Town of Essex

Technical Memorandum – Harrow-Colchester South Water Supply System Model Build

Essex Water Model Build

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C3W-221660

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1 Introduction

CIMA Canada Inc. (CIMA+), formerly C3 Water Inc. (C3W), was retained by the Town of Essex (Town) to build a hydraulic model of the Harrow-Colchester South Water Supply System (HCSWSS) in InfoWater software. The HCSWSS is owned by Town of Essex and is currently operated by the Ontario Clean Water Agency (OCWA).

The HCSWSS's primary raw water source is Lake Erie, which supplies the Harrow-Colchester South Water Treatment Facility (WTF). The HCSWSS contains one (1) WTF, three (3) high lift pumps (HLPs), and one (1) elevated tank (ET). The distribution system is a single pressure zone. A process overview of the HCSWSS is presented in Figure 1-1 below. The HCSWSS is interconnected to other adjacent water supply systems such as Amherstburg, Union and Essex (Union).

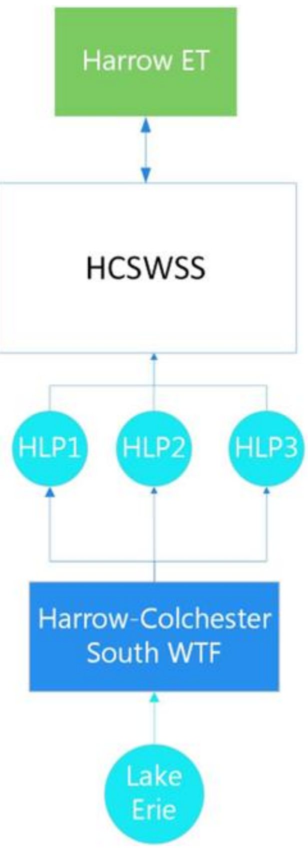

Figure 1-1: Harrow-Colchester South Supply System Process Flow Diagram

2 Model Build

Hydraulic models consist of a network of pipes, junctions, pumps, valves, tanks, and reservoirs to represent the unique set-up of each drinking water distribution system. InfoWater allows different scenarios to be created to represent operational control changes, demand fluctuations throughout the year, as well as population and water usage growth. This section describes the model build process.

2.1 Model Infrastructure

2.1.1 Scenarios

The scenario structure in InfoWater was built to include the following demand scenarios:

- ADD_2021, Average Day Demand (ADD),
- ADD_FUTURE
- MDD_2021, Maximum Day Demand (MDD),
- MDD_FUTURE

All scenarios were based on existing infrastructure conditions. The future scenarios include planned growth demands.

2.2 Infrastructure Update

2.2.1 Overall Network

The model's water distribution network was built using GIS data for pipes, valves, and hydrants. The following steps were completed for developing the system network:

- The following GIS data provided by the Town was imported into a model format;
  - Pipes: TOE_WMain
  - Valves: TOE_WValves
  - Hydrants: TOE_Hydrants
- All pipes in the GIS were created with junctions at the end of each pipe and were split at valves and hydrant laterals.
- The GIS "Asset_ID" fields were used as the InfoWater element IDs for watermains, and valves so the Town is able to identify and report on data using the common asset ID. The model pipes not included in GIS were given default IDs that can be modified if desired. The model element naming system is summarized in Table 2-1 below.

Table 2-1: Element Naming

Element	Element Type	InfoWater Element Name
Pipes	Pipe	'Asset_ID' + proceeding _1, _2, etc. where pipe splits required
Valves	Valve	'Asset_ID'

- Pipe, node and valve data including material and year of installation were imported from GIS into model elements based on the corresponding Asset IDs.
- The Town's watermains supplied by Union Water Supply System (UWSS) and HCSWSS were added to the model. However, pipes supplied by UWSS were kept inactive since the UWSS is not included in the model.
- Elevations were assigned to model nodes using available LIDAR data.
- Drawings provided by the Town were used to develop water facilities such as HLPs and ET. Figure 2-1 and Figure 2-2 show an overview of the HCSWSS and the Harrow-Colchester South WTF, respectively.

