MAPLE AVENUE SUITES

Hydrology and Hydraulic Analysis for Floodline Assessment

Hot Pond Enterprises

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1 Purpose

Jewell Engineering Inc. (JE) has prepared this floodline assessment to support Hot Pond Enterprises in their development of Maple Avenue Suites in the County of Haliburton. The site is bound by Park Street to the north, Maple Avenue to the east, and Drag River to the south. There are commercial developments to the east and south of the site and a residential development to the west. The site location is shown in Figure 1-1.

A hydrologic and hydraulic assessment was requested by Dysart et al (Dysart) to satisfy Section 13.1.9 of the 2017 Official Plan regarding the Haliburton Village Special Policy Area. In particular, Dysart requested this assessment to show that the placement of fill will present no negative impacts to the floodwater or other properties. The limits of the Special Policy Area are shown by the blue hatched area in Figure 1-2.

Section 3.18 of Zoning By-law 2005-120 identifies a minimum opening elevation of 320.2m, CGVD28. JE requested a copy of the model that was applied to calculate this 320.2m elevation. However, Dysart informed JE that no records were available to support this number. Ideally, the geometry of the previous model would be updated with proposed fill on the site to determine potential impacts compared to existing conditions. Since no model or other information was provided for this analysis, Dysart requested that Hot Pond Enterprises provide 2022 hydrologic and hydraulic models to assess potential impacts. Therefore, JE completed a topographic survey, hydrologic model, and hydraulic model as part of the work described in this floodline assessment.

JE participated in a pre-consultation phone meeting to discuss the hydrology and hydraulics approach. JE and the Municipality’s representative consulting engineers agreed on the following tasks to support the flood limit:

- Hydrologic modelling using HEC-HMS in comparison to other available methodologies
- Hydraulic modelling using HEC-RAS version 6.0
- Site-specific survey data for cross-sections of the Drag River in the vicinity of the site location. The survey includes a portion of the tributary that crosses Victoria Street and ultimately drains to the Drag River.

