Regional Groundwater Monitoring in the Grand River Watershed

Grand River Conservation Authority
Prepared by the Groundwater Resources Group

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Introduction

Groundwater is a vital source of water within the Grand River watershed. Approximately 85% of the watershed's population source their household water from municipal water supplies, with the remaining 15% obtaining water from private supplies such as wells. Thirty-five municipalities and two First Nations reserves maintain 49 drinking water systems within the watershed. Approximately 69% of the municipal drinking water is sourced either solely from groundwater or from blended groundwater/surface water supplies. There are close to 200 municipal wells within the watershed including the Region of Waterloo with over 100 municipal wells and the City of Guelph, with over 20 municipal wells, maintaining some of the largest groundwater based systems in Canada.

Increasing population and development in the watershed has necessitated a need to balance groundwater for human consumption with ecological requirements for the support of surface water baseflows, temperature regimes for fish habitat, and wetland function. Aquifer function and the protection of groundwater quality must also be maintained through responsible development of the watershed's recharge areas to the underlying groundwater systems.

Since 2002, the Grand River Conservation Authority (GRCA) has maintained a groundwater monitoring program throughout the Grand River watershed. This program began in partnership with the Ministry of Environment, Conservation and Parks (MECP) as a part of the Provincial Groundwater Monitoring Network (PGMN), and has since expanded to include GRCA monitoring wells that are not a part of the PGMN. The majority of these additional monitoring wells have been developed from studies completed by the Ontario Geological Survey (OGS). The OGS drilled the boreholes as part of subsurface mapping projects with the GRCA developing these sites into monitoring wells upon completion.

The objective of long-term groundwater monitoring has been to monitor ambient groundwater levels and chemistry within the numerous aquifers across the watershed. Monitoring data produced from these networks have been used as baseline data to support the Ontario Low Water Response Program, climate change studies, source water protection studies, planning applications, and university research studies.

The objective of this report is to provide a rationale for the GRCA's long-term groundwater monitoring program.

Figure 1 shows the location of the GRCA's groundwater monitoring wells within the watershed. There are 38 PGMN wells, 13 GRCA wells associated with the Dundas Buried Valley, and 5 other GRCA monitoring wells. Twenty five wells were brought into the monitoring network between 2002 and 2005, nineteen wells between 2006 and 2010, and fourteen wells between 2011 and 2015.

Monitoring ambient groundwater levels is a long-term process to develop a record substantial enough for analysis. Groundwater levels should be monitored for a minimum of 10 years before data can be assessed for long term trends. As of 2018, many of the GRCA's PGMN wells had a minimum 10 years of monitoring data.

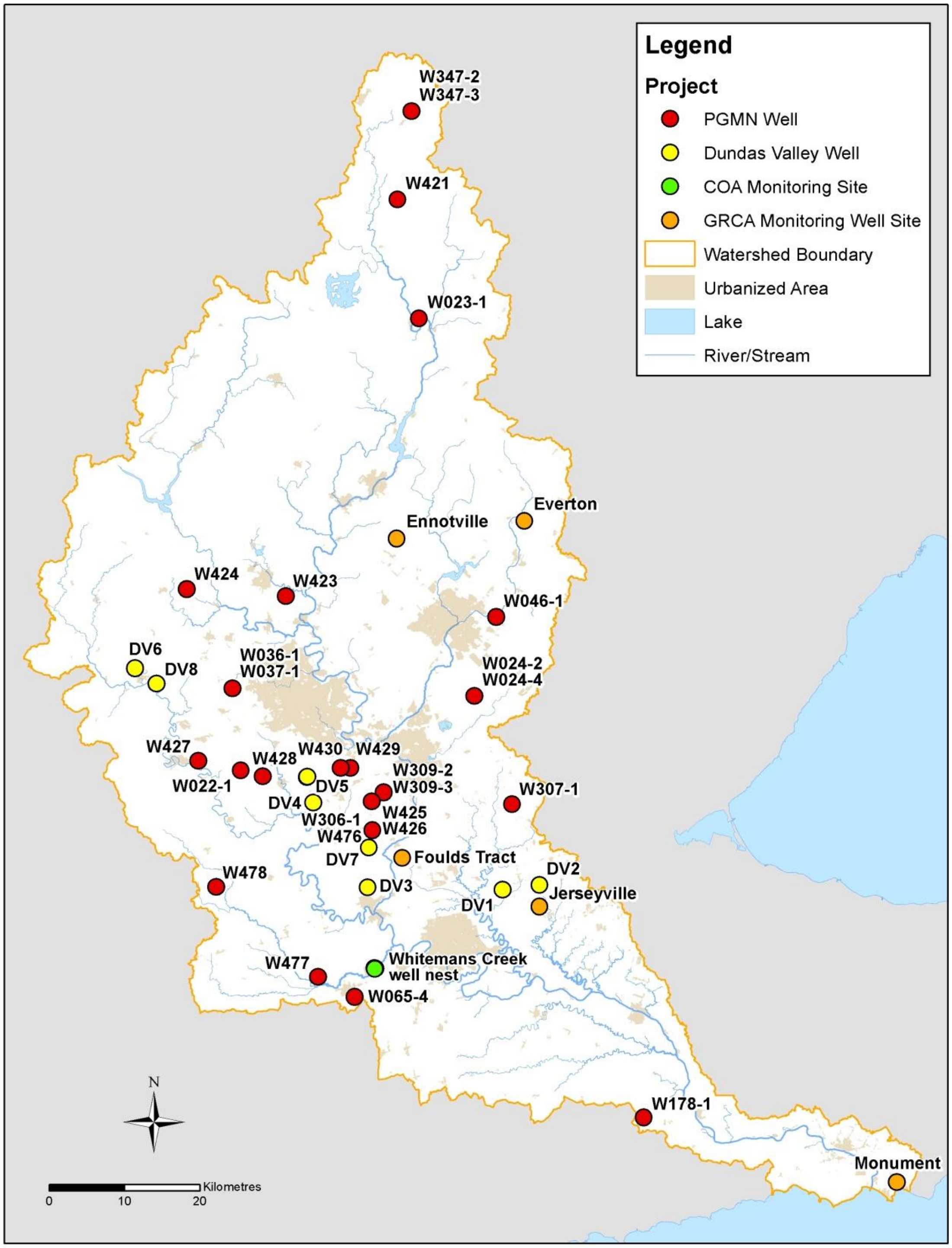

Figure 1: Groundwater monitoring wells within the Grand River watershed. COA = Canada-Ontario Agreement.

Monitoring Well Data

All monitoring wells are equipped with level loggers to continuously record water levels and temperature on an hourly basis. Static water levels in the monitoring wells are manually measured at a minimum of four times annually to verify/calibrate level logger data. All logger data is corrected to compensate for barometric pressure variation. Water quality samples are taken from each PGMN well annually, in the fall, and analyzed for a standard suite of inorganic parameters.

All regional groundwater monitoring data is stored in a Structured Query Language (SQL) Server database located at the GRCA.

Aquifers within the Grand River Watershed

An aquifer is an underground unit of permeable rock or sediment that stores, transmits, and yields economically significant amounts of water (Ford and Williams, 2007). Aquifers may be unconfined, confined, or perched depending on the depth and geological conditions. Unconfined aquifers flow freely without restriction, whereas confined aquifers store water between a lower and upper impermeable layer of rock or sediment (clay) that is incapable of transmitting significant amounts of water (Ford and Williams, 2007). Aquifers may be perched if water is suspended in the unsaturated area above the water table (vadose zone) due to an impermeable material blocking the flow path of water down to the water table. This causes ponding in a localized saturated zone (Ford and Williams, 2007). Aquifers can range in size from a few square kilometers to several thousand square kilometers.

The Grand River watershed contains aquifers within the bedrock formations and unconsolidated sediments (overburden) that transmit enough fresh groundwater to support municipal and domestic water supplies, as well as support ecological functions.

Figure 2 shows the locations of the GRCA's regional monitoring wells categorized as to whether they are monitoring groundwater levels in the bedrock or overburden sediments.

