EAGLE HEIGHTS PROPERTY
HYDROLOGICAL STUDY AND
STORMWATER MANAGEMENT REPORT

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August 2018

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1.0 INTRODUCTION

1.1 Background

Penta Properties Inc. (Penta) owns two parcels of land in Northern Aldershot Area in the City of Burlington that are part of this study. The first is approximately 93 ha of land located west of Waterdown Road and north of Flatt Road and east of Grindstone Creek. The second is about 9 ha of land south of Flatt Road and also east of Grindstone Creek which had been identified as “Taylor Property” in previous studies. Figure 1 shows the location of these two land parcels. In this report these two areas will be referred collectively as “Eagle Heights”.

Penta has been seeking approval for the development of the Eagle Heights Property since the mid-1990s. The property was draft approved in 1997. This report evaluates the stormwater management component to support revisions to the draft plans proposed by the Penta in 2002.

The draft approved plan within Niagara Escarpment Plan (NEP) has not been modified from its 1996 approved plan. Penta is seeking approval for a development permit under NEP 2017 for this area which consists of 10 single residential units. However, this area is part of the study area of this report as it is within the drainage boundary for the proposed development in the south.

1.2 Brief History of Stormwater Management for the Eagle Heights Property

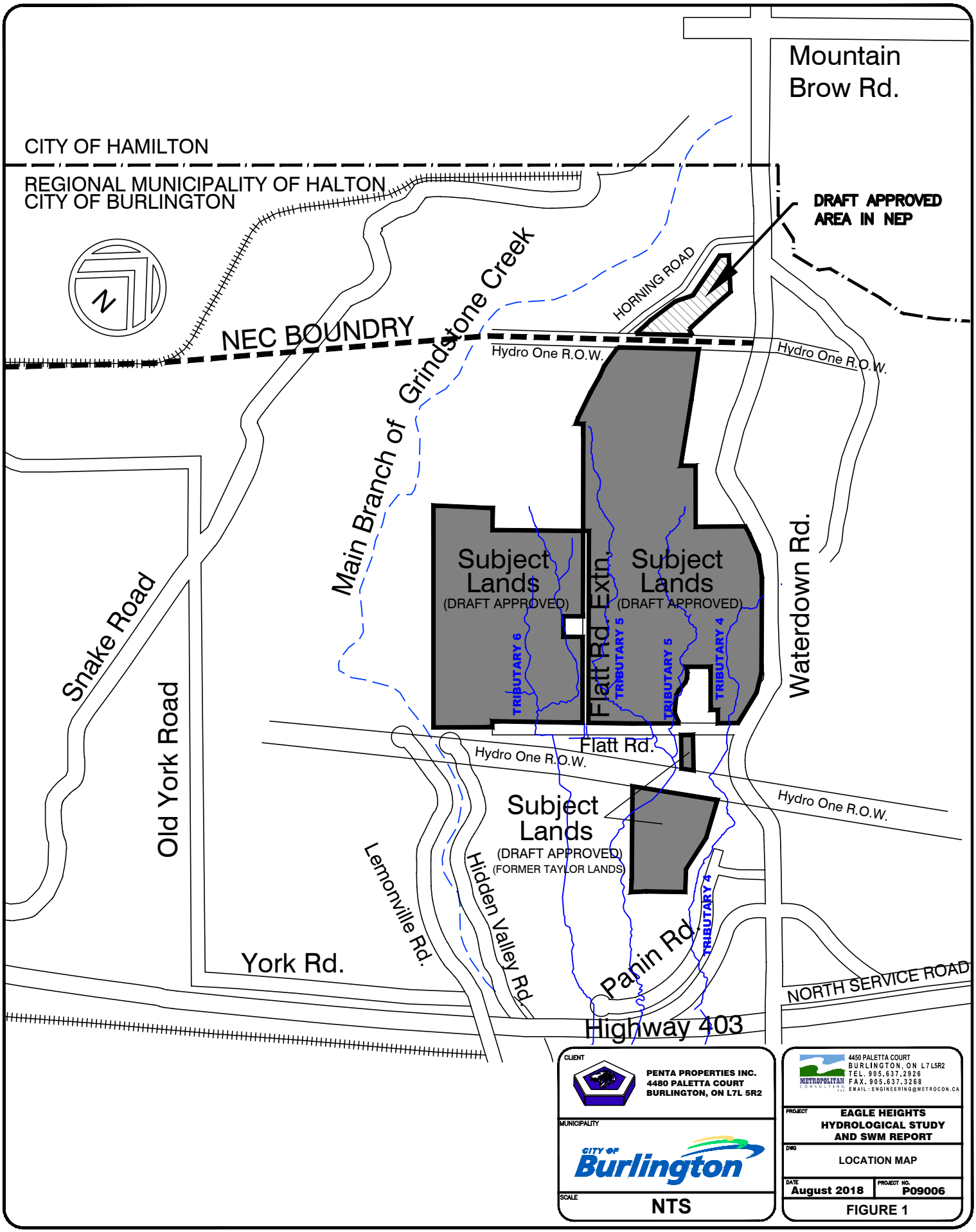
The “Grindstone Creek Subwatershed Study” which was carried out by Cosburn Patterson Wardman Limited, includes the subject land and was completed in January 1995. This subwatershed study was completed more than two decades ago and covers an area more than just Eagle Heights. This 2018 report updates the hydrological model for the proposed development area and establishes hydrological parameters for existing conditions. Continuous hydrological modelling, using the GAWSER program, has also been used to evaluate water balances and erosion assessment for pre and post development conditions.

A SWM Report was prepared by Metropolitan Consulting Inc. for the Eagle Heights Property including the area south of Flatt Road (previously referred as Taylor Property) in 2010. At that time 5 SWM ponds were proposed. In this report, only one SWM Pond is proposed. The other four SWM ponds have been replaced by Low Impact Development (LID) together with a combination of underground superpipes in roads and bioretention cells in roadside ditches.

1.3 Purpose

The main purpose of this report is to evaluate the hydrological condition within the subject land and evaluate and develop a Stormwater Management Plan (SWM) for the proposed development. The report also evaluates water balances and erosion assessments to existing and proposed conditions.

This report also addresses the comments of the agencies made on a previous submission. These responses are summarized in a comment matrix response table.



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PROJECT
EAGLE HEIGHTS
HYDROLOGICAL STUDY
AND SWM REPORT

DWG
LOCATION MAP

DATE
August 2018

PROJECT NO.
P09006

FIGURE 1

1.4 Previous Reports and Documents

Numerous technical reports have been prepared by Penta Properties Inc. (and Paletta International Corporation) and review agencies since 1994 on the subject lands. Some of the relevant reports are listed below:

- Functional Servicing Report Paletta Subdivision, October 1994, Cosburn Patterson Wardman Ltd.;
- Functional Servicing Report: Taylor Subdivision, October 1994, Cosburn Patterson Mather Ltd.;
- North Aldershot Central Sector Water and Wastewater Servicing Study, December 1994, Thornburn Penny Ltd.;
- Sanitary Drainage and Water Distribution Master Servicing Study: Grindstone Settlement Area, August 1994, Cosburn Patterson Wardman Ltd.
- Grindstone Creek Subwatershed Study, March 1995, Cosburn Patterson Wardman Ltd.;
- Addendum to Grindstone Creek Subwatershed Study, February 1996, Cosburn Patterson Mather Ltd.;
- Geotechnical Investigation Eagle Heights and Taylor Property, June 2003, Peto MacCallum Ltd.;
- Stable Top of Bank Assessment, Eagle Heights and Taylor Properties, July 2006, Peto MacCallum Ltd.;
- Planning and Environmental Analysis, January 2007, Envision & Scott Burns Planning Consultants;
- Traffic Impact Study, Eagle Heights/Taylor Draft Plans of Subdivision Burlington, July 2007, Read, Voorhees & Associates;
- Functional Servicing and Stormwater Management Report, June 2010, Metropolitan Consulting Inc.;
- Eagle Heights Erosion Assessment, May 2010, Parish Geomorphic;
- Eagle Heights and Taylor Lands Environmental Impact Assessment, 2010, Savanta Inc.;
- FSR & SWM Report Addendum Revised Section 7 to Address Region Comments March 2013

- Penta Properties Inc. Eagle Heights & Taylor Property Review of Sanitary Sewer Outlet Routes and other Related Issues July 2016

1.5 Hydrological Modelling

Hydrological modelling in Eagle Heights was done to establish the existing hydrological conditions of the area and also to evaluate effects of the proposed development on the hydrological regime of the area. Hydrological modeling is also used to design and optimize the proposed SWM storage facilities.

Two different computer programs, SWMHYMO and GAWSER (Guelph All-Weather Sequential Events Runoff) were used for hydrological modelling. The GAWSER program was used for continuous hydrological modelling to evaluate pre and post development water balance, erosion assessment and to design SWM facilities. SWMHYMO was mainly used to design SWM facilities, i.e. SWM pond, superpipes and onsite storages.

The GAWSER model is a deterministic watershed model based on the HYMO format. It has been applied widely in Ontario for planning, design, real-time flood forecasting and evaluating the effects of physical changes in drainage basins (Schroeter & Associates, 1996). The GAWSER program is capable of running continuous simulation for a long-term period (e.g. 40-50 years) as well as for shorter periods in event mode (e.g. 24, 48 hours).

SWMHYMO is used for event-based hydrological modelling. It is widely used to determine runoff from rural and urban watersheds. SWMHYMO uses the Soil Conservation Service curve number method of estimating runoff characteristics in combination with instantaneous unit hydrograph routines to produce storm hydrographs.

Often SWMHYMO uses the standard Chicago storm for the project area with different return period storm events. Due to its simplicity in application, SWMHYMO is widely used in Canada for urban runoff modelling and SWM pond design.

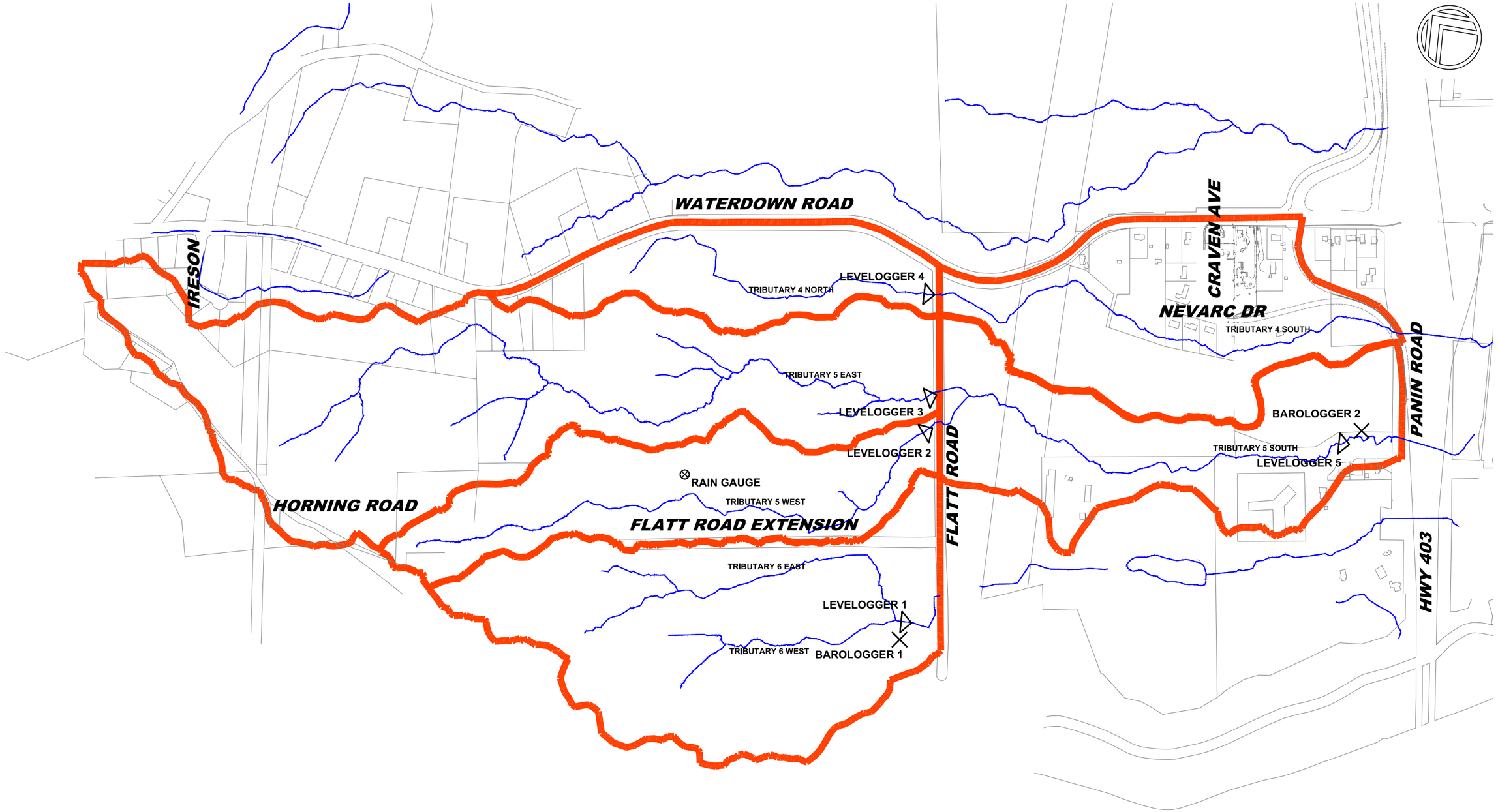
2.0 ON-SITE RAINFALL AND FLOW MONITORING

On-site rainfall and flow monitoring is very important for hydrological studies. Rainfall and flow information collected on the project site (Eagle Heights) facilitates hydrological model calibrations and increases confidence in the modelling results. Long-term rainfall and flow data (e.g. 3-4 years of data) are ideal for model calibration especially for continuous modelling but even a few good storm events will significantly improve the quality of hydrological models. Therefore it was decided to monitor on-site rainfall and monitor flows in the tributaries on the subject site.

Five leveloggers and two barologgers manufactured by Solinst Canada were installed to monitor the water levels in three main tributaries that flow through the project area in the first week of August 2016. A rain gauge [HOBO Rain Gauge – RG3- M (0.2mm)] was installed on the project site in September 2016. Figure 2 shows the locations of these five leveloggers, two barologgers and a rain gauge installed at the Project Site.

2.1 On-Site Flow Monitoring

As mentioned in the previous section, five leveloggers were installed on the project site and the downstream area to monitor flow from the three major tributaries that flow through the subject land. Levelogger 1 was installed approximately 40 meters downstream of the confluence of two branches of Tributary 6 (upstream of Flatt Road). Levelogger 2 was installed at the upstream invert of Tributary 5 West culvert at Flatt Road. Levelogger 3 was installed at upstream invert of Tributary 5 East culvert at Flatt Road. Levelogger 4 was installed at invert of Tributary 4 culvert at Flatt Road. Levelogger 5 was installed about 100 meters upstream of Tributary 5 Culvert at Panin Road. Barologger 1 was installed close to Levelogger 1 and Barologger 2 was installed close to Levelogger 5 near Panin Road. These locations are shown on Figure 2.



LEGEND

- RAIN GAGE LOCATION
- LEVELOGGER LOCATION
- BAROLOGGER LOCATION
- MAJOR DRAINAGE BOUNDARY
- TRIBUTARY

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PROJECT: EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG: Onsite Rain Gauge & Leveloggers

DATE: August 2018

PROJECT NO. P09006

FIGURE 2

The leveloggers and barologgers are basically pressure transducers which record water level pressure and atmospheric pressure respectively in a programmed time interval. To convert the levelogger information to water depth, compensation for atmospheric pressure measured with a barologger needs to be made. Once the compensated water level or depth are calculated using the levelogger and barologger data, a rating curve is established to convert water levels (m) to discharges (m^3/s).

Since three of the five leveloggers were installed just upstream of culverts, culvert hydraulics was used to convert water level to flow. For the other two leveloggers a detailed river channel survey was carried out to create HEC RAS hydraulic models to establish a rating curve for each levelogger. The rating curves for each levelogger have been included in Appendix A.

During the monitoring period, the culvert at Tributary 5 West under Flatt Road became partially blocked with sediments, therefore hydraulic computation could not be relied upon to convert water level to flow rates. As such, the data collected from Levelogger 2 was not used in this study. Subsequently, Levelogger 2 was relocated to the existing culvert just upstream of Tributary 4 at Panin Road.

All of these leveloggers were programmed to record flow information in five-minute intervals. These leveloggers can store a maximum of 40,000 events which is approximately 4.5 months of data in order to not have any gaps. Therefore, data from these leveloggers needs to be downloaded at least every 4.5 months. Since these are relatively small and steep watersheds, it was very important that flow information be recorded in smaller time steps. For example, if leveloggers were programmed to record every hour, there is a high possibility of missing the peak runoff in high intensity short duration storm events.

The flow information (hydrographs) generated from these monitoring stations have also been included in Appendix A of this report. Flow information recorded at some locations was discarded and not used in modelling because of quality of data concerns (e.g. blocked culverts or debris dam downstream of the monitoring station etc.).

2.2 On-site Rainfall Monitoring

As discussed in the previous sections, rainfall data measured at the project site is equally important for hydrological model calibration. A HOBO Pendant event logger with tipping bucket rain gauge (0.2 mm RG3-M) was installed at the project site on September 23, 2016. This rain gauge records both rainfall events and air temperature data in a programmed time interval. Rainfall events can be generated for required intervals (e.g. 5 minutes or 15 minutes) from the recorded rainfall data. As mentioned earlier, since these watersheds are relatively small in size, both rainfall events and flow measurements are required to be recorded in smaller time steps (i.e. 5 minutes) to properly capture peak rainfall intensity and runoff.

Figure 2 shows the location of the rainfall gauge installed. Figure 3 is the picture of the rain gauge installed at the Project Site or study area.



Figure 3 Rain gauge installed at the project site

2.3 Rainfall Data Comparison

Environment Canada maintains a climate station at Hamilton Royal Botanical Gardens (Hamilton RBG CS, 6153301), the closest available station to the project area with a long-term climate data record including rainfall. Hamilton RBG station is situated 2.5 km from the project site. As shown on Figure 4, rainfall recorded at the project site is slightly higher than the total precipitation data at the RBG station, especially for daily rainfall events of higher than 10mm. The Eagle Heights Project site is situated at a slightly higher elevation and just below the Niagara Escarpment, suggesting this could be a reason why the project area receives slightly more precipitation than the Hamilton RBG CS on the average.

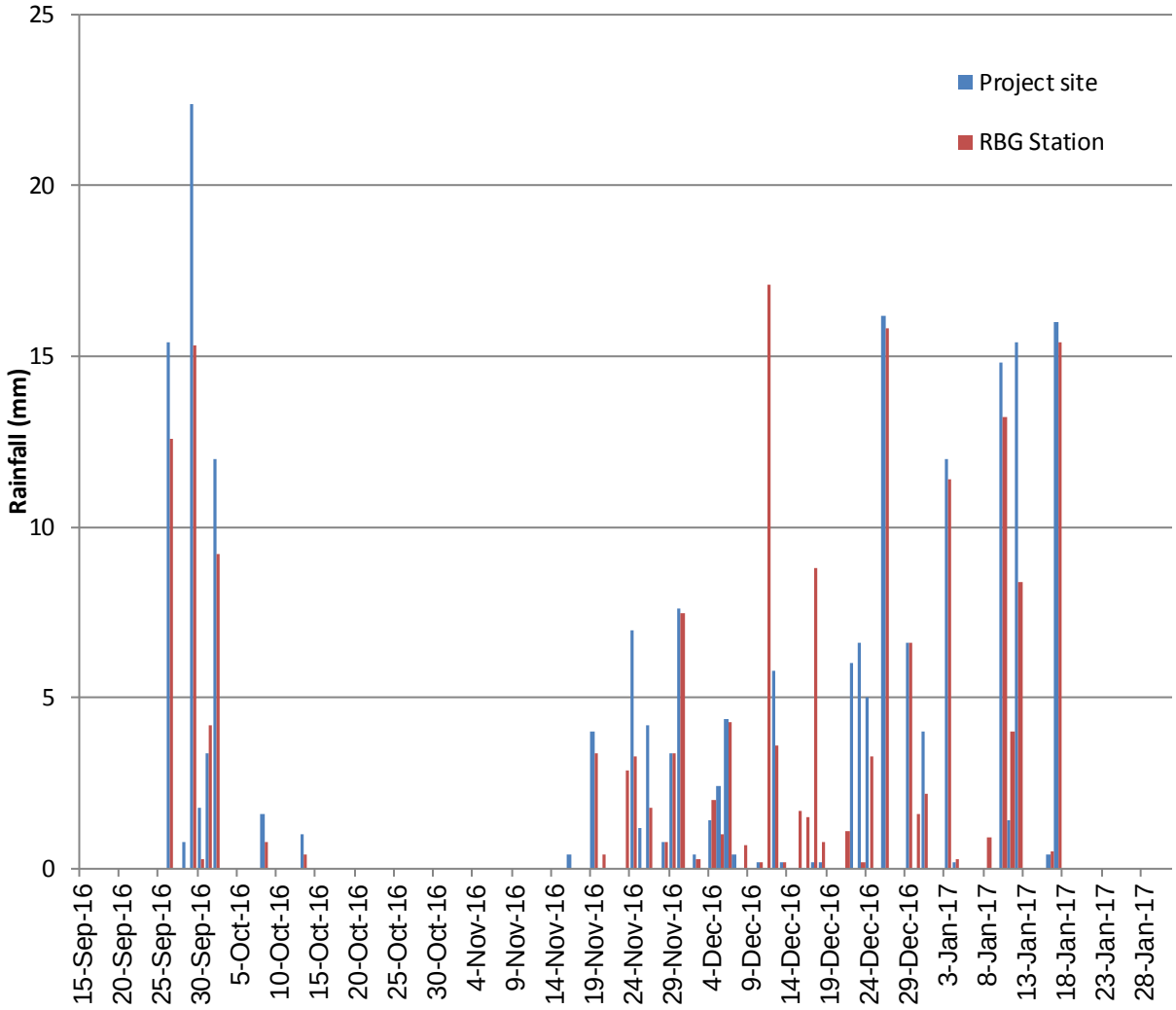


Figure 4 Comparison of Daily Precipitation Data at the Project Site and RBG CS

The data in December is different mainly because the temporary rain gauge installed at the project site only measures rainfall data whereas the permanent station at RBG records total precipitation (rainfall plus snowfall). Hourly climate data of the RBG CS from 1950 to 2016 was obtained from the Environment and Climate Change Canada and used in continuous hydrological modelling with the GAWSER Program.

Table 1 shows a comparison of daily rainfall recorded at the Eagle Heights Project Site and RBG Station for events higher than 10mm. As can be seen from Table 1, rainfall is generally higher at the project site than the RBG station. In the hydrological study most of the results are compared in relative terms (e.g. pre development vs post development), whereby these slight differences in rainfall will not have significant impacts on the overall results of the hydrological model and interpretation. The RBG station precipitation data

was used without any modification to the continuous model using GAWSER. But, the data collected at the project site was used for hydrological model calibrations in event mode.

Table 1 Comparisons of Rainfall at Eagle Heights & RBG CS

(10 mm or higher rainfall events)

Date	Eagle Heights Station (mm)	RBG Station (mm)	Difference (%)
26-Sep-16	15.4	12.6	22%
29-Sep-16	22.4	15.3	46%
2-Oct-16	12.0	9.2	30%
26-Dec-16	16.2	15.8	3%
3-Jan-17	12.0	11.4	5%
10-Jan-17	14.8	13.2	12%
12-Jan-17	15.4	8.4	83%
17-Jan-17	16.0	15.4	4%
25-Feb-17	14.4	13.9	4%
1-Mar-17	22.8	18.5	23%
25-Mar-17	10.4	10.9	-5%
30-Mar-17	15.2	12.9	18%
31-Mar-17	12.8	10.8	19%
4-Apr-17	11.4	9.6	19%
6-Apr-17	34.6	33.6	3%
20-Apr-17	65.6	72.4	-10%
20-Jun-17	14.2	15.7	-11%
22-Jun-17	7.6	11.5	-51%
23-Jun-17	28.0	27.8	1%
30-Jun-17	9.6	10.7	-11%
13-Jul-17	17.0	18.6	-9%
20-Jul-17	18.2	22.4	-23%
4-Aug-17	12.6	7.6	40%
11-Aug-17	15.6	16	-3%
15-Aug-17	10.6	2.9	73%
17-Aug-17	20.2	19.6	3%
3-Sep-17	11.8	7.7	35%
4-Sep-17	15.0	16.4	-9%
9-Oct-17	27.6	27.3	1%
12-Oct-17	11.2	10.3	8%
		Average	11%

3.0 EXISTING CONDITIONS DRAINAGE

The drainage area under existing conditions north of Flatt Road is about 107.69 ha. Most of the drainage area north of Flatt Road comprises farmland and forest woodlot. There is some residential housing at the upstream end of the drainage area along Horning Road and Waterdown Road. The total development area of Eagle Heights is 38.24 ha.

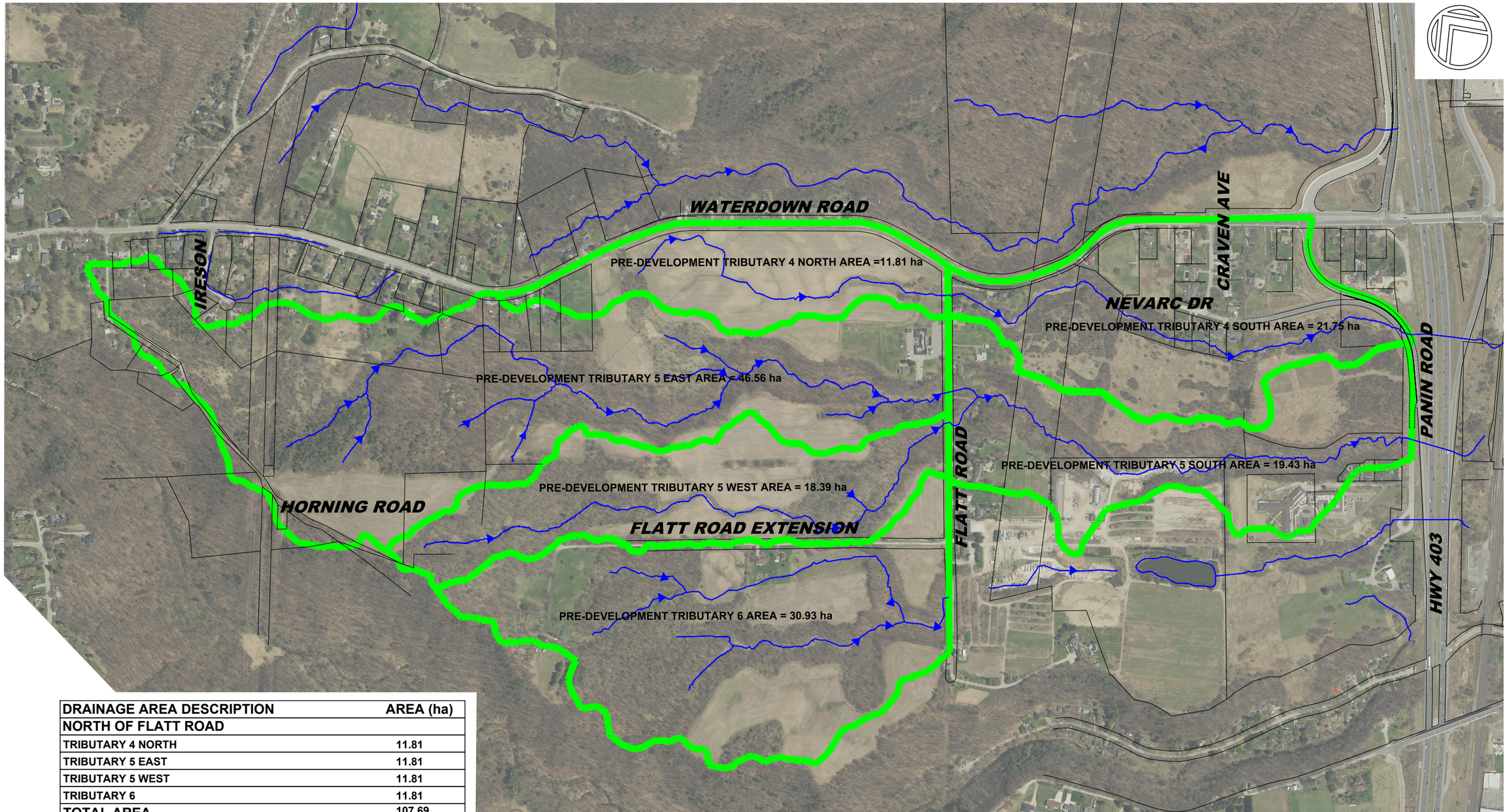
Three major tributaries flow through the subject lands and ultimately connect to the Grindstone Creek downstream of Highway 403. These tributaries are referred to as Tributary 4, Tributary 5 and Tributary 6. Tributary 5 has two branches north of Flatt Road and they are referred to as Tributary 5 East and Tributary 5 West. The two branches of Tributary 5 meet just downstream of Flatt Road. A private residence (100 Flatt Road) is located south of Tributary 5 West just upstream of the confluence of the two tributaries. Tributary 6 also has two branches which are also referred to as Tributary 6 West and Tributary 6 East, and they meet about 135 meters upstream of Flatt Road.

Figure 5 shows the four drainage areas north of Flatt Road and the two drainage areas south of Flatt Road and north of Panin Road.

Table 2 summarizes the drainage areas in the study area. The total drainage in the study area for hydrological modelling purpose is 148.87 ha.

Table 2 Existing Conditions Drainage Summary

Drainage Area Description	**Area (ha)**
North of Flatt Road	
Tributary 4 North	11.81
Tributary 5 East	46.56
Tributary 5 West	18.39
Tributary 6	30.93
Total Area	**107.69**
South of Flatt Road and North of Panin Road	
Tributary 4 South	21.75
Tributary 5 South	19.43
Total Area	**148.87**



DRAINAGE AREA DESCRIPTION	AREA (ha)
NORTH OF FLATT ROAD	
TRIBUTARY 4 NORTH	11.81
TRIBUTARY 5 EAST	11.81
TRIBUTARY 5 WEST	11.81
TRIBUTARY 6	11.81
TOTAL AREA	107.69

SOUTH OF FLATT ROAD - NORTH PANIN ROAD	
TRIBUTARY 4 SOUTH	21.75
TRIBUTARY 5 SOUTH	19.43
TOTAL AREA	148.87

LEGEND

PRE-DEVELOPMENT TRIBUTARY AREA

EXISTING WATER COURSE

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

EXISTING CONDITIONS DRAINAGE AREA

DATE

August 2018

PROJECT NO.

P09006

FIGURE 5

3.1 Existing Conditions Land Use and Land Cover

Detailed information on landcover and landuse is required for hydrological modelling when using the GAWSER program. This information was extracted from recent aerial imagery [the Southwestern Ontario Orthophotography Project (SWOOP) 2015] obtained from the Ministry of Natural Resources and Forestry (MNRF). As shown in

Table 3, the study drainage area consists of four major types of landcover and landuse, impervious area, farmland, landscaped area and forest. The drainage area north of Flatt Road consists of about 2% impervious area, 23% farmland, 16% landscaped area (lawn) and 57% Forest. The entire study area is about 3% impervious, 34% farmland, 13% landscaped area (lawn) and 48% forest.

Table 3 Existing Conditions Drainage Land-use and Land Cover

Drainage Area Description	**Area (ha)**	**Impervious**	**Farmland**	**Landscaped**	**Forest**
Tributary 4 North	11.81	0.22 ha	10.56 ha	0.75 ha	0.28 ha
		2%	90%	6%	2%
Tributary 5 East	46.56	1.02 ha	10.76 ha	7.55 ha	27.22 ha
		2%	23%	16%	59%
Tributary 5 West	18.39		7.82 ha	0.07 ha	10.50 ha
			42%		58%
Tributary 6	30.93	0.50 ha	10.64 ha	2.07 ha	17.70 ha
		2 %	34%	7%	57%
Area North of Flatt Road	**107.69**	**1.74 ha**	**39.78 ha**	**10.44 ha**	**55.70 ha**
		2%	**37%**	**10%**	**52%**
Tributary 4 South	21.75	1.62 ha	5.86 ha	5.21 ha	6.09 ha
		8%	27%	38%	28%
Tributary 5 South	19.43	1.57 ha	4.52 ha	3.18 ha	10.14 ha
		8%	**23%**	**16%**	**52%**
Total	**148.87**	4.89 ha	50.16 ha	18.83 ha	71.93 ha
		3%	**34%**	**13%**	**48%**

3.2 Surface Geology of Study Area

There are predominantly two types of surface geology formation in the study area; silty clay (Halton Till) and silty sand deposits. The area north of Flatt Road is almost 49% silty sand deposits and 51% Halton Till. The Tributary 6 drainage area north of Flatt Road is 60% silty sand and 40% is Halton till. Table 4 below summarizes the surface geology of the drainage area north and south of Flatt Road.

Table 4 Surface Geology of Drainage Areas

Tributary Areas	**Total Area**	**Sandy Silt**		**Halton Till (Clay to Silt-textured Till)**	
	(ha)	(ha)	%	(ha)	%
Tributary 4 North	11.81			11.81	100%
Tributary 5 East	46.56	25.03	54%	21.53	46%
Tributary 5 West	18.39	8.77	48%	9.62	52%
Tributary 6	30.93	18.61	60%	12.32	40%
Total North of Flatt Road	**107.69 ha**	**52.41ha**	**49%**	**55.28ha**	**51%**
Tributary 5 South	19.43	1.08	6%	18.35	94%
Tributary 4 South	21.75			21.75	100%
Total	**148.87 ha**	**53.49 ha**	**35%**	**95.38ha**	**65%**

Geotechnical investigations carried out by Peto MacCallum Ltd. in 2003 & 2006 and by Soil-Mat Engineers & Consultant Ltd. in 2017, shows up to 12.5 meters of deep silty sand or sandy silt deposits in some areas of the proposed development.

Figure 6 also shows the location of the Boreholes investigated by Peto MacCallum Ltd. in 2003 and 2006, and by Soil-Mat in 2017. Table 5 shows a list of boreholes within silty sand deposit depth. Surface geology information is very important for setting up the hydrologic model in GAWSER and helps to determine different computational parameters (e.g. infiltration rates) for the different drainage areas.

WATERDOWN ROAD

FLATT ROAD EXTENSION

FLATT ROAD

PANIN ROAD

HWY 403

TRIBUTORY 4 NORTH

TRIBUTORY 4 SOUTH

TRIBUTORY 5 EAST

TRIBUTORY 5 WEST

TRIBUTORY 6 EAST

BH 111

BH 15 (1.5m)

BH 12

BH 11

BH 110

BH 109

BH 108

BH 16

BH 17

BH 102

BH 18

BH 20

BH 19

BH 9

BH 8

BH SM6

BH SM5

BH 10

BH 101

BH 21

BH SM7 (3.4m)

BH 13 (2.1m)

BH 14 (5.35m)

BH SM4 (12.5m)

BH 107 (8.85m)

BH 7

BH 106 (2.15m)

BH 2

BH SM3

BH 5

BH 6

BH 105

BH 1 (.7m)

BH 3 (2.9m)

BH 4 (2.9m)

BH SM2 (4.8m)

BH 104 (4.0m)

BH SM1 (6.7m)

BH 103 (1m)

LEGEND

- BEACH GRAVEL
- SILT TILL, SILTY CLAY
- SHALE, DOLOSTONE
- STREAM DEPOSITS
- FILL
- SILTY SAND DEPOSITS
- BH 3 — BOREHOLE LOCATION PETO MACCALLUM LTD 2003
- BH 104 — BOREHOLE LOCATION PETO MACCALLUM LTD 2006
- BH SM1 — BOREHOLE LOCATION SOIL–MAT 2017

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

SURFACE GEOLOGY & BOREHOLES

DATE

August 2018

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P09006

FIGURE 6

Table 5 Boreholes with Silty Sand Deposits

Boreholes	Silty Sand Deposit [1] (m)
BH 1	4.7
BH 4	2.9
BH 13	5.6
BH 14	>8.1
BH 15	1.5
BH 103	1.80
BH 104	4.00
BH 106	2.15
BH 107	8.85
BH SM1	6.7
BH SM2	4.8
BH SM4	12.5
BH SM7	3.4

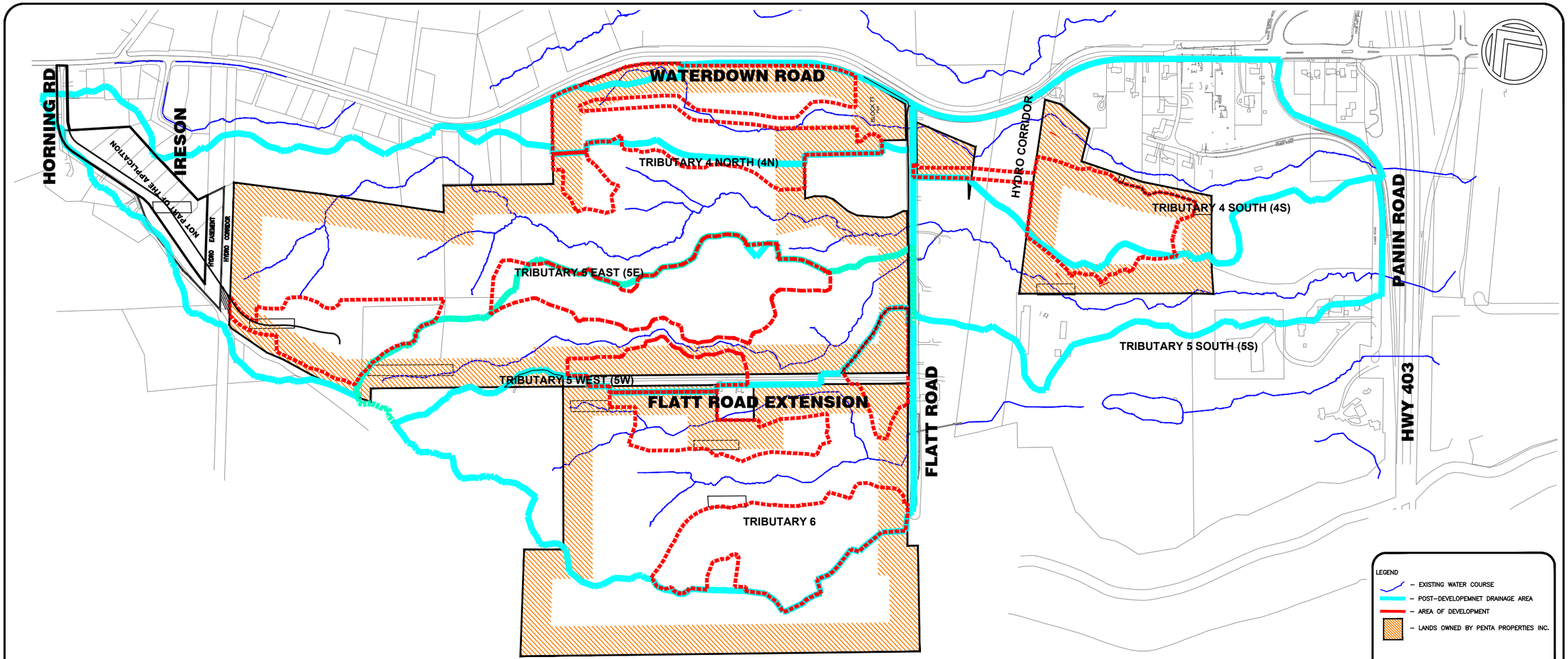
[1] *first 20-30 cm on the surface is dark brown clayey silt, low organic*

4.0 PROPOSED CONDITIONS DRAINAGE

Penta has proposed to build 914 residential units in Eagle Heights consisting of 780 north of Flatt Road and 134 units south of Flatt Road, previously referred to as “Taylor Property”. Figure 7 shows the post development drainage areas compared to pre-development drainage areas. Table 6 summarizes the number of residential units in each area proposed in the latest draft plan.

Table 6 Eagle Heights Proposed Residential Units (as per Latest Draft Plan)

Area	**Sub- Area as Per the City Official Plan (OPA 197)**	**Single Detached Residential Units**	**Cluster Housing Units**	**Single Family Condominium Units**
Tributary 4 North	Sub Area 2b	70	123	
Tributary 5 East	Sub Areas 1 and 2b	18	70+26	
Tributary 5 West	Sub Areas 5 & 6	31	64+77	21
Tributary 6	Sub Areas 5, 7 & 8	23+51	36+48+52+ +26+44	
Tributary 4 South	Sub Area 10	32	102	
Sub-total		225	668	21
Grand total		**914**		



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREAS 4 NORTH, 5 EAST, 5 WEST AND 6 (NORTH OF FLATT ROAD)				
	4 NORTH (4N) ha.	5 EAST (5E) ha.	5 WEST (5W) ha.	AREA 6 ha.	TOTAL ha.
PRE-DEVELOPMENT DRAINAGE AREA	11.81	46.56	18.40	30.93	107.70
POST-DEVELOPMENT DRAINAGE AREA	10.86	44.59	20.22	30.97	106.67
DEVELOPMENT AREA	8.77	6.70	8.63	11.30	32.63
AREA OF LANDS OWNED BY PENTA PROPERTIES INC.	10.38	28.47	18.26	36.20	93.31
IMPERVIOUS AREA OF POST-DEVELOPMENT DRAINAGE AREA	3.53	3.27	2.53	4.19	13.52
IMPERVIOUS PERCENTAGE OF POST-DEVELOPMENT DRAINAGE AREA	32.50%	7.34%	12.52%	13.55%	12.67%
IMPERVIOUS PERCENTAGE OF AREA OF DEVELOPMENT	40.25%	48.81%	29.32%	37.08%	41.43%

TRIBUTARY DRAINAGE AREA FACTORS	4 SOUTH (4S) ha.	5 SOUTH (5S) ha.
PRE-DEVELOPMENT DRAINAGE AREA	21.75	19.43
POST-DEVELOPMENT DRAINAGE AREA	21.84	18.35
DEVELOPMENT AREA	4.66	0.53
AREA OF LANDS OWNED BY PENTA PROPERTIES INC.	6.93	2.71
IMPERVIOUS AREA OF POST-DEVELOPMENT DRAINAGE AREA	3.48	
IMPERVIOUS PERCENTAGE OF POST-DEVELOPMENT DRAINAGE AREA	15.93%	
IMPERVIOUS PERCENTAGE OF AREA OF DEVELOPMENT	74.68%	

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HYDROLOGICAL STUDY
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POST DEVELOPMENT
DRAINAGE PARAMETERS

DATE
August 2018

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P09006

FIGURE 7

4.1 Tributary 4 North (Sub Area 2b)

Tributary 4 North Area lies on the west side of Waterdown Road and north of Flatt Road as shown in Figure 8. This area is also identified as Sub Area 2b in the City of Burlington Official Plan. This area is proposed to encompass 123 units of cluster housing and 70 units of detached residential homes, and a 1.34 ha Park block. Post development drainage information for Waterdown Road was provided by Hatch Engineering. Hatch Engineering is currently working on the design of the reconstruction and widening of Waterdown Road which is expected to be constructed in 2019. As per the information provided, once construction is complete, runoff from the Waterdown Road will be controlled in a new SWM facility (dry pond) located just south of Flatt Road. The front half of seven (7) proposed single detached residential units from the Eagle Heights are proposed to drain to Waterdown Road and have been included in the Hatch design.

Table 7 Tributary 4 North (Sub Area 2b) Features and Proposed Development

Description	
Overall Area	
Pre-development drainage	11.81 ha
Post-development drainage	10.86 ha
Land Owned By Penta	
Proposed development area	8.40 ha
Total area	10.34 ha
Percentage impervious of the proposed development of the drainage area	32.50%

4.2 Tributary 5 East (Sub Areas 1 and 2b)

Eighteen (18) single detached residential units and 96 cluster housing units have been proposed on the northern part of this area which is also referred to as Sub area 1 in the City of Burlington Official Plan. There are 37 cluster housing units near Sub Area 2b within this area. Table 8 summarizes the major features of this area.

Table 8 Tributary 5 East (Sub Areas 1 and 2b) Features and Proposed Development

Description	
Overall Area	
Pre-development drainage	46.56 ha
Post-development drainage	44.59 ha
Land Owned By Penta	
Proposed development area	4.72 ha
Land owned by Penta Properties Inc.	31.82 ha
Percentage impervious of the proposed development of the drainage area	7.34%

4.3 Tributary 5 West (Sub Areas 5 and 6)

There are 31 single family condominium units, 141 cluster housing units and 21 single detached residential units proposed in this area. Table 9 summarizes the major features of this area

Table 9 Tributary 5 West (Sub Areas 5 and 6) Features and Proposed Development

Description	
Overall Area	
Pre-development drainage	18.40 ha
Post-development drainage	20.22 ha
Land Owned By Penta	
Development area	8.63 ha
Land owned by Penta Properties Inc.	18.00 ha
Percentage impervious of the proposed development of the drainage area	12.52 %

4.4 Tributary 6 (Sub Areas 5, 7 & 8)

There are 76 single detached residential units and 217 cluster housing units proposed in this area. Table 10 summarizes the main features of this area.

Table 10 Tributary 6 (Sub Areas 5, 7 & 8) Features and Proposed Development

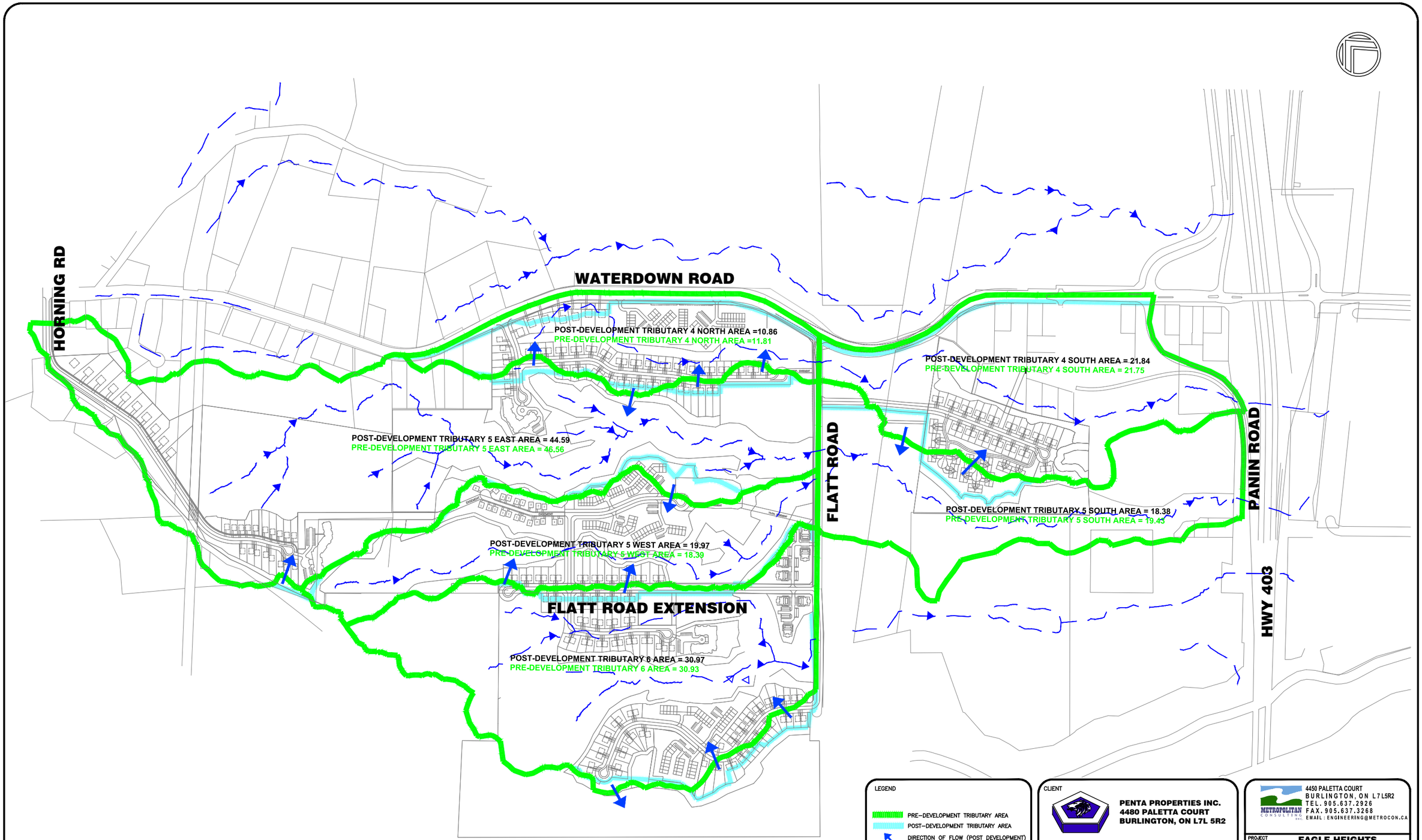
Description	
Overall Area	
Pre-development drainage	30.93 ha
Post-development drainage	30.97 ha
Land Owned By Penta	
Development area	11.30 ha
Land owned by Penta Properties Inc.	23.27 ha
Percentage impervious of the proposed development of the drainage area	13.55 %

4.5 Tributary 4 South (Sub Area 10)

32 single residential units and 102 cluster housing units have been proposed in this area. Table 11 summarizes the main features of this area. There are some existing houses (approximately 20) east of the subject lands. The proposed development within this area was also referred to as the "Taylor Property" in some of the previous reports.

Table 11 Tributary 4 South (Sub Area 10) Features and Proposed Development

Description	
Overall Area	
Pre-development drainage	21.75 ha
Post-development drainage	21.84 ha
Land Owned By Penta	
Development area	4.66 ha
Land owned by Penta Properties Inc.	6.93 ha
Percentage impervious of the proposed development of the drainage area	15.93 %



LEGEND

- PRE-DEVELOPMENT TRIBUTARY AREA
- POST-DEVELOPMENT TRIBUTARY AREA
- DIRECTION OF FLOW (POST DEVELOPMENT)
- EXISTING WATER COURSE

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EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

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PRE VS POST DEVELOPMENT AREAS

DATE **August 2018** | PROJECT NO. **P09006**

FIGURE 8

5.0 STORMWATER MANAGEMENT

In any urban development, post-development surface runoff increases compared to pre-development condition mainly due to an increase in impervious areas. The stormwater management plan summarizes how the quality and quantity aspects of post development runoff are managed within the proposed development. The main goal of SWM plan is to achieve post development runoff conditions to pre development level or better.

Eagle Heights is traversed by three major tributaries, referred to as Tributaries 4, 5 and 6. The development is situated in six (6) different locations. Each area / pod is required to be serviced by a unique SWM facility or by a number of SWM facilities. One (1) SWM Pond, six (6) superpipe storage systems on streets and nine (9) private on-site storage facilities are proposed to manage the storm runoff for both quantity and quality controls from the proposed development.

Low Impact Development (LID) is proposed as a stormwater management measures throughout the project. Bioretention cells filled with clear stone and subdrain pipes have been proposed as primary LID measures.

Figure 10 shows the typical sections for the bioretention facility. Depending on the underlying geological conditions of the area two type of bioretention cells, “Type A” and “Type B”, have been proposed. In area with silty clay, “Type A” bioretention cells have been proposed and in Silty Sand area, “Type B” bioretention cells have been proposed.

Type A and Type B bioretention cell include 722 mm to 882 mm of storage depth respectively. Table 12 shows the depth of different layers of bioretention facility and their equivalent water storage depth.

Table 12 Bioretention Facility Water Storage Depth

Layer	Depth (mm)	Equivalent water storage depth	
		Silty Clay Area (Type A)	Silty Sand Area (Type B)
Ponding	300	300*1 = 300mm	300*1 = 300mm
Mulch	75	75*.7 = 52.5mm	75*.7 = 52.5mm
Filter media	600	600*.35 = 210mm	600*.35 = 210mm
Choker layer	100	100*.4 = 40mm	100*.4 = 40mm
Pipe diameter depth	200	200*.4 = 80mm	200*.4 = 80mm
Storage reservoir	100 or 500	100*.4 = 40mm	500*.4 = 200mm
		722.5mm	882.5mm

A typical 20 meter long and 3 meter wide “Type A” bioretention facility provides about 43 m^3 of storage [(20*3*0.7225) = 43 m^3] and “Type B” provides 53 m^3 of storage [(20*3*0.8825) = 53 m^3].

“Type B” bioretention cells will be constructed in the roadside ditches of Street A and Horning Road, and “Type A” will constructed in all other streets, i.e. Street E, Street X, Street B and Flatt Road Extension as shown in Figure 9.

Runoff from the area where superpipes are proposed will first go through the LID bioretention cells and then to superpipes. This helps to improve the water quality of surface runoff which is mostly caused by frequent smaller rainfall events.

Onsite private SWM storage facilities are proposed for the cluster housing blocks. These facilities will be subject to further approval at the Site Plan application stage. The results contained within this report will serve as targets for further design. Figure 9 shows the location of these SWM facilities.

Stormwater management wet ponds are not practical to build in most cases as the drainage areas of these development pods are less than 5 ha. Ministry of the Environment

and Climate Change (MOECC) guidelines (2003) recommend a minimum 5 ha drainage for a SWM wet pond to function properly. Table 14 summarizes each individual proposed SWM structure and respective storage volume throughout the Eagle Heights. The SWM structures proposed in each subcatchment will be further discussed in subsequent sections.

Each private on-site storage facility will be equipped with an Oil-Grit Separator (OGS) in order to provide protection as per MOECC SWM Guidelines.

Percentage of impervious area for each subcatchment was calculated using the actual footprint of proposed buildings, roads and driveways. The calculation also assumes that 60% of single family homes will have backyard patio and shed of average 18m^2.

5.1 Water Quality

The proposed Eagle Heights development is a low density development with rural road cross section and with 5 meter wide ditches on either side of road. This provides a perfect opportunity to implement Low Impact Development (LID) measures on the road side ditches. As discussed in earlier sections of the report, depending on the geological conditions of the area, two types of bioretention cells are proposed in the area where superpipes are proposed as SWM storage facilities. All the flow will be first routed through LID facilities and then to superpipe storages. This helps to improve the water quality especially in smaller frequent rainfall events. Table 14 summaries required and provided water quality volume in the area where superpipes and SWM pond are proposed. Each on-site storage facility proposed in cluster housing area will be equipped with Oil-Grit Separator (OGS) to enhance water quality of the surface runoff.

