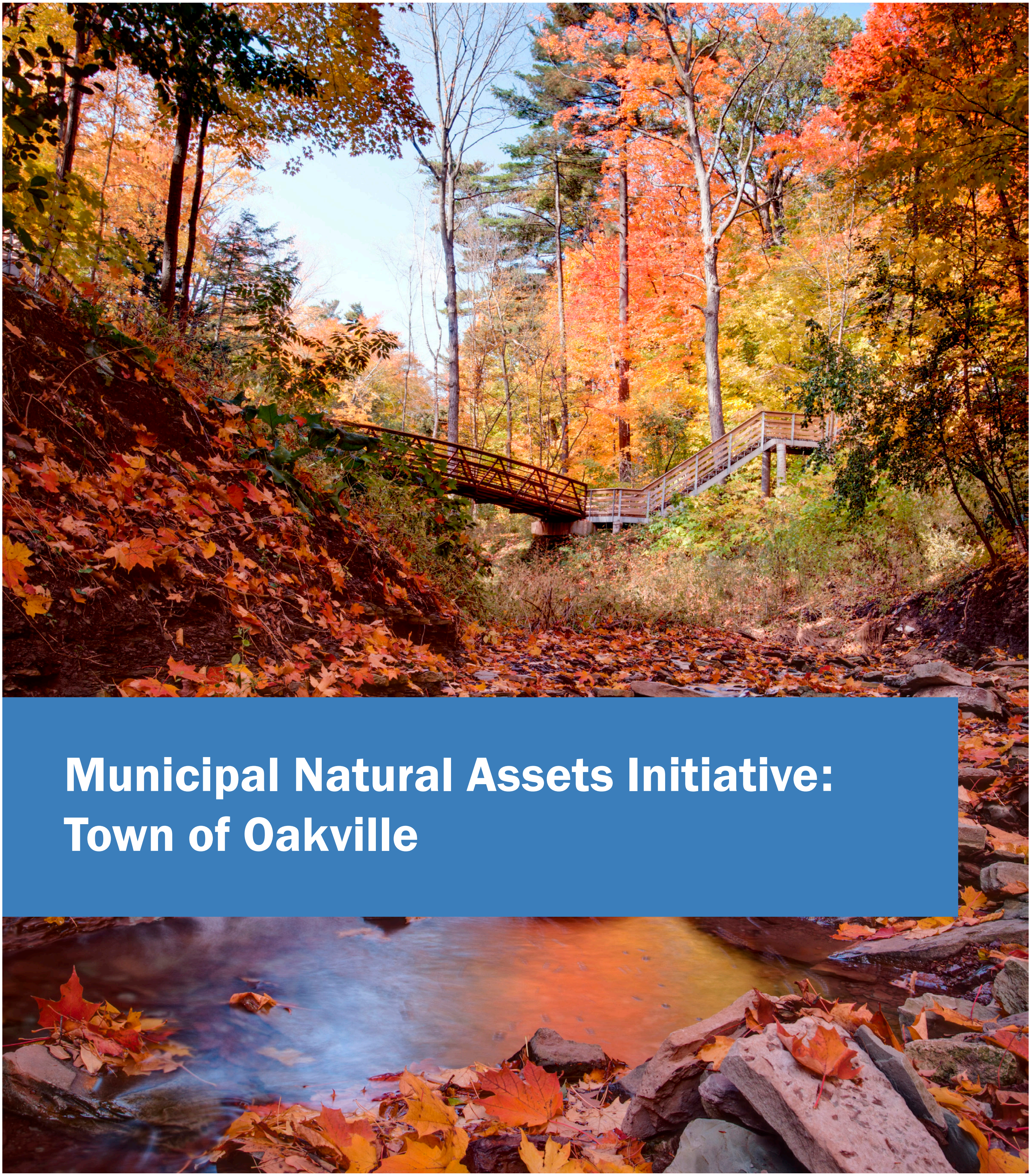

Municipal Natural Assets Initiative: Town of Oakville

Final Technical Report

Making Nature Count

The Municipal Natural Assets Initiative is changing the way municipalities deliver everyday services, increasing the quality and resilience of infrastructure at lower costs and reduced risk. The MNAI team provides scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial planning and asset management programs and developing leading-edge, sustainable and climate resilient infrastructure.

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Smart Prosperity Institute

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Town of Gibsons, BC

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ISBN 978-1-988424-20-0

Canadian Cataloguing in Publication Data for this report is available through Library and Archives Canada.

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Acronyms

EPA	Environmental Protection Agency
LID	Low Impact Development
MNAI	Municipal Natural Assets Initiative
PCSWMM	Personal Computer Storm Water Management Model
PSAB	Public Sector Accounting Board
RBG	Royal Botanical Gardens
ROW	Right of way
QEW	Queen Elizabeth Way

Executive summary

The term "municipal natural asset" refers to the stock of natural resources or ecosystems that is relied upon, managed or could be managed by a municipality, regional district, or other form of local government for the sustainable provision of one or more municipal services. Examples include wetlands, rivers, forests or foreshores. The Municipal Natural Assets Initiative (MNAI) is working to develop resources and help municipalities incorporate natural assets into asset management and financial decision-making processes.

The Town of Oakville is well-versed in asset management. It has had a complete inventory of its engineered assets since 2008 and an Asset Management Policy Statement is in place to guide decision-making. This commitment to asset management and the planned update of the stormwater management plan contributed to the Town's interest in the MNAI pilot project. Stormwater management in the older areas of the Town have been a challenge and concerns regarding the intensification of residential lots and the impact of that intensification on stormwater has resulted in a decision to better understand the existing and potential services of the various remnant channels in the Town.

As part of the MNAI pilot project, the Town of Oakville undertook a study to begin to assign financial value to its natural assets, using a remnant creek as the first example. A remnant creek is considered a non-regulated open watercourse that resides wholly, or in part, on private property. The remnant creek of interest in this project is the Maplehurst Remnant Channel, located in the older part of the Town of Oakville. The channel includes an open stream section, drainage ditches and both public and private ownership, making the results of the project more applicable to other parts of Oakville.

The specific objectives of the pilot project included:

1. Determining the value to the Town of the loss of municipal services created by the conversions of existing natural assets, and whether there are any corresponding financial risk and /or liability to Oakville
2. Determining what can be learned from the remnant channel in the pilot area that would help Oakville better prioritize and manage other streams/channels in the community
3. Determining whether the monetization of municipal services can create a basis for new municipal strategies to manage natural assets.

Using the US Environmental Protection Agency's (USEPA) Personal Computer Stormwater Management Model (PCSWMM) the existing inflow and outflow of the remnant channel under existing conditions was measured and compared to scenarios were the channel replaced with engineered infrastructure and also under intensified land use.

Using a replacement cost method for valuing the services (conveyance and attenuation) provided by the remnant channel under existing and intensified development scenarios demonstrated that it would cost the Town between $1.24 million and $1.44 million to replace a 240+ metre channel with engineered infrastructure. Expanding this methodology system-wide would almost certainly increase this figure. The infiltration and water quality services as well as the services provided under climate change scenarios are not included in these costs. As well, the long-term operation and maintenance costs of the remnant channel versus an engineered alternative are not included.

Overall, the project demonstrated that the natural asset provides equivalent stormwater services compared to engineered alternatives and supports further investigation into the other existing remnant channels in the town. Knowledge gained through the pilot will be transferred across departments and also to the public to convey the importance of municipal natural assets, the wide variety of services they can deliver and how they can be integrated into supportive policy and on-the-ground work.

Introduction

1.1 Municipal Natural Assets Initiative

The Municipal Natural Assets Initiative (MNAI) is developing resources to incorporate natural capital, i.e. natural or vegetated assets that form part of the urban landscape into asset management plans. As part of this effort, MNAI has developed the Overview Guidance Document for Stormwater Management[1] for Canadian municipalities. The present report details the application of the Guidance Document for one particular asset, a remnant stream in Oakville, Ontario. The goal is to illustrate the application of the guidance document and to provide technical details on the modelling approach.

Through the Municipal Natural Asset Initiative (MNAI), the Town of Oakville explored options to refine, replicate and scale-up the approach of a small number of municipalities that are integrating natural asset considerations into asset management and financial planning. A key objective is to explore whether and how natural assets in a pilot area of Oakville can provide the same services to the community as engineered assets, but with lower capital and operating costs and additional potential community benefits.

1.2 Town of Oakville

The town of Oakville is located in southern Ontario approximately halfway between Toronto and Hamilton, in the Halton Region on Lake Ontario. The 2016 Census reported a population of 193,832[2]. Oakville is part of the Greater Toronto Area, which is one of the most densely populated areas of Canada.

1.2.1 Policy/governance context

The Town of Oakville is well versed in asset management. In accordance with the Public Sector Account Board (PSAB) 3150 Initiative, the Town has maintained a complete inventory of the town's engineered assets since 2008 and has worked to integrate the asset replacement/repair plan into the Town's Corporate Information System and their annual Capital Budget 10 year Financial Plan.[3] Their work is guided by an Asset Management Policy Statement[4], which commits them to manage infrastructure assets in a strategic, comprehensive, enterprise-wide manner that recognizes assets as interrelated components in a unified system. The inclusion of natural assets builds upon this approach.

A number of factors contributed to the Town's decision to participate in the MNAI pilot, which included a committed asset management initiative and an ongoing update to the stormwater master plan. Stormwater management challenges in the lower portion of the municipality provided the context for the study. Given ongoing concerns regarding the impacts of (re)development on larger residential lots with urban/rural servicing, as well as the importance of the services provided by non-regulated remnant channels, it was decided to advance a more detailed investigation of the municipal services provided by remnant channels, both under existing and (re)developed land use.

1 MNAI, 2018.

2 Statistics Canada, 2017.

3 Town of Oakville, 2014

4 https://www.oakville.ca/townhall/a-bmg-004.html

1.3 Natural asset of interest

MNAI defines natural assets as ecosystem features that are nature-based and provide services that would otherwise require the costly equivalent of engineered infrastructure.[5] For local governments, natural assets can include forests, which intercept stormwater and recharge aquifers, wetlands, which capture surface runoff and reduce flooding risk, and coastal areas, which protect against storm surges and sea level rise, among others. By identifying natural assets at the community level and prioritizing those in municipal asset management portfolios, local governments can secure important savings while also delivering vital municipal services more efficiently and potentially adapting to climate change.[6]

For this study, the natural asset selected for stormwater analysis is a non-regulated remnant channel in an older part of the community. A remnant channel is considered a non-regulated open watercourse which resides either wholly, or in part, on private property, receiving drainage from upstream lands, including municipal right-of-ways and residential and employment lands. Due to the nature of these systems, there tends to be a mix of urban (storm sewers) and rural services (open ditches), conveying runoff through these areas.

1.4 Study area

The site of interest is the Maplehurst Remnant Channel site, situated centrally in the older part of Oakville. The area is generally bounded by Bridge Road to the north, Maplehurst Avenue to the west, Fourth Line to the east with the subject remnant channel essentially beginning just downstream of Bridge Road, flowing across Maplehurst Avenue towards Fourth Line, eventually discharging into the McCraney Creek system (see Figure 1).

The site was chosen as it has a remnant stream, drainage ditches and both public and private natural assets, which would make pilot results applicable to other parts of Oakville. Given the ongoing concerns which Town staff expressed regarding the impacts of (re)development on larger residential lots with urban / rural servicing primarily in the lower portion of the municipality, as well as the importance of non-regulated remnant channels, it has been decided to advance a more detailed investigation of the municipal services provided by remnant channels.

1.5 Services of interest

The remnant channel under current uses and form are considered to provide the following services:

1. Conveyance
2. Attenuation
3. Infiltration
4. Water Quality (informal)

Amec Foster Wheeler, the consultant retained to support the Town in this assessment, summarized the services provided by the remnant channel in comparison to gray infrastructure, with or without compensatory management, as follows:

5 MNAI 2017.

6 ibid.

Table 1: Summary of system services

Municipal Service / Function	System Type			
	Remnant Channel	Enclosure	Enclosure with Management	
Conveyance	✓	✓	✓	---
Attenuation	✓	✗	✓	Offsetting storage / super pipe
Water Quality	✓	✗*	✓	OGS / Bioswales
Infiltration	✓	✗*	✓	Bioswales / other LID BMPs

Note: *minor benefit if open

LID BMPs refers to Low Impact Development Best Management Practices

To define the quantum of service and potentially establish a metric for monetization of the municipal services provided, a comparative performance analysis of the current remnant channel versus an enclosure has been conducted with the intent of sizing an equivalent conveyance structure, as well as establishing the need and size for an off-setting attenuation system. System performance has been assessed under current and (re)developed land use (i.e. permissible maximum coverage plus amenity area coverage).

1.6 Pilot objectives

The main objective of this pilot project was to establish a financial value to natural assets for their stormwater services, in order to understand the relationship between the value of services from natural assets and new municipal strategies to manage stormwater in Oakville. The valuation is based on the cost of engineered stormwater infrastructure required to replace stormwater services - water quality and quantity control provided by equivalent natural assets. The specific objectives include:

- Determining the value to the Town of the loss of municipal services created by the conversion of existing natural assets, and whether there are any corresponding financial risk and/or liability to Oakville.
- Determining what can be learned from the remnant stream in the pilot area that would help Oakville better prioritize and manage other streams in the community.
- Determining whether the monetization of municipal services can create a basis for new municipal strategies to manage natural assets.

