Rideau Valley Conservation Authority
3889 Rideau Valley Drive, PO Box 599, Manotick, Ontario, Canada | 613-692-3571 | www.rvca.ca

Technical Memorandum

November 12, 2021

Subject: **Effect of Land Use Change on Stevens Creek Flood Risk Mapping**

Lead Investigator: Ferdous Ahmed, Ph.D., P.Eng.
Senior Water Resources Engineer

Contributing staff: Tyler Bauman, Engineering Assistant
David Crossman, GIS Coordinator
Chris Czerwinski, GIS Specialist

Executive Summary

The possible effects of land use change during the last fifty years on the flood risk mapping of Stevens Creek have been investigated. It was found that the land use changed only marginally from 1976 to 2020, with urban area increasing from 3.8% to 7.2% and the imperviousness increasing from 2% to 4% of the watershed area. The effect on the flood flow and flood risk was also small, within the range of ±1-9%. The effect on the 100 year flood level was also marginal, in the range of ±0-11 cm. It was concluded that the land use change during the last fifty years is small and has insignificant effect on flood risk.

Contents

1. Introduction

A new flood mapping of Stevens Creek has been completed recently (RVCA, 2020) and is expected to be presented to and adopted by the RVCA Board in near future. It was decided that, before going to the Board, the RVCA should take up a study to look at the possible effects of land use change on the flood risk. Description and findings of this study are presented here.

Four flood risk studies of the Stevens Creek have been carried out in the past, namely:

- J. L. Richards and Associates (1972) – mapping of Stevens Creek
- Robinson Consultants (1995) – mapping of Stevens Creek and Taylor Creek
- RVCA (2007) – addition of Tributary C and update of Dillon-Wallace Drain
- RVCA (2020) – full mapping of Stevens Creek, Taylor Creek, and tributaries

Details of these studies can be found in their respective reports and are not repeated here. Suffice it to say that the Robinson (1995) mapping is currently being used by RVCA for regulatory purposes. The RVCA (2020) mapping, when endorsed by RVCA's Board of Directors, will supersede the Robinson mapping.

Summary of available information in the Stevens Creek watershed has recently been compiled by RVCA in a catchment report card of Stevens Creek (RVCA, 2013).

The RVCA (2020) report provides a detailed description of the analytical methods used and underlying assumptions applied in the preparation of flood plain mapping for Stevens Creek. (see Appendix A: Figures 1 and 2). It was done in accordance with the technical guidelines set out under the Canada-Ontario Flood Damage Reduction Program (FDRP) (MNR, 1986), and the technical guide for the flood hazard delineation in Ontario (MNR, 2002) as laid out by the Ontario Ministry of Natural Resources. It also conforms to the 'generic regulation' guidelines of Conservation Ontario (2005). The 1:100 year flood lines delineated in the 2020 study are suitable for use in the RVCA's regulation limits mapping (as per Ontario Regulation 174/06) and in municipal land use planning and development approval processes under the Planning Act.

In order to understand the current report, the reader first needs to thoroughly read the last flood mapping report (RVCA, 2020). Only then the reader will be able to understand the current report in the proper context.

2. Methodology

The objective of this study is to discern and quantify the effects of land use change on the flood flow and flood levels. We have considered two modeling scenarios for this purpose (Table 1).

2.1 Scenario A (2020)

This is the modeling done by RVCA (2020) for flood risk delineation. No change is made to this modeling. Appendix A contains selected figures and tables taken directly from the 2020 study report[1]. This information provides the context of the present study and how it is connected to the 2020 study.

As shown in Table 1, Scenario A consists of a hydrologic (HEC-HMS) and a hydraulic model (HEC-RAS).

2.2 Scenario B (1976)

As shown in Table 1, Scenario B is based on Scenario A, but with some modifications as warranted by the 1976 land use data. Appendix B contains the figures and tables pertinent to Scenario B.

The hydrologic (HEC-HMS) model for Scenario B has been changed to take into account the 1976 land use data and the parameters directly affected by land use. This model was meant to estimate the flows under 1976 land use condition.

Flows thus estimated were fed into the hydraulic (HEC-RAS) model to generate flood levels along the streams. Note that, no parameter other than the flows were changed in the HEC-RAS model. In other words, it combines the 1976 flows with 2020 channel condition. In that sense it is a hypothetical situation we are investigating.

Comparison of the HEC-HMS models for the two scenarios is expected to reveal the effect of land use change on flood flows. And comparison of the HEC-RAS models is expected to reveal the probable effect of 1976 flows on the flood level under 2020 conditions.

[1] In Appendix A, figures and tables are numbered following the RVCA (2020) report, without any change. However, for easy reference, we shall refer to them with a prefix of 'A'. Therefore, Figure A.1 is simply Figure 1 in Appendix A, Table A.1 is Table 1, and so on.

3. Land Use Data

Land use is the major difference between 2020 and 1976 conditions, or between Scenarios A and B. Therefore, the details of land use data are provided below.

3.1 2020 Land use data

As described in RVCA (2020), a GIS-based land use data set, largely based on information up to 2014, was recently compiled by RVCA staff. It has 38 categories of land use (see Table A.4 and Figure A.4). This data set was used in the hydrologic parameter estimation. Vector data originally obtained during approximately the early to late 1990s by the Ministry of Natural Resources and Forests (MNRF) were used to produce a pre-classification of the area. This pre-classification provided a historical overview of the spatial distribution of transportation, settled areas, aggregate sites, evaluated and unevaluated wetlands, wooded areas and water. Updates to this land cover vector data were based on 20cm ortho-imagery acquired through the Digital Raster Acquisition Project for the East (DRAPE), a program lead by the MNRF in 2008 and 2014. DRAPE imagery was also used to incorporate crop and pasture and meadow/thicket as additional land cover classes. Currently RVCA houses two spatially continuous land cover datasets representing the Lower Rideau subwatershed in 2008 and 2014 using 10 land cover classes, which are further divided in to 38 subclasses. This vector data was produced through heads up digitizing to represent the landscape at a 1:4000 scale. Industry standard techniques were used to ensure topological integrity (remove gaps and overlaps).

The 2017 imagery provided by the city of Ottawa, as well as municipal official plan mapping, helped to integrate predicted land use changes reflecting 2020 conditions. The most recent imagery available, as well as Google street view, helped to digitize the space designated for development. Some developments have already commenced, as indicated by the 2017 imagery, and were mapped accordingly. Other developments are still in the planning phase. Official plan mapping helped to estimate the land use changes in the data to provide an estimate of land use for 2020 for Steven's creek catchment within the Lower Rideau subwatershed.

3.2 1976 Land use data

This data set was produced using the same specifications and methodology as the 2020 data set but corresponds to aerial photography provided by the City of Ottawa acquired in 1976.

The 1976 land use data set was used for Scenario B and is presented in Tables B.1 and B.4 and Figure B.4.

A few parameters are directly related to land use and thus had to be recomputed using the 1976 land use information. They are SCS curve number (CN), time to peak, initial abstraction, imperviousness, and the Manning roughness coefficients used in the hydrologic model (HEC-HMS). These parameters are listed in Tables B.3a and B.3b.

3.3 Change in land use

In order to understand the land used change in an easier way, the 38 land use categories were classified in five simpler groups: urban, agriculture, forest, wetland, and waterbody (Table 2).

In this simplified classification (Figure 1), it appears that the urban area has increased from 3.8% to 7.2% of the watershed from 1976 to 2020. Forest has also increased from 26.1% to 31.0%. These increases were compensated by the decrease in agricultural land from 48.4% to 39.3% over the same period. Wetland and waterbody remained almost the same.

Spatial distribution of land use categories reveals that, in the upper part of the watershed, agricultural lands have been converted to forests (about 8% of the watershed area). In the lower end of the watershed, some agricultural lands have been urbanized (about 8% of the watershed area).

However, the level of urbanization (currently at 7.2% of the watershed) may be considered low and not excessive.

4. Hydrological (HEC-HMS) Modeling

The details of the HEC-HMS modeling have been described by RVCA (2020) and are not repeated here. Suffice it to say that we have repeated the entire modeling for Scenario B to reflect the effects of 1976 land use condition.

Detailed input, output and associated figures are presented in Appendices A and B for Scenarios A and B respectively. A reader who is familiar with the RVCA (2020) report should have no difficulty in understanding this information.

Input data for Scenarios A and B are graphically presented in Figures 2 through 8. The land use data (Table 1) has directly changed the imperviousness (Table 2). The imperviousness has increased from 1976 to 2020 in all catchments, but is still below 20%, which is considered the threshold to urban catchments.

The SCS CN values remained relatively stable, with a range of variation of about 2-3 (Table 3).

The time of concentration remained relatively stable for all catchments, except M1 and TB1 in the headwaters with significant wetlands (Table 4).

Initial abstraction shows minor change, usually within ±1.0 mm (Table 5).

Manning roughness was used for channel routing within the HEC-HMS model. It remains the same for the main channel but increased slightly from 1976 to 2020 for the left and right banks (Table 7-9).

5. Hydraulic (HEC-RAS) Modeling

The details of the HEC-RAS modeling have been described by RVCA (2020) and are not repeated here. Suffice it to say that we have repeated the entire modeling for Scenario B with the re-calculated flows (generated by the HEC-HMS model) to reflect the effects of 1976 land use condition.

It is noted again that no change except the flows was made to the HEC-RAS model for Scenario B. Cross-sections, channel roughness, bridges, culverts, and downstream boundary condition all were the same.

The Regulatory Flood Level (RFL) was taken as the computed energy grade, following the usual RVCA custom.

Detailed input, output and associated figures are presented in Appendices A and B for Scenarios A and B respectively. A reader who is familiar with the RVCA (2020) report should have no difficulty in understanding this information.

6. Results and Analysis

6.1 Effect on Flood Flow

Flow comparison at three representative locations has been shown in Figures 9-11. In general, the flow has increased slightly (3-18%) in the upper part of the watershed from 1976 to 2020 (Figures 10 and 11). In the downstream side, the flow seems to have decreased (8%) (Figure 9).

Figures 12a-b show that the flows for both Scenarios A and B are well within the confines of reasonableness. All flow data for the Stevens basin are higher than those given by the Index Flood Method, which was based on measured streamflow data and was prescribed by MNR (1986) for estimating floods in the absence of better information. All data points are below the Creager envelope curve (Watt et al, 1989), which is the upper-most limit of extreme flood flows in Canada. On the balance, we found that the estimated Stevens flows are congruent with other information and are within the confines of pertinent estimation methods.

The runoff volume during flood events remained mostly the same and, in a few cases, slightly decreased from 1976 to 2020 (Figures 13 and 14).

It is noted that the computation flood flow depends on many factors including land use, soil type, vegetation, and their spatial distribution within the watershed. As such it is very difficult if not impossible to isolate the impact of any particular factor such as land use change. However, the overall change in flow within the Stevens basin computed here may be attributed mainly to the land use change over the last half a century.

6.2 Effect on 100 Year Flood Level

The flows that were used in the HEC-RAS model along Stevens Creek and Tylor Drain are shown in Figures 15a-b. The Scenario B flows were higher than the Scenario A flows by about 9 cms or 8% at the downstream end of Stevens Creek, but gradually tapered down to a lower value by about 3 cms (or -18%) at the upstream end. For Taylor Drain, the Scenario B flow was slightly lower than the Scenario A flows by about 1 cms (or -3%).

Since flood flow was the only difference between Scenarios A and B, its variation along the channel has predictably manifested in corresponding change in computed water

levels (Figures 16a-b) and energy grade (Figures 17a-b) (which is taken as the flood level).

Both the water level and energy grade for Scenario B is higher (9 cm) at the lower end of Stevens Creek. It becomes lower (-10 cm) rather abruptly at the upper end, which may be attributed to locally steep slope of the creek and the presence of near-critical flow conditions.

For Taylor Creek, both the water level and energy grade for Scenario B is consistently lower by about 1 cms and 2 cm respectively, except near its confluence with Stevens Creek. Near the confluence, the backwater effect from Stevens Creek increased the water level for a short distance.

Overall, we can say that the flow and flood level along Stevens Creek have increased by a small amount (by 8% and 9 cm respectively) from 1976 to 2020. The flow and flood level along Taylor Drain have decreased only slightly (by -3% and -2 cm respectively). When one considers the large number of factors influencing flood risk, this kind of change is considered rather common and small.

6.3 Effect on Flood Extent

Variation in the flood level does change the spatial extent of the flood plain. Flood plains have been drawn for both Scenarios A and B (see Drawing ST-3 in Appendix C). The difference is marginal everywhere, except at a few locations.

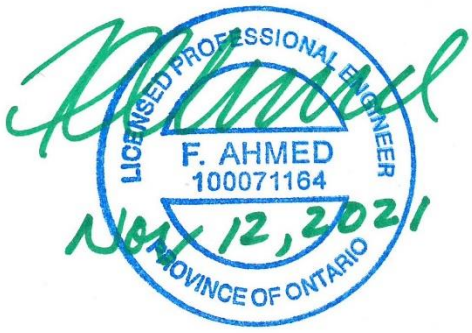
7. Conclusions

The main conclusions are:

1) The urban area has increased from 3.8% in 1976 to 7.2% in 2020. During the same period, the forest area has increased from 26.1% to 31.0% and the agricultural area has decreased from 48.4% to 39.3%. The wetlands and waterbodies have remained almost unchanged.
2) Based on the modeling, the estimated 100 year flow along Stevens Creek has increased by a small amount (8%) from 1976 to 2020. For the Taylor Drain, they decreased slightly (by about -3%).
3) Based on the modeling, the Scenario B flood level along Stevens Creek is higher than the Scenario A levels by a small amount (about 9 cm). For the Taylor Drain, they are slightly lower (by about -2 cm).
4) We conclude that the land use change from 1976 to 2020 would have only a small effect on flood flow and flood level.

8. Closure

The hydrotechnical, computational, and cartographic procedures used in this study generally conform to present day standards of water resources engineering. This study was done for the RVCA's internal use only and is not meant to be used by any other party.



Ferdous Ahmed, Ph.D., P.Eng.
Senior Water Resources Engineer

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1. Conservation Ontario (2005). Guidelines for Developing Schedules of Regulated Areas. October 2005.

2. J. L. Richards (1972). Flood Plain Mapping of Stevens Creek Between Kars and North Gower. Prepared for Rideau Valley Conservation Authority by J. L. Richards & Associates, Ottawa, Ontario, January 1972.

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7. Robinson and Associates (1994). Steven Creek Floodplain Mapping Update – Rideau River to Malakoff Road – Progress Report Hydrology 1993 Work Program. Prepared for Rideau Valley Conservation Authority by A. J. Robinson & Associates, Kanata, Ontario, November 1994.

8. Robinson Consultants Inc. (1995). Stevens Creek Floodplain Mapping Update – Rideau River to Malakoff Road – Progress Report Hydraulics, Volumes 1, 2 and 3. Prepared for Rideau Valley Conservation Authority by Robinson Consultants Inc., Kanata, Ontario, 9 May 1995. (https://www.rvca.ca/media/k2/attachments/Stevens_Creek_Rideau_River_to_Malakoff_Road_Robinson_Consultants_1995.pdf)

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2013. (https://watersheds.rvca.ca/subwatersheds-reports/lower-rideau/catchment-reports-lower-rideau/166-stevens-creek/213-stevens-creek-catchment-report)

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Table 1 Methodology and modeling scenarios

	Scenario A (2020)	Scenario B (1976)
Land use	2020	1976
Topography	2012 LIDAR	ditto
Soil classification	2012	ditto
HEC-HMS model		
Rainfall input	2007 IDF	ditto
Imperviousness	2020	Based on 1976 land use
CN	2020	Based on 1976 land use
Tp	2020	Based on 1976 land use
Manning roughness	2020	Based on 1976 land use
Routing cross section	2020	ditto
Channel length	2020	ditto
Channel slope	2020	ditto
HEC-RAS model		
Flows	HEC-HMS output based on 2020 conditions	HEC-HMS output based on 1976 conditions
Cross-sections	2020	ditto
Bridge/culvert	2020	ditto
Manning roughness	2020	ditto
Obstructions	2020	ditto
Ineffective area	2020	ditto

Table 2: Simplified Land Cover Assignment

	Land Cover Description	Group 1	Group 2	Group 3	Group 4	Group 5
		Urban	**Agriculture**	**Forest**	**Wetland**	**Waterbody**
1	Aggregate Site	X				
2	Aggregate Site - Pit	X				
3	Aggregate Site - Quarry	X				
4	Crop and Pasture		X			
5	Crop and Pasture - Cultivated		X			
6	Crop and Pasture - Fallow		X			
7	Evaluated Wetland				X	
8	Evaluated Wetland - Bog				X	
9	Evaluated Wetland - Fen				X	
10	Evaluated Wetland - Marsh				X	
11	Evaluated Wetland - Open Water				X	
12	Evaluated Wetland - Swamp				X	
13	Meadow/Thicket		X			
14	Settlement	X				
15	Settlement - Commercial	X				
16	Settlement - Industrial	X				
17	Settlement - Pervious	X				
18	Settlement - Pervious Homestead	X				
19	Settlement - Residential	X				
20	Settlement - Estate	X				
21	Settlement - Townhouse	X				
22	Transportation	X				
23	Transportation - Rail	X				
24	Transportation - Major Road	X				
25	Transportation - Minor Road	X				
26	Transportation - Unpaved Road	X				
27	Unevaluated Wetland				X	
28	Water					X
29	Water - Buffer around wetland					X
30	Water - Lake					X
31	Water - Pond					X
32	Water - River					X
33	Wooded Area			X		
34	Wooded Area - Fallow			X		
35	Wooded Area - Hedgerow			X		
36	Wooded Area - Island			X		
37	Wooded Area - Plantation			X		
38	Wooded Area - Treed			X		

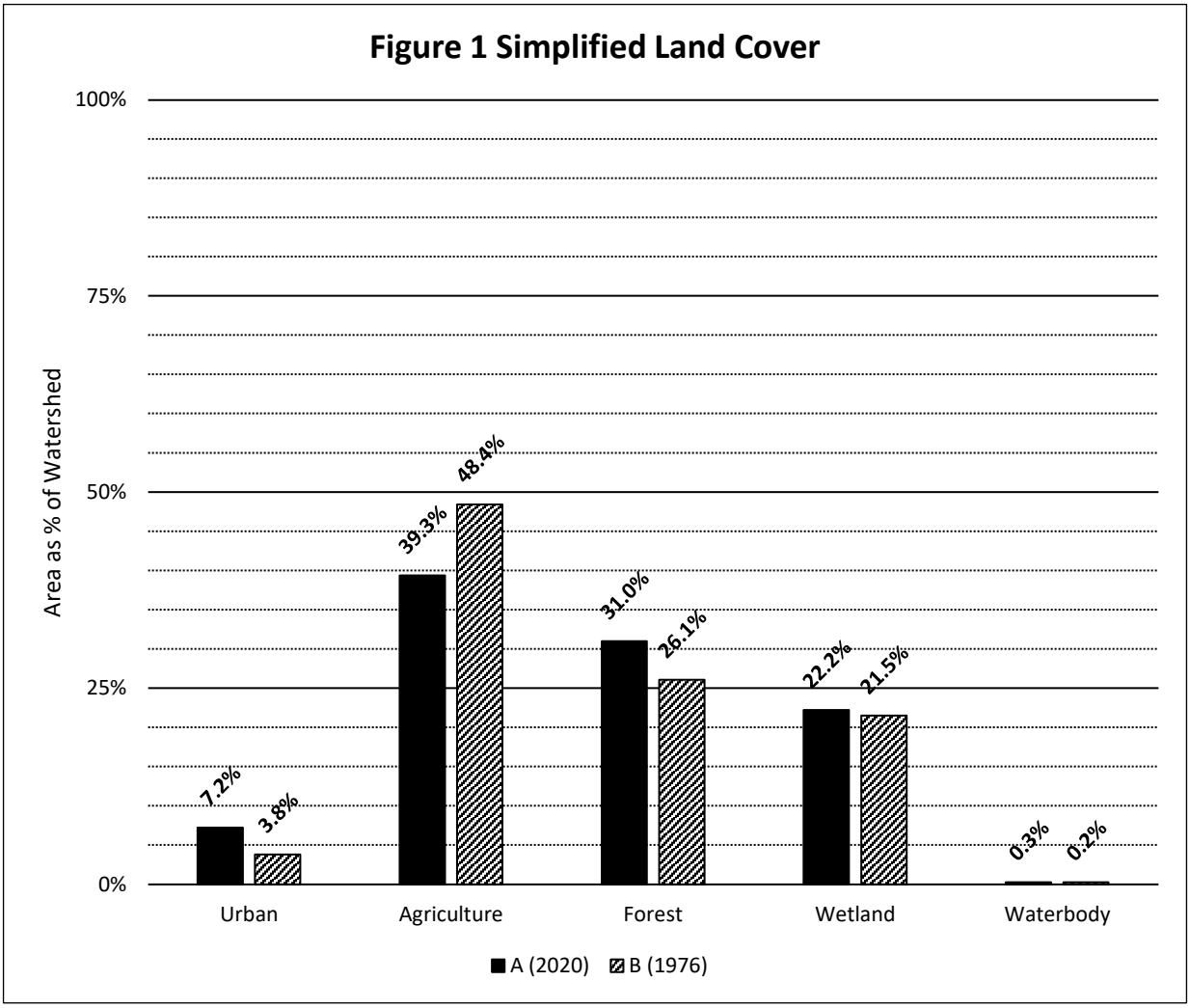


Figure 1 Simplified Land Cover
100%
75%
50%
25%
0%
Area as % of Watershed
7.2%
3.8%
39.3%
48.4%
31.0%
26.1%
22.2%
21.5%
0.3%
0.2%
Urban
Agriculture
Forest
Wetland
Waterbody
A (2020)
B (1976)

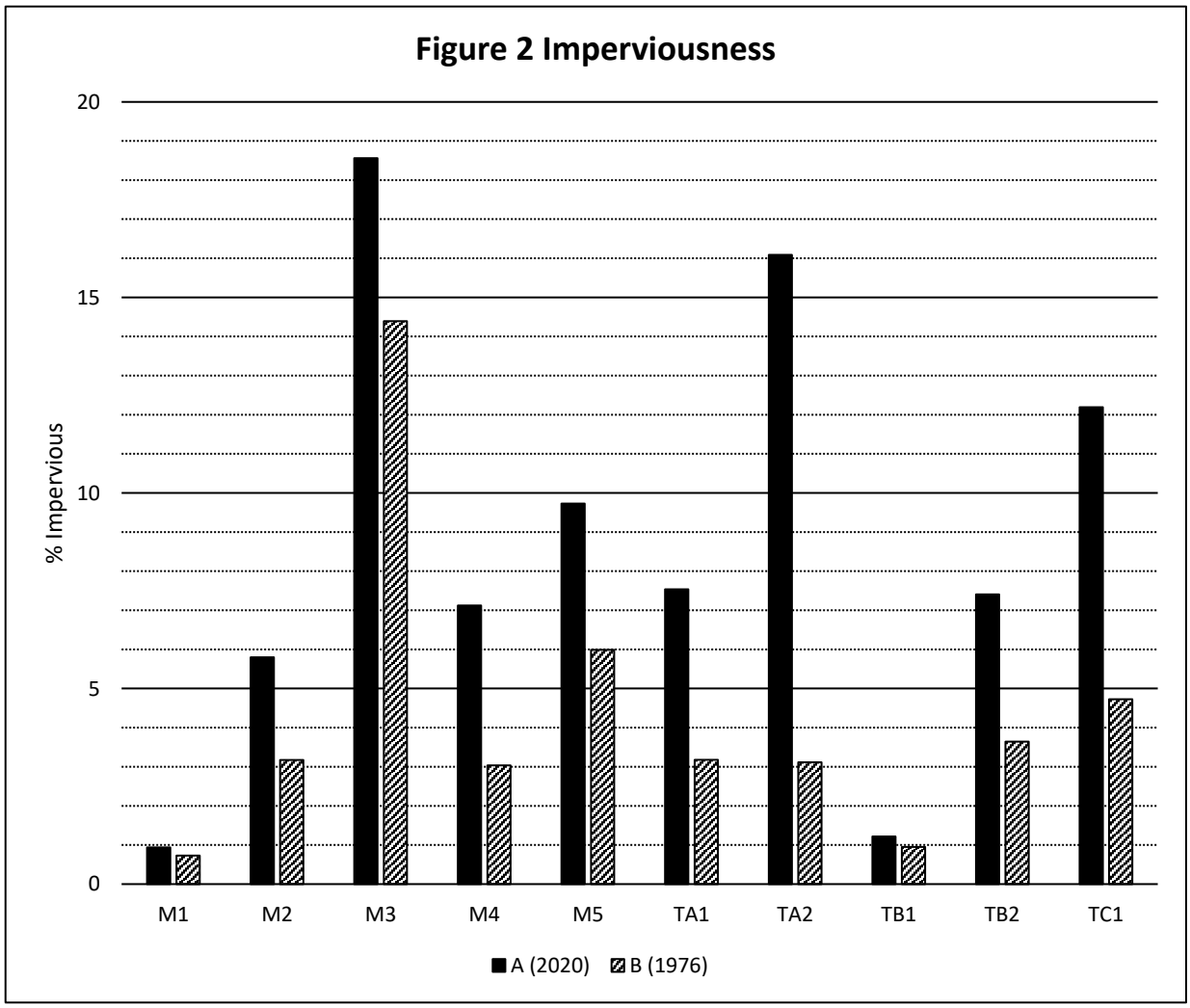


Figure 2 Imperviousness
20
15
10
5
0
% Impervious
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

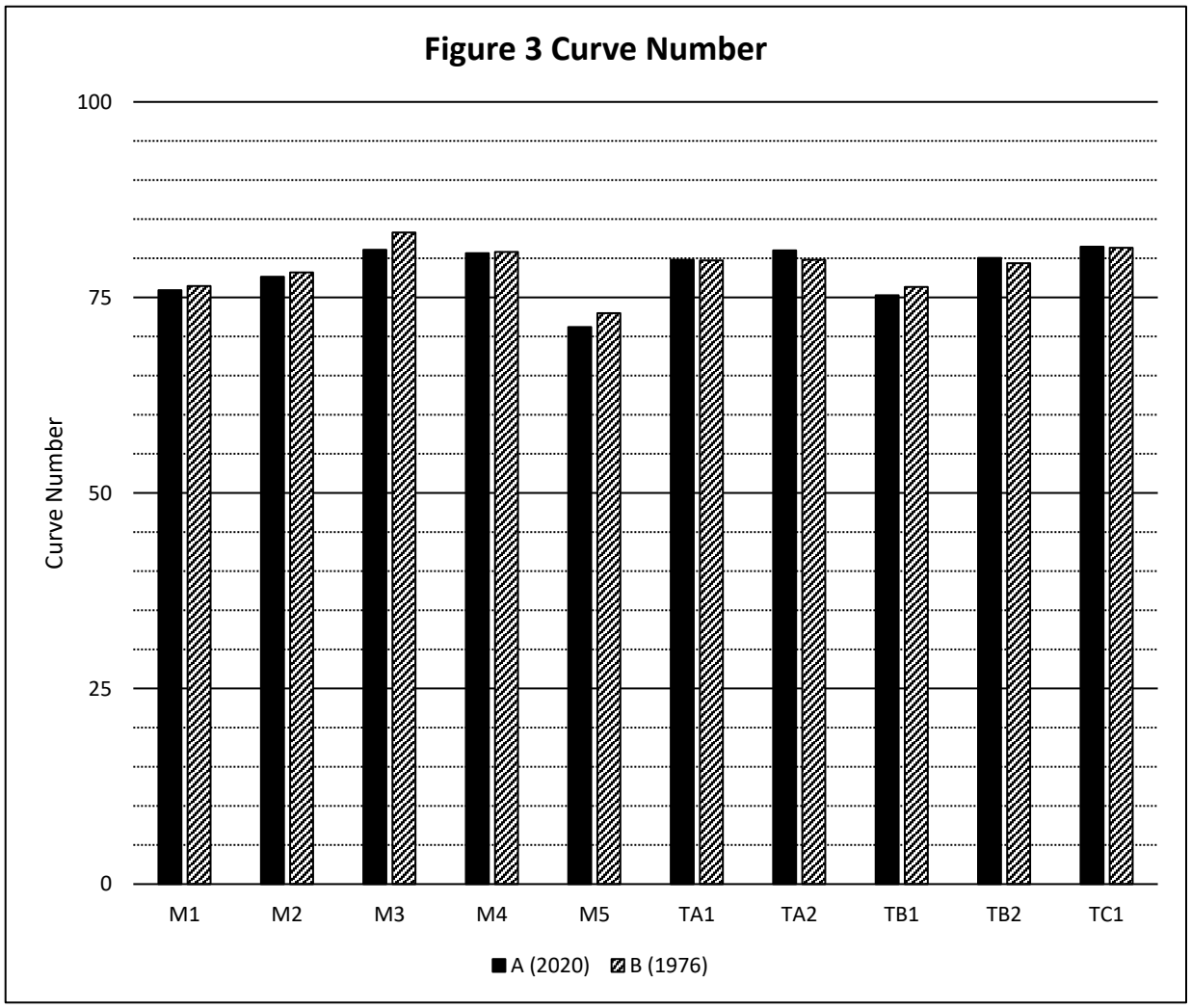


Figure 3 Curve Number
100
75
50
25
0
Curve Number
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