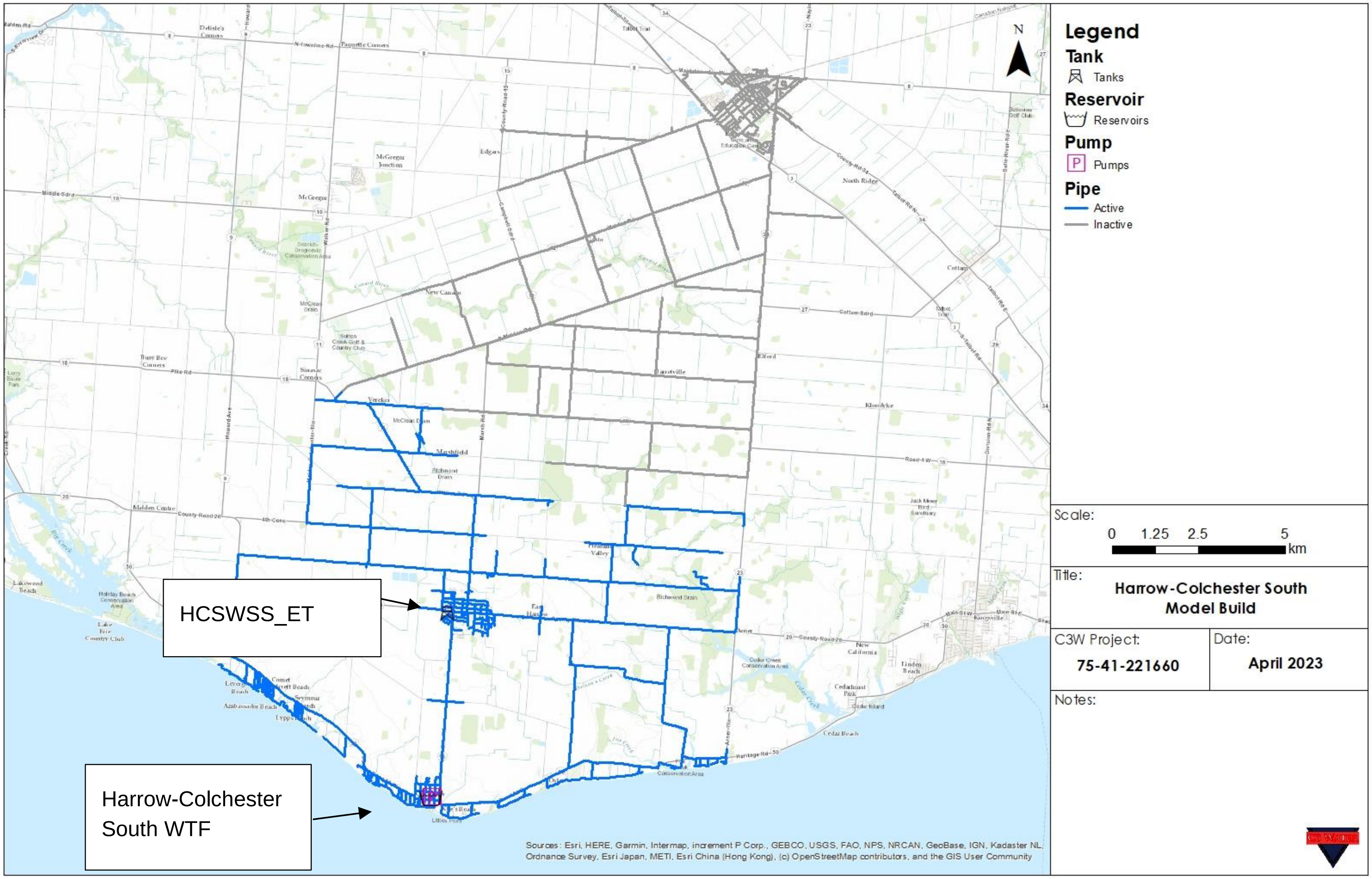

Figure 2-1: Harrow-Colchester South Supply System Model Overview

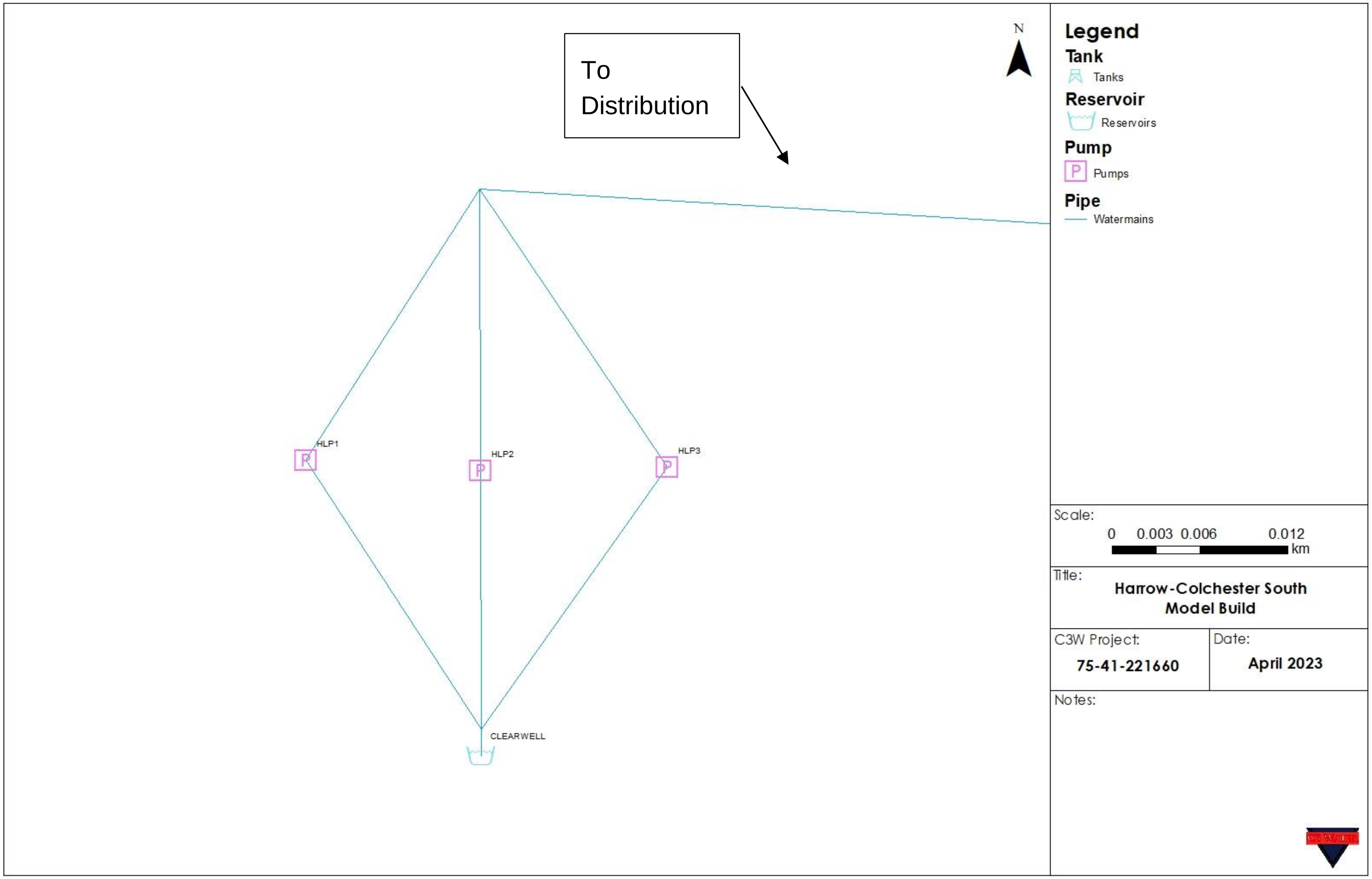

Figure 2-2: Harrow-Colchester South WTF

2.2.2 Pipes

Pipe information including material, original ID, road name and year of installation was assigned to model pipes based on the GIS data. C-factors were applied to all model pipes. C-factors are unitless numbers utilized by the Hazen-Williams hydraulic equation to calculate friction losses within the pipes. C-factors vary based on diameter, material, and age of pipe. They can be referenced from literature and tested in the field. In the absence of current tests, C-factors were applied based on literature values as shown in Table 2-2. C-factors for pipes with unknown materials were assumed to be 110.

Table 2-2: C-Factors

Material	Description	Year of Install	C-Factor
AC	Asbestos Cement	All	110
CI	Cast Iron	<1990	80
		1990-1999	95
DI	Ductile Iron	All	110
PVC	Poly-vinyl Chloride	All	130

Roughness values in the model ranged from 80 to 130 based on typical values from literature. It is recommended that these values be verified through field testing and updated in the model accordingly. In total, there are 4,437 pipes in the model, ranging from 20 mm to 450 mm in diameter, as shown in Figure 2-3. However, 2,080 pipes of the total are inactivated since they are serviced by the UWSS, which is not included in the model.

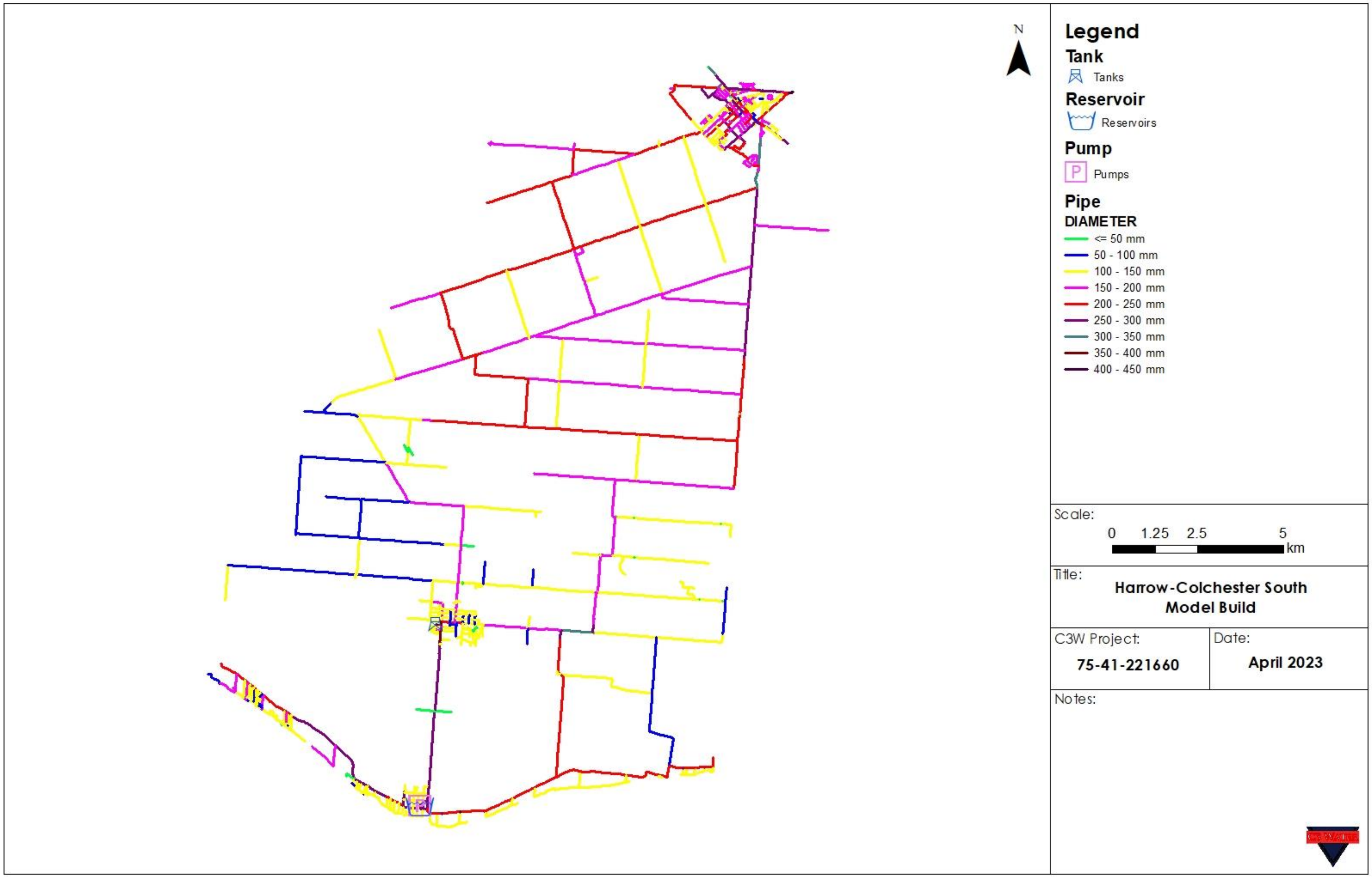

Figure 2-3: Pipe Diameters

2.2.3 Junctions

Junctions in the model are assigned demands that correspond to water usage in the system. Junctions were also used to represent hydrants from GIS. Installation years were assigned to them based on the 'TOE_Hydrant' shapefile. In total, there are 3,159 junctions in the model ranging from 174.5 to 197.0 mASL in elevation as shown in Figure 2-4. Junction elevations within WTFs were manually entered based on finished floor elevations from as-built drawings.

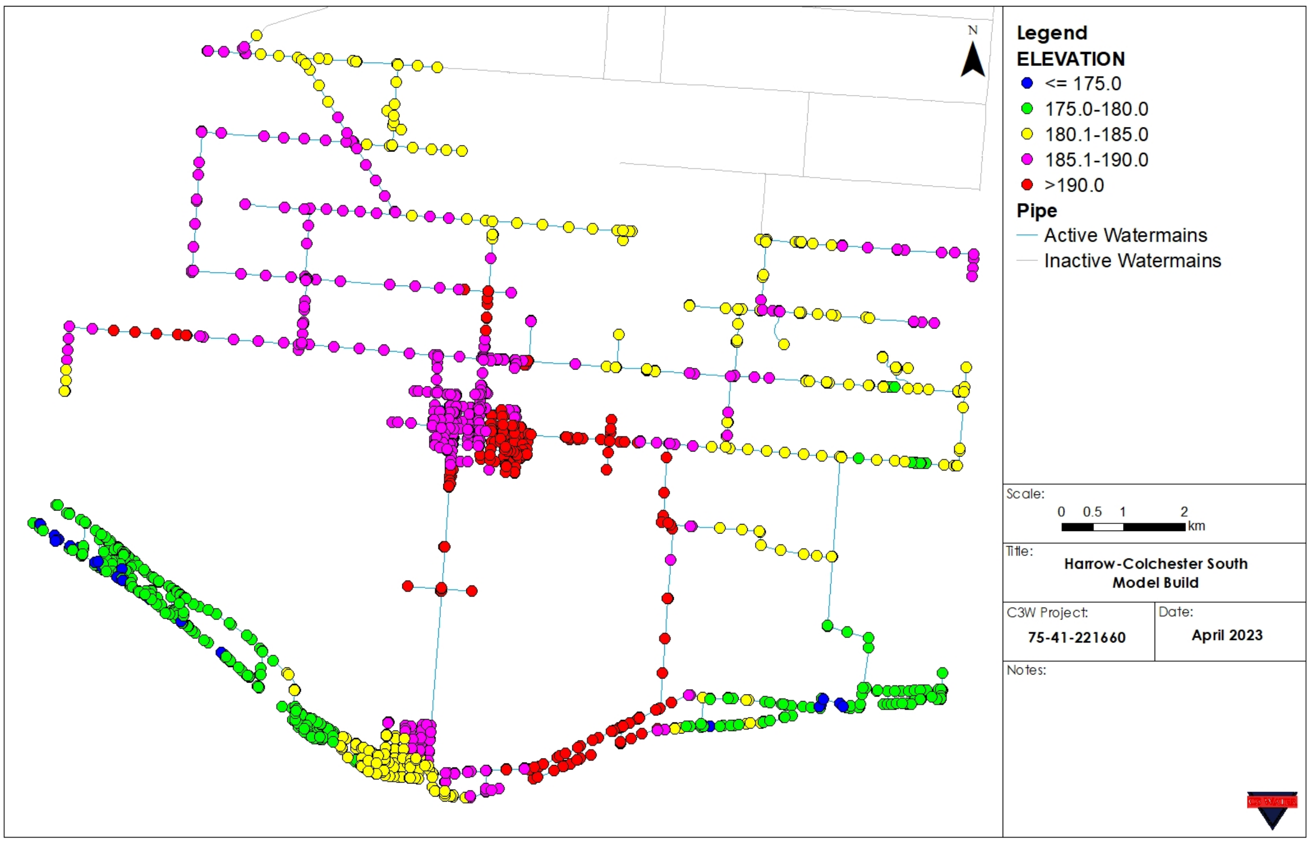

Figure 2-4: Junction Elevations

2.2.4 Reservoirs (Clearwell)

The Clearwell at the WTP was represented as a fixed head reservoir in the model. Reservoirs are used to represent sources of water such as lakes or wells and have theoretically infinite volume and constant water levels. The volume of the clearwell wasn't considered as storage in this model. Table 2-3 summarizes the reservoir data implemented in the model and associated water levels.

