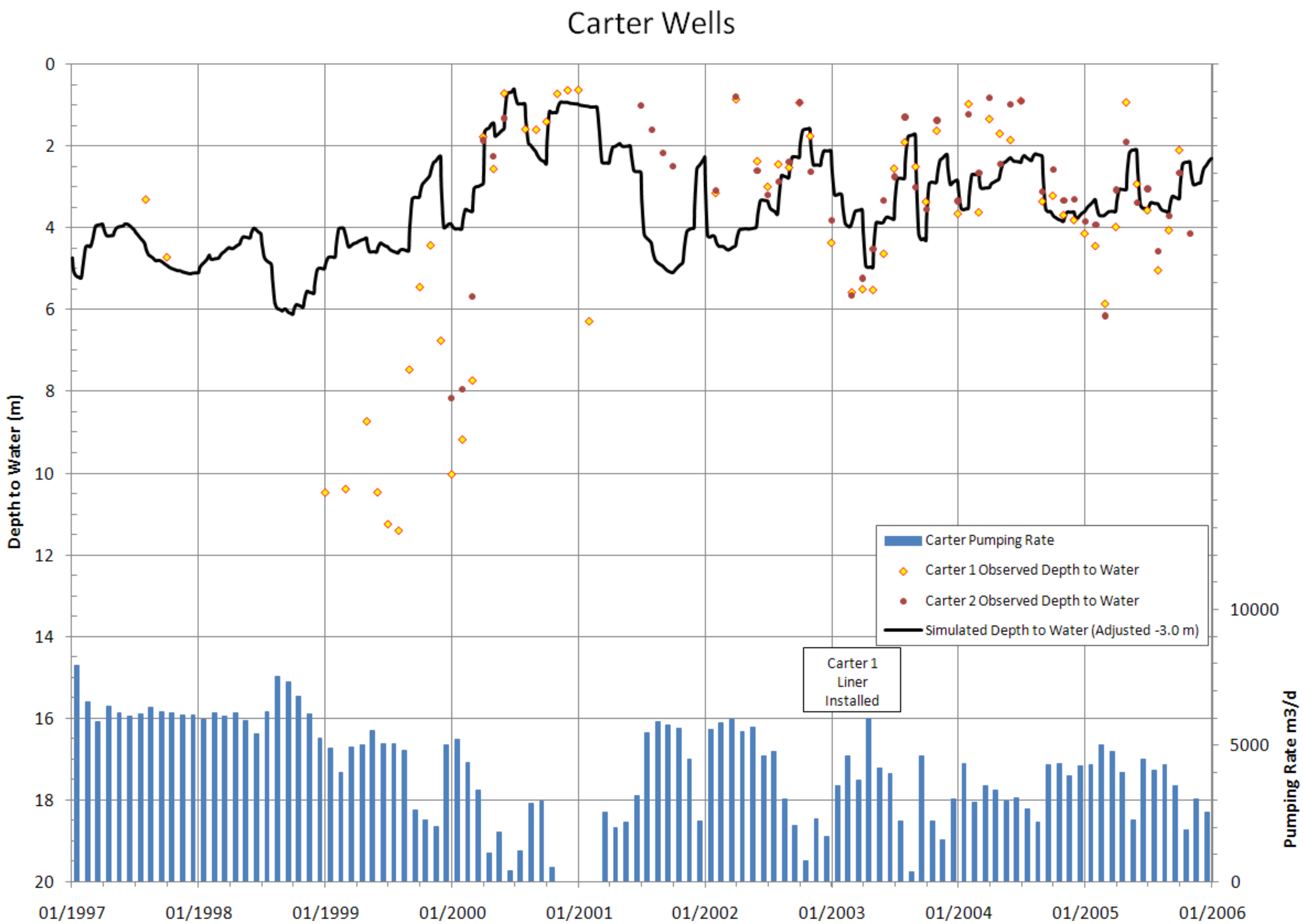

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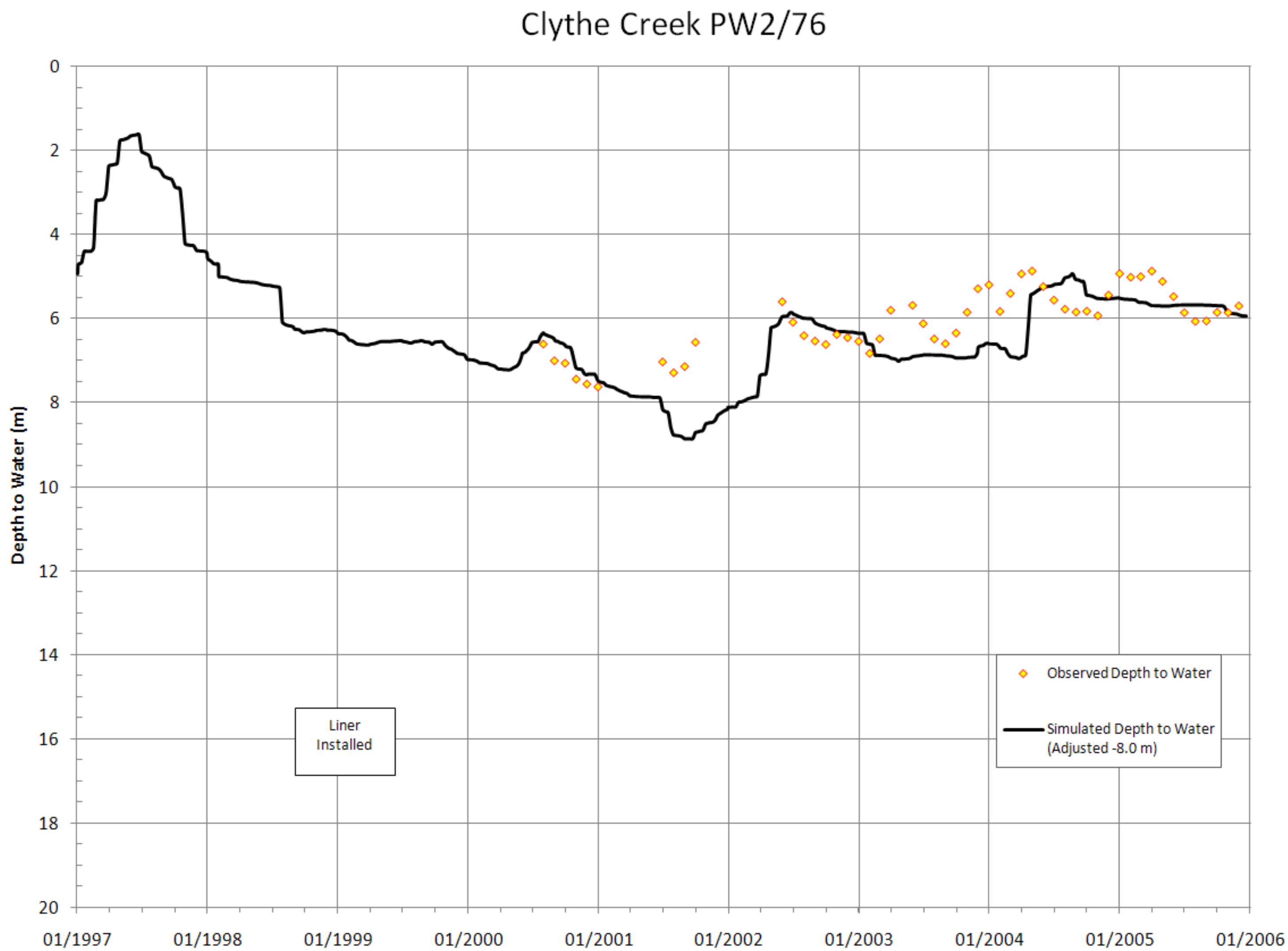
Figure B5-6
Transient Verification Results – Carter Wells

