PORT COLBORNE

Wignell Watershed
Hydrology and Hydraulics Report

August 31, 2021

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Notice:
This report is based on information and data that was available for review as provided. The analysis undertaken is for the purpose stated in the report and is not for use elsewhere.

Table of Contents

Figures

Tables

1 Introduction

The City of Port Colborne retained Paul Marsh, P.Eng of EWA Engineers Inc. to prepare a Drainage Report under the Drainage Act R.S.O. 1990 for the Wignell Drain. The Wignell Drain Engineer's Report is prepared as follows:

- Baseline Drainage Report; provides an assessment of current drainage problems and identifies the extent of the drainage area to be serviced by the municipal drain.

- Wignell Watershed Report; provides an capacity assessment of existing capacity through the use of hydrologic and hydraulic modelling to assess existing conditions and design for future conditions. The modelling will be used to identify the options for resolving problems and recommends a preferred option to improve drainage.

The final Engineer's Report is composed of the two previous reports along with supporting documentation and final drainage cost estimates and assessment schedule or table.

There are other Drain Reports being prepared concurrently. Of those drainage projects, there are two that have the Wignell Drain as their outlet and they are:

- Michener Drain, outlets to Wignell at 0+010 North of the Lakeshore East Rd. and proceeds northerly for 1.6km, ending South of the Friendship Trail.

- Port Colborne Drain, outlets to the Wignell at 2+062 South of the Friendship Trail and proceeds northerly for 3.3km ending at or near the Second Concession Road.

This report is the Wignell Watershed Report and provides a summary assessment of the existing drainage issues for the following drains:

- Wignell Drain,
- Port Colborne Drain, and
- Michener Drain.

There is a Baseline Drainage Report for each of the three drains that presents the current, as of 2018, baseline or reference conditions. In some cases, a drainage issue may be identified in the Baseline Report but deferred from implementation in the Drain Engineer's report. The Baseline Report identifies the total needs of the drain works but does not provide specific recommendations on implementation.

The Port Colborne drain originally had an outlet to Lake Erie but was diverted to the Wignell by an Engineer's report. For some number of years, the upper portion has been referred to as a branch of the Wignell Drain but by the preparation of the planned Engineer's Report with a revised Cost Assessment Schedule it will be recognized as the Port Colborne drain with an outlet to the Wignell Drain south of the Friendship Trail. This new Port Colborne Drain Engineer's Report is expected to be prepared in concert with the Wignell Report and the Michener Drain Report. The following Figure presents the proposed drain names and drainage boundaries. For a more detailed map, refer to Appendix B.

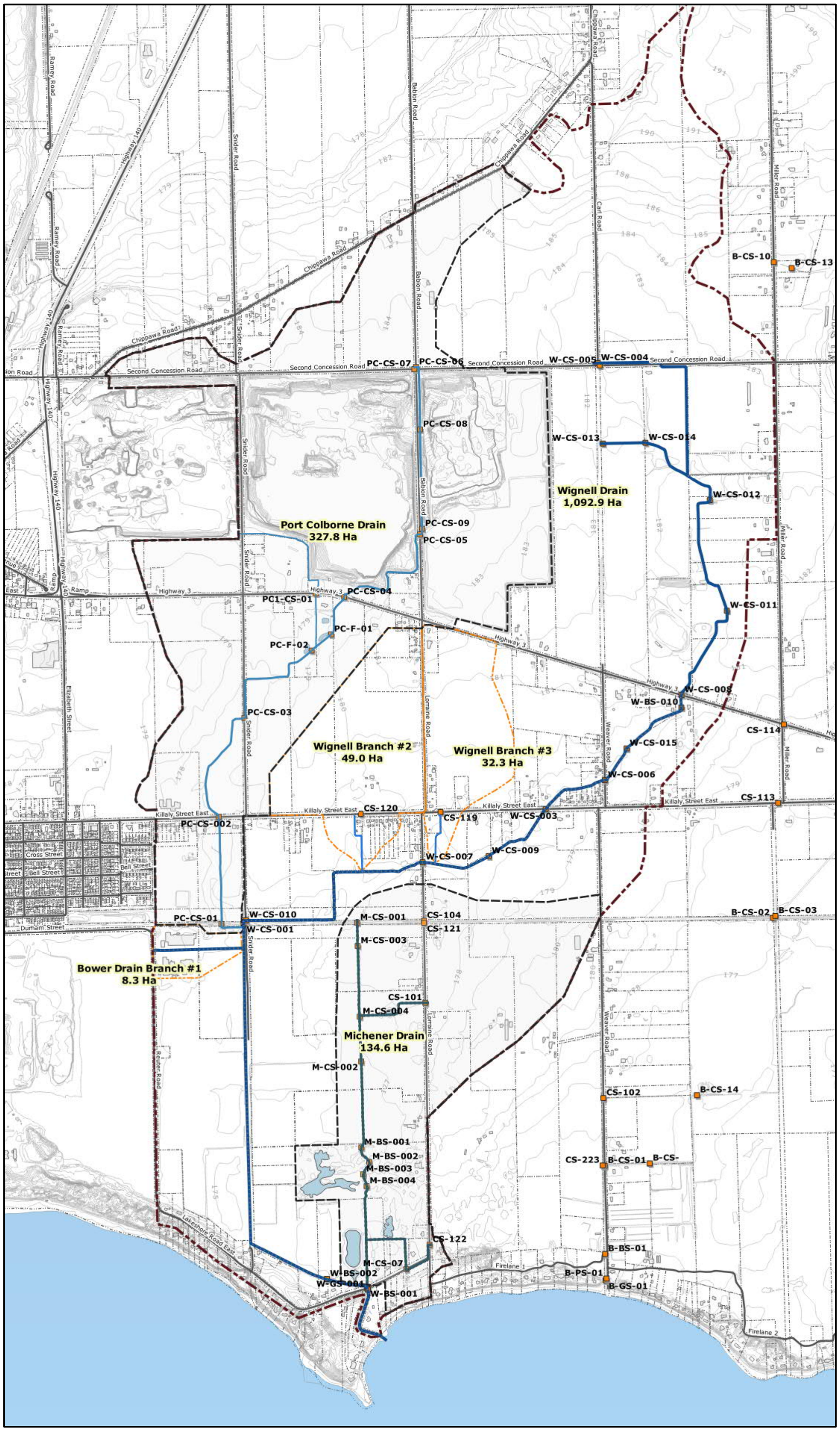


Figure 1 Municipal Drains - Wignell Boundary

1.1 Wignell Drain Watershed

The Wignell Drain Watershed is composed of four distinct municipal drains:

- **Bower Drain**; a small 400m drain that will become a branch drain of the Wignell in the 2018 Drain Report.
- **Port Colborne Drain**; renamed from Wignell W1 to return to the original name prior to the outlet being diverted into the Wignell. Has had extensive upload capture from the Quarry.
- **Michener Drain**; smaller drain, 1,700m outlets to the Wignell just north of the Lakeshore Road East Bridge and Control Structure.
- **Wignell Drain**; the main branch of the Watershed that outlets to Lake Erie and extends to Second Concession Road.

The Wignell drain serves an area of 614 hectares based on the defined drain boundary, refer to Figure 2. The main branch of the drain is 6850.8m in length from the drain origin, which is defined as the gate on the control structure south of Lakeshore East and is 289m to the outlet into Lake Erie for a total main drain length of 7139.8m.

The watershed boundary is south of Chippawa Rd. and just East of Carl Rd. with a high point of 195m. The drain is defined to end at the intersection of Carl Rd. and the Second Concession Rd. at an approximate elevation of 182m. The outlet at the lake varies with the change in Lake Levels but the recorded average lake level is given as 174.15. The lake level fluctuates and for the month of May has been 174.7m, which is higher than average and influences the water surface profile.

- Watershed average fall (slope) is given as 0.25% or 2.52m per 1000m
- Drain average fall (slope) is given as 0.11% or 1.1m per 1000m

This slope characterises the Wignell as low slope or slow watershed. In particular the lower portion of the drain is highly influenced by the Lake water elevation with a littoral sand beach influenced outlet.

North of the Friendship Trail, the Wignell Drain, was last maintained under an Engineer’s report by D. Ingram of R. V. Anderson, dated July 28, 1978. The lower reach, south of the Friendship Trail, was subsequently maintained in 1985, based on the June 21, 1969 C. J. Clarke Engineer’s report, along with periodic spot maintenance works thereafter.

Previous information and data regarding the Wignell Drain was provided to EWA Engineering for review. This information was compiled first by Wiebe Engineering Group (2001) and then by Amec Foster Wheeler (2014).

A Wignell Municipal Drain Concrete Retaining Wall was constructed in 2007.

Portions of the Wignell drain have become overgrown, degrading the performance of the drain throughout the watershed. Along with physical changes to the Drain needed for continued service, improvements at the floodgate structure, improved levels of service & securing legal outlet through the extension of branch drains, addressing irrigation purposes and the provision of water quality features have necessitated a new Engineer's report be prepared under Section 78 of the Drainage Act R.S.O. 1990 and that the City petition for new works on this drain under Section 4 of the Drainage Act R.S.O. 1990.

The City of Port Colborne made improvements to the Port Colborne drain on an emergency or opportunity basis that are not yet reflected in an Engineer's Report for the respective drain. Where improvements were performed, descriptions of the works are found in the Baseline report.

The drain can be segregated into three or four distinct geographic areas.

- Outlet and Dune environment; this area starts about 0+600 chainage marker and proceeds to the outlet. The drain follows what may have been an original watercourse path running parallel to the lake until it crosses the dune area to outlet at the lake. The outlet to the lake is perpetually changing with beach material moving across the drain outlet through wave action, referred to as littoral drift. This area has very low slope, features permanent water levels and the outlet will always require maintenance in the form of mechanical removal by equipment. While there are techniques to create a permanent outlet not affected by littoral drift, they are expensive and invasive to the lake environment. The outlet itself is a natural feature but the act of fixing it in one place isn't. Typically the outlet would move position as the dunes also moves and changes shape; however, with the beach area developed as private property, the outlet must remain in one place.

- From 0+600 to 2+400 (adjacent to Friendship Trail crossing); this area is recognised as a very low slope but transitions from the dune influenced area to a traditional open channel ditch with defined cross-sectional area. The drain in this area has standing water and is flow controlled by hydraulic gradeline rather than the ditch gradeline.

- From 2+400 to 6+065 is the main branch drain through a predominately farm land service area with rural residential properties and primarily concession roads but also Highway #3.

- From 6+065 to 6+851 main branch ends; this is the upper reach or source of the drain's runoff area. This area again features very low slopes and a low capacity drain area that is shown with 100 year flood lines that extend beyond the drain limits by a significant distance.

2 Study Approach

The analysis of the Wignell Watershed is based on Hydrologic and Hydraulic Scientific analysis. Water monitoring, gauge measurements, have not been practiced in the past and thus calibration or validation of the computer based model results is limited to historical anecdotal comparisons.

2.1 Methodology

There are two key engineering analysis methods that are key to the analysis of municipal drainage.

1. The prediction of runoff flow based on a hydrologic analysis.
2. The calculation of ditch and culvert capacity (ability to contain water flow) using hydraulic formulae.

2.1.1 Hydrologic techniques

The following figure illustrates the modelling and design process for sizing a ditch, channel or stream. The computer model predicts a peak flow (hydrograph) based on a mathematic model of runoff from a specific land use. The ditch is sized to convey the peak flow based on design parameters but significantly influenced by the available grade, slope m/m, for the ditch, channel or stream.

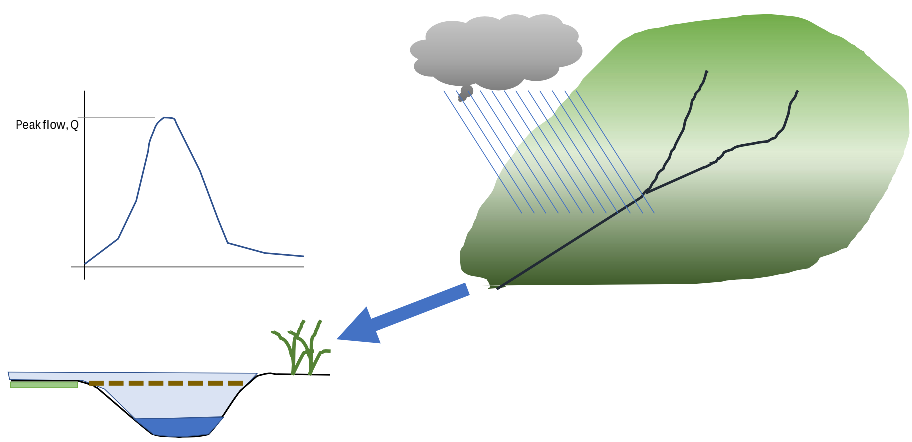


Figure 2 Watershed Predicted Runoff Peak Flow

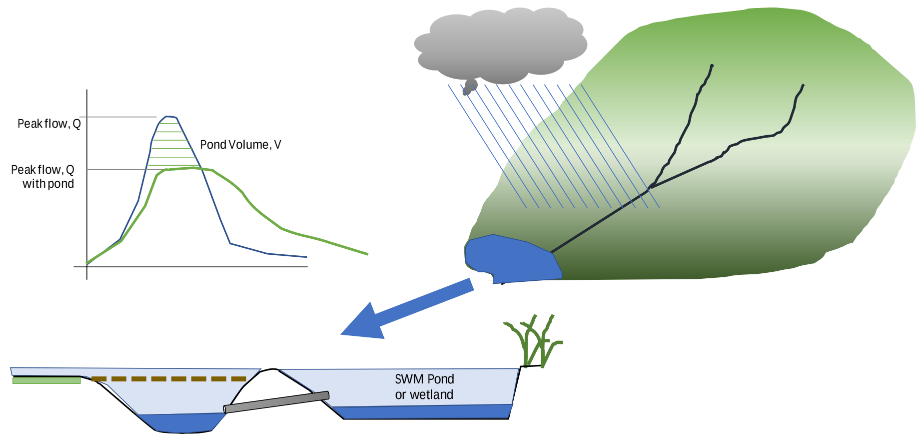


Figure 3 Watershed SWM Pond Runoff Peak Flow

The software selected for modelling is the US Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) Version 5.1

www.epa.gov/swmm

The following is provided as a description of the software and function.

> The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff-routing simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

This software was selected as being freely available, accessible and for the variety of techniques that are implemented and available. Specifically, the two techniques of interest are:

- Historically, runoff methods used for watershed modelling often implement the SCS Curve Number Method. The SCS curve number method is a simple, widely used and efficient method for determining the approximant amount of runoff from a rainfall event in a particular area.

- EPA SWMM is also used for Low Impact Development (LID) assessments. This is relevant to analysis of runoff function rather than the characterization available with the CN method.

2.1.2 Hydraulic techniques

The EPA SWMM computer based hydrology modelling implements dynamic routing in addition to the runoff methods, there is a characterization of the existing drainage system using simple hydraulic analysis. This is limited in assessing specific aspects of the existing system but provides a segment by segment and element by element comparison of previous design and current function.

The predominate analytical technique used is Manning's Equation (developed by Gauckler in 1867 and Manning in 1890) for fluid flow in open channels.

[redacted]

From this equation a prediction can be made of the existing capacity of the ditch or the maximum fluid flow for a culvert that is flowing full.

For a culvert operating in inlet control, where the head water is higher that the tail water, a different formula is used and based on MTO requirements can predict the maximum design capacity for the culvert or bridge crossing.

These hydraulic analysis techniques provide a means to compare current capacities from the upstream limit of the drainage system to the downstream outlet for the existing conditions.

The use of the hydrologic model allows a more detailed examination of the range of drainage performance conditions including the analysis of storage within the system.

These second analytical technique is used to assess the existing and potential use of additional storage elements within the drainage area such as ponds, wetlands and other runoff detection features.

2.2 Design Storm

There are in fact three primary scenarios that are proposed for investigation using EPA SWMM computer based analysis of the Wignell Watershed. They are as follows:

1. A 24 hour duration precipitation event with a range of frequency of occurrence from the likely (1:2 year) to the less probable events (1:50 year or 1:100 year). This event is characterized or described as a major precipitation event associated with a significant weather event.

2. A short duration highly intense summer time convective storm with a duration of 1 hour and a low frequency or probability of occurrence ranging to a higher probability of occurrence.

3. A winter time precipitation event. This is related to the event described in #1 but specifically occurs during the winter when the ground is frozen and limited infiltration occurs. There may also be melting contributing to the runoff but in this specific case, we are only considering the impact of rain on frozen ground as a worse case consideration for drainage performance.

These three types of scenarios will be investigated using EPA SWMM for the full range of IDF predicted storms; 1:2, 1:5, 1:10, 1:25, 1:50 and 1:100. There is a recognized risk of a Hurricane Hazel type of storm (referred to often as the Regional flood event) occurring that is not considered in this analysis other than the similarity that occurs within the rain on frozen ground case.

The storm probability analysis for Port Colborne is provided by a recording gauge and is reported at the web site:

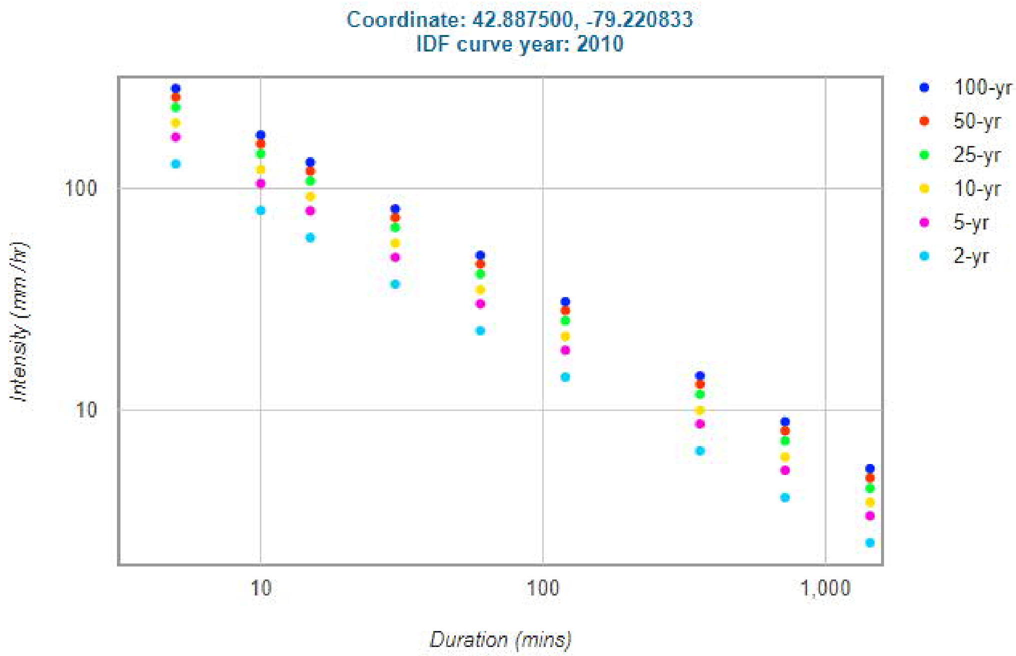


Figure 4 Port Colborne IDF Curve chart

From: http://www.eng.uwaterloo.ca/~dprincz/mto_site/results_out.shtml?coords=42.890648,-79.223098

The tables of intensity, volume values are provided in Appendix A.