Since the early 2000s there have been numerous studies which have characterized the watershed's aquifers in the watershed on a regional scale. There have been further local scale studies to complete detailed characterizations for specific aquifer units.

The first significant regional groundwater study within the watershed was the Grand River Regional Groundwater Study (Holysh *et al*., 2002). This was the first study of its kind to regionally characterize the geology, groundwater flow directions, water well distribution, and use across the watershed. This study was followed up in 2009 by an integrated water budget study through the Lake Erie Region Source Protection Program in which a regional groundwater flow model was developed for the Grand River watershed (AquaResource, 2009).

In addition to groundwater modelling efforts, the OGS, in partnership with the GRCA, undertook a multi-year project to map and hydrogeologically characterize the buried bedrock Dundas Valley and its infilling sediments in the Hamilton and Waterloo regions of the watershed (Marich *et al.*, 2011). This project included drilling boreholes, many of which were converted to monitoring wells for the GRCA, to characterize the sediments from surface to bedrock, and complete geophysics, pumping tests, and water geochemistry.

The OGS has also completed a number of surficial sediment mapping projects that fall within the Grand River watershed. As of 2017, these include Waterloo Region (Bajc and Shirota, 2007), the Brantford-Woodstock area (Bajc and Dodge, 2011), and the Orangeville-Fergus area (Burt and Dodge, 2016). One additional OGS mapping project is also near completion in the Niagara-southern Grand River area. Outcomes from these projects include detailed sedimentological reports, borehole data, regional stratigraphic models, and GIS layers, including isopach maps of the stratigraphic units. With the completion of the Niagara study, there will be a nearly complete unified stratigraphic model for the overburden sediments across the Grand River watershed.

Bedrock aquifer units within the watershed have also been characterized by the OGS. An example is Brunton's (2009) work which revises the early Silurian stratigraphy of the Niagara Escarpment and Priebe *et al.* (2014) which characterizes the bedrock hydrogeology in the vicinity of the City of Guelph.

Water budget studies in the Regional Municipality of Waterloo and the City of Guelph have both built upon work by the OGS mapping projects to develop detailed groundwater flow models for these two regions' municipal wells as a part of the province's Source Protection Program initiatives.

All of these studies highlight the major recent regional projects in the watershed and contribute to the refinement and understanding of the aquifers throughout the watershed.

Bedrock Aquifers

There are numerous bedrock formations in the watershed that formed at different points in time and under different environmental conditions. As a result, each bedrock formation has its own unique set of characteristics. Some are porous and permeable, capable of transmitting significant quantities of groundwater (aquifers), whereas others have limited connectivity (low permeability) impeding groundwater movement (aquitards). The different bedrock formations, because of their mineralogical composition, can also affect the chemistry of the groundwater. Some bedrock formations have high naturally occurring concentrations of salts and/or metals (*e.g*. fluoride, arsenic, iron) which in turn influence the chemistry of the groundwater flowing through it. The bedrock aquifers in the watershed are comprised of carbonate rock, typically leading to high hardness in groundwater, which is typical across much of Southern Ontario.

The most commonly used bedrock aquifers within the Grand River watershed are the Guelph, Gasport, and Salina Formations. The GRCA monitors groundwater levels and chemistry in each of these units, along with two other units which are not as extensive within the watershed, the Oriskany, and Bois Blanc Formations.

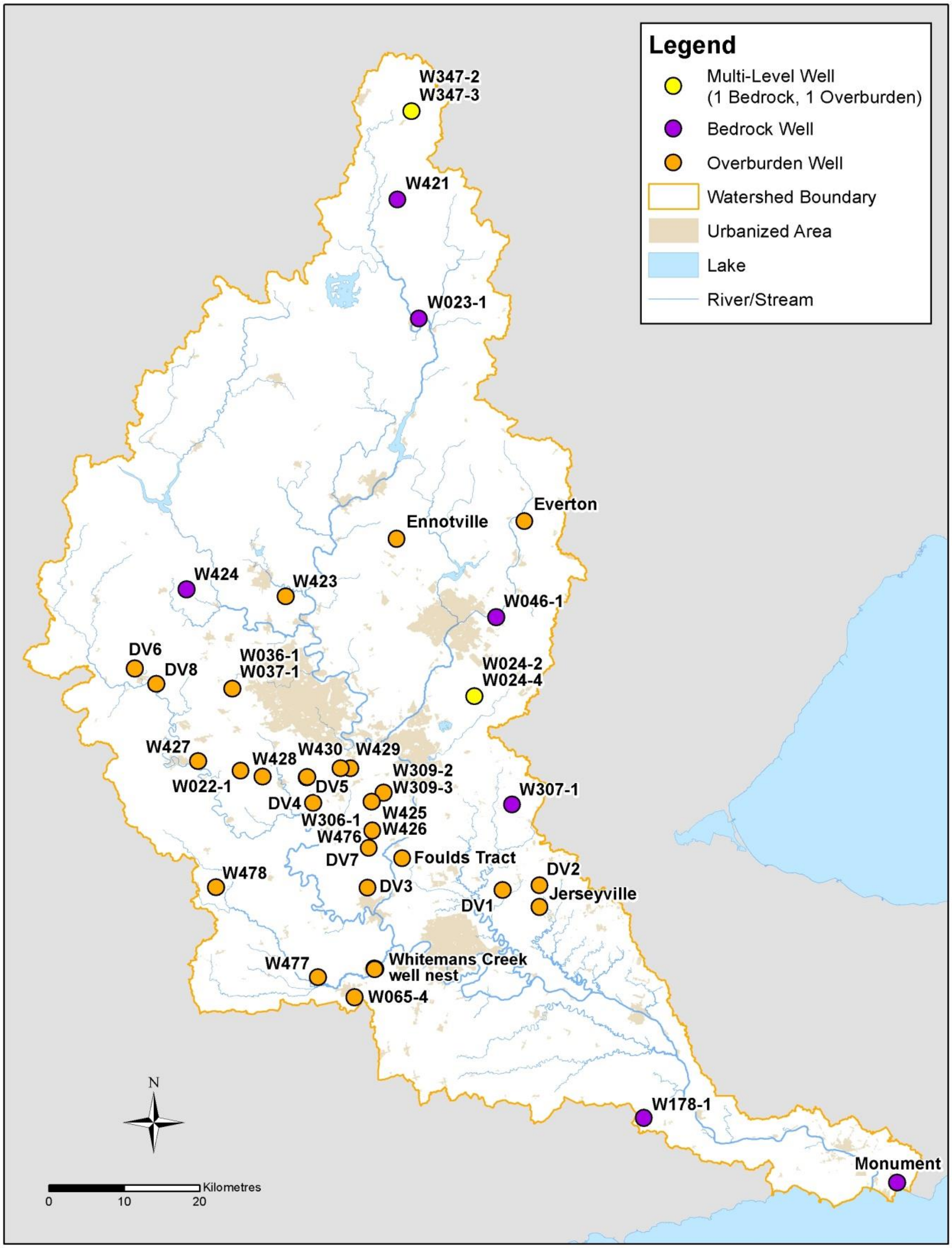

Figure 2: Location of Grand River Conservation Authority/Provincial Groundwater Monitoring Network monitoring wells grouped as bedrock and overburden wells.

Figure 3 shows the bedrock geology across the Grand River watershed, along with the GRCA's bedrock monitoring well locations. In total, the GRCA monitors nine bedrock wells across the watershed, with five wells completed in the Guelph Formation, and one well completed in each of the Gasport, Salina, Oriskany, and Bois Blanc Formations.

Table 1 below provides a summary of some of the general characteristics of the bedrock monitoring wells shown in **Figure 3**.

Table 1: Monitoring wells completed in bedrock.

