APPENDIX A: SCS TR-55 RUNOFF CURVE NUMBER TABLES

Design Chart 1.07: Runoff Coefficients

- Urban for 5 to 10-Year Storms

Land Use	Runoff Coefficient	
	Min.	Max.
Pavement - asphalt or concrete	0.80	0.95
- brick	0.70	0.85
Gravel roads and shoulders	0.40	0.60
Roofs	0.70	0.95
Business - downtown	0.70	0.95
- neighbourhood	0.50	0.70
- light	0.50	0.80
- heavy	0.60	0.90
Residential - single family urban	0.30	0.50
- multiple, detached	0.40	0.60
- multiple, attached	0.60	0.75
- suburban	0.25	0.40
Industrial - light	0.50	0.80
- heavy	0.60	0.90
Apartments	0.50	0.70
Parks, cemeteries	0.10	0.25
Playgrounds (unpaved)	0.20	0.35
Railroad yards	0.20	0.35
Unimproved areas	0.10	0.30
Lawns - Sandy soil		
- flat, to 2%	0.05	0.10
- average, 2 to 7%	0.10	0.15
- steep, over 7%	0.15	0.20
- Clayey soil		
- flat, to 2%	0.13	0.17
- average, 2 to 7%	0.18	0.22
- steep, over 7%	0.25	0.35

For flat or permeable surfaces, use the lower values. For steeper or more impervious surfaces, use the higher values. For return period of more than 10 years, increase above values as 25-year - add 10%, 50-year - add 20%, 100-year - add 25%.

The coefficients listed above are for unfrozen ground.

Design Chart 1.07: Runoff Coefficients (Continued)

- Rural

Land Use & Topography[3]	Soil Texture		
	Open Sand Loam	Loam or Silt Loam	Clay Loam or Clay
CULTIVATED			
Flat 0 - 5% Slopes	0.22	0.35	0.55
Rolling 5 - 10% Slopes	0.30	0.45	0.60
Hilly 10- 30% Slopes	0.40	0.65	0.70
PASTURE			
Flat 0 - 5% Slopes	0.10	0.28	0.40
Rolling 5 - 10% Slopes	0.15	0.35	0.45
Hilly 10- 30% Slopes	0.22	0.40	0.55
WOODLAND OR CUTOVER			
Flat 0 - 5% Slopes	0.08	0.25	0.35
Rolling 5 - 10% Slopes	0.12	0.30	0.42
Hilly 10- 30% Slopes	0.18	0.35	0.52
BARE ROCK	COVERAGE[3]		
	30%	50%	70%
Flat 0 - 5% Slopes	0.40	0.55	0.75
Rolling 5 - 10% Slopes	0.50	0.65	0.80
Hilly 10- 30% Slopes	0.55	0.70	0.85
LAKES AND WETLANDS	0.05		

2 Terrain Slopes

3 Interpolate for other values of % imperviousness

Sources: American Society of Civil Engineers - ASCE (1960)
U.S. Department of Agriculture (1972)

Design Chart 1.09: Soil/Land Use Curve Numbers

Land Use	Treatment or Practice	Hydrologic Condition[4]	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	---	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	" and terraced	Poor	66	74	8	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	" and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded	Straight row	Poor	66	77	85	89
legumes[2]	" "	Good	58	72	81	85
or	Contoured	Poor	64	75	83	85
rotation	"	Good	55	69	78	83
meadow	" and terraced	Poor	63	73	80	83
	" and terraced	Good	51	67	76	80
Pasture		Poor	68	79	86	89
or range		Fair	49	69	79	84
	Contoured	Good	39	61	74	80
	"	Poor	47	67	81	88
	"	Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		---	59	74	82	86
		---	72	82	87	89
		---	74	84	90	92

For average anticedent soil moisture condition (AMC II)
[2] Close-drilled or broadcast.

[4] The hydrologic condition of cropland is good if a good crop rotation practice is used; it is poor if one crop is grown continuously.

Source: U.S. Department of Agriculture (1972)

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.
2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1/]

Cover description: Cover type	Hydrologic condition	Curve numbers for hydrologic soil group: A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2/]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3/]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4/]	48	65	73
Woods—grass combination (orchard or tree farm). [5/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6/]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4/]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and I_a = 0.2S.
2 ***Poor:*** <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 ***Poor***: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 ***Poor:*** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-2d Runoff curve numbers for arid and semiarid rangelands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition [2]	A [3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and I_a, = 0.2S. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

APPENDIX B: IDF CURVES

Moodie Station

Ontario IDF CURVE LOOKUP

Active coordinate

45° 20' 15" N, 75° 50' 14" W (45.337500,-75.837500)

Retrieved: Wed, 13 Sep 2017 18:49:16 GMT

Location summary

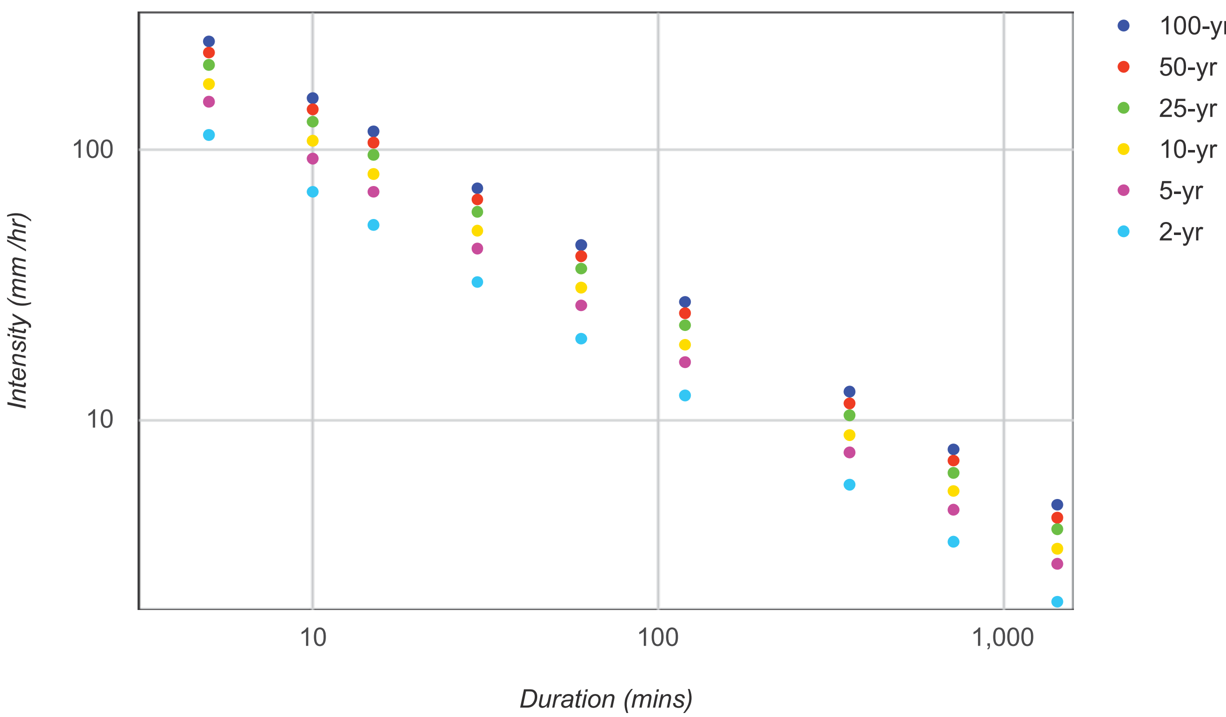
These are the locations in the selection.

IDF Curve: 45° 20' 15" N, 75° 50' 14" W (45.337500,-75.837500)

Results

An IDF curve was found.

Coordinate: 45.337500, -75.837500
IDF curve year: 2010



Coefficient summary

IDF Curve: 45° 20' 15" N, 75° 50' 14" W (45.337500,-75.837500)

Retrieved: Wed, 13 Sep 2017 18:49:16 GMT

Data year: 2010
IDF curve year: 2010

Return period	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
A	19.8	26.3	30.6	36.0	40.0	44.0
B	-0.699	-0.699	-0.699	-0.699	-0.699	-0.699

Statistics

Rainfall intensity (mm hr^{-1})

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	112.5	69.3	52.2	32.1	19.8	12.2	5.7	3.5	2.1
5-yr	149.4	92.0	69.3	42.7	26.3	16.2	7.5	4.6	2.9
10-yr	173.8	107.1	80.6	49.7	30.6	18.8	8.7	5.4	3.3
25-yr	204.5	126.0	94.9	58.4	36.0	22.2	10.3	6.3	3.9
50-yr	227.2	140.0	105.4	64.9	40.0	24.6	11.4	7.0	4.3
100-yr	249.9	154.0	116.0	71.4	44.0	27.1	12.6	7.7	4.8

Rainfall depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	9.4	11.5	13.0	16.1	19.8	24.4	34.0	41.8	51.5
5-yr	12.4	15.3	17.3	21.3	26.3	32.4	45.1	55.6	68.5
10-yr	14.5	17.8	20.2	24.8	30.6	37.7	52.5	64.6	79.6
25-yr	17.0	21.0	23.7	29.2	36.0	44.4	61.7	76.1	93.7
50-yr	18.9	23.3	26.4	32.5	40.0	49.3	68.6	84.5	104.1
100-yr	20.8	25.7	29.0	35.7	44.0	54.2	75.5	93.0	114.5

Terms of Use

Moodie Yard LMSF

Ontario IDF CURVE LOOKUP

Active coordinate

45° 20' 15" N, 75° 50' 44" W (45.337500,-75.845833)

Retrieved: Wed, 13 Sep 2017 18:51:32 GMT

Location summary

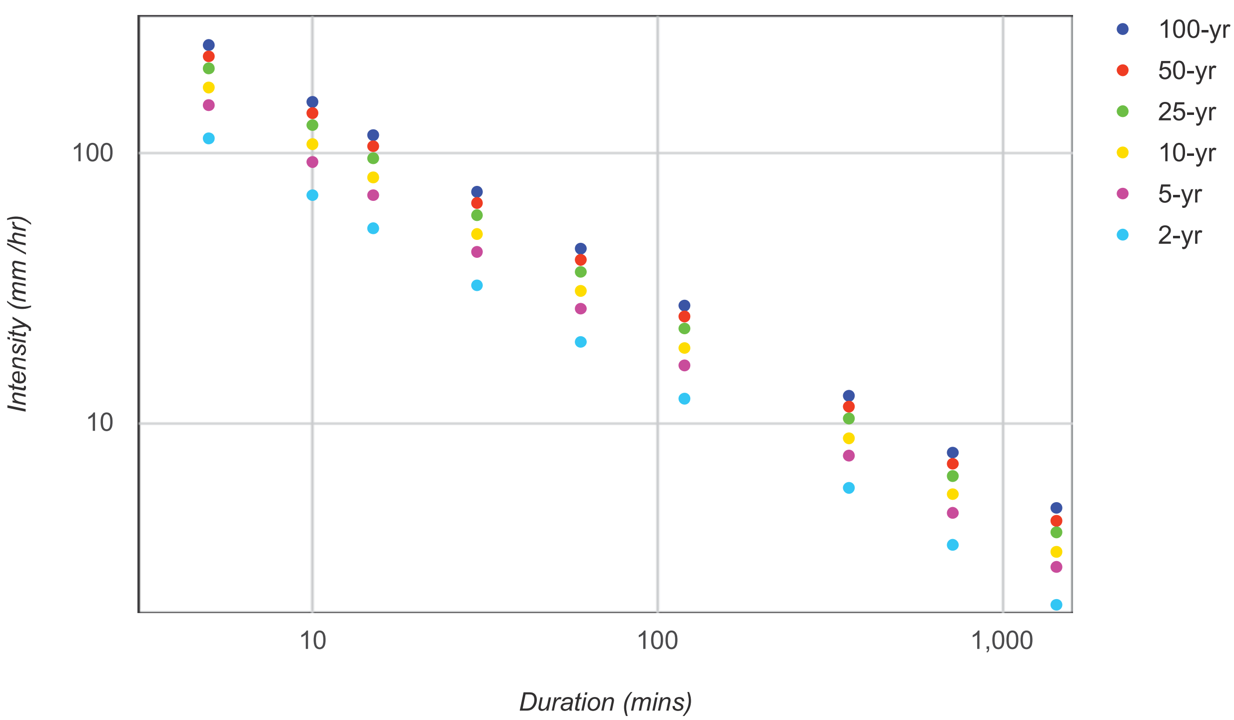
These are the locations in the selection.

IDF Curve: 45° 20' 15" N, 75° 50' 44" W (45.337500,-75.845833)

Results

An IDF curve was found.

Coordinate: 45.337500, -75.845833
IDF curve year: 2010



Coefficient summary

IDF Curve: 45° 20' 15" N, 75° 50' 44" W (45.337500,-75.845833)

Retrieved: Wed, 13 Sep 2017 18:51:32 GMT

Data year: 2010
IDF curve year: 2010

Return period	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
A	19.8	26.3	30.6	36.0	39.9	43.9
B	-0.699	-0.699	-0.699	-0.699	-0.699	-0.699

Statistics

Rainfall intensity (mm hr^{-1})

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	112.5	69.3	52.2	32.1	19.8	12.2	5.7	3.5	2.1
5-yr	149.4	92.0	69.3	42.7	26.3	16.2	7.5	4.6	2.9
10-yr	173.8	107.1	80.6	49.7	30.6	18.8	8.7	5.4	3.3
25-yr	204.5	126.0	94.9	58.4	36.0	22.2	10.3	6.3	3.9
50-yr	226.6	139.6	105.2	64.8	39.9	24.6	11.4	7.0	4.3
100-yr	249.4	153.6	115.7	71.3	43.9	27.0	12.5	7.7	4.8

Rainfall depth (mm)

Duration	5-min	10-min	15-min	30-min	1-hr	2-hr	6-hr	12-hr	24-hr
2-yr	9.4	11.5	13.0	16.1	19.8	24.4	34.0	41.8	51.5
5-yr	12.4	15.3	17.3	21.3	26.3	32.4	45.1	55.6	68.5
10-yr	14.5	17.8	20.2	24.8	30.6	37.7	52.5	64.6	79.6
25-yr	17.0	21.0	23.7	29.2	36.0	44.4	61.7	76.1	93.7
50-yr	18.9	23.3	26.3	32.4	39.9	49.2	68.4	84.3	103.9
100-yr	20.8	25.6	28.9	35.6	43.9	54.1	75.3	92.7	114.3

Terms of Use

APPENDIX C: WEST TRANSITWAY EXTENSION STORM SEWER CALCULATIONS

WEST TRANSITWAY EXTENSION

HOLLY ACRES ROAD TO MOODIE DRIVE

GRADING AND DRAINAGE XII
WEST TRANSITWAY EXTENSION

Contract No. ISD15-6002	Dwg. No. 041
Sheet 41 of XX	
Asset No.	
Asset Group	ISD
Des. MSB	Chk'd. PH
Dwn. MS/NL	Chk'd. PH
Utility Circ. No.	Index No.
Const. Inspector	

WAYNE NEWELL, P.ENG. General Manager, Infrastructure Services Department
JEFFREY WAARA, P.Eng. Project Manager, Design & Const. East
MMM GROUP
LICENSED PROFESSIONAL ENGINEER P. T. HILL PROVINCE OF ONTARIO

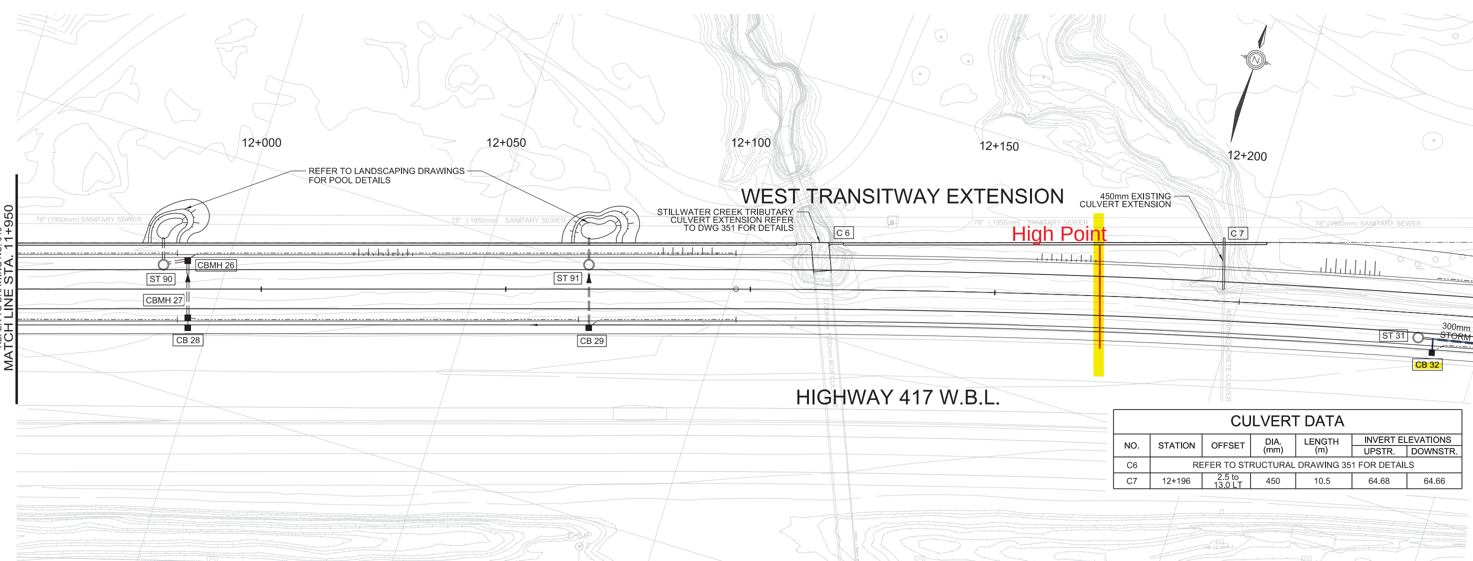
Scale: HORIZONTAL 0m 10 20; VERTICAL 0m 1 2

NOTE: The location of utilities is approximate only. The exact location should be determined by consulting the municipal authorities and utility companies concerned. The contractor shall prove the location of utilities and shall be responsible for adequate protection from damage.

REVISIONS

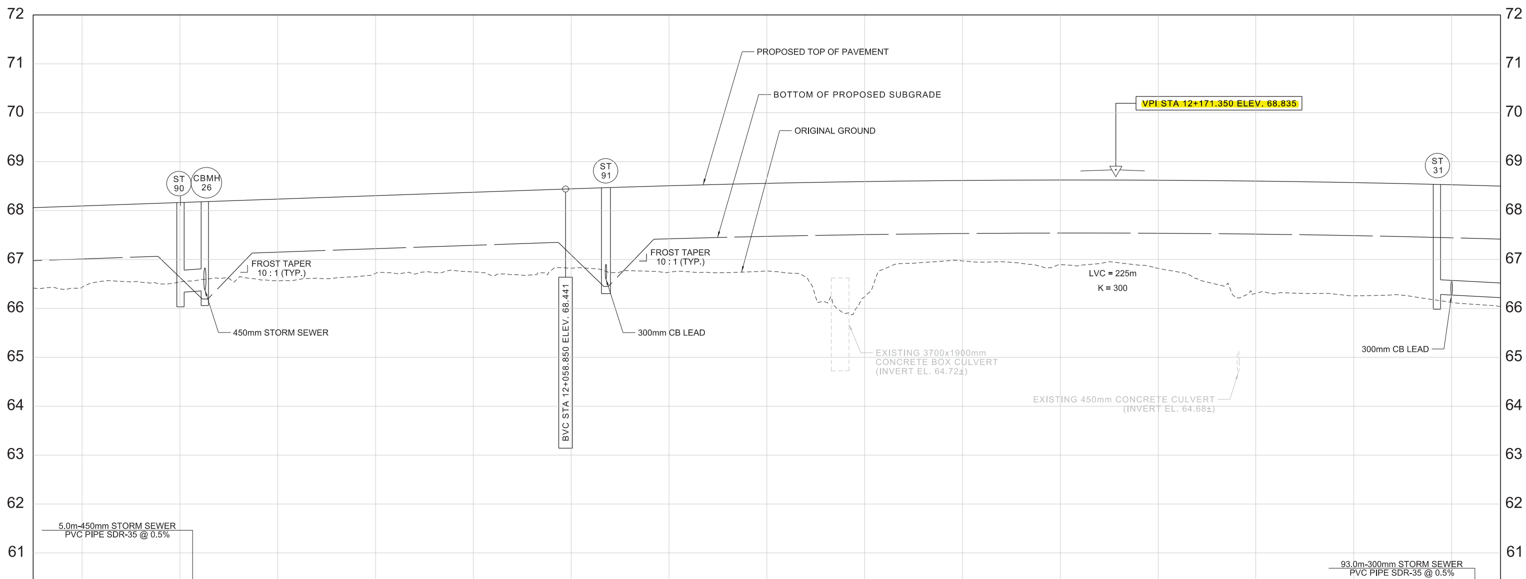
No.	Description	By	Date (dd/mm/yy)
1	ISSUED FOR TENDER	PH	16/10/15
2	ISSUED FOR CONSTRUCTION	PH	04/03/16

ISSUED FOR CONSTRUCTION



CULVERT DATA

NO.	STATION	OFFSET	DIA. (mm)	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
C6	REFER TO STRUCTURAL DRAWING 351 FOR DETAILS					
C7	12+196	2.5 to 13.0 LT	450	10.5	64.68	64.66



STATION	11+960	11+980	12+000	12+020	12+040	12+060	12+080	12+100	12+120	12+140	12+160	12+180	12+200	12+220	12+240
℄ PROFILE	68.095	68.165	68.235	68.305	68.375	68.445	68.508	68.557	68.593	68.615	68.625	68.620	68.603	68.572	68.528
STORM INVERT		E66.333 W66.358													E66.284

GENERAL NOTES:

1. REFER TO TYPICAL SECTIONS FOR PROPOSED SUBDRAIN LOCATIONS.
2. REFER TO DWG 058 FOR PROPOSED DITCH ELEVATIONS.

MAINTENANCE HOLE DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
ST 31	12+237.0	5.0 RT	S24.1*	701.01	68.384	66.284
ST 90	11+980.0	5.0 LT	S24.1*	STC1000**	68.026	66.333
ST 91	12+067.0	5.0 LT	S24.1*	STC750**	68.428	66.583

* SELF LEVELLING FRAME AND COVER
** REFER TO DRAWING 058 FOR DETAILS

CATCH BASIN DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
CBMH 26	11+985.0	6.5 LT	S28.1*	701.01	67.970	66.358
CBMH 27	11+985.0	6.5 RT	S28.1*	701.01	67.970	66.420
CB 28	11+985.0	7.3 RT	OPSD 400.020	705.01	67.840	66.655
CB 29	12+067.0	7.3 RT	OPSD 400.020	705.01	68.217	66.646
CB 32	12+240.0	7.3 RT	OPSD 400.020	705.01	68.352	66.281

