APPENDIX 3

HYDRAULIC MODELLING TECH MEMO

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TECHNICAL MEMORANDUM

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Date:	March 28, 2024		
Subject:	Carlisle Water Storage Facility and Distribution System – Hydraulic Modeling		

1.0 Introduction

R.V. Anderson Associates Limited (RVA) has been retained by the City of Hamilton (the City) to provide engineering services for the Carlisle Water Storage Facility Municipal Class Environmental Assessment (EA) and Conceptual Design (the project).

As part of the second phase of the project, this Technical Memorandum (Tech Memo) was provided to document and summarize the results of the watermain hydraulic modeling of Carlisle Rural Settlement Area's (RSA's) water distribution system to assist in providing a short list of options regarding the location of the additional storage facility per the RSA's future water demands.

The results of the steady-state modeling and hydraulic analysis were provided based on the Carlisle water distribution system's normal operating conditions under existing and future (2051) demand conditions under Average Day, Maximum Day, Maximum Day plus Fire Flow and Peak Hour demand conditions per the RSA's calculated water consumption rates and future domestic demands, including its additional storage capacity needs as documented in RVA's previously submitted tech memo (TM no. 1) dated July 2023.

1.1 Objectives

The intent of this study is to determine the capability of the existing municipal water distribution system to meet the required water demands within Carlisle under existing and future conditions including the effectiveness of the proposed upgrades to the system.

In addition, the objectives of the hydraulic analysis documented in this tech memo are to:

- Summarize the water demands used under all simulated demand conditions for existing and future planning horizons;
- Identification of the system's standard operating conditions;
- Document City of Hamilton design criteria and requirements with respect to water distribution systems;
- Validate the existing hydraulic model of Carlisle's water distribution system, and calibrate the model based on the field test data collected from the existing system;
- Determine the most efficient location/s of the proposed additional storage and its impact on the distribution system under existing and future demand scenarios;
- Evaluate the hydraulic performance of the system for both existing and future conditions including the proposed upgrades, and identify system constraints and opportunities to improve the water network's system performance, if any; and,
- Provide recommendations to improve the overall system capacity and performance while meeting the required pressures and flows under all demand conditions.

The water hydraulic model together with its results documented in this report provides an opportunity for the City to evaluate and improve system reliability and flexibility (i.e., pressures and fire flows) based on the existing (2022) and future (2051) population growth, and to use the hydraulic model for baseline planning and an analysis tool for future developments and required system upgrades for Carlisle RSA.

2.0 System Description

The majority of the residential dwellings within Carlisle RSA are serviced by the municipal water system, while the remainder are connected and serviced through private wells. The existing municipal water distribution system of Carlisle RSA is currently being supplied by four (4) groundwater wells (FDC01A, FDC02A, FDC03A, and FDC05A), while storage is provided by one (1) elevated tank (Carlisle Elevated Tank).

The Carlisle Elevated Tank (CET), which is the existing elevated tank in Carlisle, is located near the Acredale Drive and Cullum Drive intersection. This tank has a total volume capacity of 1,400 m^3 or 1.4 ML with a Top Water Level (TWL) of 323.0m and Low Water Level (LWL) of 315.5m.

Figure 2.1 shows Carlisle RSA's existing water distribution system with its watermain network design layout and the locations of the supply wells and the elevated tank (CET).

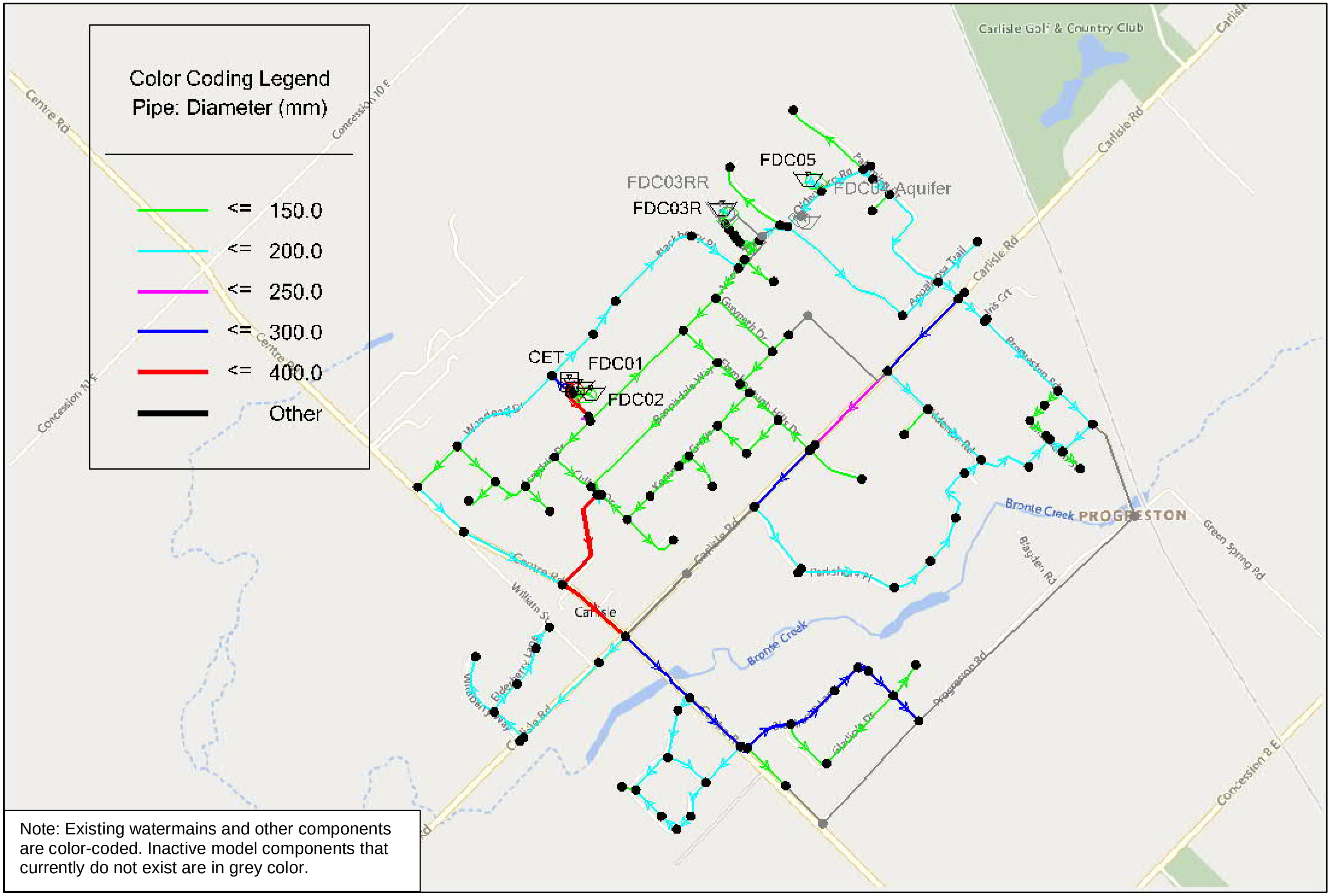

Figure 2.1: Carlisle RSA Existing Water Distribution System

There are currently four (4) pumping stations that draw water from the groundwater wells and supply water to the Carlisle water distribution system. These stations are namely FDC01, FDC02, FDC03R, and FDC05.

Table 2.1 shows the rated capacity and the maximum allowable flow rate that can be taken from each well based on the Drinking Water Works Permit (DWWP, 2019) and the Permit to Take Water (PTTW, 2021). Accordingly, the total combined yield that can be taken from the groundwater wells is 49.8 L/s with a firm capacity flow of 24.8 L/s.

Table 2.1: Carlisle RSA's Existing Well Capacity

<table>
<tr><th>Wells</th><th>Rated Capacity per DWWP (L/s)</th><th>Max. Allowable Capacity per PTTW (L/s)</th></tr>
<tr><td>FDC01</td><td>9.8</td><td rowspan="2">9.8*</td></tr>
<tr><td>FDC02</td><td>9.8</td></tr>
<tr><td>FDC05</td><td>15.0</td><td>15.0</td></tr>
<tr><td>FDC03R</td><td>25.0</td><td>25.0</td></tr>
<tr><td>Total Capacity</td><td></td><td>49.8</td></tr>
<tr><td>Firm Capacity</td><td></td><td>24.8**</td></tr>
</table>

*PTTW indicated that the supply from either or both FDC01 and FDC02 shall not exceed an annual daily average flow rate of 9.8 L/s.

**Firm capacity is defined as the total flow rate with the largest well (FDC03R) taken out of service (10 State Recommended Standards for Water Works).

The FDC01 and FDC02 stations, located at the northeast side of the Acredale Drive and Cullum Drive intersection and closest to the existing elevated tank amongst the other stations, operate separately from each other with 9.8 L/s of total allowable flow capacity for each station per the system's standard operating condition. Furthermore, both the FDC03R and the FDC05 stations, located at the north end of the system, have Variable Frequency Drive (VFD) pumps with total rated capacities of 25 L/s and 15 L/s, respectively.

3.0 Carlisle Water Distribution Network Model

The existing hydraulic water model of the Carlisle RSA's network was developed in OpenFlows WaterGEMS software. The model was calibrated/validated for this study. It is a comprehensive support tool for analyzing water distribution networks. The watermain hydraulic model provides a representation of Carlisle's water infrastructure where simulations can be conducted under various scenarios and planning horizons.

The following subsections document the data and parameters used to validate the existing watermain hydraulic model of Carlisle's water distribution network.

3.1 Modeling Theory

The watermain hydraulic model represents the piping network using connection links represented by junctions or nodes. The water usage or demands were assigned to each respective node within the network. It should be noted that not every existing pipe within the network was included (i.e., small pipe sizes lower than Ø75mm were omitted in the model). Furthermore, relatively minor demands within the network such as individual homes were grouped and represented by a single node.

The hydraulic model was set up with water supply distribution from storage facilities (i.e., reservoirs or tanks) to the demand nodes by pumps in pumping stations. Various simulations were solved using a series of mass balance and energy conservation equations developed at each network connection within the water distribution network.

3.2 Water Demands

The water demands used during the hydraulic modeling process were based on historical data on water consumption rates and calculated projected demands for Carlisle RSA under existing (2022) and future (2051) planning horizons, respectively.

Table 3.1 summarizes the domestic water demands used in the model under all simulated scenarios, while Table 3.2 shows the fire flow requirement for every dwelling type within Carlisle RSA and was used as a reference during the fire flow analysis of the water distribution network under existing and future Maximum Day plus Fire Flow scenarios.

Detailed information about Carlisle RSA's water demands including its referenced data and calculation details were provided in the RVA tech memo no.1 dated July 2023 (see Appendix A).

Table 3.1: Carlisle RSA's Calculated Domestic Water Demands Summary

Planning Horizon	Average Day (L/s)	Maximum Day (L/s)	Peak Hour* (L/s)
Existing (2022)	9.42	32.03	53.03
Future (2051)	14.54	49.43	81.86

*Peak Hour Demand peaking factor of 5.62 was selected based on the WMP/Class EA (Stantec, 2004). The MECP recommended PHD peaking factor for the population less than 2000 is 3.75, which is not conservative.

Table 3.2: City of Hamilton's Target Available Fire Flow Based on Land Use

Land Use	Target Available Fire Flow (L/s)
Commercial	150
Small I/I (<1800m^3)	100
Industrial	250
Institutional	150
Residential Multi (>3 units)	150
Residential Medium (3 or fewer units)	125
Residential Single	75
Residential Single (Dead End)	50

3.3 Node Elevation Data

The junction/node elevations were included in the existing hydraulic model provided by the City of Hamilton. It should be noted that the node elevations within the model were ground surface elevations and not the actual elevations of the watermains. This is standard practice as the pressure values determined by the model are simulated at grade.

3.4 Pipe Roughness Coefficients (C-Factors)

The Hazen-Williams "C" factor is an empirical coefficient that relates flow through a pipe of a certain size to the head loss across its length and is represented by the equation:

$$C = \frac{Q}{278.5D^{2.63}\left(\frac{H_l}{L}\right)^{0.54}}$$

where:

C = Hazen Williams C factor

Q = flow in pipe, L/s

D = pipe diameter, m

H_l = head loss, m

L = length, m

The C-factor declines as the interior wall of an unlined pipe corrodes. The rate of decline for larger-diameter pipes is typically slower than that of smaller-diameter pipes. Watermains, with pipe material like iron, are typically replaced or rehabilitated with cement mortar or epoxy lining when the C-factor declines within the 50 to 60 range (i.e., 50% capacity of a new watermain).

The initial C-Factors for various pipe sizes and materials used for calibrating the hydraulic model were based on industry standards. These C-factors were then refined during the calibration process based on field test results.

Table 3.3 shows the C-factors used to match the pressures and flows from the field test data conducted through hydrant testing and in calibrating the hydraulic model.

Table 3.3: C-Factors Used in the Hydraulic Model

Pipe Material	Diameter (mm)	C-Factor
Ductile Iron	150 to 300	100 to 130
Cast Iron	100 to 150	90 to 120
PVC	75 to 400	90 to 140

3.5 Pump Supply Capacity

The Carlisle water distribution network is currently supplied by four (4) pumping stations with each maximum allowable pumping capacity summarized in Table 2.1. Each station has a single Grundfos submersible pump that draws water out and pumps into the distribution system.

In order to match the flow capacity under existing conditions, the pump curves used in the hydraulic model were based on the pump tests conducted by Lotowater Technical Services Inc. (Lotowater) dated from June 2020 to August 2021.

Detailed results and information on the pump test data used in the hydraulic model for each station are contained in Appendix B.

3.6 Model Validation

The intent of model validation is to bring the modeling results as close as possible to real-world conditions by comparing the model results with actual field measurements and adjusting the model parameters (if necessary) to match the field test data from the hydrant flow testing. This method generally involves designating the proper C-factors per the domestic demands and comparing the simulated hydrant flow curve with the pressure and flow points gathered from the hydrant flow test results under the existing Average Day Demand (ADD) scenario.

Hydrant flow testing, based on the National Fire Protection Association (NFPA) 291 standards, was performed in November 2022 by RVA at seven (7) locations within Carlisle RSA which were strategically selected to cover the whole system.

Figure 3.1 shows a test location map with the hydrants tested and their locations within Carlisle RSA, while the field test data gathered from the hydrant flow testing are listed in Table 3.4. Complete details and information on the hydrant test results for each location shown in Figure 3.1 below are provided in Appendix C.

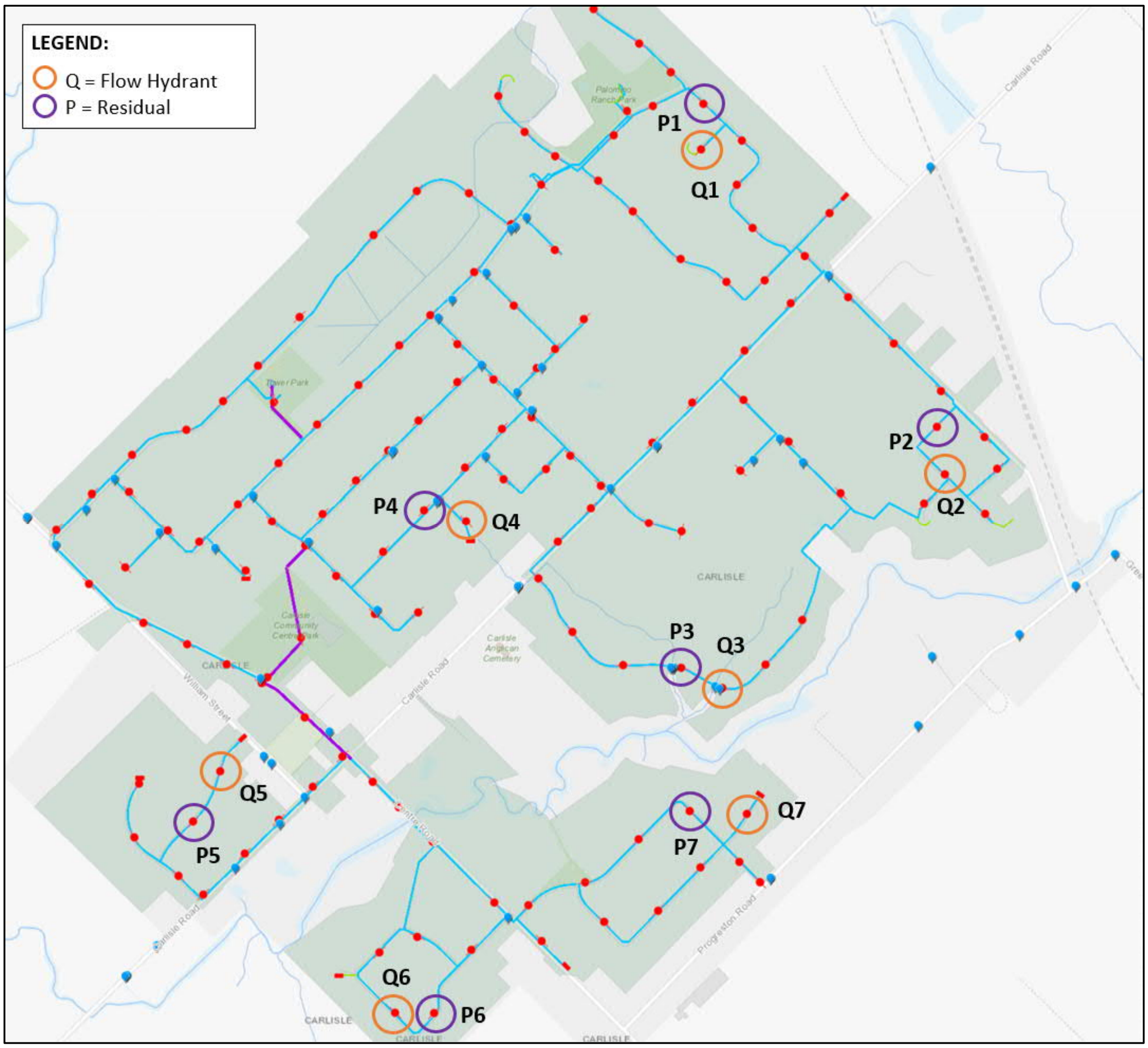

Figure 3.1: Hydrant Flow Test Location Map

Table 3.4: Hydrant Flow Test Results

Test No.	Static Pressure (psi)	Residual Pressure (psi)	Residual Flow (usgpm)	Extrapolated Flow at 20 psi Pressure (usgpm)
1	71	53	1,136	2,046
2	92	49	1,680	2,211
3	93	55	1,285	1,842
4	75	53	1,298	2,111
5	94	68	1,254	2,210
6	92	60	1,382	2,159
7	90	43	1,298	1,605

Using the results of the hydrant flow tests, the model parameters were adjusted by changing the C-factors of the pipes to a reasonable value to match the field test data. The step-by-step model validation process used during the course of the study is provided as follows:

1. Compare the measured static pressure from the field testing and the simulated pressure from the model. The static pressure is defined as the hydraulic grade at the test location under the ADD scenario.
2. Check the ground elevation at the test location where the residual pressure was measured for each test.
3. Compare the measured residual pressure and the modeled pressure on the test location and the model junction, respectively for each test. The residual pressure is defined as the hydraulic grade at the test hydrant location when the hydrant is flowing at a specific flow rate.
4. Check the pipe connectivity at each test location.
5. Check the water demands within the area of each test location.

6. If necessary, verify and update the ground elevation, pipe connectivity, and/or water demands based on new information and re-run the hydrant flow curve in the hydraulic model.
7. Compare the measured head loss and the simulated head loss for each test location. The head loss is the difference between the static pressure and the residual pressure at each test location.
8. If necessary, revise the roughness coefficients (C-factors) of pipe segments and re-run the simulations until the model reasonably matches the pressure and flow data gathered from the field measurements.

The model and field test results comparison are within ±5% static pressure, ±5% residual pressure, and ±10% available fire flow at 140 kPa (20 psi) pressure at all recorded points under the current ADD scenario.

Detailed information about the model validation and field test results are contained in Appendix C.

4.0 Analysis and Results

Following City of Hamilton's design criteria, requirements and guidelines for water distribution systems were considered for the hydraulic analysis of Carlisle RSA's water distribution network:

1. The City of Hamilton's 2006 Water and Wastewater Master Plan (WWWMP) outlines the acceptable pressures under all demand conditions between minimum and maximum pressures of 275 kPa (40 psi) and 690 kPa (100 psi), respectively.
2. Fire flow requirements for all the existing residential dwellings were based on the City's target available fire flow based on land use (see Table 3.2) which are based on the Ontario Building Code (OBC) guidelines and are not to exceed the available flows in the municipal watermains under existing (2022) and future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) conditions with a minimum maintaining residual pressure of 140 kPa (20 psi) within the system.
3. The water supply system should be designed to satisfy the greater of peak hour demand or maximum day demand plus fire flow.

