Town of Niagara-On-The-Lake

King Street Investigation

GMBP File: 618025
Draft Submitted: March 2019
Revised: November 2019

EXECUTIVE SUMMARY

GM BluePlan Engineering (GMBP) was retained by the Town of Niagara-on-the-Lake (NOTL) to complete an investigation of the King Street Storm Sewer Outlet (KSSO) which discharges east of Queens Royal Beach (QRB) located on the Niagara River. The KSSO was flagged by the Niagara River Remedial Action Plan (RAP) for elevated levels of Escherichia coli (*E. coli).* The RAP team will track progress over summer 2019 by the number of beach postings at QRB. Beach postings occur when *E. coli* levels exceed 200 CFU (Colony Forming Units)/100mL. GMBP completed a detailed investigation of the KSSO catchment area and has identified various infrastructure improvements to reduce *E. coli* loading to the storm sewer.

The following outlines the GMBP approach with **findings in bold:**

- Background Data Review: Review of 2017 sampling data (by AMEC) identified **improper sample handling**.
- Sample Plan 2018: Dry and wet weather sampling (by GMBP & NOTL) **flagged areas for high *E. coli***.
- Infrastructure Condition Assessment: Mainline and private property Closed Circuit Television (CCTV), smoke testing, dye testing, identified **improper connections, abandoned infrastructure and cross-connections between sanitary and storm assets in poor condition**.

DNA analysis of the KSSO samples was completed by Environment Canada on wet weather grab samples. At the KSSO, gull DNA marker ranged from 51-95,004 DNA copies/100mL and human DNA marker ranged from 44-942 DNA copies/100mL. The Davy Street Storm Sewer Outlet (DSSO), which ultimately drains to the KSSO, had human DNA marker levels of 44-367 DNA copies/100mL.

HUMAN *E. COLI* INFRASTRUCTURE IMPROVEMENTS

GMBP identified the following sources of Human *E. coli* in the KSSO catchment area. **GMBP recommendations are in bold:**

1. Lateral from the wading pool in Simcoe Park connected to the storm sewer (drained daily). **Lateral to be connected to the sanitary sewer prior to May 24, 2019 ($11,000).**
2. On King Street is a poor condition sanitary manhole (with a sewage forcemain connection) beside a poor condition storm manhole with a cracked storm outlet pipe, directly below the sanitary asset area of concern (storm at a lower elevation then sanitary). **Manhole replacement/rehabilitation (similar costs) and outlet improvement ($22,000).**
3. Abandoned engineering drawing review identified abandoned pipes that were not filled with concrete. The abandoned pipes act as a conduit for cross-connection flows between sanitary and storm infrastructure. To date, CCTV data has not been provided to GMBP for the Queen Street sanitary sewer, therefore its condition is currently unknown. Queen Street has the highest amount of abandoned sanitary infrastructure. The hot vapour investigation flagged 27 Queen Street (large pavement area had melted snow). This property had a CCTV attempt from private property, but the survey was abandoned due to poor lateral condition. **GMBP recommends a CCTV sanitary investigation including lateral launch of Queen Street connections ($5,000).**
4. On King Street is an abandoned clay sanitary pipe in poor condition with an active connection. **Locate property with active connection and fill pipe ($5,000).**
5. An abandoned storm pipe connected to the King Street storm sewer is in poor condition near a poor condition private property sanitary lateral exfiltrating sewage. **Cap and fill abandoned storm pipe ($4,000).**
6. Multiple sanitary pipes in the KSSO catchment area do not have CCTV data (not provided for GMBP review). **NOTL to confirm if CCTV data exists for these sanitary pipes and complete CCTV in areas (as required) and PACP defect condition assessment.**
7. Low flow cross-connections exist between mainline storm and sanitary sewers. **GMBP and NOTL to meet to determine threshold to repair mainline infrastructure based on CCTV mainline defect review to PACP standards.**
8. Sanitary lateral inspections identified six properties on Davy Street with sewage exfiltrating; four of the properties

had large joint offsets located at the property line. The Davy Street storm sewer is in very poor condition and should be improved to reduce private property sanitary contamination through cross connections. **Trenchless UV Structural Liner for Davy Street storm sewer ($126,000). Further discussion between NOTL and GMBP regarding fixing the four Davy Street lateral issues at property line.**

9. A total of 11 properties (including the Davy Street properties mentioned above) were flagged with sanitary laterals that had signs of sewage exfiltration. NOTL to either host a PIC or send a letter to **encourage residents in the KSSO project area to fix laterals. GMBP recommends postponing the PIC until other private property investigations in NOTL are completed (Garrison Village) to continue active voluntary CCTV participation.**

OTHER *E. COLI* SOURCES

Environment Canada also measured *E. coli* in Colony Forming Units (CFU) which is a live count of bacteria grown on plates as opposed to DNA marker numbers which uses a molecular technology to detect the bacteria. Environment Canada indicated *E. coli* levels ranged from 210-223,000 CFU/100mL. GMBP has outlined the following other sources of *E. coli*:

1. Racoons feces visible in the storm sewer system. **Wellington Storm inlet grate improvements prior to May 24, 2019 ($1,500).**
2. Horse carriage routes throughout KSSO catchment, with the majority of horse traffic on King Street, with feces evident on the road. **NOTL to discuss removing the horse carriage routes to reduce *E. coli* loading to KSSO to reduce *E. coli* loading at QRB.**
3. A horse polo match occurred in the Wellington Street storm sewer catchment with post samples showing an increase of 61,400 CFU/100mL of *E. coli* in the drainage ditch. **NOTL to confirm proper feces mitigation/cleanup during and after event.**

MAINTENANCE IMPROVEMENTS

Sediment acts as a protective environment for *E. coli*. This environment allows the increased survival and accumulation of *E. coli* bacteria. **Increased maintenance recommendations for the project area include:**

- System flushing of the KSSO catchment area once grates installed on Wellington Street storm inlet.
- Secondary system flushing to reduce KSSO *E. coli* levels prior to summer 2019 beach sampling.
- Sump maintenance to be performed once a month during summer 2019 to continually remove sediment and debris in storm manholes and catchbasins.
- Manual labour (difficult truck access area) for catchbasin sump cleaning in Simcoe Park once a month during summer 2019.
- Simcoe Park inlet catchbasin for the Davy Street storm sewer outlet (DSSO) to be monitored monthly for sediment build-up.

GROUNDWATER CONFIRMATION

GMBP identifies it is possible that *E. coli* could be in the groundwater prior to it entering the project area. If so, this would suggest that any storm asset with groundwater infiltration would be a source of *E. coli*. **GMBP recommends a groundwater monitoring well for summer 2019 sampling and DNA analysis be installed in the KSSO catchment area**.

The shallow aquifer discharge on Delater Street had upwards of 220 CFU/100mL which would be considered a fail for the water quality objective standards of 200 CFU/100mL. **GMBP recommends a DNA analysis of aquifer sampling be completed summer 2019. GMBP also recommends a DNA analysis be completed at QRB bi-weekly**.

As there is a relationship between surface water and groundwater whereby groundwater can serve to replenish surface water flow and vice-versa, **GMBP recommends One Mile Creek (intersecting King Street) be sampled for *E. coli***

and DNA analysis.

If sampling of One Mile Creek produces positive test results for *E. coli*, it is possible for *E. coli* to have entered the aquifer from groundwater recharge areas located upstream of the project area. **GMBP recommends NOTL investigate farming practices upstream to determine potential source of *E. coli*, including improper manure application, timing and amounts**.

CONCLUSION

GMBP believes infrastructure asset management will further identify cross-connections between storm and sanitary infrastructure in NOTL, as with any municipality. The process involves increased data collection such as manhole condition assessment, invert survey of all connections, and PACP defect coding from CCTV which is updated into GIS. Pipes missing in GIS or with no CCTV data can be flagged for follow-up. With an improved electronic dataset, NOTL can make data driven decisions for budget allocation for infrastructure improvements moving forward.

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1. INTRODUCTION

GM BluePlan Engineering Ltd. (GMBP) was retained by the Town of Niagara-on-the-Lake (NOTL) to complete an investigation of the King Street Storm Sewer Outlet (KSSO), which discharges east of Queens Royal Beach (QRB) located on the Niagara River. The KSSO was flagged by the Niagara River Remedial Action Plan (RAP) for elevated levels of *Escherichia coli* (*E. coli).* The RAP team will track progress over summer 2019 by the number of beach postings at QRB. Beach postings occur when *E. coli* levels exceed 200 CFU (Colony Forming Units)/100mL. GMBP completed a detailed investigation of the KSSO catchment area and has identified *E. coli* sources.