Project: 2008003_Guelph_Tier3



Tier Three Local Area Risk Assessment

Guelph

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Figure B5-7

Transient Verification Results – Clythe Creek

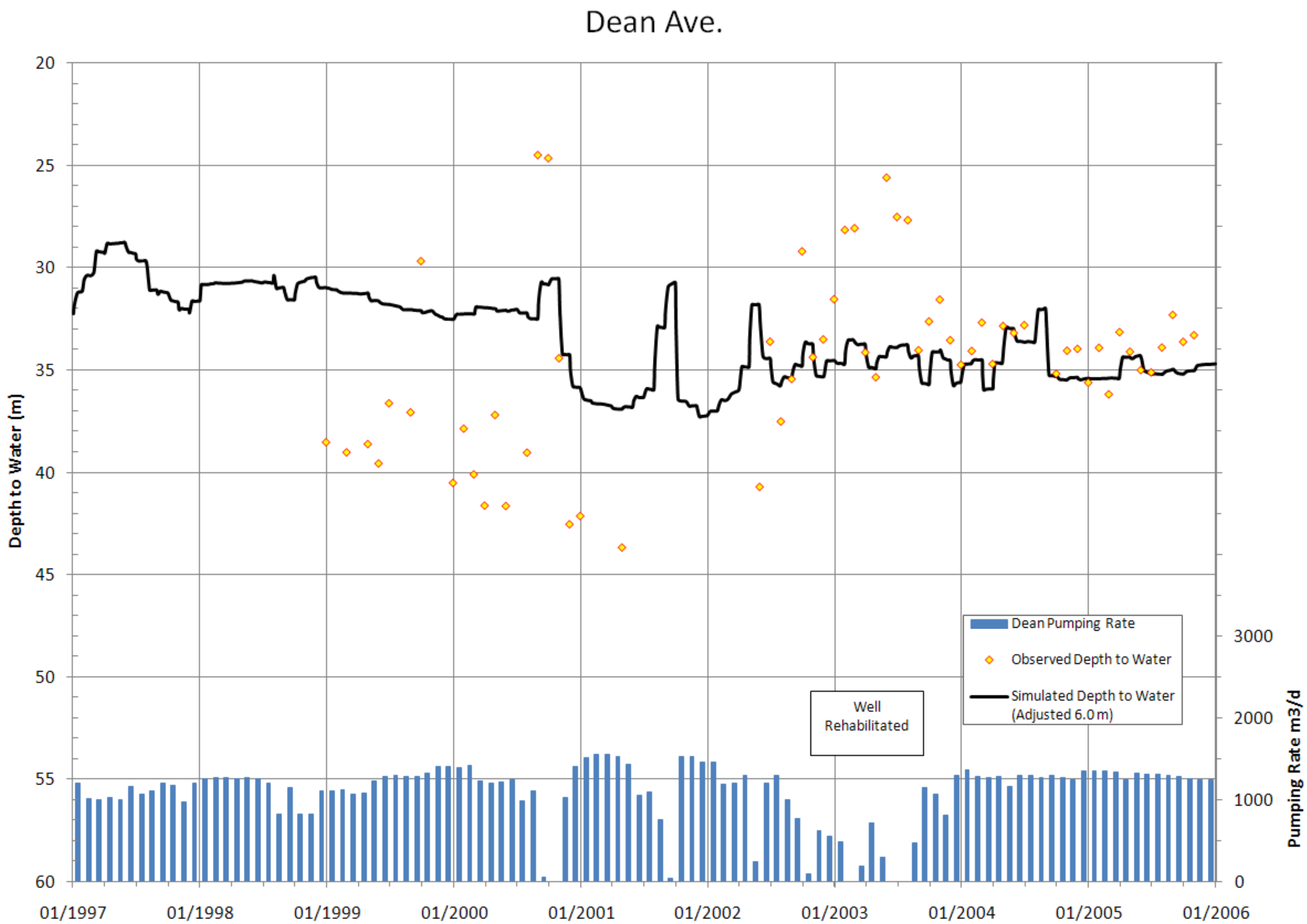

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Figure B5-8

Transient Verification Results – Dean Ave.