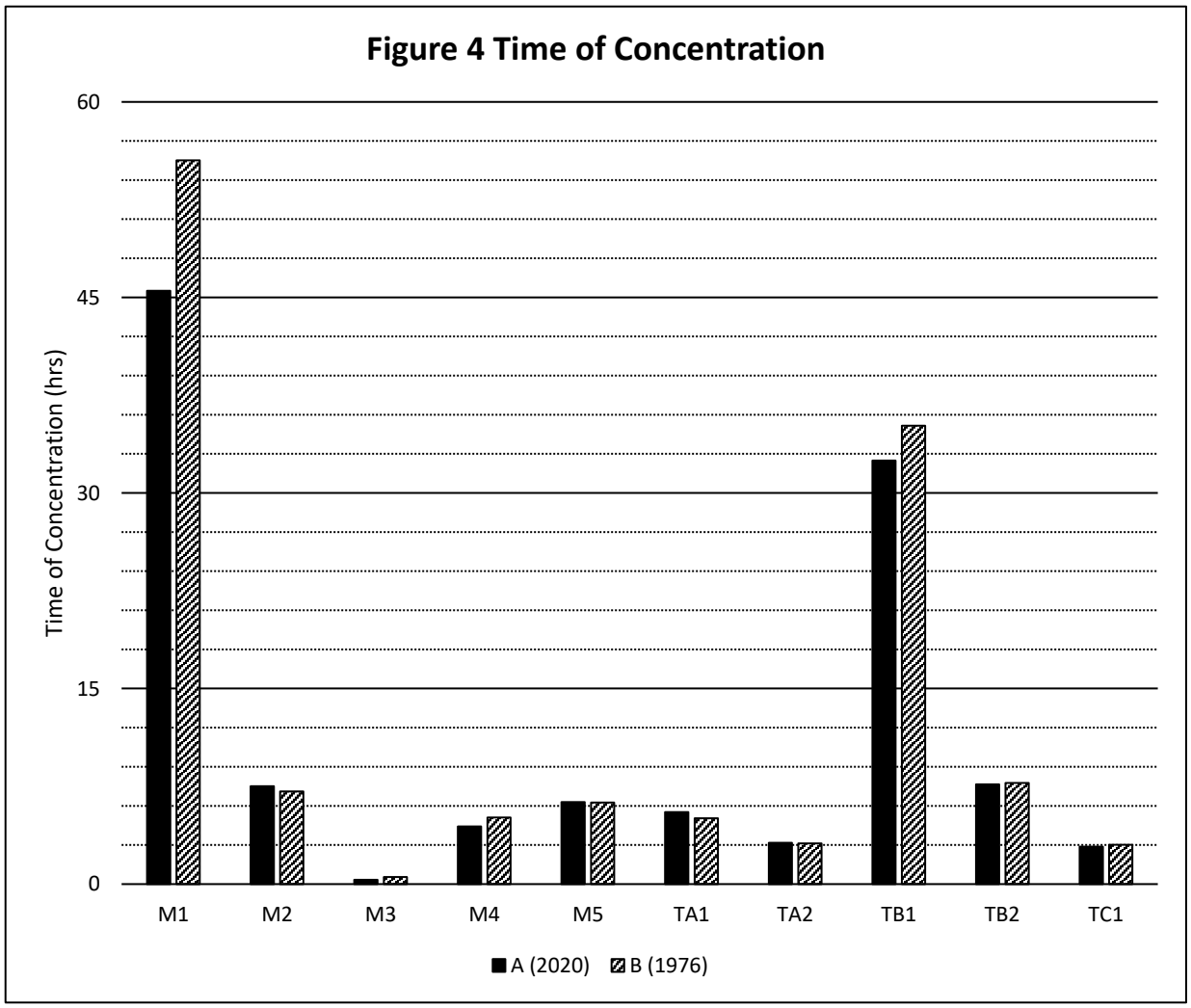


Figure 4 Time of Concentration
60
45
30
15
0
Time of Concentration (hrs)
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

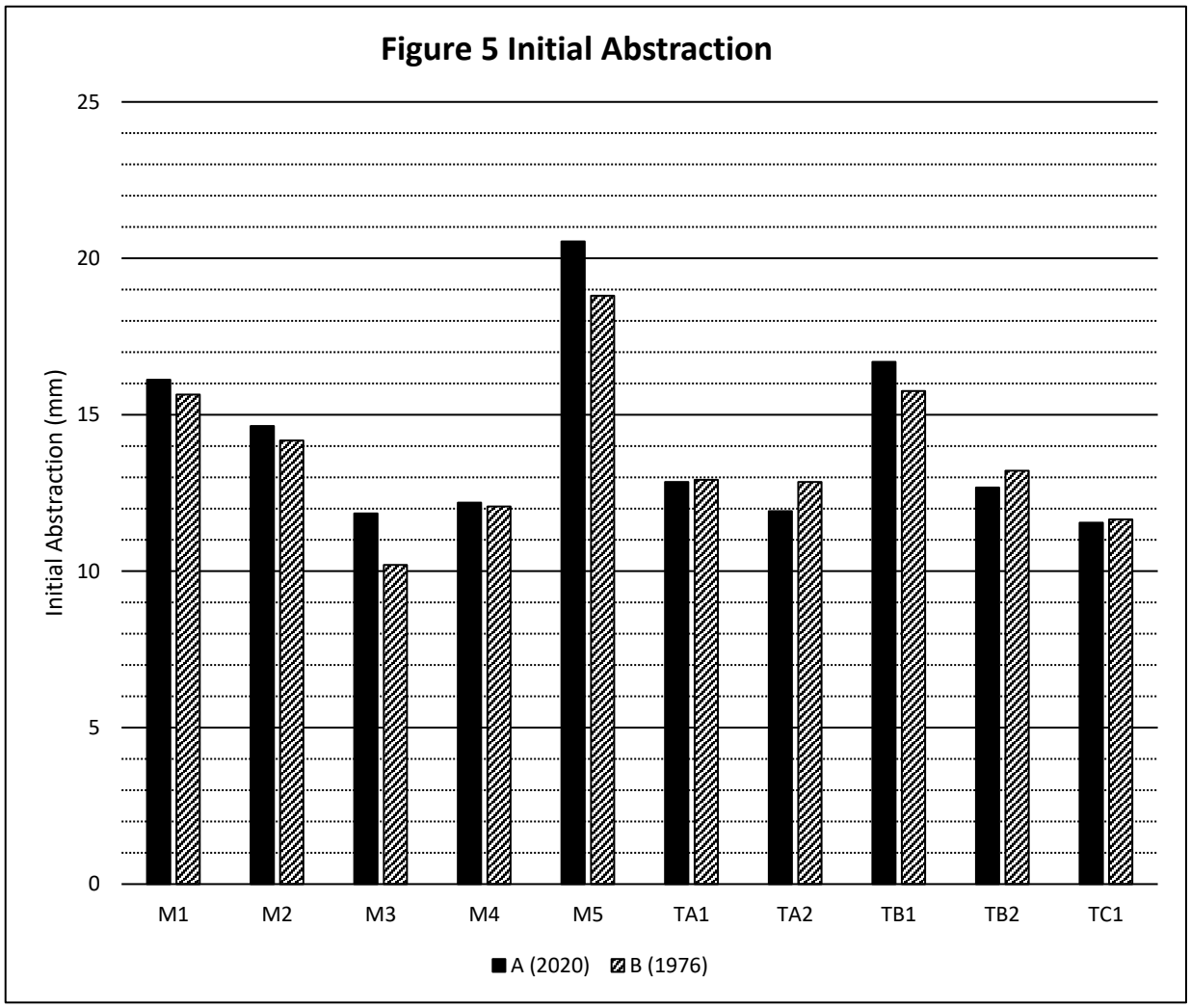


Figure 5 Initial Abstraction
25
20
15
10
5
0
Initial Abstraction (mm)
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

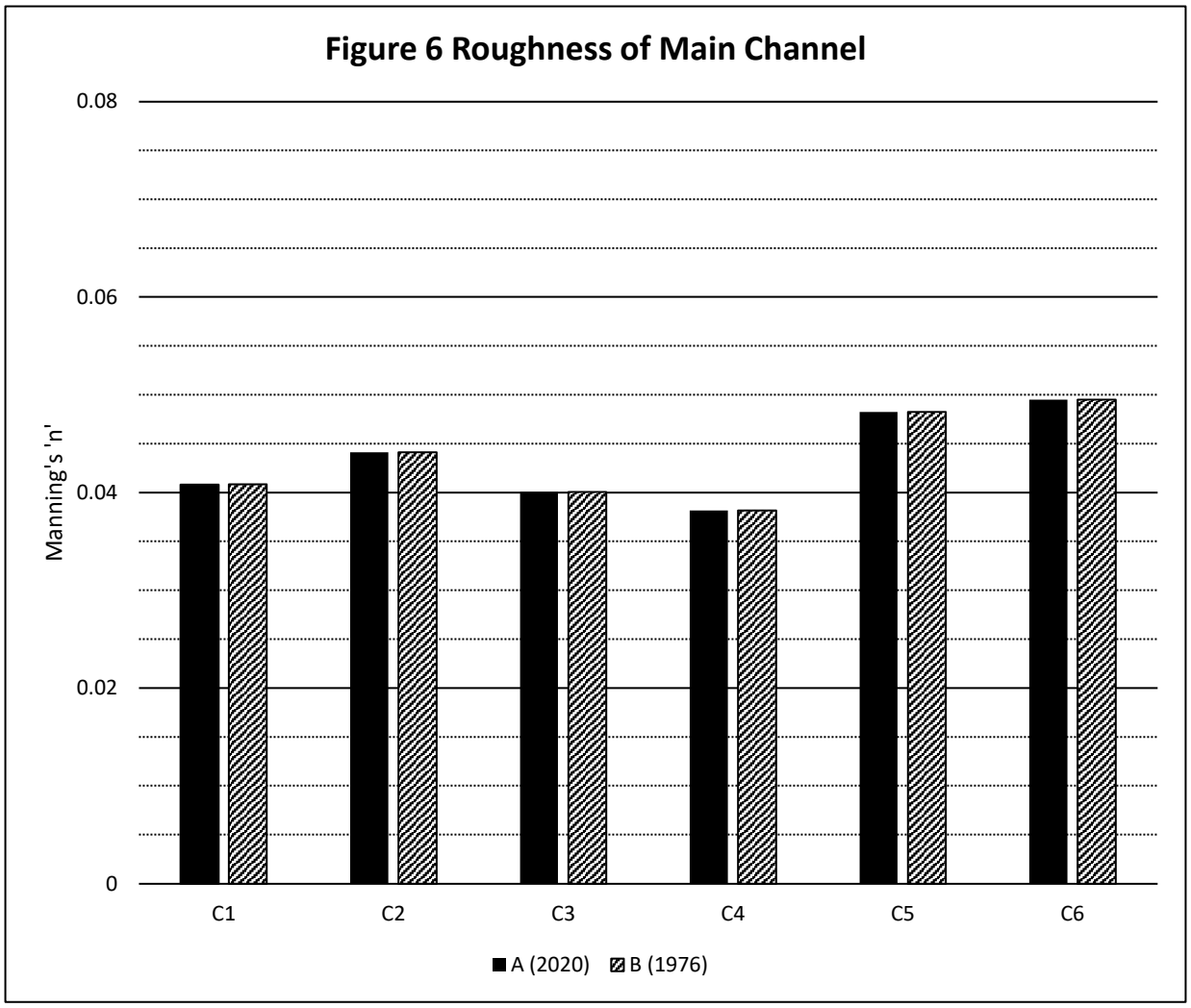


Figure 6 Roughness of Main Channel
0.08
0.06
0.04
0.02
0
Manning's 'n'
C1
C2
C3
C4
C5
C6
A (2020)
B (1976)

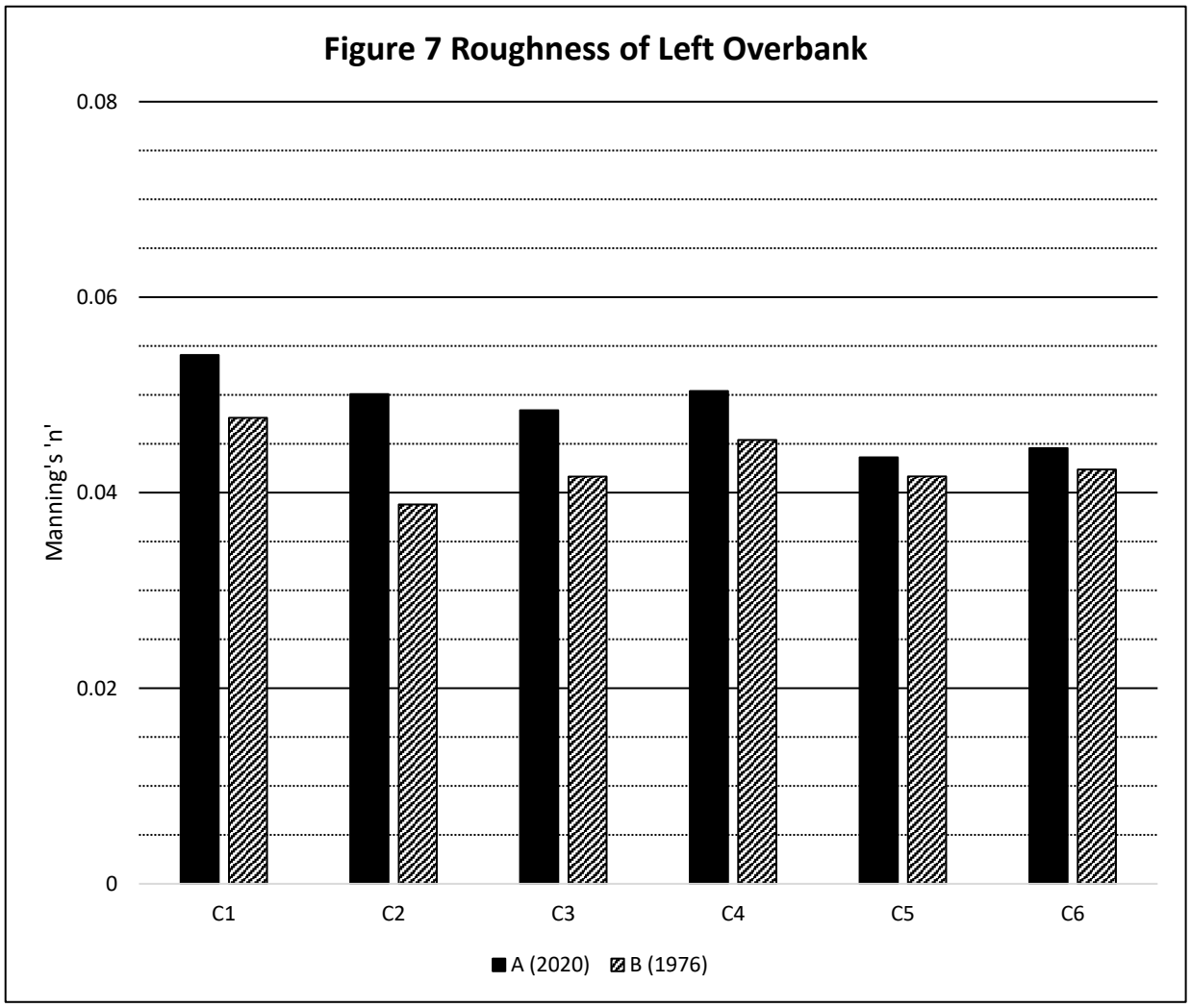


Figure 7 Roughness of Left Overbank
0.08
0.06
0.04
0.02
0
Manning's 'n'
C1
C2
C3
C4
C5
C6
A (2020)
B (1976)

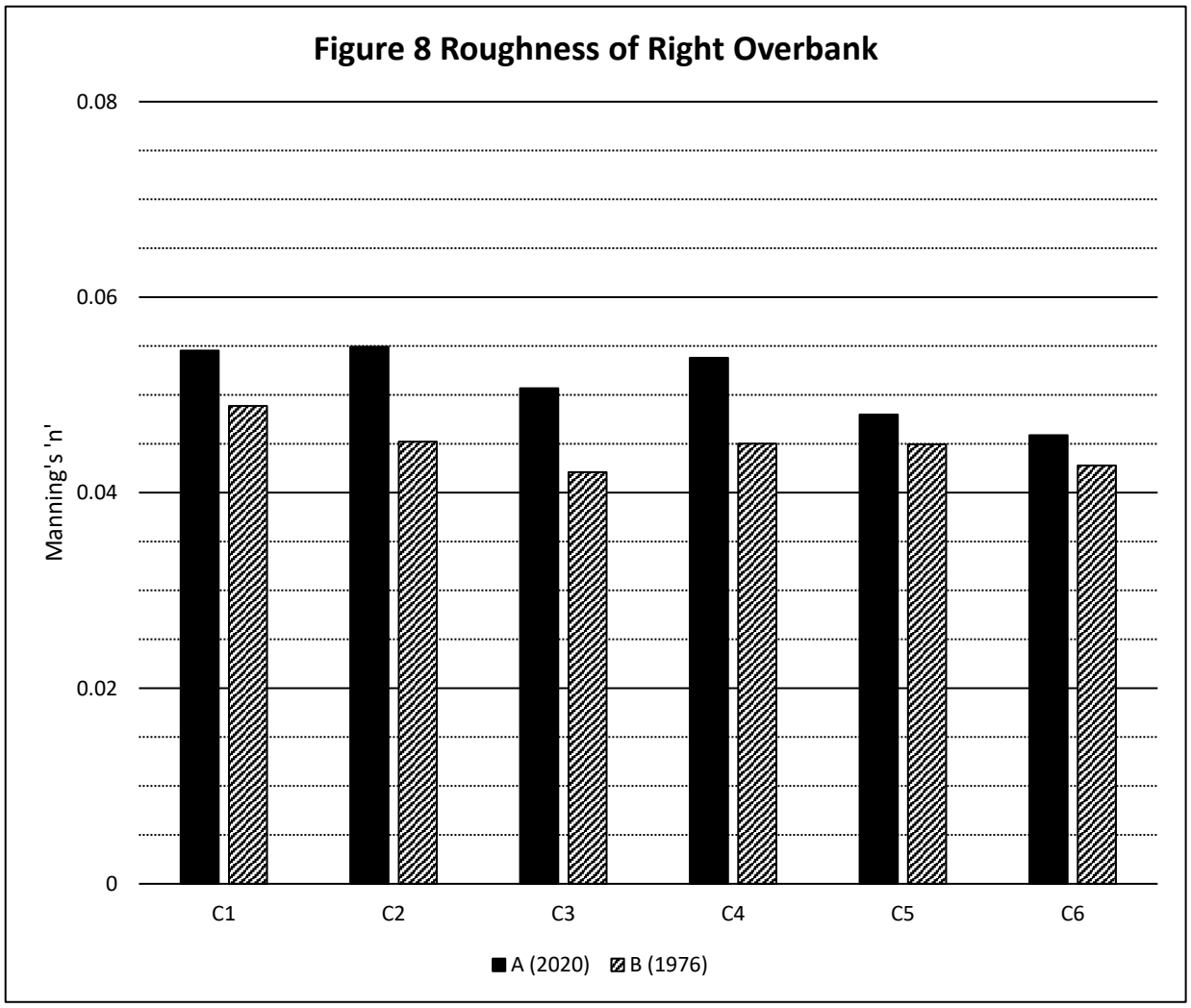


Figure 8 Roughness of Right Overbank
0.08
0.06
0.04
0.02
0
Manning's 'n'
C1
C2
C3
C4
C5
C6
A (2020)
B (1976)

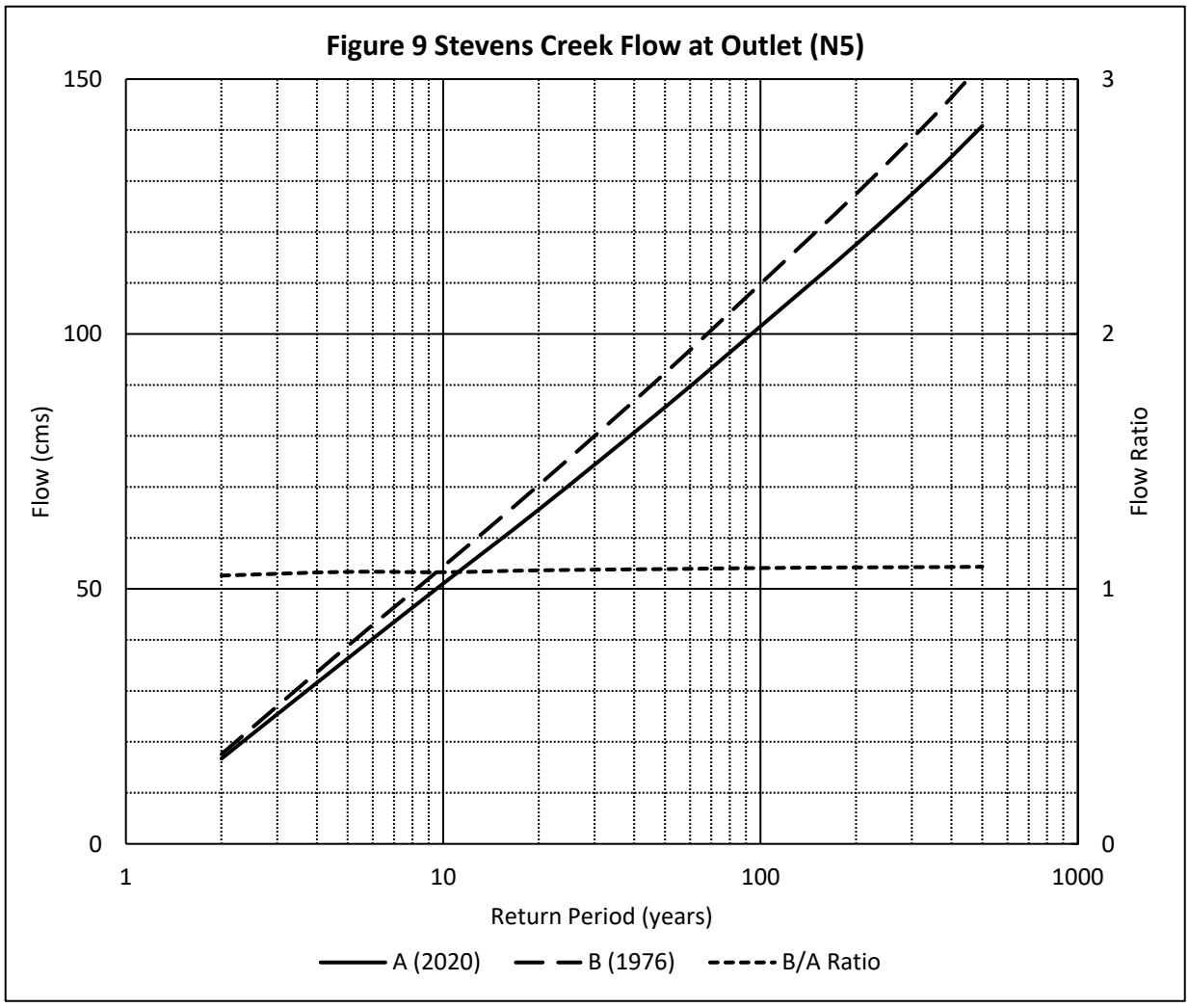


Figure 9 Stevens Creek Flow at Outlet (N5)
150
100
50
0
3
2
1
0
Flow (cms)
Flow Ratio
1
10
100
1000
Return Period (years)
A (2020)
B (1976)
B/A Ratio

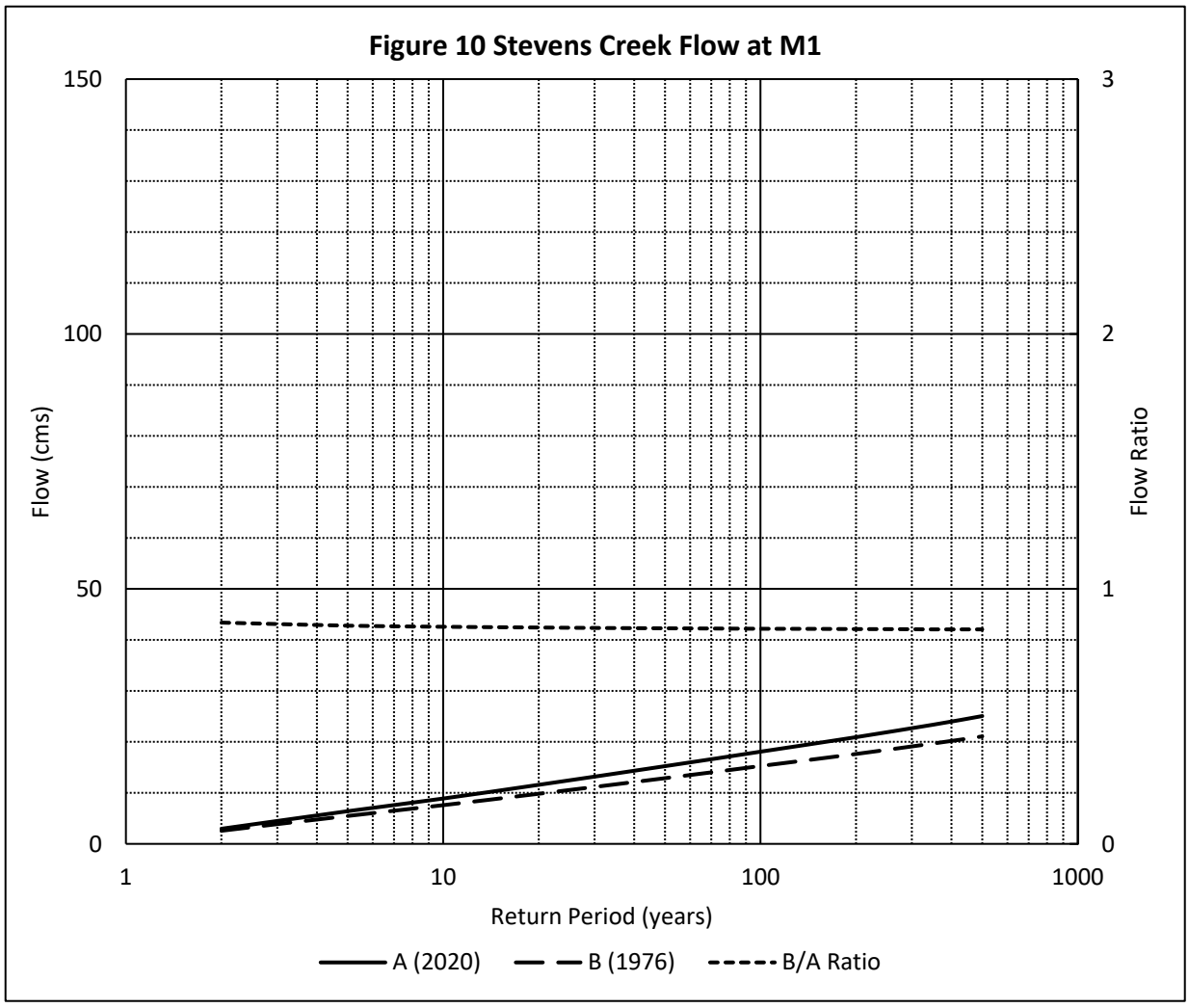


Figure 10 Stevens Creek Flow at M1
150
100
50
0
3
2
1
0
Flow (cms)
Flow Ratio
1
10
100
1000
Return Period (years)
A (2020)
B (1976)
B/A Ratio