OFFSETS ARE FROM CONTROL LINE TO FACE OF BARRIER FOR CATCH BASINS
* USE S25 AS FRAME

CATCH BASIN CONNECTION

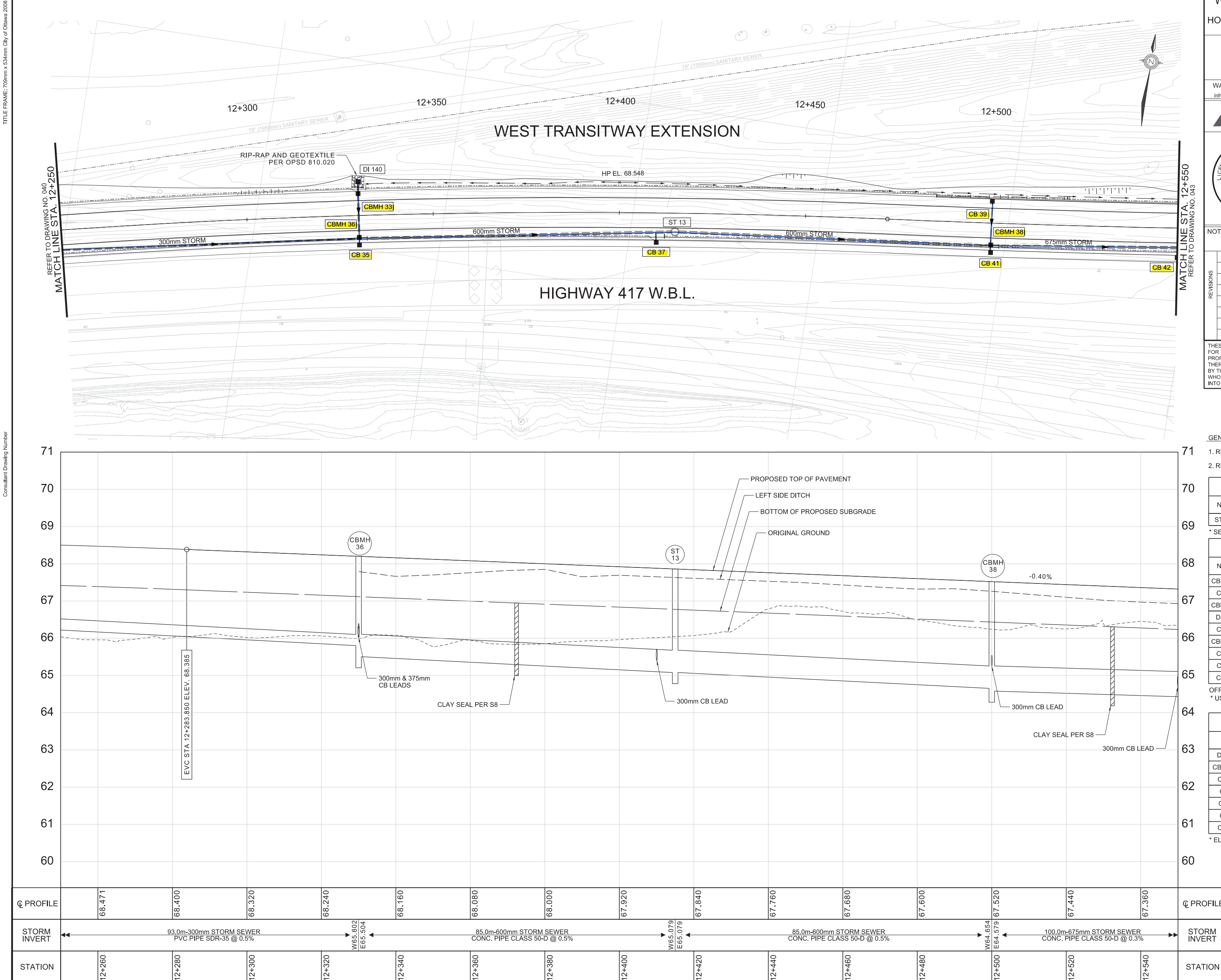
LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
CBMH 27 - CBMH 26	450	PVC SDR35	12.4	66.420	66.358
CB 28 - CBMH 27	300	PVC SDR35	1.4	66.655	66.645
CB 32 - SEWER	300	PVC SDR35	2.5	66.281	66.268*

* ELEVATION AT SPRINGLINE

STORM SEWER CONNECTION

LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
CB 29 - ST 91	300	PVC SDR35	12.6	66.646	66.583
ST 90 - OUTLET	450	PVC SDR35	3.75	66.333	66.314
ST 91 - OUTLET	300	PVC SDR35	5.5	66.583	66.555

Consultant Drawing Number



07/03/2016 3:06:06 PM Q:\M347499\CONTRACT PHASE II\M3474990 ISD15-6002-PPL.dgn ISD15-6002-042-PPL

WEST TRANSITWAY EXTENSION

HOLLY ACRES ROAD TO MOODIE DRIVE

Ottawa

Contract No. ISD15-6002	Dwg. No. 042
Sheet 42 of XX	
Asset No.	
Asset Group ISD	
Des. MSB	Chk'd. PH
Dwn. MS/NL	Chk'd. PH
Utility Circ. No.	Index No.
Const. Inspector	
Scale: HORIZONTAL 0m 10 20; VERTICAL 0m 1 2	

GRADING AND DRAINAGE XIII
WEST TRANSITWAY EXTENSION

WAYNE NEWELL, P.ENG. General Manager, Infrastructure Services Department

JEFFREY WAARA, P.Eng. Project Manager, Design & Const. East

MMM GROUP

LICENSED PROFESSIONAL ENGINEER P. T. HILL PROVINCE OF ONTARIO

NOTE: The location of utilities is approximate only. The exact location should be determined by consulting the municipal authorities and utility companies concerned. The contractor shall prove the location of utilities and shall be responsible for adequate protection from damage.

REVISIONS

No.	Description	By	Date (dd/mm/yy)
1	ISSUED FOR TENDER	PH	16/10/15
2	ISSUED FOR CONSTRUCTION	PH	04/03/16

THESE DESIGN DOCUMENTS ARE PREPARED SOLELY FOR THE USE BY THE PARTY WITH WHOM THE DESIGN PROFESSIONAL HAS ENTERED INTO A CONTRACT AND THERE ARE NO REPRESENTATIONS OF ANY KIND MADE BY THE DESIGN PROFESSIONAL TO ANY PARTY WITH WHOM THE DESIGN PROFESSIONAL HAS NOT ENTERED INTO A CONTRACT

ISSUED FOR CONSTRUCTION

GENERAL NOTES:

1. REFER TO TYPICAL SECTIONS FOR PROPOSED SUBDRAIN LOCATIONS.
2. REFER TO DWG 058 FOR PROPOSED DITCH ELEVATIONS.

MAINTENANCE HOLE DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
ST 13	12+415.0	5.0 RT	S24.1*	701.01	67.709	65.153

* SELF LEVELLING FRAME AND COVER

CATCH BASIN DATA

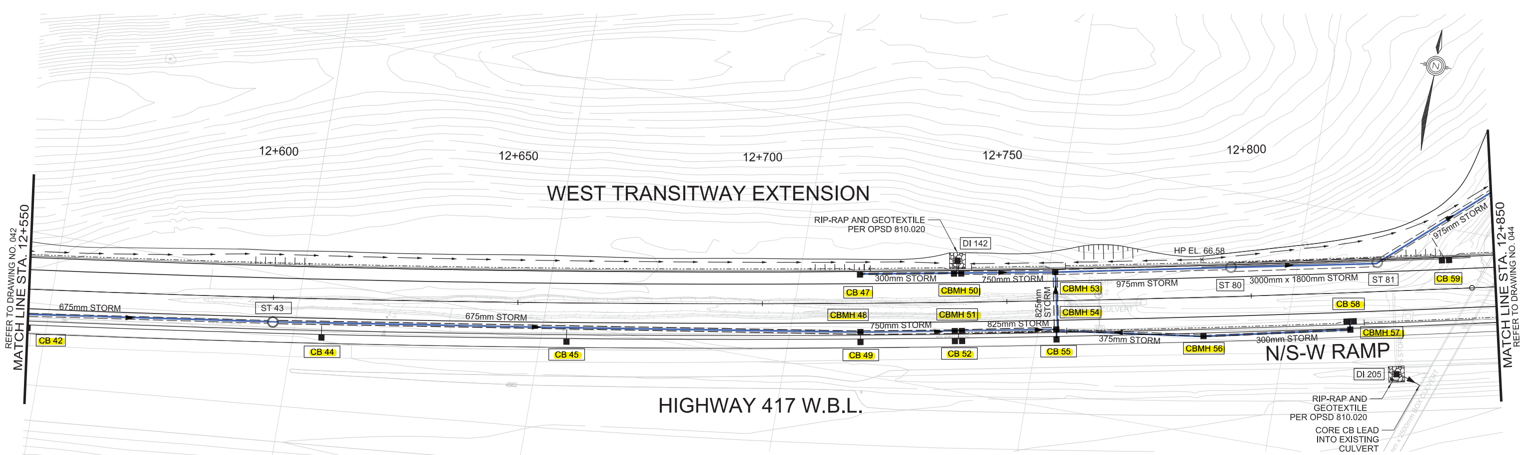
NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
CBMH 33	12+330.0	6.5 LT	S28.1*	701.01	68.217	65.791
CB 35	12+330.0	7.3 RT	OPSD 400.020	705.01	68.129	66.029
CBMH 36	12+330.0	6.5 RT	S28.1*	701.01	67.958	65.577
DI 140	12+330.0	8.5 LT	403.010 TYPE A	705.03 HOR.	67.600	65.879
CB 37	12+410.0	7.3 RT	OPSD 400.020	705.01	67.804	65.704
CBMH 38	12+500.0	5.5 RT	S28.1*	701.011	67.290	64.579
CB 39	12+500.0	6.5 LT	S19	705.01	67.426	65.426
CB 41	12+500.0	7.3 RT	OPSD 400.020	705.01	67.740	65.292
CB 42	12+550.0	7.3 RT	OPSD 400.020	705.01	67.543	65.443

OFFSETS ARE FROM CONTROL LINE TO FACE OF BARRIER FOR CATCH BASINS
* USE S25 AS FRAME

CATCH BASIN CONNECTION

LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
DI 140 - CBMH 33	300	PVC SDR35	2.5	65.879	65.866
CBMH 33 - CBMH 36	375	PVC SDR35	12.4	65.791	65.729
CB 35 - CBMH 36	300	PVC SDR35	1.4	66.029	66.022
CB 37 - SEWER	300	PVC SDR35	2.5	65.704	65.441*
CB 41 - CBMH38	300	PVC SDR35	1.4	65.292	65.250
CB 42 - SEWER	300	PVC SDR35	2.5	65.443	64.767*
CB 39 - CBMH 38	200	PVC SDR35	12.4	65.426	65.250

* ELEVATION AT SPRINGLINE



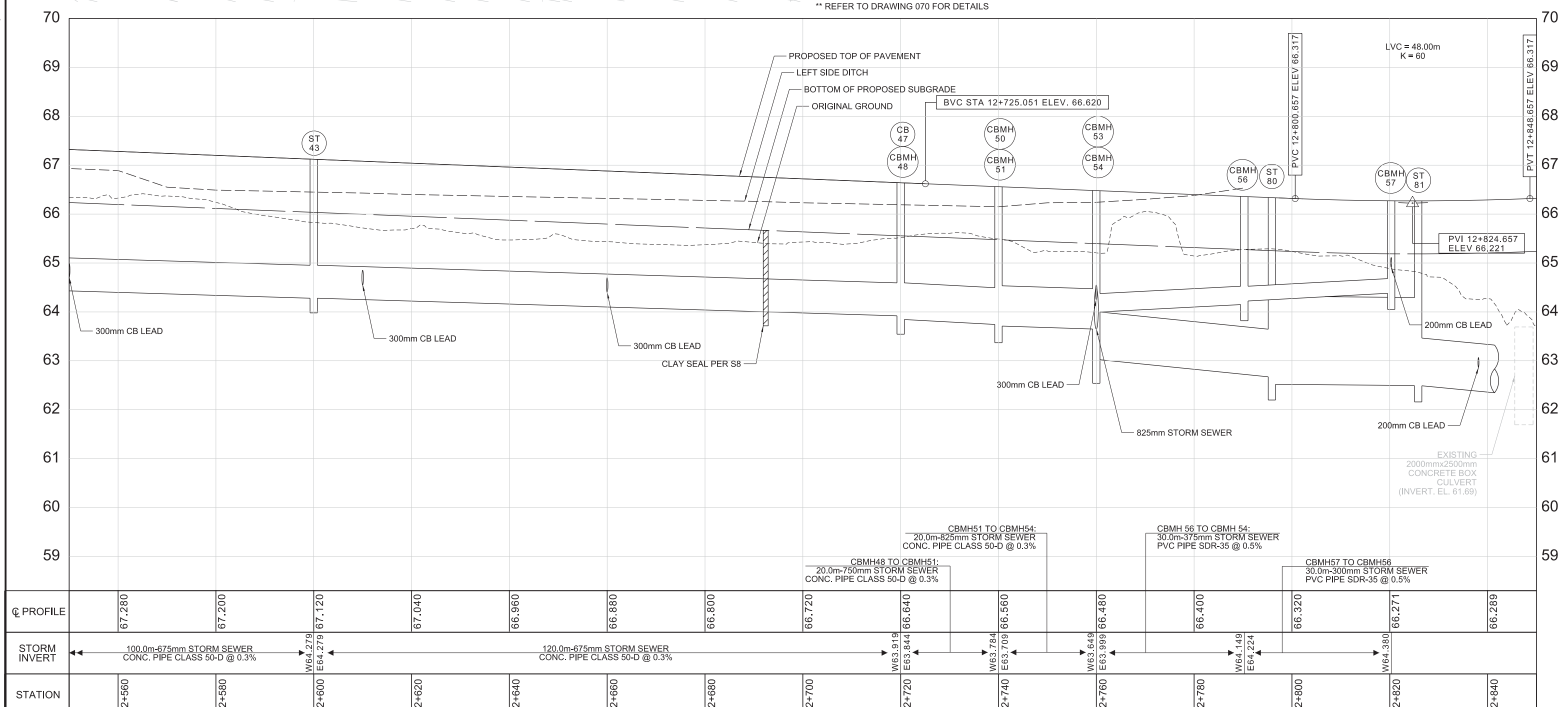
MAINTENANCE HOLE DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
ST 43	12+600.0	5.0 RT	S24.1*	701.011	66.980	64.279
ST 80	12+796.0	6.0 LT	2xS24.1*	2.4x3.8 BOX	66.136	62.520
ST 81	12+826.0	6.0 LT	2xS24.1*	2.4x3.8 BOX**	66.032	62.490

* SELF LEVELLING FRAME AND COVER
** REFER TO DRAWING 070 FOR DETAILS

STORM SEWER CONNECTION

LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
CBMH 53 - ST 80	975	CONCRETE	36.0	63.022	62.672
ST 80 - ST 81	3.0x1.8	CONCRETE	30.0	62.520	62.490
ST 81 - OUTLET	975	CONCRETE	35.8	62.490	62.383



WEST TRANSITWAY EXTENSION

HOLLY ACRES ROAD TO MOODIE DRIVE

Ottawa

Contract No.	Dwg. No.
ISD15-6002	043

Sheet 43 of XX

Asset No.

Asset Group ISD

GRADING AND DRAINAGE XIV
WEST TRANSITWAY EXTENSION

WAYNE NEWELL, P.ENG. General Manager, Infrastructure Services Department
JEFFREY WAARA, P.Eng. Project Manager, Design & Const. East

MMM GROUP

LICENSED PROFESSIONAL ENGINEER P. T. HILL PROVINCE OF ONTARIO

Des. MSB Chk'd. PH
Dwn. MS/NL Chk'd. PH
Utility Circ. No. Index No.
Const. Inspector
Scale: HORIZONTAL 0m 10 20; VERTICAL 0m 1 2

NOTE: The location of utilities is approximate only. The exact location should be determined by consulting the municipal authorities and utility companies concerned. The contractor shall prove the location of utilities and shall be responsible for adequate protection from damage.

REVISIONS

No.	Description	By	Date (dd/mm/yy)
1	ISSUED FOR TENDER	PH	16/10/15
2	ISSUED FOR CONSTRUCTION	PH	04/03/16

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ISSUED FOR CONSTRUCTION

GENERAL NOTES:

1. REFER TO TYPICAL SECTIONS FOR PROPOSED SUBDRAIN LOCATIONS.
2. REFER TO DWG 058 FOR PROPOSED DITCH ELEVATIONS.

CATCH BASIN DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
CB 42	12+550.0	7.3 RT	OPSD 400.020	705.010	67.543	65.443
CB 44	12+610.0	7.3 RT	OPSD 400.020	705.010	67.122	65.022
CB 45	12+660.0	7.3 RT	OPSD 400.020	705.010	66.909	64.809
CB 47	12+720.0	6.5 LT	S19	705.01	66.410	64.341
CBMH 48	12+720.0	6.5 RT	S28.1*	701.011	66.410	63.844
CB 49	12+720.0	7.3 RT	OPSD 400.020	705.010	66.656	64.556
CBMH 50	12+740.0	6.5 LT	S28.1 & S19	701.011**	66.330	63.787
CBMH 51	12+740.0	6.5 RT	S28.1 & S19	701.012**	66.330	63.709
CB 52	12+740.0	7.3RT	OPSD 400.020 X2	705.02	66.615	64.316
DI 142	12+740.0	8.00 LT	403.010 TYPE B	705.040 HOR.	66.150	64.247
CBMH 53	12+760.0	6.5 LT	S28.1*	701.013	66.250	63.462
CBMH 54	12+760.0	6.5 RT	S28.1*	701.012	66.250	63.649
CB 55	12+760.0	7.3 RT	OPSD 400.020	705.010	66.546	64.256
CBMH 56	12+790.0	7.3 RT	OPSD 400.020	701.010	66.324	64.149
CB 58	12+820.0	6.5 RT	2xS19	705.02	66.020	64.927
CBMH 57	12+820.0	7.3 RT	OPSD 400.020	701.01	66.190	64.380
CB 59	12+840.0	6.5 LT	2xS19	705.02	65.960	63.960
DI 205	16+000.5	7.4 RT	403.01 TYPE A 2H:1V	705.03	66.180	64.380

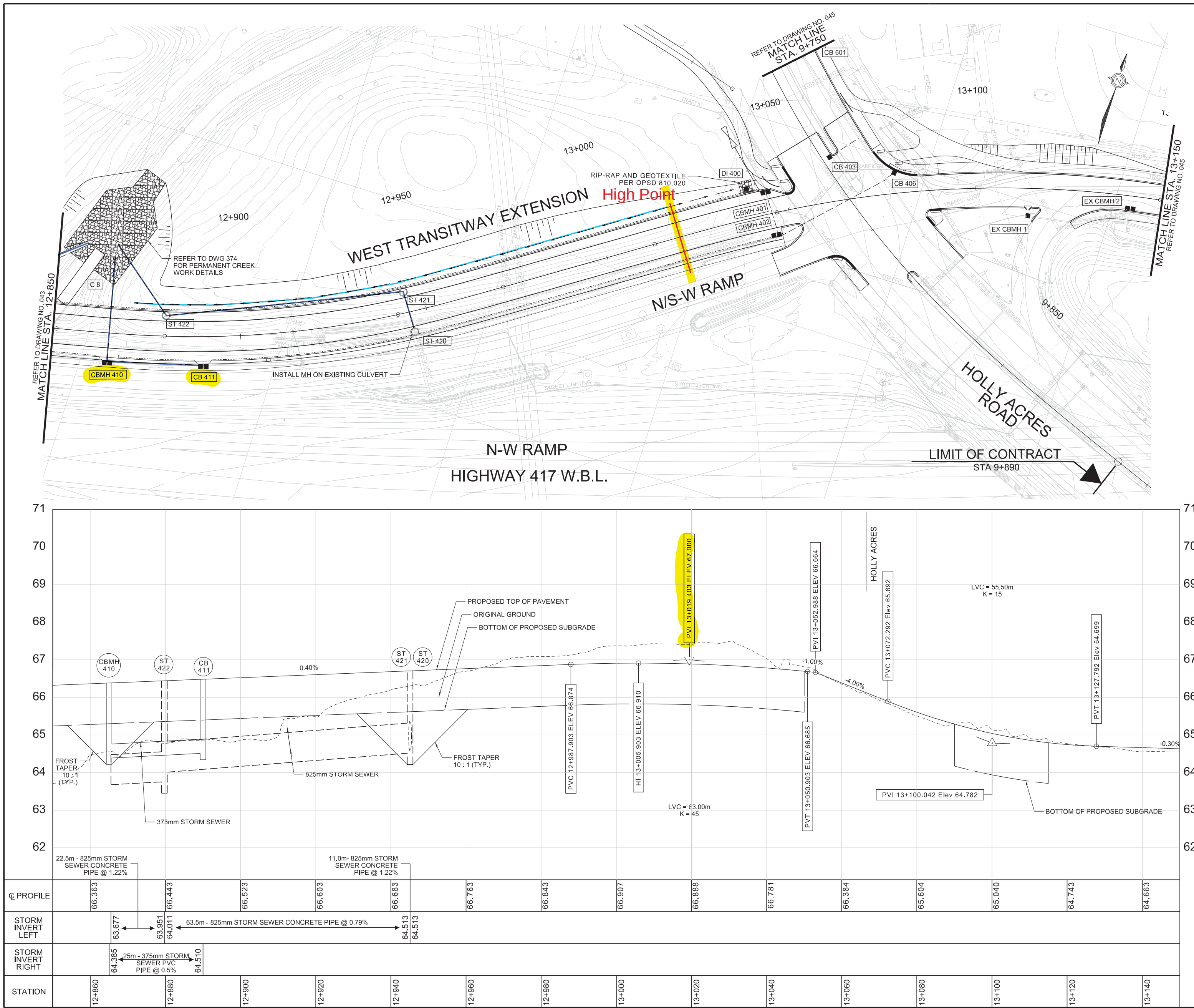
OFFSETS ARE FROM CONTROL LINE TO FACE OF BARRIER FOR CATCH BASINS
* USE S25 AS FRAME
** PRECAST CONCRETE TWIN INLET FLAT CAP PER OPSD 703.021 OR 703.022

CATCH BASIN CONNECTION

LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
CB 42 - SEWER	300	PVC SDR35	2.5	65.443	64.767*
CB 44 - SEWER	300	PVC SDR35	3.0	65.022	64.587*
CB 45 - SEWER	300	PVC SDR35	3.0	64.809	64.437*
CB 47 - CBMH 50	300	PVC SDR35	20.0	64.341	64.237
CBMH 50 - CBMH 53	750	CONCRETE	20.0	63.787	63.687
CB 49 - CBMH 48	300	PVC SDR35	1.4	64.556	64.549
CB 52 - CBMH 51	300	PVC SDR35	1.4	64.316	64.309
CB 55 - CBMH 54	300	PVC SDR35	1.4	64.256	64.249
CBMH 54 - CBMH 53	825	CONCRETE	12.4	63.649	63.612
CB 58 - CBMH 57	200	PVC SDR35	2.2	64.927	64.913
CB 59 - SEWER	200	PVC SDR35	6.6	63.960	62.942*
DI 142 - CBMH 50	300	PVC SDR35	2.0	64.247	64.237
DI 205 - CULVERT	300	PVC SDR35	7.0	64.380	63.750*

* ELEVATION AT SPRINGLINE

Consultant Drawing Number



Consultant Drawing Number

WEST TRANSITWAY EXTENSION

HOLLY ACRES ROAD TO MOODIE DRIVE

Ottawa

Contract No. ISD15-6002 | Dwg. No. 044

Sheet 44 of XX

Asset No.

GRADING AND DRAINAGE XV
WEST TRANSITWAY EXTENSION

WAYNE NEWELL, P.ENG.
General Manager
Infrastructure Services Department

JEFFREY WAARA, P.Eng.
Project Manager, Design & Const. East

MMM GROUP

Asset Group: ISD

Des. MSB | Chk'd. PH
Dwn. MS/NL | Chk'd. PH
Utility Circ. No. | Index No.
Const. Inspector
Scale: HORIZONTAL 0m 10 20; VERTICAL 0m 1 2

LICENSED PROFESSIONAL ENGINEER P. T. HILL PROVINCE OF ONTARIO

NOTE: The location of utilities is approximate only. The exact location should be determined by consulting the municipal authorities and utility companies concerned. The contractor shall prove the location of utilities and shall be responsible for adequate protection from damage.