Project: 2008003_Guelph_Tier3

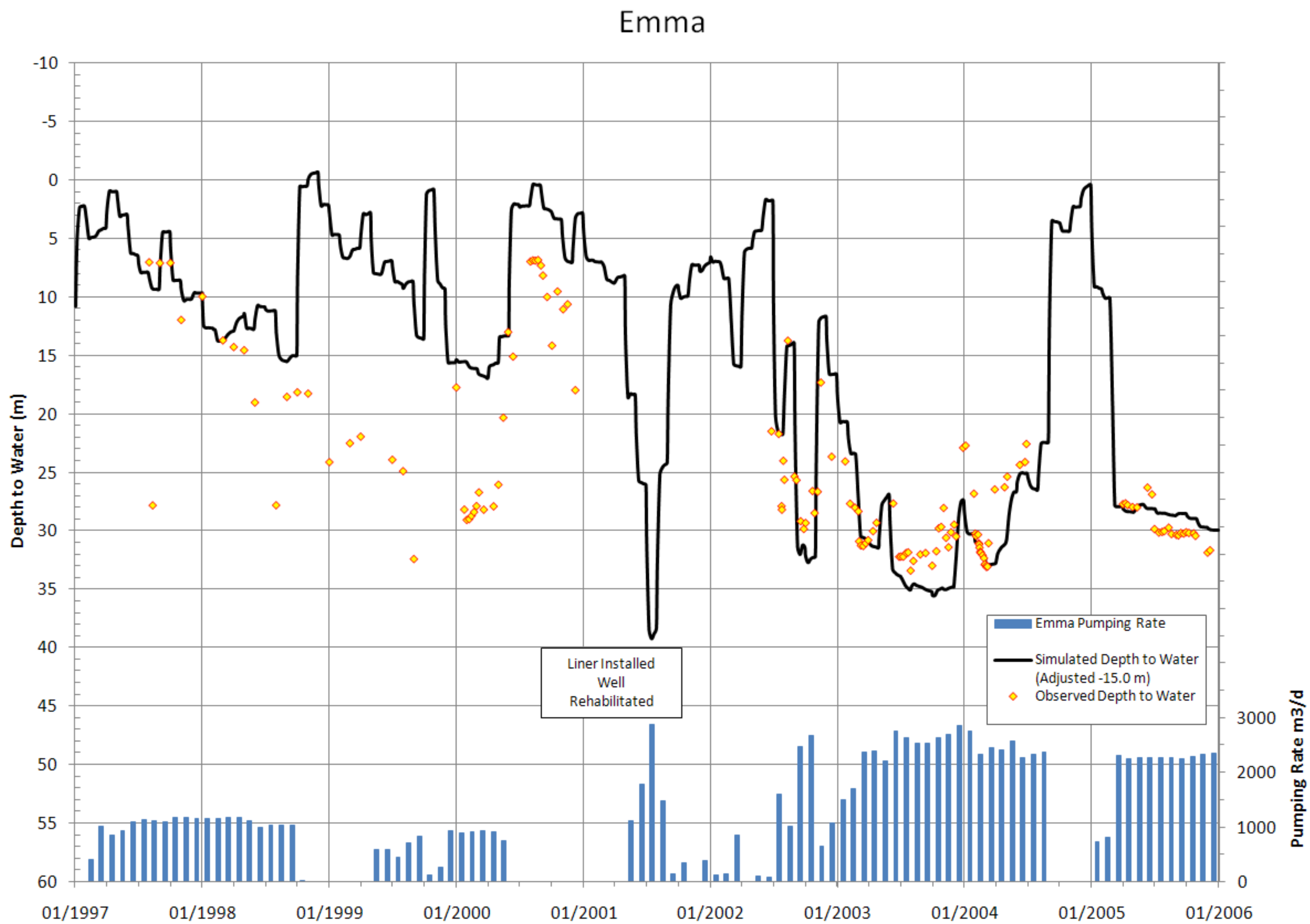

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Figure B5-9
Transient Verification Results – Emma