Table 2-3: Reservoir Levels

Reservoir Name	Water Level (mASL)
Clearwell	184.4

2.2.5 Tanks

InfoWater utilizes a tank to represent a storage facility with a fixed volume. In the HCWSS Model, storage is provided by the HCSWSS ET. Drawings provided of the ET were used to define the parameters such as elevation and tank volume and were added to the model as provided in Table 2-4. A depth vs. volume curve was developed for the ET to accurately represent the variable area of the tank based on as-built drawings and SCADA data as shown in Figure 2-5.

Table 2-4: Tank Model Data

Description	HCSWS_ET
Elevation (m)	221.00
Minimum Level (m)	0.00
Maximum Level (m)	9.18
Total Storage Volume (m^3)	1,136

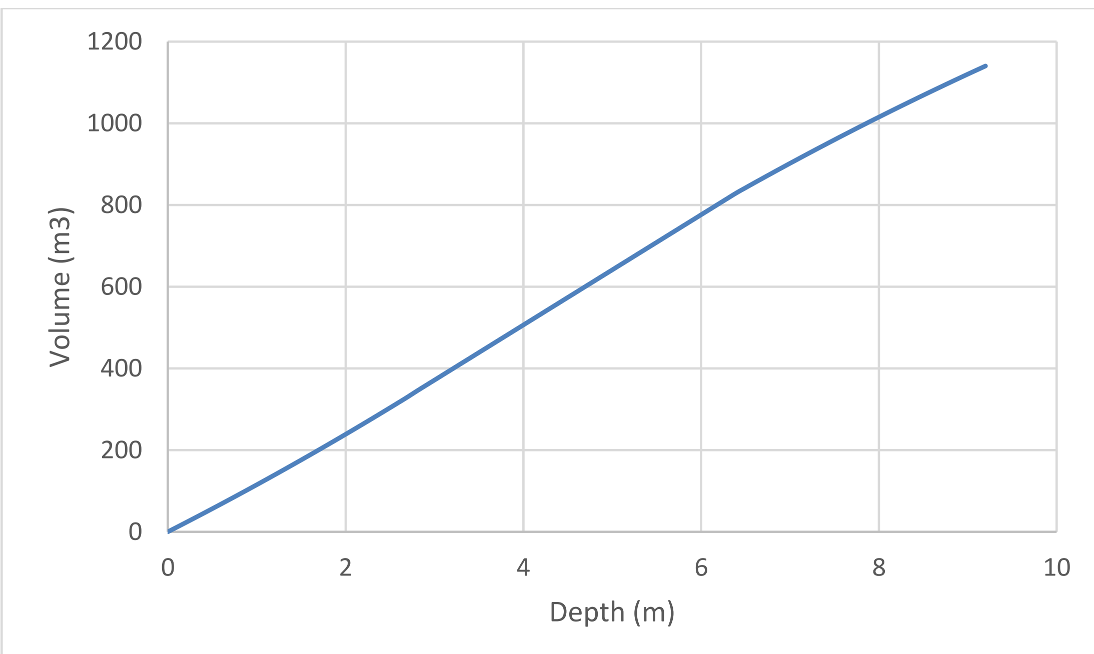

Figure 2-5: ET Storage Curve

2.2.6 Valves

The model contains a total of 1,047 valves based on GIS records, where 580 valves are active. Currently, all valves from GIS are modelled as fully open throttle control valves. Valve settings may be adjusted in the future to calibrate the model based on field test results.

2.2.7 Pumps

The model contains three (3) HLPs located at the Harrow-Colchester South WTF. The settings and controls of each pump are described in Section 2.3. The discharge flow is presented in the Validation section.

Pump curves were not available; therefore, pump design points were implemented into the model based on the Harrow-Colchester South WTF Operations Manual as shown in Table 2-5. Since the HLP curves were not available, the model simulates a pump curve from the design point which may not be an accurate representation of actual pump performance. It is recommended that pump performance testing is conducted and used to update the accuracy of the model in the future.

Table 2-5: Model Pumps

Location	Pump ID	Pump Design Point	
		Head (m)	Flow (L/s)
Harrow-Colchester South WTF	HLP1	54.90	26.5
	HLP2	57.90	68.2
	HLP3	60.98	113.7

2.3 Model Controls

InfoWater utilizes control sets to store information about how the elements are operated. The initial status of pipes, pumps and valves can be set to control how each element is operating at the beginning of the model simulation. Using the controls, the status and setting of pumps and valves can then be altered throughout the simulation’s time steps based on tank levels, pressure values, or clock time.

The controls in the model were built based on the information in the Harrow-Colchester South WTF Operations Manual and the SCADA data provided by the Town. Pump on/off setpoints based on ET levels are summarized in Table 2-6 below. HLP1 is duty 1 and will start once the ET level falls below 7.5 m, however, if the ET falls below 6.5 m, HLP1 will stop and a larger HLP2 will start. HLP3 will start if ET levels fall below 4.0 m.

Table 2-6: Control Summary

Pump ID	Duty	Control Based On	Actions
HLP1	1	Harrow-Colchester South ET	Close If level at HCSWS_ET is above 8.25
			Open If level at HCSWS_ET is below 7.5
			Close If level at HCSWS_ET is below 6.5
			Close If HLP2 is ON
HLP2	2		Open If level at HCSWS_ET is below 6.5
			Close If level at HCSWS_ET is above 7.5
HLP3	3		Open If level at HCSWS_ET is below 4.0
			Close If level at HCSWS_ET is above 6.5

2.4 Model Demands

2.4.1 Existing Demands (2021)

Junctions in the model are assigned sets of demands that correspond to water usage in the system in units of L/s by using the 2021 total production data and the 2021 metered records provided by the Town. The total production data is representative of the WTF's discharge flow into the distribution system. The average day demand (ADD) for the model was determined using the 2021 total production data, resulting in a value of 35.1 L/s. The billing meter records represent measured billed consumption and was found to be an average of 23.7 L/s for 2021. By comparing the reported consumption (billing meter records) to the total production volume, the system had approximately 33% non-revenue water (NRW) in 2021 as summarized in Table 2-7.

Table 2-7: Water Usage Summary (2021)

Demand Type	L/s
Production Data	35.1
Meter Records (Billed Consumption)	23.7
NRW	11.4

Total water production trend data from 2011 to 2021 shows maximum water demands for 2021 in the lower range when compared to previous years as shown in Figure 2-6. Therefore, an average of the maximum day demands (MDDs) over the past 5-years

(2017-2021) was implemented as MDD to the model. Table 2-8 summarizes the ADD and MDD implemented to the model.

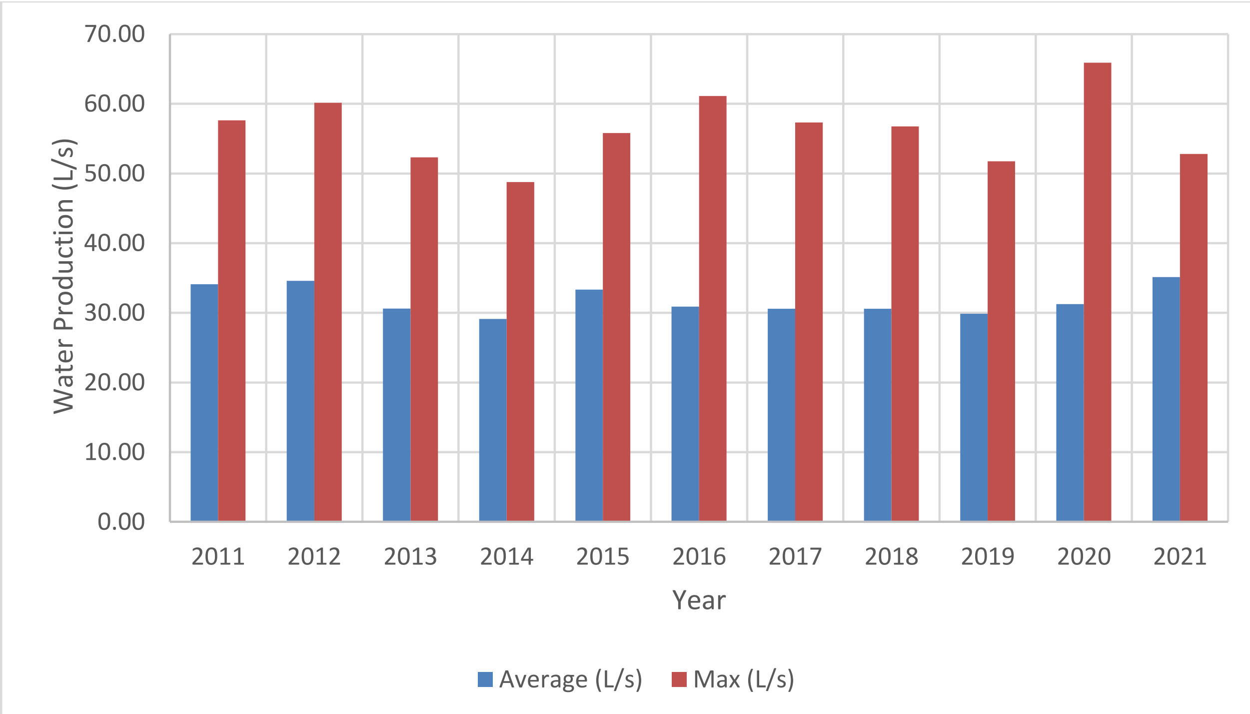

Figure 2-6: Water Production (2011-2021)

Table 2-8: 2021 Model Demands

Demand Scenario	Demands Based On:	Demand (L/s)	Source
ADD_2021	2021 Average Annual Production Data	35.1	2021 Annual Production Data
MDD_2021	5-Year Average Maximum Production Day (2017-2021)	56.9	2017-2021 Annual Production Data

2.4.2 Demand Allocation

Geocoded billing meter records were not available and therefore water demands were spatially allocated based on 2021 billing records and on the "TOE_CS_Parcels" shapefile. The following steps were followed to geocode billing meter records and allocate demands:

- 2021 Billing meter records were utilized to calculate demands for each address serviced by Harrow. Then, each demand was linked to an X and Y value based on the coordinates provided in the 'TOE_CS_Parcels'.