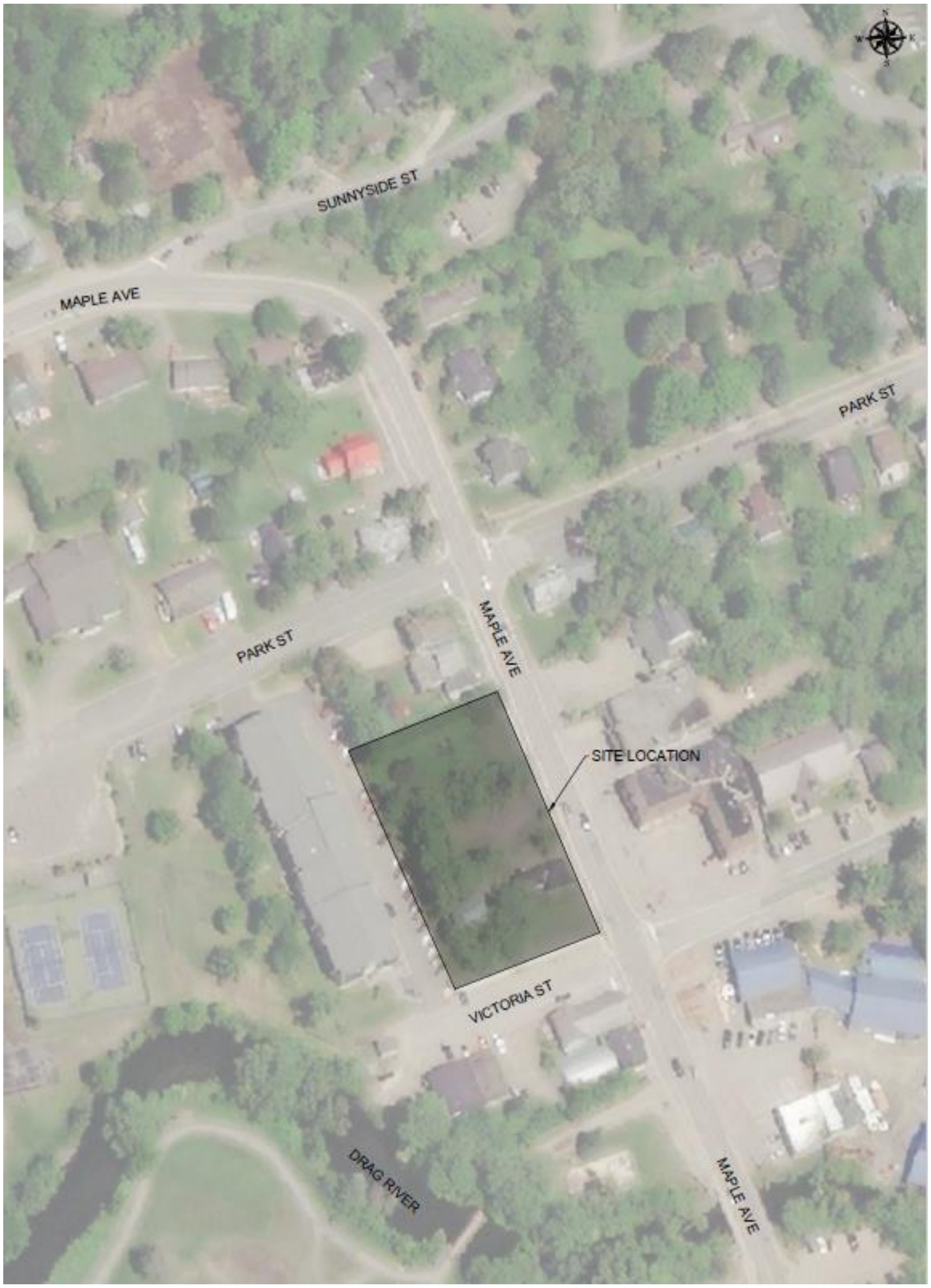

Figure 1-1: Development Lands of Interest

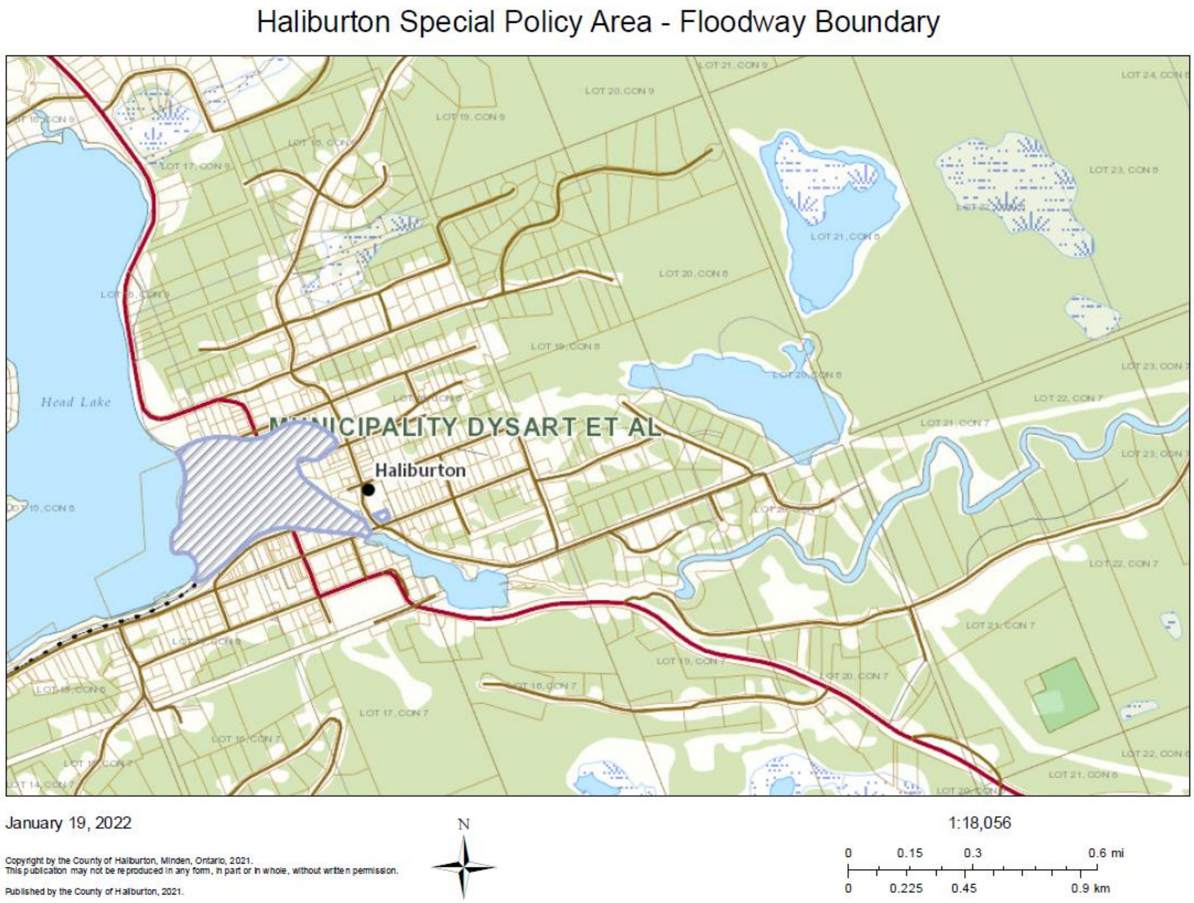

Figure 1-2: Haliburton Special Policy Area

2 Hydrology

This section summarizes the hydrologic investigation including catchment and drainage characteristics, the methodologies applied, and peak flow results.

2.1 Catchment and Drainage Characteristics

The catchment characteristics applied in the analysis were obtained using OFAT III and boundaries were reviewed by importing LiDAR data from Land Information Ontario. JE considered a small tributary to the east of the site, as well as the catchment that contributes to the Maple Avenue crossing of the Drag River. These two catchments were selected as the backwater effect from their contributing flows at the Maple Avenue crossing were analysed to determine water surface elevations in the vicinity of the site during major storm events.

2.1.1 Drag River Watershed

The Drag River watershed represents the larger catchment that contributes runoff towards the Maple Avenue crossing of Drag River (see Appendix A).

The catchment is relatively large at 131.4 km^2, or 13,400 ha and is comprised of predominantly treed land cover with 19% lakes and wetlands. The mean slope represents the average slope of overland areas and is relatively steep at 9%. With a large catchment area and steep topography, it is expected that there will be significant peak runoff rates in all return period events.

For soils data, JE referenced the Agricultural Atlas published by the Ontario Ministry of Agriculture, Foods, and Rural Affairs. There is limited soils information for this part of the province, so JE considered the land cover and surrounding soils to make a reasonable assumption for soil types. Majority of the nearest locations that have soils information available show hydrologic soils group B. Therefore, hydrologic soil group B was selected in calculating the curve number in the HEC-HMS model as shown in the table below. The SCS lag time method was applied to determine the time to peak supplied to the HEC-HMS model.

Table 2-1: Drag River Land Cover and Weighted Curve Number (CN)

Catchment	Land Use	HSG	CN	Sub-Area (ha)	A x CN	Weighted CN
100	Treed	B	58	104.7	6074	56.8
	Crop or improved		74	2.3	169	
	Lakes and wetlands	-	50	24.4	1219	
				131.4	7461	

2.1.2 Watershed for Adjacent Tributary

The adjacent tributary that drains near a commercial plaza towards Victoria Street represents the smaller catchment that contributes runoff towards the crossing near the intersection of Maple Avenue and Victoria Street (see Appendix A). This catchment is significantly smaller overall than the Drag River watershed at approximately 2.4 km^2, representing only 2% of the watershed. For modelling purposes, this tributary was included as part of the overall watershed in a lumped catchment.

The tributary drains to a pipe crossing of Victoria Street immediately east of Maple Avenue. In the regulatory event, peak flows from the tributary would become part of the flow contributing to the Maple Avenue crossing immediately upstream of the Hot Pond Enterprises site location. Therefore, this tributary was included as part of the overall watershed in a lumped catchment in JE's HEC-HMS model.

2.1.3 Precipitation and Stream Flow Gauge Data

Precipitation data from the MTO IDF Look-Up Tool at the site location was applied in the hydrology model. A feature of the MTO Look-Up Tool is that it provides projected rainfall data to consider potential impacts due to climate change. Projected rainfall data for the year 2071 was used for the SCS CN method when calculating the 100-yr peak flow. The hyetograph data per MTO Design Chart 1.04 was applied for the Timmins event. An areal reduction factor of 0.87 was applied due to the large catchment area in accordance with the MTO Drainage Manual.

There are no stream flow gauges along the Drag River based on review of Water Survey of Canada (WSOC) data. However, JE completed an analysis of stream flow gauge data for hydrologically similar watersheds that are within close proximity to Haliburton. A statistical analysis of these watersheds, in combination with a transposition of flows, applies in-field stream gauge data to estimate peak flows for the Drag River watershed. Further discussion on this method is described in Section 2.3.2.2.

Stream flow gauge data is obtained from the WSOC. Instantaneous flow data is downloaded to obtain peak runoff rates in each given year of record. The hydrologically similar watersheds selected for this analysis are part of the York River and Crowe River drainage systems. These watersheds were selected due to their similar watershed characteristics, record of stream flow gauge data, and proximity to the Drag River watershed. Since the areas contributing to the York River and Crowe River stream flow gauges are different than the Drag River watershed, a transposition of flows was calculated to account for this area difference.

Stream flow gauge data downloaded from WSOC is provided in Appendix B. The York River stream flow gauge has 41 years of streamflow data. The Crowe River stream flow gauge has 44 years of data. The HEC-SSP Manual identifies a minimum data record of 30 years in order for reliable return period flows to be calculated based on stream flow gauge data. Since both data records were greater than 30 years, their length of record was suitable for this analysis.

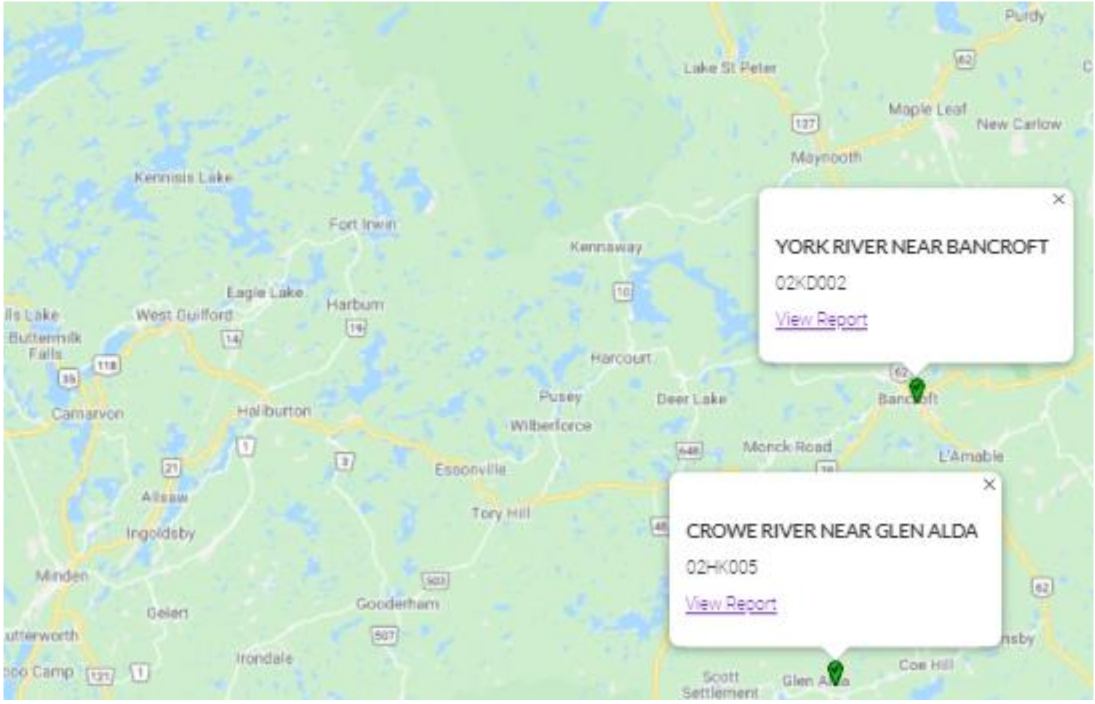

Figure 2-1: Stream Flow Gauge Locations for Hydrologically Similar Watersheds

2.2 Methodology

JE applied four modelling approaches to determine peak flows for Drag River at the Maple Avenue crossing.