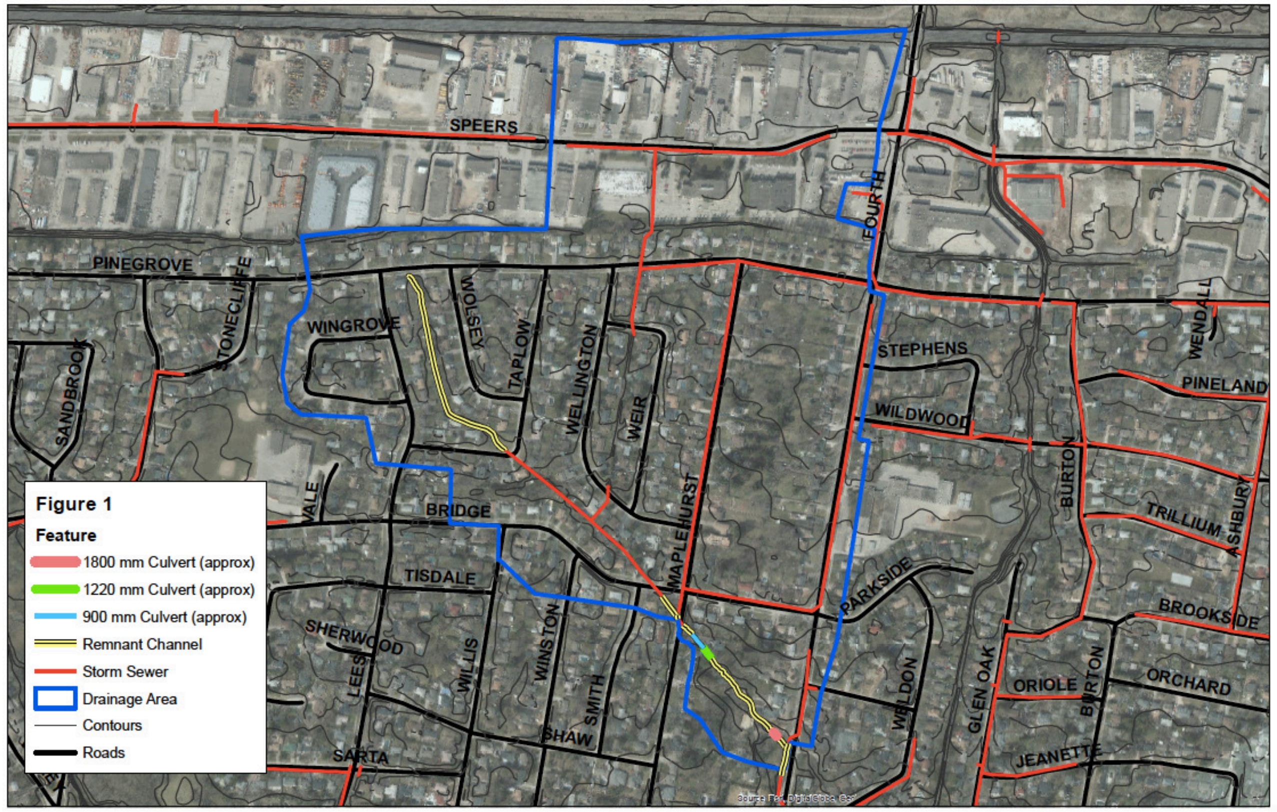

Figure 1: Study area

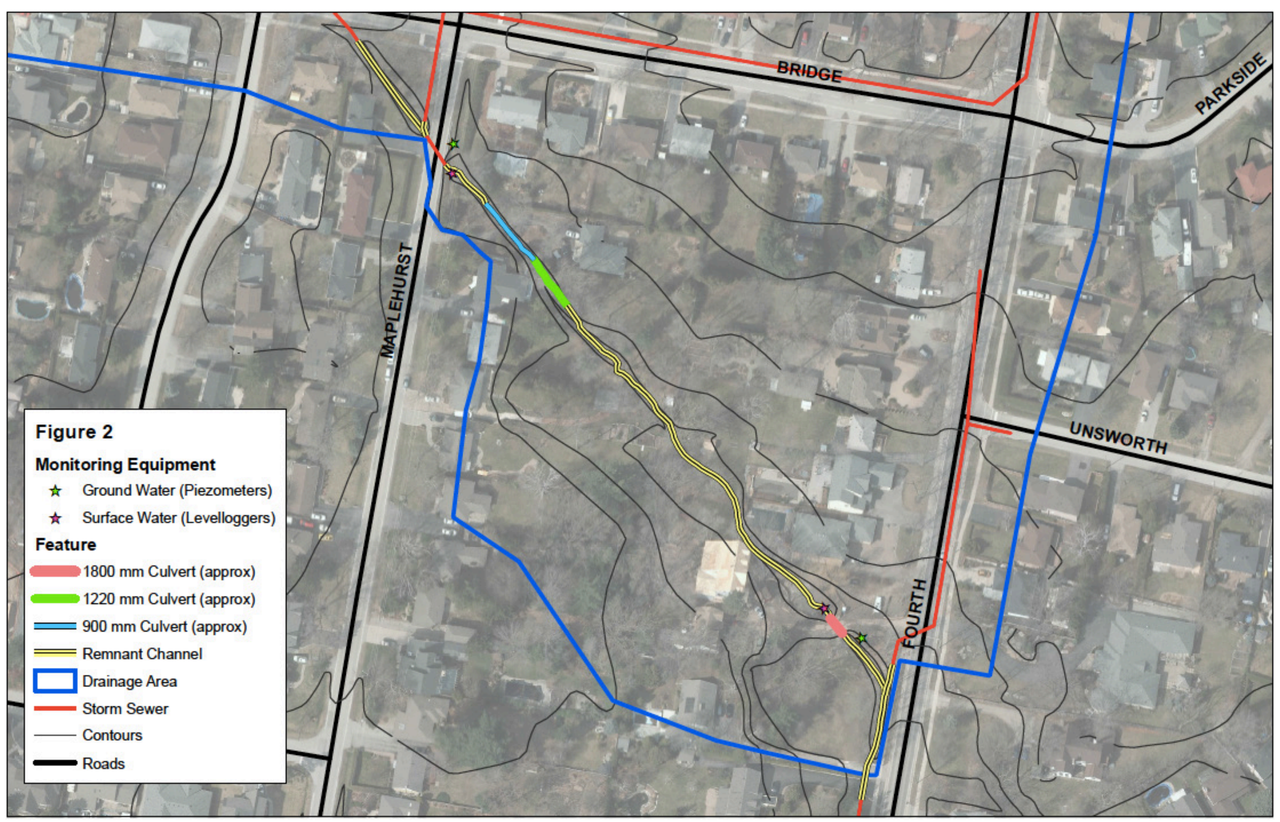

Figure 2: Monitoring equipment locations

2 Methods

2.1 Natural assets valuation methodology

For this study the following approach has been used to value all the natural assets under existing and land use (re)development conditions in the study area.

1. Gather monitoring and survey data for numerical model calibration (i.e. Integrated Hydrologic and Hydraulic model). Details of data collection are included in this section (Section 2).
2. Model natural asset (i.e. remnant channel) under existing land use conditions to determine inflow and outflow (conveyance and attenuation). Detailed modelling methodology is included in Section 4.
3. Determine size of 'grey' stormwater management infrastructure required to match inflow and outflow to the same level as provided by the natural asset. Detailed methodology for sizing stormwater management infrastructure can be found in Section 4.
4. Value the natural asset by estimating cost of constructing 'grey' stormwater management infrastructure required to replace services provided by natural assets. Details of the valuation methodology are included in Section 4.

The Town of Oakville enlisted Amec Foster Wheeler to complete the above steps. The outcomes from the modelling of the stormwater flow into and through the remnant channel were reported in a technical memorandum (January 2018). The following is a summary of the findings in that memorandum.

2.2 System characterization

The subject remnant channel is located in a low-density residential area of the town as shown in Figure 1 and Figure 2. It commences with two outfalls at the southwest corner of Maplehurst Avenue and Bridge Road where the channel is conveyed westerly through approximately a 4 metre span, 1.5 metre rise and 11.0 metre long concrete box culvert. The channel has a further four culvert crossings prior to outletting to McCraney Creek on the southeast corner of the intersection of Fourth Line and Weldon Avenue.

The main channel is comprised of exposed compacted soil and small stones, while the channel overbanks are commonly manicured lawns with low density trees and bushes. The channel is primarily on private property, hence the manicured condition of the overbank area.

The contributing drainage area (Figure 1) to the Maplehurst Avenue monitoring station is approximately 50 hectares. The drainage area to the Fourth Line monitoring station is approximately 52 hectares. The land use conditions for the contributing properties are represented by approximately 13 hectares of industrial/commercial to the north and approximately 39 hectares of low density residential to the south. The western portion of the residential area is not serviced with a piped storm sewer network, but rather roadside drainage ditches along the road right-of-way (ROW).

Topographic survey data were collected at thirteen cross sections of the remnant channel, as shown in Figure 3. One cross section for each of the two monitoring stations was also surveyed for this assessment.

Figure 3: Surveyed hydraulic section plan

2.3 Model selection

All modeling work presented in this report was completed using US Environmental Protection Agency's (EPA) Personal Computer Stormwater Management Model (PCSWMM). This model was chosen as it is being used in the development of the Stormwater Master Plan to assess the Town's drainage system south of the Queen Elizabeth Way (QEW).

PCSWMM is an integrated (hydrologic / hydraulic) modelling tool that simulates both the major and minor system to establish performance of the drainage systems. The local network, which contributes to the remnant channel for the MNAI pilot study was derived from the data provided by the Town as part of the Stormwater Master Plan and was enhanced with supplemental data through site reconnaissance and monitoring undertaken for this project and others.

2.4 Field monitoring and hydrologic model calibration

In order to better understand the performance and associated services provided by the subject remnant channel, a short duration data collection program was initiated. The field program was conducted over two periods as follows:

Fall 2016 - mid-October to early December

Spring 2017 - late March to early July

The objective of the field data collection program was to gather data to allow for the numerical model (integrated hydrologic/hydraulic PCSWMM) to be calibrated to actual data, thereby improving the use of the tool in a predictive context for performance assessment purposes. The data collected over the two monitoring periods included water levels, groundwater, precipitation, and velocity.

The following sections provide details associated with each component of the data collection program.

2.4.1 Water level monitoring

Water level data were obtained at two locations in the remnant channel as shown in Figure 4. The Maplehurst Avenue monitoring station was installed at the downstream side of the approximately 4 metre span 1.5 metre concrete culvert, while the Fourth Line monitoring station was installed on the upstream side of the approximately 1.8 metre CSP culvert. A HOBOTM level logger was installed at each location and water level data were collected from October 20, 2016 to December 6, 2016 and from March 29, 2017 to July 10, 2017. A summary of the water level data collected at each location is provided in Appendix A.

As evident from the observed data, the water level response in the remnant channel to the precipitation events was fairly quick. This is likely due to the directly connected storm outfalls at the west end of the channel and the mature urban land use in the study area.

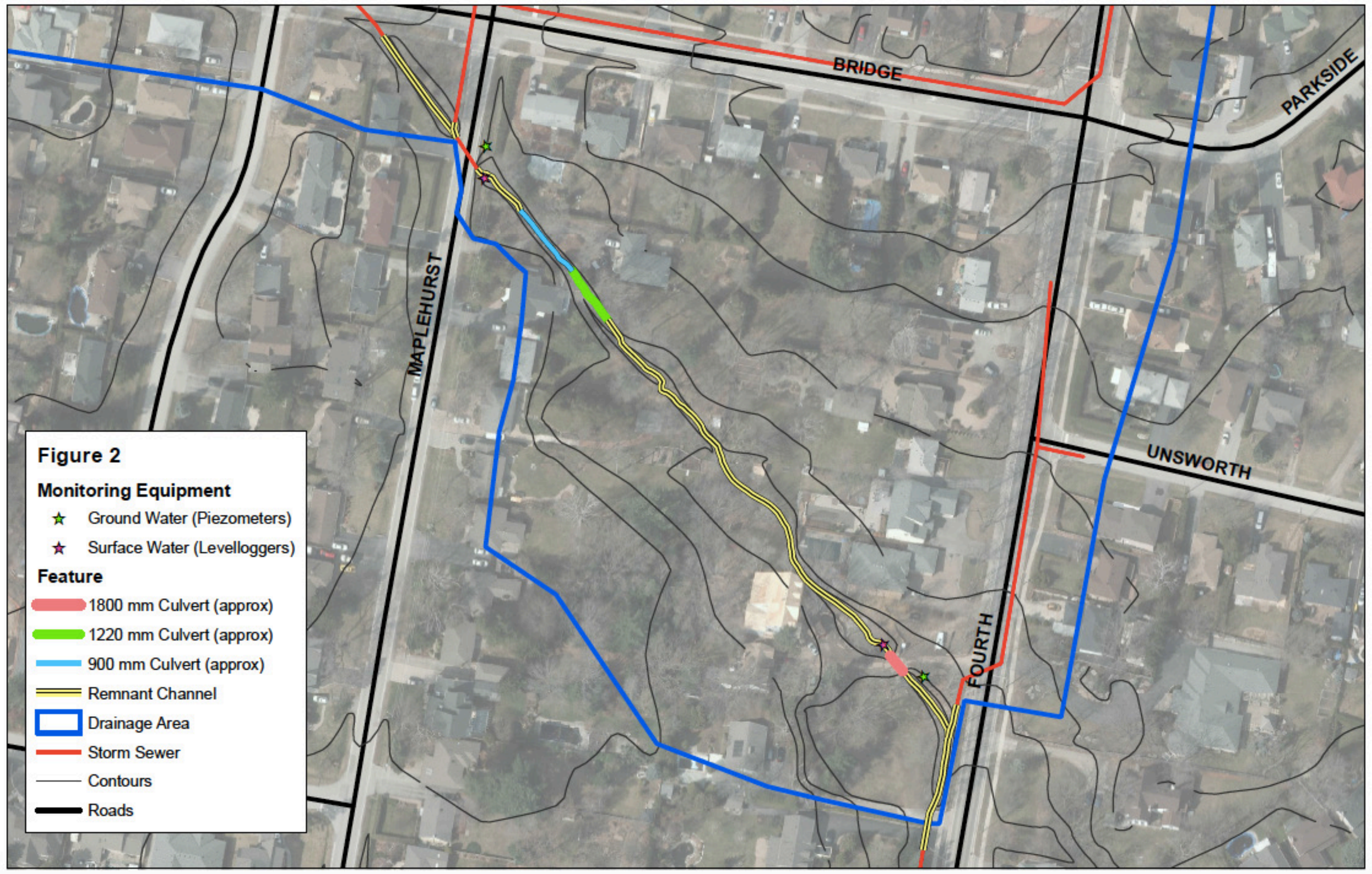

Figure 4: Monitoring locations plan

2.4.2 Groundwater monitoring

Groundwater monitoring was completed in conjunction with the channel water level monitoring with four drivepoint piezometer installations located in proximity to the surface water level monitoring stations. Each monitoring location had one 'shallow' and 'deep' piezometer to observe the impact of the remnant channel on the surface water groundwater interaction. The monitoring data (Appendix B) indicate that there is limited groundwater recharge at the Fourth Line location, unlike the Maplehurst Avenue location where there was evidence of recharge during events with high surface water levels. This would suggest there is relatively low permeability soils in the vicinity of the Fourth Line monitoring station whereas there are more permeable soils near the Maplehurst monitoring station. While this has been noted and recognized as a benefit, the Amec Foster Wheeler team did not ascertain an infiltration rate for the purposes of the project.