From these tables two design storms are prepared for use within the Hydrologic analysis;

- As described in the Canada Flood Guide a SCS type storm is used for the longer duration event, 12 to 24 hour storms.
- The short duration intense storm is represented with the Chicago storm distribution to characterize the intense type of sudden storm.

The design storms are implemented and provided in Appendix A for reference.

2.2.1 Historical Precipitation Events

Also there are storms indicated in the precipitation record; 1979 and 1991 that are in excess of the 100 year storm and would provide historical context for field verification of model results. This is not a gauged watershed verification but using historical anecdotal observations to confirm runoff values as reasonable basis for validating model results.

Figure 5 Precipitation data for Nov 1991

Year 1991 had a value greater than the 100 year storm. Data 64.2mm

100 year = 63.1 - 2 hour storm comparable event

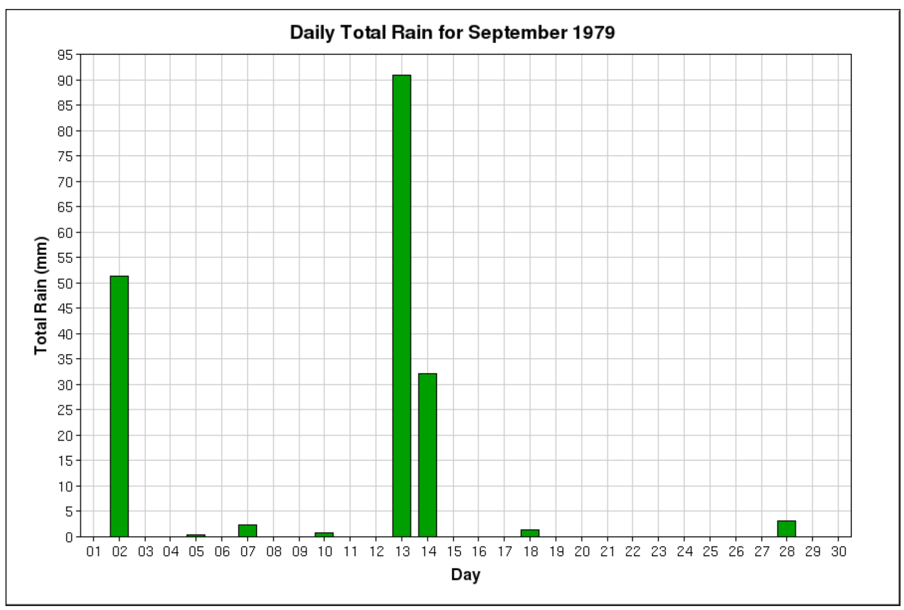


Figure 6 Precipitation data for Sept. 1979

Year 1979 had a value greater than the 100 year storm. Data 116.4mm

100 year = 105.9 - 12 hour storm comparable value.

2.2.2 August 2018 Storms

Environment Canada maintains a Metrological station in Port Colborne, which is located at or near the lighthouse along the waterfront. The following chart is the daily rainfall for that location.

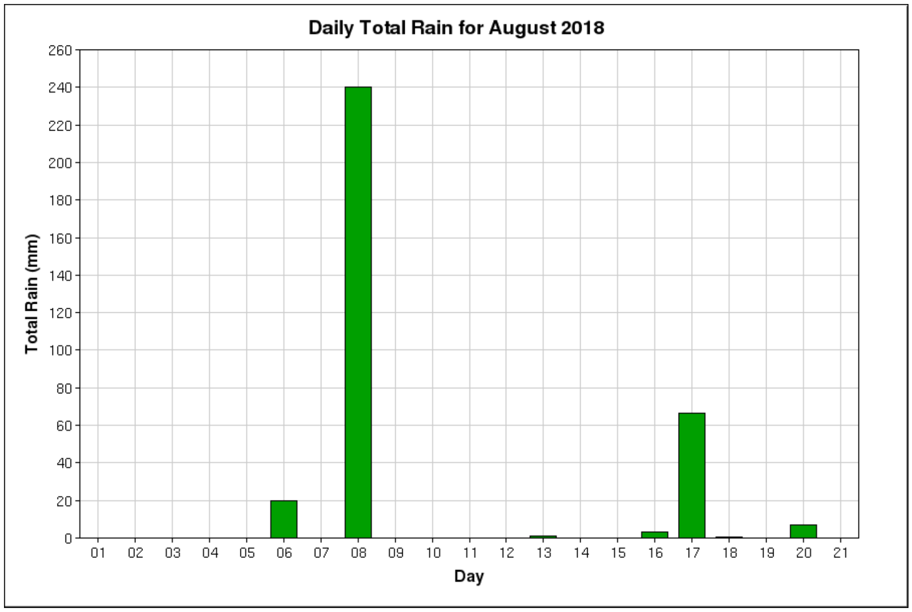


Figure 7 Env Canada Port Colborne Rain August 2018

The Regional Municpality of Niagara maintains a precipitation station on the Seaway WWTP grounds and provided data on precipitation measured at the station in 5 minute intervals for the period of August, 2018. The following chart shows the rain storm events for both the August 7th morning event and the August 8 morning event.

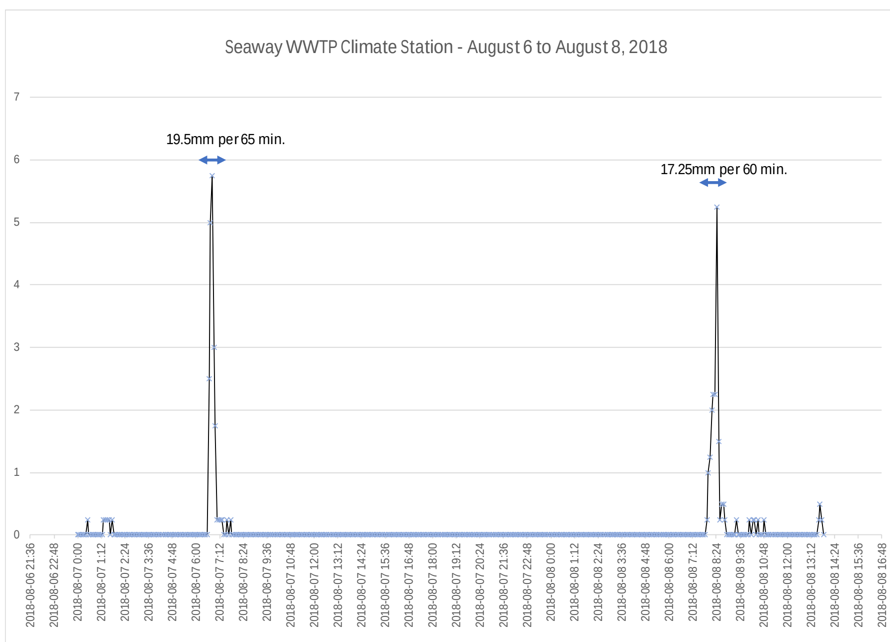


Figure 8 August 2018 Precipitation Events

Both events are characteristic of summer convective storms with short duration intense events that are not widespread but very localized.

There were significant reports of flooding in localized portions of Port Colborne but no reports of any flooding within the Drains.

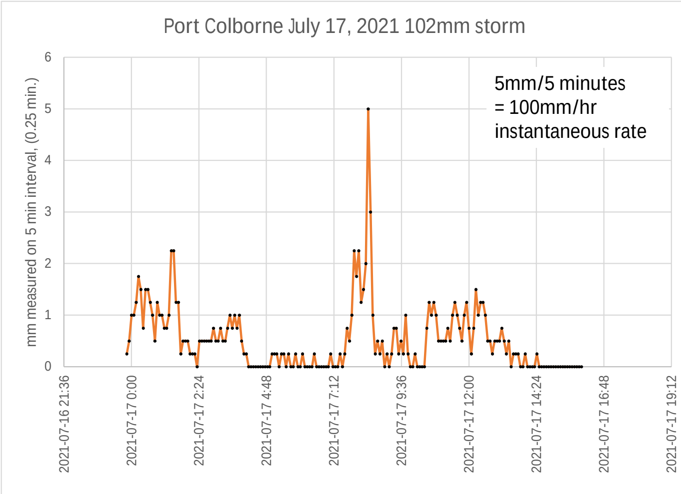
The distance between the two gauges is 2km. The one day reported total of 240mm exceeds by a significant margin the IDF intensity for a 1:100 year event while the Seaway WWTP station reported storm is below a 1:2 year event.

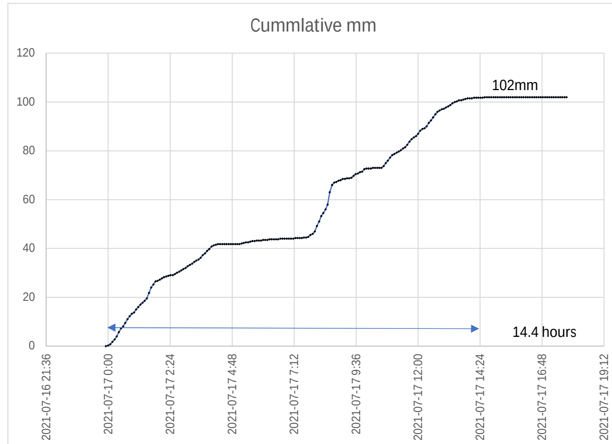
The radar from the storm available from EC website, shows that the track of the storm followed the Lake Erie North shoreline as shown in the following figure. It would appear from the image that the intense portion of the storm is just off the shore over the lake, which is consistent with the variation of rain reported by the two gauges.

Figure 9 Environment Canada Radar Image - 2018-08-08, 08:30 EDT

From this historical event, we can conclude that sudden intense rainfall events are happening but are not widely distributed. The impacts are very localized.

This was further evidenced by the storm that occurred on July 17th, 2021.





102mm over 14 hours on July 17, 2021

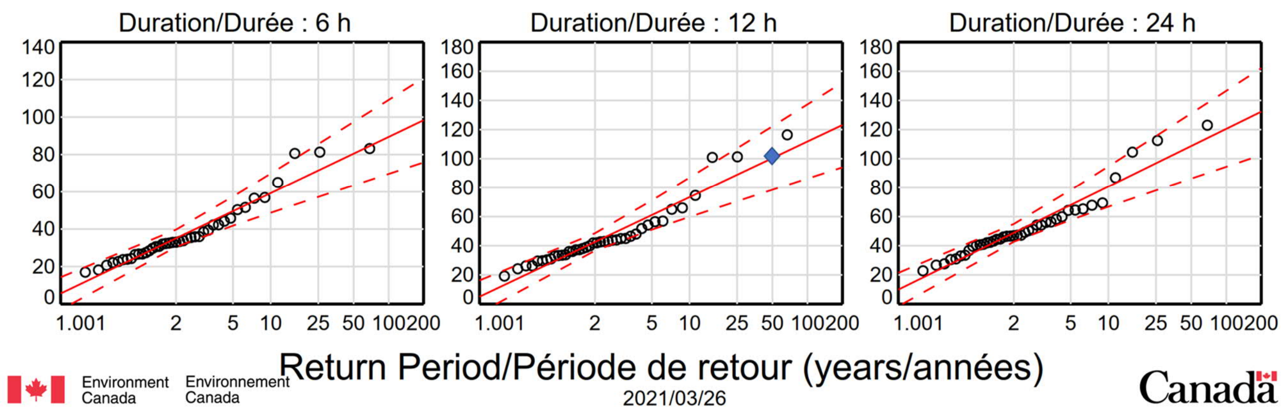
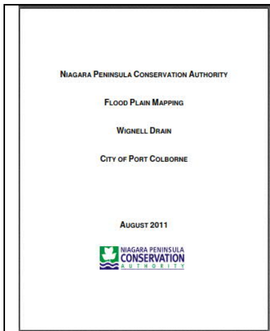
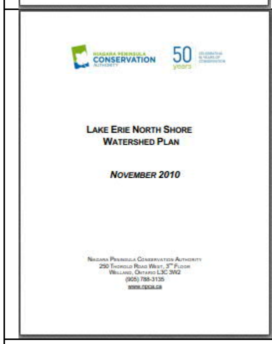
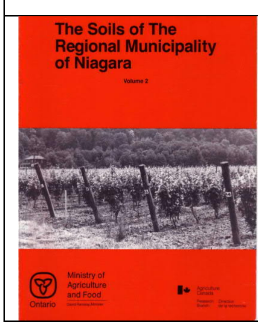


Figure 10 July 17 Storm Records

Size of the storm over a 12 hour period, actual is closer to 14 hours, suggests that the storm was a 1:50 year return period storm. Report indicate that flooding did occur. No high level marks were recorded on the Wignell. First hand account of the flow through the Port Colborne Drain was right to the top of the bank south of Highway #3.

2.3 Previous Reports and Studies

Reference Documents:

	FLOOD PLAIN MAPPING WIGNELL DRAIN CITY OF PORT COLBORNE, AUGUST 2011 NIAGARA PENINSULA CONSERVATION AUTHORITY
	LAKE ERIE NORTH SHORE WATERSHED PLAN NOVEMBER 2010 NIAGARA PENINSULA CONSERVATION AUTHORITY
	Niagara Peninsula Conservation Authority, 2009, Water Quality Monitoring Program Annual Report 2009
	NPCA Watershed Hydrology Study, Marshal, Macklin, and Monoghan Ltd., August 1989
	Wignell Drain Flood Damage Reduction Study Phase I, Acres International Ltd., 1986
	THE SOILS OF THE REGIONAL MUNICIPALITY OF NIAGARA, Vol 2 OMAF 1989

The following are highlights pulled from some of the reports that are relevant to watershed modelling in the context of the Wignell Watershed.

FLOOD PLAIN MAPPING WIGNELL DRAIN

This report provides details on the technical methodology used to predict flow runoff for the 100 year design storm and flood elevations using a variety of software and modelling techniques. The following points highlight the model techniques used:

- ArcHydro was used in conjunction with ArcGIS software and the NPCA 2010 DEM to define contributing areas used in the model physical representation.

- Field verification was limited to confirmation of culvert only data.
  * subsequent physical survey of sections by both Amec Foster Wheeler and City of Port Colborne show that NPCA 2010 is .5m to 1m error in defining channel geometry.

- Port Colborne IDF curves used with Storms 2000 software to create:
  - 1 hour AES rainfall hyetographs
  - 12 hour AES rainfall hyetographs

- The 12 hour AES Rainfall had the following parameters:
  - Total rain fall – 105.9mm with a max intensity of 22.54 mm/hr
    Storm duration 480minutes (8 hours)
    time step – 1 hour steps.
  - “Year 1979 had a value greater than the 100 year storm. Data 116.4
    100 year = 105.9” 12 hour storm
  - “Year 1991 had a value greater than the 100 year storm. Data 64.2
    100 year = 63.1” 2 hour storm

- HEC-HMS software used to generate hydrologic runoff using the following:
  - SCS Curve Number for Ia and calculate of losses
  - Tranform method – SCS Unit hydrograph
  - Channel Routing - Muskingum – Cunge

- Quarry contributing areas were set to 0 with a static outflow to model pumping set at two rates:
  - West Quarry = 0.057 m3/s, and
  - East Quarry = 0.118 m3/s.

    From the site visit conducted on Sept 19, 2018 this values are reasonable estimates of maximum flow from the installed pumping arrangements. GR T-Series pumps.

- HEC-RAS software used to solve hydraulic flow conditions to predict flow elevations based on the NPCA DEM model data along with input values for channel roughness, etc.
  A steady state solution was performed using a backwater calculation based on outlet elevation of 174.2 masl

  The yearly average is given as 174.14 with min monthly of 173.18 and max monthly of 175.04
  The Acres Report suggested a wave and wind setup values of 175.05 and 175.13 for the instantaneous peak from 1:100 year events.

- The June, 2018 mean value was 174.89.

Comments on the hydrology model and hydraulic model:

1. While the results are compared against previous modelling efforts, no actual field verification of modelling results was performed. This would have required flow monitoring for the Wignell or any adjacent or nearby watershed with similar parameters, such as the Beaverdam watershed (Port Colborne) or the BeaverCreek watershed (Fort Erie).
   Also there are storms indicated in the precipitation record; 1979 and 1991 that are in excess of the 100 year storm and would provide historical context for field verification of model results. This is not a gauged watershed verification but using historical anecdotal observations to confirm runoff values are reasonable.

2. The HEC RAS model is based on the NPCA DEM data from 2010 Orthophotography. This has been shown to under-represent the depth and width of established channels within the watershed. It is representative of overall land slope patterns and grades. The resulting impact on the model is a drain gradient that is representative but an under reporting of the available drain capacity prior to flood elevations being established.

3. HEC RAS does perform culvert analysis and this was implemented in the hydraulic model. The model showed or demonstrated t

Results:

The following are the predicted values and inputs from the NPCA model for a comparative contributary area of the two models.

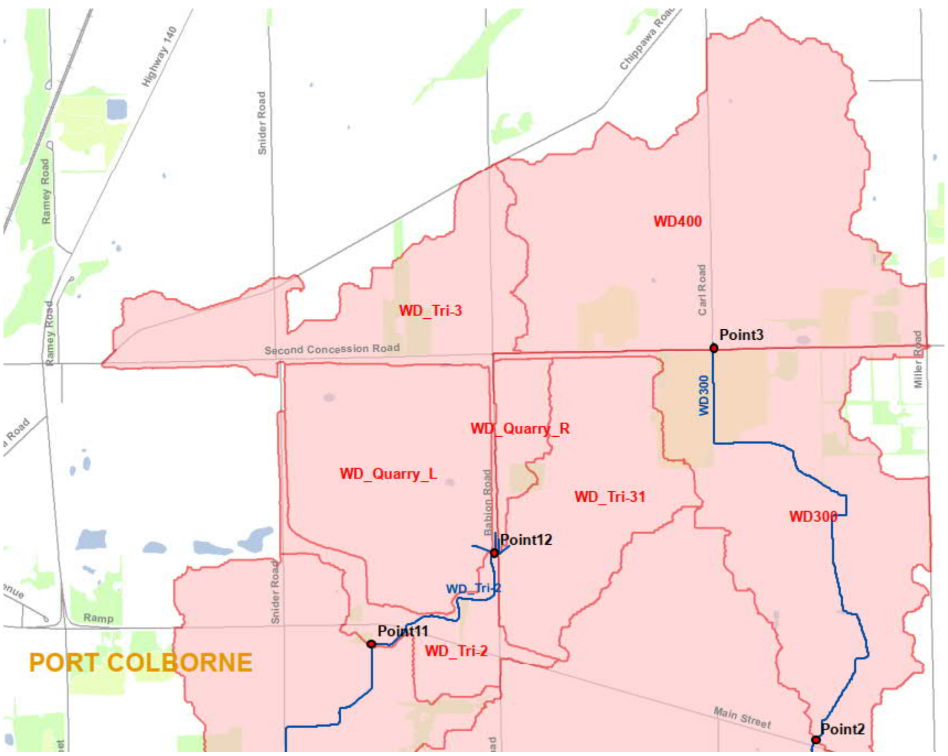


Figure 11 NPCA Model Watersheds and Junctions

The first junction point to make a comparison is Point 12 with a contributing area identified as WD_Tri-3. The following table identifies both the inputs and resulting peak runoff.