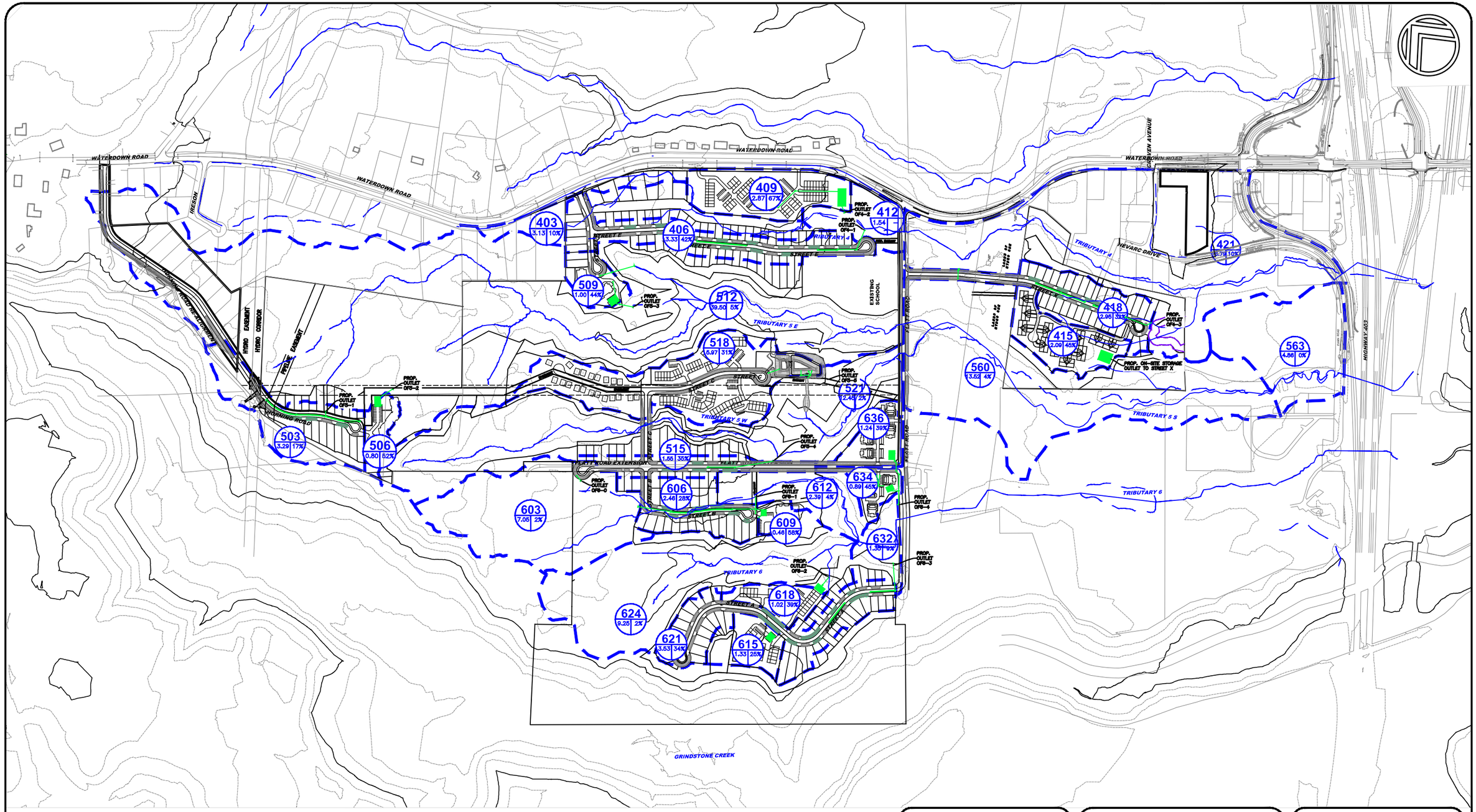
Table 13 Water Quality Storage

Protection Level	SWMP Type	Sub catchment ID	Area (ha)	Impervious Area (%)	Storage Volume Required[2] (m^3/ha)	Storage volume (m^3)	
						Required	Provided
Enhanced 80% long-term S.S. removal	LID Infiltration	406	3.33	42	27	89	320
	LID Infiltration	418	2.96	32	25	74	343
	LID Infiltration	503	3.29	17	25	82	156
	Infiltration	515	1.55	35	25	39	326
	SWM Pond	518	5.97	31	140	836	1364
	LID Infiltration	606	2.46	28	25	62	335
	LID Infiltration	621	3.53	34	25	88	723

[2] As per MOE Guidelines (2003) Table 3.2

Table 14 Summary of Proposed SWM Facilities and Strorage Volume

Drainage ID	Draft Plan Block	Type of Development	Area	Percentage Impervious	100 -Year Pre-Development Unit Area Flow Rate	100 -Year Pre-Development Total Flow Rate	100 -Year Post-Development Total Flow Rate	Outlet Orifice Pipe Size	Total Storage	Storage on Bioretention Cells LIDs	Superpipes Storage	Storage Dimension	SWM Type	Location	SWM Outfall
			(ha)	(%)	(m^3/s/ha)	(m^3/s)	(m^3/s)	(mm)	(m^3)	(m^3)	(m^3)				
406		Single Family	3.33	42%	0.052	0.172	0.167	215	907	320	587	140m [2400 X 1800]	Superpipes (SP-41)	Street E	OF 4-1
409	Block SS	Cluster Housing	2.87	67%	0.052	0.148	0.105	165	1,120			35m X 16m X 2m	On-site Storage (STC - 42)	On-site	OF 4-2
415	Block G	Cluster Housing	2.09	45%	0.045	0.093	0.047	110	1,000			25m X 20m X 2m	On-site Storage (STC-43)	On-site	OF 4-3
418		Single Family	2.96	32%	0.045	0.132	0.110	250	1,080	344	736	175m [2400 X 1800]	Superpipes (SP-44)	Street X	OF 4-3
503		Single Family	3.29	17%	0.034	0.112	0.072	140	1,015	128	887	205m [2400 X 1800]	Superpipes (SP-51)	Horning Road	OF 5-1
506	Block P	Cluster Housing	0.80	52%	0.034	0.027	0.019	75	360			20m X 12m X 1.5m	On-site Storage (STC - 52)	On-site	OF 5-2
509	Block OO	Cluster Housing	1.00	44%	0.034	0.034	0.019	75	480			20m X 16m X 1.5m	On-site Storage (STC - 53)	On-site	OF 5-3
515		Single Family	1.55	35%	0.041	0.063	0.062	130	540	327	213	50m [2400 X 1800]	Superpipes (SP-54)	Flatt Rd Extension	OF 5-4
518		Mixed	5.97	31%	0.041	0.243	0.177						SMW Pond (Pond- 5A)		OF 5-5
606		Single Family	2.46	28%	0.043	0.107	0.082	150	864	335	529	125m [2400 X 1800]	Superpipes (SP-61)	Street B	OF 6-1
609	Block H	Cluster Housing	0.46	58%	0.043	0.020	0.019	75	180			12m X 10m X1.5m	On-site Storage (STC - 62)	On-site	OF 6-1
615	Block D	Cluster Housing	1.33	25%	0.043	0.058	0.043	105	416			16m X 13m X 2m	On-site Storage (STC - 63)	On-site	OF 6-3
618	Block E	Cluster Housing	1.02	39%	0.043	0.044	0.039	90	432			18m X 12m X 2m	On-site Storage (STC - 64)	On-site	OF 6-2
621		Single Family	3.53	34%	0.043	0.153	0.118	180	1,123	725	398	95m [2400 X 1800]	Superpipes (SP-65)	Street A	OF 6-3
634	Block K	Cluster Housing	0.89	45%	0.043	0.039	0.032	90	336			14m X 10m X 2m	On-site Storage (STC - 66)	On-site	OF 6-4
636	Block JJ	Cluster Housing	1.24	39%	0.043	0.054	0.043	105	432			18m X 12m X 2m	On-site Storage (STC - 67)	On-site	OF 6-4



LEGEND

- POST DEVELOPMENT DRAINAGE BOUNDARY
- STORM SUPERPIPE
- INFILTRATION TRENCH
- STORM PIPE
- PROPOSED CULVERT
- ON-SITE STORAGE

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POST DEVELOPMENT DRAINAGE & SWM STRUCTURES

DATE: August 2018

PROJECT NO.: P09006

FIGURE 9

5.2 Subcatchment 403

Post development Subcatchment 403 is located within “Sub Area 2b’ as identified in the City of Burlington Official Plan. Half of 33 single residential buildings and backyard backing on proposed creek block are located within this subcatchment. The total drainage area of the subcatchment is 3.13 ha with 10% impervious area. A realigned channel of upstream reach of Tributary 4 flows through the middle of the subcatchment. There is no SWM structure proposed within this area. The runoff generated from this subcatchment drains uncontrolled to Tributary 4. To balance the pre and post development flows at Flatt Road, post development runoffs from other subcatchments (406 & 409) are to be over controlled, to compensate for the uncontrolled runoff from this subcatchment area.

The design for the channel realignment was led by Matrix Solution Inc., and has been described in detail in the report, *Eagle Heights Geomorphic Assessment, May 2018,* provided under separate cover

5.3 Subcatchment 406

Subcatchment 406 is located within “Sub Area 2b” as identified in the City of Burlington Official Plan. There are 61 single detached residential units within this subcatchment and it has 40% impervious area. Table 15 shows the breakdown of the subcatchment area and impervious area calculation.

As shown in Table 14, the total SWM storage required for this subcatchment is 907 m^3. The SWM storage for this area will be provided by “Type A” bioretention cells and two sections of superpipes in Street E.

A total of 7 sections of Type A bioretention cells with a total length of 148 meters will provide 320 m^3 of storage [(148*3*0.722) = 320m^3]. Bioretention cells will be equipped with a perforated subdrain pipe and Ditch Inlet Catch Basin (DICB) with appropriately sized orifice to fully utilize the storage. If a bioretention cell storage is fully utilized then

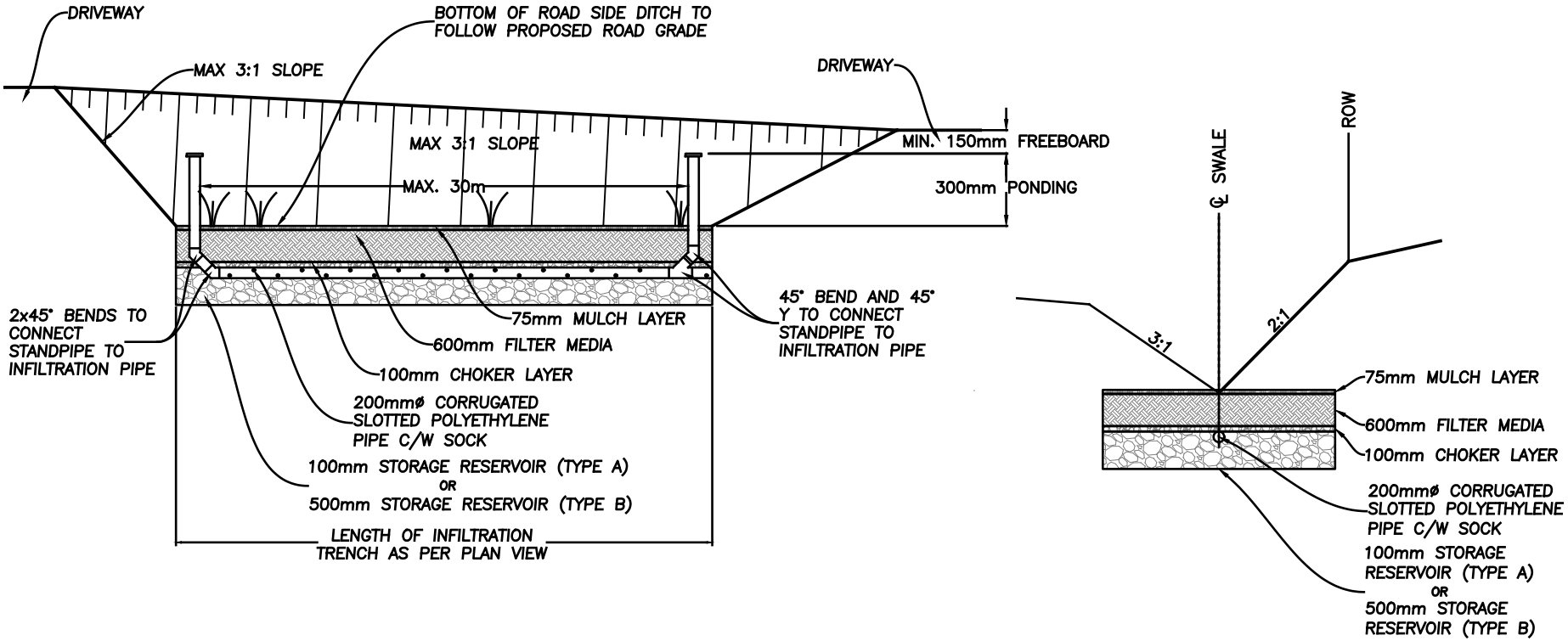
the overflow runoff will be captured by the downstream bioretention cells and then superpipes.

Table 15 Percentage Impervious Calculation of Subcatchment 406

Description	*Number of Units*	*Area (m^2)*
Total Area	-	33,271
Roads	-	4,784
Driveways	-	2,391
Single Detached Unit of 120m²	29	4,080
Single Detached Unit of 224 m²	0	-
Single Detached Unit of 60 m²	28	1,620
Patio and Shed in Single Detached Units	-	368
Cluster Units	-	-
Total Imperious Area	-	13,243
% Impervious	-	40 %

The remaining 670 m^3 storage will be provided by two sections of superpipes. Each superpipe section will be equipped with appropriately sized pipe orifices to fully utilize the storage. As shown in Table 14 the last section of superpipes will have a 215mm orifice and limit the post development flow in a 24-hour 100-year event to 0.167 m^3/s. Detail calculation has been included in Appendix B of the report.

All the runoff from this subcatchment ultimately drains to the last section of superpipes and discharge to Tributary 4 through SWM outfall (OF 4-1) as shown in Figure 9.



LONGITUDINAL PROFILE VIEW

CROSS–SECTION

CLIENT

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MUNICIPALITY

City of Burlington

SCALE

N.T.S.

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

BIORETENTION CELL DETAIL

DATE

August 2018

PROJECT NO.

P09006

FIGURE 10

5.4 Subcatchment 409

Post development Subcatchment 409 is located within “Sub Area 2b” as identified in the City of Burlington Official Plan. This area is a cluster housing development with 67% impervious area. Table 16 shows the impervious area calculation. As per the current draft plan this area consists of 123 cluster housing units.

Private on-site underground storage will serve as the SWM facility for this area. The on-site storage is designed to limit the post development flow rate to 0.105 m^3/s for a 24-hour 100-year return period storm event.

Table 16 Percentage impervious calculation of subcatchment 406

Description	***Number of Units***	***Area (m2)***
Total Area	-	28,710
Roads	-	0
Driveways	-	0
Single Detached Unit of 120m²	0	0
Single Detached Unit of 224 m²	0	0
Single Detached Unit of 60 m²	0	0
Patio and Shed in Single Detached Units	-	0
Cluster Units	-	19,235
Total Imperious Area	-	19,235
% Impervious	-	67

5.5 Subcatchment 415

Post development Subcatchment 415 is located south of Flatt Road within “Sub Area 10” as identified in the City of Burlington Official Plan. This area is 2.09 ha with 45% impervious area. Table 17 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan this area comprises 102 cluster housing units.

A private on-site underground storage equipped with OGS facility will serve as the SWM facility for this area. The onsite storage will limit the flow rate to 0.047 m^3/s for a 24 hour

100-year return period storm event. The total storage required for the area is 1,000 m^3. The outlet from the onsite storage is connected to superpipes and ultimately discharged to Tributary 4 through SWM outfall structure OF 4-3 as shown in Figure 9.

Table 17 Percentage Impervious Calculation of Subcatchment 415

Description	*Number of Units*	*Area (m^2)*
Total Area	-	20,922
Roads	-	2,735
Driveways	-	0
Single Detached Unit of 120m^2	29	0
Single Detached Unit of 224 m^2	0	0
Single Detached Unit of 60 m^2	28	0
Patio and Shed in Single Detached Units	-	0
Cluster Units	-	6,497
Total Imperious Area	-	9,232
% Impervious	-	45%

5.6 Subcatchment 418

Subcatchment 418 is located south of Flatt Road within “Sub Area 10” as identified in the City of Burlington Official Plan. This area comprises mostly single detached units with 32% impervious area. Table 18 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan this area consists of 32 single detached homes. SWM storage for this area will be provided by “Type A” bioretention cells and superpipes in Street X.

Hydrological modelling shows that to meet all requirements this area needs 1080 m^3 SWM storage. A total of 7 sections of bioretention cells with total length of 159 meters will provide 344 m^3 storage [(159*3*0.722) = 344 (m^3)]. Bioretention cells will be equipped with a perforated subdrain pipe and DICB with appropriately sized orifice to fully utilize the storage. The remaining 736 m^3 of storage will be provided by two sections of superpipes. The total length of superpipes is 175 meters, 2400mm X 1800mm concrete box culverts. Each superpipe section will be equipped with appropriately sized pipe orifices to fully utilize the storage. As shown in Table 14 the last

section of superpipes will have 250mm diameter orifice and limit the post development flow in a 24- hour 100-year event to 0.110 (m^3/s).

Table 18 Percentage Impervious Calculation of Subcatchment 418

Description	*Number of Units*	*Area (m^2)*
Total Area	-	29,583
Roads	-	3,939
Driveways	-	1,241
Single Detached Unit of 120m²	32	3,840
Single Detached Unit of 224 m²	0	
Single Detached Unit of 60 m²		
Patio and Shed in Single Detached Units	-	346
Cluster Units	-	
Total Imperious Area	-	9,366
% Impervious	-	32%

5.7 Area Within NEP Land

10 single family detached units north of hydro corridor along the east side of Horning Road have been draft approved. This area is within the Niagara Escarpment Plan (NEP). The draft plan approved in 1996 has not been changed for this area. As shown on the surficial geology and geotechnical map this area is situated on silty sand deposits, therefore all the runoff generated from this area will be treated only with LID measures. There are no SWM storage structures proposed within NEP area. The uncontrolled runoff generated from this area will be compensated with the over controlled post development runoff from other development (Subcatchment 509) to match pre and post development at Flatt Road.

Figure 11 shows the proposed development within this area with the surface geology information.

WATERDOWN ROAD

IRESON ROAD

HORNING ROAD

201.16
202.29
202.76
201.34

BH 111

BH 15 (1.5m)

HYDRO EASEMENT
HYDRO CORRIDOR

PIPELINE EASEMENT

NOTE:
DRAFT PLAN APPROVED
IN 1996 (NO CHANGE)

179.33
177.49
176.14

BH SM7 (3.4m)

BH 14 (5.35m)

SUBSURFACE
ONSITE SWM
STORAGE

186.00

BH 107 (8.85m)

BH SM4 (12.5m)

BH 13 (2.1m)

LEGEND

- AREA OF CONCERN
- LACUTRINE OUTWASH SAND
- SWM SUPERPIPE
- STM PIPE
- STM MANHOLE
- STM CATCH BASIN
- HEADWALL

CLIENT

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PROJECT
EAGLE HEIGHTS
HYDROLOGICAL STUDY
AND SWM REPORT

DWG
PROPOSED DEVELOPMENT WITHIN NEP
AREA & SURFACE GEOLOGY

DATE
August 2018

PROJECT NO.
P09006

FIGURE 11

5.8 Subcatchment 503

Post development Subcatchment 503 is situated along Horning Road at the northern most area of the proposed development. This area is within “Sub Area 1” as per the City of Burlington Official Plan. This area will have mostly single family units with 17% impervious area. Table 19 shows the breakdown of the subcatchment area and impervious area calculation.

As per the current draft plan this area consists of 18 single detached units. The rear half of 10 single residential units drain to Subcatchment 512 as sheet flow. The surface geological map and geotechnical investigation show this area is entirely situated on silty sand deposit with up to 12 meters silty sand deposit. Therefore, sheet flow from part of this area will not cause any issue as most of the runoff from the area will be absorbed (infiltrated) in the ground.

This area requires 1080 m^3 SWM storage. A total of 2 sections of Type B bioretention cells with total a length of 59 meters and will provide 128 m^3 storage [(59*3*0.722) = 128 m^3]. Bioretention cells will be equipped with a perforated subdrain pipe and DICB with appropriately sized orifice to fully utilize the storage.

The remaining 887 m^3 storage will be provided by two sections of superpipes. The total length of superpipes is 205 meters; 2400mm X 1800mm concrete box culverts. Each superpipe section will be equipped with appropriately sized pipe orifice to fully utilize the storage. As shown in Table 14, the last section of superpipes will have 250mm orifice and limits the post development flow in a 24- hour 100-year event to 0.110 m^3/s.

Table 19 Percentage Impervious Calculation of Subcatchment 418

Description	*Number of Units*	*Area (m^2)*
Total Area		32,935
Roads		2,607
Driveways		1,045
Single Detached Unit of 120m^2	8	960
Single Detached Unit of 224 m^2	0	-
Single Detached Unit of 60 m^2	10	600
Patio and Shed in Single Detached Units		87
Cluster Units		-
Total Imperious Area		5,299
% Impervious		17%

5.9 Subcatchment 506

Post development Subcatchment 506 is located at the southerly end of Horning Road. This area is within the "Sub Area 1" as per the City of Burlington Official Plan. This area has 0.80 ha drainage with 52% impervious area. Table 20 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan, this area consists of 70 cluster housing units.

A private on-site underground storage equipped with OGS will serve as the SWM facility for this area. The onsite storage will limit the flow rate to 0.019 m^3/s for a 24 hour 100-year return period storm event.

Table 20 Percentage Impervious calculation of Subcatchment 506

Description	*Number of Units*	*Area (m^2)*
Total Area		7,998
Roads		
Driveways		1,914
Single Detached Unit of 120m^2	0	
Single Detached Unit of 224 m^2	0	
Single Detached Unit of 60 m^2	0	
Patio and Shed in Single Detached Units		
Cluster Units		2,169
Total Imperious Area		4,083
% Impervious		52%

5.10 Subcatchment 509

Post development Subcatchment 509 is located within the “Sub Area 2b” as identified in the City of Burlington Official Plan. This area is has 1.00 ha drainage with 44% impervious area. Table 21 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan, this area consists of 26 units cluster housing units and 2 single detached residential units.

Private on-site underground storage equipped with OGS will serve as a SWM facility for this area. The on-site storage will limit the flow rate to 0.019 m^3/s for a 24 hour 100-year return period storm event.

Table 21 Percentage Impervious Calculation of Subcatchment 509

Description	*Number of Units*	*Area (m^2)*
Total Area		9,996
Roads		593
Driveways		1,301
Single Detached Unit of 120m^2	2	240
Single Detached Unit of 224 m^2	0	
Single Detached Unit of 60 m^2	0	
Patio and Shed in Single Detached Units		22
Cluster Units		2,186
Total Imperious Area		4,342
% Impervious		44%

5.11 Subcatchment 512

The post development subcatchment 512 extends from Horning to Flatt Road. Total area of this subcatchment is 39.50 ha, most of which will remain undeveloped. Table 22 shows the breakdown of the subcatchment area and impervious area calculation.

There are only eight single residential homes along Horning Road within NEP area within this subcatchment area which area already draft approved. Also, the rear half for 10 single residential homes along Horning Road drain to this catchment. The northwestern part of this catchment is situated on silty sand deposit as show in Figure 6. Therefore, runoff generated from this area will be mostly absorbed in the ground.

All proposed development within this catchment is proposed to drain uncontrolled via sheet flow and use of LIDs (where feasible).

Table 22 Percentage Impervious Calculation of Subcatchment 512

Description	*Number of Units*	*Area (m^2)*
Total Area		395,010
Roads		8,855
Driveways		4,690
Single Detached Unit of 120m^2	8	960
Single Detached Unit of 224 m^2		-
Single Detached Unit of 60 m^2	10	600
Patio and Shed in Single Detached Units		195
Cluster Units		3,689
Total Imperious Area		18,989
% Impervious		5%

5.12 Subcatchment 515

The post development Subcatchment 515 is along Flatt Road Extension which is within "Sub Area 5" as per the City of Burlington Official Plan.

Table 23 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan, this area consists of 31 single detached units. Only front half of 31 homes drain to the superpipes which will serve as SWM structures for this area.

This area requires 540 m^3 SWM storage. A total of 6 sections of Type B bioretention cells with a total length of 151 meters will provide 327 m^3 storage [(151*3*0.722) = 327 m^3]. Bioretention cells will be equipped with a perforated subdrain pipe and DICB with appropriately sized orifice to fully utilize the storage.

The remaining 298 m^3 storage will be provided by a section of superpipe. As shown in Table 14, the superpipes will have 130mm orifice and limits the post development flow

in a 24- hour 100-year event to 0.062 m^3/s. The total length of superpipes is 55 meters, 2400 X 1800 concrete box culverts.

Table 23 Percentage Impervious Calculation of Subcatchment 515

Description	*Number of Units*	*Area (m^2)*
Total Area		16,951
Roads		3,738
Driveways		1,192
Single Detached Unit of 120m^2		
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2	31	1,860
Patio and Shed in Single Detached Units		
Cluster Units		
Total Imperious Area		6,790
% Impervious		41%

5.13 Subcatchment 518

The post development Subcatchment 518 is located within Sub Area 6 as per the City of Burlington Official Plan. Total area of this Subcatchment is 5.97 ha with 31% impervious area.

Table 23 shows the breakdown of the subcatchment area and impervious area calculation. There are 141 cluster housing units and 21 single family condominium units proposed in this subcatchment.

The stormwater generated from this area will be managed with a SWM Pond. Table 25 shows the details of SWM pond design and rating curve information. Other details of the pond design have been included in Appendix B.

Table 24 Percentage Impervious Calculation of Subcatchment 518

Description	*Number of Units*	*Area (m^2)*
Total Area		59,665
Roads		3,869
Driveways		3,920
Single Detached Unit of 120m^2	21	2,520
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2		
Patio and Shed in Single Detached Units		227
Cluster Units		7,541
Total Imperious Area		18,077
% Impervious		31%

Table 25 SWM Pond 5A Design Table

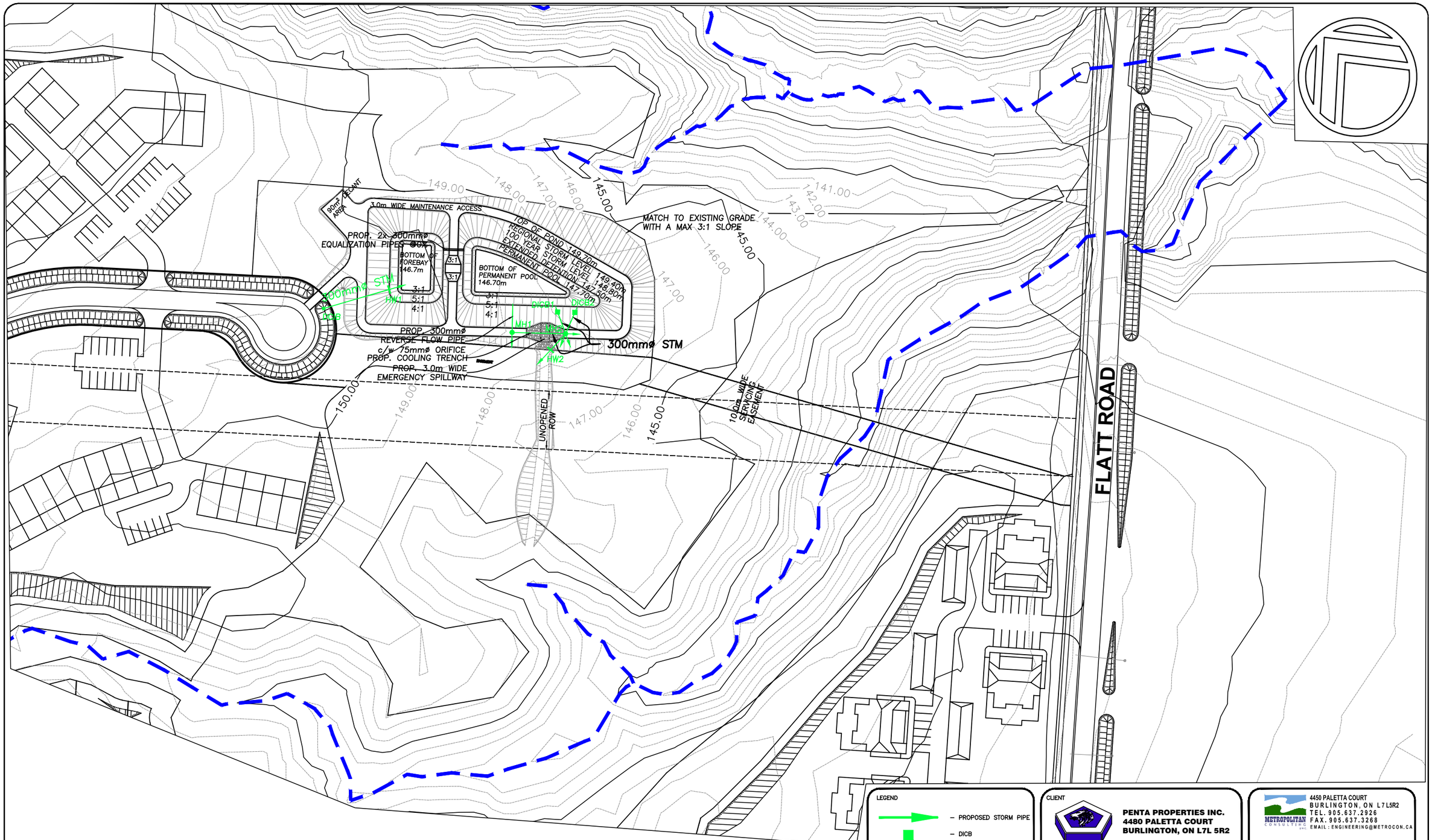
C_{pipe} =	0.63
C_{weir} =	1.48
C_{DICB} =	1.71

	Orifice Quality	Emergency Weir	DICB	Orifice 1
Pipe diameter (m)	0.075			0.180
L = Weir Width (m)		3.00	1.20	
A = Area of pipe (m^2)	0.0044			0.0254

Designed by: N. Pokharel, P.Eng.
Date: 15-May-18

	MAIN BODY OF THE POND														DETENTION TIME			
DESCRITION	Stage	Depth to Permanent Pond Level	Qout Emergency weir	Q_{out} DICB	Q_{out} DICB with orifice	Q_{out} quality	Total flow Qout	Pond Surface Area	Incremental Storage	Active Storage	Flow rate (SWMHYMO)	Required Storage (SWMHYMO)	Allowed release	Total Storage	Incremental Time	Cumulative Time	CummulativeTime	
	(m)	(m)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^2)	(m^3)	(m^3)	(m^3/s)	(m^3)	(m^3/s)	(m^3)	(Sec)	(Sec)	(hr)	
Top of Pool	149.70	**2.00**	**1.57**	7.540	0.196	0.017	1.783	3014	281	3873				4588	157	133,743	37	
	149.60	**1.90**	**1.12**	**6.798**	**0.191**	**0.017**	1.331	2921	270	3593				4307	203	133,586	37	
Regional	149.50	**1.80**	**0.73**	**6.083**	**0.186**	**0.016**	0.932	2828	260	3322				4037	280	133,383	37	
	149.40	**1.70**	**0.40**	5.395	0.180	0.016	0.593	2736	251	3062				3777	423	133,103	37	
	149.30	**1.60**	**0.14**	4.735	**0.175**	**0.015**	0.330	2643	241	2811				3526	730	132,681	37	
100-Year	149.20	**1.50**	**0.00**	4.104	0.169	0.015	0.184	2550	232	2570				3285	1,262	131,951	37	
	149.10	**1.40**		3.504	**0.163**	**0.014**	0.177	2457	222	2338				3053	1,256	130,689	36	
	149.00	**1.30**		2.937	0.156	0.014	0.170	2364	213	2116				2831	1,253	129,433	36	
	148.90	**1.20**		2.404	**0.150**	**0.013**	0.163	2272	204	1903				2618	1,253	128,180	36	
	148.80	**1.10**		1.907	**0.143**	**0.013**	0.155	2179	195	1699				2414	1,257	126,927	35	
	148.70	**1.00**		1.451	0.135	0.012	0.148	2086	187	1504				2219	1,265	125,671	35	
	148.60	**0.90**		1.038	**0.128**	**0.011**	0.139	1993	178	1317				2032	1,279	124,406	35	
	148.50	**0.80**		0.674	0.120	**0.011**	0.130	1900	170	1139				1854	1,302	123,127	34	
	148.40	**0.70**		0.367	0.111	0.010	0.121	1808	162	969				1684	1,336	121,825	34	
	148.30	**0.60**		0.130	0.101	0.009	0.111	1715	154	807				1522	1,388	120,488	33	
Extended detention	148.20	**0.50**		**0.000**	**0.000**	**0.008**	**0.008**	1622	146	654				1369	**17,389**	**119,100**	**33**	**>24HOURS**
	148.10	**0.40**				**0.007**	0.007	1529	138	508				1223	18,605	101,711	28	
	148.00	**0.30**				**0.006**	0.006	1436	131	370				1085	20,673	83,106	23	
	147.90	**0.20**				0.005	0.005	1344	123	239				954	24,792	62,433	17	
	147.80	**0.10**				0.003	0.003	1251	116	116				831	37,640	37,640	10	
Top of Permanent Pool	147.70	**0.00**				**0.000**	**0.000**	1158	-	0				715	-	-	-	

								PERMANENT POOL			SEDIMENT FOREBAY							
								Pond Surface Area (m^2)	Incremental Storage (m^3)	Total Storage (m3)	Surface Area (m^2)	Incremental Storage (m^3)	Total Storage (m3)	Total Storage (m3)				
Top of Permanent Pool	147.7	**0.00**						726	54	357	**432**	**43**	357	715				
	147.6	-0.10						682	49	304	432	42	304	608			-	
	147.5	-0.20						637	44	255	402	39	255	510				
	147.4	-0.30						593	40	211	372	36	211	421			-	
	147.3	-0.40						548	36	171	341	33	171	341				
	147.2	-0.50						504	32	135	311	30	135	270				
	147.1	-0.60						460	29	103	281	27	103	206				
	147	-0.70						415	27	74	251	24	74	148				
	146.9	-0.80						371	25	47	220	21	47	95				
	146.8	-0.90						326	23	23	190	18	23	45				
	146.7	**-1.00**						282	-	-	160	-	0	-				



LEGEND

- PROPOSED STORM PIPE
- DICB
- MH
- RIP-RAP SPILLWAY
- 3:1 SLOPE (typ.)
- CREEK

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

GENERAL LAYOUT OF SWM POND 5A

DATE: August 2018

PROJECT NO.: P09006

FIGURE 12

5.14 Subcatchment 603

No development is proposed within subcatchment 603. As shown in the surface geological map, Figure 6, most of this area sits on silty sand deposits. Therefore, this area does not generate significant runoff. The runoff generated from this area will be collected and managed through the superpipes in downstream subcatchment 606.

5.15 Subcatchment 606

Post development Subcatchment 606 is located within “Sub Area 5” as per the City of Burlington Official Plan. This subcatchment consists of single detached homes. The total drainage area of this subcatchment is 2.46 ha with 28% impervious area. Table 26 shows the breakdown of the subcatchment area and impervious area calculations.

The total SWM storage required for the area is 864 m^3. A total of 7 sections of Type B bioretention cells with a total length of 155 meters will provide 335 m^3 storage [(155*3*0.722) = 335 m^3].

The remaining 529 m^3 storage will be provided by superpipes. The total length of superpipes is 125 meters; 2400mm X 1800mm concrete box culverts. As shown in Table 14, the last section of superpipes will have 150mm orifice and limits the post development flow in a 24-hour 100-year event to 0.082 m^3/s. The post development runoff is discharged to the west branch of Tributary 6 through SWM outfall structure OF 6-1 as shown in Figure 9.

Table 26 Percentage Impervious Calculation of Subcatchment 606

Description	*Number of Units*	*Area (m^2)*
Total Area		24,599
Roads		2,093
Driveways		960
Single Detached Unit of 120m^2	23	2,760
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2	11	660
Patio and Shed in Single Detached Units		368
Cluster Units		
Total Imperious Area		6,841
% Impervious		29%

5.16 Subcatchment 609

Post development Subcatchment 609 is located within “Sub Area 5” as per the City of Burlington Official Plan.

This area is a cluster housing development with 58% impervious area. Table 27 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan, this area will have 36 cluster housing units. Private on-site underground storage equipped with an OGS will serve as a SWM facility for this area. The onsite storage will limit the flow rate to 0.019 m^3/s for a 24 hour 100-year return period storm event. The runoff from this area will also be discharged to West Branch of Tributary 6 through SWM Outfall OF-6 as shown in Figure 9.

Table 27 Percentage Impervious Calculation of Subcatchment 609

Description	*Number of Units*	*Area (m^2)*
Total Area		4,588
Roads		
Driveways		1,102
Single Detached Unit of 120m^2		
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2		
Patio and Shed in Single Detached Units		
Cluster Units		1,534
Total Imperious Area		2,636
% Impervious		58%

5.17 Subcatchment 615

Post development Subcatchment 615 is located within “Sub Area 7” as per the City of Burlington Official Plan. This area is a cluster housing development with 25 % impervious area. Table 28 shows the breakdown of the subcatchment area and impervious area calculation. As per the current draft plan this area will have 48 cluster housing units.

A private on-site underground storage equipped with an OGS will serve as the SWM facility for this area. The onsite storage will limit the flow rate to 0.043 (m^3/s) for a 24 hour 100-year return period storm event. The outlet from the on-site storage will be connected to superpipes in Street A and ultimately discharged to Tributary 6 upstream of Flatt Road through SWM Outfall OF6-3 as show in Figure 9.

Table 28 Percentage Impervious Calculation of Subcatchment 615

Description	*Number of Units*	*Area (m^2)*
Total Area		13,292
Roads		
Driveways		968
Single Detached Unit of 120m^2		
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2		
Patio and Shed in Single Detached Units		
Cluster Units		2,355
Total Imperious Area		3,323
% Impervious		25%

5.18 Subcatchment 618

Post development Subcatchment 618 is also located within “Sub Area 7” as per the City of Burlington Official Plan. This area is a cluster housing development with 39% impervious area.

Table 29 shows the breakdown of the subcatchment area and impervious area calculations. As per the current draft plan, this area will have 52 cluster housing units.

A private on-site underground storage equipped with an OGS will serve as the SWM facility for this area. The on-site storage will limit the flow rate to 0.039 m^3/s for a 24 hour 100-year return period storm event. The outlet from the on-site storage will be discharged to Tributary 6 upstream of Flatt Road through SWM outfall OF6-2 as shown in Figure 9.

Table 29 Percentage Impervious Calculation of Subcatchment 618

Description	Number *of* Units	Area (m^2)
Total Area		10,234
Roads		
Driveways		1,167
Single Detached Unit of 120m^2		
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2		
Patio and Shed in Single Detached Units		
Cluster Units		2,752
Total Imperious Area		3,919
% Impervious		39 %

5.19 Subcatchment 621

Post development Subcatchment 621 is also located within "Sub Area 7" as per the City of Burlington Official Plan. This subcatchment will have single detached residential units. The total drainage area of this subcatchment is 3.53 ha with 34% impervious area. Table 30 shows the breakdown of the subcatchment area and impervious area calculation.

The total SWM storage required for the area is 1,123 m^3 SWM storage. A total of 8 sections of Type B bioretention cells with a total length of 274 meters will provide 725 m^3 storage [(274*3**0.882) = 725 (m^3)].

Bioretention cells will be equipped with a perforated subdrain pipe and DICB with appropriately sized orifice to fully utilize the storage. As shown on surface geological drawing this area is situated entirely on silty sand deposits with high infiltration capacity.

The remaining 685 m^3 storage will be provided by superpipes. As shown in Table 14 the last section of superpipes will have a 180mm diameter orifice and limits the post development flow in a 24- hour 100-year event to 0.118 m^3/s. The runoff from this area will also be discharged to Tributary 6 upstream of Flatt Road through SWM outfall OF 6-3 as shown in Figure 9.

Table 30 Percentage Impervious Calculation of Subcatchment 621

Description	*Number of Units*	*Area (m^2)*
Total Area		35,265
Roads		3,964
Driveways		2,205
Single Detached Unit of 120m^2	35	4,200
Single Detached Unit of 224 m^2	0	-
Single Detached Unit of 60 m^2	16	960
Patio and Shed in Single Detached Units		378
Cluster Units		
Total Imperious Area		11,707
% Impervious		34%

5.20 Subcatchment 634

Post development Subcatchment 634 is located on the Northwest corner of Flatt Road and Flatt Road Extension, which is within “Sub Area 8” as per the City of Burlington Official Plan. Total area of the Subcatchment is 0.89 ha with 45% impervious area. Table 31 shows the breakdown of the subcatchment area and impervious area calculation.

As per the current draft plan this area consists of 26 cluster housing units. A private on-site underground storage equipped with an OGS will serve as the SWM facility for this area. The onsite storage will limit the flow rate to 0.032 m^3/s for a 24 hour 100-year return period storm event. The controlled flow released from on-site storage will be then discharged to the Tributary 6 upstream of Flatt Road through SWM outfall OF 6-4 as shown in Figure 9.

Table 31 Percentage Impervious Calculation of Subcatchment 634

Description	*Number of Units*	*Area (m^2)*
Total Area		8,896
Roads		878
Driveways		960
Single Detached Unit of 120m²	0	-
Single Detached Unit of 224 m²	0	-
Single Detached Unit of 60 m²	0	-
Patio and Shed in Single Detached Units		-
Cluster Units		2,108
Total Imperious Area		3,946
% Impervious		45 %

5.21 Subcatchment 636

Post development Subcatchment 636 is located on the Northeast corner of Flatt Road and Flatt Road Extension, which is within “Sub Area 8” as per the City of Burlington Official Plan. Total area of the Subcatchment is 1.24 ha with 39% impervious area. Table 32 shows the breakdown of the subcatchment area and impervious area calculation.

As per the current draft plan, this area consists of 44 cluster housing units. A private on-site underground storage equipped with an OGS will serve as a SWM facility for this area. The on-site storage will limit the flow rate to 0.043 (m^3/s) for a 24 hour 100-year return period storm event. The controlled flow released from on-site storage will be then discharged to Tributary 6 upstream of Flatt Road through SWM outfall OF 6-4 as shown in Figure 9.

Table 32 Percentage Impervious Calculation of Subcatchment 636

Description	*Number of Units*	*Area (m^2)*
Total Area		12,414
Roads		758
Driveways		960
Single Detached Unit of 120m^2		
Single Detached Unit of 224 m^2		
Single Detached Unit of 60 m^2		
Patio and Shed in Single Detached Units		
Cluster Units		3,018
Total Imperious Area		4,736
% Impervious		39 %

6.0 WATERSHED MODELLING WITH GAWSER

The GAWSER (Guelph All-Weather Sequential Events Runoff) model is a deterministic hydrologic watershed model based on the HYMO format. The GAWSER program has been applied widely in Ontario for planning, design, real-time flood forecasting and evaluating the effects of physical changes in the drainage basin (Schroeter & Associates, 1996). The GAWSER program is capable of continuous hydrologic long-term simulations (e.g. 50-60 years) as well as shorter periods in event mode (e.g. 24, 48 hours). In this, GAWSER will be primarily applied to evaluate the pre and post development water balance calculations, erosion assessments and sizing of SWM storage facilities.

6.1 OVERVIEW OF MODELLING PROCEDURES

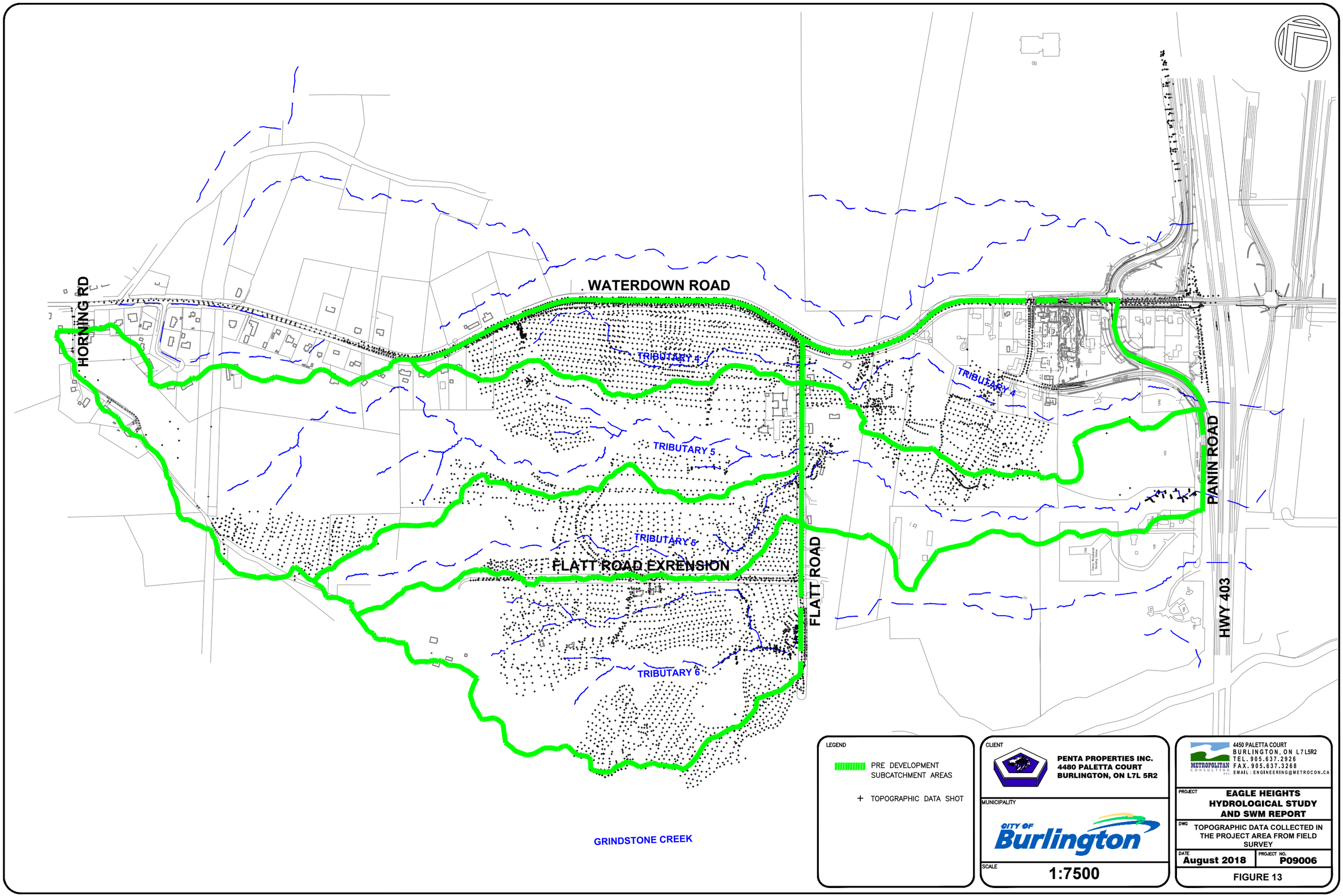
The analysis of existing hydrologic conditions in Eagle Heights was carried out using the GAWSER program, a deterministic watershed model based on the HYMO format.

Schroeter and Associates (1993) modelled all the watersheds within the boundaries of Conservation Halton as part of a flood forecast model set-up project. Cosburn Pattern and Warden (1994) applied the model in the Grindstone Creek Subwatershed Study which includes the Eagle Heights Project area, and EWRG (1997) revised the 1993 and 1994 models making use of new land cover and soils information, and additional streamflow data for calibration and validation of the model.

The present hydrologic model provides an update to 1994 and 1997 work using GAWSER for Eagle Heights incorporating new available information in the project area. As a part of this study, detailed physical characteristics of the catchment have been updated using information collected since 1997. A survey crew spent over three weeks in the project area to collect detailed topographic information. Figure 13 shows the extent of field data collection activities on the project area.

Moreover, a fairly accurate Digital Elevation Model (DEM) from the Southwestern Ontario Orthophotography Project (SWOOP) 2002 has been used in the area where field surveyed topography was not possible to obtain or was not available. Although new DEM information collected from the recent years are available within the watershed area, it is not different than SWOOP 2002 especially since there are little or no changes on the landuse within the study area since 2002.

Some recent colour aerial imageries [Southwestern Ontario (SWOOP) 2015] of the study area were obtained from Ministry of Natural Resources and Forestry (MNRF). According to the information provided by the MNRF, these colour aerial imageries were collected between April 12th and May 23rd 2015. The colour aerial imageries were used mostly to obtain land coverages and land use information. Other physical characteristic generated and calculated from the topographic survey and DEM information were channel cross-sections, channel lengths, channel slopes and subcatchment drainage areas. Response unit drainage characteristics for modelling GAWSER were obtained from surficial geology information and geotechnical investigation (boreholes) carried out in the project area by Peto MacCallum Ltd in 2003 and 2006, and by Soil-Mat Engineers in 2017.



LEGEND

PRE DEVELOPMENT SUBCATCHMENT AREAS

\+ TOPOGRAPHIC DATA SHOT

CLIENT

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

TOPOGRAPHIC DATA COLLECTED IN THE PROJECT AREA FROM FIELD SURVEY

DATE

August 2018

PROJECT NO.

P09006

FIGURE 13

6.2 MODEL SET-UP IN GAWSER

6.2.1 *Delineation of subcatchment boundaries*

The Eagle Heights area and upstream drainage that pass through the study areas and some areas downstream of the project areas have been divided into 6 subcatchments for hydrologic modelling purposes as shown on Figure 14.

As noted earlier in this report, there are three tributaries that flow through Eagle Heights, which are labelled as Tributary 4, Tributary 5 and Tributary 6. Tributary 5 has two branches of tributaries, Tributary 5 East and Tributary 5 West, which meet just downstream of Flatt Road, and Tributary 6 also has two branches of tributaries, Tributary 6 East and Tributary 6 West, which meet approximately 150 meters upstream of Flatt Road.

The downstream boundary for modelling purposes for Tributary 6 has been set at Flatt Road. Tributary 6 downstream of Flatt Road will not be affected by the proposed development. For Tributary 5 and Tributary 4, the downstream boundary for modelling has been set at the culverts at Panin Road. The total drainage area covered by the watershed model for existing conditions is 148.87 ha.

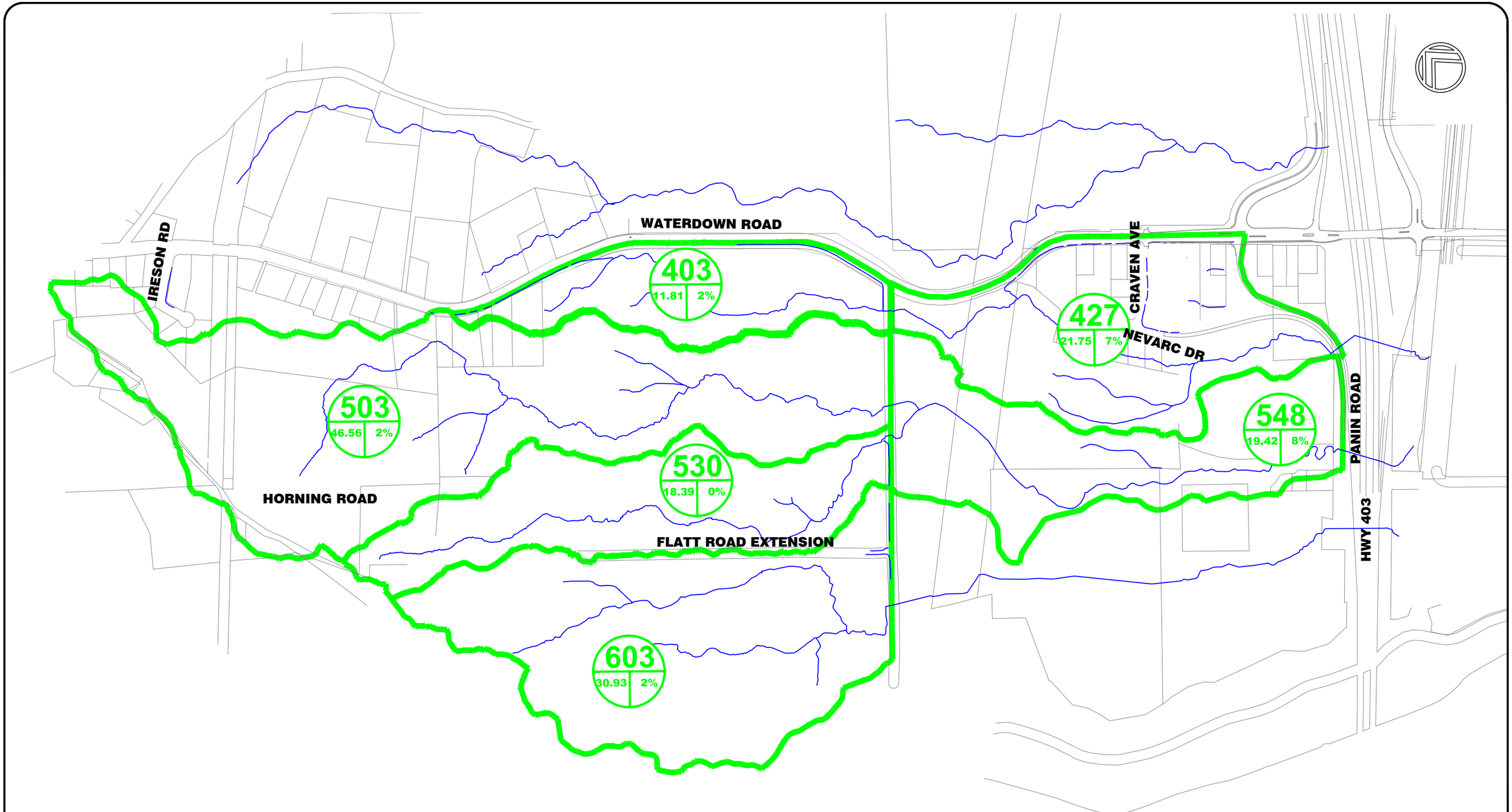
Subcatchment boundaries were generated in AutoCAD Civil 3D using the topographic information, from which drainage areas, channel lengths and wetlands surface areas were measured. Information on surficial geology was transferred to the base map so it would be overlaid on the subcatchment boundaries, from which soil types were determined.

A recent colour aerial imagery [Southwestern Ontario (SWOOP) 2015] of the study area was obtained from the MNRF. These colour aerial imageries were collected between April 12th and May 23rd 2015, and were used mostly to obtain land coverages and land uses (e.g. forest, farmland, landscaped area, etc.).

The total drainage area considered in the hydrological model was found to be 148.87 ha, of which 106 ha is owned by Penta Properties Inc. and 42.87ha is external drainage. The subject property comprises 3.78 ha land north of Hydro-Corridor, 93.26 ha situated between hydro-corridor and Flatt Road and about 8.95 ha land south of Flatt Road.

The drainage area north of Flatt Road for each tributary is lumped as one subcatchment area and the area between Flatt Road and Panin Road is also lumped into one Subcatchment for Tributary 5 and Tributary 6. Two channel routing reaches downstream of Flatt Road were modelled to account for channel routing effects

Figure 15 gives a schematic representation of the watershed model used herein. Figure 16 shows the surface geology of the study area superimposed on subcatchment areas.



LEGEND

603 (30.93 | 2%) — CATCHMENT; AREA (ha); PERCENTAGE IMPERVIOUS

PRE DEVELOPMENT SUBCATCHMENT AREAS

CLIENT

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PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

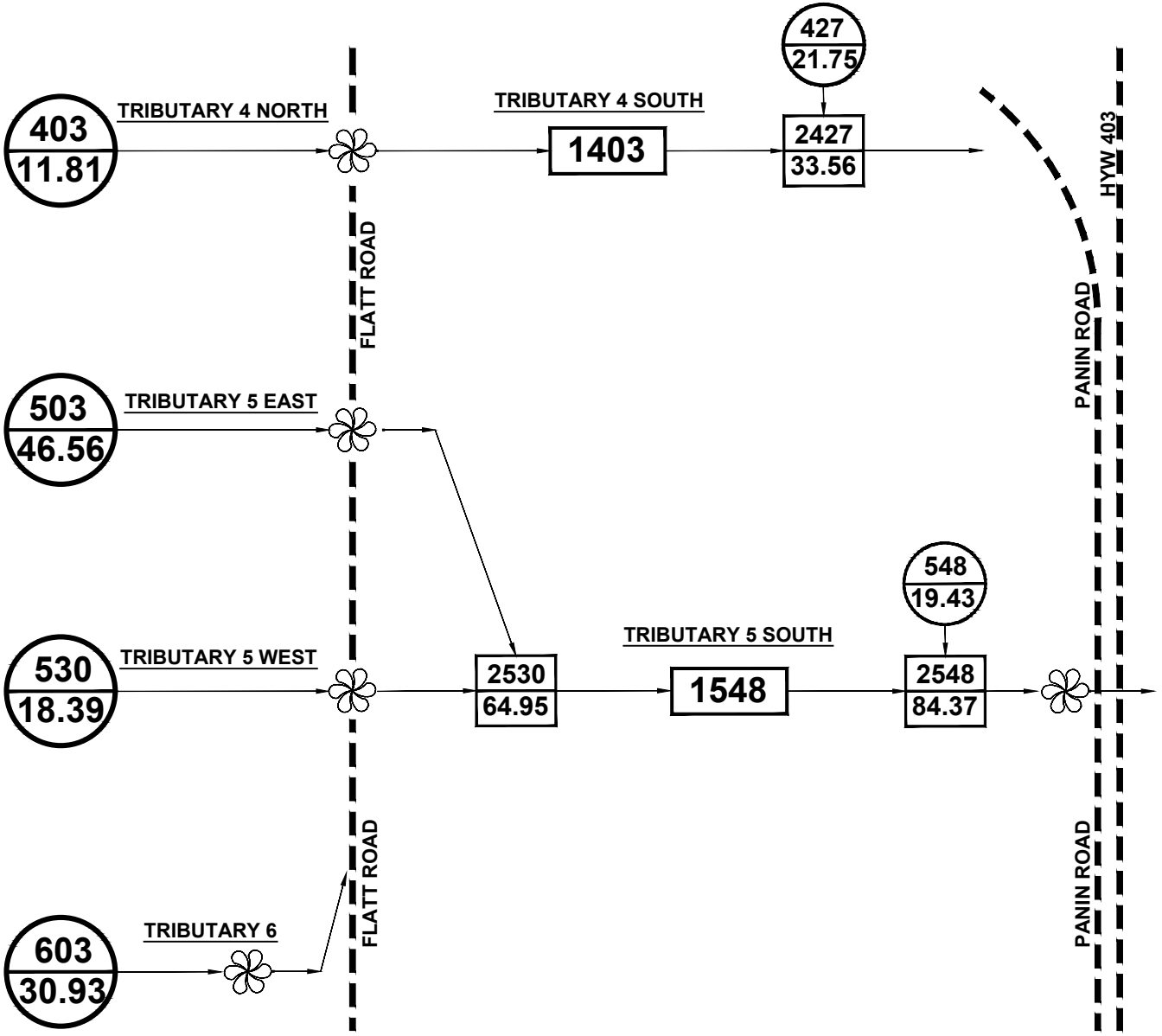
DWG

PRE-DEVELOPMENT DRAINAGE SUBCATCHMENTS

DATE: August 2018

PROJECT NO.: P09006

FIGURE 14



LEGEND

548 / 19.42 CATCHMENT ID / AREA (ha)

2548 / 84.37 ADDITION ID / AREA (ha)

1548 CHANNEL

FLOW MONITORING

CLIENT

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PROJECT

EAGLE HEIGHTS
HYDROLOGICAL STUDY
AND SWM REPORT

DWG

SCHEMATIC OF GAWSER
MODEL PRE-DEVELOPMENT
CONDITIONS

DATE: August 2018

PROJECT NO.: P09006

FIGURE 15

WATERDOWN ROAD

Pre-development Tributary 4 North Area = 11.81 ha.