2.4.3 Precipitation data

The precipitation data provided by the Town were collected at 5 minute intervals at the Central Ops rain gauge station, located at 1140 South Service Road, which is approximately 1 kilometre northwest from the Maplehurst Avenue water level monitoring station. Due to the frequent rainfall events that occurred in the spring and early summer of 2017, several "good" events were recorded with rainfall volumes greater than or equal to 12 millimetres. The same frequency of "good" events was not observed during the fall of 2016. Furthermore, the 2016 events were not appropriate for model calibration/validation due to their low intensity and longer duration. A summary of the initially selected events for the hydrologic calibration/validation process are provided in Table 2 below.

Table 2: Selected rainfall events

Date	Volume (mm)	Duration (min)	Duration (hr)	Peak Intensity (mm/hr)
6-Apr-17	26	1500	25.0	4.8
20-Apr-17	31.6	825	13.7	6.4
30-Apr-17	50	2060	34.3	12
25-May-17	43.8	740	12.3	9.2
5-Jun-17	12	20	0.3	12
22-Jun-17	39.2	1500	25.0	16.2
30-Jun-17	15.2	180	3.0	14.6

2.4.4 Rating curve development

The rating curves for the streamflow data collection sites were developed for both monitoring locations based on the observed depth and velocity measurements obtained at the surveyed cross sections. A HEC-RAS model of the channel was also created to simulate the flow depths in the channel (theoretical) and 'fit' the observed water level data to a rating curve. In addition, Manning's and Orifice equations were generated locally to also calculate the flow-depth relationship through the approximately 900 millimetre culvert and the 1800 millimetre culvert for verification of the channel HEC-RAS model. The results, shown in Figure 3 and Figure 4, indicate a close fit of the observed data for the Maplehurst Avenue monitoring station rating curve and a reasonable fit of the observed data for the Fourth Line monitoring station rating curve. The rating curves were used to calculate the channel flows based on the recorded water level data for the calibration of the PCSWMM model.

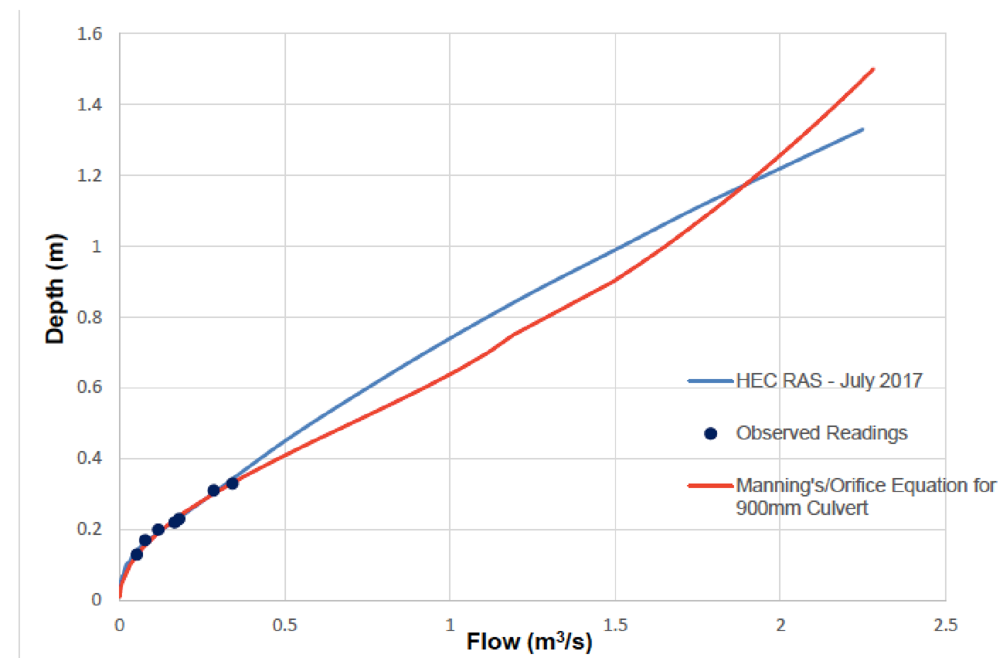

Figure 5: Maplehurst Avenue rating curve 2016-2017

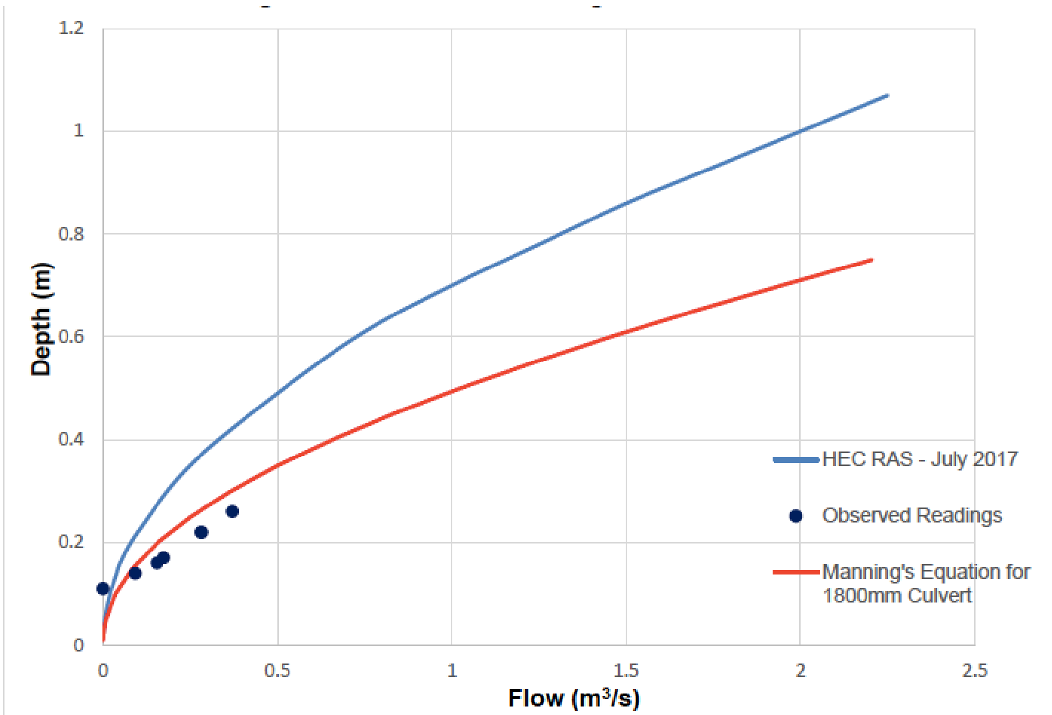

Figure 6: Fourth Line rating curve 2016-2017

3 Model calibration

Although a short-duration data collection program cannot be used for formal calibration, it can provide guidance for a form of model validation for the purpose of establishing a model's ability to predict runoff. As such, the calibration/validation of the PCSWMM model for the subject drainage network was completed on the basis of best fitting three properties of the selected simulated hydrographs in comparison to the observed data, specifically runoff volume, peak flows, and peak timing.

For this assessment, the base flow was subtracted from the observed data to assist in producing comparable simulated runoff volumes. Seven storms were initially selected for the calibration/validation process and are listed in Table 2. However, three of those storms were subsequently screened out due to data anomalies specific to simulated volumes. This was primarily due to the longer duration and low intensity nature of these storm events. The hydrographs of the remaining four storm events are shown in Figures 7, 8, 9, and 10. The Fourth Line data were not used in the calibration/validation process as the simulated results were, based on a quality check, considered to be inconsistent with the observed data, which suggests the rating curve for this location was potentially not as accurate as the rating curve for the Maplehurst Avenue location.