Name	Area	% Imp	SCS CN	Ia
WD_Tri-3	0.582494 km2 58.2494 Ha	14.198 (8.27 Ha)	85.230	8.8032
			Point 12 Area	1.85 km2 185 Ha
			Peak Runoff, cms	**5.16**

The Wignell Drainage Model is configured with more defined catchments to better represent runoff for watershed characterization. For the same area as identified above, the Wignell Drainage Model has three defined catchment areas as shown in the following figure.

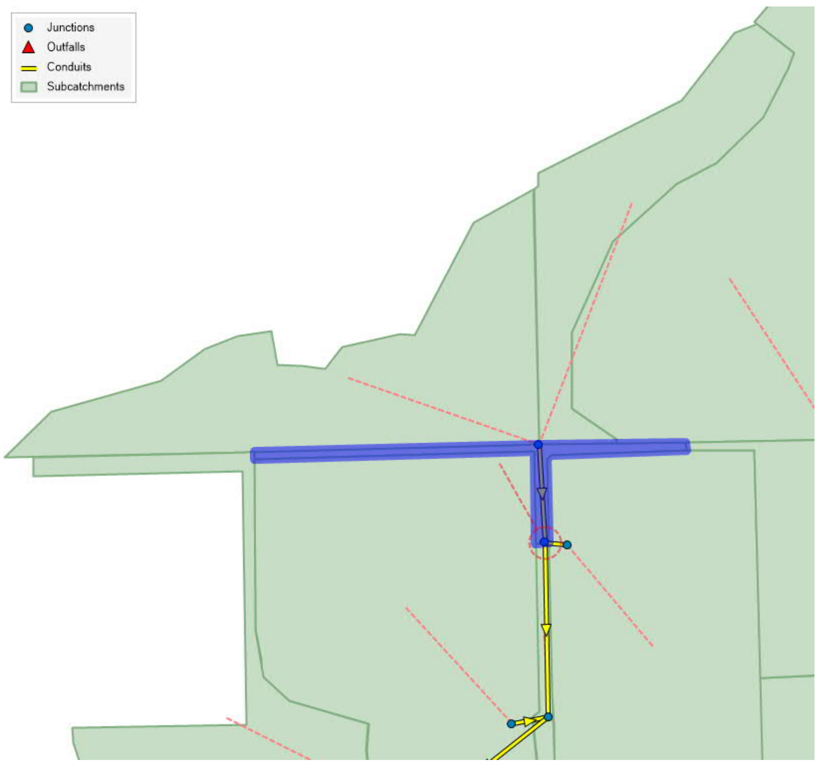


Figure 12 Port Colborne Drain Catchments in Wignell Model

The following table presents the results from the Wignell Drain Watershed Model.

Name	Area	% Imp	SCS CN	Ia
PC1	25.74	0	73	5
PC2	45.95 Ha	0	73	5
PC11	3.65 Ha	45 1.64 Ha	93	5
			J88 Area	75.34 Ha 0.75 km2

Peak Runoff, cms	**1.57**

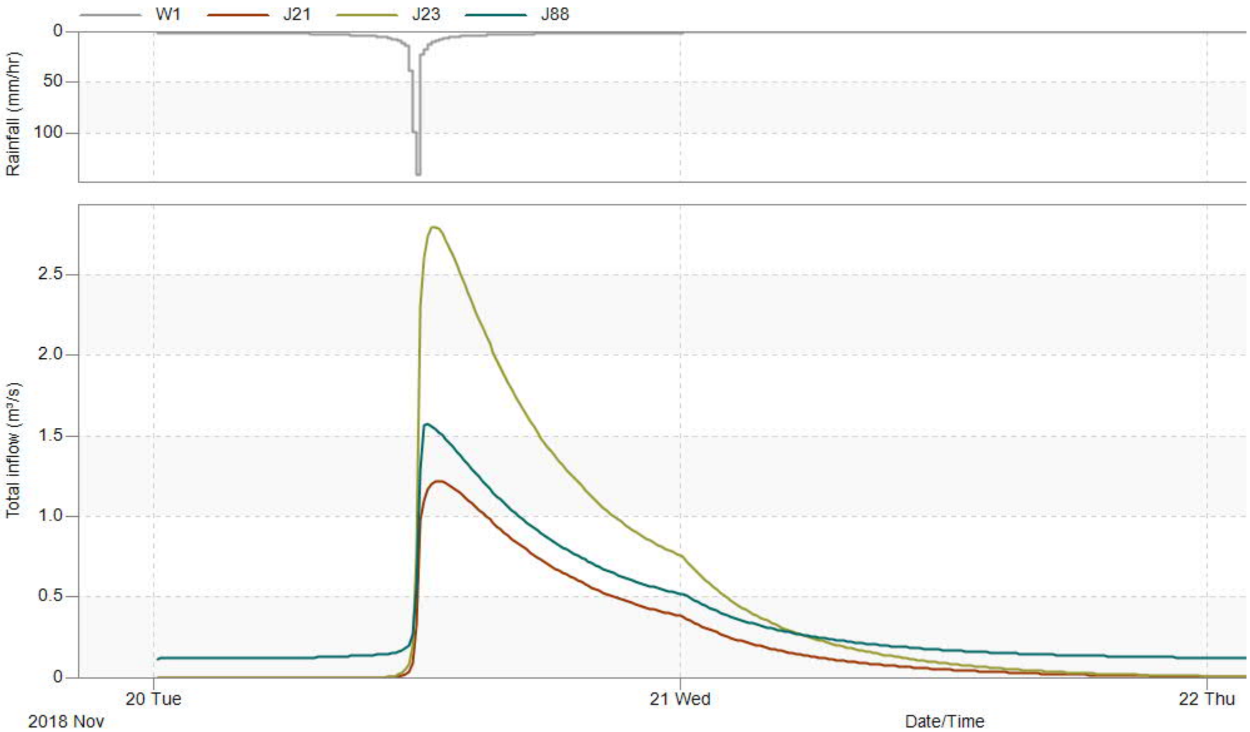


Figure 13 Wignell Model Result Hydrographs

The Wignell predicted runoff for the same contributary area is less than half the predicted runoff for the NPCA model, 1.57 cms compared to 5.16 cms. One contributing factor is the % impervious area used in NPCA model is equivalent to 8.27 Ha compared to Wignell Drain model which is 1.64 Ha and the actual calculated hard surface, both pavement and gravel road portions within Catchment area PC11 is 0.99 Ha.

From this one comparison, we conclude that the NPCA model over predicts runoff based on high estimates of the impervious areas.

To minimize the potential effects of the CN value effects, an average CN value from the NPCA was calculated to be 83. This was used in the Wignell Watershed model for those areas above the Friendship trail and is a value consistent with both mixes of C and D soil classifications. The upper portion of the Wignell is a mix of Jeddo clay loam till soil with poor drainage and Chincousy a mainly clay loam till with imperfect drainage.

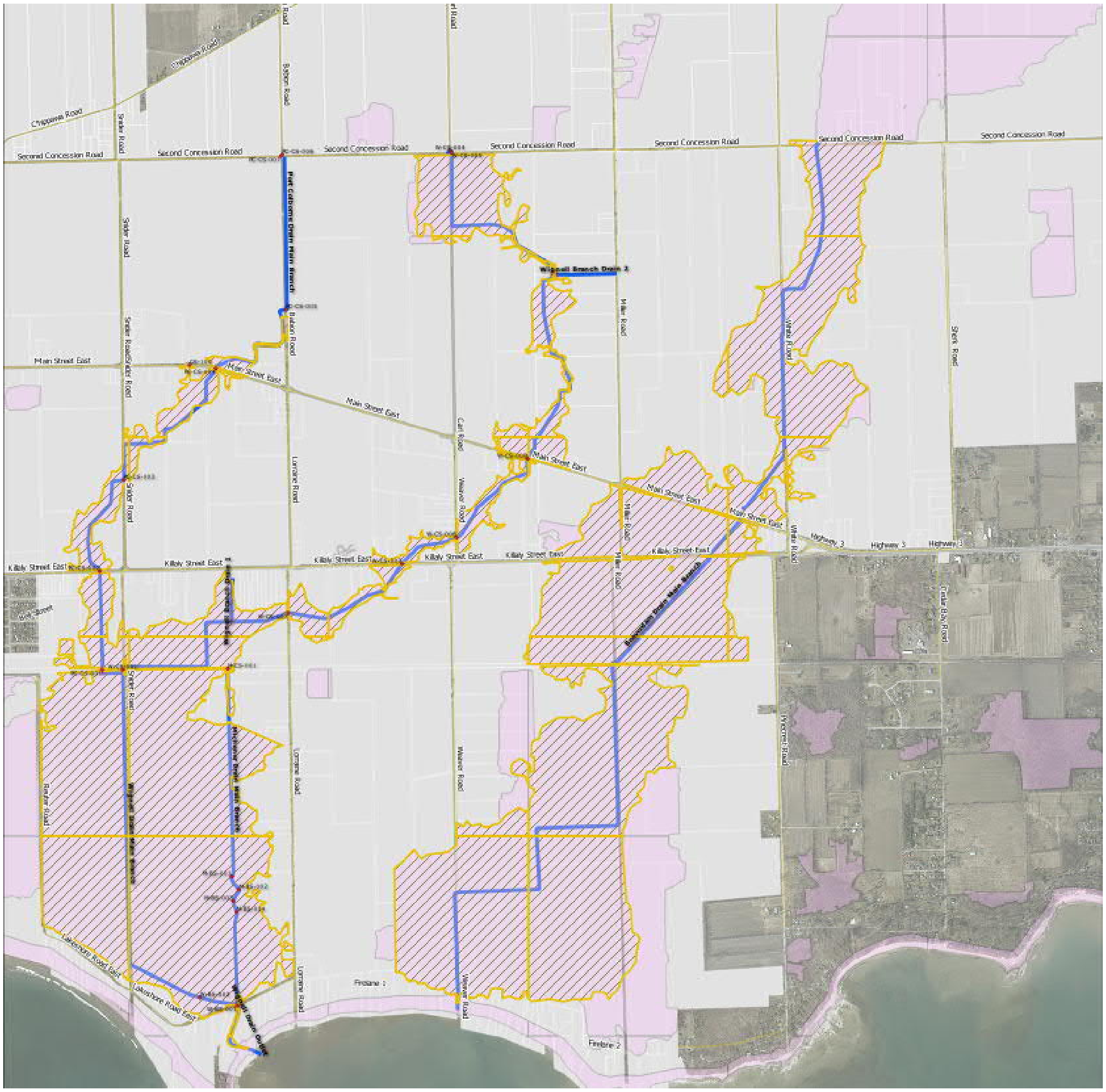


Figure 14 NPCA supplied Regulated Flood limits and Areas

The interpretation of the NPCA modelling and results is as follows:

A. The lakeshore road East and dunes are significant barriers to flow exiting to the Lake. During peak flow water has the potential to be held back. However, flow is expected to equalize with the Lake especially during high lake levels as demonstrated in 2018 and 2018.

B. The Friendship Trail formerly CNR rail is a significant barrier to flow. Culverts appear to be sized appropriately, there is a larger impoundment shown for the Wignell Hwy #3 crossing.

C. The lower reach shows wide spread flooding. This is a result of the model configuration with large capacity flows being passed through the Friendship Trail and a corresponding flow limitation through the crossing at Lakershore Rd. East.

3 Hydrology

Considerations for the landform were given in the creation of the model.

The predominate soil through the Wignell Watershed is clay with poorly drained conditions. The following figure is colour coded for the predominate soil types.

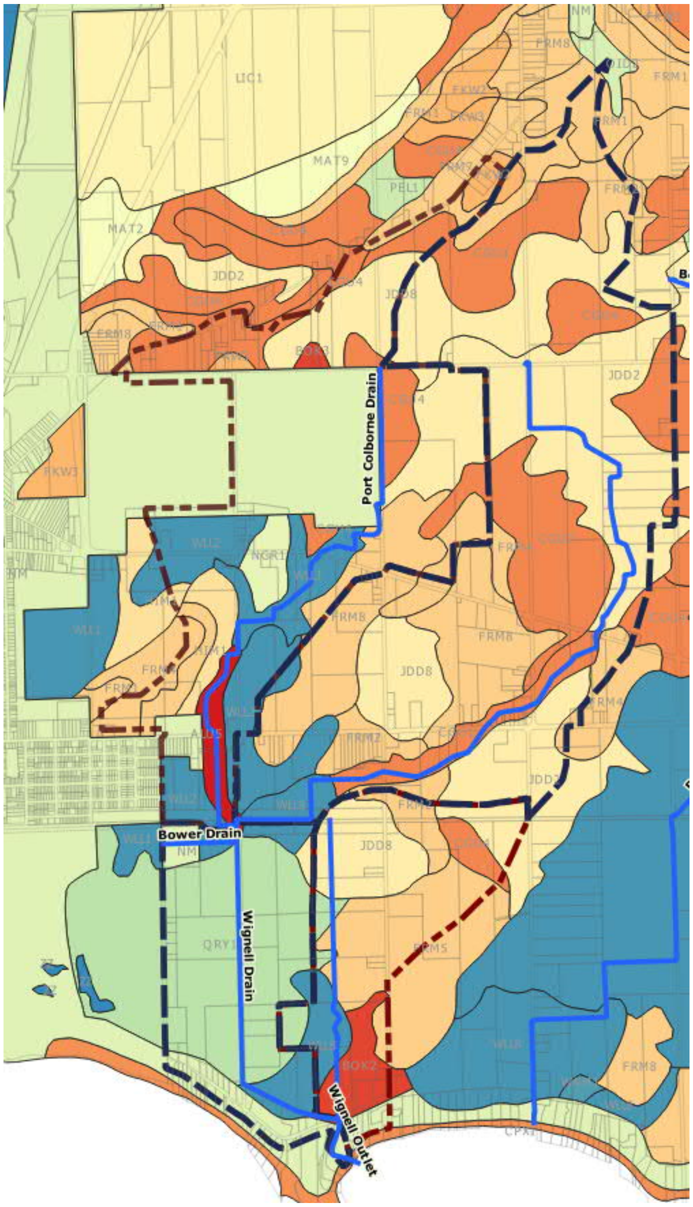


Figure 15 Wignell Watershed Soil Classifications

The light green, shown as former Wignell bog lands is Quarry Soil (QRY) an organic soil, swamp associated 40 to 160cm deep over clayey mineral soil.

Mainly clay loam till. Imperfectly drained.

10 to 20cm variable textures over mainly limestone and dolostone bedrock. Drainage is rapid.

Mainly clay loam till. Drainage is poor.

Mainly reddish-hued lacustrine heavy clay. Drainage is poor.

Alluvium Variable Floodplain deposits on an active floodplain.

Brooke Soil, 50 to100cm variable textures over mainly limestone and dolostone bedrock.

Not Mapped, covers all of the urban area, sand dune along Lakeshore and quarry lands.

From The Soils of Regional Municipality of Niagara, volume 2, dated 1989, from which the GIS data is shown in Figure 13as a map with the Wignell Drain, Port Colborne Drain and Michener Drain boundaries overlaid, we can see that the predominate feature is poor drainage above (North) of the Friendship Trail. Predominately land grades throughout the Watershed are low, with almost no land grades below the Friendship Trail.

Information on soil permeability was found online for grape growers within Niagara Region and published in the following form.

WATER INFILTRATION INTO SOIL

		WATER INFILTRATION INTO SOIL		SOIL WATER HOLDING CAPACITY				DRAINAGE - WATER MOVEMENT THROUGH ENTIRE PROFILE			
SOIL SERIES	SURFACE SOIL TEXTURE	RATE OF WATER INFILTRATION (based on surface soil texture)	RATE OF WATER INFILTRATION (in/hr)	SOIL WATER HOLDING CAPACITY	AVERAGE INCHES OF WATER/ INCH OF SOIL AT FIELD CAPACITY	GRAPE ROOTING DEPTH (36 inches or max of A and B soil profile depth) inches	AVAILABLE WATER WITHIN ROOTING DEPTH (inches)	HYDRO-LOGIC SOIL GROUP	RATE OF WATER FLOW THROUGH THE SOIL PROFILE (in/hr)	LEACHING RISK	DRAINAGE CLASS
Morley	Silty Clay	Slow	0.08-0.2	Medium	0.13	27	3.60	D	0-0.04	Very Low	Poorly drained
Toldeo	Silty Clay	Slow	0.08-0.2	Medium	0.13	22	2.93	D	0-0.04	Very Low	Poorly drained
Jeddo	Clay Loam	Medium	0.15-0.3	High	0.17	19	3.17	D	0-0.04	Very Low	Poorly drained
Beverly	Silty Clay Loam	Medium	0.15-0.3	High	0.17	26	4.33	C	0.04-0.16	Low	Imperfectly drained
Chingua-cousy	Clay Loam	Medium	0.15-0.3	High	0.19	16	3.00	C	0.04-0.16	Low	Imperfectly drained
Tavistock	Loam	Fast	0.3-0.5	Medium	0.15	28	4.08	C	0.04-0.16	Low	Imperfectly drained
Vineland	Very Fine Sandy Loam	Fast	0.3-0.5	Low	0.10	33	3.44	B	0.16-0.32	Medium	Imperfectly drained
Grimsby	Very Fine Sandy Loam	Fast	0.3-0.5	Low	0.10	36	3.75	A	0.3-0.5	High	Well drained

Sarah Krick and Donna Speranzini AAFC 2013

Figure 16 Soil Drainage Permeability Factors

This shows a low rate of infiltration of 3.8 mm/hr to 7.62 mm/hr for both Chinguacousy Clay loam and Jeddo Clay Loam within the Wignell Watershed. From this a setting of Ia = 5mm was selected.

The major landform features constructed through the Wignell Watershed are as follows:

- The first major constructed landform impacting runoff is the former rail bed lands now the Friendship Trail. This is a major East West barrier to overland flows. Existing bridge openings are fixed concrete passageways that form the basis for calculating drainage flows.

- North South roads that influence drainage boundaries are:
  - Lorraine Road,
  - Babion Rd. (in association with the Quarry lands)
  - Miller Rd. and
  - Snider Road

- There are also significant impacts from East West roads with the three major impacts of:
  - Killaly Street East,
  - Main Street East / Highway #3, and
  - Second Concession Road.

The roadway impacts were considered in the discretization of the watershed catchments.

3.1 Municipal Drain Model

An EPA SWMM v5.1 model was setup based on a sub-catchment discretization and channel segregation using GIS data as the based for model determinations. A GIS map of the data used for model set up is included in Appendix B. The Catchment definitions are shown in the following figure and table with runoff parameters for the CN runoff model. Consideration was given in the catchment definitions to major roads and culvert crossing along with drainage junctions for branch drains.

A component within the Wignell Watershed are the quarry lands, where surface soil is removed to extract the limestone below. The result is a large impoundment of water that the quarry pumps to the surface and outlets into the Drain at two specific points along the Port Colborne Drain adjacent to Babion Rd. The only runoff possible from quarry lands is that which is pumped directly into the drain.

We have adopted the same direct connection with pumping rates as the NPCA model used. Two sources of 0.057 m3s-1 and 0.118 m3s-1 were added in the HEC-HMS model to represent the operation discharge from Quarry _L and Quarry_R respectively. The groundwater pump rate at the quarries were considered as the flow generated from the respective catchments and discharged into Wignell Drain. The operation discharge may vary from time to time, but the maximum discharge was used to conservatively represent the catchments. From discussions with quarry staff, pumps are not operated during precipitation events and thus the contributions included in the model are conservative.