REVISIONS

No.	Description	By	Date (dd/mm/yy)
1	ISSUED FOR TENDER	PH	16/10/15
2	ISSUED FOR CONSTRUCTION	PH	17/06/16
3	ISSUED FOR CONSTRUCTION	PH	09/12/15
4	RE-ISSUED FOR CONSTRUCTION	PH	12/04/17

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ISSUED FOR CONSTRUCTION

GENERAL NOTES:

1. REFER TO TYPICAL SECTIONS FOR PROPOSED SUBDRAIN LOCATIONS.
2. REFER TO DWG 058 FOR PROPOSED DITCH ELEVATIONS.

MAINTENANCE HOLE DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
ST 420	12+946	5.5 RT	S24.1	701.011	66.864	64.600
ST 421	12+945	5.5 LT	S24.1	701.012	66.434	64.513
ST422	12+880	5.5 LT	S24.1	701.012	66.161	63.951

CATCH BASIN DATA

NO.	STATION	OFFSET	COVER	STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
DI 400	13+040	8.5 LT*	403.010 TYPE A	705.030 HOR	66.410	64.790
CBMH 401	13+045	6.5 LT	S28.1 & S19	701.011**	66.740	64.640
CBMH 402	13+046	6.5RT	S28.1 & S19	701.011**	66.440	64.280
CB 403	9+777	2.5 LT	S19	705.010	66.259	64.259
CB 406	13+079	6.0 LT	S19	EXISTING	65.478	63.998*
CBMH 410	12+865	7.3 RT	S28.1 & S19	701.011**	66.010	64.325
CB 411	12+890	7.3 RT	2xS19	705.020	65.980	64.510

OFFSETS ARE FROM CONTROL LINE TO FACE OF BARRIER FOR CATCH BASINS
* PROPOSED LOW INVERTS TO MATCH INVERT OF EXISTING STRUCTURE
** PRECAST CONCRETE TWIN INLET FLAT CAP PER OPSD 703.021

CATCH BASIN CONNECTION

LOCATION	DIA. (mm)	TYPE	LENGTH (m)	INVERT ELEVATIONS UPSTR.	INVERT ELEVATIONS DOWNSTR.
CB 401 - CB 402	300	PVC SDR35	13.0	64.640	64.340
CB 402 - EX. PIPE	300	PVC SDR35	32.5	64.280	63.614*
DI 400 - CB 401	200	PVC SDR35	5.5	64.790	64.740
CB 403 - EX. PIPE	200	PVC SDR35	8.7	64.259	63.782*
CB 406 - EX. PIPE	200	PVC SDR35	2.4	64.248	63.618*
CBMH 410 - OUT	375	PVC SDR35	29.0	64.325	64.180
CB 411 - CBMH 410	375	PVC SDR35	25.0	64.510	64.385
ST 420 - ST 421	825	CONC.	11	64.600	64.513

* ELEVATION AT SPRINGLINE. CONTRACTOR TO VERIFY ELEVATIONS AND LOCATIONS.

EXISTING CATCH BASIN DATA

NO.	STATION	OFFSET	NEW COVER	EXISTING STRUCTURE	ELEVATION T/GRATE	ELEVATION LOW/INV.
EX CBMH 1	13+114	7.3 RT	S19.1*	701.011	64.710	N.A.
EX CBMH 2	13+142	4.0 RT	2xS19.1*	701.011	64.430	N.A.

OFFSETS ARE FROM CONTROL LINE TO FACE OF BARRIER FOR CATCH BASINS
* EXISTING CATCHBASIN COVERS TO BE CHANGED.

12/04/2017 5:10:42 PM Q:\M347499\CONTRACT PHASE II\M3474990 ISD15-6002-PPL.dgn

Client/Subject: City of Ottawa
Description: Ottawa Light Rail Transit
Prepared by: V. Tricome
Date: 6/13/2017

Print Date: 12 Sep 17 11:43 a
Project #: 4018023_0001

Ottawa

PRELIMINARY INLET SPACING DESIGN SHEET (RATIONAL METHOD)

100 Calculated

CB North Side	CB South Side	Road Chainaige	Drainage Area: Gutter Grade So (m/m)	Cross Slope Sx (m/m)	Average Area Width (m)	Runoff Coefficient x Area (Ha): 0.3	0.4	0.7	0.95	Runoff Coeff. C	Travel Time Ti (min)	Total Time Tt (min)	Time of Conc.	Rainfall Intensity I (mm/hr)	Flow: Lateral Spread T (m)	Gutter Flow Qg (m^3/sec)	Local Runoff Qr (m^3/sec)	Calc Spacing L (m)	Spacing Used Lm (m)	Runoff Used Qr (m^3/sec)	Actual Spread T (m)	Depth of Flow d (m)	Area of Flow A (m^2)	Velocity of Flow v (m/s)	Inlet Capacity Qi (m3/sec)	Carry over Qc (m3/sec)	Remarks
Moodie Transitway Extension																											
ST 421			0.0064	0.0600									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 59)
ST 422			0.0040	0.0600									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass from CB 59)
CB 59			0.0030	0.0200					0.272	0.95			5	242.7		0.175	0.189			0.189			0.00	0.00		0.189	Sumped Double Inlets (Bypass from ST 422 & ST 81)
ST 420			0.0033	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 58)
CB 58			0.0037	0.0200					0.107	0.95			5	242.7		0.069	0.103			0.103			0.00	0.00	0.043	0.060	Double Inlet Sumped (Bypass from ST 420 & CBMH 54)
CB 411			0.0030	**0.0200**					0.031	0.95			5	242.7		0.020	0.020			0.020	1.50	0.080	0.06	2.98	0.013	0.007	Double Inlet (Bypass to CBMH 410)
CBMH 410			Flat	**0.0200**					0.024	0.95			5	242.7		0.016	0.028			0.028			0.00	0.00	0.013	0.000	Double Inlet Sumped (Bypass from CB 411 & CBMH 57)
CBMH 33			0.0040	0.0200					0.045	0.95			5	242.7		0.029	0.029			0.029	1.80	0.085	0.08	2.66	0.025	0.004	(Bypass to CB 39)
CB 39			0.0070	0.0200					0.107	0.95			5	242.7		0.069	0.072			0.072	2.50	0.100	0.13	1.82	0.040	0.032	(Bypass to CB 47)
CB 47			0.0040	0.0200					0.142	0.95			5	242.7		0.091	0.124			0.124	3.00	0.110	0.17	1.81	0.042	0.082	(Bypass to CBMH 50)
CBMH 50			0.0040	0.0200					0.013	0.95			5	242.7		0.008	0.090			0.090	3.00	0.110	0.17	19.95	0.042	0.048	Double Inlet (Bypass to CBMH 53)
CBMH 53			0.0040	0.0200					0.013	0.95			5	242.7		0.008	0.056			0.056	3.00	0.110	0.17	19.80	0.042	0.014	(Bypass to ST 80)
ST 80			0.0040	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to ST 81)
ST 81			0.0030	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 59)
CB 59			0.0030	0.0200					0.272	0.95			5	242.7		0.175	0.189			0.189			0.00			0.189	Sumped Double Inlets (Bypass from ST 422 & ST 81)
ST 31			0.0014	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 36)
CBMH 36			0.0400	0.0200					0.180	0.95			5	242.7		0.115	0.115			0.115	3.00	0.110	0.17	1.43	0.042	0.073	(Bypass to CBMH 38)
ST 13			0.0040	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 38)
CBMH 38			0.0040	0.0200					0.059	0.95			5	242.7		0.038	0.038			0.038	3.00	0.110	0.17	4.37	0.042	*0.000*	(Bypass to CBMH 48)
ST 43			0.0040	0.0200									5	242.7		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 48)
CBMH 48			0.0040	0.0200					0.161	0.95			5	242.7		0.103	0.103			0.103			0.00	0.00		0.103	(Bypass to CBMH 51)
CBMH 51			0.0040	0.0200					0.015	0.95			5	242.7		0.009	0.112			0.112	3.00	0.110	0.17	17.75	0.044	0.068	Double Inlet (Bypass to CBMH 54)
CBMH 54			0.0040	0.0200					0.015	0.95			5	242.7		0.009	0.078			0.078	3.00	0.110	0.17	17.63	0.044	0.034	(Bypass to CB 58)
CB 58			0.0037	0.0200					0.089	0.95			5	242.7		0.057	0.091			0.091			0.00	0.00		0.091	Double Inlet Sumped (Bypass from ST 420 & CBMH 54)
CB 32			*0.0030*	**0.0200**					0.017	0.95			5	242.7		0.011	0.011			0.011	0.50	0.060	0.02	1.00	0.042	*0.000*	(Bypass to CB 35)
CB 35			*0.0030*	**0.0200**					0.025	0.95			5	242.7		0.016	0.016			0.016	1.00	0.060	0.03	1.00	0.010	0.006	(Bypass to CB 32)
CB 37			*0.0030*	**0.0200**					0.022	0.95			5	242.7		0.014	0.020			0.020	1.40	0.078	0.05	1.00	0.013	0.007	(Bypass to CB 41)
CB 41			*0.0050*	**0.0200**					0.022	0.95			5	242.7		0.014	0.021			0.021	1.30	0.070	0.11	1.00	0.013	0.008	(Bypass to CB 42)
CB 42			*0.0083*	**0.0200**					0.032	0.95			5	242.7		0.021	0.028			0.028	1.50	0.080	0.06	1.00	0.022	0.006	(Bypass to CB 44)
CB 44			*0.0033*	**0.0200**					0.041	0.95			5	242.7		0.026	0.033			0.033	2.00	0.090	0.11	0.00	0.025	0.008	(Bypass to CB 45)
CB 45			*0.0030*	**0.0200**					0.038	0.95			5	242.7		0.024	0.032			0.032	2.00	0.090	0.11	1.00	0.025	0.007	(Bypass to CB 49)
CB 49			0.0040	**0.0200**					0.047	0.95			5	242.7		0.030	0.037			0.037	2.10	0.092	0.11	1.00	0.027	0.010	(Bypass to CB 52)
CB 52			0.0030	0.0200					0.014	0.95			5	242.7		0.009	0.019			0.019	1.20	0.075	0.11	12.62	0.012	0.007	Double Inlet (Bypass to CB 55)
CB 55			0.0039	**0.0200**					0.012	0.95			5	242.7		0.008	0.015			0.015	1.00	0.070	0.11	14.18	0.010	0.005	(Bypass to CBMH 56)
CBMH 56			0.0047	**0.0200**					0.019	0.95			5	242.7		0.012	0.017			0.017	1.10	0.062	0.03	2.74	0.012	0.005	(Bypass to CBMH 57)
CBMH 57			0.0041	**0.0200**					0.021	0.95			5	242.7		0.013	0.018			0.018	1.20	0.070	0.04	3.17	0.013	0.005	(Bypass to CBMH-410)
CBMH 410			Flat	**0.0200**					0.024	0.95			5	242.7		0.016	0.028			0.028			0.00	0.00		0.000	Double Inlet Sumped (Bypass from CB 411 & CBMH 57)
DI 142						0.843	0.484			0.34			10	178.6		0.221	0.221			0.221			0.00	1.00		0.221	
DI 140									0.077	0.95			5	242.7		0.049	0.049			0.049			0.00	1.00		0.049	

Notes:

1) Install Inlet Control Device in Catch Basin - use approved Inlet Control Type A (Capacity = 20.0 liters/sec. @ 1.22 m head); note the ICD does not restrict ability to collect the 5 year storm runoff.

2) Install Inlet Control Device in Catch Basin - use approved Inlet Control Type B (Capacity = 28.4 liters/sec. @ 1.22 m head); note the ICD does not restrict ability to collect the 5 year storm runoff.

Designed: V. Tricome	PROJECT:			
Checked:	LOCATION:			
Dwg. Reference:	File Reference:	Date:	Sheet No.:	

Client/Subject: City of Ottawa
Description: Ottawa Light Rail Transit
Prepared by: V. Tricome
Date: 7/28/2017

Print Date: 12 Sep 17 11:44 a
Project #: 4018023_0001

PRELIMINARY INLET SPACING DESIGN SHEET (RATIONAL METHOD) **STRESS TEST**

100 + 20% Calculated

CB North Side	CB South Side	Road Chainage	Gutter Grade So (m/m)	Cross Slope Sx (m/m)	Average Area Width (m)	Drainage Area: Runoff Coefficient x Area (Ha) 0.3	0.4	0.7	0.95	Runoff Coeff. C	Travel Time Ti (min)	Total Time Tt (min)	Time of Conc.	Rainfall Intensity I (mm/hr)	Lateral Spread T (m)	Gutter Flow Qg (m^3/sec)	Local Runoff Qr (m^3/sec)	Calc Spacing L (m)	Spacing Used Lm (m)	Flow: Runoff Used Qr (m^3/sec)	Actual Spread T (m)	Depth of Flow d (m)	Area of Flow A (m^2)	Velocity of Flow v (m/s)	Inlet Capacity Qi (m3/sec)	Carry over Qc (m3/sec)	Remarks
Moodie Transitway Extension																											
ST 421			0.0064	0.0600									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 59)
ST 422			0.0040	0.0600									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass from CB 59)
CB 59			0.0030	0.0200					0.272	0.95			5	291.2		0.210	0.265			0.265		**0.178**	0.00	0.00		0.265	Sumped Double Inlets (Bypass from ST 422 & ST 81)
ST 420			0.0033	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 58)
CB 58			0.0037	0.0200					0.107	0.95			5	291.2		0.083	0.141			0.141		**0.117**	0.00	0.00	0.043	0.098	Double Inlet Sumped (Bypass from ST 420 & CBMH 54)
CB 411			0.0030	**0.0200**					0.031	0.95			5	291.2		0.024	0.024			0.024	1.50	0.060	0.05	1.86	0.013	0.011	Double Inlet (Bypass to CBMH 410)
CBMH 410			Flat	**0.0200**					0.024	0.95			5	291.2		0.019	0.073			0.073		**0.075**	0.00	0.00	0.013	0.000	Double Inlet Sumped (Bypass from CB 411 & CBMH 57)
CBMH 33			0.0040	0.0200					0.045	0.95			5	291.2		0.035	0.035			0.035	1.80	0.085	0.08	2.22	0.025	0.010	(Bypass to CB 39)
CB 39			0.0070	0.0200					0.107	0.95			5	291.2		0.082	0.092			0.092	3.00	0.110	0.17	2.00	0.040	0.052	(Bypass to CB 47)
CB 47			0.0040	0.0200					0.142	0.95			5	291.2		0.109	0.161			0.161	3.00	0.110	0.17	1.51	0.042	0.119	(Bypass to CBMH 50)
CBMH 50			0.0040	0.0200					0.013	0.95			5	291.2		0.010	0.129			0.129	3.00	0.110	0.17	16.63	0.042	0.087	Double Inlet (Bypass to CBMH 53)
CBMH 53			0.0040	0.0200					0.013	0.95			5	291.2		0.010	0.097			0.097	3.00	0.110	0.17	16.50	0.042	0.055	(Bypass to ST 80)
ST 80			0.0040	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to ST 81)
ST 81			0.0030	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CB 59)
CB 59			0.0030	0.0200					0.272	0.95			5	291.2		0.210	0.265			0.265			0.00			0.265	Sumped Double Inlets (Bypass from ST 422 & ST 81)
ST 31			0.0014	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 36)
CBMH 36			0.0400	0.0200					0.180	0.95			5	291.2		0.138	0.138			0.138	3.00	0.110	0.17	1.19	0.042	0.096	(Bypass to CBMH 38)
ST 13			0.0040	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 38)
CBMH 38			0.0040	0.0200					0.059	0.95			5	291.2		0.045	0.045			0.045	3.00	0.110	0.17	3.64	0.042	*0.000*	(Bypass to CBMH 48)
ST 43			0.0040	0.0200									5	291.2		0.000	0.000			0.000			0.00			0.000	(Bypass to CBMH 48)
CBMH 48			0.0040	0.0200					0.161	0.95			5	291.2		0.124	0.124			0.124			0.00	0.00		0.124	(Bypass to CBMH 51)
CBMH 51			0.0040	0.0200					0.015	0.95			5	291.2		0.011	0.135			0.135	3.00	0.110	0.17	14.79	0.044	0.091	Double Inlet (Bypass to CBMH 54)
CBMH 54			0.0040	0.0200					0.015	0.95			5	291.2		0.011	0.102			0.102	3.00	0.110	0.17	14.69	0.044	0.058	(Bypass to CB 58)
CB 58			0.0037	0.0200					0.089	0.95			5	291.2		0.068	0.127			0.127			0.00	0.00		0.127	Double Inlet Sumped (Bypass from ST 420 & CBMH 54)
CB 32			*0.0030*	**0.0200**					0.017	0.95			5	291.2		0.013	0.013			0.013	0.90	0.070	0.03	1.00	0.042	*0.000*	(Bypass to CB 35)
CB 35			*0.0030*	**0.0200**					0.025	0.95			5	291.2		0.019	0.019			0.019	1.20	0.075	0.05	1.00	0.010	0.009	(Bypass to CB 32)
CB 37			*0.0030*	**0.0200**					0.022	0.95			5	291.2		0.017	0.026			0.026	1.50	0.078	0.06	1.00	0.013	0.013	(Bypass to CB 41)
CB 41			*0.0050*	**0.0200**					0.022	0.95			5	291.2		0.017	0.029			0.029	1.30	0.080	0.11	1.00	0.013	0.016	(Bypass to CB 42)
CB 42			*0.0083*	**0.0200**					0.032	0.95			5	291.2		0.025	0.041			0.041	2.00	0.090	0.09	1.00	0.022	0.019	(Bypass to CB 44)
CB 44			*0.0033*	**0.0200**					0.041	0.95			5	291.2		0.032	0.051			0.051	2.10	0.092	0.11	0.00	0.025	0.026	(Bypass to CB 45)
CB 45			*0.0030*	**0.0200**					0.038	0.95			5	291.2		0.029	0.055			0.055	2.60	0.100	0.11	1.00	0.025	0.030	(Bypass to CB 49)
CB 49			0.0040	**0.0200**					0.047	0.95			5	291.2		0.036	0.066			0.066	2.70	0.105	0.11	1.00	0.027	0.039	(Bypass to CB 52)
CB 52			0.0030	0.0200					0.014	0.95			5	291.2		0.010	0.050			0.050	2.50	0.100	0.11	10.52	0.012	0.038	Double Inlet (Bypass to CB 55)
CB 55			0.0039	**0.0200**					0.012	0.95			5	291.2		0.009	0.047			0.047	2.50	0.100	0.11	11.82	0.010	0.037	(Bypass to CBMH 56)
CBMH 56			0.0047	**0.0200**					0.019	0.95			5	291.2		0.015	0.052			0.052	2.50	0.100	0.13	8.38	0.012	0.040	(Bypass to CBMH 57)
CBMH 57			0.0041	**0.0200**					0.021	0.95			5	291.2		0.016	0.056			0.056	2.60	0.100	0.13	8.16	0.013	0.043	(Bypass to CBMH-410)
CBMH 410			Flat	**0.0200**					0.024	0.95			5	291.2		0.019	0.073			0.073			0.00	0.00		0.000	Double Inlet Sumped (Bypass from CB 411 & CBMH 57)
DI 142						0.843	0.484			0.34			10	214.3		0.266	0.266			0.266			0.00	1.00		0.266	
DI 140									0.077	0.95			5	291.2		0.059	0.059			0.059			0.00	1.00		0.059	

Notes:

1) Install Inlet Control Device in Catch Basin - use approved Inlet Control Type A (Capacity = 20.0 liters/sec. @ 1.22 m head); note the ICD does not restrict ability to collect the 5 year storm runoff.

2) Install Inlet Control Device in Catch Basin - use approved Inlet Control Type B (Capacity = 28.4 liters/sec. @ 1.22 m head); note the ICD does not restrict ability to collect the 5 year storm runoff.

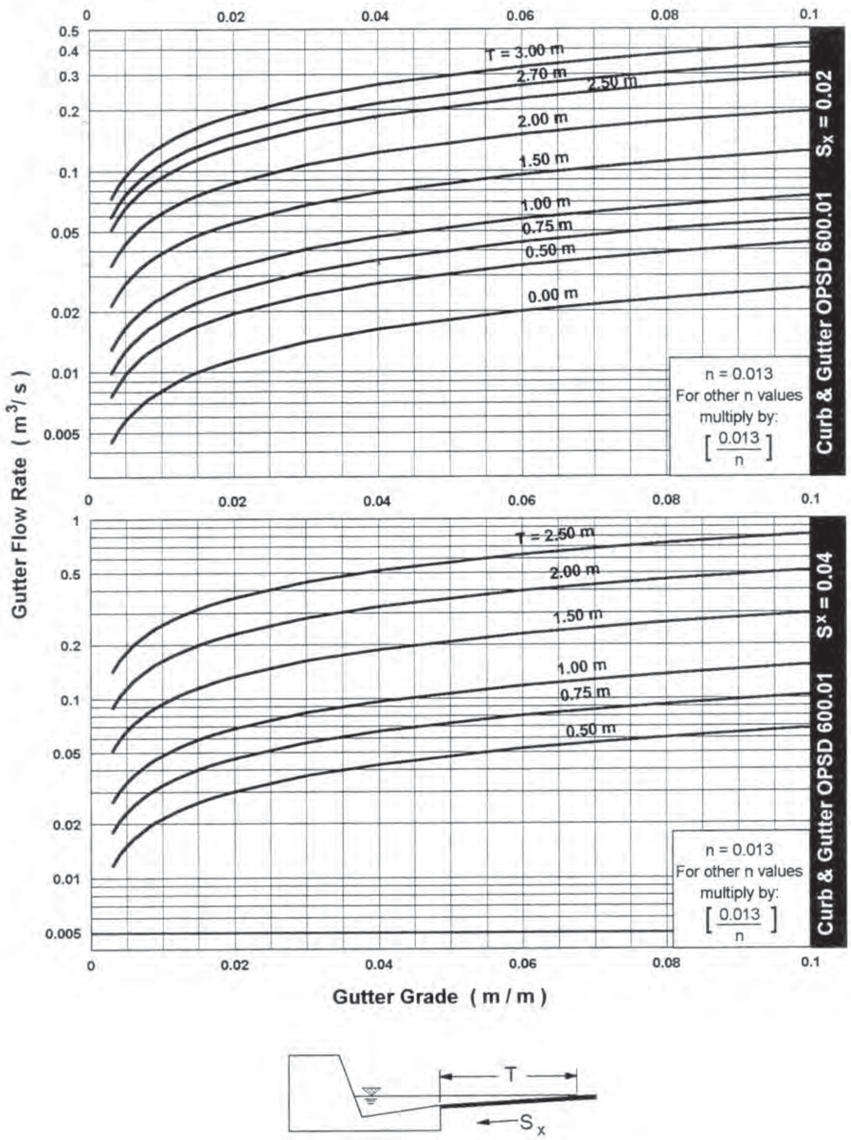
Designed: V. Tricome	PROJECT:			
Checked:	LOCATION:			
Dwg. Reference:	File Reference:	Date:	Sheet No.:	

\\stvgroup.stvinc.com\v3\DGPA\Vol3\Projects\4018023\4018023_0001\60_Discipline Info\Moodie PE - Design\Drainage Calculations\[CLW_Moodie Extension Storm Sewer_Calculation Sheet.xls]Stress Test Design Ottawa

Gutter Flow Rates – Barrier Curb with Gutter[1]