- InfoWater's Demand Allocator tool was used to apply the meter records to Demand 1 by using the "closest junction" method,
  - Each billing record point was matched with the nearest distribution junction in the system. Hydrant nodes and facility nodes were not included in the demand allocation.
- The NRW was applied evenly across the distribution system to Demand 2 to develop the ADD and MDD scenarios.
- Table 2-9 shows the model demand breakdown for the ADD and MDD existing scenarios.

Table 2-9: 2021 Model Demand Breakdown

Scenarios	Demand 1 – Metered Consumption (L/s)	Demand 2 – NRW (L/s)	Total (L/s)
ADD_2021	23.7	11.4	35.1
MDD_2021	45.4	11.4	56.9

2.4.3 Future Demands

Historical production data was reviewed to establish a representative water demand per capita and MDD peaking factor for the purpose of estimating growth demands based on population projections.

The recorded annal average and maximum day production for a 5-year period (2017 to 2021) are summarized in Table 2-10 below, with the respective MDD peaking factor for each year. Peaking factors are calculated as MDD divided by ADD. The average peaking factor of 1.81 over the 5-years was utilized to calculate the MDD for future demands as shown in Table 2-10.

Table 2-10: 5-Year Water Production Summary (2017-2021)

Year	ADD (m^3/day)	MDD (m^3/day)	Max Day Factor
2017	2641.94	4952.00	1.87
2018	2643.12	4904.00	1.86
2019	2579.37	4472.00	1.73
2020	2700.98	5694.00	2.11
2021	3035.24	4562.00	1.50
Average	**2720.13**	**4916.80**	**1.81**

A demand per capita value was calculated based on the 5-year average (2017-2021) total production and the existing service population of 10,400, resulting in an ADD of 262 L/cap/day. The demand per capita was estimated based on current available data and should be revised approximately every 2 years. Future ADD was calculated for each development by multiplying estimated population to the demand per capita (262.0 L/cap/day) as shown in Table 2-11.

Future development information was provided by the Town and is summarized in Table 2-11 below. Population estimates for future developments 1 through 15 were provided by the Town. For developments 16 and 17, only the area of the development was provided. Therefore, an assumption of 35 people per hectare for dry industrial area was used to calculate future population based on the Sanitary Design Criteria for the Town. For developments 18 and 19, only the number of units were provided by the developer, and so an assumption of 3 people per unit was used to calculate future population based on the Sanitary Design Criteria for the Town for Low-Medium Density Residential Criteria.

The growth due to intensification within the existing developed area (#20) was calculated based on the assumption of a population increase of 21 people per year based on 2016 and 2021 Statistic Canada data, resulting in an intensification population increase of 420 people. Figure 2-7 shows the location where each future development was allocated to.

Table 2-12 shows the model demand breakdown for the ADD and MDD under future scenarios. Future ADD and MDD should be revisited and updated if additional data becomes available.

Table 2-11: Future Developments Demands

Development	Area	Population	Demand (L/s)	
	(ha)	(capita)	ADD = Population x 262.0 L/cap/day	MDD = ADD x 1.81
1. Erie Blue	10.4	364	1.10	2.00
2. Erie Shores	8.9	312	0.95	1.71
3. Colchester Heights	5.4	189	0.57	1.04
4. Wellesley Drive	3.4	119	0.36	0.65
5. Lypps Beach	29.1	1,019	3.09	5.59
6. The Grove Motel	0.35	13	0.04	0.07

Development	Area	Population	Demand (L/s)	
	(ha)	(capita)	ADD = Population x 262.0 L/cap/day	MDD = ADD x 1.81
7. Roseborough Area	10.6	370	1.12	2.03
8. Dalla Bona Development	29	879	2.67	4.82
9. Pollard Development	5.57	147	0.45	0.81
10. Roseborough	0.76	27	0.08	0.15
11. Sunset Gardens Phase 2	5.23	180	0.55	0.99
12. Walnut & Given	3.33	120	0.36	0.66
13. Roseborough & Clark	2.13	160	0.49	0.88
14. 3rd Concession & Queen Street	8.22	300	0.91	1.65
15. 2544 County Road 20	4.35	300	0.91	1.65
16. 44 Sinasac	0.05	1.75	0.01	0.01
17. 2562 County Road 20	0.08	2.8	0.01	0.02
18. Colchester Bay - Phase 1	15.5	1338	4.06	7.34
19. Colchester Bay - Phase 2	9	1128	3.42	6.19
20. Intensification Growth		441	1.34	2.42
Total Original Service Area	**151**	**7411**	**22.47**	**40.67**

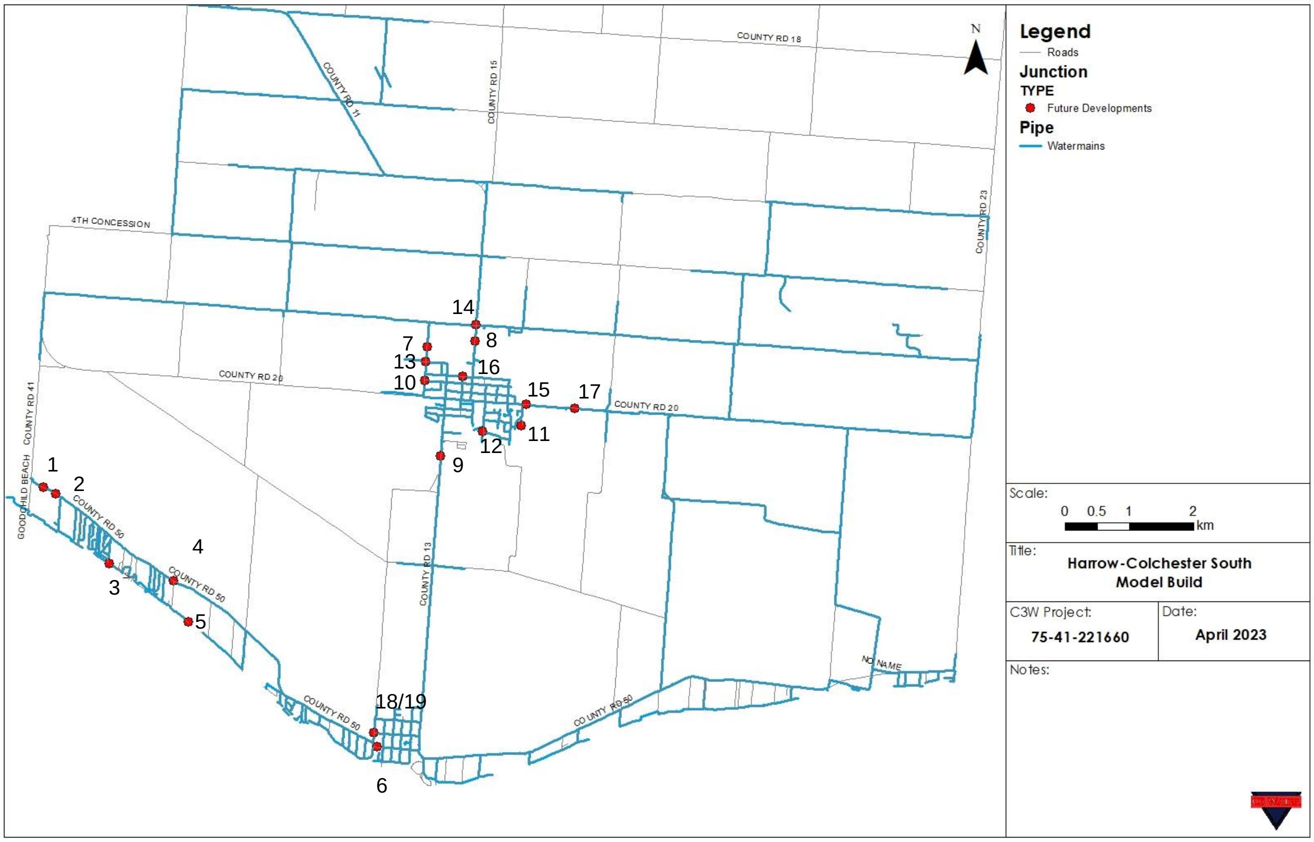

Figure 2-7: Future Development Locations

Table 2-12: Future Model Demand Breakdown

Scenarios	Demand 1 – Existing Metered Consumption (L/s)	Demand 2 – Existing NRW (L/s)	Demand 3 – Growth (L/s)	Total (L/s)
ADD_Future	23.7	11.4	22.5	57.6
MDD_Future	45.4	11.4	40.7	97.5

2.4.4 Demand Patterns and Peak Hour Demand

Each junction was assigned a demand pattern which applies a multiplication factor at different times throughout the day to create a diurnal curve. Different patterns can be applied to simulate trends observed for specific customer types, pressure zones, or other factors.

Demand patterns were developed by comparing WTF discharge flow and storage and subtracting the NRW at each time step throughout the day. Demand patterns were applied to Demand 1; however, a demand pattern was not applied to Demand 2 (NRW) as system water loss is expected to be relatively constant throughout the day.

The dates used to develop demand patterns are summarized in Table 2-13 below. Based on the production data provided, these dates were representative of typical ADDs and MDDs.

Table 2-13: Model Demand Patterns

Pattern	SCADA Data Used (Average of Dates)
ADD_2021	March 17, May 8
MDD_2021	May 22

Figure 2-8 and Figure 2-9 show the ADD and MDD demand patterns, respectively.