Site Name (Well Number)	**County/ Township**	**Monitoring Start Date (year)**	**Screen/Open Hole Depth From – To (m bgs)**	**Formation Monitored**
Dundalk Deep (W347-3)	County of Dufferin, Melancthon	2003	6.27 – 21.69	Guelph
Grand Valley (W023-1)	County of Dufferin, Amaranth	2001	26.82 – 29.87	Guelph
Puslinch Deep (W024-4)	County of Wellington, Puslinch	2001	38.1 – 39.62	Guelph
Westfield (W307-1)	City of Hamilton, Flamborough	2003	2.89 – 18.9	Guelph
Jessopville (W421)	Town of Grand Valley	2005	16.46 – 19.51	Guelph
Guelph (W046-1)	County of Wellington, Puslinch	2001	6.4 – 30.48	Gasport
Cayuga (W178-1)	County of Haldimand	2002	6.71 – 25.91	Oriskany
Linwood (W424)	RMOW, Wellesley	2005	85.4 – 86.9	Salina
Monument	Haldimand County	2015	44.31 – 46.81	Bois Blanc

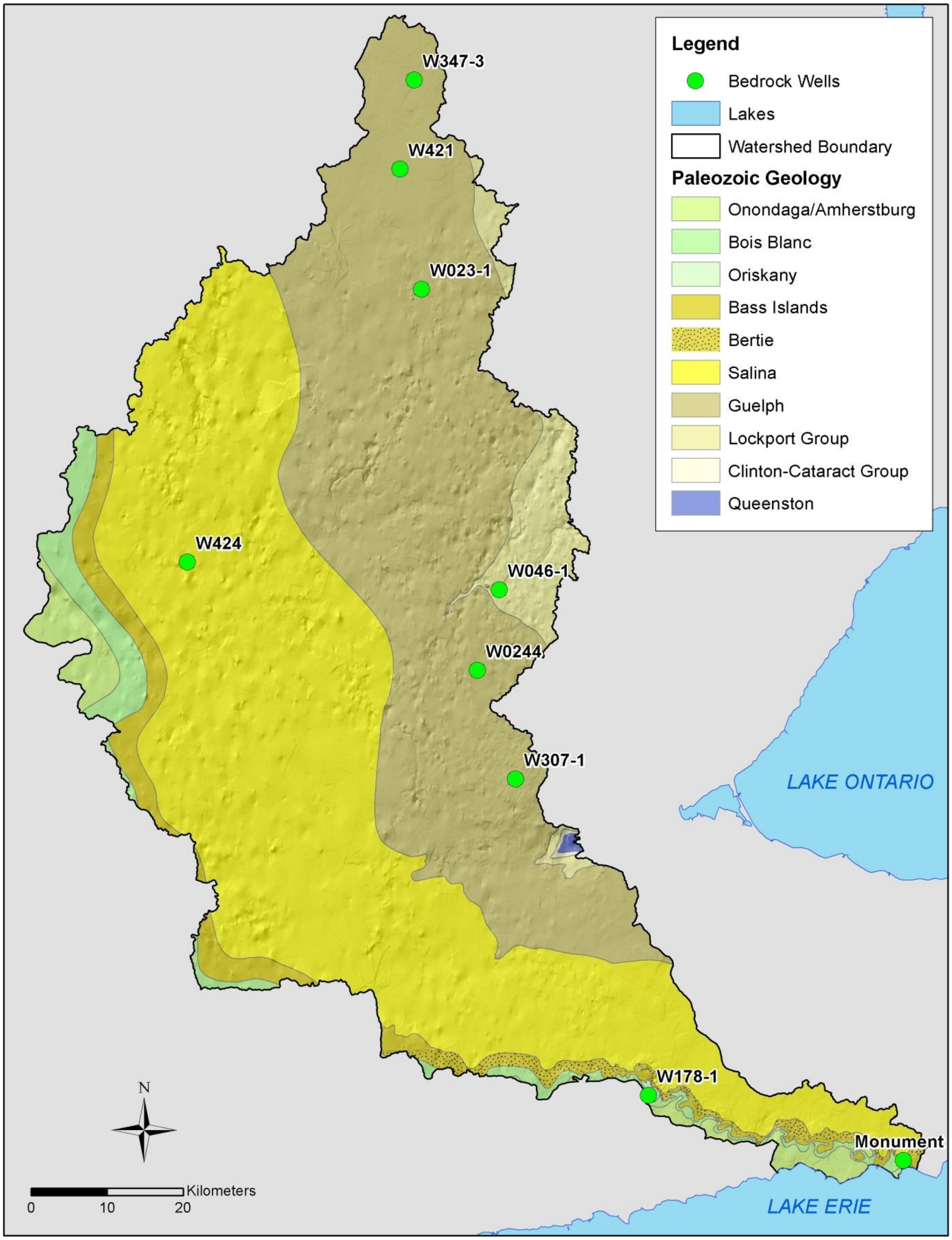

Figure 3: Bedrock geology of the Grand River watershed and groundwater monitoring wells completed in bedrock.

Guelph Formation

The Guelph Formation is the most frequently utilized bedrock aquifer for private and domestic groundwater supplies within the Grand River watershed. The GRCA monitors five bedrock wells completed in the Guelph Formation.

The northern reaches of the watershed contains the highest elevations and groundwater conditions in the Guelph Formation are artesian. The southern reaches of the watershed have lower elevations and also unconfined groundwater conditions such as in the Flamborough Plains physiographic region.

The northernmost well in the watershed, Dundalk Deep (W347-3), is artesian through most months except the summer, with head levels at most 1m above ground surface. This well has been monitored since 2003.

Jessopville (W421), although not normally artesian, shows a strong upward head above the top of bedrock surface. Groundwater levels have been monitored continuously at this site since 2005.

The Grand Valley well (W023) has been monitoring groundwater levels in the Guelph Formation since 2002. Similar to the Jessopville well, groundwater levels at W023, although not artesian, are well above the top of the bedrock surface.

The Puslinch well (W024-4) is one of the longest monitored wells in the monitoring network, with data collection beginning in 2001. This well, which is completed in the Guelph Formation, shows a strong upward gradient from the bedrock, with head values approximately 22 m above the top of bedrock.

The Westfield well (W307-1) is completed in a location where the Guelph Formation is exposed at surface (Flamborough Plains physiographic region). Water levels have been monitored at this well since 2003.

Gasport, Salina, Oriskany, and Bois Blanc Formations

The Gasport, Salina, Oriskany, and Bois Blanc Formations are all groundwater-bearing bedrock formations within the Grand River watershed. The Gasport is extensively used as a municipal water supply in and around the City of Guelph. The Salina Formation, although it has a good specific capacity, often yields groundwater with poor natural quality, such as elevated sulphate and chloride which affects taste and odour of the water. The Oriskany and Bois Blanc Formations are utilized to a much lesser extent, as they have a smaller footprint within the watershed, and are only used for private domestic supplies.

The GRCA has one regional monitoring well within each of these bedrock formations, as shown on **Figure** 3. The Arkell (W046-1; Gasport Fm), Linwood (W424; Salina Fm), and Cayuga (W178-1; Oriskany Fm) wells are all a part of the PGMN. The Monument well (Bois Blanc Fm) was drilled as part of the OGS study to characterize the Niagara Peninsula overburden geology (Burt, 2014).

The Arkell well (W046-1), completed in the Gasport Formation, is an artesian well with head levels often greater than 1 m above ground surface. Monitoring began at this well in 2002.

The Linwood well (W424) is completed in the Salina Formation with a thick confining layer (85.7 m) of clay, till, and clayey till with intermittent silt and sand overlying the bedrock. This well has been monitoring groundwater levels since 2005.

The Cayuga well (W178-1) has monitored groundwater levels in the Oriskany Formation since 2003.

The Monument well is completed in the southernmost portion of the watershed in the Bois Blanc Formation. This well was obtained through the OGS and in partnership with the Niagara Region Conservation Authority. The collection of continuous data began for this well at the end of 2014.

Overburden Aquifers

Within the Grand River watershed, aquifers in the unconsolidated sediments above bedrock are highly complex. Some aquifers are laterally continuous, often located within the moraine areas of the watershed, and support municipal water supplies. Other overburden aquifers are smaller sand and gravel seams within till units that are capable of supplying water to domestic wells.