The steady-state model simulations were performed to determine the hydraulic conditions of the distribution system under all demand conditions. The results were then compared under existing and future demand conditions including the system performance with the proposed upgrades which are summarized in the following subsections.

4.1 Existing (2022) Conditions – Normal Operations (without Upgrades)

Under the existing (2022) conditions without the proposed upgrades to the system, three (3) pumping stations were in operation with each flow capacity summarized in Table 4.1 per the results of the pump testing for each station (see Appendix B). In addition, the CET was set to 80% full under this condition per the tank's normal operating condition.

Table 4.1: Pump Status and Capacity Flow Under Existing (2022) Conditions

Pump Station	Average Day Demand (L/s)	Maximum Day Demand (L/s)	Peak Hour Demand (L/s)
FDC01	Offline	Offline	Offline
FDC02	9.78	9.78	9.78
FDC03R	14.16	14.23	14.29
FDC05	12.61	12.67	12.73

Based on the results of the hydraulic analysis, the service pressures within the distribution network range from 409 kPa (59 psi) to 643 kPa (93 psi) per the boundary conditions mentioned above during the existing conditions. Accordingly, the resulting pressures are within the acceptable range for water distribution systems.

Table 4.2 shows a summary of the simulated pressures under the existing conditions.

Table 4.2: Simulated Pressures Under Existing (2022) Conditions

Planning Horizon	Average Day Demand (kPa)	Maximum Day Demand (kPa)	Peak Hour Demand (kPa)
Existing (2022)	421 – 643	416 – 637	409 – 630

Figure 4.1, Figure 4.2, and Figure 4.3 were provided to show the resulting pressure range within the Carlisle RSA's water distribution network for the Average Day, Maximum Day, and Peak Hour demand scenarios, respectively under the existing (2022) planning horizon. Furthermore, it can be noticed from the figures that the lowest pressures from the spectrum are located north of Carlisle Road. This is due to the elevation difference where the northern area of Carlisle RSA has higher elevations compared to its southern area. The results, however, show that the pressures are within the acceptable range under existing conditions per the City of Hamiton's design criteria and requirements.

In addition, under the existing Average Day Demand condition where all three wells are offline (worst-case scenario), the system was simulated and analyzed. Accordingly, the resulting pressures within the network range from 409 kPa to 635 kPa as shown in Figure 4.4.

The overall results of the simulated pressure range show that the municipal system has enough capacity to maintain the required pressures within the system under existing conditions with normal operations. The impact of the calculated demands under Average Day, Maximum Day, and Peak Hour demand scenarios has minimal effect on the pressures with pressure drops ranging from 5 kPa (1 psi) to 13 kPa (2 psi) only; therefore, the system can maintain the required pressures while supplying the domestic demands under these existing conditions.

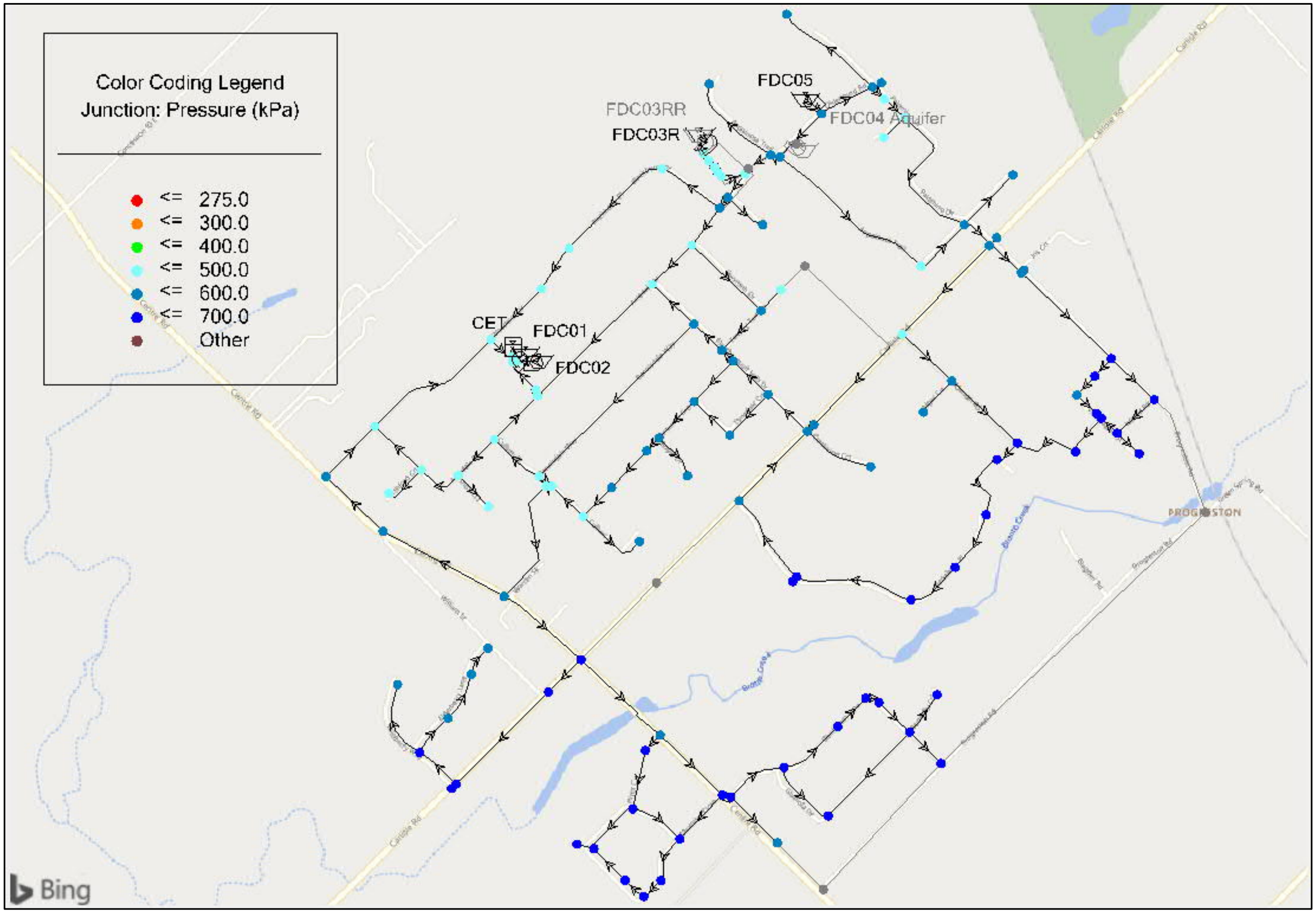

Figure 4.1: Resulting Pressures Under Existing (2022) Average Day Demand (ADD)

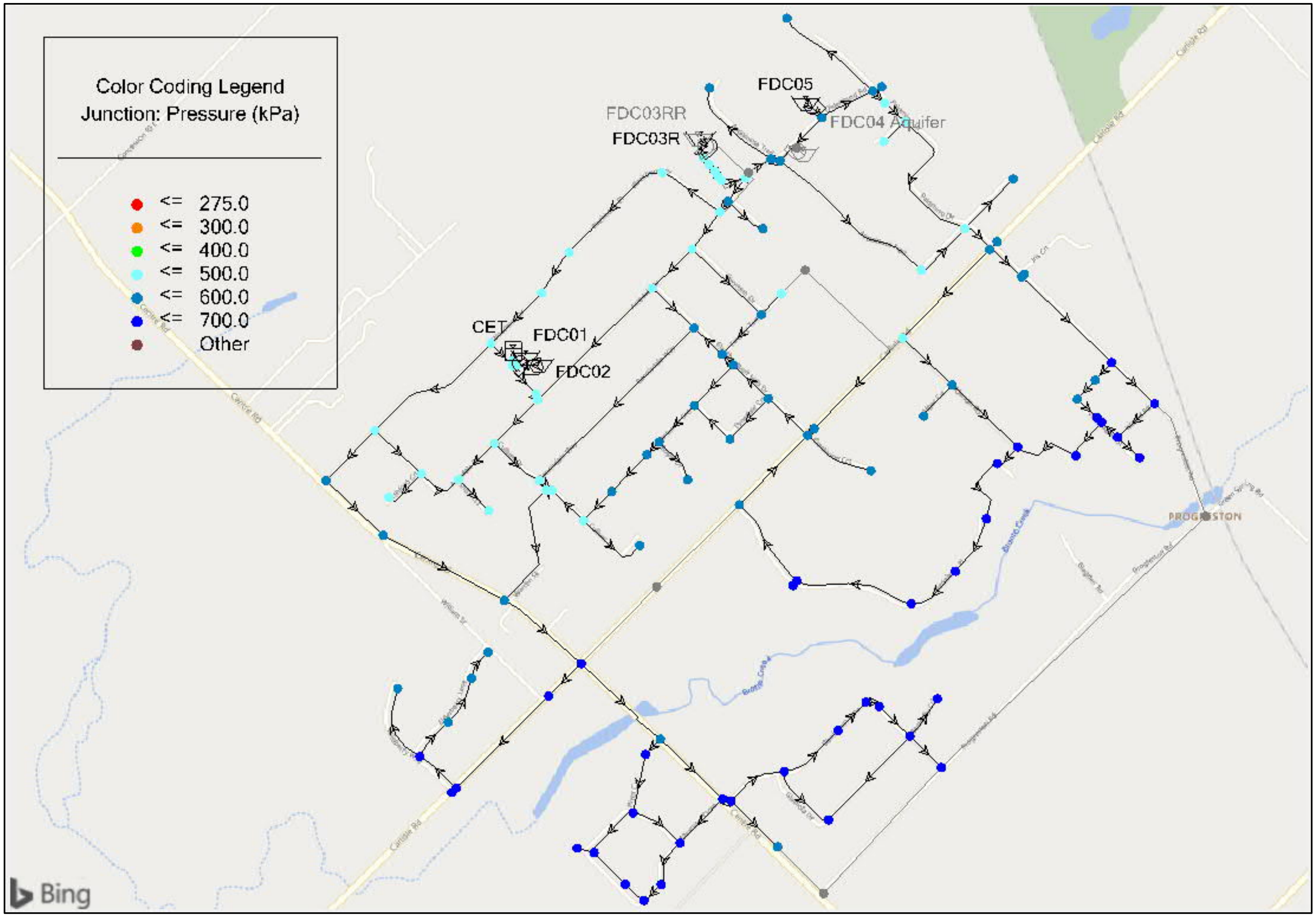

Figure 4.2: Resulting Pressures Under Existing (2022) Maximum Day Demand (MDD)

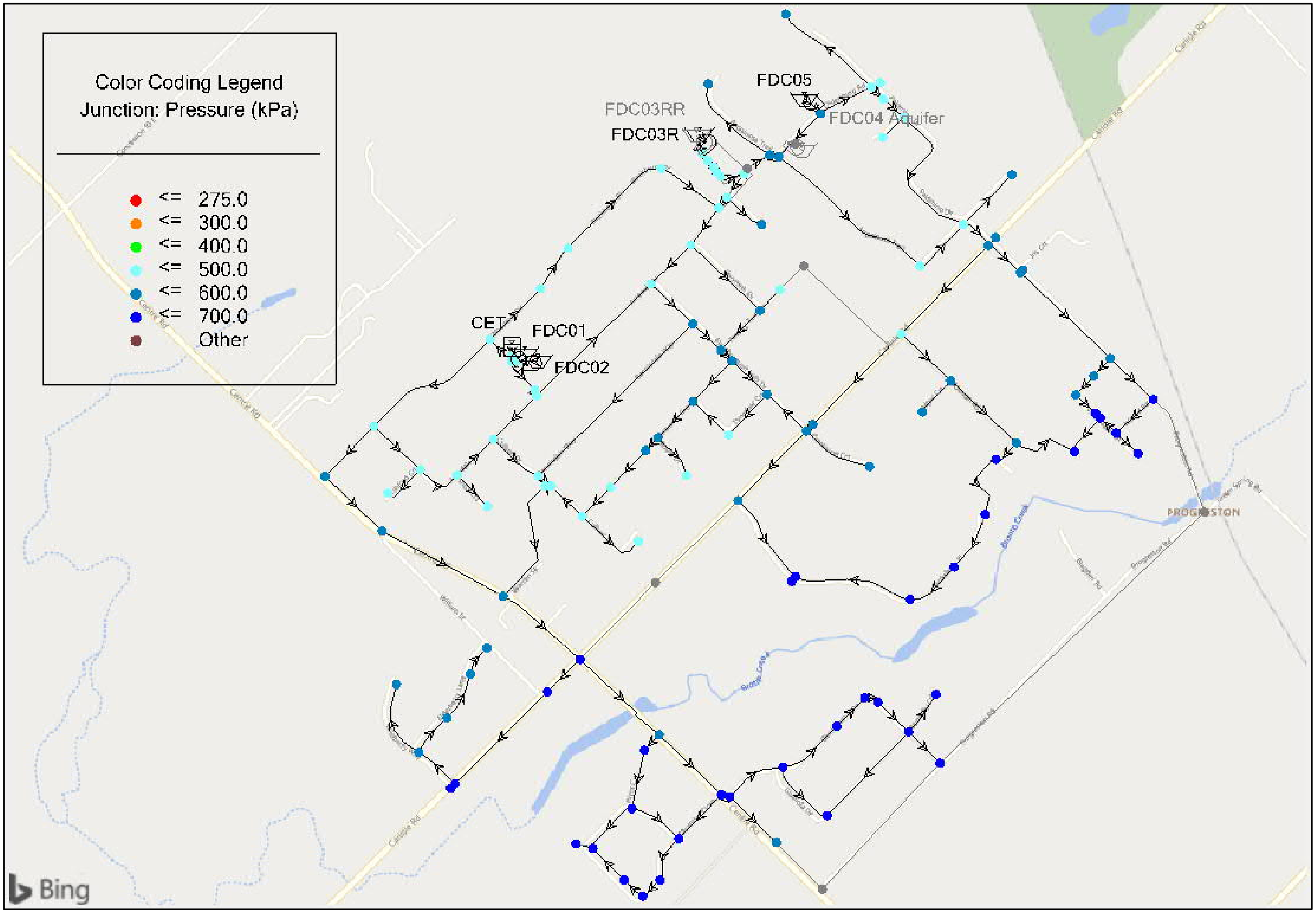

Figure 4.3: Resulting Pressures Under Existing (2022) Peak Hour Demand (PHD)

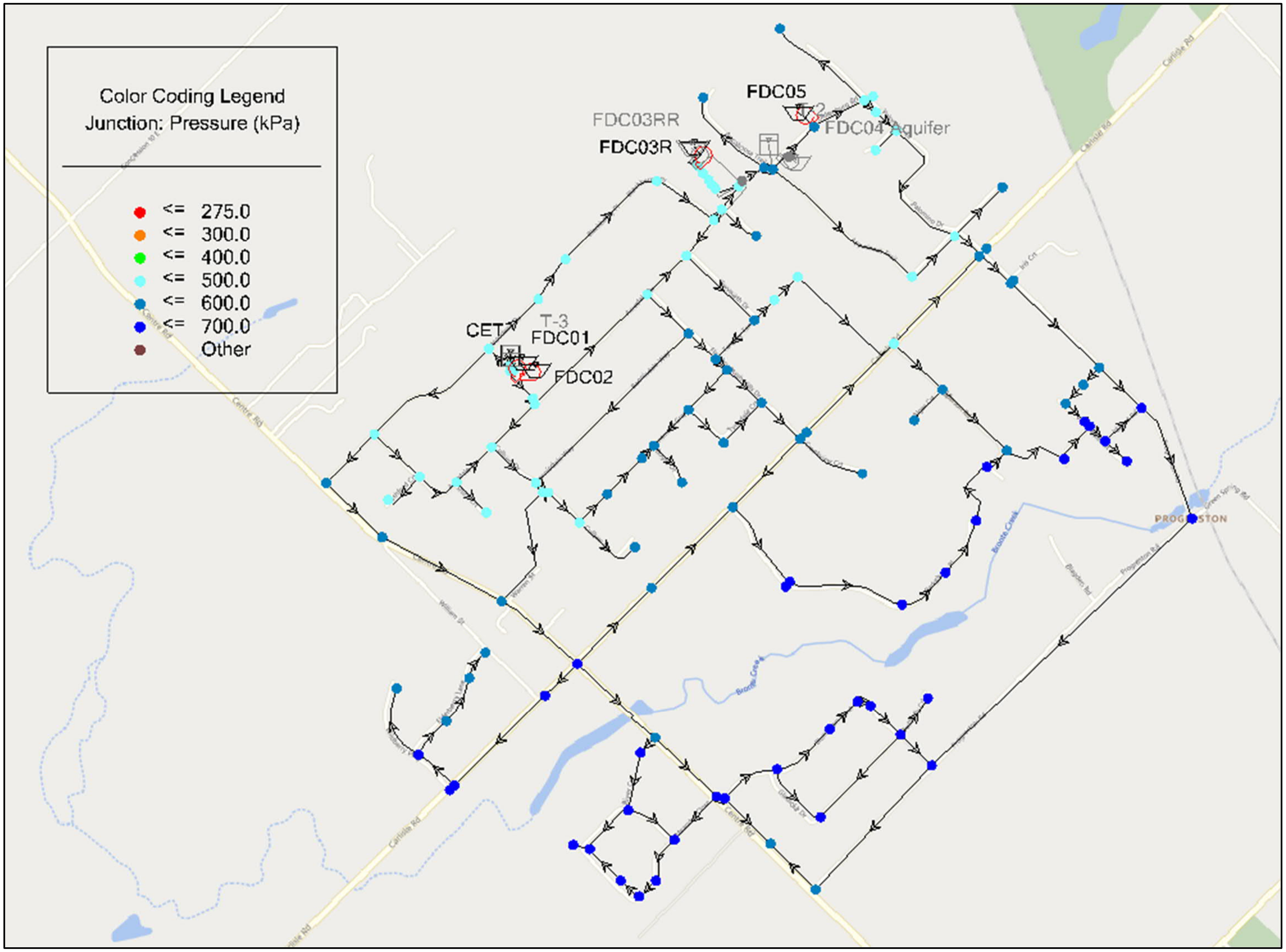

Figure 4.4: Resulting Pressures Under Existing (2022) Average Day Demand with All Wells Offline

In terms of the fire flow availability under the existing (2022) Maximum Day plus Fire Flow (MDD+FF), Figure 4.5 and Figure 4.6 show the resulting available fire flow range and the fire flow constraints within the system, respectively. Accordingly, the simulated available flows under this condition range from 70 L/s to 256 L/s.

According to the results shown in Figure 4.6, a couple of junctions/nodes were not able to meet the fire flow requirement under this condition. These nodes have a required fire flow of 150 L/s where an existing retirement home is situated including two available parcels that can be developed potentially with apartment buildings. The fire flow deficiency can be addressed by extending the Ø300mm watermain along Carlisle Road and looping the system as shown in Figure 4.7 and Figure 4.8 to improve the fire flow availability at this location to satisfy the fire flow requirement. The remaining junctions could satisfy each respective fire flow requirement ranging from 50 L/s to 75 L/s.

