APPENDIX H
Local Area Overlap Memo

MEMORANDUM

To: Martin Keller, Grand River Conservation Authority

CC: Region of Waterloo (Richard Wootton and Eric Hodgins), City of Guelph (Dave Belanger)

From: Paul Chin and Patricia Meyer, Matrix Solutions Inc.

Re: Division of the Combined Local Area between the Cities of Guelph and Cambridge

Date: March 29, 2017

1. INTRODUCTION

As part of the Tier Three Water Budget and Local Area Risk Assessments (Tier Three Assessment) for the City of Guelph and Township of Guelph/Eramosa (Guelph/GET; Matrix 2017) and Region of Waterloo (Region; Matrix and SSPA 2014), groundwater flow models were developed to simulate groundwater flow conditions and groundwater-surface water interactions. Figure 1 illustrates the model area for both the Cambridge model and part of the Guelph/GET model.

One of the key outcomes of the Tier Three Assessments was the delineation of water quantity vulnerable areas, termed Local Areas. Local Areas are areas on the landscape where reductions in recharge (due to land use development) or increases in groundwater demand, may impact the sustainability of the municipal wells under current or future conditions. A Risk Level (Significant, Moderate or Low) was assigned based on the results of modelling scenarios that assessed potential impacts associated with increased demands, climatic variability and reductions in recharge. A Risk Level of Significant or Moderate will require identified water quantity threats in the Local Area to be managed.

The Cambridge and Guelph/GET groundwater flow models were developed and calibrated simultaneously and effort was spent to ensure consistency and integration between the two models, as documented in Matrix, 2014. In 2014, the groundwater flow model calibration in the Cambridge Model was completed, and the Risk Assessment Report was drafted (Matrix and SSPA 2014). While the Region of Waterloo Tier Three Assessment was concluding, updates were made in the Guelph/GET model, including changes to the conceptual and numerical models in the Rockwood and Hamilton Drive area as part of a Risk Assessment for those water supply systems. Updates were also made in 2015 and 2016 to the Guelph/GET model in the south Guelph and Puslinch Township areas. The impact of these changes on the Risk Assessment results in Cambridge were tested and found to be negligible (see Appendix A for details).

The Local Areas for the Region and Guelph/GET were delineated following the Technical Rules laid out for the Tier Three Assessment water budget framework (MOECC 2016). Local Area A for the City of Guelph/GET was delineated in 2016 and encompasses the entire city and surrounding lands, and extends south into Cambridge (Figure 2). Local Area B for the City of Cambridge wells was delineated in 2014 and encompasses much of the Cambridge area and south Guelph (Figure 3). As noted previously,

the Local Areas were delineated using separate, yet complementary, groundwater flow models designed to simulate the groundwater flow conditions within the respective cities. Each of the two Local Areas was delineated by contouring the drawdown induced by the estimated future municipal and non-municipal permitted pumping rates in the area (relative to historic non-pumping conditions), with consideration for the location and impact of future land use development on water levels in the municipal wells (see Matrix and SSPA 2014 and Matrix 2017 for additional details).

Several bedrock aquifers including productive horizons in the Guelph, Gasport and Goat Island formations, underlie the cities of Guelph and Cambridge and are used as a water supply sources in both cities. The drawdown cones induced by the future estimated municipal groundwater demand (Allocated Rates) for the two cities overlap and underlie the Cities of Guelph and Cambridge. As such, the overlapping Local Area (based on the 2 m drawdown contour) underlies both cities. The Risk Level applied to Local Area A of the Guelph/GET Tier Three Assessment was Significant, whereas a Risk Level of Low was assigned to Local Area B of the Region's Tier Three Assessment. As the two areas overlap, there was a need to separate the Local Area that is common to Guelph/GET and Cambridge, so appropriate water resource policies can be drafted to address the water quantity threats in the area.

2. METHODOLOGY APPLIED TO DELINEATE SEPARATE LOCAL AREAS

This section outlines the technical methodology used to separate the overlapping Local Area between the Cities of Guelph and Cambridge, recognizing the groundwater interaction within the bedrock aquifer system that supplies the two cities. The management zones will identify areas where water use policies under the Clean Water Act could be implemented. The underlying subsections outline the technical rationale used to subdivide the common Local Area for Guelph/GET and Cambridge to create a unique groundwater management area (Local Area) for each of the two cities.

2.1 Bedrock Groundwater Level Elevations

While the drawdown and the Local Area between the two cities overlap, observed and simulated groundwater level elevations in the Gasport Formation indicate a groundwater flow divide exists between the two cities. Figure 4 illustrates the simulated groundwater level elevations and the interpreted groundwater flow divide location in the Middle Gasport Formation, as simulated in the Guelph/GET and Cambridge groundwater flow models under future Allocated Rates. North of the divide, groundwater flows toward Guelph, and south of the divide, groundwater flows toward Cambridge. This flow divide represents a logical location to subdivide the common Local Area; however, this boundary is not fixed and will move dynamically as recharge and municipal and non-municipal pumping in Cambridge and Guelph changes. As such, this groundwater divide was one piece of technical information used to divide the Local Area between the two cities.

2.2 Potential Areas of Well Contribution

Backward particle tracking was conducted within the two groundwater flow models. Hypothetical particles of water were released at the municipal wells in Cambridge and Guelph, and they were tracked backward in time to their sources (i.e., the recharge areas). The particle tracking was undertaken to provide insight on the source areas of the Cambridge and Guelph municipal supply wells and to enhance the understanding of the groundwater flow divide noted in the deep bedrock aquifer (Gasport Formation). Figure 5 illustrates a cross-sectional view from the Clemens Mill Well Field in Cambridge in the south (left) through the Downey Road Well in Guelph in the northeast (right). As illustrated, a

groundwater flow divide exists within the Gasport Formation, and a shallower groundwater flow divide within the overburden lies northeast of the flow divide in the bedrock (Figure 5). (Note: three-dimensional particles are projected onto the two-dimensional cross-section so some particles that are behind the cross-sectional plane appear to extend above ground surface).

As part of the Region's Tier Three Assessment, three alternative (calibrated) numerical models were created (see Appendix C of Matrix and SSPA 2014 for details) to test the uncertainties associated with model input parameters on the model results. As part of this memorandum, backward particle tracking was conducted in the base case and each of the three uncertainty case models to test the uncertainties associated with model input parameters on the particle traces and the groundwater flow divide. Figure 6 illustrates the resultant steady-state particle traces from all of the calibrated Cambridge models and the Guelph/GET model. As illustrated on the figure, the source areas for the Cambridge and City of Guelph wells lies south of the City of Guelph.

[Note: The particle tracking presented on Figure 6 represents only backward tracking particles that were released at the municipal wells. The wells were pumped at their future Allocated Rates; these rates may be different than the pumping rates applied to delineated capture zones for the City of Guelph and Region of Waterloo water supply wells.]

2.3 Model Simulated Drawdown Contours

In addition to the groundwater level elevations and the potential well contribution areas, the model simulated drawdown contours generated in the two models were also reviewed to provide further support for the delineation of the separate Local Areas. The drawdown was calculated as the difference between the groundwater level elevations under non-pumping conditions and groundwater level elevations when all municipal wells are pumped at their future Allocated Rates (and non-municipal water supplies were pumped at their existing consumptive rates). As noted earlier, the 2 m drawdown contour encompassed both cities; however, the 4 and 5 m drawdown contours (Figure 7) do not overlap and provide insight on the groundwater divide between the two cities.

3. LOCAL AREA DELINEATION RESULTS

Using all of the technical data assembled and described in Section 2, separate Local Areas were delineated for the Cities of Cambridge and Guelph. The Local Area for Cambridge was extended to the southern portion of Guelph to coincide with the interpreted groundwater flow divide (Figure 8). Similarly, the southern extent of Guelph's Local Area was informed by the extent of the 5 m drawdown contours (Section 2.3), and where the 2 m drawdown cone narrows east of Cambridge (Figure 9). Figure 10 illustrates both Local Areas on the same map and illustrates the overlap area within Wellington County where groundwater policies for the Region and Guelph will apply. As Guelph has a Significant Risk Level, their policies will be mandatory; however, within that overlap area, the Region may choose to comment on or review any new water demands that may have a potential impact on their groundwater supplies.