- General Frequency Analysis (HEC-SSP)
- SCS Curve Number Method (HEC-HMS)
- Index Flood Analysis (OFAT III)
- Multiple Regression Analysis (OFAT III)

Further discussion on each of these modelling methods is described in Section 2.2.2.

2.2.1 Selected Modelling Programs

The following three modelling tools were used to determine peak flows in this report.

1) HEC-HMS version 4.2.1. This hydrologic modeling software is developed by the U.S. Army Corps of Engineers and distributed freely.

Parameters applied in HEC-HMS include:

- Precipitation – intensity, duration and frequency as well as distribution
- Catchment area
- Percent imperviousness – runoff volume, time to peak and peak flow increase with percent imperviousness

- Soil conditions – these determine how much and how quickly water will be removed from runoff through infiltration. This may be expressed as a curve number, or by a runoff coefficient or using an infiltration model such as Horton's Infiltration
- Slope – peak flows increase with slope
- Initial abstraction – depth of precipitation input that is subtracted from the model and does not contribute to runoff. This value is different for impervious and pervious areas and is expressed as two values.
- Manning's n – frictional coefficient that affects the time to peak. This value is different for impervious and pervious areas and is expressed as two values.
- Basin lag or time to peak.

2) HEC-SSP version 2.0. This is another software that is publicly available and developed by the U.S. Army Corps of Engineers. This software program is used to perform statistical analyses of hydrologic data obtained by stream flow gauges in the field.

The program has six statistical analysis components (HEC-SSP Statistical Software Pacakage User's Manual, 2016).

1) Flow Frequency Analysis (Bulletin 17)
2) General Frequency Analysis
3) Volume Frequency Analysis
4) Duration Analysis
5) Coincident Frequency Analysis
6) Balanced Hydrograph Analysis

For the purposes of obtaining return period flood flows, the General Frequency Analysis (GFA) component can be employed and is a recommended method in the 2002 MNR guidelines. This statistical component performs a peak flow frequency analysis using various methods. Parameters other than peak flows, such as stage or precipitation data, can also be calculated using a GFA.

In performing a flood frequency analysis, data is provided to the program and the calculated results are output in graphical and tabular formats. Prior to providing input data, a variety of settings are defined by the user. Some notable settings and their descriptions are shown in Table 2-2.

Table 2-2: HEC-SSP Settings and Descriptions

Setting	Description
Log Transform	• This setting can be selected to have the frequency analysis performed on the logs of the data • Log Transform needs to be used to allow for the LogNormal and LogPeason III distributions to be selected • If the Log Transform setting is not used, the Normal and Pearson III distributions can be selected
Confidence Limits	• Confidence limits measure the uncertainty of the computed value for a selected exceedance probability • Default settings calculate the 90% confidence interval, with confidence limits of 0.05 and 0.95
Distribution	• This setting provides the analytical distribution options used to perform the frequency analysis • Distribution choices are None, Normal, LogNormal, Pearson III, and LogPearson III
Generalized Skew	• Computes a skew value for the data • Three options that can be selected are Station Skew, Weighted Skew, and Regional Skew • The default option is Station Skew, where the skew of the computed curve is based solely on computing a skew from the provided data points

3) Ontario Flow Assessment Tool (OFAT III). OFAT III is developed by the Ministry of Natural Resources to estimate design flows and analyse the hydrology of the contributing drainage area. OFAT III contains two methodologies for determining the return period flows for streams in Ontario. These are Index Flood Method and the Multiple Regression Analysis Method.

The methods are described in various papers and summarized in the OFAT III Users Guide. Both methods are supported by the Province for use in Ontario in the MTO, *Drainage Management Manual*, *1997* and the MNRF, *Technical Guide for River and Streams; Flood Hazard Limit, 2002*.

OFAT provides hydrologic characterizations of watersheds for modelling purposes. This would include the slope of the main channel, slope of the land, shape factor and area of lakes/wetlands. The tool also provides land cover characterization to determine the percentages and areas of forested areas, wetlands and lakes, as well as open fields.

2.2.2 Drag River Hydrologic Models

Four modelling approaches were used to determine peak flows. The peak flow results are summarized in Table 2-5. The Timmins peak flow is selected as the regulatory event to determine the minimum opening elevation in accordance with *MNR's Technical Guide – River and Stream Systems: Flood Hazard Limit*. The results for the 100-yr return period event is also shown, since these represent more realistic peak flows based on JE's analysis of stream flow gauge data obtained for nearby hydrologically similar watersheds.

Table 2-5 shows the results from the following four modelling methods

- General Frequency Analysis (HEC-SSP)
- SCS Curve Number Method (HEC-HMS)
- Index Flood Analysis (OFAT III)
- Multiple Regression Analysis (OFAT III)

The General Frequency Analysis (GFA) was prepared based on stream flow gauge data for the nearby watersheds contributing to York River and Crowe River. The return period peak flows calculated from the GFA were used to derive 100-yr peak flows for the Drag River adjacent to the site's location using a transposition of flows.

The SCS CN method was applied using the HEC-HMS modelling program. With this program, catchment parameters specific to the Drag River were calculated and supplied as inputs to a basin model with simulated rainfall events. The SCS CN method with a 24-hr, SCS rainfall distribution yielded the largest peak flow for the 100-yr return period event as shown in Table 2-3.

The Timmins event was also modelled using the SCS CN method. A GFA cannot be performed for the Timmins event since it is not a return period event. Rather, the rainfall distribution for the Timmins event is obtained from MTO Design Chart 1.04. As per the MTO Drainage Manual, an areal reduction factor of 0.87 was applied to this distribution since the watershed area is between 101 and 150 km^2.

The Index Flood and Multiple Regression methods were used for comparison purposes using OFAT III.

Further details on the modelling approaches used to determine the peak flows shown in Table 2-3 are described in the following subsections.

Table 2-3: Drag River Peak Flow Summary at Maple Avenue Crossing (m^3/s)

Drag River - Transposition of Flows		Index Flood	*Multiple Regression	24-Hr, SCS CN	Timmins
York River	Crowe River				
34	28	54	79	81	156

**Parameters outside of range*

2.2.2.1 SCS Curve Number (HEC-HMS)

The SCS Curve Number (CN) method uses the land use and hydrologic soils group information from Section 2 to develop the CN as the loss method. This modelling approach is supported by the HEC-HMS program. Hydrologic soils group data is provided by the Agricultural Atlas published by the Ontario Ministry of Agriculture, Food, and Rural Affairs. However, for this portion Haliburton County, no soils data was available. Therefore, soils data for the surrounding counties was reviewed and applied for the Drag River watershed. JE expects the selected CN was conservatively applied since the peak flow results from the SCS CN method produced the largest value for the 100-yr event of 81 m^3/s, slightly above the 79 m^3/s produced from the Multiple Regression Analysis as was shown in Table 2-3.

2.2.2.2 General Frequency Analysis (HEC-SSP)

A general frequency analysis (GFA) was used to incorporate stream flow gauge data into the hydrology results. Drag River does not have a stream flow gauge based on WSOC records. Therefore, a GFA was applied on stream flow gauge results for hydrologically similar watersheds in close proximity to the Drag River watershed. Two similar watersheds were selected due to their similar watershed characteristics, length of data records, and proximity to Drag River. These are the watersheds for York River and Crowe River that drain to the WSOC stream flow gauges identified below.

York River: ***Station Number 02KD002***

Crowe River: ***Station Number 02HK005***

The GFA method calculates return period flows using HEC-SSP and a Log Pearson Type III distribution. In Ontario, the Log Pearson Type III distribution is used when the coefficient of skew is negative (Floodplain Management in Ontario Technical Guidelines, Ministry of Natural Resources). The skew was negative for the analysis performed on both the York River and Crowe River data sets. The HEC-SSP model is available upon request.