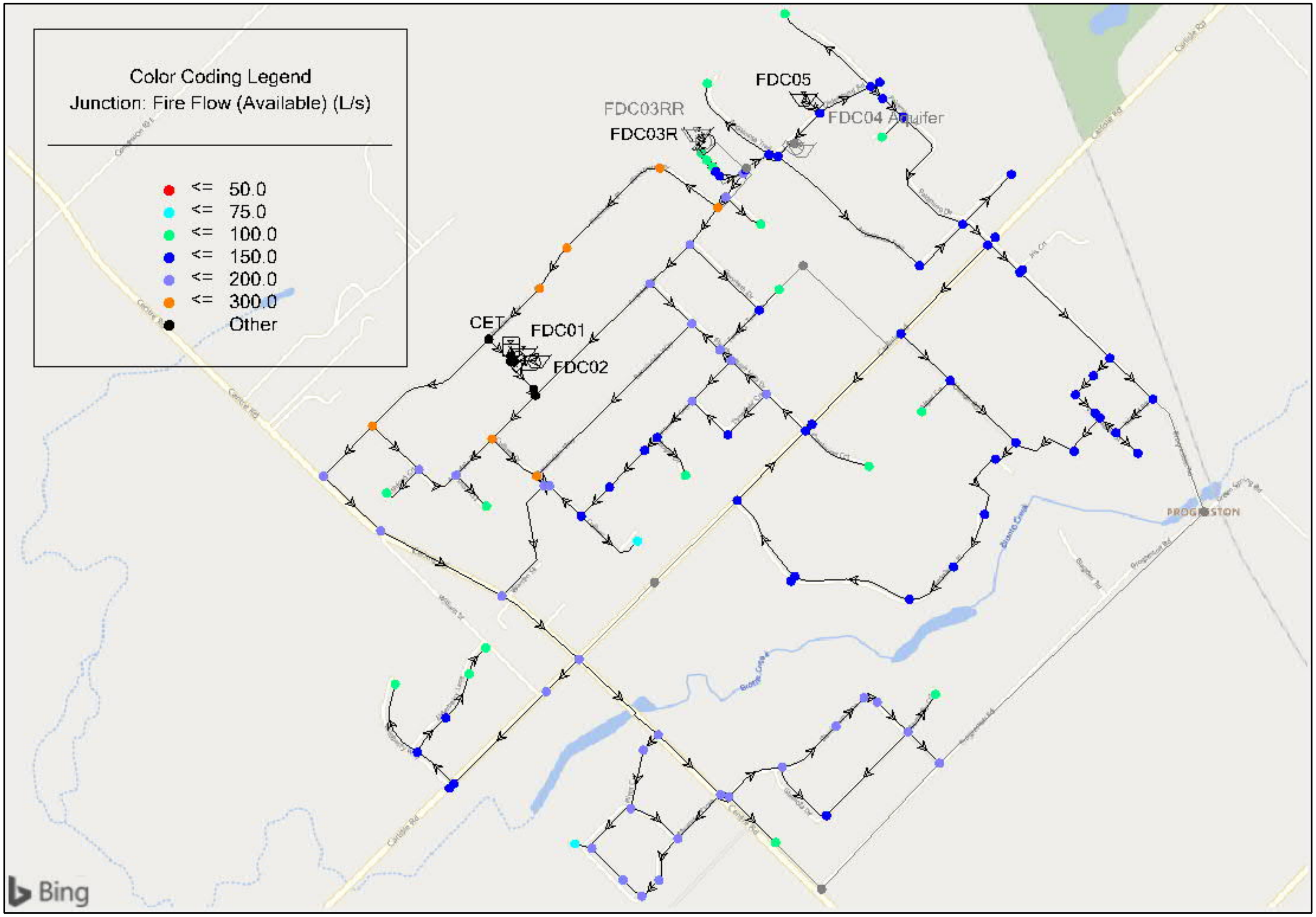

Figure 4.5: Resulting Available Fire Flows Under Existing (2022) Maximum Day Demand plus Fire Flow (MDD+FF)

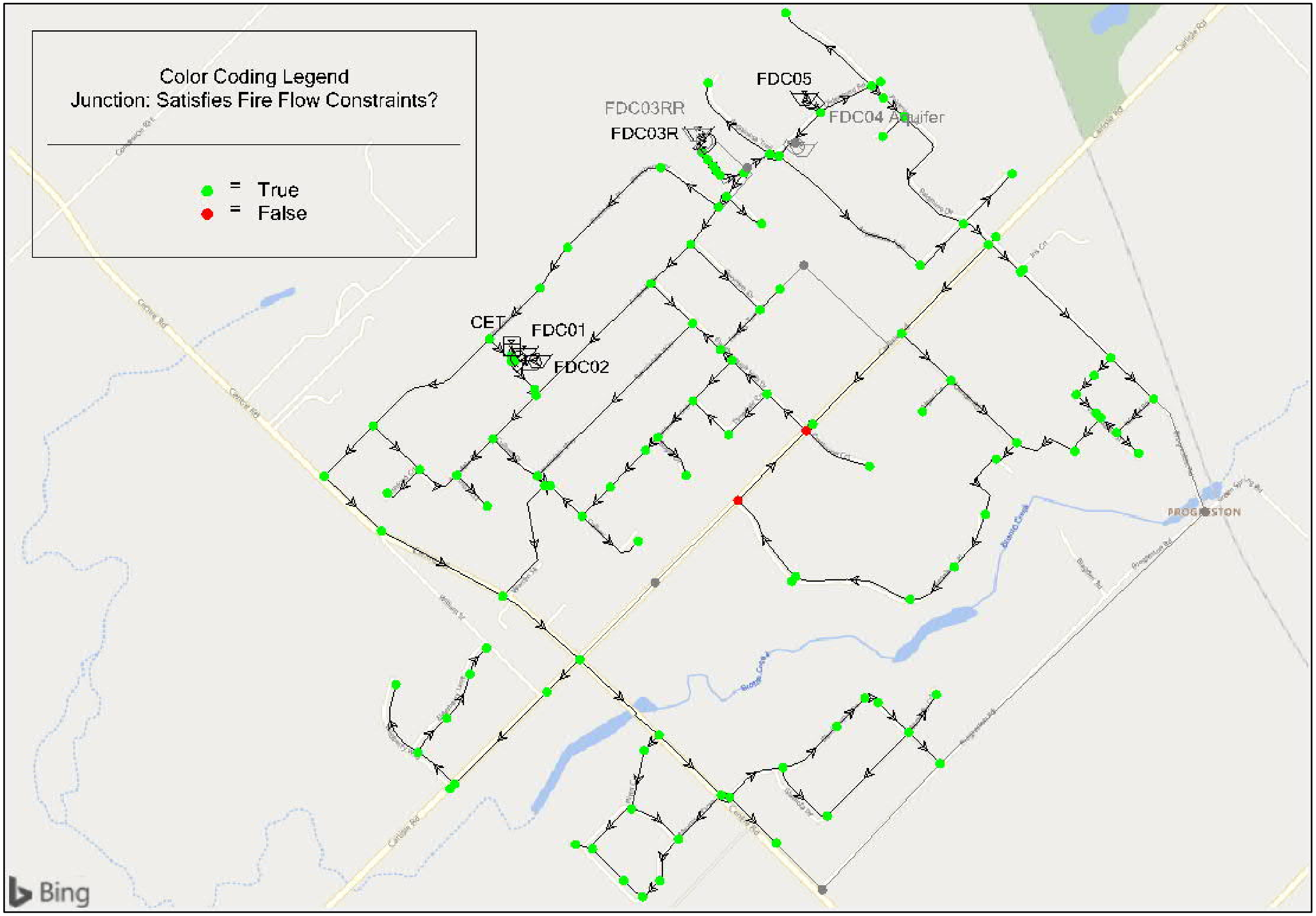

Figure 4.6: Resulting Fire Flow Constraints Under Existing (2022) Maximum Day Demand plus Fire Flow (MDD+FF)

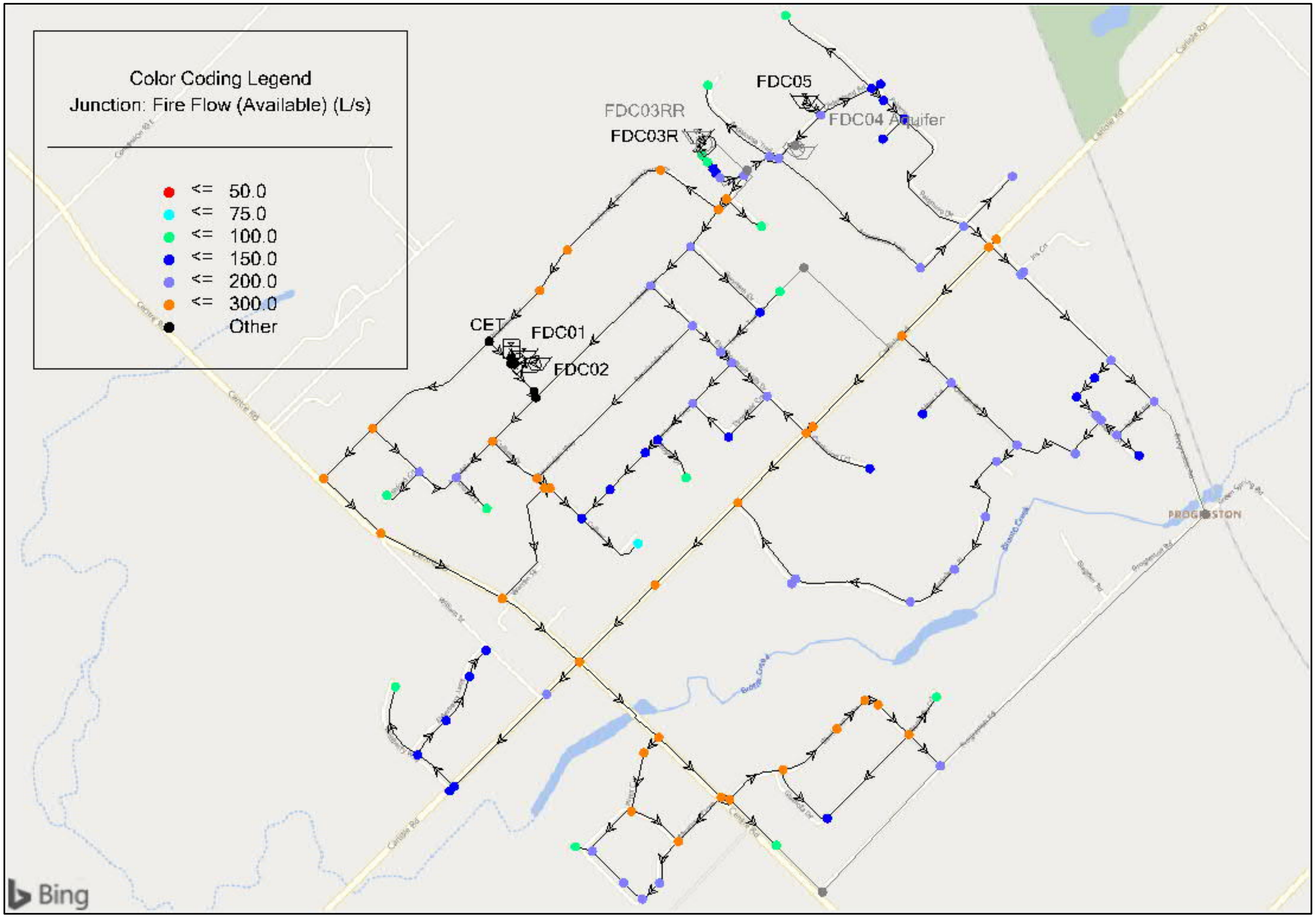

Figure 4.7: Resulting Available Fire Flows Under Existing (2022) Maximum Day Demand plus Fire Flow (MDD+FF) with a Ø300mm Loop along Carlisle Road

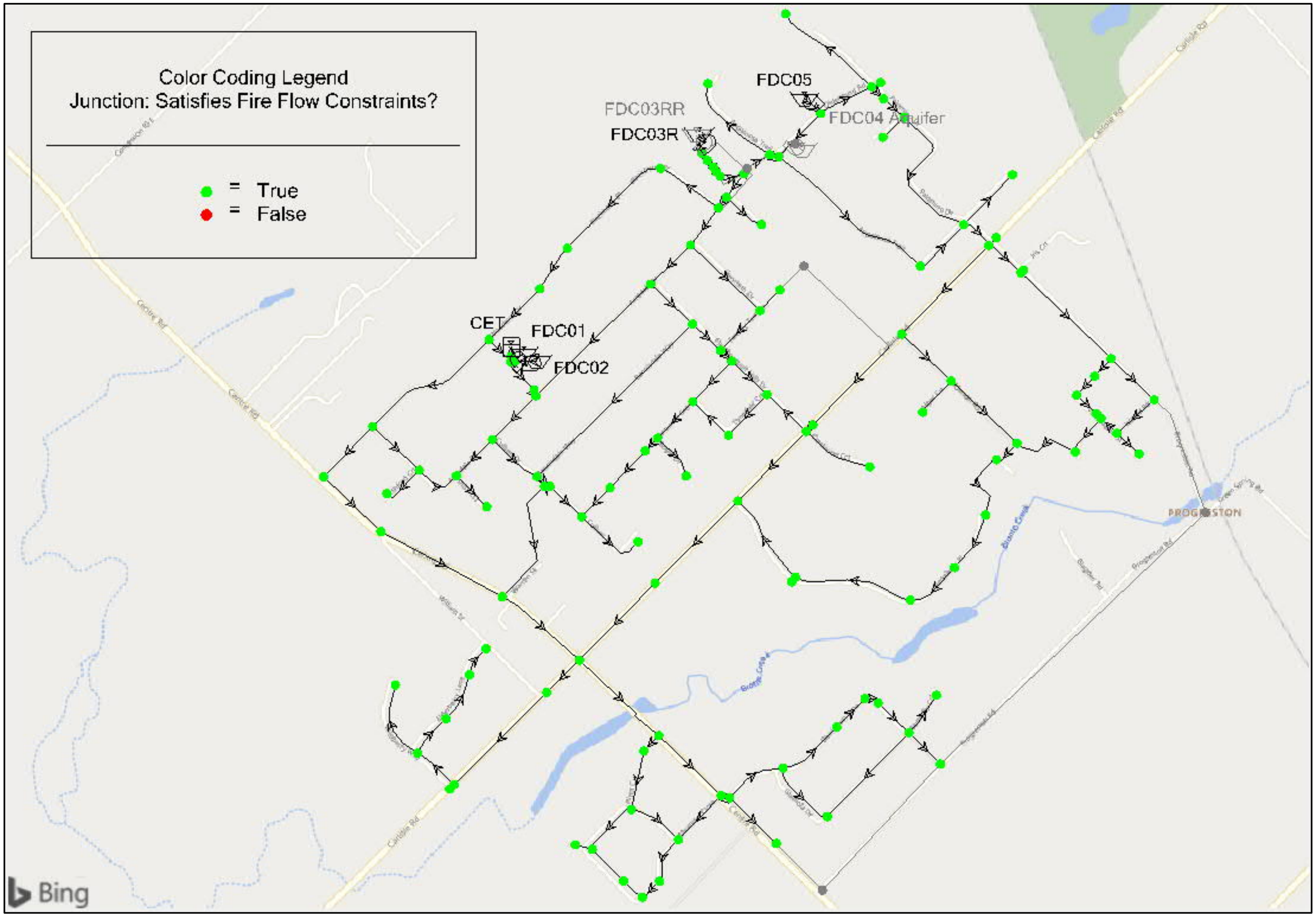

Figure 4.8: Resulting Fire Flow Constraints Under Existing (2022) Maximum Day Demand plus Fire Flow (MDD+FF) with a Ø300mm Loop along Carlisle Road

4.2 Future (2051) Conditions – Normal Operations

Under the future (2051) conditions without the proposed upgrades to the system, the same boundary conditions were used as the existing (2022) conditions. Three (3) pumping stations were in operation with each flow capacity summarized in Table 4.3 per the results of the pump testing for each station (see Appendix B). The CET was set to 80% full under this condition per the tank's normal operating condition. In addition, it was assumed that under this planning horizon, all the residential dwellings within Carlisle RSA are supplied by the municipal system as a part of the worst-case scenario per the calculated future demands. In order to service all the residential units, additional watermains are required and were assumed in the hydraulic model as follows:

1. Ø300mm watermain loop connection along Carlisle Road from Centre Road to Parkshore Place (approximately 177m).
2. Ø150mm watermain loop connection along Progreston Road from Centre Road to Idared Road (approximately 574m).
3. Ø150mm watermain loop connection east of Tansley Terrace going south to Carlisle Road (approximately 133m).

Table 4.3: Pump Status and Capacity Flow Under Future (2051) Conditions

Pump Station	Average Day Demand (L/s)	Maximum Day Demand (L/s)	Peak Hour Demand (L/s)
FDC01	Offline	Offline	Offline
FDC02	9.78	9.78	9.78
FDC03R	14.16	14.23	14.29
FDC05	12.61	12.67	12.73

Figure 4.9 shows the full-buildout connection with the assumptions mentioned above under future (2051) demand conditions.

Based on the results of the hydraulic analysis, the service pressures within the distribution network range from 399 kPa (58 psi) to 637 kPa (92 psi) per the boundary conditions mentioned above under future conditions. Accordingly, the resulting pressures are within the acceptable range for water distribution systems.

Table 4.4 summarizes the simulated pressures under the future (2051) demand conditions with and without the recommended watermain loop connections at full buildout (Figure 4.9). According to the results of the hydraulic modeling, the modeled pressures range from 399 kPa (57.9 psi) to 641 kPa (93.0 psi). Based on these results, there is about a 1% improvement in the overall pressures within the system with the addition of the recommended watermain looping. Although this is not a significant improvement, looping the connection will have the most benefit on the available fire flows especially along Carlisle Rd.

Table 4.4: Simulated Pressures Under Future (2051) Conditions

Planning Horizon	Average Day Demand (kPa)	Maximum Day Demand (kPa)	Peak Hour Demand (kPa)
Future (2051) without Recommended Watermain Loop Connections	415 – 637	409 – 631	399 – 618
Future (2051) with Recommended Watermain Loop Connections	419 – 641	410 – 632	401 – 619

Figures 4.10 (a) to 4.12 (a) and Figures 4.10 (b) to 4.12 (b) were provided to show the resulting pressures within the system under future demand conditions per the results in Table 4.4 above and for comparison between the system with and without the recommended watermain upgrades, respectively. The results show that the pressures are still within the acceptable range under existing conditions per the City of Hamiton's design criteria and requirements.

Furthermore, these results show that the municipal system has enough capacity to maintain the required pressures within the system under existing conditions with normal operations. The impact of the calculated demands under future Average Day, Maximum Day, and Peak Hour demand scenarios has minimal effect on the pressures with pressure drops ranging from 6 kPa (0.9 psi) to 13 kPa (1.9 psi) only; therefore, the system is capable of maintaining the required pressures while supplying the domestic demands under these future conditions.

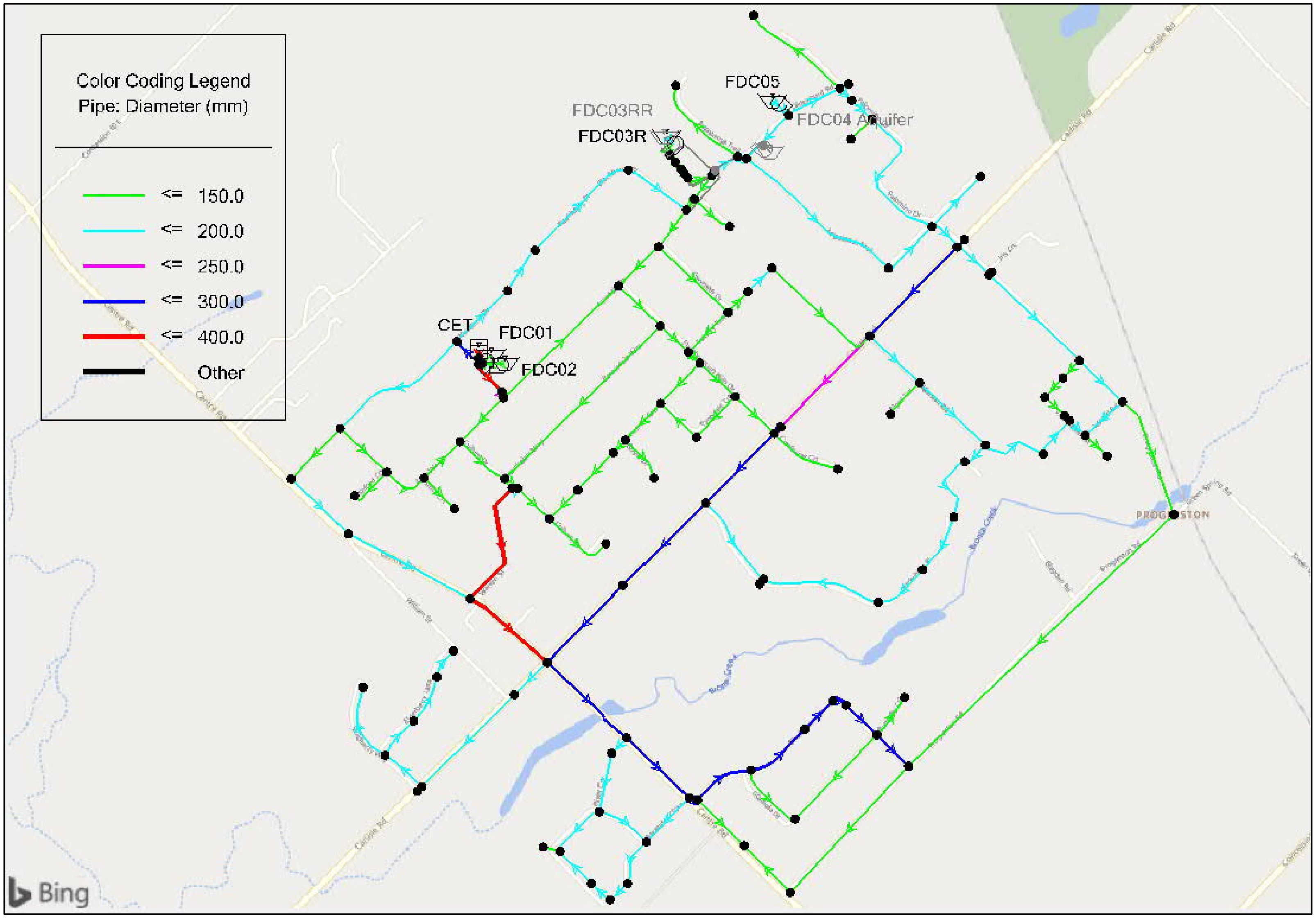

Figure 4.9: Carlisle RSA’s Modeled Water Distribution Network Under Future (2051) Demand Conditions