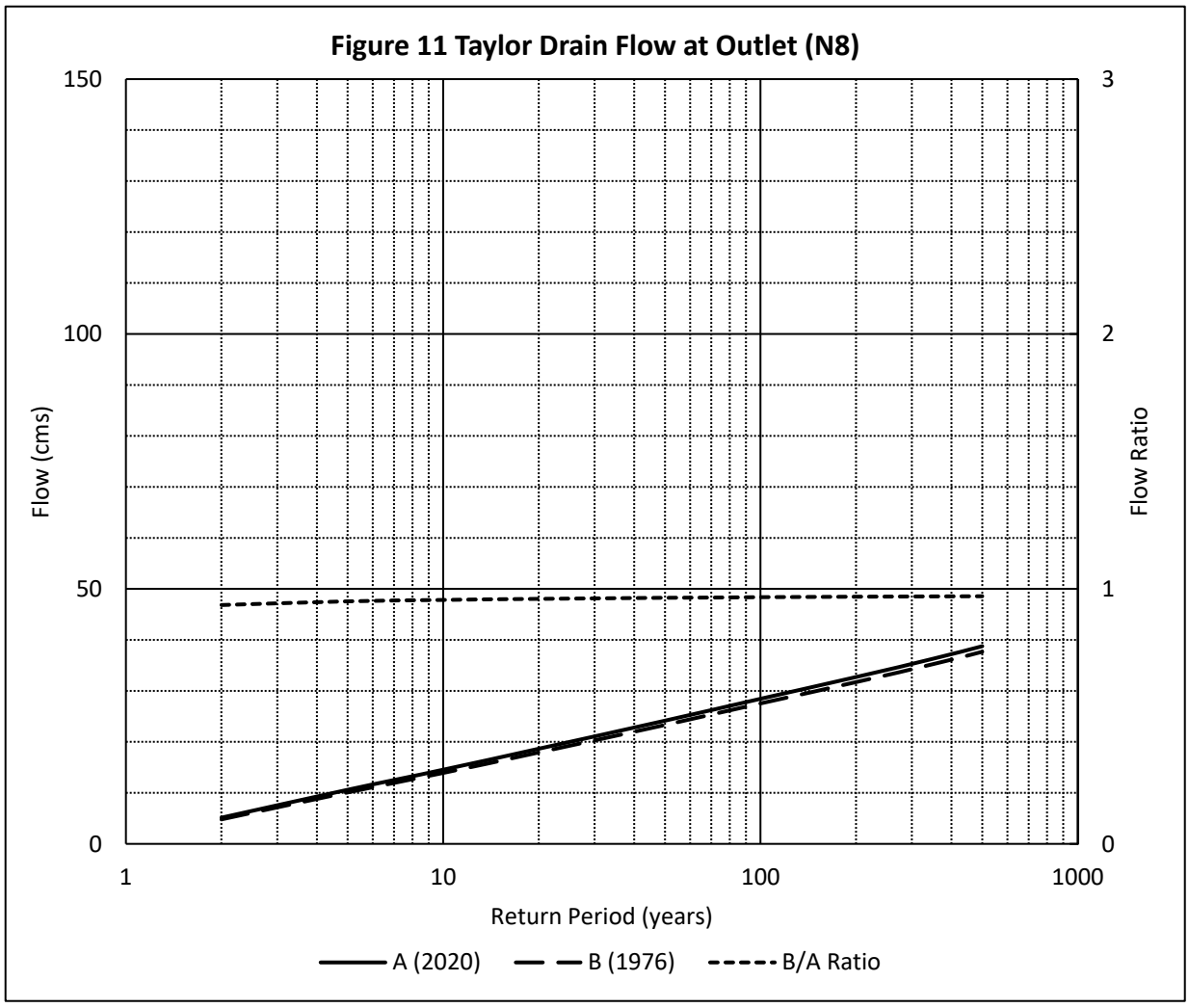


Figure 11 Taylor Drain Flow at Outlet (N8)
150
100
50
0
3
2
1
0
Flow (cms)
Flow Ratio
1
10
100
1000
Return Period (years)
A (2020)
B (1976)
B/A Ratio

Figure 12a Comparison of estimated 1:100 year flows

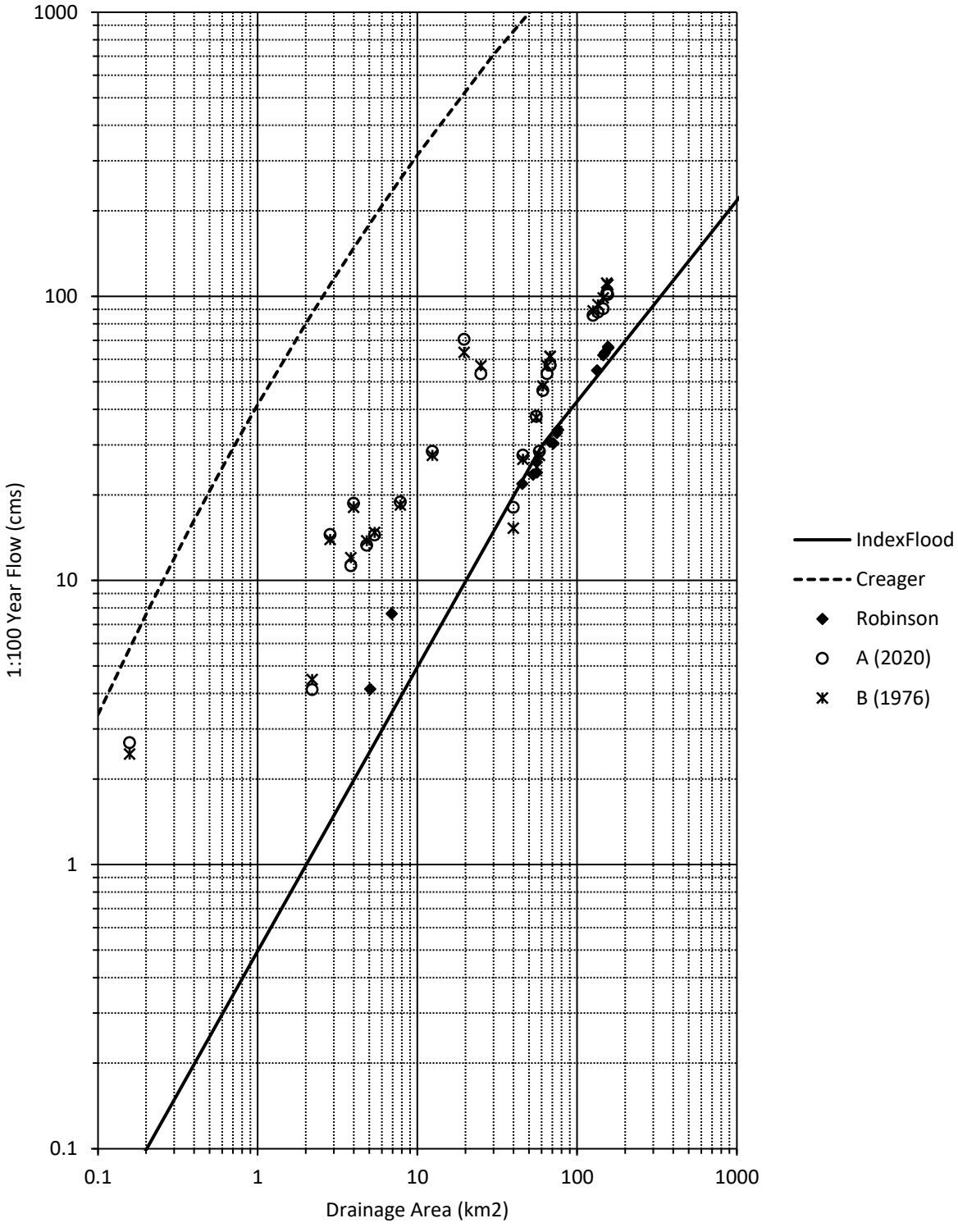
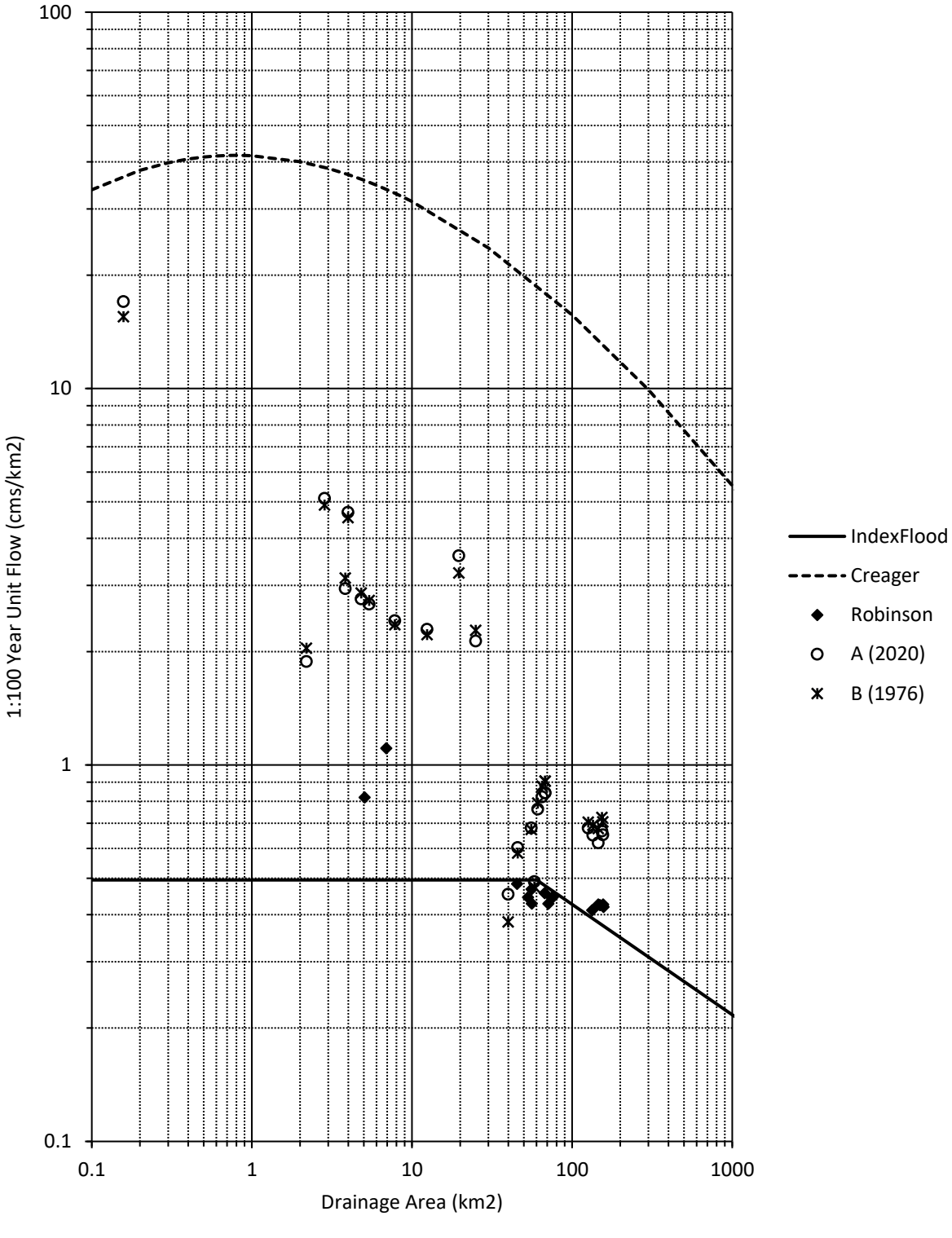


Figure 12b Comparison of 1:100 year flows per unit area



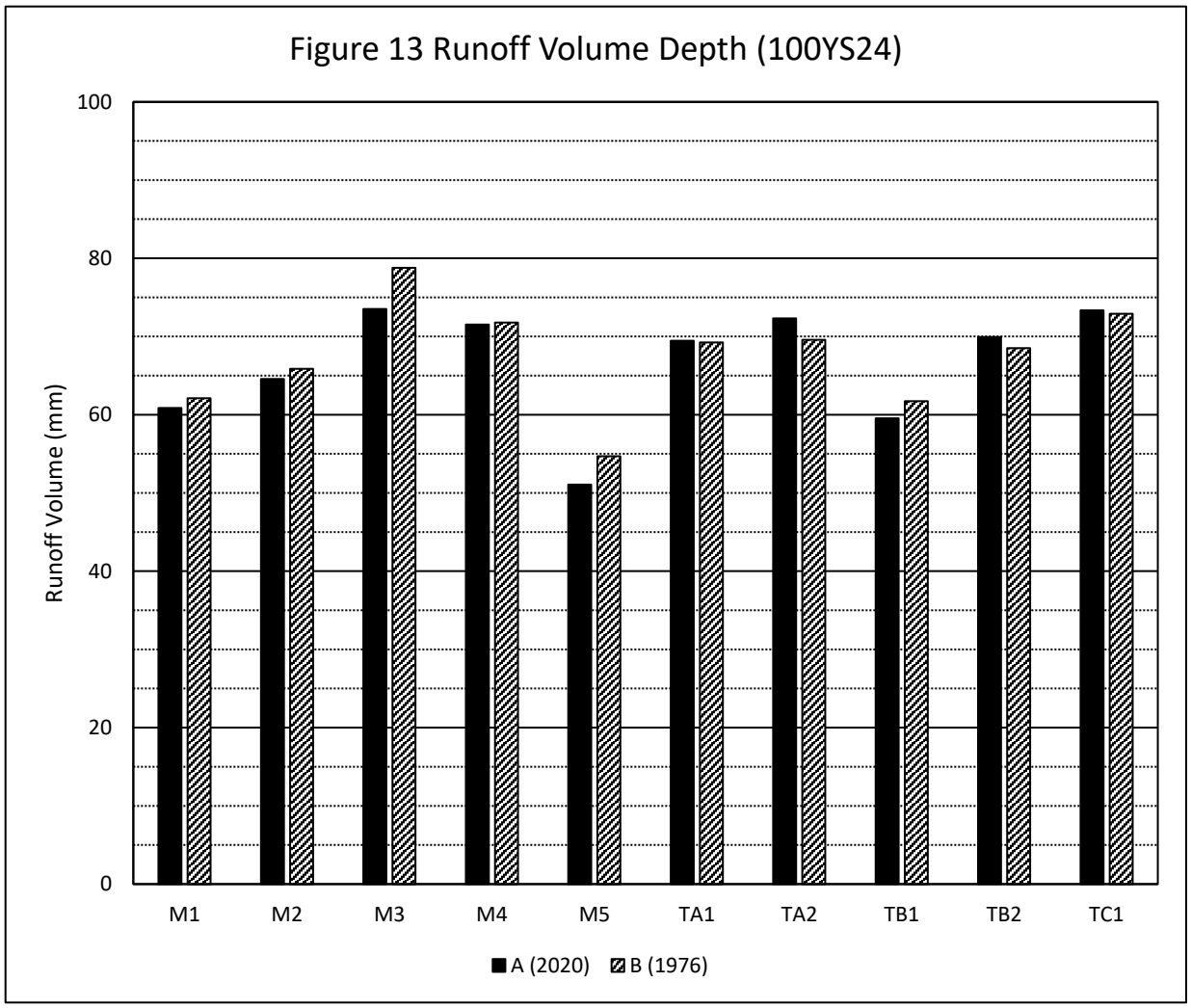


Figure 13 Runoff Volume Depth (100YS24)
Runoff Volume (mm)
100
80
60
40
20
0
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

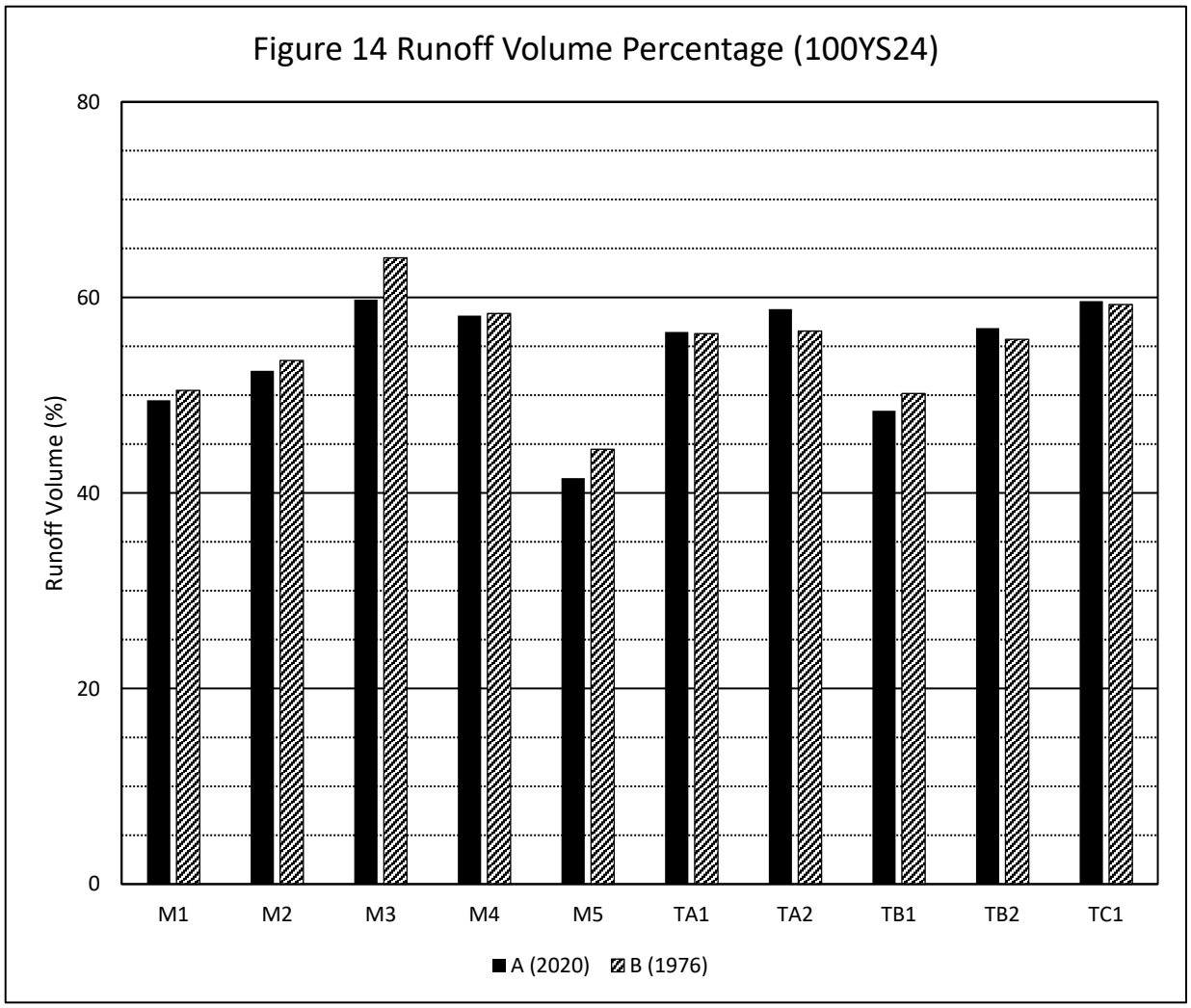


Figure 14 Runoff Volume Percentage (100YS24)
Runoff Volume (%)
80
60
40
20
0
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
A (2020)
B (1976)

Figure 15a Comparison of flows (Stevens Creek)

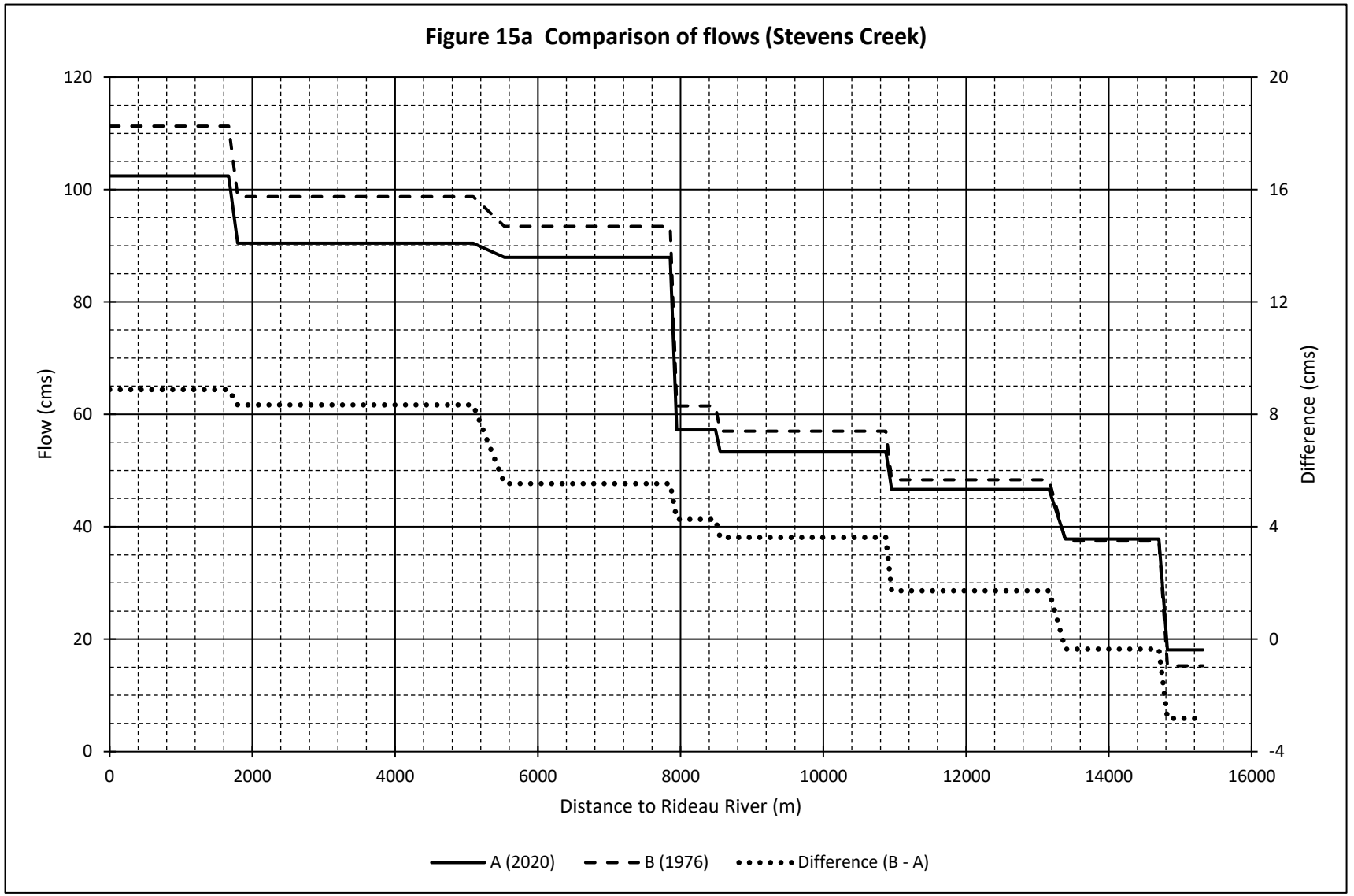


Figure 15b Comparison of flows (Taylor Drain)

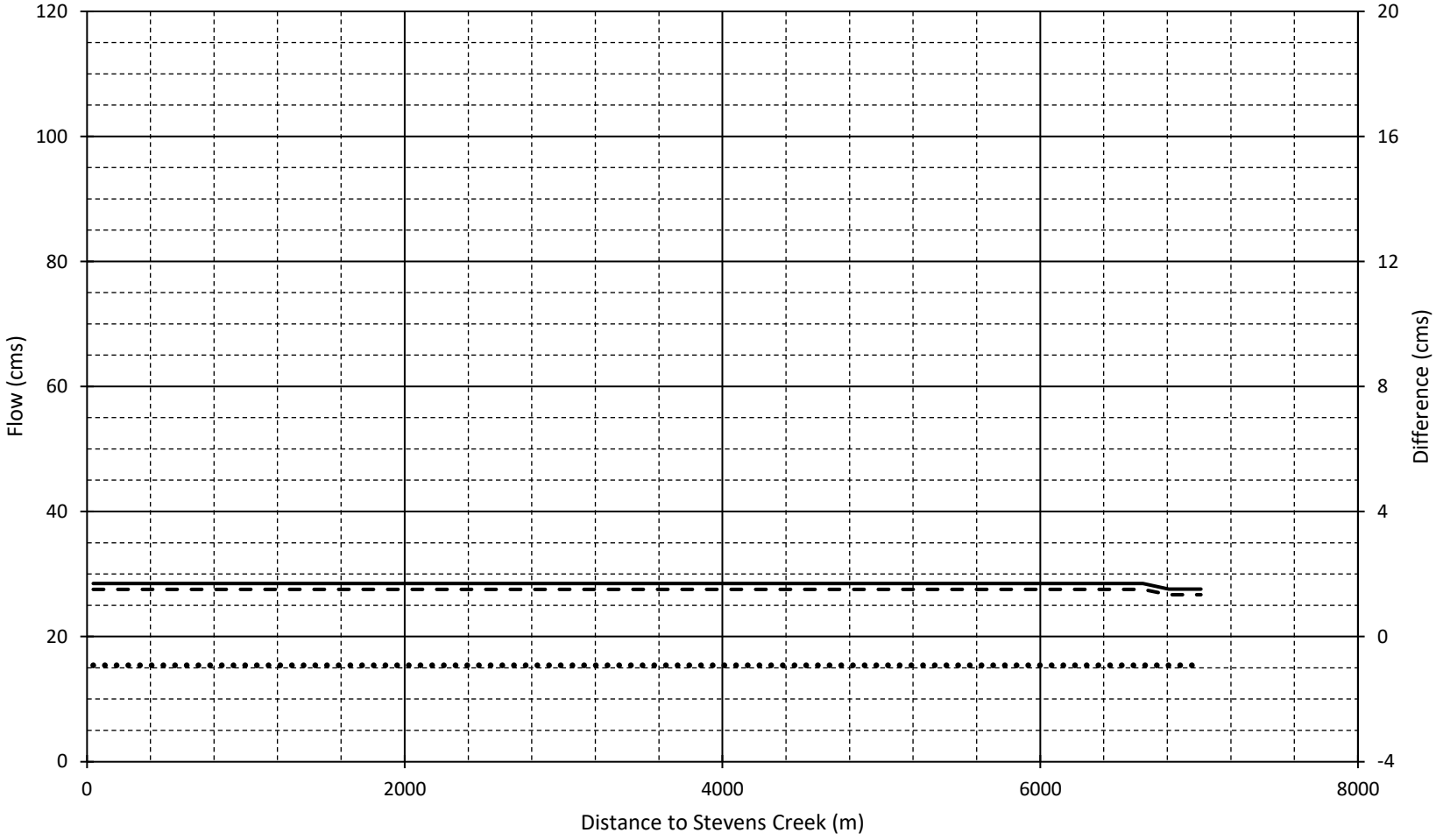


Figure 16a Comparison of computed water levels (Stevens Creek)

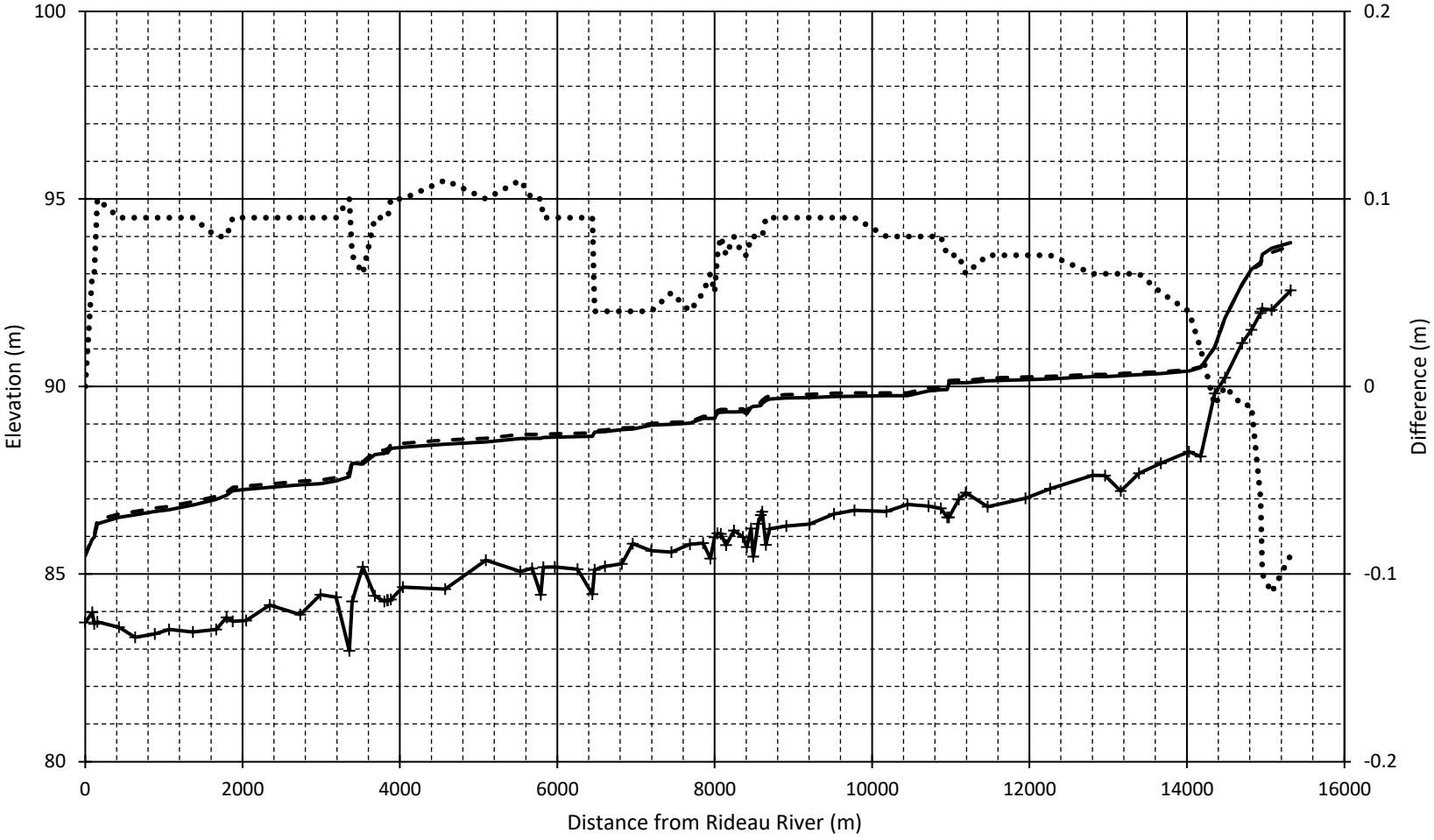


Figure 16b Comparison of computed water levels (Taylor Drain)