The surficial overburden geology (OGS, 2010), shown in **Figure 4**, maps the uppermost 3 m of sediment across the Grand River watershed. Monitoring wells screened in the overburden sediment are also shown in this figure. From this map, the watershed can be divided into three regions: till plains across the north end of the watershed, moraine complexes and outwash deposits through the central portion of the watershed, and low-lying clay deposits in the southern portion of the watershed.

The OGS has completed extensive mapping of the subsurface sediments within the Grand River watershed (see Bajc and Shirota, 2007; Bajc and Dodge, 2011; Burt, 2014; 2016; Burt and Dodge, 2016). This work has characterized numerous sedimentary packages and identifies the major lithostratigraphic units, including their thickness, depth, and extent. Building on this source of geological data, it was possible to assign the GRCA's overburden regional monitoring wells to specific stratigraphic units, making it possible to monitor groundwater levels within specific overburden units across the watershed.

Current three-dimensional surficial deposit mapping from the OGS is available for the Waterloo, Woodstock-Brantford, and Orangeville-Fergus areas of the Grand River watershed. An upcoming report for the Niagara Peninsula will cover the southern Grand River area.

The overburden units, which are being monitored independently by the GRCA through the PGMN program, include the following:

- Grand River Valley sand and gravel outwash deposits
- Upper Erie Phase Aquifers (Includes the upper Waterloo moraine, Orangeville moraine, and equivalent sediments)
- Wentworth Till Aquitard (includes the Paris and Galt Moraines)
- Port Stanley, Maryhill, and Tavistock Tills
- Catfish Creek Till
- Pre-Catfish Creek (Canning and sub-Canning till) deposits

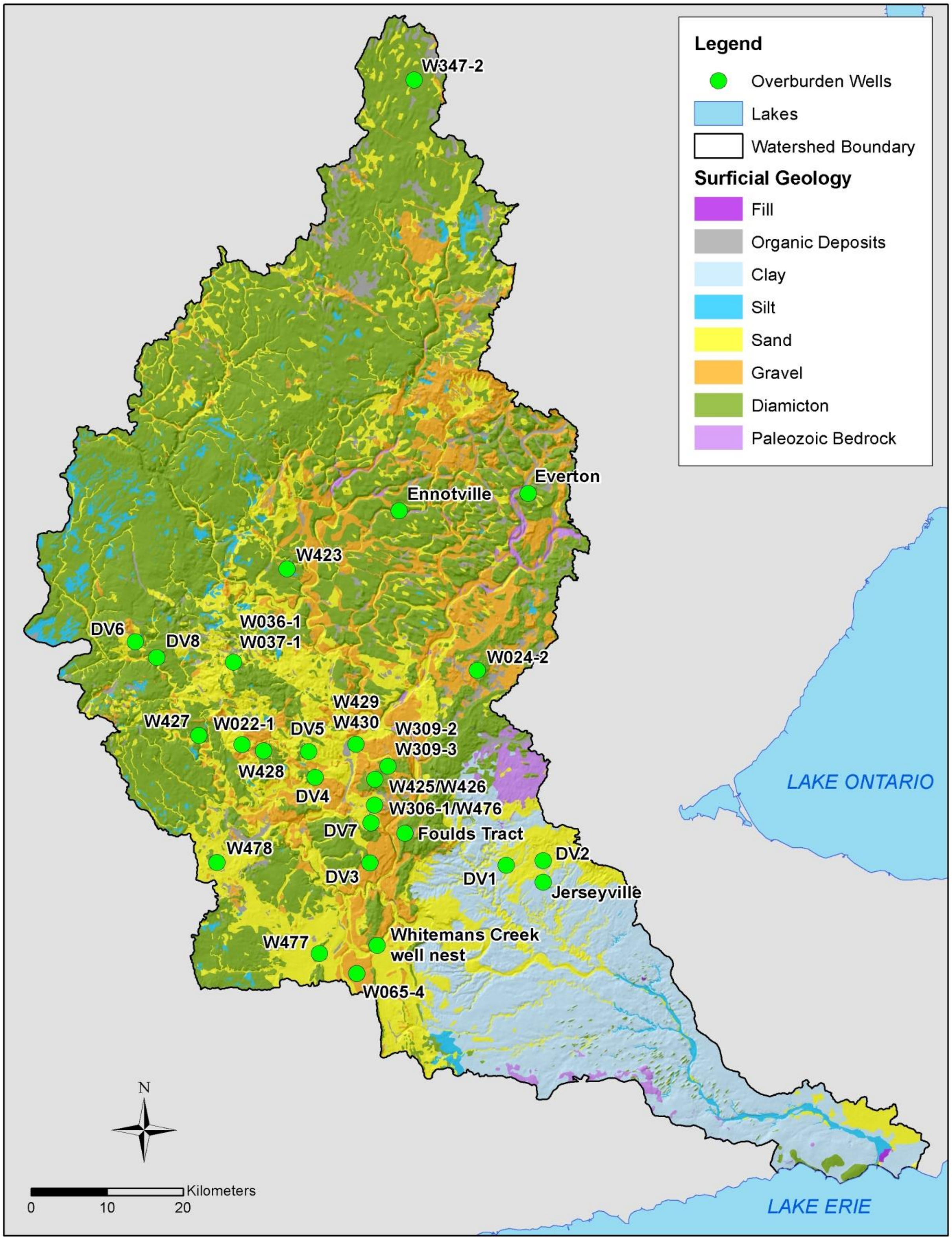

Figure 4: Surficial geology of the Grand River watershed and monitoring wells completed in the overburden.

The isopach maps display the thickness of these deposits in Figures 5 through 9. It should be noted that these figures show thickness of the unit only, and not the vertical position of the unit in relation to the other overburden deposits. However, the relative positions of each stratigraphic layer can generally be described through the geologic principle of superposition, with the oldest sediments occupying the lowest stratigraphic position and the most recent sediments occupying the highest stratigraphic position.

Outwash Deposits

Outwash deposits are primarily located in the Grand, Nith, Speed, Conestogo and Horner river valleys, as shown on **Figure 5**. These deposits tend to be gravelly, and overlay the Waterloo moraine where it is present. These deposits also create a locally confining aquifer when overlying the Paris moraine and Wentworth Till.

The GRCA has two PGMN wells located within these outwash deposits; one located near the village of Burford (W065-4) and the other at Bannister Lake (W306-1). The wells are completed in unconfined aquifers and have been monitoring groundwater levels and temperature since 2001 (Burford) and 2003 (Bannister). There are also 6 multi-level PGMN wells in the Whitemans Creek area. The shallow intervals are all completed within the unconfined aquifer of the outwash deposits. These wells have been monitored since 2012. **Table 2** below provides further details for all of the wells completed within the outwash deposits.

Table 2: Monitoring wells screened within outwash deposits.

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From – To (m bgs)	Formation Monitored
Bannister Lake (W306-1)	Brant County	2003	9.14 – 13.87	Outwash Deposits
Burford (W065-4)	Norfolk County	2001	18.29 – 21.34	Outwash Deposits
W1-S	County of Brant	2012	1.52 – 3.04	Outwash Deposits
W2-S	County of Brant	2012	1.52 – 3.05	Outwash Deposits
W3-S	County of Brant	2012	1.52 – 3.04	Outwash Deposits
W4-S	County of Brant	2012	1.22 – 2.74	Outwash Deposits
W5-S	County of Brant	2012	0.61 – 2.14	Outwash Deposits
W6-S	County of Brant	2012	1.22 – 2.74	Outwash Deposits