MTO Drainage Management Manual

Design Chart 4.04: Gutter Flow Rate - Curb & Gutter OPSD 600.01

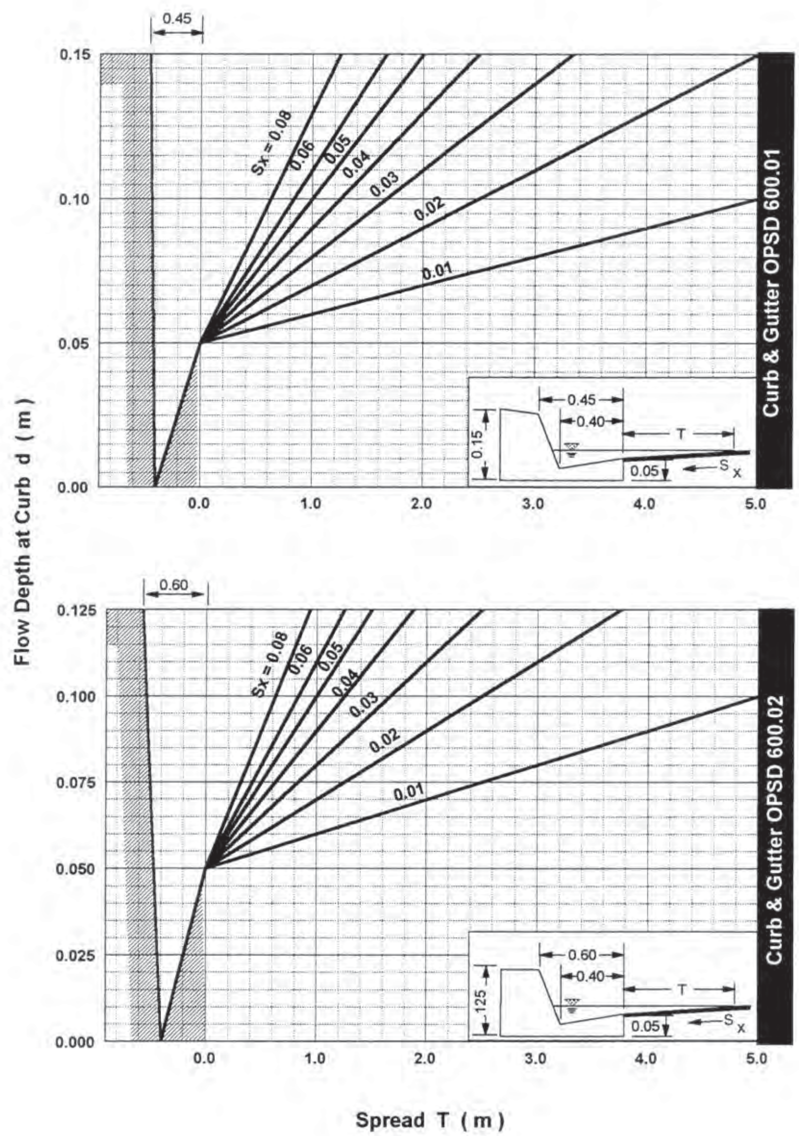


88

[1] From the *MTO Drainage Management Manual*

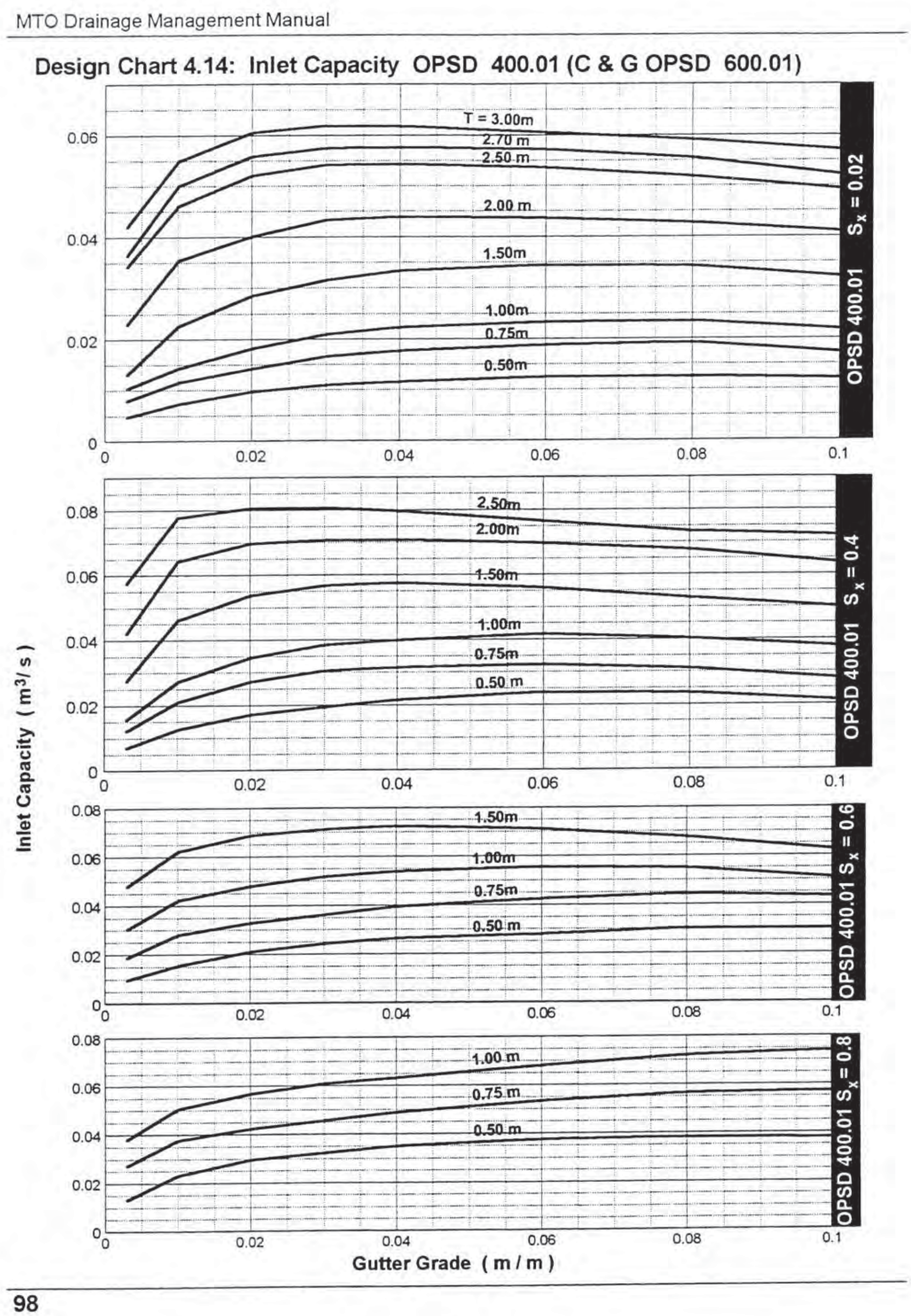
Curb and Gutter Flow Depth – Barrier and Mountable Curbs[5]

Design Chart 4.12: Curb & Gutter Flow Depth - OPSD 600.01, 600.02



[5] From the *MTO Drainage Management Manual*

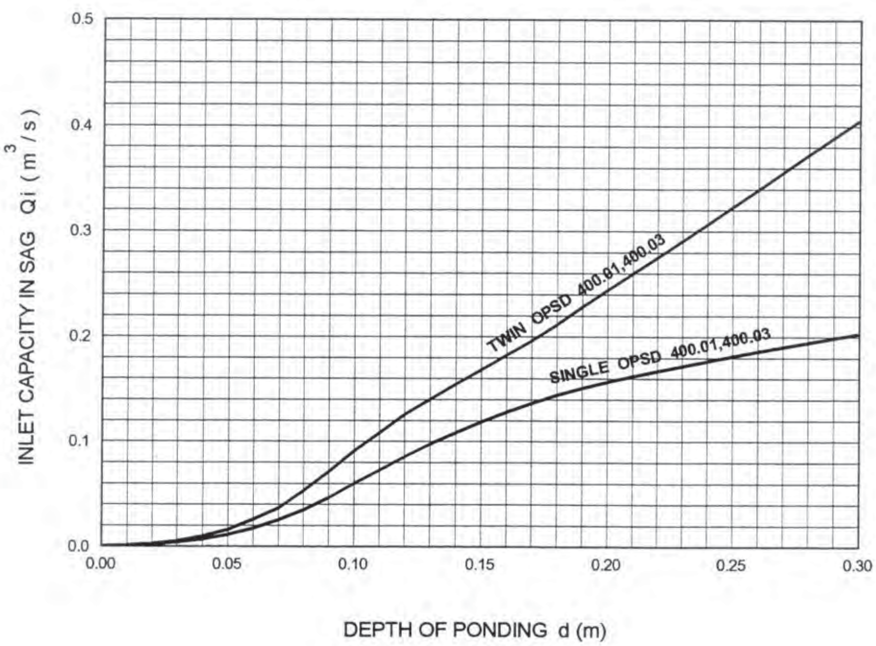
Surface Inlet Capacity Curves for Barrier Curb[6]



[6] From the *MTO Drainage Management Manual*

Surface Inlet Capacity At Road Sags[8]

Design Chart 4.19: Inlet Capacity at Road Sag



[8] From the *MTO Drainage Management Manual*

APPENDIX D: WEST TRANSITWAY EXTENSION FROM BAYSHORE STATION TO MOODIE DRIVE BY MCCORMICK RANKIN CORPORATION, DATED APRIL 2013

West Transitway Extension

From Bayshore Station to Moodie Drive

Detail Design

DRAINAGE AND STORMWATER MANAGEMENT REPORT

FINAL REPORT

A member of MMM GROUP

McCormick Rankin
April 2013

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1.0 INTRODUCTION

1.1 Project Description

The City of Ottawa (City) proposes to extend the West Transitway from Bayshore Station westerly for 3.5 km to Moodie Drive on the north side of Highway 417. The study area is shown in Exhibit 1. The area surrounding the proposed route consists of flat terrain with rocky outcrops and several watercourses. Existing nearby highway drainage is achieved through some ditches and transverse culverts and sheets naturally northward towards the receiving watercourses. The project involves portions of Ontario Ministry of Transportation (MTO) lands as well as National Capital Commission (NCC) lands and crosses two major watercourses at Stillwater Creek and Graham Creek.

1.2 Study Purpose

The following are the drainage study objectives for this study:

- Identify the required modifications to existing drainage infrastructure along the existing highway which will be impacted following the extension of the Transitway; and
- Identify drainage requirements and controls to accommodate the proposed Transitway.

These objectives were achieved through:

- Determination of culvert and sewer design flows;
- Hydraulic analysis to assess existing culvert capacities and to size proposed culverts and sewers using current design standards;
- Recommendations for existing and proposed drainage structures and storm water management facilities; and
- Creek realignment/modification as required.

DRAWING NAME: I:\KITCHENER\MRC\DRAWINGS\7400-7599\7499 - WEST TRANSITWAY EXTENSION\REPORT EXHIBITS\7499 STUDAY AREA.DWG

MODIFIED: Jun. 30, 2011 1:15 PM

McCORMICK RANKIN CORPORATION
A member of MMM GROUP

STUDY AREA

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT 1

1.3 Objectives

The proposed Transitway will meet all City standards for that road classification. However, the proposed Transitway is to be designed adjacent to a freeway and must also ensure that any drainage impacts meet the appropriate highway design standards. The drainage and stormwater management strategy implemented in conjunction with any proposed road project must:

i) Provide an effective/efficient drainage system;
ii) Minimize risk to public safety;
iii) Maintain flow paths for lands upstream of the proposed works;
iv) Protect or enhance aquatic habitat, where required;
v) Provide water quality treatment to minimize adverse stormwater quality and quantity impacts to receiving watercourses;
vi) Maintain or reduce existing erosion potential in receiving drainage features;
vii) Minimize flood risk for lands in the Transitway right-of-way as well as for lands upstream and downstream of the proposed works;
viii) Integrate with existing roadway surface water conveyance works located outside of the proposed Transitway improvements; and
ix) Minimize future maintenance requirements;

Existing guidelines and policies provide a framework for the assessment of drainage in the study area, including:

1. *City of Ottawa Sewer Design Guidelines* (2012);
2. *MTO Drainage Management Manuals* (1997);
3. *MTO Highway Drainage Design Standards* (2008);
4. Ministry of the Environment *Stormwater Management Planning and Design Manual* (2003); and

1.4 Drainage Standards

In general, there are three factors which need to be considered for stormwater management (SWM) and criteria should be identified in order to address the potential impacts of:

- Flooding;
- Erosion; and
- Water quality.

At the onset of this project, it was determined that the approval authorities (City, MOE, RVCA, and NCC) did not have any specific SWM criteria for the nearby watercourses or this project site. Therefore, it was necessary to develop reasonable SWM criteria to apply to the project.

Flooding: Stillwater Creek conveys flow through this area and the RVCA has confirmed there is no existing floodplain mapping for the creek. For this part of the province, the regulatory floodplain is defined by the 1:100 year flood. The RVCA requires no increase to floodwater elevations, either upstream or downstream, as a result of the proposed works. With respect to this criterion, the time to peak of the upstream drainage basin (approximately 2200 ha) is over 9 hours for the 12 hour SCS design storm. Therefore the overall maximum peak flow in Stillwater Creek will be produced from this large upstream drainage basin. Since the overall peak flow in the creek and the travel time through the reach is governed by the larger upstream drainage basin, the overall peak water level in Stillwater Creek will not change with the construction of the West Transitway Extension. This analysis is described in greater detail in the West Transitway Extension Stillwater Creek Flood Plain Assessment (MRC, January, 2011) found in Appendix A.

Erosion: It was identified early in the design process that a special criterion would need to be developed for new proposed outlets discharging directly to Stillwater Creek as it has been identified as an erosion sensitive watercourse. JTB Environmental Systems Inc. completed a study to determine appropriate erosion threshold analysis for stormwater discharge to Stillwater Creek as a means of defining an erosion criterion. The conclusion and recommendation of the report is that release of stormwater to Stillwater Creek should be at a velocity of less than 0.225m/s. The results of the JTB Environmental Systems Inc. report were discussed at a meeting in mid-January 2011 with representatives of the RVCA, the NCC and the City and it was decided to explore SWM options to implement the recommendations of the report. Thus, controlling and limiting the velocity of stormwater discharge will be one of the SWM criteria used in the design of the storm water system discharging directly to Stillwater Creek for the West Transitway extension. A full copy of the JTB report can be found in Appendix A.

For drainage to existing swales and ditches upstream of their receiving watercourse as well as Graham Creek, increased erosion potential is already addressed as the vegetation has taken a strong hold and velocities are generally low and, in the case of Graham Creek, is already well-armoured. As such, it is proposed in those areas to limit post-development peak flows to pre-development levels so as not to cause any detrimental impacts.

Water Quality: Given the fisheries sensitivity of both Stillwater Creek and Graham Creek, the RVCA recommended providing an enhanced level of treatment (80% TSS removal) for all new paved area for this project.

In summary, the criteria to be followed for this project include:

- Meeting a maximum outlet velocity of 0.225m/s for all new outlets discharging directly to Stillwater Creek;
- Limiting post-development flows to pre-development flows for all other outlets, including Graham Creek; and
- Providing an enhanced level of treatment (80% TSS removal).

2.0 EXISTING DRAINAGE CONDITIONS

The drainage catchments of the watercourses (Stillwater Creek and Graham Creek) within the study area are comprised of predominantly natural headland areas combined with highly urban downstream watershed areas. For the smaller local crossings, the catchment areas are largely composed of highway ROW. The slopes in the area are relatively flat, ranging from 0-5% and the majority of the soils in the study area are Rideau clay with some shallow bedrock. Throughout the study limits, the roadside vegetation located within and immediately adjacent to the Transitway ROW is mostly long grasses and bushes.

Runoff from the existing Highway 417 generally sheet drains to the north to ditches or swales, sometimes intermittent, which convey drainage to overland flow path locations which direct runoff to the nearby watercourses. There is an existing MTO pond located in the eastern portion of the Moodie Drive interchange which accepts drainage from approximately 14 ha of nearby lands, including 9 ha of MTO ROW, and ultimately discharges to Stillwater Creek via a constructed wet swale.

2.1 Study Data

The background information reviewed for this study includes:

- Engineering & Title Records;
- Detailed drainage survey information with 0.2m contour intervals for lands along the Transitway ROW;
- 2m contour interval mapping for the remainder of the study area;
- 1:10,000 Ontario Base Maps (OBM) for the study area;
- Aerial photographs;
- Municipal drainage plans; and
- Information obtained from the site reviews.

2.2 Hydrologic Modelling

Hydrologic modelling used to assess the floodplain impact on Stillwater Creek was developed in the 1988 Hydrology and Hydraulics Report prepared by Totten Sims Hubicki Associates (TSH). This report delineated the catchment area and provided flows based on rainfall depths measured, at the time, at the Ottawa CDA gauge site. While the detailed hydrologic modelling routine was not presented in the report, it does contain the

OTTHYMO basin parameters used to calculate the various return period flows. Based on these parameters and using more up to date hydrologic data, a SWMHYMO model was assembled. SWMHYMO is an event-based model widely used to determine runoff characteristics for rural and urban watersheds. The intensity-duration-frequency parameters from the Ottawa CDA site were used to estimate rainfall depths for various return period events for input to the model. The detailed flood analysis is presented in the Stillwater Creek Floodplain Assessment (January, 2011) which is included in Appendix B.

For other smaller catchment areas, such as those to storm sewers, micro-pool/filter strips, swales, and minor culverts, the Rational Method was used to determine stormwater runoff rates.

3.0 PROPOSED CONDITIONS

This section addresses the drainage requirements to accommodate the proposed Transitway extension. It contains the hydrologic and hydraulic assessment results which address the two main design criteria.

3.1 Proposed Transitway Extension

The proposed Transitway road extension occurs almost exclusively within the MTO ROW and includes the following:

- Construction of one westbound and one eastbound lane adjacent to the existing highway with the provision for conversion to rail in the future;
- Construction of several bridge structures;
- Construction of a Transit Station on the east of Corkstown Road ;
- Extension of the MTO culverts in the study area; and
- Fluvial improvements at the confluence between Stillwater Creek and its main tributary east of Moodie Drive.

3.2 Proposed Alternatives

The construction of the Transitway requires the entire width of the MTO ROW lands. Therefore, there are few SWM alternatives that can address the required SWM control within the ROW lands alone. Several alternatives were developed for the proposed drainage design and are described below. These options were then evaluated to determine the options to be carried forward as described in Section 3.3.

Alternative A (Underground Storage): Underground storage options in combination with stormwater interceptors were examined in order to meet the water quality and erosion criteria. The interceptors would provide primary treatment and the detention time in the storage units would provide secondary treatment to meet the enhanced level of treatment and a specialized vortex inducing outlet structure would be used at the downstream end of each facility to reduce flows to gain an acceptable outlet velocity to meet the erosion criterion.

Alternative B (divert to MTO median): This option involves diverting the Transitway drainage south to the median of Highway 417 where this area could be used to detain stormwater before discharging into the MTO culverts via the existing ditch inlets and catchbasins. This option mixes the City and MTO drainage systems and makes coordination of maintenance a potential challenge, but is inexpensive and uses potentially existing available space which has not been earmarked for future development.

Alternative C (MTO Pond): This option involves diverting Transitway drainage to the existing MTO pond in the Moodie Drive interchange. While the pond is close to its design capacity, it could potentially be modified (either by widening or deepening) to provide the extra volume required to store and treat the Transitway stormwater. The outlet structure would also need to be adapted in order to meet the Transitway SWM criteria.

Alternative D (diversion to pump station): In order to reduce land use, diverting drainage westerly to a location where more City land was available for storage was examined. This option would involve using storm sewers to convey stormwater runoff from Station 12+160 westerly to a pumping station in the Moodie Drive interchange and then pumping the stormwater northerly to the stilling basin location which could then be expanded into a wet pond facility.

Alternative E (diversion to Graham Tributary): Drainage could be diverted easterly to the Graham Creek Tributary where a pond could be constructed on City lands north of the Transitway near the existing sanitary pumping station. This option allows for SWM to be carried out at a single location using land that has not been earmarked for any development. There are concerns, however, that proximity to the sanitary pumping station and may have an impact on effluent quality depending on the depth of the pond required.

Alternative F (diversion down Corkstown Road): This option involves diverting the Transitway drainage westerly towards the Moodie Drive interchange, similarly to Alternative D. Rather than divert the drainage to a pump station, it would be carried by gravity easterly down Corkstown Road to the existing culvert crossing of Stillwater Creek at Creekwood Cres. This diversion pipe would be located under the newly retrofitted crossing of Stillwater Creek just north of the proposed station and would be placed at minimum slope to meet the grade requirements at the proposed outlet. A stormwater interceptor would be installed to provide quality control and meeting the erosion criterion would not be necessary as the outlet would be located in a more stable reach of the creek.

Alternative G (Micro-pool/Filter Strips): This option involves duplicating as much as possible the existing sheet drainage condition from the highway by installing a greater number of new storm sewer outlets on the north side of the Transitway and placing micro-pools at the downstream end. The runoff would then be conveyed across a filter strip to main branch of Stillwater Creek or a tributary of Stillwater Creek. The micro-pools/filter strips will provide treatment and will cause flows to spread out downstream to promote sheet flow which will slow velocities and promote settling and filtering of suspended solids.

Alternative H (Ponds on NCC lands): This option involves the construction of ponds at the downstream end of the MTO culverts under the Highway a directing the runoff from the Transitway to these culverts. This option places these potential facilities, by necessity, on NCC land. These ponds could be wet or dry ponds and could be amalgamated into a single pond location. They can provide all quantity, quality, and erosion control at a single location which is easier in terms of maintenance and overall SWM control. They are a cost effective and proven SWM solution.

Alternative I (divert drainage to south of highway): This option involves diverting the Transitway drainage southerly to the south side of Highway 417 and using the storage available in the local drainage ditches which drain the downstream end of the farmer's fields. Stormwater would then flow naturally to the MTO culverts which service these ditches under existing conditions. Outlets structures would be required to limit existing flow contributions and meet the erosion criterion.

Alternative J (retrofit existing channels): As the erosion criterion is the most restrictive of the criteria in terms of potential volume of detention required for SWM, retrofitting the existing outlet channels to provide greater resistance against erosion is a possible option. Increasing the grain size of the substrate material would allow for greater velocities and shear stresses in the outlet channels/ditches from the MTO culverts.

3.3 Alternative Analysis and Screening

The Environmental Project Report (EPR) set forth a number of guiding principles with respect to the selection of the preferred design option which are described below.

- Is consistent with the City of Ottawa's vision and objectives for transit as identified in the approved 2008 Official Plan and Transportation Master Plan;
- Provides a cost-effective interim solution to current operational concerns while not precluding plans for the ultimate westerly extension of the West Transitway to Kanata (including conversion to rail);
- Minimizes impacts on terrestrial and aquatic ecosystems and processes and avoids impacts that cannot be mitigated through the design;
- Minimizes impacts on the adjacent community (noise, vibration, etc.) and avoids impacts that cannot be mitigated through the design;

- Minimizes impacts on Greenbelt lands (property requirements and impacts on user experience, etc.);
- Minimizes impacts on provincial highway infrastructure;
- Supports municipal and federal land use planning objectives (transit oriented development, bundling of transportation corridors, etc.); and
- Represents a responsible use of public funds.

In addition to these guiding principles, there are also technical components which must be considered as part of the selection of SWM alternatives to be carried forward in the design, including:

- Minimize ongoing maintenance costs;
- Design for ease of maintenance safety of maintenance crews when carry out their ongoing work; and
- Minimize risks to public safety.

Based on these guiding principles and technical components, the alternatives were evaluated and two options were carried forward to be further analyzed as shown in Table 1. The easterly and westerly diversion options were discarded on the basis that they would require excavations for the sewers which would be excessively disruptive. In many locations, they would be required to tunnel through bedrock and would be located at great depths such that excavating near the highway becomes unacceptable as it would cause serious disruptions to highway operations. Moreover, the cost implications would be significant. There is also a significant element of public safety involved as the greater the area draining to the Transitway sag point the higher the risk that significant flooding could occur there. Similarly, diversion options which direct stormwater to MTO lands (either the median or the pond) were discarded as MTO indicated they would not accept any extra drainage to their facilities as it would be a concern with respect to the capacity of their infrastructure and, as such, potentially have an impact on public safety (potential highway flooding).

Table 1: Proposed Drainage/SWM Alternatives

Alternative	Description	Pros	Cons	Note
A	Provide underground storage using box pipes located upstream of existing culvert crossings.	• Hard engineering controls easier to guarantee results • Concentrates controls in Transitway ROW	• High capital cost for installation • High maintenance costs • Difficult to maintain	**Carried Forward**
B	Divert drainage to MTO median for quality and quantity control.	• Uses existing drainage paths and outlets	• Increases risk to MTO lands and infrastructure • Increased risks to public safety • Difficult to meet criteria • Not supported by MTO	**Not Carried Forward**
C	Divert drainage to the MTO pond.	• Makes use of existing SWM facility	• Increases risk to MTO lands and infrastructure • Difficult to meet erosion criterion • Not supported by MTO	**Not Carried Forward**
D	Divert drainage to the pump station at Transitway sag.	• Single point control for SWM	• Significant increase in costs for larger pumping station and difficult storm sewer construction in rock • Increases risk by concentrating flow at Transitway low point	**Not Carried Forward**
E	Divert drainage to Graham tributary and construction large pond on City land near the sanitary pumping station.	• Single point control for SWM • Lower impact from SWM pond and potentially greater treatment	• Diverts water supply from one watercourse to another • Significant increase in costs for larger facility?	**Not Carried Forward**
F	Divert as much drainage as possible easterly towards to a new pipe system under Corkstown Road to outlet at the Stillwater Creek crossing at Creekwood Cres.	• Diverts drainage to more stable reach of the creek • Single point control for SWM	• High capital cost for installation • Major disruption of Corkstown Road and nearby community	**Not Carried Forward**
G	Use micro-pool/filter strips and other low impact development (LID) best management practices (BMPs).	• Low maintenance costs • Low capital costs • Low overall impact	• Minor disruption and occupation of NCC land	**Carried Forward**
H	Construct one of more SWM ponds at downstream end of existing MTO culverts.	• Low maintenance costs • Low capital costs	• Significant disruption and occupation of NCC land	**Not Carried Forward**
I	Divert drainage to south side of Highway 417 and construct ponds upstream.	• Low maintenance costs • Low capital costs	• Significant disruption and occupation of NCC land • Difficult to meet erosion criterion	**Not Carried Forward**
J	Retrofit existing channels from MTO culvert outlets to withstand increased velocities.	• No storage required	• Significant disruption and occupation of NCC land • High capital cost • Still requires stormwater interceptors • Significant ecological impact	**Not Carried Forward**

The NCC has also indicated that it is highly preferable to minimize the use of their lands for SWM facilities as much as possible. Consequently, options to locate large ponds either on their lands north or south of the highway or to retrofit the outlet channels have been discarded as their impacts would be significant in terms of disruption, aesthetics and the required permanent land occupation.