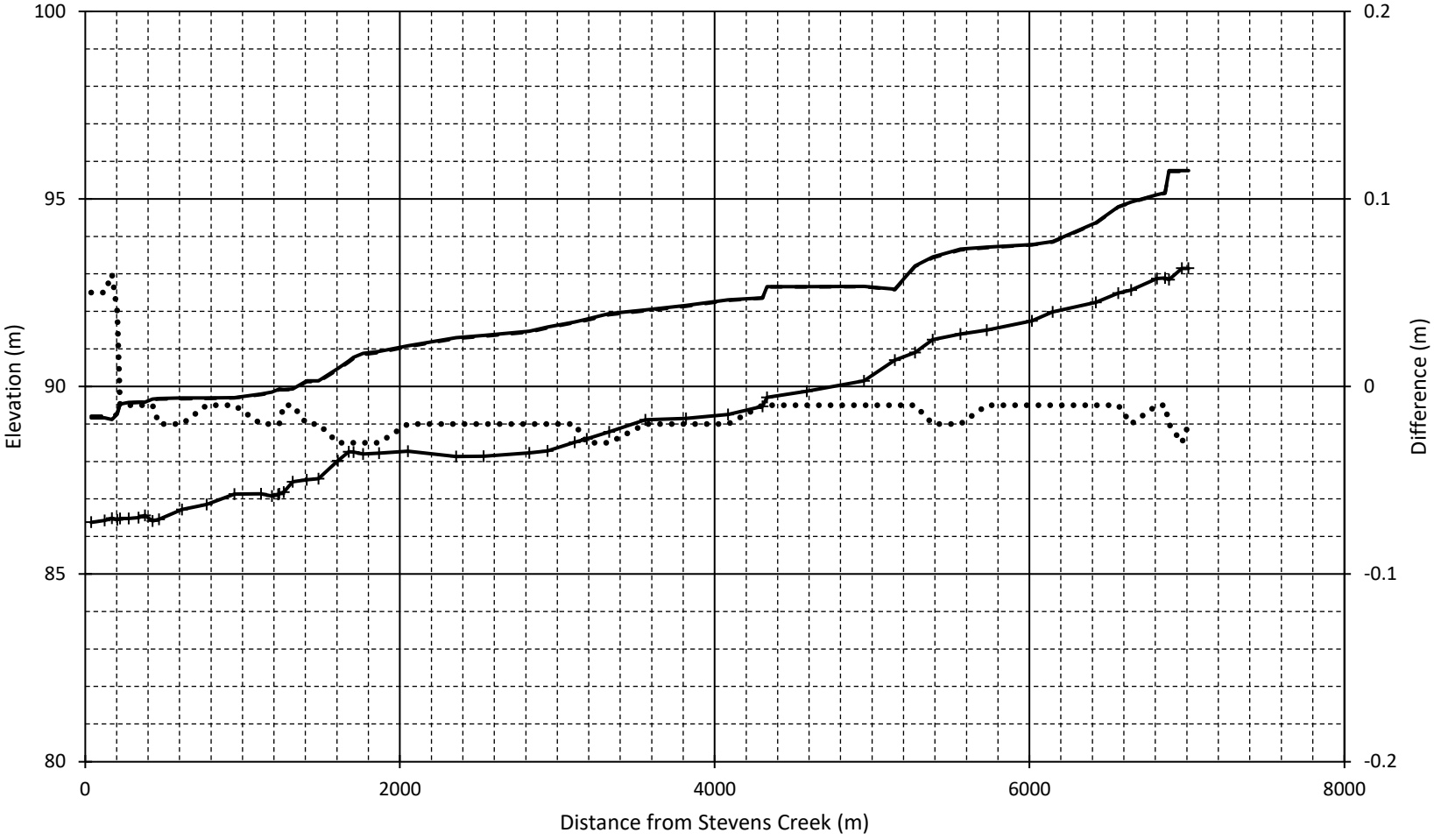


Figure 17a Comparison of computed energy grade (Stevens Creek)

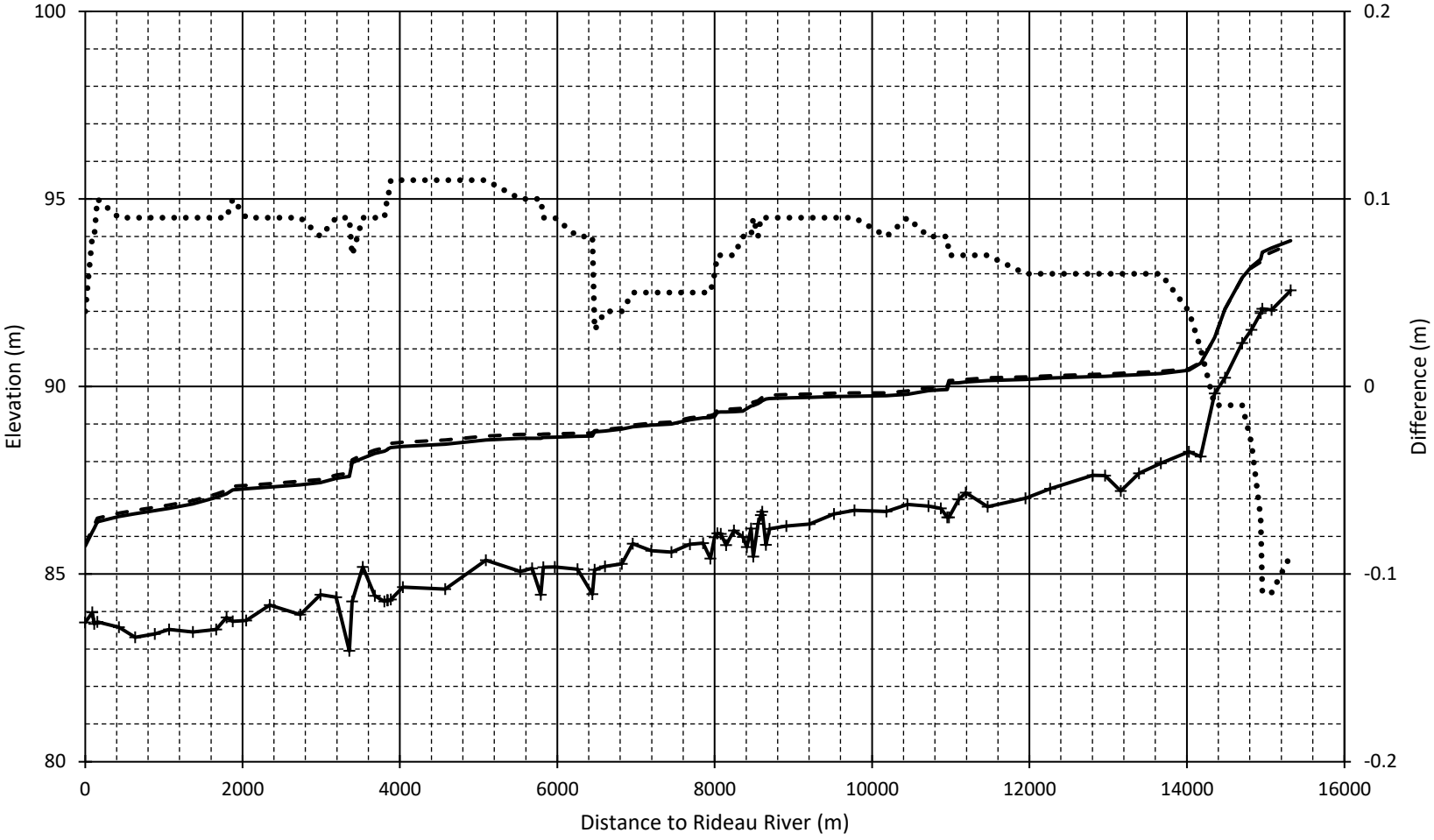
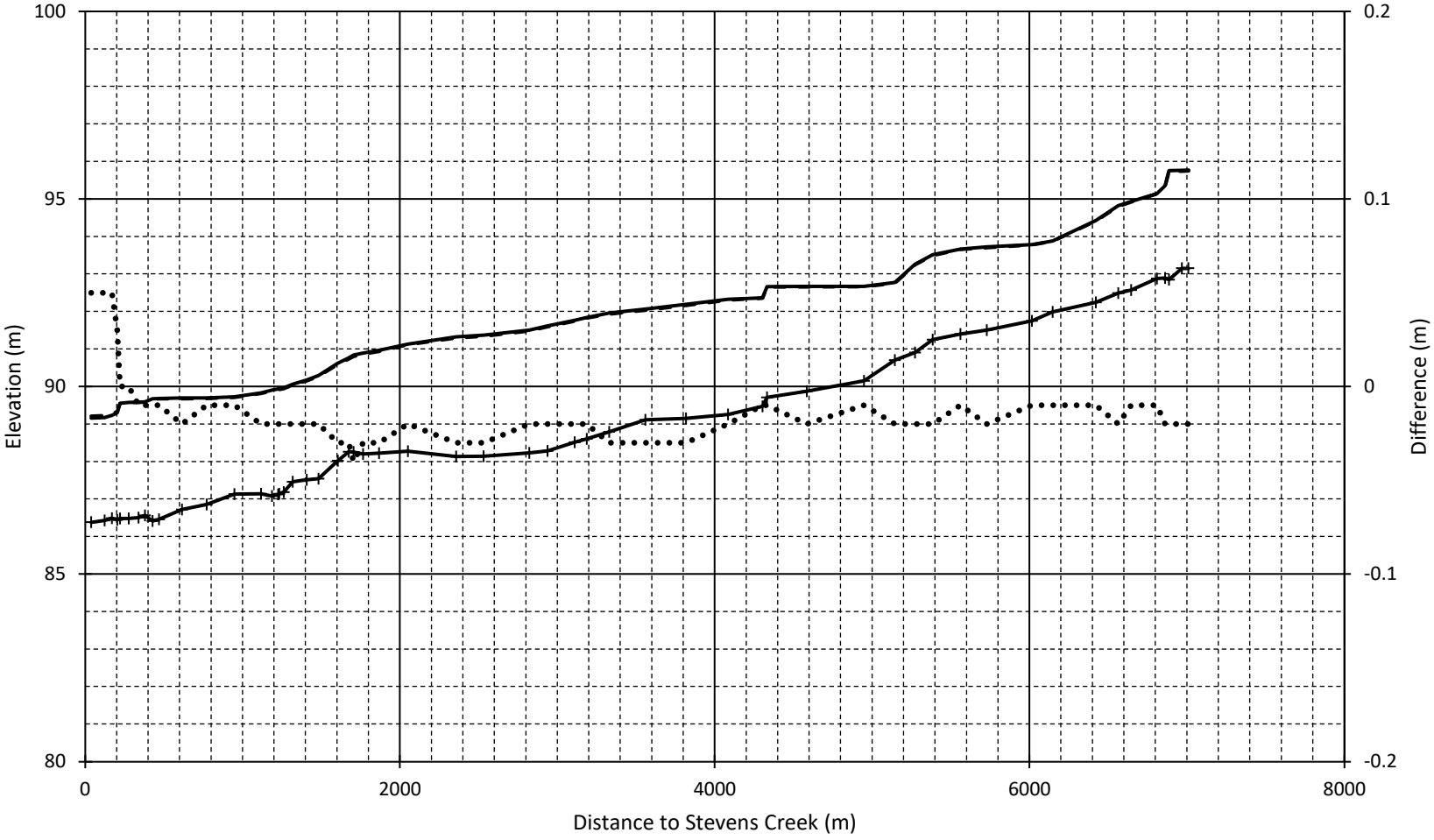


Figure 17b Comparison of computed energy grade (Taylor Drain)

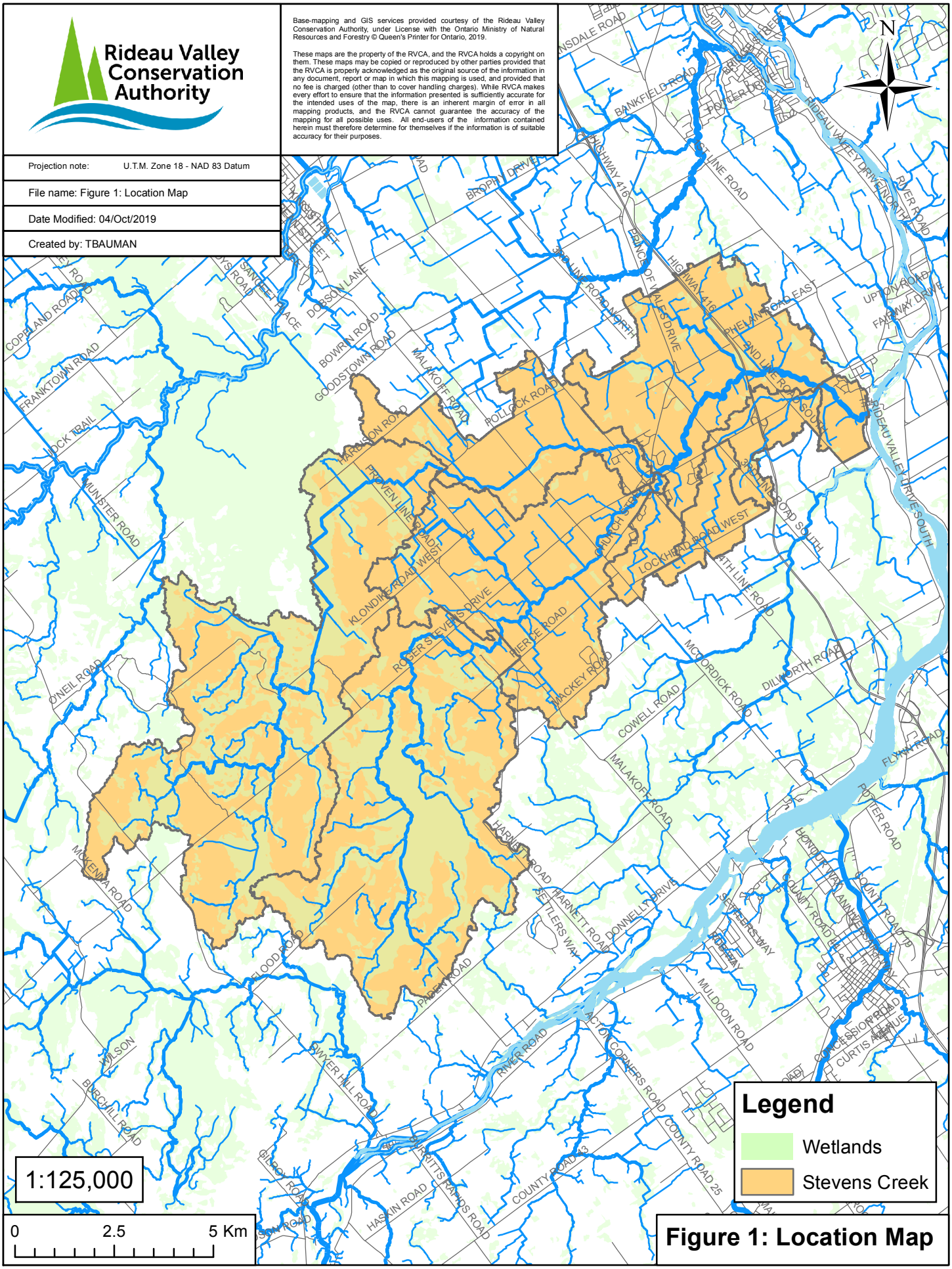


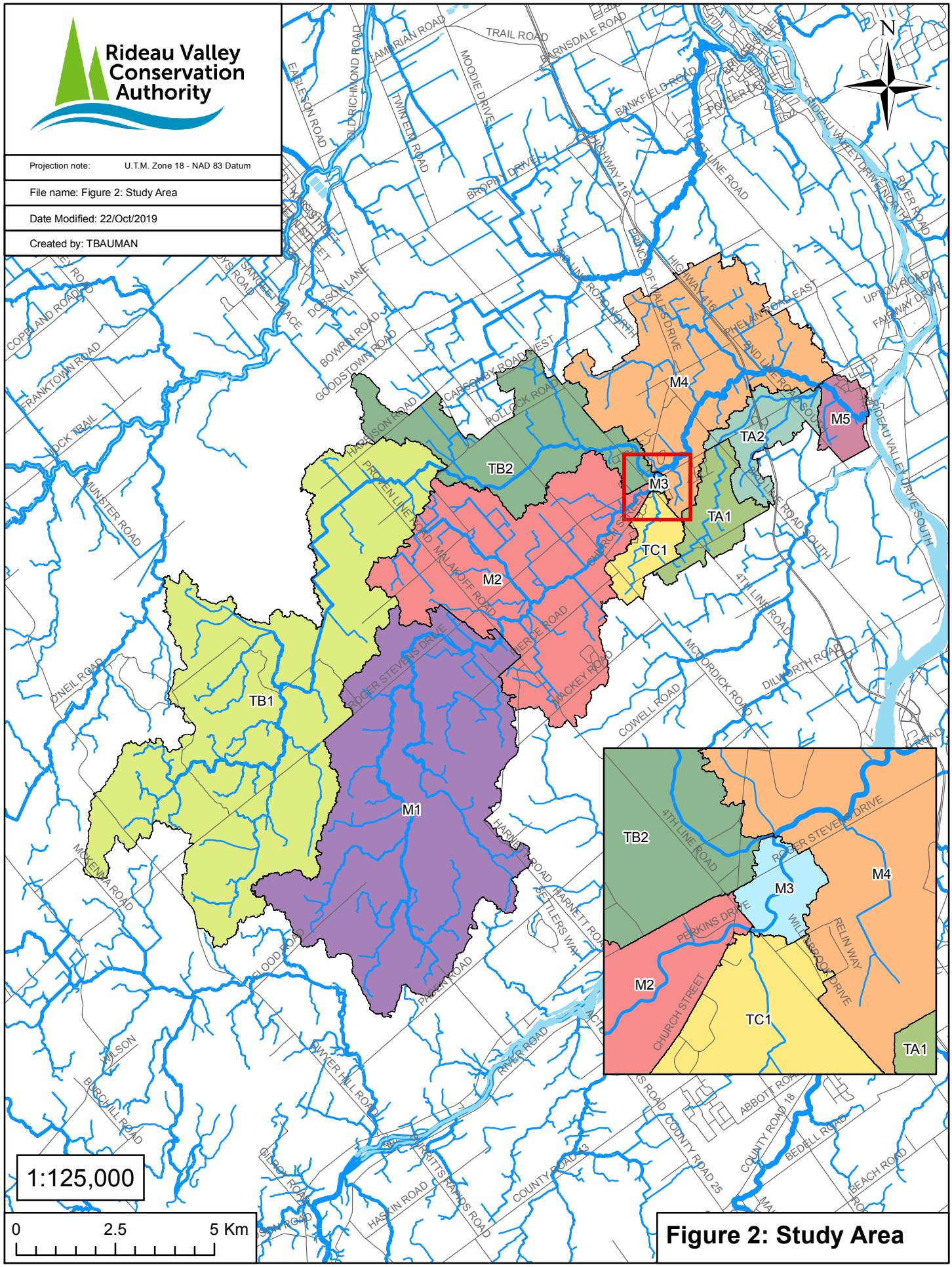
Appendix A

Figures and Tables for Scenario A (2020)

Reproduced from the flood mapping report (RVCA, 2020)

RVCA (2020). Stevens Creek Flood Risk Mapping from Malakoff Road to Rideau River. Rideau Valley Conservation Authority, Manotick, Ontario. 27 August 2020.


Rideau Valley Conservation Authority
Base-mapping and GIS services provided courtesy of the Rideau Valley Conservation Authority, under License with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2019.
These maps are the property of the RVCA, and the RVCA holds a copyright on them. These maps may be copied or reproduced by other parties provided that the RVCA is properly acknowledged as the original source of the information in any document, report or map in which this mapping is used, and provided that no fee is charged (other than to cover handling charges). While RVCA makes every effort to ensure that the information presented is sufficiently accurate for the intended uses of the map, there is an inherent margin of error in all mapping products, and the RVCA cannot guarantee the accuracy of the mapping for all possible uses. All end-users of the information contained herein must therefore determine for themselves if the information is of suitable accuracy for their purposes.
Projection note: U.T.M. Zone 18 - NAD 83 Datum
File name: Figure 1: Location Map
Date Modified: 04/Oct/2019
Created by: TBAUMAN
N
Legend
Wetlands
Stevens Creek
1:125,000
0
2.5
5 Km
Figure 1: Location Map


Rideau Valley Conservation Authority
Projection note: U.T.M. Zone 18 - NAD 83 Datum
File name: Figure 2: Study Area
Date Modified: 22/Oct/2019
Created by: TBAUMAN
N
TB1
TB2
M1
M2
M3
M4
M5
TA1
TA2
TC1
1:125,000
0
2.5
5 Km
Figure 2: Study Area

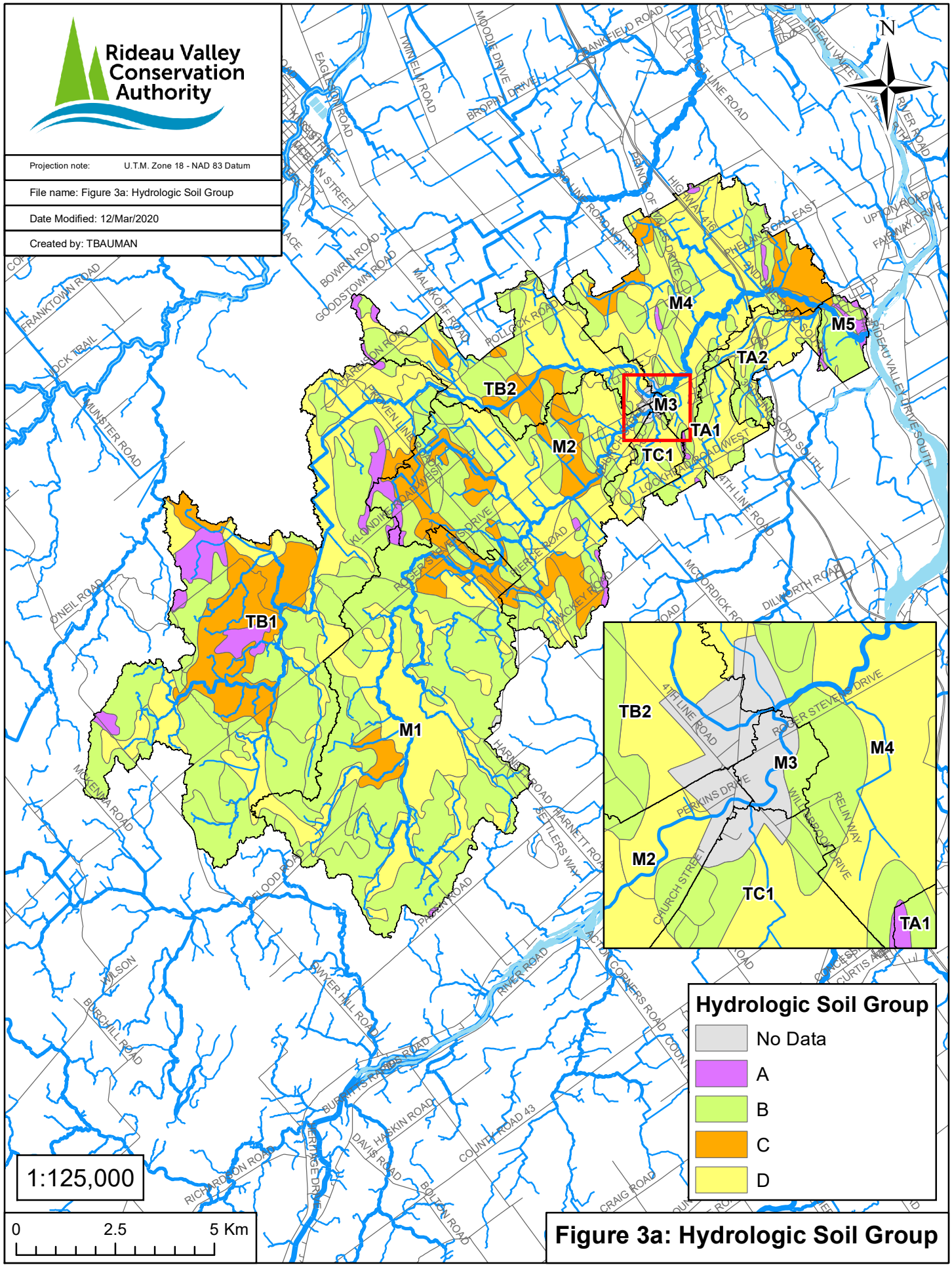
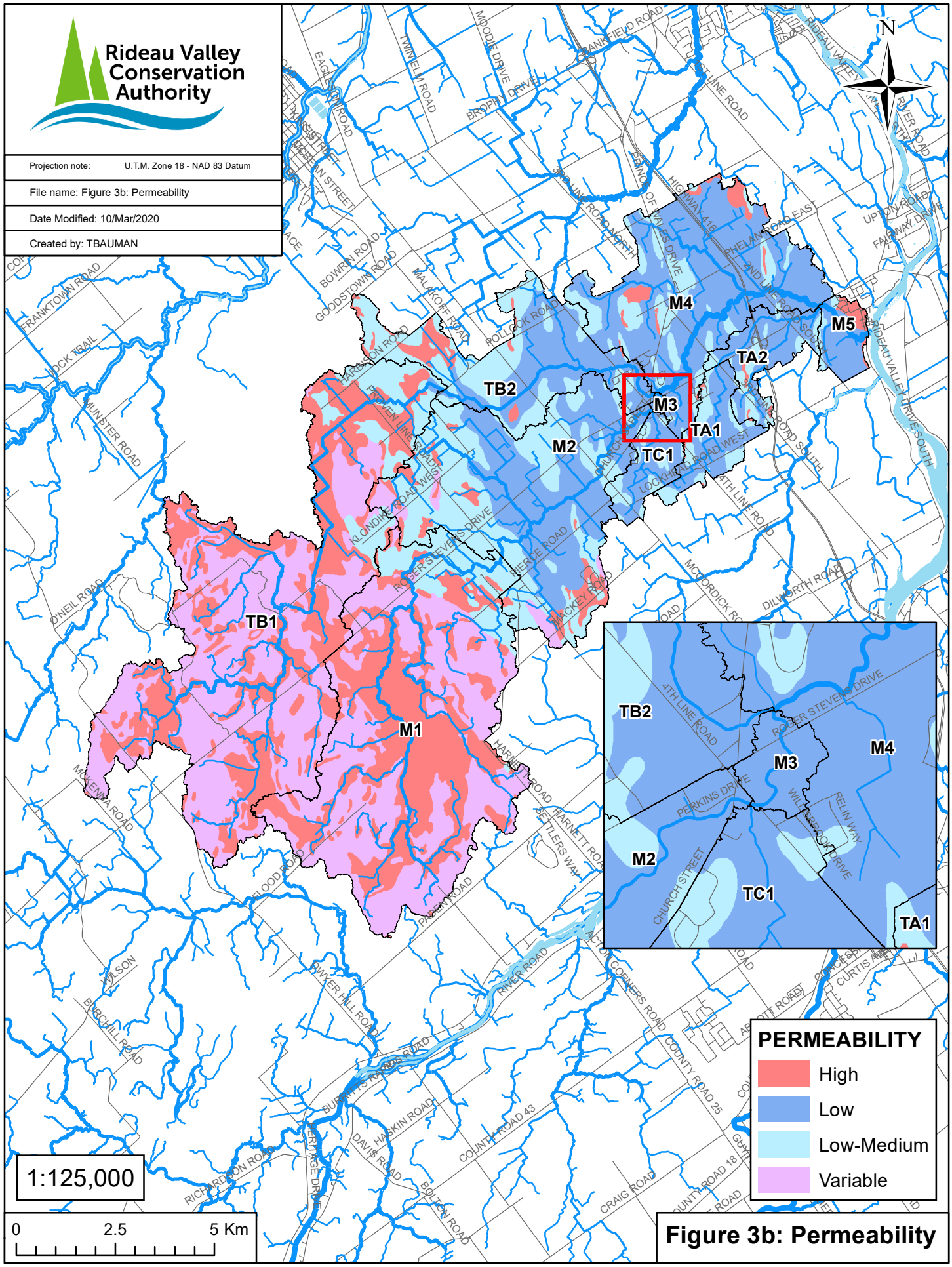
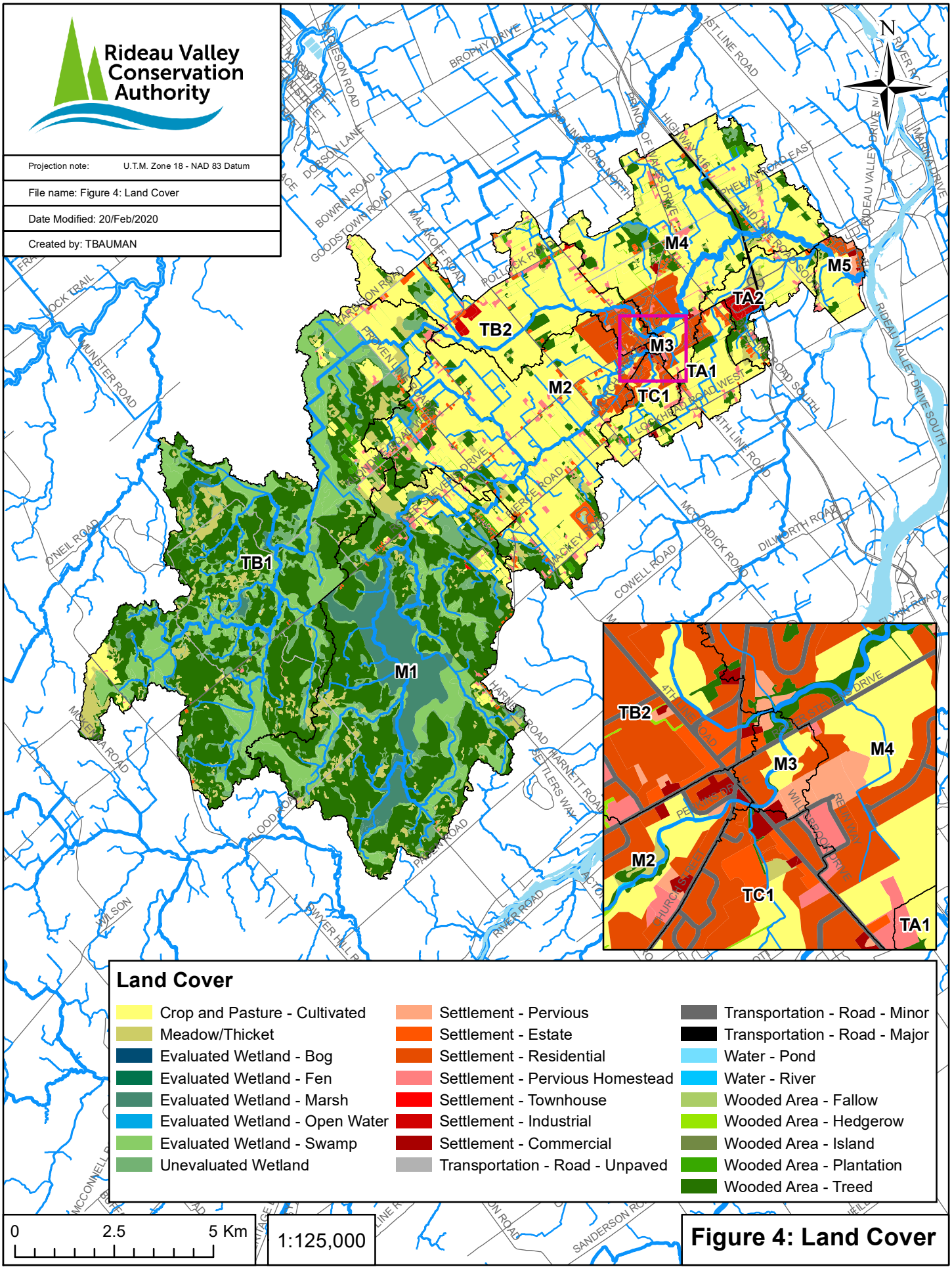