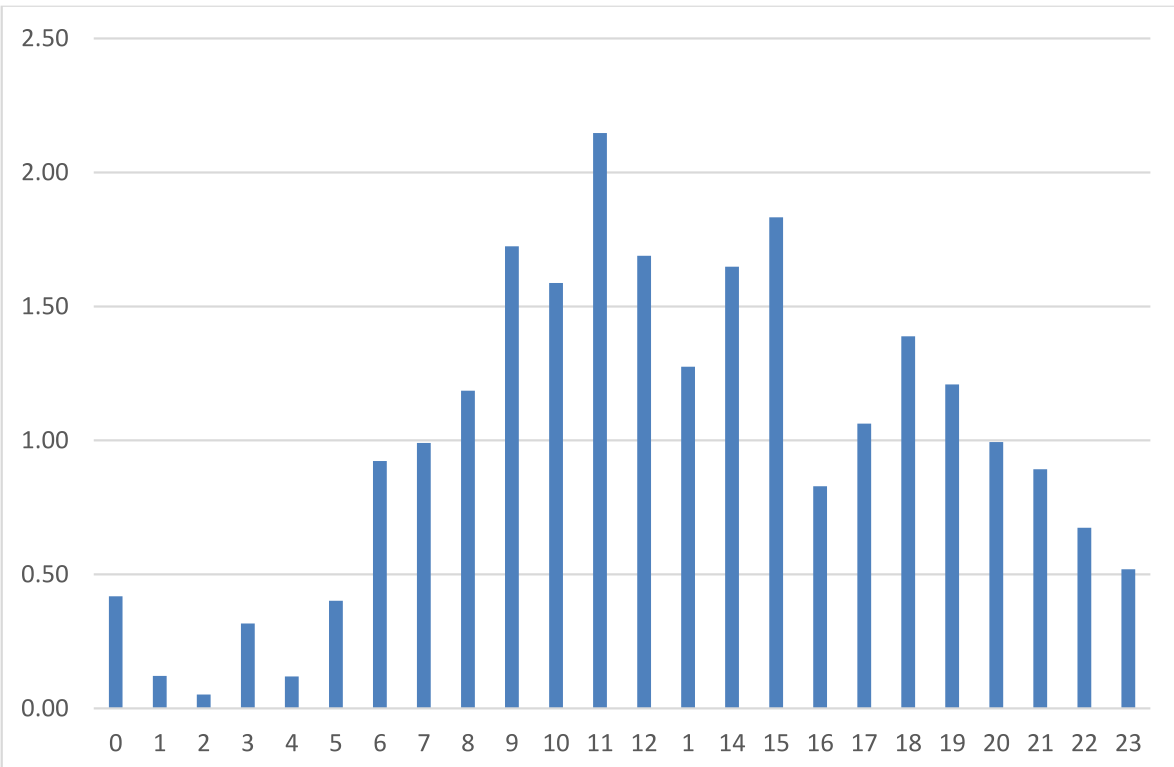

Figure 2-8: ADD 2021 Diurnal Curve

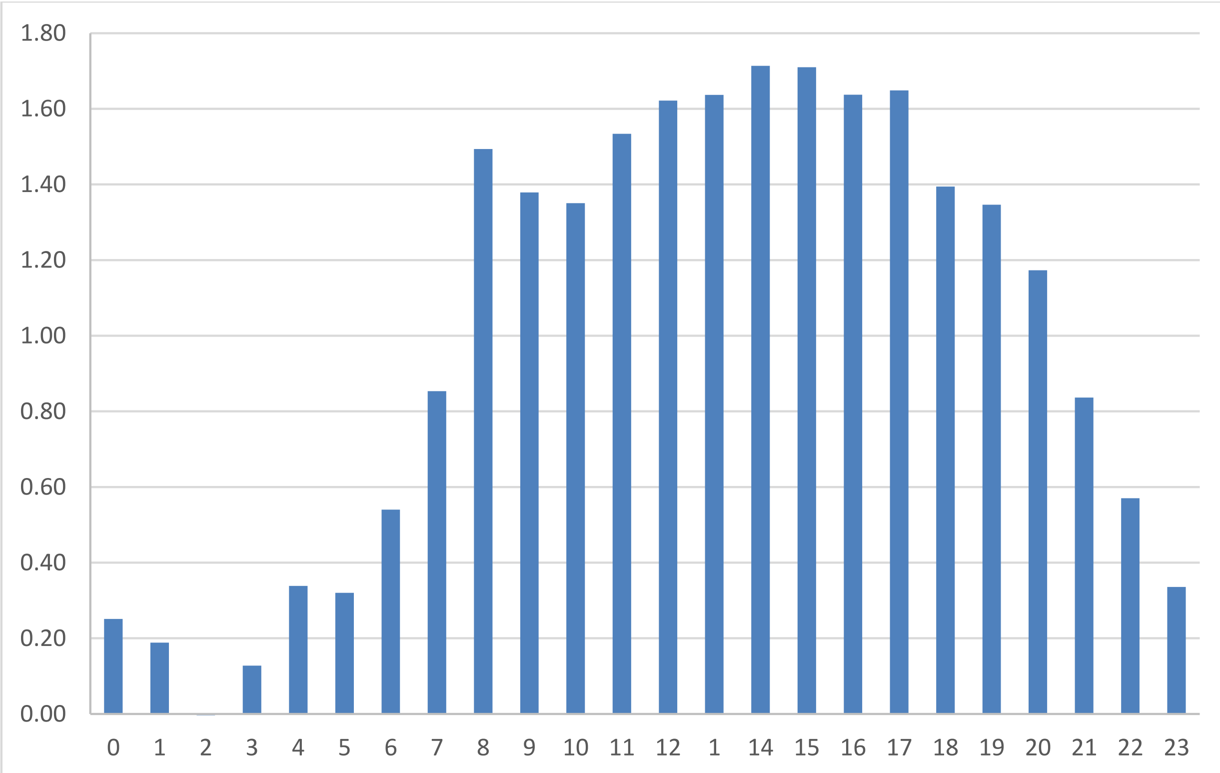

Figure 2-9: MDD 2021 Diurnal Curve

2.4.4.1 Peak Hour Demand

Based on the diurnal pattern developed for MDD conditions, the peak hour demand (PHD) factor is 1.71 x MDD for metered consumption. As discussed above, no diurnal pattern is applied for NRW. The overall system (including both metered demand and NRW) PHD is 89 L/s under existing conditions and 159 L/s under future conditions. PHD is summarized in Table 2-14 below.

Table 2-14: PHD Summary

Scenario	PHD Factor	Overall PHD (including NRW)
Existing	1.71 x MDD (metered consumption only)	89 L/s
Future		159 L/s

3 Model Results

3.1 Existing Scenarios Model Validation

The model results for the system were compared to SCADA data under ADD and MDD conditions. Table 3-1 shows a summary of the dates selected for the ADD and MDD validation. These dates were selected as they were found to represent a typical average day and maximum day, respectively. Pump operations at the WTF were set to replicate conditions on March 17, 2021, for ADD and May 22, 2021, for MDD.

Table 3-1: 2022 ADD and MDD

	Demand Based On	Demand (L/s)	Source	Pattern Based on
ADD	March 17, 2021	35.2	SCADA Data	March 17,2021
MDD	May 22, 2021	52.8	SCADA Data	May 22, 2021

SCADA data was provided by the Town for the WTF's discharge flow and ET level for a 24-hour period and a 30-minute step time; and compared to the model results. SCADA discharge flow data from the WTF is compared with model results for the ADD and MDD scenario as shown in Figure 3-1 and Figure 3-2, respectively. The HLP flows are slightly higher in the model than in the SCADA measured flow values, which could be a consequence of difference on the pump performance curve or pipe's C-factors.