4. CONCLUSIONS/IMPLICATIONS

Two Local Areas were delineated for the Cities of Cambridge and Guelph and these will become groundwater management areas to safeguard the long-term sustainability of the respective cities' groundwater resources under the *Clean Water Act*. The delineation of the two Local Areas was based on

observed groundwater level elevations and results of numerical modelling analyses. The overlap area between the two zones acknowledges the variability in the location of the groundwater flow divide between the two cities. This overlap area represents a groundwater management area within which the City of Guelph and the Region will work cooperatively to assess any potential impacts on their municipal water supplies that may arise, for example, due to a new groundwater permit or a reduction in groundwater recharge due to land development.

5. REFERENCES

Matrix Solutions Inc. (Matrix) 2017. City of Guelph and Township of Guelph/Eramosa Tier Three Water Budget and Local Area Risk Assessment; Draft Risk Assessment Report. January, 2017.

Matrix Solutions Inc. (Matrix) 2014. Comparison and Integration of the Region of Waterloo Cambridge Model and City of Guelph Tier Three Assessment Model. Memorandum to Region of Waterloo Tier Three Peer Review Committee. August 13, 2014.

Matrix Solutions Inc. (Matrix) and S.S. Papadopulos and Associates (SSPA). 2014. Region of Waterloo Tier Three Water Budget and Local Area Risk Assessment; Final Risk Assessment Report. September, 2014.

Ontario Ministry of the Environment and Climate Change. (MOECC). 2016. *Technical Rules: Assessment Report, Clean Water Act, 2006*. November 20, 2008. Amended on December 12, 2008 (administrative amendments), November 16, 2009 (EBR Posting Number EBRO10-7573), and December 2, 2013 (Technical Bulletin). Updated on May 19, 2016. https://www.ontario.ca/page/technical-rules-assessment-report

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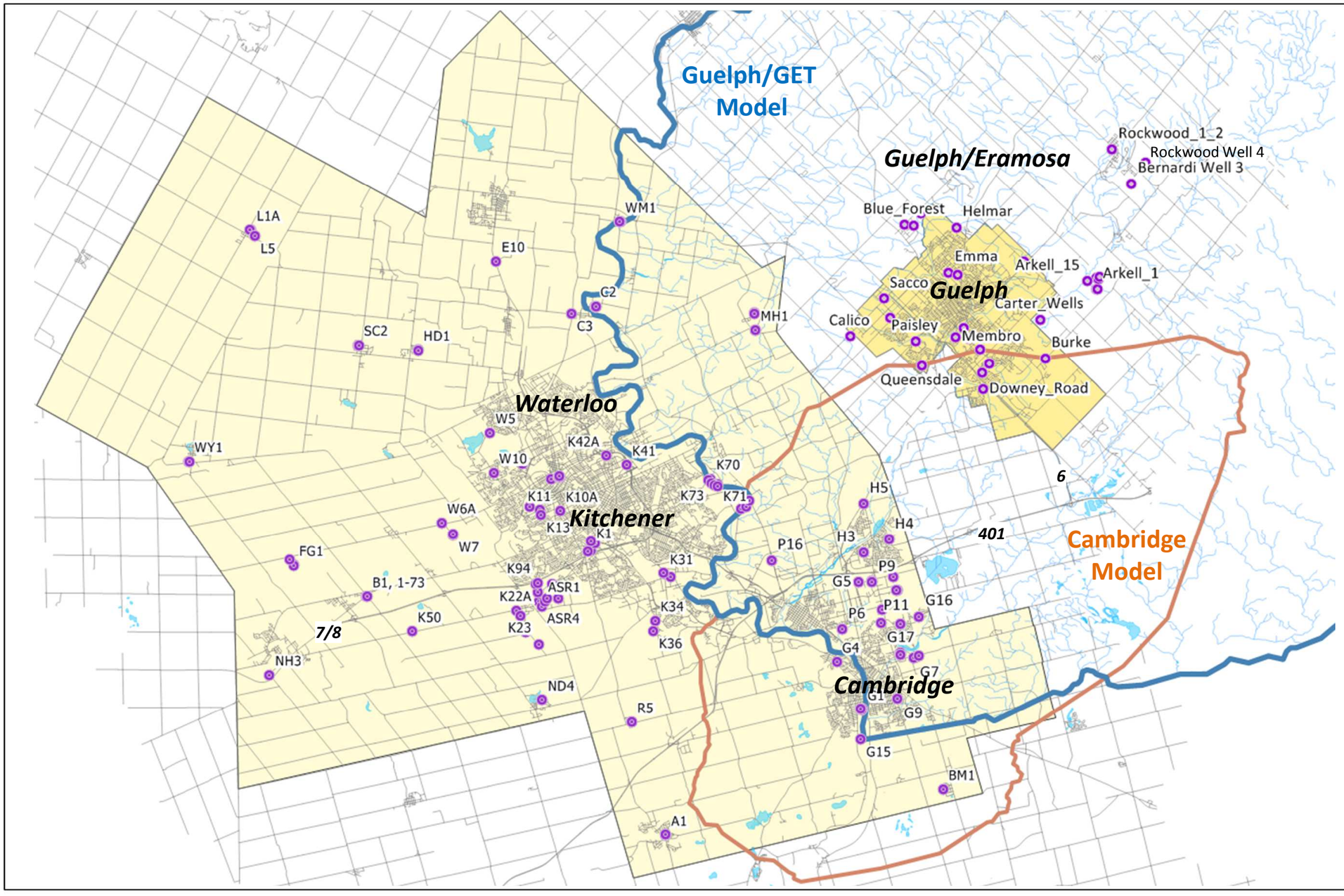

Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Streams
- Lakes
- Roads
- City of Guelph Boundary
- Region of Waterloo Boundary
- Municipal Wells
- Guelph/GET Model Domain
- Cambridge Model Domain