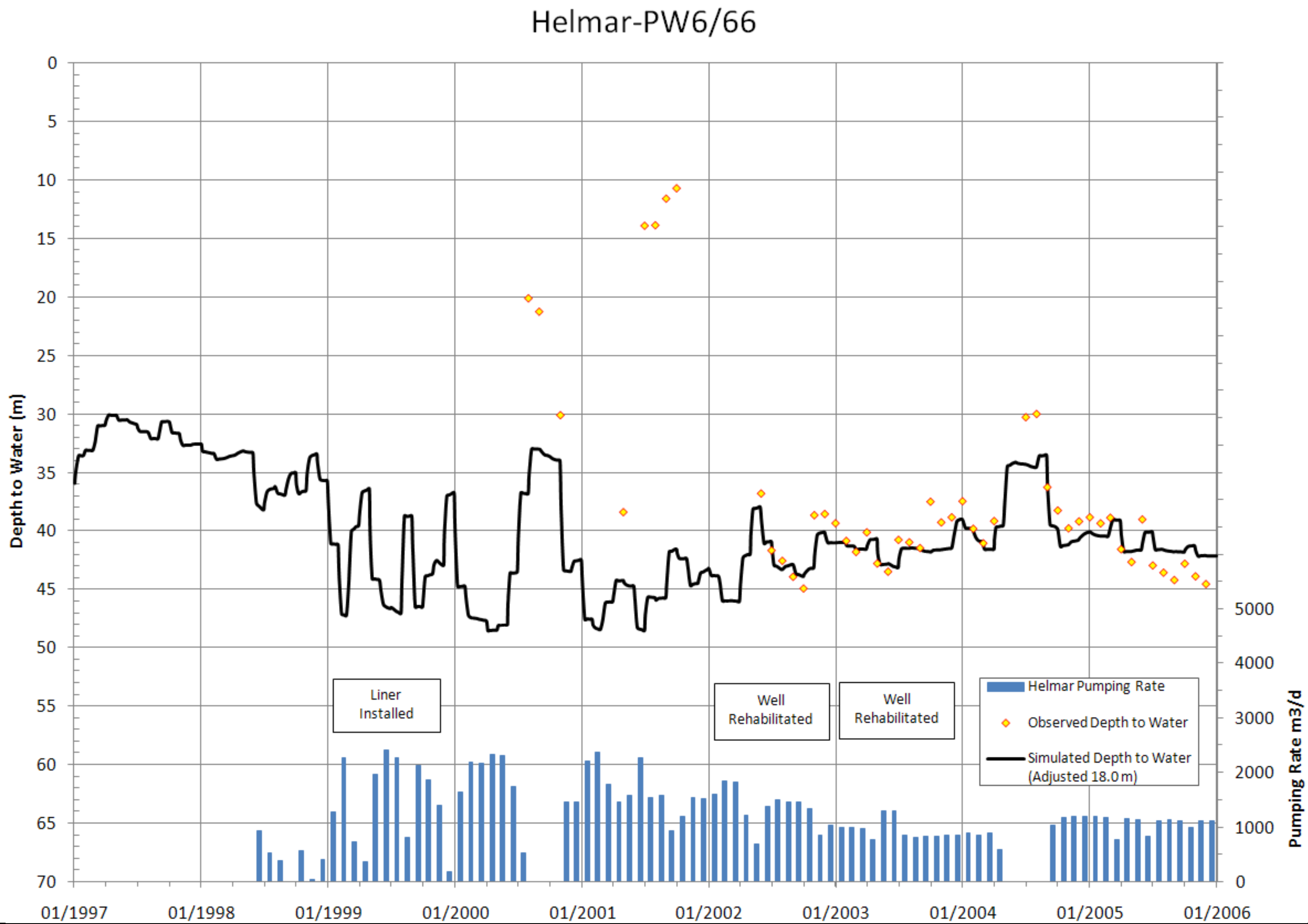

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Figure B5-10

Transient Verification Results – Helmar