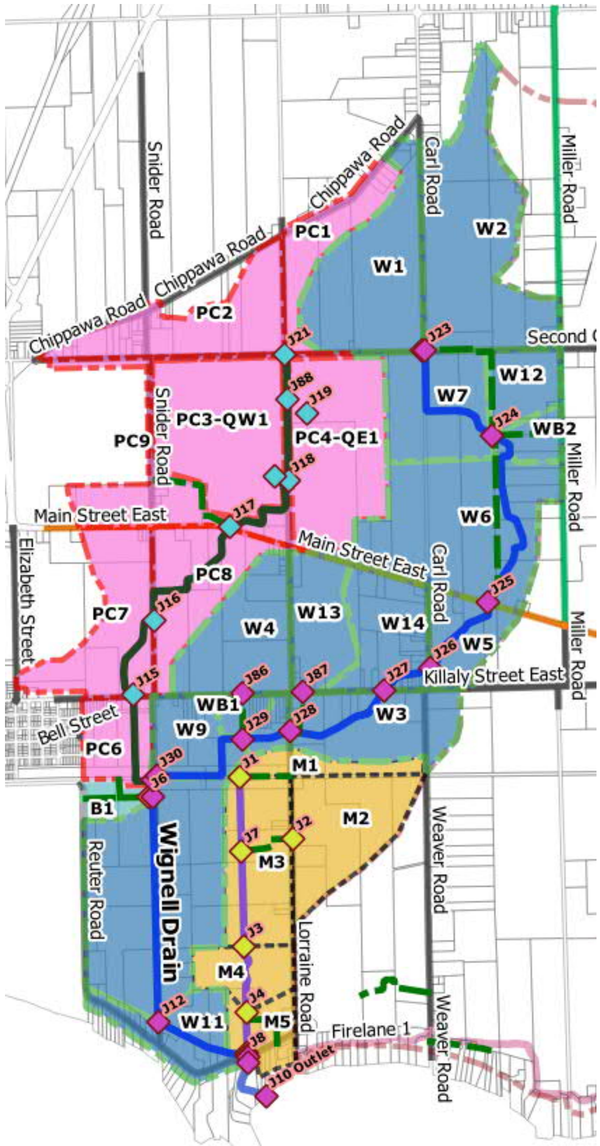


Figure 17 SWMM Model view

Catchment areas:

The Catchments were defined in GIS and specific areas calculated and runoff characteristics were selected based on landforms, land use and other factors for each catchment, those variables are listed in the following table.

The percent impervious was calculated from GIS for area PC2 and found to be 4.3% based on paved surfaces with directed runoff paths. An average percent impervious was used for the other watersheds with variations made to account for specific catchment definitions. For example, PC10 and PC11 are defined by road allowances and are almost wholly road based catchments and have higher % impervious values assigned.

Table 1 Wignell Watershed Catchment Variables

Name	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	Curve Number
B1	J6	8.32	201	413.93	0.25	5	83
M1	J1	13.11	114	1150	0.17	4.5	73
M2	J2	43.92	624	703.846	0.43	4.5	83

M3	J7	41.95	411	1020.681	0.01	4.5	73
M4	J4	18.79	469.75	400	0.001	4.5	73
M5	J5	15.52	597	259.966	0.001	4.5	73
PC1	J21	25.74	198	1300	0.53	4.5	83
PC10	J18	1.98	40	495	0.4	55	93
PC11	J88	3.65	36.5	1000	0.4	45	93
PC2	J21	45.95	374	1228.61	0.24	4.73	83
PC3-QW1	J20	66.06	660	1000.909	0.01	0	73
PC4-QE1	J19	63.43	906	700.11	0.01	0	73
PC5	J17	7.7	153	503.268	0.4	4.5	83
PC6	J14	21.44	447	479.642	0.2	4.5	83
PC7	J15	46.29	455	1017.363	0.2	4.5	83
PC8	J16	39.25	441	890.023	0.56	4.5	83
PC9	J17	28.68	239	1200	0.75	4.5	83
W1	J22	59.85	511	1171.233	0.77	4.5	83
W10	J12	100.6	680	1479.412	0.01	4.5	73
W11	J8	26.23	1380	190.072	3	4.5	73
W12	J24	18.67	275	678.909	0.15	4.5	83
W13	J87	28.59	342	835.965	0.36	4.5	83
W14	J27	34.15	491	695.519	0.29	4.5	83
W2	J23	87.36	488	1790.164	0.5	4.5	83
W3	J28	41.21	330	1248.788	0.16	4.5	83
W4	J86	42.97	511	840.9	0.6	4.5	83
W5	J26	22.3	354	629.944	0.16	4.5	83
W6	J25	83.88	986	850.71	0.12	4.5	83
W7	J24	41.66	495	841.616	0.12	4.5	83
W8	J29	6.61	220	300.455	0.33	4.5	83
W9	J30	23.23	502.06	462.694	0.81	4.5	83
WB1	J29	6.88	260	264.615	0.38	4.5	83
WB2	J24	10.34	250	413.6	0.24	4.5	83

The total area of the Wignell watershed is given as 1126.1 Ha including the quarries and 1006.5 excluding the quarry subcatchments. The quarry subcatchments are 100 percent capture and pump into the drain and do not have runoff characteristics in the same form as all the other subcatchments.

The model was set up as a Junction (node) and conduit (link) model in EPA SWMM software. The software map view appears in PC-SWMM as shown in the following figure with catchment PC1 selected.

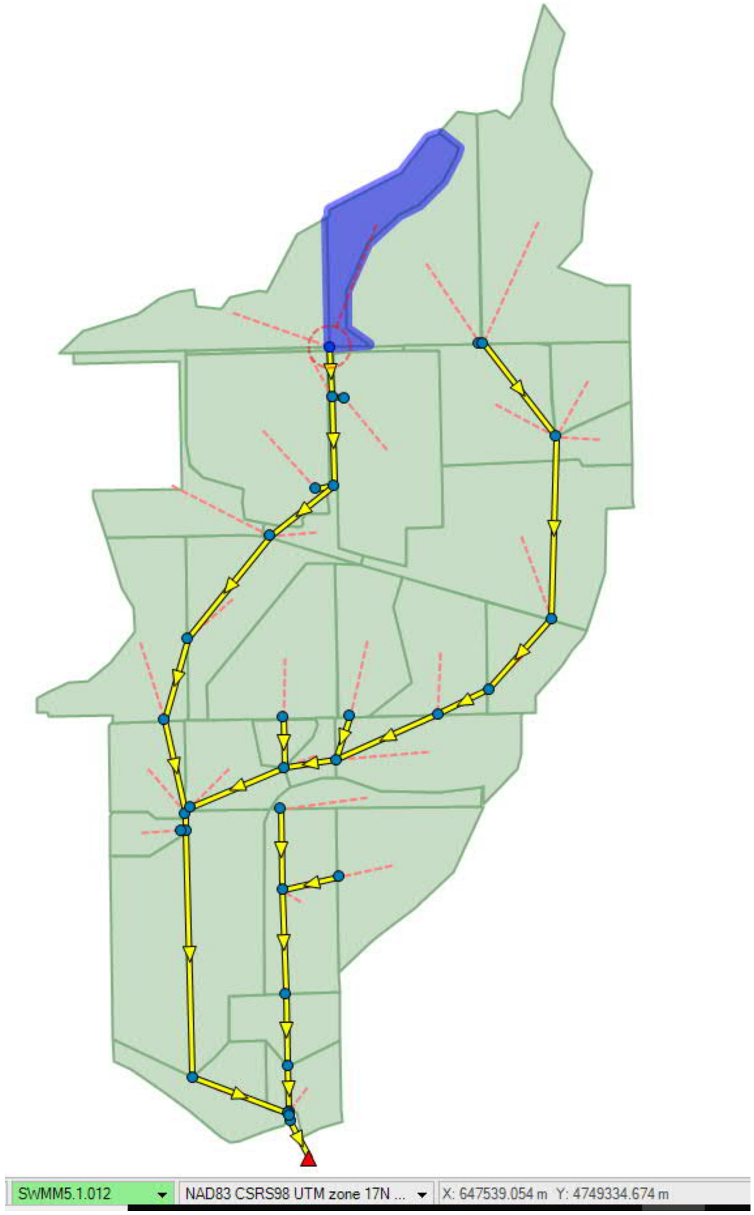


Figure 18 PCSWMM View of EPA SWMM

A logical Model Diagram is included in the modelling Appendix. The logical Diagram represents the organization of the specific nodes and links irrespective of the geographic representation shown in the figure above.

Idealized Channels are used to represent flows without surcharging conditions. Channels are typically designed to a lower capacity than the 1:100 year design storm and thus an idealized version is required unless a 2D model is implemented.

The model still has surcharge points. There are issues with the channel definition along Wignell from J25 to J28 with small flooding at J25 and J26 and more significant flooding J27 and J28. However, adjustments to reflect a larger bottom channel width consistent with a slightly higher capacity channel basis is expected to resolve these issues.

There are two areas with significant flood impacts shown in the model results:

1. J7 on the Michener with a confluence from a Branch Connection to the East that is draining a significant area. This area needs to be reviewed and considered in greater detail.

2. The significant model flood area is J14, the confluence of the Wignell and Port Colborne Drains just below the Friendship Trail. This flood event is shown in profile view with the Energy Grade Line in red.

   The following figure shows a time step just before flooding occurs, 12:10PM from the start of modelling the event at 00:00.

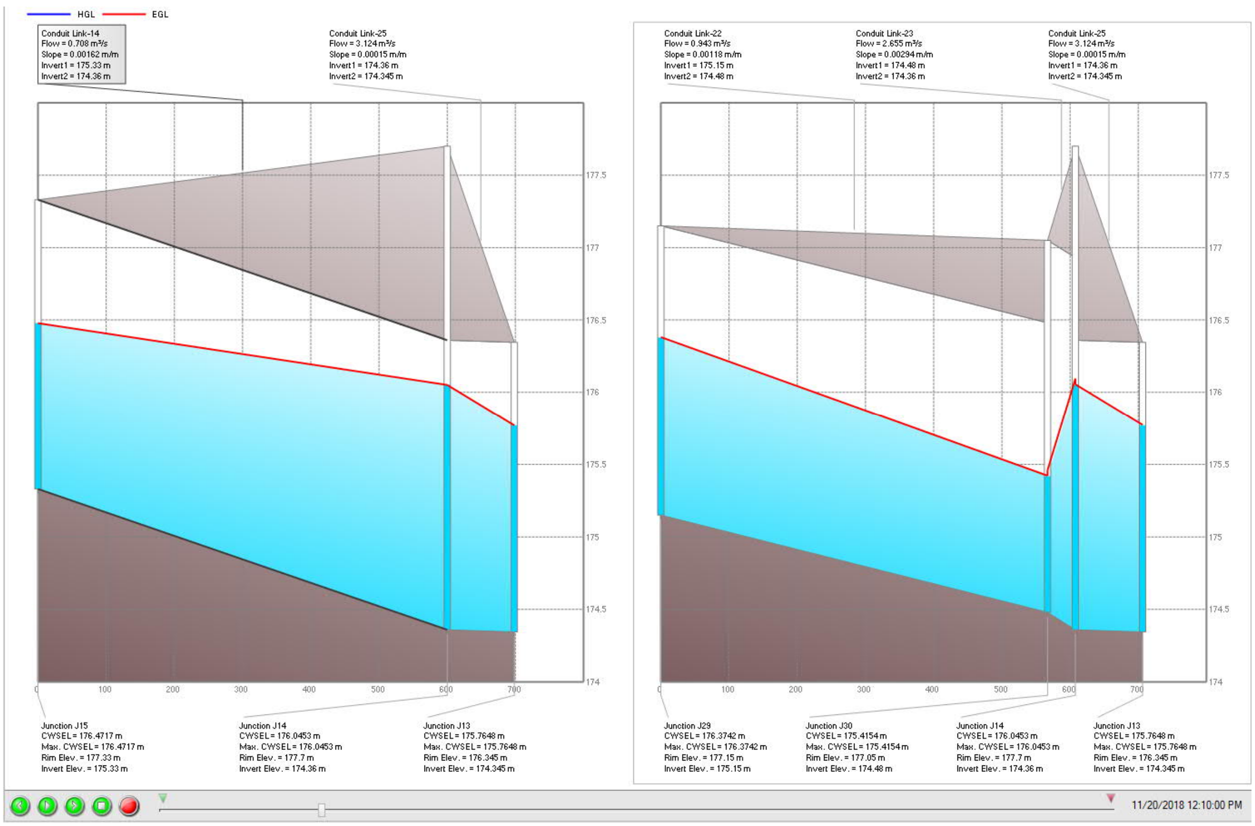


Figure 19 HGL before flooding at J14

The profile on the left is for the Port Colborne drain. Top of the channel elevations are shown as the heavy gray line. Grey shading above indicates increasing surface levels and the J14 point has the elevation of the Friendship Trail crossing.

The profile on the right side of Figure 17 is the Wignell Branch and is shown for the square opening passing the Friendship Trail upstream of the confluence.

The next time step shows the onset of the flood condition where the over toping of the Friendship Trail is indicated.

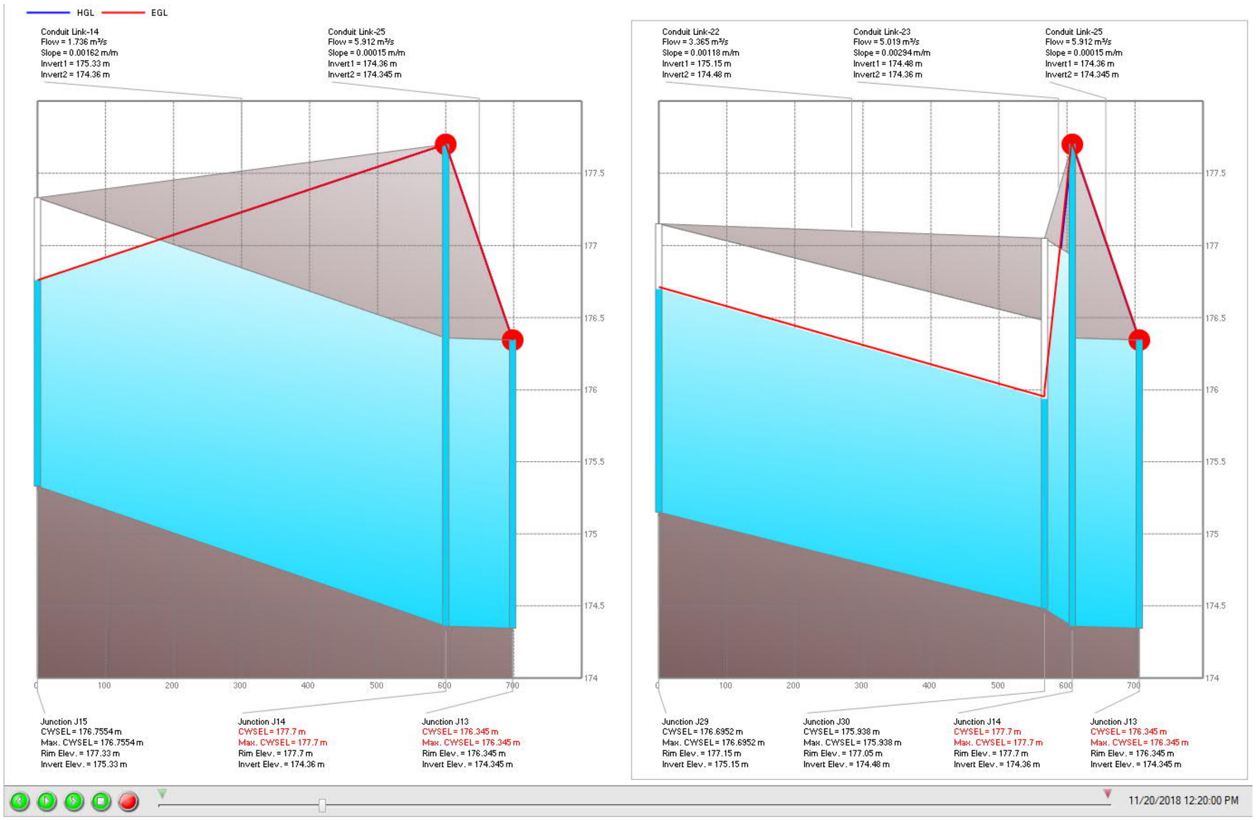


Figure 20 HGL flooding at J14

The following figure shows the flood HGL at the peak flow event, a peak flow event of 15 cms is being passed at the lower reach without any grade line to the outlet as per the CJ Clarke report of 1979.

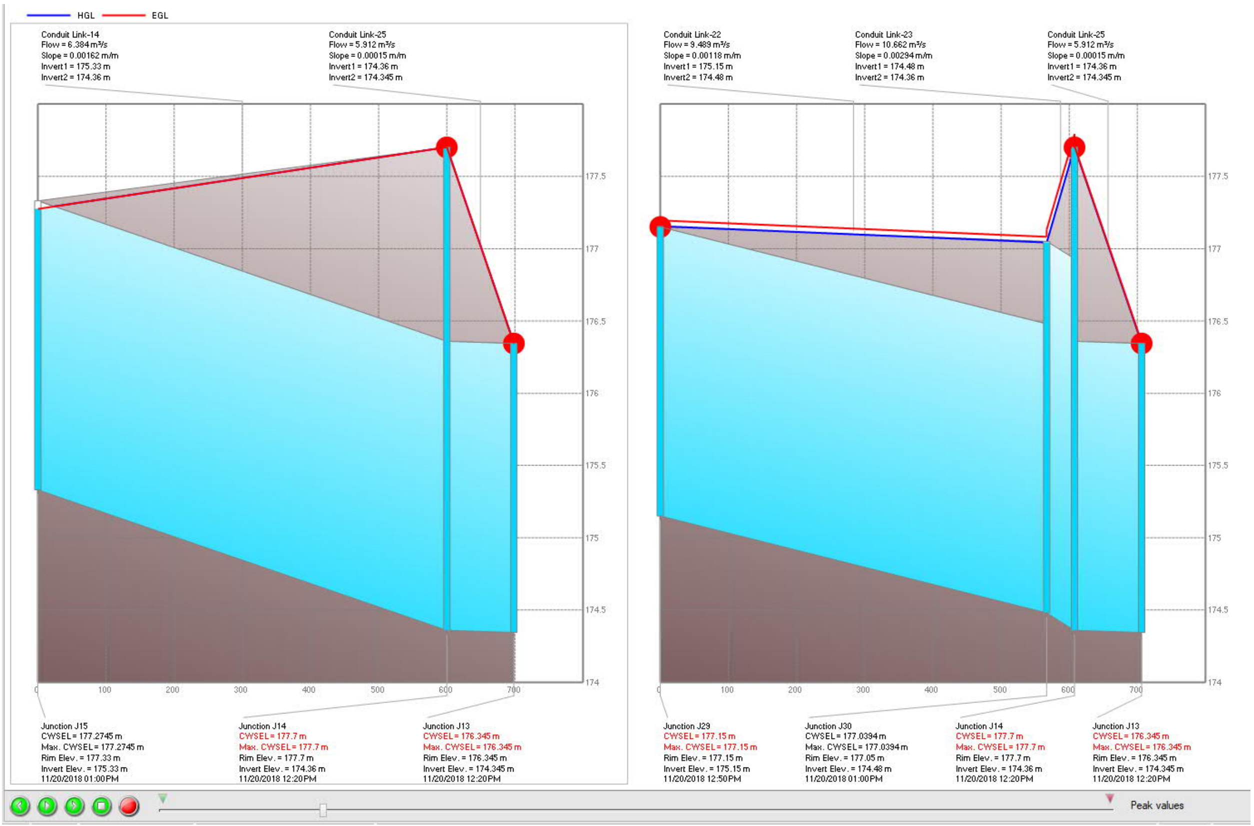


Figure 21 Model HGL Peak Flow for J14

There are some important considerations that have to be recognized with the EPA SWMM model implementation. The current implementation is for a 1D solution only and impacts such a storage are not recognized within the model analysis. This would occur where a culvert designed to pass a 1:25 year storm, for the Wignell this could be at Main St E. / Highway #3, has a 100 year storm cause water to back up behind the culvert. The culvert will only pass the outlet condition flow case, see analysis using HY-8 in a later section. However, the flow is stored and passed later. At present the impact of the culverts and storage is not accounted for in the model.