WSOC maximum annual instantaneous peak flow data was supplied to HEC-SSP. As mentioned in Section 2.1.3, the York River stream flow gauge has 41 years of streamflow data. The Crowe River stream flow gauge has 44 years of data. Both gauges have a data record greater than the 30-yr minimum requirement to calculate an extreme event such as the 100-yr flood (MNR Technical Guidelines).

While these watersheds are similar, the input parameters are not specific to the Drag River watershed. Therefore, the GFA was used for comparison purposes. The watershed areas contributing to York River and Crowe River are significantly greater than the catchment areas for the Drag River (844 km^2 and 444 km^2, respectively). To accommodate this area discrepancy, a transposition of flows was completed using the equation provided from MTO drainage publications (see excerpt below).

> Transposition and interpolation of data from a stream gauge can be done based on the Modified Index Flood method as follows:
>
> $Q2 = Q1\ [A2 / A1]^{0.75}$
> Where:
> Q1 = Known peak discharge
> Q2 = Unknown peak discharge
> A1 = Known basin area
> A2 = Unknown basin area

Figure 2-2: Excerpt from MTO Online Drainage Manual

A benefit of the GFA is that it gives a reasonable expectation for the 100-yr peak flow for the Drag River watershed based on measured data. In a review of the data records for York River and Crowe River, the vast majority of the annual instantaneous peak flows consistently occur during common snow-melt and freeze-thaw times of year. This strongly suggests that the 100-yr peak flow for the Drag River would occur from a snow melt condition rather than a single rainfall event.

The transposed results for the Drag River 100-yr peak flow previously shown in Table 2-3 are less than the peak flows produced from the HEC-HMS model. Therefore, the 100-yr WSELs cover potential extents of flooding that would occur during a freeze-thaw event since the peak flow applied from the HEC-HMS model is greater than the expected peak flow calculated based on the GFA that is derived primarily from freeze-thaw conditions.

While the HMS model accounts for Lakes & Wetlands coverage with the curve number parameter, the significant storage within these lake areas would act as reservoirs and is expected to provide some flow attenuation. The storage offered by high coverage of Lakes & Wetlands is accounted for in the stream flow gauge data since it is observed data based on in-field measurements. The storage from lakes and wetlands is not included in the HMS model since the bathymetry data and level of detail required to incorporate this component is beyond the scope of JE’s analysis. A review of the transposed flows in comparison to the HEC-HMS model for the SCS CN method strongly suggests that the 100-yr and Timmins peak flows are over-estimates and present a very conservative value. The stream flow gauge data is a useful comparison in this analysis as it highlights the conservatism in the HMS model that ultimately results in a conservative minimum opening elevation of 320.65m.

The table below shows similarities in land coverage between the Drag River watershed and its comparable watersheds.

Table 2-4: Land Cover for York River and Crowe River Watersheds to Stream Flow Gauges vs. Drag River to Maple Ave. Crossing (%)

	Land Cover (%)		
	York River	Crowe River	Drag River
Agriculture / Improved	2	3	2
Lakes and Wetlands	11	16	19
Treed	86	81	80
Impervious	1	0	0

2.2.2.3 Modified Index Flood Analysis

JE employed the Ontario Flow Assessment Tool (OFAT III) developed by the Ministry of Natural Resources to estimate design flows and analyse the hydrology of the contributing drainage area. OFAT III contains two methodologies for determining the return period flows for streams in Ontario. These are Index Flood Method (this section) and the Multiple Regression Analysis Method (next section).

The Index Flood method relates the annual peak instantaneous flow determined for 247 stream gauges across Ontario to drainage area. Twelve regions across the province were identified as having similar characteristics and a regression curve was developed for each region. See Figure 2-3.

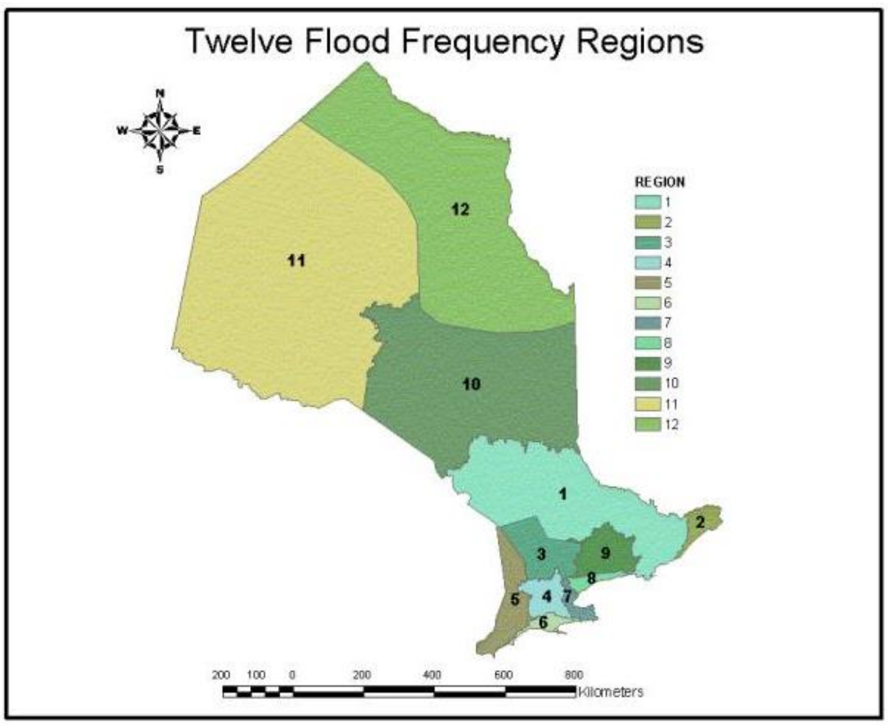

Figure 2-3: Index Flood Regions (from OFAT III)

The 2-yr flows are resolved directly from the equation using the constant and exponent from Table 2-5. OFAT III determines the region based on location of the catchment and selects the appropriate constants. Other return period flows may be derived from the 2-yr flow by multiplying with the factors provided in Table 2-6.

Equation 1: Index Flood Method

$$Q_2 = CA^n$$

Where:

Q_2 = 2 year return period (3 parameter Log Normal) flood
A = Drainage Area (km^2)
C = constant
n = exponent (slope of the line)

Table 2-5: Table of Constant (C) and Exponent (n) for use in the Modified Index Flood Equation

Region	Constant (C)	Exponent n
1(a)	0.22 (A < 60 km^2)	1.000
1 (b)	0.73 (A > 60 km^2)	0.707
2	0.51	0.896
3	0.20	0.957
4	0.71	0.842
5	0.45	0.775
6	0.41	0.806
7	1.13	0.696
8	0.73	0.785
9	0.40	0.810
10	0.28	0.849
11	0.38	0.706
12	0.59	0.765

Table 2-6: Ratio of Various Flood Frequencies to Q_2

Region	$Q_{1.25}/Q_2$	Q_2/Q_2	Q_5/Q_2	Q_{10}/Q_2	Q_{20}/Q_2	Q_{50}/Q_2	Q_{100}/Q_2	Q_{200}/Q_2	Q_{500}/Q_2
1	0.95	1.00	1.24	1.43	1.62	1.86	2.04	2.23	2.48
2	0.94	1.00	1.29	1.52	1.74	2.04	2.25	2.45	2.72
3	0.93	1.00	1.33	1.62	1.89	2.25	2.54	2.82	3.19
4	0.93	1.00	1.32	1.57	1.80	2.13	2.37	2.60	2.92
5	0.94	1.00	1.27	1.50	1.74	2.06	2.34	2.62	2.96
6	0.91	1.00	1.43	1.78	2.13	2.60	2.96	3.33	3.84
7	0.94	1.00	1.27	1.47	1.66	1.90	2.07	2.24	2.47
8	0.92	1.00	1.43	1.85	2.30	2.96	3.46	4.00	4.77
9	0.94	1.00	1.27	1.50	1.72	2.02	2.26	2.49	2.80
10	0.95	1.00	1.20	1.35	1.48	1.64	1.77	1.90	2.07
11	0.93	1.00	1.33	1.62	1.90	2.32	2.67	3.05	3.55
12	0.94	1.00	1.22	1.38	1.52	1.68	1.80	1.90	2.05

Table 2-7: Limitation of Application of Index Flood Method based on Drainage Area

Region	Minimum (km^2)	Maximum (km^2)
1	0.11	9270
2	76.1	3816
3	86.0	3960
4	2.5	5910
5	14.2	4300
6	5.2	697
7	63.5	293
8	4.9	800
9	24.3	1520
10	18.6	11900
11	0.7	24200
12	4250	94300

The parameters for the Drag River were within the allowable range for use of the Index Flood method. Peak flows from the Index Flood method were shown in Table 2-3.