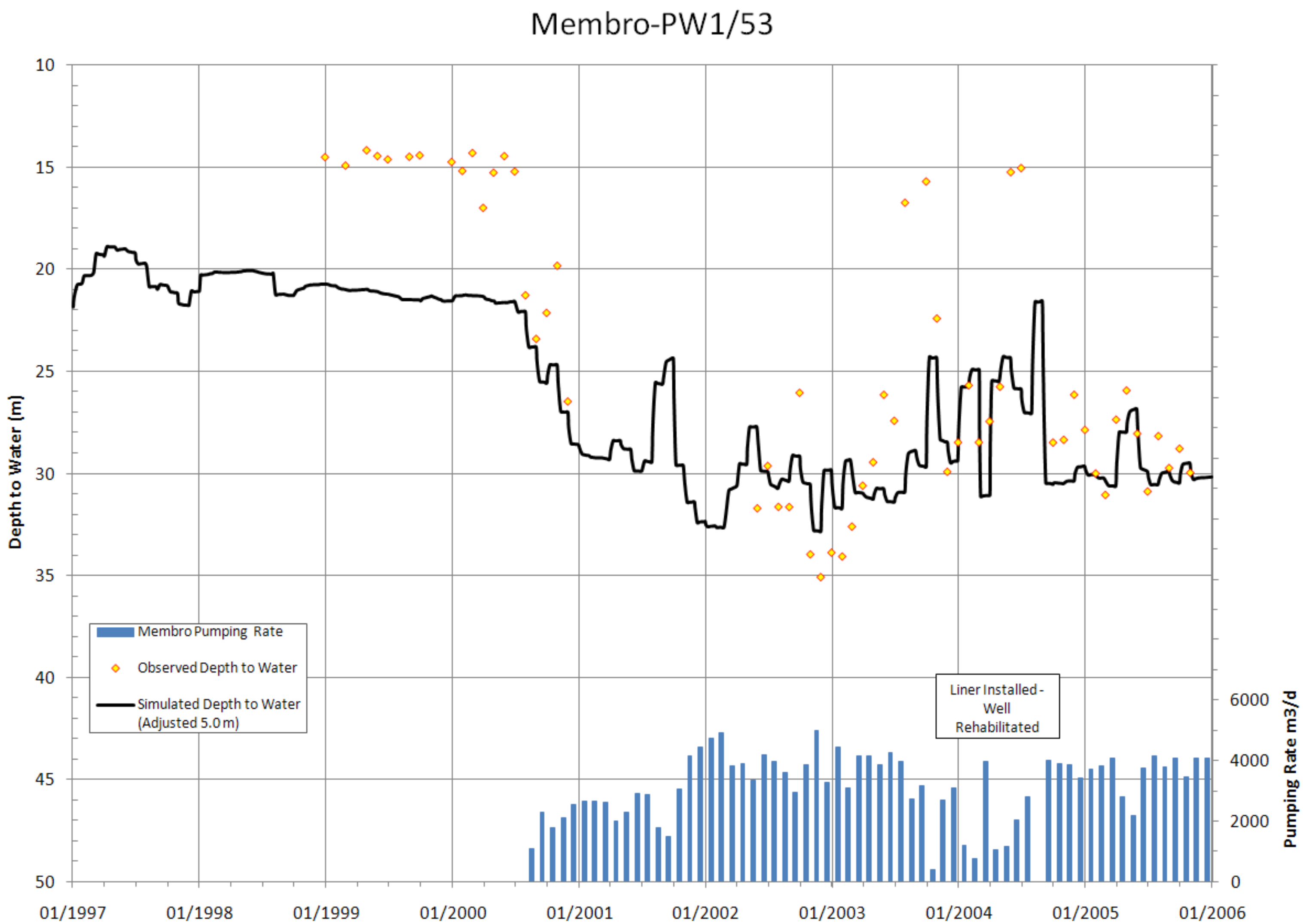

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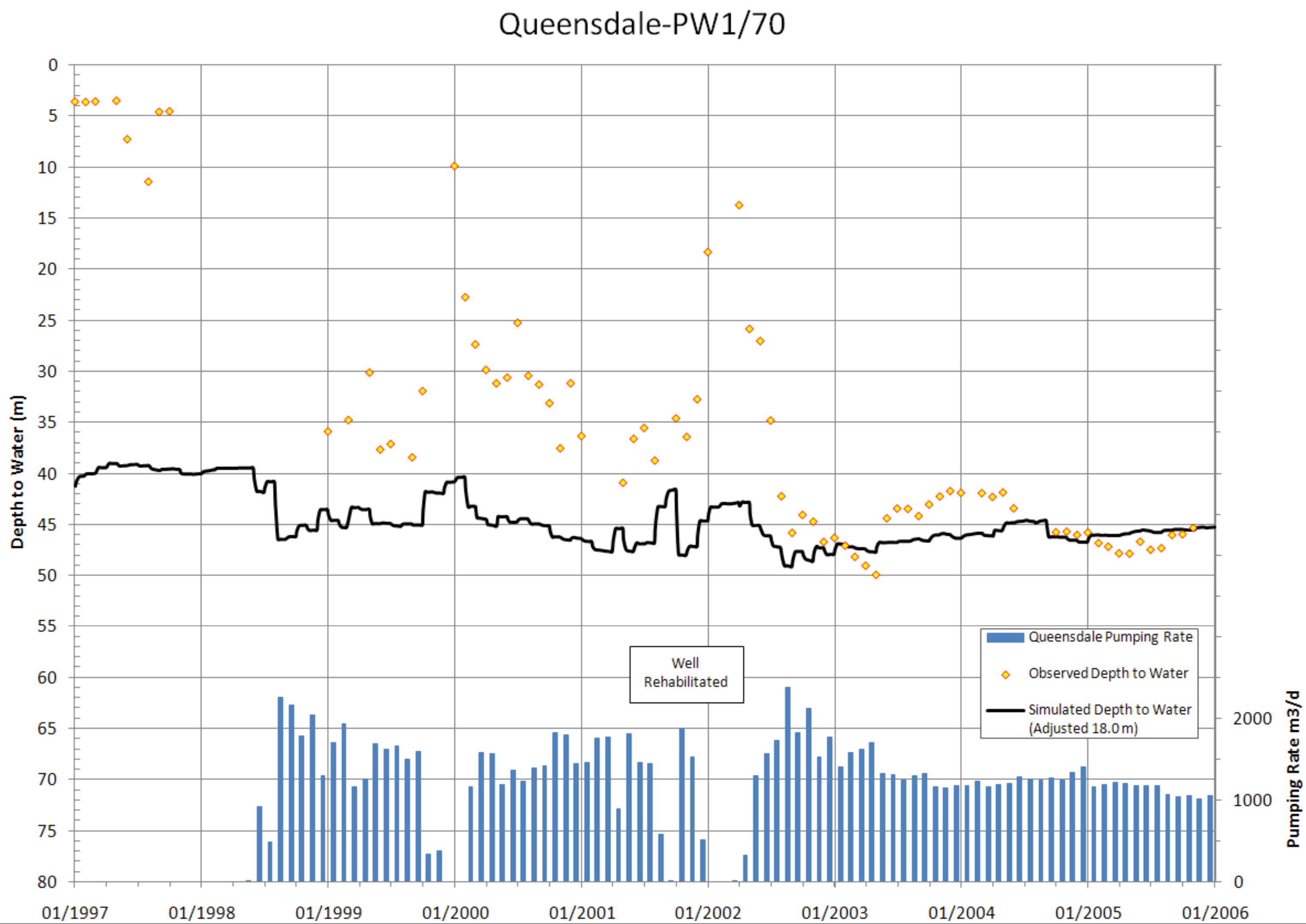
Figure B5-11
Transient Verification Results – Membro