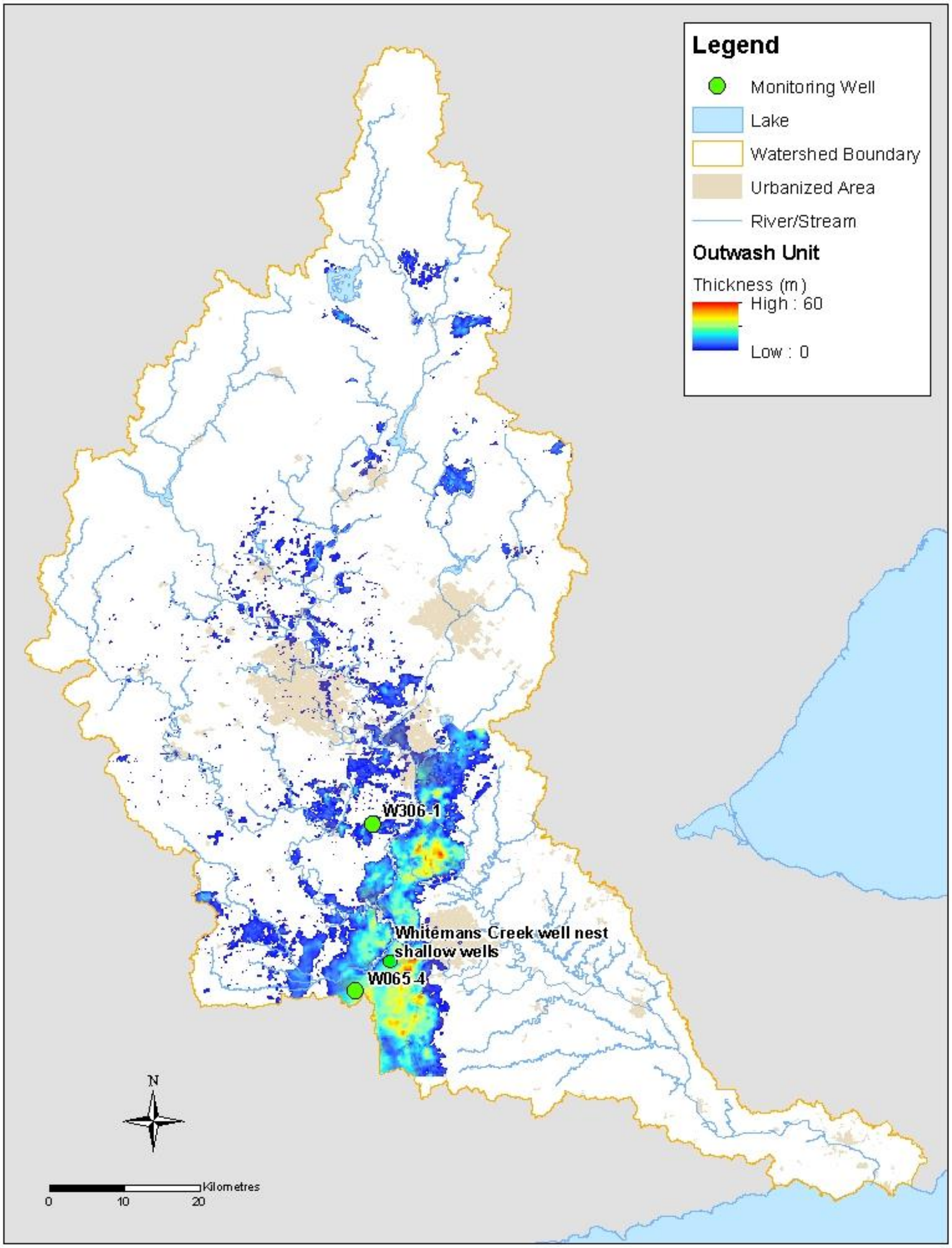

Figure 5: Outwash deposits isopach.

Waterloo Moraine and Equivalent Sediments

The Waterloo Moraine, also locally known as the Mannheim aquifer, is one of the largest producing aquifers in southwestern Ontario, providing water to numerous municipal well fields within the Regional Municipality of Waterloo. Moraine sediments were modelled by Bajc and Shirota (2007) to be between 15 and 100 m in thickness, with layers 15 to 40 m thick being more common. The isopach map for the Waterloo Moraine (and equivalent) sediments is shown on **Figure 6,** including monitoring wells screened in this unit.

The GRCA maintains 12 monitoring wells within the Waterloo Moraine and equivalent sediments. Nine of these are PGMN wells, and the remaining three are owned by the GRCA. In **Table 3** below, the W-series wells are a part of the PGMN and the DV# series are monitoring wells that have been incorporated into the GRCA monitoring network at the conclusion of the Dundas Valley Study completed by the OGS and GRCA (Marich *et al*., 2011). The Foulds Tract well is owned by the GRCA and was incorporated into the GRCA network at the conclusion of the Brantford-Woodstock geological study by the OGS (Bajc and Dodge, 2011).

The New Hamburg well (W427) is located within approximately 170 m east of the Nith River and is likely hydraulically connected to the river. Annually, the well quickly recharges between February and April and on average peaks in April, corresponding to spring freshet. This well reaches its annual low water levels in late August/early September, which corresponds to low flows in the river.

Table 3: Monitoring wells screened within the Waterloo Moraine.

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From – To (m bgs)	Formation Monitored
Huron Rd (W022-1)	RMOW Wellesley	2001	21.74 – 24.84	Upper Waterloo Moraine
Monastery Creek (shallow) (W037-1)	RMOW Wilmot	2001	6.25 – 9.14	Upper Waterloo Moraine
Edworthy Rd (deep) (W309-3)	RMOW North Dumfries	2003	58.22 – 62.78	Lower Waterloo Moraine
Edworthy Rd (shallow) (W309-2)	RMOW North Dumfries	2003	32 – 36.7	Upper Waterloo Moraine
Dryden Tract (shallow) (W426)	RMOW North Dumfries	2005	60.66 – 62.18	Upper Waterloo Moraine
New Hamburg (W427)	RMOW Wilmot	2005	22.9 – 24.4	Upper Waterloo Moraine
Kings Road (shallow) (W430)	RMOW North Dumfries	2005	12.19 – 15.24	Upper Waterloo Moraine

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From – To (m bgs)	Formation Monitored
Burford Tree Nursery (W477)	Brant County	2008	14.9 – 17.9	Upper Erie Phase Aquifer (including Waterloo Moraine sediments)
Chesney Bog (W478)	County of Oxford Blandford-Blenheim	2008	14.0 – 17.0	Upper Erie Phase Aquifer (including Waterloo Moraine sediments)
Highway 24A (DV3)	RMOW North Dumfries	2014	55.42 – 58.46	Waterloo Moraine
Pinehurst (DV7)	Brant County	2014	69.49 – 72.54	Waterloo Moraine
Foulds Tract	Brant County	2014	50.29 – 54.85	Waterloo Moraine