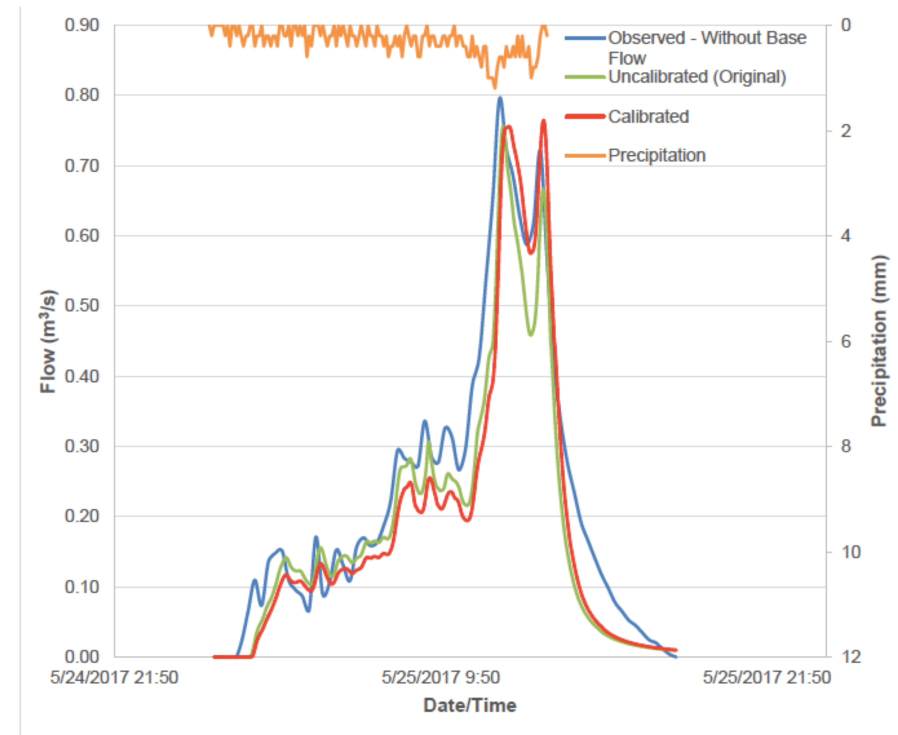

Figure 7: Maplehurst Avenue May 25, 2017

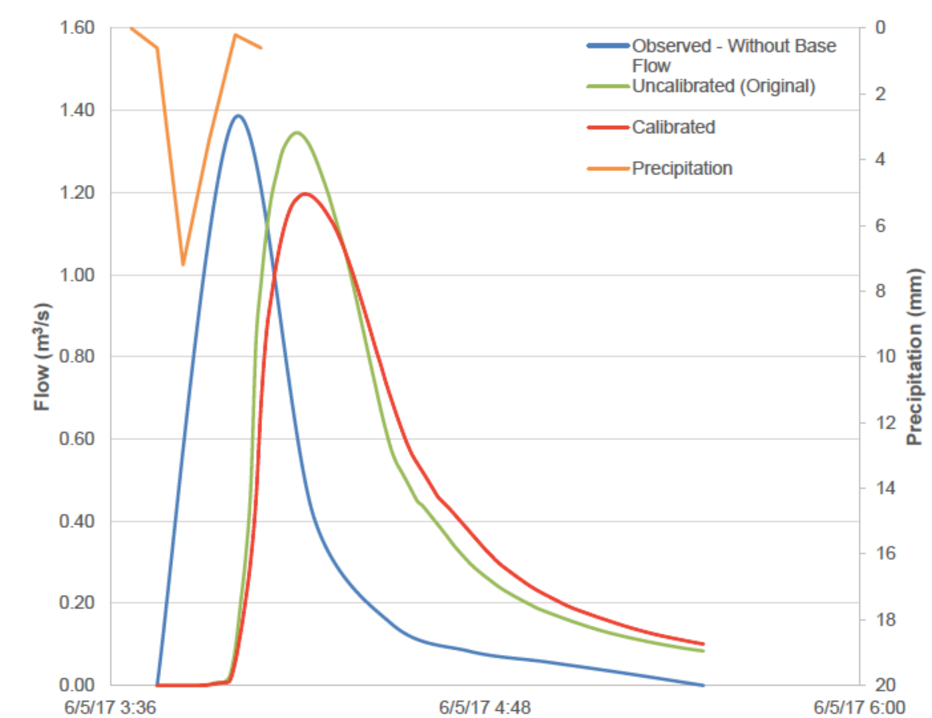

Figure 8: Maplehurst Avenue June 5, 2017

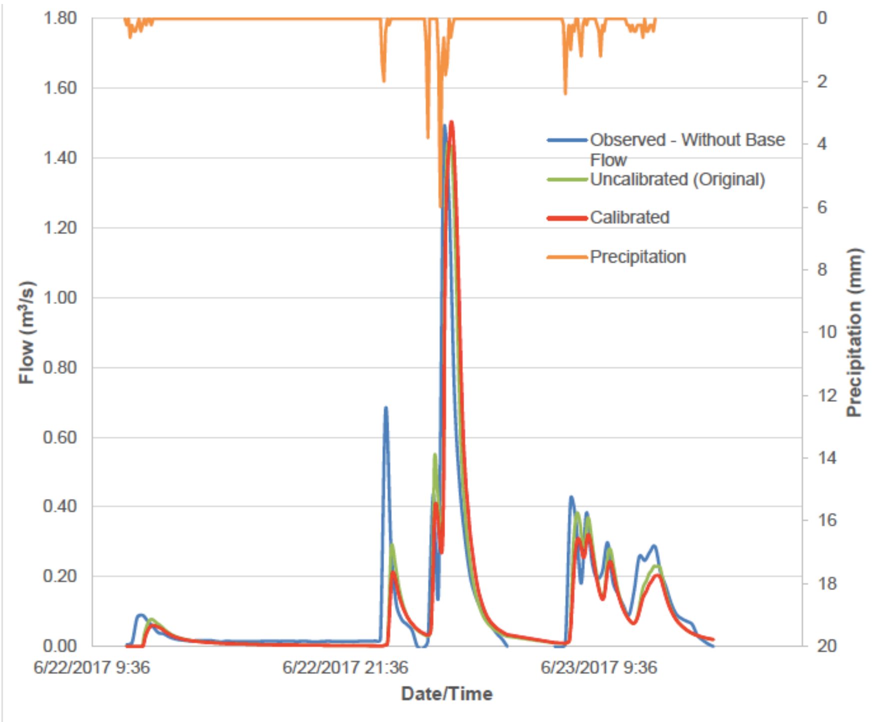

Figure 9: Maplehurst Avenue June 22, 2017

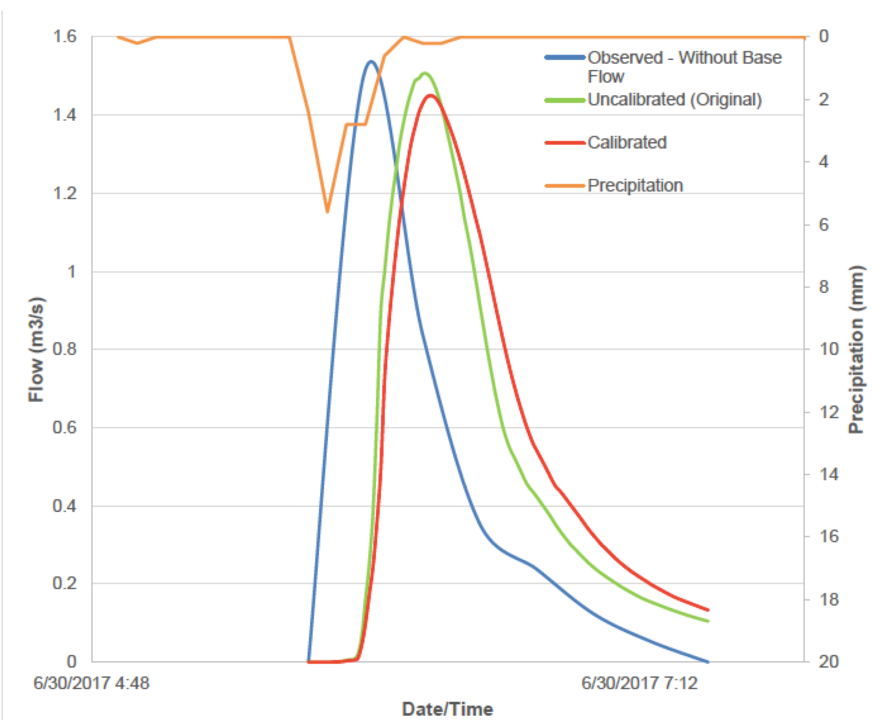

Figure 10: Maplehurst Avenue June 30, 2017

The initial (uncalibrated) soil parameters (based on Green and Ampt) for the PCSWMM model were obtained from those established for the broader based Town of Oakville Stormwater Master Plan PCSWMM model, which was regionally calibrated. The impervious values for the subcatchments were calculated from GIS mapping. For the MNAI study, the impervious measurements were taken directly from aerial imagery to confirm the impervious values previously assigned to the subcatchments. Given the close fit of the simulated volume and peak flow results for the selected rain events (ref. Scatter plots in Figures 11 and 12) it was considered that the PCSWMM model is adequately calibrated/validated for study purposes.

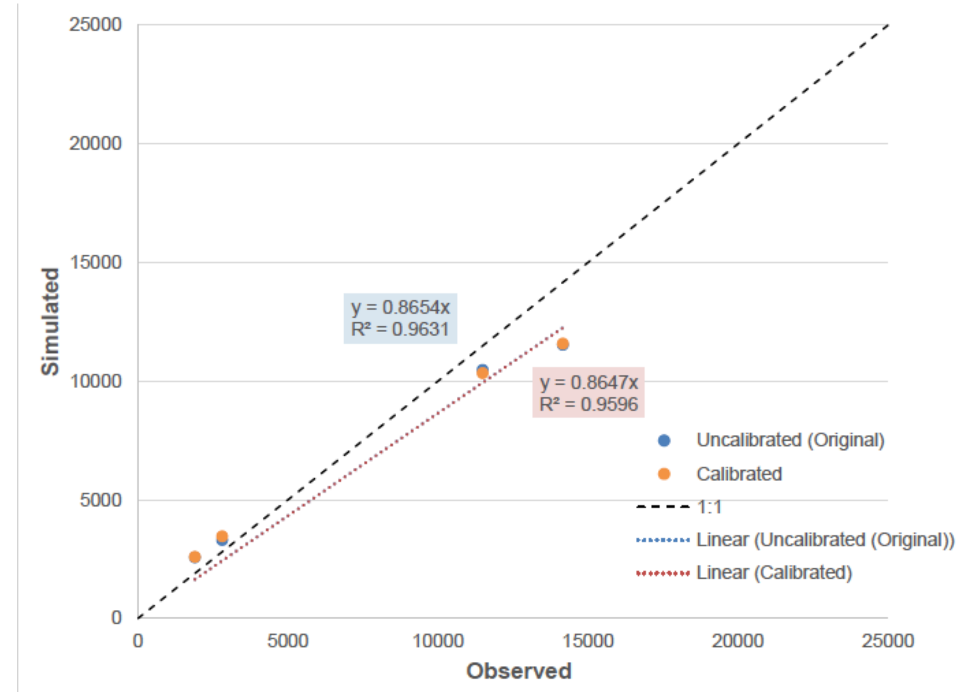

Figure 11: Calibration - volume (m3)

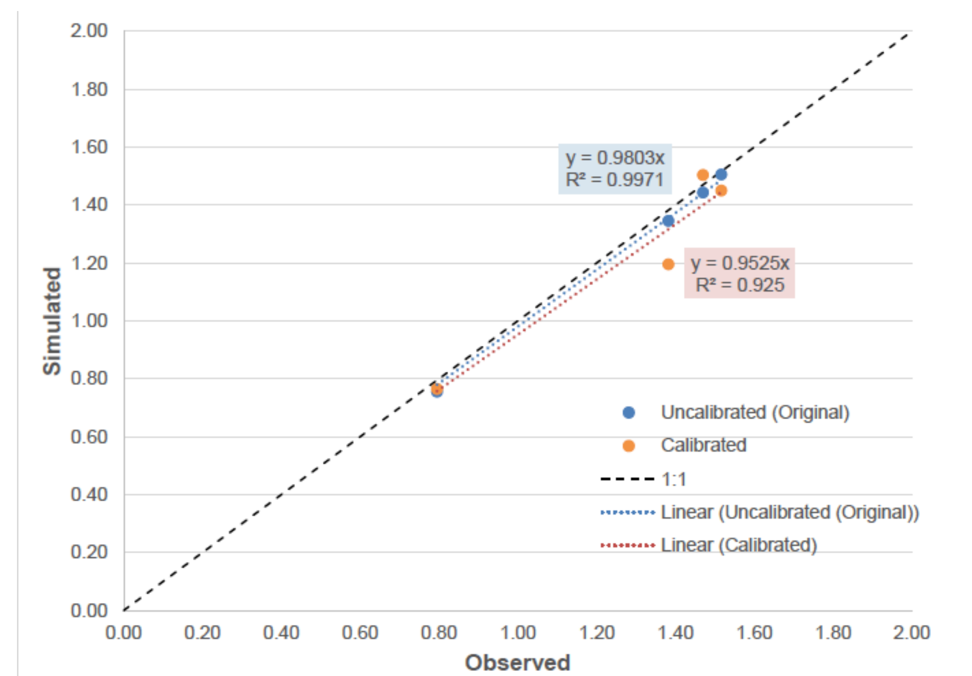

Figure 12: Calibration - peak flow (m3/s)

Table 3: PCSWMM parameters

PCSWMM Parameters	Uncalibrated	Calibrated
Depression Storage Impervious (mm)	1	1
Depression Storage Pervious (mm)	5	5
Zero Impervious (%)	25	25
Subarea Routing	Pervious	Pervious
Per cent Routed (%)	40	40
Suction Head (mm)	200	50
Conductivity (mm/hr)	7.5	3.5
Initial Deficit (ratio)	0.25	0.25

4 Results

4.1 Continuous simulation hydrologic frequency analysis

A continuous forty-two year hourly precipitation dataset was developed from the Royal Botanical Gardens (RBG) gauge (January 1962 – December 1995) and supplemented with the Pearson Airport gauge (January 1960 – December 2007) dataset. The data collected from the Pearson Airport gauge from January 2004 to December 2007 were not used as gaps occurred in the data during this period. It was considered that this combined data set was the most appropriate for the continuous simulation given the proximity of the both RBG gauge station and the Pearson Airport gauge station to the Town of Oakville.

The simulated annual peak flows for the continuous simulation were subsequently extracted from the long-term simulation and used to conduct a frequency analysis applying a Log Pearson Type III Distribution. A comparison of the frequency analysis flows to select design storms has been provided in Tables 4, 5, and 6.

Table 4: Maplehurst Avenue monitoring station frequency analysis

Return Period (year)	Per cent Chance Exceedance	Computed Flow (m^3/s)	*Confidence Limits – Flow (m^3/s)*	
			0.05 (Percentile)	0.95 (Percentile)
1.25	80	1.2	1.3	1
2	50	1.7	1.9	1.5
5	20	2.4	2.8	2.2
10	10	2.9	3.4	2.5
20	5	3.3	4.0	2.8
50	2	3.8	4.7	3.2
100	1	4.1	5.2	3.5

Table 5: Fourth Line monitoring station frequency analysis

Return Period (year)	Per cent Chance Exceedance	Computed Flow (m^3/s)	*Confidence Limits – Flow (m^3/s)*	
			0.05 (Percentile)	0.95 (Percentile)
1.25	80	1.2	1.4	1.1
2	50	1.8	2	1.6
5	20	2.5	2.9	2.3
10	10	3.0	3.5	2.6
20	5	3.4	4.1	3.0
50	2	3.9	4.9	3.4
100	1	4.3	5.4	3.6

Table 6: Comparison of frequency analysis to design storms

Return period (year)	*Maplehurst Avenue Peak Flows (m^3/s)*			*Fourth Line Peak Flows (m^3/s)*		
	Frequency Analysis	6 hr Chicago	24 hr Chicago	Frequency Analysis	6 hr Chicago	24 hr Chicago
2	1.7	3.1	3.4	1.8	3.1	3.5
5	2.4	4.4	4.8	2.5	4.6	5.0
10	2.9	5.2	5.6	3.0	5.5	5.9
25	3.3	6.1	6.5	3.4	6.4	6.8
50	3.8	6.5	6.8	3.9	6.9	7.2
100	4.1	6.8	7.1	4.3	7.3	9.1

4.2 Scenarios

In order to define the quantum of service and establish a metric for monetization of the municipal services provided, a comparative performance analysis of the current remnant channel versus an enclosure (i.e. grey infrastructure) has been conducted. The intent is to size an equivalent conveyance structure, and determine the need for and size of an attenuation system. System performance has been assessed under current and (re)developed land use (permissible maximum coverage plus amenity area coverage). The services of water quality and infiltration were not addressed in the study.

The (re)developed land use scenario is represented in the following tables as 'Maximum permissible coverage'. This refers to a (re)developed land use in the study area, which tends to result in a reduction in pervious surfaces. The percentage of pervious service loss through (re)development has been estimated through a town-wide review of trends and level of conversion (i.e. lot coverage) in other similar settings.

No climate change scenarios were included in the analysis as these were considered to be common to both the natural and gray versions of the infrastructure.

4.3 Conveyance

Table 7 provides peak flows for the 5, 25 and 100-year events at the downstream limits of the remnant channel under existing and maximum permissible coverage conditions.