Tier Three Local Area Risk Assessment

Guelph

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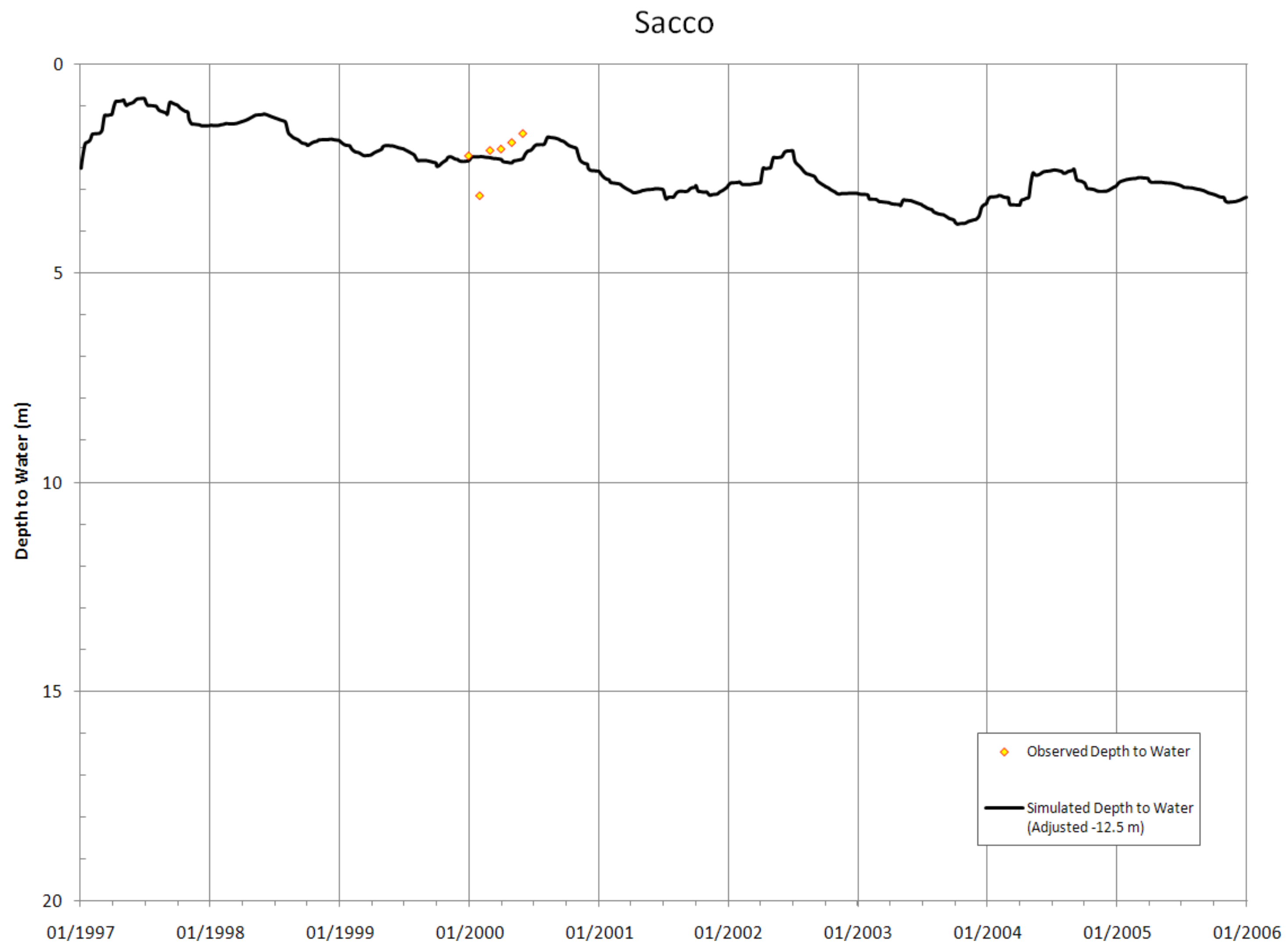
Figure B5-12