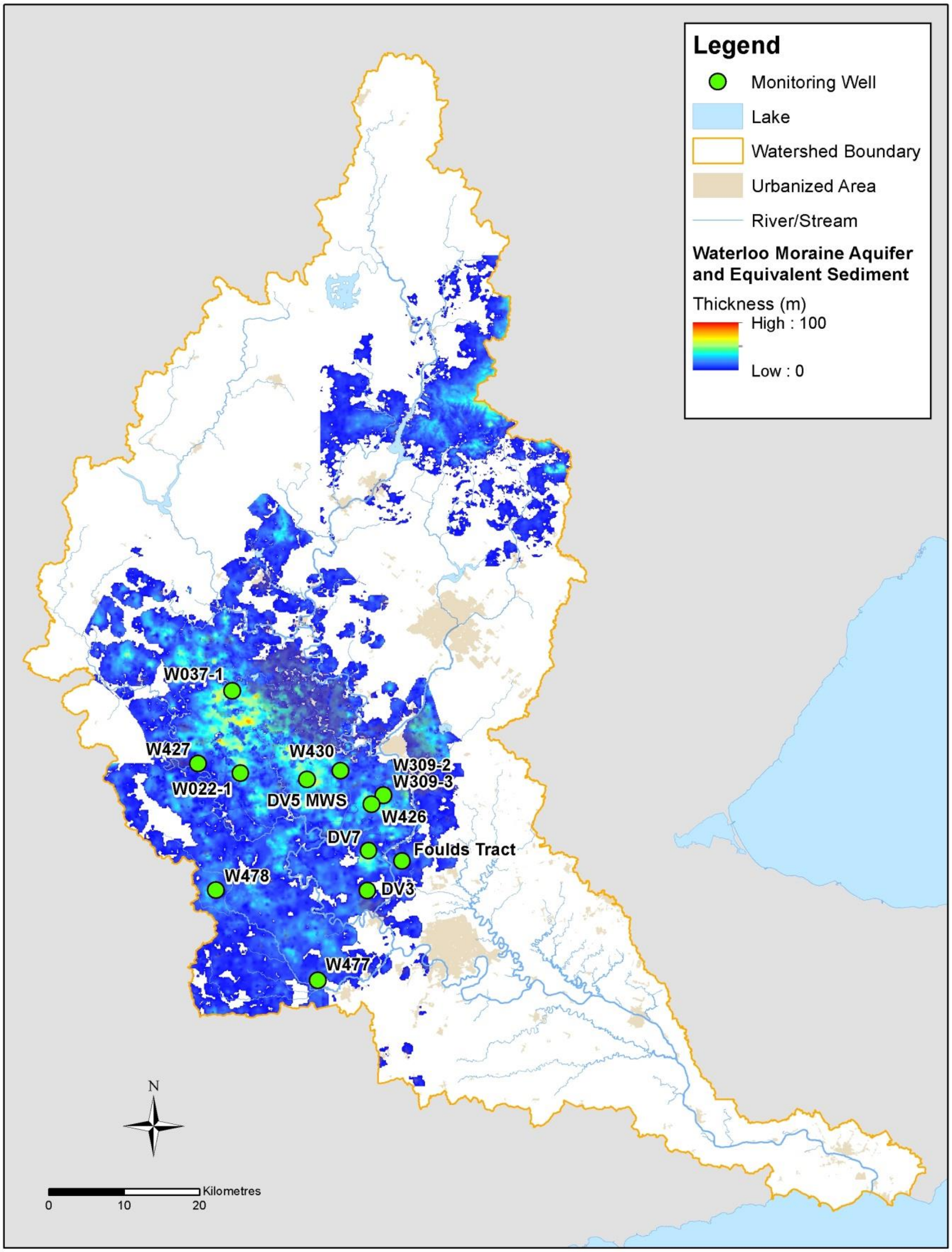

Figure 6: Isopach for Waterloo Moraine deposits.

Paris Galt Moraine

The Paris and Galt Moraines were deposited by Erie-Ontario lobate ice. The sediments were deposited by meltwater and sediments flowing off the ice front (Burt & Dodge, 2016). The composition of these moraines consists of stony, coarse-textured Wentworth Till. The Paris and Galt Moraine sediments are typically less than 35 m and locally up to 68 m thick (Bajc & Dodge, 2011; Burt and Dodge, 2016).

The GRCA maintains 1 PGMN monitoring well within the Wentworth Till and Paris and Galt Moraines shown in **Table 4** below.

Table 4: Monitoring well screened within the Wentworth Till of the Paris and Galt Moraines.

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From - To (m bgs)	Formation Monitored
W024-2	Puslinch	2001	24.38 – 25.91	Paris Galt Moraine

Port Stanley, Maryhill, and Tavistock Tills

The Port Stanley, Maryhill, and Tavistock till units have been mapped and grouped together as the Port Bruce Phase aquitard in the Brantford-Woodstock/Orangeville-Fergus areas (Bajc and Dodge, 2011; Burt and Dodge, 2016) and the Upper Maryhill and equivalents (ATB1 aquitard) in the Waterloo area (Bajc and Shirota, 2007). The isopach map for the till units is shown on **Figure 7**. This figure also shows the monitoring wells which are screened in this unit.

The GRCA monitors 10 locations in these tills where there is significant enough transmissivity in the units to allow for groundwater flow. The Cedar Creek well (DV4) is a deep well that was drilled as a part of the Dundas Valley study. The Ennottville well was drilled by the OGS as a part of their characterization of the Orangeville moraine (Burt and Chartrand, 2014). A cluster of 12 wells were drilled along Whiteman's Creek in this unit as a part of an initiative by the MECP to look at long term climate change in a high water use subwatershed (Whiteman's Creek subwatershed). **Table 5** below provides a summary of these wells.

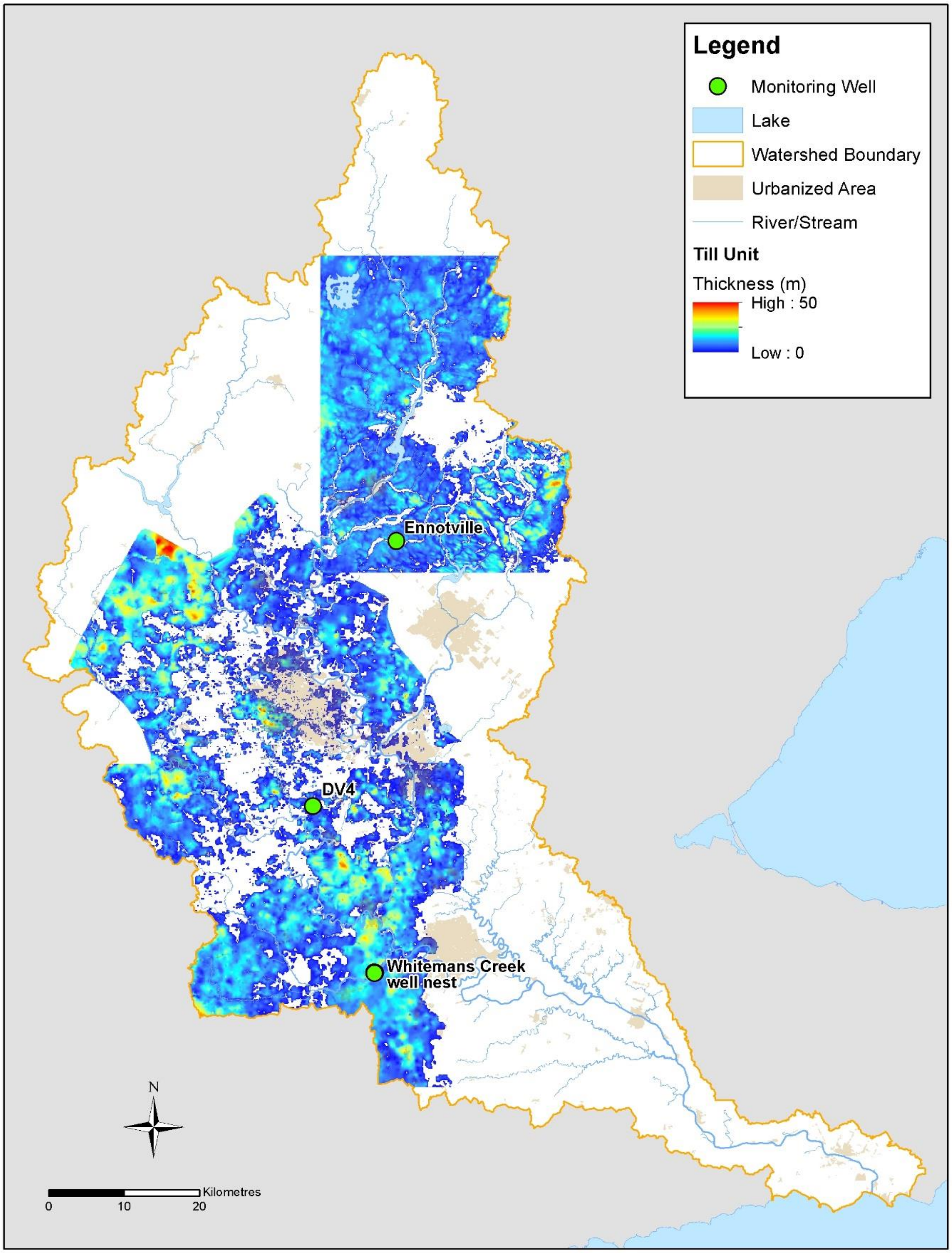

Figure 7: Tills isopach and monitoring wells.

Table 5: Monitoring wells screened in Port Stanley, Maryhill, and Tavistock Tills.