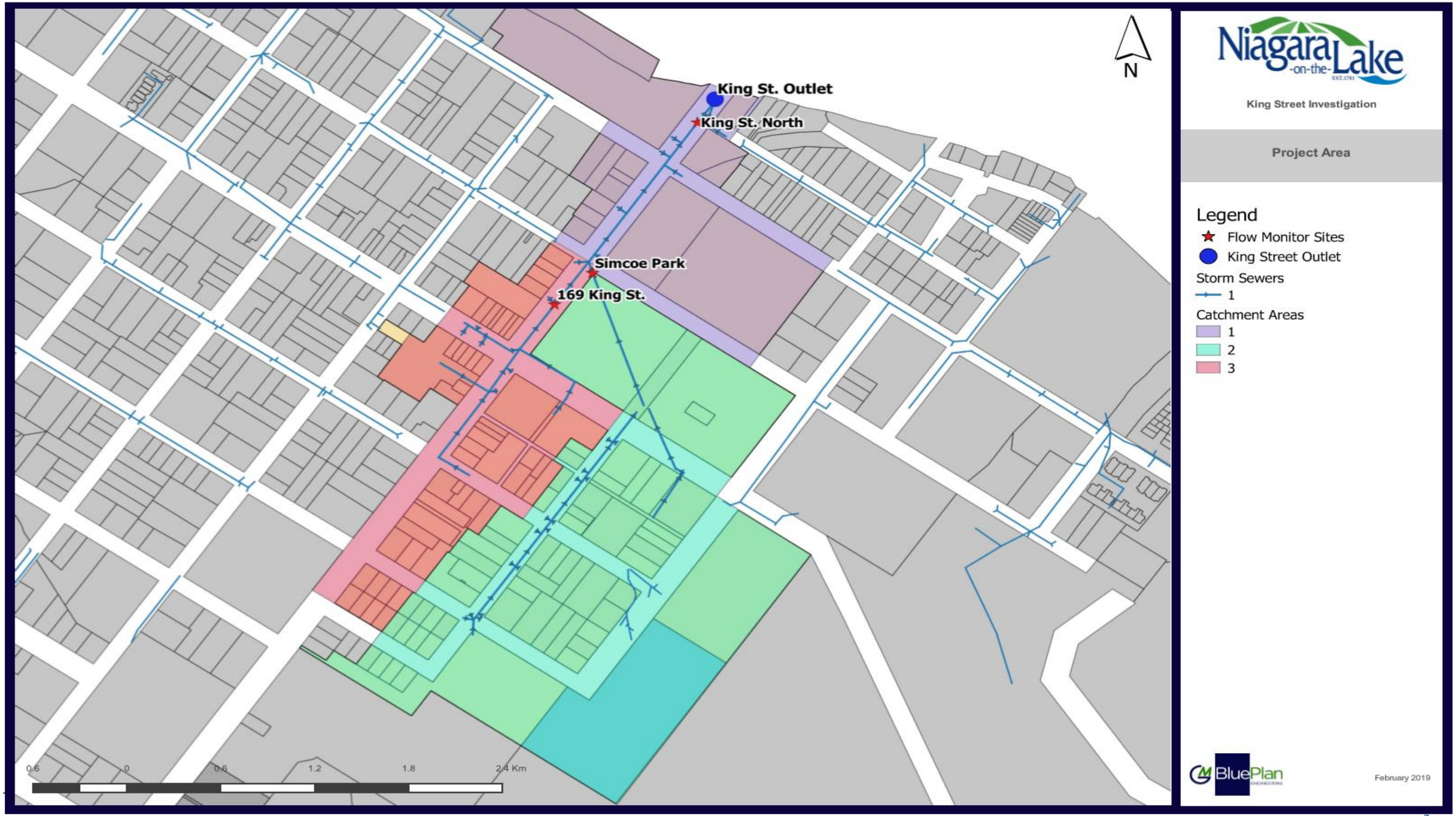
2. INVESTIGATION PROCESS OVERVIEW

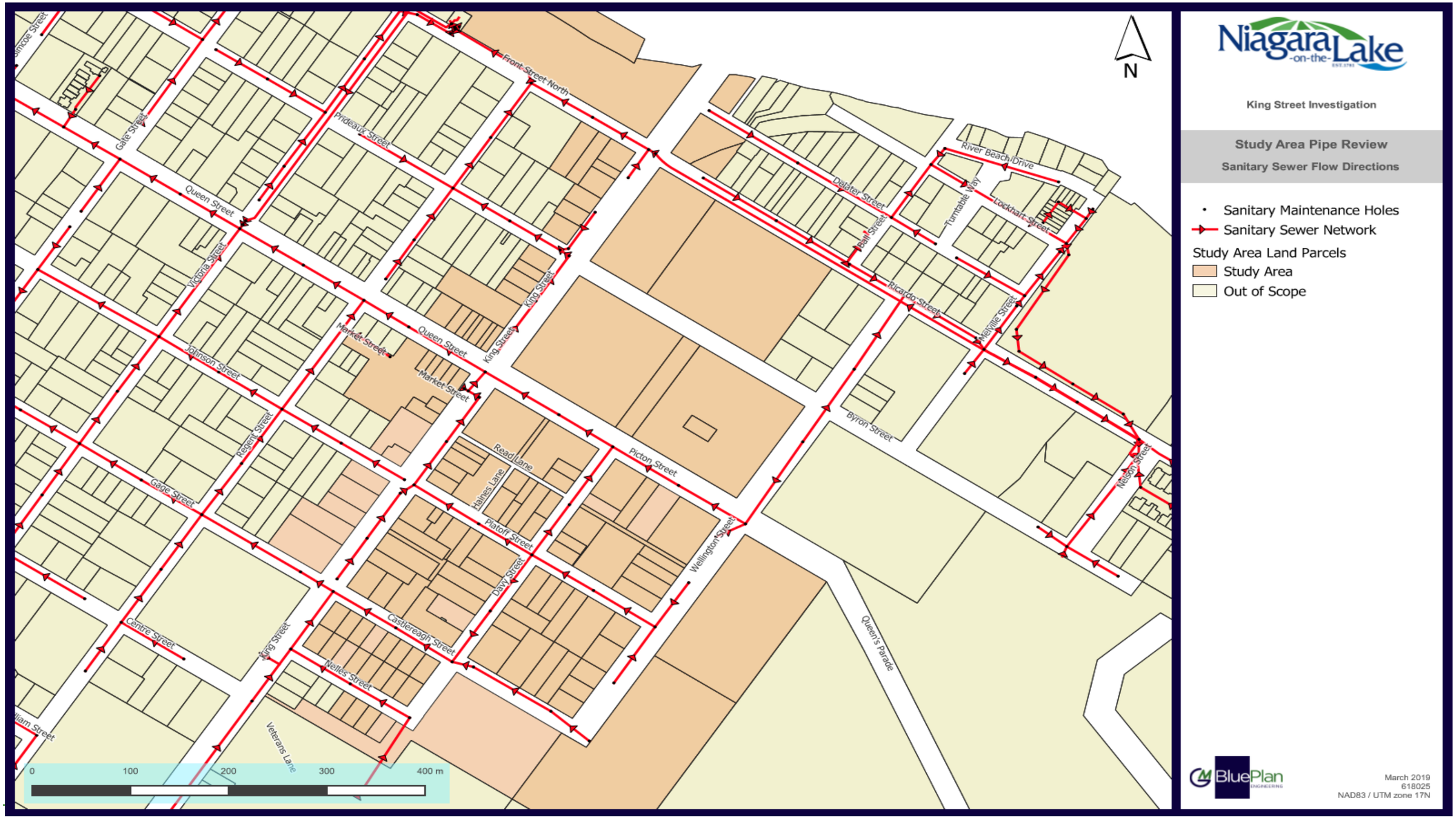
The following summarizes GMBP's "no stone left unturned" approach to the KSSO catchment area:

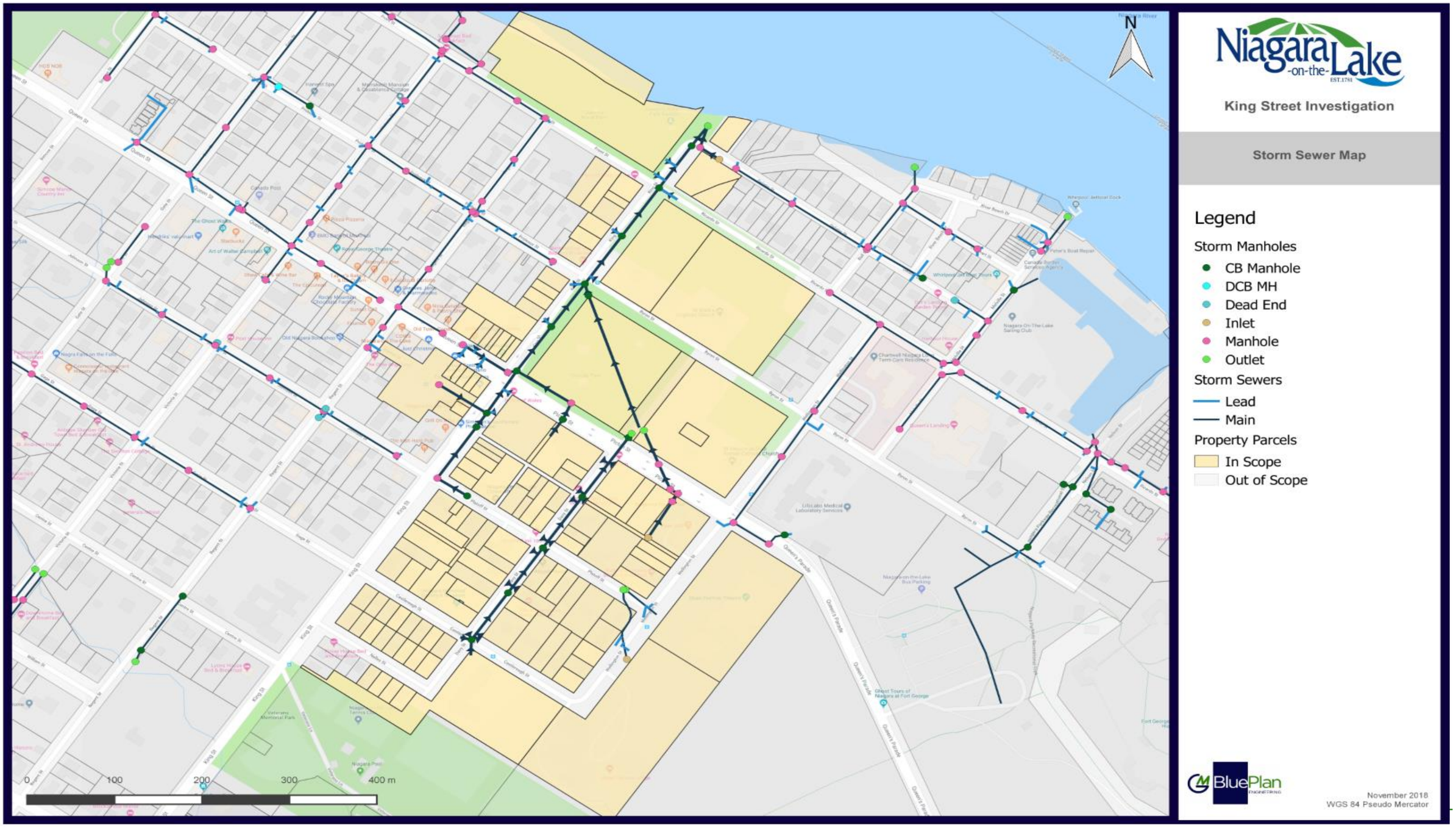
1. Background Data Review: GMBP completed a detailed data review of the previous sampling completed by Wood (formerly Amec Foster Wheeler) in 2017 and flow monitoring data (from April – December 2017).
    a. **Appendix A:** Analysis of 2017 sample data.
    b. **Appendix B:** Detailed data register of all background documents provided for GMBP review.
    c. **Appendix F:** Flow monitoring analysis.
2. Because of improper sample handling and protocol during 2017 sampling, GMBP developed a sample plan procedure implemented summer 2018.
    a. **Appendix C:** GMBP 2018 sample plan.
    b. **Appendix D:** Reference proper sampling protocol and *E. coli* bacteria interaction with sediment.
3. GMBP Sample Plan 2018 used dry and wet weather sampling to flag areas for high *E. coli*.
    a. **Appendix E:** QRB sample analysis
    b. **Appendix N:** Dry and wet weather sample analysis.
4. GMBP completed site investigations involving condition assessment of all storm and sanitary assets in the project area, smoke testing, dye testing to confirm connection locations, mainline and private property CCTV, and hot vapour investigations (winter 2019) to determine sources of heat in the storm sewer.
    a. **Appendix G:** Mainline (PACP defect review) summary visuals and maps.
    b. **Appendix H:** Smoke testing communication material provided to residents.
    c. **Appendix I:** Smoke testing results and participation summary maps.
    d. **Appendix J:** Hot vapour investigation results and horse carriage route investigation results.
    e. **Appendix K**: Detailed field notes.
    f. **Appendix L:** Groundwater aquifer data from Niagara Peninsula Conservation Authority (NPCA).
    g. **Appendix O:** Private property CCTV data.
5. GMBP identified abandoned pipes (storm and sanitary) in the KSSO catchment area that are in poor condition, with active connections and pipes providing a conduit for cross-connection flows between sanitary and storm infrastructure.
    a. **Appendix M:** Abandoned infrastructure review of engineering drawings.
    b. **Appendix P:** Infrastructure asset management recommendations for NOTL to apply Town-wide.

This methodical investigation process successfully identified improper connections, abandoned infrastructure, and low flow cross-connections between sanitary and storm assets that are in poor condition on municipal and private property. GMBP has provided detailed infrastructure improvements to reduce *E. coli* loading to the KSSO.

The following maps visually introduce the project area.


King St. Outlet
King St. North
Simcoe Park
169 King St.
N
0.6
0
0.6
1.2
1.8
2.4 Km
Niagara-on-the-Lake
King Street Investigation
Project Area
Legend
Flow Monitor Sites
King Street Outlet
Storm Sewers
1
Catchment Areas
1
2
3
February 2019


N
Front Street North
Prideaux Street
Gale Street
Queen Street
Victoria Street
King Street
Market Street
Johnson Street
Regent Street
Gage Street
Centre Street
Nelles Street
Veterans Lane
Read Lane
Haines Lane
Platoff Street
Davy Street
Castlereagh Street
Picton Street
Wellington Street
Queen's Parade
Byron Street
Nelson Street
Delater Street
Ball Street
Ricardo Street
Melville Street
Turntable Way
River Beach Drive
Lockhart Street
0
100
200
300
400 m
Niagara-on-the-Lake
King Street Investigation
Study Area Pipe Review
Sanitary Sewer Flow Directions
Sanitary Maintenance Holes
Sanitary Sewer Network
Study Area Land Parcels
Study Area
Out of Scope
BluePlan ENGINEERING
March 2019
618025
NAD83 / UTM zone 17N