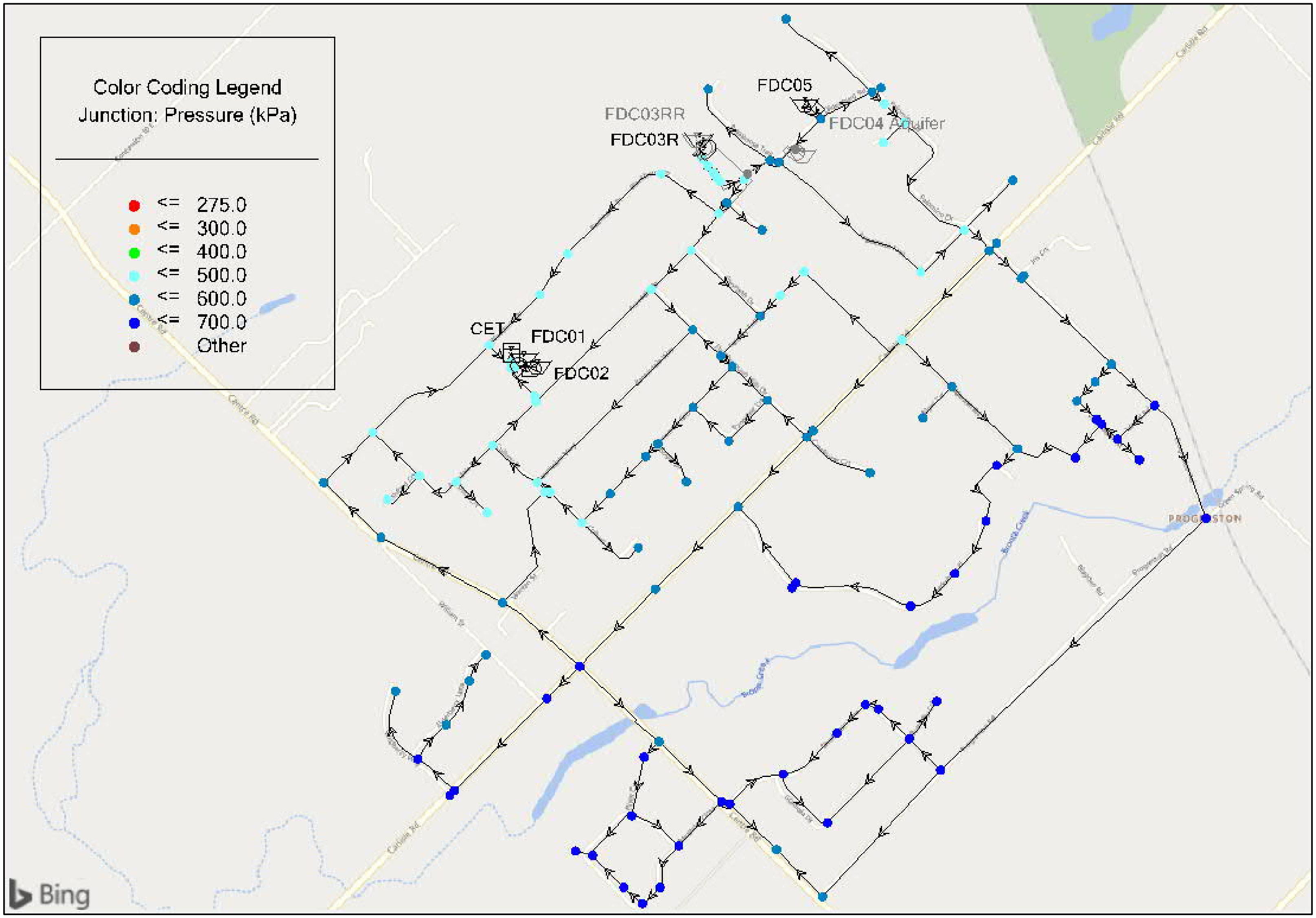

Figure 4.10 (a): Resulting Pressures Under Future (2051) Average Day Demand (ADD) with Loop Connections

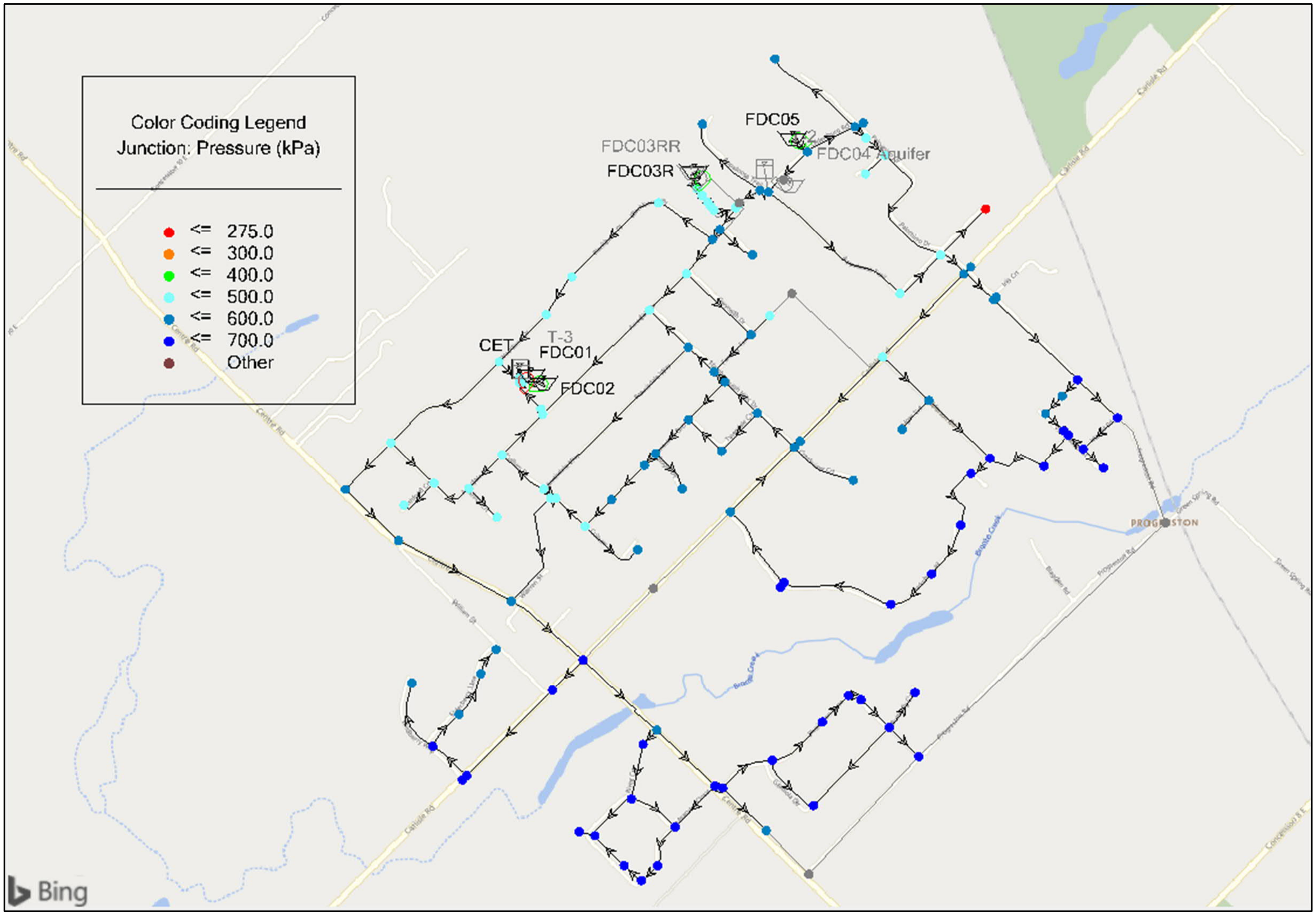

Figure 4.10 (b): Resulting Pressures Under Future (2051) Average Day Demand (ADD) without Loop Connections

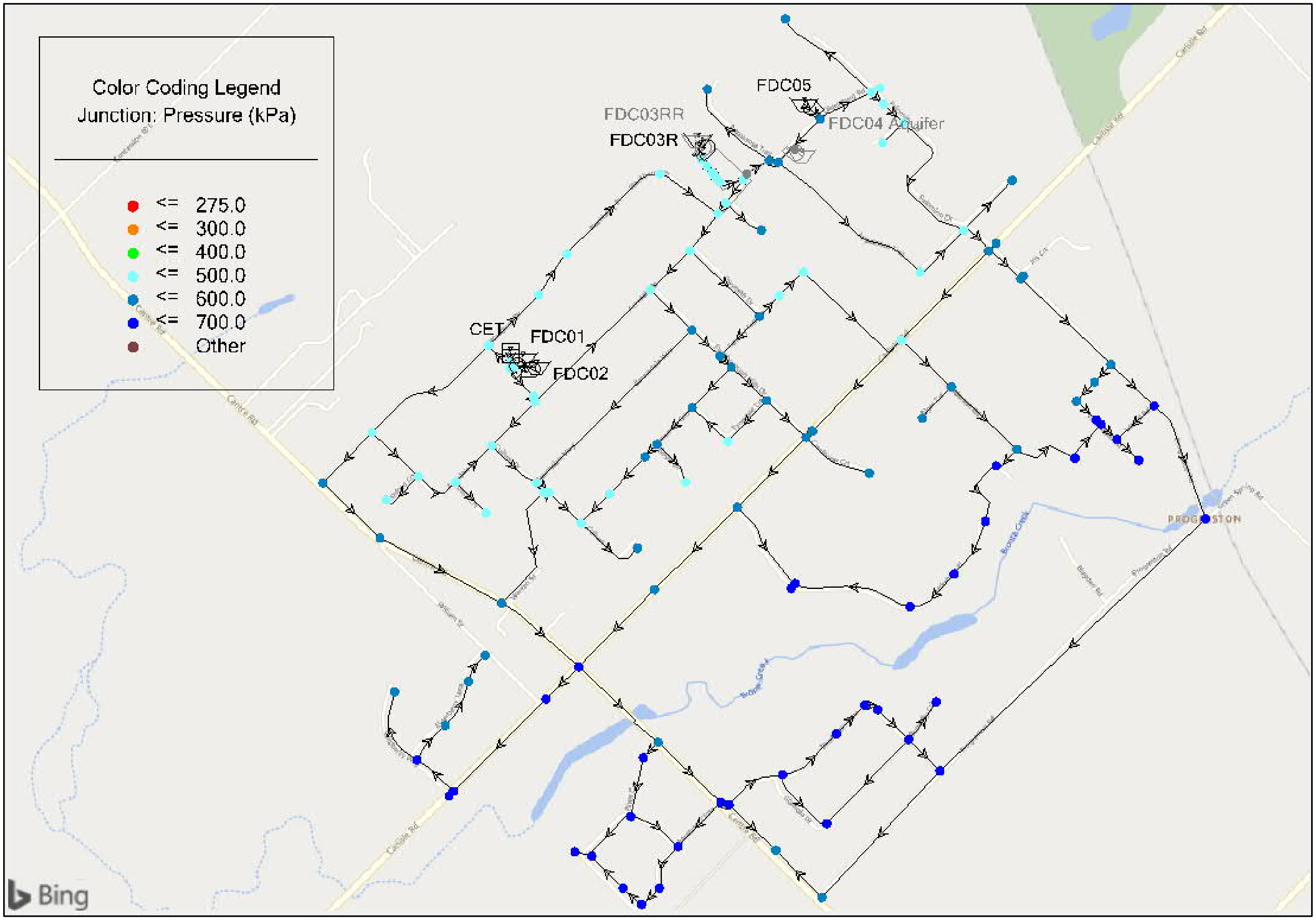

Figure 4.11 (a): Resulting Pressures Under Future (2051) Maximum Day Demand (MDD) with Loop Connections

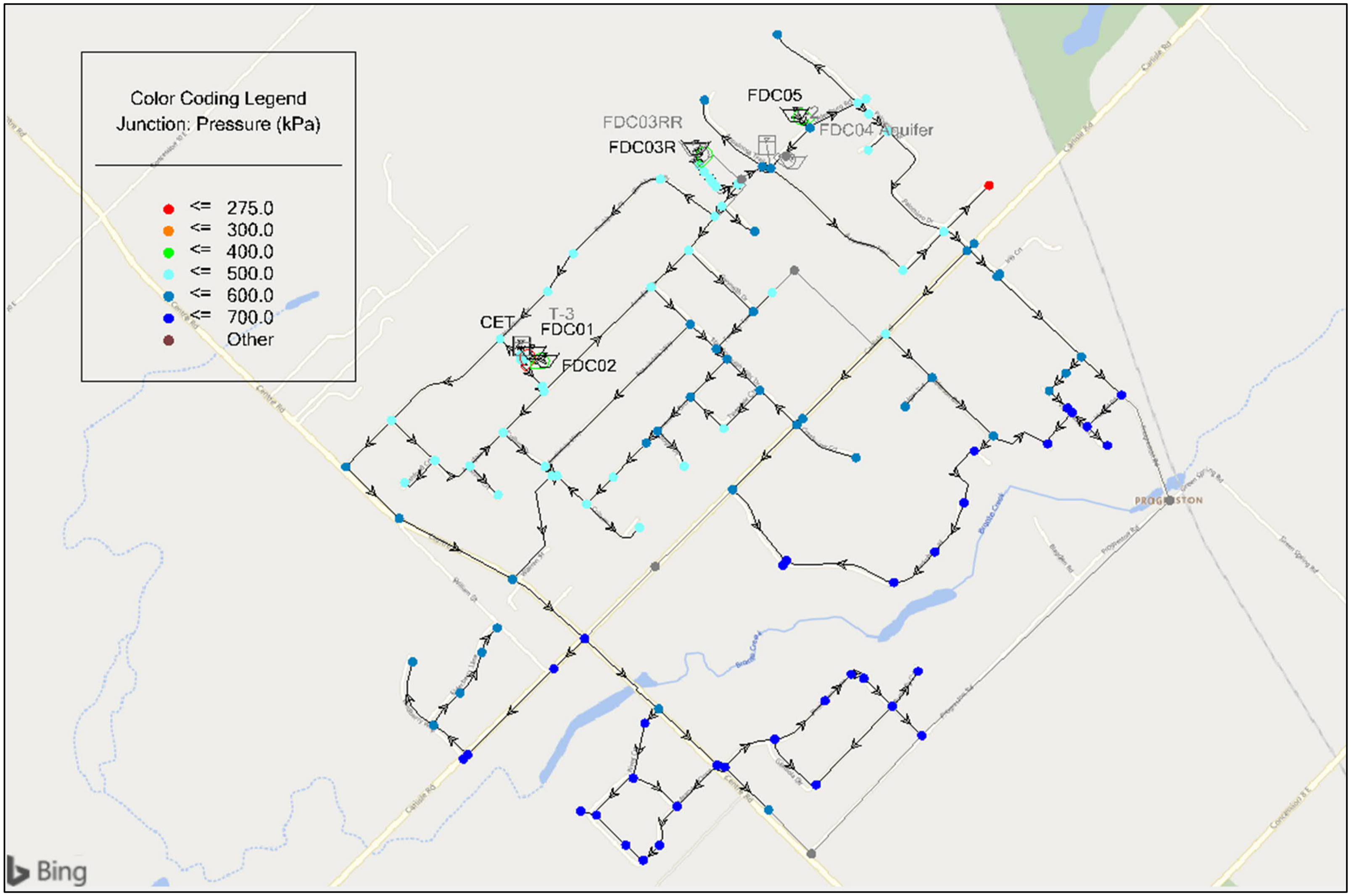

Figure 4.11 (b): Resulting Pressures Under Future (2051) Maximum Day Demand (MDD) without Loop Connections

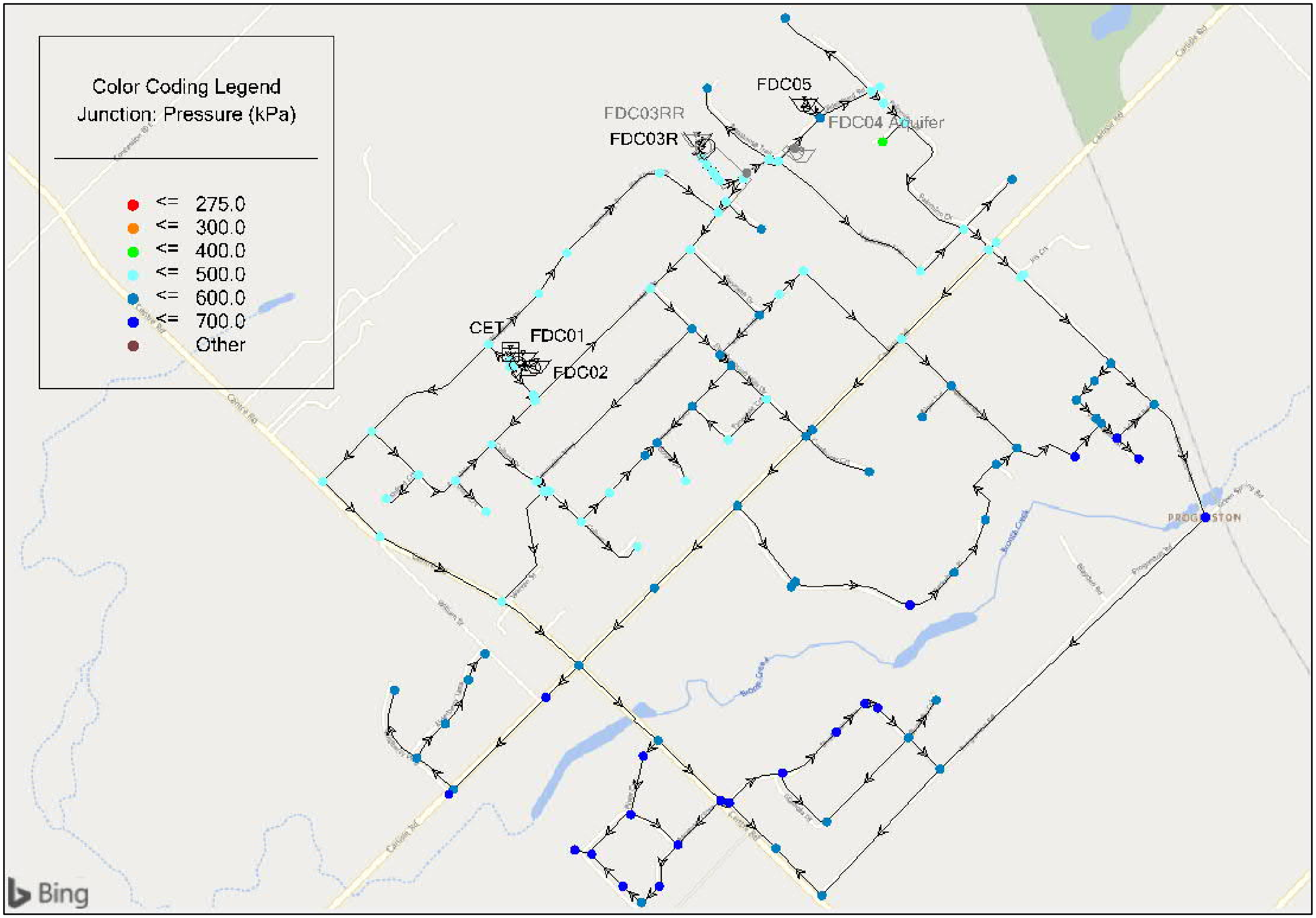

Figure 4.12 (a): Resulting Pressures Under Future (2051) Peak Hour Demand (PHD) with Loop Connections