Pre-development Tributary 4 South Area = 21.75 ha.

Pre-development Tributary 5 East Area = 46.56 ha.

Pre-development Tributary 5 West Area = 18.39 ha.

Pre-development Tributary 5 South Area = 19.43 ha.

Pre-development Tributary 6 Area = 30.93 ha.

FLATT ROAD

FLATT ROAD EXRENSION

PANIN ROAD

BH 111
BH 15 (1.5m)
BH 12
BH 11
BH 110
BH 109
BH 108
BH 9
BH 8
BH SM6
BH SM5
BH 10
BH SM7 (3.4m)
BH 13 (2.1m)
BH 14 (5.35m)
BH SM4 (12.5m)
BH 107 (8.85m)
BH 7
BH 106 (2.15m)
BH 2
BH SM3
BH 5
BH 6
BH 105
BH 1 (4.7m)
BH 3 (2.9m)
BH 4 (2.9m)
BH SM2 (4.8m)
BH 104 (4.0m)
BH SM1 (6.7m)
BH 103 (1m)
BH 16
BH 17
BH 18
BH 102
BH 21
BH 20
BH 19
BH 101

LEGEND

- PRE–DEVELOPMENT DRAINAGE AREA
- BEACH GRAVEL
- *SILT TILL, SILTY CLAY*
- SHALE, DOLOSTONE
- STREAM DEPOSITS
- FILL
- *SILTY SAND DEPOSIT*
- BH 3 — BOREHOLE LOCATION PETO MACCALLUM LTD 2003
- BH 104 — BOREHOLE LOCATION PETO MACCALLUM LTD 2006
- BH SM1 — BOREHOLE LOCATION SOIL–MAT 2017

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PROJECT
EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG
SURFACE GEOLOGY & BOREHOLES

DATE
August 2018

PROJECT NO.
P09006

FIGURE 16

2.2.2 Soil and land cover characteristics

To account for the wide variation in runoff generation response attributed to different land cover features and soil types, the subcatchment elements were further subdivided into nine 'hydrologic response units' (HRUs); one impervious and eight pervious. The HRUs defined in Table 33 below were originally established in the Bronte Creek Hydrology and Geomorphology Study (PEI, 2002), and adopted here.

HRUs 2 and 3 have not been used in this modelling as those land coverages are not prominent within this study area.

Table 33 Response units considered in the hydrologic model

Hydrologic Response Unit (HRU)	Description (Vegetation / Soil type)
1	Impervious Surfaces (includes open water & exposed bedrock areas)
2	Wetland areas (not used in this case)
	Low Vegetative Cover (includes farmland and landscaped area)
3	Peat and muck (not used in this case) =====>contributes to SS
4	Silt Till, Silty Clays (farmland) =====>contributes to SS
5	Silt Till, Silty Clays (landscaped area) =====>contributes to SS
6	Sand, Gravel, minor Silt and Clay (farmland) =====> contributes to GW
7	Sand, Gravel, minor Silt and Clay (landscaped area =====>contributes to GW
	High Vegetative Cover (Forests)
8	Low infiltration (includes soils in response units 4 to 6)
9	High infiltration (includes soils in response units 5 and7)

Farmland and landscaped areas were considered low vegetation cover areas. For existing conditions, about 48% (72 ha) of modelled drainage is covered with forest and the remaining 52% drainage is covered with farmland, landscaped area and impervious areas.

As shown in Figure 16 the land cover and soil type maps were overlaid on the subcatchment boundary map, from which the area contributing to each response unit

group within a subcatchment could be measured directly. The impervious areas include buildings, driveways, roads and adjoining shoulders which were calculated from the aerial imagery (SWOOP 2015).

6.2.2 *Response unit drainage characteristics*

Each pervious zone or response unit in GAWSER is considered as two soil layers (Figure 17). The top or first layer has specified thicknesses up to 300 mm (in the soils examined to date), which typically corresponds to the 'A' horizon (e.g. Chapman and Putman, 1984). The thickness of the second layer is usually set in the range of 250 to 1250 mm, depending on whether the response unit contributes to subsurface flow or groundwater storage. The second layer generally corresponds to the 'B' horizon.

Rainfall (or snowmelt) falling on a response unit is separated into overland runoff and infiltrated components (Figure 18). The term infiltration is used here to describe the rate of water movement downward through the soil surface. Seepage indicates the water movement downward from the bottom of the first soil layer into the second layer, whereas percolation refers to the downward movement out of the bottom of the second layer of a response unit. Percolated water appears as subsurface flow (e.g. tile drainage) in response units assumed to contribute to this storm flow component, or to groundwater baseflow in all other response units. The rate of water movement into each soil layer (either from rainfall, snowmelt, or soil-water) depends on the drainage characteristics of each soil layer. The selection of these drainage characteristics is fully explained below.

Previously published values were employed wherever possible as first estimates for most parameters. Generally, parameter values were selected from a review of values given in Watt et al. (1989, chapter 8) for like soil groups and land cover types. However, where published values do not exist, starting values were assumed based on field observations and experience. In this study, calibrated drainage characteristics were available from the recently completed South Waterdown Subwatershed Study

(Schroeter & Associates, 2005), Bronte Creek Hydrology and Geomorphology Study (PEI, 2002), the Grindstone Creek Water Resources Support Study (EWRG, 1997), and the Halton Region Integrated Flood Forecast System (HRIFFS) – Final Technical Report (Schroeter & Associates, 1993).

Initially, some parameters (e.g. saturated soil-water content, field capacity soil-water content) were believed to have different values for each soil layer within a response unit type. GAWSER has been structured to allow independent specification of such parameters for each response unit and soil layer, but as first estimates (except when obvious differences are identified, e.g. hydraulic conductivity for clay over sandy soils), the same parameter values are used for all layers in a given response unit.

Soil Layer Thickness, HI and HII (mm): Generally, the first soil layer is set at 200 mm for well-drained soils, and 100 mm for poorly drained soils. The second soil layer is generally set at 600 mm for response units that contribute to subsurface flow and 1000 mm for those that contribute to groundwater storage. The soil layer thicknesses listed in Table 34 were selected based on information given on the surficial geology maps, aerial imagery, reports and previous experiences

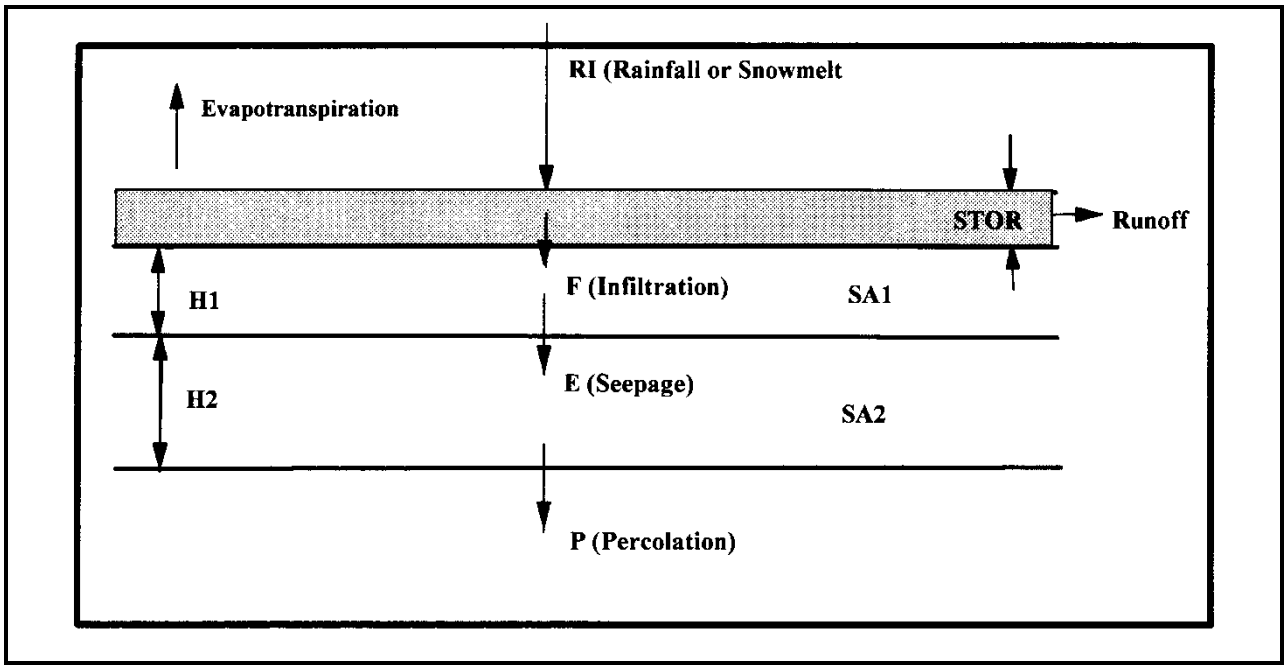


Figure 17 Two-layer soil concept used in runoff generation model

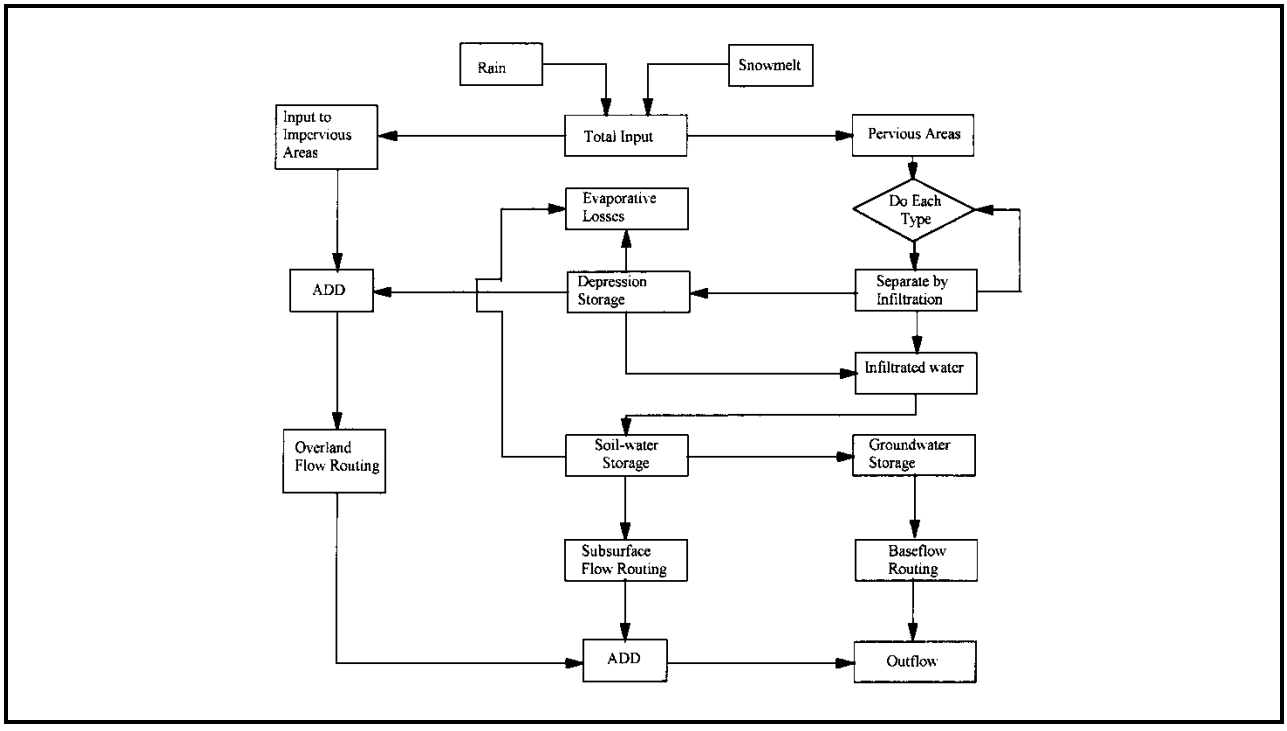


Figure 18 Flow chart for runoff generation and subwatershed modelling

Maximum depth of interception storage, INC (mm):

This represents the depth of water that is intercepted and held on the surface of vegetative growth (e.g. leaves), and gradually depleted by evapotranspiration only. It depends on the type of vegetative surfaces, with forest cover having the largest values. Typical values were determined by Schroeter and Boyd (1998).

Maximum depth of depression storage, DS (mm):

This parameter represents the maximum depth that water can pond temporarily on the surface of a response unit, and is gradually depleted by evaporation or infiltration. It depends on surface topography (e.g. potholes, slope) and vegetative cover. For example, a relatively smooth surface (no potholes) on grade so that water does not remain ponded after a heavy rainfall would have a depressional storage value of 1 to 5 mm. The values selected were taken from a review of Table 8.1 in the Hydrology of Floods in Canada (Watt et al., 1989).

Effective hydraulic conductivity, KEFF (mm/h) at the soil surface:

In some publications, this parameter is referred to as the 'net infiltration capacity' of a soil, and is a function of soil type and vegetative cover. For instance, in Table 8.4 of Watt et al. (1989), KEFF=1.3 mm/h for a fine textured clay with bare ground cover. This same table suggests KEFF for the same soil with "good pasture" cover is 5.0 mm/h and 6.4 mm/h with forest cover.

Maximum seepage rate, CS (mm/h) and maximum percolation rate, D (mm/h):

These control soil-water movement out of the first and second soil layers. They are a function of the soil hydraulic conductivity in each layer, which generally, decreases with depth in the unsaturated zone (the area above the water table). This happens because the macro pores (caused by roots, worm holes, cracks, bugs) are larger near the

surface, yielding a higher hydraulic conductivity. With depth, the macro pores decrease, and so the conductivity is reduced.

Since there is no detailed information about the hydraulic conductivity of the soils in each response unit just a few meters from the surface, these parameters are estimated from the KEFF values. In earlier applications of GAWSER (see Schroeter & Associates, 1996), the percolation rate (D) was estimated as half of KEFF, with CS being set at some value between D and KEFF, or CS=0.5*(KEFF+D). Recent applications in the moraine areas (see Schroeter et al., 2003), suggest percolation rates (D) should be set much less than KEFF/2, more like KEFF/10 or KEFF/20. In this study, the percolation rates were set at D=KEFF/10, and CS=0.75*KEFF.

Average suction at the wetting front, SAV (mm):

This is a parameter in the Green and Ampt infiltration formula (see Eq. [A.18], GAWSER Training Guide). It can be estimated from soil-water characteristic curves, a plot of volumetric water content versus pressure head, which can be measured in a laboratory using soil samples taken in the field. In the absence of detailed information, previously published estimates of SAV will suffice. Mein and Larsen (1973) and Skaggs (1982) give representative values of SAV for several different soil types. The values selected in Table 34 were taken from a review of these documents.

Soil-water contents; saturated, SMC; field capacity, FCAP; and Wilting point, WILT:

They are important for defining the amount of water stored in each soil layer of a response unit. Each variable is defined separately below.

The saturated soil-water content, SMC (vol/vol) is the condition of the soil when all the void space is filled with water and no storage is available. Any infiltration into a saturated top soil layer must equal the seepage, the rate at which soil-water leaves the bottom of the first soil layer. Any seepage to a saturated second layer must equal the

percolation rate to subsurface or groundwater storage. Generally, the saturated soil-water content is estimated by the porosity of the soil.

The field capacity soil-water content, FCAP (vol/vol) is the condition where the soil void space contains the maximum residual water that can be held by capillary forces after gravity drainage. When soil-water characteristics are available, FCAP is estimated at a pressure head of 0.33 bar.

The wilting point soil-water content, WILT (vol/vol) is the amount of water contained in the void spaces that cannot be removed by evaporation. This water is held by the capillary forces. WILT can be estimated from soil-water characteristic curves, and is defined at a pressure head of 15 bar.

Typical values of SMC, FCAP and WILT for various soil types are listed in Table 8.2 of Watt et al. (1989). The values selected here were taken directly from this source.

Although it is possible in GAWSER to specify separate values of SMC, FCAP and WILT for each soil layer, they were set equal as first estimates. This means, for instance, that the SMC used for layer 1 (e.g. SMCI) was also used for layer 2 (SMCII).

Initial soil-water content, IMC (vol/vol): This variable specifies how much soil-water is present in a soil layer at the start of the simulation. In most GAWSER applications to date, IMC is set equal to FCAP for that layer. Actual values of IMC used in the calculations are set by applying an adjustment factor (in this case FIMCI or FIMCII).

Selected values for the response unit drainage characteristics are summarized in Table 34. They represent mid-summer (around July 30th) values.

Table 34 Pre-Development Hydrologic response unit drainage characteristics

						Low Vegetative Cover				*Forest Cover*	
						Farmland		**Landscaped**			
Symbol	**Description**	**Units**	**Imp**	**Wet Lands**	**Peat Muck**	**Silty Clays**	**Sand/ Gravel**	**Silty Clays**	**Sand/ Gravel**	**Silty Clays**	**Sand/ Gravel**
	Response Unit Number		**1**	**2**	**3**	**4**	**6**	**5**	**7**	**8**	**9**
DS	Maximum depth of depression Storage	(mm)	2	60	1	1	1	1		1	1
KEFF	Infiltration into 1st soil layer	(mm/h)	0	0.2	8	10	10	12	12	10	12
CS	Infiltration into 2nd soil layer	(mm/h)	0	0.2	6	8	8	9	9	8	9
D	Infiltration out of 2nd layer	(mm/h)	0	0.2	0.8	0.9	0.9	1.2	1.2	0.9	1.2
SAV	Average suction at the wetting front	(mm)	0	200	200	200	200	200	200	200	200
X	Groundwater Contribution Indicator: 1=SS, 0=GW		0	200	150	120	120	120	120	120	120
FATR	Groundwater Fraction (not used in this model, set=1)		0	0.56	0.56	0.54	0.54	0.54	0.54	0.54	0.54
INC	Maximum depth of interception storage	(mm)	0	0.46	0.46	0.4	0.4	0.4	0.4	0.4	0.4
	First Soil Layer										
HI	Soil layer thickness	(mm)	0	0.46	0.46	0.4	0.4	0.4	0.4	0.4	0.4
SMCI	Saturated soil-water content (porosity)	(vol/vol)	0	0.27	0.27	0.19	0.19	0.19	0.19	0.19	0.19
IMCI	Initial soil-water content	(vol/vol)	0	0.01	150	200	200	3000	3000	200	3000
FCAPI	Field capacity soil-water content	(vol/vol)	0	0.56	0.56	0.54	0.54	0.4	0.4	0.54	0.4
WILTI	Wilting point soil-water content	(vol/vol)	0	0.46	0.46	0.4	0.4	0.1	0.1	0.4	0.1
	Second Soil Layer										
HII	Soil layer thickness	(mm)	0	0.46	0.46	0.4	0.4	0.1	0.1	0.4	0.1
SMCII	Saturated soil-water content (porosity)	(vol/vol)	0	0.27	0.27	0.19	0.19	0.04	0.04	0.19	0.04
IMCII	Initial soil-water content	(vol/vol)	1	1	1	1	1	0	0	1	0
FACPII	Field capacity soil-water content	(vol/vol)	1	1	1	1	1	1	1	1	1
WILTII	Wilting point soil-water content	(vol/vol)	0	3	3	3	3	3	3	5	5

Background Sources: Hydrology of Floods in Canada (Watt et al., 1989), South Waterdown Subwatershed Study (Schroeter & Associates, 2005).

6.2.3 *Subcatchment Characteristics*

Most natural watersheds contain numerous side or off-channels which collect runoff water that feeds a main stream channel. For subcatchment runoff hydrograph calculations, representative cross-sections must be specified for the main and off channels. GAWSER uses these sections, the subcatchment drainage area, main and off-channel slopes, and a representative length (L) and width (W), to determine the overland routing parameters required in the area/time versus time method (e.g. main channel travel time, TMC, off-channel travel time, TOC and the linear reservoir lag, KO). To compute TMC and TOC, reference flows are specified (QRMC, QROC), which typically correspond to bankfull conditions in the representative main and off-channel cross-sections (noted by identification numbers, MCVS, and OCVS).

Subcatchment areas (A), lengths (L), and main channel slopes were measured from the available topographical maps.

In GAWSER, the overland flow linear reservoir lag (KO) is specified as a function of the base time (TB) of the area/time versus time curve, or

KO = FTB * TB

where TB=TMC+TOC, and FTB is the overland flow basetime factor. In previous applications of GAWSER, FTB has been set at 2.0 for rural subcatchments. However, for swampy or hummocky topography dominated subcatchments, FTB is set between 3 and 6. In the present study, FTB set at 3.5 to better match the peak flow from the observed calibration model.

For urban subcatchments, with an imperviousness greater than 10%, we set FTB=1.2.

These subcatchments characteristics, length (L), Width (W) and FTB were adjusted in the calibration process.

Outflows from subsurface and groundwater storage are modelled in GAWSER using a linear reservoir procedure, which requires two recession constants to be specified; KGW for discharge from groundwater storage and KSS for subsurface flow. These constants are estimated from observed hydrograph data or hydrogeological studies, when available. Nevertheless, previous values were deemed to be acceptable here, and so KSS=5 h, and KGW=384 h for each subcatchment (see GAWSER Training Guide, Lesson 5 and 7).

The groundwater factor, GWFACT, which tells the program how much infiltrated water generated, will not return as baseflow at the subcatchment outlet, is usually set to zero for most applications. If the computed baseflow is to leave the watershed totally, and not be available for re-entry at some downstream location, then the GWON parameter would be set to zero (otherwise it would be set to 1.0). For this study (Table 35), GWFACT=0.10 for all the subcatchments, which means only 10% of computed baseflow available for re-entry at some downstream location.

Table 35 lists the drainage areas, length and width, the response unit percentages, cross-section and reference flow rate assignment for the main and off-channels, overland runoff lag and subsurface and groundwater (baseflow) recession constants, as well as the GWFACT values for each subcatchment under existing conditions. The symbols for the column headings have been defined in this chapter.

Table 35 Subcatchment characteristics for existing conditions

Eagle Heights Watershed Characteristics: Current UNITS=2 August 17, 2017 Updated- Nava Pokharel

	Area	Length	Width	Lake	WLD<== Low Veg ==>							<HiVeg>		<MainChannel><=OffChannel><Overland><Recess><Other Parameters													
Number	(ha)	(m)	(m)	Imp	RU2	RU3	RU4	RU5	RU6	RU7	RU8	RU9	MCVS	MCQR	OCVS	OCQR	FTB	FTLO	KSS	KGW	HUM	QGWI	HPND	GWFACT	GWON	QTH,SwP,S		Hyd
-9999 Current Conditions: Tributary 4																												
403	11.81	750	500*	2	0	0	89	6	0	0	3	0	403	0.07	1.50	0.025	3.50*	0	5	384	0	0	0	0.10	1	0	0 0	403
427	21.75	950	630	7	0	0	27	38	0	0	28	0	427	0.07	1.50	0.025	2.00	0	5	384	0	0	0	0.10	1	0	0 0	427
-9999 Current Conditions: Tributary 5																												
503	46.56	1800	760*	2	0	0	12	12	12	4	35	24	503	0.07	1.50	0.025	3.50	0	5	384	0	0	0	0.10	1	0	0 0	503
530	18.39	1200	640*	0	0	0	33	0	10	0	23	34	527	0.07	1.50	0.025	3.50	0	5	384	0	0	0	0.10	1	0	0 0	527
548	19.43	1200	640*	8	0	0	23	16	0	0	52	1	548	0.07	1.50	0.025	3.50	0	5	384	0	0	0	0.10	1	0	0 0	548
-9999 Current Conditions: Tributary 6																												
603	30.93	840	640*	2	0	0	15	7	14	5	34	23	603	0.05	1.50	0.025	3.50	0	5	384	0	0	0	0.10	1	0	0 0	603

6.2.4 *Stream channel data*

Stream channel data are necessary inputs to both the overland flow (runoff) and channel routing calculations in GAWSER. Consequently, representative cross-sections are required inputs to the routing procedures, where the parameters are computed directly by the program using the channel length, bed slope and a characteristic rating curve developed for the section.

As discussed in earlier sections, a detailed topographic survey was conducted in the project area and SWOOP 2002 DEM information was used for the rest of the modelled watershed area. The channel cross sections for channel segment were generated from this topographic information.

Table 36 below summarizes the characteristics for the channel routing reaches (elements) considered in the model. The average slope of channels is 2.1%.

Table 36 Channel element characteristics

Channel Number	*Length (m)*	*Slope (m/m)*	*Cross-Section Number*	*Watercourse*
1403	1360	0.0230	1406	Tributary 4 South
1548	1080	0.0195	1515	Tributary 5 South

6.2.5 *Treatment of special groundwater seepage and discharge*

Each subcatchment element in the normal usage of GAWSER is considered to be a total self-contained hydrologic unit. This means that all the precipitation falling on a given subcatchment is accounted for in the computations. Infiltrated water returns as baseflow, so the total outflow becomes the sum of computed runoff, subsurface and baseflow components. Although this is an idealized situation that facilitates hydrograph calculations, it is not always true in nature; infiltrated water may reappear as baseflow at some other point downstream in the watershed, or flow to another watercourse entirely, a characteristic of karst environments. The GWFACT factor, noted earlier, accounts for deeper groundwater contributions that can be re-directed to a ‘groundwater storage

array' in program memory. At some other point downstream in the drainage network, water can be released from this storage array, usually at a rate specified as a percentage of the water remaining in the 'groundwater storage array'. Spot baseflow measurements and qualitative observations are useful in determining which subcatchments contribute to the groundwater storage array, and where the releases (discharges) from this array are considered in the model.

Since the Eagle Heights area is primarily the headwaters for the streams on the site, only 10% of water generated within the 4 subcatchments was modelled to return within the study area.

6.2.6 *Sensitivity analysis*

A sensitivity analysis of the hydrological model in the GAWSER program was not undertaken as part of this project, because the model was calibrated and validated using on-site measured rainfall and flow information.

6.3 MODEL VALIDATION

6.3.1 *Procedures*

In any hydrologic modelling exercise, it is generally assumed that if a given model reproduces an observed or measured sequence of quantities (e.g. streamflow volume, reservoir water levels) that 'confidence' can be placed in its predictive capability, from which management options or decisions are often made. Obviously, if additional comparisons between model output and measured quantities are made and their agreement is deemed to be 'acceptable', then more confidence can be placed in predictions from the model, particularly for impact analyses. Consequently, an important step in any hydrologic modelling exercise is to establish the 'level of confidence' in the predictive results, or 'validating the model'.

This important confidence building or 'validation' step in the modelling procedures is often referred to as 'calibration', although the term 'calibration' has been used interchangeably with 'verification', 'validation' and 'confirmation'.

Model *calibration* is a process of adjusting model parameters, variables or other inputs in order to reduce the differences between simulated and observed flows (or other hydrologic quantities) to levels that are deemed acceptable (see Watt et al., 1989; James and Burgess, 1982). The 'adjusted' or 'calibrated' parameters or variables are then 'verified' or 'validated' by applying the model to an independent data set that was not used for calibration.

According to James and Burgess (1982), model *calibration* involves a trial-and-error procedure to achieve optimum parameter levels that produce a reasonably good match between model results and observed data. The parameters, whose values are based on field measurements or are well-established from previous studies, *remain fixed*. Those to be calibrated are adjusted based on a goodness of fit criterion using visual or statistical comparisons between measured and simulated results (see James and Burgess, 1982; Schroeter and Boyd, 1998). A model is said to be 'robust' if its

parameter settings can be transferred from one watershed to another (Schroeter and Watt, 1989).

A simple comparison of model output with any measured values does not constitute a 'calibration' exercise, unless the parameters are adjusted to improve the agreement between observed and simulated results. On the whole, any comparison between measured and modelled results is always considered part of the model 'confirmation' or 'validation' procedures.

In summary, the Eagle Heights model has been adequately 'confirmed' or 'validated', because the following validation checks have been made.

1. The GAWSER (Guelph All-Weather Sequential-Events Runoff) model has been extensively calibrated, verified and validated in more than 40 watershed modelling studies within the last two decades across Ontarian watersheds. These applications constitute model comparisons with observed flow data from more than 140 gauges for more than 2000 gauge-events. For continuous simulation work, the model has been compared with long-term streamflow data from more than 45 gauges for some 800 gauge-years of application. For urban runoff modelling, the model has been tested with data from more than 20 gauges for more than 200 gauge-events. This massive amount of experience gained in applying the model in Ontario over the last two decades was utilized directly in formulating the Eagle Heights Project area model. The monthly parameter adjustment table (GAWSPARM) has proved to be an extremely 'robust' tool in applying GAWSER throughout Ontario.
2. The Grindstone Creek Subwatershed Study (Cosburn Patterson Wardman Ltd., 1995) model which included the Eagle Heights area was formulated using the GAWSER program. A model was created using GAWSER for the South Waterdown Subwatershed Study (SWSS), which lies within 5 km of the Eagle Heights Project site. The parameters used on these previous studies have been referred to and utilized on the present modelling.

3. Of particular relevance to the present work, GAWSER was applied in Halton Region Integrated Flood Forecast System (HRIFFS) set-up Study (Schroeter & Associates, 1993), the Grindstone Creek Water Resources Support Study (EWRG, 1997), and the Bronte Creek Hydrology and Geomorphology Study (PEI, 2002). The monthly parameter adjustment table applied in those applications was utilized directly in the present study with no major alterations.
4. Mean annual evapotranspiration amounts estimated by the physically-based GAWSER model were well within acceptable ranges reported in numerous southern Ontario climatology documents and maps (e.g. Brown et al., 1974; OMNR, 1984), as well as those estimated in the EWRG (1997) and Ecoplans (1996) studies.

In the Eagle Heights study, the main objective of the 'validation' procedures was to ensure that the level of performance provided by the Eagle Heights model was consistent with previous modelling exercises in Grindstone Creek, and elsewhere in southern Ontario. 'Readily' available meteorological data were used for 'validating' the hydrology model where ever possible. For this purpose, a tipping-bucket rain gauge and 5 flow leveloggers were installed to measure water level in three tributaries in the Project Site area in the fall of 2016. This has been discussed in detail earlier in section 2.0 of this report.

Since long-term flow data are not available within the project area for the calibration and validation process, different rainfall events recorded in 2016 and 2017 were used for the model calibration and validation process.

This process permitted the routing calculations in the different hydrologic elements (e.g. overland flow, channel and reservoir) to be assessed, in terms of hydrograph timing and peak flows estimates.

6.3.2 *Meteorological Input Data*

As mentioned earlier, an objective of the model validation procedures was to utilize as much as possible with existing meteorological data taken from previous GAWSER applications in Halton Region. Meteorological data were assembled and processed for

the two AES (Atmospheric Environment Service) climate stations that are the closest to the study area, namely Hamilton RBG (6153300), and Hamilton RBG CS (6153301).

For long-term simulations, 65 year (1950 to 2015) meteorological datasets were obtained for the RBG climate station from the previous studies and the data acquired from Environment Canada for the recent years. For all the long-term simulations outlined in the report, the dataset for RBG was used exclusively, because that climate station was the closest to the study area, which is located at about 2.5 km from the Project Site.

6.3.3 *Snowmelt Input Data*

Snow accumulation and melt in different land cover units within a watershed are accounted for in GAWSER by defining 'blocks of equivalent accumulation' (BEAs). For the Eagle Heights Model, six BEAs were identified and considered: two types of field blocks (ploughed and grass/pasture/grains), forests, and three edge blocks (e.g. road easements, fence lines and forest/field edges). Edge blocks are areas with significant capacity to store snow during blowing snow conditions. Schroeter and Whiteley (1986) and Burkart et al. (1991) provide further information about snow accumulation characteristics among differing landscape units in southern Ontario.

The BEAs were from land cover information available in Table 37 using similar relationships between blocks found in other parts of southern Ontario. The snowmelt model parameters listed in Table 37 were taken directly from EWRG (1997), for Grindstone Creek.

Table 37 Model parameters for each block of equivalent snow accumulation

Parameter	*Symbol*	*Units*	*Fields Ploughed*	*Fields Grass*	*Forest*	*Roadway Easements*	*Fence Lines*	*Forest Edges*
Constant melt factor	KMI	(mm/d-C^{o})	0.3	2.0	0.2	4	4	0.2
Variable melt factor	KMII	(mm/d-C^{o})	32	29	22	24	24	23
Refreeze factor	KF	(mm/d-C^{o})	16	16	11	16	12	11
Base Temperature	TBAS	(C^{o})	0	0	0	0	0	0
Sublimation rate	SUBLIM	(mm/d)	0.33	0.33	0.33	0.33	0.33	0.33
Threshold density	MRHO	(vol/vol)	0.40	0.37	0.35	0.40	0.70	0.37
Compaction Constant	A	(hours)	0.10	0.10	0.10	0.10	0.10	0.10
Compaction Constant	B	(1/C^{o})	7.0	7.0	7.0	7.0	7.0	7.0
Holding Capacity	HCAP	(cm)	9.5	17	44	35	55	2000
Percentage of Area	AREA	(%)	31	12	35	3	14	5

General Parameters Applied to All Blocks

Parameter	**Symbol**	**Units**	**Value**
New snow density	NEWDEN	(vol/vol)	0.100
Eroded snow density	RHOE	(vol/vol)	0.120
Irreducible water saturation	SWI	(vol/vol)	0.07
Initial liquid water content	ILWC	(mm)	0.00

6.3.4 *Initial conditions*

Initial watershed conditions are represented by three variables in the GAWSER program: initial soil-water content, initial streamflow at time zero (also called initial baseflow), and initial snowpack conditions.

The initial soil-water content is usually set at field capacity for all flood flow generation events (e.g. Regional Storm), which is believed to be the 'normal' condition. In long-term simulations, this variable is adjusted (upward or downward) upon review of the meteorological data for the early part of the computational period and any available streamflow data. Otherwise, this variable was rarely altered beyond its starting value.

Streamflow at time zero was attributed either entirely to baseflow (outflow from groundwater storage) or a mixture of baseflow and subsurface stormflow. The initial flows were estimated by area-proration on a subcatchment basis from any available gauge data.

Initial snowpack conditions are easily set for long-term simulations by starting the model in a period when there is no snow. By defining the simulation period according to a 'water year' (Nov.1 to the following Oct. 31), the initial snowpack conditions are easily set at zero.

6.3.5 *Potential Evaporation Estimates*

In GAWSER, there are two evapotranspiration models, one using a set daily potential for each month (the climatology approach) developed from available lake evaporation estimates, and the Linacre (1977) formula, which uses daily mean air temperatures, the elevation and latitude to compute daily potential evaporation rates. The first method is well described in Appendix A of the GAWSER Training Guide and Reference Manual (Schroeter & Associates, 1996, updated October 2004), but the second approach uses Linacre (1977) method. In the present application, the Linacre method with limiting daily PET rates was used;

The Linacre (1977) lake evaporation rate formula is expressed as

$$PE = [700\ T_M/(100 - A) + 15\ (T - T_D)]/(80 - T)$$

[6.3.5] $$T_M = T + 0.006\ H$$

$$(T - T_D) = 0.0023\ H + 0.37\ T + 0.53\ R + 0.35\ R_{ANN} - 10.9$$

where PE is the daily potential evaporation rate (in mm/day), H is the elevation (in m), T is the mean daily temperature (in C), A is the latitude (in degrees), T_D is the mean dew point temperature, R is the mean daily range of temperature, and R_{ANN} is the annual difference between the mean temperatures of the hottest and coldest months.

Limiting PET values in values in mm/d

Jan	Feb	Mar	Apr	May	Jun
1.98	2.50	3.36	4.97	5.74	6.37
Jul	Aug	Sep	Oct	Nov	Dec
6.16	5.25	3.92	2.80	1.96	1.83

In applying the Linacre model to the entire Grand River watershed, Schroeter et al. (2000a) found that the Eq. [6.3.5] caused the mean annual actual evapotranspiration amount to be over-estimated. By applying a factor of 0.60 to potential rates determined using [6.3.5], they found good agreement between the computed values and those published on maps for southern Ontario (see Brown et al., 1974; OMNR, 1984).

6.3.6 *Parameter selection and seasonal adjustments*

Previously published values were employed as first estimates for all model parameters. In this case, parameter values were taken directly from the *Grindstone Creek* (EWRG,

1997) and the *Bronte Creek Studies* (PEI, 2002), and the South Waterdown Subwatershed Study (Schroeter & Associates, 2005).

Once the model is completely set-up, the number of parameters requiring additional adjustment during calibration, should that become necessary, are relatively few. Previously published values were used for the starting and adjusted as per the calibration results.

The program adjusts the specified parameters for all response units and subcatchments in a similar manner, as shown here for effective hydraulic conductivity (KEFF).

[6.3.6] $KEFF(i)_{used} = FKEFF * KEFF(i)_{specified}$

where FKEFF is the effective hydraulic conductivity adjustment factor, the subscript 'used' denotes the value of KEFF actually used in the runoff calculations for response unit (i), and the subscript 'specified' represents the value of the parameter (e.g. KEFF in Table 38) for response unit (i) actually entered in the input files during model set-up. In previous applications of GAWSER, the most commonly adjusted parameter factors have been the following:

FDS	Maximum depth of depression storage factor
FKEFF	Effective hydraulic conductivity factor (for surface infiltration)
FCS	Maximum seepage rate (movement of water from layer 1 to 2)
FD	Maximum percolation rate (movement of water out of layer 2)
FKO	Overland runoff lag factor
FKMF	Combined refreeze/snowmelt factor
FIMCI	Initial soil-water content adjustment factor for soil layer 1
FIMCII	Initial soil-water content adjustment factor for soil layer 2
FEDAY	Potential evapotranspiration adjustment factor
FINS	Interception storage adjustment factor

Values of unity for any of the above factors means that the 'as set-up' values specified in the watershed files are used directly in the calculations. The rationale for adjusting these factors is given below.

Depression storage, FDS: This factor diverts water from overland runoff. During snowmelt, depressions may be ice-filled and hence ineffective. Because total streamflow

is modelled in GAWSER, including subsurface storm flow and groundwater baseflow, the effect of depression storage is to alter the amounts of overland and subsurface components. If the soil is initially at field capacity or wetter, depression storage does not represent a loss from input to total streamflow.

Effective hydraulic conductivity, FKEFF: This factor allows for changes in the hydraulic conductivity due to viscosity changes as the ground surface temperature varies. This effect accounts for a reduction to 0.25 of the midsummer values for early spring and fall rainfall events. Moreover, the presence of frozen water in the upper soil layers causes additional loss in hydraulic conductivity. For snowmelt events, reductions in KEFF of 0.02 to 0.05 of the midsummer values are common to account for frozen ground conditions in different parts of the watershed.

Maximum seepage (FCS) and percolation (FD) rates: These factors allow for changes in the rates of water movement between soil layers. Their influence can be seen on the recession tails of simulated hydrographs. Depending on the amount of frost penetration in a soil, these factors may be reduced from their midsummer values, as with FKEFF. Generally, these parameters should not change much between events, although they can be influenced by soil cracking as well (e.g. higher values). For large events, where the top soil layer can become saturated (e.g. Regional Storm), these factors will control the amount of infiltration.

Overland linear runoff lag constant, FKO: A major adjustment factor of the shape of the overland runoff hydrograph is the linear reservoir lag constant through which the translated hydrograph developed from the area/time versus time curve is routed. Recall, that KO is set equal to two times the basetime (TB) of the area/time curve. Each subcatchment was set-up with KO=2*TB as an initial value (with KO=3*TB for swampy areas), and hence FKO=1. However, for snowmelt events FKO is set higher (around 4.0) to account for the delayed routing effects caused by the presence of a snow cover in fields. Similarly, higher FKO values (about 4 to 5) were required for late summer and early fall events to account for the presence of unharvested crop cover.

Snowmelt factor, FKMF: Variations in the amount of melt per degree-day occur depending on the amount of incoming solar radiation. This quantity varies with season, cloudiness and surface cover type (e.g. forests or open fields) and is imperfectly related to air temperature. Heavily forested sub watersheds will have smaller melt factors than those dominated by open fields (Schroeter, 1988). The variability of air temperature through the day is a further complication. Reduction in reflectivity of the snow surface as it ages means that more energy is available for melt from the same solar radiation as snow ages. The general tendency of these trends is to produce a higher melt factor in late spring events (about 0.7 to 1.0).

Initial soil-water content for first layer, FIMCI: This has a major influence on the initiation of runoff and the overall hydrograph volume. Initially dry soils produce less runoff, whereas initially wet soils produce more runoff. Usually, the soil-water contents were set initially at field capacity, and so FIMCI=1.0. Rarely was this factor adjusted for spring and fall events. For summer events, FIMCI may be less than unity (say about 0.3 to 0.5).

The subsurface and groundwater recession constant, KSS: This factor controls the linear reservoir lag constant for subsurface and groundwater storage, which determines when the percolated water (output from the second soil layer) appears as baseflow. This value is normally kept at unity, but it will be higher than this for the midsummer to early fall period.

Relative density of freshly fallen snow factor, FNEW: Observations have shown that values for the relative density of fresh snow range from 0.02 to 0.15, depending on what time during the winter (early, middle or late), and the prevailing weather system. For most applications in southern Ontario to date, the fresh snow relative density has been set at 0.085. The FNEW factor allows for some variation in this parameter throughout the winter. Generally, new snowfalls in the late winter will be wetter or denser.

Potential Evapotranspiration adjustment factor, FEVAP: In the GAWSER model, the potential daily evapotranspiration rate (EDAY) is set as a constant. FEVAP provides a means of varying EDAY on a monthly basis, representative values of which are given in climate reports (e.g. Hare and Thomas, 1979). At present, EDAY is set at 1 mm/d, which

means that the stated values for FEVAP directly represent the monthly average values for EDAY.

Interception storage adjustment factor, FDINS: This new feature in GAWSER has seen limited application. Further experience in applying this factor will yield more refined values.

The monthly parameter adjustment factors used in the present applications are given in Table 38 below. This table represents parameter factor values at the midpoint of each month (say the 15th). The actual parameter adjustments used in the calculations are then linearly interpolated from the monthly table depending on the Julian date as shown in

Figure 19 for FKEFF.

Table 38 Monthly Parameter Adjustment Factors

Symbol	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FDS	0.75	1.00	1.00	1.00	1.00	1.15	1.15	1.00	1.00	1.00	1.00	0.75
FKEFF	0.02	0.02	0.02	0.10	0.40	0.70	0.80	0.90	0.65	0.25	0.20	0.02
FCS	0.03	0.02	0.02	0.09	0.40	0.50	0.60	0.75	0.35	0.30	0.13	0.06
FD	0.04	0.03	0.03	0.05	0.05	0.05	0.05	0.06	0.07	0.06	0.05	0.05
FKO	1.75	2.00	2.00	2.00	1.50	2.25	2.75	3.00	2.50	1.50	1.50	1.50
FKSS	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FHI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FKMF	0.25	0.33	0.93	1.23	1.46	1.57	1.52	1.33	1.05	0.76	0.25	0.15
FNEW	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
FEVAP	0.00	0.00	0.00	2.60	3.77	4.43	4.61	3.77	2.50	1.39	1.00	0.00
FDINS	0.20	0.20	0.20	0.50	0.70	1.00	1.00	1.00	1.00	0.20	0.20	0.20

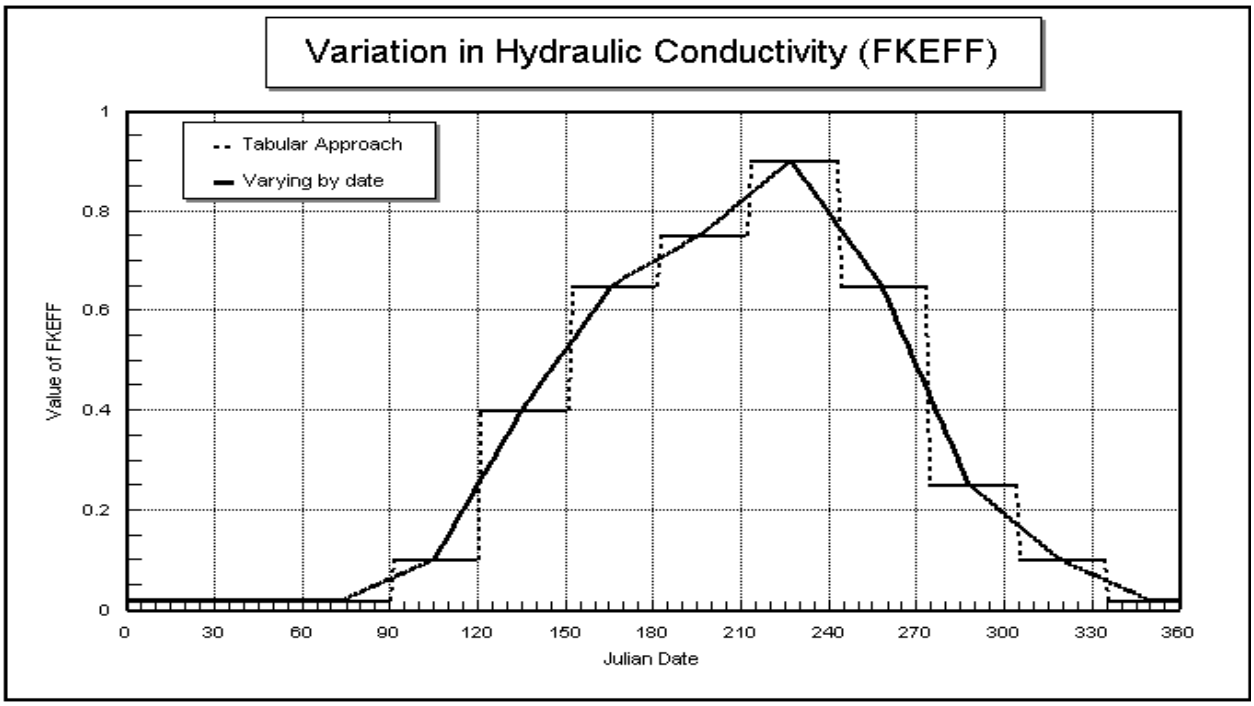


Figure 19 Variation in the effective hydraulic conductivity factor (FKEFF) throughout the year

6.4 GAWSER Model Calibration Results

As discussed in Section 2 of this report, a number of flow meters (level loggers) and one rain gauge were installed at the project site in August 2016. Data obtained from these level loggers and the rain gauge were used to calibrate the GAWSER model for the different storm events. Figure 20 to Figure 29 show simulated and observed hydrographs at different locations.

As perviously mentioned, the quality of data obtained from some of the levelloggers were not suitable for the model calibration. However flow information collected from three level loggers in Tributary 4, Tributary 5 and Tributary 6 were used in the calibration exercise. These recorded hydrographs and rainfall information have also been included in Appendix A of this report.

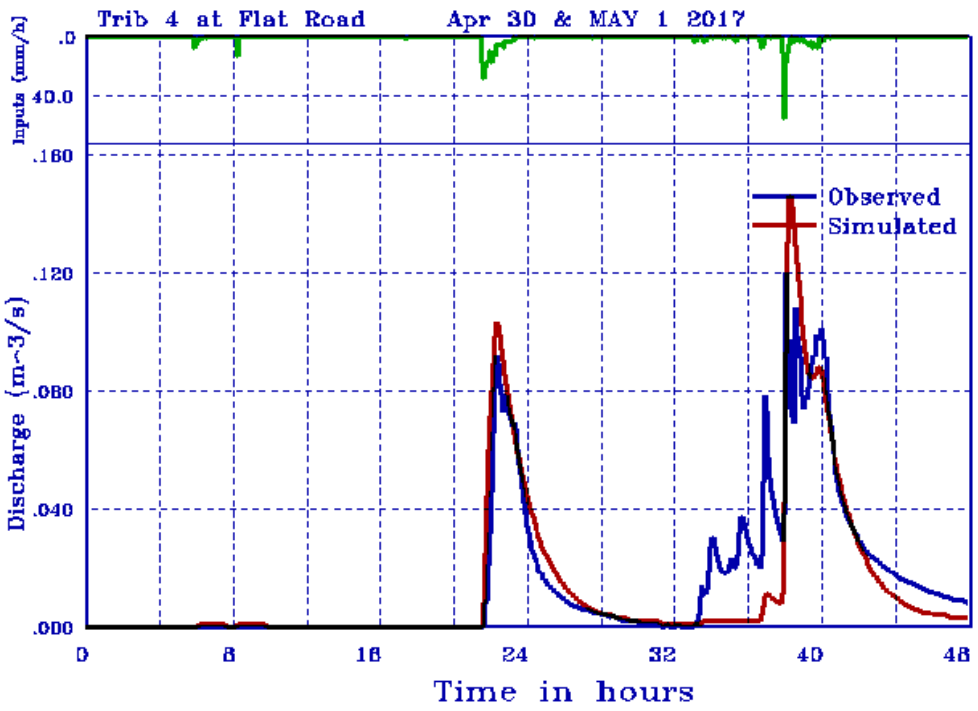


Figure 20 Tributary 4 North at Flatt Road Culvert (April 30 and May 1, 2017)

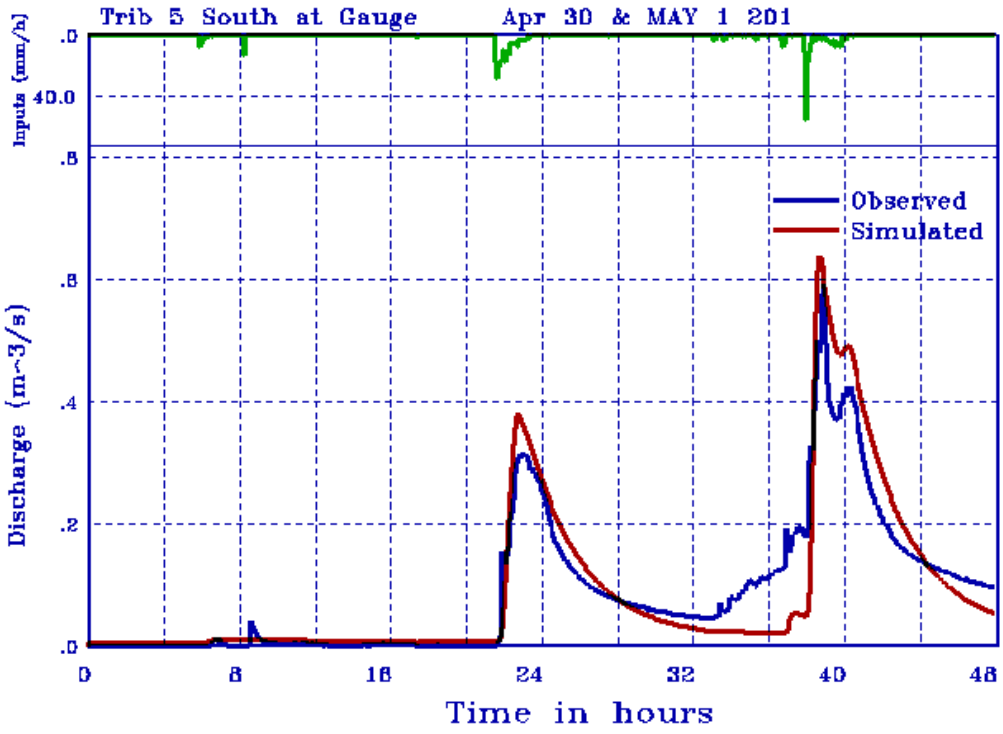


Figure 21 Tributary 5 South at Gauge (April 30 & May 1, 2017)

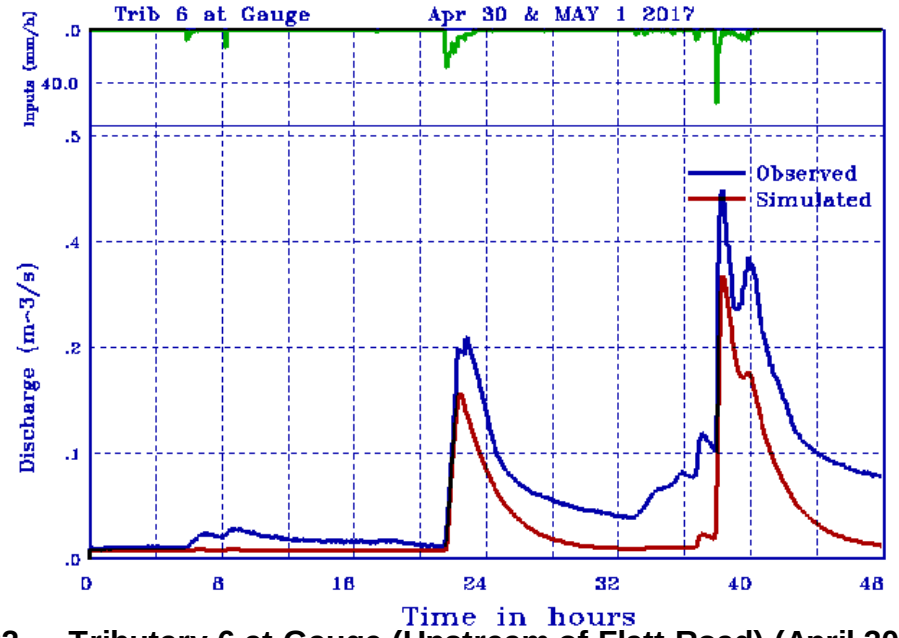


Figure 22 Tributary 6 at Gauge (Upstream of Flatt Road) (April 30 & May 1, 2017)

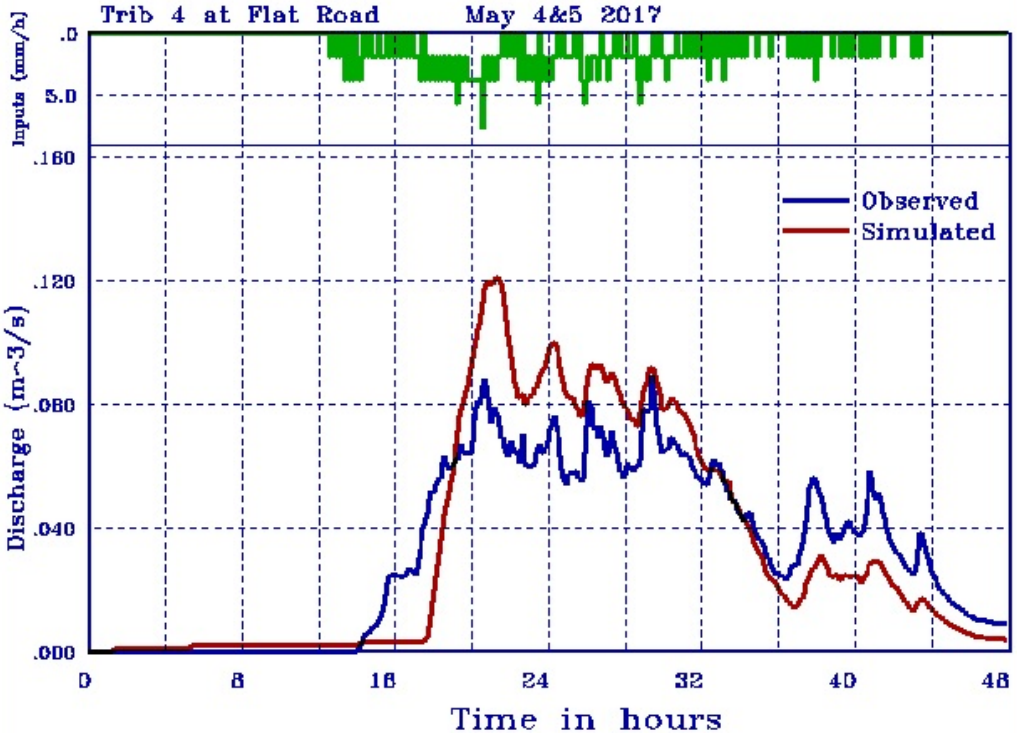


Figure 23 Tributary 4 at Flatt Road (May 4 & 5, 2017)