N
Niagara-on-the-Lake
EST.1791
King Street Investigation
Storm Sewer Map
Legend
Storm Manholes
CB Manhole
DCB MH
Dead End
Inlet
Manhole
Outlet
Storm Sewers
Lead
Main
Property Parcels
In Scope
Out of Scope
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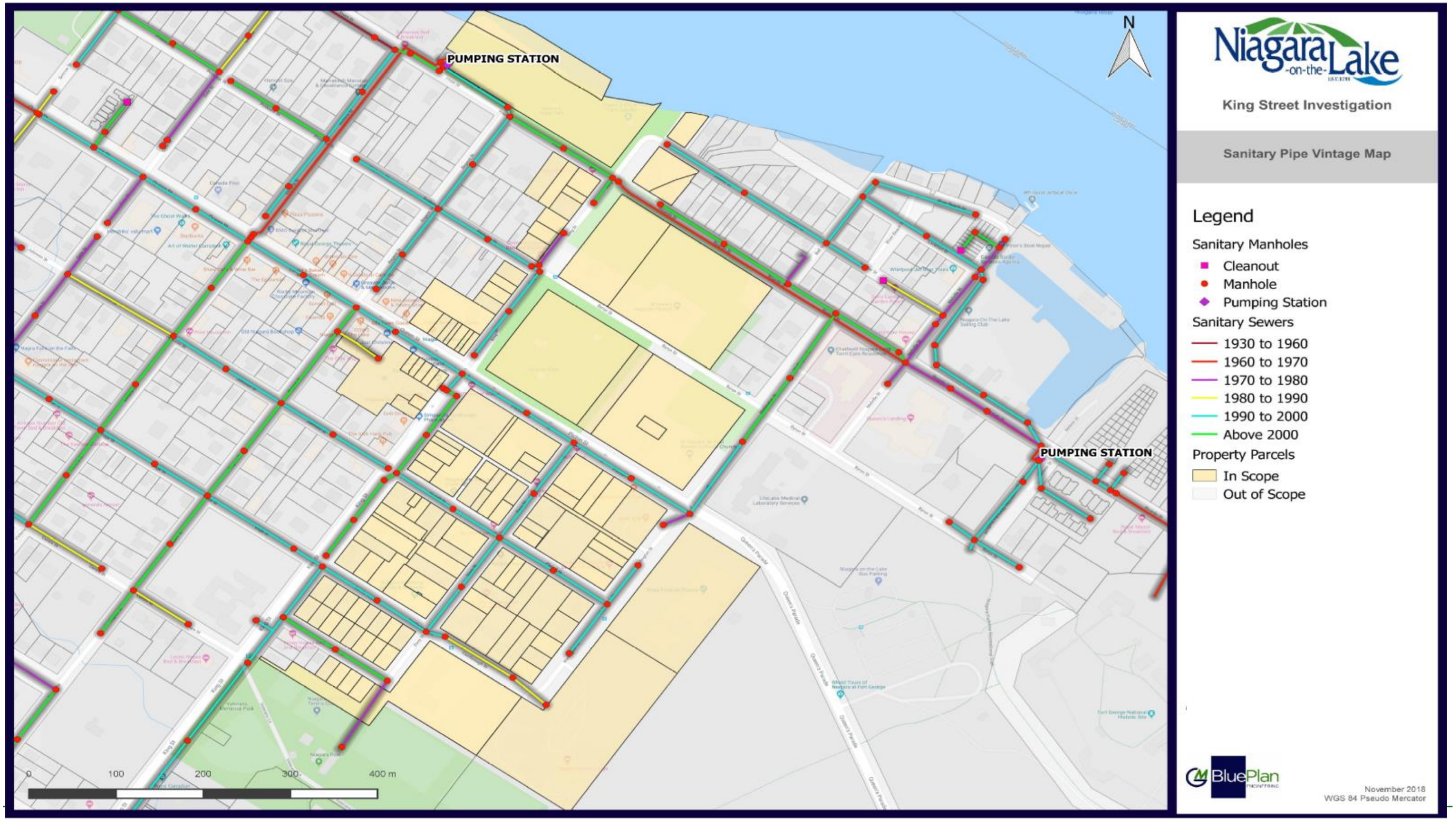
300
400 m
November 2018
WGS 84 Pseudo Mercator


PUMPING STATION
PUMPING STATION
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100
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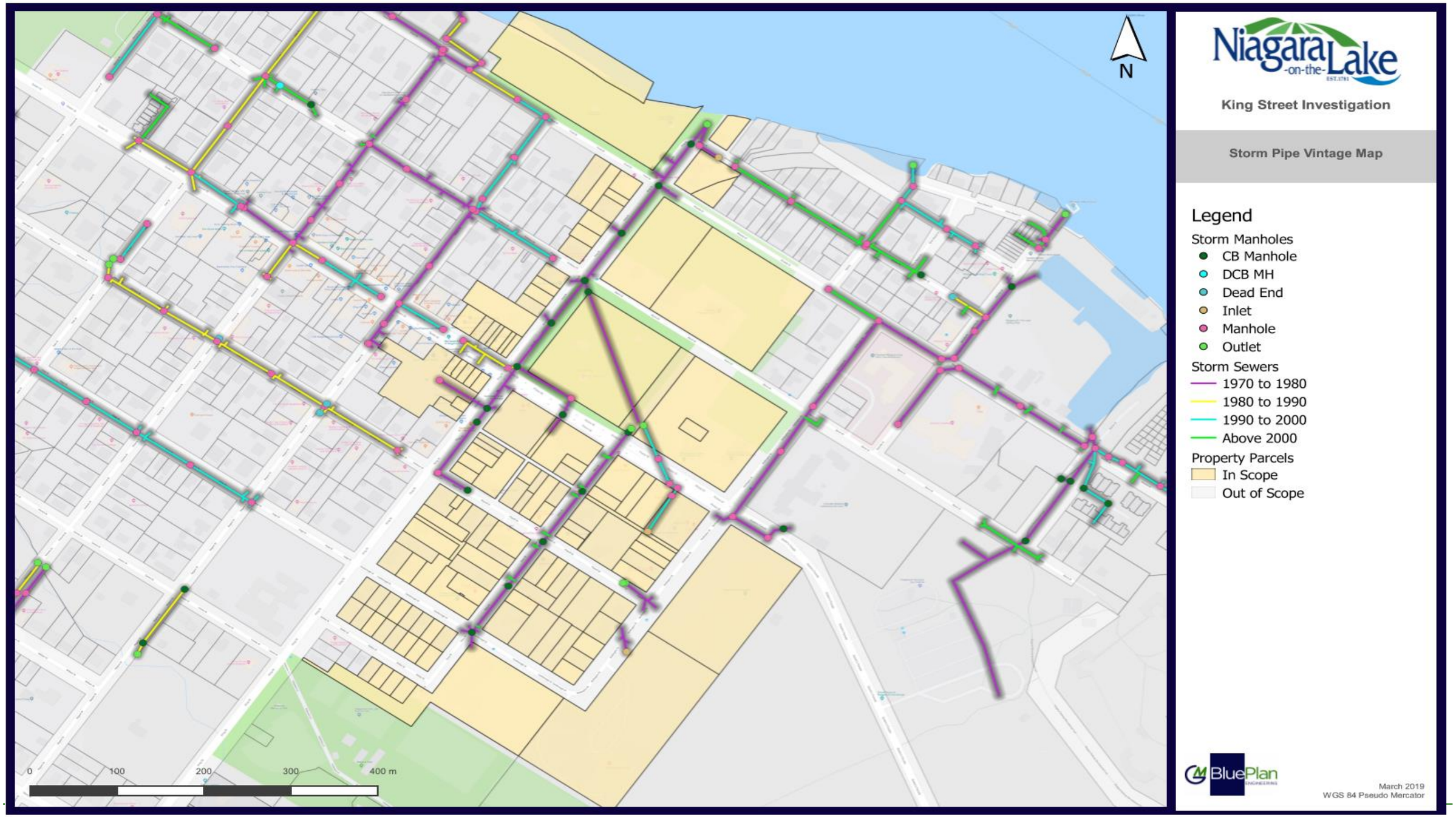
300
400 m
Niagara-on-the-Lake
King Street Investigation
Sanitary Pipe Vintage Map
Legend
Sanitary Manholes
Cleanout
Manhole
Pumping Station
Sanitary Sewers
1930 to 1960
1960 to 1970
1970 to 1980
1980 to 1990
1990 to 2000
Above 2000
Property Parcels
In Scope
Out of Scope
BluePlan
November 2018
WGS 84 Pseudo Mercator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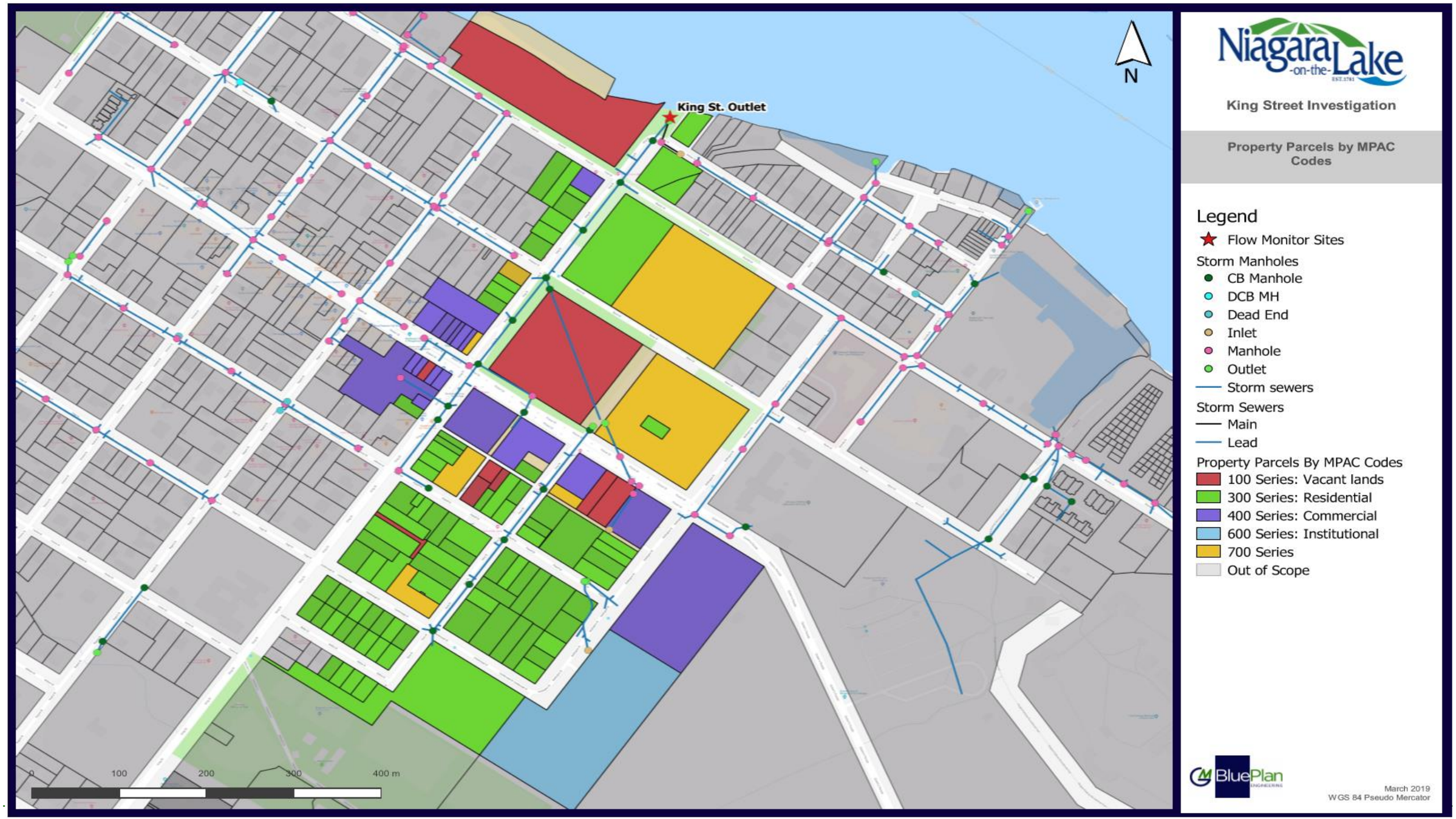
Niagara-on-the-Lake
King Street Investigation
Storm Pipe Vintage Map
Legend
Storm Manholes
CB Manhole
DCB MH
Dead End
Inlet
Manhole
Outlet
Storm Sewers
1970 to 1980
1980 to 1990
1990 to 2000
Above 2000
Property Parcels
In Scope
Out of Scope
BluePlan
March 2019
WGS 84 Pseudo Mercator


King St. Outlet
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400 m
Niagara-on-the-Lake
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Property Parcels by MPAC Codes
Legend
Flow Monitor Sites
Storm Manholes
CB Manhole
DCB MH
Dead End
Inlet
Manhole
Outlet
Storm sewers
Storm Sewers
Main
Lead
Property Parcels By MPAC Codes
100 Series: Vacant lands
300 Series: Residential
400 Series: Commercial
600 Series: Institutional
700 Series
Out of Scope
BluePlan
March 2019
WGS 84 Pseudo Mercator

3. PROJECT AREA & MAINLINE CCTV REVIEW

The KSSO catchment is located in the downtown tourist core of NOTL. The catchment has a mixture of residential and commercial properties, many of which are historic and were built in the 1800s or early 1900s. The area is serviced by a separated storm and sanitary collection system, installed from 1970-1990.