Figure 3a: Hydrologic Soil Group


Rideau Valley Conservation Authority
Projection note: U.T.M. Zone 18 - NAD 83 Datum
File name: Figure 3b: Permeability
Date Modified: 10/Mar/2020
Created by: TBAUMAN
N
M4
M5
TA2
TB2
M3
TA1
M2
TC1
TB1
M1
PERMEABILITY
High
Low
Low-Medium
Variable
1:125,000
0
2.5
5 Km
Figure 3b: Permeability


Rideau Valley Conservation Authority
Projection note: U.T.M. Zone 18 - NAD 83 Datum
File name: Figure 4: Land Cover
Date Modified: 20/Feb/2020
Created by: TBAUMAN
N
TB1
TB2
M1
M2
M3
M4
M5
TA1
TA2
TC1
Land Cover
Crop and Pasture - Cultivated
Meadow/Thicket
Evaluated Wetland - Bog
Evaluated Wetland - Fen
Evaluated Wetland - Marsh
Evaluated Wetland - Open Water
Evaluated Wetland - Swamp
Unevaluated Wetland
Settlement - Pervious
Settlement - Estate
Settlement - Residential
Settlement - Pervious Homestead
Settlement - Townhouse
Settlement - Industrial
Settlement - Commercial
Transportation - Road - Unpaved
Transportation - Road - Minor
Transportation - Road - Major
Water - Pond
Water - River
Wooded Area - Fallow
Wooded Area - Hedgerow
Wooded Area - Island
Wooded Area - Plantation
Wooded Area - Treed
0
2.5
5 Km
1:125,000
Figure 4: Land Cover

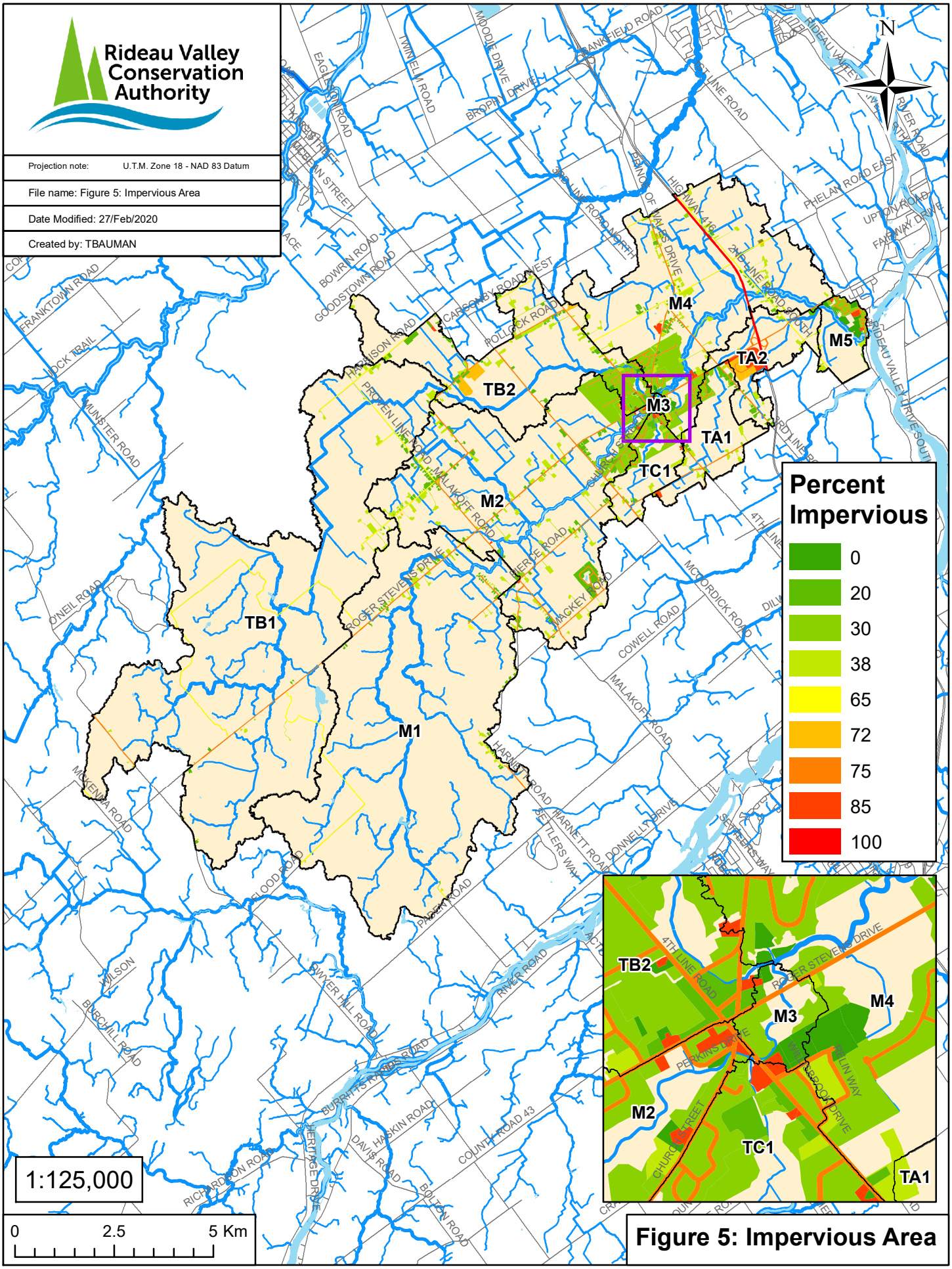
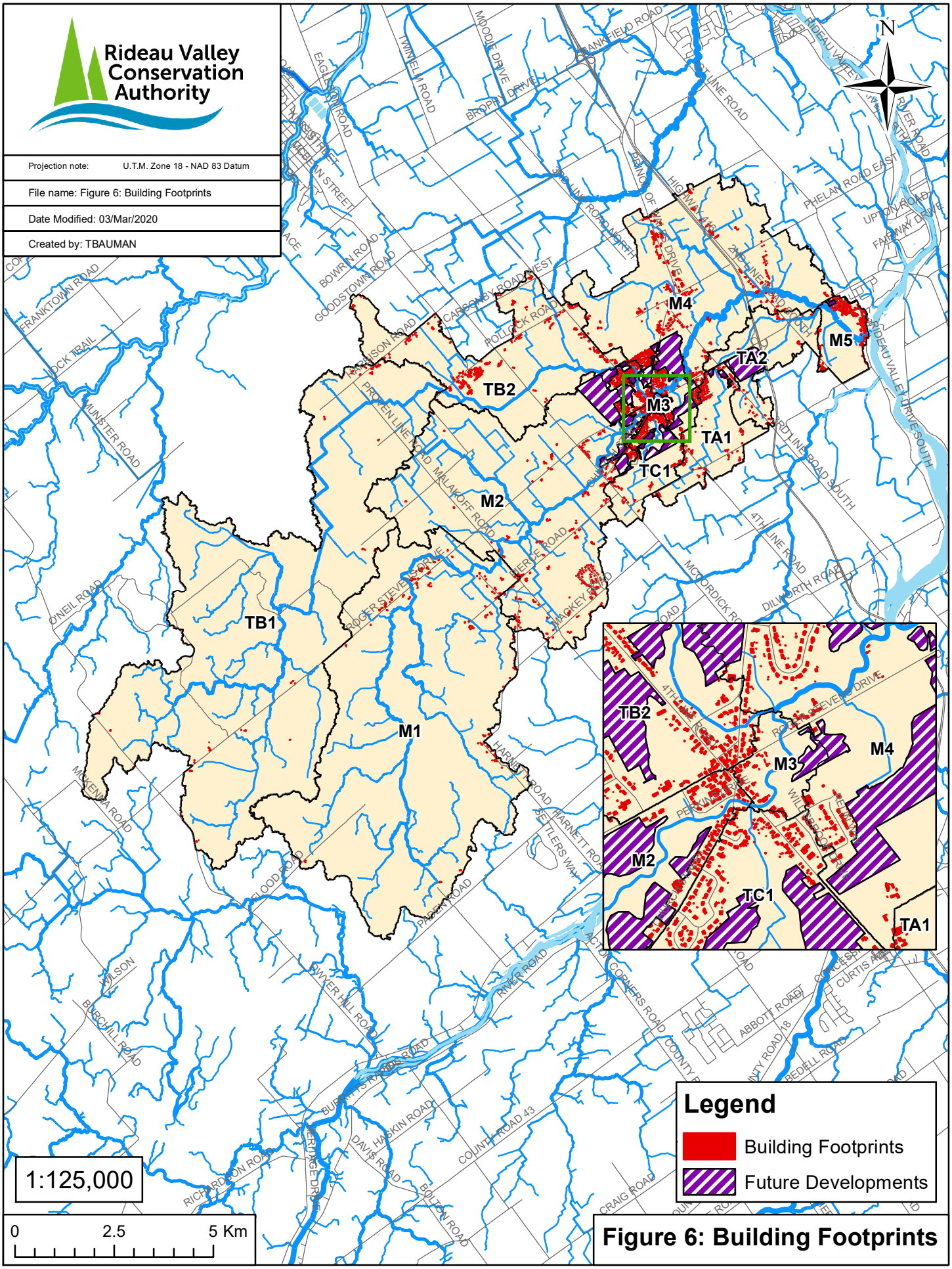


Figure 5: Impervious Area


Rideau Valley Conservation Authority
Projection note: U.T.M. Zone 18 - NAD 83 Datum
File name: Figure 6: Building Footprints
Date Modified: 03/Mar/2020
Created by: TBAUMAN
N
M1
M2
M3
M4
M5
TA1
TA2
TB1
TB2
TC1
Legend
Building Footprints
Future Developments
1:125,000
0
2.5
5 Km
Figure 6: Building Footprints

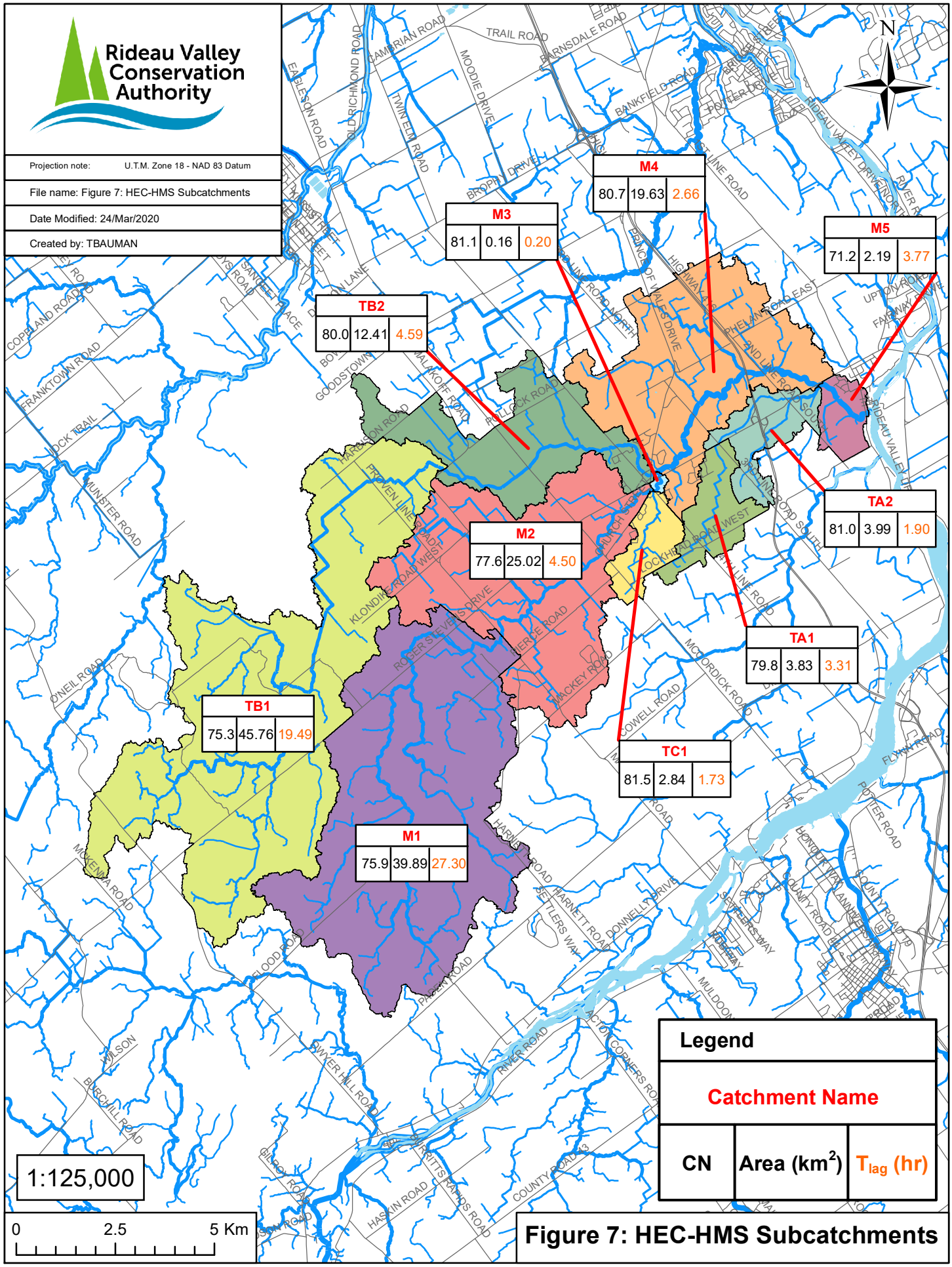


Figure 7: HEC-HMS Subcatchments

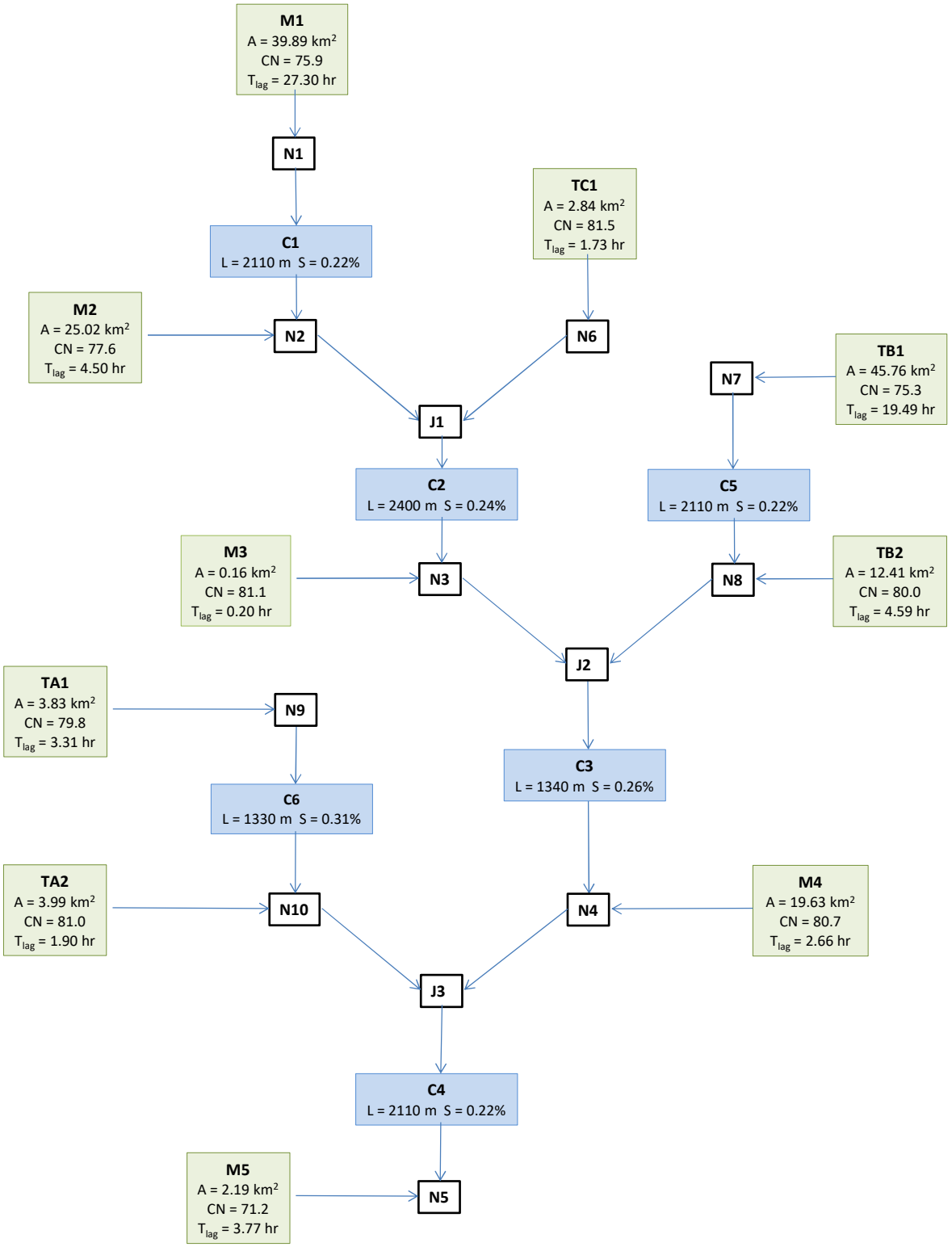
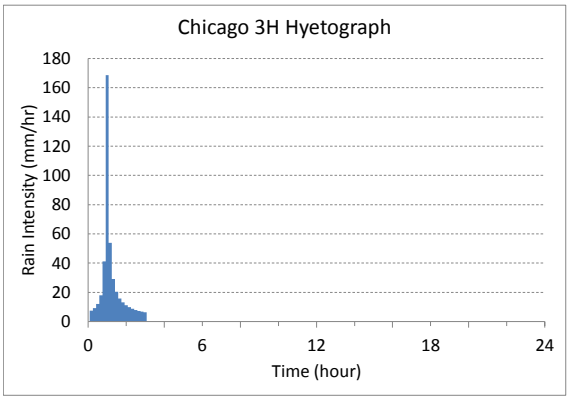
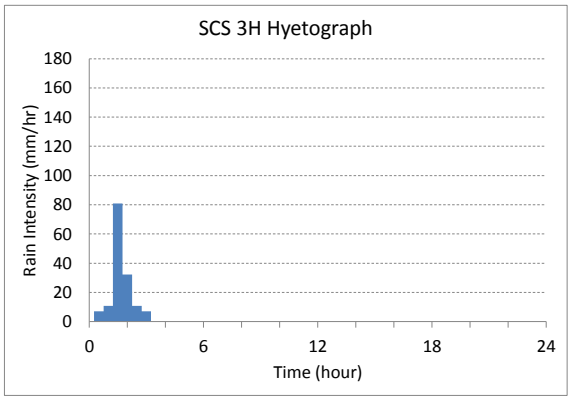
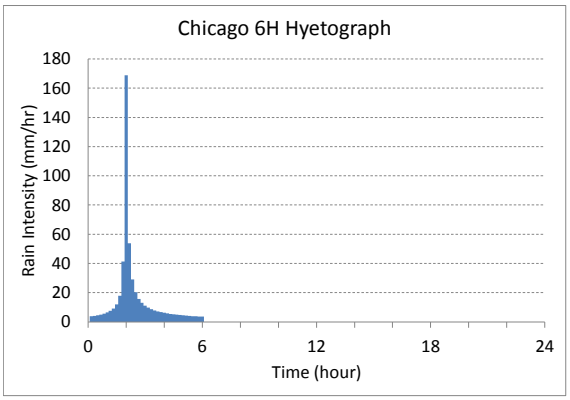


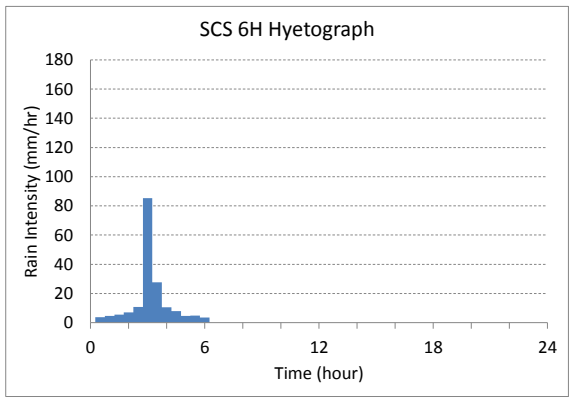
Figure 8 HEC-HMS Schematic

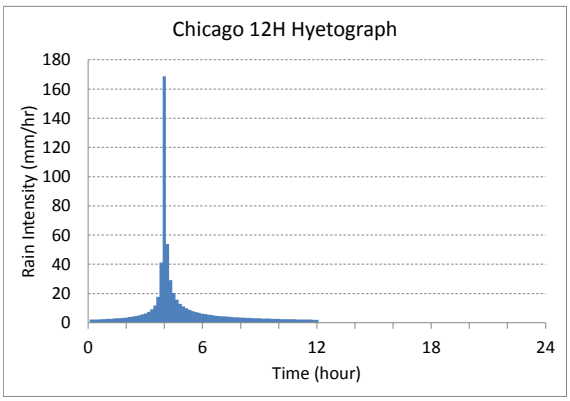
Figure 11 Hyetographs of various design storms

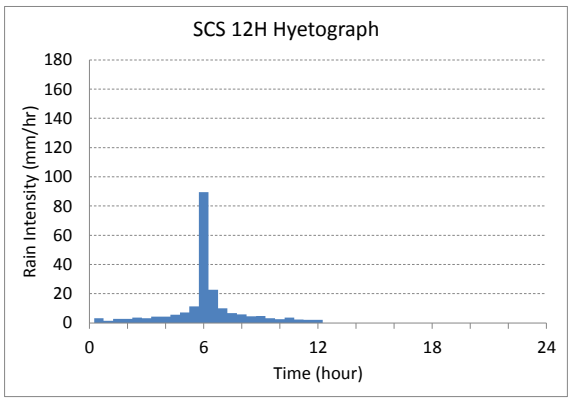


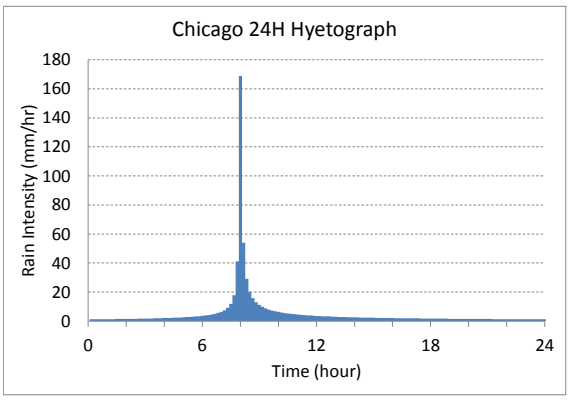












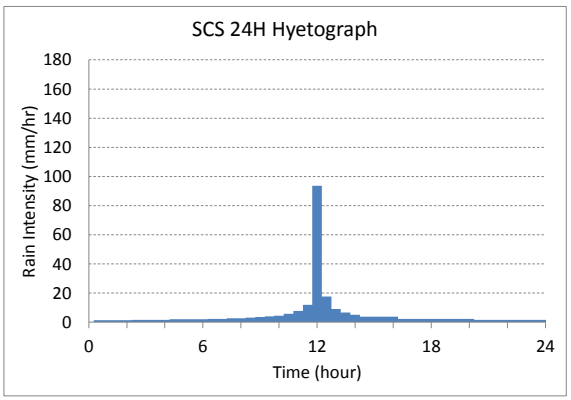
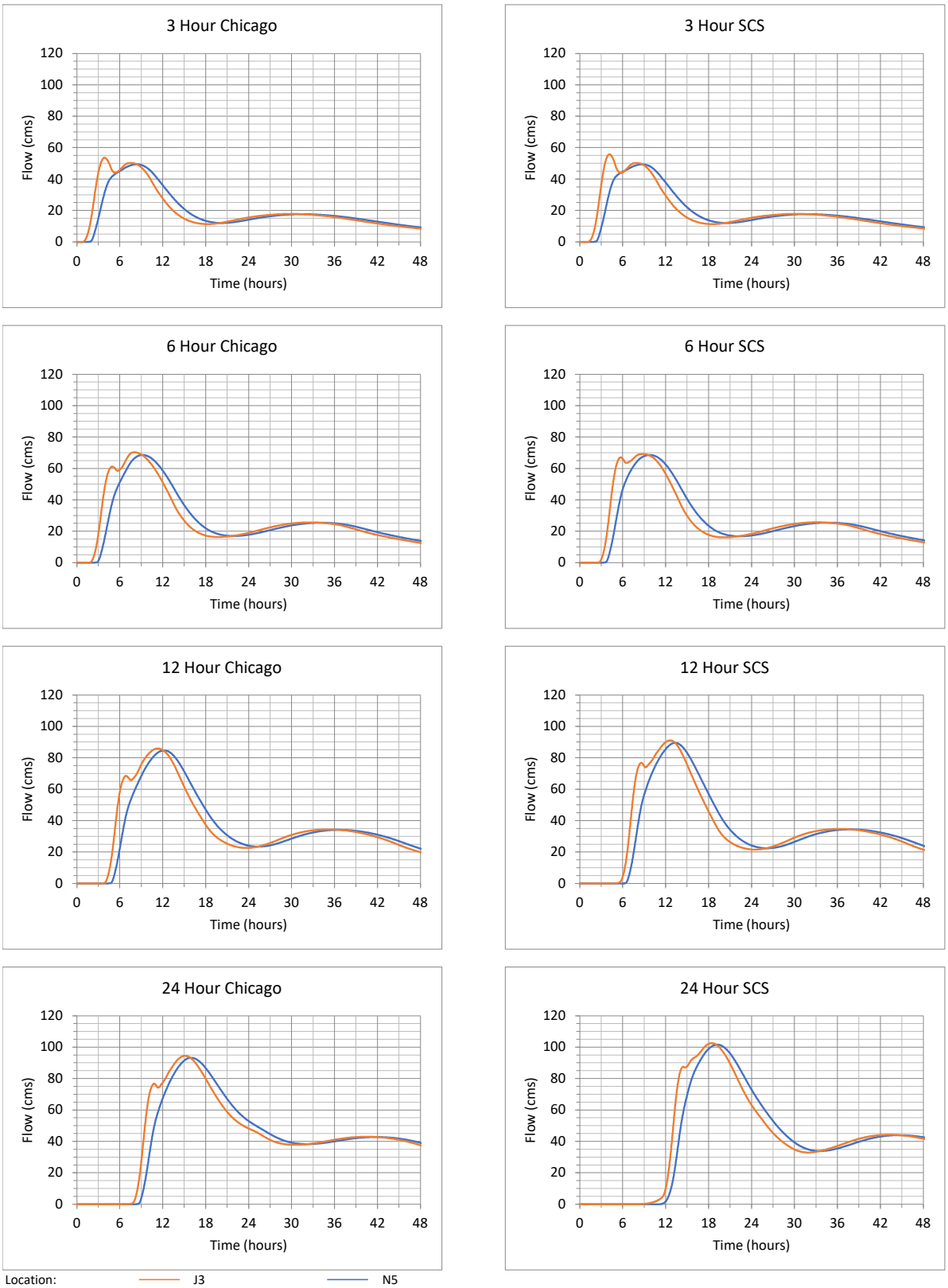