Transient Verification Results – Queensdale

Project: 2008003_Guelph_Tier3



Tier Three Local Area Risk Assessment

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Figure B5-13

Transient Verification Results – Sacco

Project: 2008003_Guelph_Tier3

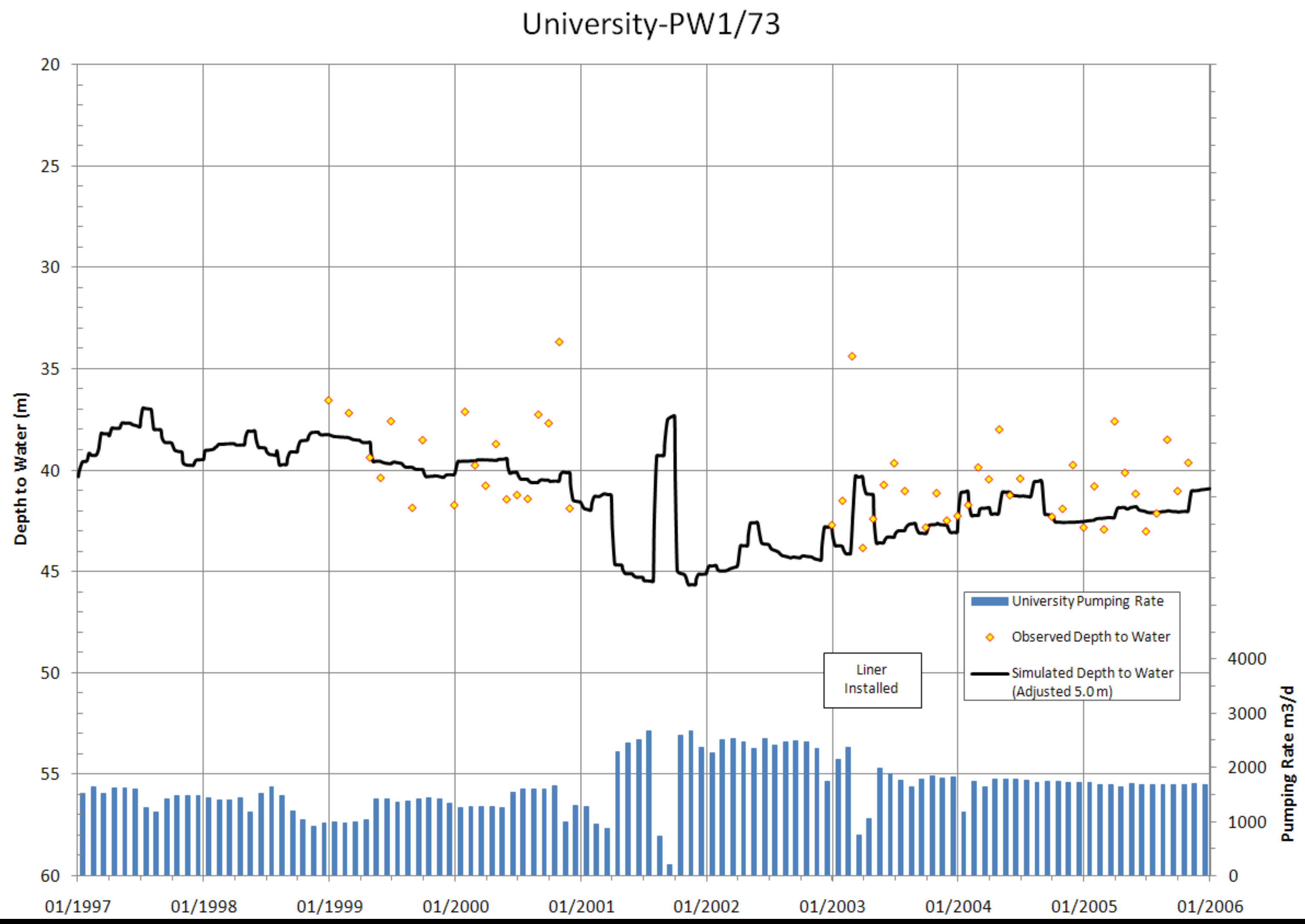