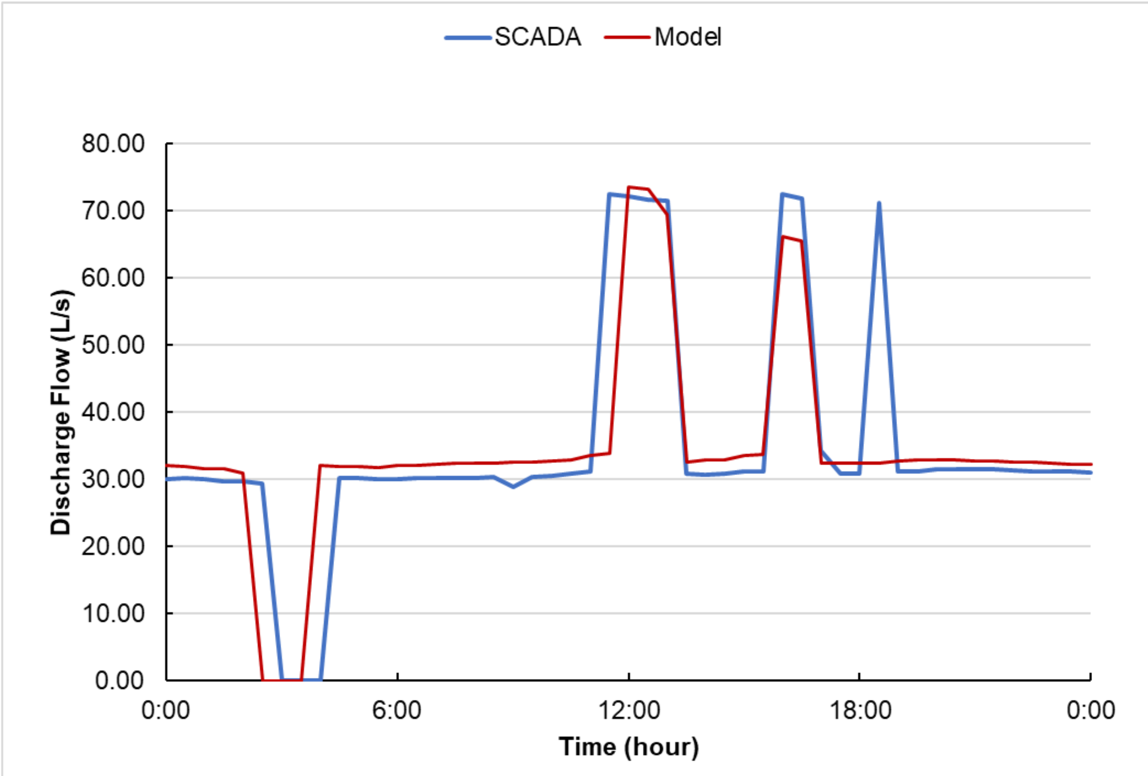

Figure 3-1: Harrow-Colchester South WTF Discharge Flow – ADD 2021

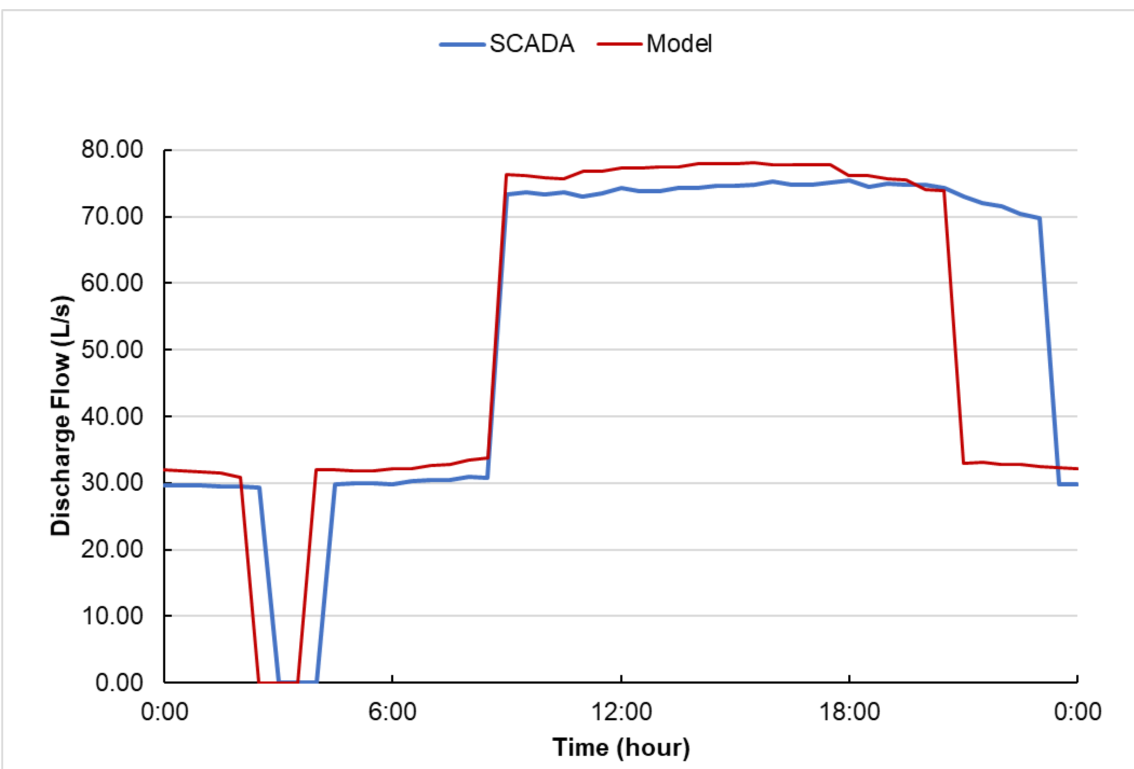

Figure 3-2: Harrow-Colchester South WTF Discharge Flow – MDD 2021

Modelled water levels at the Harrow-Colchester South ET are shown in Figure 3-3 and Figure 3-4 below for ADD and MDD, respectively. Under ADD, the model results were within 1 meter of what was recorded in SCADA. Under MDD, the model validation results show the ET filling at a rate faster than the SCADA, which could be a consequence of a difference in pump performance, pipe's C-factors or demand pattern error from flow meter records.

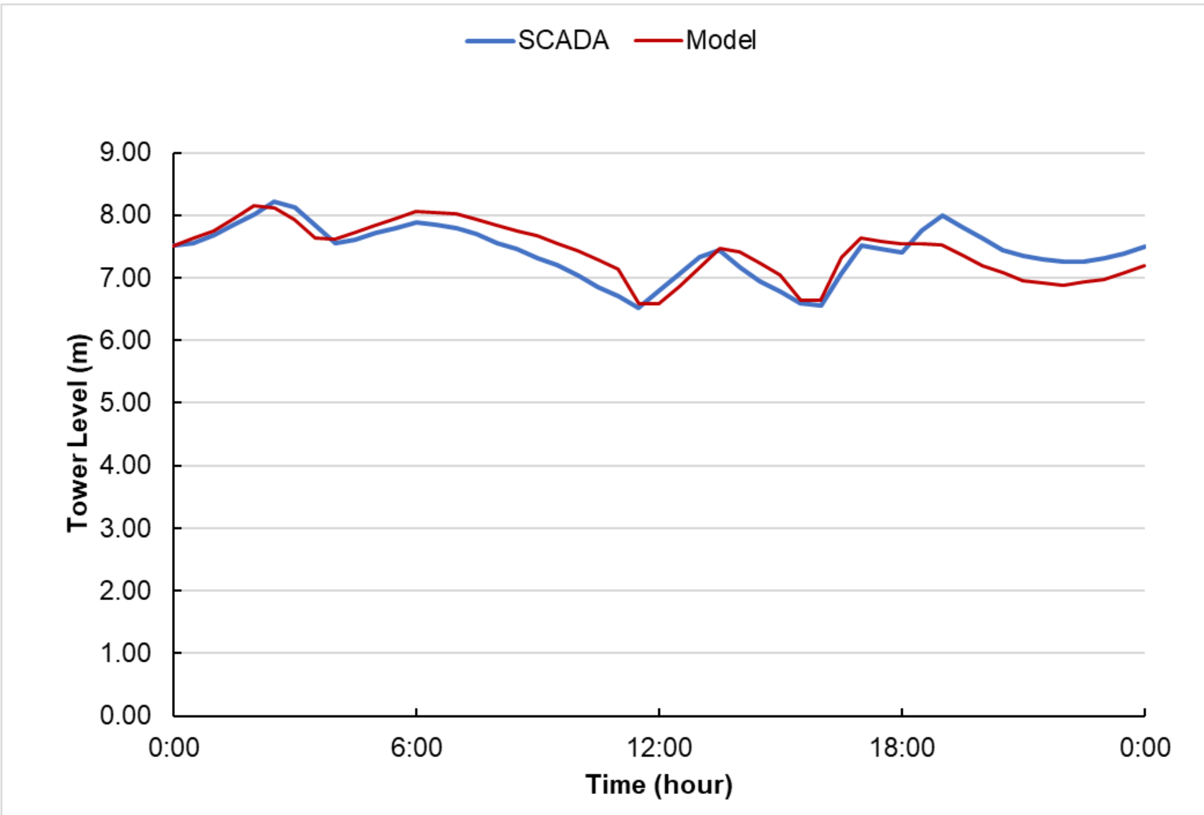

Figure 3-3: Harrow-Colchester ET Level – ADD 2021

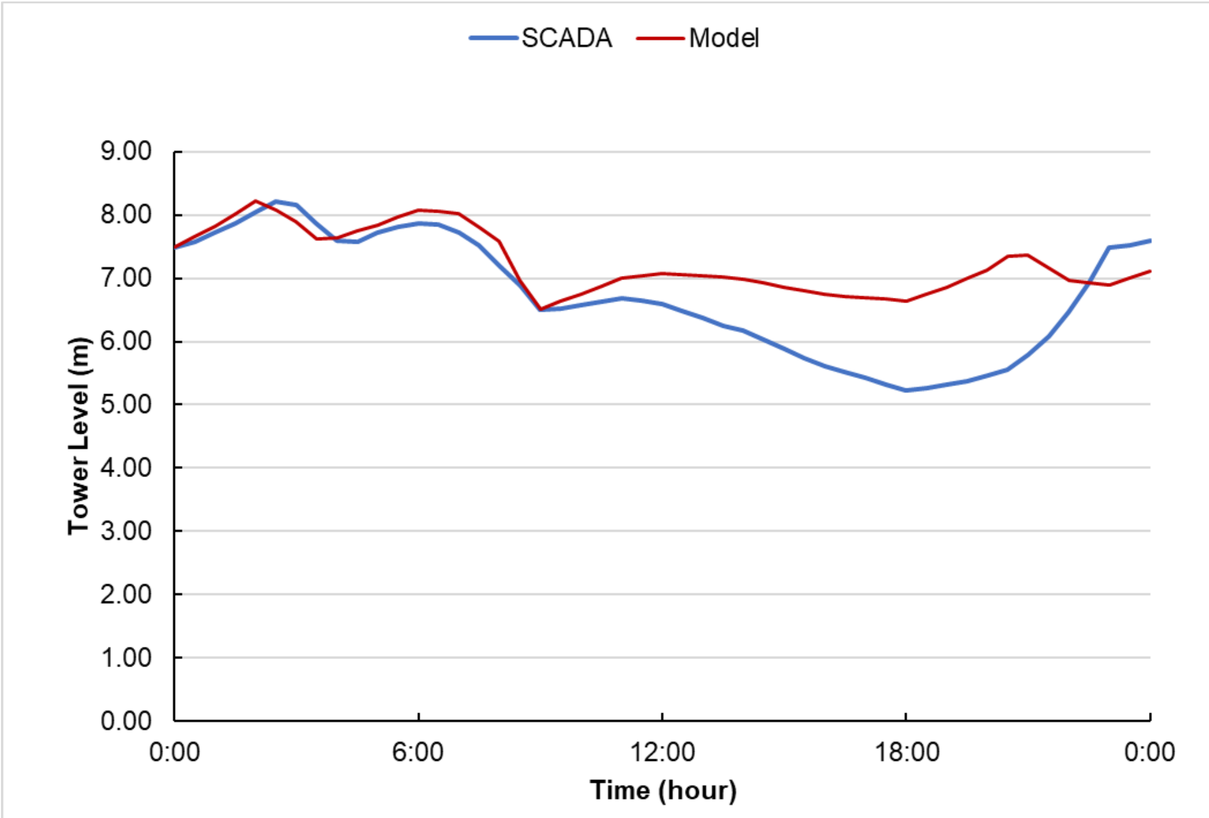

Figure 3-4: Harrow-Colchester ET Level – MDD 2021

Model results for both maximum pressure under the ADD scenario and minimum pressure at the MDD scenario were analyzed. Under the ADD scenario, the majority of the system was operating within a pressure range of 50-80 psi. A few areas along the lake, however, were operating within a range of 80 – 100 psi as shown in Figure 3-5. Under the MDD scenario, most of the system was within the pressure range of 50 – 80 psi, with a few areas operating at a range of 40 – 50 psi as shown in Figure 3-6.