Alternatives A and G were carried forward and are described in greater detail in Section 3.4.

3.4 Alternatives Carried Forward

Alternative A: The underground storage plan involves the use of concrete box pipes to provide storage upstream of vortex-inducing outlet structures to be used to significantly reduce incoming flows to meet the erosion criterion. The plan also involves the use of stormwater interceptors at each outlet to provide the required quality control. This underground storage plan can also be further subdivided into two alternatives based on the amount of area required to meet the treatment criteria. The first alternative (A-1) is to control the entire area draining to the SWM facilities. The second alternative (A-2) is to control only the equivalent area representing the new impervious area (about half the total area). The advantage to Alternative A-2 is smaller facilities and thus lower capital and maintenance costs. It should be noted, however, that for smaller and much more frequent events, the SWM facilities of Alternative A-2 will still provide the same control (both erosion and quality) as Alternative A-1. Only for large storm events will the bypass weir be utilized. Table 2 shows a comparison of the SWM facility sizes for both alternatives.

Alternative A has the advantage that it does not use any land outside of the Transitway ROW. However, City Sewer Operations staff members have made it clear that underground storage facilities should be avoided where possible due to the ongoing difficulties maintaining them. They are generally difficult spaces to access and it is more difficult to use conventional means of sediment removal (i.e. flushing) owing to the flat bottom and shallow slope of the boxes. While round pipes could be used, they are much less efficient in terms of the cost per unit volume that they can provide and they require a larger overall footprint which may be a concern with respect to the eventual conversion to rail.

Table 2: Preliminary Underground SWM Facility Alternatives				
Alternative	**Location**	**Treated Area (ha)**	**Storage Volume (m^3)**	**SWM Facility Configuration**
A-1	11+550	0.94	660	140m @ 3.0 x 1.8m box pipe
A-2		0.47	330	70m @ 3.0 x 1.8m box pipe
A-1	11+890	0.97	680	145m @ 3.0 x 1.8m box pipe
A-2		0.44	310	65m @ 3.0 x 1.8m box pipe
A-1	12+725	2.56	1800	380m @ 3.0 x 1.8m box pipe
A-2		1.14	800	170m @ 3.0 x 1.8m box pipe

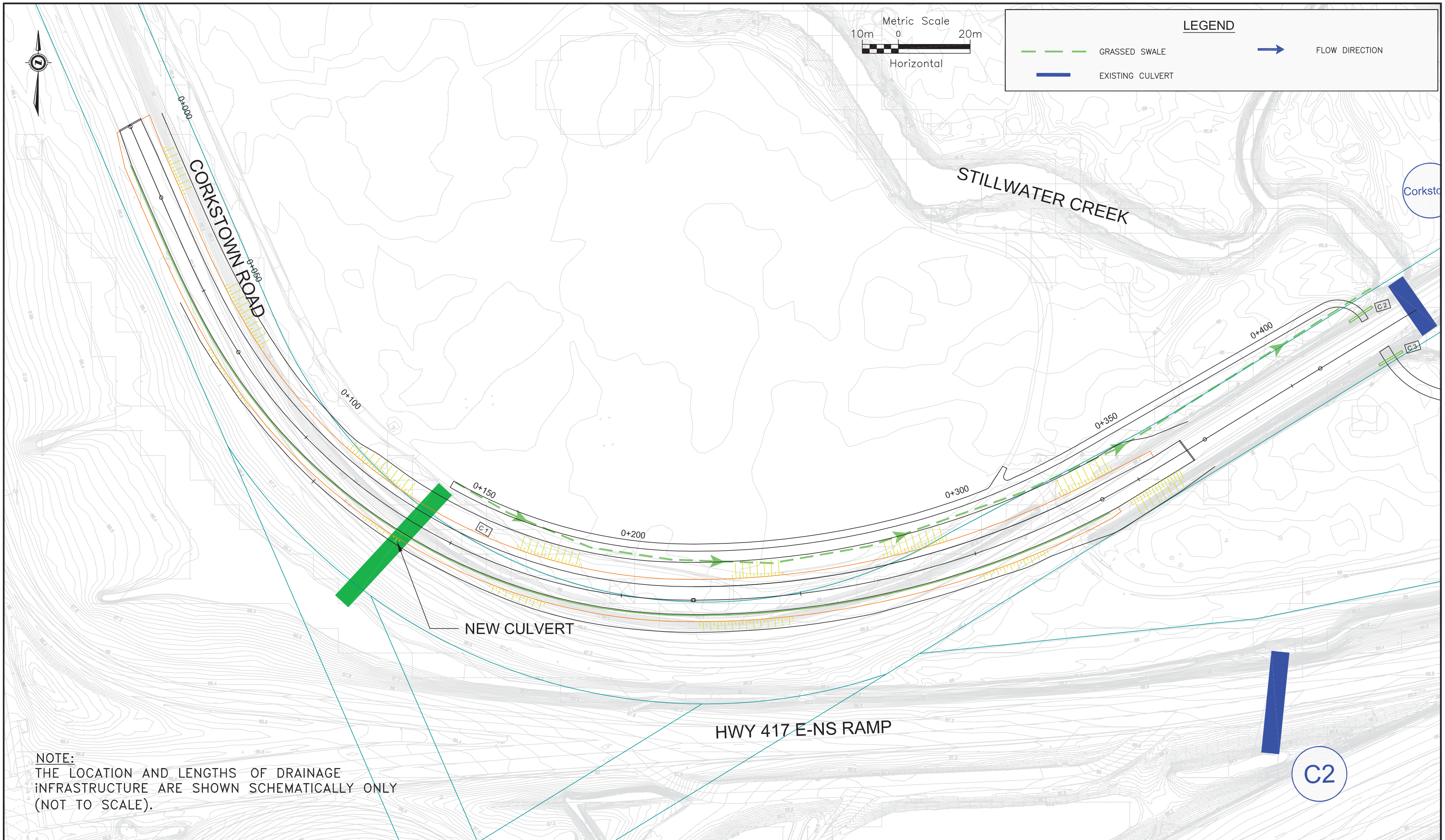
Alternative G: This plan involves the installation of "soft features" in accordance with best management practices and low impact development strategies that will treat the proposed new impervious area as well as the intercepted existing highway drainage area. In order to best reproduce existing drainage patterns, an increase in the number of outlets is proposed to encourage sheet flow towards the creek systems. Outlets to the Stillwater Creek system are proposed at 11+680, 11+740, 11+845, 11+980 and 12+065. Increasing the number of outlets to Stillwater Creek reduces the flow quantity at any individual discharge point as an initial step in addressing the maximum discharge velocity.

Each of the above outlets will be treated as shown in Exhibit 9 with a micro-pool/filter strip. Exhibit 9 shows an engineering rendering of the micro-pool/filter strip and the constructed design includes landscaping features such as natural plantings and shaping of the micro-pool/ filter strip to blend into the natural landscape. This system involves the excavation of a small sump at the outlet and lining that sump with erosion protection (i.e. rip rap). This sump will help provide primary treatment and will act as a depository for coarse settled sediments. As it is an exposed area, it remains an easy location to provide regular maintenance such that the system can continue to function at peak efficiency. Immediately downstream of the sump pit, a berm will be constructed, surrounding the outlet, with a height of 0.3m above the invert of the outlet pipe. The berm will be constructed of earth fill and will be grassed for both aesthetic and quality enhancement purposes. The height of the berm will be a maximum of 0.3m above the invert of the pipe, will have a top width of 0.3m and will act as a broad-crested weir. This berm, with a constant crest elevation, will cause flow exiting the pipe to rise slightly, slowing it down and promoting settlement of suspended sediment as well as causing it to fan out as it overtops the berm. Fanning the flow out in this way is a means of duplicating, as closely as possible, the existing sheet flow towards the creek. As the flow is conveyed to the creek as overland flow, it will spread out further and thus the depth of flow will be reduced to allow the plant material to provide an effective filtering system and further reduce sediment load.

With respect to runoff draining to Graham Creek, a single outlet is proposed downstream of Station 12+840. This outlet is proposed immediately downstream of the proposed culvert extension. Runoff to this outlet would drain to an underground storage facility which will provide quality and erosion control before outletting to the Graham Creek tributary.

This sub-basin also includes the proposed future transit station east of Corkstown Road. In the design of the station will incorporate, as much as possible, lot level SWM features such as infiltration beds, grassed swales and vegetated filter strips.

Due to overall lower environmental impacts, lower costs, and fewer ongoing maintenance concerns, a fusion of the two alternatives is preferred. Alternative G (the use of micro-pool/filter strips) was selected as the preferred alternative for most of the study area, while Alternative A (underground storage) is seen as the best solution for the Graham Tributary site. The water quality control provided by the micro-pool/filter strip system will be enhanced by installing an oil and grit interceptor upstream of each storm sewer outlet. The proposed drainage strategy for the entire study area is shown on Exhibits 2 to 8. These exhibits illustrate the drainage patterns within the proposed highway corridor and show the existing and proposed culvert locations and other drainage infrastructure. It is anticipated that the City of Ottawa will be responsible for any maintenance requirements for ensuring the long-term functionality of these works.



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DETAIL DRAINAGE DESIGN - MAP 1

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT
2

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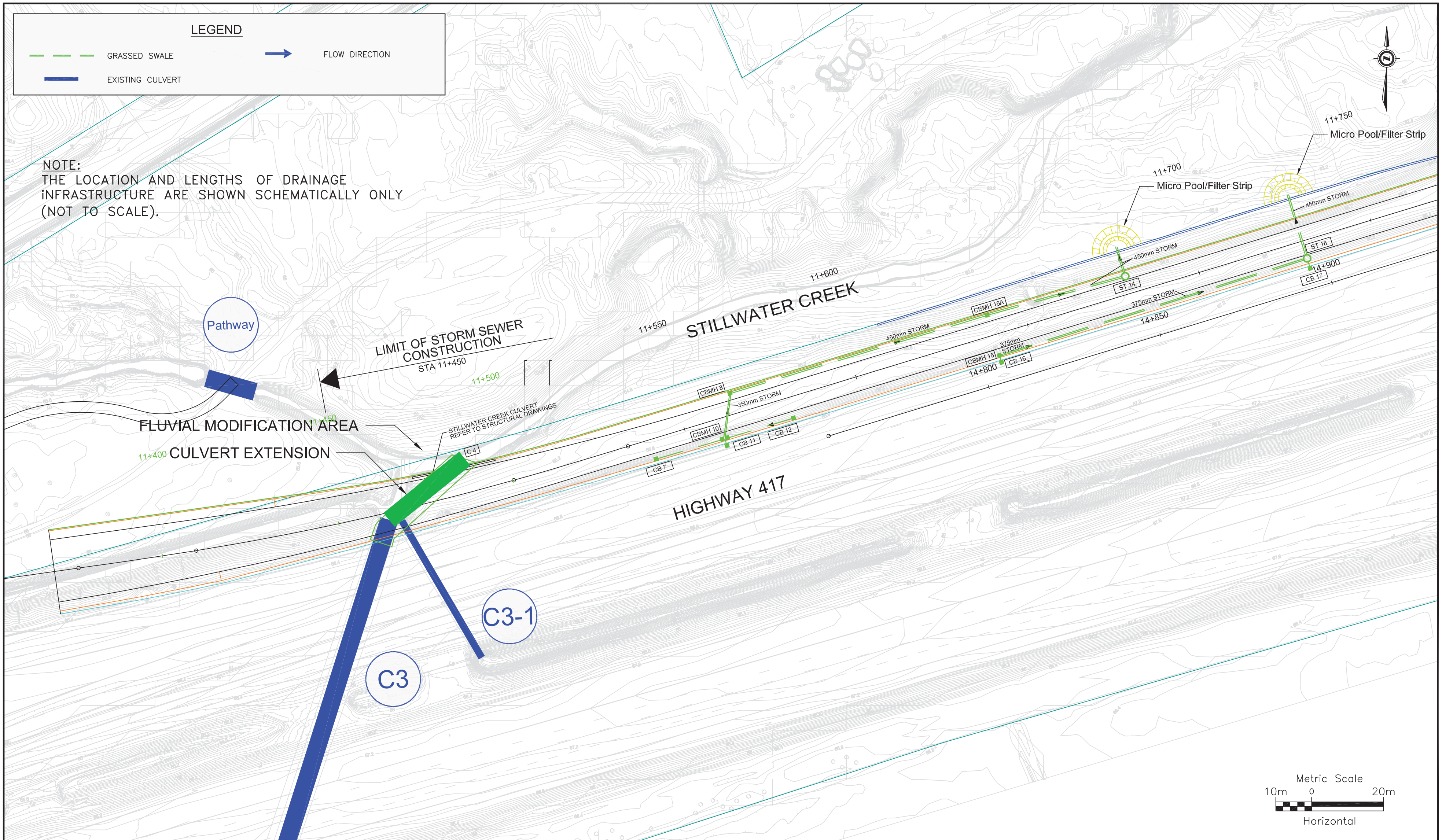

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DETAIL DRAINAGE DESIGN - MAP 2

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT

3

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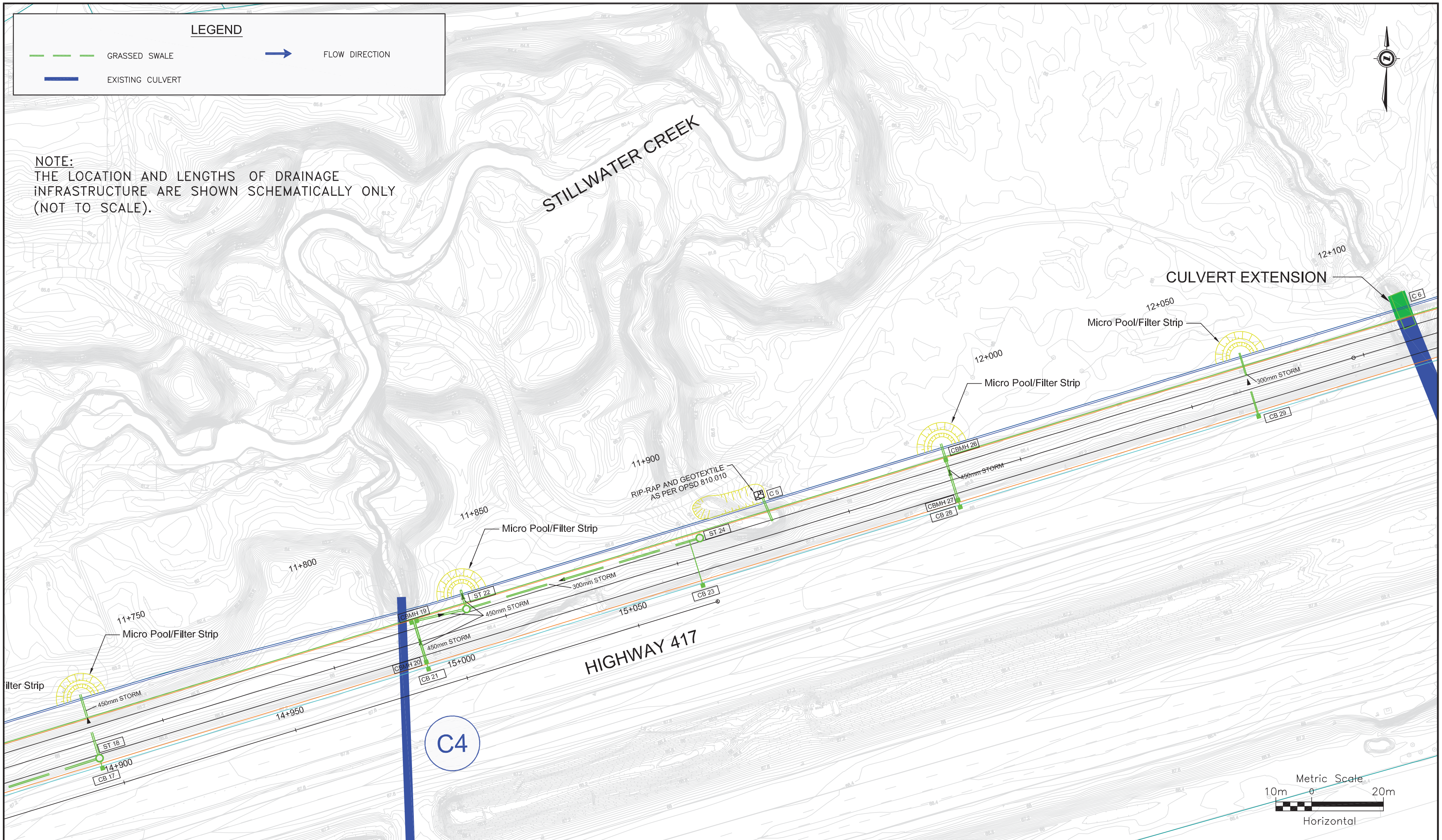

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DETAIL DRAINAGE DESIGN - MAP 3

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT
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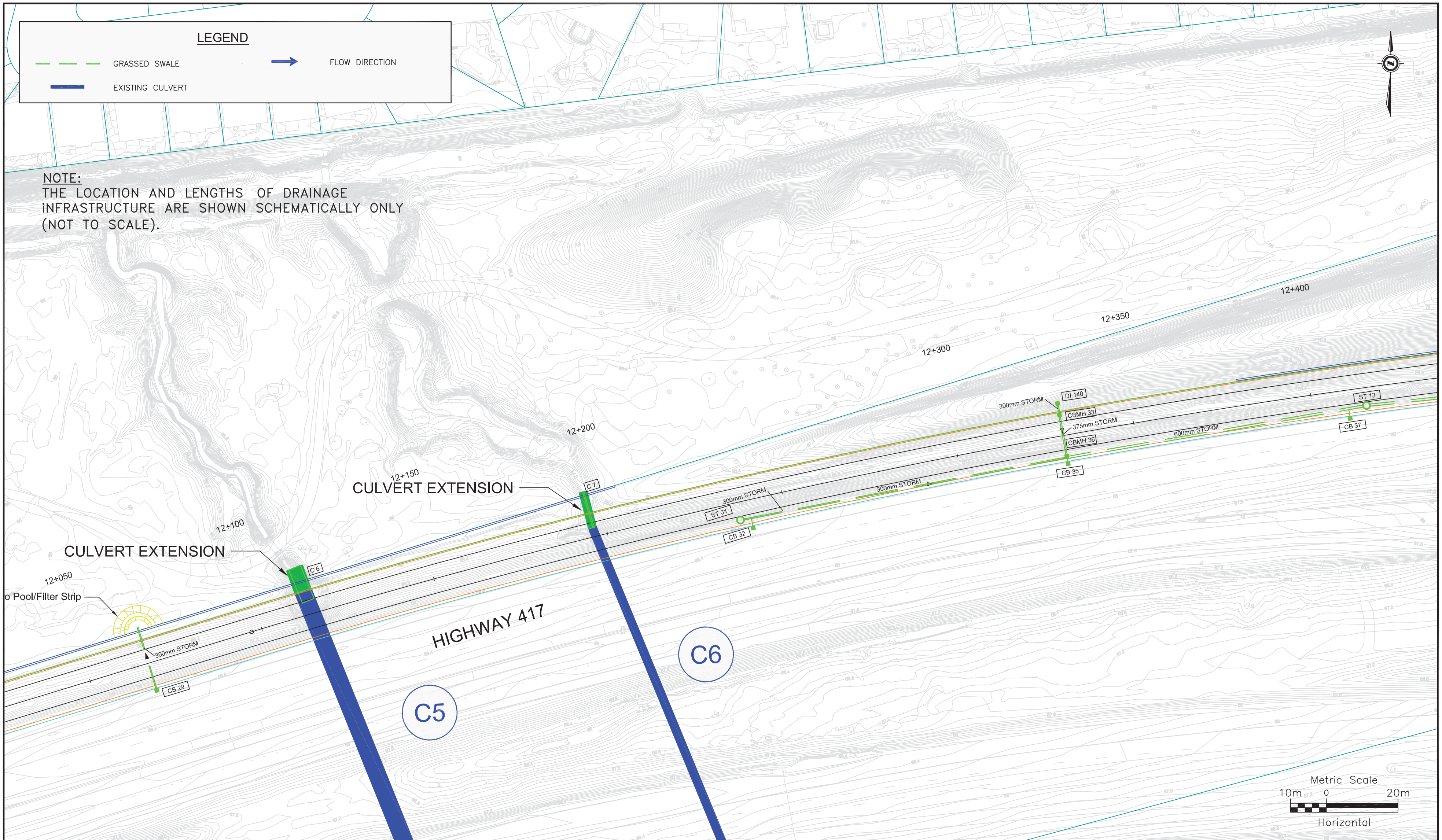

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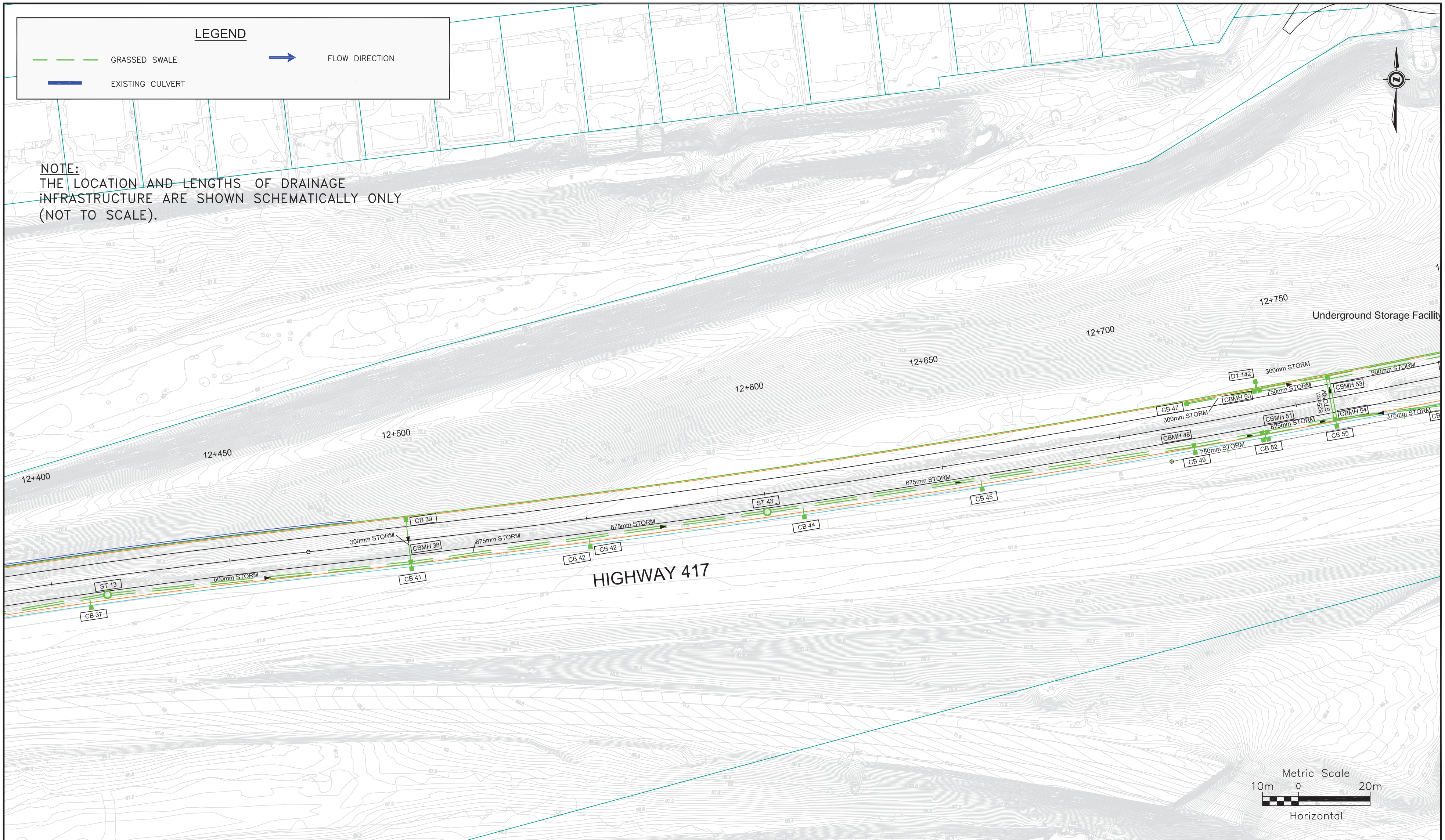
DETAIL DRAINAGE DESIGN - MAP 4