N

0 10 km

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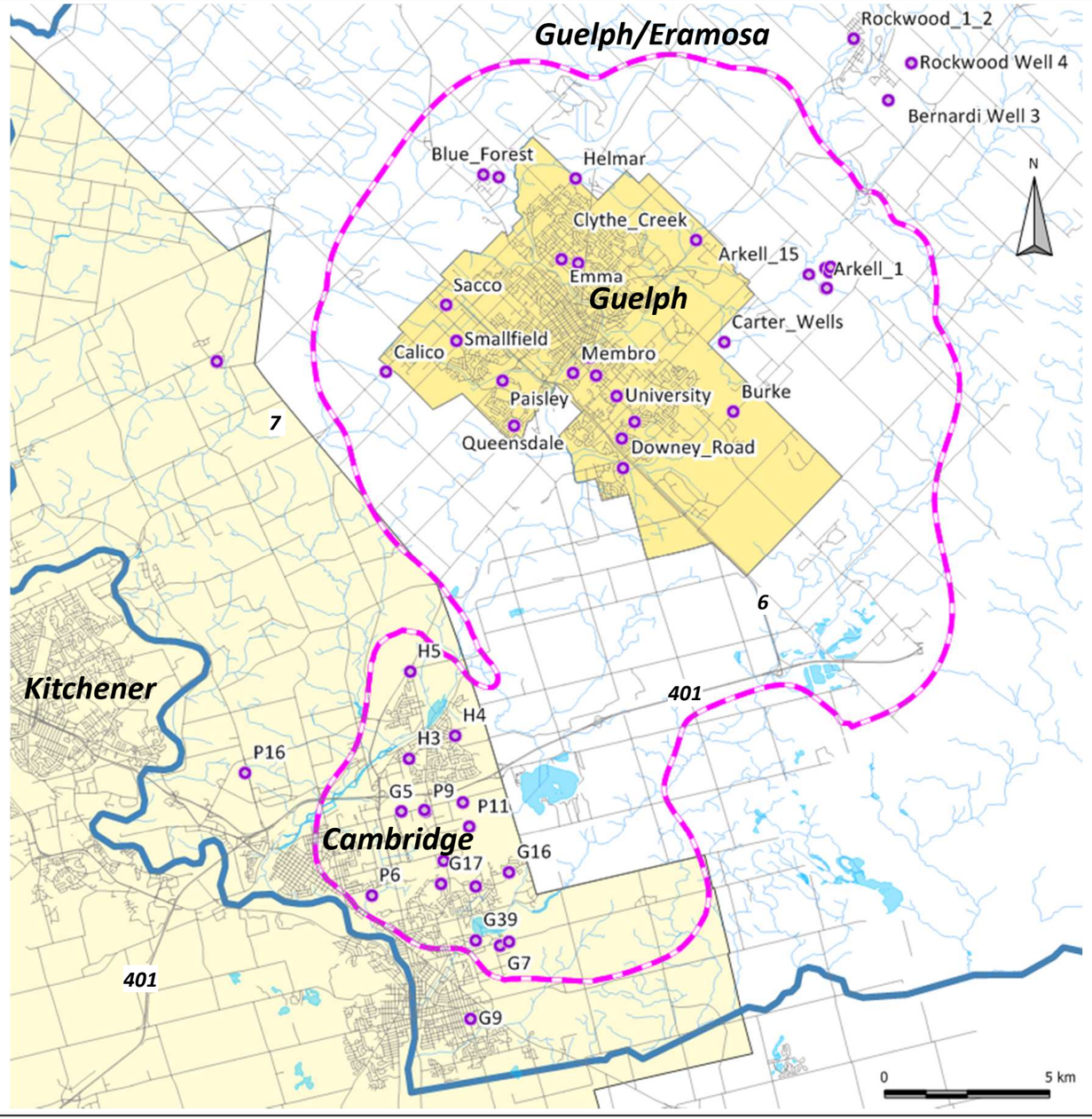
Figure 1: Cambridge and Guelph/ GET Groundwater Flow Models



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Guelph/GET Local Area A
- Guelph/GET Model Domain

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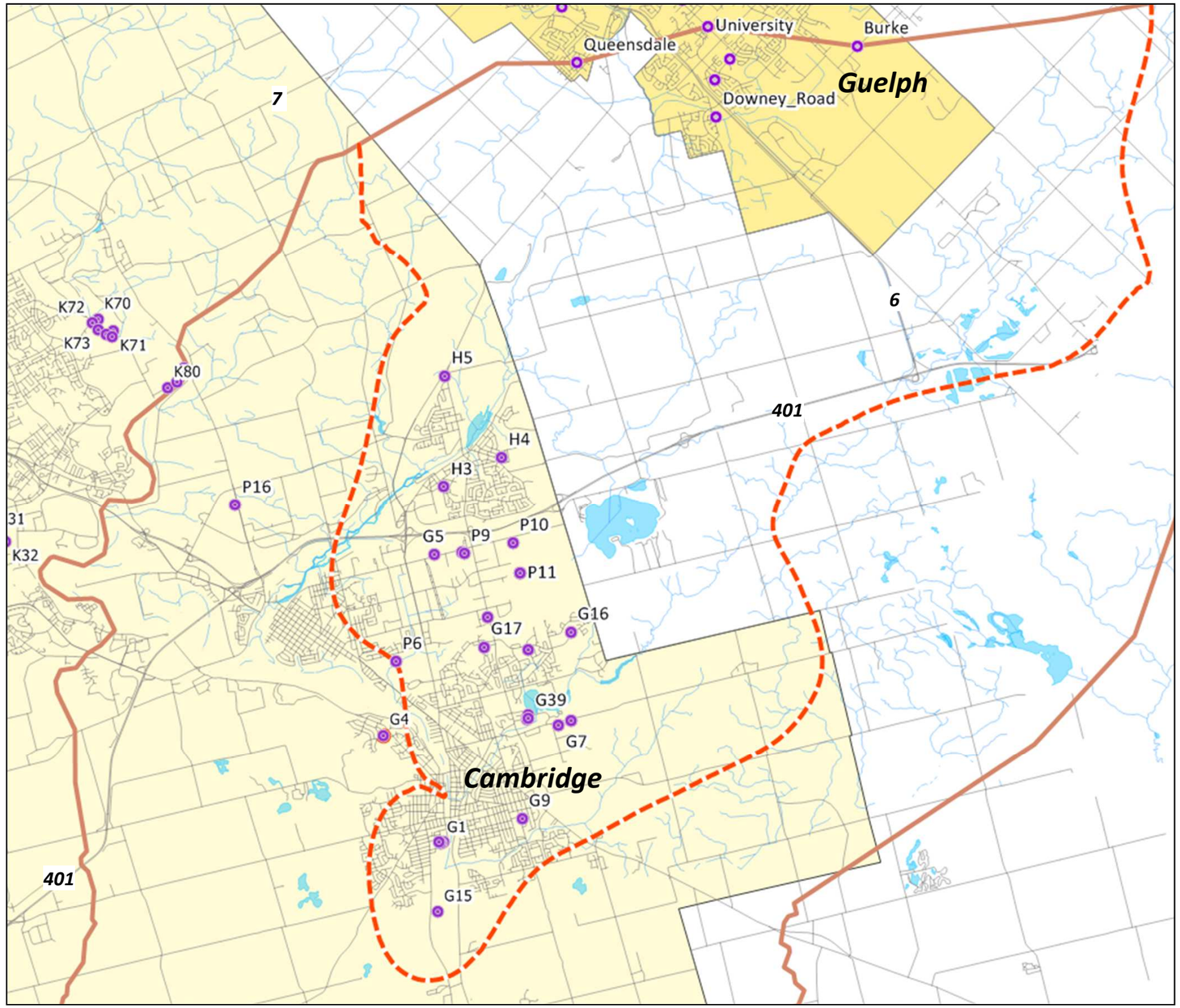
Figure 2: City of Guelph and Township of Guelph/Eramosa Local Area A