Figure 12 HEC-HMS generated flows at J3 and N5 for different design storms



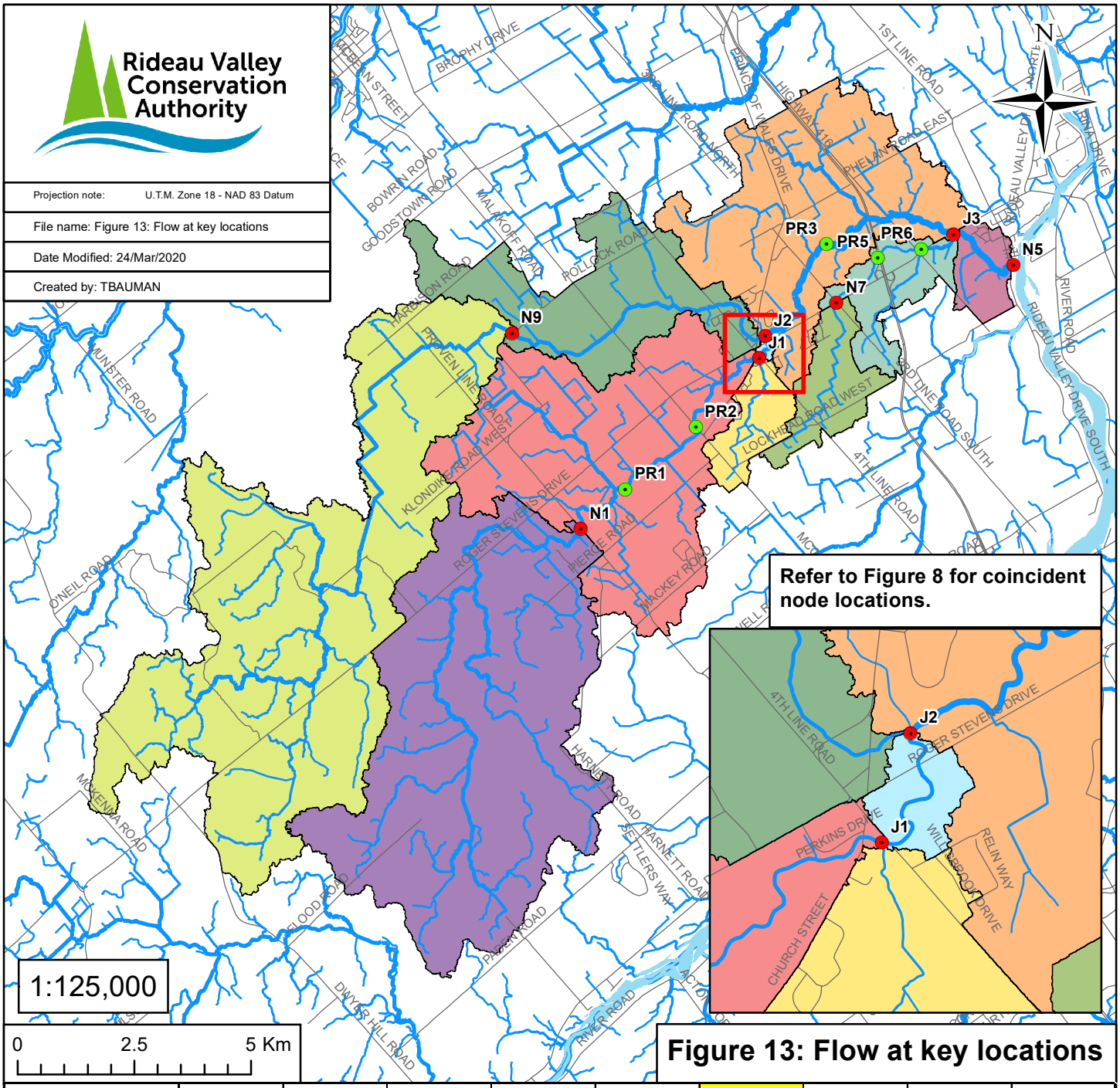


Figure 13: Flow at key locations

Return Period (year)	2	5	10	20	50	100	200	350	500
Nodes	Flow (cms)								
N1	2.98	6.40	8.91	11.60	15.22	18.10	20.94	23.37	25.07
PR1	6.08	13.25	18.55	24.19	31.80	37.84	43.78	48.84	52.38
PR2	7.45	16.28	22.84	29.79	39.19	46.65	53.98	60.20	64.56
N2	8.49	18.61	26.13	34.10	44.87	53.42	61.81	68.93	73.92
N3	9.34	20.21	28.23	36.73	48.17	57.25	66.14	73.69	78.98
PR3	15.05	32.01	44.42	56.99	74.24	87.98	101.48	112.98	121.04
N4	15.70	33.39	46.30	58.81	76.41	90.51	104.44	116.37	124.73
N5	16.74	36.33	51.05	65.58	85.57	101.63	117.55	131.21	140.83
N6	2.75	5.58	7.58	9.65	12.38	14.52	16.58	18.32	19.53
N7	4.39	9.59	13.44	17.58	23.18	27.64	32.04	35.81	38.46
N8	5.15	10.60	14.54	18.67	24.15	28.49	32.72	36.29	38.78
N9	1.98	4.14	5.71	7.36	9.54	11.27	12.95	14.37	15.36
PR5	2.36	4.92	6.77	8.69	11.25	13.30	15.31	17.01	18.19
PR6	2.59	5.36	7.36	9.44	12.21	14.45	16.65	18.51	19.79
N10	3.45	7.09	9.68	12.37	15.93	18.89	21.83	24.32	26.03
J1	9.32	20.17	28.18	36.67	48.09	57.17	66.05	73.59	78.87
J2	14.49	30.81	42.78	55.39	72.32	85.74	98.85	109.98	117.76
J3	17.82	37.91	52.68	66.70	86.59	102.55	118.35	131.92	141.48

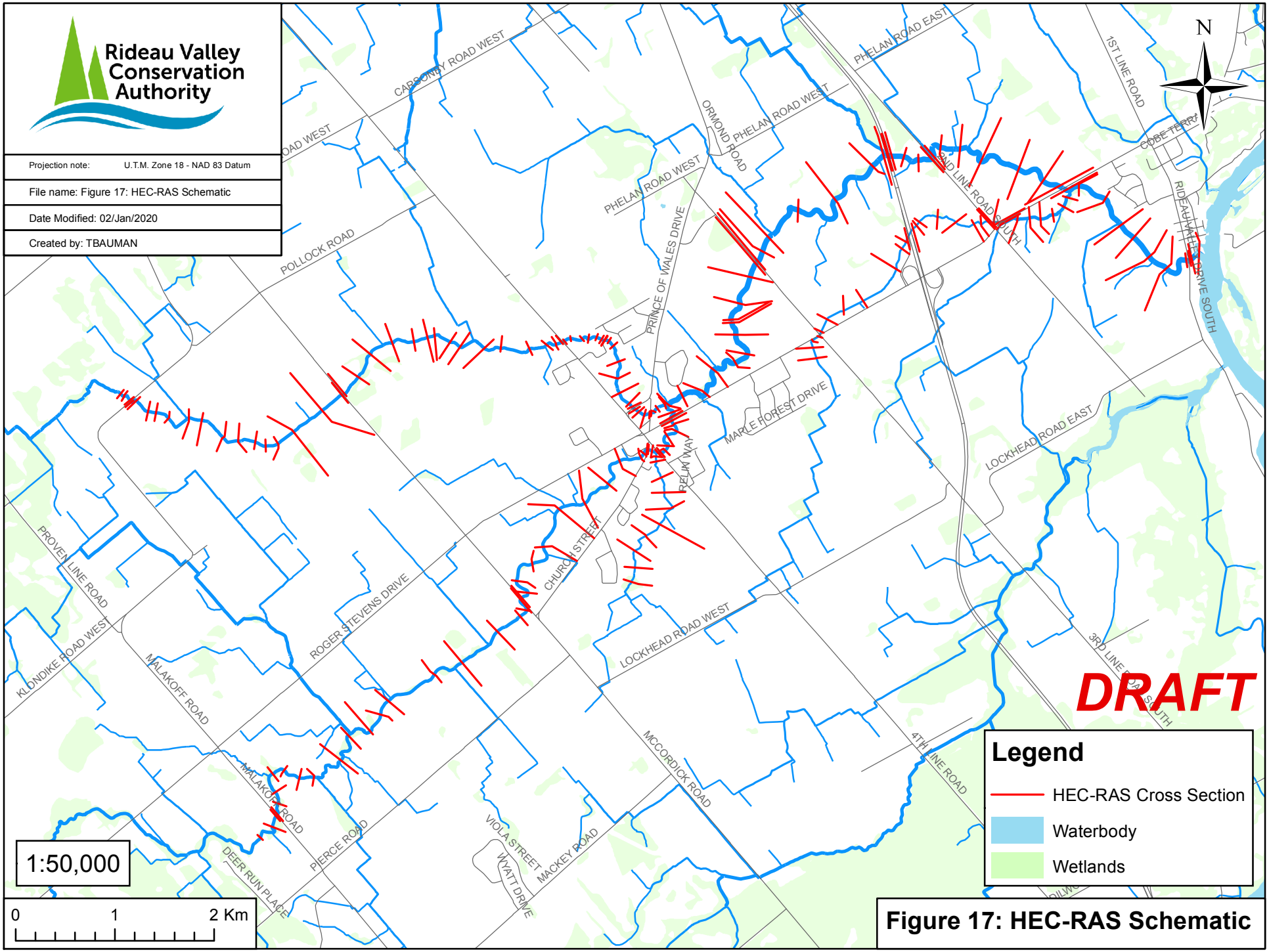


Figure 17: HEC-RAS Schematic

Table 1a: Land cover breakdown in the Stevens basin*

	Catchment	M1		M2		M3		M4	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	0.10	0.25	1.15	4.59	0.00	0.00	6.87	35.01
5	Crop and Pasture - Cultivated	2.04	5.13	15.54	62.14	0.05	34.89	7.20	36.69
6	Crop and Pasture - Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Evaluated Wetland - Marsh	6.41	16.08	0.00	0.00	0.00	0.00	0.00	0.00
11	Evaluated Wetland - Open Water	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	5.98	15.01	0.00	0.00	0.00	0.00	0.00	0.00
13	Meadow/Thicket	1.90	4.76	0.84	3.36	0.00	0.00	0.49	2.51
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.00	0.00	0.03	0.13	0.01	3.50	0.07	0.37
16	Settlement - Industrial	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
17	Settlement - Pervious	0.01	0.02	0.02	0.07	0.03	17.81	0.08	0.40
18	Settlement - Pervious Homestead	0.23	0.59	0.84	3.34	0.00	0.38	0.62	3.17
19	Settlement - Residential	0.00	0.01	0.89	3.56	0.03	19.97	0.45	2.31
20	Settlement - Estate	0.13	0.32	0.71	2.85	0.00	2.49	0.21	1.07
21	Settlement - Townhouse	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.96
25	Transportation - Minor Road	0.19	0.48	0.66	2.63	0.01	7.71	0.31	1.58
26	Transportation - Unpaved Road	0.15	0.37	0.05	0.22	0.00	0.00	0.26	1.35
27	Unevaluated Wetland	3.99	10.02	0.45	1.80	0.00	0.00	0.20	1.04
28	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00
32	Water - River	0.02	0.05	0.12	0.49	0.01	5.79	0.14	0.70
33	Wooded Area	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
34	Wooded Area - Fallow	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
35	Wooded Area - Hedgerow	0.12	0.30	0.43	1.71	0.00	0.00	0.33	1.66
36	Wooded Area - Island	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
37	Wooded Area - Plantation	0.10	0.25	0.12	0.48	0.00	0.00	0.12	0.61
38	Wooded Area - Treed	18.45	46.28	3.14	12.58	0.01	7.44	2.07	10.55
	Total	39.87	100.00	25.00	100.00	0.16	100.00	19.61	100.00

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table 1b: Land cover breakdown in the Stevens basin*

	Catchment	M5		TA1		TA2		TB1	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	0.00	0.00	0.08	2.15	0.01	0.20	1.68	3.68
5	Crop and Pasture - Cultivated	1.28	58.45	2.73	71.32	2.60	65.37	1.50	3.27
6	Crop and Pasture - Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
10	Evaluated Wetland - Marsh	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.56
11	Evaluated Wetland - Open Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	0.00	0.00	0.00	0.00	0.00	0.00	12.97	28.36
13	Meadow/Thicket	0.08	3.46	0.05	1.33	0.32	8.03	3.54	7.73
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.04	2.00	0.02	0.49	0.00	0.00	0.00	0.00
16	Settlement - Industrial	0.00	0.00	0.01	0.18	0.00	0.00	0.00	0.00
17	Settlement - Pervious	0.13	5.84	0.01	0.14	0.00	0.00	0.01	0.02
18	Settlement - Pervious Homestead	0.07	3.16	0.17	4.46	0.10	2.52	0.27	0.59
19	Settlement - Residential	0.18	8.16	0.08	2.04	0.00	0.06	0.01	0.03
20	Settlement - Estate	0.04	1.79	0.12	3.24	0.09	2.30	0.06	0.14
21	Settlement - Townhouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.09	2.33	0.00	0.00
25	Transportation - Minor Road	0.09	4.08	0.14	3.73	0.13	3.36	0.17	0.38
26	Transportation - Unpaved Road	0.02	1.08	0.00	0.00	0.03	0.77	0.47	1.02
27	Unevaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	3.57	7.80
28	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
32	Water - River	0.06	2.61	0.00	0.00	0.00	0.00	0.00	0.00
33	Wooded Area	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.33
34	Wooded Area - Fallow	0.00	0.00	0.01	0.23	0.02	0.47	0.04	0.10
35	Wooded Area - Hedgerow	0.04	1.71	0.01	0.25	0.06	1.57	0.03	0.08
36	Wooded Area - Island	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07
37	Wooded Area - Plantation	0.00	0.09	0.00	0.00	0.00	0.04	0.25	0.55
38	Wooded Area - Treed	0.17	7.58	0.40	10.45	0.52	12.97	20.24	44.25
	Total	2.19	100.00	3.83	100.00	3.98	100.00	45.73	100.00

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table 1c: Land cover breakdown in the Stevens basin*

	Catchment	TB2		TC1		Total Stevens	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.00	0.00	0.00	0.00	0.00	0.00
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	2.66	21.48	0.01	0.20	12.56	8.07
5	Crop and Pasture - Cultivated	6.38	51.39	1.98	69.89	41.31	26.54
6	Crop and Pasture - Fallow	0.00	0.00	0.00	0.00	0.00	0.00
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.01	0.01
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.01	0.01
10	Evaluated Wetland - Marsh	0.00	0.00	0.00	0.00	7.12	4.58
11	Evaluated Wetland - Open Water	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	0.00	0.00	0.00	0.00	18.95	12.18
13	Meadow/Thicket	0.09	0.73	0.06	2.16	7.37	4.73
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.03	0.20	0.03	0.99	0.23	0.15
16	Settlement - Industrial	0.22	1.76	0.00	0.00	0.23	0.15
17	Settlement - Pervious	0.03	0.20	0.00	0.16	0.30	0.19
18	Settlement - Pervious Homestead	0.37	3.01	0.10	3.46	2.77	1.78
19	Settlement - Residential	0.61	4.94	0.22	7.80	2.49	1.60
20	Settlement - Estate	0.31	2.51	0.03	1.17	1.72	1.10
21	Settlement - Townhouse	0.00	0.00	0.00	0.00	0.01	0.01
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.28	0.18
25	Transportation - Minor Road	0.30	2.42	0.14	4.78	2.15	1.38
26	Transportation - Unpaved Road	0.07	0.53	0.00	0.00	1.06	0.68
27	Unevaluated Wetland	0.22	1.78	0.00	0.00	8.43	5.42
28	Water	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.00	0.00	0.02	0.01
32	Water - River	0.03	0.24	0.00	0.00	0.38	0.24
33	Wooded Area	0.00	0.00	0.00	0.00	0.16	0.10
34	Wooded Area - Fallow	0.00	0.00	0.00	0.00	0.07	0.05
35	Wooded Area - Hedgerow	0.19	1.55	0.05	1.76	1.26	0.81
36	Wooded Area - Island	0.00	0.00	0.00	0.00	0.04	0.02
37	Wooded Area - Plantation	0.07	0.55	0.04	1.57	0.71	0.45
38	Wooded Area - Treed	0.83	6.72	0.17	6.06	46.00	29.56
	Total	12.41	100.00	2.84	100.00	155.63	100

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table 2a Hydrological Soil Groups in Stevens Basin

		Soil Group area (km^2)					as percent (%) of catchment area				
Catchment	Area (km^2)	A	B	C	D	Unclassified	A	B	C	D	Unclassified
M1	39.89	0.14	23.76	2.92	13.00	0.04	0.36	59.57	7.33	32.59	0.10
M2	25.02	0.60	9.87	5.85	8.62	0.07	2.39	39.44	23.39	34.44	0.28
M3	0.16	0.00	0.05	0.00	0.00	0.11	0.00	32.20	0.00	0.00	67.74
M4	19.63	0.24	5.00	2.85	11.46	0.07	1.20	25.45	14.51	58.40	0.38
M5	2.19	0.38	1.67	0.06	0.01	0.07	17.20	76.27	2.78	0.66	3.02
TA1	3.83	0.06	1.25	0.00	2.52	0.00	1.69	32.49	0.00	65.75	0.00
TA2	3.99	0.01	1.23	0.11	2.63	0.00	0.23	30.82	2.83	66.06	0.00
TB1	45.76	2.89	21.58	8.53	12.73	0.00	6.32	47.16	18.64	27.81	0.00
TB2	12.41	0.22	4.78	1.64	5.62	0.15	1.75	38.53	13.24	45.23	1.19
TC1	2.84	0.02	0.79	0.00	1.97	0.07	0.54	27.74	0.00	69.33	2.33
Entire Stevens	155.72	4.55	69.97	21.97	58.56	0.57	2.93	44.94	14.11	37.61	0.37

Note: Based on MNRF's LIO (Land Information System) database and documentation by MNR (2012)

Note: Unclassified soils were treated as HSG D. This was guided by an inspection of Figure 3, where such soils are generally surrounded by HSG D and the areas also coincided with built landscapes such North Gower. Development activities will compact and degrade the hydraulic properties of the soil.

Table 2b Permeability in Stevens Basin

		Permeability area (km^2)				as percent (%) of catchment area			
Catchment	Area (km^2)	High	Low-medium	Variable	Low	High	Low-medium	Variable	Low
M1	39.89	17.08	3.80	19.01	0.00	42.82	9.53	47.64	0.00
M2	25.02	1.72	11.33	1.07	10.89	6.88	45.29	4.28	43.55
M3	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.00	100.00
M4	19.63	0.79	3.64	0.00	15.20	4.01	18.54	0.00	77.46
M5	2.19	0.44	0.19	0.00	1.56	20.05	8.55	0.00	71.40
TA1	3.83	0.04	1.22	0.00	2.56	1.16	31.95	0.00	66.88
TA2	3.99	0.09	1.10	0.00	2.80	2.25	27.58	0.00	70.17
TB1	45.76	18.35	3.68	23.62	0.10	40.10	8.05	51.63	0.22
TB2	12.41	1.07	5.68	0.00	5.67	8.60	45.73	0.00	45.67
TC1	2.84	0.01	0.79	0.00	2.04	0.39	27.74	0.00	71.87
Entire Stevens	155.72	39.59	31.43	43.70	40.99	25.43	20.19	28.06	26.32

Note: Based on Ontario Geological Survey surficial geology layer (OGS 2010)

Table 3a Hydrologic parameters for rural catchments (Stevens Creek)

Catchment	Area	Imperviousness [1]	CN [1]	IA [3]	CN* [2]	IA* [3]	Tc [4]	T_{lag} [5]
	(km^2)	(%)		(mm)		(mm)	(hr)	(hr)
M1	39.89	0.9	75.9	16.11	66.6	6.37	45.51	27.30
M2	25.02	5.8	77.6	14.64	69.0	5.71	7.51	4.50
M3	0.16	18.6	81.1	11.85	74.0	4.47	0.33	0.20
M4	19.63	7.1	80.7	12.19	73.3	4.62	4.43	2.66
M5	2.19	9.7	71.2	20.54	60.1	8.42	6.29	3.77
TA1	3.83	7.5	79.8	12.85	72.1	4.91	5.52	3.31
TA2	3.99	16.1	81.0	11.92	73.8	4.50	3.16	1.90
TB1	45.76	1.2	75.3	16.69	65.7	6.63	32.49	19.49
TB2	12.41	7.4	80.0	12.67	72.4	4.83	7.65	4.59
TC1	2.84	12.2	81.5	11.55	74.5	4.34	2.88	1.73
Entire Stevens	155.72	4.0	77.2	15.06	68.4	5.90	---	---

1) Calculated from land cover and TR-55 Curve Number tables (Urban Hydrology for Small Watersheds by USDA-SCS, 1986)

2) Calculated based on equation $CN^*=100/(1.879((100/CN)-1)^{1.15}+1)$ (Curve Number Hydrology by Hawkins et al., 2009)

3) Calculated based $IA=((25400/CN_\lambda)-254)*\lambda$, where $\lambda=0.2$ for CN and $\lambda=0.05$ for CN* (Curve Number Hydrology by Hawkins et al., 2009)

4) Calculated based on the velocity method (National engineering handbook Chapter 15 by USDA-NRCS, 2010)

5) Calculated based on $T_{lag} = 0.6 \times Tc$ (HEC-HMS Technical Reference Manual by USACE, 2000)

6) Hydrologic calculations used CN and IA, not CN* and IA*. The latter are included for information purposes only.

Table 3b Estimated channel parameters (Stevens Creek)

Channel	Length [1]	Slope [2]	Manning's "n" [3]		
	(m)	(%)	LOB	Channel	ROB
C1 [4]	5210	0.0453	0.054	0.041	0.055
C2 [5]	640	0.0126	0.050	0.044	0.055
C3	6130	0.0323	0.048	0.040	0.051
C4	1670	0.0250 [6]	0.050	0.038	0.054
C5	6690	0.0932	0.044	0.048	0.048
C6	3330	0.0529	0.045	0.050	0.046
Entire Stevens	23670	0.0525	0.048	0.044	0.050

1) Length of HEC-RAS centerline flowpath for the 100-yr event, within associated routing catchment.

2) Slope = Rise/Run, where Rise was the difference in minimum channel elevations of HEC-RAS cross-sections closest to channel ends.

3) Obtained by averaging the HEC-RAS values within each channel, which themselves were determined from site visits and DRAPE (2014) photography using roughness coefficients outlined by Chow (1959).

4) C1 is considered to start at XS 1480, as upstream is steeper and more confined.

5) A lag time of 15 minutes, determined through analysis of HEC-RAS results, was used for C2 in HEC-HMS.

5) The slope of C4 was increased to offset potential overestimation of attenuation by mildly sloped reaches.

Table 4 Curve number for different land covers and soil groups

	RVCA Land Cover [1]	Corresponding TR-55 land cover category [2]		Assigned Curve Number (CN) [2]				Average [3] Percent Impervious
		Cover description		Soil group				
	Land cover description	Cover type	Hydrologic condition	A	B	C	D	
1	Aggregate Site	Industrial	N/A	81	88	91	93	0
2	Aggregate Site - Pit	Industrial	N/A	81	88	91	93	0
3	Aggregate Site - Quarry	Industrial	N/A	81	88	91	93	0
4	Crop and Pasture	Row crops (SR + CR)	Good	64	75	82	85	0
5	Crop and Pasture - Cultivated	Row crops (SR + CR)	Good	64	75	82	85	0
6	Crop and Pasture - Fallow	Fallow (Crop residue cover)	Good	76	85	90	93	0
7	Evaluated Wetland	N/A	N/A	98	98	98	98	0
8	Evaluated Wetland - Bog	N/A	N/A	98	98	98	98	0
9	Evaluated Wetland - Fen	N/A	N/A	98	98	98	98	0
10	Evaluated Wetland - Marsh	N/A	N/A	98	98	98	98	0
11	Evaluated Wetland - Open Water	N/A	N/A	98	98	98	98	0
12	Evaluated Wetland - Swamp	N/A	N/A	98	98	98	98	0
13	Meadow/Thicket	Pasture, grassland, or range - continuous forage for grazing	Good (>75% ground cover, lightly grazed)	39	61	74	80	0
14	Settlement	Residential district (average lot size 1/4 acre)	N/A	61	75	83	87	38
15	Settlement - Commercial	Urban district (Commercial and business)	N/A	89	92	94	95	85
16	Settlement - Industrial	Urban district (Industrial)	N/A	81	88	91	93	72
17	Settlement - Pervious	Open space (lawns, parks, golf courses, cemeteries, etc)	Good (>75% ground cover)	39	61	74	80	0
18	Settlement - Townhouse	Residential district (average lot size 1/8 acre or less (town houses))	N/A	77	85	90	82	65
19	Settlement - Pervious Homestead	Residential district (average lot size 1/4 acre)	N/A	61	75	83	87	38
20	Settlement - Residential	Residential district (average lot size 1/3 acre)	N/A	57	72	81	86	30
21	Settlement - Estate	Residential district (average lot size 1 acre)	N/A	51	68	79	84	20
22	Transportation	Streets and roads (Paved; curbs and sewers, excluding right of way)	N/A	98	98	98	98	100
23	Transportation - Rail	Streets and roads (Gravel, including right of way)	N/A	76	85	89	91	65
24	Transportation - Major Road	Streets and roads (Paved; curbs and sewers, excluding right of way)	N/A	98	98	98	98	100
25	Transportation - Minor Road	Streets and roads (Paved; open ditches, including right of way)	N/A	83	89	92	93	75
26	Transportation - Unpaved Road	Streets and roads (Gravel, including right of way)	N/A	76	85	89	91	65
27	Unevaluated Wetland	N/A	N/A	98	98	98	98	0
28	Water	N/A	N/A	98	98	98	98	0
29	Water - Buffer around wetland	N/A	N/A	98	98	98	98	0
30	Water - Lake	N/A	N/A	98	98	98	98	0
31	Water - Pond	N/A	N/A	98	98	98	98	0
32	Water - River	N/A	N/A	98	98	98	98	0
33	Wooded Area	Woods	Good	30	55	70	77	0
34	Wooded Area - Fallow	Pasture, grassland, or range - continuous forage for grazing	Fair (50-75% ground cover, grazed)	49	69	79	84	0
35	Wooded Area - Hedgerow	Woods	Poor	45	66	77	83	0
36	Wooded Area - Island	Woods	Good	30	55	70	77	0
37	Wooded Area - Plantation	Woods	Poor	45	66	77	83	0
38	Wooded Area - Treed	Woods	Good	30	55	70	77	0

1) Land cover classes inferred from DRAPE 2014 imagery

2) Values and descriptors extracted from TR-55 "Urban Hydrology for Small Watersheds", USDA, Natural Resources Conservation Service, June 1986

3) Values extracted from TR-55 "Urban Hydrology for Small Watersheds" (USDA-NRCS, 1986) for Settlement classes and inferred for Transportation classes based on CN values and visual assessment.