Table 1 and **Table 2** summarize storm and sanitary infrastructure.

Table 1: Study Area Storm Sewer Details

Street	Type	Storm Sewer Install Year	Material	Diameter
King Street	Buried	1976	Concrete	300-750
Queen Street	Buried	1988	Concrete	450
Picton Street	Buried	1977	Concrete	300
Davy Street	Buried	1976	Concrete	450
Wellington St	Buried and Open Ditch	1972	Concrete	450
Platoff Street	Buried	1977	Concrete	300

Table 2: Study Area Sanitary Sewer Details

Street	Type	Sanitary Sewer Install Year	Material	Diameter
King Street	Buried	1979-2011	PVC, AC	200-450
Queen Street	Buried	1990	PVC	350
Picton Street	Buried	1992	PVC	250-375
Davy Street	Buried	1996-1998	PVC	200
Wellington St	Buried	1970-2013	PVC, AC	200-250
Platoff Street	Buried	1998	PVC	200

Project area storm sewer and sanitary sewer mainline CCTV videos were reviewed following PACP standards, the North American standard for infrastructure condition evaluation. GMBP summarized defects into GIS and flagged areas which do not have CCTV mainline data. Defect maps for the storm and sanitary sewers were overlaid to identify high risk areas for cross-connections flow between sanitary and storm assets.

Results from the storm mainline CCTV review identified Davy Street as the worst condition storm sewer in the project area. Davy Street storm sewer includes multiple areas with cracks, fractures, groundwater infiltration, rebar exposed in majority of areas, defective taps, and broken pipe sections. The sanitary sewer on Davy Street is PVC which is in good condition, but an area does exist with encrustations (low flow leaks create encrustations) near Platoff Street.

King Street storm sewer was considered the second worst condition sewer pipe due to cracks, fractures, surface damage, rebar exposed, defective taps. The sanitary sewer review of King Street identified an area with large tree roots within the sanitary sewer near King Street and Platoff Street. It is interesting to note the King Street storm sewer is a concrete pipe but has sections of PVC pipe installed within the concrete pipe. The condition of the concrete pipe below the PVC sections is unknown and could be adding low flow cross-connections.

Sample visuals of defects and PACP defect maps are included on the following pages.


Front Street North
Gate Street
Prideaux Street
Victoria Street
Queen Street
King Street
Market Street
Johnson Street
Regent Street
Read Lane
Haines Lane
Gage Street
Platoff Street
Davy Street
Centre Street
Castlereagh Street
Nelles Street
Veterans Lane
Delater Street
Ball Street
Ricardo Street
River Beach Drive
Turnable Way
Lockhart Street
Melville Street
Byron Street
Picton Street
Wellington Street
Queen's Parade
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400 m
Niagara-on-the-Lake
King Street Investigation
Study Area Pipe Review
Sanitary Sewers Without CCTV Review
Sanitary Maintenance Holes
Sanitary Sewer Network
Sanitary Pipes Missing CCTV Data
Study Area Land Parcels
Study Area
Out of Scope
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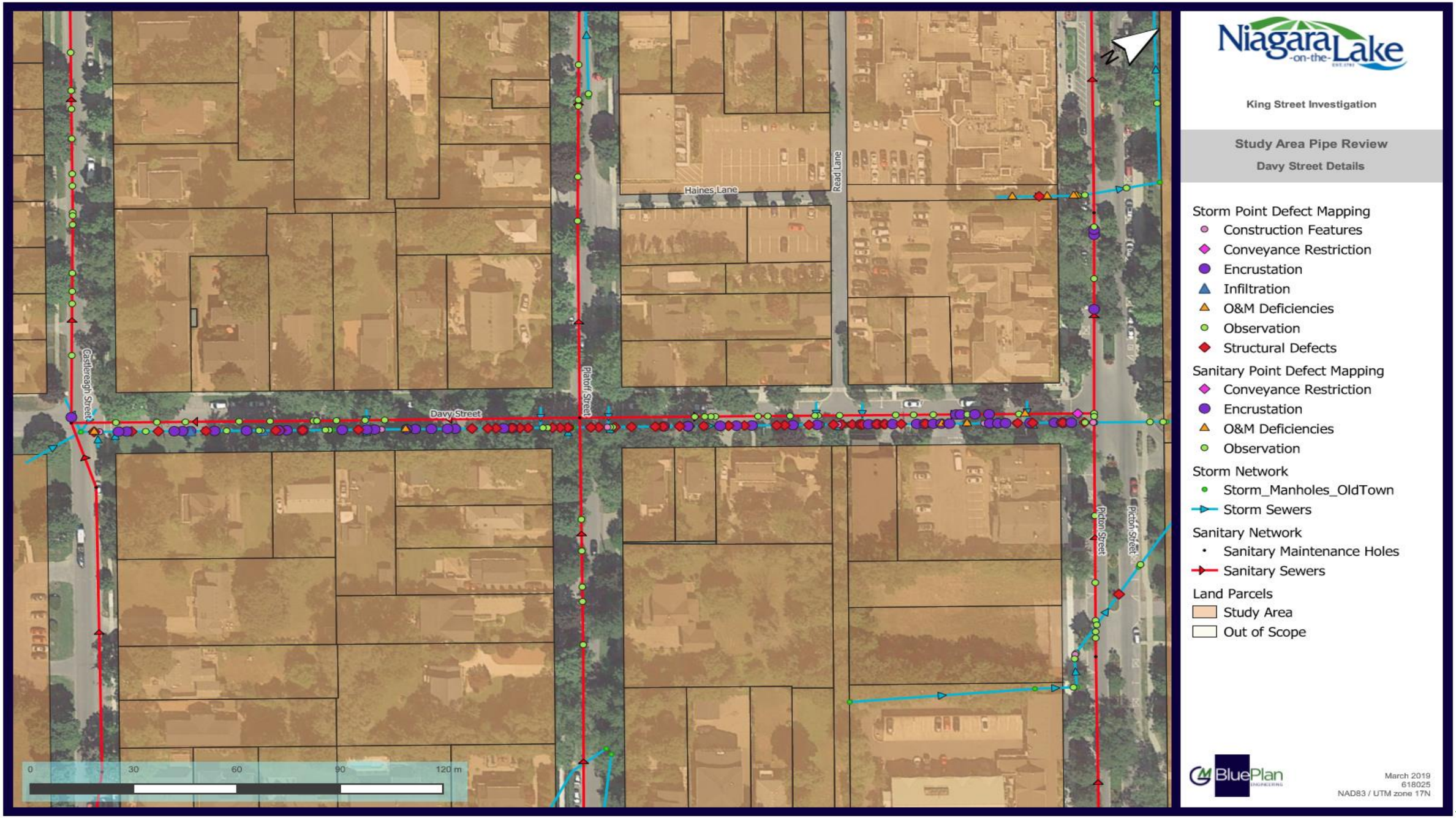
Haines Lane
Read Lane
Davy Street
Castlereagh Street
Picton Street
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60
90
120 m
N
Niagara-on-the-Lake
King Street Investigation
Study Area Pipe Review
Davy Street Details
Storm Point Defect Mapping
Construction Features
Conveyance Restriction
Encrustation
Infiltration
O&M Deficiencies
Observation
Structural Defects
Sanitary Point Defect Mapping
Conveyance Restriction
Encrustation
O&M Deficiencies
Observation
Storm Network
Storm_Manholes_OldTown
Storm Sewers
Sanitary Network
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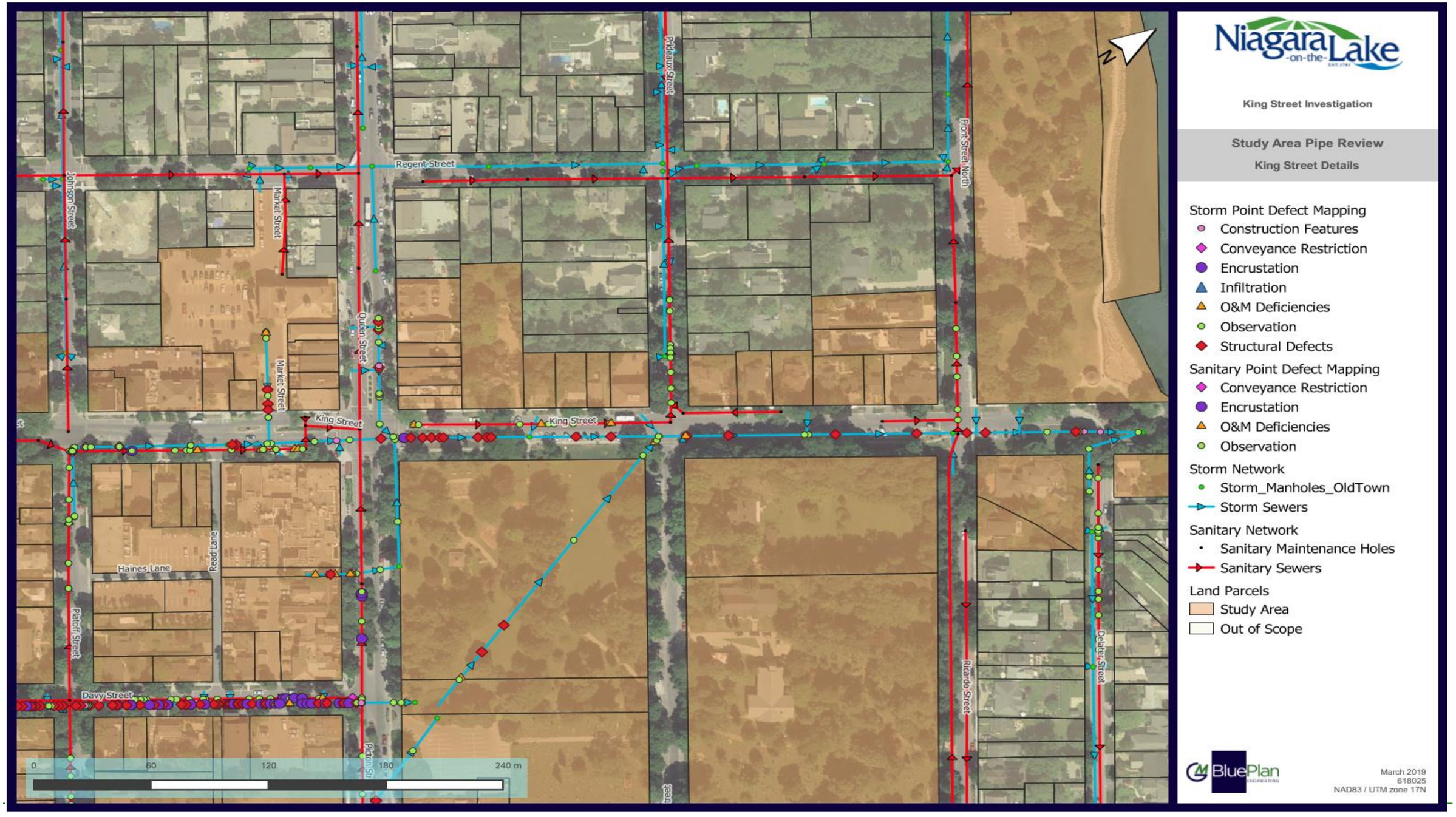
Sanitary Sewers
Land Parcels
Study Area
Out of Scope
BluePlan
March 2019
618025
NAD83 / UTM zone 17N