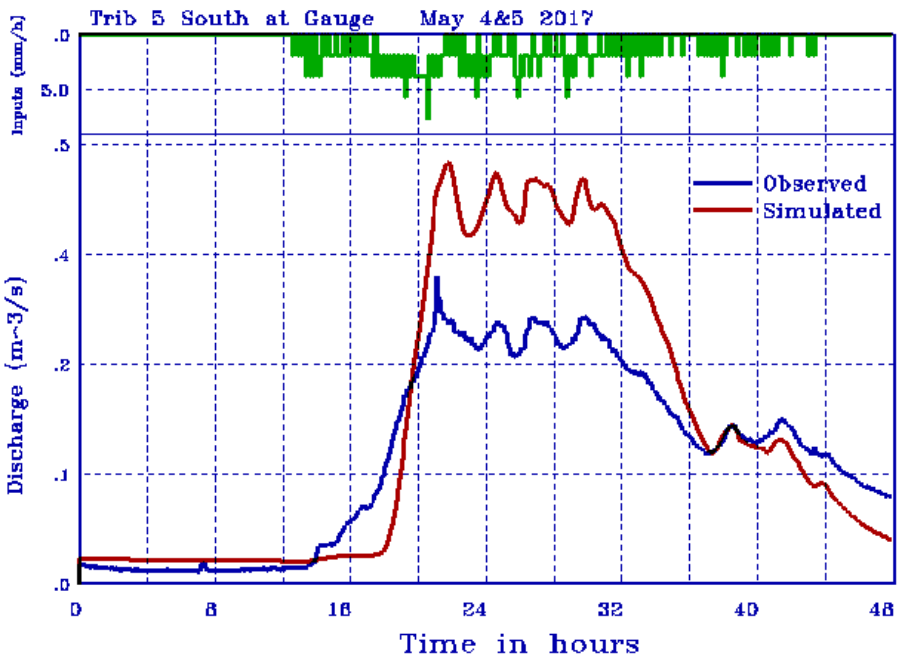


Figure 24 Tributary 5 South at Gauge (May 4 & 5, 2017)

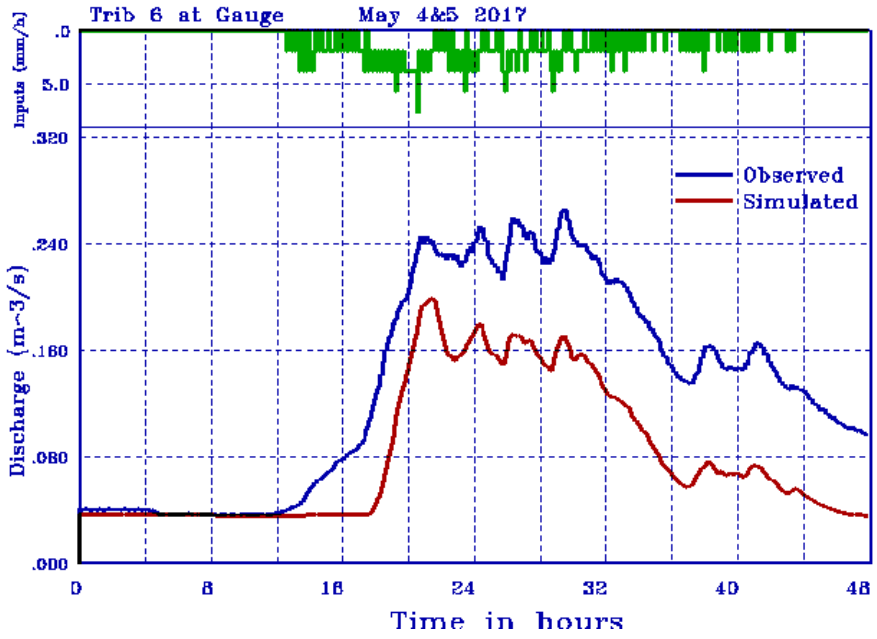


Figure 25 Tributary 6 at Gauge (May 4 & 5, 2017)

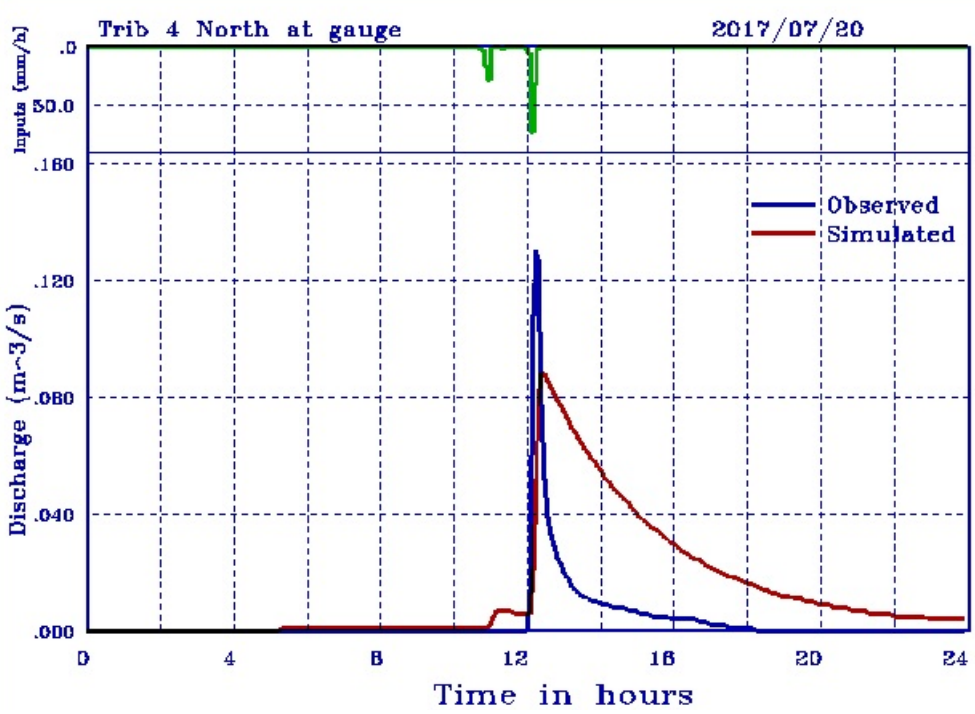


Figure 26 Tributary 4 at Flatt Rd Gauge (July 20, 2017)

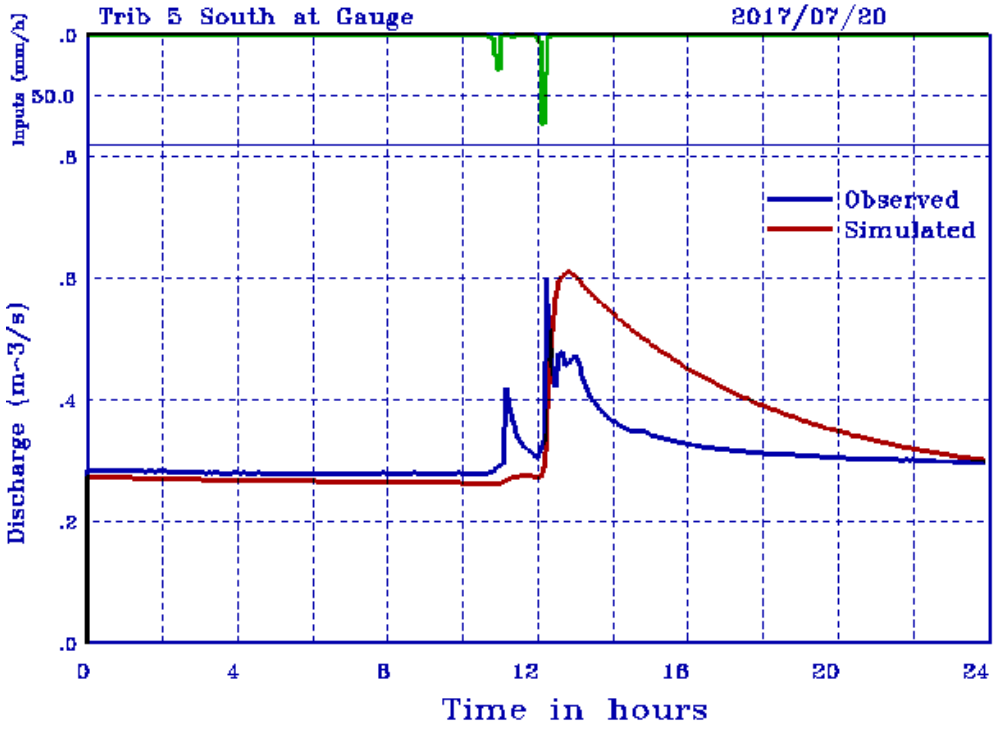


Figure 27 Tributary 5 South at Gauge (July 20, 2017)

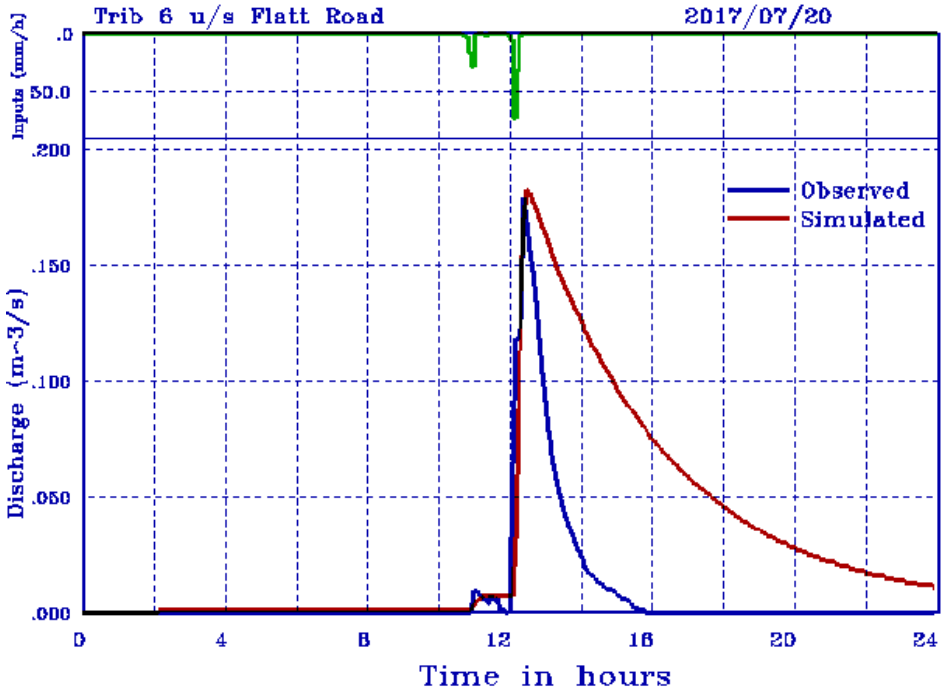


Figure 28 Tributary 6 at Gauge (July 20, 2017)

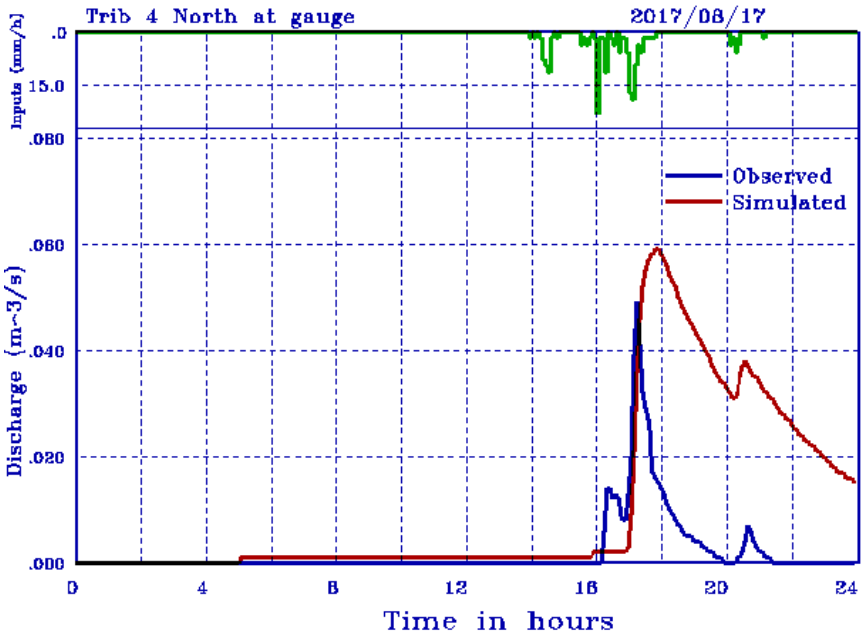


Figure 29 Tributary 6 at Gauge (August 17, 2017)

6.5 SWMHYMO Model Calibration Results

Similar to the GAWSER Model calibration, on-site measured rainfall and flow data were also used to calibrate the SWMHYMO model. SWMHYMO is a fairly simple program compared to

GAWSER with just three major parameters to calibrate for individual events. The three parameters are SCS CN Value, Initial abstraction and Time to Peak. Table 39 shows the summary of calibrated parameters for Tributary 4 North, Tributary 5 South and Tributary 6 at Flatt Road.

Figure 30 to Figure 34 show the SWMHYMO Calibrated hydrographs for the April 30th and May 1st event and May 25 2017 event. The April 30th and May 1st storm event had a total of 54.6 mm rainfall over two days and May 25, 2017 recorded 44 mm rainfall event.

This SWMHYMO calibration gives confidence on both the SWMHYMO model parameters and measured flow data as well.

Table 39 SWMHYMO Calibrated parameters for April 30th, May 1st Event

Drainage Description	Area (ha)	CN	Initial abstraction (mm)	Time to Peak (hr)
Tributary 4 North	11.80	74	5	0.333
Tributary 5 East	46.55	70	5	1.50
Tributary 5 West	18.39	70	5	0.75
Tributary 5 South	14.56	72	5	0.50
Tributary 6 North of Flatt Road	30.93	72	5	0.50

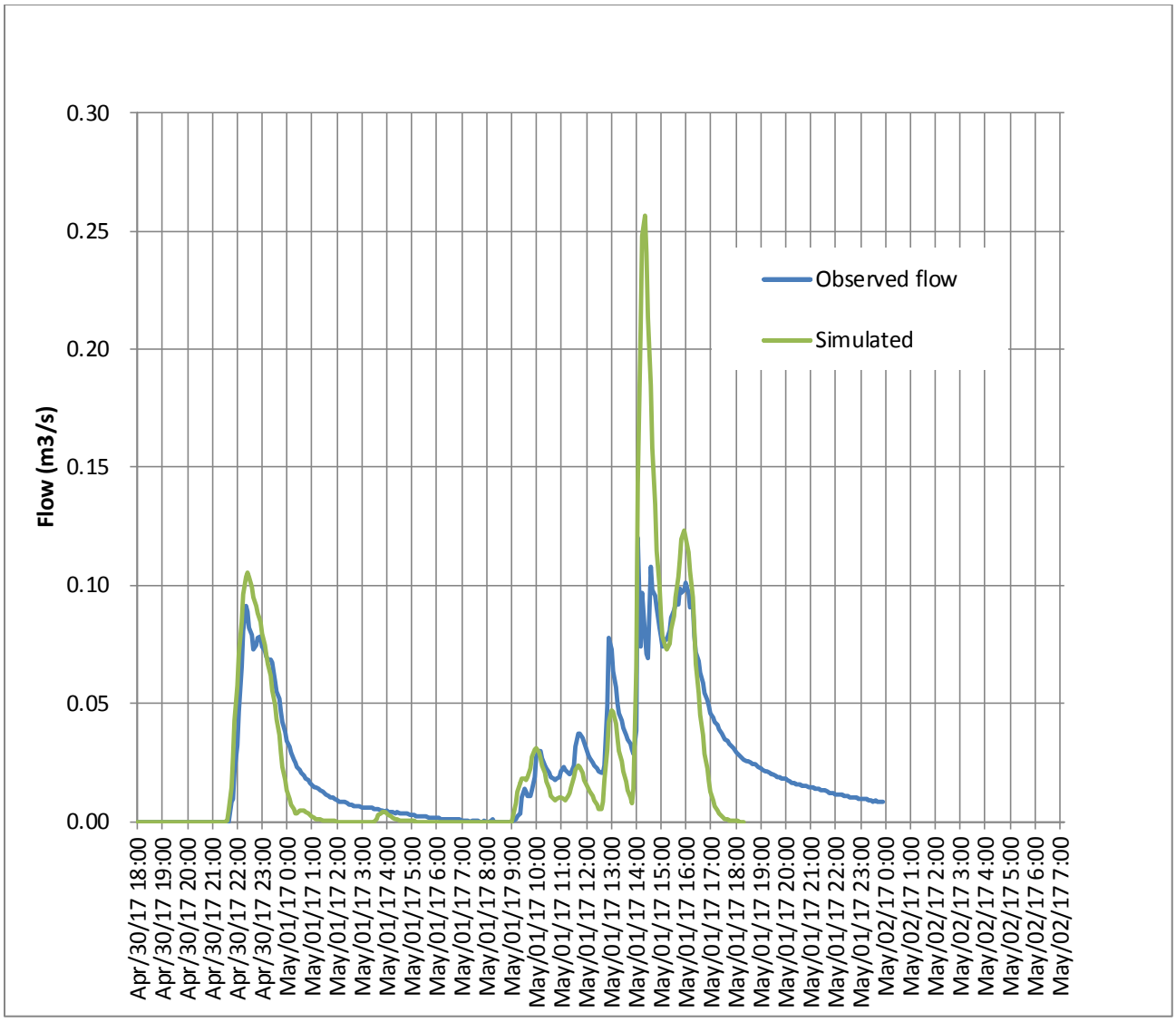


Figure 30 SWMHYMO Simulated and Observed Hydrographs Tributary 4 at Flatt Road (April 30 and May 1, 2017)

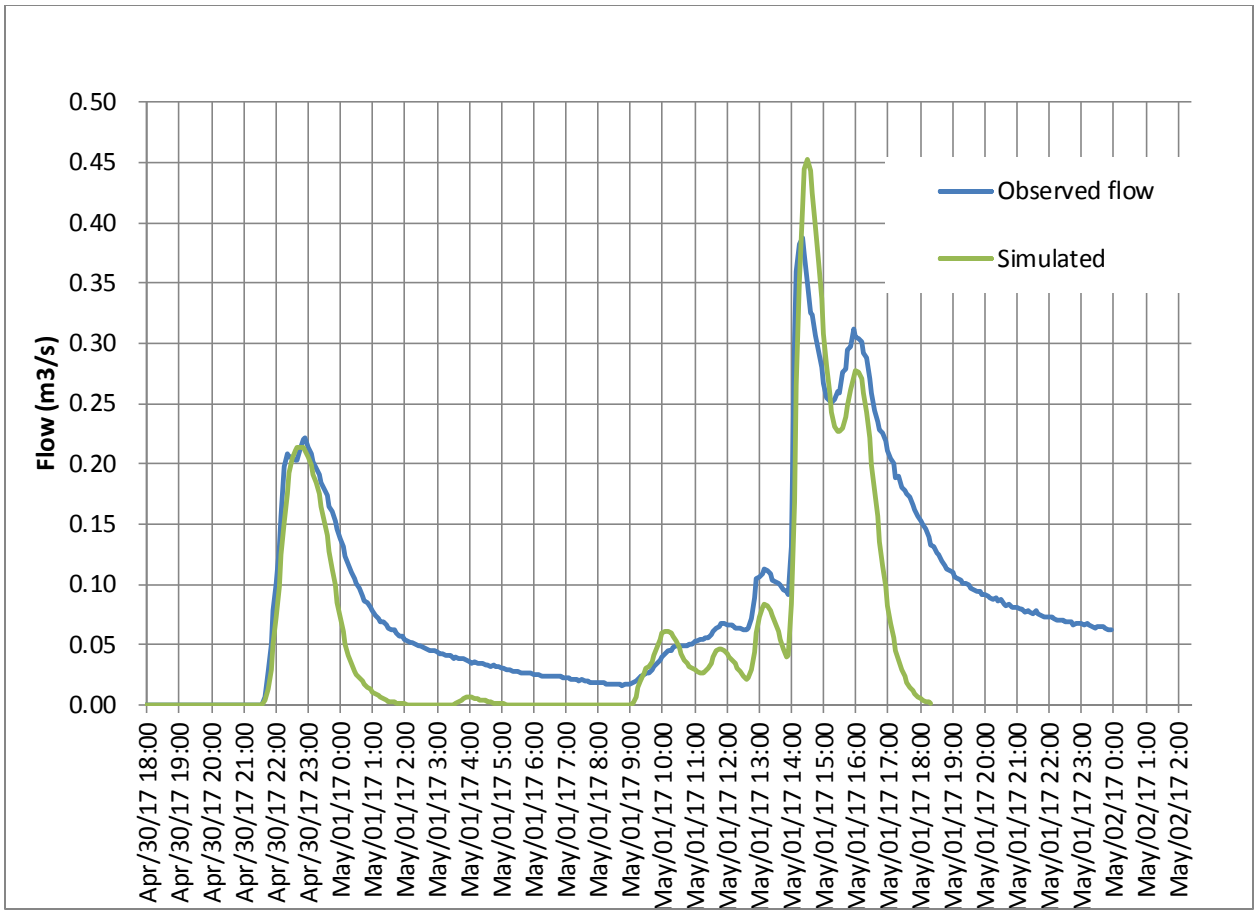


Figure 31 SWMHYMO Simulated and Observed Hydrographs Tributary 6 at Flatt Road (April 30 and May 1, 2017)

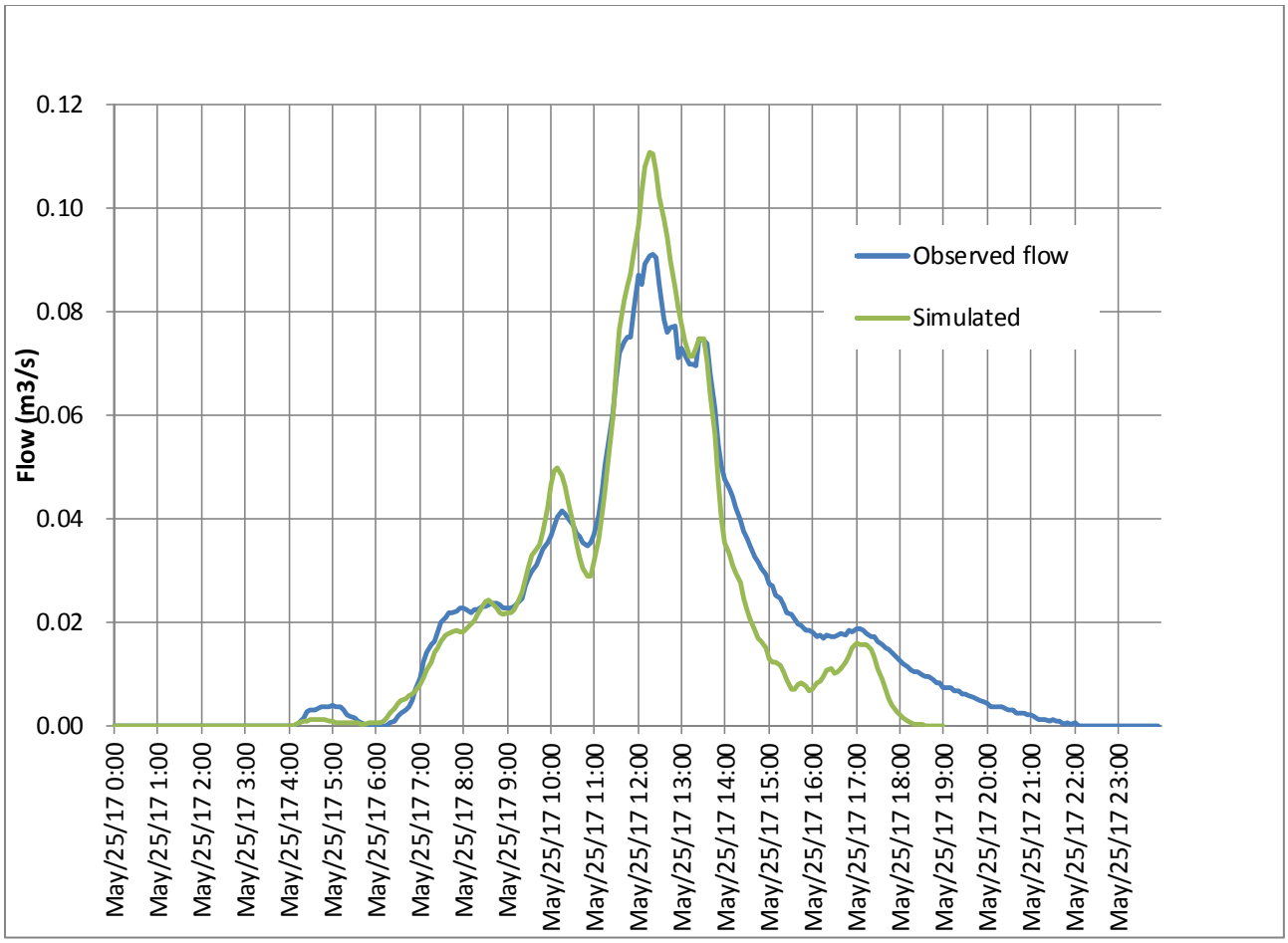


Figure 32 SWMHYMO Simulated and Observed Hydrographs Tributary 4 at Flatt Road (May 25, 2017)

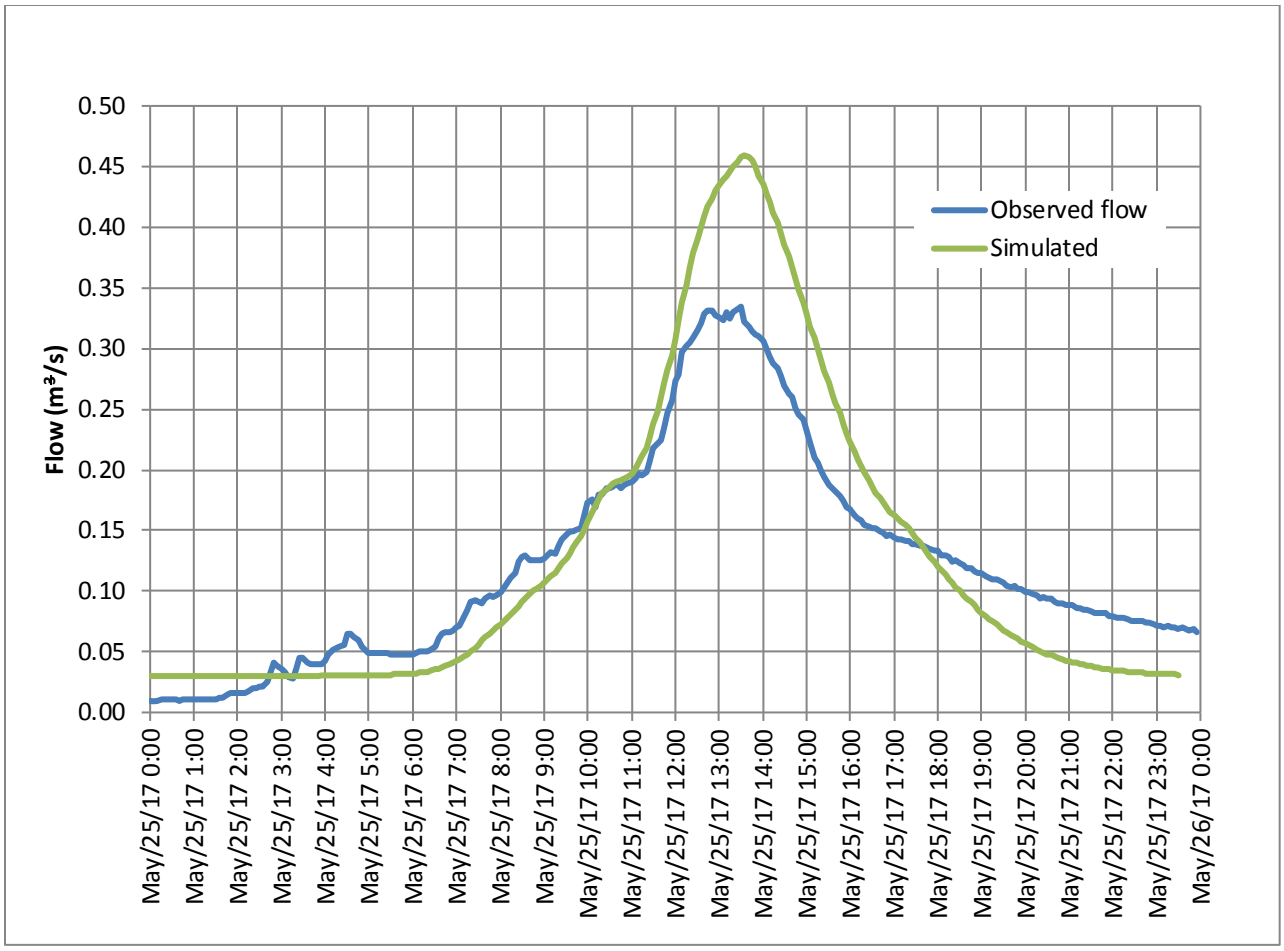


Figure 33 SWMHYMO Simulated and Observed Hydrographs Tributary 5 South at Gauge (May 25, 2017)

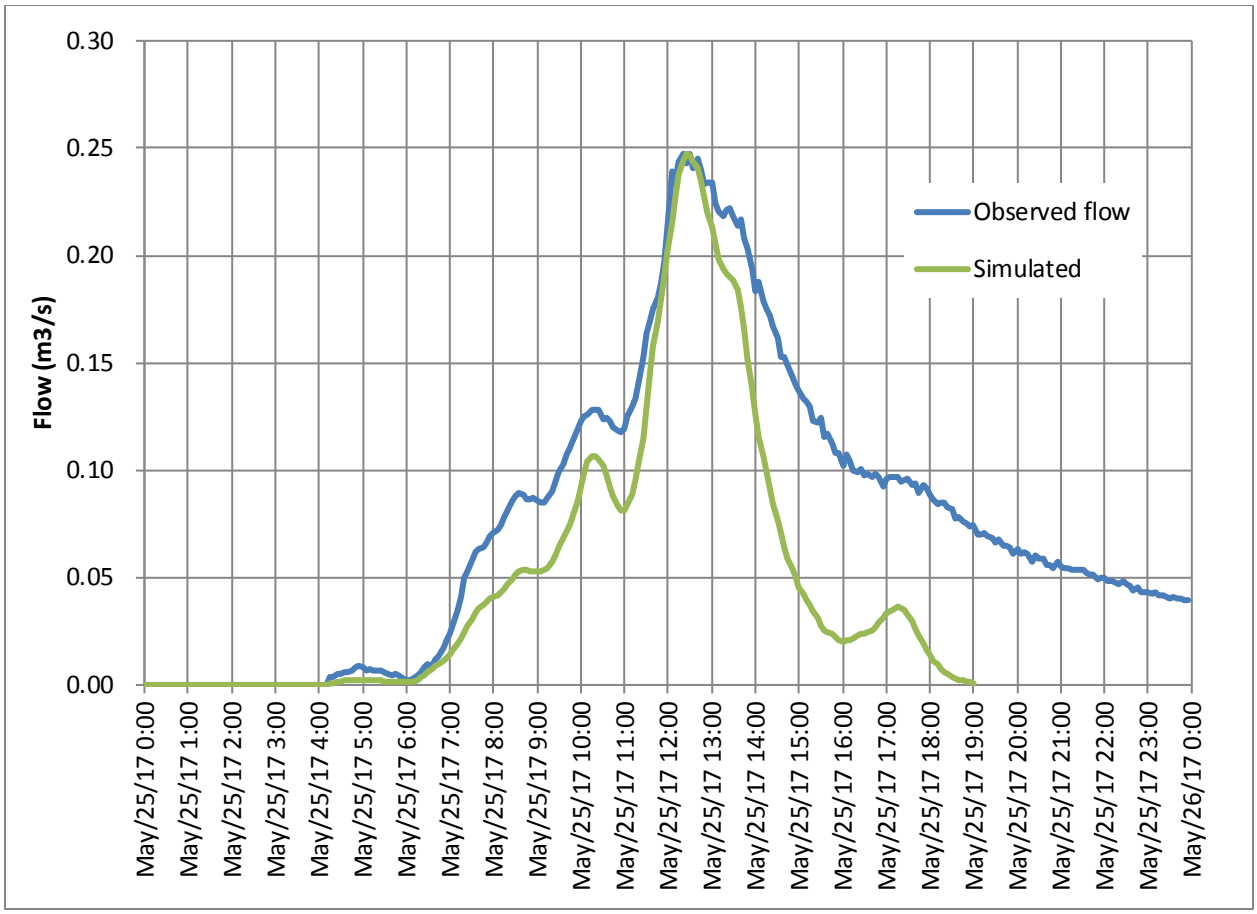


Figure 34 SWMHYMO Simulated and Observed Hydrographs Tributary 6 at Flatt Road (May 25, 2017)

7.0 MODELLING RESULTS AND DISCUSSION

The hydrologic model of Eagle Heights, once validated, was ready for use in assessing the hydrologic response of the subwatershed under existing conditions. Flood flow estimates are made by applying return period and Regional Storm events to the model. A 65 year meteorological data sequence was applied to the model for determining long-term water balance quantities, and erosion assessment.

7.1 FLOOD FLOW ESTIMATES

The validated watershed model was used to generate flood flow estimates resulting from return period events and the Regional Storm. The 24 hour City of Burlington Storm Chicago storm parameters were used to generate the return period flood flows. Table 40 lists the City of Burlington Chicago Storm parameters used in the Eagle Heights Model and total rainfall volume (mm) for a 24-hour storm event.

Table 41 gives the temporal distribution patterns of the Regional Storm. No reduction factors to account for spatial variations in rainfall volume were applied to the Chicago and Regional storms.

Table 40 Rainfall IDF Parameters for the Return Period Events

Return Period (Years) or Event	***A***	***B***	***C***	***24-Hour Volume (mm)***
25mm				25.00
2	592.6	6.0	0.780	48.76
5	697.4	5.0	0.764	64.50
10	798.5	5.0	0.763	74.39
25	926.9	5.0	0.762	86.98
50	1019.4	5.0	0.761	96.36
100	1114.2	5.0	0.761	105.32

Table 41 Temporal Rainfall Distribution Patterns of Regional Storm

Event	*Time Step (min)*	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	*Total Rain (mm)*
Regional	60	2	2	2	2	2	2	2	2	2	2	2	2	
		2	2	2	2	2	2	2	2	2	2	2	2	285
		2	2	2	2	2	2	2	2	2	2	2	3	
		6	4	6	13	17	13	23	13	13	53	38	13	

7.2 Exising Conditions Event Based GAWSER Result

The calibrated existing condition model using GAWSER was applied to run Chicago Storm for different returned period events. Table 42 and Table 43 show existing conditions flow rate m^3/s and unit area flow rate $m^3/s/ha$ at different point of interest along Flatt Road and Panin Road. Table 43 shows the 100-year return period flows vary between 0.061 $m^3/s/ha$ and 0.033 $m^3/s/ha$ and the average is 0.043 $m^3/s/ha$.

The 100-year return period unit flow rates listed on Table 43 was used to design SWM facilities in the proposed development. The proposed development area North of Flatt Road in Tributary 4 was designed for 0.052 $m^3/s/ha$ for a 24 hour 100 year Chicago Storm. Similarly, the Area between Flatt road and Panin Road in Tributary 4 was designed for 0.061 $m^3/s/ha$ and so on.

Table 42 Existing Conditions Flow for Different Return Period Chicago Storms (24-Hour)

Point of Interest	Area	25 mm	1:2 Year	1:5 Year	1:10 Year	1:25 Year	1:50 Year	1:100 Year	Regional
	(ha)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Trib 4 North at Flatt Road	11.81	0.094	0.213	0.314	0.384	0.474	0.541	0.609	1.120
Trib 4 at Panin Road	33.54	0.238	0.541	0.793	0.964	1.180	1.340	1.500	2.250
Trib 5 East Flatt Rd	46.55	0.191	0.516	0.783	0.967	1.200	1.390	1.580	3.600
Trib 5 W at Flatt Rd	18.39	0.096	0.250	0.376	0.464	0.577	0.661	0.749	1.580
Trib 5 Panin Road	84.36	0.326	0.884	1.360	1.690	2.110	2.430	2.770	6.450
Trib 6 at Flatt Road	30.91	0.163	0.444	0.674	0.830	1.030	1.180	1.340	2.670

Table 43 Existing Conditions Unit Area Flow for Different Return Period Chicago Storms (24 Hour)

Point of Interest	Area	25 mm	1:2 Year	1:5 Year	1:10 Year	1:25 Year	1:50 Year	1:100 Year	Regional Year
	(ha)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)	($m^3/s/ha$)
Trib 4 North at Flatt Road	11.81	0.008	0.018	0.027	0.033	0.040	0.046	0.052	0.095
Trib 4 at Panin Road	33.54	0.007	0.016	0.024	0.029	0.035	0.040	0.045	0.067
Trib 5 East Flatt Rd	46.55	0.004	0.011	0.017	0.021	0.026	0.030	0.034	0.077
Trib 5 W at Flatt Rd	18.39	0.005	0.014	0.020	0.025	0.031	0.036	0.041	0.086
Trib 5 Panin Road	84.36	0.004	0.010	0.016	0.020	0.025	0.029	0.033	0.076
Trib 6 at Flatt Road	30.91	0.005	0.014	0.022	0.027	0.033	0.038	0.043	0.086
Average		**0.006**	**0.014**	**0.021**	**0.026**	**0.032**	**0.036**	**0.041**	**0.081**

As mentioned in an earlier section in this report, GAWSER Modelling in the project area was also carried out as part of Grindstone Creek Subwatershed Study 1995. Table 44 compares 1995 and the current (2017) GAWSER model results for a 100-year Chicago Storm event. The model results of these two studies are very similar.

Table 44 Comparision of 1995 and 2017 Gawser Model Results (Existing Condition) for 100 –year event

	1995 Study			2017 Study		
Point of Interest	Area (ha)	100-year flow (m^3/s)	Unit Area Flow ($m^3/s/ha$)	Area (ha)	100-year flow (m^3/s)	Unit Area Flow ($m^3/s/ha$)
Tributary 4 North at Flatt Road				11.81	0.609	0.052
Trib 4 at Panin Road	32.50	1.40	0.043	33.54	1.500	0.045
Trib 5 East Flatt Rd				46.55	1.580	0.034
Trib 5 W at Flatt Rd				18.39	0.749	0.041
Trib 5 Total at Flatt Road	60.10	1.97	0.033	64.94	2.310	0.036
Trib 5 Panin Road				84.36	2.770	0.033
Trib 6 at Flatt Road	31.10	1.34	0.043	30.91	1.340	0.043

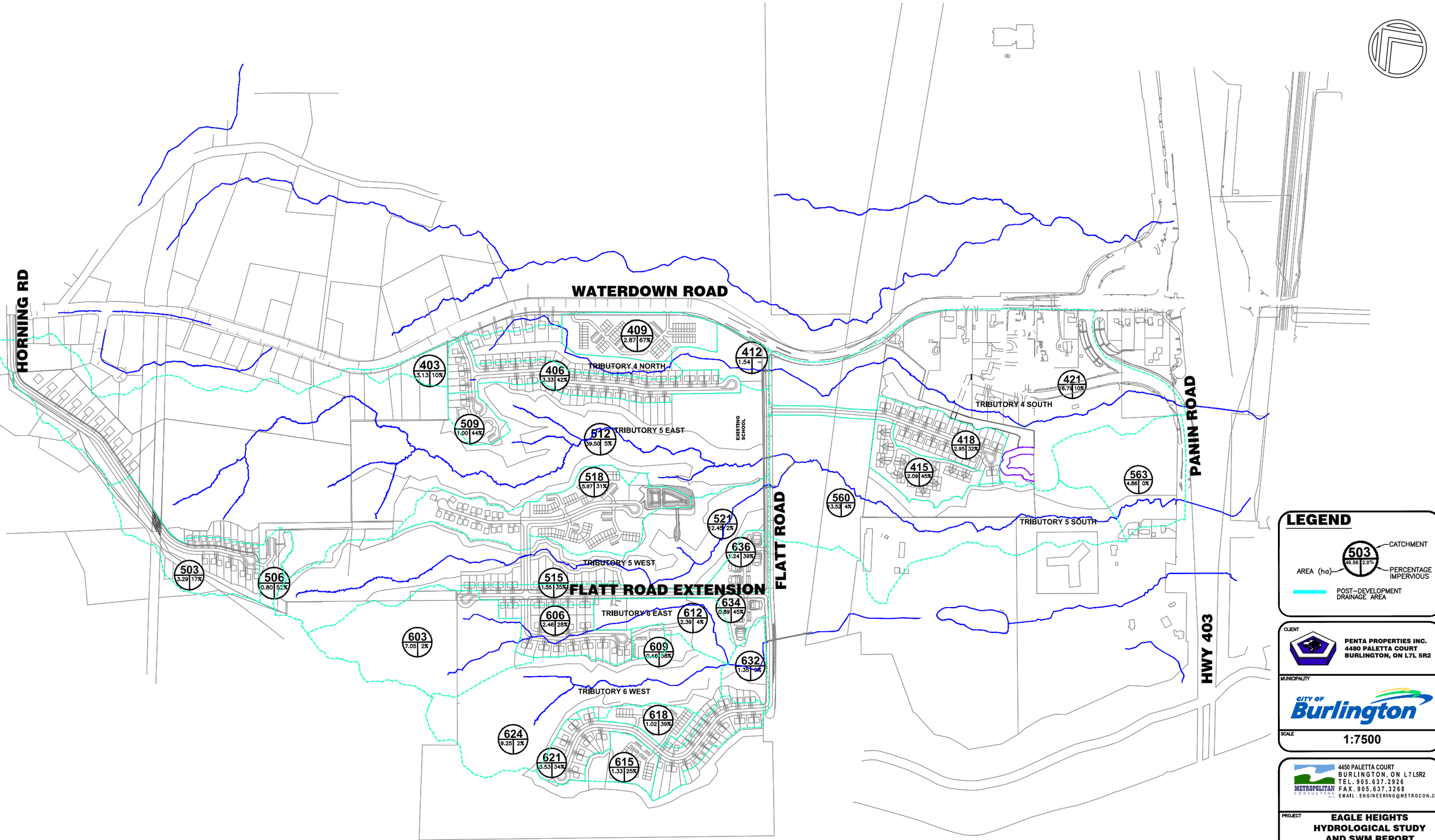
7.3 MODELLING RESULTS AND APPLICATION FOR POST DEVELOPMENT CONDITIONS

A post-development model was created using GAWSER to evaluate the effect of the proposed development and sizing of the SWM structures. In the proposed conditions, subcatchments were divided as per the proposed development and each subcatchment in the development is serviced with at least one SWM facility. All of the calibrated parameters of the existing model were used in the proposed conditions model. The only additional information incorporated in the post development conditions were increases in the percentage of imperviousness and SWM structures.

7.3.1 *Delineation of Subcatchment in Proposed conditions*

For the post-developments scenario, the study area was divided into 27 subcatchments, compared to six subcatchments for existing conditions. In the proposed development area, each subcatchment was serviced with at least one SWM facility. Outside the proposed development areas, areas were combined as much as practically possible to reduce the modelling uncertainties associated with smaller catchments and time-steps.

Figure 35 shows the delineation of subcatchments for the post development conditions used in GAWSER Model. Figure 36 shows the schematic diagram in post development conditions. Table 42 shows the characteristics of subcatchments in the post development conditions.



LEGEND

503 — 46.56 | 2.0%
- CATCHMENT
- AREA (ha)
- PERCENTAGE IMPERVIOUS
- POST–DEVELOPMENT DRAINAGE AREA

CLIENT
PENTA PROPERTIES INC.
4480 PALETTA COURT
BURLINGTON, ON L7L 5R2

MUNICIPALITY
CITY OF Burlington

SCALE
1:7500

METROPOLITAN CONSULTING INC.
4450 PALETTA COURT
BURLINGTON, ON L7L5R2
TEL. 905.637.2926
FAX. 905.637.3268
EMAIL: ENGINEERING@METROCON.CA

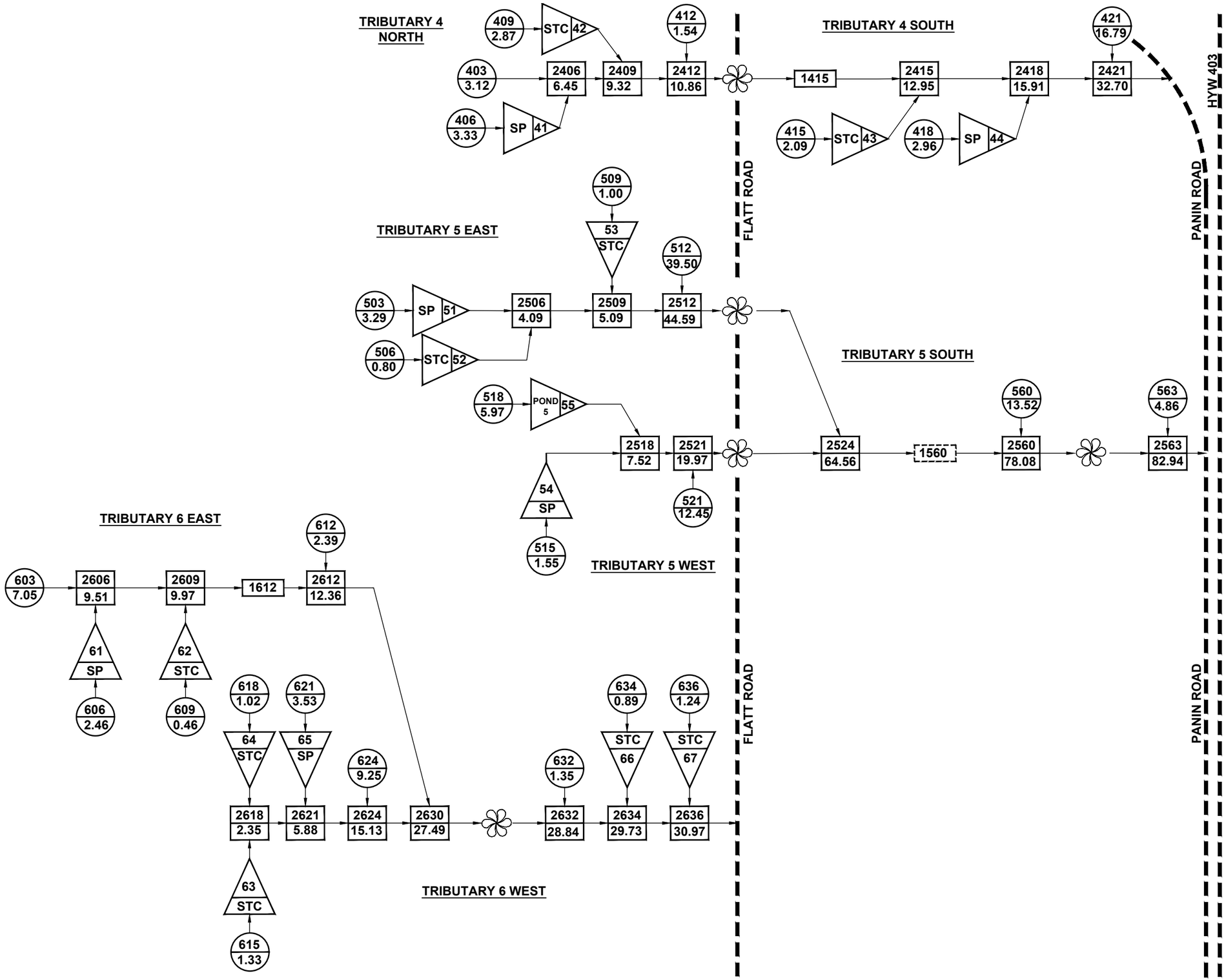
PROJECT
EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG
POST DEVELOPMENT SUBCATCHMENTS FOR GAWSER MODELING

DATE
August 2018

PROJECT NO.
P09006

FIGURE 35



LEGEND

563 4.86 CATCHMENT ID AREA (ha)

2560 78.29 ADDITION ID AREA (ha)

1560 CHANNEL

FLOW MONITORING

CLIENT

PENTA PROPERTIES INC.
4480 PALETTA COURT
BURLINGTON, ON L7L 5R2

MUNICIPALITY

City of Burlington

SCALE

NTS

METROPOLITAN CONSULTING INC.
4450 PALETTA COURT
BURLINGTON, ON L7L5R2
TEL. 905.637.2926
FAX. 905.637.3268
EMAIL : ENGINEERING@METROCON.CA

PROJECT

EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG

SCHEMATIC OF GAWSER MODEL POST DEVELOPMENT CONDITIONS

DATE

August 2018

PROJECT NO.

P09006

FIGURE 36

Table 45 Subcatchment Characteristics for Post Development Conditions

Eagle Heights Watershed Characteristics: Current UNITS=2 Feb 06, 2018 Updated- Nava Pokharel, P.Eng.

	Area	Length	Width	Lake	WLD<== Low Veg ==>|<HiVeg>|<MainChannel><=OffChannel><Overland><Recess><Other Parameters																					
Number	(ha)	(m)	(m)	Imp	RU2	RU3	RU4	RU5	RU6	RU7	RU8	RU9	MCVS	MCQR	OCVS	OCQR	FTB	FTLO	KSS	KGW	HUM	QGWI	HPND	GWFACT	GWON	QTH,SwP,S	Hyd
-9999 Current Conditions: Tributary 4																											
403	4.65	750	200	7	0	0	0	93	0	0	0	0	111	0.07	3.0	0.025	2.00	0	5	384	0	0	0	1.00	1	0 0 0	403
406	3.33	200	150	42	0	0	0	58	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	406
409	2.87	150	100	67	0	0	0	33	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	409
412	0.01	250	150	00	0	0	0	100	0	0	0	0	111	0.07	3.0	0.025	2.00	0	5	384	0	0	0	1.00	1	0 0 0	412
415	2.09	150	100	45	0	0	0	55	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	415
418	2.96	150	100	32	0	0	0	68	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	418
421	16.79	950	630	8	0	0	26	38	0	0	28	0	427	0.07	2.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	421
-9999 Current Conditions: Tributary 5																											
503	3.29	150	100	17	0	0	0	4	0	43	18	18	111	0.07	3.0	0.025	3.50	0	5	384	1.0	0	0	1.00	1	0 0 0	503
506	0.80	150	100	52	0	0	0	0	0	42	0	6	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	506
509	1.00	150	100	44	0	0	0	56	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	509
512	39.50	1800	760	5	0	0	12	12	12	4	31	24	503	0.07	2.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	512
515	1.55	150	100	35	0	0	0	65	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	515
518	5.97	150	100	31	0	0	0	60	0	9	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	518
521	12.45	1200	640	2	0	0	10	0	20	0	23	45	527	0.07	3.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	521
560	13.52	1200	640	4	0	0	20	17	0	0	55	0	548	0.07	3.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	560
563	4.86	340	100	0	0	0	37	10	0	0	53	0	563	0.07	3.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	563
-9999 Current Conditions: Tributary 6																											
603	7.05	840	640	2	0	0	0	0	0	10	0	88	603	0.05	2.0	0.025	4.00	0	5	384	0	0	0	1.00	1	0 0 0	603
606	2.46	150	100	28	0	0	0	36	0	36	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	606
609	0.46	150	100	58	0	0	0	42	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	609
612	0.01	550	450	4	0	0	15	12	0	7	62	0	612	0.05	2.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	612
615	1.33	150	100	25	0	0	0	0	75	0	0	0	111	0.07	3.0	0.025	1.80	0	5	384	1.0	0	0	1.00	1	0 0 0	615
618	1.02	150	100	39	0	0	0	0	61	0	0	0	111	0.07	3.0	0.025	1.80	0	5	384	1.0	0	0	1.00	1	0 0 0	618
621	3.53	150	100	34	0	0	0	0	66	0	0	0	111	0.07	3.0	0.025	1.80	0	5	384	1.0	0	0	1.00	1	0 0 0	621
624	12.97*	700	550	3	0	0	15	7	14	5	33	23	603	0.05	2.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	624
632	0.01	200	125	9	0	0	0	0	0	0	19	72	632	0.05	2.0	0.025	3.50	0	5	384	0	0	0	1.00	1	0 0 0	632
634	0.89	150	100	45	0	0	0	55	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	634
636	1.24	150	100	39	0	0	0	61	0	0	0	0	111	0.07	3.0	0.025	1.20	0	5	384	1.0	0	0	1.00	1	0 0 0	636

7.3.2 *Post Development Conditions Event based GAWSER Modelling Results*

A GAWSER model for post development conditions was created to evalute the effects of the proposed development on the hydrogical regime of the area.

From the existing conditions modelling, the design storm for the proposed development has been established as a 24-hour 100 year Chicago Storm. The rating curves for each SWM structure (Superpipes, On-site underground storages and SWM Pond) were first established in an Excel design table with the existing condition flow rates for a 100 year storm event. This stage-outflow-storage-surface area information was incorporated in the GAWSER Model. All the design Excel tables for the proposed SWM stuructures have been included in Appendix B of this report.

Six points of interest (POI) were establised on Flatt Road and Panin Road to evalute and compare the hydrogical regime for pre and post development conditions.

Table 46 summarizes the post development conditions flow rates for each subcatchment with SWM structures and at different POIs on Flatt Road and Panin Road. In this study, SWM structures are designed in such a way that POI 24-hour 100 year post development flows are less than or equal to pre development flows. At the detail design stage, all return period flood flows in the post development conditions will be less than or equal to the pre development values.

As discussed earlier, SWM structures are designed to control up to 24-hour 100-year (105.32mm)storm. For storms higher than the 100 year return period (e.g. regional storm) excess runoff will be directed through overland flow routes and safely discharged to the receiving water bodies.

Table 46 Post Development Flows for Different Return Period Chicago Storms (24-Hour)

Subcatchment or POI	Point of Interest	Area	25 mm	1:2 Year	1:5 Year	1:10 Year	1:25 Year	1:50 Year	1:100 Year	Regional
		(ha)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
2412	Trib 4 North at Flatt Road	10.86	0.146	0.248	0.330	0.384	0.451	0.499	0.550	0.895
2421	Trib 4 at Panin Road	32.70	0.306	0.597	0.837	0.997	1.200	1.350	1.500	2.690
2512	Trib 5 East at Flatt Road	44.59	0.214	0.544	0.809	0.990	1.220	1.400	1.580	3.410
2521	Trib 5 West at Flatt Road	19.97	0.050	0.207	0.271	0.315	0.372	0.416	0.457	1.400
2563	Trib 5 South at Panin Road	82.94	0.300	0.849	1.240	1.510	1.860	2.130	2.410	5.860
2636	Trib 6 at Flatt Road	30.97	0.229	0.505	0.723	0.868	1.050	1.190	1.330	2.420
406		3.33	0.057	0.086	0.109	0.123	0.139	0.152	0.163	0.254*
409		2.87	0.045	0.061	0.073	0.081	0.090	0.097	0.103	0.174*
415		2.09	0.018	0.026	0.031	0.034	0.039	0.041	0.044	0.080*
418		2.96	0.034	0.052	0.066	0.074	0.083	0.090	0.097	0.161*
503		3.29	0.017	0.033	0.044	0.052	0.060	0.066	0.071	0.152*
506		0.80	0.008	0.011	0.013	0.015	0.016	0.017	0.018	0.044*
509		1.00	0.007	0.01	0.013	0.014	0.016	0.017	0.018	0.037*
515		1.55	0.022	0.032	0.041	0.045	0.051	0.056	0.060	0.109*
518		5.97	0.007	0.113	0.131	0.143	0.158	0.168	0.177	0.796
606		2.46	0.028	0.043	0.054	0.061	0.069	0.075	0.081	0.140*
609		0.46	0.008	0.010	0.013	0.014	0.016	0.017	0.018	0.036*
615		1.33	0.014	0.022	0.028	0.032	0.036	0.040	0.043	0.072*
618		1.02	0.010	0.015	0.020	0.022	0.024	0.026	0.029	0.053*
621		3.53	0.039	0.061	0.077	0.088	0.101	0.110	0.118	0.203*
634		0.89	0.012	0.018	0.021	0.023	0.026	0.029	0.031	0.057*
636		1.24	0.020	0.024	0.029	0.033	0.037	0.040	0.043	0.073*

* Storage exceeded

7.3.3 *Comparision of Pre and Post Development Flows at POI*

Table 47 shows the comparison of 100-year pre and post development flows at the POIs at Flatt Road and Panin Road. Notice that at all POIs in Table 47 the post-development flows are less than or equal to pre development flows.