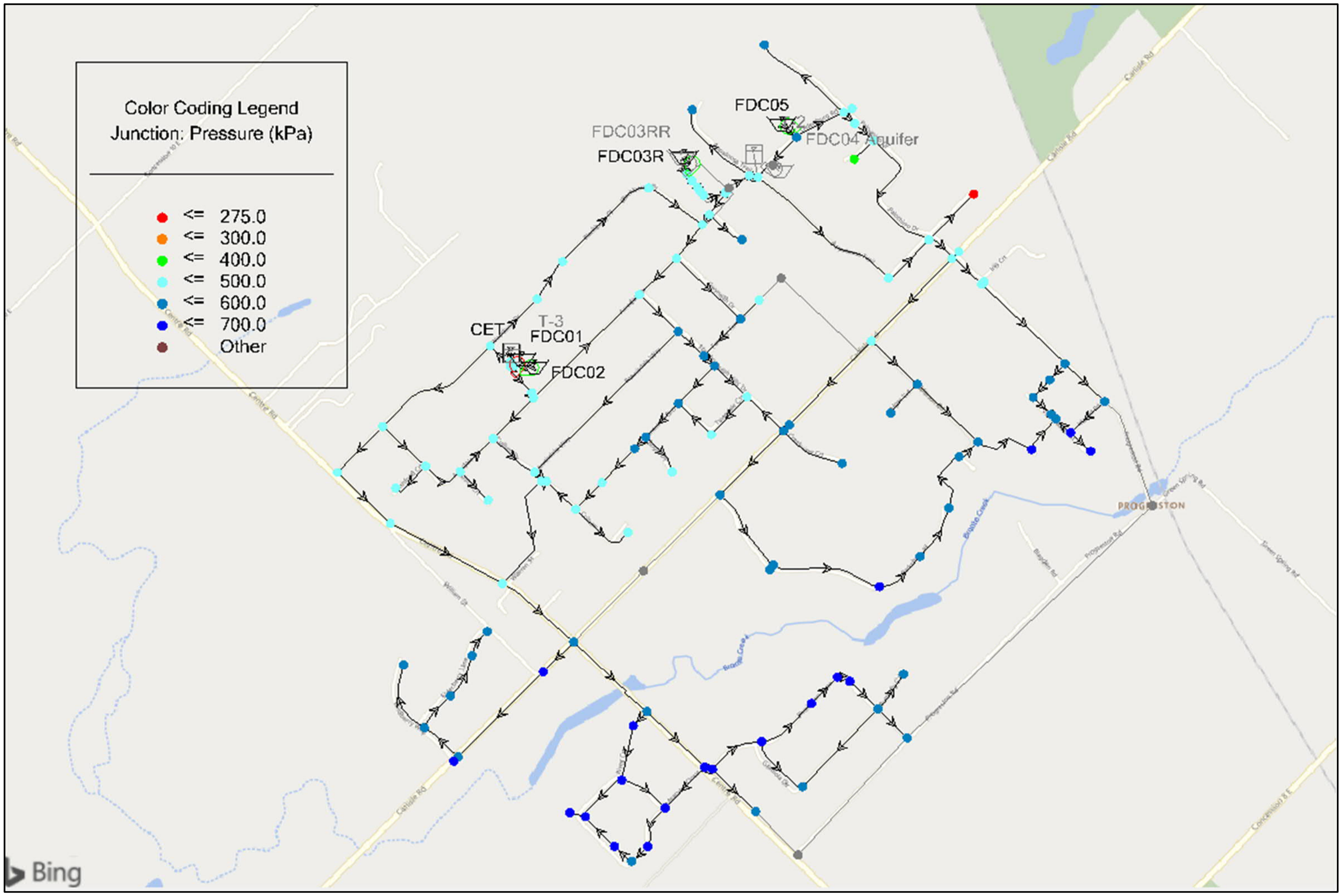

Figure 4.12 (b): Resulting Pressures Under Future (2051) Peak Hour Demand (PHD) without Loop Connections

In terms of the fire flow availability under the future (2051) Maximum Day plus Fire Flow (MDD+FF), Figure 4.11 and Figure 4.12 show the resulting available fire flow range and the fire flow constraints within the system, respectively. Accordingly, the system layout shown in Figure 4.7 can meet all the fire flow requirements within the distribution network by adding loop connections that improve the system's capacity and fire flow availability.

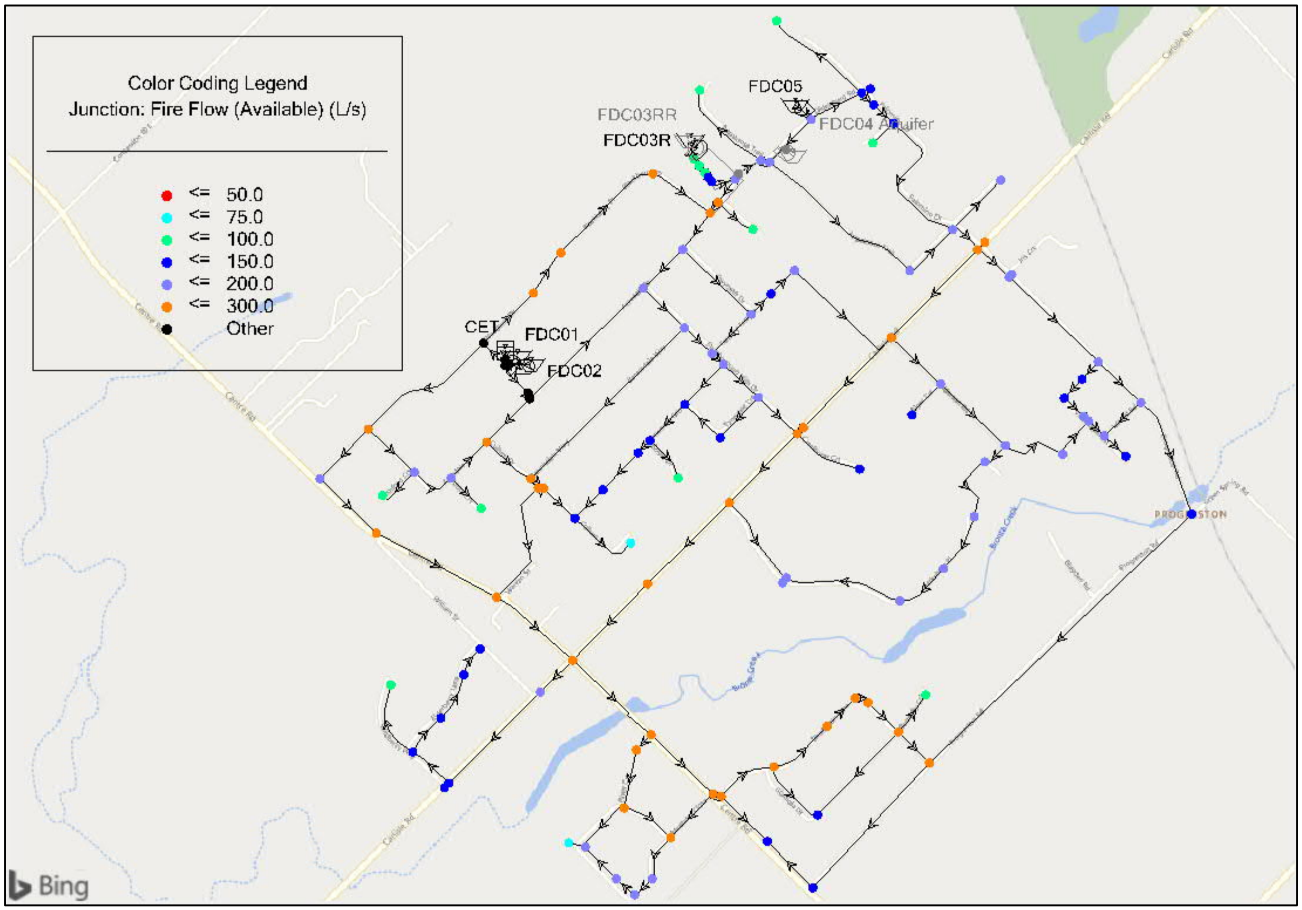

Figure 4.13: Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF)

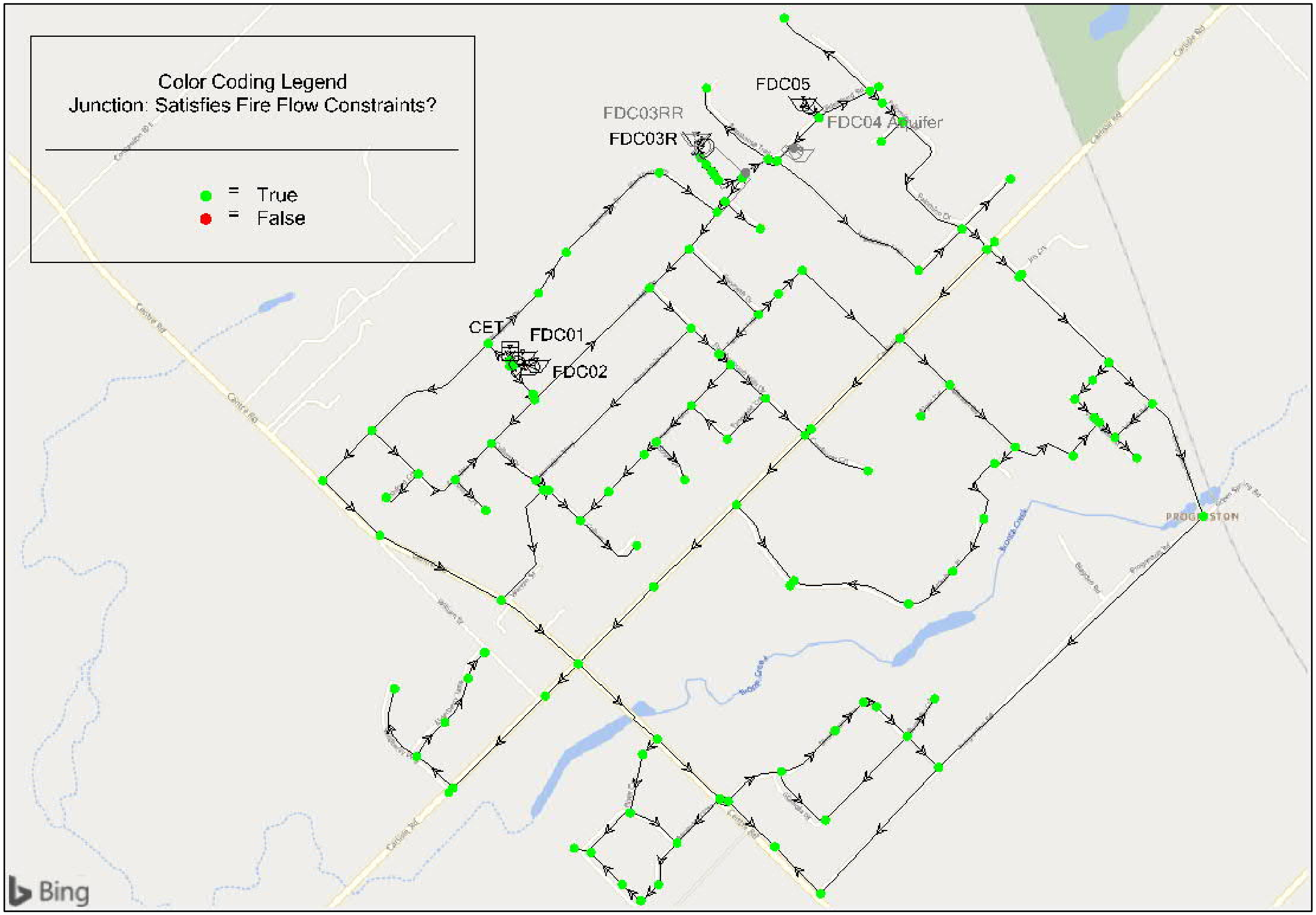

Figure 4.14: Resulting Fire Flow Constraints Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF)

4.3 Proposed Additional Storage and Potential Locations

The additional storage required to meet all the future projected demands and system requirements per the Ministry of Environment, Conservation and Parks (MECP) design guidelines was estimated to be 1,285m^3. Although the results of the hydraulic modeling shown in Section 4.1 and Section 4.2 demonstrated that the system can provide the required pressures and flows with the existing CET and some additional watermain loops in the system, the steady-state model only analyzes the performance of the system and it does not consider other factors such as fire, equalization, and emergency storage requirements for an emergency situation.

A long list of potential locations for the additional storage tank was considered. Considering that storage tanks are frequently located at high points in the system to reduce the height at which they need to be built, and other factors such as constructability, area, lot availability, etc., three (3) potential lots that are situated in the high-elevation areas of Carlisle RSA were considered which are as follows:

1. Carlisle Tower Park – existing elevated tank location (ground elevation: 275m)
2. Oldenburg Road – northeast corner of the Appaloosa Trail intersection (ground elevation: 270m)
3. William Street – 1535 Centre Road (ground elevation: 270m)

Figure 4.15 shows an aerial view of the potential locations of the new storage tank, while Table 4.5 shows the simulated pressures under all future demand conditions where the demands are expected to be higher with the proposed additional storage per the potential locations mentioned above. Figures 4.16 (a) to 4.18 (a) show the resulting pressures within the network with the additional storage at the Carlisle Tower Park. The simulated pressures with the additional storage located at Oldenburg Road and William Street were provided in Figures 4.15 (b) to 4.18 (b). and Figures 4.15 (c) to 4.18 (c), respectively.

It can be noticed that the resulting pressures with the additional storage at the CET location are comparable to the simulated pressures under the future demand conditions (see Table 4.4) with the existing CET storage. This is due to the equal demands in the distribution system and the same location of the additional storage.

In addition, comparable results can be noticed under the simulated future demand scenarios between the three (3) potential locations with 1 kPa (0.1 psi) to 41 kPa (6 psi) difference. It was only under the future Peak Hour Demand scenario that the pressures improved slightly. This is because the Oldenburg Road location is situated close to Steeplehill Court which is the low-pressure area from the resulting pressure spectrum. Under this scenario, the pressures were slightly improved. It should be noted that under all simulated scenarios shown in Table 4.5, FDC03R, which has the largest supply well within Carlisle, is only operating at 41 Hz which is equivalent to a total discharge flow capacity of 14 L/s. This pump station has a total allowable capacity of 25 L/s; therefore, it is recommended to operate the pump at a higher frequency up to its fully allowable capacity under high water demand conditions where low pressures are experienced to improve the pressures within this area.

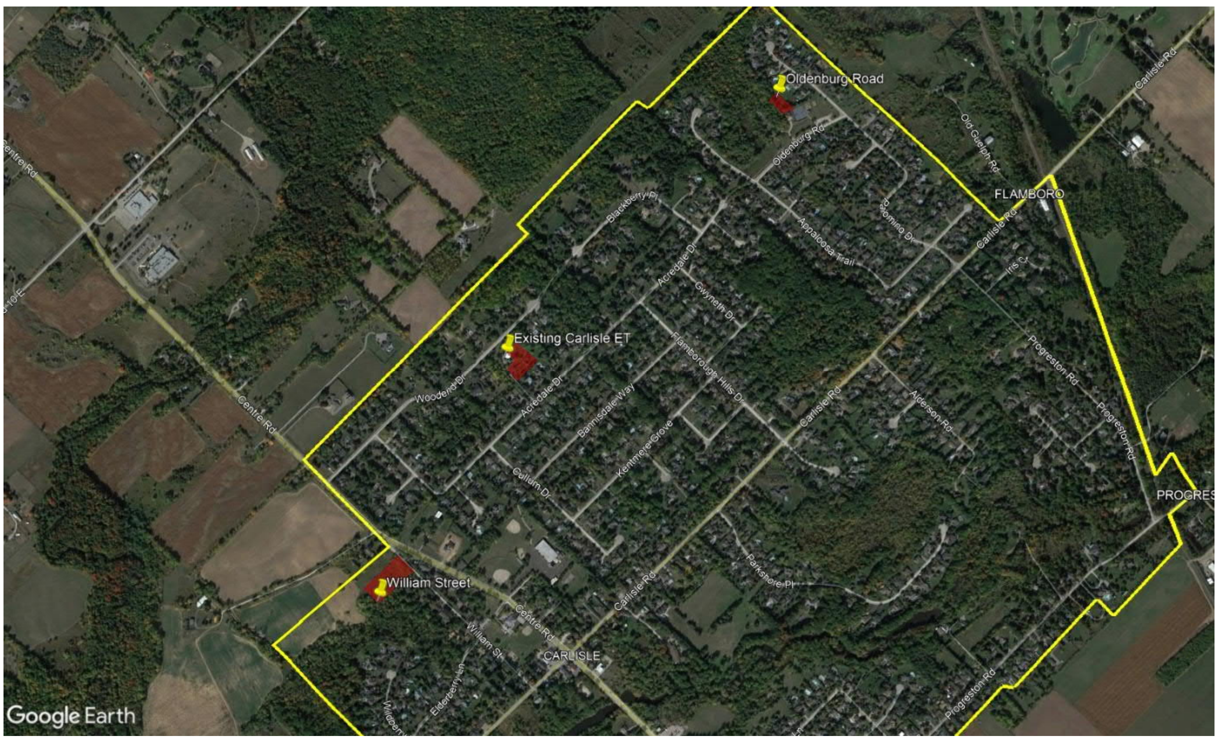

Figure 4.15: Aerial View of Short List Locations

Table 4.5: Simulated Pressures Under Future (2051) Demand Conditions with the Proposed Additional Water Storage per the Potential Locations

Potential Locations	Average Day Demand (kPa)	Maximum Day Demand (kPa)	Peak Hour Demand (kPa)
Carlisle Tower Park	385 – 607	380 – 602	370 – 589
Oldenburg Road	380 – 606	379 – 601	376 – 592

Potential Locations	Average Day Demand (kPa)	Maximum Day Demand (kPa)	Peak Hour Demand (kPa)
William Street	414 – 636	411 – 634	407 - 630

Tables 4.6 and 4.7 summarize the simulated available fire flow values and comparison between the potential locations for the new storage tank under future conditions with and without the proposed watermain additions, respectively and also shown in Figures 4.19 to 4.21. Accordingly, there is an average difference of about 1% in terms of the available fire flows within the whole system. However, a significant increase in fire flow availability of about 22% can be expected at the highest elevation in the system along Steeplehill Court if the proposed new tank is installed at the Oldenburg Road location compared to the existing Carlisle Tower Park location.

Table 4.6: Simulated Available Fire Flows Under Future (2051) MDD+FF Conditions with the Proposed Additional Water Storage per the Potential Locations and without the Proposed Watermain Looping Connections

Potential Locations	Available Fire Flow (L/s)	Steeplehill Court (L/s)
Carlisle Tower Park	65 - 244	83
Oldenburg Road	67 - 349	111
William Street	72 - 435	90

Table 4.7: Simulated Available Fire Flows Under Future (2051) MDD+FF Conditions with the Proposed Additional Water Storage per the Potential Locations with the Proposed Watermain Looping Connections

Potential Locations	Available Fire Flow Range (L/s)	Steeplehill Court (L/s)
Carlisle Tower Park	65 - 397	94
Oldenburg Road	66 - 408	114
William Street	72 - 487	108

These results show that the Oldenburg Road location is a better-suited location for the new elevated tank since it is closer to the low-pressure area from the resulting pressure spectrum of Carlisle RSA compared to the existing location of the CET with higher pressures and flows within the water distribution network.

In addition to the existing CET, a standpipe or a second elevated tank can be considered for the design of the new storage tank. The simulated pressures under all future demand conditions are adequate per the tables and figures above.

An in-ground or above-ground reservoir type storage facility can also be considered in addition to the existing CET. A reservoir type storage facility would work in conjunction with the existing CET. Pumps would be required to draw water to the existing CET. The existing CET would provide adequate pressures to the distribution system. The pumps for a reservoir storage facility must be sized to provide appropriate flows to the existing CET, or to the distribution system if the existing CET is removed.