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT 5



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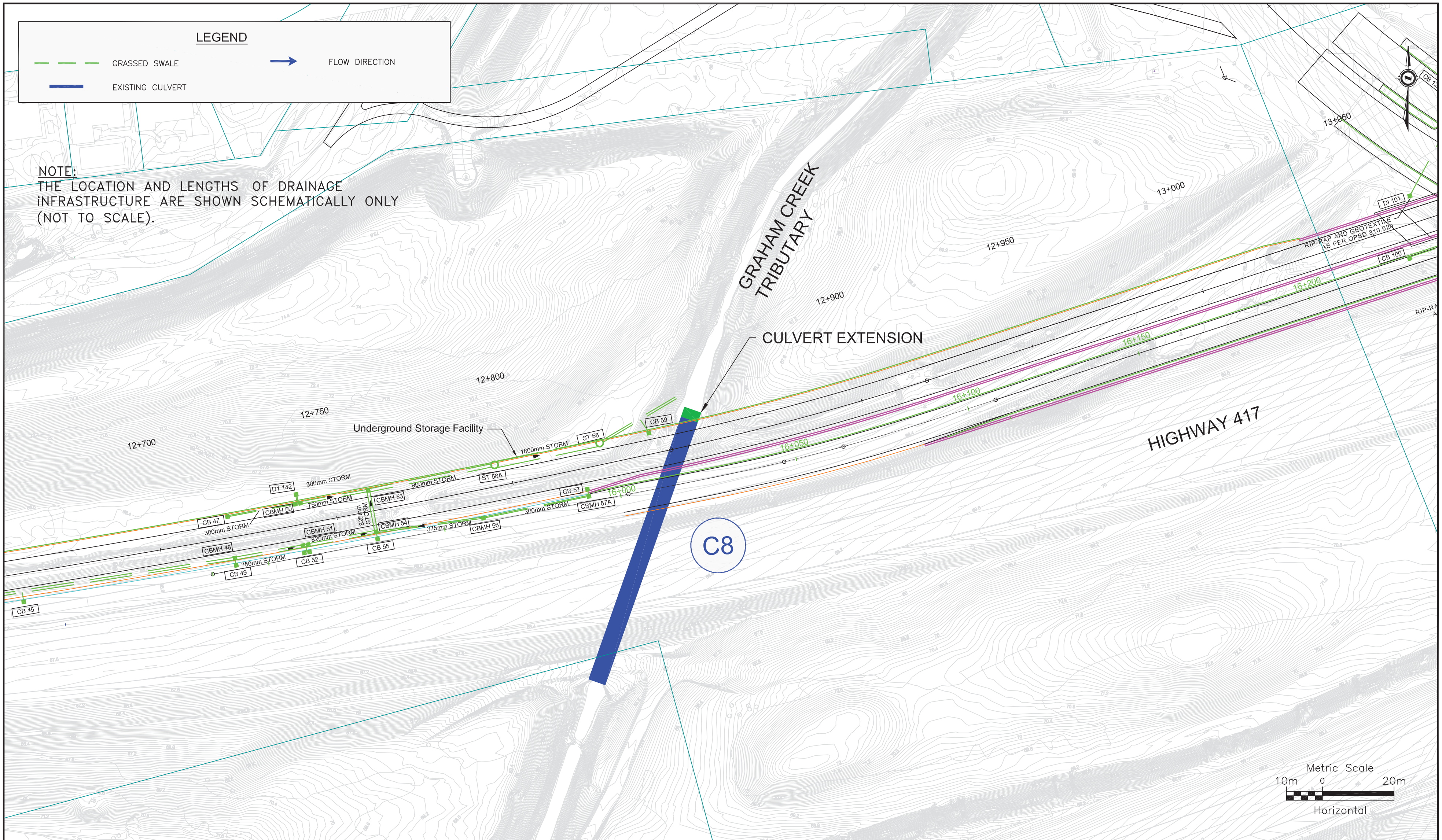
DETAIL DRAINAGE DESIGN - MAP 5

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT
6



DETAIL DRAINAGE DESIGN - MAP 6

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT 7

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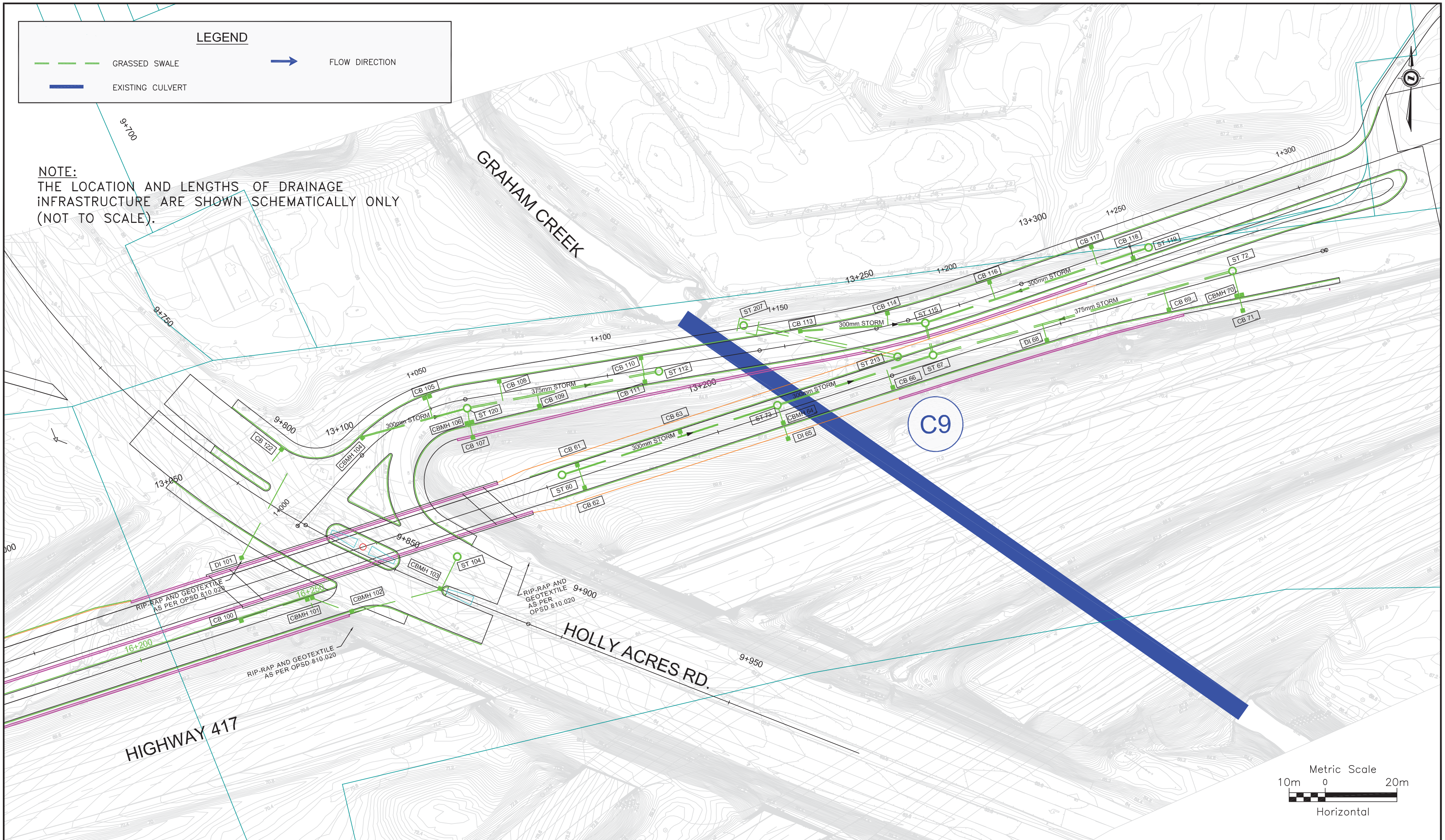

DETAIL DRAINAGE DESIGN - MAP 7

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

EXHIBIT 8

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DRAWING NAME: I:\KITCHENER\MRC\DRAWINGS\7400-7599\7499 - WEST TRANSITWAY EXTENSION\DRAINAGE\7499 DETAIL DESIGN - CONTRACT 1.DWG

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3.5 Erosion

JTB Environmental Systems Inc. completed an erosion threshold analysis study for Stillwater Creek to determine an appropriate SWM erosion criterion for discharge directly to the creek. The conclusion and recommendation of the report is that discharge for direct release of stormwater to Stillwater Creek should be at a velocity of less than 0.225m/s. The memo detailing the rationale for the erosion criterion is included as Appendix A.

This criterion is met through the use of the micro-pool/filter strips and other SWM controls at the outlet locations. These drainage structures cause the stormwater runoff to fan out at the outlet, promoting sheet overland flow towards the creek and slowing down the flow to acceptable levels. Calculations supporting the velocity analysis can be found in Appendix C.

In the drainage area for the western section of the study area stormwater is being discharged to existing vegetated ditches and swales well upstream of the receiving watercourse. Therefore, erosion impacts are already addressed in the flow path length prior to discharge to Stillwater Creek. For these areas, post-development flows are being controlled to pre-development levels via the use of storage in swales, ditches, dry ponds, and stilling basins.

3.6 Water Quality

There exists the possibility for adverse water quality impacts resulting from the increased pavement area within the construction of the Transitway. For water quality an enhanced level of stormwater treatment (minimum 80% of Total Suspended Sediment removal efficiency as per MOE guidelines) is proposed. Currently, much of the existing Hwy 417 runoff is discharged without any specific SWM measures. Under the overall proposed scheme, some of the presently uncontrolled highway runoff will be incorporated into the Transitway drainage conveyance infrastructure and thus also be provided with SWM treatment and control. The proposed storm water management strategy for treatment of the roadway runoff within the study area includes the use of micro-pools/filter strips, flat bottom grassed swales and other SWM BMPs.

The Ministry of the Environment (MOE) *Storm Water Management Planning and Design Manual* (March 2003) identifies grassed swales as an appropriate measure for water quality enhancement provided that the peak flow velocity for the 25mm (4 hour) storm event is not greater than 0.5m/s. In addition, the velocity generated by the 100-year design storm should not exceed 1.5m/s, at which point, rock protection should be provided to prevent erosion.

Grassed swales with minimum 1.0m wide flat-bottom is recommended for all new swales proposed along the Transitway to provide water quality enhancement. The proposed grassed swales are shown on the Preliminary Drainage Plans on Exhibits 2 to 7.

While not strictly represented in the MOE Design Manual as a SWM Design the micro-pool/ filter strips represents a “soft engineering” approach to stormwater treatment. The system preform as a hybrid between a grassed swale and a vegetated filter strip which are both identified in the MOE Design Manual. In accordance with the design criteria for a vegetated filter strip, the catchment areas are all kept less than 2 ha and are located in relatively flat areas to promote infiltration and treatment. The sheet drainage promoted by the micro-pool/ filter strip is also between 20-30m wide and no specific detention storage is required as the flow depth over the weir is maintained at less than 100mm for flows up to the design event. The calculations contained in Appendix C show that the flow velocities out of and downstream of the micro-pools is substantially less than those detailed above for grassed swales. This micro-pool/filter strip system also does not create a new point source discharge to the creek.

Table 3 shows the criteria from the MOE SWMPDM for a vegetated filter strip and the design parameters for the West Transitway extension micro-pool/filter strip system. It should be noted that the MOE SWMPDM depth over the level spreader and hence through the vegetation is to be calculated for a peak flow from a 4 hour Chicago 10 mm storm, whereas, the depth listed for the West Transitway design, in Table 3, is for the peak flow from a 100 year storm flow since the outlet velocity calculations were to account for this storm.

Table 3: Vegetated Filter Strips Design Parameters

Criteria	MOE SWMPDM	West Transitway Design
Maximum Drainage Area	2 ha	0.35 - 0.55 ha
Slope	1% - 10%	0.5% - 5%
Minimum Length of Filter Strip (in direction of Flow)	10 - 20 m	Minimum of 20 m
Required Flow Depth Over Level Spreader	50 - 100 mm	60 - 80 mm

Appendix C also contains the flow depths and velocities for various rainfall storms. The storm sewer outlet at 11+680 has the largest drainage area and the results for the 10 mm and 25 mm 4 hour Chicago Storm distribution are shown for that outlet. As shown in Appendix

C, the flow depth and flow velocity for the 10 mm storm flow is well below the required design parameters from the MOE SWMPDM. As detailed earlier, to enhance the water quality performance of the system, a stormwater interceptor will be installed prior to the stormwater discharge to each of the micro-pool/filter strip systems.

For the Transitway drainage area tributary to Graham Creek, an underground storage facility is proposed as primary treatment for the area, to provide some initial reduction in peak flow and velocity such that they meet the pre-to-post condition. The storage outlet is proposed to be a vortex inducing system which will dramatically reduce outlet velocities, resulting in attenuation and settlement of particulates in the storage pipe. The maximum draw down time is estimated to be 4 hours. Due to the concrete weir to be constructed in the outlet facility, the vast majority of particles will settle below the top of weir elevation and will be detained in the storage system. Consequently, an enhanced level of treatment will be achieved.

It is also worth noting that, under existing conditions, no SWM measures are being employed for the existing Highway 417 east of the Moodie Drive interchange. The proposed Transitway SWM plan, owing to the location of the proposed Transitway, addresses runoff from the MTO ROW as well as the Transitway and provides treatment to existing runoff from paved areas which are presently being conveyed untreated to the receiving watercourse. Highway 417 represents approximately half of the total paved area draining to the proposed SWM facilities and, as such, the proposed treatment system represents a significant gain in water quality treatment for the receiving watercourses.

4.0 SUMMARY

This report presents the detail design for the drainage and stormwater management for the proposed extension of the West Transitway from Bayshore Station to Moodie Drive. Two main criteria (erosion and water quality) are addressed for this site. Flooding is addressed in the Floodplain Assessment Report included in Appendix A. The findings on how to address each criterion are presented below. Design integration with other disciplines, including landscaping, will be refined during detail design.

Erosion: A maximum velocity of 0.225 m/s was imposed on all outlet locations discharging directly to Stillwater Creek. In order to meet this criterion, micro-pool/filter strips are proposed to maintain sheet drainage and to reduce velocities to acceptable levels before entering the receiving watercourse. For drainage areas discharging to existing swales and ditches upstream of their receiving watercourse as well as Graham Creek, it is proposed in those areas to limit post-development peak flows to pre-development levels so as not to cause any detrimental impacts. An underground storage facility is proposed for the area draining to the Graham Creek tributary.

Water Quality: An enhanced level of treatment (80% TSS removal) is achieved for the West Transitway Extension by the use of a combination of SWM BMPs including underground storage, grassed swales, and micro-pool/filter strips (vegetated filter strip) with oil and grit interceptors. These treatment methods include not only the Transitway but also previously untreated MTO ROW and result in a significant net gain for quality treatment.

Flood risk analysis was defined in a separate study which has been included as Appendix A in this report. In summary, there is no significant change in the 100-year floodplain elevation between the existing and proposed conditions.

Respectfully,

Bryan Orendorff, M.A.Sc., P. Eng.

John Price, P. Eng.

MRC McCORMICK RANKIN
A member of MMM GROUP

APPENDIX A

STILLWATER CREEK FLOODPLAIN ASSESSMENT

McCormick Rankin Corporation

West Transitway Extension Stillwater Creek Flood Plain Assessment

January 2011
Revision 1

A member of MMM GROUP

Table of Contents

1.0 Introduction

The City of Ottawa retained McCormick Rankin Corporation (MRC) to complete the Environmental Assessment Study for the extension of the West Transitway from Bayshore to Moodie Drive. From this EA process the preferred alignment for the extension is along the north side of Highway 417 and a station is to be constructed on the east side of Corkstown Road (See Figure 1.1). Stillwater Creek conveys flow through this area and there is no existing flood plain mapping for the creek. For this part of the Province, the Regulatory flood plain is defined by the 1:100 year flood.

To assess the potential impact of this project on the 1:100 year flood plain of Stillwater Creek and to recommend mitigation measures requires the delineation of the existing flood plain limit and the assessment of the interaction and impact of the transitway extension and proposed station on this existing flood plain.

Therefore the purpose of this study is to:

1. Define the existing (base condition) 1:100 year flood plain for the reach of Stillwater Creek in the area of Corkstown Road immediately east of Moodie Drive to 50m downstream of the confluence between Stillwater Creek and its main tributary.

2. Define the encroachment (if any) of the proposed construction of the extension and station into the existing 1:100 year flood plain.

3. Provide recommendations to mitigate any impacts and provide a flood proofed design for the project.

2.0 Background Reports

Initial consultation, regarding the flood plain aspects of Stillwater Creek, was completed with the staff of Rideau Valley Conservation Authority (RVCA) on April 27, 2010. Although there is no existing flood plain mapping for Stillwater Creek there are several existing reports that provide background information regarding the hydrology and hydraulics of the creek. Reports received from the RVCA included:

- Stillwater Creek Erosion Control Study, City of Nepean – June 1987 prepared by Totten Sims Hubicki Associates
- Stillwater Creek Erosion Control Project Environmental Study Report, City of Nepean - May 1988 prepared by Totten Sims Hubicki Associates
- Stillwater Creek Erosion Control Study - Hydrology and Hydraulics Report, City of Nepean – May 1988 prepared by Totten Sims Hubicki Associates.
- A copy of the report that was prepared in support of the permit application for the replacement of the Corkstown Road culvert crossing of Stillwater Creek.

The latter two reports were reviewed in detail to extract relevant hydrologic and hydraulic information that would be applicable in furthering the flood plain analysis for Stillwater Creek.

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STUDY REACH

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

FIGURE 1.1

1. **Stillwater Creek Erosion Control Study - Hydrology and Hydraulics Report, City of Nepean – May 1988 prepared by Totten Sims Hubicki Associates**.

   This report was a background report for the Stillwater Creek Erosion Control Study completed by the RVCA in 1988. As detailed in the report, the watershed of Stillwater Creek was divided into three drainage basins and an OTTHYMO model was assembled to calculate a range of return period flows. The Ministry of

   Transportation (MTO) Watershed Classification Method was also used to calculate flows for comparison purposes. The report concluded that the discharges determined using the OTTHYMO hydrology model were reasonable and representative for Stillwater Creek and it was recommended that the peak flows calculated using the OTTHYMO model be used for the hydraulic analysis as part of the erosion control study.

   A HEC-2 backwater analysis was also completed as part of the study. However the analysis terminated just upstream of the eastern most Corkstown Road crossing of Stillwater Creek and thus does not include the reach of interest for the West Transitway Extension project.

2. **Corkstown Road Culvert – Preliminary Design Report – September 2007 prepared by Harmer Podolak Engineering Consultants Inc**.

   This report detailed the preliminary and final design of the replacement of the Corkstown Road culvert structure crossing of Stillwater Creek located 0.6 km east of Moodie Drive. As part of this study, the Modified Flood Index Method was employed to calculate the 25 year and 100 year flows to be used in the design.

   The culvert design was completed using the MTO design charts for inlet and outlet control.

3.0 Hydrology

3.1 Original (1988) Conditions

Figure 3.1 shows the drainage basins delineated in the 1988 Hydrology and Hydraulics Report prepared by Totten Sims Hubicki Associates (TSH). As shown, the confluence of Basins A1 and A2 essentially defines the area of interest for this project. Detailed OTTHYMO input data used in the 1988 report was not available, however the report does contain the OTTHYMO basin parameters used to calculate the various return period flows.

The report also contains the following total rainfall depths for the various return period storms based on rainfall data from the Ottawa CDA (Canadian Department of Agriculture) weather station. This information, employing the 12 hour SCS Type II rainfall distribution, was used in the original analysis.

Table 3.1 Basin Parameters 1988 Study

Basin	Area (ha)	Time to peak (hrs)	K (hrs)	CN
A1	1077	2.75	4.52	69
A2	1124	2.62	4.16	71
A3	132	1.3	4.15	83

Table 3.2 Rainfall Depth

Return Period (Yrs)	Rainfall Depth (mm)
2	40.76
5	49.52
10	55.52
100	73.52

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SUB-BASIN DELINEATION

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

FIGURE 3.1

DRAWING NAME: I:\KITCHENER\MRC\DRAWINGS\7400-7599\7499 - WEST TRANSITWAY EXTENSION\REPORT EXHIBITS\7499 FIGURE 3-1.DWG

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Using these parameters from the original 1988 study a SWMHYMO model for Stillwater Creek was assembled. The WILHYD command in SWMHYMO was employed for this simulation since it allows the user to define both the Time to Peak (T_p) and Recession Constant (K) values. An initial abstraction (I_a) value of 1.5 mm was used in the original model and this same value was also used in the SWMHYMO model.

The 1988 report only lists peak flow values at the downstream end of Stillwater Creek at the confluence with the Ottawa River and in the absence of detailed output these are the only values that can be used for comparison purposes. Table 3.3 shows a comparison of the peak flows at the outlet of Stillwater Creek from the 1988 OTTHYMO model and the 2010 SWMHYMO model.

Table 3.3 Peak Flows - Outlet of Stillwater Creek

Return Period (Yrs)	1988 Model Peak Flows (m3/s)	2010 Model Peak Flows (m3/s)
2	6.9	7.2
5	9.8	10.2
10	11.9	12.3
100	19.2	19.9

In the 1988 OTTHYMO model the sum of the hydrographs from Basins A1 and A2 was routed down to the outlet of Stillwater Creek. Since the present area of interest is upstream of the confluence of Basins A1 and A2, in the 2010 SWMHYMO model, this routing was not included. Thus the overall peak flow values at the outlet are slightly higher as compared to those generated by the original OTTHYMO model. Therefore, considering the above, Table 3.3 shows that there is good agreement between the results from the two models and the SWMHYMO model can be used as a basis to assess the changes in hydrology on Stillwater Creek.

3.2 Updated (2010) Conditions

Since 1988 there has been some additional development in the Stillwater Creek watershed and there is also over twenty years of additional rainfall data which will modify the Ottawa CDA IDF curve. These factors were considered in producing a revised SWMHYMO model to calculate 1:100 year flows to be used in this analysis.

In the upstream watershed of Stillwater Creek (Basins A1 and A2) additional development has occurred north Robertson Road, west of Moodie Drive and the old Nortel site east of Corkstown Road. In Basin A1 approximately 65 additional hectares has been developed and in Basin A2 an additional 90 hectares has been developed. Assuming the overall imperviousness of these additional areas is 60% the CN values for these two basins were increased by the weighted average of this imperviousness. Therefore the CN value for Basin A1 was increased to 71 and to 73 for Basin A2.

The rainfall depths for the Ottawa CDA station based on data from 1903 to 2003 have also increased to the values shown in Table 3.4.