The following figure illustrates some of the challenges with implementing the hydraulic portion of the model using 1D flow analysis.

The left portion of the figure shows the highlighted link section as being a rectangular cross-section for flows. This section corresponds to the dimensions of the concrete bridge crossing Lakeshore Road East and establishes a reasonable flow constraint other than the control gate structure, which is not represented at all in the hydrology model. (neither NPCA nor EPA SWMM versions). The dimensions of the rectangular channel are 5.2m wide by 2.73m high, which is dimensions of the bridge structure. The lengths do not correspond with the channel length in the model being greater.

The right portion of the Figure shows the outlet of the Wignell Drain to Lake Erie. The outlet is considered for the purposes of the model to be a free flowing outlet, which means that the elevation shown for the outlet invert does not have a Lake Elevation that is higher. This is not the truth as the actual water levels are marked on the Profile Figure.

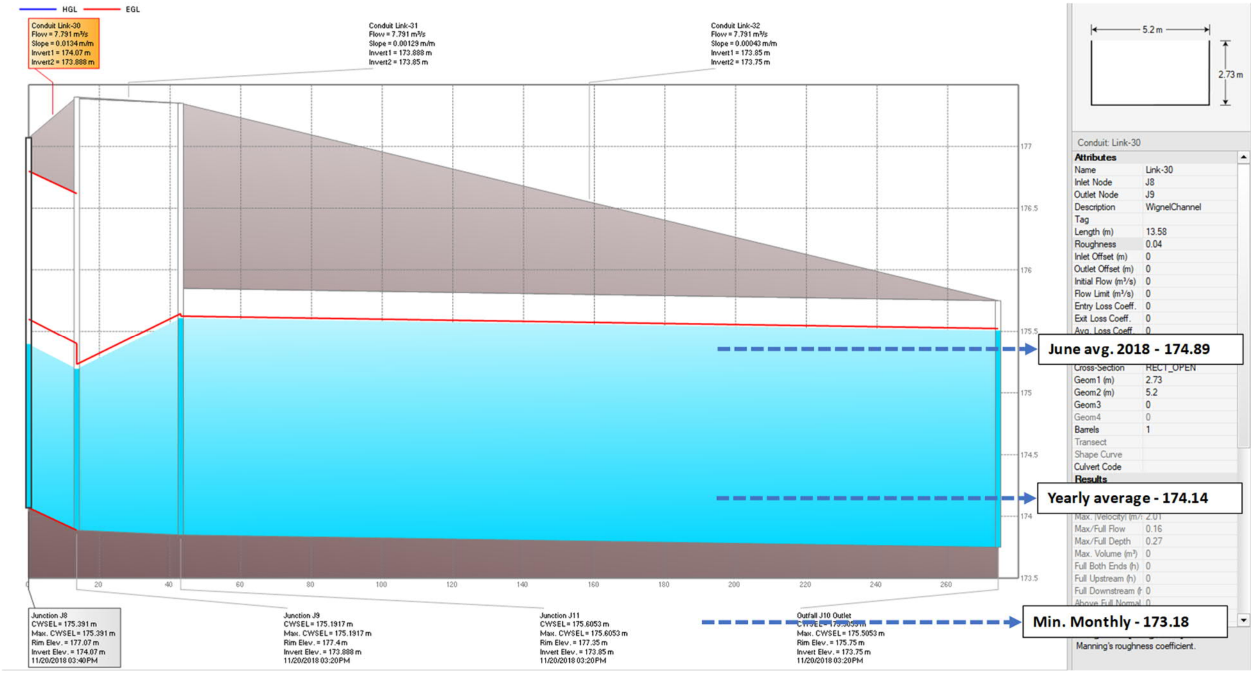


Figure 22 Wignell Outlet for the 100 year Flow

What we can appreciate is that attendance at the outlet indicates that there is a consistent and steady flow to Lake Erie but this is not a result of the drain grade line but of the Energy Grade Line driven by upstream flows. The following figure shows the same profile but for the 1:2 year design storm runoff flows.

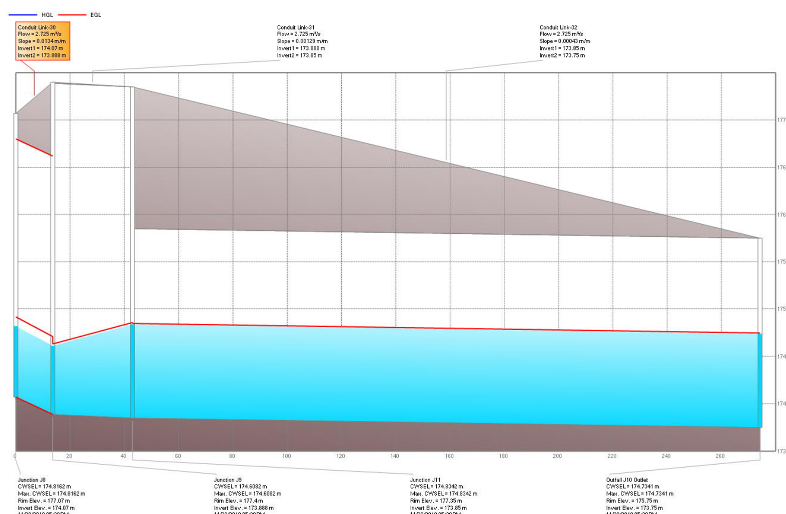


Figure 23 Wignell Outlet for 2 year Flow

The model predicts runoff as follows at the model junctions.

Table 2 Junction Runoff Results

Wignell Watershed - Junction Runoff Rates									
		Model	Max. Total Inflow (m³/s)						
Drain	Crossing	Junction	100 YR	50 YR	25 YR	10 YR	5 YR	2 YR	1 YR
Port Colborne	PC-CS-007 2nd Conc. East	J21	2.928	2.425	1.966	1.417	1.049	0.606	
Port Colborne		J88	3.392	2.841	2.335	1.727	1.316	0.812	
PC Quarry P1		J19	0.118	0.118	0.118	0.118	0.118	0.118	
Port Colborne	PC-CS-005 Babion Rd.	J18	3.554	2.986	2.47	1.848	1.425	0.903	
PC Quarry P2		J20	0.057	0.057	0.057	0.057	0.057	0.057	
Port Colborne	PC-CS-004 Main Street East MTO Hwy #3 Rural Arterial	J17	4.893	4.041	3.26	2.328	1.708	0.977	
Port Colborne	PC-CS-003 Snider Road	J16	6.26	5.12	4.077	2.835	2.015	1.066	
Port Colborne	PC-CS-002 Killaly St East	J15	6.952	5.986	4.735	3.251	2.274	1.154	
		.. J14							
Michener		J1	0.37	0.31	0.255	0.19	0.146	0.092	
M- Branch	CS-101 Lorraine Rd.	J2	2.7	2.202	1.746	1.203	0.846	0.436	
Michener		J7	3.225	2.632	2.093	1.458	1.042	0.566	
Michener		J3	0.88	0.88	0.88	0.88	0.831	0.452	
Michener		J4	0.991	0.967	0.946	0.924	0.815	0.421	
Michener		J5	1.11	1.058	1.014	0.967	0.844	0.435	
		..J8							
Wignell		J22	3.217	2.632	2.098	1.463	1.045	0.559	
Wignell	W-CS-005 2nd Conc. East	J23	6.414	5.283	4.252	3.025	2.209	1.241	
Wignell		J24	6.717	5.519	4.324	2.884	1.988	1.015	
Wignell	W-CS-008 Main Street East	J25	8.667	7.004	5.419	3.537	2.325	1.021	
Wignell		J26	8.492	7.581	5.868	3.834	2.52	1.091	
Wignell	W-CS-003 Killaly St. East	J27	9.678	8.574	6.646	4.352	2.865	1.228	
W. Branch	CS-119 Killaly St. East	J87	1.497	1.226	0.978	0.684	0.49	0.264	
Wignell	W-CS-007 Lorraine Rd.	J28	8.793	8.354	7.776	5.098	3.356	1.417	
W. Branch	CS-120 Killaly St. East	J86	2.623	2.139	1.697	1.17	0.823	0.425	
Wignell		J29	10.06	9.321	8.681	6.095	4.036	1.71	
Wignell	W-CS-010 Snider Road	J30	11.311	10.211	9.317	6.55	4.357	1.857	
Wignell - Port Colborne Confluence	Friendship Trail	J14	18.449	16.801	14.5	9.942	6.698	2.996	
Bower/ W. Branch		J6	0.618	0.505	0.4	0.274	0.191	0.096	
Wignell		J13	6.528	6.385	6.24	6.102	6.026	3.04	
Wignell		J12	6.55	6.42	6.303	6.201	6.07	2.781	
Wignell - Michener Confluence	W-BS-001 Lakeshore Rd. East	J8	7.886	7.671	7.478	7.069	6.71	3.081	
Wignell		J9	7.886	7.671	7.478	7.069	6.71	3.081	
Wignell		J11	7.886	7.671	7.478	7.069	6.71	3.081	
Wignell		J10 Outlet						3.081	

The model uses colours for culvert design flow requirements. Yellow for local and MTO requirements.

The model provides runoff results for channels, which are represented in the model as idealized channels rather than actual channels. The results are shown for the 5 year precipitation event.

Table 3 Model Link parameters

Wignell Watershed Channel Sections: 5 year runoff results														
Name	Inlet Node	Outlet Node	Length (m)	Roughness	Cross-Section	Geom1 (m)	Geom2 (m)	Geom3	Geom4	Slope (m/m)	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth	Contributing Area (ha)
Link-01	J1	J7	455	0.04	TRAPEZOIDAL	0.9	0.6	1.5	1.5	0.00097	0.101	0.32	0.35	13.11
Link-02	J2	J7	352	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00136	0.719	0.56	0.39	43.92
Link-04	J7	J3	533	0.04	TRAPEZOIDAL	0.9	0.6	1.5	1.5	0.00114	0.831	0.51	0.97	98.98
Link-05	J3	J4	510	0.04	TRAPEZOIDAL	1.2	0.6	1.5	1.5	0.00135	0.773	0.53	0.68	98.98
Link-06	J4	J5	230	0.04	TRAPEZOIDAL	1	0.6	1.5	1.5	0.00217	0.811	0.63	0.75	117.77
Link-07	J21	J88	302	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00219	0.947	0.71	0.4	71.69
Link-08	J88	J18	500	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00336	1.23	0.87	0.41	138.77
Link-09	J19	J88	70	0.032	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00029	0.118	0.21	0.22	63.43
Link-10	J20	J18	110	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.01564	0.057	0.62	0.06	66.06
Link-11	J18	J17	640	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00295	1.301	0.83	0.43	206.81
Link-12	J17	J16	860	0.04	TRAPEZOIDAL	2	0.6	2	2	0.00255	1.578	0.78	0.44	243.19
Link-13	J16	J15	580	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00112	1.956	0.62	0.64	282.44
Link-14	J15	J14	600	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00162	2.243	0.73	0.63	328.73
Link-15	J22	J23	21.42	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00093	1.036	0.49	0.5	59.85
Link-16	J23	J24	840	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00073	1.358	0.49	0.6	147.21
Link-17	J24	J25	1250	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00194	1.78	0.73	0.54	217.88
Link-18	J25	J26	522.47	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00205	2.321	0.8	0.6	301.76
Link-19	J26	J27	313.77	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00239	2.519	0.86	0.61	324.06
Link-20	J27	J28	618.63	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00158	2.857	0.76	0.7	358.21
Link-21	J28	J29	289.09	0.04	TRAPEZOIDAL	2	1	1.5	1.5	0.00128	3.354	0.73	0.72	428.01
Link-22	J29	J30	567	0.04	TRAPEZOIDAL	2	1.65	2	2	0.00118	4.025	0.71	0.66	484.47
Link-23	J30	J14	40.77	0.04	RECT_OPEN	2.57	3.13	0	0	0.00294	4.357	1.08	0.5	507.7
Link-25	J14	J13	98.5	0.04	TRAPEZOIDAL	2.5	5	1.5	1.5	0.00015	6.697	0.38	0.85	857.87
Link-26	J6	J13	25	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.0062	0.19	0.64	0.14	8.32
Link-27	J13	J12	1364.61	0.04	TRAPEZOIDAL	2	15	1.5	1.5	0.00015	6.286	0.32	0.59	866.19
Link-28	J12	J8	566.25	0.04	TRAPEZOIDAL	2	15	1.5	1.5	0.00011	6.359	0.29	0.65	966.79
Link-29	J5	J8	12	0.04	TRAPEZOIDAL	1	1.6	1.5	1.5	0.0025	0.844	0.64	0.54	133.29
Link-30	J8	J9	13.58	0.04	RECT_OPEN	2.73	5.2	0	0	0.0134	7.067	1.94	0.26	1126.31
Link-31	J9	J11	29.42	0.04	TRAPEZOIDAL	3.5	5	1.5	1.5	0.00129	7.067	0.83	0.35	1126.31
Link-32	J11	J10 Outlet	231.24	0.04	TRAPEZOIDAL	2	5	1.5	1.5	0.00043	7.066	0.57	0.83	1126.31
Link-33	J87	J28	254.29	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00189	0.437	0.55	0.29	28.59
Link-34	J86	J29	278.16	0.04	TRAPEZOIDAL	2	0.6	1.5	1.5	0.00306	0.752	0.74	0.33	42.97

Link -23 and Link-30 are rectangular culverts shown based on information about the sizes available. Link-23 is actually composed of two culvert sections; a rectangular culvert crossing the Friendship trail and a twin barrel CSP culvert crossing Babion Rd. but in the model is only represented by the rectangular portion. Link-30 is the Lakeshore Rd. East bridge crossing.

3.2 Hydrologic Model Update 2021

Based on additional information provided along with additional survey data, revisions in catchment boundaries for Port Colborne, Michener and Wignell were updated in the stormwater model. Final catchments are printed and shown in Appendix B.

The model profile shows that the proposed channel confirmation works for the design storm.

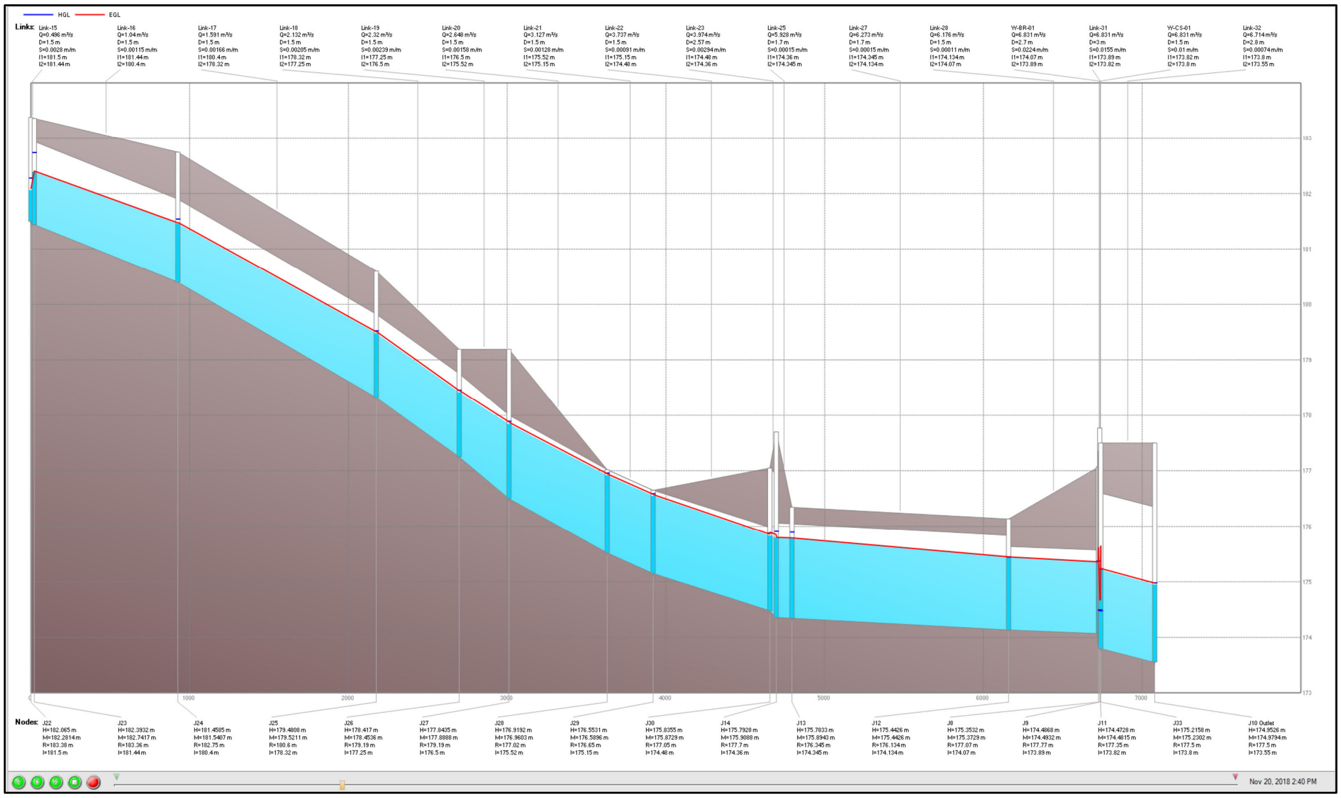


Figure 24 Wignell Drain Design Model Profile

For the same Drain, the 100 year storm, (Probable Maximum Precipitation, PMP) results in channel capacity exceedances throughout the drain.