During the detailed design, post development flood flows for all return period events will be controlled to pre development conditions to the largest extent possible with available practical engineering solutions, e.g. a stepped weir will be installed upstream of the outlet control orifice to regulate smaller storm events (e. g. 2-year or 5-year events).

Table 47 100 Year Pre and Post Development Flows Comparision at POI

	Pre-Development		Post-Development	
	Drainage Area	100 year Flow	Drainage Area	100 year Flow
Point of Interest (POI)	(ha)	(m^3/s)	(ha)	(m^3/s)
Trib 4 North at Flatt Road	11.81	0.609	10.86	0.550
Trib 4 at Panin Road	33.54	1.500	32.70	1.500
Trib 5 East at Flatt Road	46.55	1.580	44.59	1.580
Trib 5 West at Flatt Road	18.39	0.749	19.97	0.457
Trib 5 South at Panin Road	84.36	2.770	82.94	2.410
Trib 6 at Flatt Road	30.91	1.340	30.97	1.330

8.0 WATER BALANCE ASSESSMENTS

A 65 year time-series (November 1, 1950 to October 31, 2015) of meteorological inputs (e.g. daily maximum and minimum air temperatures, daily rainfall and snowfall depths, and hourly rainfall depths) prepared for the Hamilton RBG CS (6153301) was applied to the hydrologic model for existing conditions. These applications provided estimates of water balance quantities for six selected locations in the study area, as well as 7-day low flows, and flow duration information. Since these subcatchments are relatively small and the available data for continuous modelling is only hourly, flood flow rates (m^3/s) information generated from continuous simulation are not representative. Moreover, the size of computational time steps does not affect runoff volume and water balance modelling results, and the 7-day low flows.

Table 48 gives a sample of the mean annual water balance quantities and how they are distributed by month throughout the year for Tributary 4 at Flatt Road

The individual quantities in Table 48 can be expressed in a water balance

Precip = ET + Runoff + Baseflow + Losses (or net storage)

where ‘Precip’ represents the total precipitation (rainfall plus snowfall), ET is the combined evapotranspiration and sublimation total, ‘Runoff’ is the mean annual runoff, ‘Baseflow’ is the portion of the infiltrated water that returns to the stream, and ‘Losses’ signifies the amount of infiltrated water that does not return to the receiving stream. The ‘Losses’ total also includes water stored in the system, and is also referred to as the ‘net storage’ term. For instance, the positive totals for ‘Losses’ during the winter months (e.g. December to April) represents snow on the ground, whereas the negative values during the summer months (e.g. May to August) denotes water pulled from soil- water storage. Total Flow’ is the sum of ‘Runoff' and ‘Baseflow’. The water balance summary tables have been included in Appendix D.

Table 48 Water Balance Summary at Tributary 5 East at Flatt Road (Existing Conditions)

Period: 1950/11/01 to 2015/10/30 Area: 0.4655 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.2	9.5	10.7	20.1	20.2
FEB	45.2	8.2	13.5	9.1	14.5	22.6
MAR	61.7	19.4	28.9	12.7	0.7	41.6
APR	76.2	48.5	13.4	16.4	-2.1	29.8
MAY	72.3	85.2	4.6	11.1	-28.6	15.7
JUN	72.5	103.0	2.1	4.2	-36.7	6.3
JUL	89.2	105.3	6.0	2.4	-24.4	8.4
AUG	76.3	96.3	2.7	2.5	-25.1	5.2
SEP	76.6	67.9	1.7	2.2	4.8	4.0
OCT	72.2	51.1	3.9	3.3	13.9	7.2
NOV	71.8	25.7	4.9	7.3	33.8	12.3
DEC	63.5	11.5	10.8	12.5	28.6	23.3
Total	827.1	631.3	102.1	94.3	-0.6	196.5

From Table 48, the mean annual precipitation for 1950 to 2015 is about 827 mm, of which 76% returns to the atmosphere as evapotranspiration (ET). The average annual ET is about 631 mm, a typical value for southern Ontario (see Brown et al., 1980; OMNR, 1984). The mean annual total streamflow is 196.5 mm (or 24% of precipitation), of which 48% (94 mm) appears as surface runoff, and 52% (102 mm) as baseflow. Negative values of net storage (losses) occur in May to August because the ET potential cannot be satisfied by the available precipitation, and must be taken from soil-water storage.

The results of the long-term (65 year) water balance simulations are summarized in Table 49 for existing conditions at selected locations within the study area. Table 50 summarizes water balance for the proposed conditions at the selected locations. Table 49 and Table 50 also show comparative results of existing and post development conditions. For the entire study area, evapotranspiration (ET) and sublimation decrease from 72% to 68 % of the total precipitation and total runoff increases from 28% to 30% of the total precipitation or 230 mm to 251 mm. The increase total flow or runoff from the

study area is due to the increase in imperviousness in the proposed conditions. There will be some positive effects of LIDs incorporated in the project area which have not been incorporated in the proposed conditions modelling.

As a part of the EIA, SAVANTA Inc. has identified a number of wetlands/marshy areas in Eagle Heights. Additional water balance modeling results have been provided to SAVANTA for the existing and post development conditions to evaluate the effects of changes in water balance on some of these features.

Table 49 Water balance summary for selected locations within the study area in existing conditions

Location	Hyd No	Area	Prep	ET/SUB	Runoff	Baseflow	Net Storage (Loss)	Total Flow
		(ha)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Trib 4 at Flatt Road	403	11.81	827	566	127	135	-0.2	261
Trib 4 at Panin Road	2427	33.55	827	553	145	130	-0.8	275
Trib 5 East at Flatt Road	503	46.55	827	631	102	94	-0.6	197
Trib 5 West at Flatt Road	530	18.39	827	607	104	117	-1.0	221
Trib 5 at Panin Road	2551	84.36	827	606	115	106	-0.6	222
Trib 6 at Flatt Road	603	30.91	827	635	101	92	-0.5	193
Average			827	598	120	109	-1	230
			100%	72%	15%	13%	-0.1%	28%

Table 50 Water balance summary for selected locations within the study area in proposed conditions

Location	Hyd No	Area	Prep	ET/SUB	Runoff	Baseflow	Net Storage (Loss)	Total Flow
		(ha)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
Trib 4 at Flatt Road	2412	10.86	827	438	293	95	1.2	388
Trib 4 at Panin Road	2421	32.70	827	489	214	124	1.0	337
Trib 5 East at Flatt Road	2512	44.59	827	610	130	71	15.9	201
Trib 5 West at Flatt Road	2521	19.97	827	591	144	71	20.4	217
Trib 5 at Panin Road	2563	82.94	827	595	122	97	13.8	218
Trib 6 at Flatt Road			827	609	147	49	22.4	196
Average			827	564	161	90	12	251
			100%	68%	19%	11%	1.5%	30%

9.0 EROSION ASSESSMENTS

9.1 Erosion Assements using continues modeling

The long-term modelling with 65 years of meteorological data was also used to assess the erosion impacts within the project area. As discussed in the previous section, with the increase in imperviousness due to the proposed development, there will be an increase in runoff volume, which could potentially increase the erosion in the project area.

As a part of the current submission, Matrix Solution Inc. has also updated the geomorphic assessment of the project area, "*Eagle Heights Geomorphic Assessment*", *May 2018*. Matrix was requested to provide the erosion threshold in the project area as a part of the geomorphic assessment. Table E of the Matrix report summarizes erosion threshold analysis.

In the long-term modeling, using GAWSER, critical discharge (m^3/s) was used as a basis for comparing the erosion impacts in the existing and post development conditions. Table 51 gives a sample of the mean annual flow exceedance summary and how they are distributed by month throughout the year for the Tributary 4 at Flatt Road. Matrix's report identifies the critical discharge for reach 4-4 as 0.08 m^3/s. Table 51 shows in 65 years (1950 to 2015) the critical discharge at this location will be exceeded 413 times or 6.35 times per year on average. It also shows that most of these events will occur in March and September will have the least events which exceed the critical discharge. Results for all reaches but the reach 5 (Ravine) identified in geomorphic report are included in Appendix E of this report. SWM Pond 5-A is located just upstream of reach 5 Ravine. The outlet from the SWM Pond will bypass the ravine and the pond outlet will be connected to Tributary 5 West downstream of the ravine. Therefore, the erosion issues identified in the existing conditions will not occur in the post development conditions.

Table 51 Flow exceedance summary- Tributary 4 at Flatt Road (Reach 4-4)

Location: Trib 4 at Flatt Rd (Reach 4-4)
Period: 1950/11/ 1 to 2015/10/30

	Mean	Flow Extremes			Threshold 1:			
	Flow	Highest	Lowest	Total	Flow:	0.0800 (m^3/s)		
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration
JAN	0.00127	0.20300	0.00000	48360.	37.	0.1	13.	2.8
FEB	0.00145	0.15370	0.00000	44064.	33.	0.1	16.	2.1
MAR	0.00242	0.22410	0.00000	48360.	87.	0.2	30.	2.9
APR	0.00207	0.25350	0.00000	46800.	62.	0.1	21.	3.0
MAY	0.00097	0.23300	0.00000	48360.	19.	0.0	9.	2.1
JUN	0.00028	0.20250	0.00000	46800.	9.	0.0	4.	2.3
JUL	0.00034	0.49390	0.00000	48360.	40.	0.1	5.	8.0
AUG	0.00021	0.25240	0.00000	48360.	14.	0.0	3.	4.7
SEP	0.00019	0.12330	0.00000	46800.	4.	0.0	1.	4.0
OCT	0.00037	0.25920	0.00000	48336.	27.	0.1	6.	4.5
NOV	0.00078	0.18510	0.00000	46800.	29.	0.1	11.	2.6
DEC	0.00143	0.18280	0.00000	48360.	52.	0.1	19.	2.7
Annual	0.00098	0.49390	0.00000	569760.	413.	0.1	138.	3.0

Table 52 summarizes flow exceedances for the erosion thresholds identified in the geomorphic report. For example, in reach 4-4 critical flow for the erosion threshold is 0.08 (m^3/s). For existing conditions in 65 years only 413 hours or 0.07% of the time, the flow will exceed the critical flow. The average duration of pulses is 3.0 hours for the existing condition.

In the post development conditions, critical flows will be exceeded 694 hours or 0.12% of the total time and the number of pulses will be 289 or 4.45 times per year. But the average duration of pulse in post development conditions will drop to 2.4 hours from 3.0 hours in the existing conditions.

In the case of the Tributary 5 West (reach 5-4) and Tributary 6 (reach 6-5), critical flow exceedance hours and pulses will be reduced in post development condition compared to the existing conditions. In general, these results show that the erosion condition will not be of concern compared to the existing condition in the Project Site area.

Table 52 Tributary flow exceedance summary for erosion threshold

Location	Reach	Watershed Conditions	Total Duration (Hours)	Erosion Threshold				
				Critical Flow (m3/s)	Critical Flow Exceedance (hours)	Critical Flow Exceedance (%)	No. of Pulses	Avg Pulse Duration (hr)
Trib 4 at Flatt Road	Reach 4-4	Existing	569,760	0.08	413	0.07%	138	3.0
		Post Dev	569,760	0.08	694	0.12%	289	2.4
Trib 4 at Panin Road	Reach 4-1a	Existing	569,760	0.10	2096	0.37%	496	4.2
		Post Dev	569,760	0.10	2424	0.43%	653	3.7
Trib 4 at Panin Road	Reach 4-1b	Existing	569,760	1.10	4	0.00%	1	2.0
		Post Dev	569,760	1.10	1	0.00%	1	1.0
Trib 5 West at Flatt Road	Reach 5-4	Existing	569,760	0.04	2441	0.43%	480	5.1
		Post Dev	569,760	0.04	1322	0.23%	253	5.2
Trib 6 at Flatt Road	Reach 6-5	Existing	569,760	0.18	363	0.06%	103	3.5
		Post Dev	569,760	0.18	144	0.03%	43	3.3

9.2 Erosion Assements in Event Based Modeling

The continuous modelling in GAWSER can be run only in hourly time steps. Eagle Heights consist of relatively small watersheds, therefore flow rates information generated from hourly times steps might not be accurate representations in some cases.

A 2–year 24-hour Chicago storm event was run in 5 - minute time steps in GAWSER for existing and post development conditions. Figure 37 to Figure 40 show hydrographs at the critical reaches identified in the geomorphology report. These hydrographs show pre development and post development hydrographs are quite similar, therefore, the proposed developments will not affect the hydraulic regime of the creeks.

As discussed earlier these GAWSER model do not take in to account LID measures (bioretention cells). The positive effects from these LID measures will be added benefit to the results presented here.

Figure 37 Existing and Post Development Hydrographs (2 -Year Chicago Storm - Reach 4-4)

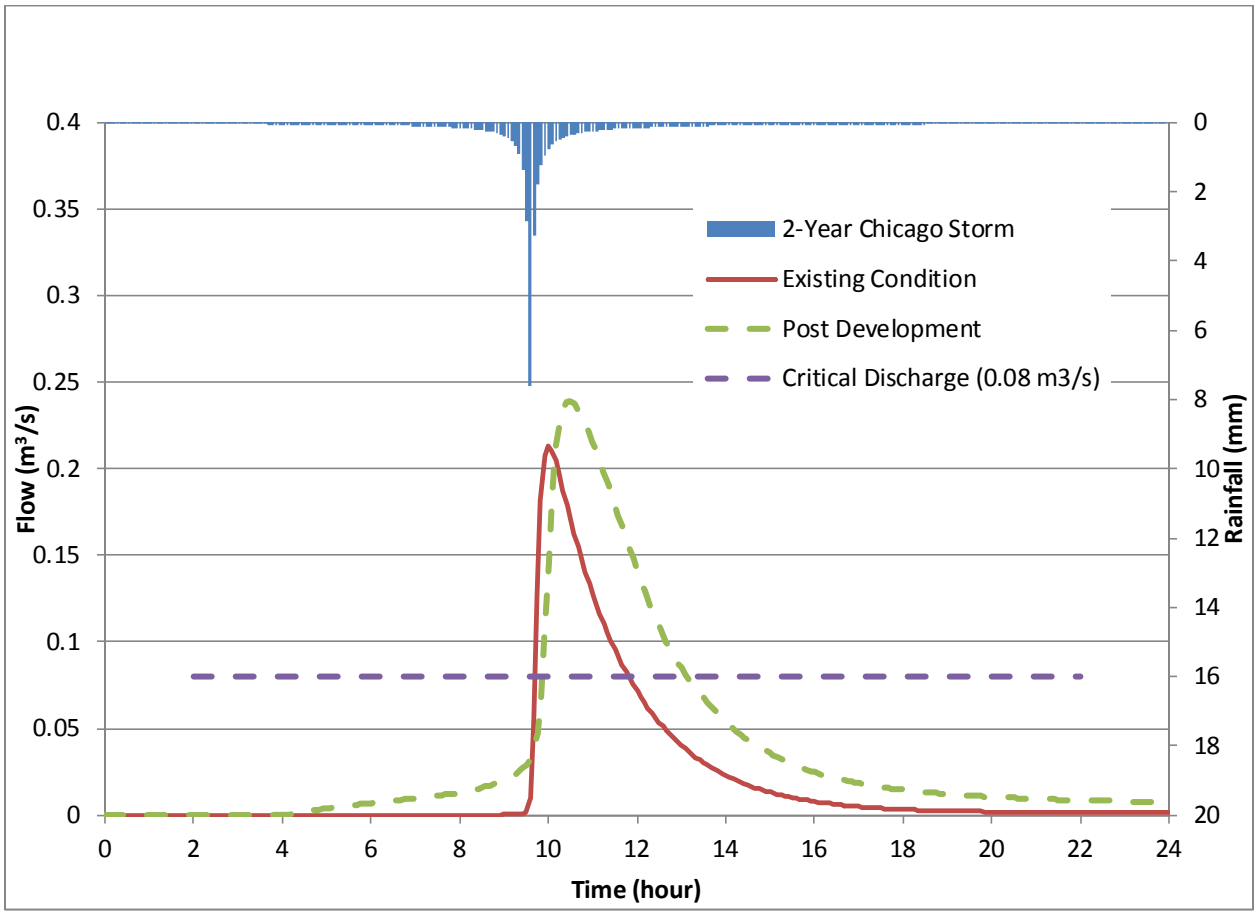


Figure 38 Existing and Post Development Hydrographs 2 -Year Chicago Storm - Reach 4-1a

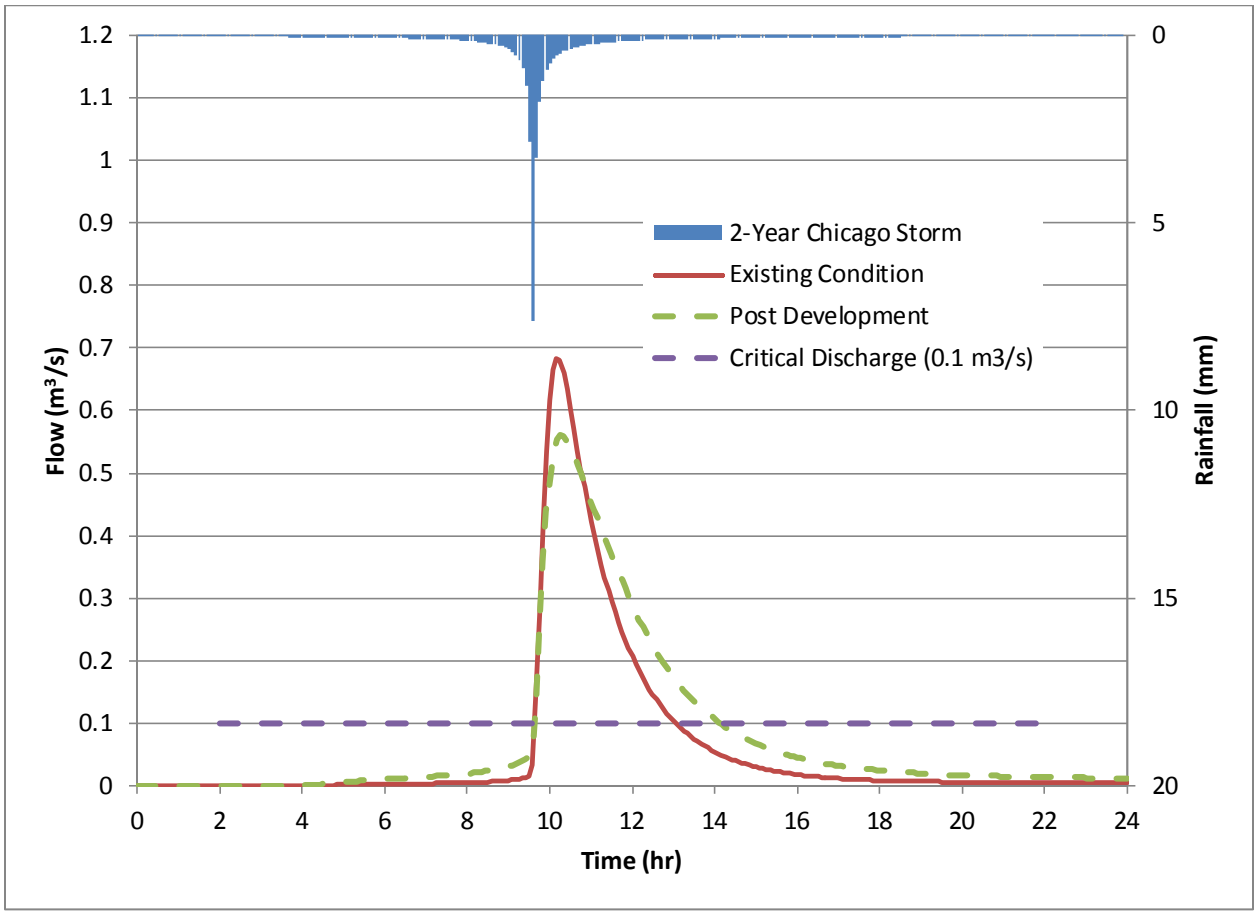


Figure 39 Existing and Post Development Hydrographs 2 -Year Chicago Storm - Reach 5-4

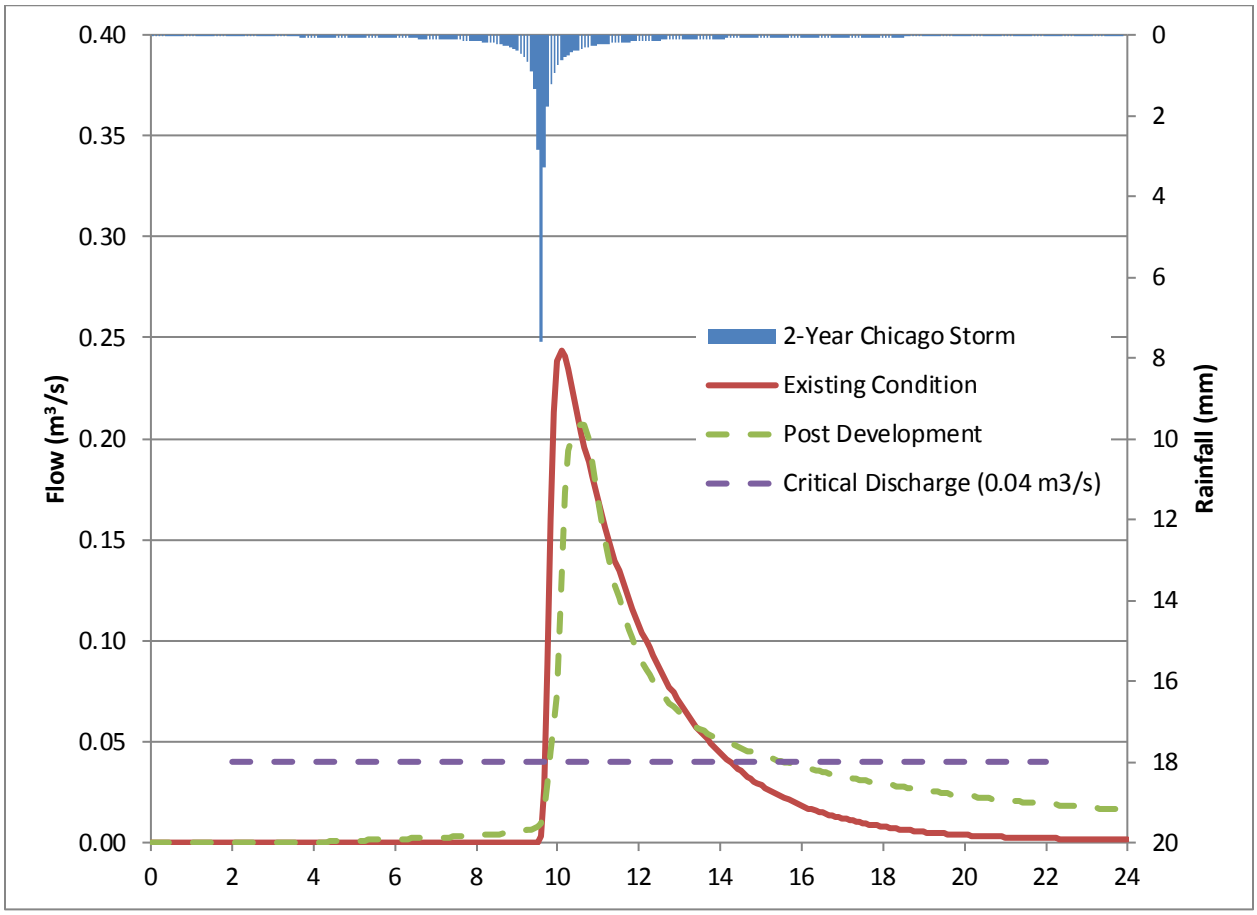
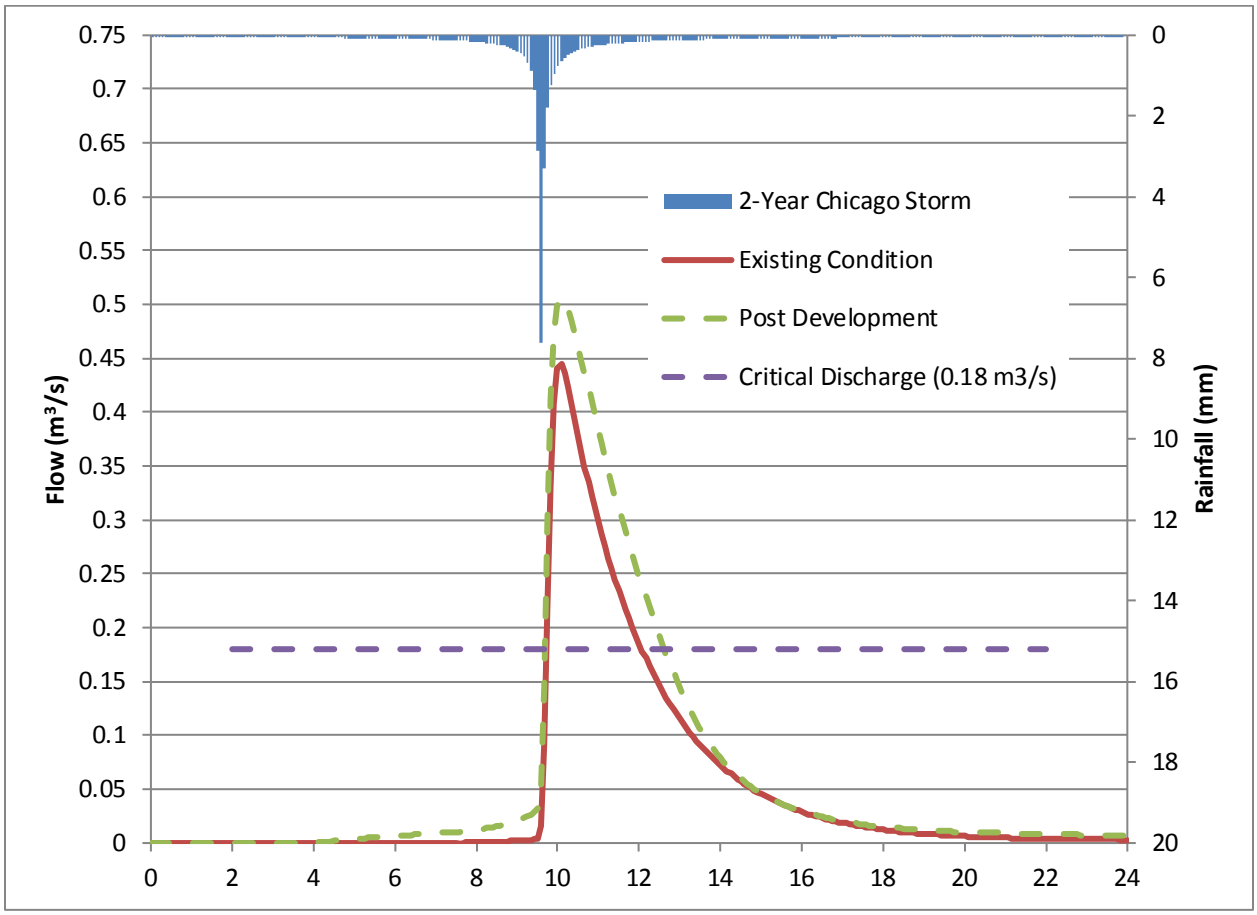


Figure 40 Existing and Post Development Hydrographs 2 -Year Chicago Storm- Reach 6-2



10.0 FLOOD INUNDATION MAPPING

It is very important to assess the flood inundation risk in any development, especially for development near unconfined valleys. The creeks that flow through the Eagle Heights development are mostly in confined valleys in most cases with deep valleys. All of the subcatchments north of Flatt Road are also less than 50 ha.

Flood Inundation modelling and mapping was created for Tributary 5 West and Tributary 4 north of Flatt Road. Inundation mapping of all the other tribtuary reaches were not deemed necessary as they are either very deep and wide valleys even for regional level flood flows or pose no risk to any proposed or existing develoment/residences.

River cross-sections used in the HEC RAS model were generated using the topographical information collected from the field survey and inundation mapping was created using AutoCAD 3D program.

HEC RAS results and inundation mapping has been included in Appendix F of this report.

11.0 LOW IMPACT DEVELOPMENT(LID) MEASURES

In recent years, Low Impact Development (LID) have been encouraged to be implemented in new developments by municipalities, provincial govement agencies and Conservation Authorities. The Ministry of the Enviroment & Climate Change (MOECC) has recently issued the *Low Impact Development Stormwater Management Guidance Manual* (Draft Version 1.0, April 20, 2017), which will most likely come into effect in the near future.

There are opportunities within the subject land where LID measures can be implemented to reduce the impact of post development runoff where it is deemed beneficial and practical.

LID measures will help to enhance the water quality, reduce erosion and improve water balance for post development conditions. LIDs also significantly reduce runoff from frequent smaller events, for example 2-year, 5-year return period events, which results in signficant increase in water quality for post development runoff and also reduces erosion potential.

According to the Credit Valley Conservation report (http://www.creditvalleyca.ca/wp-content/uploads/2014/08/Grey-to-Green-Road-ROW-Retrofits-Complete_1.pdf), on July 8, 2013, one rain guage located in Mississauga recorded 100 mm of precipitation over a five hour period, with a 240 mm/h peak intensity over a 10 minute interval. LID practices installed on Elm Drive in Mississauga were found to provide 60% peak and 30% volume reductions as well as a 20 minute lag time for discharge to leave the site.

The proposed development is proposed with rural road cross-sections with 5 meter roadside ditches on either side of the roads. These roadside ditches provide excellent opportunities to implement LID measures as they are within the municipal right of way (ROW).

In this case, bioretention cells are proposed as primary LID measures throughout the development. They are proposed to be constructed under the roadside ditches within the public ROW. Typical sections of bioretention cells are shown in Figure 10.

Depending on the underlying geological conditions, two types of bioretetion cells (Type A and Type B) have been proposed. In area with higher infiltration rates, there will be 500mm storage (Type B) below underdrain pipe and in area with slower infiltration rates, there will be 100 mm storage (Type A).

Even if the soil conditions underneath bioretention cells are not favourable for infiltration, it will help to enhance water quality and reduce peak stormwater runoff. Figure 9 shows the location of all these infiltration trenches and Figure 10 shows the typical cross sections of the bioretention cells which will also function as stormwater storage facilities.

The storage volume requirements for the proposed development, 24-hour 100-year return period Chicago Storm, does not take into consideration the effect of LID measures. If runoff is absorbed by infiltration, then this will be an added advantage over the provided stormwater storage.

LID measures that will be implemented on this project at the lot level have also been discussed in further detail in section 3.2 of Funcational Servicing Report, Metropolitan Consulting Inc, April 2018.

Penta Propertries Inc. has also engaged hydrogeologist (Terra-Dynamics Consulting Inc.) to assess the hydrogeology of the Eagle Heights. The findings and recommendations from the hydrogeological study will be incorporated in the design and implementation of all proposed LID measures. This report has been submitted under separate cover.

12.0 SUMMARY & CONCLUSIONS

Penta owns approximately 102 ha of land in Northern Aldershot Area. The proposed Eagle Heights development encompasses 37.82 ha. The remaining lands are to be transferred to the Public Agencies.

This report assesses the existing hydrolgical conditions of the proposed Eagle Heights Development. A stormwater management plan has been prepared for the proposed development based on the existing hydrological parameters of the Project Site area.

A number of actual storm events recorded on the project site in 2016 and 2017 were used to calibrate GAWSER and SWMHYMO Model using the on-site measured rainfall and tributary flow data.

The calibrated model was used to establish flood flows at various on-site and downstream points of interest including the tributary crossings at Flatt Road and Panin Road. The stormwater storage sizes for the project have been designed using a 24-hour 100-year return period Chicago Storm for the City of Burlington. One (1) SWM pond, six (6) underground superpipes and nine (9) private underground on-site storages facilities are proposed to manage design storm event (24-hour 100-year return period storm).

In the previous SWM Report by prepared by Metropolitan Inc in 2010, there were 5 SWM Ponds including one (1) online SWM pond were proposed in Eagle Heights. The online SWM Pond have been removed and replaced with Superpipes and Bioretention in this report.

Each private on-site storage facility will be equipped with a an oil-grit separator before releasing the runoff from the proposed development to receiving water bodies or creeks.

In the areas where underground storage (superpipes) have been proposed, surface runoff will first go through bioretention cells and then to superpipes, which will enhance the water quality of the post-development runoff.

Inundation mappings for Tributary 4 North and Tributary 5 West were created for the regional storm (Hurricane Hazel) flows. Other tributatries do not affect the proposed or

existing developments, therefore, inundation mappings for other creeks were not created.

The continuous hydrological modelling for the project was done using the GAWSER program with 65 years of climate and rainfall data from Enviroment Canada's Hamilton RBG CS (Climate ID: 6153301). The calibrated GAWSER model was used for the continuous hydrological modelling to assess water balance and erosion assessments for the project area. As shown on Table 49 and Table 50, there is only about a 9% increase in total runoff from existing conditions to post development conditions which is about a 2% increase of total precipitation.

Bioretention cells are proposed as primary LID measures throughout the development. They are proposed to be constructed under the roadside ditches within the public ROW. Depending on the underlying geological conditions, two types of bioretetion cells (Type A and Type B) have been proposed. In area with higher infiltration rates, there will be 500mm storage (Type B) below underdrain pipe and in area with slower infiltration rates, there will be 100 mm storage (Type A).

In the GAWSER modelling, LID measures proposed in the project area have not been incorporated. Any positive effects of LID measures, e.g. reduction in peak flow rates, increase in travel time, reduction in runoff volume or erosion will be additional to the results included in this report.

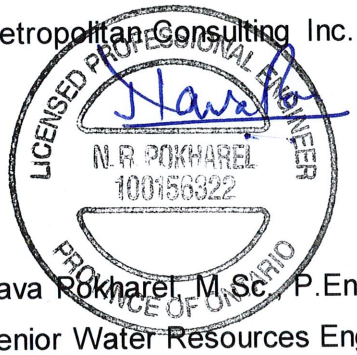
As discussed in this report, the proposed development is located in different isolated pods and traversed by three major tributaries Therefore, traditional SWM ponds are not feasible in all but one case as the drainage areas are less than 5 ha. According to MOE 2003 guidelines, SWM pond needs at minimum 5 ha drainage to function properly.

The continuous modelling results show that post development erosion increases slightly compared to pre development conditions . As discussed in section 9 of the report, the continuous modeling in GAWSER can be run only in hourly time steps. As Eagle Heights consists of relatively small and steep watersheds flow rates generated from hourly time steps is not ideal. Therefore a 24-hour 2-year Chicago storm events were modeled in a 5-minute time steps for the existing and post-development conditions. These hydrographs (Figure 37 to Figure 40) show existing and post development flow

hydrographs for a 2-year return period 24-hour Chicago storm are fairly similar which implies that hydraulic or sediment regime of the area will not be affected by the proposed development in Eagle Heights.

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(GAWSER modelling setup, troubleshooting and wrote section 6.0 of the report)

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APPENDIX A: Flow Hydrographs Measured on the Project Site & Leveloggers Rating Curves