Table 3.4 Rainfall Depths - Ottawa CDA	
Return Period (Yrs)	Rainfall Depth (mm)
2	42.4
5	54.9
10	63.1
100	88.9

These parameters were used to calculate the updated flows for Stillwater Creek. Table 3.5 shows the updated peak flow values at various locations in the watershed.

Table 3.5 2010 Peak Flows				
	Peak Flows (m3/s)			
Return Period (Yrs)	Basin A1	Basin A2	Basins A1 +A2	Outlet
2	3.5	4.1	7.6	8.3
5	5.5	6.5	11.9	12.9
10	6.9	9.2	15.1	16.3
100	12.1	14.2	26.3	28.4

4.0 Flood Plain Analysis

4.1 Existing Conditions

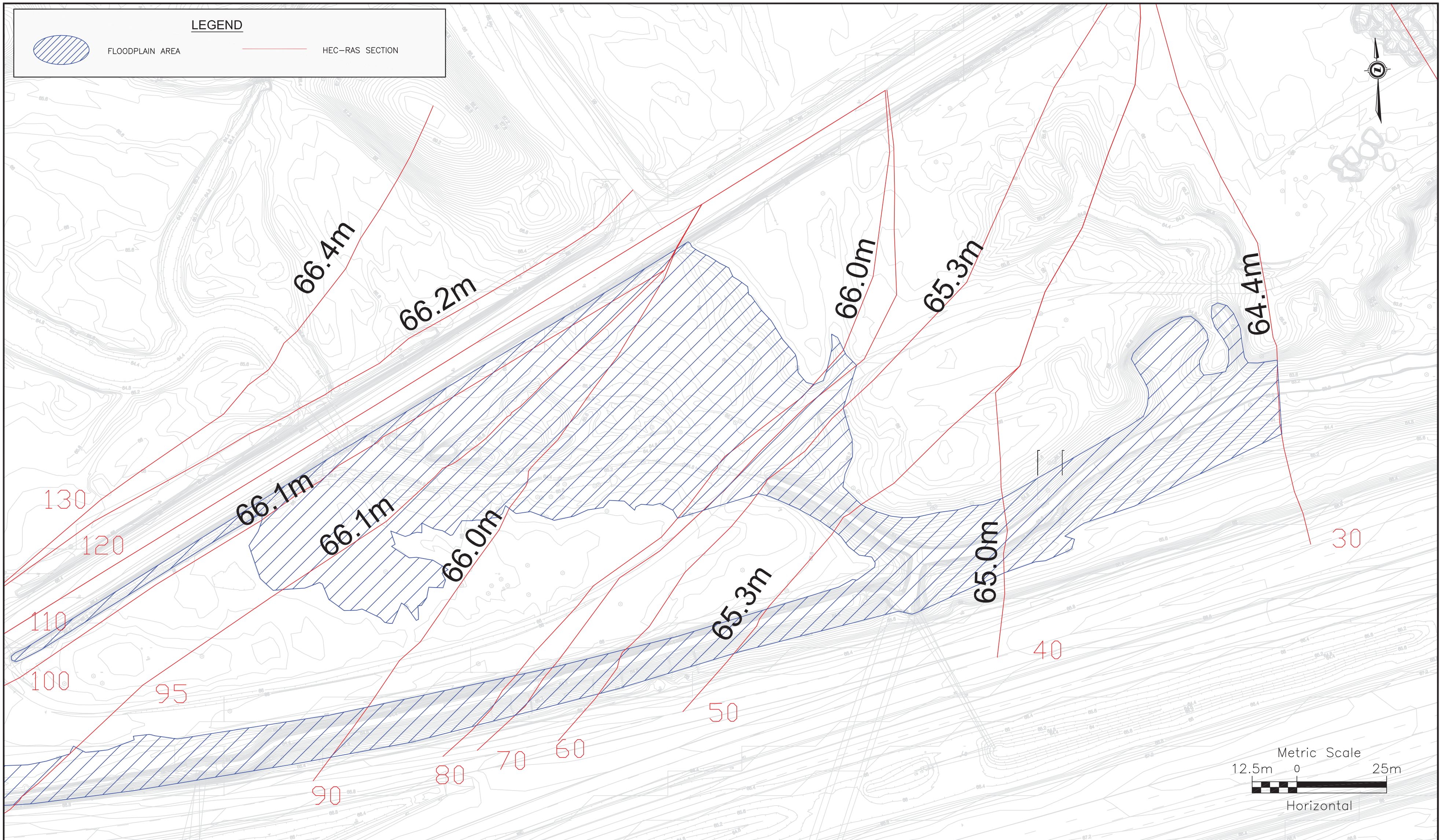
To delineate the existing 1:100 year flood plain a HEC-RAS model was assembled for the subject reach in the area of Corkstown Road. Cross-section locations are shown on Figure 4.1 and topographic information was obtained from the existing Ontario Base Mapping (OBM). Cross-section 10 is at a rapid drop in channel invert (waterfall) and therefore the model was started at critical depth at this location. There are two watercourse crossings within the subject reach, the NCC pedestrian crossing at Cross-section 70 and the Corkstown Road crossing at Cross-section 110. The crossing information for the pedestrian crossing was obtained from field measurements and for the Corkstown Road crossing the required information was obtained from the report for the replacement of the culvert at Corkstown Road described above. Therefore the proposed crossing for Corkstown Road was inserted in the HEC-RAS model and not the existing crossing. This new crossing is under construction and therefore in the context of the West Transitway project this will be the crossing in place at the time of construction.

The peak flows used in the analysis were based on the updated 1:100 year flows detailed in Table 3.5. Therefore for Cross-section 10 to 40 the input flow used was 26.3 m^3/s and from Cross-section 50 to 150 the flow was 14.2 m^3/s. The Manning n value used for the reach was 0.05 for the overbank flood plain areas and 0.035 for the channel sections. These values represent the general sparse vegetation of the subject reach. Table 4.1 shows the calculated 1:100 year water levels, rounded to the nearest 0.1 m, for the reach for existing conditions and Figure 4.1 shows extent of the flood plain. As shown, upstream of the NCC pedestrian pathway to Corkstown Road the 1:100 year flood plain elevation is 66.0 metres. There is also a channel on the north side of Highway 417 that provides the outlet for the stormwater management pond located at the Highway 417 interchange with Corkstown Road which is under the influence of backwater from Stillwater Creek during the 1:100 year flood. Since this channel only has a downstream connection this is a backwater area and would not have any positive velocity in the context of flow conveyance down Stillwater Creek.

For the most part, the energy grade line and hydraulic grade line are very similar. In the section downstream of the confluence (Section 50), the EGL rises to about 0.2m above HGL. The channel has increased flow in this area and, moreover, it steepens in this reach to roughly 0.5% before it reaches the short falls at Section 10. Consequently, the water is largely contained within the rock wall bank and velocities increase to more than 2.0m/s (approximately 0.2m of velocity head) compared with much more slowly moving water upstream. At Section 60, however, there is an EGL spike of 0.54m which can be attributed to the higher velocities at the culvert outlet due to the increase in head upstream of the crossing.

Table 4.1 1:100 Year Water Elevations – Existing Conditions

Cross-section	Flow (m3/s)	Water Surface Elevation (m)	Energy Grade Line Elevation (m)
10	26.3	61.80	62.03
20	26.3	63.57	63.76
30	26.3	64.40	64.60
40	26.3	65.04	65.21
50	14.2	65.32	65.42
60	14.2	65.28	65.82
80	14.2	65.98	66.01
90	14.2	66.03	66.04
95	14.2	66.05	66.06
100	14.2	66.06	66.07
120	14.2	66.17	66.35
130	14.2	66.37	66.37
140	14.2	66.38	66.38
150	14.2	66.38	66.38



FLOODPLAIN DELINEATION - EXISTING CONDITIONS

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

FIGURE 4.1

McCORMICK RANKIN CORPORATION
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DRAWING NAME: I:\KITCHENER\MRC\DRAWINGS\7400-7599\7499 - WEST TRANSITWAY EXTENSION\REPORT EXHIBITS\7499 FIGURE 4-1.DWG

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4.2 Post Transitway Conditions

The cross sectional topographic information in the existing conditions HEC-RAS model was modified to include the construction of the transitway and station (see Figure 4.2). The modifications included the removal of the storage in the channel on the north side of Highway 417 and the filling to represent the construction of the transit station. Table 4.2 shows the 1:100 year water levels along the reach of Stillwater Creek under these conditions. As shown, the 1:100 year water levels are the same as existing conditions.

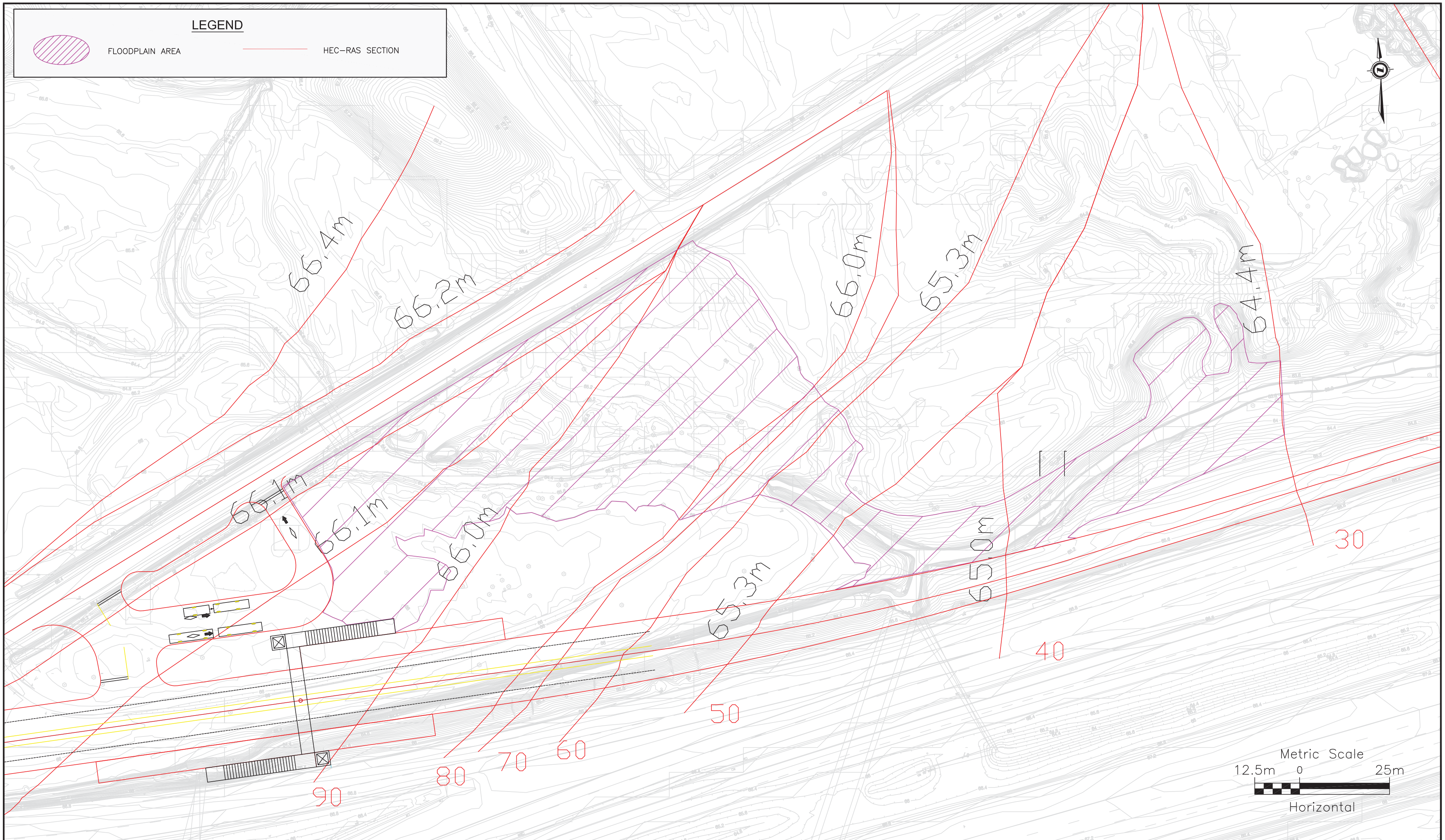
Table 4.2 1:100 Year Water Elevations-Post Transitway Conditions

Cross-section	Flow (m3/s)	Water Surface Elevation (m)	Energy Grade Line Elevation (m)
10	26.3	61.80	62.03
20	26.3	63.57	63.76
30	26.3	64.40	64.60
40	26.3	65.04	65.21
50	14.2	65.32	65.42
60	14.2	65.28	65.82
80	14.2	65.98	66.01
90	14.2	66.03	66.04
95	14.2	66.05	66.06
100	14.2	66.06	66.07
120	14.2	66.17	66.35
130	14.2	66.37	66.37
140	14.2	66.38	66.38
150	14.2	66.38	66.38

4.3 Floodplain Impacts

With the modifications of the 1:100 year flood plain with the construction of the West Transitway extension there will be a loss of overall flood plain storage with the filling of existing flood plain area. As shown on Figure 4.2, there is minimal encroachment into the 1:100 year flood plain for the construction of the transit station. The maximum existing depth of flooding, during the 1:100 year flood at the proposed location of the station is less than 0.1 m.

There is a total loss in flood plain storage of approximately 2850 m^3 with the proposed construction of the transitway and station, but this is almost entirely due to the loss of the open channel along the north side of Highway 417. Since the loss of flood plain storage associated with the outlet channel from the existing stormwater management pond is not in the active flow area of Stillwater Creek, the flow velocities and travel time were reviewed to assess the impact of the loss of this backwater storage area. Table 4.3 shows the velocities for the left and right overbank and channel areas as defined in the HEC-RAS model.



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DRAWING NAME: I:\KITCHENER\MRC\DRAWINGS\7400–7599\7499 – WEST TRANSITWAY EXTENSION\REPORT EXHIBITS\7499 FIGURE 4–2.DWG

McCORMICK RANKIN CORPORATION
A member of MMM GROUP

FLOODPLAIN DELINEATION - PROPOSED CONDITIONS

WEST TRANSITWAY EXTENSION - BAYSHORE TO MOODIE

FIGURE 4.2

Table 4.3 1:100 Year Velocity Values

	Existing Conditions			Post Transitway Conditions			Increase in Velocity		
Cross Section	Left Overbank Velocity (m/s)	Channel Velocity (m/s)	Right Overbank Velocity (m/s)	Left Overbank Velocity (m/s)	Channel Velocity (m/s)	Right Overbank Velocity (m/s)	Left Overbank (m/s)	Channel (m/s)	Right Overbank (m/s)
30	0.00	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00
40	0.00	1.81	0.00	0.00	1.81	0.00	0.00	0.00	0.00
50	0.17	1.45	0.00	0.17	1.45	0.00	0.00	0.00	0.00
60	0.00	3.27	0.00	0.00	3.27	0.00	0.00	0.00	0.00
80	0.24	0.80	0.21	0.24	0.80	0.21	0.00	0.00	0.00
90	0.26	0.68	0.15	0.26	0.68	0.16	0.00	0.00	0.01
95	0.21	0.61	0.07	0.21	0.61	0.10	0.00	0.00	0.03
100	0.09	0.28	0.03	0.09	0.28	0.03	0.00	0.00	0.00
120	0.00	1.87	0.00	0.00	1.87	0.00	0.00	0.00	0.00
130	0.09	0.28	0.07	0.09	0.27	0.07	0.00	-0.01	0.00
140	0.05	0.24	0.08	0.05	0.24	0.08	0.00	0.00	0.00
150	0.10	0.27	0.11	0.10	0.27	0.11	0.00	0.00	0.00

As shown in the table, the velocities are largely the same except for some slight differences at Sections 90, 95 and 130. These increased velocities are generally not erosive. From this assessment it is concluded that the flood plain storage provided in the open channel on the north side of Highway 417 is not effective in flow conveyance or flood plain management for Stillwater Creek. Therefore the elimination of this backwater volume will not have a detrimental impact on overall flood plain or result in an increase in flood risk on Stillwater Creek.

There is a residential area downstream of the study reach. The impact on the flood plain of Stillwater Creek of the construction of the West Transitway will not directly affect this reach of the area. However the loss of flood plain storage could change the timing of the conveyance of flow through the subject reach which could result in an increase in downstream peak flows. As shown in Table 4.3 there are only minimal changes in the 1:100 year flow velocities through the reach. The travel time from the HEC-RAS model was also reviewed to determine and assess any changes. Although the HEC-RAS program completes calculations from the downstream cross-section in an upstream direction, the cumulative travel time is still valid for the subject reach. Table 4.3 shows the cumulative travel by cross-section. As shown in the table, the overall travel time for the 1:100 year flow through the subject reach is 0.72 hours (43 minutes) for both the existing and post-development conditions.

The drainage area of Stillwater Creek upstream of the discharge point from the future West Transitway is over 2000 ha (Basins A1 and A2) and the total remaining drainage area, to the Ottawa River, (Basin A3) is 132 ha. The time to peak of the two upstream drainage basins is over 9 hours for the 12 hour SCS design storm. Therefore the overall maximum peak flow in Stillwater Creek will be produced from this large upstream drainage basin. Since the overall peak flow in the creek and the travel time through the reach will not change, the lose of flood plain storage, with the construction of the West Transitway Extension, will also not increase downstream flood risk.

Table 4.3 Cumulative 1:100-year Travel Time (hours)

Cross-section	Pre-development	Post-development	Change
[redacted]	[redacted]	[redacted]	[redacted]
150	0.72	0.72	0.00
140	0.5	0.49	0.01
130	0.16	0.16	0.00
120	0.16	0.15	0.01
100	0.15	0.15	0.00
95	0.11	0.11	0.00
90	0.09	0.09	0.00
80	0.05	0.05	0.00
60	0.05	0.05	0.00
50	0.05	0.05	0.00
40	0.04	0.04	0.00
30	0.03	0.03	0.00
20	0.01	0.01	0.00

5.0 Conclusions and Recommendations

The purpose of this study was to define the limit of the existing 1:100 year flood plain for Stillwater Creek in the area of Corkstown Road and Highway 417 (Cross-Section 30 upstream) and potential impact on that flood plain and flow conveyance after the construction of the West Transitway Extension and station located directly east of Corkstown Road. After the completion of this study it can be concluded that:

1. The water levels shown in Table 4.1 and the area shown on Figure 4.1 represent the extent of the existing 1:100 year flood plain of Stillwater Creek.
2. The water levels shown in Table 4.2 and the area shown on Figure 4.2 represent the change in the extent and elevation of 1:100 year flood plain of Stillwater Creek after the construction of the transitway extension.
3. The loss of flood plain storage with the construction of the transitway extension, mainly due to the piping of the outlet channel along the north side of Highway 417, does not result in any detrimental impact on flood levels, flood flow conveyance or downstream flood risk and thus does not need to be replaced.

It is recommended that:

1. The station and transitway be constructed at an elevation a minimum of 0.3 m above the elevation shown on Table 4.2 to provide adequate flood proofing and no direct flooding from Stillwater Creek.
2. Storm sewer infrastructure be designed for the 25-year return period to be consistent with the level of service as detailed in the City of Ottawa Sewer Design Guidelines.

Appendix A – HEC-RAS Results

HEC-RAS Plan: ExCond1 River: Stillwater Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	150	2-year	4.10	64.47	65.96		65.97	0.000053	0.21	44.28	158.26	0.07
1	150	5-year	6.50	64.47	66.09		66.09	0.000053	0.23	64.16	160.91	0.07
1	150	10-year	9.20	64.47	66.17		66.17	0.000066	0.27	76.84	162.96	0.08
1	150	100-year	14.20	64.47	66.38		66.38	0.000053	0.27	112.11	168.88	0.07
1	140	2-year	4.10	64.47	65.96	64.78	65.96	0.000041	0.19	37.02	184.34	0.06
1	140	5-year	6.50	64.47	66.08	64.89	66.09	0.000045	0.21	60.00	186.51	0.06
1	140	10-year	9.20	64.47	66.16	64.99	66.16	0.000057	0.25	76.47	227.85	0.07
1	140	100-year	14.20	64.47	66.38	65.14	66.38	0.000042	0.24	127.18	255.59	0.06
1	130	2-year	4.10	64.26	65.96		65.96	0.000023	0.17	42.83	108.05	0.05
1	130	5-year	6.50	64.26	66.08		66.08	0.000037	0.22	59.62	183.23	0.06
1	130	10-year	9.20	64.26	66.15		66.16	0.000051	0.27	74.98	219.35	0.07
1	130	100-year	14.20	64.26	66.37		66.37	0.000042	0.27	126.80	249.95	0.06
1	120	2-year	4.10	64.26	65.93	64.75	65.95	0.000239	0.62	6.63	88.91	0.15
1	120	5-year	6.50	64.26	66.03	64.92	66.07	0.000499	0.93	7.01	167.23	0.22
1	120	10-year	9.20	64.26	66.06	65.09	66.15	0.000944	1.29	7.13	198.18	0.31
1	120	100-year	14.20	64.26	66.17	65.36	66.35	0.001836	1.87	7.58	266.81	0.43
1	110		Culvert									
1	100	2-year	4.10	64.26	65.93	64.73	65.95	0.000235	0.62	6.66	88.31	0.15
1	100	5-year	6.50	64.26	66.01	64.91	66.02	0.000026	0.14	56.65	114.19	0.05
1	100	10-year	9.20	64.26	66.03	65.07	66.03	0.000050	0.19	58.13	121.77	0.06
1	100	100-year	14.20	64.26	66.06	65.35	66.07	0.000104	0.28	63.07	144.32	0.09
1	95	2-year	4.10	64.26	65.93	64.74	65.94	0.000051	0.21	30.86	90.14	0.06
1	95	5-year	6.50	64.26	66.01	64.88	66.01	0.000090	0.30	36.52	107.37	0.09
1	95	10-year	9.20	64.26	66.02	65.01	66.02	0.000173	0.41	37.22	111.60	0.12
1	95	100-year	14.20	64.26	66.05	65.21	66.06	0.000369	0.61	39.75	126.84	0.18
1	90	2-year	4.10	64.26	65.93	64.80	65.93	0.000068	0.23	29.75	82.17	0.07
1	90	5-year	6.50	64.26	66.01	64.99	66.01	0.000123	0.32	34.57	91.31	0.10
1	90	10-year	9.20	64.26	66.01	65.20	66.02	0.000241	0.45	34.91	92.98	0.14
1	90	100-year	14.20	64.26	66.03	65.39	66.04	0.000528	0.68	36.33	99.47	0.20
1	80	2-year	4.10	64.27	65.93	64.93	65.93	0.000098	0.26	24.37	66.39	0.09
1	80	5-year	6.50	64.27	66.00	65.08	66.00	0.000172	0.36	29.40	78.04	0.12
1	80	10-year	9.20	64.27	65.99	65.22	66.00	0.000355	0.51	28.97	77.12	0.17
1	80	100-year	14.20	64.27	65.98	65.46	66.01	0.000894	0.80	28.15	75.32	0.26
1	70		Culvert									
1	60	2-year	4.10	64.10	64.74	64.67	64.92	0.009471	1.86	2.21	17.58	0.80
1	60	5-year	6.50	64.10	64.87	64.84	65.16	0.011848	2.39	2.72	20.54	0.92
1	60	10-year	9.20	64.10	65.00	65.00	65.41	0.013140	2.83	3.25	23.58	1.00
1	60	100-year	14.20	64.10	65.28	65.28	65.82	0.011953	3.27	4.34	39.81	1.00
1	50	2-year	4.10	63.90	64.58	64.46	64.68	0.007917	1.42	2.88	13.94	0.69
1	50	5-year	6.50	63.90	64.81	64.61	64.91	0.005562	1.41	4.62	18.23	0.60
1	50	10-year	9.20	63.90	64.95	64.74	65.08	0.005734	1.55	5.92	20.93	0.63
1	50	100-year	14.20	63.90	65.32	64.94	65.42	0.003404	1.45	9.88	29.04	0.51
1	40	2-year	7.60	63.48	64.39		64.47	0.003609	1.26	6.01	9.17	0.50
1	40	5-year	11.90	63.48	64.58		64.70	0.004260	1.50	7.95	10.64	0.55
1	40	10-year	15.10	63.48	64.72		64.84	0.004850	1.59	9.48	12.80	0.59
1	40	100-year	26.30	63.48	65.04		65.21	0.005680	1.81	14.55	18.46	0.65
1	30	2-year	7.60	63.10	63.98		64.06	0.006627	1.30	5.85	13.72	0.63
1	30	5-year	11.90	63.10	64.11		64.23	0.007516	1.51	7.88	16.25	0.69
1	30	10-year	15.10	63.10	64.19		64.33	0.007848	1.64	9.22	17.39	0.72
1	30	100-year	26.30	63.10	64.40		64.60	0.009031	2.00	13.13	20.37	0.80
1	20	2-year	7.60	62.77	63.33	63.33	63.42	0.011244	1.61	7.40	36.31	0.82
1	20	5-year	11.90	62.77	63.40	63.40	63.52	0.012223	1.88	10.00	37.72	0.88
1	20	10-year	15.10	62.77	63.44	63.44	63.58	0.013096	2.05	11.57	38.55	0.92
1	20	100-year	26.30	62.77	63.57	63.57	63.76	0.014257	2.49	16.65	42.61	1.00
1	10	2-year	7.60	60.93	61.35	61.35	61.52	0.017329	1.86	4.08	11.58	1.00
1	10	5-year	11.90	60.93	61.50	61.50	61.70	0.015135	1.97	6.19	17.76	0.96
1	10	10-year	15.10	60.93	61.59	61.59	61.79	0.012633	2.03	8.15	26.63	0.91
1	10	100-year	26.30	60.93	61.80	61.80	62.03	0.009457	2.22	15.55	41.86	0.83