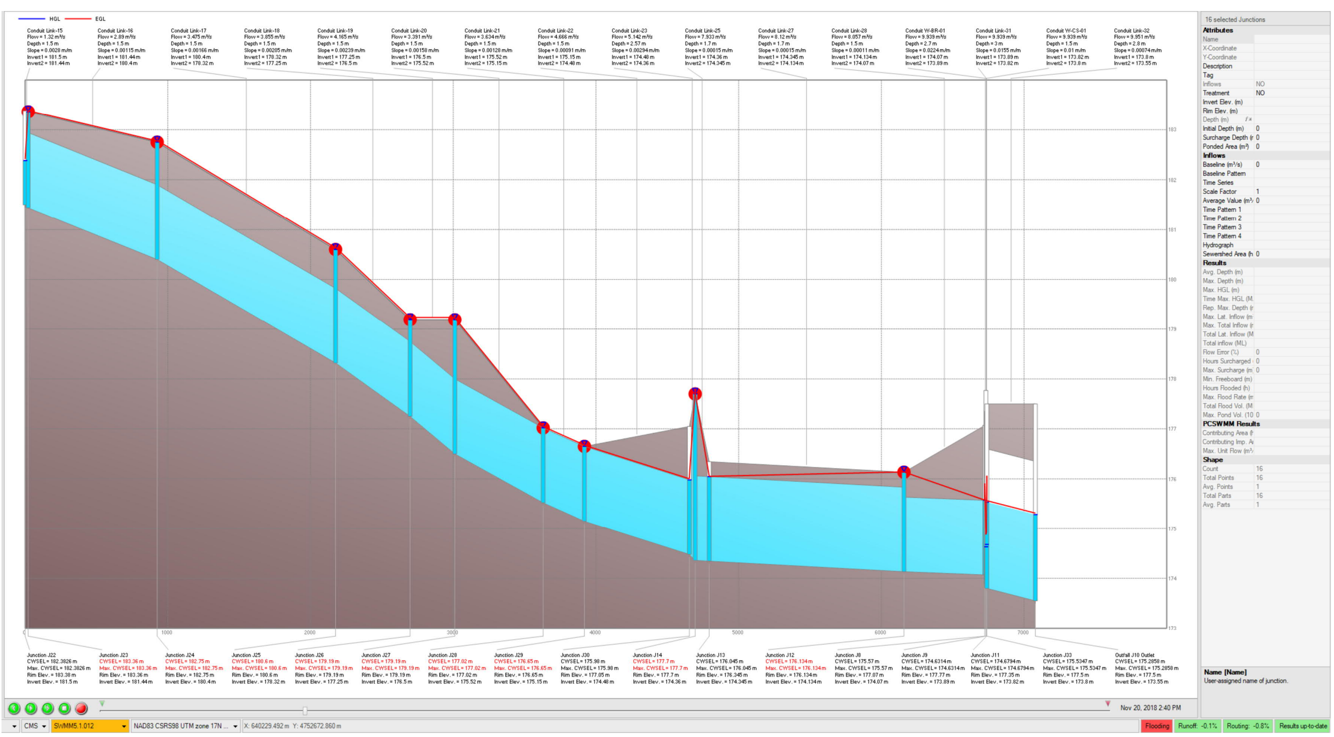


Figure 25 Wignell Drain PMP Model Profile

In the model, exceedances leak flows that are unaccounted for in downstream capacities and a more comprehensive model allowing for storage within the network would have to be implemented. This model would calculate storages and confirm longer duration flows, without exceedances. The following figure indicating existing ground at or below 175.5m identifies that there exists significant storage capability within the Wignell Bog lands.

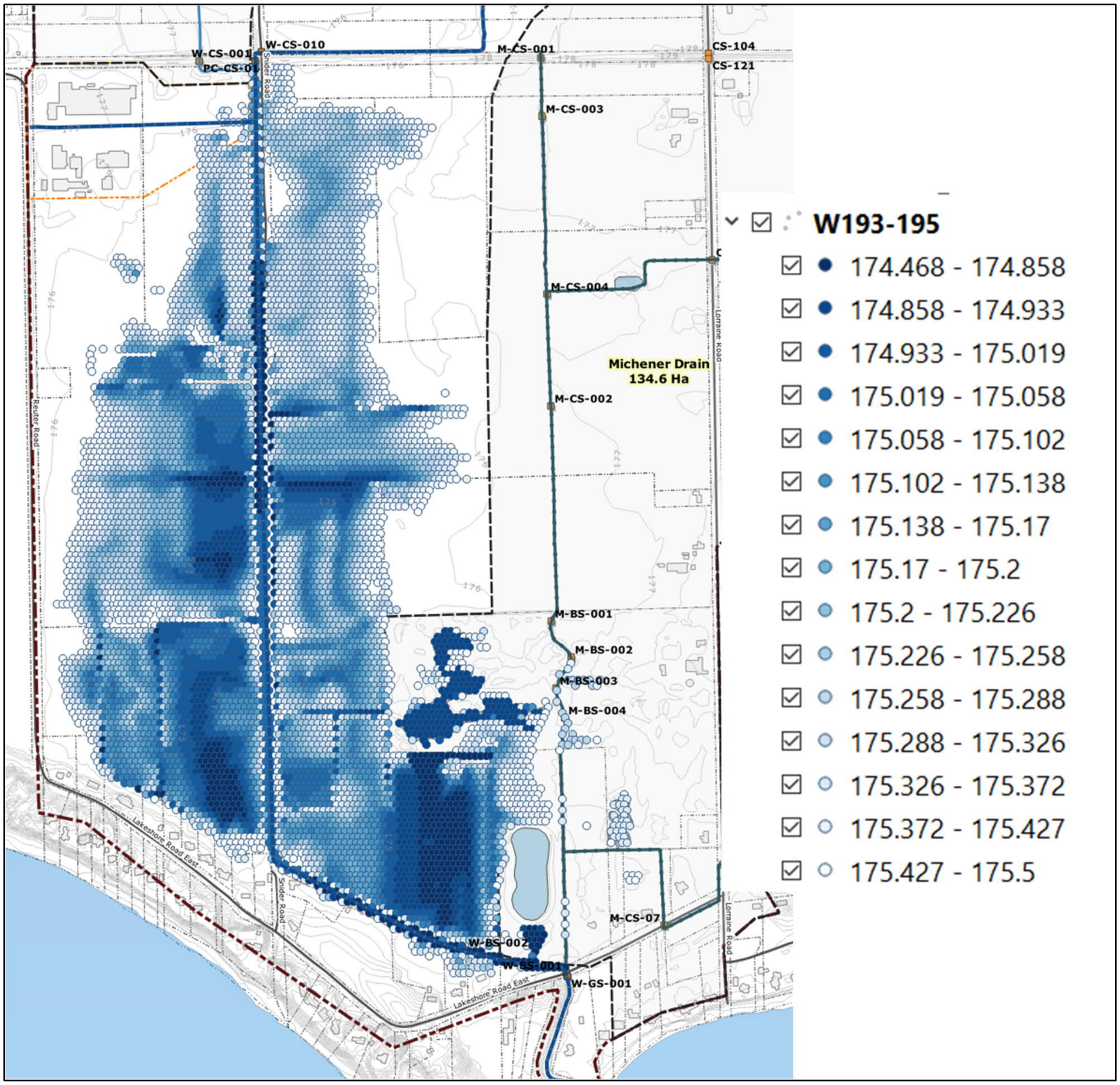


Figure 26 Wignell Bog Depths Adjacent to Drain

With a predicted design flow elevation in the range of 175.4m and 175.35 (Jnct J12 & J8) there is significant storage associated with the Wignell Bog lands as represented in the dark shaded blue dots for the 10m mass points from the NPCA DEM file. The darker the shade of blue, the greater depth of volume storage during runoff events. The dark blue dots range to light blue dots from 174.45 to 175.5m

With the current gate opening to a height of 175.13, the design storm will have a slight backwater effect from the gate; however, with the plan for a greater opening height target of 175.52m this restriction is removed. Even in the PMP modelling the existing gate is not identified as a significant restriction for flows to the lake. This can be understood in the context of the large slow channel and associated storage volume that is behind the Lakeshore Rd. E crossing.

Wignell Outlet Model update

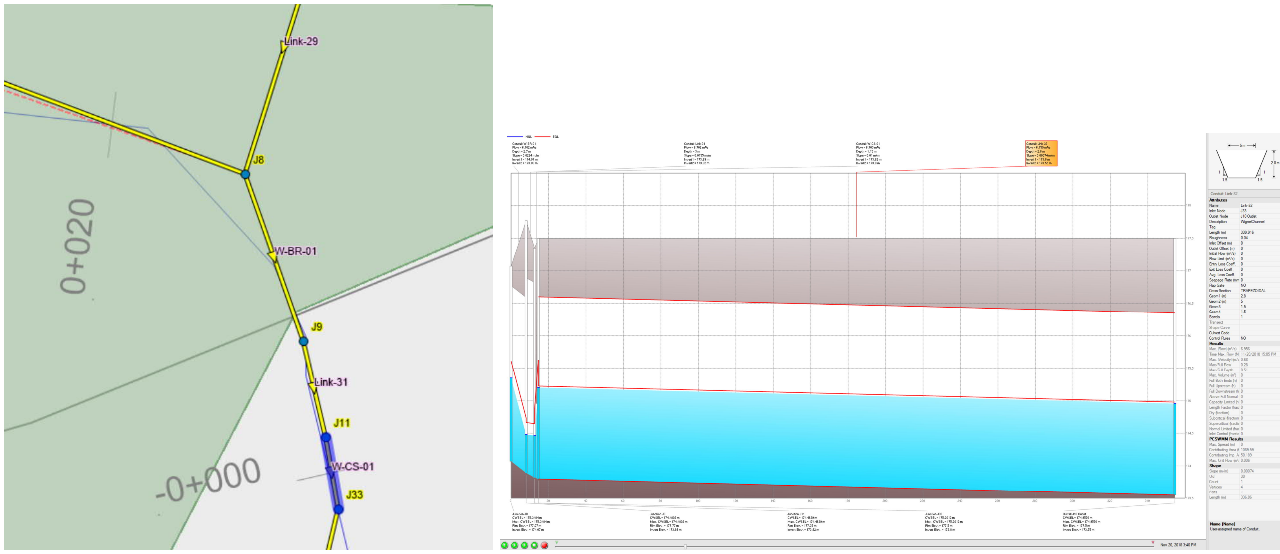


Figure 27 Outlet Model Flows

The outlet was modelled to show the existing Lakeshore bridge crossing as a rectangular closed conduit (W-BR-01), trapezoidal open section (Link-31), Gates as rectangular opening (W-CS-01 - existing height of 1.15m) and the trapezoidal channel to Lake Erie.

The result shows that the existing design flow intersects with the top of the gate during the peak event period but only for a short duration. The flow to the lake having a very low slope and wide bottom controls flow profile

4 Drain Hydraulics

The Wignell Drain below the Friendship Trail appears to be unchanged from the survey conducted in 1969 and which had a recommended flat gradeline at **174.378**m (based on a conversion of the elevation reported in feet [not NAD83 referenced]). The Friendship Trail, station 2+060 on the drain shows that the lower 2km of the drain is controlled by water surface rather than grade. This means that no matter how much excavation occurs the water will only move as quickly as the hydraulic surface water grade will move it. A deeper excavation will not move more water more quickly and will only influence water storage.

The following presents the existing grades assumed to be available based on the survey performed by Amec in 2013. These are not the actual grades but results from the survey of inverts at road crossings, actual grades may vary along the drain as the survey did not collect ditch grades throughout each reach.

Table 4 Drain Segment Average Grades

Segment	Grade Values, m/m	% of Fall
1: Outlet to Friendship Trail	0/2100	0.000%
2: Friendship Trail to Lorraine Rd.	1.191 / 1025	0.115%
3: Lorraine Rd. to Killaly St East	1.28 / 665	0.193%
4: Killaly St East to Weaver Rd.	0.83 / 302	0.274%
5: Weaver Rd to Main St East	1.07 / 552	0.193%
6: Main St East to Second Concession Rd	3.12 / 2084	0.149%

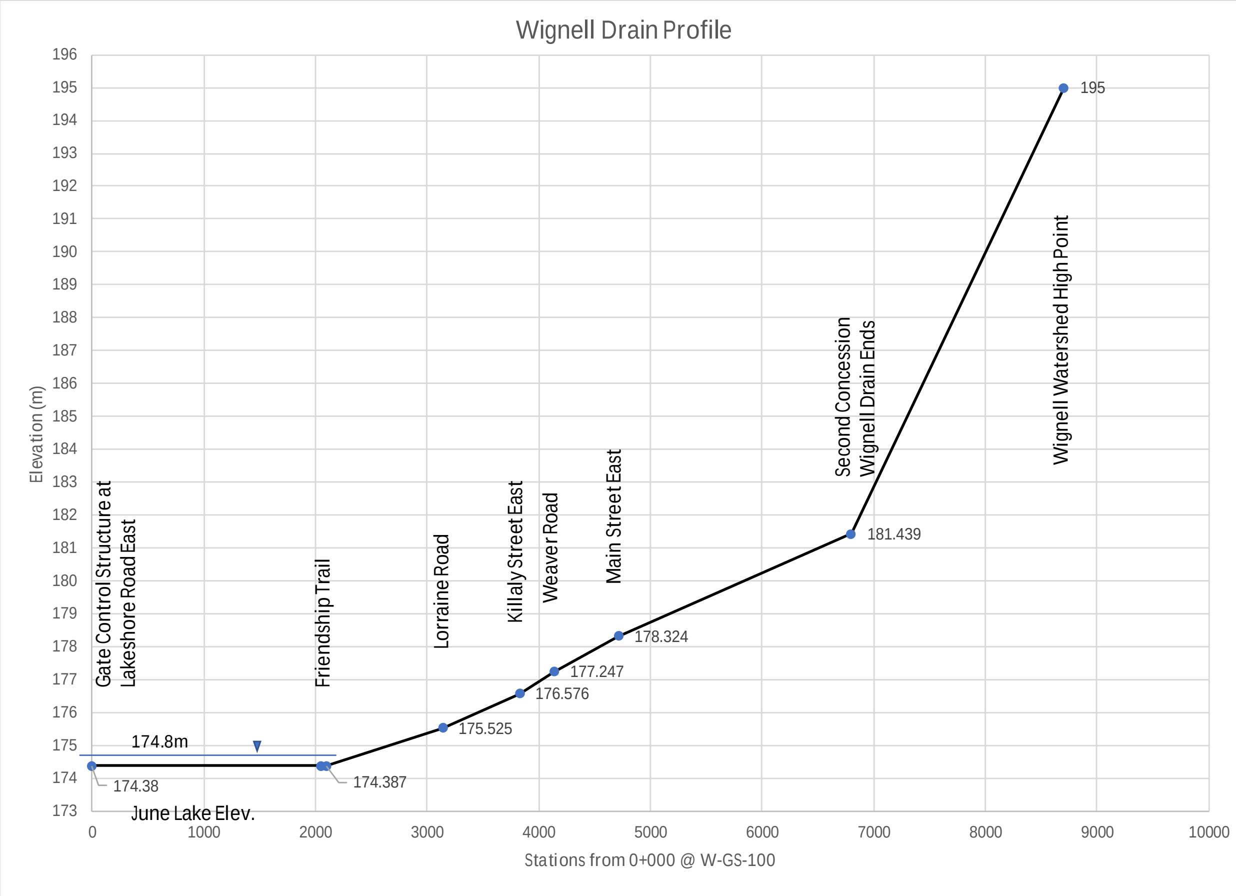


Figure 28 Wignell Drain Profile

The static water is undesirable but directly influenced by the lake level. There are opportunities to control the difference water elevations by restricting the flow back from the Lake and pumping out from the land side. This is done in many locations in Ontario to achieve positive drainage

Segment 2 is the transition from the water surface profile gradeline ditch to a flowing graded ditch. The transition point would appear to be the road crossing at Lorraine Rd.

The following are the profiles for both the Port Colborne Drain and the Michener Drain.

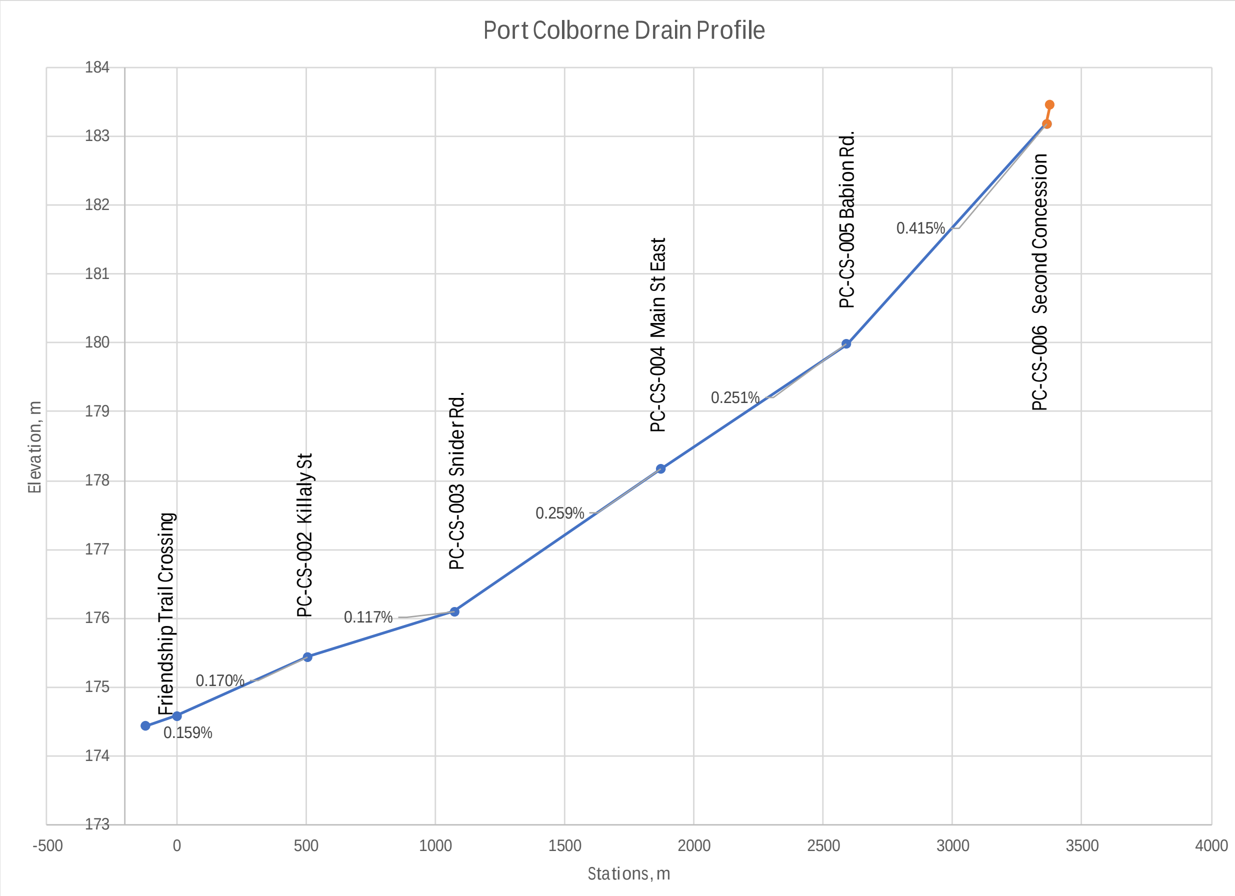


Figure 29 Port Colborne Drain Profile

DnStream Elev	UpStream Elev	Fall	Dn Stn	Up Stn	Distance	Slope %
183.1883	183.468	0.2797	3363.99	3377.9	13.91	2.011%
179.9808	183.1883	3.2075	2590.69	3363.99	773.3	0.415%
178.1701	179.9808	1.8107	1870.2	2590.69	720.49	0.251%
176.1035	178.1701	2.0666	1072.82	1870.2	797.38	0.259%
175.4436	176.1035	0.6599	507.38	1072.82	565.44	0.117%
174.5832	175.4436	0.8604	0	507.38	507.38	0.170%
174.4389	174.6302	0.1913	-120	0	120	0.159%

The Port Colborne Drain reflects positive drainage achieved throughout its length with the lower sections before the confluence with the Wignell Drain at the Friendship trail.