Table 7: Peak flow comparison (m3/s)

Model Scenario	*Existing conditions imperviousness*			*Maximum permissible coverage imperviousness*		
	5 Year	25 Year	100 Year	5 Year	25 Year	100 Year
Existing Conditions	5.03	6.75	7.63	5.31	6.96	7.58
Existing Conditions – Private Culverts and Local Drainage Removed	4.48	5.45	5.78	4.66	5.52	6.04
Proposed Conditions – Pipe and Swale	4.89	6.35	6.51	5.26	6.38	6.71
Proposed Conditions – 1350 mm and 1500 mm Pipe and Swale				5.28	6.63	7.11

The flows reported at the downstream flow node have removed the influence of the private culverts (i.e. local attenuation) and local drainage area contributions to strictly determine the attenuation effects of the remnant channel configuration in reducing peak flows. For sizing and design purposes, the system has been considered to convey the 25 year flow vis-à-vis an enclosure, with flows in excess of the 25 year event assumed to be flowing overland (i.e. in an open system above the pipe enclosures). This latter assessment has resulted in a pipe size of 1350 mm diameter, some 252.9 m in length for Existing Conditions. Table 8 provides an estimate of the supply and construction costs associated with a system of this configuration, conservatively not including the cost of the overland flow swale (notionally considered to be largely represented by a restoration allowance).

Table 8: Cost of proposed pipes for conveyance (existing imperviousness)

Diameter (mm)	Length (m)	Unit Supply Price ($/m)	Supply Cost ($)	Supply + Construction Cost ($)
1350	20.3	847	17,235	51,704
1350	86.6	847	73,355	220,066
1350	57.8	847	48,981	146,943
1350	59.3	847	50,244	150,732
1350	28.9	847	24,512	73,537
Total ($)	252.9		**$214,327**	**$642,982**

In terms of land requirements for the conveyance function, it is considered that both the current configuration and an enclosed configuration are similar. Hence this has been discounted from the assessment.

For comparison, the enclosed system (grey infrastructure) has also been sized for (re)developed land use condition, which suggests an increase of approximately 13% (see Table 9).

Table 9: Cost of proposed pipes for conveyance [(re)development imperviousness]

Diameter (mm)	Length (m)	Unit supply price ($/m)	Supply cost ($)	Supply + construction cost ($)
1350	20.3	847	17,235	51,704
1350	86.6	847	73,355	220,066
1500	57.8	847	59,911	179,733
1500	59.3	847	61,456	187,367
1500	28.9	847	29,982	89,946
Total ($)	252.9		**$241,938**	**$725,815**

4.4 Attenuation

For the attenuation function, the storage volume necessary to maintain the peak flow with the pipe enclosure in-place (i.e. oversized sewer / enclosure with reduced outlet) has been calculated. A Super Pipe (i.e. oversized sewer/enclosure with reduced outlet) has been assessed for costing / functional purposes. However, due to the size of the watershed (>40 hectares) and limited overall grade along the remnant channel, the system could not be functionally designed, as it would surcharge and flood to surface, thus eliminating the potential for effective attenuation. Therefore an alternate approach has been established assuming an end-of-pipe facility, either surface based (which would be more land consumption) or subsurface (which would be more costly to implement) but consume less land.

Industry rates have been used to develop estimates for capital construction costs for the required storage to reflect the off-setting attenuation function with enclosure for three alternate systems [see Table 10 for existing land use and Table 11 for (re)developed land use].

Table 10: Existing imperviousness storage volume cost estimate

Storm event	Storage volume required for post-pre outflow (m^3)	Surface storage sost ($)	Subsurface storage cost – plastic ($)	Subsurface storage cost – concrete ($)
5	921	59,884	230,321	552,771
25	1,960	127,388	489,953	1,175,887
100	2,406	156,377	601,450	1,443,481
Unitary Construction Rates ($/$m^3$)		65	250	600

Table 11: (Re)developed imperviousness storage volume cost estimate

Storm event	Storage volume required for post-pre outflow (m^3)	Surface storage sost ($)	Subsurface storage cost – plastic ($)	Subsurface storage cost – concrete ($)
2	1,386	88,907	341,950	820,680
25	2,396	155,754	599,056	1,437,733
100	2,862	715,508	715,508	1,717,219
Unitary Construction Rates ($/$m^3$)		65	250	600

4.5 Water quality

In terms of water quality, well-vegetated open systems (e.g. swales) are generally considered to provide water quality benefits through filtration to remove contaminants when their length exceeds 50 metres and the velocity is less than 0.5 meters per second. For the subject remnant channel, while it meets the criteria for length, velocity is exceeded for relatively frequent storms (2 year and less) and furthermore its current condition tends not to reflect a well-vegetated system. As such, its true water quality benefits would be considered negligible (this is also a function of the comparatively large contributing drainage area > 40 hectares).

A methodology could be devised to estimate residual water quality benefits, by determining the storm event for which velocities remain below 0.5 metres per second and proportioning this to the water quality event of 25 millimetres. However given the large drainage area (> 40 ha) and lack of any existing dense vegetation, the application in this setting is not considered warranted. That said, systems of remnant channels with smaller drainage areas and more significant vegetation would be considered to provide water quality benefits.

For this project we chose a water course with relatively steady base flow suggesting it is more indicative of a stream rather than a swale. Rivers, streams, and channel tend to have a more dominant conveyance and attenuation function and lower water quality and infiltration attributes by natural design. While these systems can have quality and infiltration benefits they tend to exist within identifiable features such as bogs or marshes. The subject remnant channel does not contain these features. In essence, the remnant channels within an urban setting are part of the hierarchy of an overall natural conveyance system. Smaller supportive systems (swale and ditches) that feed into the rivers, streams and channels tend to offer greater water quality and infiltration benefits. It should be noted that with the urban fabric upstream of the subject remnant stream, you will find grass lined ditches and swales that offer these benefits and through an examination of the system as a whole, these benefits could be better defined and measured.

4.6 Infiltration

In terms of infiltration, data from the monitoring program tend not to provide a conclusive finding, for two reasons.

First, the large drainage area as well as the contribution of drainage along the watercourses length confound the interpretation of data at this scale. While recharge appeared to be occurring in the higher permeability soils towards Maplehurst Avenue over the monitoring period, establishing a meaningful quantum for a range of flow conditions given the high number of variables is not considered practical with the data collected as part of this study.

Second, as noted in section 4.5 above, the grassed lined ditches and swale in the upstream area tend to offer greater water quality and infiltration benefits.

4.7 Valuation of grey infrastructure equivalent

Based on the foregoing, it is apparent that the subject remnant channel of approximately 250 metres serves a well-defined conveyance function. In addition, it helps to attenuate peak flows downstream. The water quality function is less definable and while some benefits may accrue, it is unlikely that this service is meaningful for the current setting due to the large drainage area; as noted, a smaller system with less flow and more dense vegetation would be expected to perform more of a defined function for water quality. Similarly, the subject remnant channel, while providing some recharge (infiltration), particularly towards Maplehurst Avenue, with the data available the actual benefit (service) cannot be defined.

The monetized service provided by the grey infrastructure equivalent for the current open remnant channel was calculated using the 25-year conveyance pipe and the 100-year storage requirements. In terms of storage construction options, the less expensive, yet shorter life-span, option of plastic was used in the calculations that follow.

Table 12: Land use - existing replacement cost (using plastic tank pricing)

Service	Required Infrastructure Scenarios	Sizing	Infrastructure Dimensions (m)	Cost
Conveyance	25 year pipe	1350 mm	252.9 m	$642,982
Storage	5 year	921 m^3	20 x 20 x 2.5	$230,321
	25 year	1,960 m^3	20 x 40 x 2.5	$489,953
	100 year	2,406 m^3	20 x 48 x 2.5	$601,450
Total: Conveyance + 100 year storage				**$1,244,432**

Table 13: Land use - intensified replacement cost

Service	Required Infrastructure Scenarios	Sizing	Infrastructure Dimensions (m)	Cost
Conveyance	25 year pipe	1350/1500 mm	252.9 m	$725,815
Storage	5 year	1,368 m^3	20 x 30 x 2.5	$341,950
	25 year	2,396 m^3	20 x 48 x 2.5	$599,056
	100 year	2,862 m^3	20 x 60 x 2.5	$715,508
Total: Conveyance + 100 year storage				**$1,441,323**

As such, the subject remnant channel for this pilot study, when considering only the conveyance and attenuative function, would require grey infrastructure (pipes and tanks) costing $1.24 million for existing conditions and $1.44 million for intensified land use conditions (excluding land requirements for the storage system).

4.8 Beneficiary considerations

MNAI worked with the Town of Oakville to identify relevant indicators to capture the population segments affected by changes to natural assets in the study area. Understanding the range of beneficiaries can help decision makers consider where a change in provision of a service may have a large impact on vulnerable populations or other social groups of special concern. The appropriate indicators should identify changes in ecological condition that are displayed in units relevant to the beneficiaries.

Table 14 identifies the broad-based beneficiary considerations developed over the course of the pilot study. Further work is underway to identify appropriate assessment methods.

Table 14: Beneficiary considerations

Service	E.g. beneficiaries	Driver of demand
Flood mitigation	Residents, businesses and other land owners in flood prone areas	Presence and vulnerability of land owners in flood prone areas
Water quality improvement	Water treatment facilities (Great Lakes intakes – Intake Protection Zones under Source Water Protection Plans) (avoided sedimentation)	Sensitivity of water treatment facilities to increases in sediment loads or water quality impairment
Improvement of stream health	Taxpayers, recreationists, stakeholders valuing clean water	Stormwater regulations, current biological state of stream waters
Increase in groundwater recharge	Within town or downstream groundwater users	Whether the area is prone to water scarcity
Flow control / management	Residents, businesses and other land owners in flood prone or uncontrolled flow areas	Whether area is potentially an overland flow route
Erosion control	Residents, businesses and other land owners in flood prone or uncontrolled flow areas	Presence of land owners in areas prone to uncontrolled flows potentially impacting their lands
Ecological function	Taxpayers, recreationists, stakeholders valuing clean water	Stormwater regulations, current biological state of stream waters

5 Assumptions and limitations

Limitations to the work presented in this report may impact the certainty of results. It should be noted, however, that this was a pilot study to test the approach. More detailed data at the site and sub-watershed scale can be used to better inform the modelling analysis and subsequently the decision making process.

Model calibration:

Model results can be improved by calibrating with a longer time series including larger storms. A short-duration data collection program was used for calibration, recognizing that it can provide guidance for a form of model validation for establishing a model's ability to predict runoff.

Fourth Line data were not used in the calibration/validation process as the simulated results were, based on a quality check, considered to be inconsistent with the observed data. This suggests that the rating curve for this location was potentially not as accurate as the rating curve for the Maplehurst Avenue location.

Infiltration data:

In terms of infiltration, data from the monitoring program tend not to provide a conclusive finding. Firstly, the large drainage area, as well as the contribution of drainage along the watercourses length confounded the interpretation of data at this scale. While recharge appeared to be occurring in the higher permeability soils towards Maplehurst Avenue over the monitoring period, establishing a meaningful quantum for a range of flow conditions is not considered practical with the data collected as part of this study.

Climate projections:

Lastly, this analysis included no climate change component. The 5-year, 25-year and 100-year storm events were based on historical past events. There is a potential for actual storm frequency events to have a greater magnitude, leading to more extreme impacts in the study area.

6 Conclusions

This analysis applied a replacement cost approach to determine an economic value for the stormwater management services provided by a remnant channel in the Maplehurst Remnant Channel site, situated centrally in the older part of Oakville. The study found the value of municipal services provided by the remnant channel is increasing as the region experiences (re)development.

Project results indicate that the remnant channel of approximately 250 metres serves a well-defined conveyance function. It also attenuates peak flows downstream. The water quality function is less definable and while some benefits may accrue, it is unlikely that this service is meaningful for the current setting due to the large drainage area. Similarly, the subject remnant channel, while providing some recharge (infiltration), particularly towards Maplehurst Avenue, the actual benefit (service) cannot be defined using the available data.

An asset value was assigned to the remnant channel based on its conveyance and attenuation function. The costs associated with equivalent grey infrastructure conveyance dictated pipe sizes of 1350 millimetres diameter and 1500 millimetres diameter, some 252.9 metre in length using a unit cost of $847/metre. This valuation method was used to determine an estimated value of about $725,000 under intensified land use conditions. The costs associated with the attenuation function considered the storage volume necessary to maintain the peak flow with the pipe enclosure in-place for the 100-year storm event. The industry rates were used to develop estimates for an end-of-pipe facility, which resulted in an estimated value of roughly $715,000 under (re)development conditions.

As such, the subject remnant channel for this pilot study, when considering only the conveyance and attenuative function, would require grey infrastructure (pipes and tanks) costing $1.24 million for existing conditions and $1.44 million for (re) development conditions. Expanding the methodology system-wide would almost certainly increase this figure.

It is noteworthy that the Town of Oakville is currently assessing a policy framework for remnant channels. As part of this work it has been recommended by MNAI that more detailed site specific investigations be conducted of remnant channels. As such, this remnant channel could be monitored as part of the Town's Natural Assets Pilot Study to complement the understanding of the functions provided. This would help the Town acquire more knowledge and data regarding the importance of these systems.

6.1 Next steps

The Environmental Policy Department and Development Engineering Department submitted a report to the Community Services Committee in June 2018 to provide an overview of the pilot and recommended next steps.[7] The following is a summary from that report. The portion of the report addressing next steps is provided in Appendix C.