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- ROW Local Area B

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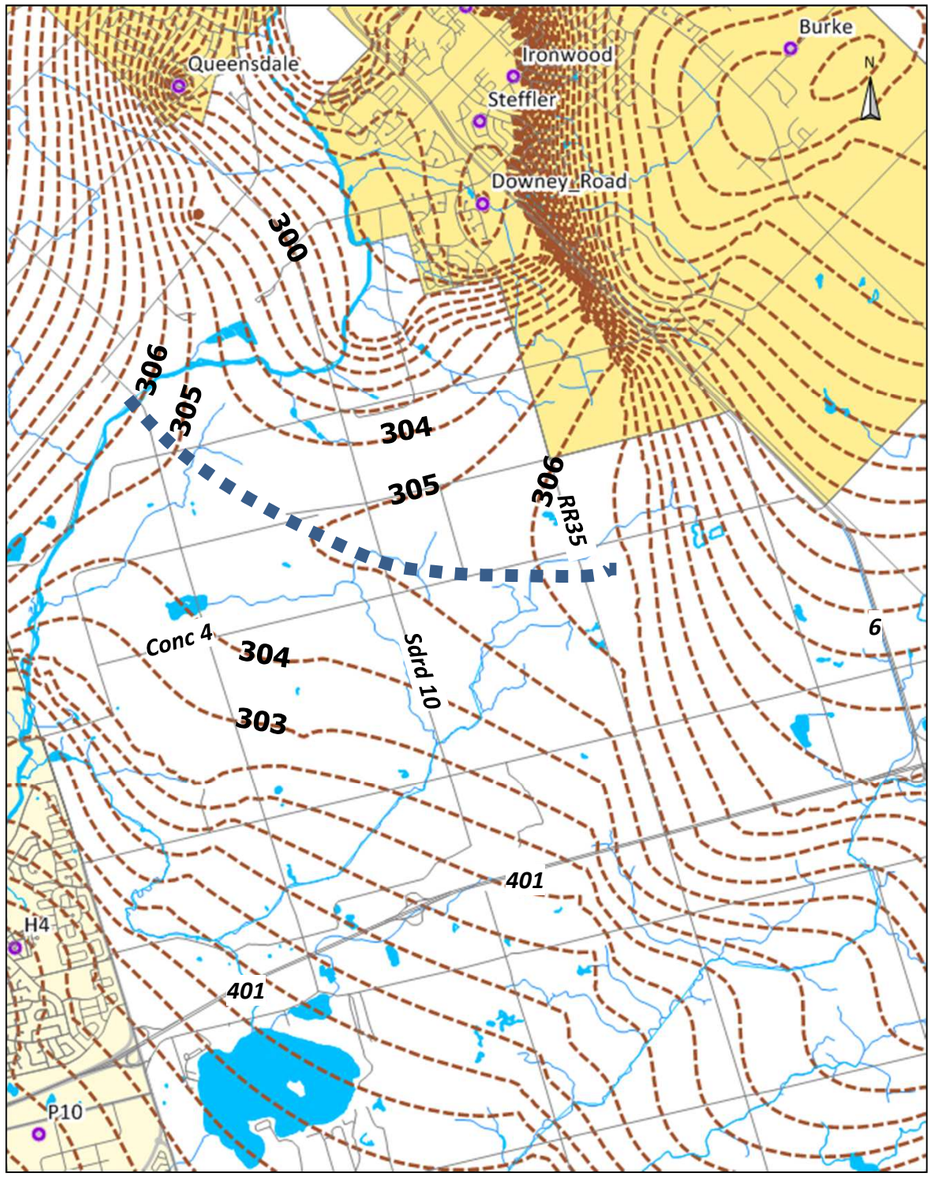
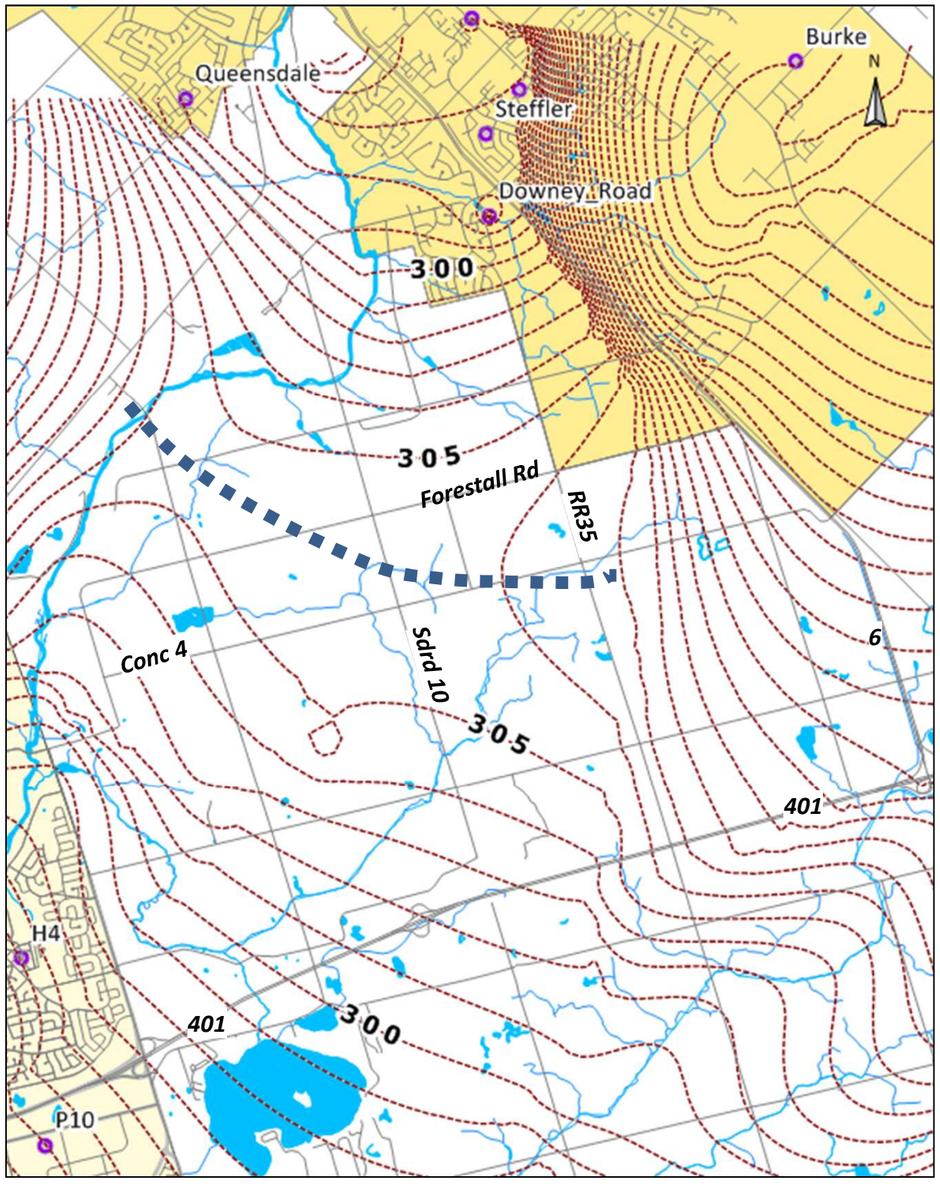
Figure 3: Region of Waterloo Local Area B

Simulated Water Levels – Guelph/GET Model



Simulated Water Levels – Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Lakes
- Roads
- Streams
- City of Guelph Boundary
- Region of Waterloo Boundary
- Municipal Wells
- Cambridge Model Boundary
- Groundwater Level Elevations (masl)
- Interpreted Groundwater Flow Divide

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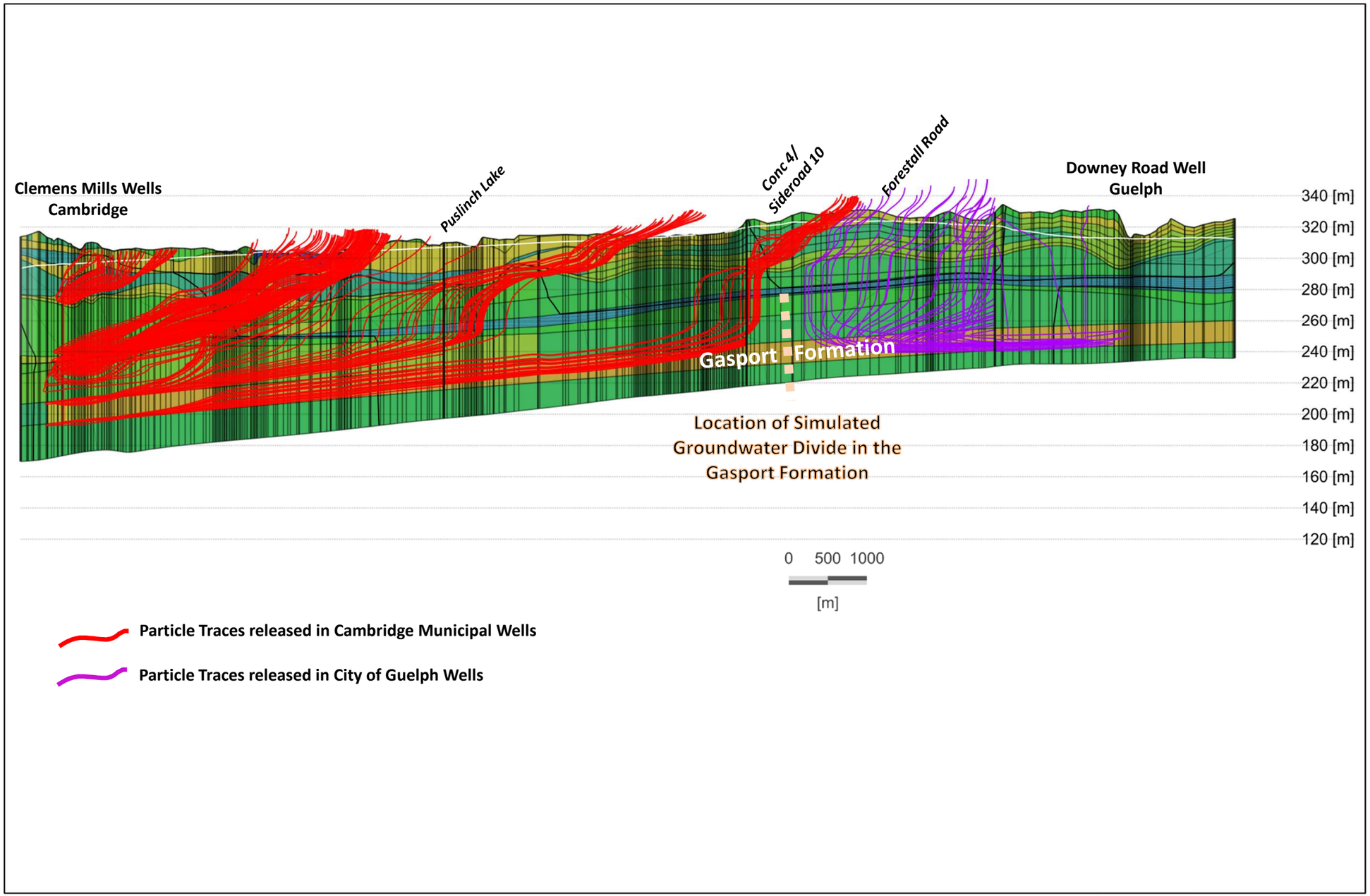
Figure 4: Simulated Groundwater Level Elevations – Gasport Formation