2.2.2.4 Multiple Regression Analysis

The Multiple Regression methodology compares watershed characteristics of the watershed under study with those of other watersheds within a similar region. The province was broken into four regions of similar response to weightings of watershed characteristics to flow. The Figure 2-4 image shows the regions. OFAT III determines the region based on location of the catchment and selects the appropriate constants.

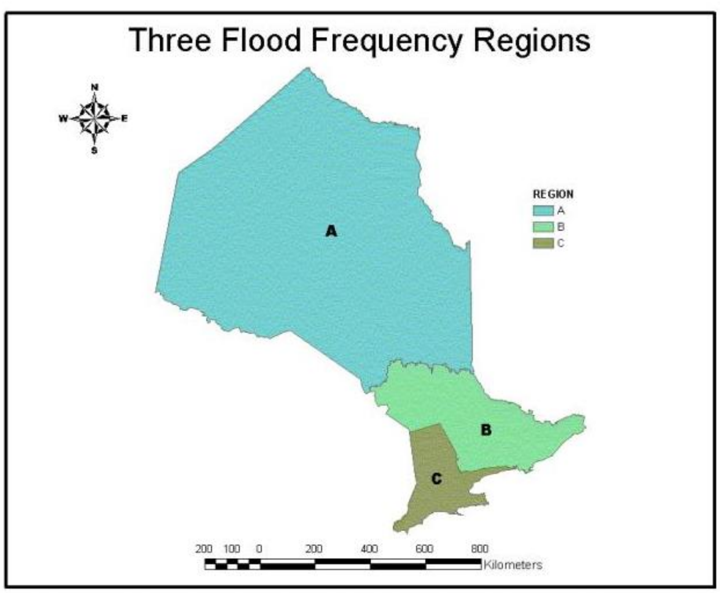

Figure 2-4: Regions of Similar Response for Multiple Regression Method

The characteristic values are entered into Equation 2 using constants provided by either the All Ontario Values or those specifically derived for the region. The coefficients for Eastern Ontario (Region B) are provided below as well as those for All Ontario (Tables 2-14 and 2-15).

The Multiple Regression method has been tested and verified for use within parameter limitations given in Table 2-10. The method should not be applied if any of the drainage area parameters lie outside of these limitations.

Equation 2: Multiple Regression Method

$$\text{Log}(QT) = a_0 + a_1\text{Log}(DA) + a_2(BFI)^{1/2} + a_3(SLP)^{1/3} + a_4(ACLS)^{1/2} + a_5(SLP) + a_6\text{Log}(MAR) + a_7(MAR) + a_8\text{Log}(ACLS+1) + a_9(MAP) + a_{10}(SF)$$

Where:

DA = Drainage Area (km2)
SLP = Mean Channel Slope (m/km)
ACLS = Index of Area Controlled by Water & Wetland (%)
SF = Shape Factor (dimensionless) (=$LNTH^2/DA$, where LNTH = length of main channel (km) and DA = drainage area (km2))
BFI = Base Flow Index (dimensionless)
MAR = Mean annual Runoff (mm)
MAP = Mean Annual Precipitation (mm)

Table 2-8: Multiple Regression Coefficients for Region B (Eastern Ontario)

Flow (cms)	a_0	a_1	a_3	a_4	a_{10}	SF	R^2
Q_2	0.2143	0.7464	-0.2172	-0.0194	-0.0077	0.14	0.91
Q_5	0.2746	0.7443	-0.1961	-0.0198	No data	0.14	0.89
Q_{10}	0.3795	0.7217	-0.1799	-0.0202	No data	0.15	0.87
Q_{20}	0.2311	0.7461	No data	-0.0197	-0.0081	0.15	0.87
Q_{50}	0.3659	0.6989	No data	-0.0275	No data	0.15	0.85
Q_{100}	0.4471	0.6839	No data	-0.0276	No data	0.16	0.83

Table 2-9: Multiple Regression Coefficients for All Ontario

Flow (cms)	a_0	a_1	a_3	a_4	a_{10}	SF	R^2
Q_2	0.2143	0.7464	-0.2172	-0.0194	-0.0077	0.14	0.91
Q_5	0.2746	0.7443	-0.1961	-0.0198	No data	0.14	0.89
Q_{10}	0.3795	0.7217	-0.1799	-0.0202	No data	0.15	0.87
Q_{20}	0.2311	0.7461	No data	-0.0197	-0.0081	0.15	0.87
Q_{50}	0.3659	0.6989	No data	-0.0275	No data	0.15	0.85
Q_{100}	0.4471	0.6839	No data	-0.0276	No data	0.16	0.83

Table 2-10: Multiple Regression Parameter Limitations for Region B

Variable	Q2-Q20 Minimum	Q2-Q20 Maximum	Q50-Q100 Minimum	Q50-Q100 Maximum
DA	13.9	3810.0	13.9	4770.0
BFI	0.26	0.82	0.26	0.90
SLP	0.14	5.77	0.02	5.77
ACLS	0.0	97.0	0.0	100.0
SHP	1.41	42.14	1.38	42.14

The parameters for the Drag River watershed were outside of the recommended range for use of the Multiple Regression method. Peak flows from the Multiple Regression method were provided in Table 2-3.

2.3 Climate Change

With potential impacts due to climate change, there is concern for increased frequency and intensities of severe rainfall events. Therefore, JE has considered potential impacts due to climate change in the hydrologic and hydraulic analysis.

Potential climate change impacts on peak flows are inherently difficult to quantify due to the earth's extremely complex global atmospheric and hydrologic systems. The MTO IDF Look-Up Tool offers projected rainfall data for future years. JE selected rainfall data for the year 2071. This projected rainfall data has a 24-hr rainfall depth of 134.4mm as shown in Appendix B.

The stream flow gauge data from Section 2.1.3. strongly suggests that the statistical 100-yr return period flow will occur during a freeze-thaw/snow-melt condition. These events produce high peak flows due to a large volume of stored water content that is released when warmer temperatures occur. With potentially warmer seasonal temperatures due to climate change, there is potential for less stored water content during the winter months, since the period of below-freezing temperatures would be shortened due to the higher average temperatures. With less stored water content, it is possible that the statistical 100-yr peak flow would not increase if freeze/thaw events govern the 100-yr statistical return period peak flow even with increased rainfall depths for single event conditions. However, for conservatism, the 2071 rainfall data was applied in the HEC-RAS model to determine potential impacts on flood hazard limits with increased rainfall depths.

3 Hydraulics

JE applied the regulatory (Timmins) peak flow identified in Section 2 to a hydraulic model to determine the water surface elevation (WSEL) at the site location as well as potential impacts due to the placement of fill with the proposed development.

The hydraulic model was prepared using the HEC-RAS version 6.0 software program. Geometric data from JE's topographic survey as well as supplemental LiDAR from Land Information Ontario was applied in the model. The WSELs are affected by bridge/culvert crossing data that JE enters into the Geometric Data Editor. These WSELs are compared to the local topograhy to delineate the floodline in plan view.

Eleven cross-sections of the Drag River and surrounding overbank areas within the Village of Haliburton were prepared and entered as geometry data into the steady flow model. Detailed survey data for these cross sections was obtained by JE using GPS and a total station. Supplemental LiDAR data from Land Information Ontario was applied in the model in areas beyond the JE survey. A PDF showing JE survey points is available upon request.