Prideaux Street
Front Street North
Regent Street
Johnson Street
Market Street
Queen Street
King Street
King Street
Haines Lane
Read Lane
Platoff Street
Davy Street
Ricardo Street
Delater Street
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180
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Niagara-on-the-Lake
King Street Investigation
Study Area Pipe Review
King Street Details
Storm Point Defect Mapping
Construction Features
Conveyance Restriction
Encrustation
Infiltration
O&M Deficiencies
Observation
Structural Defects
Sanitary Point Defect Mapping
Conveyance Restriction
Encrustation
O&M Deficiencies
Observation
Storm Network
Storm_Manholes_OldTown
Storm Sewers
Sanitary Network
Sanitary Maintenance Holes
Sanitary Sewers
Land Parcels
Study Area
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BluePlan
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CCTV Storm & Sanitary Defect Photos

Davy St., Storm - Rebar Visible

Davy St., Storm - Rebar Visible

Davy St., Storm – Fractures Multiple

King St., Sanitary – Heavy Roots

Davy St., Storm – Broken, Soil Visible

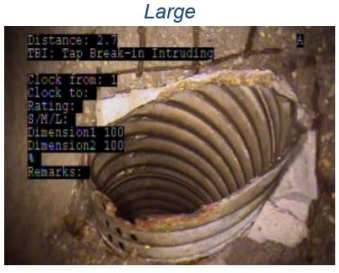
Davy St., Storm – Crack Multiple

Platoff St., Storm – Joint Offset Large

King St., Sanitary – Grease Deposits

Platoff St., Storm – Joint Offset

Platoff St., Storm – Broken



King St., Storm – Defective Tap

King St., Sanitary – Settled Gravel

4. QUEENS ROYAL BEACH SAMPLING

NOTL employees sampled the water quality at Queens Royal Beach (QRB) three times a week throughout summer 2018. NOTL employees were trained by staff at Region of Niagara Public Health. Due to funding availability, NOTL assumed the role of sampling the water quality near the beach in seven sample locations. Laboratory results were provided to GMBP for analysis and detailed results are located in **Appendix E**. During summer 2018 there were a total of six beach postings. A correlation exits between elevated levels of *E. coli* after rain events and QRB beach closures.

A maximum laboratory dilution of 1000 CFU/100mL was used for all samples taken. For future QRB sampling, GMBP recommends increasing the sample dilution to understand the total value of *E. coli* when greater than 1000 CFU/100mL. While the amount of *E. coli* that is present above 200 CFU/100mL is irrelevant to beach postings, tracking the value helps indicate progress in *E. coli* reduction as upstream infrastructure improvements are implemented.

There are likely multiple sources of *E. coli* contamination at QRB such as wildlife, storm outfalls, as well as upstream contributions from the Niagara River. GMBP provides the following information regarding the interaction of *E. coli* and a beach environment also contributing to the high *E. coli* environment at QRB:

- *E. coli can exist in the groundwater below the beach adjacent to the shore line.*
- *Sand protects E. coli from breaking down from UV light.*

- *Sand acts as a nutrient source for the E. coli.*
- *E. coli lives longer in the sand.*
- *E. coli attach themselves to the sand particles.*
- *E. coli levels in the shoreline adjacent to sand can remain high even if E. coli levels are lower in the water body further from shore.*
- *E. coli have the ability to accumulate in the sand environment and then as waves hit the shore, the shore acts as a non-point source of contamination for the water body.*
- *Freshly placed sand can have E. coli contamination within two weeks (Whitman and Nevers, 2003).*

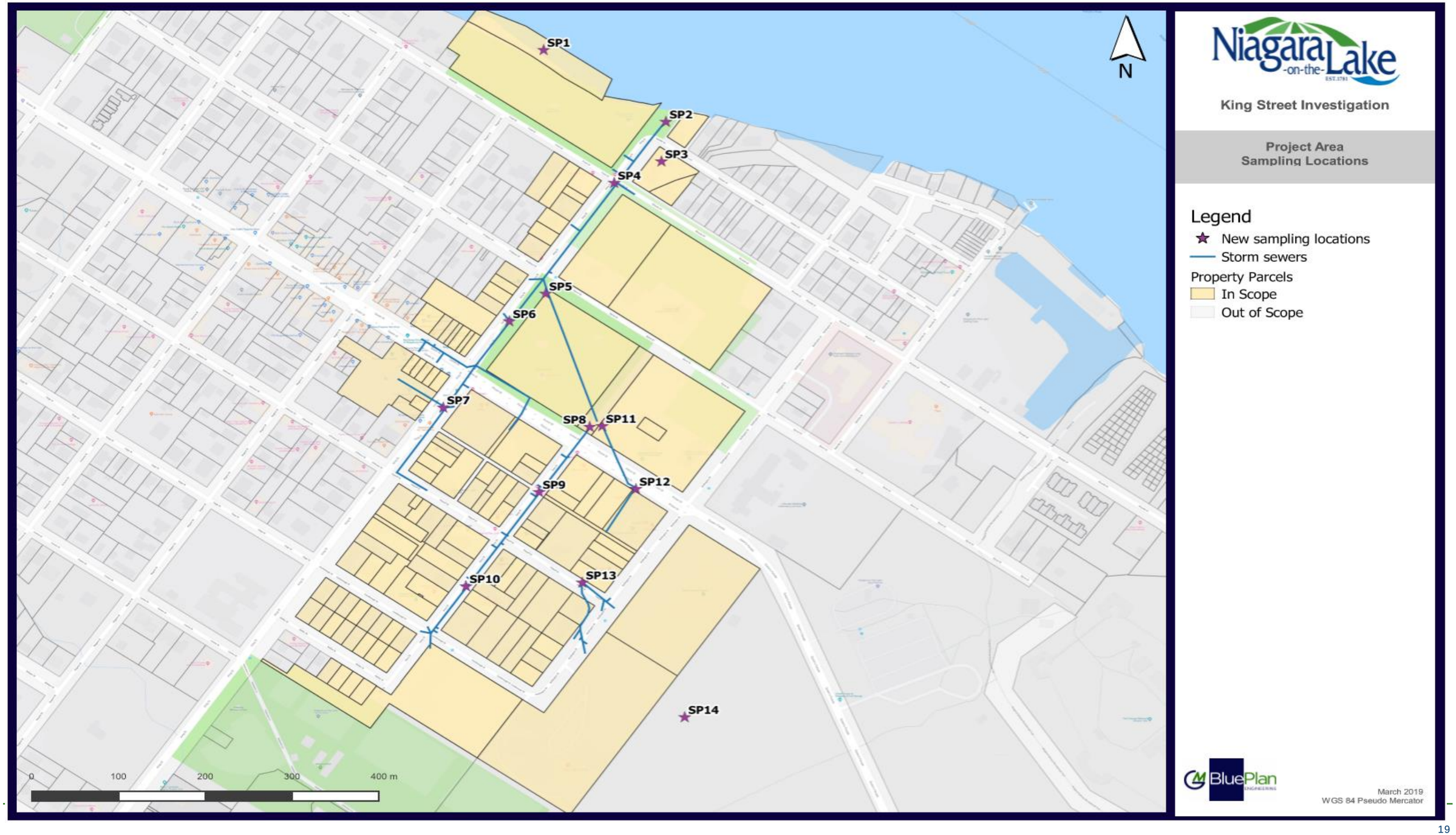
GMBP recommends NOTL completes a DNA analysis bi-weekly during beach sampling to understand the source of high *E. coli* levels at the beach. This will assist in determining if gull, human, or other *E. coli* sources are significant contributors impairing beach water quality. If gull *E. coli* is identified as a significant contributor, NOTL should implement wildlife management (decoy wolves or owls moved at intervals or noise makers) to prevent geese from visiting QRB.

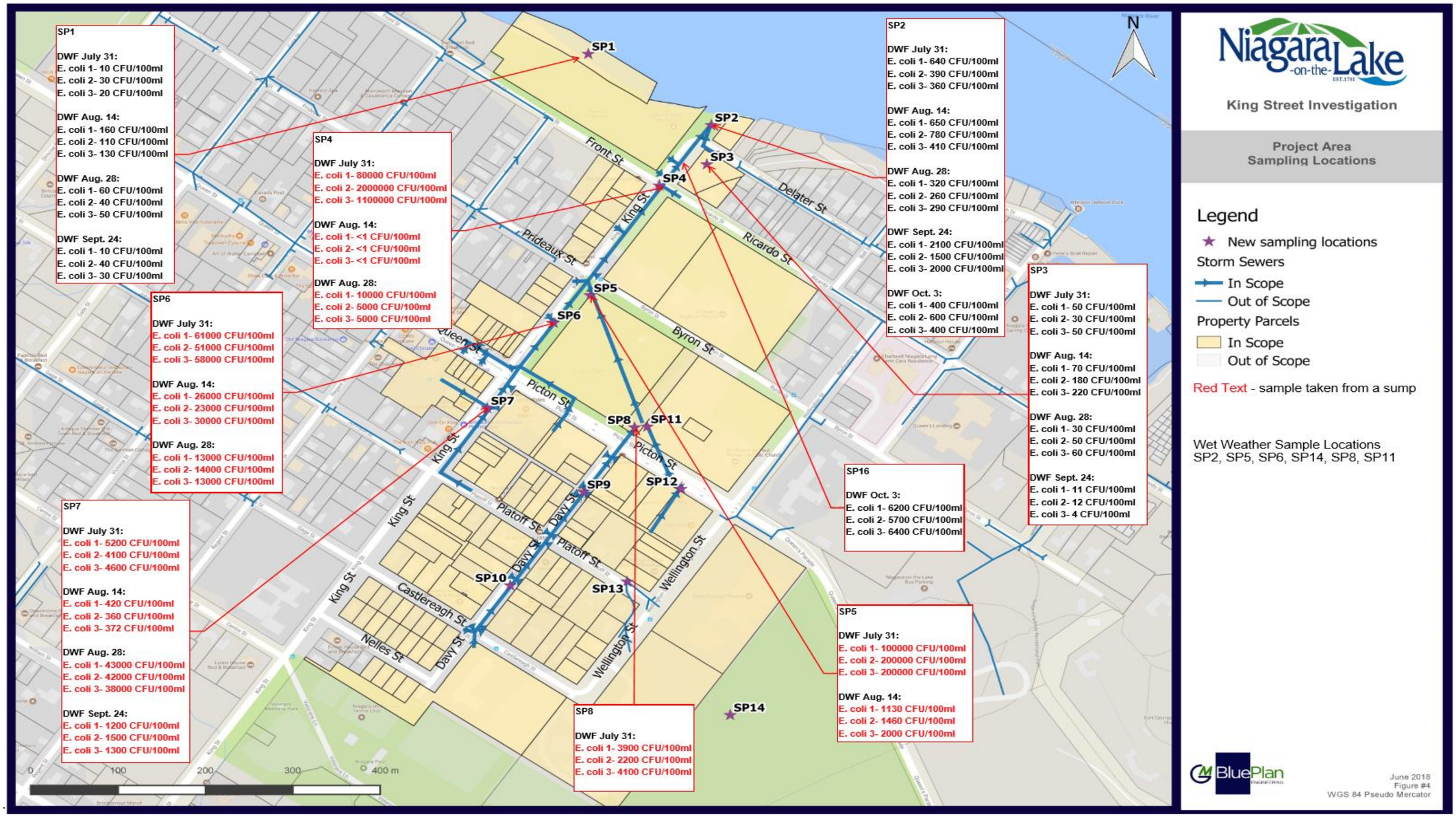
5. SAMPLE PLAN 2018 (GMBP)