Participation in the MNAI pilot represented an important step in moving not just the town, but municipal practice forward in addressing the value of natural assets and green infrastructure. This is increasingly important in light of a rapidly changing environment due to variables such as climate change and redevelopment. To continue moving forward to incorporate the results into the town's work a number of cross-departmental next steps are recommended. These include:

- Phase 2 of the Stormwater Management Master Plan will be informed by pilot outcomes with rationalized natural asset values. These natural assets, especially on a system-wide basis, provide important conveyance, storage, water quality improvement, cooling, biodiversity and other services at lower costs than grey infrastructure along with many other benefits.
- Policy outcomes will be leveraged to develop stormwater management policy. A policy framework integrating municipal natural assets will ensure the value of municipal services provided by natural assets is recognized, protected wherever possible and even potentially restored to achieve the benefits of green infrastructure over grey.
- Collaboration with other municipal and conservation authority networks are being established to explore opportunities for framing policies and approaches to better support municipal natural asset initiatives including community partnerships, outreach and education, Low Impact Development and stormwater source controls.
- Policy development will recognize municipal natural asset services and benefits and how these services can be better supported through monitoring and maintenance and perhaps protection and enhancement to ensure these services are not compromised, degraded or lost. In cases where the municipal natural asset service can be quantified, replacement of like for like can be appropriately entertained.
- Work is underway to include municipal natural assets not currently in the asset management system as green infrastructure. These assets deliver service and value to the town and require monitoring and maintenance to support effective operation and service.
- Knowledge gained through the pilot will be transferred across departments and also to the public to convey the importance of municipal natural assets, the wide variety of services they can deliver and how they can be integrated into supportive policy and on-the-ground work.

7 Town of Oakville, 2018.

Appendix A: Water level monitoring

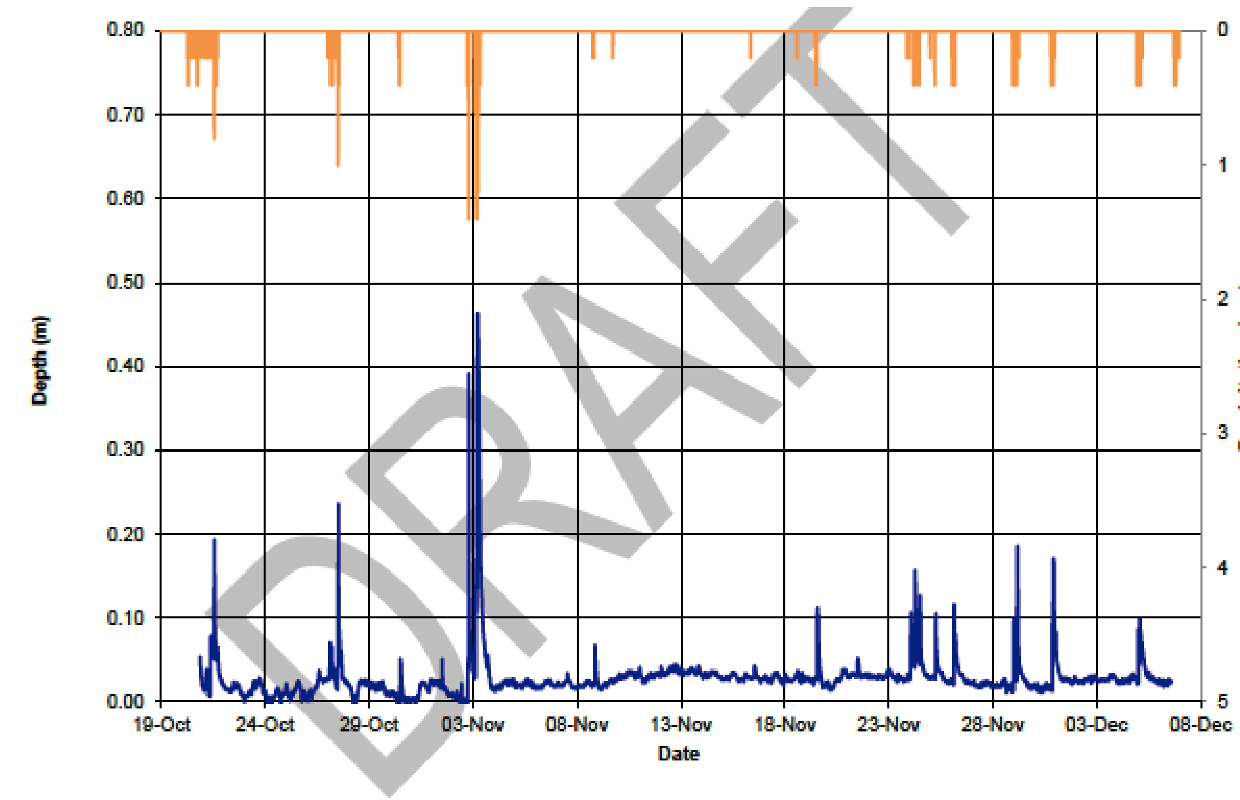

Figure 13: Maplehurst recorded water level 2016

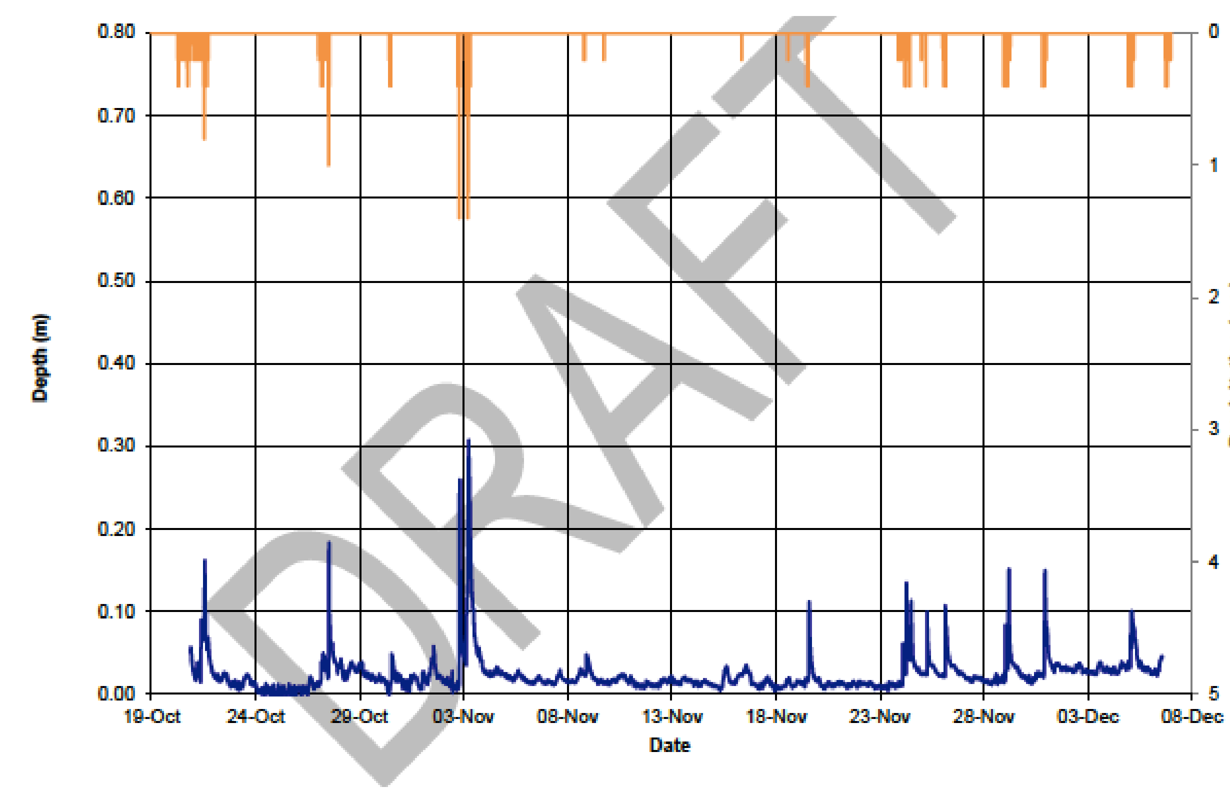

Figure 14: Fourth Line recorded water level 2016

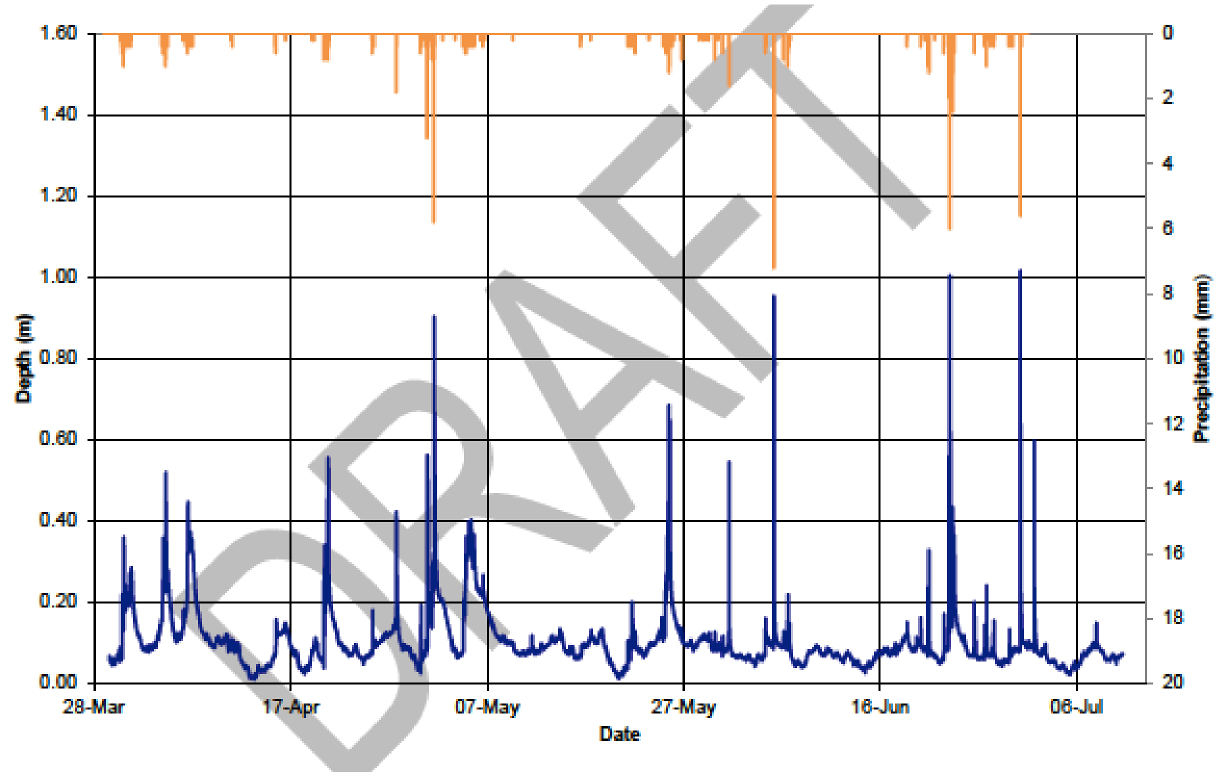

Figure 15: Maplehurst recorded water level 2017

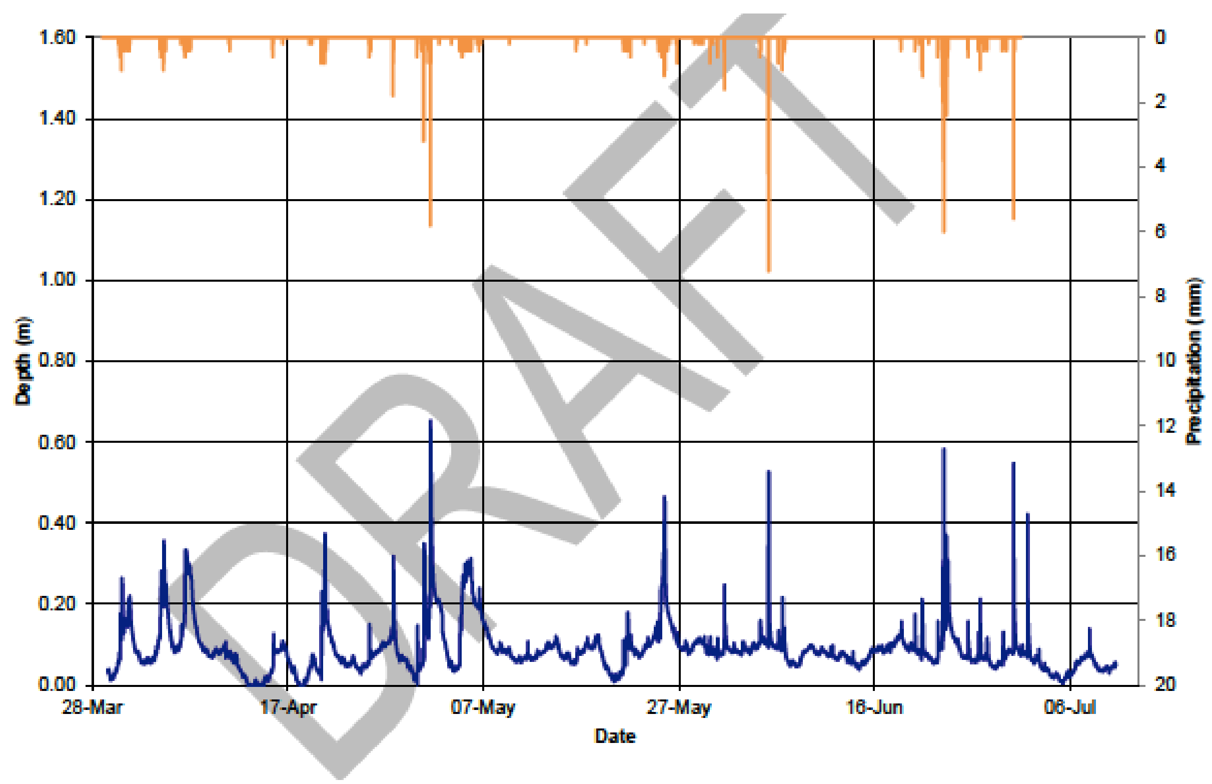

Figure 16: Fourth Line recorded water level

Appendix B: Groundwater monitoring

Field conditions and installation

Two monitoring installations were installed adjacent to the creek bed each comprising a 'shallow' and 'deep' piezometer. The installations were downstream of the surface water monitoring gaugevat 432 Fourth Line (downstream) and adjacent to the one at Bridge and Maplehurst (upstream). Access conditions did not permit the use of a drill rig and therefore drive-point piezometers were installed with 12'' screen lengths that were driven in to the ground manually with a post hammer.