Figure A-1 : Measured Hydrograph at Tributary 4 at Flatt Rd Culvert

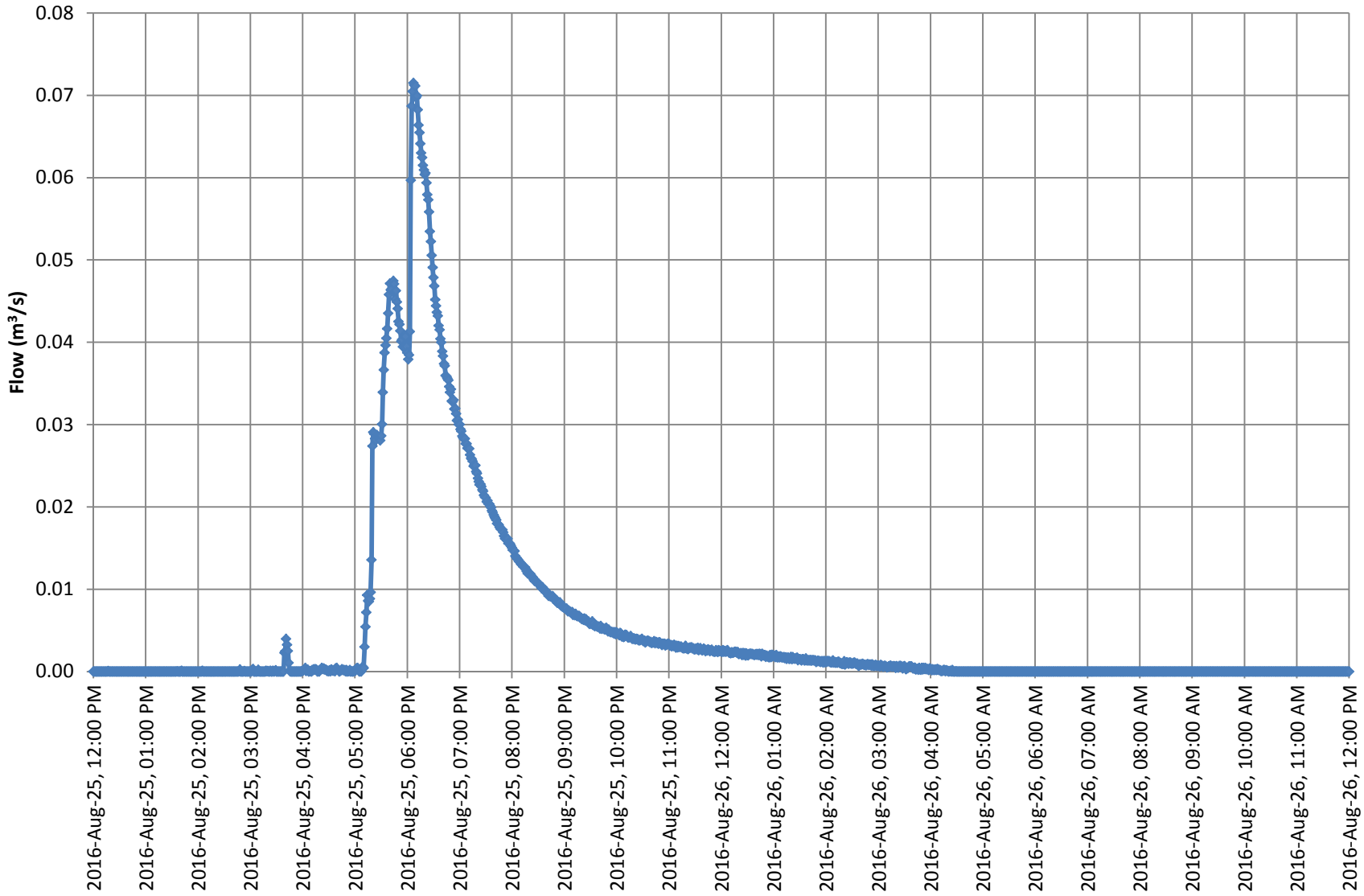


Figure A-2 : Tributary 6 flow just D/S of confluence of two branches

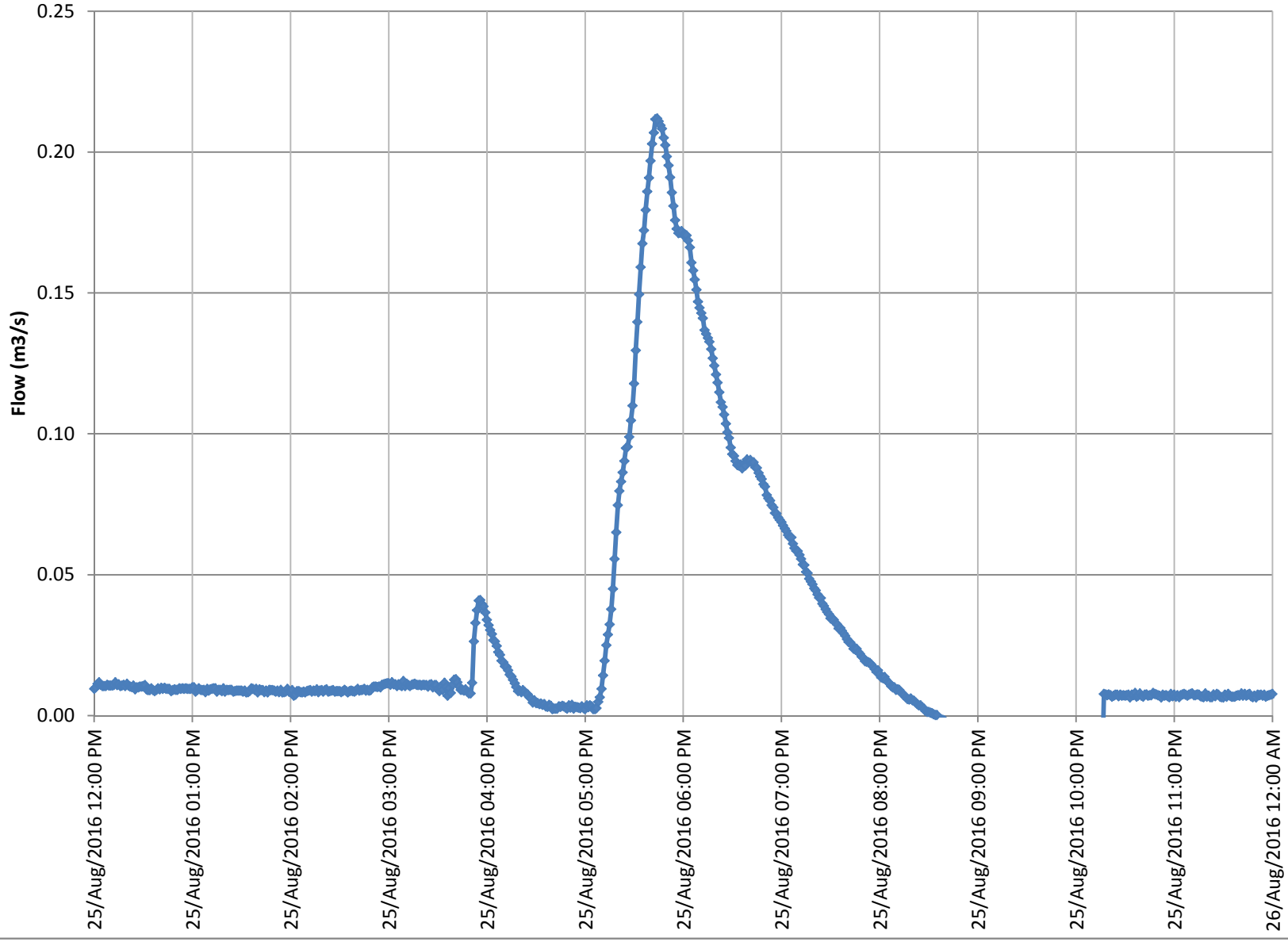


Figure A-3: Tributary 5 south flow upstream of Panin Road

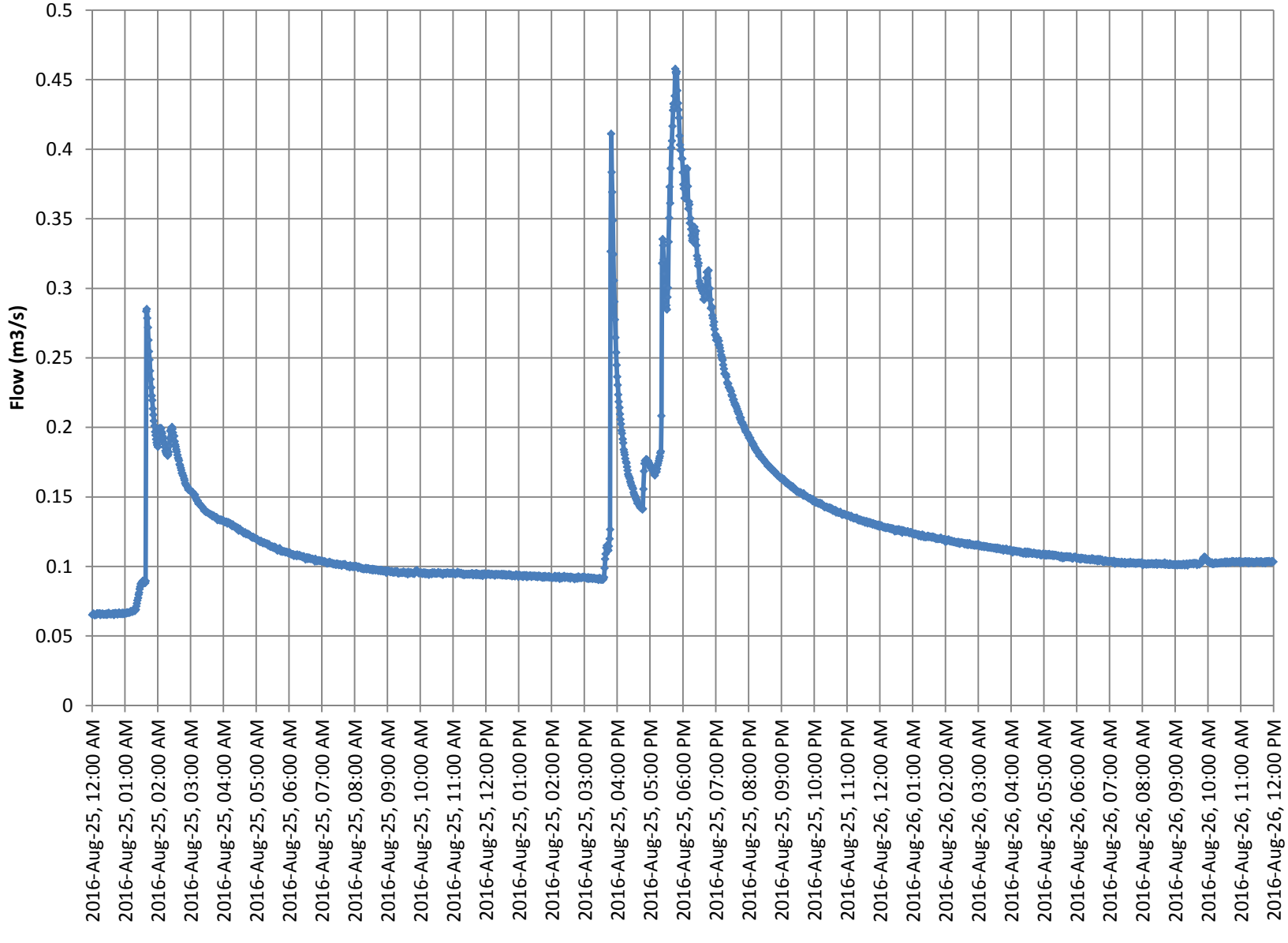


Figure A-4: Tributary 4 flow hydrograph at Flatt Rd culvert

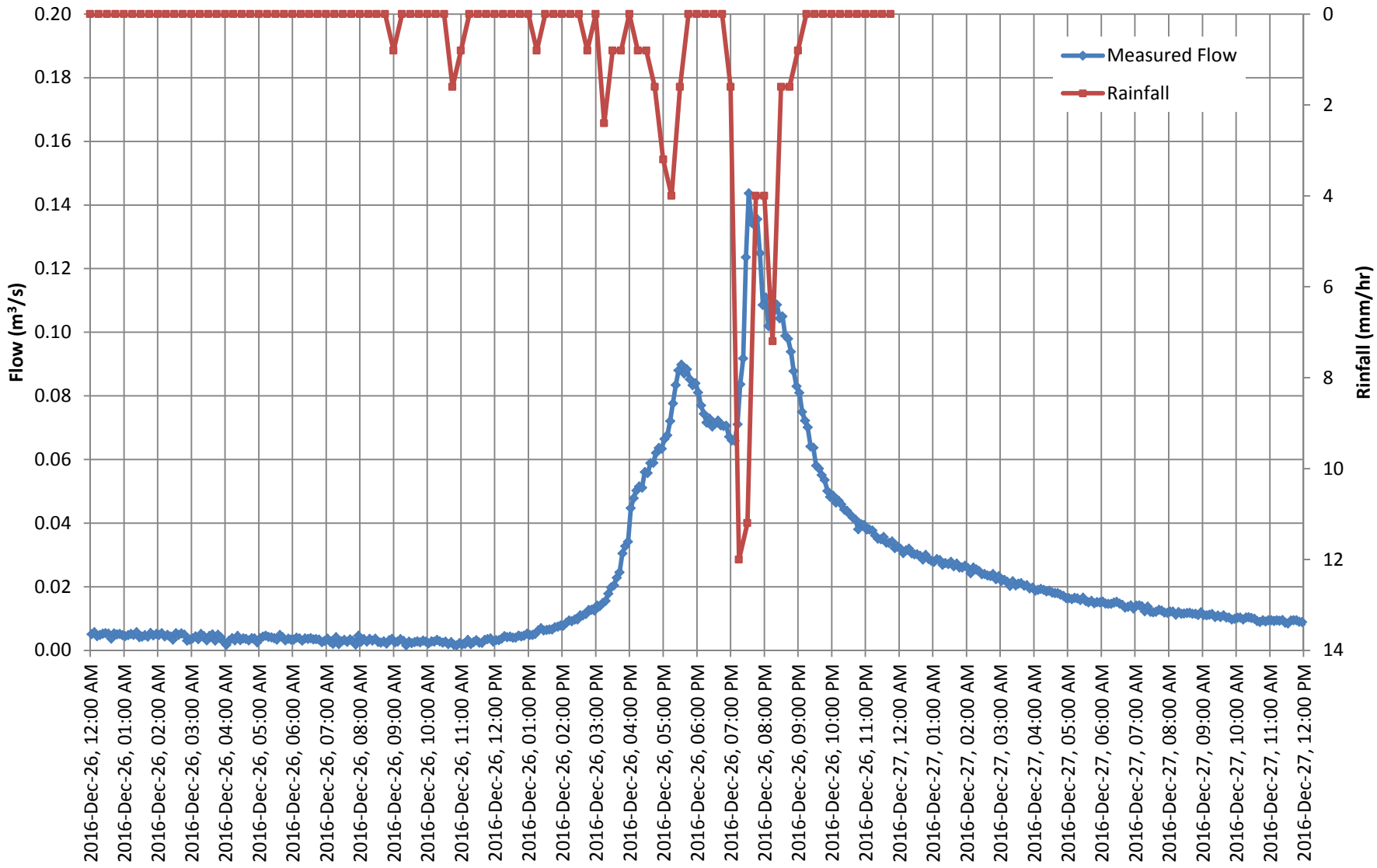


Figure A-5: Tributary 5 south flow at upstream of Panin Road

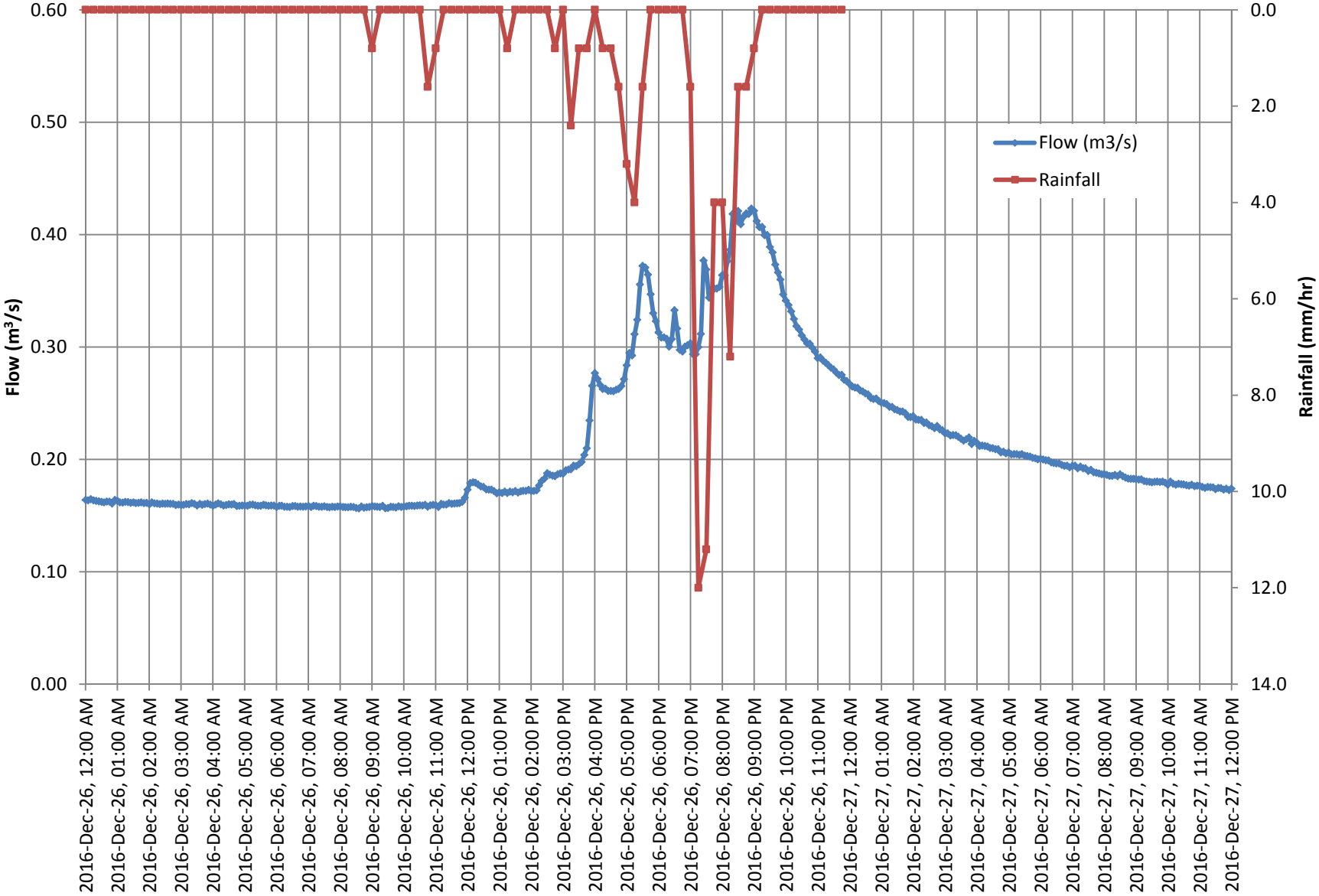


Figure A-6: Tributary 6 flow just d/s of confluence two branches

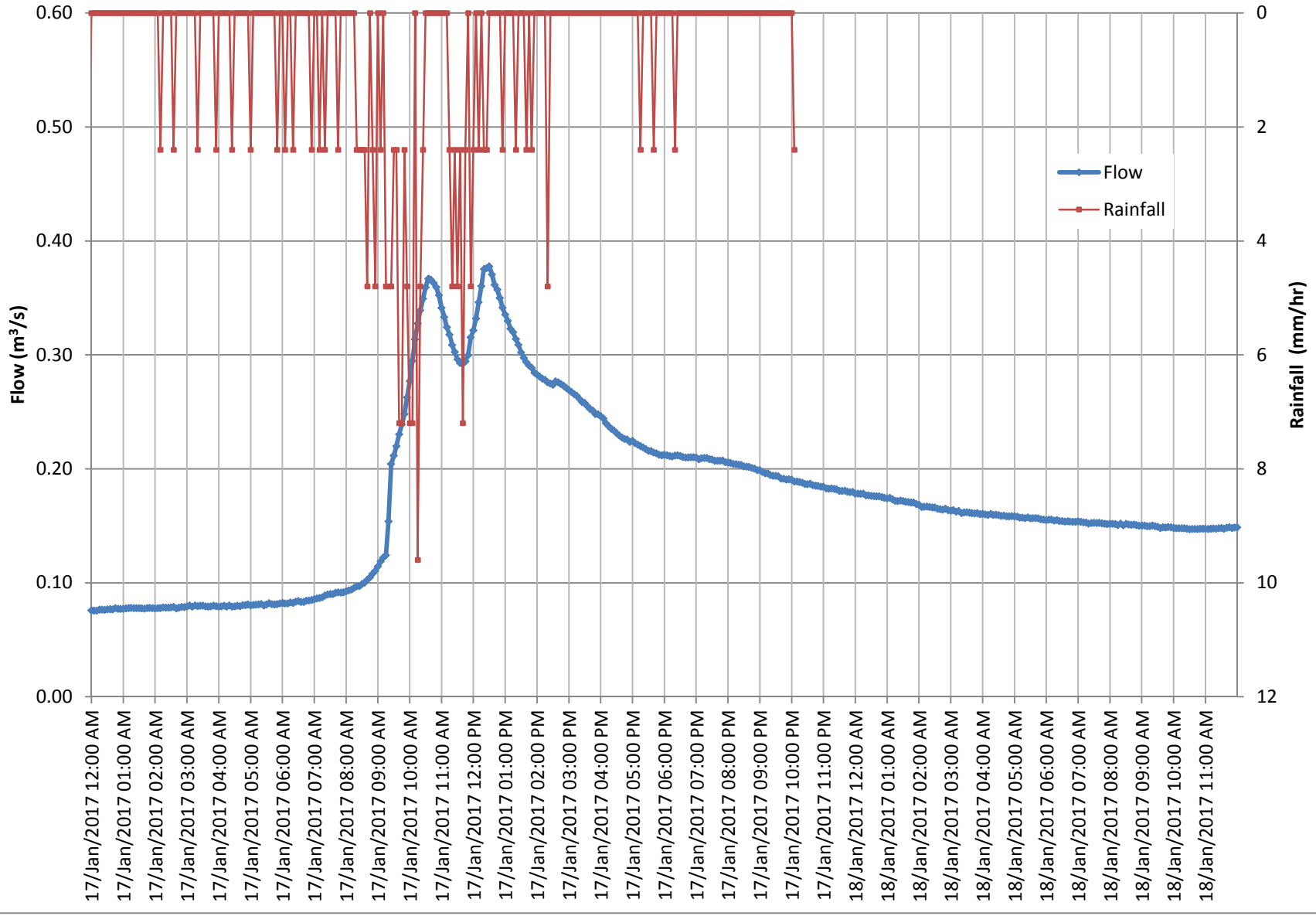


Figure A-7: Measured Hydrograph at Tributary 4 at Flatt Road & Rainfall

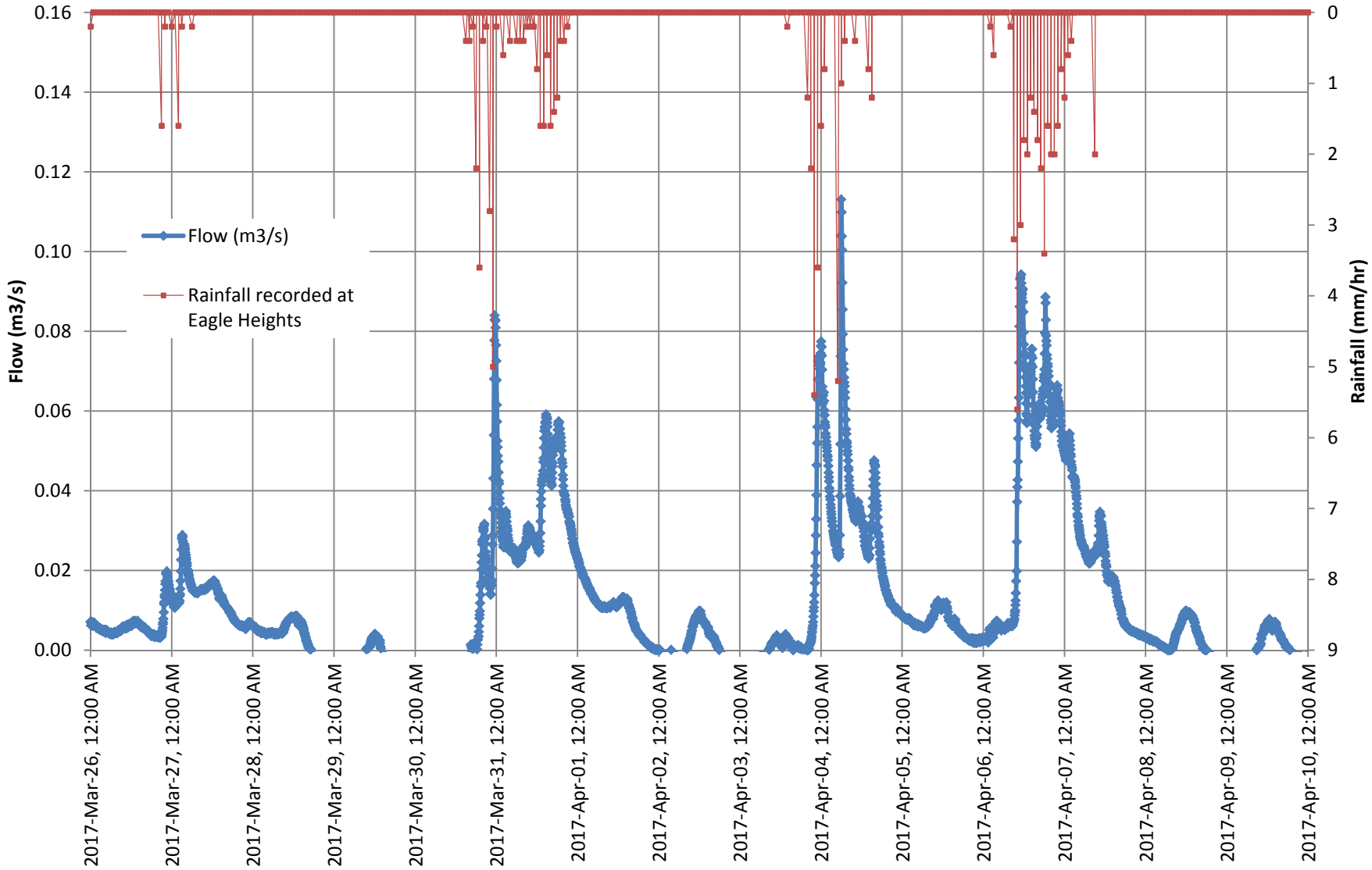


Figure A-8: Tributary 5 South Flow at Upstream of Panin Road and Rainfall

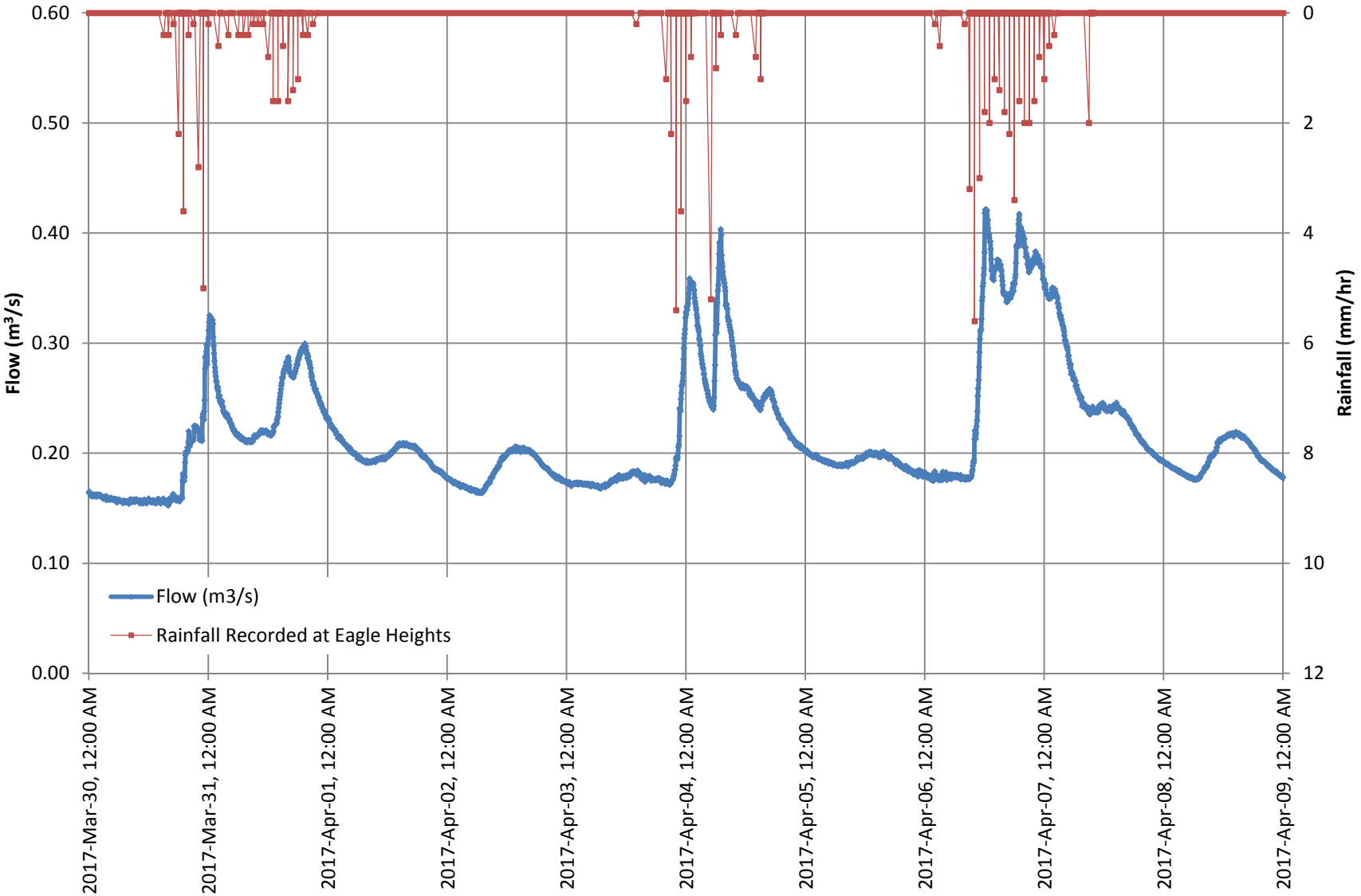


Figure A-9: Tributary 6 Flow just d/s of confluence of two branches and rainfall

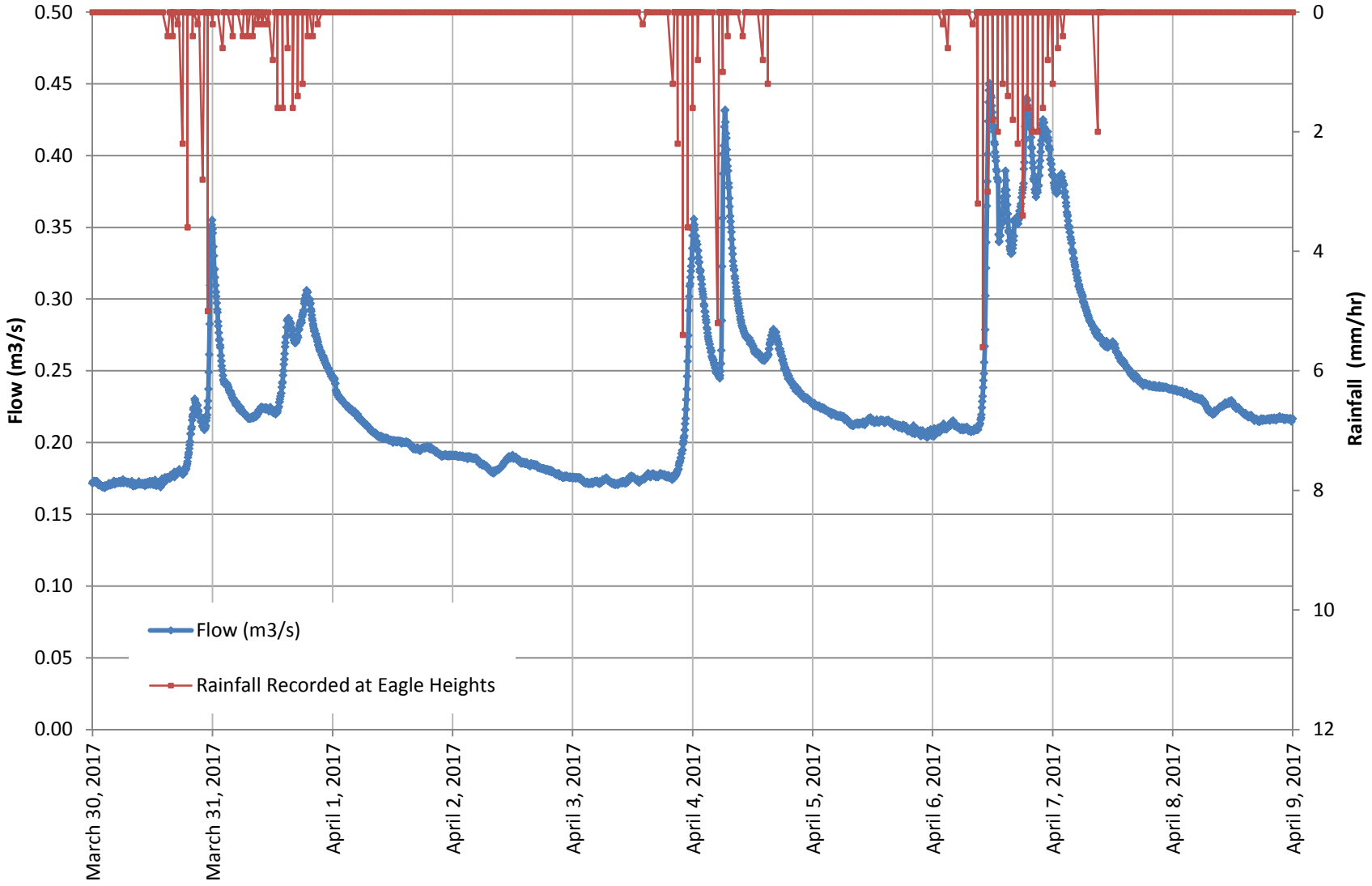


Figure A-10: Tributary 6 Upstream of Flatt Road Flow and Rainfall

(April 28 to June 14, 2017)

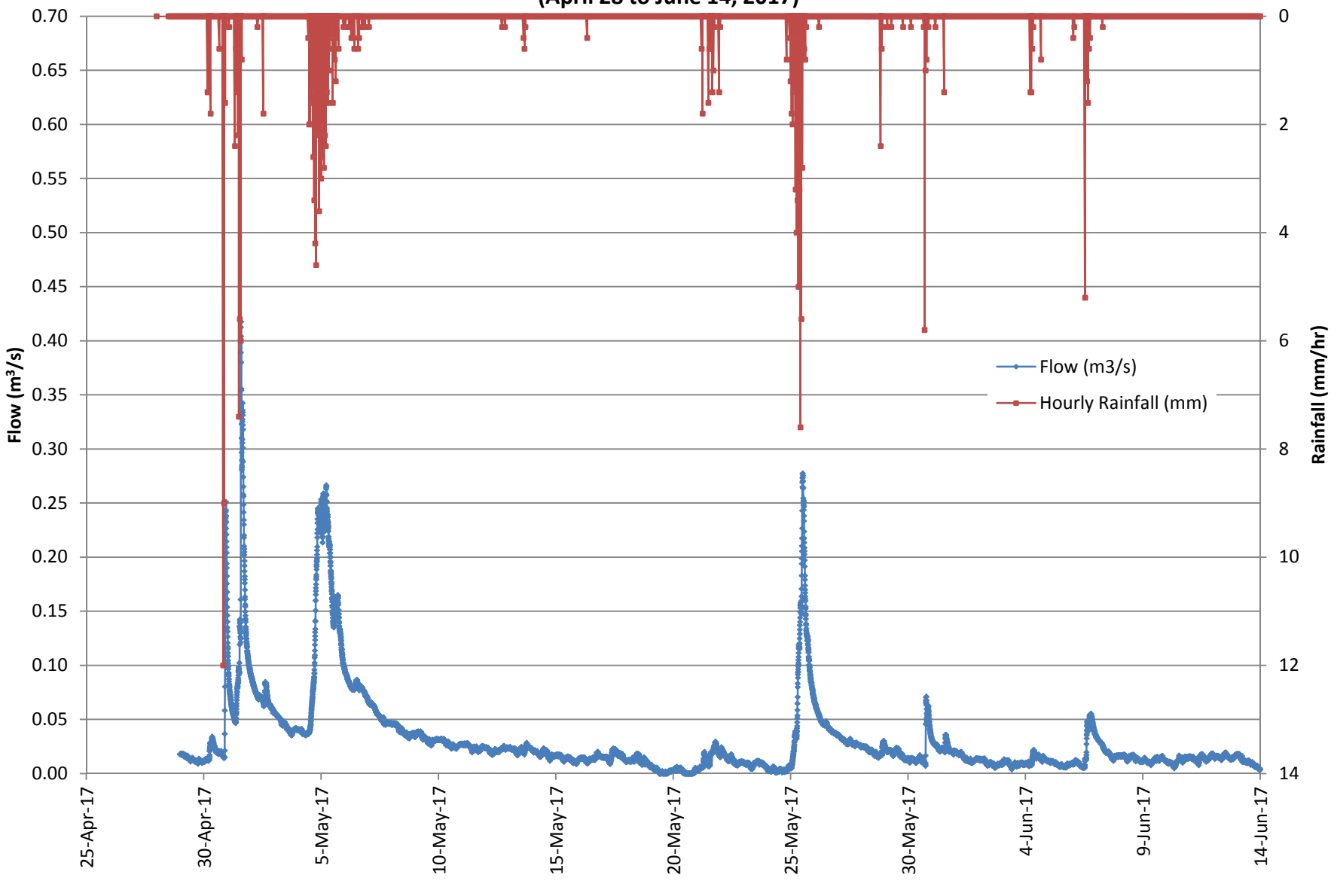
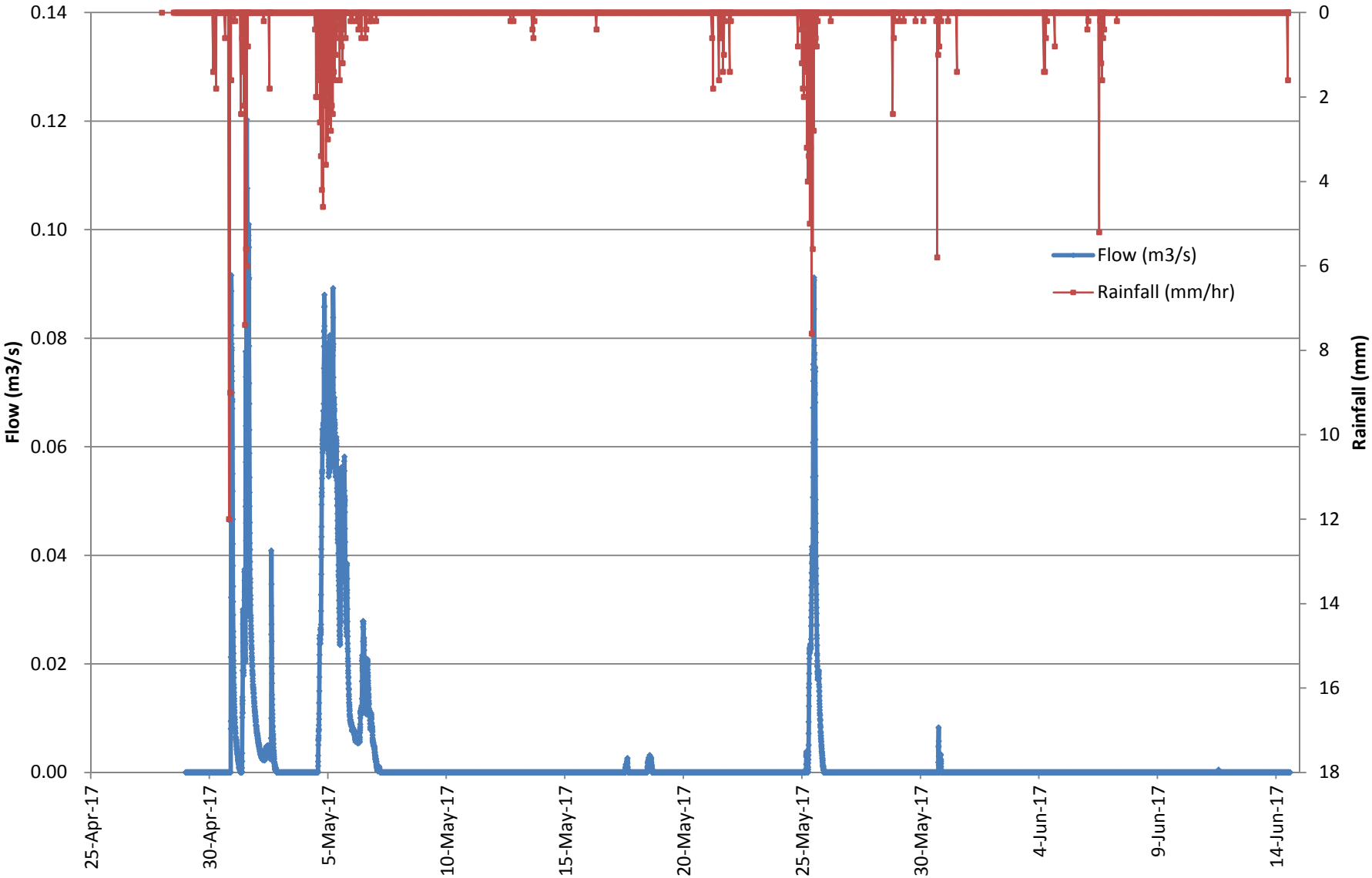


Figure A -11: Tributary 4 at Flatt Road Flow and Rainfall (April 28 to June 14, 2017)



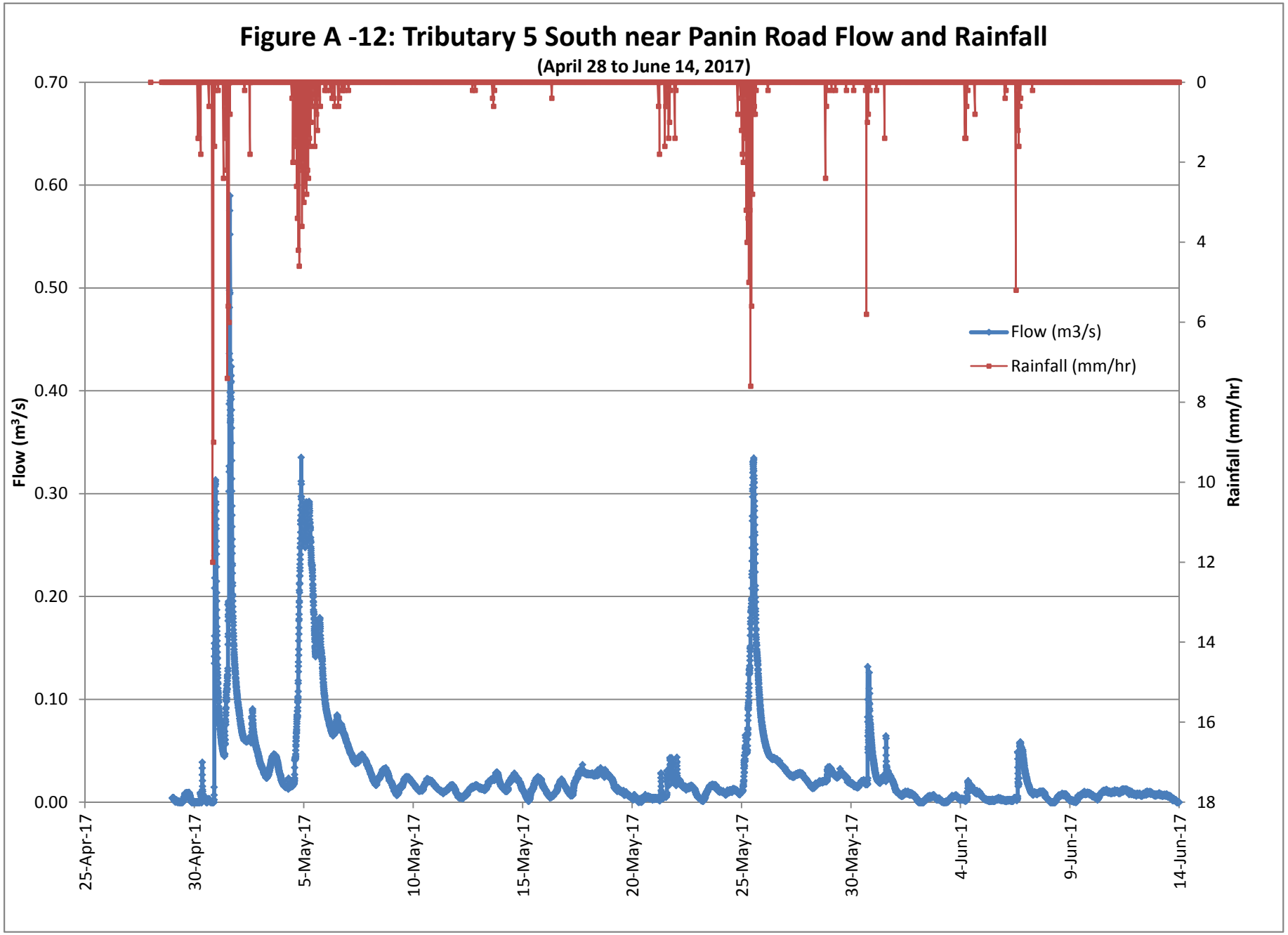

Figure A -12: Tributary 5 South near Panin Road Flow and Rainfall
(April 28 to June 14, 2017)
Flow (m3/s)
Rainfall (mm/hr)
Flow (m³/s)
Rainfall (mm/hr)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
2
4
6
8
10
12
14
16
18
25-Apr-17
30-Apr-17
5-May-17
10-May-17
15-May-17
20-May-17
25-May-17
30-May-17
4-Jun-17
9-Jun-17
14-Jun-17

Figure A -13: Rating Curve of Levellogger # 1

(Tributary 6 just d/s of confluence of two branches)

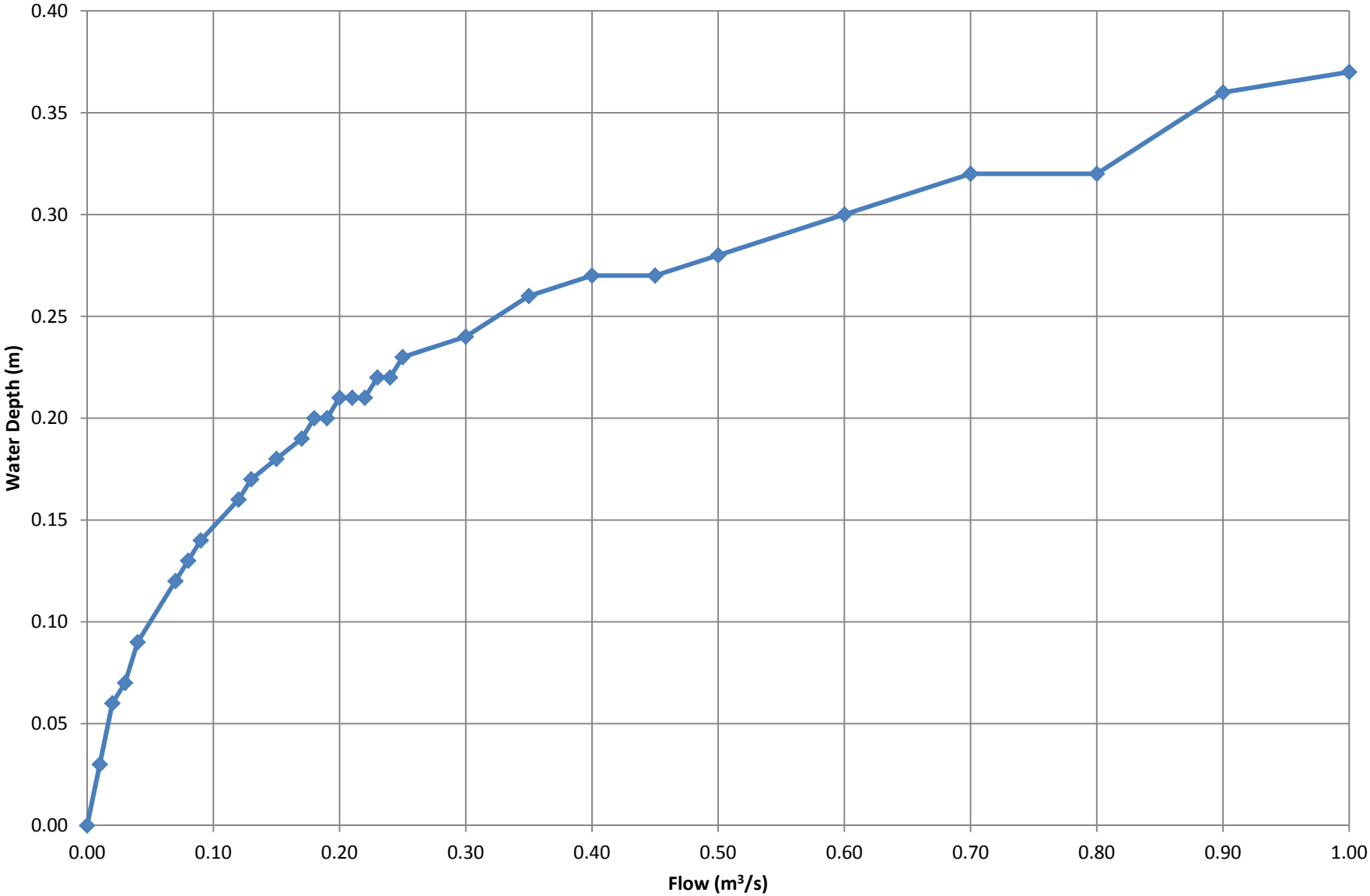


Figure A -14: Rating Curve of Levelogger # 3

(Tributary 5 East at Flatt Road)

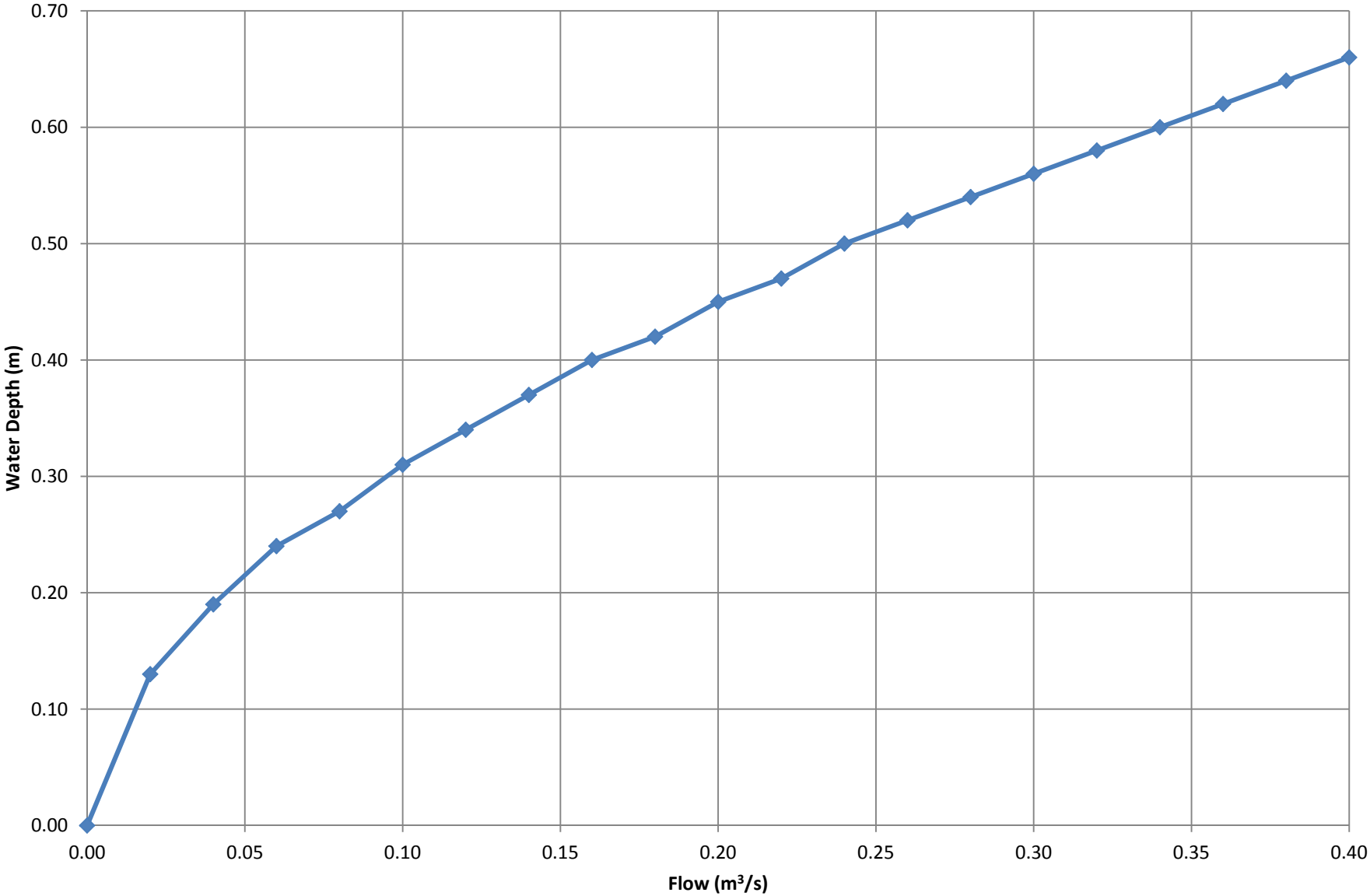


Figure A -15: Rating Curve of Levelogger # 4

(Tributary 4 at Flatt Road)

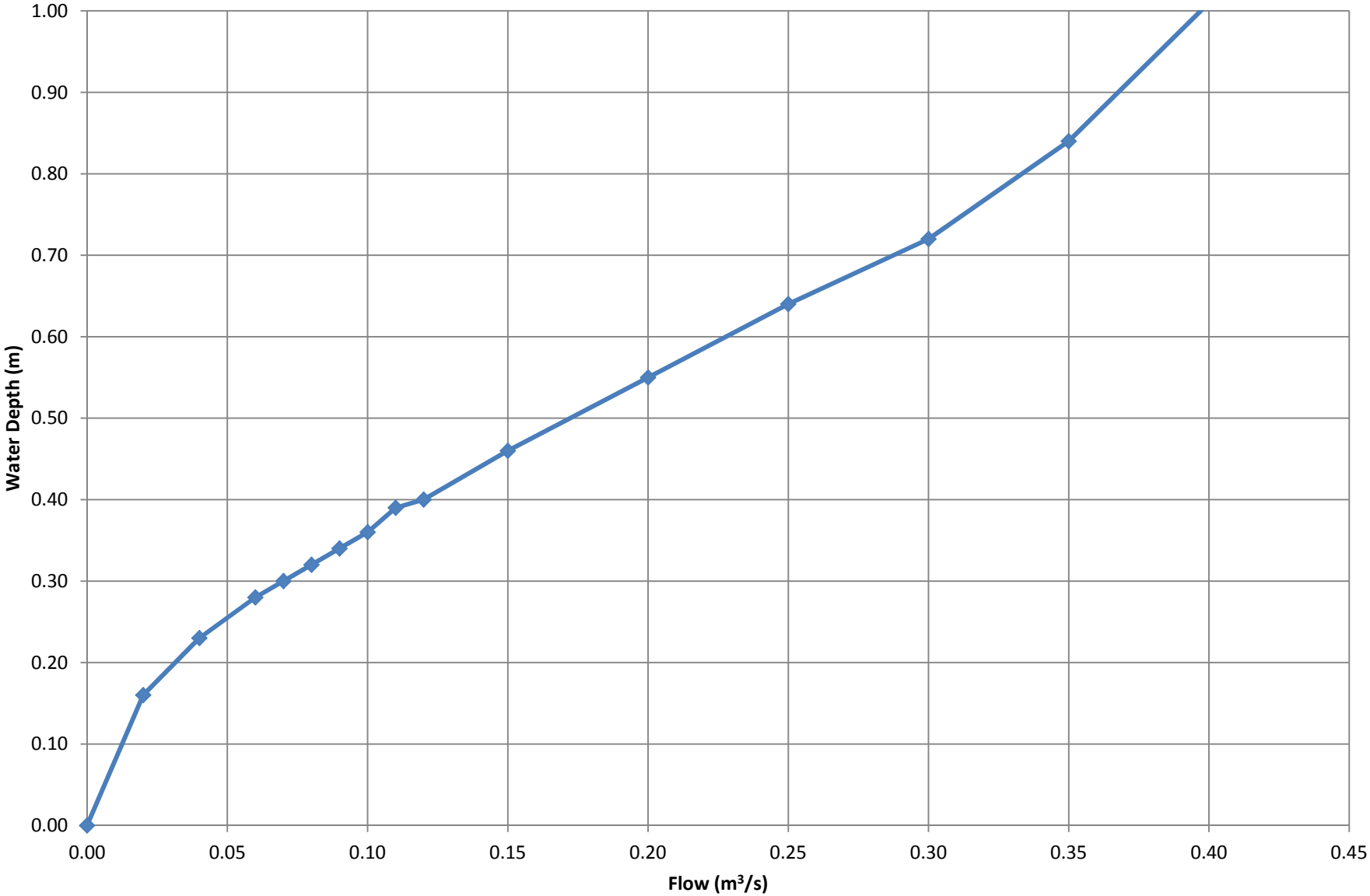
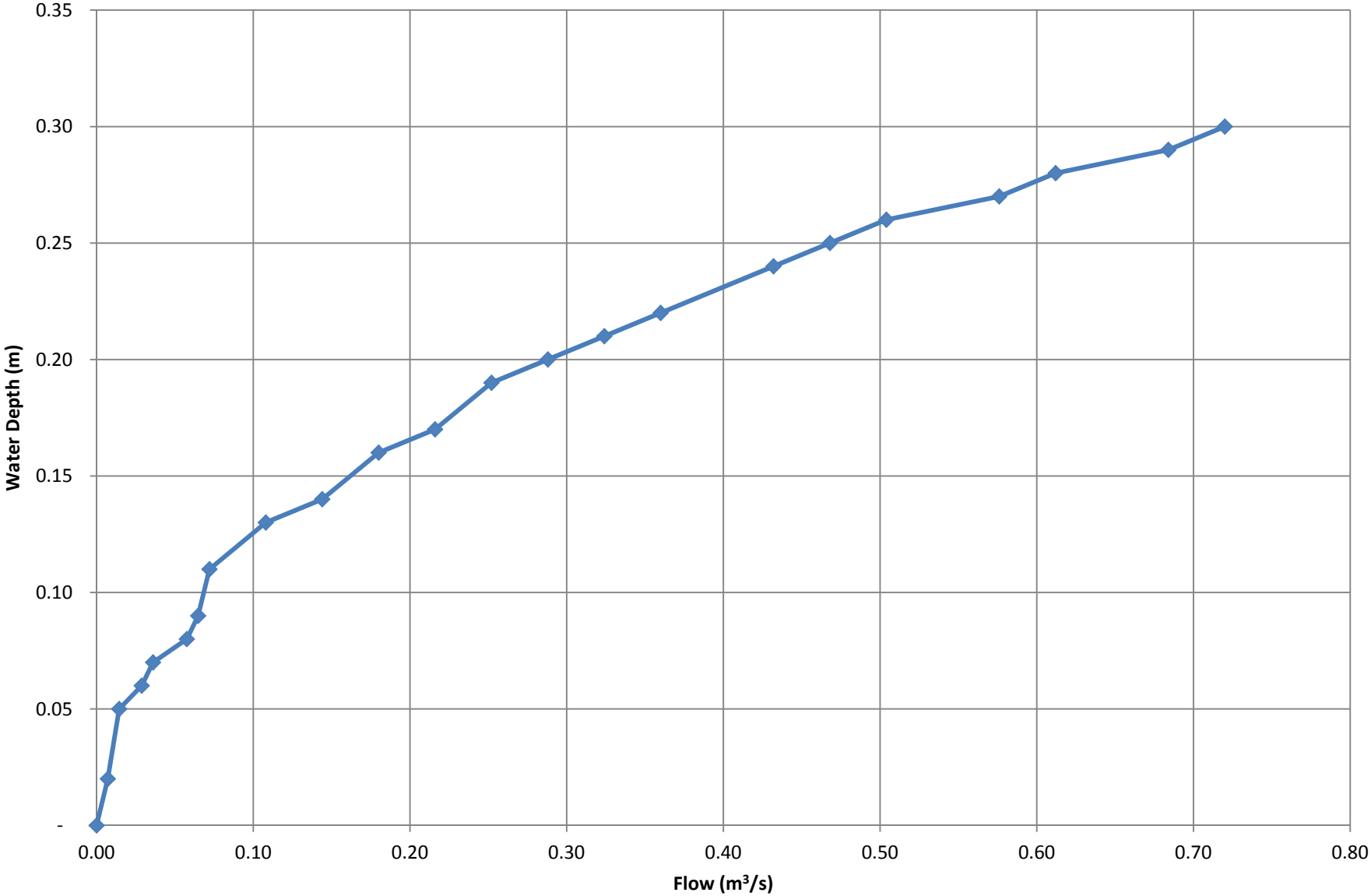


Figure A -16: Rating Curve of Levelogger # 5

(Tributary 5 South Near Panin Road)



APPENDIX B: SWM Pond and other SWM Structures Design Tables

Table B-1 : Eagle Heights SWM - Superpipes and On-site Storages

Drainage ID	Draft Plan Block	Type of Development	Area (ha)	Percentage Impervious (%)	100 -Year Pre-Development Unit Area Flow Rate (m3/s/ha)	100 -Year Pre-Development Total Flow Rate (m3/s)	100 -Year Post-Development Total Flow Rate (m3/s)	Outlet Orifice Pipe Size (mm)	Total Storage (m3)	Storage on Road Side Ditches (m3)	Superpipes Storage (m3)	Storage Dimension	SWM Type	Location
406		Single Family	3.33	42%	0.052	0.172	0.167	215	907	237	670	155m [2400 X 1800]	Superpipes (SP-41)	Street E
409	Block SS	Cluster Housing	2.87	67%	0.052	0.148	0.105	165	1,120			35m X 16m X 2m	On-site Storage (STC -42)	On-site
415	Block G	Cluster Housing	2.09	45%	0.045	0.093	0.047	110	1,000			25m X 20m X 2m	On-site Storage (STC-43)	On-site
418		Single Family	2.96	32%	0.045	0.132	0.110	250	1,080	254	826	195 m [2400 X 1800]	Superpipes (SP-44)	Street X
503		Single Family	3.29	17%	0.034	0.112	0.072	140	1,015	94	921	215 m [2400 X 1800]	Superpipes (SP-51)	Horning Road
506	Block P	Cluster Housing	0.80	52%	0.034	0.027	0.019	75	360			20m X 12m X 1.5m	On-site Storage (STC -52)	On-site
509	Block OO	Cluster Housing	1.00	44%	0.034	0.034	0.019	75	480			20m X 16m X 1.5m	On-site Storage (STC -53)	On-site
515		Single Family	1.55	35%	0.041	0.063	0.062	130	540	242	298	70 m [2400 X 1800]	Superpipes (SP-54)	Flatt Rd Extension
518		Mixed	5.97	31%	0.041	0.243	0.177						SMW Pond (Pond- 5A)	
606		Single Family	2.46	28%	0.043	0.107	0.082	150	864	248	616	145m [2400 X 1800]	Superpipes (SP-61)	Street B
609	Block H	Cluster Housing	0.46	58%	0.043	0.020	0.019	75	180			12m X 10m X1.5m	On-site Storage (STC -62)	On-site
615	Block D	Cluster Housing	1.33	25%	0.043	0.058	0.043	105	416			16m X 13m X 2m	On-site Storage (STC -63)	On-site
618	Block E	Cluster Housing	1.02	39%	0.043	0.044	0.039	90	432			18m X 12m X 2m	On-site Storage (STC -64)	On-site
621		Single Family	3.53	34%	0.043	0.153	0.118	180	1,123	438	685	160 m [2400 X 1800]	Superpipes (SP-65)	Street A
634	Block K	Cluster Housing	0.89	45%	0.043	0.039	0.032	90	336			14m X 10m X 2m	On-site Storage (STC -66)	On-site
636	Block JJ	Cluster Housing	1.24	39%	0.043	0.054	0.043	105	432			18m X 12m X 2m	On-site Storage (STC -67)	On-site

Notes:

- Post-development flow rates in some cases are less then pre-development flow rates to match the pre and post development flow rates at the point of interests at Flatt Road and Panin Road.

Table B-2: Box Culvert Superpipes (SP-41)

Designer Inputs: Box Culvert Superpipes

Orifice

Orifice Pipe Diameter (m) = 0.215 m

Area of Pipe = 0.036 m2

Cd = 0.80

Height= 1800 mm = 1.80 m

Width= 2400 mm = 2.40 m

Length (L)= 210 m

Storage Provided 907 m3

Date: January 30, 2018

Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 406

Drainage Area= 3.33 ha

Percentage Impervious= 42%

100-year Allowable Flow Rate= 0.167 (m3/s)

Location = Street E

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.693	0.167	Orifice	0.167	167	0.22	907	0.0907	5,420	55,645	15.5
	95	1710	1.710	1.603	0.163	Orifice	0.163	163	0.22	862	0.0862	5,292	50,224	14.0
	90	1620	1.620	1.513	0.158	Orifice	0.158	158	0.19	816	0.0816	5,160	44,932	12.5
	85	1539	1.539	1.431	0.154	Orifice	0.154	154	0.10	776	0.0776	5,039	39,772	11.0
	83	1496	1.496	1.388	0.152	Orifice	0.152	152	0.13	754	0.0754	4,973	34,819	9.7
	80	1440	1.440	1.333	0.149	Orifice	0.149	149	0.22	726	0.0726	4,887	34,733	9.6
	75	1350	1.350	1.243	0.143	Orifice	0.143	143	0.22	680	0.0680	4,745	29,846	8.3
	70	1260	1.260	1.153	0.138	Orifice	0.138	138	0.43	635	0.0635	4,598	25,101	7.0
	60	1080	1.080	0.973	0.127	Orifice	0.127	127	0.43	544	0.0544	4,290	20,503	5.7
	50	900	0.900	0.793	0.115	Orifice	0.115	115	0.43	454	0.0454	3,961	16,212	4.5
	40	720	0.720	0.613	0.101	Orifice	0.101	101	0.43	363	0.0363	3,604	12,252	3.4
	30	540	0.540	0.433	0.085	Orifice	0.085	85	0.43	272	0.0272	3,217	8,647	2.4
	20	360	0.360	0.253	0.065	Orifice	0.065	65	0.22	181	0.0181	2,807	5,431	1.5
	15	270	0.270	0.163	0.052	Orifice	0.052	52	0.65	136	0.0136	2,624	2,624	0.7
Bottom of pipes	0	0	0.000	0.000	0.000	Orifice	0.000	0	0.00	0	0.0000	-	-	0.0

Table B-3: Onsite Storage (STC - 42) Design Table

Designer Inputs: On-site Storage

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

	Orifice		Height=	2000	mm	Length=	35 m
Orifice Pipe Diameter (m) =	0.165	m		2.00	m	Width=	16 m
Area of Pipe (m^2) =	0.021	m2				Storage Provide=	1120 (m^3)
Cd =	0.80						

Sub-catchment ID = 409
Drainage Area= 2.87 ha
Percentage Impervious= 67%
100-year Allowable Flow Rate= 0.105 (m3/s)
Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.918	0.105	Orifice	0.105	105	56.0	1120	0.1120	10,675	107,883	30.0
	95	1900	1.900	1.818	0.102	Orifice	0.102	102	56.0	1064	0.1064	10,416	97,208	27.0
	90	1800	1.800	1.718	0.099	Orifice	0.099	99	50.5	1008	0.1008	10,151	86,792	24.1
	85	1710	1.710	1.627	0.097	Orifice	0.097	97	26.8	957	0.0957	9,906	76,641	21.3
	83	1662	1.662	1.580	0.095	Orifice	0.095	95	34.7	931	0.0931	9,774	66,909	18.6
	80	1600	1.600	1.518	0.093	Orifice	0.093	93	56.0	896	0.0896	9,599	66,735	18.5
	75	1500	1.500	1.418	0.090	Orifice	0.090	90	56.0	840	0.0840	9,312	57,135	15.9
	70	1400	1.400	1.318	0.087	Orifice	0.087	87	112.0	784	0.0784	9,015	47,824	13.3
	60	1200	1.200	1.118	0.080	Orifice	0.080	80	112.0	672	0.0672	8,390	38,809	10.8
	50	1000	1.000	0.918	0.073	Orifice	0.073	73	112.0	560	0.0560	7,716	30,419	8.4
	40	800	0.800	0.718	0.064	Orifice	0.064	64	112.0	448	0.0448	6,980	22,703	6.3
	30	600	0.600	0.518	0.055	Orifice	0.055	55	112.0	336	0.0336	6,164	15,723	4.4
	20	400	0.400	0.318	0.043	Orifice	0.043	43	112.0	224	0.0224	5,247	9,559	2.7
	10	200	0.200	0.118	0.026	Orifice	0.026	26	112.0	112	0.0112	4,312	4,312	1.2
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0	0.0	0	0.0000	-	-	0.0

Table B-4: Onsite Storage (STC - 43) Design Table

Designer Inputs: On-site Storage

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

	Orifice							
Orifice Pipe diameter (m) =	0.110	m	Height=	2000 mm 2.00 m	Length- Width=	25 m 20 m	Sub-catchment ID =	415
							Drainage Area=	2.09 ha
Area of Pipe (m^2) =	0.010	m^2			Storage	1000 (m^3)	Percentage Impervious=	45%
Cd =	0.80						100-year Allowable Flow Rate=	0.047 (m3/s)
							Location =	On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.945	0.047	Orifice pipe	0.047	47	50	1000	0.1000	21,292	213,253	59
	95	1900	1.900	1.845	0.046	Orifice pipe	0.046	46	50	950	0.0950	20,769	191,961	53
	90	1800	1.800	1.745	0.044	Orifice pipe	0.044	44	45	900	0.0900	20,232	171,192	48
	85	1710	1.710	1.655	0.043	Orifice pipe	0.043	43	24	855	0.0855	19,735	150,960	42
	83	1662	1.662	1.607	0.043	Orifice pipe	0.043	43	31	831	0.0831	19,466	131,580	37
	80	1600	1.600	1.545	0.042	Orifice pipe	0.042	42	50	800	0.0800	19,112	131,226	36
	75	1500	1.500	1.445	0.040	Orifice pipe	0.040	40	50	750	0.0750	18,527	112,113	31
	70	1400	1.400	1.345	0.039	Orifice pipe	0.039	39	100	700	0.0700	17,923	93,586	26
	60	1200	1.200	1.145	0.036	Orifice pipe	0.036	36	100	600	0.0600	16,651	75,663	21
	50	1000	1.000	0.945	0.033	Orifice pipe	0.033	33	100	500	0.0500	15,274	59,012	16
	40	800	0.800	0.745	0.029	Orifice pipe	0.029	29	100	400	0.0400	13,762	43,738	12
	30	600	0.600	0.545	0.025	Orifice pipe	0.025	25	100	300	0.0300	12,067	29,977	8
	20	400	0.400	0.345	0.020	Orifice pipe	0.020	20	100	200	0.0200	10,111	17,910	5
	10	200	0.200	0.145	0.013	Orifice pipe	0.013	13	100	100	0.0100	7,798	7,798	2
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice pipe	0.000	0	0	0	0.0000	-	-	0

Table B-5: Superpipes Degin Table (SP-44)

Designer Inputs: Box Culvert Superpipes

	Orifice							
Orifice Pipe Diameter (m) =	0.165	m	Height=	1800	mm	Length=	250	m
				1.80	m			
			Width=	2400	mm	Storage Provided=	1080	m3
Area of Pipe (m^2) =	0.021	m2		2.40	m			
Cd =	0.80							

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID =	418	
Drainage Area=	2.96	ha
Percentage Impervious=	32%	
100-year Allowable Flow Rate=	0.110	(m3/s)
Location =	Street X	

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (m-ha)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.718	0.099	Orifice Pipe	0.099	99	0.22	1080	0.1080	10,876	110,295	30.6
	95	1710	1.710	1.628	0.097	Orifice Pipe	0.097	97	0.22	1026	0.1026	10,614	99,419	27.6
	90	1620	1.620	1.538	0.094	Orifice Pipe	0.094	94	0.19	972	0.0972	10,346	88,805	24.7
	85	1539	1.539	1.456	0.091	Orifice Pipe	0.091	91	0.10	923	0.0923	10,097	78,459	21.8
	83	1496	1.496	1.413	0.090	Orifice Pipe	0.090	90	0.13	897	0.0897	9,963	68,538	19.0
	80	1440	1.440	1.358	0.088	Orifice Pipe	0.088	88	0.22	864	0.0864	9,787	68,362	19.0
	75	1350	1.350	1.268	0.085	Orifice Pipe	0.085	85	0.22	810	0.0810	9,495	58,575	16.3
	70	1260	1.260	1.178	0.082	Orifice Pipe	0.082	82	0.43	756	0.0756	9,195	49,079	13.6
	60	1080	1.080	0.998	0.076	Orifice Pipe	0.076	76	0.43	648	0.0648	8,563	39,884	11.1
	50	900	0.900	0.818	0.069	Orifice Pipe	0.069	69	0.43	540	0.0540	7,882	31,321	8.7
	40	720	0.720	0.638	0.060	Orifice Pipe	0.060	60	0.43	432	0.0432	7,141	23,439	6.5
	30	540	0.540	0.458	0.051	Orifice Pipe	0.051	51	0.43	324	0.0324	6,322	16,298	4.5
	20	360	0.360	0.278	0.040	Orifice Pipe	0.040	40	0.43	216	0.0216	5,412	9,976	2.8
	10	180	0.180	0.098	0.024	Orifice Pipe	0.024	24	0.43	108	0.0108	4,565	4,565	1.3
Bottom of Pipes	0	0	0.000	0.000	0.000	Orifice Pipe	0.000	0	0.00	0	0.0000	-	-	0.0

Table B-6: Box Culvert Superpipes (SP-51) Design Table

Designer Inputs: Box Culvert Superpipes

	Orifice						
Orifice Pipe Diameter (m) =	0.140	m	H=	1800 mm 1.80 m	Length=	235 m	
			W=	2400 mm 2.40 m	Volume=	1015 m3	
Area of Pipe (m^2) =	0.015	m2					
Cd =	0.80						

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID =	503	
Drainage Area=	3.29	ha
Percentage Impervious=	17%	
100-year Allowable Flow Rate=	0.072	(m3/s)
Location =	Horning Road	

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.730	0.072	Orifice Pipe	0.072	72	0.22	1015	0.1015	14,150	143,394	40
	95	1710	1.710	1.640	0.070	Orifice Pipe	0.070	70	0.22	964	0.0964	13,806	129,245	36
	90	1620	1.620	1.550	0.068	Orifice Pipe	0.068	68	0.19	914	0.0914	13,454	115,439	32
	85	1539	1.539	1.469	0.066	Orifice Pipe	0.066	66	0.10	868	0.0868	13,128	101,985	28
	83	1496	1.496	1.426	0.065	Orifice Pipe	0.065	65	0.13	844	0.0844	12,952	89,089	25
	80	1440	1.440	1.370	0.064	Orifice Pipe	0.064	64	0.22	812	0.0812	12,720	88,857	25
	75	1350	1.350	1.280	0.062	Orifice Pipe	0.062	62	0.22	761	0.0761	12,337	76,137	21
	70	1260	1.260	1.190	0.060	Orifice Pipe	0.060	60	0.43	711	0.0711	11,942	63,799	18
	60	1080	1.080	1.010	0.055	Orifice Pipe	0.055	55	0.43	609	0.0609	11,111	51,857	14
	50	900	0.900	0.830	0.050	Orifice Pipe	0.050	50	0.43	508	0.0508	10,214	40,746	11
	40	720	0.720	0.650	0.044	Orifice Pipe	0.044	44	0.43	406	0.0406	9,234	30,532	8
	30	540	0.540	0.470	0.037	Orifice Pipe	0.037	37	0.43	305	0.0305	8,144	21,298	6
	20	360	0.360	0.290	0.029	Orifice Pipe	0.029	29	0.22	203	0.0203	6,912	13,154	4
	15	270	0.270	0.200	0.024	Orifice Pipe	0.024	24	0.65	152	0.0152	6,242	6,242	2
Bottom of Pipes	0	0	0.000	0.000	0.000	Orifice Pipe	0.000	0	0.00	0	0.0000	-	-	0