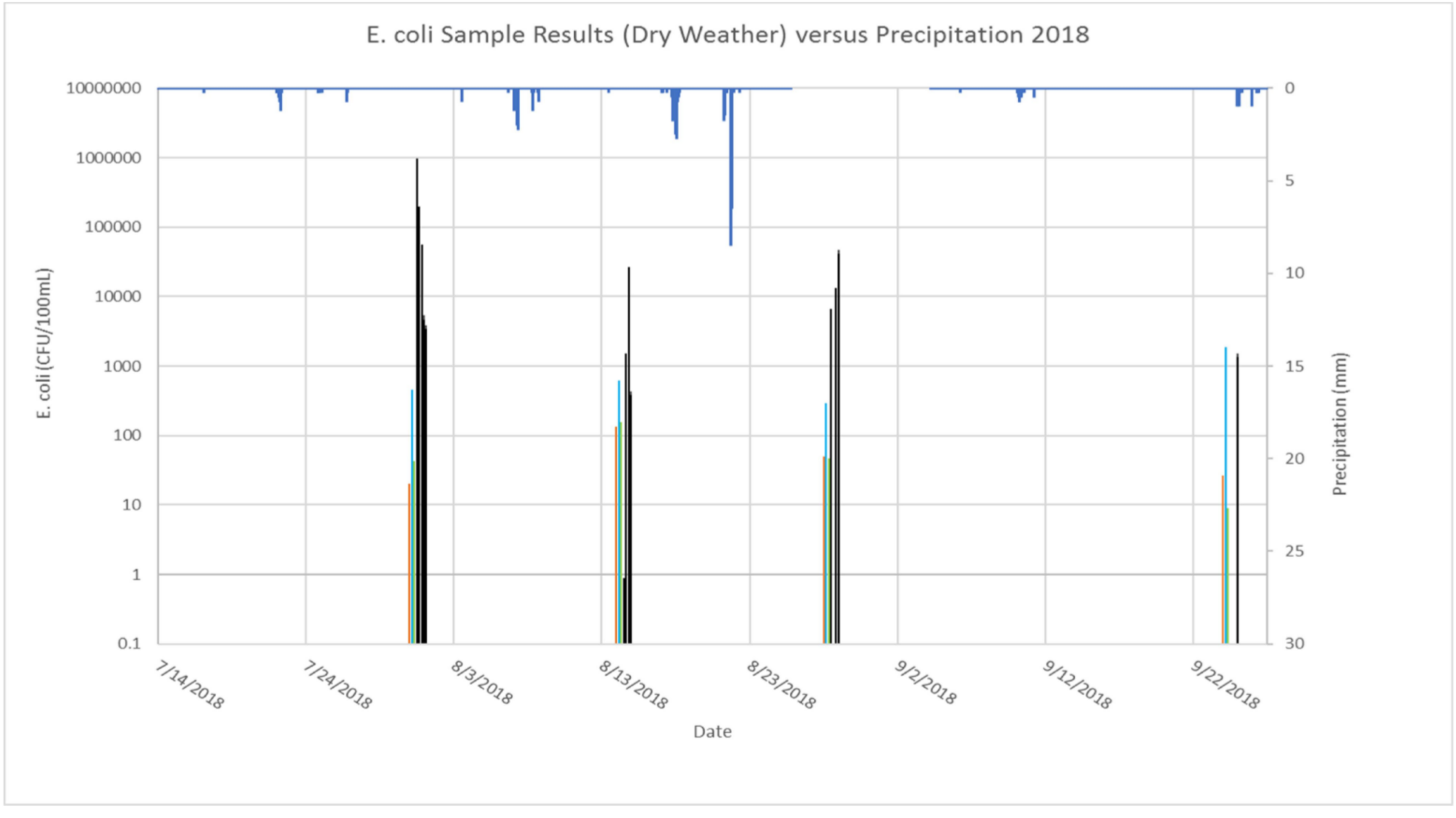
GMBP outlined a new sampling plan which was implemented July-September 2018. For a detailed rationale of each sample location selected, refer to the GMBP sample plan located in **Appendix C**. A detailed schedule was developed for dry weather sampling to allow for long term comparison of results.

The tri-weekly sampling was initiated on July 31, 2018 by NOTL employees and was conducted until Sept. 24, 2018. GMBP provided initial supervision to ensure collection and transportation procedures followed the sample plan. The samples collected in dry weather were analyzed by E3 Laboratories Inc. due to their proximity to the study area, as the sample biological composition is time and temperature sensitive. For more information on water sampling protocols, please refer to **Appendix D**. GMBP sample result analysis for dry flow, wet weather flow, and QRB sampling is included in **Appendix N.**

The 2018 sample plan also outlined the procedure for wet weather sampling. When a rain event took place, six sample locations had wet weather sampling. A grab sample was taken during the first flush (first 30 minutes of a storm event) and an additional 3 grab samples were taken each hour after the first flush event, following MECP protocol for wet weather sampling. Wet weather samples were submitted to Environment Canada for a DNA analysis using a micro-chip based approach to digital PCR to compare amounts of gull or human DNA markers. The following maps outline sample locations and dry weather sampling results.


SP1
SP2
SP3
SP4
SP5
SP6
SP7
SP8
SP11
SP9
SP12
SP10
SP13
SP14
N
0
100
200
300
400 m
King Street Investigation
Project Area
Sampling Locations
Legend
New sampling locations
Storm sewers
Property Parcels
In Scope
Out of Scope
March 2019
WGS 84 Pseudo Mercator


SP1
DWF July 31:
E. coli 1- 10 CFU/100ml
E. coli 2- 30 CFU/100ml
E. coli 3- 20 CFU/100ml
DWF Aug. 14:
E. coli 1- 160 CFU/100ml
E. coli 2- 110 CFU/100ml
E. coli 3- 130 CFU/100ml
DWF Aug. 28:
E. coli 1- 60 CFU/100ml
E. coli 2- 40 CFU/100ml
E. coli 3- 50 CFU/100ml
DWF Sept. 24:
E. coli 1- 10 CFU/100ml
E. coli 2- 40 CFU/100ml
E. coli 3- 30 CFU/100ml
SP2
DWF July 31:
E. coli 1- 640 CFU/100ml
E. coli 2- 390 CFU/100ml
E. coli 3- 360 CFU/100ml
DWF Aug. 14:
E. coli 1- 650 CFU/100ml
E. coli 2- 780 CFU/100ml
E. coli 3- 410 CFU/100ml
DWF Aug. 28:
E. coli 1- 320 CFU/100ml
E. coli 2- 260 CFU/100ml
E. coli 3- 290 CFU/100ml
DWF Sept. 24:
E. coli 1- 2100 CFU/100ml
E. coli 2- 1500 CFU/100ml
E. coli 3- 2000 CFU/100ml
DWF Oct. 3:
E. coli 1- 400 CFU/100ml
E. coli 2- 600 CFU/100ml
E. coli 3- 400 CFU/100ml
SP3
DWF July 31:
E. coli 1- 50 CFU/100ml
E. coli 2- 30 CFU/100ml
E. coli 3- 50 CFU/100ml
DWF Aug. 14:
E. coli 1- 70 CFU/100ml
E. coli 2- 180 CFU/100ml
E. coli 3- 220 CFU/100ml
DWF Aug. 28:
E. coli 1- 30 CFU/100ml
E. coli 2- 50 CFU/100ml
E. coli 3- 60 CFU/100ml
DWF Sept. 24:
E. coli 1- 11 CFU/100ml
E. coli 2- 12 CFU/100ml
E. coli 3- 4 CFU/100ml
SP4
DWF July 31:
E. coli 1- 80000 CFU/100ml
E. coli 2- 2000000 CFU/100ml
E. coli 3- 1100000 CFU/100ml
DWF Aug. 14:
E. coli 1- <1 CFU/100ml
E. coli 2- <1 CFU/100ml
E. coli 3- <1 CFU/100ml
DWF Aug. 28:
E. coli 1- 10000 CFU/100ml
E. coli 2- 5000 CFU/100ml
E. coli 3- 5000 CFU/100ml
SP5
DWF July 31:
E. coli 1- 100000 CFU/100ml
E. coli 2- 200000 CFU/100ml
E. coli 3- 200000 CFU/100ml
DWF Aug. 14:
E. coli 1- 1130 CFU/100ml
E. coli 2- 1460 CFU/100ml
E. coli 3- 2000 CFU/100ml
SP6
DWF July 31:
E. coli 1- 61000 CFU/100ml
E. coli 2- 51000 CFU/100ml
E. coli 3- 58000 CFU/100ml
DWF Aug. 14:
E. coli 1- 26000 CFU/100ml
E. coli 2- 23000 CFU/100ml
E. coli 3- 30000 CFU/100ml
DWF Aug. 28:
E. coli 1- 13000 CFU/100ml
E. coli 2- 14000 CFU/100ml
E. coli 3- 13000 CFU/100ml
SP7
DWF July 31:
E. coli 1- 5200 CFU/100ml
E. coli 2- 4100 CFU/100ml
E. coli 3- 4600 CFU/100ml
DWF Aug. 14:
E. coli 1- 420 CFU/100ml
E. coli 2- 360 CFU/100ml
E. coli 3- 372 CFU/100ml
DWF Aug. 28:
E. coli 1- 43000 CFU/100ml
E. coli 2- 42000 CFU/100ml
E. coli 3- 38000 CFU/100ml
DWF Sept. 24:
E. coli 1- 1200 CFU/100ml
E. coli 2- 1500 CFU/100ml
E. coli 3- 1300 CFU/100ml
SP8
DWF July 31:
E. coli 1- 3900 CFU/100ml
E. coli 2- 2200 CFU/100ml
E. coli 3- 4100 CFU/100ml
SP16
DWF Oct. 3:
E. coli 1- 6200 CFU/100ml
E. coli 2- 5700 CFU/100ml
E. coli 3- 6400 CFU/100ml
SP1
SP2
SP3
SP4
SP5
SP6
SP7
SP8
SP9
SP10
SP11
SP12
SP13
SP14
Front St
Prideaux St
King St
Queen St
Picton St
Delater St
Ricardo St
Byron St
Platoff St
Davy St
Castlereagh St
Nelles St
Wellington St
N
0
100
200
300
400 m
Niagara-on-the-Lake
EST.1781
King Street Investigation
Project Area
Sampling Locations
Legend
New sampling locations
Storm Sewers
In Scope
Out of Scope
Property Parcels
In Scope
Out of Scope
Red Text - sample taken from a sump
Wet Weather Sample Locations
SP2, SP5, SP6, SP14, SP8, SP11
BluePlan ENGINEERING
June 2018
Figure #4
WGS 84 Pseudo Mercator


E. coli Sample Results (Dry Weather) versus Precipitation 2018
E. coli (CFU/100mL)
10000000
1000000
100000
10000
1000
100
10
1
0.1
Precipitation (mm)
0
5
10
15
20
25
30
7/14/2018
7/24/2018
8/3/2018
8/13/2018
8/23/2018
9/2/2018
9/12/2018
9/22/2018
Date

6. HUMAN *E. COLI* INFRASTRUCTURE IMPROVEMENTS

DNA analysis of the KSSO samples was completed by Environment Canada on wet weather grab samples. At the KSSO, gull DNA marker ranges from 51-95,004 DNA copies/100mL. Human DNA marker ranges from 44-942 DNA copies/100mL. The Davy Street Storm Sewer Outlet (DSSO) which ultimately drains to the KSSO, has Human 44-367 DNA marker copies/100mL. The following section summarizes the field investigation process used to determine areas which needed improvement to reduce human *E. coli* contamination.