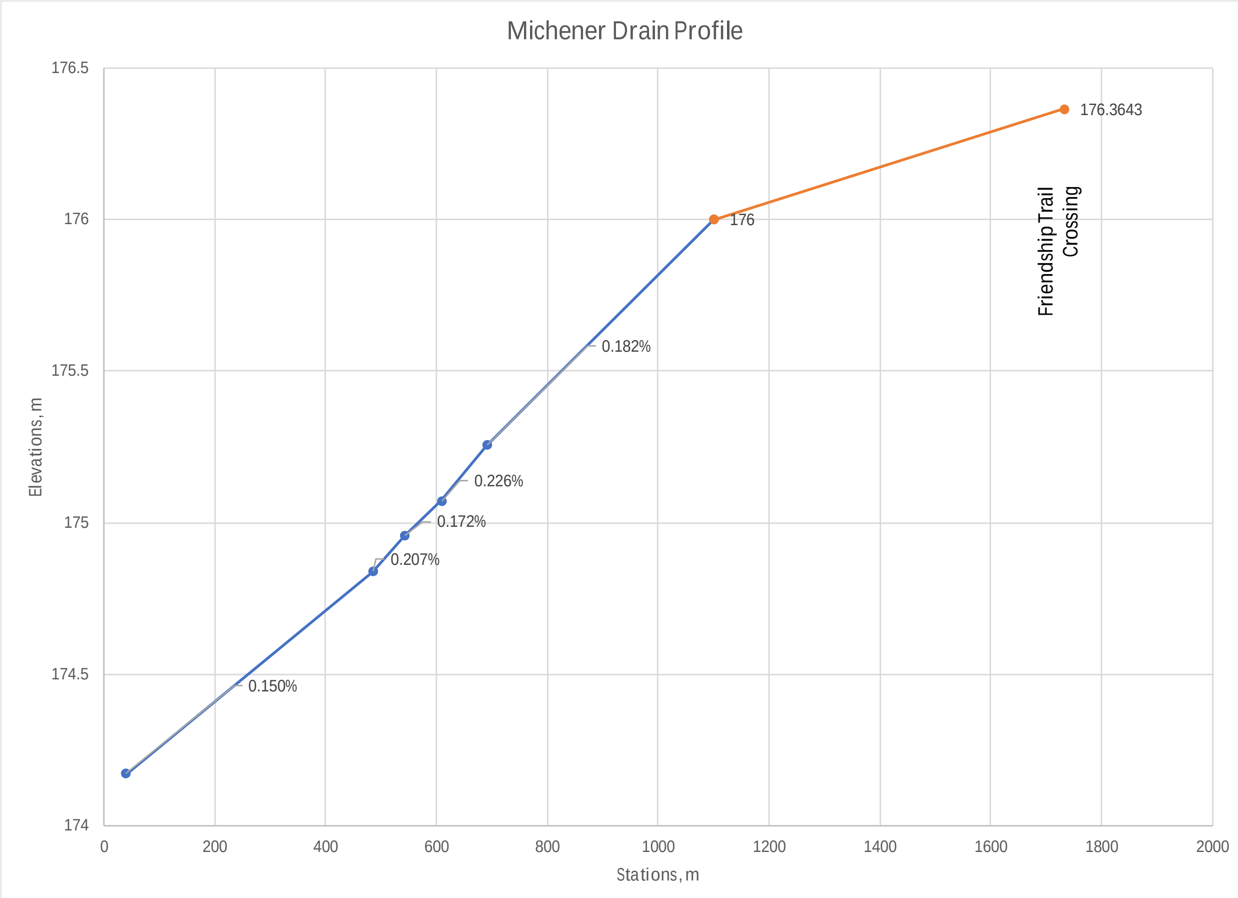


Figure 30 Michener Drain Profile

DnStream Elev	UpStream Elev	Fall	Dn Stn	Up Stn	Distance	Slope %
174.1723	174.838	0.6657	40	485.04	445.04	0.150%
174.838	174.9565	0.1185	485.04	542.4	57.36	0.207%
174.9565	175.0725	0.116	542.4	609.81	67.41	0.172%
175.0725	175.2558	0.1833	609.81	691.05	81.24	0.226%
175.2558	176	0.7442	691.05	1100	408.95	0.182%
176	176.3643	0.3643	1100	1732.6	632.6	0.058%

The Michener Drain is lacking some specific survey data to provide actual grade line data for the last portion of the drain where it connects to the Wignell Drain. A final gradeline point has been used based on the Wignell drain survey data and assuming that the elevations at the confluence are similar. However, the elevation reported from the NPCA data shows a lack of positive drainage but this is likely due to measurement error within the NPCA data.

4.1.1 Drain Channel Capacity Analysis

The cross-section of each drain channel, where drain channels are defined by the model set up with specific junctions as shown in the Model Map Diagrams in Appendix B was used to calculate a top of bank channel flow capacity.

This calculation is best completed with accurate survey data such as x-sections surveyed perpendicular to the drain at a 20m or 25m interval. However, in several sections no survey data was available. The x-section was analyzed by on the available data as provided by the NPCA 1m contour data file. This imposes some limitations in accuracy that should be addressed with additional survey. However, an assessment based on the available data is made for every section.

Where a channel is shown without a clear bottom width, in the x-section a triangle is shown, then a 0.2m bottom trapezoidal channel is assumed. Where specific survey points are known to show a bottom, then that bottom width is used. Where a side slope is not known then a 1:1 side slope is assumed. Manning’s n values were used from the US DOT reference, included in Appendix D.

Where there a top bank on either side of the channel has different heights then the lowest height, providing the least capacity, is used in the calculation.

The slopes of each channel are determined from the Amec survey of 2013. The Amec survey has very good detail on each of the culvert or bridge crossings but few x-section surveys in specific sections of the three drains. For the slope of each channel an average slope is used based on the crossing elevations obtained from the Amec survey in 2013. Those slopes are shown in the figures above for the Wignell, Port Colborne and Michener Drains.

For the runoff model idealize channels are used to ensure that a predicted design flow is achieved and used to benchmark against actual drain performance. The model link parameters used for idealized channel is shown in Table 3 Model Link parameters. The model profile is shown in the follow figure for the 5 year precipitation event.

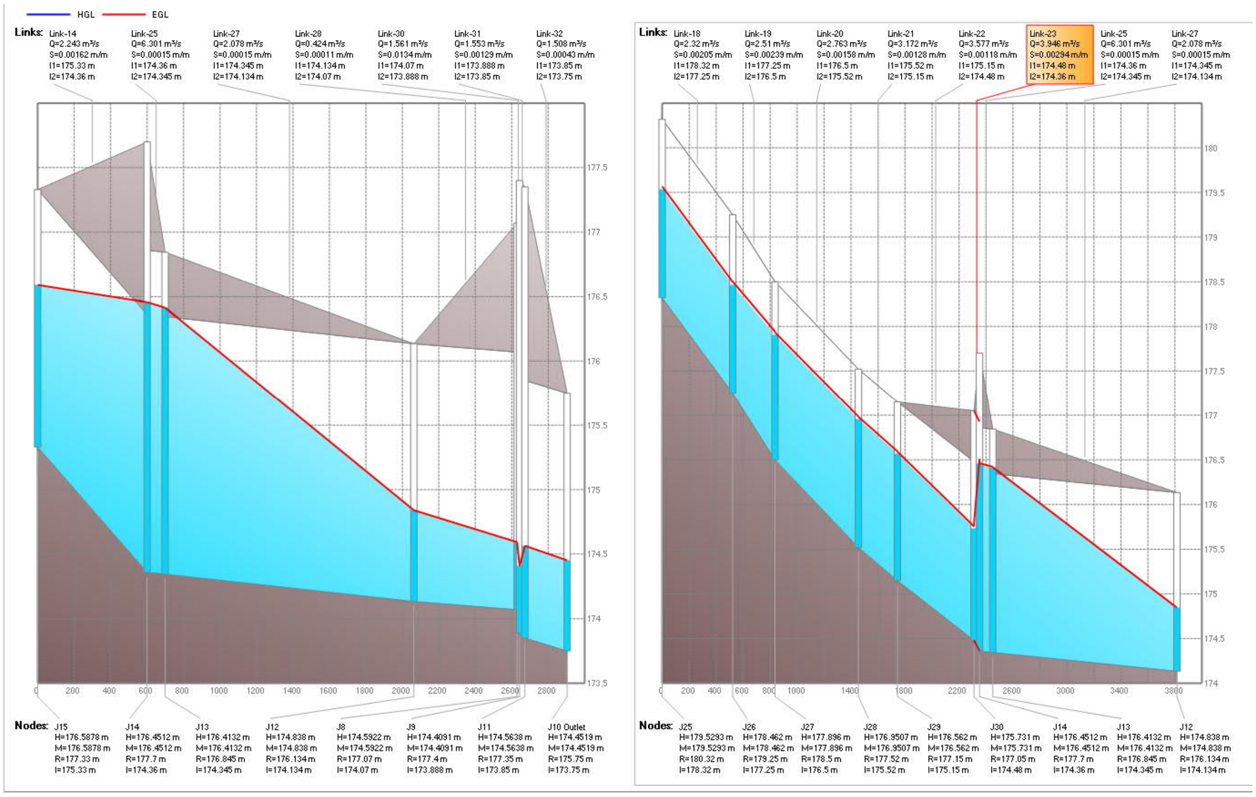


Figure 31 PC-SWM profile view of 5yr runoff peak flows

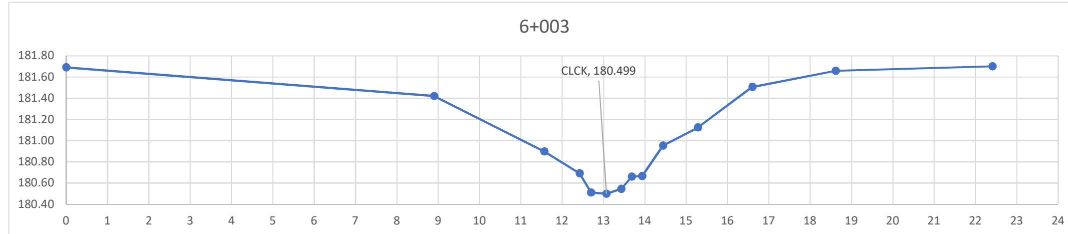
The Channel analysis along with proposed channel design capacity analysis is presented in the following table along with sediment basin analysis. Presented design target flows are from the Hydrology Model implementation.

Table 5 Hydraulic Drain Channel Capacity Analysis

	STN	Depth	Btm- W	TW	SS (Rise / Run)	n	slope
					(1/2=.5)	0.025	0.0011
					(1/4=.25)		
					(1/1.5=.67)		
AFW - 2011	6+003	1.01	1.26	7.70	0.21		
					4.8		

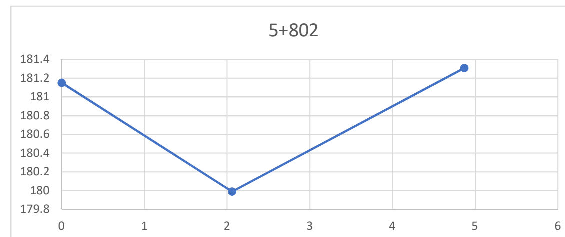
GO	GO	GO	EW	GO	CLCK	GO	EW	GO	GO	GO	TB	GO	GO
0	8.9	2.667	0.855	0.276	0.37	0.362	0.252	0.252	0.507	0.842	1.318	2.017	3.789
0	8.9	11.567	12.422	12.698	13.068	13.43	13.682	13.934	14.441	15.283	16.601	18.618	22.407
181.6925	181.4207	180.8978	180.692	180.5106	180.499	180.5448	180.6618	180.6666	180.954	181.1251	181.5076	181.6587	181.7013

	Q	5.511	9.34
J24	1 in 5 yr	1.988	
	100 yr	6.717	



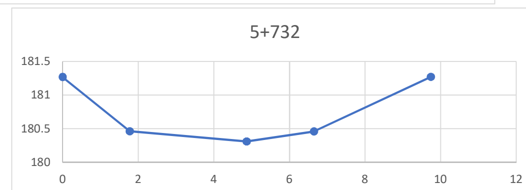
	STN	Depth	Btm- W	TW	SS			
						T/B	CL	T/B
EWA/CofPC	5+802	1.32	0.00	4.87	0.56	0	2.059	2.809
					1.8	0	2.059	4.868
						181.151	179.989	181.3099
							1.162	-0.1589

	Q	2.884	5.28
J24	1 in 5 yr	1.988	
	100 yr	6.717	



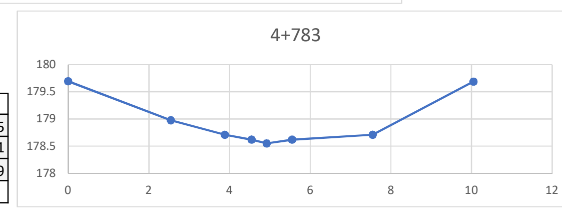
	STN	Depth	Btm- W	TW	SS					
						T/B	BTM-LB	CL	BTM-RB	T/B
EWA/CofPC	5+732	0.96	4.87	9.74	0.45	0	1.777	3.092	1.78	3.09
					2.2	0	1.777	4.869	6.649	9.739
						181.269	180.4607	180.3098	180.46	181.27
						0	0.8083	0.9592		

	Q	7.042
J24	1 in 5 yr	1.988
	100 yr	6.717



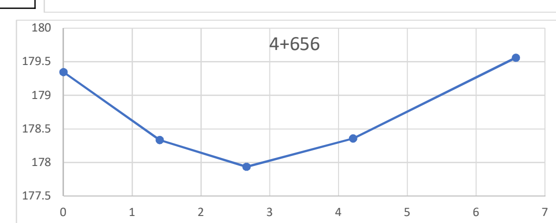
	STN	Depth	Btm- W	TW	SS								
						T/B				CL			
EWA/CofPC	4+783	1.14	1.67	9.85	0.24	0	2.548	1.335	0.666	0.375	0.627	2	2.5
					4.2	0	2.548	3.883	4.549	4.924	5.551	7.551	10.051
						179.6944	178.978	178.7101	178.6216	178.5507	178.6214	178.71	179.69
						0	0.7164	0.9843	1.0728	1.1437	1.073		

	Q	7.249
J25	1 in 5 yr	2.325
	100 yr	8.667



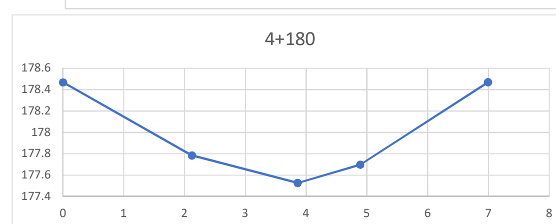
	STN	Depth	Btm- W	TW	SS					
						T/B		CL		T/B
EWA/CofPC	4+656	1.41	2.81	6.58	0.72	0	1.401	1.259	1.552	2.366
					1.4	0	1.401	2.66	4.212	6.578
						179.3449	178.3335	177.9349	178.3572	179.5604
						0	1.0114	1.41	0.9877	-0.2155

	Q	8.220	7.04
	n 0.045	4.567	
J25	1 in 5 yr	2.325	
	100 yr	8.667	



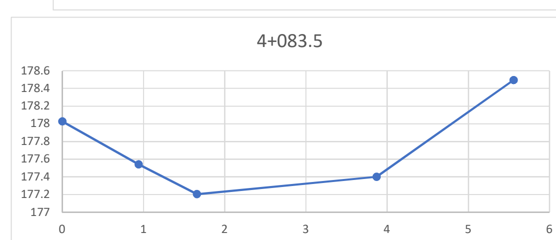
	STN	Depth	Btm- W	TW	SS					
						T/B		CL		T/B
EWA/CofPC	4+180	0.94	2.77	6.99	0.32	0	2.121	1.74	1.031	2.1
					3.1	0	2.121	3.861	4.892	6.992
						178.4683	177.7836	177.5266	177.6988	178.47
						0	0.6847	0.9417	0.7695	-0.0017

	Q	5.527
	n 0.045	3.685
J26	1 in 5 yr	2.520
	100 yr	8.492



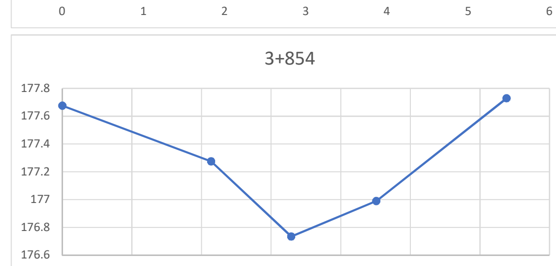
	STN	Depth	Btm- W	TW	SS					
						T/B		CL		T/B
EWA/CofPC	4+083.5	0.82	2.93	5.56	0.52	0	0.939	0.719	2.212	1.686
					1.9	0	0.939	1.658	3.87	5.556
						178.0272	177.541	177.205	177.4001	178.4949
						0	0.4862	0.8222	0.6271	-0.4677

	Q	3.867
	n 0.045	2.578
J26	1 in 5 yr	2.520
	100 yr	8.492



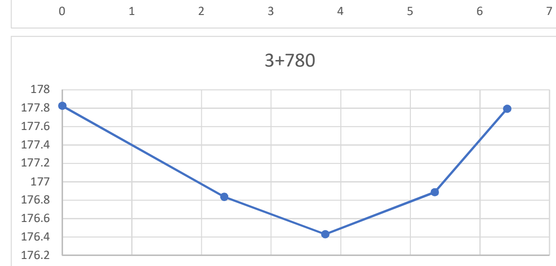
	STN	Depth	Btm- W	TW	SS					
						T/B		CL		T/B
EWA/CofPC	3+854	0.94	1.22	6.38	0.19	0	2.138	1.15	1.223	1.871
					5.4	0	2.138	3.288	4.511	6.382
						177.675	177.2755	176.7339	176.9892	177.7289
						0	0.7517	1.2933	1.038	0.2983

	Q	5.719
	n 0.045	3.860
j27	1 in 5 yr	2.865
	100 yr	9.678



	STN	Depth	Btm- W	TW	SS					
						T/B		CL		T/B
EWA/CofPC	3+780	1.39	1.57	6.39	0.43	0	2.325	1.452	1.573	1.04
					2.3	0	2.325	3.777	5.35	6.39
						177.8252	176.8356	176.4306	176.8862	177.7934
						0	1.1916	1.5966	1.141	0.2338

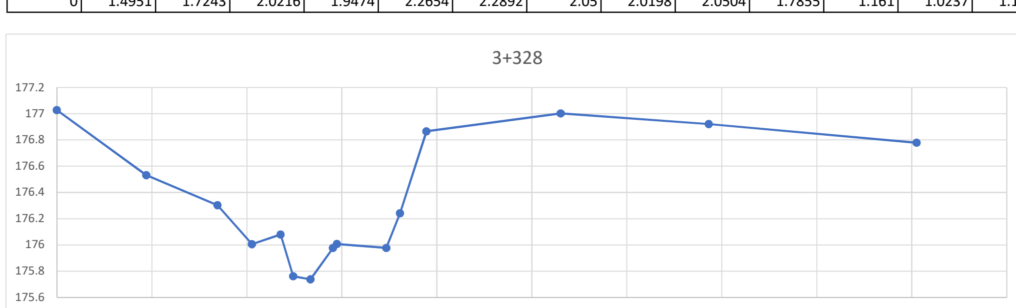
	Q	7.620
	n 0.045	5.080
J27	1 in 5 yr	2.865
	100 yr	9.678



	STN	Depth	Btm- W	TW	SS
EWA/CofPC	3+328	1.29	1.79	7.78	0.20
					5.0

T/B				EW		CLCK	EW				T/B			
0	1.885	1.498	0.725	0.604	0.266	0.363	0.471	0.085	1.039	0.29	0.556	2.828	3.118	4.376
0	1.885	3.383	4.108	4.712	4.978	5.341	5.812	5.897	6.936	7.226	7.782	10.61	13.728	18.104
177.0273	176.5321	176.3029	176.0056	176.0798	175.7618	175.738	175.9772	176.0074	175.9768	176.2417	176.8662	177.0035	176.922	176.7788
0	1.4951	1.7243	2.0216	1.9474	2.2654	2.2892	2.05	2.0198	2.0504	1.7855	1.161	1.0237	1.1052	1.2484

	Q	10.854
	n 0.045	7.236
J28	1 in 5 yr	3.356
	100 yr	8.793



The result of the analysis is as follows:

- The Port Colborne Drain has good capacity, which is largely a result of the recent cleanout south of the Main St East crossing. Average capacity of 1.5 cms with lower capacity in the lower channels.