The locations of the piezometer sites are shown on Figure 1. At 432 Fourth Line the piezometers are slightly above the bed on the bank of the creek (Figure 2), whereas the piezometers at Bridge and Maplehurst were installed at an elevation closer to the creek bed (Figure 3).

Prior to installation, augering was undertaken to determine the nature of the subsoil, which in both cases comprised weathered shale. The observations accord with OGS mapping, which shows the Queenston Shale at surface within the study area (Figure 1). The details of the subsoil and piezometer installation are given in Table 1 below. At 432 Fourth Line, the piezometers were both dry on installation, whereas a shallow groundwater level was measured at Bridge and Maplehurst.

Continuous groundwater level monitoring in the piezometers commenced on the November 4, 2016 with installation of pressure transducers with a measurement interval of ten minutes. Data collection ceased on July 21, 2017.

Table 15: Details of piezometer installations

Site	Geology	Drive-point
432 Fourth Line	Hand augered to 0.3 mbgs refusal. Hole dug confirming 15 cm of topsoil over reddish-brown clayey silt with shale fragments (weathered Queenston Shale)	DP-1 Shallow – 0.78 mbgs – refusal Stickup ≈ 1.1 mags
		DP-1 Deep – 0.93 mbgs – refusal Stickup ≈ 0.9 mags
Bridge and Maplehurst	Hand augered to 0.5 mbgs refusal. Wet at 0.4 mbgs. 30 cm of topsoil over reddish brown shale fragments (weathered Queenston Shale)	DP-2 Shallow – 1.0 mbgs – target depth Stickup ≈ 0.8 mags
		DP-2 Deep – 1.6 mbgs – refusal Stickup ≈ 1.1 mags

Groundwater conditions

The results of groundwater monitoring at 432 Fourth Line and Bridge and Maplehurst are shown on Figure 4 and Figure 5 respectively, together with the water level measurements from the nearby surface water gauges. The groundwater conditions at 432 Fourth Line and Bridge and Maplehurst are distinct and these are discussed separately below.

432 Fourth Line

The groundwater levels at both piezometers at 432 Fourth Line have limited groundwater recharge. At DP-1 Deep it takes four months for the groundwater level to establish a normal dynamic equilibrium condition. Very limited response can be seen to water level variations in the creek at DP-1 Deep. These two observations indicate relatively low permeability of the monitored interval possibly associated with a limited weathered thickness of shale.

At DP-2 Shallow the pressure transducer was above the groundwater level initially. This was adjusted at the beginning of March, 2017. There is some limited groundwater level variation in DP-2 Shallow in response to the surface water level variation. The groundwater levels of DP-1 and DP-2 are below the water level of the creek, however, the surface water gauge is further upstream. Overall the site appears to have insignificant groundwater-surface water interaction.

Bridge and Maplehurst

Both piezometers at Bridge and Maplehurst respond readily to surface water level variations in the creek. At this location, the deeper piezometer (DP-2 Deep) responds more when surface water levels increase, indicative of some local heterogeneity in the groundwater system at this site. In comparison to 432 Fourth Line, the site appears to have more permeable soils, but it is also closer to the creek bed. In detail (Figure 6) the relationship between groundwater and surface water level indicate recharge conditions when the surface water levels are high reversing to discharge conditions (i.e. baseflow) when the surface water level drops. It is interesting to note that the deep piezometer at this site tends to have the most subdued temperature profile, particularly during higher groundwater levels, despite it have the greatest response to surface water levels. However, the groundwater levels at DP2-Deep are on occasions above the peak surface water levels in the creek, indicating it is connected to a more upstream part of the creek; the more subdued groundwater temperature profile is consistent with a relatively longer, deeper groundwater pathway being measured. Overall the site shows greater surface water – groundwater interaction than 432 Fourth Line, however, the site is almost within the creek bed, which may also enhance the interaction with the creek.

Groundwater Accretion between Monitoring Locations

The term 'groundwater accretion' is often used for the increase or decrease in groundwater contribution over a reach of a creek. Groundwater accretion can be estimated from the difference between an upstream (Maplehurst Avenue) and downstream (Fourth Line) flow record of a creek. It should be noted that:

- The accuracy of the obtained rating curve for the Fourth Line gauge leads to some uncertainty between difference in flows between the two gauges; and,
- During periods of dry weather there is very limited flow or no flow in the creek and the difference between the two flow records is likely to be insignificant.

Nevertheless, some qualitative analysis may be performed. Gauged flows at the upstream gauge are sometimes higher and lower than the downstream gauge. Both groundwater recharge and discharge conditions were measured at the Bridge and Maplehurst piezometers (DP-2 Shallow and DP-2 Deep) and these observations are therefore consistent.

Conclusions

Groundwater interaction with the creek between Fourth Line and Maplehurst Avenue occurs through a thin weathered profile of Queenston Shale. At the downstream site (432 Fourth Line) there is insignificant interaction with an apparently limited weathered profile. The upstream site (Bridge and Maplehurst) shows evidence of groundwater recharge during high surface water levels and temporary discharge (i.e. baseflow) during periods of low surface water levels, consistent with the gauged flow records. During warmer summer conditions, the data indicate that discharge of groundwater to surface water is very limited.

The groundwater–surface interaction at these types of creeks may be considerably different when the creek runs across areas underlaid by overburden, as found upstream.