Table B-7: Onsite Storage (STC - 52) Design Table

Designer Inputs: Onsite Storage

	Orifice		Height =	1500	mm	Length=	20	m	Date: January 30, 2018
Pipe diameter (m) =	0.075	m		1.50	m	Width=	12	m	Designed by: N Pokharel, P.Eng.
							3.00		
Area of pipe (m^2) =	0.004	m2				Storage Provided=	360	(m^3)	Sub-catchment ID = 506
Cd =	0.80								Drainage Area= 1.00 ha
									Percentage Impervious= 53%
									100-year Allowable Flow Rate= 0.019 (m3/s)
									Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (m-ha)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	1500	1.500	1.463	0.019	Orifice	0.019	19	0.00	360	0.0360	19,015	190,162	53
	95	1425	1.425	1.388	0.018	Orifice	0.018	18	0.00	342	0.0342	18,546	171,147	48
	90	1350	1.350	1.313	0.018	Orifice	0.018	18	0.00	324	0.0324	18,065	152,601	42
	85	1282	1.282	1.245	0.017	Orifice	0.017	17	0.00	308	0.0308	17,620	134,536	37
	83	1247	1.247	1.209	0.017	Orifice	0.017	17	0.00	299	0.0299	17,380	117,232	33
	80	1200	1.200	1.163	0.017	Orifice	0.017	17	0.00	288	0.0288	17,063	116,915	32
	75	1125	1.125	1.088	0.016	Orifice	0.016	16	0.00	270	0.0270	16,539	99,853	28
	70	1050	1.050	1.013	0.016	Orifice	0.016	16	0.00	252	0.0252	15,997	83,314	23
	60	900	0.900	0.863	0.015	Orifice	0.015	15	0.00	216	0.0216	14,857	67,317	19
	50	750	0.750	0.713	0.013	Orifice	0.013	13	0.00	180	0.0180	13,622	52,460	15
	40	600	0.600	0.563	0.012	Orifice	0.012	12	0.00	144	0.0144	12,264	38,839	11
	30	450	0.450	0.413	0.010	Orifice	0.010	10	0.00	108	0.0108	10,741	26,574	7
	20	300	0.300	0.263	0.008	Orifice	0.008	8	0.00	72	0.0072	8,977	15,833	4
	10	150	0.150	0.113	0.005	Orifice	0.005	5	0.00	36	0.0036	6,856	6,856	2
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0	0.00	0	0.0000	-	-	0

Table B-8: Onsite Storage (STC - 53) Design Table

Designer Inputs: Onsite Storage

	Orifice		Height =	1500	mm	Length=	20	m	Date: January 30, 2018
Pipe diameter (m) =	0.075	m		1.50	m	Width=	16	m	Designed by: N Pokharel, P.Eng.
Area of pipe (m^2) =	0.004	m2				Storage Provided =	480	(m^3)	Sub-catchment ID = 509
Cd =	0.80								Drainage Area= 1.00 ha
									Percentage Impervious= 44%
									100-year Allowable Flow Rate= 0.019 (m3/s)
									Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (m-ha)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	1500	1.500	1.463	0.019	Orifice	0.0189	19	24	480	0.0480	25,354	253,550	70
	95	1425	1.425	1.388	0.018	Orifice	0.0184	18	24	456	0.0456	24,728	228,196	63
	90	1350	1.350	1.313	0.018	Orifice	0.0179	18	22	432	0.0432	24,087	203,468	57
	85	1282	1.282	1.245	0.017	Orifice	0.0175	17	11	410	0.0410	23,493	179,381	50
	83	1247	1.247	1.209	0.017	Orifice	0.0172	17	15	399	0.0399	23,173	156,310	43
	80	1200	1.200	1.163	0.017	Orifice	0.0169	17	24	384	0.0384	22,750	155,887	43
	75	1125	1.125	1.088	0.016	Orifice	0.0163	16	24	360	0.0360	22,051	133,137	37
	70	1050	1.050	1.013	0.016	Orifice	0.0158	16	48	336	0.0336	21,330	111,086	31
	60	900	0.900	0.863	0.015	Orifice	0.0145	15	48	288	0.0288	19,809	89,756	25
	50	750	0.750	0.713	0.013	Orifice	0.0132	13	48	240	0.0240	18,162	69,947	19
	40	600	0.600	0.563	0.012	Orifice	0.0117	12	48	192	0.0192	16,353	51,785	14
	30	450	0.450	0.413	0.010	Orifice	0.0101	10	48	144	0.0144	14,322	35,432	10
	20	300	0.300	0.263	0.008	Orifice	0.0080	8	48	96	0.0096	11,969	21,110	6
	10	150	0.150	0.113	0.005	Orifice	0.0053	5	48	48	0.0048	9,141	9,141	3
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.0000	0	0	0	0.0000	-	-	0

Table B- 9: Box Culvert Superpipes (SP-54) Design Table

Designer Inputs: Box Culvert Superpipes

	Orifice						
Orifice Pipe Diameter (m) =	0.130	m	H=	1800	mm	Length=	125 m
				1.80	m		
			W=	2400	mm	Storage Provided=	540 m3
Area of Pipe (m^2) =	0.013	m2		2.40	m		
Cd =	0.80						

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 515
Drainage Area= 1.55 ha
Percentage Impervious= 35%
100-year Allowable Flow Rate= 0.062 (m3/s)
Location = Flatt Road Extension

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.735	0.062	Orifice	0.062	62	0.22	540	0.0540	8,716	88,194	24
	95	1710	1.710	1.645	0.060	Orifice	0.060	60	0.22	513	0.0513	8,504	79,478	22
	90	1620	1.620	1.555	0.059	Orifice	0.059	59	0.19	486	0.0486	8,286	70,974	20
	85	1539	1.539	1.474	0.057	Orifice	0.057	57	0.10	462	0.0462	8,085	62,688	17
	83	1496	1.496	1.431	0.056	Orifice	0.056	56	0.13	449	0.0449	7,976	54,747	15
	80	1440	1.440	1.375	0.055	Orifice	0.055	55	0.22	432	0.0432	7,833	54,603	15
	75	1350	1.350	1.285	0.053	Orifice	0.053	53	0.22	405	0.0405	7,596	46,770	13
	70	1260	1.260	1.195	0.051	Orifice	0.051	51	0.43	378	0.0378	7,352	39,174	11
	60	1080	1.080	1.015	0.047	Orifice	0.047	47	0.43	324	0.0324	6,837	31,823	9
	50	900	0.900	0.835	0.043	Orifice	0.043	43	0.43	270	0.0270	6,282	24,985	7
	40	720	0.720	0.655	0.038	Orifice	0.038	38	0.43	216	0.0216	5,674	18,703	5
	30	540	0.540	0.475	0.032	Orifice	0.032	32	0.43	162	0.0162	4,997	13,029	4
	20	360	0.360	0.295	0.026	Orifice	0.026	26	0.22	108	0.0108	4,228	8,031	2
	15	270	0.270	0.205	0.021	Orifice	0.021	21	0.65	81	0.0081	3,804	3,804	1
Bottom of Pipes	0	0	0.000	0.000	0.000	Orifice	0.000	0	0.00	0	0.0000	-	-	0

Table B-10 - Pond 5A Design in Sub Catchment 518

C_{pipe} =	**0.63**
C_{weir} =	**1.48**
C_{DICB} =	**1.71**

	Orifice Quality	Emergency Weir	DICB	Orifice 1
Pipe diameter (m)	**0.075**			**0.180**
L = Weir Width (m)		**3.00**	**1.20**	
A = Area of pipe (m^2)	**0.0044**			**0.0254**

Designed by: N. Pokharel, P.Eng.
Date: 30-Jan-18

	MAIN BODY OF THE POND														DETENTION TIME			
DESCRITION	**Stage**	**Depth to Permanent Pond Level**	**Qout Emergency weir**	**Q_{out} DICB**	**Q_{out} DICB with orifice**	**Q_{out} quality**	**Total flow Qout**	**Pond Surface Area**	**Incremental Storage**	**Active Storage**	**Flow rate (SWMHYMO)**	**Required Storage (SWMHYMO)**	**Allowed release**	**Total Storage**	**Incremental Time**	**Cumulative Time**	**CummulativeTime**	
	(m)	**(m)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^3/s)**	**(m^2)**	**(m^3)**	**(m^3)**	**(m^3/s)**	**(m^3)**	**(m^3/s)**	**(m^3)**	**(Sec)**	**(Sec)**	**(hr)**	
Top of Pool	149.70	**2.00**	**1.57**	7.540	0.196	0.017	1.783	3014	281	3873				4588	157	133,743	37	
	149.60	**1.90**	**1.12**	**6.798**	**0.191**	**0.017**	1.331	2921	270	3593				4307	203	133,586	37	
Regional	149.50	**1.80**	**0.73**	**6.083**	**0.186**	**0.016**	0.932	2828	260	3322				4037	280	133,383	37	
	149.40	**1.70**	**0.40**	5.395	0.180	0.016	0.593	2736	251	3062				3777	423	133,103	37	
	149.30	**1.60**	**0.14**	4.735	**0.175**	**0.015**	0.330	2643	241	2811				3526	730	132,681	37	
100-Year	149.20	**1.50**	**0.00**	4.104	0.169	0.015	0.184	2550	232	2570				3285	1,262	131,951	37	
	149.10	**1.40**		3.504	**0.163**	**0.014**	0.177	2457	222	2338				3053	1,256	130,689	36	
	149.00	**1.30**		2.937	0.156	0.014	0.170	2364	213	2116				2831	1,253	129,433	36	
	148.90	**1.20**		2.404	**0.150**	**0.013**	0.163	2272	204	1903				2618	1,253	128,180	36	
	148.80	**1.10**		1.907	**0.143**	**0.013**	0.155	2179	195	1699				2414	1,257	126,927	35	
	148.70	**1.00**		1.451	0.135	0.012	0.148	2086	187	1504				2219	1,265	125,671	35	
	148.60	**0.90**		1.038	**0.128**	**0.011**	0.139	1993	178	1317				2032	1,279	124,406	35	
	148.50	**0.80**		0.674	0.120	**0.011**	0.130	1900	170	1139				1854	1,302	123,127	34	
	148.40	**0.70**		0.367	0.111	0.010	0.121	1808	162	969				1684	1,336	121,825	34	
	148.30	**0.60**		0.130	0.101	0.009	0.111	1715	154	807				1522	1,388	120,488	33	
Extended detention	148.20	**0.50**		**0.000**	**0.000**	**0.008**	**0.008**	1622	146	654				1369	**17,389**	**119,100**	**33**	**>24HOURS**
	148.10	**0.40**				**0.007**	0.007	1529	138	508				1223	18,605	101,711	28	
	148.00	**0.30**				**0.006**	0.006	1436	131	370				1085	20,673	83,106	23	
	147.90	**0.20**				0.005	0.005	1344	123	239				954	24,792	62,433	17	
	147.80	**0.10**				0.003	0.003	1251	116	116				831	37,640	37,640	10	
Top of Permanent Pool	147.70	**0.00**				**0.000**	**0.000**	1158	**-**	0				715	**-**	**-**	**-**	

								PERMANENT POOL			SEDIMENT FOREBAY							
								Pond Surface Area (m^2)	**Incremental Storage (m^3)**	**Total Storage (m3)**	**Surface Area (m^2)**	**Incremental Storage (m^3)**	**Total Storage (m3)**	**Total Storage (m3)**				
Top of Permanent Pool	147.7	**0.00**						726	54	357	**432**	**43**	357	715				
	147.6	-0.10						682	49	304	432	42	304	608			-	
	147.5	-0.20						637	44	255	402	39	255	510				
	147.4	-0.30						593	40	211	372	36	211	421			-	
	147.3	-0.40						548	36	171	341	33	171	341				
	147.2	-0.50						504	32	135	311	30	135	270				
	147.1	-0.60						460	29	103	281	27	103	206				
	147	-0.70						415	27	74	251	24	74	148				
	146.9	-0.80						371	25	47	220	21	47	95				
	146.8	-0.90						326	23	23	190	18	23	45				
	146.7	**-1.00**						282	-	-	160	-	0	-				

Table B- 11: Box Culvert Superpipes (SP-61)

Designer Inputs: Box Culvert Superpipes

	Orifice							
			Heights=	1800	mm	Length=	200	m
Orifice Pipe Diameter (m) =	0.150	m		1.80	m			
			Width=	2400	mm	Strorage Provided=	864	m^3
Area of Pipe (m^2) =	0.018	m^2		2.40	m			
Cd =	0.80							

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 606
Drainage Area= 2.46 ha
Percentage Impervious= 28%
100-year Allowable Flow Rate= 0.082 (m^3/s)
Location = Street B

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.725	0.082	Pipe Orifice	0.082	82	0.22	864	0.0864	10,505	106,632	30
	95	1710	1.710	1.635	0.080	Pipe Orifice	0.080	80	0.22	821	0.0821	10,251	96,126	27
	90	1620	1.620	1.545	0.078	Pipe Orifice	0.078	78	0.19	778	0.0778	9,990	85,875	24
	85	1539	1.539	1.464	0.076	Pipe Orifice	0.076	76	0.10	739	0.0739	9,749	75,885	21
	83	1496	1.496	1.421	0.075	Pipe Orifice	0.075	75	0.13	718	0.0718	9,619	66,307	18
	80	1440	1.440	1.365	0.073	Pipe Orifice	0.073	73	0.22	691	0.0691	9,448	66,136	18
	75	1350	1.350	1.275	0.071	Pipe Orifice	0.071	71	0.22	648	0.0648	9,164	56,688	16
	70	1260	1.260	1.185	0.068	Pipe Orifice	0.068	68	0.43	605	0.0605	8,872	47,524	13
	60	1080	1.080	1.005	0.063	Pipe Orifice	0.063	63	0.43	518	0.0518	8,258	38,651	11
	50	900	0.900	0.825	0.057	Pipe Orifice	0.057	57	0.43	432	0.0432	7,595	30,393	8
	40	720	0.720	0.645	0.050	Pipe Orifice	0.050	50	0.43	346	0.0346	6,872	22,798	6
	30	540	0.540	0.465	0.043	Pipe Orifice	0.043	43	0.43	259	0.0259	6,070	15,926	4
	20	360	0.360	0.285	0.033	Pipe Orifice	0.033	33	0.22	173	0.0173	5,169	9,856	3
	15	270	0.270	0.195	0.028	Pipe Orifice	0.028	28	0.65	130	0.0130	4,687	4,687	1
Bottom of Pipes	0	0	0.000	0.000	0.000	Pipe Orifice	0.000	0	0.00	0	0.0000	-	-	0.0

Table B-12: On-site Storage (STC - 62) Design Table

Designer Inputs: On-site Storage

	Orifice						
			Height =	1500 mm	Length=	12 m	
Orifice Pipe Diameter (m) =	0.075	m		1.50 m	Width=	10 m	
Area of Pipe (m^2) =	0.004	m2			Storage Provided =	180 (m^3)	
Cd =	0.80						

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 609
Drainage Area= 0.46 ha
Percentage Impervious= 58%
100-year Allowable Flow Rate= 0.019 (m3/s)
Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	1500	1.500	1.463	0.019	Orifice Pipe	0.019	19	0.00	180	0.0180	9,508	95,081	26.4
	95	1425	1.425	1.388	0.018	Orifice Pipe	0.018	18	0.00	171	0.0171	9,273	85,574	23.8
	90	1350	1.350	1.313	0.018	Orifice Pipe	0.018	18	0.00	162	0.0162	9,033	76,300	21.2
	85	1282	1.282	1.245	0.017	Orifice Pipe	0.017	17	0.00	154	0.0154	8,810	67,268	18.7
	83	1247	1.247	1.209	0.017	Orifice Pipe	0.017	17	0.00	150	0.0150	8,690	58,616	16.3
	80	1200	1.200	1.163	0.017	Orifice Pipe	0.017	17	0.00	144	0.0144	8,531	58,458	16.2
	75	1125	1.125	1.088	0.016	Orifice Pipe	0.016	16	0.00	135	0.0135	8,269	49,926	13.9
	70	1050	1.050	1.013	0.016	Orifice Pipe	0.016	16	0.00	126	0.0126	7,999	41,657	11.6
	60	900	0.900	0.863	0.015	Orifice Pipe	0.015	15	0.00	108	0.0108	7,428	33,658	9.3
	50	750	0.750	0.713	0.013	Orifice Pipe	0.013	13	0.00	90	0.0090	6,811	26,230	7.3
	40	600	0.600	0.563	0.012	Orifice Pipe	0.012	12	0.00	72	0.0072	6,132	19,419	5.4
	30	450	0.450	0.413	0.010	Orifice Pipe	0.010	10	0.00	54	0.0054	5,371	13,287	3.7
	20	300	0.300	0.263	0.008	Orifice Pipe	0.008	8	0.00	36	0.0036	4,488	7,916	2.2
	10	150	0.150	0.113	0.005	Orifice Pipe	0.005	5	0.00	18	0.0018	3,428	3,428	1.0
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice Pipe	0.000	0	0.00	0	0.0000	-	-	0.0

Table B- 13: On-site Storage (STC - 63) Design Table

Designer Inputs: On-site Storage

	Orifice							
			Height =	2000	mm	Length=	16	m
Orifice Pipe diameter (m) =	0.105	m		2.00	m	Width=	13	m
Area of pipe (m^2) =	0.009	m2				Storage provided =	416	(m^3)
Cd =	0.80							

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 615
Drainage Area= 1.33 ha
Percentage Impervious= 25%
100-year Allowable Flow Rate= 0.043 (m3/s)
Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (m-ha)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.948	0.043	Orifice	0.043	43	21	416	0.0416	9,715	97,228	27.0
	95	1900	1.900	1.848	0.042	Orifice	0.042	42	21	395	0.0395	9,476	87,513	24.3
	90	1800	1.800	1.748	0.041	Orifice	0.041	41	19	374	0.0374	9,230	78,037	21.7
	85	1710	1.710	1.657	0.040	Orifice	0.040	40	10	356	0.0356	9,003	68,806	19.1
	83	1662	1.662	1.610	0.039	Orifice	0.039	39	13	346	0.0346	8,881	59,965	16.7
	80	1600	1.600	1.548	0.038	Orifice	0.038	38	21	333	0.0333	8,719	59,803	16.6
	75	1500	1.500	1.448	0.037	Orifice	0.037	37	21	312	0.0312	8,452	51,084	14.2
	70	1400	1.400	1.348	0.036	Orifice	0.036	36	42	291	0.0291	8,176	42,633	11.8
	60	1200	1.200	1.148	0.033	Orifice	0.033	33	42	250	0.0250	7,594	34,457	9.6
	50	1000	1.000	0.948	0.030	Orifice	0.030	30	42	208	0.0208	6,964	26,863	7.5
	40	800	0.800	0.748	0.027	Orifice	0.027	27	42	166	0.0166	6,272	19,899	5.5
	30	600	0.600	0.548	0.023	Orifice	0.023	23	42	125	0.0125	5,497	13,627	3.8
	20	400	0.400	0.348	0.018	Orifice	0.018	18	42	83	0.0083	4,600	8,130	2.3
	10	200	0.200	0.148	0.012	Orifice	0.012	12	42	42	0.0042	3,530	3,530	1.0
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0		0	0.0000	-	-	0.0

Table B-14: Onsite Storage (STC - 64) Design Table

Designer Inputs: Box Culvert Superpipe

	Orifice		Height =	2000	mm	Length=	18	m	
Pipe diameter (m) =	0.090	m		2.00	m	Width=	12	m	
Area of pipe (m^2) =	0.006	m2				Storage	432	(m^3)	
Cd =	0.80								

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 618
Drainage Area= 1.02 ha
Percentage Impervious= 39%
100-year Allowable Flow Rate= 0.032 (m^3/s)
Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.955	0.032	Orifice	0.032	32	22	432	0.0432	13,706	136,863	38.0
	95	1900	1.900	1.855	0.031	Orifice	0.031	31	22	410	0.0410	13,367	123,158	34.2
	90	1800	1.800	1.755	0.030	Orifice	0.030	30	19	389	0.0389	13,019	109,791	30.5
	85	1710	1.710	1.665	0.029	Orifice	0.029	29	10	369	0.0369	12,697	96,772	26.9
	83	1662	1.662	1.617	0.029	Orifice	0.029	29	13	359	0.0359	12,523	84,304	23.4
	80	1600	1.600	1.555	0.028	Orifice	0.028	28	22	346	0.0346	12,294	84,075	23.4
	75	1500	1.500	1.455	0.027	Orifice	0.027	27	22	324	0.0324	11,915	71,781	19.9
	70	1400	1.400	1.355	0.026	Orifice	0.026	26	43	302	0.0302	11,524	59,866	16.6
	60	1200	1.200	1.155	0.024	Orifice	0.024	24	43	259	0.0259	10,699	48,342	13.4
	50	1000	1.000	0.955	0.022	Orifice	0.022	22	43	216	0.0216	9,805	37,644	10.5
	40	800	0.800	0.755	0.020	Orifice	0.020	20	43	173	0.0173	8,822	27,839	7.7
	30	600	0.600	0.555	0.017	Orifice	0.017	17	43	130	0.0130	7,717	19,017	5.3
	20	400	0.400	0.355	0.013	Orifice	0.013	13	43	86	0.0086	6,433	11,300	3.1
	10	200	0.200	0.155	0.009	Orifice	0.009	9	43	43	0.0043	4,867	4,867	1.4
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0		0	0.0000	-	-	0.0

Table B-15: Box Culvert Superpipes (SP-65) Design Table

Designer Inputs: Box Culvert Superpipes

	Orifice						
			Height=	1800	mm	Length=	260 m
Orifice Pipe Diameter (m) =	0.180	m		1.80	m		
			Width=	2400	mm	Storage Provided=	1123 m^3
Area of Pipe (m^2) =	0.025	m2		2.40	m		
Cd =	0.80						

Date: January 30, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 621
Drainage Area= 3.53 ha
Percentage Impervious= 34%
100-year Allowable Flow Rate= 0.118 (m3/s)
Location = Street A

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (m-ha)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Superpipes	100	1800	1.800	1.710	0.118	Orifice	0.118	118	0.22	1123	0.1123	9,525	97,170	27.0
	95	1710	1.710	1.620	0.115	Orifice	0.115	115	0.22	1067	0.1067	9,297	87,645	24.3
	90	1620	1.620	1.530	0.112	Orifice	0.112	112	0.19	1011	0.1011	9,063	78,348	21.8
	85	1539	1.539	1.449	0.109	Orifice	0.109	109	0.10	960	0.0960	8,847	69,284	19.2
	83	1496	1.496	1.406	0.107	Orifice	0.107	107	0.13	933	0.0933	8,730	60,591	16.8
	80	1440	1.440	1.350	0.105	Orifice	0.105	105	0.22	899	0.0899	8,576	60,437	16.8
	75	1350	1.350	1.260	0.101	Orifice	0.101	101	0.22	842	0.0842	8,323	51,861	14.4
	70	1260	1.260	1.170	0.098	Orifice	0.098	98	0.43	786	0.0786	8,061	43,538	12.1
	60	1080	1.080	0.990	0.090	Orifice	0.090	90	0.43	674	0.0674	7,511	35,477	9.9
	50	900	0.900	0.810	0.081	Orifice	0.081	81	0.43	562	0.0562	6,920	27,966	7.8
	40	720	0.720	0.630	0.072	Orifice	0.072	72	0.43	449	0.0449	6,277	21,046	5.8
	30	540	0.540	0.450	0.060	Orifice	0.060	60	0.43	337	0.0337	5,571	14,769	4.1
	20	360	0.360	0.270	0.047	Orifice	0.047	47	0.22	225	0.0225	4,794	9,198	2.6
	15	270	0.270	0.180	0.038	Orifice	0.038	38	0.65	168	0.0168	4,404	4,404	1.2
Bottom of pipes	0	0	0.000	0.000	0.000	Orifice	0.000	0	0.00	0	0.0000	-	-	0.0

Table B-16: Onsite Storage (STC - 66) Design Table

Designer Inputs: Onsite Storage

Orifice

Orifice Pipe Diameter (m) = 0.090 m

Area of pipe (m^2) = 0.006 m2

Cd = 0.80

Height = 2000 mm / 2.00 m

Length= 14 m

Width= 12 m

Storage Provided= 336 (m^3)

Date: January 30, 2018

Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 634

Drainage Area= 0.89 ha

Percentage Impervious= 45%

100-year Allowable Flow Rate= 0.032 (m3/s)

Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.955	0.032	Orifice	0.032	32	17	336	0.0336	10,660	106,449	29.6
	95	1900	1.900	1.855	0.031	Orifice	0.031	31	17	319	0.0319	10,396	95,789	26.6
	90	1800	1.800	1.755	0.030	Orifice	0.030	30	15	302	0.0302	10,126	85,393	23.7
	85	1710	1.710	1.665	0.029	Orifice	0.029	29	8	287	0.0287	9,876	75,267	20.9
	83	1662	1.662	1.617	0.029	Orifice	0.029	29	10	279	0.0279	9,740	65,570	18.2
	80	1600	1.600	1.555	0.028	Orifice	0.028	28	17	269	0.0269	9,562	65,392	18.2
	75	1500	1.500	1.455	0.027	Orifice	0.027	27	17	252	0.0252	9,267	55,830	15.5
	70	1400	1.400	1.355	0.026	Orifice	0.026	26	34	235	0.0235	8,963	46,562	12.9
	60	1200	1.200	1.155	0.024	Orifice	0.024	24	34	202	0.0202	8,321	37,599	10.4
	50	1000	1.000	0.955	0.022	Orifice	0.022	22	34	168	0.0168	7,626	29,278	8.1
	40	800	0.800	0.755	0.020	Orifice	0.020	20	34	134	0.0134	6,861	21,652	6.0
	30	600	0.600	0.555	0.017	Orifice	0.017	17	34	101	0.0101	6,002	14,791	4.1
	20	400	0.400	0.355	0.013	Orifice	0.013	13	34	67	0.0067	5,003	8,789	2.4
	10	200	0.200	0.155	0.009	Orifice	0.009	9	34	34	0.0034	3,786	3,786	1.1
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0	0	0	0.0000	-	-	0.0

Table B- 17: Onsite Storage (STC - 67) Design Table

Designer Inputs: Box Culvert Superpipe

	Orifice		Height =	2000 mm	Length=	18 m	
Orifice Pipe diameter (m) =	0.105	m		2.00 m	Width=	12 m	
Area of pipe (m^2) =	0.009	m^2			Storage	432 (m^3)	
Cd =	0.80						

Date: January 29, 2018
Designed by: N Pokharel, P.Eng.

Sub-catchment ID = 636
Drainage Area= 1.24 ha
Percentage Impervious= 39%
100-year Allowable Flow Rate= 0.043 (m3/s)
Location = On-site

	Stage (%)	stage (mm)	Stage (m)	Depth to Centre of Orifice (m)	Q_{out} Orifice (m^3/s)	Flow Control	Qout (m^3/s)	Qout (L/s)	Incremental Area (m^2)	Total Storage (m^3)	Total Storage (ha-m)	Inc. Time (s)	Cum. Time (s)	Cum. Time (hr)
Top of Storage	100	2000	2.000	1.948	0.043	Orifice	0.043	43	22	432	0.0432	10,089	100,967	28.0
	95	1900	1.900	1.848	0.042	Orifice	0.042	42	22	410	0.0410	9,840	90,879	25.2
	90	1800	1.800	1.748	0.041	Orifice	0.041	41	19	389	0.0389	9,585	81,038	22.5
	85	1710	1.710	1.657	0.040	Orifice	0.040	40	10	369	0.0369	9,350	71,453	19.8
	83	1662	1.662	1.610	0.039	Orifice	0.039	39	13	359	0.0359	9,222	62,271	17.3
	80	1600	1.600	1.548	0.038	Orifice	0.038	38	22	346	0.0346	9,054	62,103	17.3
	75	1500	1.500	1.448	0.037	Orifice	0.037	37	22	324	0.0324	8,777	53,049	14.7
	70	1400	1.400	1.348	0.036	Orifice	0.036	36	43	302	0.0302	8,490	44,272	12.3
	60	1200	1.200	1.148	0.033	Orifice	0.033	33	43	259	0.0259	7,886	35,782	9.9
	50	1000	1.000	0.948	0.030	Orifice	0.030	30	43	216	0.0216	7,232	27,897	7.7
	40	800	0.800	0.748	0.027	Orifice	0.027	27	43	173	0.0173	6,514	20,665	5.7
	30	600	0.600	0.548	0.023	Orifice	0.023	23	43	130	0.0130	5,708	14,151	3.9
	20	400	0.400	0.348	0.018	Orifice	0.018	18	43	86	0.0086	4,777	8,443	2.3
	10	200	0.200	0.148	0.012	Orifice	0.012	12	43	43	0.0043	3,666	3,666	1.0
Bottom of Storage	0	0	0.000	0.000	0.000	Orifice	0.000	0		0	0.0000	-	-	0.0

Sediment Removal Frequency

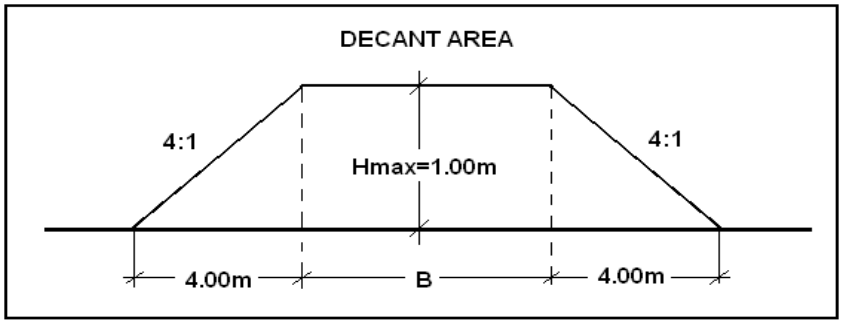
Design by : N Pokharel, P.Eng	
Date :	02-Mar-18

Catchment Imperviousness =	29	%
Catchment Area =	7.04	ha
Annual Loading =	0.6	m^3/ha
Removal Efficiency =	100	%
Annual Sediment Accumulation =	4.2	m^3/yr
Sediment Accumulation in 10 years =	**42**	m^3

Required Average Area of Decant Area **42** m^2

Provided Decant Area

Bottom Area	90	m^2
Top Area	0	m^2
Average Area	**45**	**m^2 (> 42 m2 requirements)**



Conveyence Flow From Sediment Forebay to Main Pond

Design by:	**N Pokharel, P.Eng.**
Date :	March 2, 2018

1. Flow in Pipe

Head (H) =	0.3	m
Pipe Diameter (D)	**300**	**mm**
Pipe Diameter (D)	**0.3**	**m**
Pipe Area (A)	0.0707	m^2
Orifice cofficient (C)	0.63	
Flow through one pipe	**0.108**	**m^3/s**
Flow through two pipes	0.216	**m^3/s**

2. 10 - Year Storm

Inflow to Pond = **0.720** **m^3/s** *(From Uncontrolled GAWSER Model)*

3. Flow over weir

Qweir = **0.504** **m^3/s**

Height (H) =	**0.3**	**m**	
Length (L) =	**3**	**m**	
Coefficient (Cv) =	1.27		
Tan y/2 =	**3**		**Slope 3 : 1**
Coefficient (Cw) =	1.48		

Qweir =	**0.917**	**m^3/s**	>	**0.504**
Qtot =	**1.133**	**m^3/s**	>	**0.720**

APPENDIX C: Impervious Calculations Figures for the proposed Development



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 406
POST–DEVELOPMENT DRAINAGE AREA	3.33 ha
ROAD	0.48 ha
DRIVEWAYS	0.24 ha
SINGLE FAMILY UNITS (29 UNITS x 120m²)	0.35 ha
SINGLE FAMILY UNITS (28 UNITS x 60m²)	0.16 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.04 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	1.32 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	40%

LEGEND

503 (46.56 | 2.0%) — CATCHMENT; AREA (ha); PERCENTAGE IMPERVIOUS

- POST–DEVELOPMENT DRAINAGE AREA
- IMPERVIOUS AREA
- SWM SUPERPIPE
- STM PIPE
- STM MANHOLE
- STM CATCH BASIN
- HEADWALL

CLIENT

PENTA PROPERTIES INC.
4480 PALETTA COURT
BURLINGTON, ON L7L 5R2

MUNICIPALITY

CITY OF Burlington

SCALE

1:1500

METROPOLITAN CONSULTING INC.
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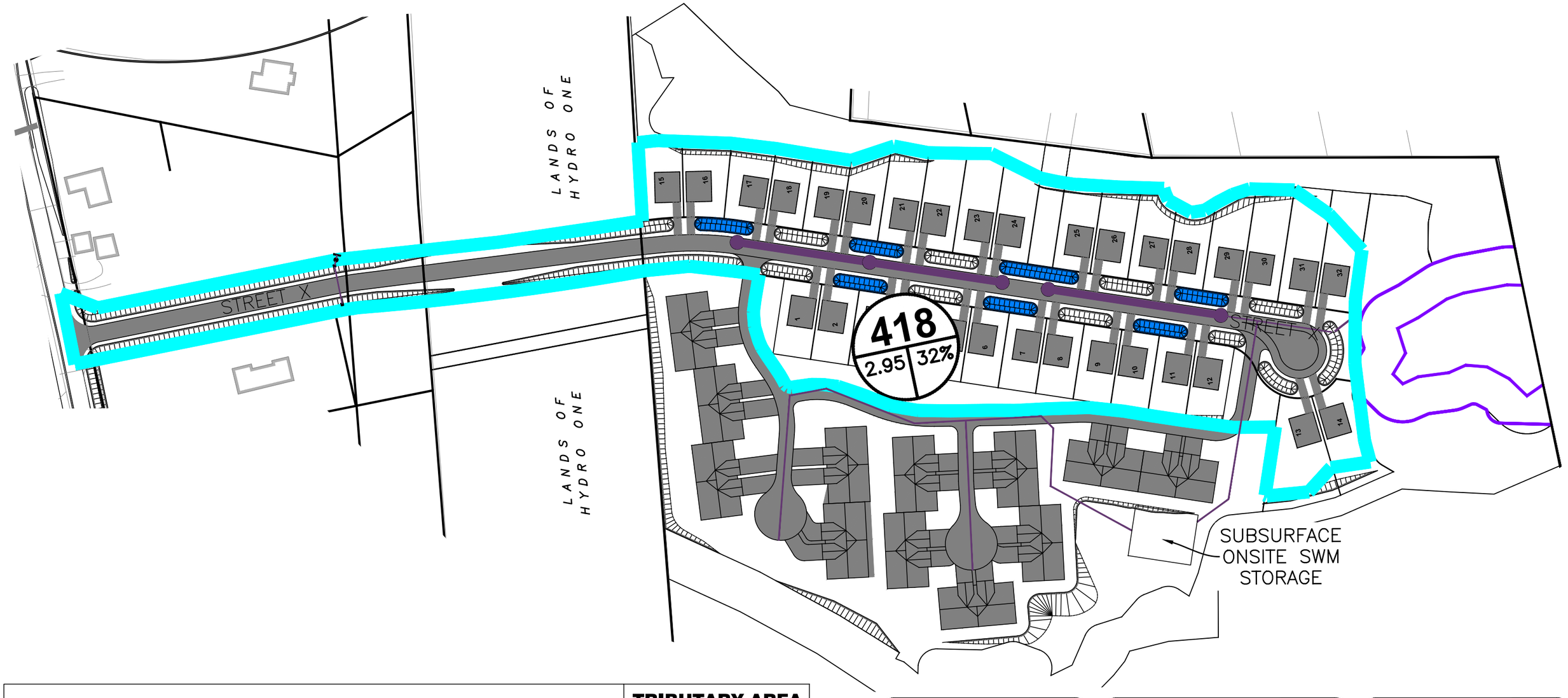
PROJECT: EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG: POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

DATE: August 2018

PROJECT NO.: P09006

FIGURE C-1



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 418
POST–DEVELOPMENT DRAINAGE AREA	2.96 ha
ROAD	0.39 ha
DRIVEWAYS	0.12 ha
SINGLE FAMILY UNITS (32 UNITS x 120m²)	0.38 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.03 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	0.94 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	32%

LEGEND

503 (46.56 | 2.0%)
AREA (ha) — CATCHMENT — PERCENTAGE IMPERVIOUS

POST–DEVELOPMENT DRAINAGE AREA
IMPERVIOUS AREA
SWM SUPERPIPE
STM PIPE
STM MANHOLE
STM CATCH BASIN
HEADWALL

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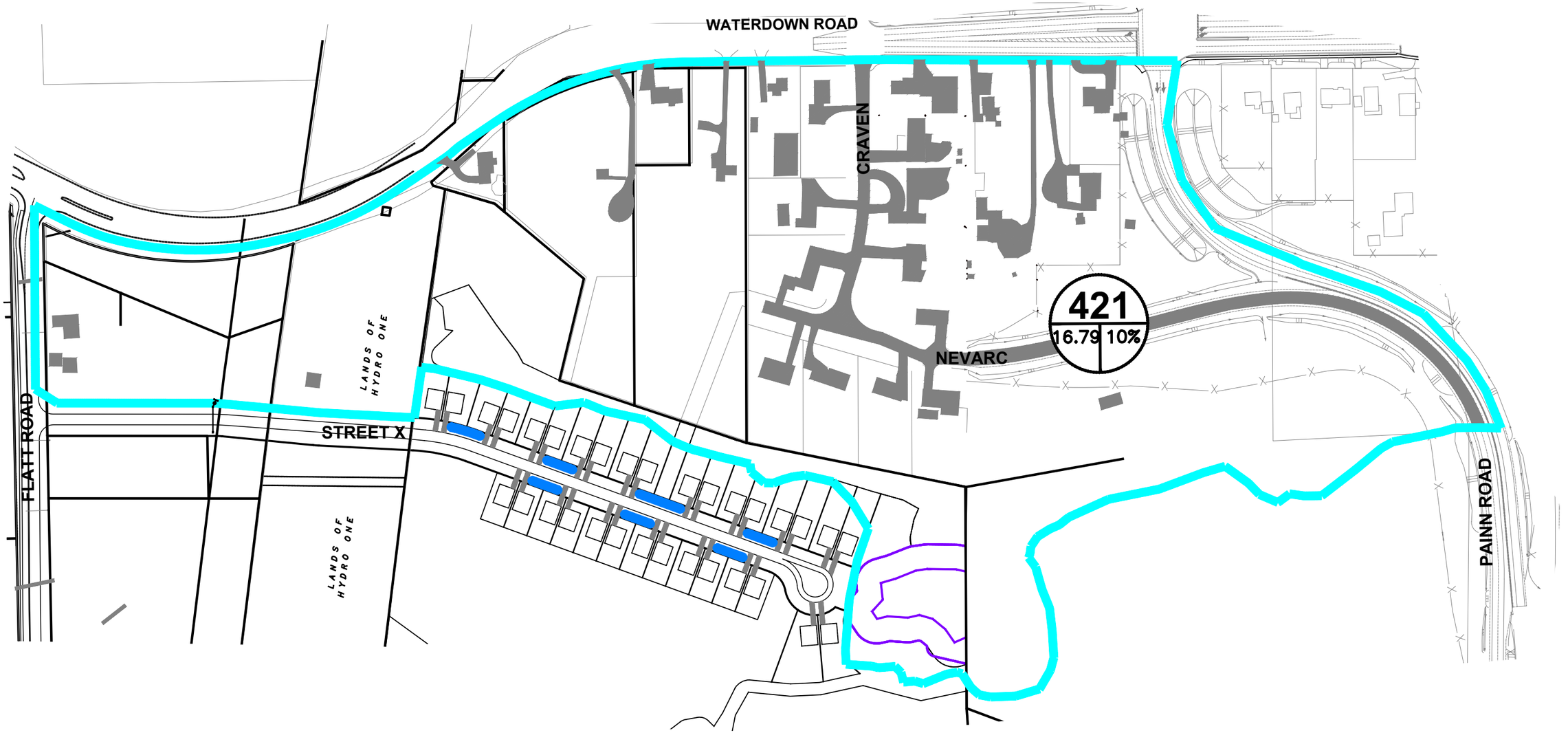
PROJECT
EAGLE HEIGHTS HYDROLOGICAL STUDY AND SWM REPORT

DWG
POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

DATE
August 2018

PROJECT NO.
P09006

FIGURE C-2



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 421
POST–DEVELOPMENT DRAINAGE AREA	16.79 ha
ROAD	0.48 ha
DRIVEWAYS	0.50 ha
EX.BUILDINGS	0.63 ha
SINGLE FAMILY UNITS (11 UNITS x 60m²)	0.00 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.00 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	1.62 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	10%

LEGEND

503 (46.56 2.0%)
AREA (ha) — CATCHMENT — PERCENTAGE IMPERVIOUS

POST–DEVELOPMENT DRAINAGE AREA

IMPERVIOUS AREA

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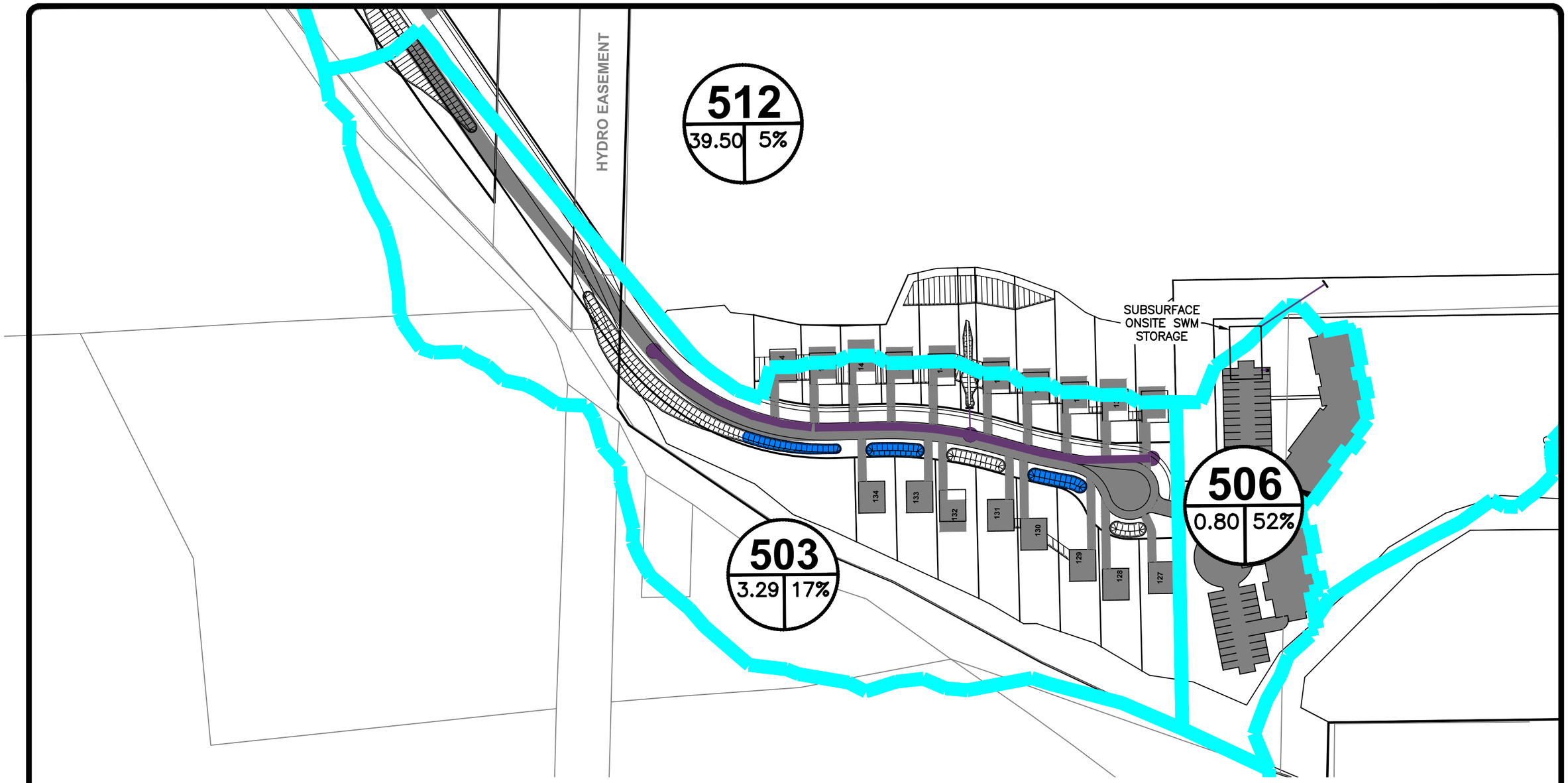
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POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

DATE: August 2018

PROJECT NO.: P09006

FIGURE C-3



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 503
POST–DEVELOPMENT DRAINAGE AREA	3.29 ha
ROAD	0.26 ha
DRIVEWAYS	0.10 ha
SINGLE FAMILY UNITS (8 UNITS x 120m²)	0.10 ha
SINGLE FAMILY UNITS (10 UNITS x 60m²)	0.06 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.01 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	0.53 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	17%

LEGEND

503 (46.56 | 2.0%) — CATCHMENT; AREA (ha); PERCENTAGE IMPERVIOUS

POST–DEVELOPMENT DRAINAGE AREA

IMPERVIOUS AREA

SWM SUPERPIPE

STM PIPE

STM MANHOLE

STM CATCH BASIN

HEADWALL

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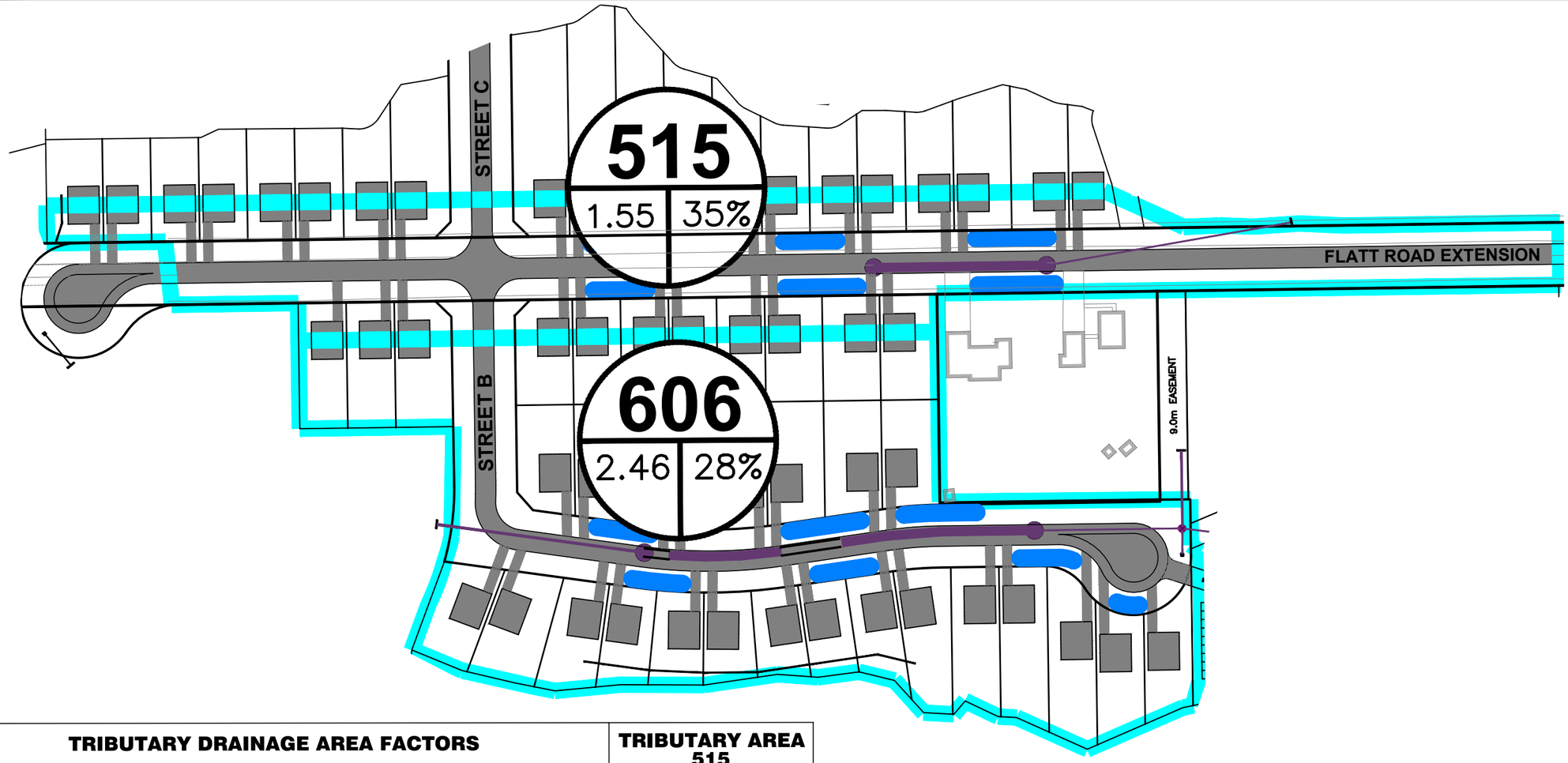
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POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

DATE: August 2018

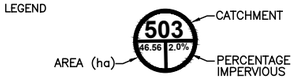
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FIGURE C-4



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 515
POST–DEVELOPMENT DRAINAGE AREA	1.55 ha
ROAD	0.23 ha
DRIVEWAYS	0.12 ha
SINGLE FAMILY UNITS (31 UNITS x 60m²)	0.19 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.00 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	0.53 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	35%
TRIBUTARY DRAINAGE AREA FACTORS	**TRIBUTARY AREA 606**
POST–DEVELOPMENT DRAINAGE AREA	2.46 ha
ROAD	0.21 ha
DRIVEWAYS	0.10 ha
SINGLE FAMILY UNITS (23 UNITS x 120m²)	0.28 ha
SINGLE FAMILY UNITS (11 UNITS x 60m²)	0.07 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.04 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	0.68 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	28%

LEGEND



POST–DEVELOPMENT DRAINAGE AREA
IMPERVIOUS AREA
SWM SUPERPIPE
STM PIPE
STM MANHOLE
STM CATCH BASIN
HEADWALL

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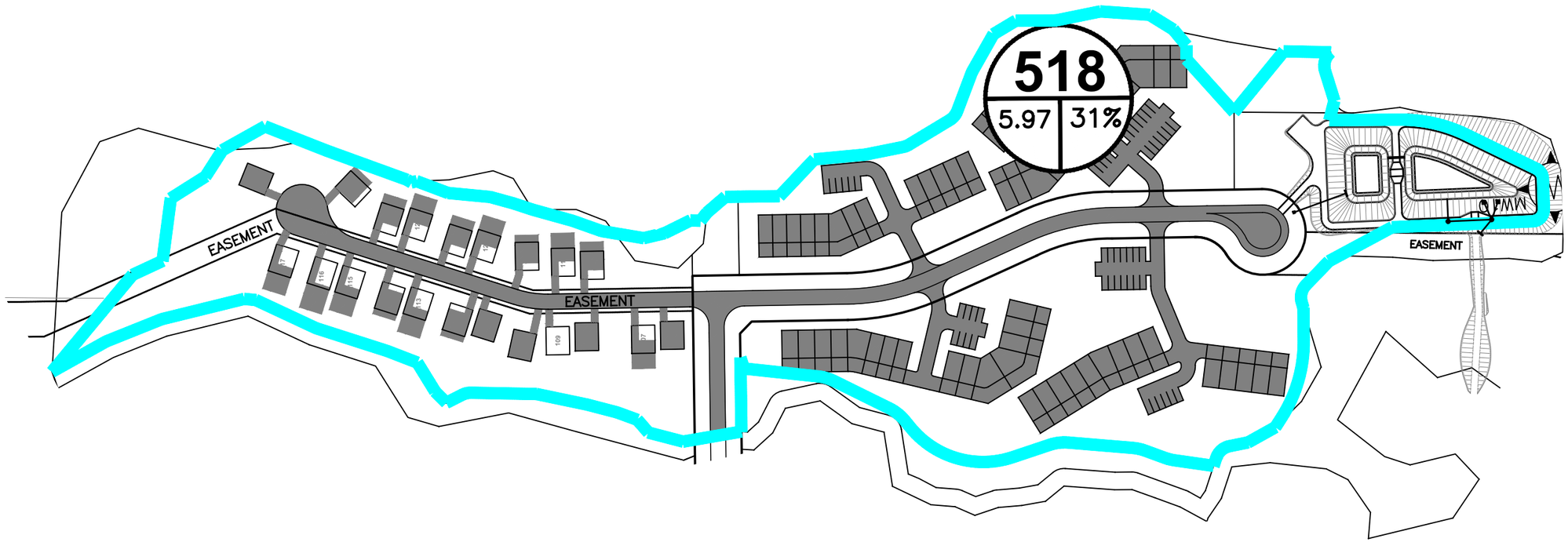
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POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

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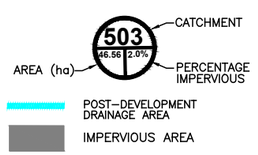
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FIGURE C-5



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 518
POST–DEVELOPMENT DRAINAGE AREA	5.97 ha
ROAD	0.39 ha
DRIVEWAYS	0.39 ha
SINGLE FAMILY UNITS (8 UNITS x 120m²)	0.25 ha
SINGLE FAMILY UNITS (10 UNITS x 60m²)	0.00 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.02 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	1.81 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	31%

LEGEND



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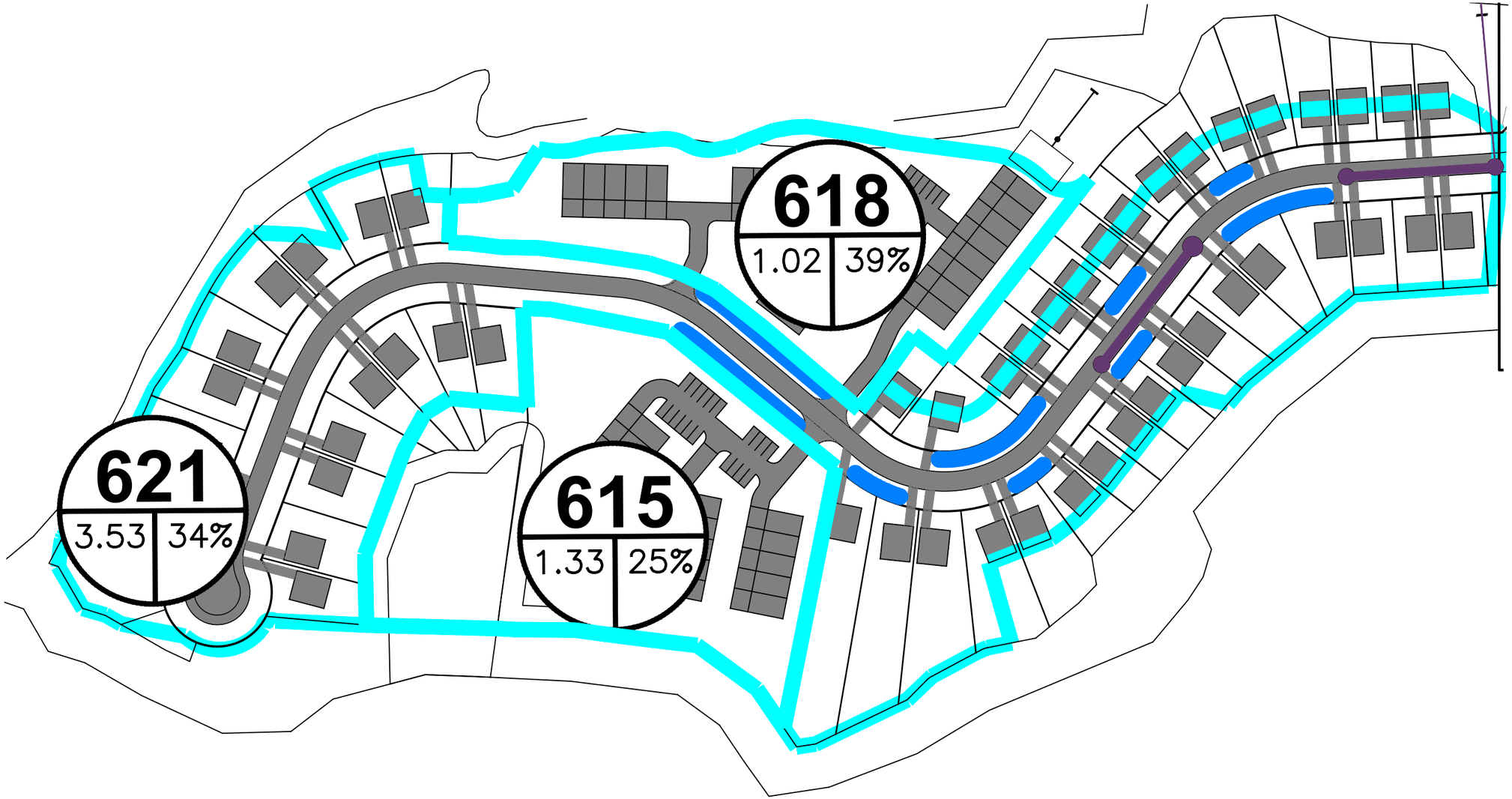
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POST DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