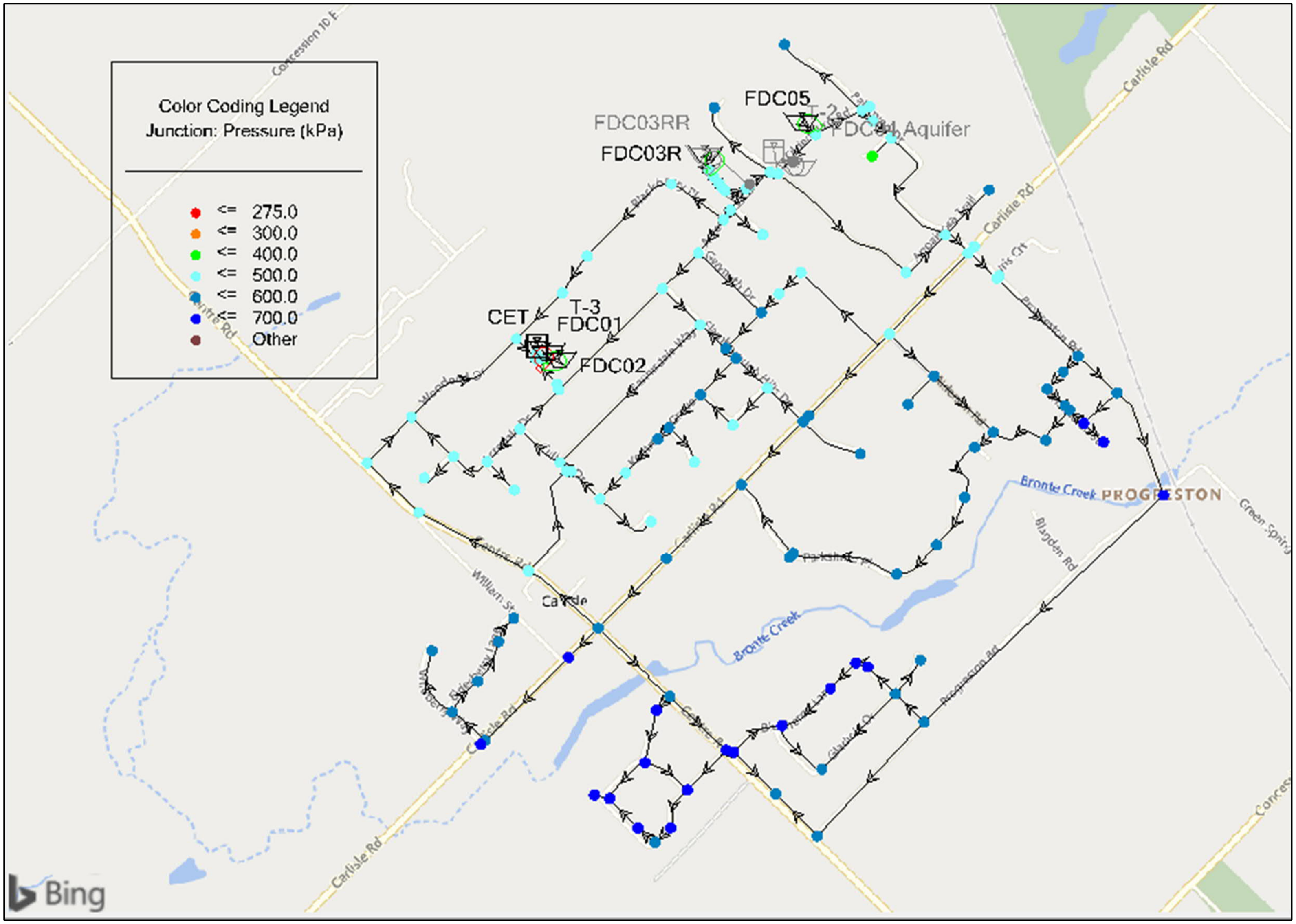

Figure 4.16 (a): Resulting Pressures Under Future (2051) ADD with Additional Storage at Carlisle Tower Park

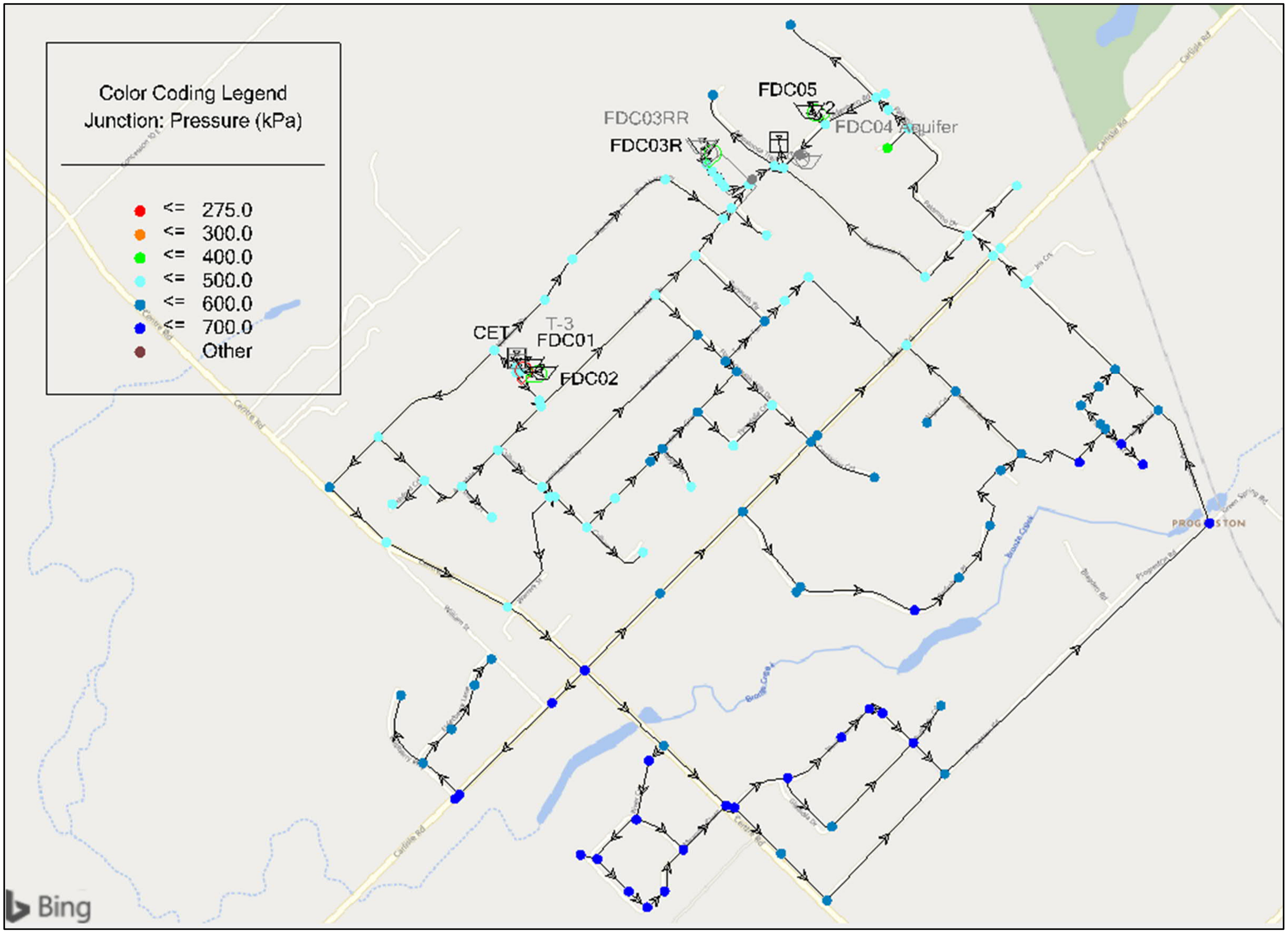

Figure 4.16 (b): Resulting Pressures Under Future (2051) ADD with Additional Storage at Oldenburg Rd.

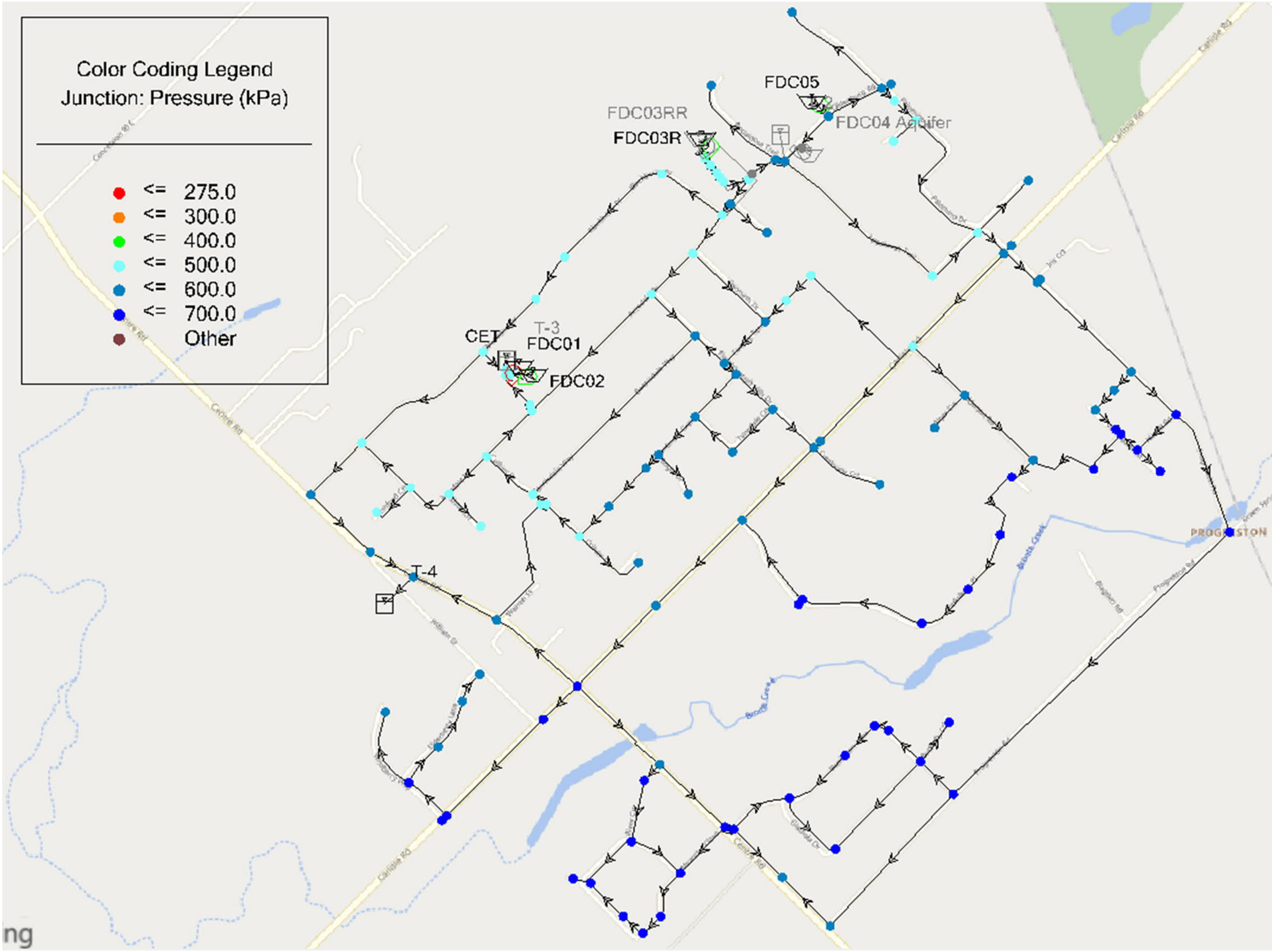

Figure 4.16 (c): Resulting Pressures Under Future (2051) ADD with Additional Storage at William St.

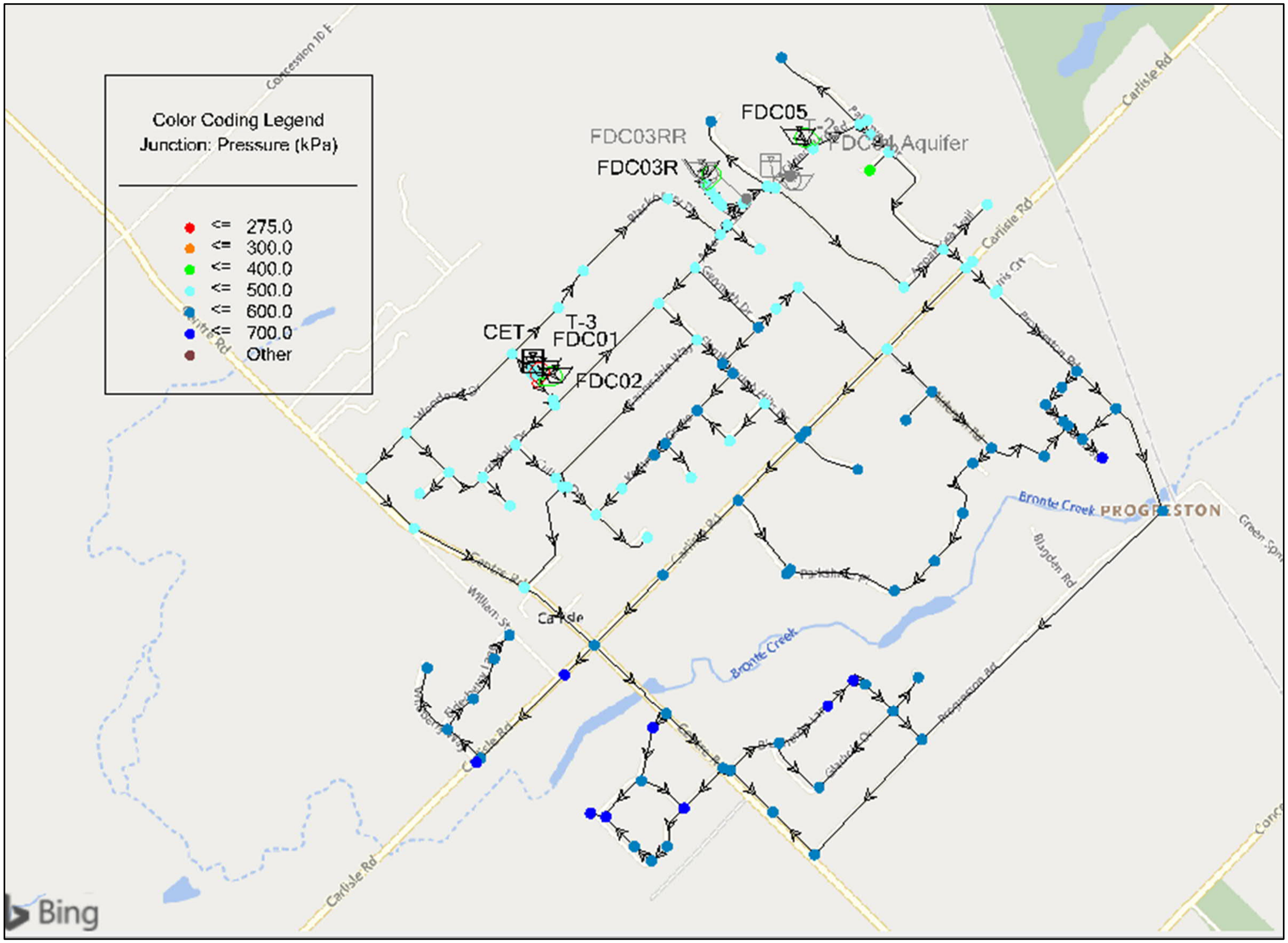

Figure 4.17 (a): Resulting Pressures Under Future (2051) MDD with Additional Storage at Carlisle Tower Park

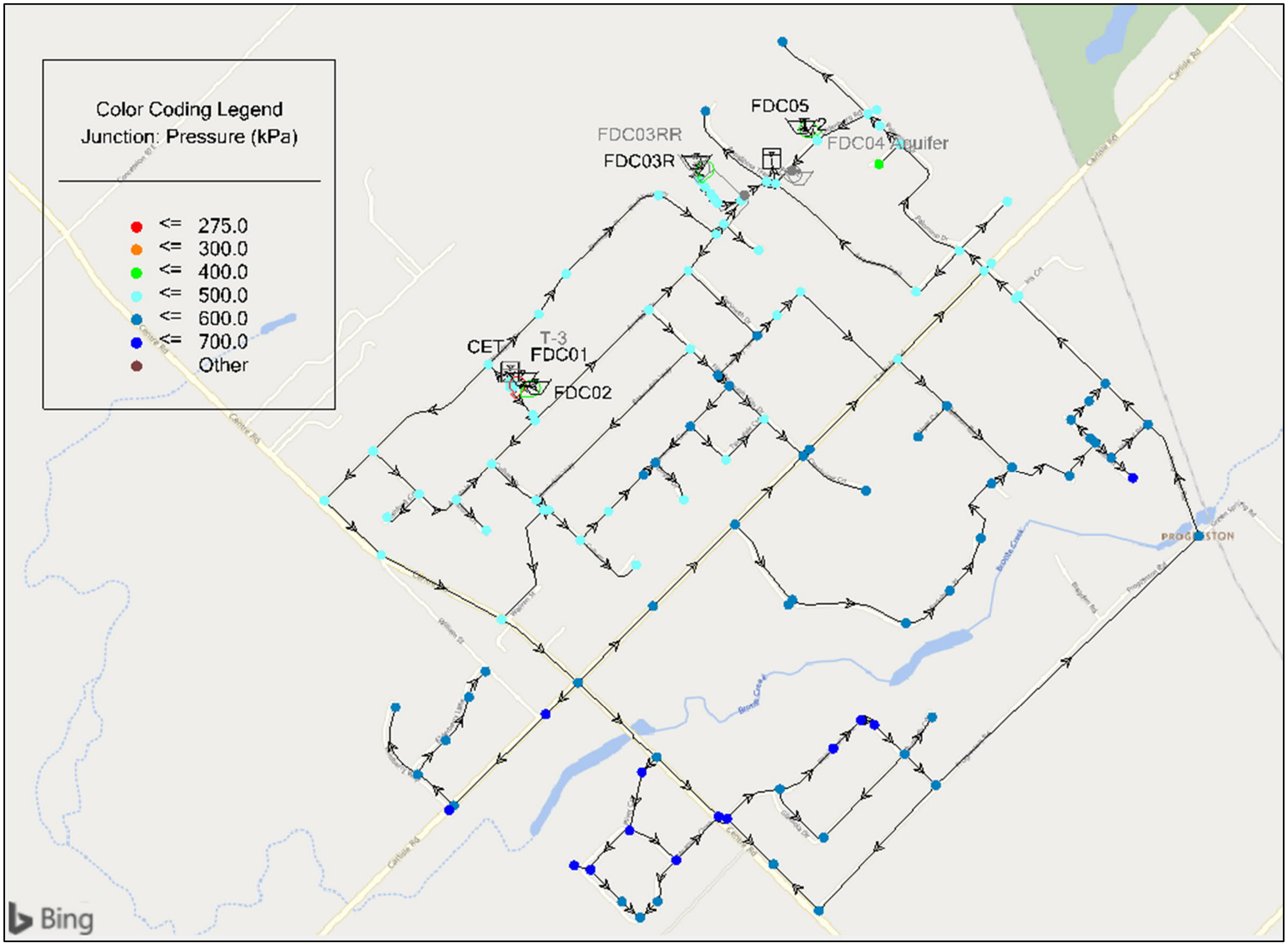

Figure 4.17 (b): Resulting Pressures Under Future (2051) MDD with Additional Storage on Oldenburg Rd.

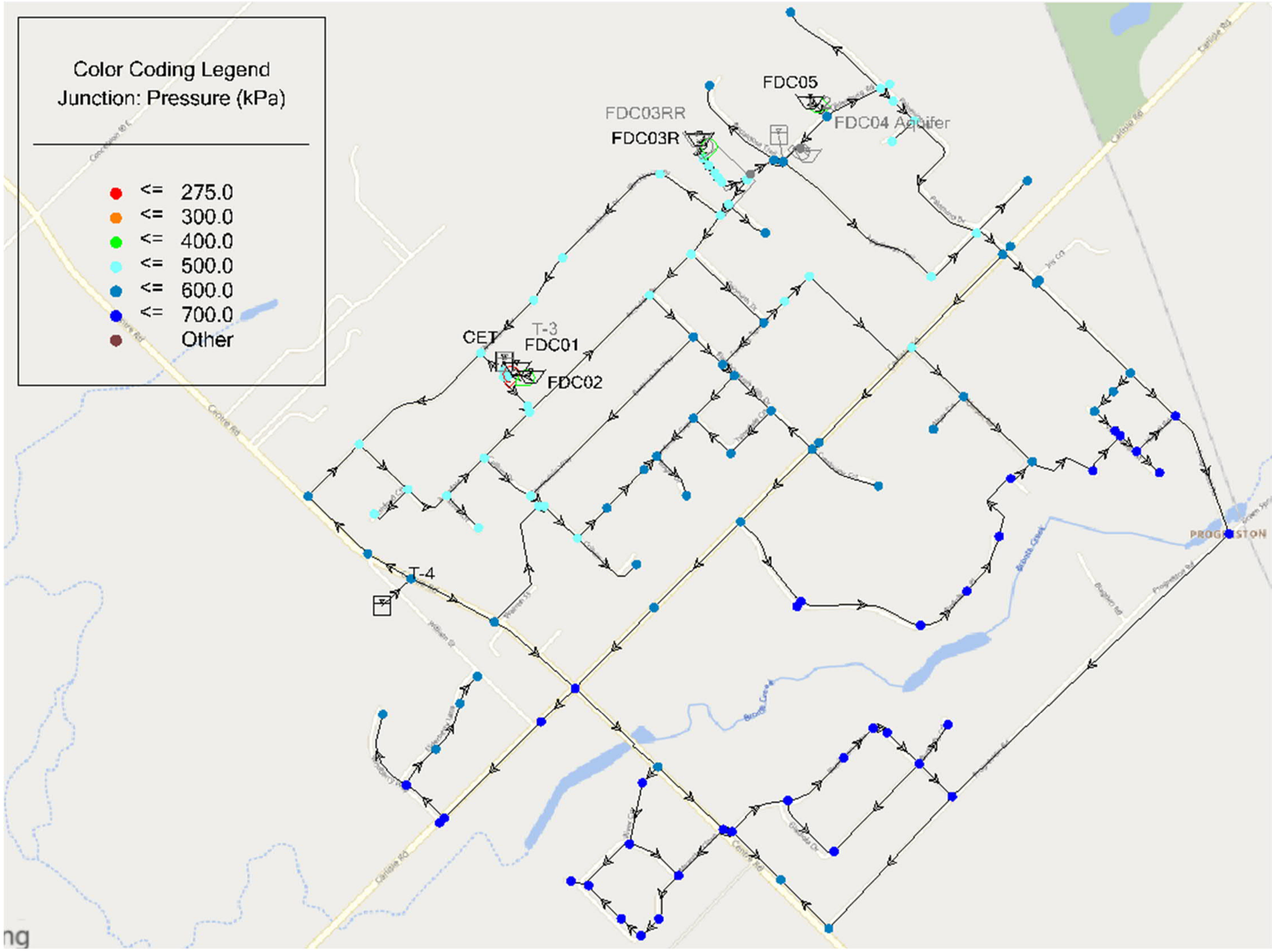

Figure 4.17 (c): Resulting Pressures Under Future (2051) MDD with Additional Storage on William St.