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From - To (m bgs)	Formation Monitored
Weir Rd. (DV-1)	Hamilton	2009	40.11 – 43.16	Port Stanley/ Tavistock Till
Field Rd. (DV-2)	Hamilton	2009	68.35 – 71.40	Port Stanley/ Tavistock Till
Cedar Creek Rd. (DV4)	RMOW North Dumfries	2014	72.69 – 75.74	Upper Maryhill Till
Ennotville	County of Centre Wellington	2012	17.9 – 19.4	Upper Maryhill Till
W1-D (SS Deep)	County of Brant	2012	9.14 – 10.66	Port Stanley/ Tavistock Till
W2-D (SW Deep)	County of Brant	2014	8.23 – 9.75	Port Stanley/ Tavistock Till
W3-D (SE Deep)	County of Brant	2012	6.70 – 8.23	Port Stanley/ Tavistock Till
W4-D (NW Deep)	County of Brant	2013	7.62 – 9.14	Port Stanley/ Tavistock Till
W5-D (NE Deep)	County of Brant	2012	6.10 – 7.62	Port Stanley/ Tavistock Till
W6-D (NN Deep)	County of Brant	2012	6.09 – 7.62	Port Stanley/ Tavistock Till

Catfish Creek Till

Catfish Creek Till is found widely across southwestern Ontario and is largely regarded as a regional aquitard. The properties of Catfish Creek Till are regionally consistent, with an olive-grey colour (when unoxidized) containing stones, and a silty to sandy matrix (Bajc and Shirota, 2007). The unit is generally overconsolidated and water well drillers frequently refer to this till unit as 'hardpan' in their well logs.

Bajc and Shirota (2007) subdivided Catfish Creek drift into an upper and lower aquitard with an intervening aquifer. Small areas of intervening aquifer unit within upper and lower aquitards were found in several areas across the Region of Waterloo.

As shown on **Figure 8**, the GRCA monitors groundwater levels at 11 sites within the Catfish Creek Till unit, as summarized in **Table 6**. Five of these sites are a part of the PGMN and the remaining six locations were drilled as a part of the Dundas Valley Study (Marich *et al*., 2011). The Cedar Creek Road (DV4) site consists of three nested monitors (DV4, DV4 MWS, DV4 MWD). All three of these wells are screened within the Catfish Creek Till, with DV4 MWS monitoring a shallower aquifer unit, and DV4 MWD monitoring a deeper water bearing unit within the till.

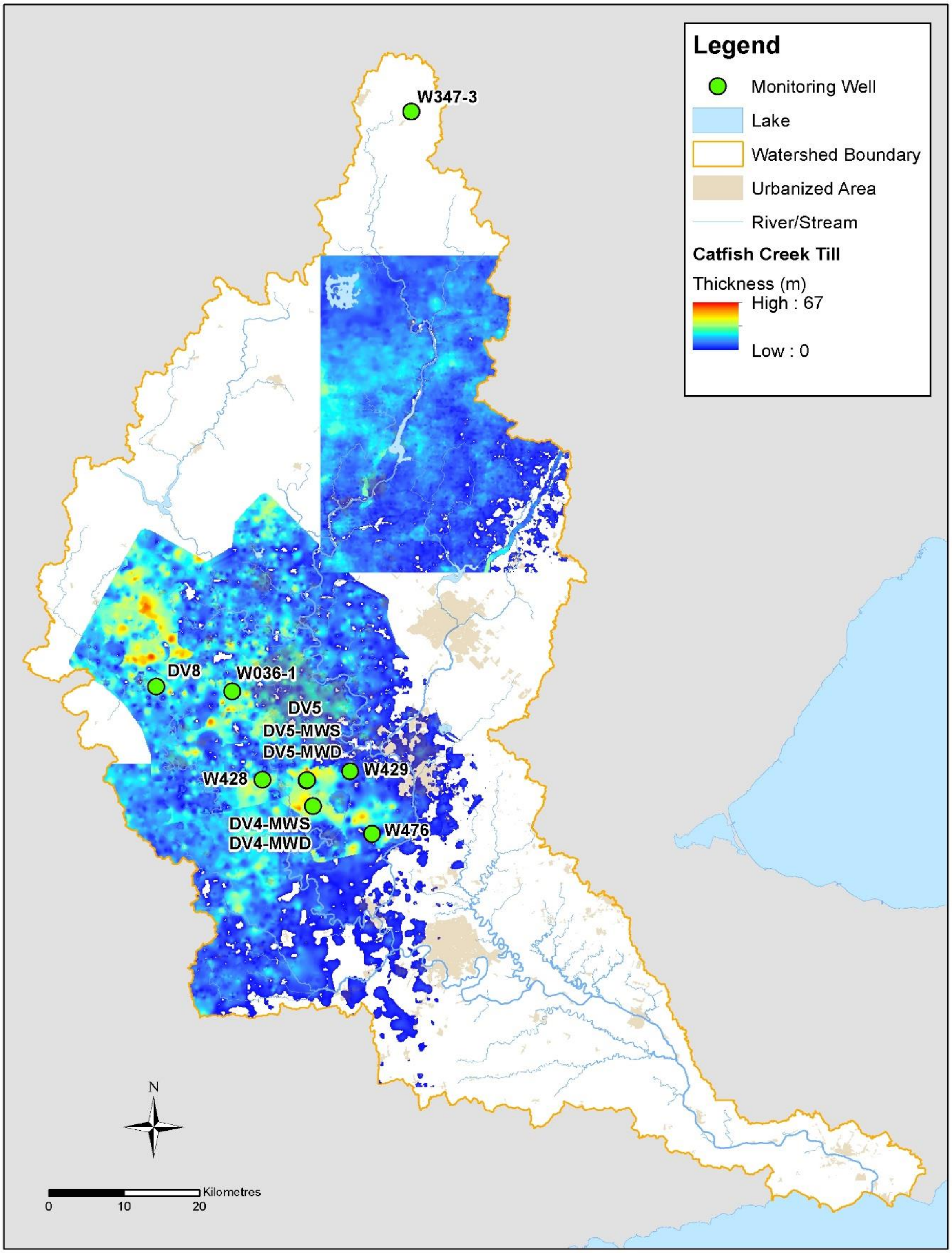

Figure 8: Isopach for Catfish Creek Till and monitoring wells.

Table 6: Monitoring wells screened within Catfish Creek Till.

Site Name (Well Number)	County/ Township	Monitoring Start Date	Screen Depth From - To (m bgs)	Formation Monitored
Monastery Creek (deep) (W036-1)	RMOW Wilmot	2003	73.15 – 76.35	Catfish Creek Till
Dundalk (shallow) (W347-2)	County of Dufferin Melancthon Twp	2003	3.35 – 6.40	Catfish Creek Till
New Dundee (W428)	RMOW Wilmot	2005	46.0 – 47.50	Catfish Creek Till
Kings Road (deep) (W429)	RMOW North Dumfries	2005	41.15 – 44.20	Catfish Creek Till
Bannister Lake (deep) (W476)	Brant County	2009	54.0 – 57.0	Catfish Creek Till
Cedar Creek Road (Deep) (DV4-MWD)	RMOW North Dumfries	2014	70.71 – 73.76	Catfish Creek Till
Cedar Creek Road (Shallow) (DV4-MWS)	RMOW North Dumfries	2014	57.61 – 60.65	Catfish Creek Till
New Dundee Road (DV5)	City of Kitchener	2014	100.85 – 103.90	Catfish Creek Till
New Dundee Road (Deep) (DV5-MWD)	RMOW North Dumfries	2014	85.0 – 91.0	Catfish Creek Till
New Dundee Road (Intermediate) (DV5-MWI)	RMOW North Dumfries	2014	62.0 – 65.0	Catfish Creek Till
Settlement Road (DV8)	RMOW Wilmot	2014	61.95 – 65.0	Catfish Creek Till

Pre-Catfish Creek Till Deposits

Aquifers underlying Catfish Creek Till are widespread across the Regional Municipality of Waterloo, where they primarily occur within bedrock depressions and valleys where glaciofluvial sediments associated with the advance of the Catfish ice would have been concentrated (Bajc and Shirota, 2007). This group of aquifers is locally referred to as the Parkway aquifer within the Region of Waterloo.