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

Simulated Hydraulic Conductivity (m/s)

- 0.01
- 0.001
- 0.0001
- 1e-05
- 1e-06
- 1e-07
- 1e-08
- 1e-09
- 1e-10

Simulated Hydraulic Head Contour (m)

Simulated Water Table

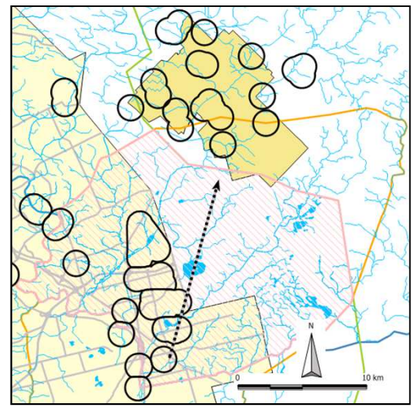


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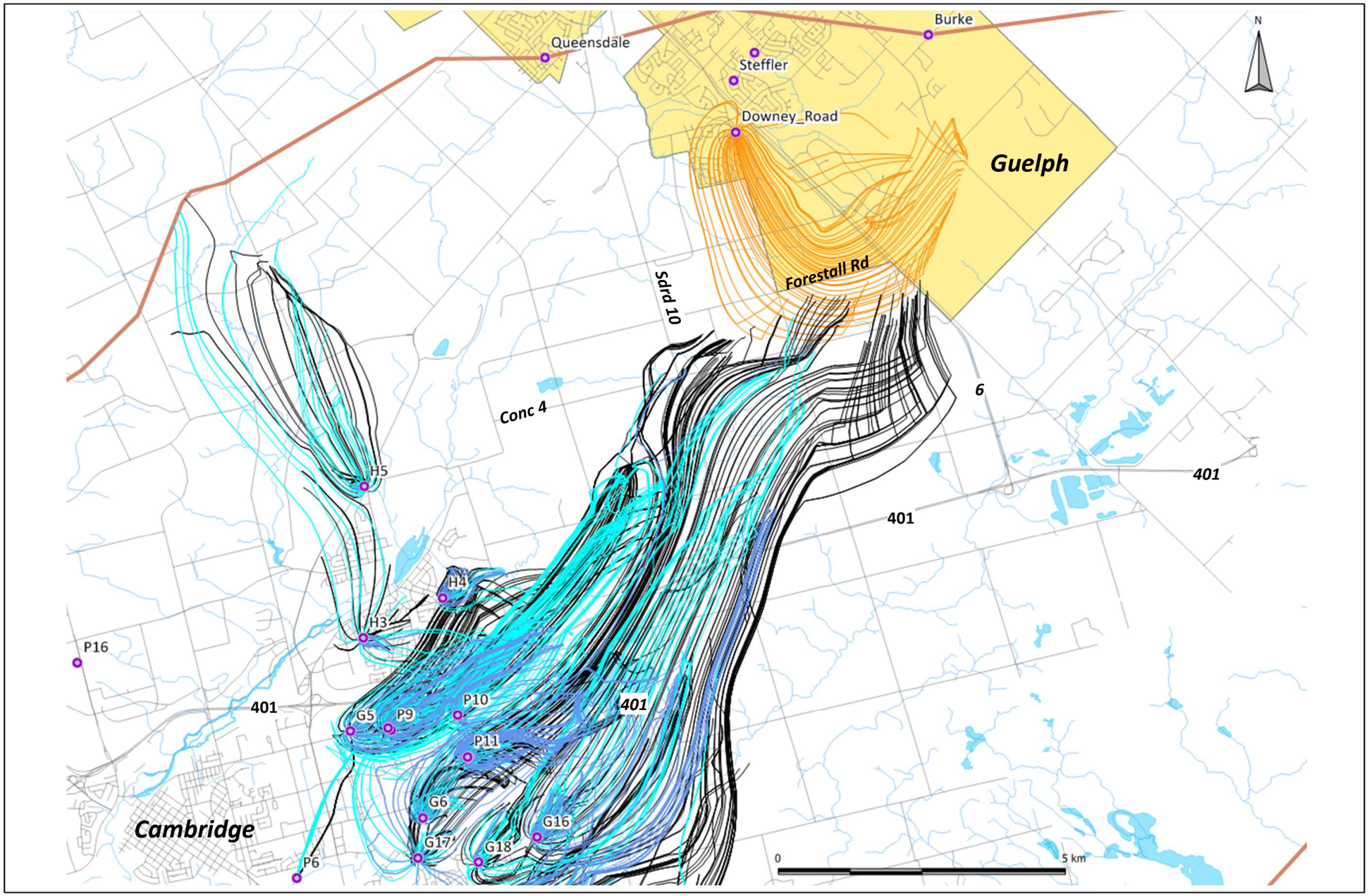
Figure 5: Backward Tracking Particle Traces – Cross-Section Through Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers and Streams
- Lakes
- Cambridge Model Domain
- City of Guelph Municipal Boundary
- Region of Waterloo Municipal Boundary

Region of Waterloo Model

- Particle Pathlines 1
- Particle Pathlines 2
- Particle Pathlines 3
- Particle Pathlines – Downey Well