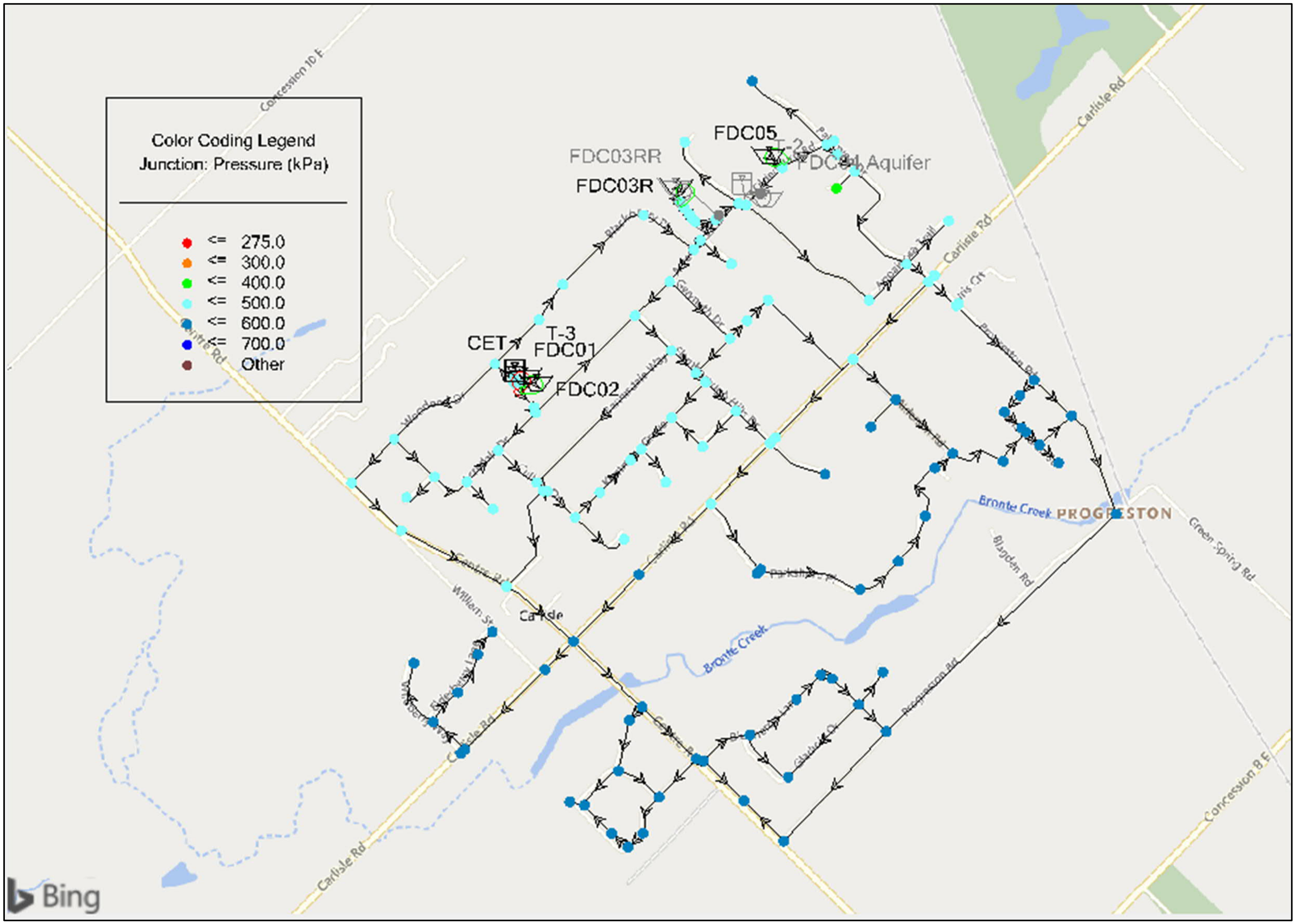

Figure 4.18 (a): Resulting Pressures Under Future (2051) PHD with Additional Storage at Carlisle Tower Park

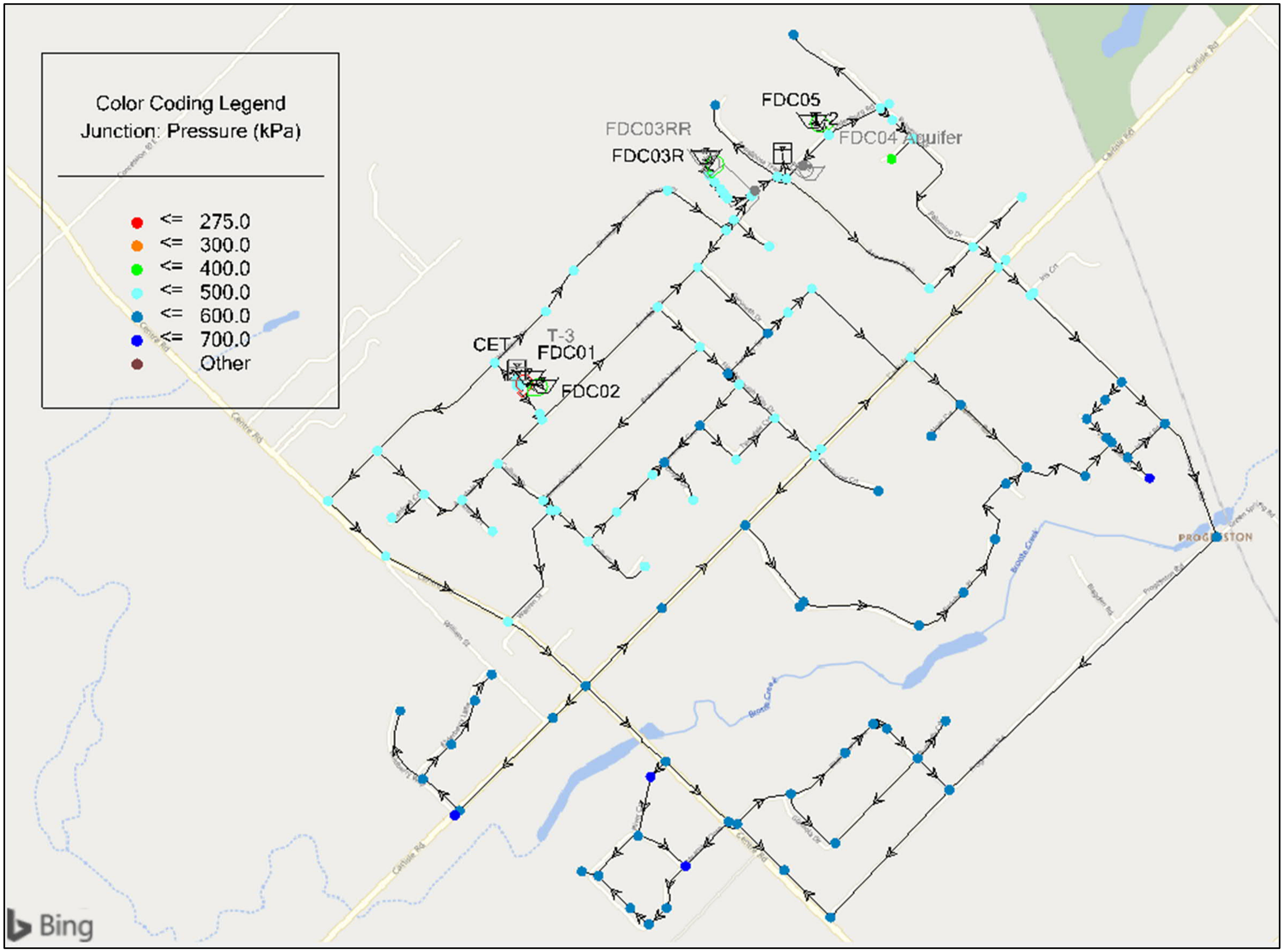

Figure 4.18 (b): Resulting Pressures Under Future (2051) PHD with Additional Storage at Oldenburg Rd.

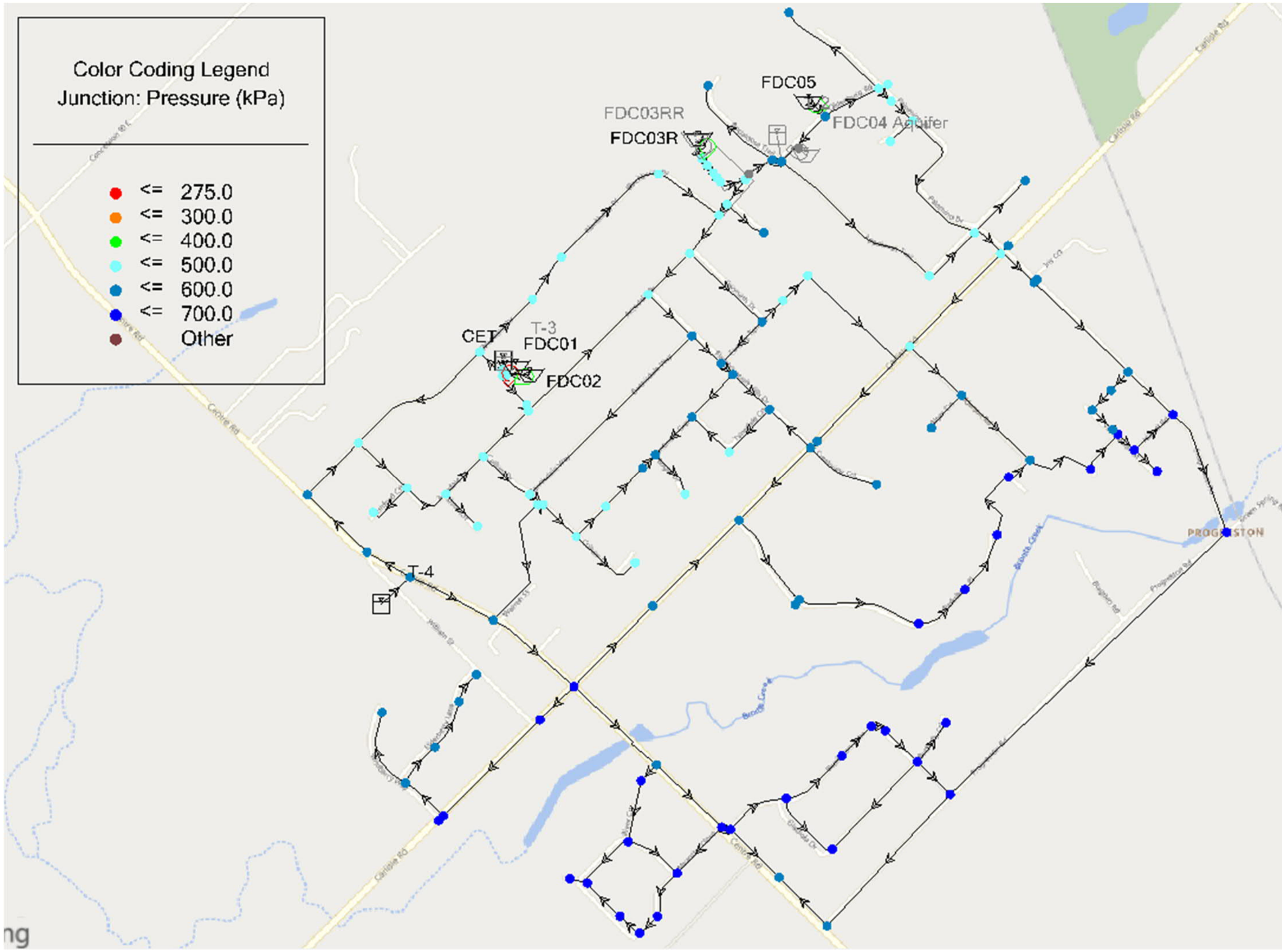

Figure 4.18 (c): Resulting Pressures Under Future (2051) PHD with Additional Storage at William St.

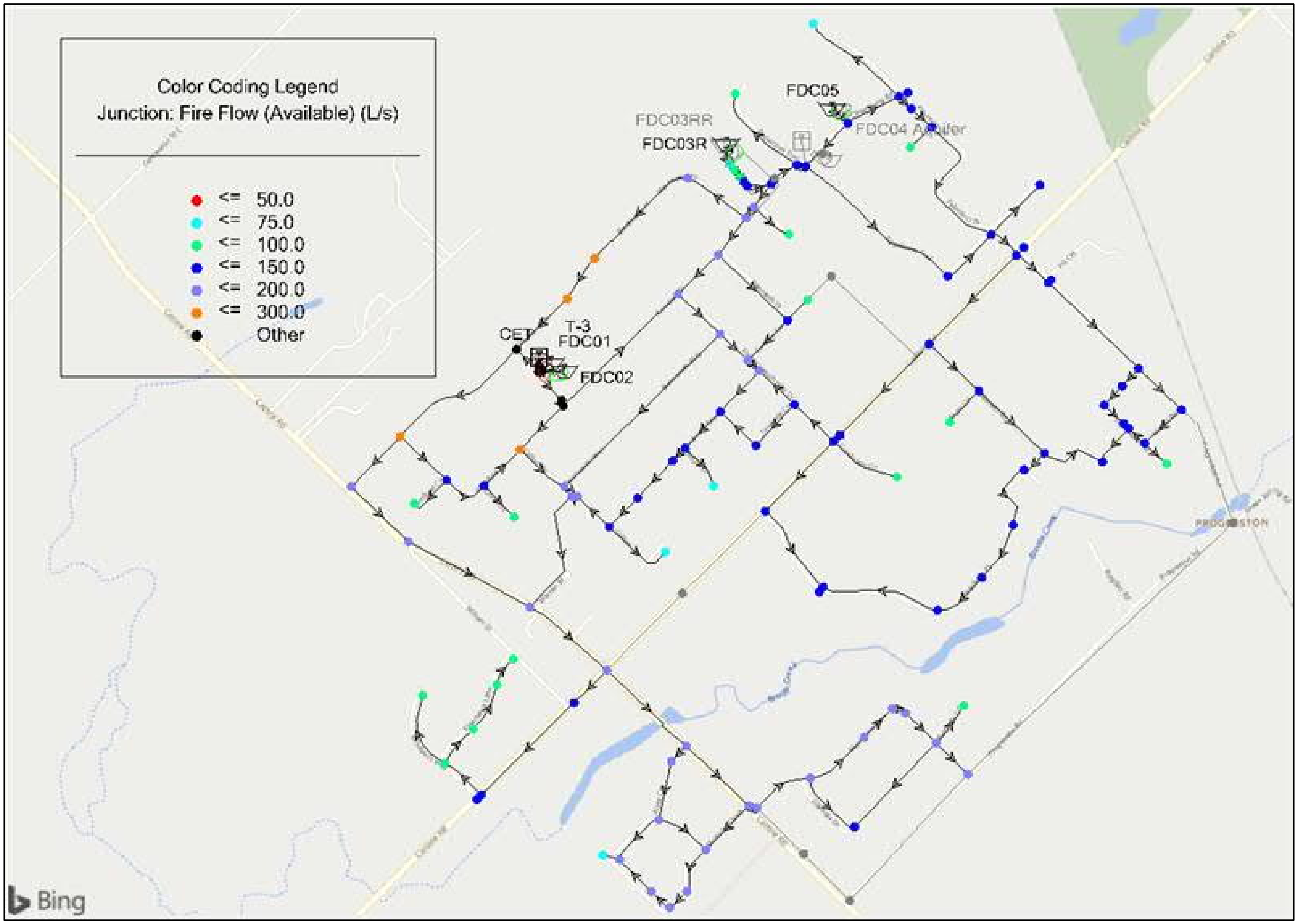

Figure 4.19 (a): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the Carlisle Tower Park Facility and without the Recommended Loop Connections

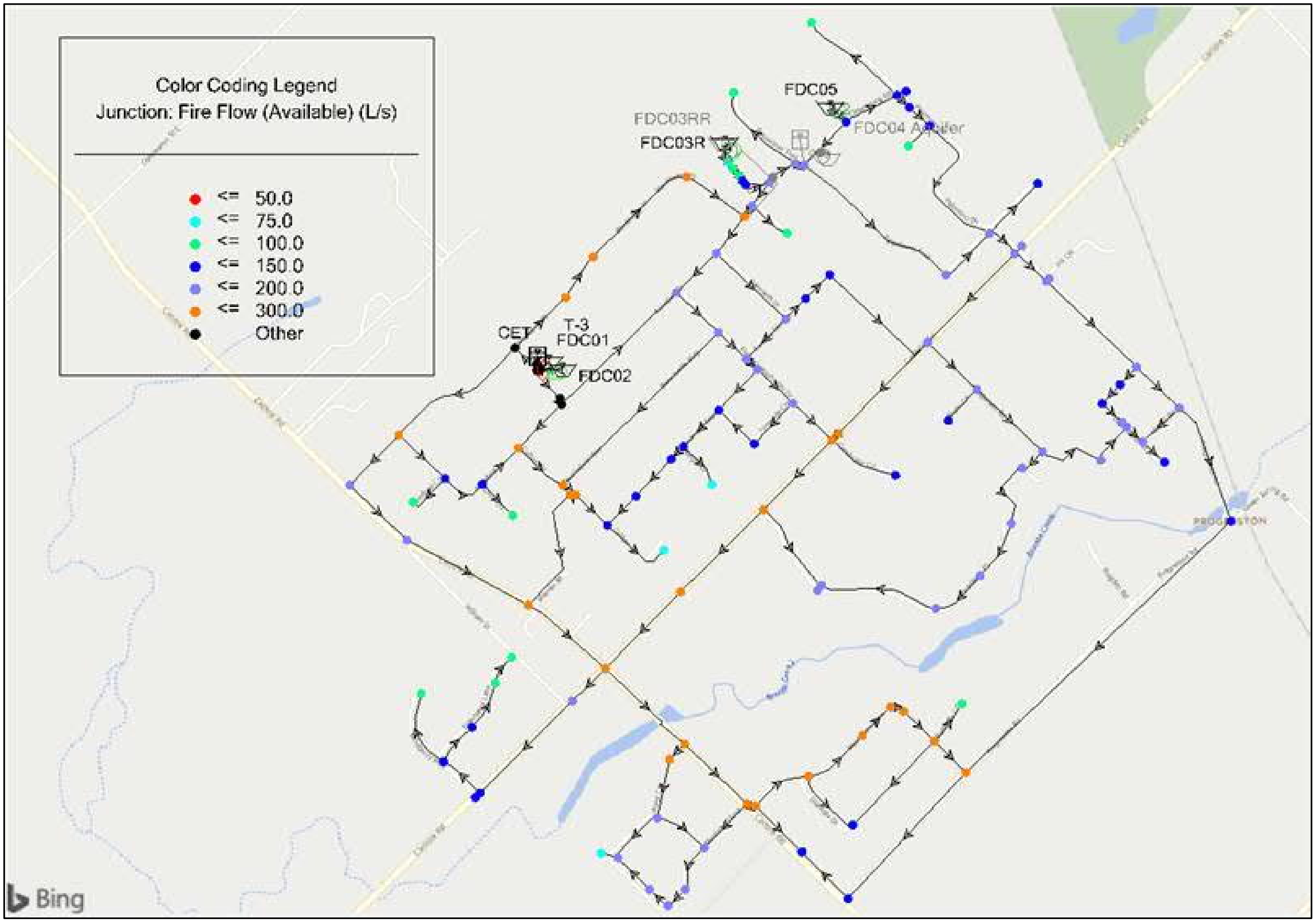

Figure 4.19 (b): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the Carlisle Tower Park Facility and with the Recommended Loop Connections