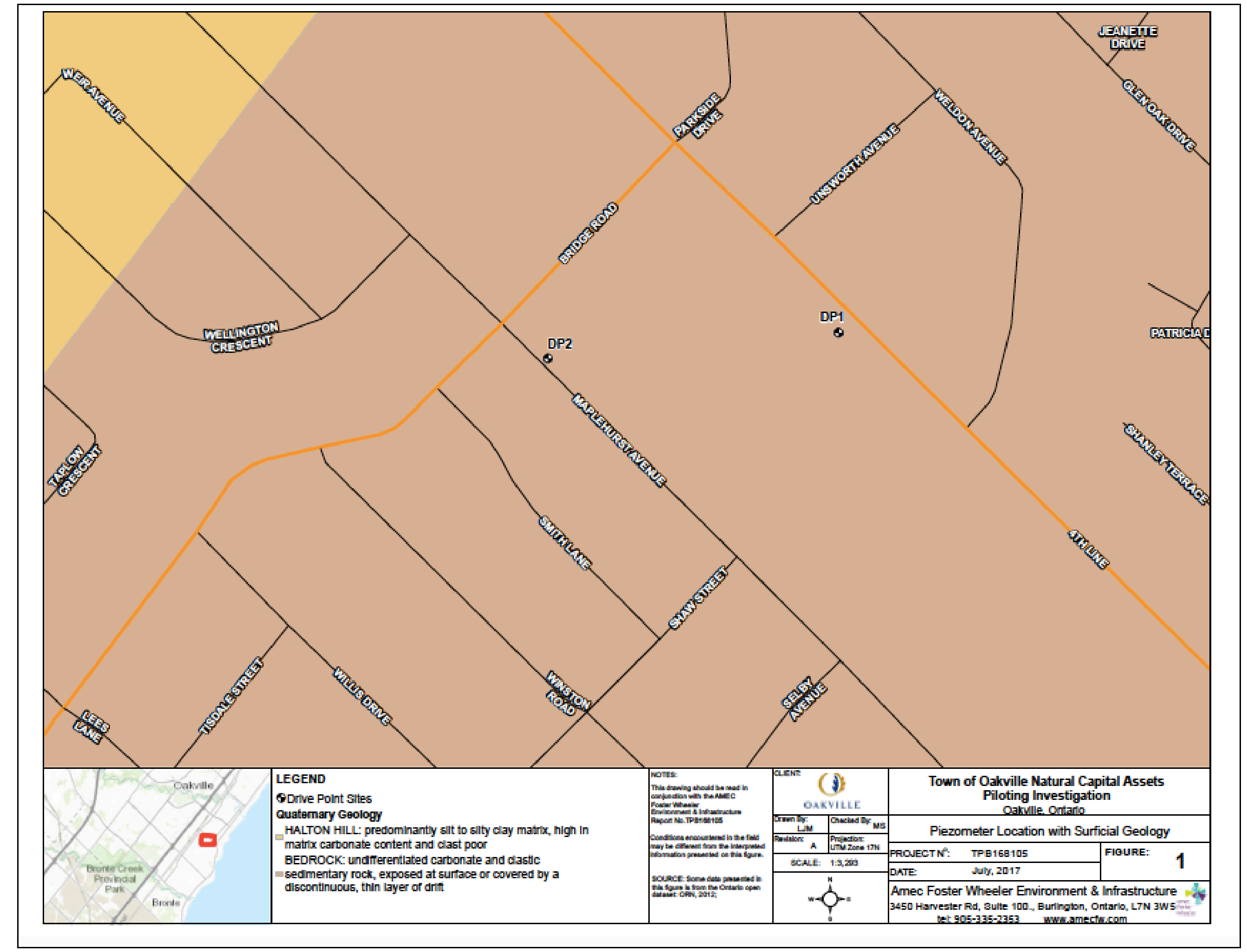

Figure 17: Piezometer location with surface geology

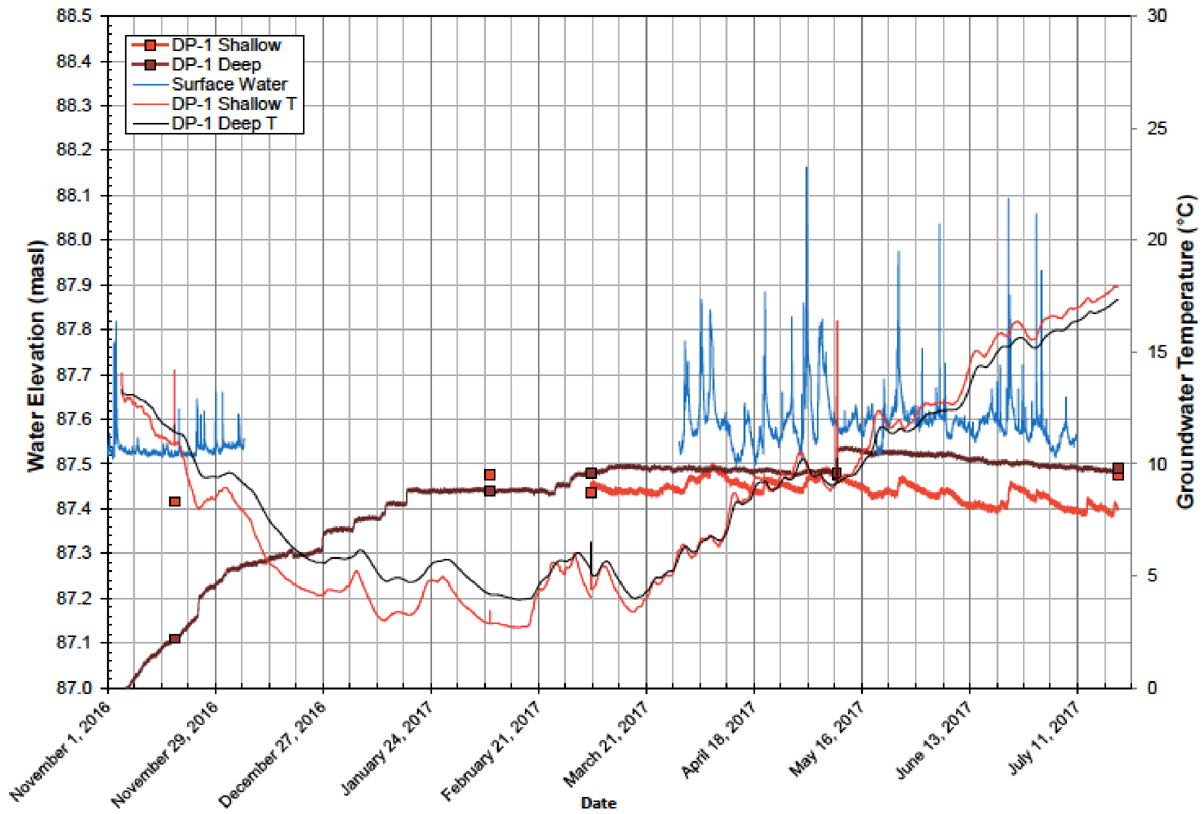

Figure 18: 432 Fourth Line groundwater data

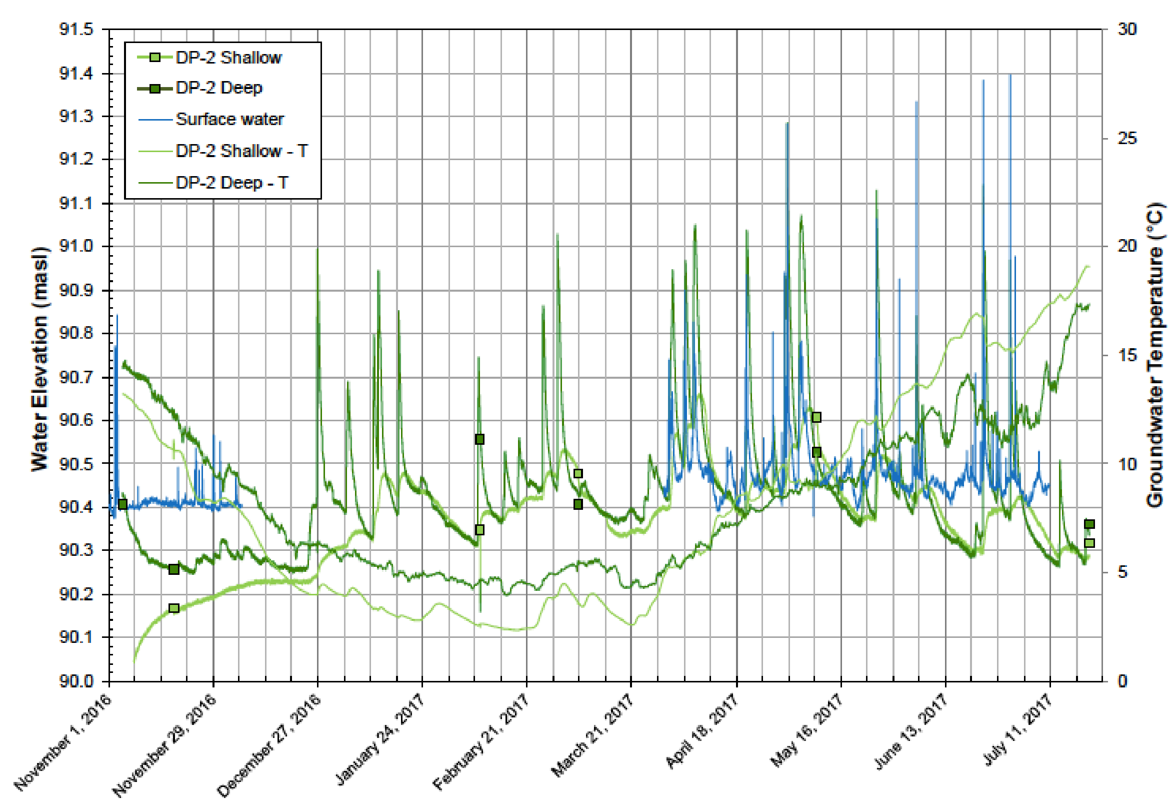

Figure 19: Bridge and Maplehurst groundwater data

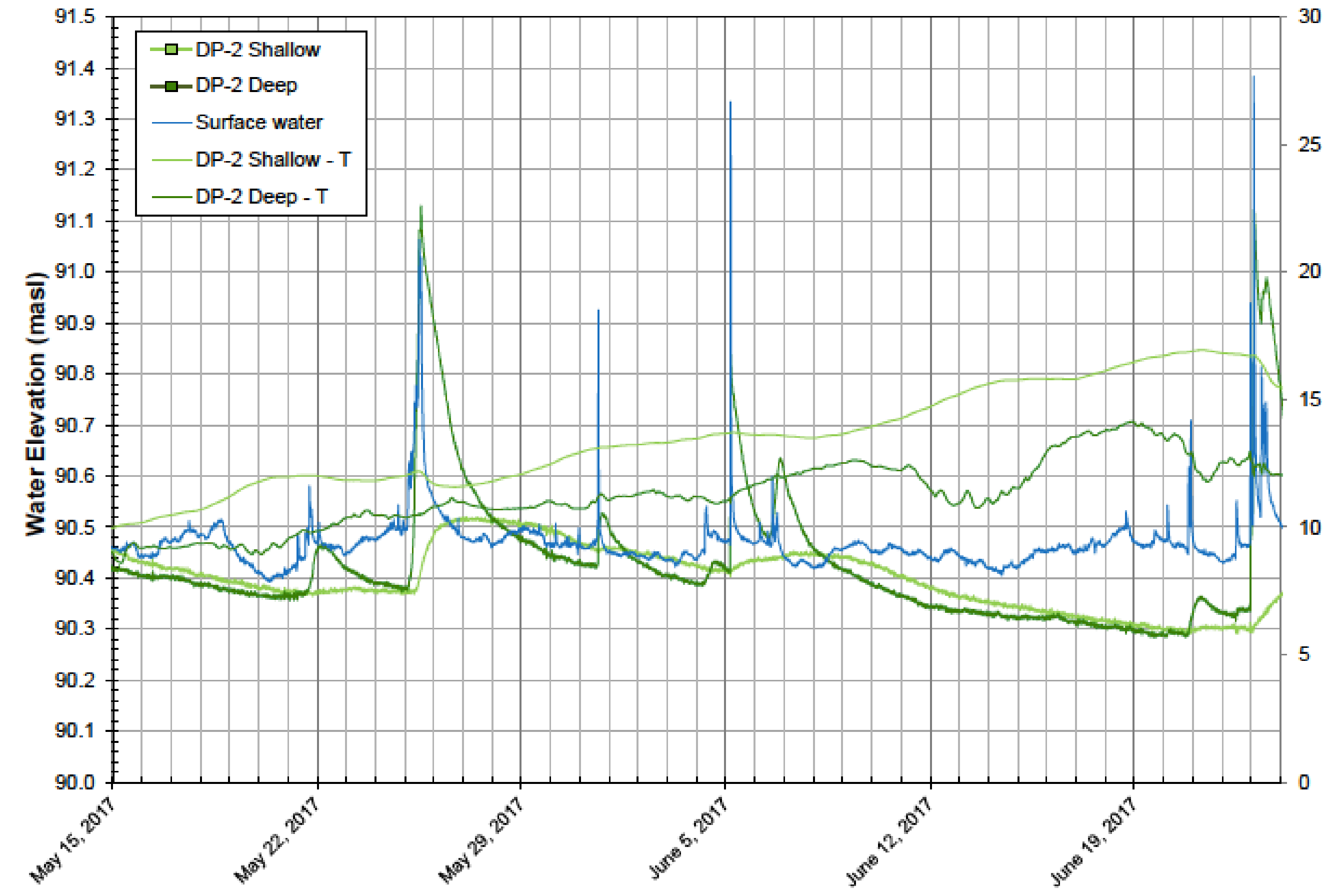

Figure 20: Bridge and Maplehurst groundwater data - detailed

Appendix C: Report to the Community Services Committee

Key Outcome Summary:

- *A natural system such as a remnant channel or ditch provides a service that goes beyond simply flow conveyance.*
- *The stormwater system relies on MNA for overland conveyance and storage of SW along with other benefits including infiltration that reduce flows.*
- *The value of the municipal stormwater service provided by the 240+ meter remnant channel is in the order of $1.24M (existing) to $1.44M (stressed) conditions.*
- *Replacing natural systems with engineered or gray systems that fail to replicate or provide equivalent service, can introduce unnecessary risk and negative environmental impacts.*
- *Evaluating the options of a MNA system and/or gray infrastructure remain an important element in determining the appropriate action ensuring that we have mitigated our risk responsibly.*
- *The value of municipal services provided by the remnant channel is important when assessing proposals that seek to alter these systems.*
- *MNA support multiple and broad community benefits that can be monetized and would improve the cost benefit understanding of NA options to manage stormwater.*

Next Steps

Participation in the MNAI pilot represented an important step in moving not just the town, but municipal practice forward in addressing the value of NA and green infrastructure. This is increasingly important in light of a rapidly changing environment due to variables such as climate change and redevelopment. To continue moving forward to incorporate the results into the town's work a number of cross departmental next steps are recommended.

<u>Stormwater Management Master Plan – Phase 2</u>

The SWMP is being carried out to determine urban flood risk by assessing the existing and needed capacities of the minor (pipes, gray infrastructure) and major (overland flow, e.g. NA's remnant channels, ditches, swales, roadways, ponds, NHS, and more) stormwater management system. Pilot outcomes will inform the SWMP with rationalized NA value especially the understanding that natural assets including ecosystem features such as remnant channels, ditches, swales, creeks and the urban forest, provide essential municipal stormwater management services. These NA, especially on a system-wide basis, provide important conveyance, storage, water quality improvement, cooling, biodiversity, and other services at lower costs than gray infrastructure along with many other benefits noted above.

The SWMP will integrate pilot findings when considering, for example, the value of maintaining or improving the function of a rural road cross section with

ditches/swales versus an urban cross section with buried pipes. The full MNAI Technical report will be included as an appendix to the SWMP.

<u>Policy Framework</u>

Pilot outcomes will be leveraged to develop stormwater management policy including a planning context to reflect stormwater management needs, the value of MNA in providing SW service with additional benefits to deal with the impacts of intensification, and climate variability. A policy framework integrating MNA will ensure the value of municipal services provided by MNA is recognized, protected wherever possible and even potentially restored to achieve the benefits of green infrastructure over gray. Collaboration with other municipal and conservation authority networks are being established to explore opportunities for framing policies and approaches to better support MNA initiatives including community partnerships, outreach and education, Low Impact Development and SW source controls such as bioswales.

MNA such as remnant channels, ditches and swales provide a key service that is relied upon for stormwater management. These assets are in public and private ownership. Policy development will recognize MNA services and benefits and how these services can be better supported though monitoring and maintenance and perhaps protection and enhancement to ensure these services are not compromised, degraded or lost. In cases where the MNA service can be quantified, replacement of like for like can be appropriately entertained. Before this pilot work, there was an incomplete understanding of the potential significance of MNA to provide municipal stormwater services. There is now a better comprehension of the benefits that MNA can provide in mitigating threats such as redevelopment, private landowner actions, and the shift from rural to urban road cross sections.

<u>Integrate findings into town's Asset Management System</u>

The pilot findings will also be integrated into future improvements to account for the value of service provided by MNA and also to better reflect the replacement, operation and maintenance aspects of MNA to support desired municipal service levels. Work is underway to include MNA not currently in the asset management system as green infrastructure. These assets deliver service and value to the town and require monitoring and maintenance to support effective operation and service.

The way MNA can be integrated into the asset management system will require further work since the standard accounting practice for MNA replacement does not reflect the service provided, i.e. a tree replacement cost reflects a small tree that would provide less in terms of municipal services. This consideration of MNA (some not yet inventoried) for their municipal service builds upon the already well-established asset management work.

Knowledge Transfer

MNA in both public and private ownership provide valuable services. Project staff have an improved understanding of the rationalized approach to assessing the municipal stormwater services of MNA. This knowledge will be transferred across departments and also to the public to convey the importance of MNA, the wide variety of services they can deliver, and how they can be integrated into supportive policy and on-the-ground work.

The findings of the five national pilots align with other emerging provincial and federal policies, guidelines and regulatory trends. Stormwater management options are trending towards greater consideration of source control through on lot/on road and Low Impact Development options and less on the traditional end-of-pipe solutions. Through the pilot findings, there is a much clearer understanding of the monetary impacts of MNA loss with respect to stormwater management services and the costs of moving from green to gray infrastructure along with the loss of additional community and environmental benefits.

Summary

The results of this pilot provide a better understanding of the stormwater management service and value of natural systems as they exist today across the town with remnant channels, ditches and other overland flow routes in watercourses, parks, natural areas, urban forests and open spaces, and along roads, in the public and private realm. The magnitude of this system of MNA provides a potentially significantly under-valued municipal service in managing stormwater that is now better defined. The impact of replacing these resilient green infrastructure stormwater management system elements with gray can now be monetized. With this information staff are better able to understand and represent the costs and risks associated when the town's MNA providing stormwater management services are compromised.

CONSIDERATIONS:

(A) PUBLIC

The MNAI pilot project provides better understanding of the value of the community's natural assets to provide municipal stormwater management services. These assets held in both public and private ownership include creeks, remnant channels, ditches, bioswales, open spaces, urban forests and other features.

(B) FINANCIAL

The value of natural assets as green infrastructure components of the stormwater management system have been estimated to be comparable to works exceeding $1.2M to $1.4M for conveyance, attenuation, and

infiltration functions without including co-benefits or operations and maintenance costs (expected to be lower order magnitude). This information will be integrated into the Stormwater Master Plan when considering management recommendations and the Asset Management System to improve accountability and represent service function.

(C) IMPACT ON OTHER DEPARTMENTS & USERS

The cross-departmental team facilitated knowledge and awareness transfer that will benefit many departments including Development Engineering, Environmental Policy, Financial Operations/Asset Management, Financial Planning, Parks and Open Space, Roads and Works Operations among others.

(D) CORPORATE AND/OR DEPARTMENT STRATEGIC GOALS

This report addresses the corporate strategic goal to:

- enhance our natural environment
- have environmentally sustainable programs/services
- continuously improve our programs and services
- be innovative in everything we do
- be fiscally sustainable
- be the most livable town in Canada

(E) COMMUNITY SUSTAINABILITY

Consideration of the value of Oakville's natural assets supports the four pillars of sustainability: social, economic, environment and cultural aspects of our community. Better understanding the importance of the town's natural assets in providing cost-effective municipal stormwater services as well as supporting community well-being and environmental sustainability was an important outcome of this work,

Prepared and submitted by:
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Development Engineering

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