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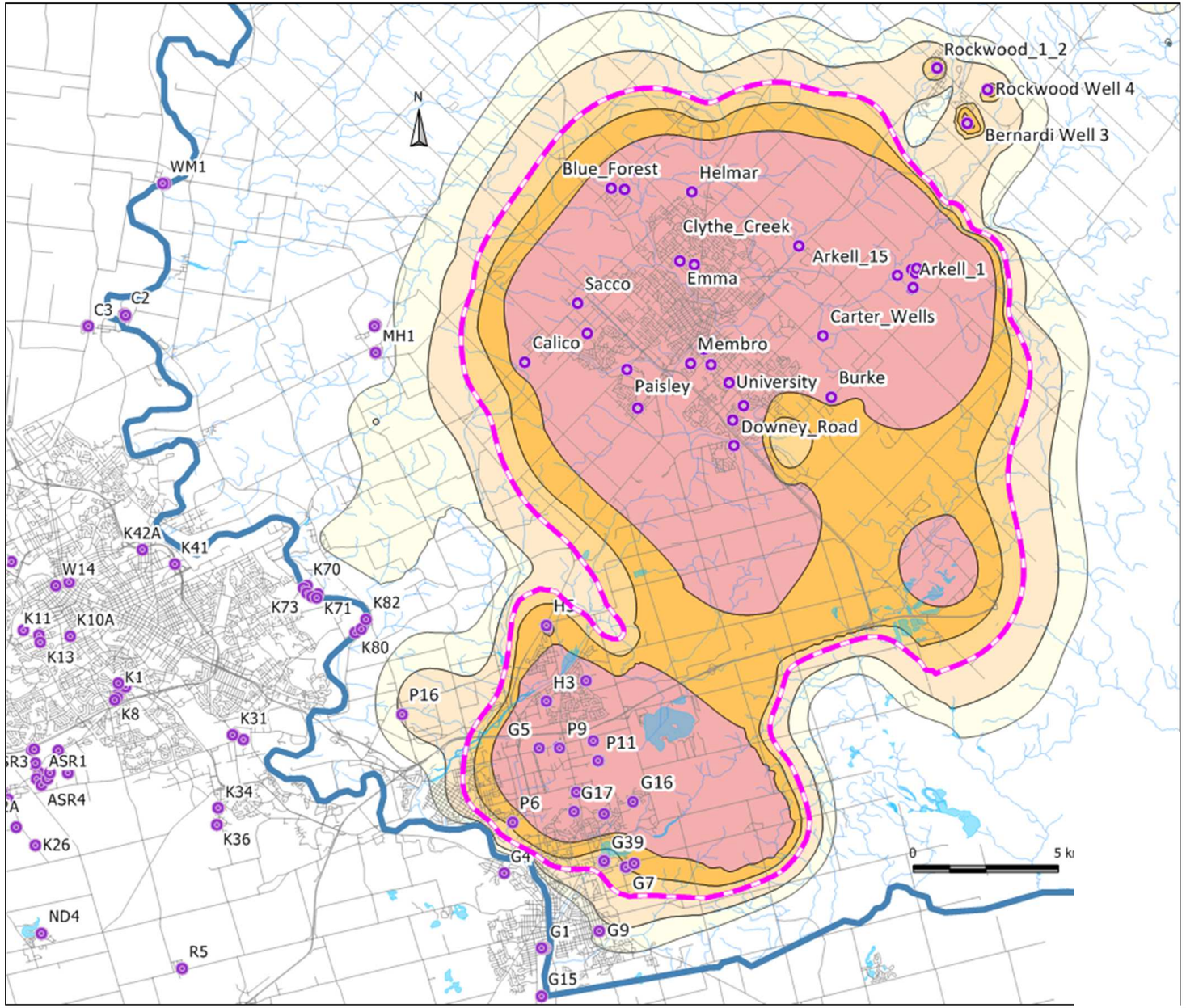
Figure 6: Backward Tracking Particle Traces in Cambridge Model



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Guelph FEFLOW Model Boundary

Simulated Drawdown in Gasport Fm

- 0.50 - 1.00 m
- 1.00 - 2.00 m
- 2.00 - 3.00 m
- 3.00 - 5.00 m
- > 5.00 m
- Guelph WHPA-Q1/Q2

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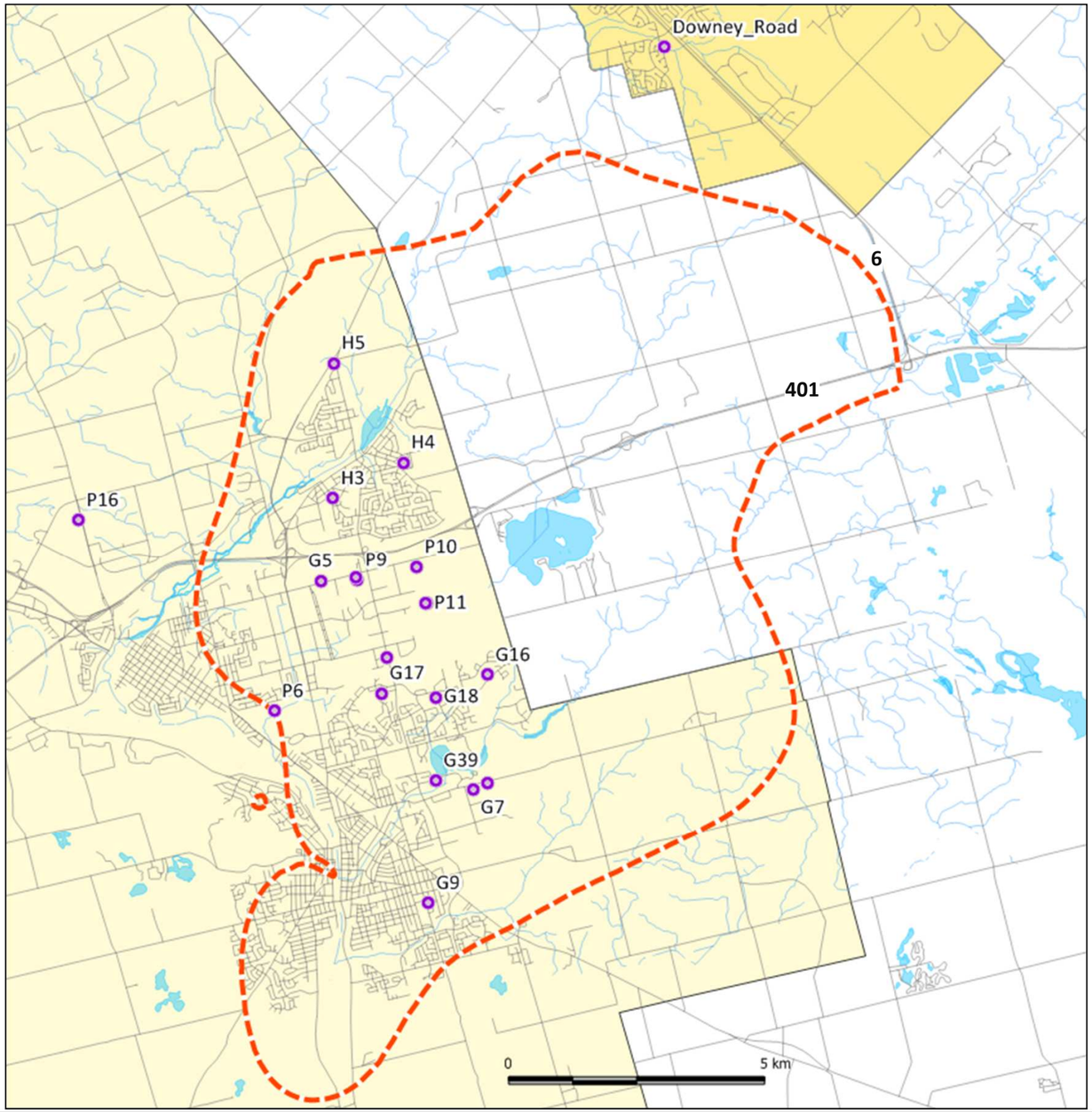
Figure 7: Simulated drawdown in the Gasport Fm (Guelph Model)