As shown on **Figure 9, t**he GRCA monitors groundwater levels at three sites within the Pre-Catfish Creek Till. The monitoring wells are summarized in **Table 7** below. Two of these sites are a part of the PGMN and the remaining location was drilled as a part of the Dundas Valley Study (Marich *et al.*, 2011). The Elmira (W423) and Hutchinson Road (DV-6) wells are screened in aquifers that predate the Canning drift. According to Bajc and Shirota (2007), the absolute ages of these deposits are unknown. Notable occurrences of these deposits occur within the buried Wellesley bedrock valley along the western edge of Wellesley Township. Extensive deposits are also found in the Elmira area where thicknesses are in excess of 30 m. The aquifer material within these deposits is largely confined by Canning drift; however local windows are present. The Dryden Tract (W425) well is screened in the Pre-Catfish sand and gravel aquifer.

Table 7: Monitoring wells screened in Pre-Catfish Creek Till deposits.

Site Name (Well Number)	**County/ Township**	**Monitoring Start Date**	**Screen Depth From - To (m bgs)**	**Formation Monitored**
Elmira (W423)	RMOW Woolwich	2005	44.5 – 46.0	Sub-Canning drift
Dryden Tract Deep (W425)	RMOW North Dumfries	2005	81.38 – 84.43	Sub-Catfish sand and gravel
Hutchinson Road (DV6)	RMOW Wellesley	2014	75.13 – 78.18	Sub-Canning drift

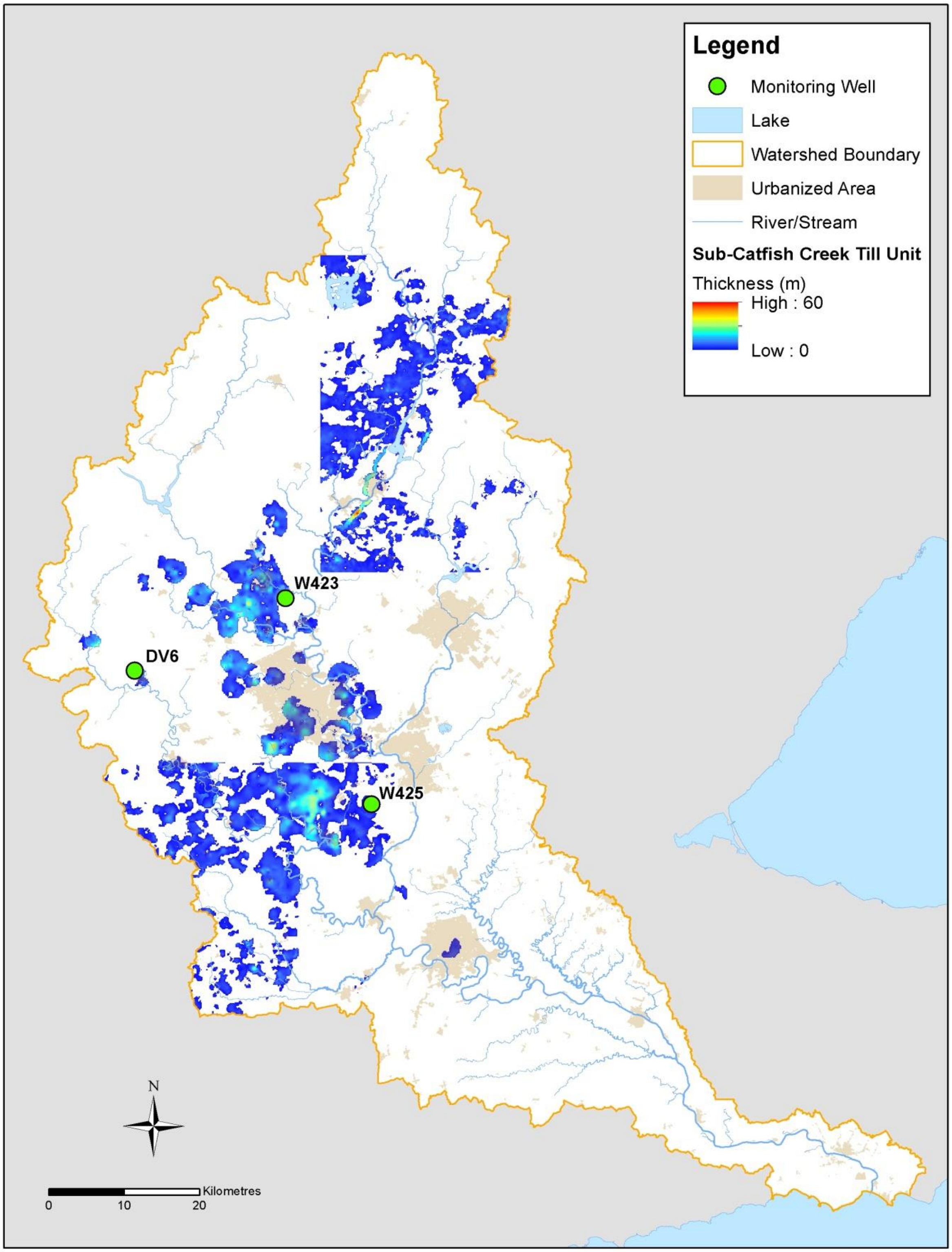

Figure 9: Pre-Catfish Creek Till isopach and monitoring wells.

Nested Wells

At 9 locations in the watershed, monitoring wells are nested with the objective of screening multiple aquifer units at the same location. The following table summarizes the nested well locations and attributes.

Table 8: Nested monitoring wells screened in multiple units at the same location.

Site Name	Well Name	Screen Depth (m bgs)	Unit Monitored	Monitoring Start Date
Dundalk	W347-2 (shallow)	3.35 – 6.40	Catfish Creek Till	2003
	W347-3 (deep)	6.27 – 21.69 (open hole)	Guelph Formation	2003
Monastery Creek	W037-1 (shallow)	6.25 – 9.14	Upper Waterloo Moraine	2001
	W036-1 (deep)	73.15 – 76.35	Catfish Creek Till	2003
Puslinch	W024-2 (shallow)	24.38 – 25.91	Paris Galt Moraine	2001
	W024-4 (deep)	38.1 – 39.62	Guelph Formation	2001
Kings Road	W430 (shallow)	12.19 – 15.24	Upper Waterloo Moraine	2005
	W429 (deep)	41.15 – 44.20	Catfish Creek Till	2005
Dryden Tract	W426 (shallow)	60.66 – 62.18	Upper Waterloo Moraine	2005
	W425 (deep)	81.38 – 84.43	Sub Catfish Creek Sand and Gravel	2005
Edworthy Road	W309-3 (deep)	58.22 – 62.78	Lower Waterloo Moraine	2003
	W309-2 (shallow)	32 – 36.7	Upper Waterloo Moraine	2003
Bannister Lake	W306-1 (shallow)	9.14 – 13.87	Outwash deposits	2003
	W476 (deep)	54.0 – 57.0	Catfish Creek Till	2009
Cedar Creek Road	DV4-MWS	57.61 – 60.65	Catfish Creek Till	2014
	DV4-MWD	70.71 – 73.76	Catfish Creek Till	2014
New Dundee Road	DV5	100.85 – 103.90	Catfish Creek Till	2014
New Dundee Road	DV5-MWI (Intermediate)	62.0 – 65.0	Catfish Creek Till	2014
	DV5-MWD (Deep)	85.0 – 91.0	Catfish Creek Till	2014

Conclusions and Next Steps

The purpose of this report was to provide a summary of regional groundwater monitoring carried out by the GRCA. The objective of this monitoring is to develop a baseline dataset of regional groundwater levels, temperature, and chemistry.

The first step in understanding the monitoring data was to work with regional stratigraphy published by the OGS to assign stratigraphic layers to the monitoring wells completed in the overburden.

The next steps are to continue to maintain the existing monitoring program and add monitoring wells in strategically located areas. The current program does not include monitoring wells in the northwest portion of the watershed, therefore efforts will be focused on obtaining wells in this area in the future.

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