The combination of wet and dry weather sampling with field investigations (discussed in subsequent sections) allowed GMBP to identify the following sources of Human *E. coli* in the KSSO catchment area. **GMBP recommendations are in bold:**

1. Lateral from the wading pool in Simcoe Park connected to the storm sewer (drained daily). **Lateral to be connected to the sanitary sewer prior to May 24, 2019 ($11,000).**
2. On King Street, a poor condition sanitary manhole (with a sewage forcemain connection) beside a poor condition storm manhole with a cracked storm outlet pipe, directly below the sanitary asset area of concern (storm at a lower elevation then sanitary). **Manhole replacement/rehabilitation (similar costs) and outlet improvement ($22,000).**
3. Abandoned engineering drawing review identified abandoned pipes that were not filled with concrete. The abandoned pipes act as a conduit for cross-connection flows between sanitary and storm infrastructure. To date CCTV data has not been provided to GMBP for Queen Street sanitary sewer, therefore the condition is currently unknown. Queen Street has the highest amount of abandoned sanitary infrastructure. The hot vapour investigation flagged 27 Queen Street (large pavement area had melted snow). This property had a CCTV attempt from private property, but the survey was abandoned due to lateral condition. **GMBP recommends a CCTV sanitary investigation including lateral launch of Queen Street connections ($5,000).**
4. On King Street is an abandoned clay sanitary pipe in poor condition with an active connection. **Locate property with active connection and fill pipe ($5,000).**
5. An abandoned storm pipe is connected to the King Street storm sewer, in poor condition, near a poor condition private property sanitary lateral exfiltrating sewage. **Cap and fill abandoned storm pipe ($4,000).**
6. GMBP has identified multiple sanitary pipes in the KSSO catchment area that do not have CCTV data (was not provided for GMBP review). **NOTL to confirm if CCTV data exists for these sanitary pipes and complete CCTV in areas (as required) and PACP defect condition assessment. GMBP estimates $7,000 to CCTV if all data gaps exist.**
7. Low flow cross-connections exist between mainline storm and sanitary sewers. **Meeting with GMBP and NOTL to determine threshold to repair mainline infrastructure based on CCTV mainline defect review to PACP standards.**
8. Sanitary lateral inspections identified six properties on Davy Street with sewage exfiltrating; four of the properties had large joint offsets located at the property line. Davy Street storm sewer is in very poor condition and should be improved to reduce private property sanitary contamination through cross connections. **Trenchless UV Structural Liner for Davy Street storm sewer ($126,000). Further discussion between NOTL and GMBP regarding fixing the four Davy Street lateral issues at property line.**
9. A total of 11 properties (including the Davy Street properties mentioned above) were flagged with sanitary laterals that had signs of sewage exfiltration. NOTL to either host a PIC or send a letter to **encourage residents in the KSSO project area to fix laterals. GMBP recommends postponing the PIC until other private property investigations in NOTL are completed (Garrison Village) to continue active voluntary CCTV participation.**

6.1 Other *E.Coli* Sources & Infrastructure Improvements

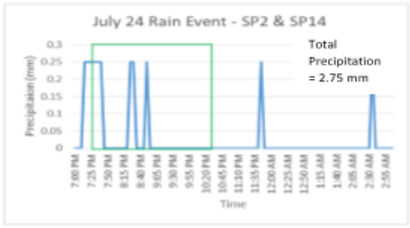
Environment Canada also measured *E. coli* in Colony Forming Units (CFU) which is a live count of bacteria grown on plates as opposed to DNA marker numbers which uses a molecular technology to detect the bacteria. Environment Canada indicated *E. coli* levels range from 210-223,000 CFU/100mL. GMBP has outlined the following other sources of *E. coli* with recommendations in **bold**:

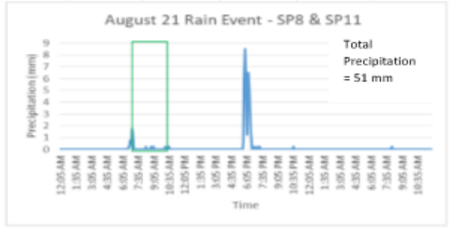
1. Racoons feces visible in the storm sewer system. **Wellington Storm inlet grate improvements prior to May 24, 2019 ($1,500).**
2. Horse carriage routes throughout KSSO catchment, with the majority of horse traffic on King Street, with feces evident on the road. **NOTL to discuss removing the horse carriage routes to reduce *E. coli* loading to KSSO to reduce *E. coli* loading at QRB.**
3. A horse polo match occurred in the Wellington Street storm sewer catchment, post sampling showed an increase of 61,400 CFU/100mL of *E. coli* in the drainage ditch. **NOTL to confirm proper feces mitigation/cleanup during and after event.**

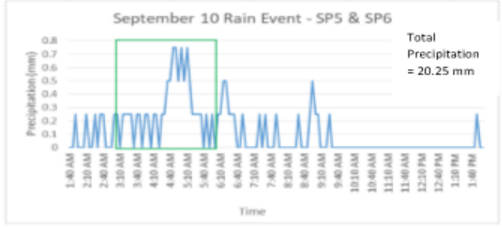
For a detailed summary of Environment Canada sampling results, refer to the following visual.

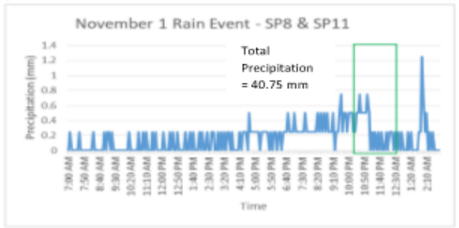
		Total E.coli (CFU/100mL)					Human DNA (DNA copies/100mL)					Gull DNA (DNA copies/100mL)				
		24-Jul	21-Aug	10-Sep	24-Sep	1-Nov	24-Jul	21-Aug	10-Sep	24-Sep	1-Nov	24-Jul	21-Aug	10-Sep	24-Sep	1-Nov
SP2	SP2-1	10*			142,000		747			96		449			No detection	
	SP2-2	94,000			67,000		942			115		46,329			No detection	
	SP2-3	86,000			45,000		567			78		95,004			No detection	
	SP2-4	46,000			21,000		570			44		33,200			No detection	
SP14	SP14-1	4,900			71,000		No detection			No detection		210			No detection	
	SP14-2	5,700			56,000		No detection			No detection		51			No detection	
	SP14-3	9,600			68,000		No detection			No detection		64			No detection	
	SP14-4	7,400			71,000		No detection			No detection		53			No detection	
SP5	SP5-1			204,000					126					98		
	SP5-2			108,000					No detection					No detection		
	SP5-3			223,000					76					No detection		
	SP5-4			40,000					183					No detection		
SP6	SP6-1			0*					No detection					No detection		
	SP6-2			23,000					No detection					1,250		
	SP6-3			11,800					51					350		
	SP6-4			4,800					No detection					186		
SP8	SP8-1		8,200			11,800		273			138		53			No detection
	SP8-2		12,000			112,000		110			100		No detection			No detection
	SP8-3					220,000					367					No detection
SP11	SP11-1		210			6,400		64			119		No detection			No detection
	SP11-2		6,600			1,770		191			128		117			No detection
SP18 (Wellington St. Storm Outlet)	SP18-1					116,000					226					No detection
	SP18-2					22,000					233					No detection
	SP18-3					17,700					192					82

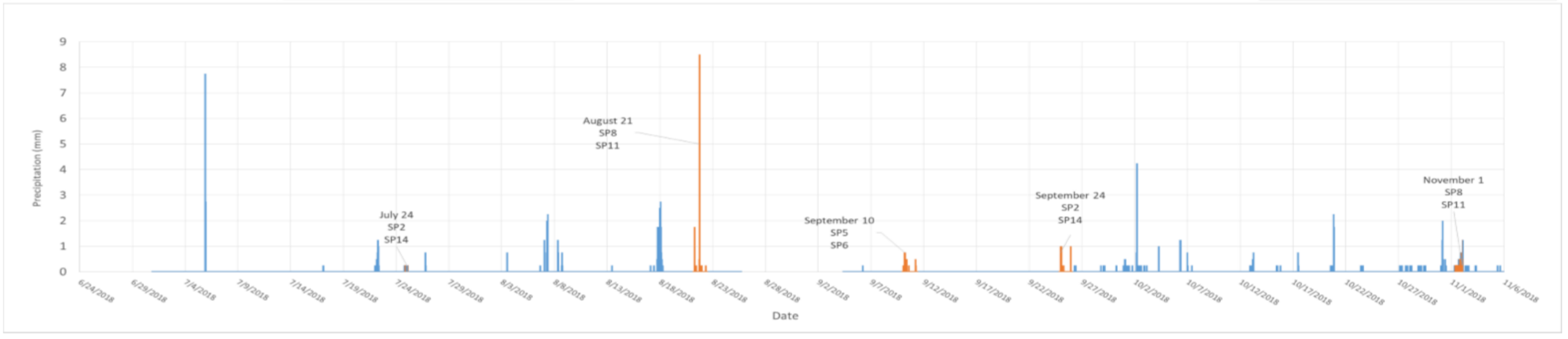
* indicates inaccurate laboratory reading due to high levels of suspended solids











6.2 GMBP Field Investigations

Field investigations were completed including:

- Smoke testing to flag properties for private property CCTV
- Horse carriage route
- Hot vapour to determine storm sewers with heat
- Infrastructure condition assessments
- Abandoned infrastructure investigations
- Comparison of in-field conditions to GIS data set

GMBP identified that the majority of Human *E. coli* sources at the KSSO are from low-flow cross-connections. From the background data review, GMBP notes that no sanitary products (toilet paper etc.) have been found in the storm sewer system. The following figure shows a low flow cross-connection between sanitary and storm infrastructure.

6.3 Smoke Testing & Private Property CCTV

GMBP smoke tested storm and sanitary sewers in the KSSO catchment area to flag properties with irregular results. Smoke testing helps locate improper connections. Detailed communication materials were hand delivered by GMBP inspectors to residents prior to smoke testing, to explain in person the test procedure and reduce calls to emergency services. Communication materials provided to properties in the project area are included in **Appendix H**.

Properties flagged from smoke testing were offered a voluntary private property CCTV investigation to determine the condition of the sanitary lateral. A total of 42 properties were flagged from the smoke testing investigations: 8 with smoke in the building, 7 with I/I sources (foundation drains and downspouts connected to sewer) and 27 total vent stack issues (sanitary vent stack on property did not smoke during sanitary smoke testing). For a map summarizing smoke testing results and CCTV participation summary map refer to **Appendix I**. Detailed documentation of findings at each property is included in **Appendix J**.

Table 3 summarizes 11 poor condition sanitary laterals which contribute sanitary flow to the subsurface environment and ultimately the groundwater table. GMBP notes a sanitary lateral launch from the mainline sewer was only completed for Davy Street to date. GMBP recommends Queen Street to have a similar investigation as no sanitary CCTV data was provided for GMBP review; this street has been flagged as having the highest amount of abandoned infrastructure in the KSSO catchment area and 27 Queen Street was flagged during the hot vapour investigation.

Table 3: Sanitary Laterals with Sewage Exfiltration in the KSSO Catchment Area

Urgency to Fix	Address	Property Type	Sanitary Lateral Issues	Result from Investigation Type
Low	**20 Queen St.**	Commercial (LCBO)	Sanitary lateral dislodged joint (slight).	Private Property CCTV
High	**163 King St.**	Residential	Portion of sanitary lateral missing the bottom of pipe under house foundation, significant sewage flow exiting the lateral.	Private Property CCTV
High	**153 King St.**	Commercial (Art Gallery)	Sanitary lateral in poor condition, three areas of broken pipe with significant sewage flow exiting the lateral.	Private Property CCTV
High	**135 King St.**	Residential	Irregular lateral connection identified through abandoned infrastructure CCTV investigation. Sanitary lateral appeared to connect to mainline sanitary pipe through a small diameter hole. Possible poor mainline connection. Homeowner indicated they would contact GMBP for a CCTV once back from vacation.	Follow up required
Med	**66 Platoff St.**	Residential	Sanitary lateral has multiple cracks (clay pipe) and joint dislodge.	Private Property CCTV
High	**230 Davy St.**	Commercial (Bed and Breakfast)	Sanitary lateral broken pipe, significant sewage flow exiting the lateral.	Private Property CCTV
High	**222 Davy St.**	Institutional (Church)	Joint Offset Large (JOL) at property line connection (9.0m).	Private Property CCTV and Mainline Lateral Launch
High	**287 Davy St.**	Residential	Roots Medium Joint (RMJ) and Joint Offset Medium (JOM) at property line connection (11.9m).	Mainline Lateral Launch
High	**270 Davy St.**	Residential	Roots Medium Ball (RMB) - 25% at property line connection (11.0m).	Mainline Lateral Launch
High	**238 Davy St.**	Residential	Joint Offset Large (JOL) at property line connection (7.6m).	Mainline Lateral Launch
Med	**60 Picton St.**	Residential	No issues with lateral or connection. Private side noted heavy encrustation.	Mainline Lateral Launch

6.4 Condition Assessment & GIS Data Comparison

A condition assessment involving visual inspection of all storm and sanitary manholes was completed for the project area. Connections to manholes were compared to NOTL GIS data. Areas were flagged with missing GIS data, poor condition manholes, areas with the storm assets at a lower elevation than the sanitary assets, and high-risk areas for cross-connection flows between sanitary and storm assets. **Appendix K** provides a detailed overview of field investigation results which also identified that abandoned storm and sanitary infrastructure exist in the project area.