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- ROW Local Area B

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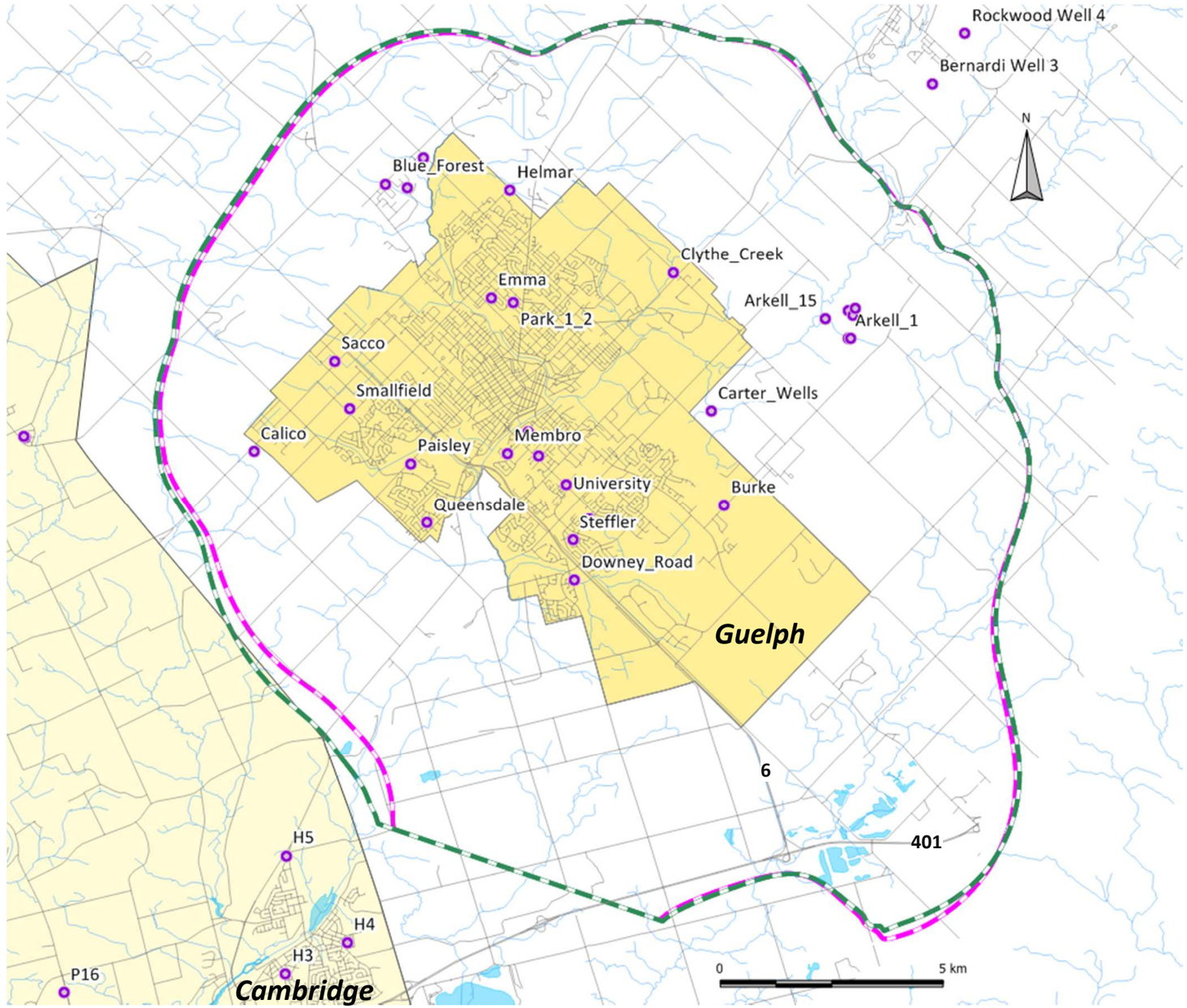
Figure 8: Region of Waterloo Local Area B



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Previous Guelph Local Area A
- Revised Guelph Local Area A

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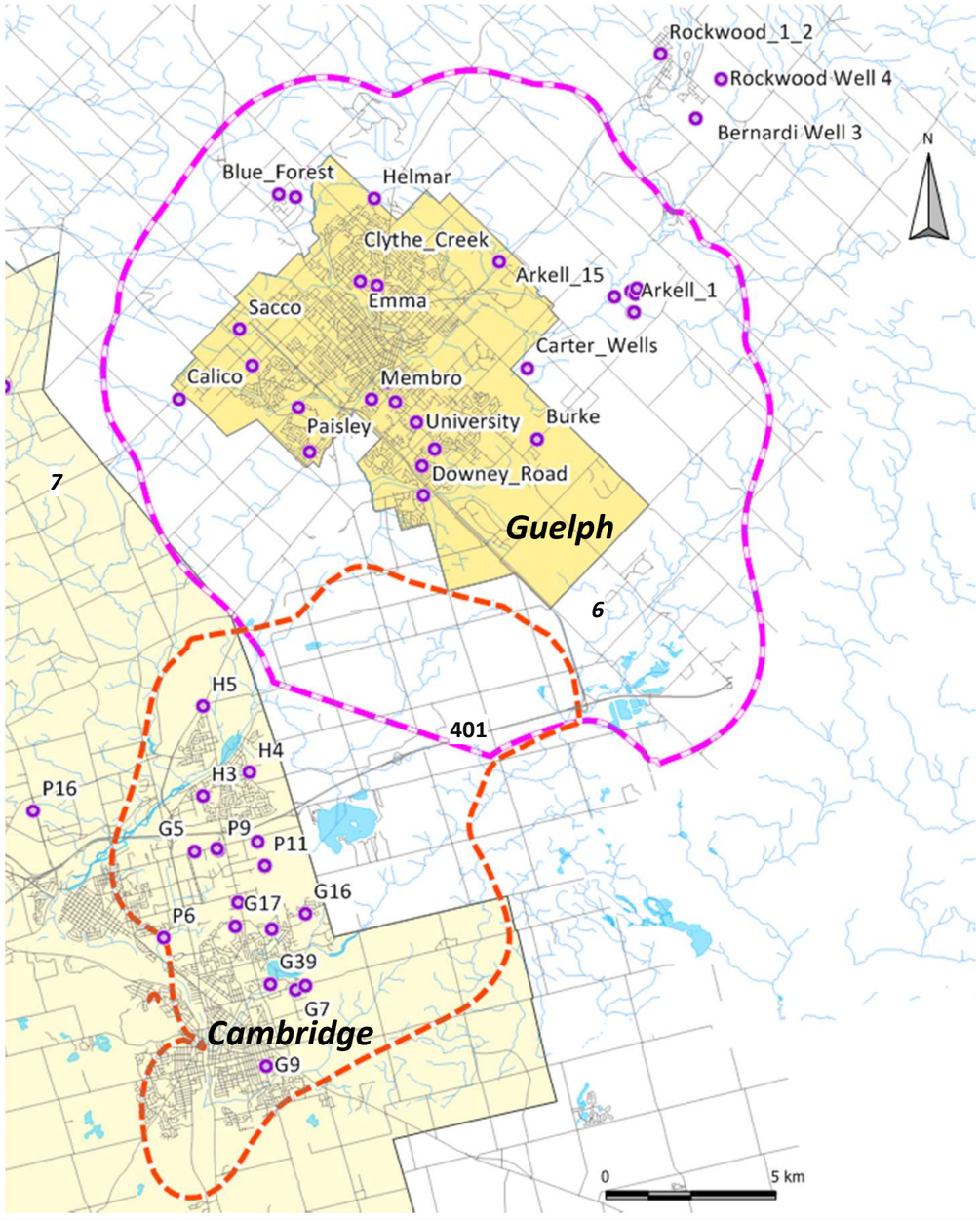
Figure 9: Guelph/GET Local Area A (2014 and 2016)



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Roads
- Rivers/ Streams
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary
- Region of Waterloo Local Area B
- Guelph Local Area A

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Figure 10: Region of Waterloo and City of Guelph/GET Local Areas

APPENDIX A

Assessment of the Impact of Updates to the Guelph/GET Model on the Cambridge Model

As part of the Guelph-Guelph/Eramosa Tier Three Assessment, updates were made in the Guelph/GET groundwater flow model in the Guelph and Puslinch Lake area after the Region of Waterloo Tier Three Assessment was completed. Consequently, some of the input parameters applied in the Cambridge Model and the Guelph/GET model are inconsistent; however, the inconsistencies in the parameters and boundary conditions lie over 5 km away from the Cambridge municipal water supply wells. However, as the WHPA-Q1 for Cambridge and Guelph overlap, the impact of these changes on the Cambridge water supply wells was evaluated.