- Port Colborne Drain is to be extended on the East Side of Babion to north of Second Concession Road. Proposed channel design to meet 5yr Runoff flows with sediment basin located in the South East corner of the intersection between Second Concession and Babion Road.

- The capacity of the Wignell drain above the Lorraine Rd crossing is low relative to the Port Colborne drain. Capacities range from 0.24 cms to 0.98 cms. This reflects the opportunity to clear and re-establish both grade and well formed ditch channel sections to increase capacity.

- The flat section of the Wignell drain has little to no grade and thus flow is based on the hydraulic head and the water surface profile to the lake. For the purposes of a calculation, a water surface profile of 0.0001 or 10 cm per 1km of drain was used with the Manning equation.

4.1.2 Wignell Bridge and Culvert Structures

The culvert capacity analysis was conducted using HY-8 software for each culvert. Software Output reports are available in Appendix E.

Table 6 Wignell Watershed Culverts

id	NameID	Crossing	Drain	Culv_desc	num_culv	Station	Condition, 2012	Cross_CAT	Length	Model Junction
Michener Drain Crossing Structures										
85	M-CS-07	Lakeshore Road East	Michener Branch Drain 1	CSP 375	1	0+332	new, 2017	Local Road - 5	12	NA
22	M-BS-004	Golf #4	Michener Drain	Bridge	1	0+470		ND	3	NA
21	M-BS-003	Golf #3	Michener Drain	Bridge	1	0+527		ND	3	NA
20	M-BS-002	Golf #2	Michener Drain	CSP ?600		0+593		ND	3	NA
19	M-BS-001	Golf #1	Michener Drain	Bridge		0+672		ND	3	NA
66	M-CS-002	Private	Michener Drain	Concrete Box ?	1	1+073		Private - 2	4.8	J7
67	M-CS-003	Private	Michener Drain	CSP 450	1	1+610		Private - 2	4.6	J1
5	M-CS-001	Friendship Trail	Michener Drain	Concrete 1200	1	1+720		Local Path - 2	7.6	J1

id	NameID	Crossing	Drain	Culv_desc	num_culv	Station	Condition, 2012	Cross_CAT	Length	Model Junction
Port Colborne Drain Crossing Structures										
2	PC-CS-001	Friendship Trail	Port Colborne Drain	Concrete Box 2570x3130	1	0+002		Local Path - 2	6	J15+PC6
6	PC-CS-002	Killaly Street East	Port Colborne Drain	Concrete Box 2370x1520	1	0+500		Local Road - 5	20	J15
8	PC-CS-003	Snider Road	Port Colborne Drain	Concrete Pipe 1500	1	1+070		Local Road - 5	7.4	J16
89	PC-F-002	Private	Port Colborne Drain	Fording		1+618	new 2016			
83	PC-F-001	Private	Port Colborne Drain	Fording		1+760	new 2016		3	
9	PC-CS-004	Main Street East	Port Colborne Drain	Concrete Box Open Bottom	1	1+946		MTO - 25	24.7	J17
11	PC-CS-005	Babion Road	Port Colborne Drain	Conc Box 3'x6'	1	2+575		Local Road - 5	13.5	J18
	Proposed	Private Entrance culvert	Port Colborne Drain	HDPE 2-W 900	1			Private - 2	30	J88
13	PC-CS-007	Second Concession Road	Port Colborne Drain	PVCO 750	1	3+363		Local Road - 5	13.6	J21
12	PC-CS-006	Babion Road	Port Colborne Drain	PVCO 600	1	3+378		Local Road - 5	11.3	PC1

Wignell Drain Crossing Structures										
id	NameID	Crossing	Drain	Culv_desc	num_culv	Station	Condition, 2012	Cross_CAT	Length	Model Junction
3	W-BS-001	Lakeshore Road East	Wignell Drain	Concrete Box 5200x2730	1	0+008		Local Road - 5	5	NA
4	W-BS-002	Property	Wignell Drain	Bridge 16500x1710	1	0+202	None	Private - 2	4	J12
63	W-CS-001	Friendship Trail	Wignell Drain	Concrete Box 3130x2570		2+068		Local Path - 2	6	J30
70	W-CS-010	Snider ROW	Wignell Drain	Twin 1500 Corrugated Steel Pipe	2	2+105		Local Road - 5	20	J30
17	W-CS-007	Lorraine Road	Wignell Drain	Concrete Box 3090x1510	1	3+141		Local Road - 5	12	J28
68	W-CS-009	Private	Wignell Drain	Concrete Box 3800x1180	1	3+463		Private Farm	4.2	J27
7	W-CS-003	Killaly Street East	Wignell Drain	Concrete Box 3800x1400		3+822		Local Road - 5	24.1	J27
16	W-CS-006	Weaver Road	Wignell Drain	Concrete Box 2520x1100	1	4+143		Local Road - 5	8.4	J26
69	W-CS-015	Private	Wignell Drain	Concrete Box 2350x1040	1	4+327		Private Farm	4.4	J25
82	W-BS-010	Private	Wignell Drain	Wooden Bridge		4+655		Private - 1	1.5	J25
18	W-CS-008	Main Street East	Wignell Drain	Concrete Box 2370x1200	1	4+712		MTO - 25	25	J25
71	W-CS-011	Private (to be replaced)	Wignell Drain	CSP 1640	1	5+200		Private - 2	9.2	J24
72	W-CS-012	Private (to be abandoned)	Wignell Drain	Concrete Box 5000x1300	1	5+800		Private - 2	3	J24
81	W-CS-014	Private (to be abandoned)	Wignell Drain	CSP 1.3 HW	1	6+250		Private - 2	8.4	
80	W-CS-013	Private (to be abandoned)	Wignell Drain	CSP 1.7	1	6+448			3.3	
15	W-CS-005	Second Concession Road (to be relocated)	Wignell Drain	CSP 1700	1	6+812		Local Road - 5	12	J23
14	W-CS-004	Carl Road (to be re-laid lower)	Wignell Drain	CSP 1300	1	6+832		Local Road - 5	11	J22
44	W-GS-001	Wignell Gate Control Structure	Wignell Drain	Gates	3	0+000				J8

4.2 Wignell Gate and Pump Structure

Wignell Drain includes a control structure located immediately south of Lakeshore Rd. East. Identified on the maps as W-GS-001.

Figure 32 Wignell Control Structure - 01

The control structure at the outlet of the Wignell/Michener Drain consists of a concrete dam with three steel sluice gates with gate actuators, a bypass well formerly installed with a well pump but not currently in operation, an emergency bypass river pump mount and associated piping. The well pump was installed in a small pump house mounted directly above the well structure but is not currently operational.

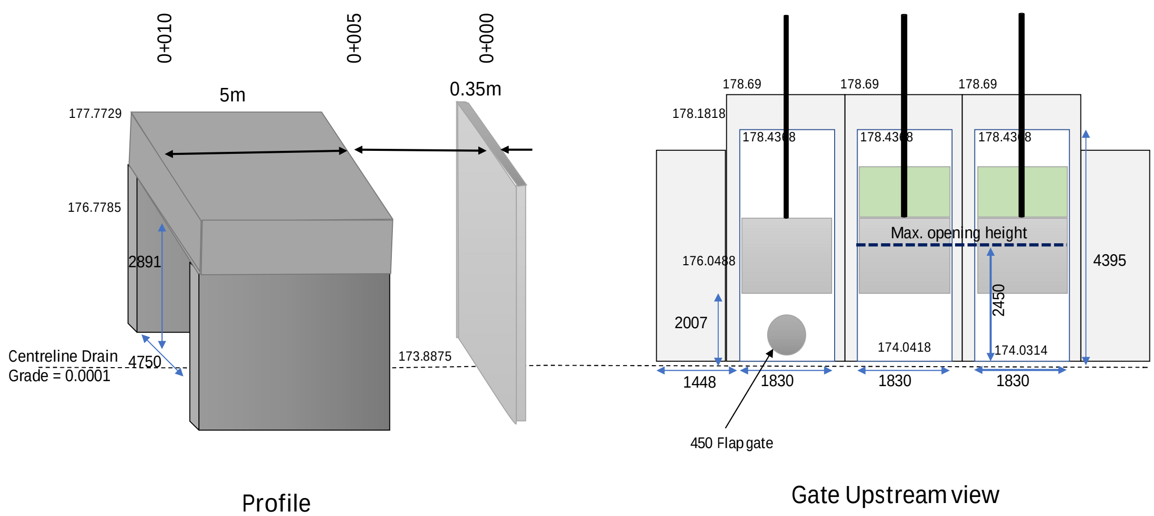


Figure 33 Wignell Control Structure Dimensional Parametes

The control structure opening was modelled using HY-8 software. The output report is included in Appendix E.

The predicted elevation for the 1in 100 year flood event of 7.89 cms is shown in the following figure.

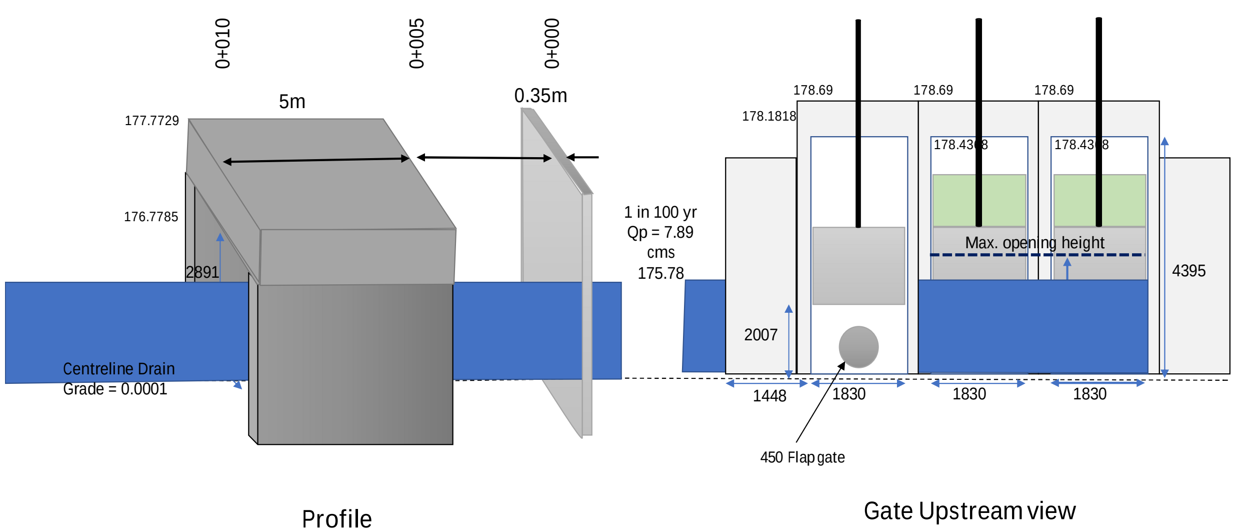
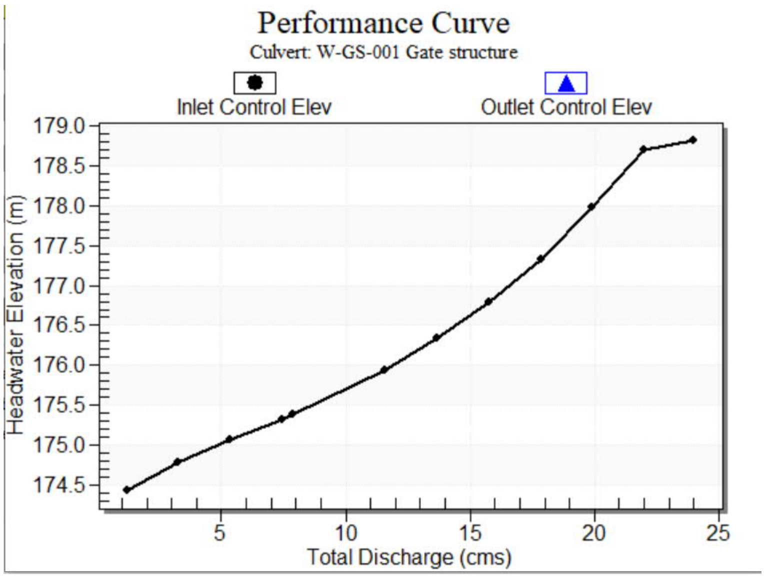


Figure 34 Predicted Flood elevation through Wignell Control Structure

The output table is provided as follows.

Table 7 Wignell Gate Structure Capacity Results

Total Discharge (cms)	Culvert Discharge (cms)	Headwater Elevation (m)	Inlet Control Depth(m)	Outlet Control Depth(m)	Flow Type	Normal Depth (m)	Critical Depth (m)	Outlet Depth (m)	Tailwater Depth (m)	Outlet Velocity (m/s)	Tailwater Velocity (m/s)
1.20	1.20	174.47	0.38	**0.43**	7-H2t	NA	0.22	0.37	0.53	0.88	0.43
3.28	3.28	174.93	0.74	**0.89**	7-H2t	NA	0.43	0.79	0.94	1.14	0.59
5.36	5.36	175.26	1.02	**1.22**	7-H2t	NA	0.60	1.08	1.24	1.36	0.68
7.44	7.44	175.61	1.28	**1.57**	4-FFf	NA	0.75	1.15	1.48	1.77	0.75
7.89	7.89	175.69	1.34	**1.64**	4-FFf	NA	0.78	1.15	1.52	1.87	0.76
11.60	11.60	176.35	1.90	**2.31**	4-FFf	NA	1.01	1.15	1.87	2.76	0.85
13.68	13.68	176.76	2.29	**2.72**	4-FFf	NA	1.12	1.15	2.04	3.25	0.89
15.76	15.76	177.18	2.75	**3.14**	4-FFf	NA	1.15	1.15	2.19	3.74	0.92
17.84	17.84	177.64	3.29	**3.60**	4-FFf	NA	1.15	1.15	2.34	4.24	0.95
19.92	19.92	178.12	3.94	**4.08**	4-FFf	NA	1.15	1.15	2.47	4.73	0.98
22.00	21.96	178.70	**4.66**	4.59	4-FFf	NA	1.15	1.15	2.60	5.22	1.01



From the analysis conducted with HY-8 software, we can conclude that there is adequate capacity in the existing two gate openings. However, this capacity is reduced when the gate opening limit is 1.15m and that an increase to 1.5m should be implemented as a drainage improvement. This improvement has a minor impact on the design storm but has implications for higher return period events with larger runoff flows being realized at the Wignell outlet.

5 Wignell Watershed Summary

The following summarizes the results of the hydrology and hydraulic analysis.

1. There is a single outlet to Lake Erie for three municipal drains; Wignell Drain, Port Colborne Drain and the Michener Drain. The Wignell and Port Colborne Drain have major components above the Friendship Trail that are Positively Graded to outlet at the Friendship Trail. These serve predominately agricultural lands but are influenced by urban fringe dwellings. Major industry in the upstream area of the Wignell Watershed is the limestone quarry operated by Rankin Construction.

2. The lower reach of the Wignell Drain after the confluence with the Port Colborne Drain has zero (or nearly zero) positive graded channel to the outlet. The lower lands are historically the Wignell Bog and are bog wetland that was formerly operated as a market garden and is now vacant land. The primary soil constituent of these lands is underlying peat, which acts as a sponge for runoff flows. This process is outside the scope of the model implementation.

3. The hydrology model is implemented using SCS runoff procedures suitable for agricultural lands with analysis using EPA SWMM 5.1.015 and PC-SWMM version 7.4. The implementation is a 1D model idealized for channel routing. This provides channel flow design values suitable for use in channel assessment and design.

   A 2D model implementation to represent the effect and role of storage from culvert performance was outside the scope of this assignment but could be considered for future implementation and analysis of the role that culverts and storage from road crossings and the Wignell Bog plays in the watershed. For this to be implemented a more detailed Digital Elevation Model (DEM) would be required.

   a. Note: the provincial DEM lidar for Lake Erie does not extend East as far as Port Colborne otherwise it would have been ideal to use for implementing the 2D local storage model.

4. Channel hydraulics are assessed for current conditions, using information available from survey data and NPCA where suitable to assess current performance based on channel obstructions from tree growth. This current capacity is compared against the idealized capacity predicted from the hydrology model and finally a proposed channel design is developed.

5. Culverts have been in place for a considerable length of time, most culverts are not expected to be found low in capacity. All culverts are assessed using the HY-8 software for culvert analysis. The control condition is reported along with the maximum flow with 0.3m freeboard from Centreline Elevation of the crossing roadway.

6. The existing Wignell outlet control structure will pass the predicted design storm, based on two gate structures open to existing level and a free flowing outlet to the lake. Refer to analysis using HY-8 software. Based on this analysis, the existing gate structure with two openings being improved for increased opening height and the 3rd opening currently built with a wet well for pumping can remain as is without further modification.
   A modernization of the Wignell Control Structure is recommended to achieve the following:

a. Compliance with updated health and safety requirements,

b. Additional of flow monitoring capabilities on both sides of the control gate structure using sondes.

c. Rehabilitation of the existing sluice gates is recommended a preventative maintenance activity. Repair, cleaning and repainting of the gates with the addition of remote operation of the gate structures using telemetry. Improving the gates to close against a sealed drain bottom is recommended.

d. Reconstruction of electrical services to the facility using NEMA 4 / IP54 rated enclosures and updated electrical switches all to be found above the NPCA flood proofing elevation of 177.3m.

7. Pumping capabilities were removed from the Wignell Control Structure and to date have not been restored. During that time, removals by pumping has been limited to the WRGC, which has 3 Permits to Take Water granted by the MOE. All runoff events have been ‘managed’ without the use of pumping. During the 2017 and 2018 summers significant lake levels have been recorded and this has caused water to back up in the Wignell Drain as far as the Friendship Trail and further.

   Restoring the pumping to the existing wetwell would require significant modernization and improvements consistent with the improvements made to the gates. Restoration of pumping is not recommended as a requirement for improvements to the Wignell Drain as the existing flows through the gates are adequate for most runoff events, up to the design event.