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FIGURE C-6



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 621
POST–DEVELOPMENT DRAINAGE AREA	3.53 ha
ROAD	0.40 ha
DRIVEWAYS	0.22 ha
SINGLE FAMILY UNITS (35 UNITS x 120m²)	0.42 ha
SINGLE FAMILY UNITS (16 UNITS x 60m²)	0.10 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.04 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	1.17 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	34%

LEGEND

503 (10.56 | 2.0%) — CATCHMENT; AREA (ha); PERCENTAGE IMPERVIOUS

- POST–DEVELOPMENT DRAINAGE AREA
- IMPERVIOUS AREA
- SWM SUPERPIPE
- STM PIPE
- STM MANHOLE
- STM CATCH BASIN
- HEADWALL

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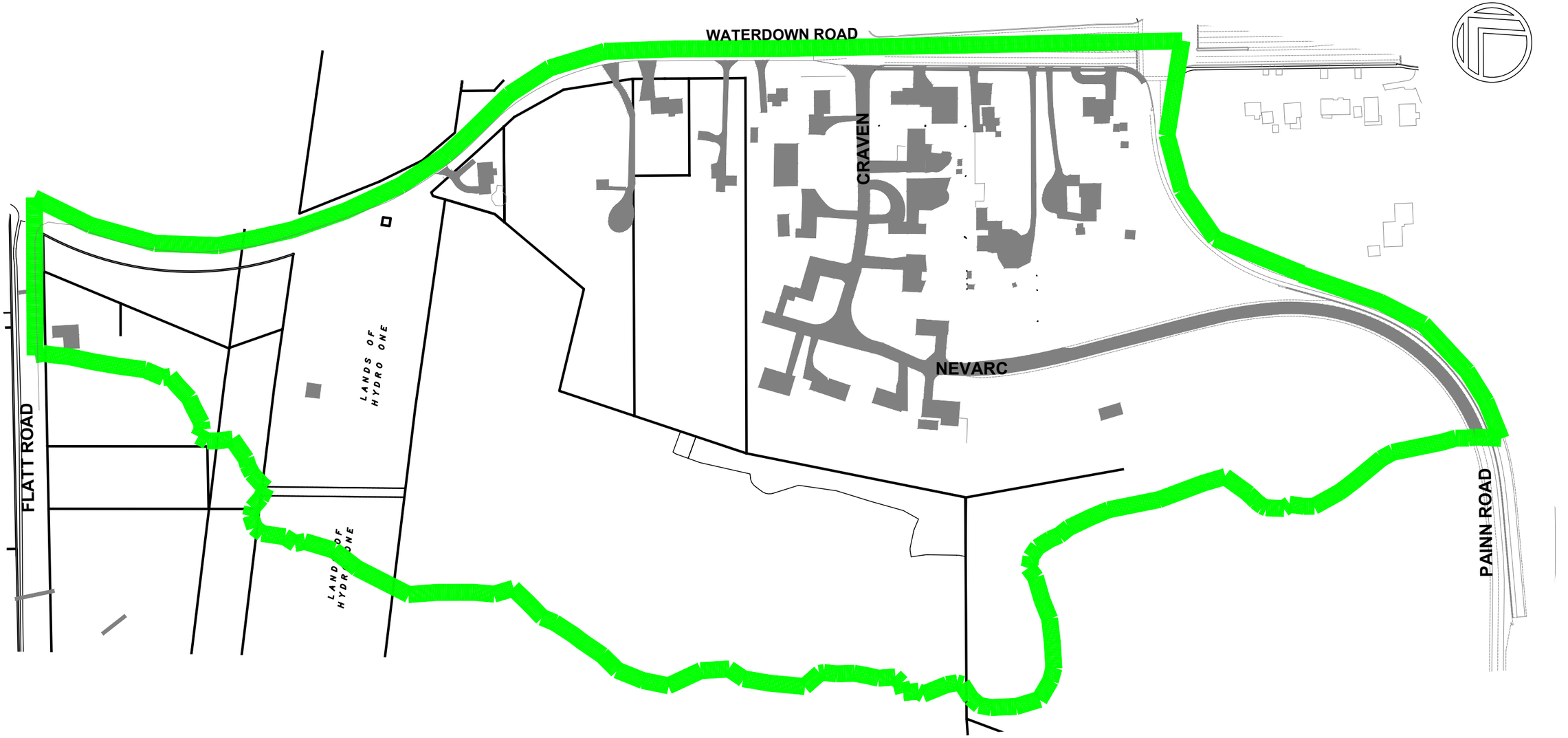
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FIGURE C-7



TRIBUTARY DRAINAGE AREA FACTORS	TRIBUTARY AREA 421
POST–DEVELOPMENT DRAINAGE AREA	21.75 ha
ROAD	0.49 ha
DRIVEWAYS	0.55 ha
EX.BUILDINGS	0.62 ha
SINGLE FAMILY UNITS (11 UNITS x 60m²)	0.00 ha
60% SINGLE FAMILY UNIT WITH PORCH AND/OR SHED @ 18 m²	0.00 ha
IMPERVIOUS AREA OF POST–DEVELOPMENT DRAINAGE AREA	1.62 ha
IMPERVIOUS PERCENTAGE OF POST–DEVELOPMENT DRAINAGE AREA	8%

LEGEND

503 (CATCHMENT)
46.56 (AREA (ha)) 2.0% (PERCENTAGE IMPERVIOUS)

PRE–DEVELOPMENT DRAINAGE AREA

IMPERVIOUS AREA

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PRE DEVELOPMENT IMPERVIOUS DRAINAGE PARAMETERS

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FIGURE C-8

APPENDIX D: Water Balance Summary Table from GAWSER Continuous Modelling

GAWSER V6.9.18 - Released - Sep. 21, 2016
==========

Eagle Heights Watersheds Model
General Water Balance Summary
1950 to 2015: Existing Conditions
==========

```
   Input file 1=wbsum1.dat
   Input file 2=
   Output file =wbsum1.txt
* ============================================================================
* File created by Dr. H.O. Schroeter,
* Revised: N Pokharel
* ============================================================================
START               KUNITS=2 TOTAL WATERSHED AREA=1.50   SQ KM
                    INITIAL BASEFLOW AT OUTLET: QBSS= 0.0000 QBGW= 0.000
                    PRINT OPTIONS: ECHO=3 OUTPUT=1 PLOTS=0 RCS=1 SUBW=1
                      PLOT CUTOFF=576 SUM=4 FREE=0
                    PARAMETER ADJUSTMENT FACTORS: FDS=1.00 FKEFF=0.25
                      FCS=0.30 FD=0.30 FSAV=1.0 FKO=1.00 FKSS=1.0 FKMF=1.00
                    INITIAL SOIL/SNOW WATER FACTORS:
                      FIMCI=1.00 FIMCII=1.00 FIWE=0.0000
                    GLOBAL RAINFALL SCALING FACTOR: GFRF=1.0000
                    SIMULATION CONTROLS: TTI=1.00000 IDEL=4 HOURS=576
                    SUBWATERSHED INITIAL BASEFLOWS: -999
```

WATER BALANCE SUMMARY FOR HYDROGRAPH 403

Location: Trib 4 North at gauge (Lump)
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.1181 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.2	10.9	16.5	12.8	27.5
FEB	45.2	8.2	15.3	14.0	7.7	29.3
MAR	61.7	19.4	37.1	19.9	-14.7	57.1
APR	76.2	48.5	19.8	25.3	-17.3	45.1
MAY	72.3	84.5	6.8	15.2	-34.2	22.1
JUN	72.5	91.6	2.5	3.7	-25.2	6.1
JUL	89.2	82.6	6.4	1.3	-1.1	7.7
AUG	76.3	78.1	2.8	2.0	-6.6	4.8
SEP	76.6	57.8	2.0	2.2	14.6	4.1
OCT	72.2	49.1	4.3	4.2	14.7	8.5
NOV	71.8	25.6	6.5	10.5	29.2	17.0
DEC	63.5	11.5	12.5	19.6	19.8	32.1
Total	827.1	566.0	126.8	134.5	-0.2	261.3

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.077	0.0000
2.00	0.120	0.0000
5.00	0.180	0.0000
10.00	0.230	0.0000
20.00	0.280	0.0000
25.00	0.300	0.0000
50.00	0.360	0.0000
100.00	0.420	0.0000
200.00	0.480	0.0000
500.00	0.580	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00039
90.0	0.00000	40.0	0.00074
80.0	0.00000	30.0	0.00093
70.0	0.00000	20.0	0.00100
60.0	0.00008	10.0	0.00100

WATER BALANCE SUMMARY FOR HYDROGRAPH 2427
==========

Location: Hydrograph 2427
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.3355 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.2	11.7	15.9	12.7	27.6
FEB	45.2	8.2	16.3	13.3	7.4	29.6
MAR	61.7	19.1	37.9	19.5	-14.9	57.4
APR	76.2	47.4	21.3	24.4	-16.8	45.6
MAY	72.3	82.3	8.3	14.8	-33.1	23.1
JUN	72.5	89.2	4.3	3.5	-24.5	7.8
JUL	89.2	80.6	8.4	1.4	-1.2	9.8
AUG	76.3	76.2	4.8	1.8	-6.5	6.6
SEP	76.6	56.5	3.9	2.1	14.1	6.0
OCT	72.2	48.0	6.0	4.1	14.2	10.1
NOV	71.8	25.2	8.2	10.2	28.2	18.4
DEC	63.5	11.4	13.5	19.1	19.4	32.6
Total	827.1	553.2	144.6	130.0	-0.8	274.6

Extreme Flows Summary
==========

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.230	0.0000
2.00	0.350	0.0000
5.00	0.560	0.0000
10.00	0.710	0.0000
20.00	0.880	0.0000
25.00	0.940	0.0000
50.00	1.120	0.0000
100.00	1.320	0.0000
200.00	1.530	0.0000
500.00	1.830	0.0000

Flow-Duration Summary
==========

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00100
90.0	0.00000	40.0	0.00200
80.0	0.00000	30.0	0.00300
70.0	0.00000	20.0	0.00300
60.0	0.00048	10.0	0.00400

WATER BALANCE SUMMARY FOR HYDROGRAPH 503

Location: Trib 5 East Flatt Rd
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.4655 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.2	9.5	10.7	20.1	20.2
FEB	45.2	8.2	13.5	9.1	14.5	22.6
MAR	61.7	19.4	28.9	12.7	0.7	41.6
APR	76.2	48.5	13.4	16.4	-2.1	29.8
MAY	72.3	85.2	4.6	11.1	-28.6	15.7
JUN	72.5	103.0	2.1	4.2	-36.7	6.3
JUL	89.2	105.3	6.0	2.4	-24.4	8.4
AUG	76.3	96.3	2.7	2.5	-25.1	5.2
SEP	76.6	67.9	1.7	2.2	4.8	4.0
OCT	72.2	51.1	3.9	3.3	13.9	7.2
NOV	71.8	25.7	4.9	7.3	33.8	12.3
DEC	63.5	11.5	10.8	12.5	28.6	23.3
Total	827.1	631.3	102.1	94.3	-0.6	196.5

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.210	0.0002
2.00	0.330	0.0000
5.00	0.510	0.0000
10.00	0.640	0.0000
20.00	0.780	0.0000
25.00	0.830	0.0000
50.00	0.970	0.0000
100.00	1.120	0.0000
200.00	1.280	0.0000
500.00	1.510	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00100
90.0	0.00002	40.0	0.00200
80.0	0.00011	30.0	0.00200
70.0	0.00035	20.0	0.00300
60.0	0.00069	10.0	0.00400

WATER BALANCE SUMMARY FOR HYDROGRAPH 530

Location: Trib 5 W at Flatt Rd
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.1839 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.2	9.8	13.9	16.5	23.7
FEB	45.2	8.2	14.0	11.8	11.3	25.7
MAR	61.7	19.5	32.4	16.7	-6.9	49.1
APR	76.2	49.1	15.7	21.3	-9.9	37.0
MAY	72.3	86.2	4.8	13.5	-32.1	18.2
JUN	72.5	98.9	1.2	4.0	-31.6	5.2
JUL	89.2	95.5	4.9	1.9	-13.0	6.8
AUG	76.3	88.5	1.6	2.3	-16.1	3.9
SEP	76.6	63.8	0.7	2.2	9.9	3.0
OCT	72.2	50.8	3.1	3.8	14.5	7.0
NOV	71.8	25.9	4.7	9.1	32.0	13.9
DEC	63.5	11.6	11.0	16.5	24.4	27.5
Total	827.1	607.2	104.1	116.8	-1.0	221.0

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.100	0.0000
2.00	0.150	0.0000
5.00	0.230	0.0000
10.00	0.290	0.0000
20.00	0.360	0.0000
25.00	0.380	0.0000
50.00	0.440	0.0000
100.00	0.510	0.0000
200.00	0.590	0.0000
500.00	0.690	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00043
90.0	0.00001	40.0	0.00093
80.0	0.00001	30.0	0.00100
70.0	0.00004	20.0	0.00200
60.0	0.00011	10.0	0.00200

WATER BALANCE SUMMARY FOR HYDROGRAPH 2551

Location: Hydrograph 2551
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.8436 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.2	10.4	12.3	17.6	22.6
FEB	45.2	8.2	14.6	10.2	12.2	24.9
MAR	61.7	19.3	31.4	15.4	-4.4	46.8
APR	76.2	48.2	16.2	19.0	-7.0	35.1
MAY	72.3	84.3	5.8	12.4	-30.2	18.1
JUN	72.5	98.6	2.8	3.9	-32.7	6.7
JUL	89.2	97.2	6.5	2.2	-16.7	8.7
AUG	76.3	89.7	3.5	2.1	-18.9	5.6
SEP	76.6	64.2	2.3	2.2	7.9	4.5
OCT	72.2	50.1	4.5	3.5	14.0	8.1
NOV	71.8	25.6	5.9	8.3	32.0	14.2
DEC	63.5	11.5	11.4	14.9	25.6	26.3
Total	827.1	606.0	115.4	106.3	-0.6	221.8

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.390	0.0003
2.00	0.590	0.0000
5.00	0.900	0.0000
10.00	1.140	0.0000
20.00	1.370	0.0000
25.00	1.450	0.0000
50.00	1.700	0.0000
100.00	1.970	0.0000
200.00	2.240	0.0000
500.00	2.630	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00300
90.0	0.00003	40.0	0.00400
80.0	0.00017	30.0	0.00500
70.0	0.00052	20.0	0.00700
60.0	0.00100	10.0	0.00800

WATER BALANCE SUMMARY FOR HYDROGRAPH 603

Location: Trib 6 at Flatt Road
Scenario File: wbsum1.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.3091 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.2	9.4	10.3	20.5	19.7
FEB	45.2	8.2	13.4	8.7	14.9	22.2
MAR	61.7	19.4	28.5	12.3	1.6	40.8
APR	76.2	48.5	13.0	15.9	-1.1	28.8
MAY	72.3	85.3	4.5	10.8	-28.2	15.3
JUN	72.5	103.7	2.1	4.2	-37.4	6.3
JUL	89.2	106.6	6.0	2.5	-25.8	8.5
AUG	76.3	97.3	2.7	2.5	-26.2	5.2
SEP	76.6	68.5	1.7	2.2	4.2	4.0
OCT	72.2	51.3	3.9	3.2	13.8	7.2
NOV	71.8	25.7	4.8	7.1	34.1	12.0
DEC	63.5	11.5	10.7	12.1	29.1	22.8
Total	827.1	635.1	100.6	91.9	-0.5	192.6

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.160	0.0001
2.00	0.250	0.0000
5.00	0.390	0.0000
10.00	0.500	0.0000
20.00	0.610	0.0000
25.00	0.640	0.0000
50.00	0.760	0.0000
100.00	0.880	0.0000
200.00	1.020	0.0000
500.00	1.200	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00083
90.0	0.00001	40.0	0.00100
80.0	0.00008	30.0	0.00200
70.0	0.00024	20.0	0.00200
60.0	0.00047	10.0	0.00200

GAWSER V6.9.18 - Released - Sep. 21, 2016
==========

Eagle Heights Watersheds Model
General Water Balance Summary
1950 to 2015: Post Condn (With SWM)
==========

```
   Input file 1=wbsum2.dat
   Input file 2=
   Output file =wbsum2.txt
* ============================================================================
* File created by Dr. H.O. Schroeter, September 30, 2004
* Revised: Dec. 11, 2016; January 27, 2017; March 8, 2017
* ============================================================================
START               KUNITS=2 TOTAL WATERSHED AREA=1.50   SQ KM
                    INITIAL BASEFLOW AT OUTLET: QBSS= 0.0000 QBGW= 0.000
                    PRINT OPTIONS: ECHO=3 OUTPUT=1 PLOTS=0 RCS=1 SUBW=1
                      PLOT CUTOFF=576 SUM=4 FREE=0
                    PARAMETER ADJUSTMENT FACTORS: FDS=1.00 FKEFF=0.25
                      FCS=0.30 FD=0.30 FSAV=1.0 FKO=1.00 FKSS=1.0 FKMF=1.00
                    INITIAL SOIL/SNOW WATER FACTORS:
                      FIMCI=1.00 FIMCII=1.00 FIWE=0.0000
                    GLOBAL RAINFALL SCALING FACTOR: GFRF=1.0000
                    SIMULATION CONTROLS: TTI=1.00000 IDEL=4 HOURS=576
                    SUBWATERSHED INITIAL BASEFLOWS: -999
```

WATER BALANCE SUMMARY FOR HYDROGRAPH 2412
==========

Location: Trib 4 North at gauge
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.1086 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	8.9	17.8	11.5	11.2	29.3
FEB	45.2	7.9	23.1	9.9	4.2	33.0
MAR	61.7	16.6	44.1	14.0	-13.0	58.1
APR	76.2	37.9	32.9	18.1	-12.6	50.9
MAY	72.3	63.0	21.4	11.0	-23.2	32.5
JUN	72.5	67.7	19.3	2.8	-17.2	22.1
JUL	89.2	61.6	27.4	0.9	-0.7	28.3
AUG	76.3	58.6	20.8	1.5	-4.6	22.3
SEP	76.6	44.7	20.3	1.6	10.0	21.9
OCT	72.2	38.5	20.7	3.0	10.0	23.7
NOV	71.8	21.7	22.3	6.7	21.1	29.0
DEC	63.5	10.8	23.2	13.5	15.9	36.7
Total	827.1	438.0	293.4	94.5	1.2	387.9

Extreme Flows Summary
==========

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.100	0.0000
2.00	0.150	0.0000
5.00	0.230	0.0000
10.00	0.290	0.0000
20.00	0.350	0.0000
25.00	0.370	0.0000
50.00	0.430	0.0000
100.00	0.500	0.0000
200.00	0.570	0.0000
500.00	0.680	0.0000

Flow-Duration Summary
==========

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00049
90.0	0.00000	40.0	0.00063
80.0	0.00000	30.0	0.00083
70.0	0.00000	20.0	0.00100
60.0	0.00024	10.0	0.00300

WATER BALANCE SUMMARY FOR HYDROGRAPH 2421

Location: Hydrograph 2421
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.3270 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.0	15.0	13.8	11.7	28.8
FEB	45.2	8.0	20.0	11.7	5.4	31.8
MAR	61.7	17.6	39.5	17.3	-12.7	56.8
APR	76.2	42.0	26.9	22.0	-14.7	48.9
MAY	72.3	71.5	14.4	14.0	-27.6	28.4
JUN	72.5	77.3	11.0	4.8	-20.5	15.8
JUL	89.2	70.1	16.7	3.4	-0.9	20.1
AUG	76.3	66.4	11.7	3.7	-5.4	15.4
SEP	76.6	50.0	11.6	3.2	11.8	14.8
OCT	72.2	42.7	13.2	4.5	11.8	17.7
NOV	71.8	23.2	15.3	8.6	24.7	23.9
DEC	63.5	11.1	18.5	16.4	17.4	34.9
Total	827.1	488.9	213.7	123.5	1.0	337.2

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.240	0.0000
2.00	0.350	0.0000
5.00	0.520	0.0000
10.00	0.640	0.0000
20.00	0.770	0.0000
25.00	0.820	0.0000
50.00	0.950	0.0000
100.00	1.100	0.0000
200.00	1.250	0.0000
500.00	1.460	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00200
90.0	0.00000	40.0	0.00200
80.0	0.00000	30.0	0.00300
70.0	0.00000	20.0	0.00300
60.0	0.00077	10.0	0.00700

WATER BALANCE SUMMARY FOR HYDROGRAPH 2512
==========

Location: Hydrograph 2512
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.4459 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.1	10.9	8.8	20.7	19.7
FEB	45.2	8.1	14.9	7.5	14.6	22.5
MAR	61.7	18.6	28.2	10.6	4.3	38.7
APR	76.2	46.4	15.8	13.5	0.5	29.3
MAY	72.3	81.4	7.2	8.2	-24.5	15.4
JUN	72.5	99.1	5.1	2.0	-33.7	7.1
JUL	89.2	102.2	9.7	0.7	-23.4	10.4
AUG	76.3	93.4	5.9	1.1	-24.0	7.0
SEP	76.6	65.9	5.0	1.1	4.6	6.1
OCT	72.2	49.4	6.8	2.2	13.7	9.1
NOV	71.8	25.1	7.7	5.0	34.0	12.7
DEC	63.5	11.4	12.8	10.2	29.0	23.1
Total	827.1	610.2	129.9	71.0	15.9	201.0

Extreme Flows Summary
==========

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.200	0.0000
2.00	0.310	0.0000
5.00	0.490	0.0000
10.00	0.620	0.0000
20.00	0.750	0.0000
25.00	0.790	0.0000
50.00	0.940	0.0000
100.00	1.090	0.0000
200.00	1.250	0.0000
500.00	1.470	0.0000

Flow-Duration Summary
==========

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00100
90.0	0.00000	40.0	0.00200
80.0	0.00000	30.0	0.00200
70.0	0.00000	20.0	0.00300
60.0	0.00062	10.0	0.00400

WATER BALANCE SUMMARY FOR HYDROGRAPH 2521
==========

Location: Hydrograph 2521
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.1997 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.1	11.1	8.2	21.0	19.4
FEB	45.2	8.1	15.2	7.1	14.8	22.3
MAR	61.7	18.2	27.4	10.6	5.5	38.0
APR	76.2	44.6	15.5	13.7	2.5	29.2
MAY	72.3	77.6	8.0	8.5	-21.8	16.6
JUN	72.5	95.5	7.1	2.4	-32.4	9.7
JUL	89.2	99.8	12.6	0.8	-24.0	13.8
AUG	76.3	91.0	8.3	1.3	-24.2	9.9
SEP	76.6	64.1	7.5	1.3	3.7	9.0
OCT	72.2	47.7	8.9	2.3	13.3	11.5
NOV	71.8	24.4	9.3	5.1	33.0	14.5
DEC	63.5	11.3	13.3	9.7	29.1	23.1
Total	827.1	591.3	144.4	71.0	20.4	217.0

Extreme Flows Summary
==========

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.075	0.0000
2.00	0.130	0.0000
5.00	0.240	0.0000
10.00	0.330	0.0000
20.00	0.430	0.0000
25.00	0.470	0.0000
50.00	0.590	0.0000
100.00	0.730	0.0000
200.00	0.880	0.0000
500.00	1.110	0.0000

Flow-Duration Summary
==========

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00062
90.0	0.00000	40.0	0.00079
80.0	0.00000	30.0	0.00100
70.0	0.00008	20.0	0.00100
60.0	0.00035	10.0	0.00300

File=DUMP0518.WTB Does not exist

WATER BALANCE SUMMARY FOR HYDROGRAPH 2563
==========

Location: Hydrograph 2563
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.8294 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
JAN	49.5	9.1	10.7	10.7	18.9	21.4
FEB	45.2	8.1	14.9	9.1	13.0	24.0
MAR	61.7	18.6	27.9	14.2	1.0	42.0
APR	76.2	46.3	15.9	17.0	-3.0	33.0
MAY	72.3	81.0	6.5	10.7	-25.9	17.2
JUN	72.5	96.4	4.0	3.7	-31.5	7.6
JUL	89.2	97.2	8.0	2.7	-18.7	10.7
AUG	76.3	89.3	4.7	2.6	-20.3	7.3
SEP	76.6	63.6	3.8	2.6	6.6	6.4
OCT	72.2	48.9	6.0	3.6	13.8	9.6
NOV	71.8	25.0	7.1	6.9	32.8	14.0
DEC	63.5	11.4	12.2	12.9	27.0	25.1
Total	827.1	595.0	121.7	96.7	13.8	218.4

Extreme Flows Summary
==========

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.340	0.0000
2.00	0.530	0.0000
5.00	0.850	0.0000
10.00	1.080	0.0000
20.00	1.320	0.0000
25.00	1.400	0.0000
50.00	1.670	0.0000
100.00	1.940	0.0000
200.00	2.230	0.0000
500.00	2.650	0.0000

Flow-Duration Summary
==========

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00300
90.0	0.00000	40.0	0.00400
80.0	0.00000	30.0	0.00500
70.0	0.00013	20.0	0.00600
60.0	0.00100	10.0	0.00900

WATER BALANCE SUMMARY FOR HYDROGRAPH 2636

Location: Hydrograph 2636
Scenario File: wbsum2.dat
Period: 1950/11/01 to 2015/10/30 Area: 0.3097 km^2

Water Balance Quantities (in mm)

Month	Precip	ET	Runoff	Infiltration (Baseflow)	Infiltration (Losses)	Total Flow
JAN	49.5	9.1	11.3	5.4	23.6	16.8
FEB	45.2	8.1	15.5	4.7	17.0	20.1
MAR	61.7	18.1	26.4	6.9	10.3	33.3
APR	76.2	44.4	15.1	8.7	8.0	23.9
MAY	72.3	77.4	8.6	5.6	-19.3	14.2
JUN	72.5	98.5	7.6	1.9	-35.5	9.6
JUL	89.2	106.3	12.7	1.4	-31.3	14.2
AUG	76.3	96.2	8.5	1.5	-29.9	10.1
SEP	76.6	67.0	7.9	1.3	0.5	9.2
OCT	72.2	48.1	9.5	1.8	12.8	11.3
NOV	71.8	24.4	9.8	3.4	34.3	13.2
DEC	63.5	11.3	13.7	6.5	31.9	20.3
Total	827.1	608.7	146.7	49.2	22.4	196.0

Extreme Flows Summary

Return Period (Years)	High Flows (m^3/s)	Low Flows (m^3/s)
1.25	0.180	0.0000
2.00	0.280	0.0000
5.00	0.430	0.0000
10.00	0.540	0.0000
20.00	0.660	0.0000
25.00	0.700	0.0000
50.00	0.820	0.0000
100.00	0.950	0.0000
200.00	1.080	0.0000
500.00	1.280	0.0000

Flow-Duration Summary

PCT% Time	Flow (m^3/s)	PCT% Time	Flow (m^3/s)
98.0	0.00000	50.0	0.00064
90.0	0.00000	40.0	0.00082
80.0	0.00000	30.0	0.00100
70.0	0.00000	20.0	0.00100
60.0	0.00031	10.0	0.00400

APPENDIX E: Erosion Assessment Summary Table from GAWSER Continuous Modelling

GAWSER V6.9.18 - Released - Sep. 21, 2016
==========

Eagle Heights River Watershed
Critical Flow Exceedace Summaries
For Existing Conditions
==========

Input file 1=exceed.dat
Input file 2=
Output file =exceed.txt

```
* ===============================================================================
* Created by Dr. H. Schroeter
* Revised: Nava Pokharel Feb 09, 2018
* ===============================================================================
START               KUNITS=2 TOTAL WATERSHED AREA=  1.48810 SQ KM
                    INITIAL BASEFLOW AT OUTLET: QBSS= 0.0000 QBGW= 0.0640
                    PRINT OPTIONS: ECHO=3 OUTPUT=0 PLOTS=0 RCS=1 SUBW=1
                      PLOT CUTOFF= 576 SUM=6 FREE=0
                    PARAMETER ADJUSTMENT FACTORS: FDS=1.00 FKEFF=0.25*
                      FCS=0.06 FD=0.05 FSAV=1.0 FKO=1.50 FKSS=1.00 FKMF=1.0*
                    INITIAL SOIL/SNOW WATER FACTORS:
                      FIMCI=1.00*   FIMCII=1.00*   FIWE= 0.00**
                    GLOBAL RAINFALL SCALING FACTOR: GFRF=1.00
                    SIMULATION CONTROLS: TTI= 1.00   IDEL=4 HOURS= 576
                    SUBWATERSHED INITIAL BASEFLOWS: -999
```

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 403
==========

Location: Trib 4 at Flatt Rd (Reach 4-4)
Period: 1950/11/ 1   to   2015/10/30

	Mean	Flow Extremes			Threshold 1:					Threshold 2:				
	Flow	Highest	Lowest	Total	Flow:	0.0800 (m^3/s)				Flow:	1.2000 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration		Hours	PCT	Pulses	Duration	
JAN	0.00127	0.20300	0.00000	48360.	37.	0.1	13.	2.8		0.	0.0	0.	0.0	
FEB	0.00145	0.15370	0.00000	44064.	33.	0.1	16.	2.1		0.	0.0	0.	0.0	
MAR	0.00242	0.22410	0.00000	48360.	87.	0.2	30.	2.9		0.	0.0	0.	0.0	
APR	0.00207	0.25350	0.00000	46800.	62.	0.1	21.	3.0		0.	0.0	0.	0.0	
MAY	0.00097	0.23300	0.00000	48360.	19.	0.0	9.	2.1		0.	0.0	0.	0.0	
JUN	0.00028	0.20250	0.00000	46800.	9.	0.0	4.	2.3		0.	0.0	0.	0.0	
JUL	0.00034	0.49390	0.00000	48360.	40.	0.1	5.	8.0		0.	0.0	0.	0.0	
AUG	0.00021	0.25240	0.00000	48360.	14.	0.0	3.	4.7		0.	0.0	0.	0.0	
SEP	0.00019	0.12330	0.00000	46800.	4.	0.0	1.	4.0		0.	0.0	0.	0.0	
OCT	0.00037	0.25920	0.00000	48336.	27.	0.1	6.	4.5		0.	0.0	0.	0.0	
NOV	0.00078	0.18510	0.00000	46800.	29.	0.1	11.	2.6		0.	0.0	0.	0.0	
DEC	0.00143	0.18280	0.00000	48360.	52.	0.1	19.	2.7		0.	0.0	0.	0.0	
Annual	0.00098	0.49390	0.00000	569760.	413.	0.1	138.	3.0		0.	0.0	0.	0.0	

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2427
==========

Location: Trib 4 Near Panin Road (Reach 4-1a)
Period: 1950/11/ 1   to   2015/10/30

	Mean	Flow Extremes			Threshold 1:					Threshold 2:				
	Flow	Highest	Lowest	Total	Flow:	0.100 (m^3/s)				Flow:	1.100 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration		Hours	PCT	Pulses	Duration	
JAN	0.00364	0.61640	0.00000	48360.	208.	0.4	50.	4.2		0.	0.0	0.	0.0	
FEB	0.00416	0.46900	0.00000	44064.	260.	0.6	58.	4.5		0.	0.0	0.	0.0	
MAR	0.00694	0.67960	0.00000	48360.	588.	1.2	129.	4.6		0.	0.0	0.	0.0	
APR	0.00599	0.79270	0.00000	46800.	380.	0.8	93.	4.1		0.	0.0	0.	0.0	
MAY	0.00291	0.71410	0.00000	48360.	131.	0.3	36.	3.6		0.	0.0	0.	0.0	
JUN	0.00101	0.63910	0.00000	46800.	32.	0.1	8.	4.0		0.	0.0	0.	0.0	
JUL	0.00123	1.60380	0.00000	48360.	61.	0.1	9.	6.8		4.	0.0	2.	2.0	
AUG	0.00083	0.82750	0.00000	48360.	29.	0.1	5.	5.8		0.	0.0	0.	0.0	
SEP	0.00077	0.38490	0.00000	46800.	19.	0.0	5.	3.8		0.	0.0	0.	0.0	
OCT	0.00126	0.80260	0.00000	48336.	58.	0.1	12.	4.8		0.	0.0	0.	0.0	

NOV	0.00239	0.56710	0.00000	46800.	108.	0.2	23.	4.7	0.	0.0	0.	0.0
DEC	0.00416	0.53400	0.00000	48360.	222.	0.5	68.	3.3	0.	0.0	0.	0.0
Annual	0.00294	1.60380	0.00000	569760.	2096.	0.4	496.	4.2	4.	0.0	2.	2.0

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2427

Location: Trib 4 Near Panin Road (Reach 4-1b)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow: 1.10 (m^3/s)				Threshold 2: Flow: 1.20 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00364	0.61640	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
FEB	0.00416	0.46900	0.00000	44064.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
MAR	0.00694	0.67960	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
APR	0.00599	0.79270	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
MAY	0.00291	0.71410	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
JUN	0.00101	0.63910	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
JUL	0.00123	1.60380	0.00000	48360.	4.	0.0	2.	2.0	1.	0.0	1.	1.0
AUG	0.00083	0.82750	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
SEP	0.00077	0.38490	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
OCT	0.00126	0.80260	0.00000	48336.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
NOV	0.00239	0.56710	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
DEC	0.00416	0.53400	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
Annual	0.00294	1.60380	0.00000	569760.	4.	0.0	2.	2.0	1.	0.0	1.	1.0

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 530

Location: Trib 5 W at Flatt Rd(Reach 5-4)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow: 0.0400 (m^3/s)				Threshold 2: Flow: 0.0600 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00171	0.26650	0.00000	48360.	250.	0.5	46.	5.4	152.	0.3	35.	4.3
FEB	0.00198	0.20230	0.00000	44064.	351.	0.8	58.	6.1	191.	0.4	41.	4.7
MAR	0.00323	0.31070	0.00000	48360.	694.	1.4	129.	5.4	347.	0.7	71.	4.9
APR	0.00266	0.31130	0.00000	46800.	390.	0.8	86.	4.5	188.	0.4	48.	3.9
MAY	0.00125	0.27000	0.00000	48360.	133.	0.3	32.	4.2	58.	0.1	19.	3.1
JUN	0.00037	0.24750	0.00000	46800.	34.	0.1	8.	4.3	23.	0.0	7.	3.3
JUL	0.00047	0.62610	0.00000	48360.	72.	0.1	8.	9.0	58.	0.1	6.	9.7
AUG	0.00027	0.29730	0.00000	48360.	37.	0.1	5.	7.4	28.	0.1	5.	5.6
SEP	0.00021	0.12870	0.00000	46800.	19.	0.0	5.	3.8	9.	0.0	3.	3.0
OCT	0.00048	0.34550	0.00000	48336.	64.	0.1	10.	6.4	43.	0.1	8.	5.4
NOV	0.00099	0.24170	0.00000	46800.	123.	0.3	22.	5.6	65.	0.1	14.	4.6
DEC	0.00191	0.26580	0.00000	48360.	274.	0.6	71.	3.9	147.	0.3	49.	3.0
Annual	0.00129	0.62610	0.00000	569760.	2441.	0.4	480.	5.1	1309.	0.2	306.	4.3

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 603

Location: Trib 6 at Flatt Road(Reach 6-2)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow: 0.180 (m^3/s)				Threshold 2: Flow: 0.270 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00240	0.46710	0.00000	48360.	42.	0.1	12.	3.5	11.	0.0	5.	2.2
FEB	0.00286	0.34120	0.00000	44064.	44.	0.1	16.	2.8	10.	0.0	5.	2.0
MAR	0.00447	0.53500	0.00000	48360.	79.	0.2	25.	3.2	23.	0.0	9.	2.6
APR	0.00348	0.51470	0.00000	46800.	24.	0.1	8.	3.0	6.	0.0	2.	3.0
MAY	0.00177	0.41220	0.00000	48360.	6.	0.0	3.	2.0	3.	0.0	1.	3.0
JUN	0.00076	0.42150	0.00000	46800.	6.	0.0	2.	3.0	3.	0.0	2.	1.5
JUL	0.00098	1.10680	0.00000	48360.	44.	0.1	5.	8.8	33.	0.1	4.	8.3
AUG	0.00061	0.49460	0.00000	48360.	17.	0.0	3.	5.7	10.	0.0	3.	3.3

SEP	0.00048	0.16400	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
OCT	0.00083	0.60430	0.00000	48336.	29.	0.1	5.	5.8	20.	0.0	4.	5.0
NOV	0.00144	0.39490	0.00000	46800.	21.	0.0	8.	2.6	5.	0.0	2.	2.5
DEC	0.00268	0.44350	0.00000	48360.	51.	0.1	16.	3.2	22.	0.0	10.	2.2
Annual	0.00189	1.10680	0.00000	569760.	363.	0.1	103.	3.5	146.	0.0	47.	3.1

GAWSER V6.9.18 - Released - Sep. 21, 2016
==========

Eagle Heights River Watershed
Critical Flow Exceedace Summaries
For Post Development with SWM Conditions
==========

Input file 1=exceed.dat
Input file 2=
Output file =exceed.txt

```
* ===============================================================================
* Created by Dr. H. Schroeter
* Revised: Nava Pokharel March 28, 2017
* ===============================================================================
START               KUNITS=2 TOTAL WATERSHED AREA=  1.48810 SQ KM
                    INITIAL BASEFLOW AT OUTLET: QBSS= 0.0000 QBGW= 0.0640
                    PRINT OPTIONS: ECHO=3 OUTPUT=0 PLOTS=0 RCS=1 SUBW=1
                      PLOT CUTOFF= 576 SUM=6 FREE=0
                    PARAMETER ADJUSTMENT FACTORS: FDS=1.00 FKEFF=0.25*
                      FCS=0.06 FD=0.05 FSAV=1.0 FKO=1.50 FKSS=1.00 FKMF=1.0*
                    INITIAL SOIL/SNOW WATER FACTORS:
                      FIMCI=1.00*   FIMCII=1.00*   FIWE= 0.00**
                    GLOBAL RAINFALL SCALING FACTOR: GFRF=1.00
                    SIMULATION CONTROLS: TTI= 1.00   IDEL=4 HOURS= 576
                    SUBWATERSHED INITIAL BASEFLOWS: -999
```

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2412
==========

Location: Trib 4 at Flatt Rd (Reach 4-4)
Period: 1950/11/ 1   to   2015/10/30

	Mean	Flow Extremes			Threshold 1:					Threshold 2:				
	Flow	Highest	Lowest	Total	Flow:	0.0800 (m^3/s)				Flow:	1.2000 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration		Hours	PCT	Pulses	Duration	
JAN	0.00123	0.23100	0.00000	48360.	55.	0.1	21.	2.6		0.	0.0	0.	0.0	
FEB	0.00147	0.17280	0.00000	44064.	49.	0.1	26.	1.9		0.	0.0	0.	0.0	
MAR	0.00236	0.23750	0.00000	48360.	127.	0.3	49.	2.6		0.	0.0	0.	0.0	
APR	0.00213	0.29420	0.00000	46800.	80.	0.2	34.	2.4		0.	0.0	0.	0.0	
MAY	0.00132	0.26740	0.00000	48360.	26.	0.1	13.	2.0		0.	0.0	0.	0.0	
JUN	0.00092	0.27270	0.00000	46800.	34.	0.1	18.	1.9		0.	0.0	0.	0.0	
JUL	0.00115	0.57960	0.00000	48360.	90.	0.2	34.	2.6		0.	0.0	0.	0.0	
AUG	0.00091	0.37240	0.00000	48360.	57.	0.1	25.	2.3		0.	0.0	0.	0.0	
SEP	0.00092	0.15930	0.00000	46800.	32.	0.1	16.	2.0		0.	0.0	0.	0.0	
OCT	0.00096	0.30460	0.00000	48336.	39.	0.1	10.	3.9		0.	0.0	0.	0.0	
NOV	0.00121	0.21370	0.00000	46800.	36.	0.1	13.	2.8		0.	0.0	0.	0.0	
DEC	0.00149	0.19300	0.00000	48360.	69.	0.1	30.	2.3		0.	0.0	0.	0.0	
Annual	0.00134	0.57960	0.00000	569760.	694.	0.1	289.	2.4		0.	0.0	0.	0.0	

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2421
==========

Location: Trib 4 at Panin Road (Reach 4-1a)
Period: 1950/11/ 1   to   2015/10/30

	Mean	Flow Extremes			Threshold 1:					Threshold 2:				
	Flow	Highest	Lowest	Total	Flow:	0.100 (m^3/s)				Flow:	1.200 (m^3/s)			
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration		Hours	PCT	Pulses	Duration	
JAN	0.00362	0.55030	0.00000	48360.	227.	0.5	51.	4.5		0.	0.0	0.	0.0	
FEB	0.00425	0.43110	0.00000	44064.	258.	0.6	56.	4.6		0.	0.0	0.	0.0	
MAR	0.00693	0.60230	0.00000	48360.	574.	1.2	132.	4.3		0.	0.0	0.	0.0	
APR	0.00616	0.69070	0.00000	46800.	373.	0.8	96.	3.9		0.	0.0	0.	0.0	
MAY	0.00346	0.63890	0.00000	48360.	137.	0.3	44.	3.1		0.	0.0	0.	0.0	
JUN	0.00199	0.60580	0.00000	46800.	81.	0.2	34.	2.4		0.	0.0	0.	0.0	
JUL	0.00245	1.32390	0.00000	48360.	160.	0.3	54.	3.0		1.	0.0	1.	1.0	
AUG	0.00188	0.77470	0.00000	48360.	113.	0.2	43.	2.6		0.	0.0	0.	0.0	
SEP	0.00187	0.36450	0.00000	46800.	69.	0.1	28.	2.5		0.	0.0	0.	0.0	
OCT	0.00216	0.74890	0.00000	48336.	74.	0.2	17.	4.4		0.	0.0	0.	0.0	

NOV	0.00301	0.51700	0.00000	46800.	128.	0.3	29.	4.4	0.	0.0	0.	0.0
DEC	0.00426	0.49230	0.00000	48360.	230.	0.5	69.	3.3	0.	0.0	0.	0.0
Annual	0.00350	1.32390	0.00000	569760.	2424.	0.4	653.	3.7	1.	0.0	1.	1.0

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2421

Location: Trib 4 at Panin Road (Reach 4-1b)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow:	1.10 (m^3/s)			Threshold 2: Flow:	1.20 (m^3/s)		
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00362	0.55030	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
FEB	0.00425	0.43110	0.00000	44064.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
MAR	0.00693	0.60230	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
APR	0.00616	0.69070	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
MAY	0.00346	0.63890	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
JUN	0.00199	0.60580	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
JUL	0.00245	1.32390	0.00000	48360.	1.	0.0	1.	1.0	1.	0.0	1.	1.0
AUG	0.00188	0.77470	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
SEP	0.00187	0.36450	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
OCT	0.00216	0.74890	0.00000	48336.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
NOV	0.00301	0.51700	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
DEC	0.00426	0.49230	0.00000	48360.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
Annual	0.00350	1.32390	0.00000	569760.	1.	0.0	1.	1.0	1.	0.0	1.	1.0

STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2521

Location: Trib 5 West at Flatt Road (Reach 5-4)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow:	0.0400 (m^3/s)			Threshold 2: Flow:	1.5000 (m^3/s)		
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00149	0.23380	0.00000	48360.	168.	0.3	30.	5.6	0.	0.0	0.	0.0
FEB	0.00183	0.22250	0.00000	44064.	235.	0.5	34.	6.9	0.	0.0	0.	0.0
MAR	0.00284	0.27550	0.00000	48360.	299.	0.6	59.	5.1	0.	0.0	0.	0.0
APR	0.00225	0.25530	0.00000	46800.	125.	0.3	30.	4.2	0.	0.0	0.	0.0
MAY	0.00124	0.22430	0.00000	48360.	36.	0.1	13.	2.8	0.	0.0	0.	0.0
JUN	0.00075	0.24340	0.00000	46800.	21.	0.0	8.	2.6	0.	0.0	0.	0.0
JUL	0.00103	0.79210	0.00000	48360.	96.	0.2	9.	10.7	0.	0.0	0.	0.0
AUG	0.00074	0.28210	0.00000	48360.	40.	0.1	6.	6.7	0.	0.0	0.	0.0
SEP	0.00069	0.12590	0.00000	46800.	13.	0.0	7.	1.9	0.	0.0	0.	0.0
OCT	0.00086	0.31020	0.00000	48336.	63.	0.1	8.	7.9	0.	0.0	0.	0.0
NOV	0.00112	0.22180	0.00000	46800.	68.	0.1	12.	5.7	0.	0.0	0.	0.0
DEC	0.00173	0.24220	0.00000	48360.	158.	0.3	37.	4.3	0.	0.0	0.	0.0
Annual	0.00138	0.79210	0.00000	569760.	1322.	0.2	253.	5.2	0.	0.0	0.	0.0

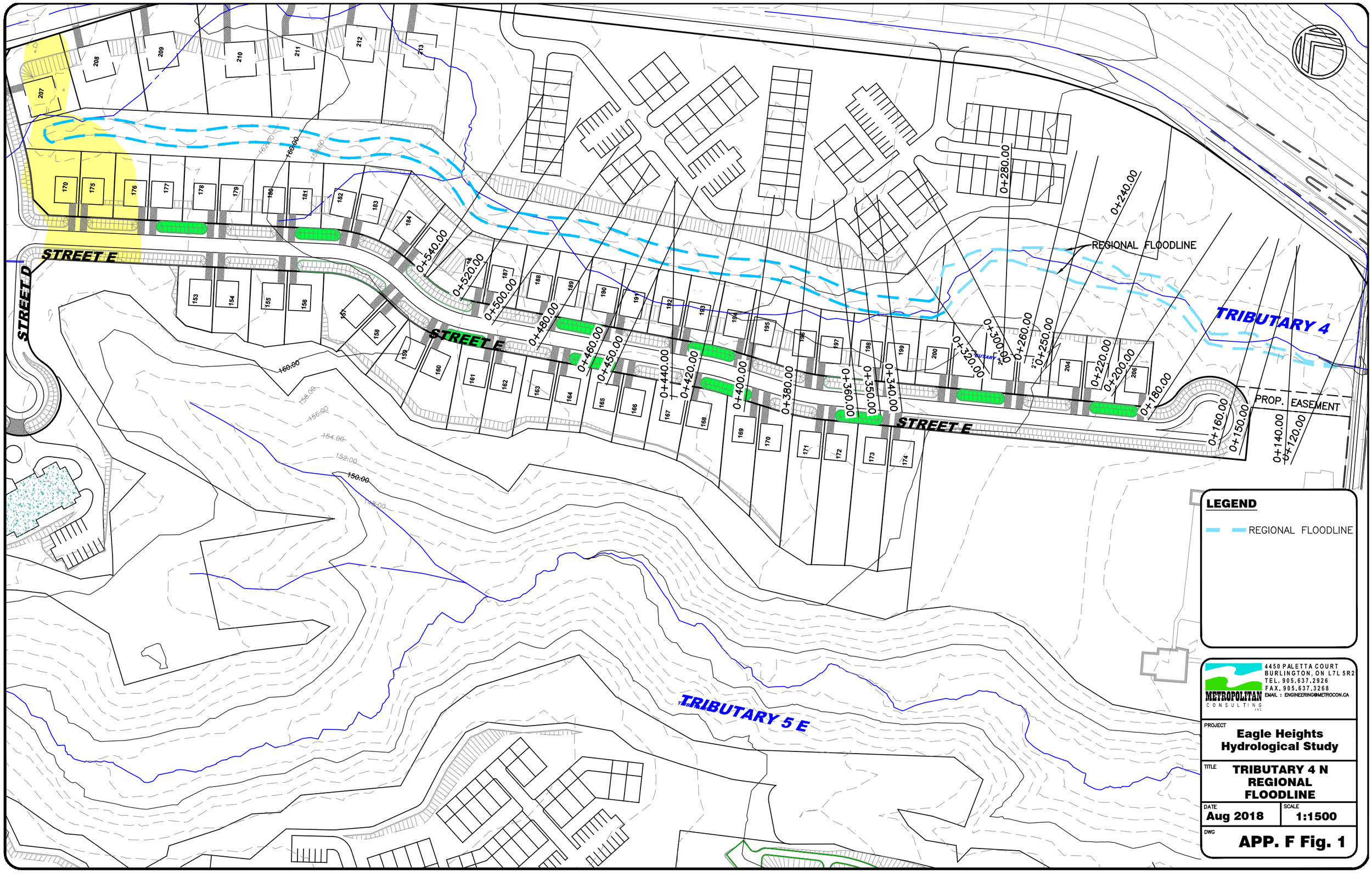
STREAM DISCHARGE EXCEEDANCE SUMMARY FOR 2636

Location: Trib 6 at Flatt Road (Reach 6-2)
Period: 1950/11/ 1 to 2015/10/30

	Mean Flow	Flow Extremes Highest	Lowest	Total	Threshold 1: Flow:	0.180 (m^3/s)			Threshold 2: Flow:	1.000 (m^3/s)		
Month	(m^3/s)	(m^3/s)	(m^3/s)	Hours	Hours	PCT	Pulses	Duration	Hours	PCT	Pulses	Duration
JAN	0.00104	0.28890	0.00000	48360.	7.	0.0	3.	2.3	0.	0.0	0.	0.0
FEB	0.00140	0.21840	0.00000	44064.	8.	0.0	4.	2.0	0.	0.0	0.	0.0
MAR	0.00202	0.32220	0.00000	48360.	19.	0.0	7.	2.7	0.	0.0	0.	0.0
APR	0.00146	0.31330	0.00000	46800.	3.	0.0	1.	3.0	0.	0.0	0.	0.0
MAY	0.00099	0.24350	0.00000	48360.	3.	0.0	2.	1.5	0.	0.0	0.	0.0
JUN	0.00091	0.29840	0.00000	46800.	6.	0.0	2.	3.0	0.	0.0	0.	0.0
JUL	0.00128	0.66820	0.00000	48360.	39.	0.1	5.	7.8	0.	0.0	0.	0.0
AUG	0.00095	0.41140	0.00000	48360.	14.	0.0	4.	3.5	0.	0.0	0.	0.0

SEP	0.00092	0.15670	0.00000	46800.	0.	0.0	0.	0.0	0.	0.0	0.	0.0
OCT	0.00098	0.39560	0.00000	48336.	22.	0.0	4.	5.5	0.	0.0	0.	0.0
NOV	0.00104	0.23660	0.00000	46800.	5.	0.0	2.	2.5	0.	0.0	0.	0.0
DEC	0.00127	0.25470	0.00000	48360.	18.	0.0	9.	2.0	0.	0.0	0.	0.0
Annual	0.00119	0.66820	0.00000	569760.	144.	0.0	43.	3.3	0.	0.0	0.	0.0

APPENDIX F: Flood Mapping of Tributary 4 and Tributary 5 West



LEGEND

REGIONAL FLOODLINE

METROPOLITAN CONSULTING INC
4450 PALETTA COURT
BURLINGTON, ON L7L 5R2
TEL. 905.637.2926
FAX. 905.637.3268
EMAIL : ENGINEERING@METROCON.CA

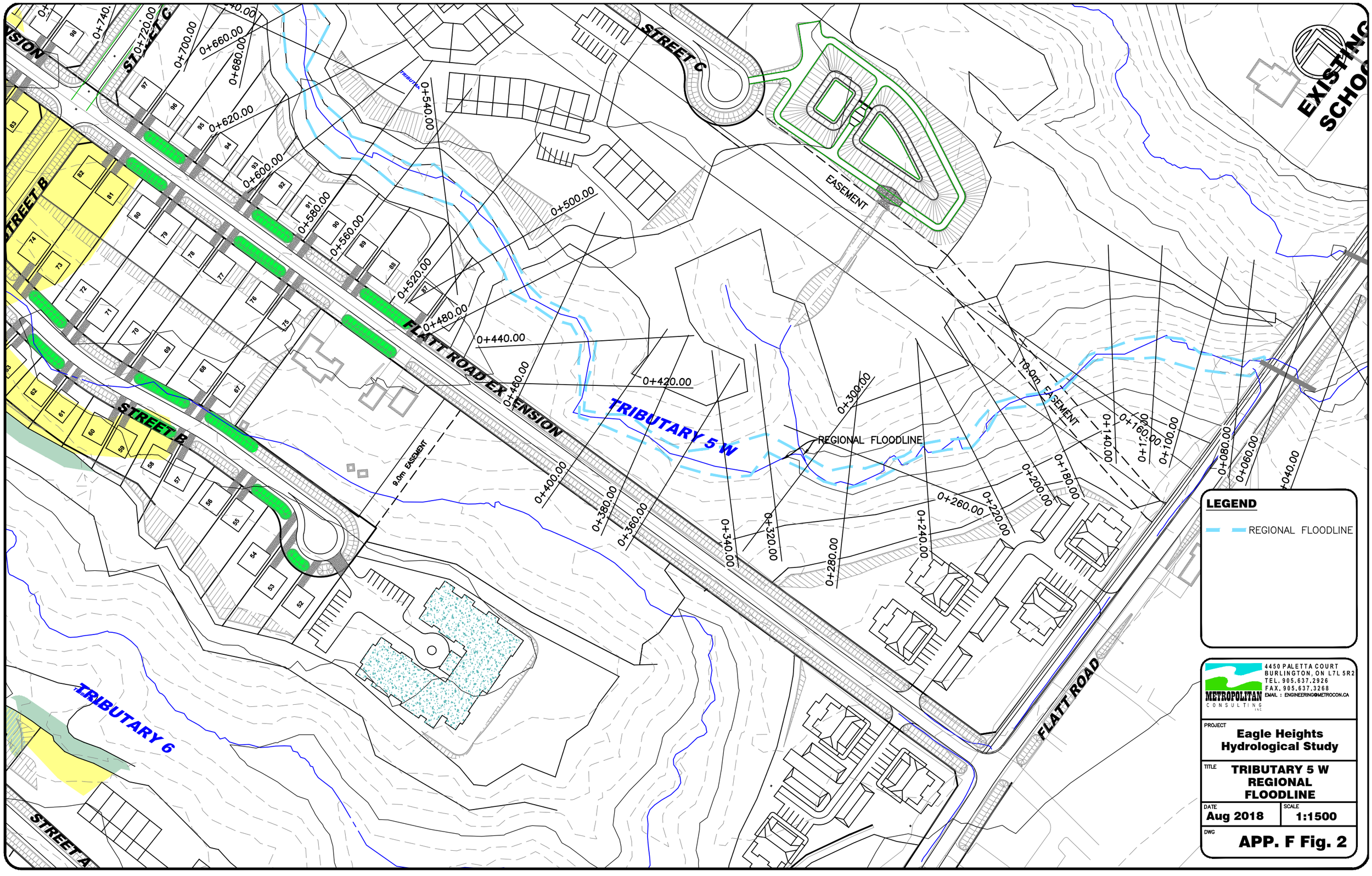
PROJECT
Eagle Heights Hydrological Study

TITLE
TRIBUTARY 4 N REGIONAL FLOODLINE

DATE
Aug 2018

SCALE
1:1500

DWG
APP. F Fig. 1



LEGEND

REGIONAL FLOODLINE

METROPOLITAN CONSULTING INC.
4450 PALETTA COURT
BURLINGTON, ON L7L 5R2
TEL. 905.637.2926
FAX. 905.637.3268
EMAIL : ENGINEERING@METROCON.CA

PROJECT
Eagle Heights Hydrological Study

TITLE
TRIBUTARY 5 W REGIONAL FLOODLINE

DATE	SCALE
Aug 2018	1:1500

DWG
APP. F Fig. 2

APPENDIX G: GAWSER, SWMHYMO, HEC RAS MODEL FILES, POND AND SWM STRUCTURES DESIGN TABLES

APPENDIX H: Photographs (Project Site Tributaries during and after flood)



Photo 1: Tributary 4 downstream of Flatt Road (April 6, 2017)



Photo2 : Upstream side of Culvert at Flatt Road (April 6, 2017)



Photo 3: Tributary 5 East looking upstream of Flatt Road (April 6, 2017)



Photo 4 – Tributary 5 South looking downstream of Flatt Road (April 6, 2017)



Photo 5: Tributary 5 West looking upstream from Flatt Road (April 6, 2017)



Photo 6: Tributary 5 West looking downstream of Flatt Road (May 4, 2016)



Photo 7: Tributary 5 South at Panin Road Culvert (April 6, 2017)



Photo 8: Tributary 5 South at Panin Road Culvert (April 28, 2017)
(74mm rain on April 20, 2017))



Photo 9 : Tributary 6 Upstream of Flatt Road (April 6, 2017)



Photo 10: Tributary 6 Upstream of Flatt Road Culvert (April 6, 2017)



Photo 11: Tributary 5 West looking upstream of Flatt Road (April 10, 2017)



Photo 12: Culvert at Tributary 4 South at Panin Road (1200mm CONC)