The model extends from approximately 135m upstream of the Maple Avenue crossing, to approximately 150m downstream of the Maple Avenue Crossing. Within the model extents, there are two crossings. The first is the Maple Avenue crossing that has a concrete span bridge. The second is the pedestrian crossing approximately 80m downstream of the Maple Avenue crossing.

A digital copy of the HEC-RAS model is provided in Appendix E.

While the hydraulic analysis was prepared solely for the use of the Hot Pond Enterprises site location, we note that in both existing and proposed conditions, the regulatory storm event would result in significant flooding to the developments immediately upstream of the Maple Avenue crossing and south of Victoria Street. If the municipality were to have a floodplain analysis prepared for the community of Haliburton, then we recommend it be noted that this would be a significant area of interest for the study.

There is a weir located upstream of the Maple Avenue crossing that was conservatively not included in this analysis. For the regulatory event, the Timmins peak flow is large enough in magnitude that we would not recommend relying on the weir for flow reduction based on its size and potential failure or blockage in the Timmins event.

3.1.1 Minimum Opening Elevation

Section 3.18 of the 2005 Dysart et al Comprehensive Zoning By-Law identifies a minimum opening elevation of 320.2m within the Special Policy Area. As discussed in Section 1, no information was able to be provided from the Municipality to support this number. JE prepared their own hydrologic and hydraulic models to investigate an appropriate WSEL per the City's request. The results from JE's analysis show that the WSEL produced in the regulatory (Timmins) event at Maple Avenue crossing is 320.34m. This is similar to the 320.2m elevation referenced in the Municipality documents.

WSELs for the largest 100-yr peak flow (81 m^3/s) and Timmins event (156 m^3/s) are shown in the table below. The peak flow from the GFA (34m^3/s) was also included for comparison purposes. While the minimum opening elevation is conservatively based on the Timmins peak flow, the GFA offers a value of interest since it is based on stream flow gauge data for similar watersheds. It suggests that the modelling methods for the SCS CN method and Timmins event are very conservative. A schematic of floodlines that correspond to the three peak flows in Table 7-2 are shown in Appendix C.

The Timmins WSELs are higher than those in the 100-yr event due to the significantly higher Timmins peak flows. This was expected since in our experience, the Timmins peak flow tends to have a magnitude of 2-3x greater than that produced from the 100-yr event.

The site location is immediately downstream of the Maple Avenue crossing. However, the WSEL at the cross section immediately upstream of the Maple Avenue crossing was conservatively applied for the minimum opening elevation.

JE recommends a minimum opening elevation of 320.65m.

Table 7-2: Water Surface Elevation Summary Applied in 2022 Existing Conditions Floodplain Mapping

Cross Section	100-yr (HMS)		Timmins	
	Q = 81 m^3/s		Q = 156 m^3/s	
	Ex.	Pr.	Ex.	Pr.
159	320.02	320.01	320.86	320.86
150	319.63	319.63	320.06	320.06
143	319.67	319.67	320.05	320.07
123	319.74	319.74	320.33	320.34
Maple Ave*	319.74	319.74	320.33	320.33
119	319.08	319.17	319.88	319.88
112	319.05	319.06	319.91	319.9
101	319.14	319.14	319.92	319.92
96	319.06	319.06	319.96	319.95
Pedestrian Bridge	319.06	319.06	319.95	319.95
94	318.76	318.76	319.81	319.81
81	318.68	318.68	319.61	319.61
73	318.16	318.16	318.85	318.85

**Cross Section Elevation at Maple Avenue applied as minimum opening elevation in Timmins storm event*

3.1.2 Assessment of Potential Impacts with Placement of Fill

The site will require fill to have the minimum opening elevation at 320.65m. As described in Section 1, an assessment of potential impacts with the fill placement was required. JE assessed this fill placement for the 100-yr return period event as well as the Timmins event.

In the 100-yr event (HMS modelling conservatively selected), there is negligable increase in WSELs as a result of the fill placement. Therefore, the proposed development would present no negative impacts in any of the return period events.

In the Timmins event, the modelling results show neglible increase in water surface elevation at the Maple Avenue crossing as a result of the fill placement. With an understanding of hydraulic principles, we recognize that there are large residential and commercial buildings immediately upstream and downstream of the site that are perpendicular to the direction of flow from the Drag River. These buildings act as an ineffective flow area (i.e. blocked obstruction), and this is reflected in the existing conditions model. In proposed conditions, the on-site fill for the proposed development is included.

In summary, the proposed development presents no negative flooding impacts to other property owners during any return period event. A negligible increase in WSEL is expected during the Timmins event after review of the model results in combination with an understanding of hydrologic and hydrualic principles. We also note that stream flow gauge data, which in JE's opinion is the most reliable since it relies on data observed in the field, suggests that the 100-yr return period event would be 34 m^3/s. The Timmins peak flow of 156 m^3/s is an extraordinary event that is 4.6 times greater than the expected 100-yr peak flow. It is also 1.9 times greater than the conservative 100-yr peak flow estimate of 81 m^3/s from the HEC-HMS model when using the SCS CN method. Based on JE's analysis and site observations, no negative impacts to surrounding property owners are expected with the proposed developemnt.

4 Conclusions

JE prepared this floodline assessment to support Hot Pond Enterprises in their development of Maple Avenue Suites in the County of Haliburton.

A hydrologic and hydraulic assessment was requested by Dysart et al to satisfy Section 13.1.9 of the 2017 Official Plan regarding the Haliburton Village Special Policy Area. In particular, Dysart requested this assessment to show that the placement of fill will present no negative impacts to the floodwater or other properties. The limits of the Special Policy Area were shown by the hatched area in Figure 1-2.

Section 3.18 of the 2005 Dysart et al Comprehensive Zoning By-Law identifies a minimum opening elevation of 320.2m within the Special Policy Area.

The results from JE's analysis show that the WSEL produced in the regulatory (Timmins) event at Maple Avenue crossing is 320.34m. This is similar to the 320.2m elevation referenced in the Municipality documents. A schematic of floodlines that correspond to the three peak flows in Table 7-2 is shown in Appendix C. JE recommends a minimum opening elevation is 320.65m.

The site will require fill to have the minimum opening elevation at 320.65m. The proposed development presents no negative flooding impacts to other property owners during any return period event.

A negligible increase in WSEL is expected during the Timmins event after review of the model results in combination with an understanding of hydrologic and hydrualic principles. We also note that stream flow gauge data, which in JE's opinion is the most reliable since it relies on data observed in the field, suggests that the 100-yr return period event would be 34 m^3/s. The Timmins peak flow of 156 m^3/s is an extraordinary event that is 4.6 times greater than the expected 100-yr peak flow. It is also 1.9 times greater than the conservative 100-yr peak flow estimate of 81 m^3/s from the HEC-HMS model when using the SCS CN method.

Based on JE's analysis and site observations, no negative impacts to surrounding property owners are expected with the proposed developemnt.

Prepared by:

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Jewell Engineering Inc.