Figure 3-5: HCSWSS Maximum Pressure - ADD 2021

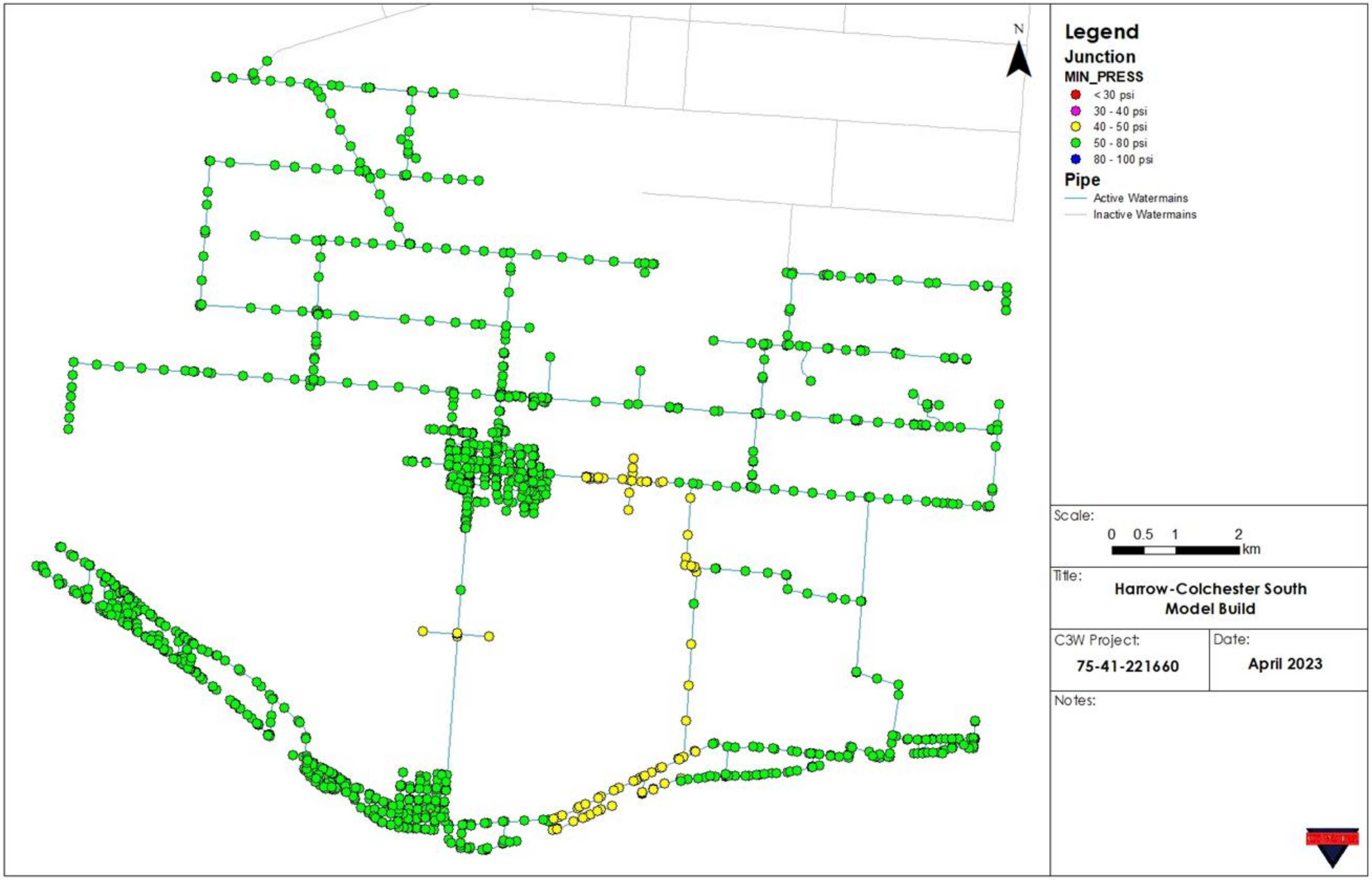

Figure 3-6: HCSWSS Minimum Pressure - MDD 2021

3.2 Existing Fire Flow Model Results

The available fire flow (FF) under the MDD 2021 scenario was analyzed. Figure 3-7 illustrates the pipe diameters and available FF within the water system. As expected, hydrants near the WTP and the HCSWSS ET exhibit the highest available fire flows in the system. However, most hydrants located near the Northeast and Northwest sections of the water system present an available fire flow of less than 30.0 L/s, which could be due to the limited capacity and looping of the 100-150 mm watermains in the extremities of the system.

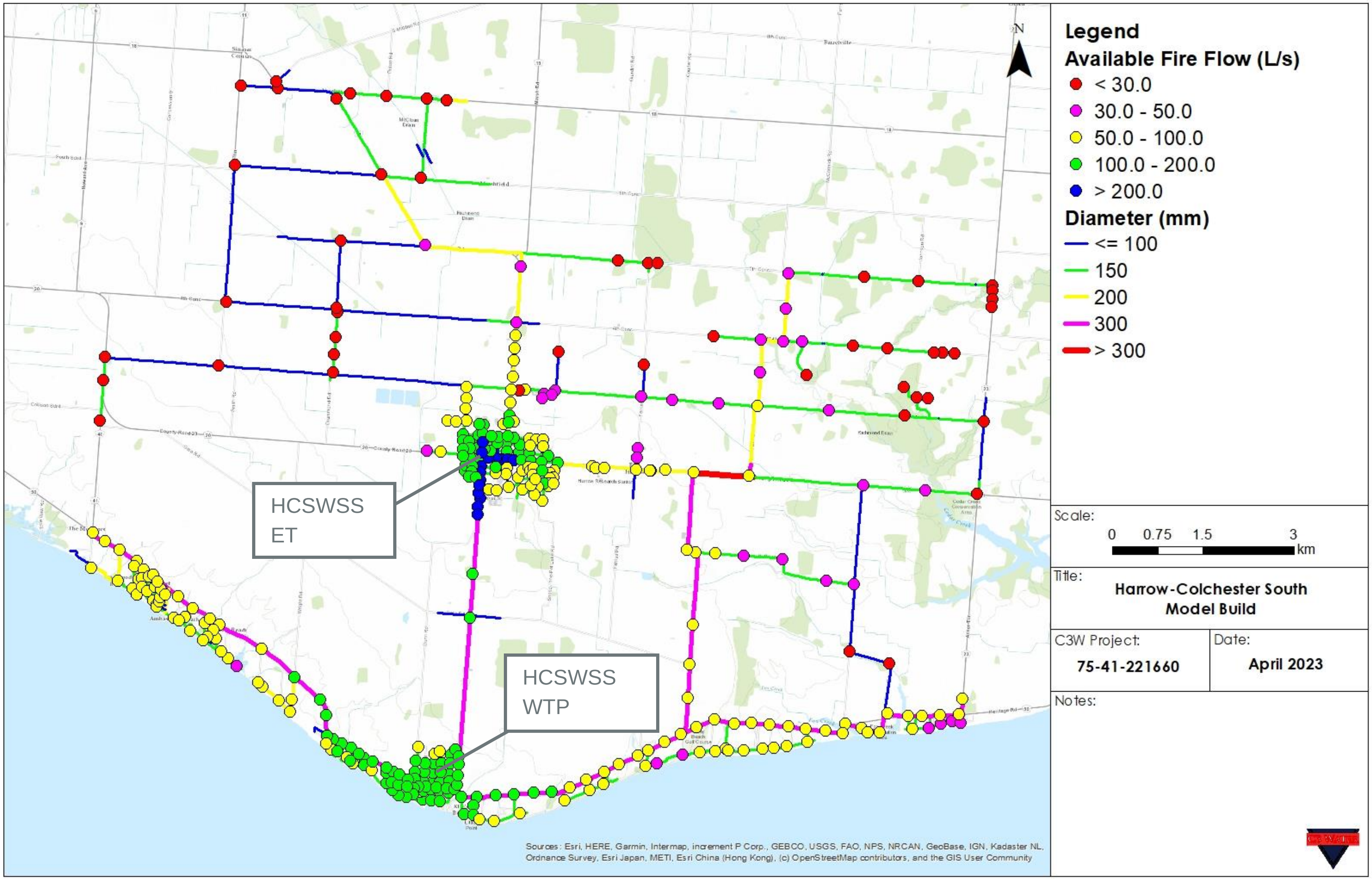

Figure 3-7: Fire Flow Results – MDD 2021

3.3 Future Scenarios Model Results

The Harrow-Colchester South WTF currently has a treatment firm capacity of 118.4 L/s based on the 2022 Annual Summary Report Harrow / Colchester South. Figure 3-8 shows the existing and future demand. The future MDD is 97.5 L/s, which is below the existing WTF firm capacity. However, the future PHD is 159 L/s. The existing WTF can supply the future MDD, however it is not capable of supplying the future 2041 PHD. As such, system storage would be relied upon to meet future PHD.

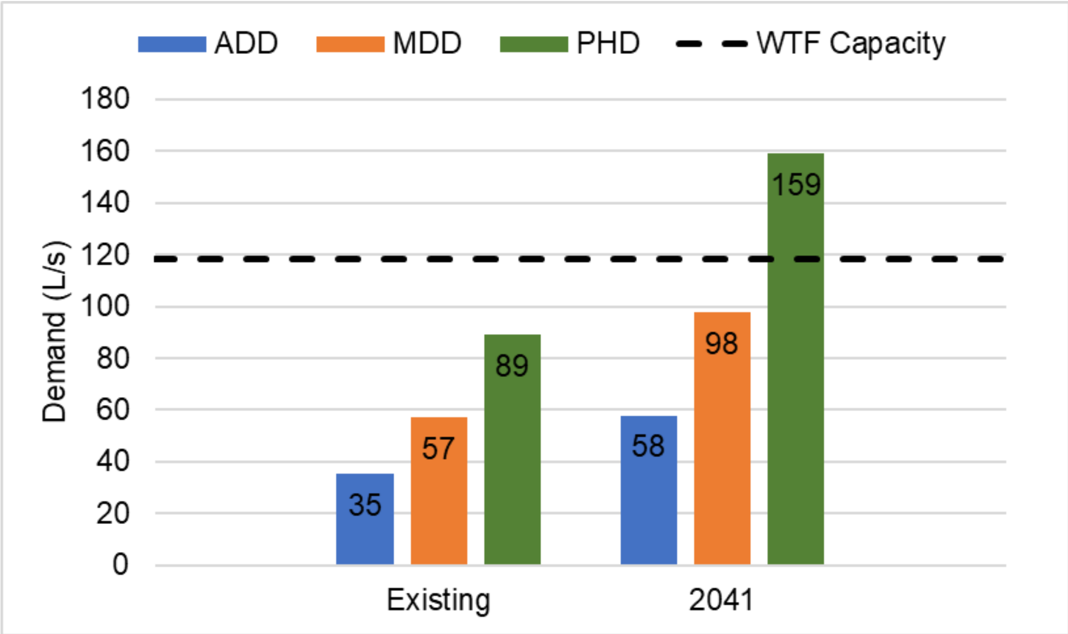

Figure 3-8: System Demand and WTF Capacity

Model results for future scenarios were analyzed over a 24-hour period utilizing existing infrastructure. Figure 3-9 and Figure 3-10 show the impact caused by growth on the existing system if no infrastructure upgrades were undertaken. The future MDD scenario resulted in an average MDD discharge flow of 96.2 L/s from the Harrow-Colchester South WTF pump station. The peak flow of 156.1 L/s was achieved by running existing HLP 2 & 3 together. It should be noted that the WTF and clearwell have been represented in the model as a fixed-head reservoir of infinite volume. Therefore, the ability for the WTF to maintain the clearwell level under future MDD conditions should be confirmed. The existing ET was found to drop to a minimum level of 4 m (45%) but re-filled once pump 3 turned on.