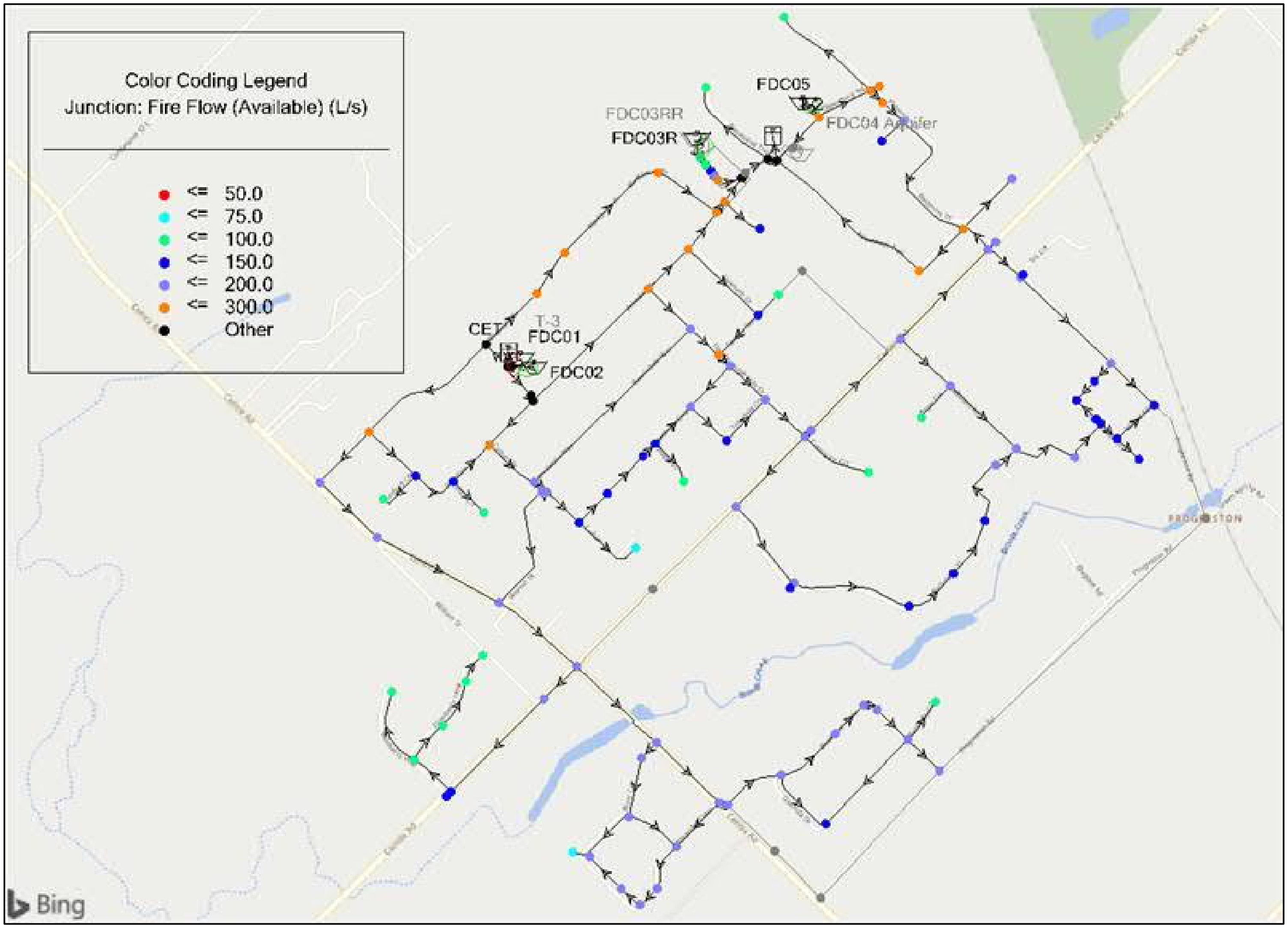

Figure 4.20 (a): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the Oldenburg Rd. Facility and without the Recommended Loop Connections

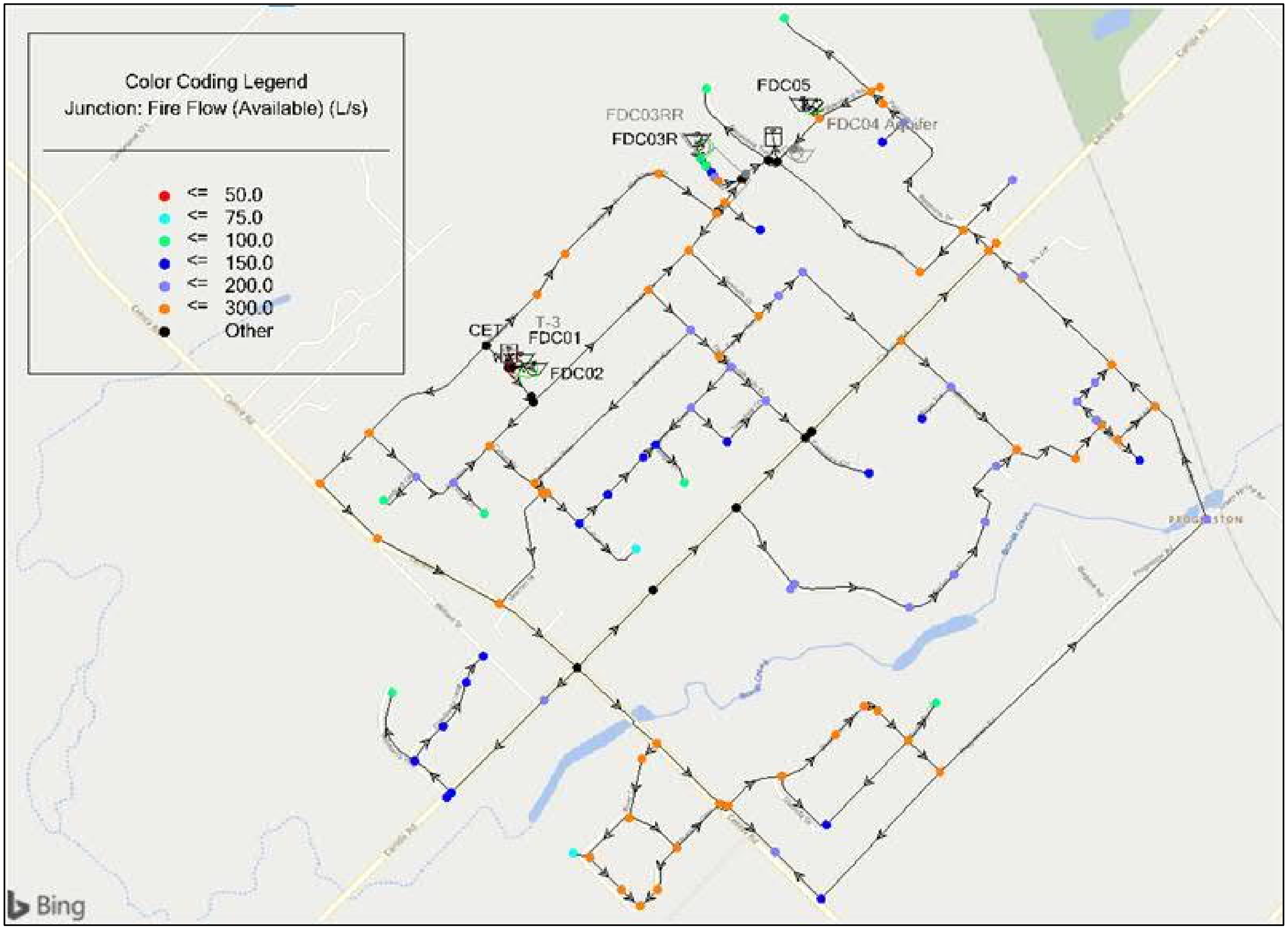

Figure 4.20 (b): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the Oldenburg Rd. Facility and with the Recommended Loop Connections

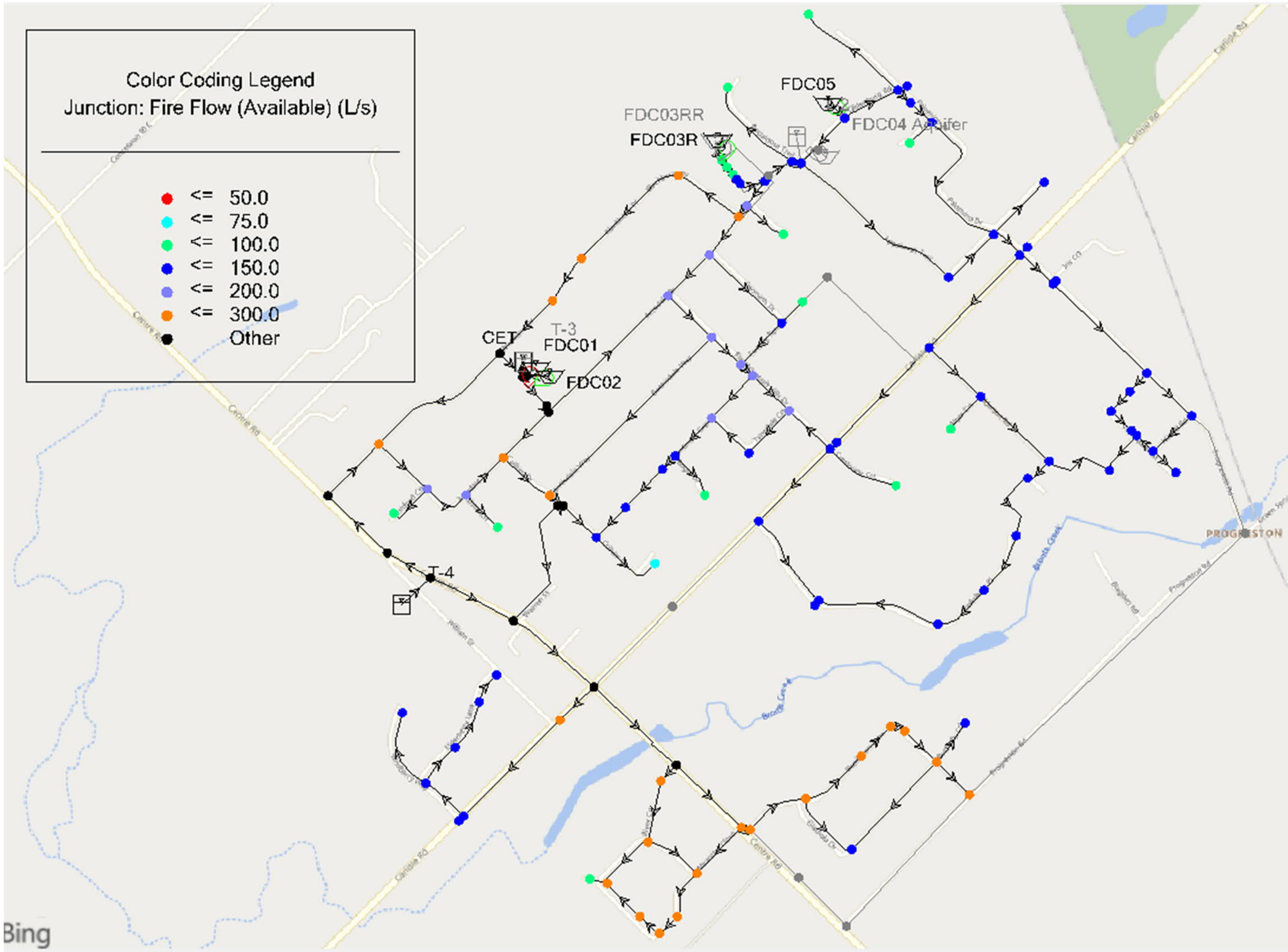

Figure 4.21 (a): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the William St. Facility and without the Recommended Loop Connections

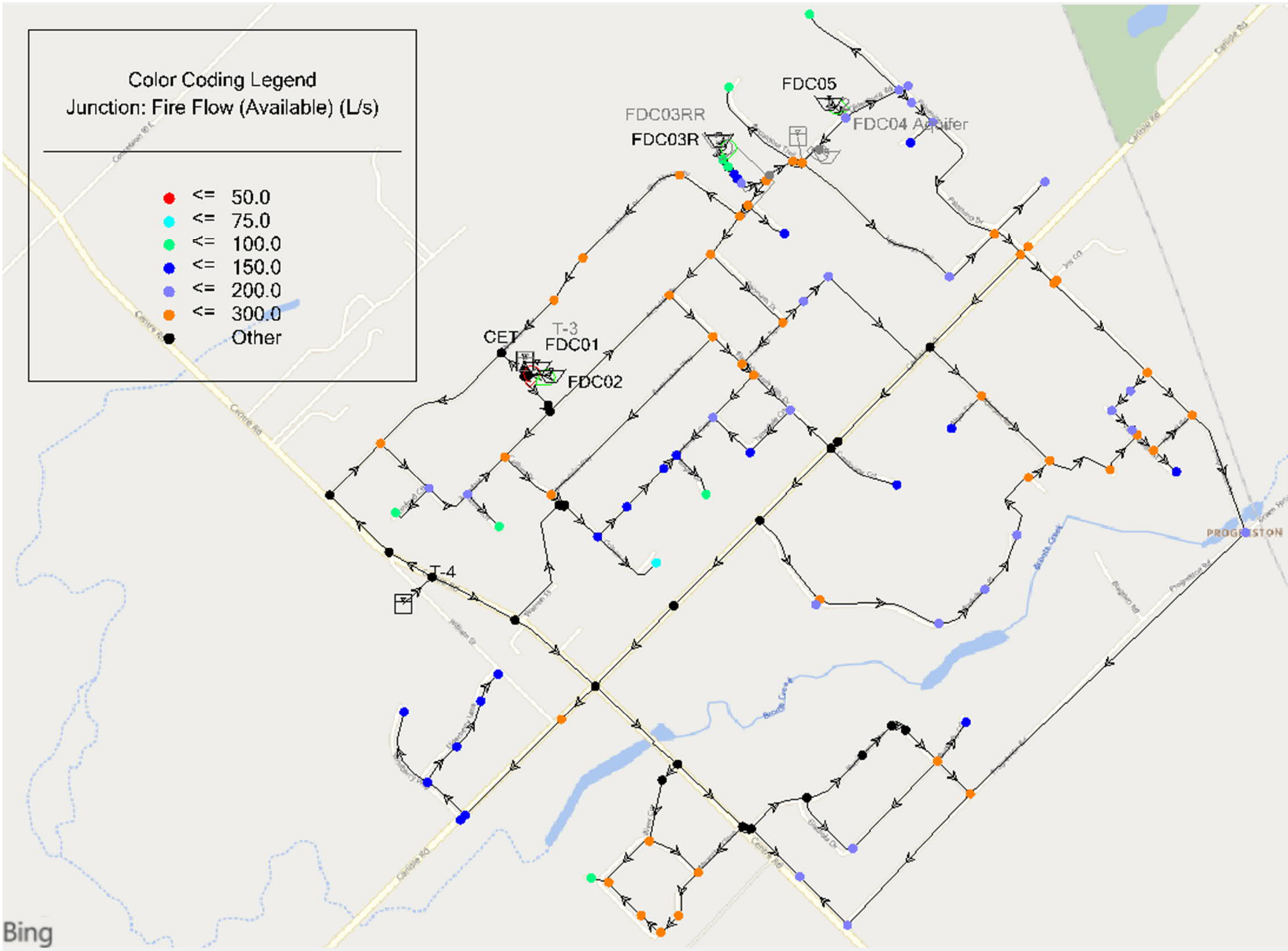

Figure 4.21 (b): Resulting Available Fire Flows Under Future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) with the William St. Facility and with the Recommended Loop Connections

5.0 Conclusions and Recommendations

The following conclusions and recommendations were provided based on the watermain hydraulic analysis of the Carlisle Rural Settlement Area's (RSA's) water distribution system:

1. All simulated pressures are within the acceptable range under existing (2022) and future (2051) demand conditions per the City of Hamilton's design criteria and standards for water distribution systems. To service all the residential units more efficiently within the RSA, additional watermains should be installed as follows:

   - Ø300mm watermain loop connection along Carlisle Road from Centre Road to Parkshore Place (approximately 177m).

   - Ø150mm watermain loop connection along Progreston Road from Centre Road to Idared Road (approximately 574m).

   - Ø150mm watermain loop connection east of Tansley Terrace going south to Carlisle Road (approximately 133m).

2. Based on the resulting pressure spectrum from the hydraulic modeling, the northern part of the RSA near the intersection of Palomino Drive and Steeplehill Court has relatively low pressures, ranging from 365 to 379 kPa, compared to other areas. Although these pressures are still within the acceptable range. This area of the RSA has the highest elevations within the entire community. It should be noted that FDC03R, which has the largest supply well within Carlisle, is currently operating at 41 Hz which is equivalent to a total discharge flow capacity of 14 L/s. This pump station has a total allowable capacity of 25 L/s; therefore, if needed, the pump can operate at a higher frequency up to its fully allowable capacity under high water demand conditions where low pressures are experienced to improve the pressures within this area.

3. Under existing (2022) and future (2051) Maximum Day Demand plus Fire Flow (MDD+FF) conditions, the fire flow requirement was not met at one location. This location has a required fire flow of 150 L/s where an existing retirement home is situated including two available parcels that can be developed. The fire flow deficiency can be addressed by extending the 300mm Ø watermain along Carlisle Road and looping the system to improve the flows at this location and to satisfy the fire flow requirement. The remaining junctions were able to satisfy each respective fire flow requirement ranging from 50 L/s to 75 L/s. In addition, the system was able

to maintain a minimum required pressure of 140 kPa (20 psi) under these conditions within the distribution system.

4. The additional storage required to meet all the future projected demands and system requirements per the Ministry of Environment, Conservation and Parks (MECP) design guidelines was estimated to be 1,285m^3. Although the results of the hydraulic modeling demonstrated that the system could provide the required pressures and flows with the existing CET and some additional watermain loops in the system, the steady-state model only analyzes the performance of the system and it does not take into account other factors such as fire, equalization, and emergency storage requirements for an emergency situation. Therefore, this additional storage is calculated outside the model (included in Appendix A).

5. A long list of potential locations for the additional storage tank was considered. Considering that storage tanks are frequently located at high points in the system to reduce the height at which they need to be built, and other factors such as constructability, area, lot availability, etc., three (3) potential lots that are situated in the high-elevation areas of Carlisle RSA were considered which are as follows:

   - Carlisle Tower Park – existing elevated tank location (ground elevation: 275m)

   - Oldenburg Road – northeast corner of the Appaloosa Trail intersection (ground elevation: 270m)

   - William Street – 1535 Centre Road (ground elevation: 270m)

6. A significant increase in fire flow availability of about 22% can be expected at the highest elevation in the system along Steeplehill Court if the proposed new tank is installed at the Oldenburg Road location compared to the existing Carlisle Tower Park location. Furthermore, the results of the hydraulic modeling show that the Oldenburg Road location is a more suitable location for the new elevated tank since it is closer to the low-pressure area from the resulting pressure spectrum of Carlisle RSA compared to the existing location of the CET with higher pressures and flows within the water distribution network.

7. In addition to the existing CET, a standpipe or a second elevated tank can be considered for the new storage tank for a more cost-effective design compared to in-ground storage which will require a pumping station to draw water out into the

distribution system. In addition, a lower elevation (i.e., a standpipe instead of an elevated tank) for the water storage design can also be considered for faster filling of the storage.

8. As mentioned in RVA's Tech Memo No. 1 (see Appendix A), a backup well (FDC03RR) located at the largest well site (FDC03R) is required to meet Carlisle RSA's supply capacity requirement, especially under maintenance conditions of the largest supply well (FDC03R).

6.0 References

In preparation of this report, the following information were obtained and reviewed:

- City of Hamilton Interactive Mapping for watermain, sewer and utility infrastructure information (link).
- Existing watermain hydraulic model of Carlisle RSA provided by the City of Hamilton.
- Carlisle RSA Well Capacity and Storage Requirements by RVA (July 2023).
- Carlisle Water Supply System Master Plan and Class Environmental Assessment by Stantec Consulting Ltd. (April 2004).
- Carlisle System – Closed Loop Operation Investigation by Aecom (March 2017).
- Hydrant flow test data conducted by RVA in November 2022 at various locations within Carlisle.