Table 5 Characteristics of design storms

	Duration	Total volume	Peak intensity	Time step	Source of hyetograph shape
	(hour)	(mm)	(mm/hr)	(minutes)	
Chicago 3 hour	3	74.43	168.71	10	Generated by STORMS software
Chicago 6 hour	6	88.42	168.71	10	Generated by STORMS software
Chicago 12 hour	12	104.44	168.71	10	Generated by STORMS software
Chicago 24 hour	24	123.02	168.71	10	Generated by STORMS software
SCS 3 hour	3	74.47	80.87	30	City of Ottawa Sewer Design Guidelines 2012
SCS 6 hour	6	88.43	85.25	30	City of Ottawa Sewer Design Guidelines 2012
SCS 12 hour	12	104.44	89.40	30	City of Ottawa Sewer Design Guidelines 2012
SCS 24 hour	24	123.01	93.49	30	Generated by STORMS software

Table 6 Estimated peak flows generated by various storms

Storm	3H Chicago	6H Chicago	12H Chicago	24H Chicago	3H SCS	6H SCS	12H SCS	**24H SCS**
Return Period	100 year	100 year	100 year	100 year	100 year	100 year	100 year	**100 year**
Flow	(cms)	(cms)	(cms)	(cms)	(cms)	(cms)	(cms)	**(cms)**
Catchments								
M1	7.43	10.37	13.91	17.68	7.44	10.38	13.98	**18.10**
M2	29.96	37.56	42.21	47.25	30.35	39.73	46.80	**53.40**
M3	1.74	2.06	2.37	2.66	1.52	1.93	2.32	**2.69**
M4	43.56	49.83	55.70	62.35	45.21	54.53	62.35	**70.62**
M5	2.12	2.71	3.09	3.53	2.17	2.93	3.50	**4.13**
TA1	6.78	7.98	8.90	9.96	6.94	8.64	9.93	**11.27**
TA2	11.58	13.04	14.65	16.42	12.29	14.42	16.51	**18.69**
TB1	11.52	16.14	21.52	26.36	11.53	16.17	21.77	**27.64**
TB2	16.57	20.51	22.91	25.48	16.77	21.62	25.24	**28.49**
TC1	9.03	10.16	11.42	12.79	9.65	11.24	12.87	**14.52**
Nodes								
N1	7.43	10.37	13.91	17.68	7.44	10.38	13.98	**18.10**
N2	29.97	37.57	42.22	47.27	30.36	39.74	46.81	**53.42**
N3	31.45	40.63	45.80	51.11	31.77	42.24	50.41	**57.25**
N4	44.20	61.05	75.83	83.43	45.22	60.37	80.15	**90.51**
N5	49.42	68.65	84.70	93.27	49.42	68.61	89.53	**101.63**
N6	9.03	10.16	11.42	12.79	9.65	11.24	12.87	**14.52**
N7	11.52	16.14	21.52	26.36	11.53	16.17	21.77	**27.64**
N8	16.58	20.52	22.92	26.40	16.78	21.63	25.25	**28.49**
N9	6.78	7.98	8.90	9.96	6.94	8.64	9.93	**11.27**
N10	11.58	13.04	14.66	16.43	12.30	14.43	16.52	**18.89**
J1	31.45	40.63	45.70	51.00	31.77	42.24	50.32	**57.17**
J2	48.03	61.15	68.72	76.60	48.54	63.87	75.66	**85.74**
J3	53.67	70.33	85.95	94.55	55.79	69.18	91.14	**102.55**
Channels								
C1	7.42	10.35	13.87	17.59	7.43	10.36	13.95	**18.02**
C2	31.45	40.63	45.70	51.00	31.77	42.24	50.32	**57.17**
C3	39.36	51.06	59.09	65.46	39.65	52.53	64.10	**72.54**
C4	48.58	67.01	82.87	91.21	48.62	67.03	87.48	**99.34**
C5	11.28	15.98	21.31	26.21	11.29	16.03	21.58	**27.44**
C6	5.73	7.07	7.90	8.82	5.82	7.50	8.74	**9.91**

Table 7 SCS Type II 24 hour design storms for different return periods

Return Period	Total volume	Peak intensity	Time step	hyetograph generated by
(year)	(mm)	(mm/hr)	(minutes)	
2	50.48	38.08	30	STORMS software
5	70.01	53.21	30	STORMS software
10	82.57	62.75	30	STORMS software
20	95.07	72.25	30	STORMS software
50	110.92	84.3	30	STORMS software
100	**123.01**	**93.49**	**30**	**STORMS software**
200	134.57	102.27	30	STORMS software
350	144.20	109.59	30	STORMS software
500	150.84	114.64	30	STORMS software

Table 8 Estimated peak flows for SCS Type II 24 hour design storm

Storm	24 hour SCS Type II								
Return Period	2 year	5 year	10 year	20 year	50 year	**100 year**	200 year	350year	500 year
Flow	(cms)	(cms)	(cms)	(cms)	(cms)	**(cms)**	(cms)	(cms)	(cms)
Catchments									
M1	2.98	6.40	8.91	11.60	15.22	**18.10**	20.94	23.37	25.07
M2	8.48	18.60	26.12	34.09	44.85	**53.40**	61.78	68.90	73.88
M3	0.54	1.07	1.43	1.81	2.30	**2.69**	3.05	3.36	3.58
M4	12.88	26.55	36.33	46.52	60.00	**70.62**	80.92	89.61	95.66
M5	0.43	1.17	1.77	2.44	3.37	**4.13**	4.89	5.54	6.00
TA1	1.98	4.14	5.71	7.36	9.54	**11.27**	12.95	14.37	15.36
TA2	3.45	7.09	9.67	12.36	15.90	**18.69**	21.39	23.67	25.25
TB1	4.39	9.59	13.44	17.58	23.18	**27.64**	32.04	35.81	38.46
TB2	5.14	10.59	14.53	18.66	24.15	**28.49**	32.71	36.28	38.77
TC1	2.75	5.58	7.58	9.65	12.38	**14.52**	16.58	18.32	19.53
Nodes									
N1	2.98	6.40	8.91	11.60	15.22	**18.10**	20.94	23.37	25.07
N2	8.49	18.61	26.13	34.10	44.87	**53.42**	61.81	68.93	73.92
N3	9.34	20.21	28.23	36.73	48.17	**57.25**	66.14	73.69	78.98
N4	15.70	33.39	46.30	58.81	76.41	**90.51**	104.44	116.37	124.73
N5	16.74	36.33	51.05	65.58	85.57	**101.63**	117.55	131.21	140.83
N6	2.75	5.58	7.58	9.65	12.38	**14.52**	16.58	18.32	19.53
N7	4.39	9.59	13.44	17.58	23.18	**27.64**	32.04	35.81	38.46
N8	5.15	10.60	14.54	18.67	24.15	**28.49**	32.72	36.29	38.78
N9	1.98	4.14	5.71	7.36	9.54	**11.27**	12.95	14.37	15.36
N10	3.45	7.09	9.68	12.37	15.93	**18.89**	21.83	24.32	26.03
J1	9.32	20.17	28.18	36.67	48.09	**57.17**	66.05	73.59	78.87
J2	14.49	30.81	42.78	55.39	72.32	**85.74**	98.85	109.98	117.76
J3	17.82	37.91	52.68	66.70	86.59	**102.55**	118.35	131.92	141.48
Channels									
C1	2.97	6.38	8.87	11.55	15.16	**18.02**	20.83	23.23	24.93
C2	9.32	20.17	28.18	36.67	48.09	**57.17**	66.05	73.59	78.87
C3	12.27	26.36	36.70	47.07	61.23	**72.54**	83.67	93.16	99.80
C4	16.51	35.73	50.12	64.30	83.74	**99.34**	114.77	127.99	137.30
C5	4.37	9.54	13.27	17.38	22.96	**27.44**	31.83	35.61	38.31
C6	1.64	3.58	4.97	6.42	8.37	**9.91**	11.41	12.68	13.57

Table 9 Estimated flows for hydraulic modeling (HEC-RAS)

			Return Period (year)	2	5	10	20	50	**100**	200	350	500
Stream	Reach	Nearest Cross Section	Distance from Rideau Confluence (m)	Flow (cms)								
Stevens Creek	Reach 4	1525	15318	2.98	6.40	8.91	11.60	15.22	**18.10**	20.94	23.37	25.07
Stevens Creek	Reach 4	1500	14702	6.08	13.25	18.55	24.19	31.80	**37.84**	43.78	48.84	52.38
Stevens Creek	Reach 4	1465	13162	7.45	16.28	22.84	29.79	39.19	**46.65**	53.98	60.20	64.56
Stevens Creek	Reach 4	1415	10875	8.49	18.61	26.13	34.10	44.87	**53.42**	61.81	68.93	73.92
Stevens Creek	Reach 3	1350	8489	9.34	20.21	28.23	36.73	48.17	**57.25**	66.14	73.69	78.98
Stevens Creek	Reach 2	1300	7854	15.05	32.01	44.42	56.99	74.24	**87.98**	101.48	112.98	121.04
Stevens Creek	Reach 2	1225	5094	15.70	33.39	46.30	58.81	76.41	**90.51**	104.44	116.37	124.73
Stevens Creek	Reach 1	1145	1667	17.82	37.91	52.68	66.70	86.59	**102.55**	118.35	131.92	141.48
Tributary A	Reach 1	2225	5376	1.98	4.14	5.71	7.36	9.54	**11.27**	12.95	14.37	15.36
Tributary A	Reach 1	2210	5050	2.36	4.92	6.77	8.69	11.25	**13.30**	15.31	17.01	18.19
Tributary A	Reach 1	2175	3576	2.59	5.36	7.36	9.44	12.21	**14.45**	16.65	18.51	19.79
Tributary A	Reach 1	2125	2434	3.45	7.09	9.68	12.37	15.93	**18.89**	21.83	24.32	26.03
Tributary B	Reach 1	3355	14865	4.39	9.59	13.44	17.58	23.18	**27.64**	32.04	35.81	38.46
Tributary B	Reach 1	3330	14501	5.15	10.60	14.54	18.67	24.15	**28.49**	32.72	36.29	38.78
Tributary C	Reach 1	4145	10070	2.75	5.58	7.58	9.65	12.38	**14.52**	16.58	18.32	19.53

Appendix B

Figures and Tables for Scenario B (1976)

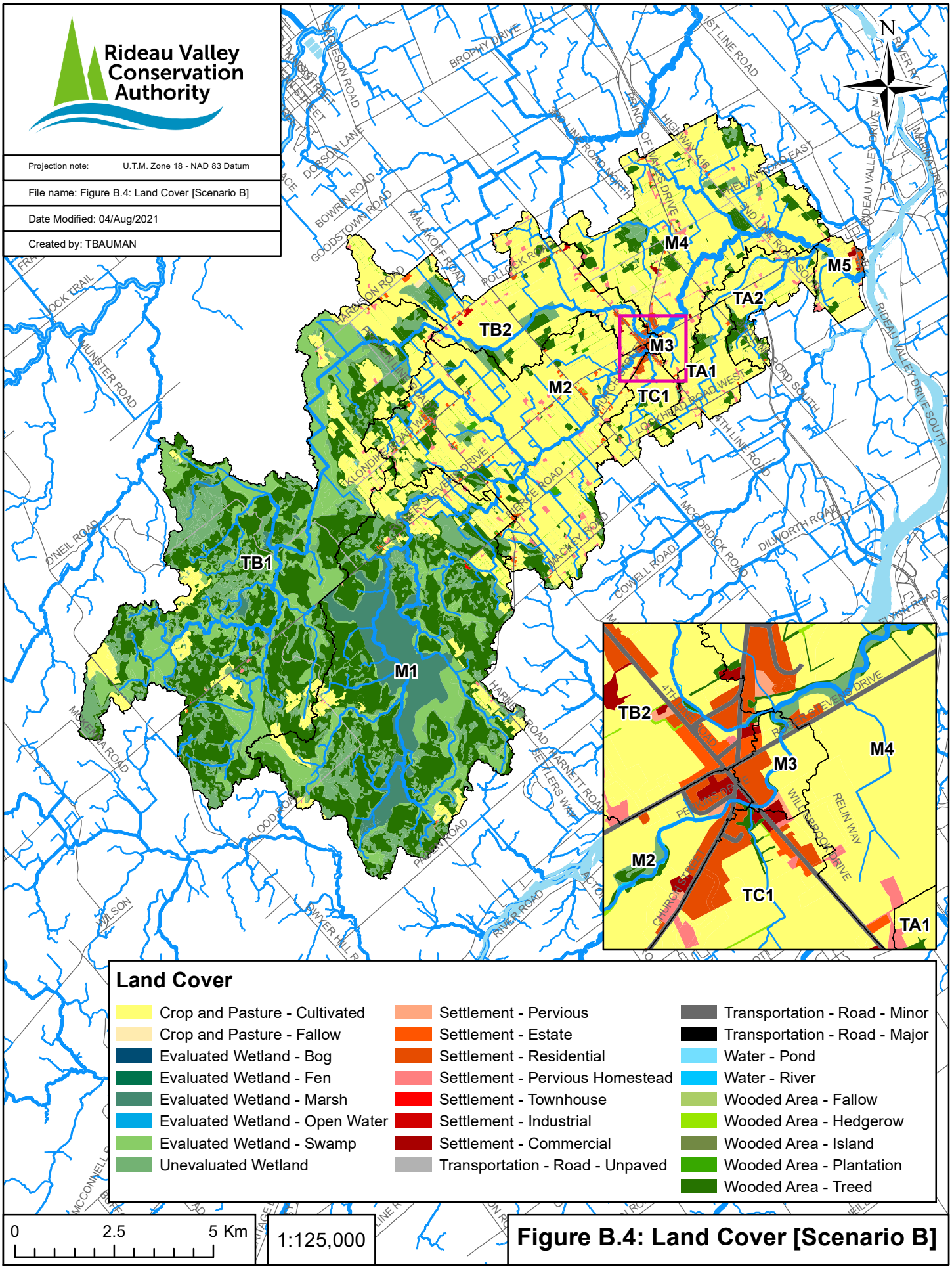


Figure B.4: Land Cover [Scenario B]

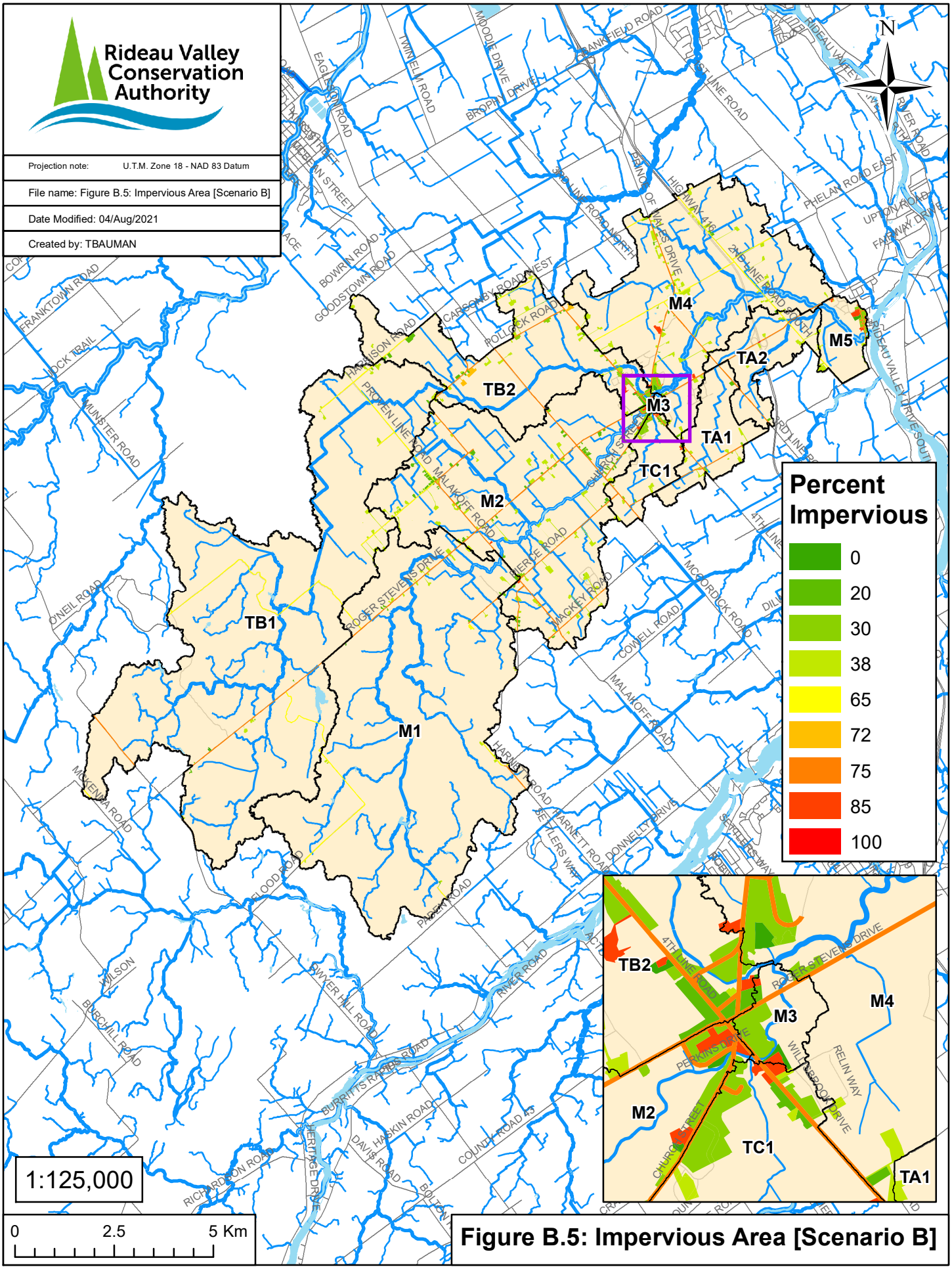


Figure B.5: Impervious Area [Scenario B]

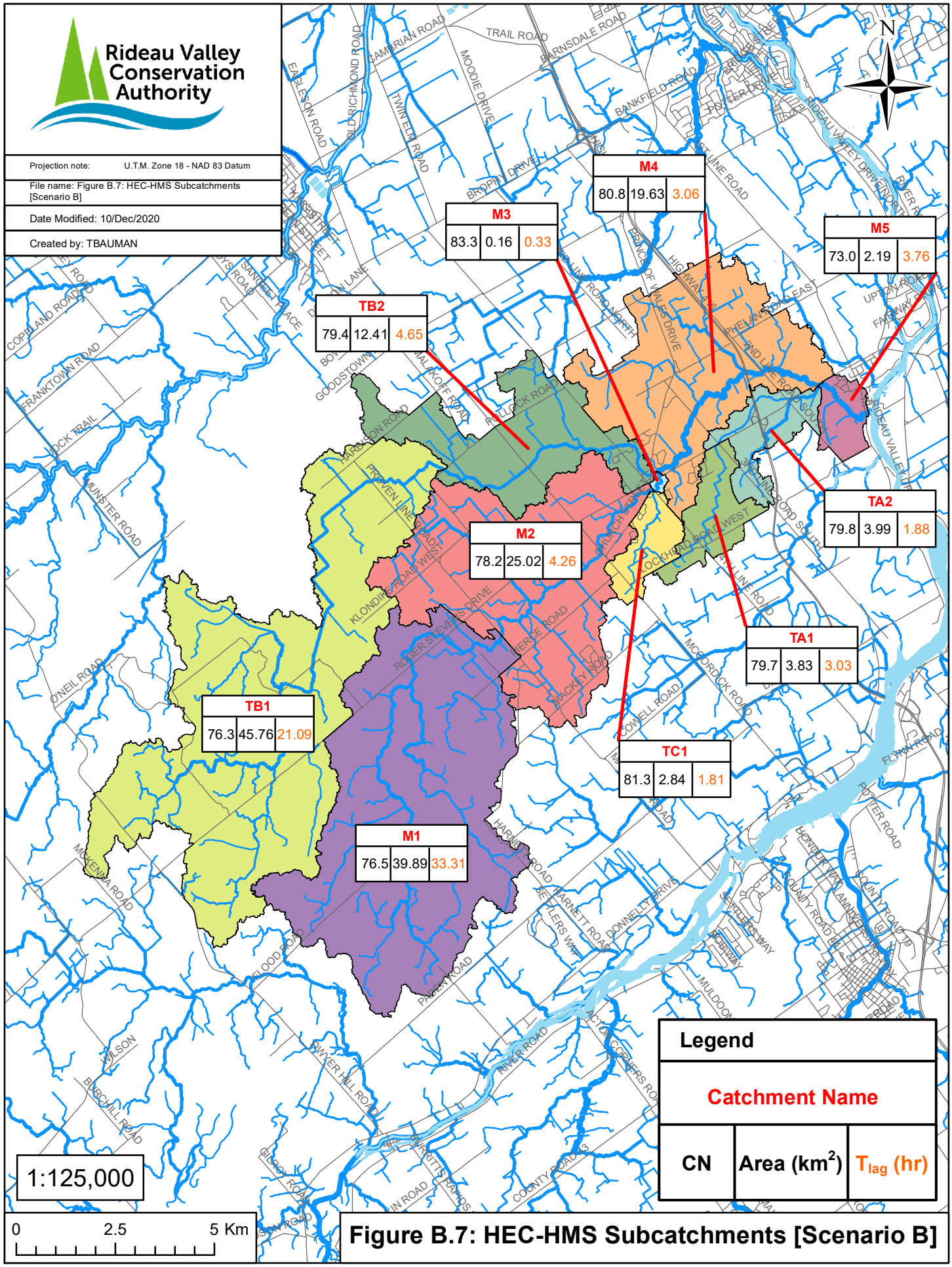


Figure B.7: HEC-HMS Subcatchments [Scenario B]

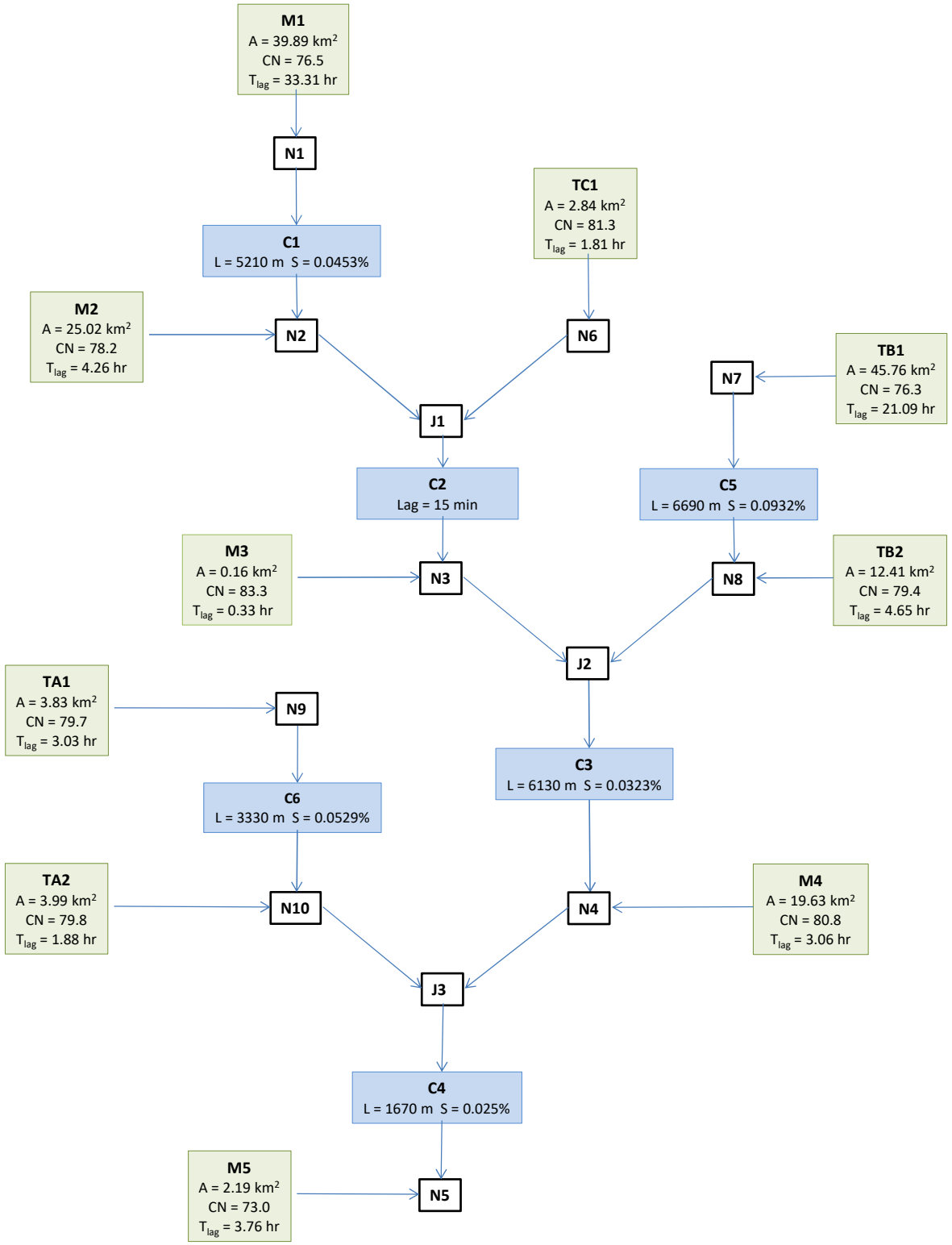
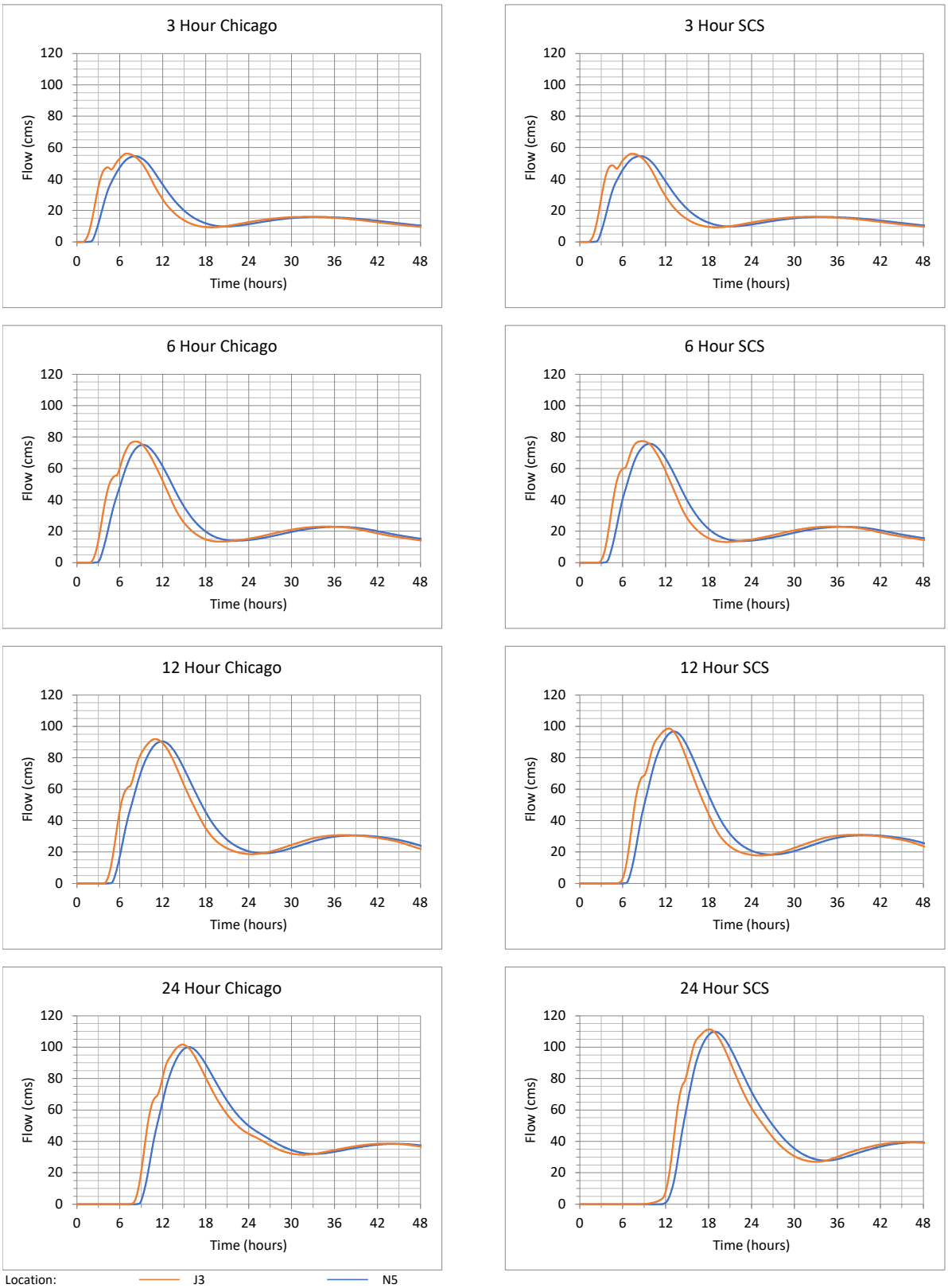