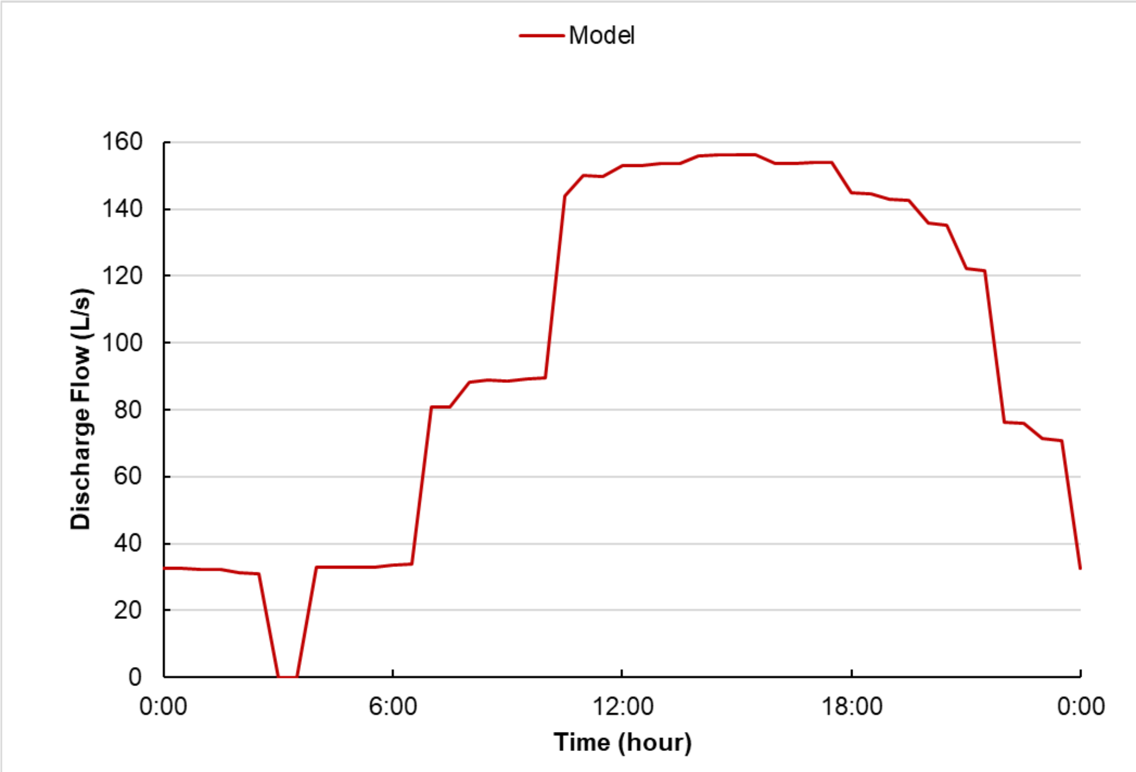

Figure 3-9: Harrow-Colchester South WTF Discharge Flow – MDD Future

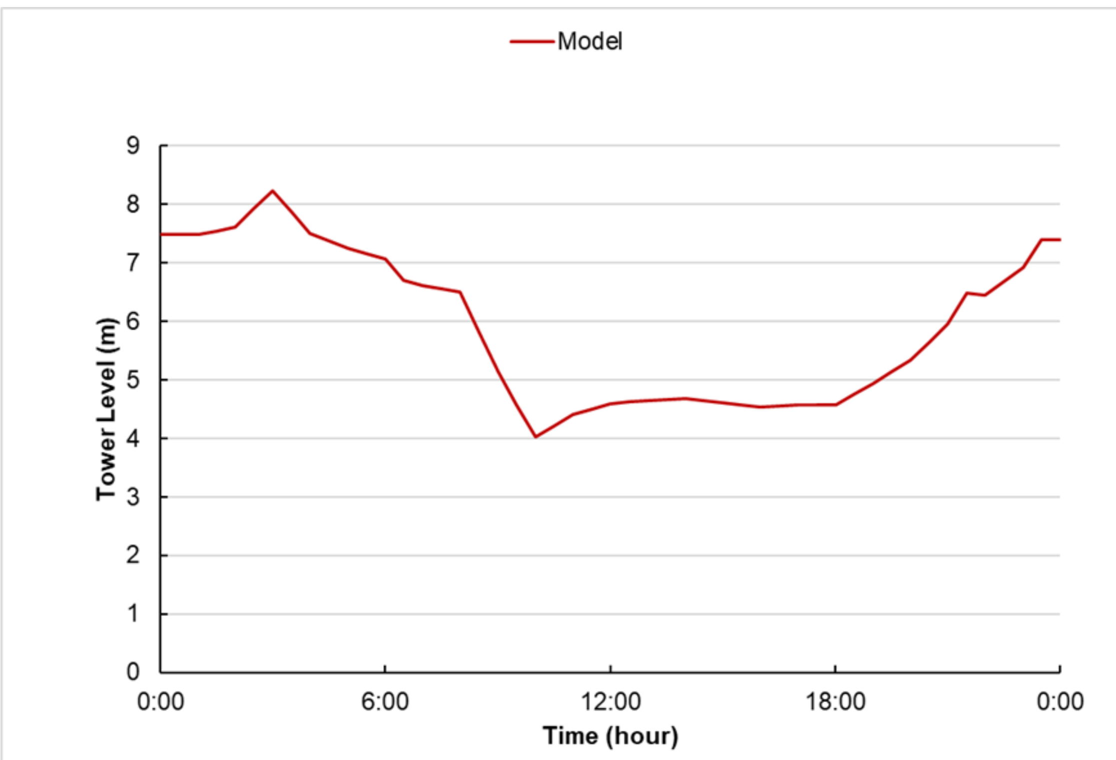

Figure 3-10: Harrow-Colchester ET Level – MDD Future

Figure 3-11 shows the future MDD minimum pressures in the system. The model showed a decrease in pressure throughout part of the system, compared to existing conditions, with a few areas falling below 50 psi, but no areas below 40 psi. The reduction in pressure is due to the ET dropping to approximately 4m to meet the peak hour demands.

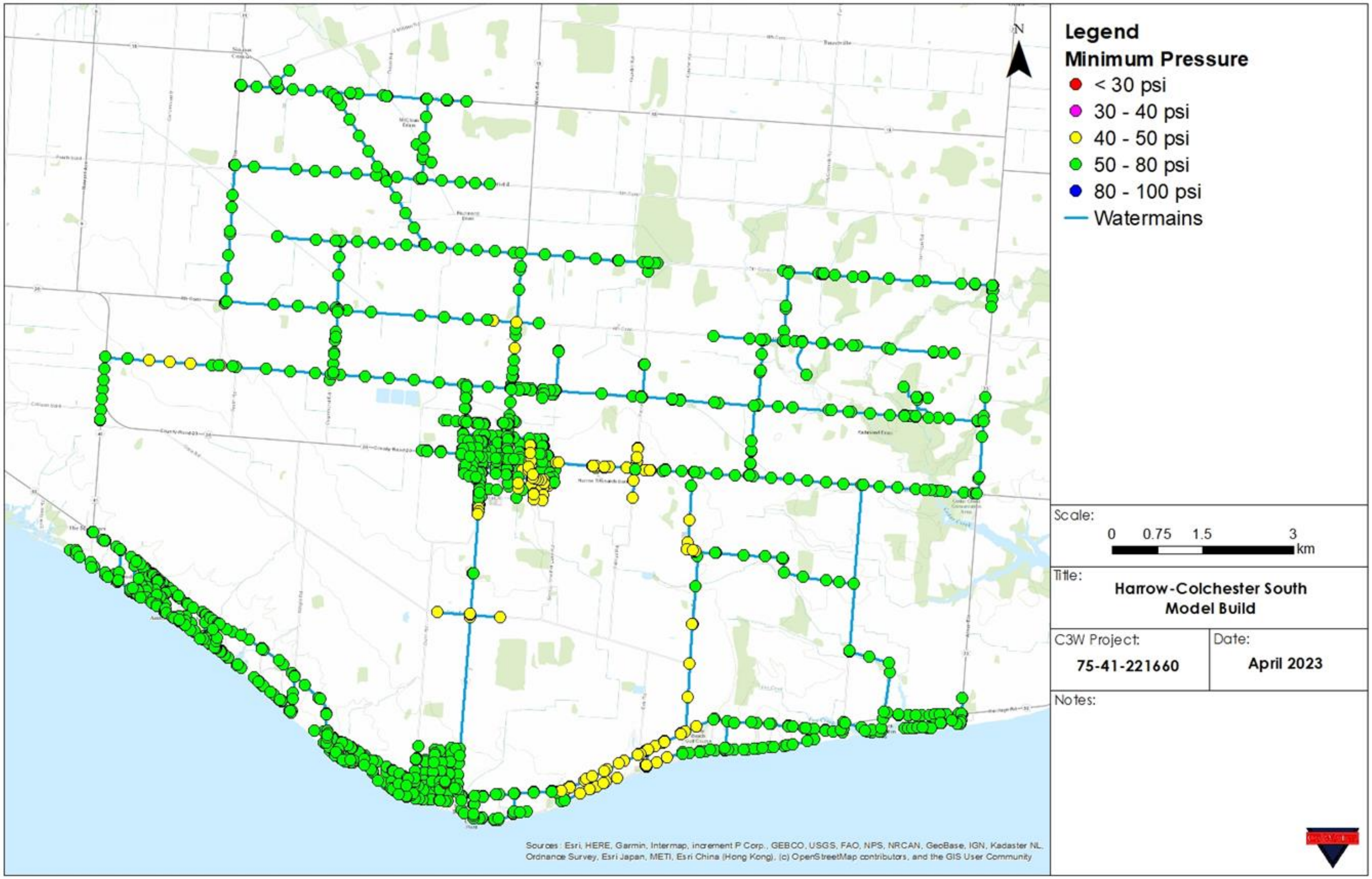

Figure 3-11: HCSWSS Minimum Pressure - MDD Future

4 Summary and Recommendations

The following recommendations will contribute to the continual improvement of the model:

- It is recommended that the Town complete some level of model calibration. This could include field testing for:
    - C-factors and fire flows, installation of hydrant dataloggers for additional pressure monitoring and potentially transients.
    - Pump testing should be conducted to understand existing pump performance.
- The existing system demands and per capita demand for future projections should be updated approximately every 2 years to keep the model up to date as development occurs and reflect water usage changes.
- Existing distribution system pipes should be updated every 2 years based on GIS records as changes to the distribution system are made. More frequent updates should be considered if a large infrastructure is added.
- It is suggested that the Town completes a water audit according to the IWA/AWWA methodology to better understand potential sources of NRW in the system.

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