A new groundwater flow model realization (herein termed the "Cambridge test model") was created using the calibrated base case Cambridge model as a starting point. The future Allocated Rates and the current land use (groundwater recharge) were assigned in the model to be coincident with Risk Assessment "Scenario G2". The parameters and boundary conditions in the Cambridge test model were updated so the model would contain all the recent changes made in the Guelph/GET model in 2015 and 2016. The following changes were made in the Cambridge test model:

1. Updates were made to the hydraulic conductivity values representing the Middle Gasport Formation layer of the model in the Dolime Quarry area of south-west Guelph. The areas where updates were made are illustrated on Figure A1. These updates are over 7 km away from the closest Cambridge water supply well (Well H5) and are separated by the municipal groundwater flow divide.

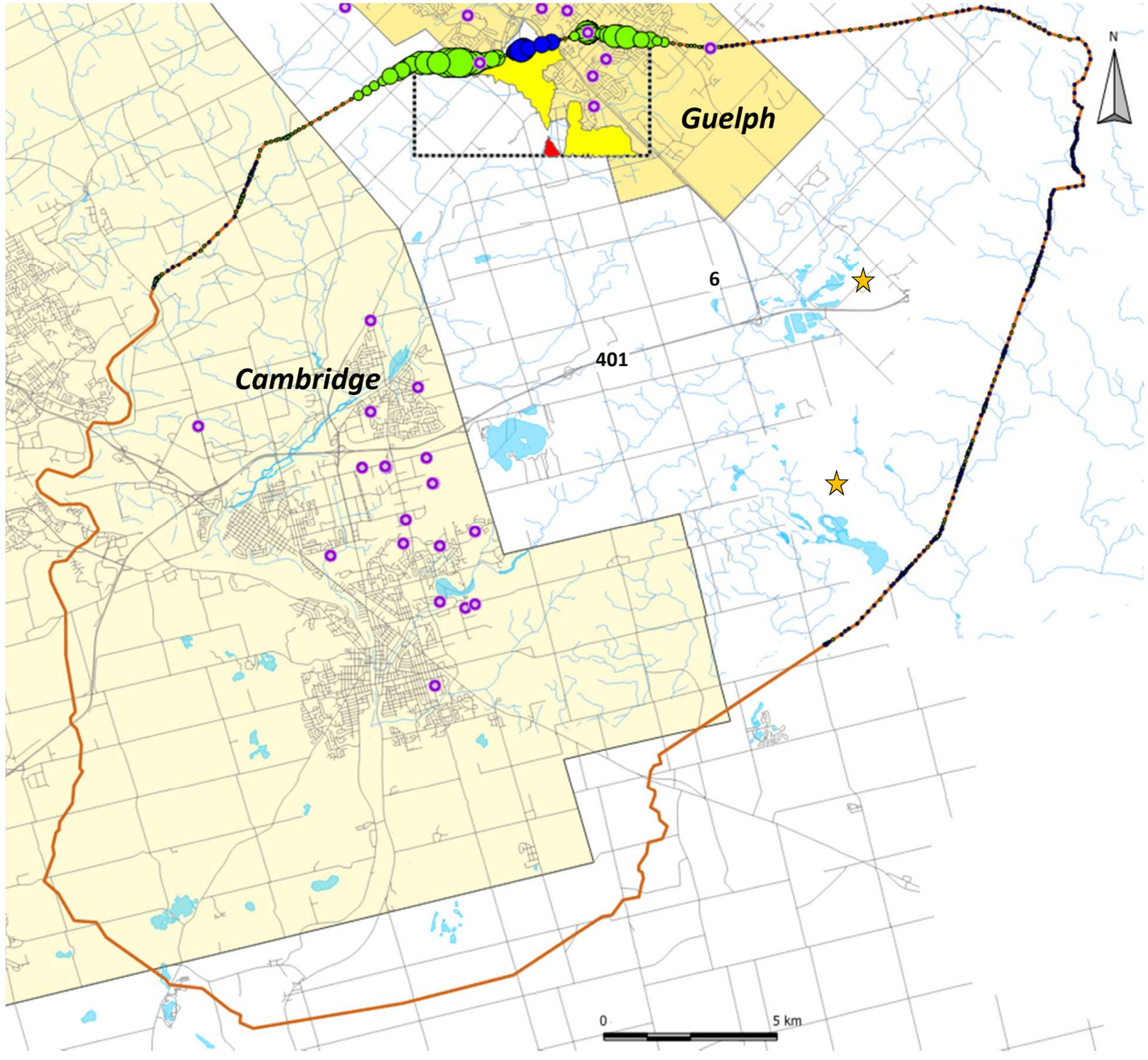
2. A hydraulic conductivity zone was added to the layer representing the Goat Island Formation in the Aberfoyle area to refine the representation of the Nestle water taking in this area. The well was previously simulated in the Gasport Formation and was updated to the Goat Island Formation, and a higher hydraulic conductivity area was added in the vicinity of the well. This change was over 13 km from the closest Cambridge water supply well (Well H4).

3. The constant head values along the perimeter of the Cambridge model were derived from the previous Guelph/GET groundwater flow model. As part of this memo, the constant heads in the Cambridge test model were updated to coincide with simulated heads in the updated Guelph/GET model. The differences between the groundwater level elevation in the current Cambridge Model and the updated test model are illustrated on Figure A1. The areas of the greatest updates to the groundwater level elevations in the Guelph area are over 10 km away from the closest Cambridge water supply well (Well H5).

4. Two large permitted water wells originally simulated in the Guelph/GET model, and subsequently removed as part of a detailed review of permits in Puslinch Township, were also removed from the Cambridge test model as the permits were in the correct locations and are expired. These two wells (Kraus Nurseries and Kats Okashimo Fish Farm) were over 10-15 km from the closest municipal water supply well (Well G16) and represent a reduction in total water taking of approximately 1,700 m^3/day (20 L/s) from the model. The locations of the two permits are illustrated on Figure A1.

To assess the potential impact of the above noted changes in model input parameters and boundary conditions on the Risk Assessment results in the Region, the Cambridge test model was run and the simulated groundwater level elevations at six water supply wells in Cambridge area were exported. The simulated groundwater level elevations in the current Cambridge model were also exported, and used to calculate the differences in elevations at the municipal wells between the two models. The changes made in the Guelph/GET model were negligible and led to negligible (1 to 4 cm) increases in groundwater level elevations at three water supply wells in Hespeler (Wells H3, H4 and H5) and three wells in the Pinebush Well Field (Wells P10, P11 and G5). The wells are located closest to the areas of model updates, and are completed across various bedrock aquifers, ensuring changes in simulated groundwater level elevations in various aquifers would be assessed by one or more wells.

In summary, inconsistencies between the model boundary conditions and hydraulic conductivity values in the Cambridge and Guelph/GET models in the Puslinch Township area exist; however, these were determined to have no impact on the groundwater levels at the municipal wells within the Cambridge area, and therefore, will not impact the Risk Assessment results in the City of Cambridge. Many of the changes are located near the northern boundary of the Cambridge model where it would be unfit to be applied to make predictions, as the boundary conditions in that area would influence the model results. The Guelph/GET model is recommended for use in this south Guelph area.



Division of Combined Local Area between the Cities of Guelph and Cambridge

Legend

- Municipal Wells
- Cambridge Model Boundary
- Roads
- Rivers/ Streams
- Updated Guelph Model Area
- Lakes
- Region of Waterloo Boundary
- City of Guelph Boundary

Revised Kx (m/s)

- Changed from 8e-5 to 5e-4
- Changed from 5e-4 to 1e-4

***Updated Guelph Model Heads - Existing Cambridge Model Heads**

Guelph/GET Model heads higher than Cambridge Model heads

- -6...-4 m
- -4...-2 m
- -2...-1 m
- -1...0 m
- 0...1 m
- 1...2 m
- 2...4 m
- 4...6 m
- 6...8 m

Guelph/GET Model heads lower than Cambridge Model heads

- Inactive Permit to Take Water

*Note: head difference calculation uses simulated heads in the Middle Gasport Fm.

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Figure A1: Differences between Cambridge Model and Revised Guelph/GET Model