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Figure B5-14
Transient Verification Results – University

Project: 2008003_Guelph_Tier3

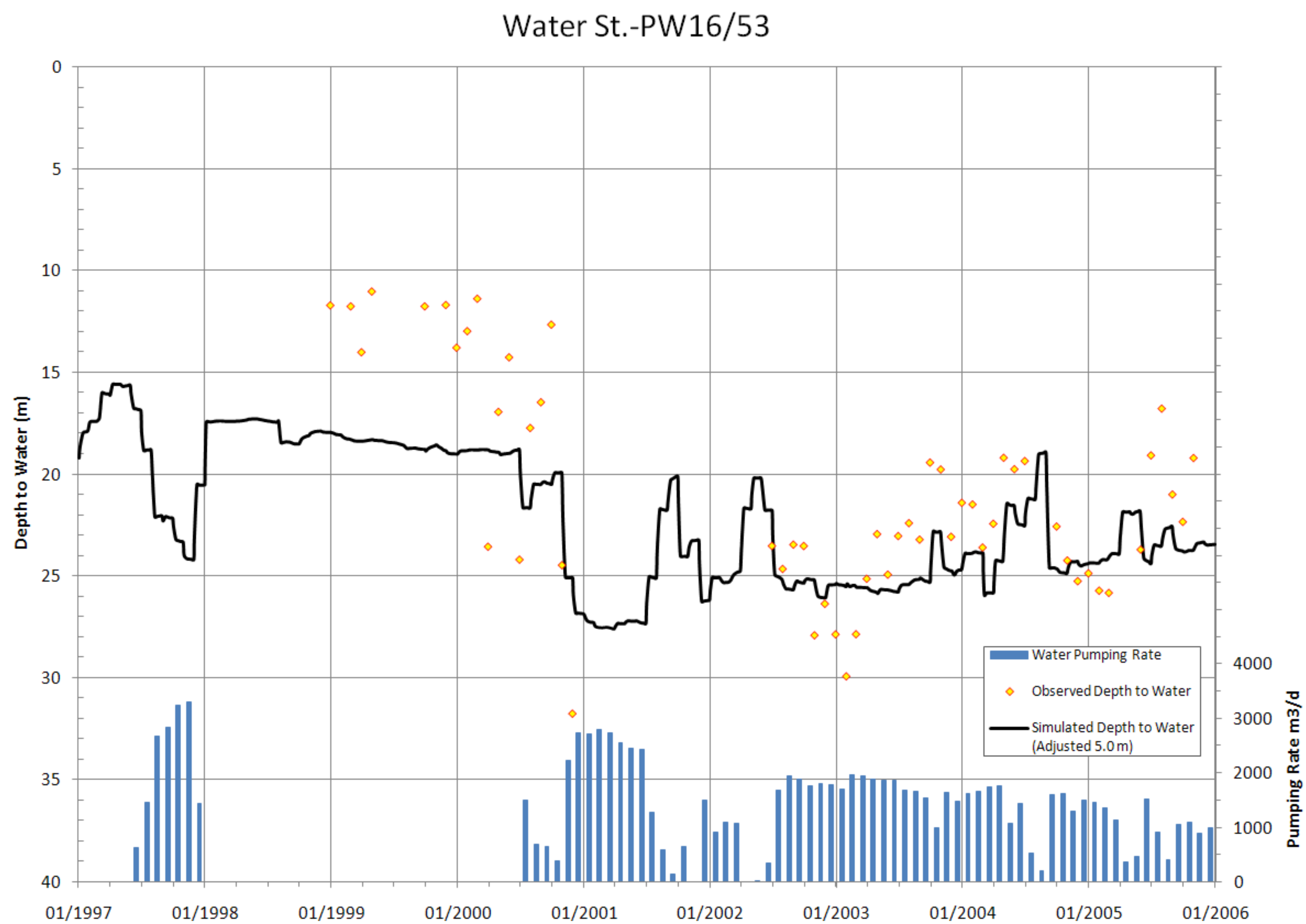

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Figure B5-15

Transient Verification Results – Water St.