Figure B.8 HEC-HMS Schematic [Scenario B]

Figure B.12 HEC-HMS generated flows at J3 and N5 for different design storms [Scenario B]



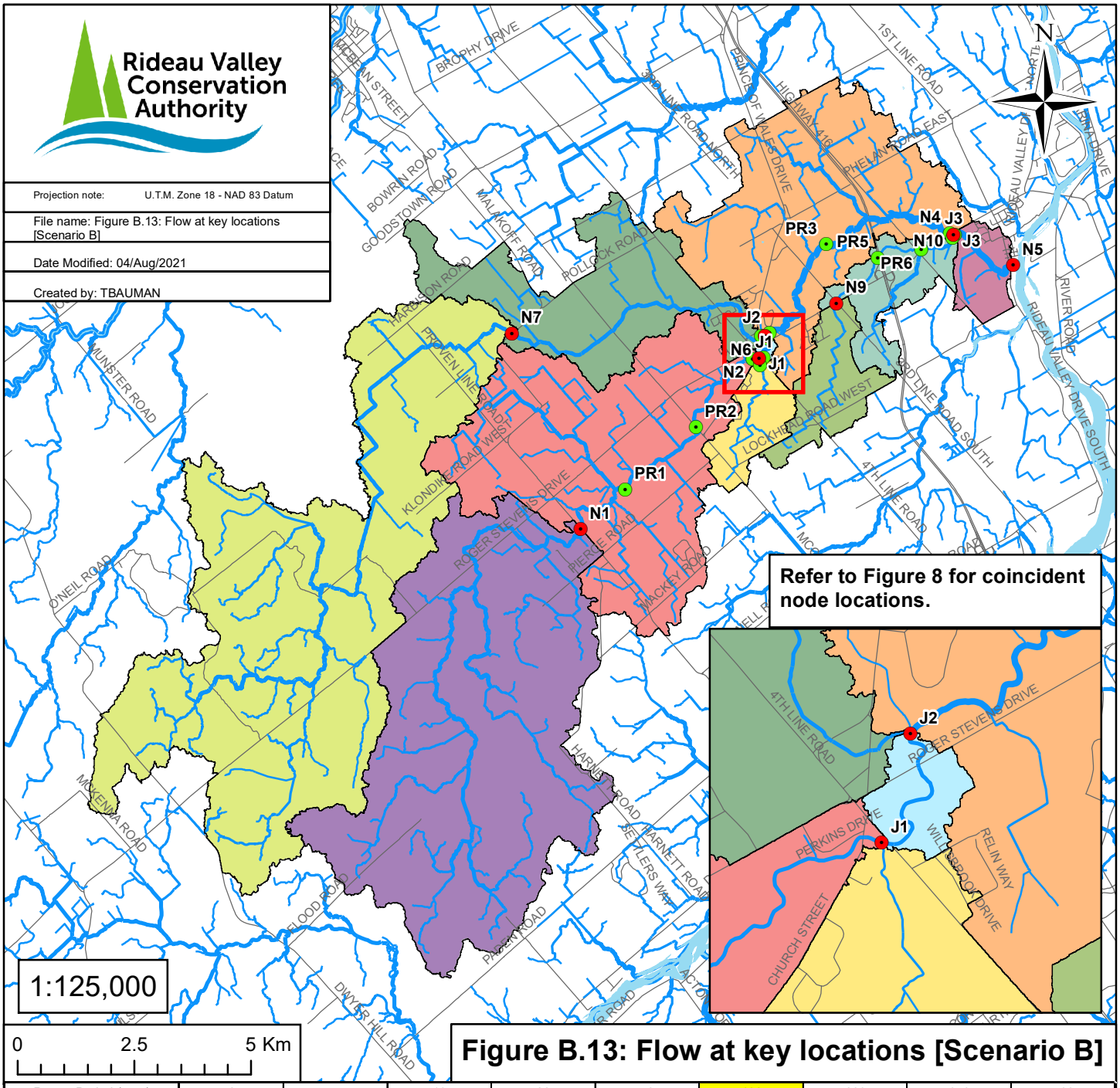


Figure B.13: Flow at key locations [Scenario B]

Return Period (year)	2	5	10	20	50	100	200	350	500
Nodes	Flow (cms)								
N1	2.59	5.49	7.59	9.84	12.89	15.26	17.65	19.68	21.09
PR1	6.19	13.33	18.54	24.10	31.59	37.46	43.30	48.26	51.69
PR2	7.93	17.15	23.90	31.07	40.74	48.34	55.86	62.26	66.66
N2	9.30	20.18	28.16	36.63	48.03	57.00	65.86	73.41	78.59
N3	10.27	22.02	30.59	39.68	51.90	61.48	70.96	79.03	84.57
PR3	15.74	33.84	46.80	60.31	78.84	93.44	107.97	120.38	128.91
N4	16.52	35.90	49.55	63.54	83.18	98.75	114.35	127.71	136.93
N5	17.62	38.83	54.41	70.38	92.35	109.88	127.48	142.62	153.06
N6	2.62	5.34	7.25	9.24	11.88	13.93	15.93	17.62	18.78
N7	4.47	9.53	13.21	17.16	22.52	26.69	30.89	34.46	36.94
N8	4.82	10.10	13.92	17.95	23.33	27.56	31.72	35.26	37.68
N9	2.09	4.41	6.08	7.84	10.19	12.02	13.82	15.35	16.40
PR5	2.38	5.03	6.94	8.94	11.64	13.79	15.90	17.70	18.92
PR6	2.54	5.37	7.41	9.55	12.44	14.77	17.06	19.00	20.32
N10	3.12	6.64	9.17	11.81	15.43	18.43	21.41	23.91	25.60
J1	10.24	21.97	30.54	39.61	51.81	61.38	70.85	78.91	84.44
J2	15.06	32.06	44.42	57.50	75.08	88.85	102.47	114.06	122.01
J3	18.65	40.45	56.09	71.69	93.76	111.33	128.99	144.18	154.69

Table B.1a: Land cover breakdown in the Stevens basin [Scenario B]

	Catchment	M1		M2		M3		M4	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Crop and Pasture - Cultivated	4.42	11.08	19.31	77.17	0.09	55.33	15.47	78.84
6	Crop and Pasture - Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.25
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Evaluated Wetland - Marsh	6.40	16.04	0.00	0.00	0.00	0.00	0.00	0.00
11	Evaluated Wetland - Open Water	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	5.87	14.73	0.00	0.00	0.00	0.00	0.00	0.00
13	Meadow/Thicket	3.41	8.54	0.48	1.90	0.00	1.88	0.21	1.07
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.00	0.00	0.03	0.12	0.01	3.27	0.03	0.18
16	Settlement - Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
17	Settlement - Pervious	0.00	0.00	0.00	0.02	0.00	2.49	0.01	0.05
18	Settlement - Pervious Homestead	0.13	0.33	0.57	2.26	0.00	0.24	0.48	2.47
19	Settlement - Residential	0.00	0.01	0.10	0.40	0.03	19.97	0.10	0.49
20	Settlement - Estate	0.03	0.07	0.23	0.92	0.00	1.85	0.05	0.24
21	Settlement - Townhouse	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	Transportation - Minor Road	0.17	0.44	0.59	2.36	0.01	6.88	0.22	1.13
26	Transportation - Unpaved Road	0.15	0.37	0.05	0.22	0.00	0.00	0.27	1.36
27	Unevaluated Wetland	3.36	8.43	0.31	1.23	0.00	0.00	0.30	1.53
28	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
32	Water - River	0.02	0.05	0.12	0.49	0.01	5.79	0.14	0.71
33	Wooded Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	Wooded Area - Fallow	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.00
35	Wooded Area - Hedgerow	0.17	0.43	0.68	2.71	0.00	0.00	0.32	1.62
36	Wooded Area - Island	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
37	Wooded Area - Plantation	0.01	0.04	0.12	0.47	0.00	0.00	0.00	0.01
38	Wooded Area - Treed	15.70	39.36	2.43	9.70	0.00	2.29	1.97	10.03
	Total	39.89	100.00	25.02	100.00	0.16	100.00	19.63	100.00

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table B.1b: Land cover breakdown in the Stevens basin [Scenario B]

	Catchment	M5		TA1		TA2		TB1	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Crop and Pasture - Cultivated	1.65	75.33	3.17	82.62	3.16	79.22	5.87	12.84
6	Crop and Pasture - Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
10	Evaluated Wetland - Marsh	0.00	0.00	0.00	0.00	0.00	0.00	0.71	1.55
11	Evaluated Wetland - Open Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	0.00	0.00	0.00	0.00	0.00	0.00	12.89	28.17
13	Meadow/Thicket	0.06	2.89	0.05	1.18	0.06	1.43	5.46	11.93
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.05	2.13	0.00	0.03	0.00	0.00	0.00	0.00
16	Settlement - Industrial	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	Settlement - Pervious	0.02	0.72	0.00	0.01	0.00	0.00	0.00	0.01
18	Settlement - Pervious Homestead	0.06	2.65	0.08	2.18	0.07	1.76	0.14	0.31
19	Settlement - Residential	0.06	2.86	0.01	0.32	0.00	0.06	0.01	0.02
20	Settlement - Estate	0.01	0.24	0.01	0.24	0.01	0.13	0.01	0.03
21	Settlement - Townhouse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00
25	Transportation - Minor Road	0.05	2.09	0.11	2.91	0.10	2.47	0.17	0.38
26	Transportation - Unpaved Road	0.02	1.08	0.00	0.00	0.03	0.77	0.38	0.83
27	Unevaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00	3.42	7.47
28	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
32	Water - River	0.06	2.61	0.00	0.00	0.00	0.00	0.00	0.00
33	Wooded Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	Wooded Area - Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	Wooded Area - Hedgerow	0.03	1.27	0.03	0.71	0.06	1.46	0.06	0.14
36	Wooded Area - Island	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03
37	Wooded Area - Plantation	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.01
38	Wooded Area - Treed	0.13	6.15	0.38	9.80	0.50	12.61	16.59	36.25
	Total	2.19	100.00	3.83	100.00	3.99	100.00	45.76	100.00

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table B.1c: Land cover breakdown in the Stevens basin [Scenario B]

	Catchment	TB2		TC1		Total Stevens	
	Land Cover Description	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
1	Aggregate Site	0.00	0.00	0.00	0.00	0.00	0.00
2	Aggregate Site - Pit	0.00	0.00	0.00	0.00	0.01	0.01
3	Aggregate Site - Quarry	0.00	0.00	0.00	0.00	0.00	0.00
4	Crop and Pasture	0.00	0.00	0.00	0.00	0.00	0.00
5	Crop and Pasture - Cultivated	9.43	75.93	2.28	80.26	64.84	41.64
6	Crop and Pasture - Fallow	0.04	0.33	0.00	0.00	0.09	0.06
7	Evaluated Wetland	0.00	0.00	0.00	0.00	0.00	0.00
8	Evaluated Wetland - Bog	0.00	0.00	0.00	0.00	0.01	0.01
9	Evaluated Wetland - Fen	0.00	0.00	0.00	0.00	0.01	0.01
10	Evaluated Wetland - Marsh	0.00	0.00	0.00	0.00	7.11	4.56
11	Evaluated Wetland - Open Water	0.00	0.00	0.00	0.00	0.00	0.00
12	Evaluated Wetland - Swamp	0.00	0.00	0.00	0.00	18.77	12.05
13	Meadow/Thicket	0.71	5.72	0.02	0.73	10.45	6.71
14	Settlement	0.00	0.00	0.00	0.00	0.00	0.00
15	Settlement - Commercial	0.02	0.17	0.02	0.64	0.16	0.10
16	Settlement - Industrial	0.06	0.51	0.00	0.00	0.07	0.04
17	Settlement - Pervious	0.01	0.09	0.00	0.03	0.05	0.03
18	Settlement - Pervious Homestead	0.26	2.11	0.06	1.99	1.85	1.19
19	Settlement - Residential	0.11	0.85	0.09	3.13	0.51	0.33
20	Settlement - Estate	0.14	1.11	0.01	0.43	0.49	0.32
21	Settlement - Townhouse	0.00	0.00	0.00	0.00	0.01	0.01
22	Transportation	0.00	0.00	0.00	0.00	0.00	0.00
23	Transportation - Rail	0.00	0.00	0.00	0.00	0.00	0.00
24	Transportation - Major Road	0.00	0.00	0.00	0.00	0.00	0.00
25	Transportation - Minor Road	0.25	2.01	0.09	3.20	1.77	1.13
26	Transportation - Unpaved Road	0.07	0.53	0.00	0.00	0.97	0.62
27	Unevaluated Wetland	0.18	1.47	0.00	0.00	7.57	4.86
28	Water	0.00	0.00	0.00	0.00	0.00	0.00
29	Water - Buffer around wetland	0.00	0.00	0.00	0.00	0.00	0.00
30	Water - Lake	0.00	0.00	0.00	0.00	0.00	0.00
31	Water - Pond	0.00	0.00	0.00	0.00	0.00	0.00
32	Water - River	0.03	0.25	0.00	0.00	0.38	0.24
33	Wooded Area	0.00	0.00	0.00	0.00	0.00	0.00
34	Wooded Area - Fallow	0.00	0.00	0.02	0.54	0.03	0.02
35	Wooded Area - Hedgerow	0.16	1.26	0.07	2.61	1.57	1.01
36	Wooded Area - Island	0.00	0.00	0.00	0.00	0.02	0.01
37	Wooded Area - Plantation	0.00	0.00	0.00	0.00	0.14	0.09
38	Wooded Area - Treed	0.95	7.67	0.18	6.43	38.83	24.94
	Total	12.41	100.00	2.84	100.00	155.72	100

Note: Land cover is based on DRAPE 2014 imagery and the Official Plan of 2003, updated to Official Plan Amendment #211 in 2018, guided projections for land cover changes. Further refinements to the projection were made when suitable development information was available, as was the case with the Maple Forest Estates and Williams Farm subdivisions.

Table B.3a Hydrologic parameters for rural catchments (Stevens Creek Scenario B)

Catchment	Area (km^2)	Imperviousness [1] (%)	CN [1]	IA [3] (mm)	CN* [2]	IA* [3] (mm)	Tc [4] (hr)	T_{lag} [5] (hr)
M1	39.89	0.7	76.5	15.65	67.3	6.16	55.51	33.31
M2	25.02	3.2	78.2	14.18	69.8	5.50	7.10	4.26
M3	0.16	14.4	83.3	10.20	77.1	3.77	0.55	0.33
M4	19.63	3.0	80.8	12.07	73.5	4.57	5.10	3.06
M5	2.19	6.0	73.0	18.80	62.5	7.61	6.26	3.76
TA1	3.83	3.2	79.7	12.92	72.0	4.94	5.05	3.03
TA2	3.99	3.1	79.8	12.85	72.1	4.91	3.13	1.88
TB1	45.76	1.0	76.3	15.76	67.2	6.21	35.16	21.09
TB2	12.41	3.6	79.4	13.21	71.5	5.07	7.75	4.65
TC1	2.84	4.7	81.3	11.65	74.3	4.39	3.01	1.81
Entire Stevens	155.72	2.0	77.7	14.62	69.1	5.90	---	---

1) Calculated from land cover and TR-55 Curve Number tables (Urban Hydrology for Small Watersheds by USDA-SCS, 1986)

2) Calculated based on equation $CN^*=100/(1.879((100/CN)-1)^{1.15}+1)$ (Curve Number Hydrology by Hawkins et al., 2009)

3) Calculated based $IA=((25400/CN_\lambda)-254)*\lambda$, where $\lambda=0.2$ for CN and $\lambda=0.05$ for CN* (Curve Number Hydrology by Hawkins et al., 2009)

4) Calculated based on the velocity method (National engineering handbook Chapter 15 by USDA-NRCS, 2010)

5) Calculated based on $T_{lag} = 0.6 \times Tc$ (HEC-HMS Technical Reference Manual by USACE, 2000)

6) Hydrologic calculations used CN and IA, not CN* and IA*. The latter are included for information purposes only.

Table B.3b Estimated channel parameters (Stevens Creek Scenario B)

Channel	Length [1]	Slope [2]	Manning's "n" [3]		
	(m)	(%)	LOB	Channel	ROB
C1 [4]	5210	0.0453	0.048	0.041	0.049
C2 [5]	640	0.0126	0.039	0.044	0.045
C3	6130	0.0323	0.042	0.040	0.042
C4	1670	0.0250 [6]	0.045	0.038	0.045
C5	6690	0.0932	0.042	0.048	0.045
C6	3330	0.0529	0.042	0.050	0.043
Entire Stevens	23670	0.0525	0.043	0.044	0.045

1) Length of HEC-RAS centerline flowpath for the 100-yr event, within associated routing catchment.

2) Slope = Rise/Run, where Rise was the difference in minimum channel elevations of HEC-RAS cross-sections closest to channel ends.

3) Obtained by averaging the HEC-RAS values within each channel, which themselves were determined from site visits and DRAPE (2014) photography using roughness coefficients outlined by Chow (1959).

4) C1 is considered to start at XS 1480, as upstream is steeper and more confined.

5) A lag time of 15 minutes, determined through analysis of HEC-RAS results, was used for C2 in HEC-HMS.

5) The slope of C4 was increased to offset potential overestimation of attenuation by mildly sloped reaches.

Table B.6 Estimated peak flows generated by various storms (Stevens Creek Scenario B)

Storm	3H Chicago	6H Chicago	12H Chicago	24H Chicago	3H SCS	6H SCS	12H SCS	**24H SCS**
Return Period	100 year	100 year	100 year	100 year	100 year	100 year	100 year	**100 year**
Flow	(cms)	(cms)	(cms)	(cms)	(cms)	(cms)	(cms)	**(cms)**
Catchments								
M1	6.29	8.74	11.71	15.06	6.30	8.74	11.74	**15.26**
M2	32.53	40.26	45.08	50.46	33.01	42.75	50.00	**56.99**
M3	1.59	1.83	2.06	2.27	1.44	1.76	2.12	**2.45**
M4	39.04	45.29	50.46	56.36	40.16	49.18	56.21	**63.52**
M5	2.38	2.99	3.39	3.85	2.43	3.22	3.83	**4.48**
TA1	7.26	8.46	9.45	10.60	7.48	9.21	10.57	**12.02**
TA2	10.97	12.40	13.98	15.76	11.68	13.76	15.85	**18.09**
TB1	11.27	15.67	20.82	25.65	11.29	15.69	20.99	**26.69**
TB2	15.84	19.72	22.08	24.60	16.03	20.78	24.34	**27.55**
TC1	8.67	9.75	10.96	12.27	9.23	10.78	12.34	**13.93**
Nodes								
N1	6.29	8.74	11.71	15.06	6.30	8.74	11.74	**15.26**
N2	32.54	40.27	45.09	50.47	33.02	42.76	50.01	**57.00**
N3	34.66	43.94	49.22	54.92	35.05	46.07	54.28	**61.48**
N4	49.44	68.16	81.52	90.14	49.38	68.27	87.43	**98.75**
N5	54.57	75.09	90.49	100.05	54.68	75.76	96.76	**109.88**
N6	8.67	9.75	10.96	12.27	9.23	10.78	12.34	**13.93**
N7	11.27	15.67	20.82	25.65	11.29	15.69	20.99	**26.69**
N8	15.85	19.73	22.09	25.62	16.04	20.79	24.35	**27.56**
N9	7.26	8.46	9.45	10.60	7.48	9.21	10.57	**12.02**
N10	10.98	12.40	13.99	15.77	11.69	13.77	15.86	**18.43**
J1	34.66	43.93	49.10	54.80	35.05	46.06	54.16	**61.38**
J2	50.33	63.51	71.15	79.35	50.91	66.64	78.43	**88.85**
J3	56.29	77.22	91.95	101.64	56.18	77.43	98.66	**111.33**
Channels								
C1	6.28	8.73	11.69	15.02	6.29	8.73	11.72	**15.23**
C2	34.66	43.93	49.10	54.80	35.05	46.06	54.16	**61.38**
C3	40.79	52.98	61.02	67.71	41.15	54.66	66.41	**75.22**
C4	53.53	73.32	88.43	97.73	53.67	74.01	94.48	**107.25**
C5	11.24	15.55	20.66	25.51	11.25	15.59	20.85	**26.53**
C6	6.11	7.45	8.33	9.31	6.23	7.97	9.25	**10.49**

Table B.8 Estimated peak flows for SCS Type II 24 hour design storm (Stevens Creek Scenario B)

Storm	24 hour SCS Type II								
Return Period	2 year	5 year	10 year	20 year	50 year	**100 year**	200 year	350year	500 year
Flow	(cms)	(cms)	(cms)	(cms)	(cms)	**(cms)**	(cms)	(cms)	(cms)
Catchments									
M1	2.59	5.49	7.59	9.84	12.89	**15.26**	17.65	19.68	21.09
M2	9.30	20.17	28.15	36.62	48.02	**56.99**	65.85	73.39	78.57
M3	0.52	1.00	1.33	1.67	2.11	**2.45**	2.77	3.05	3.24
M4	11.72	24.03	32.77	41.91	54.06	**63.52**	72.77	80.63	86.02
M5	0.53	1.35	2.00	2.70	3.69	**4.48**	5.27	5.95	6.42
TA1	2.09	4.41	6.08	7.84	10.19	**12.02**	13.82	15.35	16.40
TA2	3.12	6.64	9.16	11.80	15.33	**18.09**	20.78	23.06	24.63
TB1	4.47	9.53	13.21	17.16	22.52	**26.69**	30.89	34.46	36.94
TB2	4.81	10.09	13.91	17.94	23.33	**27.55**	31.71	35.25	37.67
TC1	2.62	5.34	7.25	9.24	11.88	**13.93**	15.93	17.62	18.78
Nodes									
N1	2.59	5.49	7.59	9.84	12.89	**15.26**	17.65	19.68	21.09
N2	9.30	20.18	28.16	36.63	48.03	**57.00**	65.86	73.41	78.59
N3	10.27	22.02	30.59	39.68	51.90	**61.48**	70.96	79.03	84.57
N4	16.52	35.90	49.55	63.54	83.18	**98.75**	114.35	127.71	136.93
N5	17.62	38.83	54.41	70.38	92.35	**109.88**	127.48	142.62	153.06
N6	2.62	5.34	7.25	9.24	11.88	**13.93**	15.93	17.62	18.78
N7	4.47	9.53	13.21	17.16	22.52	**26.69**	30.89	34.46	36.94
N8	4.82	10.10	13.92	17.95	23.33	**27.56**	31.72	35.26	37.68
N9	2.09	4.41	6.08	7.84	10.19	**12.02**	13.82	15.35	16.40
N10	3.12	6.64	9.17	11.81	15.43	**18.43**	21.41	23.91	25.60
J1	10.24	21.97	30.54	39.61	51.81	**61.38**	70.85	78.91	84.44
J2	15.06	32.06	44.42	57.50	75.08	**88.85**	102.47	114.06	122.01
J3	18.65	40.45	56.09	71.69	93.76	**111.33**	128.99	144.18	154.69
Channels									
C1	2.58	5.47	7.57	9.81	12.86	**15.23**	17.60	19.62	21.03
C2	10.24	21.97	30.54	39.61	51.81	**61.38**	70.85	78.91	84.44
C3	12.58	27.29	37.72	48.64	63.48	**75.22**	86.88	96.86	103.73
C4	17.35	38.13	53.34	68.90	90.25	**107.25**	124.30	138.97	149.08
C5	4.45	9.49	13.05	17.00	22.34	**26.53**	30.72	34.28	36.79
C6	1.71	3.78	5.25	6.79	8.87	**10.49**	12.10	13.46	14.40

Table B.9 Estimated flows for hydraulic modeling (HEC-RAS) [Stevens Creek Scenario B]

			Return Period (year)	2	5	10	20	50	**100**	200	350	500
Stream	Reach	Nearest Cross Section	Distance from Rideau Confluence (m)	Flow (cms)								
Stevens Creek	Reach 4	1525	15318	2.59	5.49	7.59	9.84	12.89	**15.26**	17.65	19.68	21.09
Stevens Creek	Reach 4	1500	14702	6.19	13.33	18.54	24.10	31.59	**37.46**	43.30	48.26	51.69
Stevens Creek	Reach 4	1465	13162	7.93	17.15	23.90	31.07	40.74	**48.34**	55.86	62.26	66.66
Stevens Creek	Reach 4	1415	10875	9.30	20.18	28.16	36.63	48.03	**57.00**	65.86	73.41	78.59
Stevens Creek	Reach 3	1350	8489	10.27	22.02	30.59	39.68	51.90	**61.48**	70.96	79.03	84.57
Stevens Creek	Reach 2	1300	7854	15.74	33.84	46.80	60.31	78.84	**93.44**	107.97	120.38	128.91
Stevens Creek	Reach 2	1225	5094	16.52	35.90	49.55	63.54	83.18	**98.75**	114.35	127.71	136.93
Stevens Creek	Reach 1	1145	1667	18.65	40.45	56.09	71.69	93.76	**111.33**	128.99	144.18	154.69
Tributary A	Reach 1	2225	5376	2.09	4.41	6.08	7.84	10.19	**12.02**	13.82	15.35	16.40
Tributary A	Reach 1	2210	5050	2.38	5.03	6.94	8.94	11.64	**13.79**	15.90	17.70	18.92
Tributary A	Reach 1	2175	3576	2.54	5.37	7.41	9.55	12.44	**14.77**	17.06	19.00	20.32
Tributary A	Reach 1	2125	2434	3.12	6.64	9.17	11.81	15.43	**18.43**	21.41	23.91	25.60
Tributary B	Reach 1	3355	14865	4.47	9.53	13.21	17.16	22.52	**26.69**	30.89	34.46	36.94
Tributary B	Reach 1	3330	14501	4.82	10.10	13.92	17.95	23.33	**27.56**	31.72	35.26	37.68
Tributary C	Reach 1	4145	10070	2.62	5.34	7.25	9.24	11.88	**13.93**	15.93	17.62	18.78

Appendix C

Full-Size Drawings

(Drawing ST-3)

Drawing ST-3
Stevens Creek Floodplain for Scenarios A and B

- Cross Section
- Study Limit
- 100yr Floodline A (2020)
- 100yr Floodline B (1976)
- 100yr Floodplain A (2020)
- A to B Floodplain Reduction
- A to B Floodplain Expansion
- 1m LiDAR-derived contours

12 NOV 2021

Rideau Valley Conservation Authority

Projection note: U.T.M. Zone 18 - NAD 83 Datum

N

File name: Drawing ST-3

Modified by: TB

Date Modified: 11/12/2021 9:11:16 AM

Location: Z:\GIS_Data\CA_Data\FPM\RVCA\RV4\Stevens2018\Drawing_ST-3.mxd

Scale 1:15,000

0 500 1,000 1,500

Meters

Mud Creek

Pratt Drain

Stevens Creek

Presley Drain

Tributary B (John Taylor Drain)

Study Limit

Study Limit Spill Section

Study Limit (Possible spill through culverts)

Johnston Drain

Rideau River

Cranberry Creek

Tributary A (Dillon-Wallace Drain)

Tributary C

Pettapiece Drain

Stevens Creek

Cranberry Creek McFadden Branch

Thomasing Solman Drain

Cross sections, floodline, and map layout created in ArcGIS 10.8.1.

The information in this drawing is for information purposes only. Authoritative information on flood hazard is maintained in RVCA's GIS system and is updated from time to time based on new data.

LiDAR captured by Airborne Imaging between November 15 - 22, 2012.

Scale 1:5,000

0 200

Meters

Export Date: 12 NOV 2021 9:17:34 AM