6.5 Abandoned Infrastructure

GMBP completed a detailed review of abandoned infrastructure using 50 engineering drawings provided by NOTL ranging in date from 1960-2011, with the majority of drawings from 1970. GMBP compiled abandoned water transmission lines, sanitary, and storm infrastructure into a GIS layer. **Appendix M** provides a detailed review of each engineering drawing and GIS summary visuals of abandoned infrastructure locations.

Reviewing the abandoned engineering drawings shed light on the historic process to abandoned infrastructure, which did not involve filling the pipe with concrete, only the manhole. Neglecting to fill a pipe with concrete during abandonment creates a conduit for future cross-connections as the pipe condition degrades.

An abandoned storm and sanitary pipe was identified in the KSSO catchment area. An abandoned clay sanitary pipe in poor condition (multiple breaks, sewage exfiltration) is located on King Street which also appears to still have an active connection (toilet paper throughout).

An abandoned storm sewer was identified on Prideaux Street which connects to the King Street storm sewer. The abandoned concrete storm sewer had holes in the pipe and is in close proximity to a private property (153 King Street) which had a broken sanitary lateral in poor condition exfiltrating sanitary sewage.

6.6 Hot Vapour Investigation

A project area walk was completed during winter weather (below -10 degrees Celsius) between 6am-7am (the time for peak sanitary sewer diurnal curve) to identify catchbasins steaming with hot water vapour. No catchbasins were identified as smoking with hot vapour yet 47% of catchbasins in the project area had enough heat to melt the snow piles surrounding the catchbasin. This indicates that no direct sanitary connections to the storm exist, rather low flow cross-connections are adding heat to the storm sewer. Refer to **Appendix J** for a summary map of melted catchbasin locations and summary of two private properties flagged from the investigation.

6.7 Horse Carriage Investigation

A GMBP inspector monitored horse carriage routes on Dec 22, 2018. Four horse drawn carriages completed routes during the four hours of GMBP monitoring in the downtown core of NOTL. **Appendix J** outlines a horse route heat map which demonstrates King Street receives the most horse traffic. Horse feces were evident on the road in multiple locations in the KSSO catchment area.

This confirms that the horse collection bags do not collect all horse droppings. This presumably contributes *E. coli* to the storm sewer during rainfall events. NOTL indicated the project area has street sweeping completed once a week.

7. CONCLUSION

NOTL and GMBP staff teams have taken a systematic and evidence-based approach to this project. This project has shown a compelling case toward the fact that NOTL, like all other municipalities, have some low flow cross-connections between sanitary and storm assets and local fauna bacterial issues in their storm sewer system.

Prioritization rehabilitation calculations were completed to support the order of repairs based on the *E. coli* source using factors to score the recommendation based on the *E. coli* loading rate, flow rate, volume of *E. coli*, DNA type (higher priority given to Human DNA) and the cost to fix. The prioritization table is included in **Appendix P**.

The following section outlines short term goals for NOTL, maintenance tasks, political discussion points, sampling for summer 2019 and long-term asset management recommendations for NOTL to apply Town wide.

7.1 King Street Working Group

GMBP, NOTL, Region of Niagara, Environment Canada, NPCA, and the MECP developed a working group which met once every 2-3 months to discuss project updates, findings, and initiatives since May 2018. The group has identified that success will be measured in summer 2019 by the number of beach postings (if *E. coli* levels are above 200 CFU/100mL).

MECP and NPCA have been given valuable insight to the process to apply moving forward including:

- The investigation process to apply.
- The power of the DNA analysis to distinguish between gull and human *E. coli* levels. Insight that racoons, horses, and gulls are likely high contributors of *E. coli* to the storm sewer system.
- Sample plan process (wet weather, dry weather, proper protocol, locations to sample).
- The importance of data collection of assets (condition assessment of infrastructure, connections to manholes compared to GIS data records).
- The importance of digital data records.
- Unique field investigations and the order in which to apply them.
- Historical areas and abandoned assets adding to cross-connection flows.
- Historical processes (connecting new infrastructure to existing manholes, not filling abandoned pipes).
- Private property homes with poor condition laterals.
- Poor quality connections of the sanitary lateral located at property line.
- The importance of CCTV data and a database submission.

MECP has encouraged GMBP and NOTL to present findings moving forward to educate other municipalities.

7.2 *E. coli* in Stormwater at Other Municipalities

High levels of *E. coli* are a common challenge in stormwater in municipalities across Ontario. Access to *E. coli* data is limited as it is sensitive information due to public perception. GMBP has outlined the following areas that have similar *E. coli* issues with storms sewer outlets:

- The Hamilton Harbour has an ongoing contamination and *E. coli* issue. Beaches were closed to the public between 70 and 90% of the days in 2017. The *E. coli* levels reached over 1000 CFU/100mL several times during the season at Bayfront Beach. Much of this *E. coli* is known to come from bird fecal droppings.
- Toronto Harbour. *E. coli* levels as high as 24,000 CFU/100mL.
- Lake Erie State Park beach in New York had *E. coli* levels of 45,000 CFU/100mL.

The Lake Erie State Park applied a unique Low Impact Development (LID) using mycofiltration (mushrooms) in which

post LID water quality monitoring showed *E. coli* reduction by 40%.

7.3 LID Implementation in NOTL

At the King Street working group meeting on Oct 30, 2018, it was suggested that the Ministry of the Environment and Climate Change may provide funding to NOTL through the Great Lakes Protection Initiative for projects that support the goals of the Remedial Action Plan such as implementation of Low Impact Development (LID) stormwater management techniques in the project area. LID installations are also encouraged by MECP. As a result, NOTL will be working towards installation of a LID at Simcoe Park and KSSO. Details are discussed under separate cover. GMBP stresses the importance of funds going towards infrastructure improvements to remove *E. coli* loading to the storm sewer system first and foremost.

7.4 Short-Term Goals for NOTL

The following short-term goals have been outlined for NOTL to be completed prior to May 24, 2019 since a Region bylaw prevents construction in tourist areas until after Labour Day weekend:

- Disconnect wading pool lateral connection to the storm sewer in Simcoe Park and connect to the sanitary sewer (cost estimate $11,000).
- Replace the sanitary manhole with the Region of Niagara sewage forcemain connection and rehabilitation of the storm manhole and outlet in poor condition (and at a lower elevation) located on King Street and Front Street (cost estimate $22,000).
- Grate improvements to the Wellington Street storm sewer inlet to prevent racoon entry (cost estimate $1,500).

7.5 Maintenance Improvements for NOTL

Sediment acts as a protective environment for *E. coli*. This environment allows increased survival and accumulation of *E. coli* bacteria. Increased maintenance recommendations for the project area include:

- System flushing of the KSSO catchment area once grates are installed on Wellington Street storm inlet.
- Secondary system flushing to reduce KSSO *E. coli* levels during summer 2019.
- Sump maintenance to be performed once a month in summer 2019 to continually remove sediment and debris in storm manholes and catchbasins.
- Manual labour (difficult truck access area) for catchbasin sump cleaning in Simcoe Park once a month in summer 2019.
- Simcoe Park inlet catchbasin for the DSSO to be monitored monthly for sediment build-up.

7.6 Political Discussion for NOTL Improvements

Horses in the project area likely add *E. coli* to the storm sewer system through runoff during rain events. GMBP investigated the route of the horse carriages and found that King Street receives the most horse traffic. GMBP gathered photo evidence of multiple areas with horse feces. Thus, the horse droppings may be an additional source of *E. coli* to the storm sewer system. NOTL should weigh the benefit of the horses as a tourist attraction to the *E. coli* being received to KSSO and ultimately QRB.

7.7 Summer 2019 Sampling Recommendations

GMBP identifies that it is possible *E. coli* is in the groundwater prior to entering the project area. If so, this would suggest that any storm asset with groundwater infiltration would be a source of *E. coli*. **GMBP recommends a groundwater monitoring well for summer 2019 sampling and DNA analysis be installed in the KSSO catchment area.**

The shallow aquifer discharge on Delater Street had upwards of 220 CFU/100mL which would be considered a fail for the water quality objective standards of 200 CFU/100mL. **GMBP recommends a DNA analysis be completed summer 2019.**

As there is a relationship between surface water and groundwater, whereby groundwater can serve to replenish surface water flow and vice-versa, **GMBP recommends One Mile Creek (intersecting King Street) be sampled for *E. coli* and DNA analysis.**

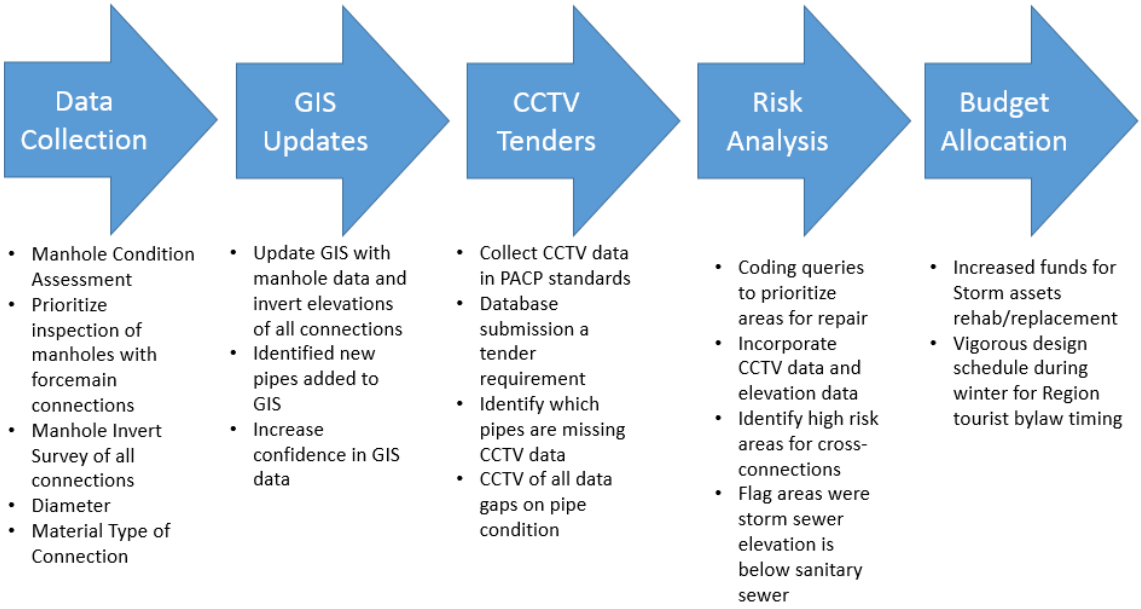
If sampling of One Mile Creek produces positive test results for *E. coli*, it is possible *E. coli* has entered the groundwater aquifer due to farming in groundwater recharge areas and highly vulnerable aquifers located upstream of the project area, based on Niagara Peninsula Conservation Authority (NPCA) aquifer data**. GMBP recommends NOTL investigate farming practices upstream to determine potential source of *E. coli*, including improper manure application, timing, and amounts.**

During summer 2019, QRB beach sampling is recommended to include a bi-weekly DNA analysis. If gull is found to be the highest contributor of *E. coli* at QRB, **NOTL to consider wildlife management** (decoys moved at intervals, sound makers) to reduce geese presence at QRB. GMBP also recommends that the QRB beach grab samples be analyzed by the laboratory for ***E. coli* values greater than 1000 CFU/100mL** (summer 2018 maximum dilution value). This will allow for comparison of *E. coli* levels as upstream infrastructure improvements are made in the KSSO catchment area.

Refer to **Appendix L** for further details regarding NPCA data on aquifers in the area and recommended sampling points map for summer 2019.

8. LONG TERM BEST MANAGEMENT PRACTICES FOR NOTL

GMBP believes infrastructure asset management will further identify cross-connections between storm and sanitary infrastructure in NOTL, as with any municipality. The process involves increased data collection (manhole condition assessment, invert survey of all connections). New data is updated into GIS to flag pipes missing in the GIS dataset and pipes with no CCTV data. With improved electronic data, NOTL can make data driven decisions for budget allocation for infrastructure improvements moving forward. The process has been summarized in the following Figure and discussed in **Appendix P** in more detail.



Moving forward, GMBP recommends that NOTL increase funds to improve storm and sanitary mainline infrastructure that are in poor condition and which allow cross-connection flows between the sanitary and storm systems.