5 References

Ministry of Agriculture, Food and Rural Affairs. (2020, August 2020). *Agricultural Information Atlas Help*. Retrieved from omafra.gov.on.ca: http://www.omafra.gov.on.ca/english/landuse/gis/agatlas-help.htm

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Appendix A – Catchment Area Schematics

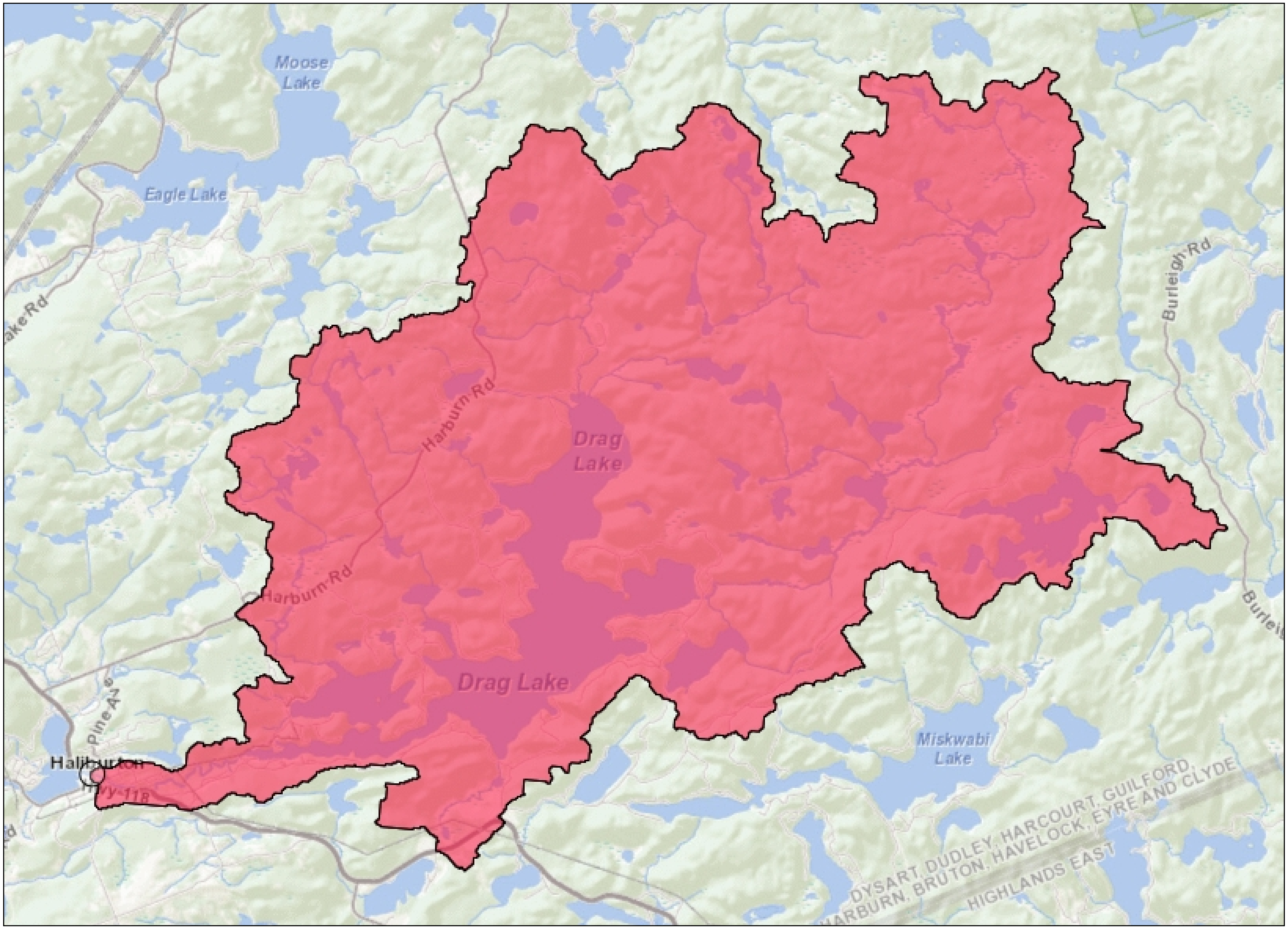
Ontario

MINISTRY OF NATURAL RESOURCES AND FORESTRY

Ontario Flow Assessment Tools

Drag River Catchment to Maple Ave. Crossing

Notes:



Legend

- Assessment Parcel
- Secondary Watershed
- Tertiary Watershed
- Quaternary Watershed
- Great Lakes - St. Lawrence Basin
- Hudson - James Bay Basin
- Nelson River Basin
- Diversions
- Waterbody Outlet
- Conservation Authority Dam
- Provincial Dam
- Federal Dam
- OPG Dam
- Other Dam
- HYDAT Gauge
- HYDAT Gauge (RHBN)
- Virtual Flow Segment

Land Cover Compilation

- Other
- Cloud/Shadow
- Clear Open Water
- Turbid Water
- Shoreline
- Mudflats
- Marsh
- Swamp
- Fen
- Bog
- Heath
- Sparse Treed
- Treed Upland
- Deciduous Treed
- Mixed Treed
- Coniferous Treed
- Plantations - Treed Cultivated
- Hedge Rows
- Disturbance
- Open Cliff and Talus
- Alvar
- Sand Barren and Dune
- Open Tallgrass Prairie
- Tallgrass Savannah
- Tallgrass Woodland
- Sand/Gravel/Mine Tailings/Extraction
- Bedrock
- Community/Infrastructure
- Agriculture and Undifferentiated Rural Land Use

5.2 | 0 km | 2.59 | 5.2

Scale: 1 : 101,970

Projection: Web Mercator

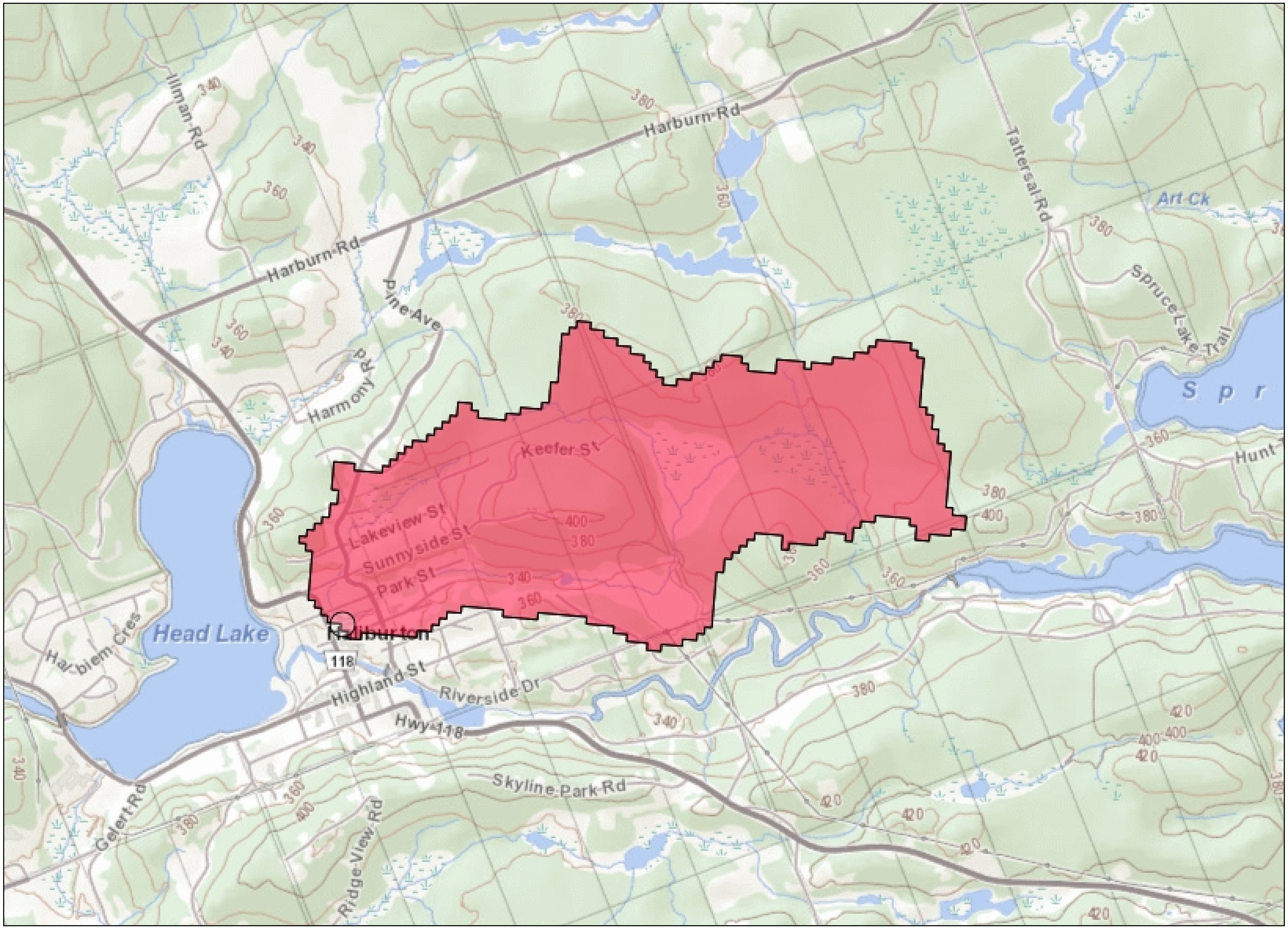
Ontario

MINISTRY OF NATURAL RESOURCES AND FORESTRY

Ontario Flow Assessment Tools

Tributary to Commercial Plaza

Notes:



Legend

- Assessment Parcel
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- Open Tallgrass Prairie
- Tallgrass Savannah
- Tallgrass Woodland
- Sand/Gravel/Mine Tailings/Extraction
- Bedrock
- Community/Infrastructure
- Agriculture and Undifferentiated Rural Land Use

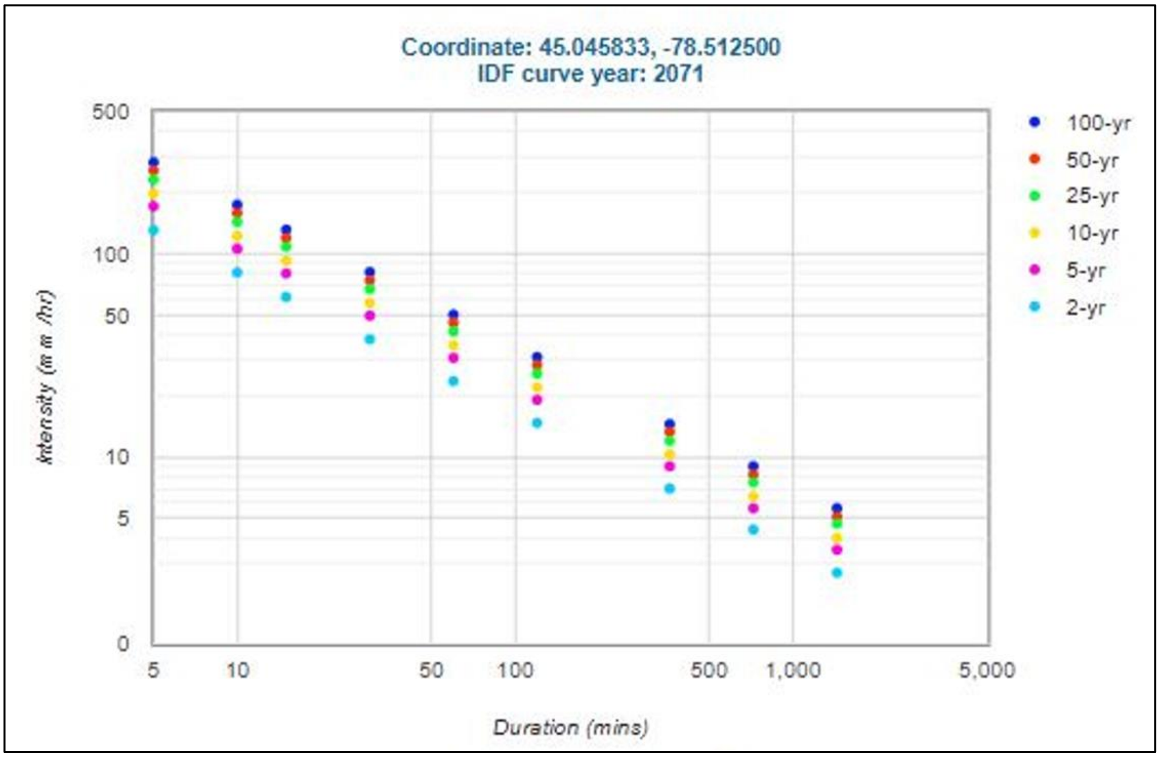
1.3 0 km 0.65 1.3

Scale: 1 : 25,510

Projection: Web Mercator

Appendix B – MTO IDF Look-Up Data and Streamflow Gauge Data for Hydrologically Similar Watersheds

2071 MTO IDF Look-Up Curve and Tabular Data for Drag River at Maple Avenue Crossing:



Coefficient summary

Data year: 2010
IDF curve year: 2071

Click a return period in the table header for more detail.

Statistics

Rainfall intensity (mm hr^{-1})

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	130.2	80.7	61.1	37.9	23.6	14.7	7.0	4.4	2.7
5-yr	170.5	105.6	79.8	49.5	30.7	19.1	9.0	5.6	3.5
10-yr	197.2	122.0	92.2	57.1	35.4	22.0	10.3	6.4	4.0
25-yr	231.3	143.0	108.0	66.8	41.4	25.7	12.0	7.5	4.7
50-yr	255.7	158.1	119.3	73.8	45.7	28.3	13.3	8.2	5.1
100-yr	280.7	173.5	130.9	81.0	50.1	31.0	14.5	9.0	5.6

Rainfall depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	10.8	13.5	15.3	18.9	23.6	29.4	42.0	52.8	64.8
5-yr	14.2	17.6	19.9	24.8	30.7	38.2	54.0	67.2	84.0
10-yr	16.4	20.3	23.1	28.6	35.4	44.0	61.8	76.8	96.0
25-yr	19.3	23.8	27.0	33.4	41.4	51.4	72.0	90.0	112.8
50-yr	21.3	26.4	29.8	36.9	45.7	56.6	79.8	98.4	122.4
100-yr	23.4	28.9	32.7	40.5	50.1	62.0	87.0	108.0	134.4

Terms of Use

You agree to the Terms of Use of this site by reviewing, using, or interpreting these data.

York River Instantaneous WSOC Stream Flow Gauge Data Record at Station *02KD002:*

Year	Flow (cms)	Flow (cfs)
1967	56.4	1992
1968	70.2	2479
1969	75.6	2670
1970	75.3	2659
1971	77.6	2740
1972	92	3249
1973	81.6	2882
1974	80.7	2850
1975	79.6	2811
1976	101	3567
1977	52.7	1861
1978	85.8	3030
1979	79.5	2807
1980	86.1	3040
1981	86.2	3044
1982	84.6	2988
1983	105	3708
1984	75.7	2673
1985	106	3743
1986	69.6	2458
1987	82.8	2924
1988	80.7	2850
1989	54.8	1935
1990	57.2	2020
1991	99.9	3528
1992	78	2754
1993	61.2	2161
2007	33.3	1176
2008	87.1	3076
2009	85.7	3026
2010	57.4	2027
2011	60.1	2122
2012	80.2	2832
2013	142	5015
2014	97.4	3440
2015	56.7	2002
2016	94.7	3344
2017	98.2	3468
2018	84.4	2980
2019	134	4732
2020	64.8	2288

Crowe River Instantaneous WSOC Stream Flow Gauge Data Record at Station *02HK005:*

Year	Flow (cms)	Flow (cfs)
1969	37.4	1321
1970	36	1271
1971	46.7	1649
1972	43.3	1529
1973	43.3	1529
1974	39.9	1409
1975	41.6	1469
1976	68.8	2430
1977	19.9	703
1978	45.3	1600
1979	48.7	1720
1980	41.3	1458
1981	44.4	1568
1982	43.3	1529
1983	36.5	1289
1984	42.1	1487
1985	42.3	1494
1986	30.9	1091
1987	47.2	1667
1988	36.2	1278
1989	25.3	893
1990	25.6	904
1991	54.8	1935
1992	37.7	1331
1993	38.6	1363
1994	20.9	738
1995	32.1	1134
1996	46.1	1628
1997	35.3	1247
2005	34	1201
2006	39.6	1398
2007	19.7	696
2008	44.6	1575
2009	47.1	1663
2011	29	1024
2012	21.3	752
2013	45.8	1617
2014	49.7	1755
2015	22.6	798
2016	50.4	1780
2017	40	1413
2018	46.2	1631
2019	61.3	2165

Appendix C – Floodline Schematic for Site Location

Appendix D – HEC-HMS Model (see attached files)

Appendix E – HEC-RAS Model (see attached files)