HEC-RAS Plan: FutCond1   River: Stillwater Creek   Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
1	150	2-year	4.10	64.47	65.96		65.97	0.000053	0.21	44.28	158.26	0.07
1	150	5-year	6.50	64.47	66.09		66.09	0.000053	0.23	64.16	160.91	0.07
1	150	10-year	9.20	64.47	66.17		66.17	0.000066	0.27	76.84	162.96	0.08
1	150	100-year	14.20	64.47	66.38		66.38	0.000053	0.27	112.10	168.88	0.07
1	140	2-year	4.10	64.47	65.96	64.78	65.96	0.000041	0.19	37.02	184.34	0.06
1	140	5-year	6.50	64.47	66.08	64.89	66.09	0.000045	0.21	60.00	186.51	0.06
1	140	10-year	9.20	64.47	66.16	64.99	66.16	0.000057	0.25	76.46	227.84	0.07
1	140	100-year	14.20	64.47	66.38	65.14	66.38	0.000042	0.24	127.16	255.58	0.06
1	130	2-year	4.10	64.26	65.96		65.96	0.000023	0.17	42.83	108.05	0.05
1	130	5-year	6.50	64.26	66.08		66.08	0.000037	0.22	59.62	183.23	0.06
1	130	10-year	9.20	64.26	66.15		66.16	0.000051	0.27	74.98	219.34	0.07
1	130	100-year	14.20	64.26	66.37		66.37	0.000042	0.27	126.78	249.94	0.06
1	120	2-year	4.10	64.26	65.93	64.75	65.95	0.000239	0.62	6.63	88.92	0.15
1	120	5-year	6.50	64.26	66.03	64.92	66.07	0.000499	0.93	7.01	167.23	0.22
1	120	10-year	9.20	64.26	66.06	65.09	66.14	0.000944	1.29	7.13	198.17	0.31
1	120	100-year	14.20	64.26	66.17	65.36	66.35	0.001836	1.87	7.58	266.79	0.43
1	110		Culvert									
1	100	2-year	4.10	64.26	65.93	64.73	65.95	0.000235	0.62	6.66	88.31	0.15
1	100	5-year	6.50	64.26	66.01	64.91	66.02	0.000026	0.14	56.65	114.19	0.05
1	100	10-year	9.20	64.26	66.03	65.07	66.03	0.000050	0.19	58.13	121.76	0.06
1	100	100-year	14.20	64.26	66.06	65.35	66.07	0.000104	0.28	63.06	144.28	0.09
1	95	2-year	4.10	64.26	65.93		65.94	0.000051	0.21	30.86	70.80	0.06
1	95	5-year	6.50	64.26	66.01		66.01	0.000090	0.30	36.50	78.38	0.09
1	95	10-year	9.20	64.26	66.02		66.02	0.000173	0.41	37.17	79.09	0.12
1	95	100-year	14.20	64.26	66.05		66.06	0.000368	0.61	39.39	82.78	0.18
1	90	2-year	4.10	64.26	65.93		65.93	0.000068	0.23	29.75	61.62	0.07
1	90	5-year	6.50	64.26	66.01		66.01	0.000123	0.32	34.56	68.40	0.10
1	90	10-year	9.20	64.26	66.01		66.02	0.000241	0.45	34.90	68.88	0.14
1	90	100-year	14.20	64.26	66.03		66.04	0.000528	0.68	36.22	70.75	0.20
1	80	2-year	4.10	64.27	65.93	64.93	65.93	0.000098	0.26	24.37	66.39	0.09
1	80	5-year	6.50	64.27	66.00	65.08	66.00	0.000172	0.36	29.40	78.04	0.12
1	80	10-year	9.20	64.27	65.99	65.22	66.00	0.000355	0.51	28.97	77.12	0.17
1	80	100-year	14.20	64.27	65.98	65.46	66.01	0.000895	0.80	28.14	75.30	0.26
1	70		Culvert									
1	60	2-year	4.10	64.10	64.74	64.67	64.92	0.009471	1.86	2.21	10.38	0.80
1	60	5-year	6.50	64.10	64.87	64.84	65.16	0.011848	2.39	2.72	12.26	0.92
1	60	10-year	9.20	64.10	65.00	65.00	65.41	0.013140	2.83	3.25	14.18	1.00
1	60	100-year	14.20	64.10	65.28	65.28	65.82	0.011953	3.27	4.34	27.56	1.00
1	50	2-year	4.10	63.90	64.58		64.68	0.007917	1.42	2.88	6.71	0.69
1	50	5-year	6.50	63.90	64.81		64.91	0.005562	1.41	4.62	8.38	0.60
1	50	10-year	9.20	63.90	64.95		65.08	0.005734	1.55	5.92	9.43	0.63
1	50	100-year	14.20	63.90	65.32		65.42	0.003404	1.45	9.88	13.46	0.51
1	40	2-year	7.60	63.48	64.39		64.47	0.003609	1.26	6.01	9.17	0.50
1	40	5-year	11.90	63.48	64.58		64.70	0.004260	1.50	7.95	10.64	0.55
1	40	10-year	15.10	63.48	64.72		64.84	0.004850	1.59	9.48	12.80	0.59
1	40	100-year	26.30	63.48	65.04		65.21	0.005680	1.81	14.55	18.46	0.65
1	30	2-year	7.60	63.10	63.98		64.06	0.006627	1.30	5.85	13.72	0.63
1	30	5-year	11.90	63.10	64.11		64.23	0.007516	1.51	7.88	16.25	0.69
1	30	10-year	15.10	63.10	64.19		64.33	0.007848	1.64	9.22	17.39	0.72
1	30	100-year	26.30	63.10	64.40		64.60	0.009031	2.00	13.13	20.37	0.80
1	20	2-year	7.60	62.77	63.33	63.33	63.42	0.011244	1.61	7.40	36.31	0.82
1	20	5-year	11.90	62.77	63.40	63.40	63.52	0.012223	1.88	10.00	37.72	0.88
1	20	10-year	15.10	62.77	63.44	63.44	63.58	0.013096	2.05	11.57	38.55	0.92
1	20	100-year	26.30	62.77	63.57	63.57	63.76	0.014257	2.49	16.65	42.61	1.00
1	10	2-year	7.60	60.93	61.35	61.35	61.52	0.017329	1.86	4.08	11.58	1.00
1	10	5-year	11.90	60.93	61.50	61.50	61.70	0.015135	1.97	6.19	17.76	0.96
1	10	10-year	15.10	60.93	61.59	61.59	61.79	0.012633	2.03	8.15	26.63	0.91
1	10	100-year	26.30	60.93	61.80	61.80	62.03	0.009457	2.22	15.55	41.86	0.83

APPENDIX B

EROSION CRITERION REPORT

TECHNICAL MEMORANDUM

JTB Environmental Systems Inc.

JTBES

Fluvial Geomorphology Natural Channel Design Coastal Processes Erosion Control

Tim Dickinson, M.Pl., MCIP, RPP
MMM Group Limited
Senior Project Planner
1111 Prince of Wales Drive, Suite 302
Ottawa ON K2C 3T2

13 December 2010

VIA EMAIL

Re: West Transitway Stillwater Creek Culvert SWM Thresholds: Our File 20090928

Mr. Dickinson,

The extension of impermeable surfaces which are created through the design and implementation of the proposed West Transitway system will result in additional runoff from storm events than occur under existing conditions. The delivery of this stormwater to the receiving system (Stillwater Creek) is subject to threshold analysis to prevent excessive erosion at the discharge location and potential siltation downstream.

JTBES has undertaken a detailed study to determine appropriate erosion thresholds for stormwater discharge from the Transitway site. This analysis included:

- Survey of cross-sections (6) on Stillwater Creek to determine existing conditions
- Grain size analysis of four subsets of channel segments (upstream riffle, downstream riffle, fine accumulated sediment on the bed and bed subpavement) in the vicinity of the proposed creek realignment
- Velocity analysis relative to D_{50} results of bed grain size
- Velocity analysis relative to bank materials

SURVEY

Six (6) cross-sections were surveyed to determine channel characteristics and parameters as they relate to erosion and ability of the creek to withstand additional stormwater discharge. Hydraulic calculations based on channel geometry have bee undertaken as part of the threshold determination.

Appendix 1 contains the cross-sections used in the analysis.

GRAIN SIZE ANALYSIS

Stillwater Creek is a diverse system with a range of substrate characteristics, ranging from bedrock outcrops upstream of the east trail crossing at Corkstown Road to cobble/gravel riffles to sand/silt deposition areas in the vicinity of the tributary confluence east of Moodie Drive.

In order to assess the impacts of stormwater discharge on sediment erosion and transport four samples were taken and sent for grain size interpretation. The samples represent: 1) riffle upstream of the tributary confluence; 2) riffle downstream of the tributary confluence; 3) surface depositional material downstream of the tributary confluence; and 4) sub-pavement material downstream of the tributary confluence (beneath the surface depositional materials).

Grain size plots are found in Appendix 2.

CRITICAL VELOCITY ANALYSIS

Table 1 shows the results of the grain size analysis for each of the samples with the corresponding critical velocities for entrainment.

Table 1: Grain Size Results with Corresponding Critical Velocities for Entrainment

	Grain Diameter (mm)	Critical Velocity (m sec^{-1})
Upstream Riffle		
D_{16}	12.0	0.620
D_{35}	27.0	0.901
D_{50}	40.0	1.079
D_{65}	57.0	1.270
D_{84}	110.0	1.718
D_{95}	180.0	2.154
Downstream Riffle		
D_{16}	18.0	0.747
D_{35}	53.0	1.228
D_{50}	79.0	1.475
D_{65}	110.0	1.718
D_{84}	170.0	2.098
D_{95}	270.0	2.596
Surface Deposition		
D_{16}	---	--
D_{35}	0.190	0.090
D_{50}	0.250	0.105
D_{65}	0.400	0.129
D_{84}	0.930	0.191
D_{95}	3.50	0.352
Subpavement Sample		
D_{16}	1.20	0.215
D_{35}	3.60	0.356
D_{50}	7.90	0.514
D_{65}	13.0	0.643
D_{84}	20.0	0.784
D_{95}	27.0	0.901

The degree to which the critical velocity has been exceeded for the D_{50} grain size under all conditions has been assessed through hydraulic analysis, results are found in Appendix 3.

Tables in Appendix 3 show the existing condition velocities relative to critical velocities for entrainment for all grain samples, for the D_{50} grain size velocity. A value of less than 1.0 indicates the grains will remain stable and not erode; values greater than 1.0 indicate the grains will be entrained under existing conditions flow.

In all cases entrainment of the D_{50} sediment size is exceeded under less-than-bankfull conditions, indicating that the Stillwater Creek system is an energy-rich system and is actively eroding and depositing sediment within the channel cross-section.

BANK MATERIAL VELOCITY ANALYSIS

Results from the sediment analysis indicate the Stillwater Creek system is an energy rich system, which erodes and deposits bed material under rising and falling hydrographs under existing conditions.

The ability of the creek to maintain this sediment regime factors in to the bank erosion condition: as long as there is bed material (which is less cohesive than bank material and therefore more susceptible to erosion and transport) available for transport, then bank erosion will be minimal.

That said, with the potential for land use change and an alteration to sediment supply, bed material may not always be available to maintain this process.

Erosion along banks can be caused by flows that exceed the theoretical critical velocity for entrainment of the cohesive bank material. Assessment of the conditions of the creek show that the banks are comprised of consolidated clay materials, ranging from coarse to fine clay. When these materials are exposed to flowing water, velocities of between 0.225 metres per second (coarse clay) and 0.400 metres per second (fine clay) are required to entrain (erode) these materials (ref. Hjulstrom, 1935).

THRESHOLD FOR STORMWATER DISCHARGE

Analysis shows that stormwater discharge at a rate not exceeding 0.225 metres per second velocity is the optimal discharge, based on the following:

1. It is the minimum threshold for bank erosion of coarse clay materials according to Hjustrom;
2. It will not entrain any of the D_{50} sediments for the upstream or downstream riffles nor the subpavement materials in the fine sediment deposition zone near the tributary confluence;
3. It will allow for the flushing of fine sediments (as indicated by the surface deposition grain size results), exposing the natural bed of the creek.

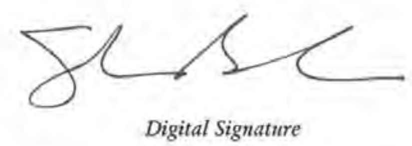
Therefore, it is recommended that the threshold discharge for stormwater from the Transitway footprint to Stillwater Creek should not exceed a value of 0.225 metres per second velocity.

SUMMARY

Threshold analysis of creek conditions in the vicinity of stormwater discharge has shown that the critical discharge for release of stormwater should be less than 0.225 metres per second velocity, based on sediment and section analysis of Stillwater Creek.

I trust this memo is sufficient for your immediate needs. If you require further information as we move forward with this project please do not hesitate to contact me.

Respectfully Submitted,

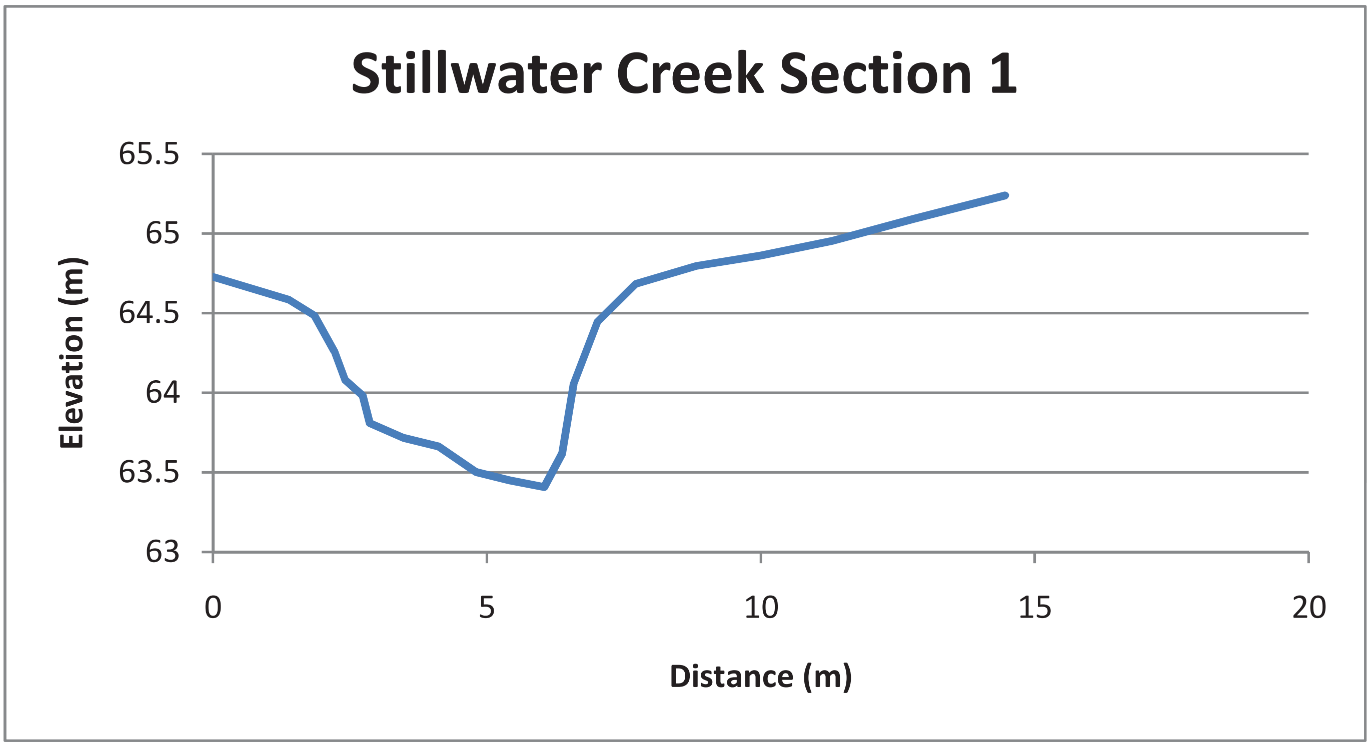


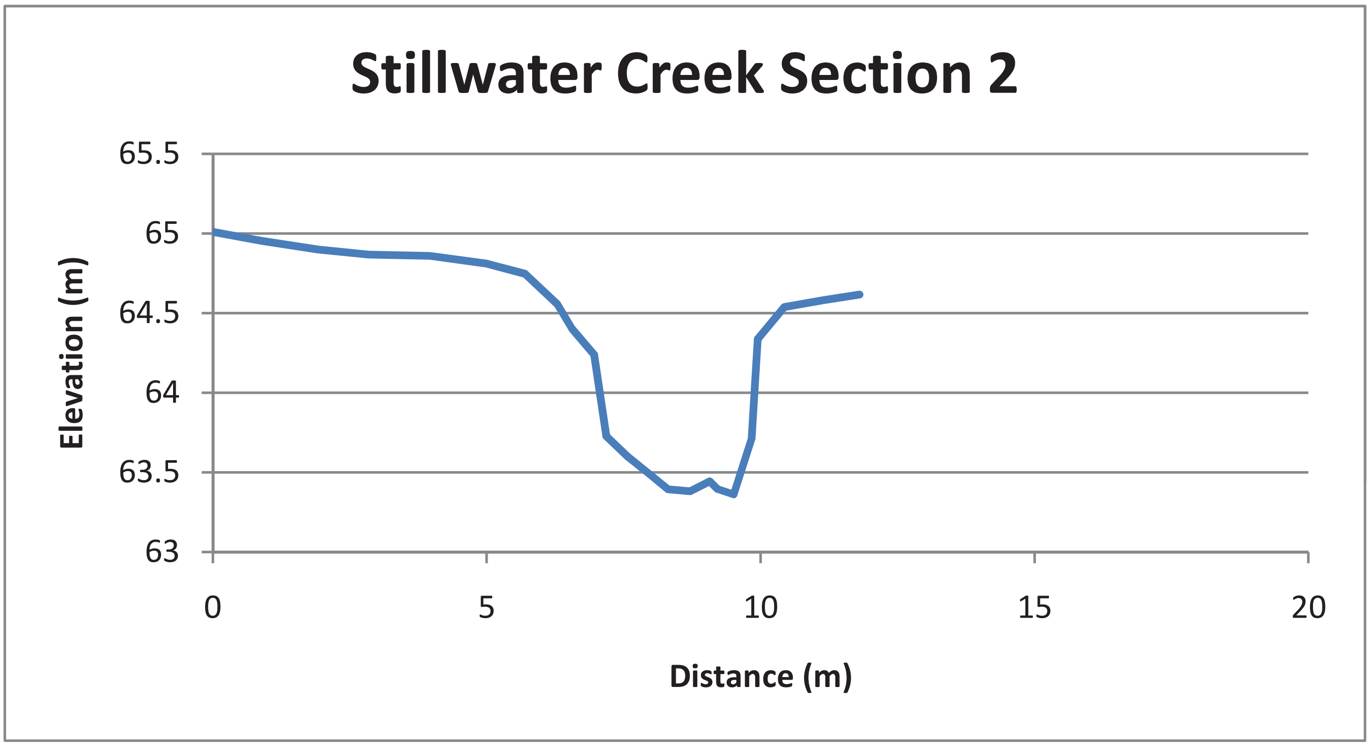
John T. Beebe, PhD
JTB Environmental Systems Inc.
Cambridge, Ontario.

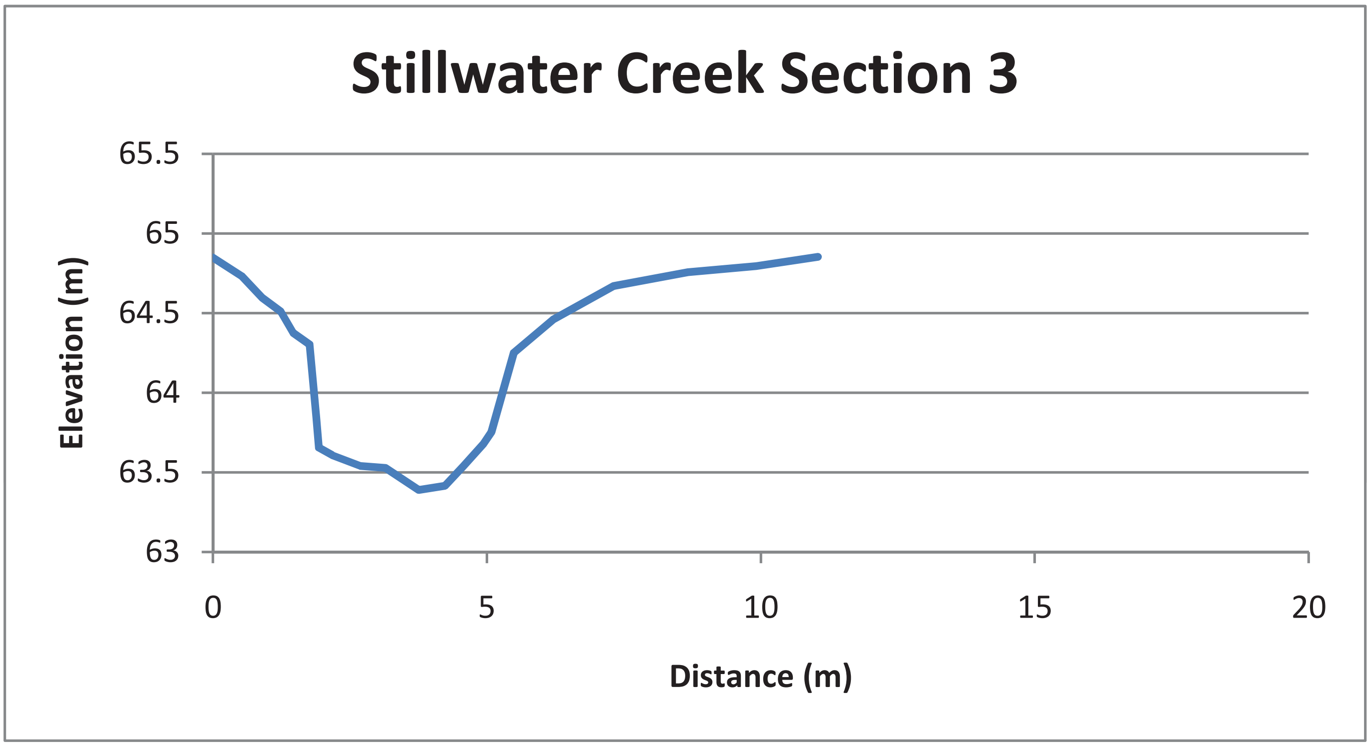
Append: **Appendix 1: Cross-sections**
Appendix 2: Grain Size Results
Appendix 3: Critical Velocity Tables

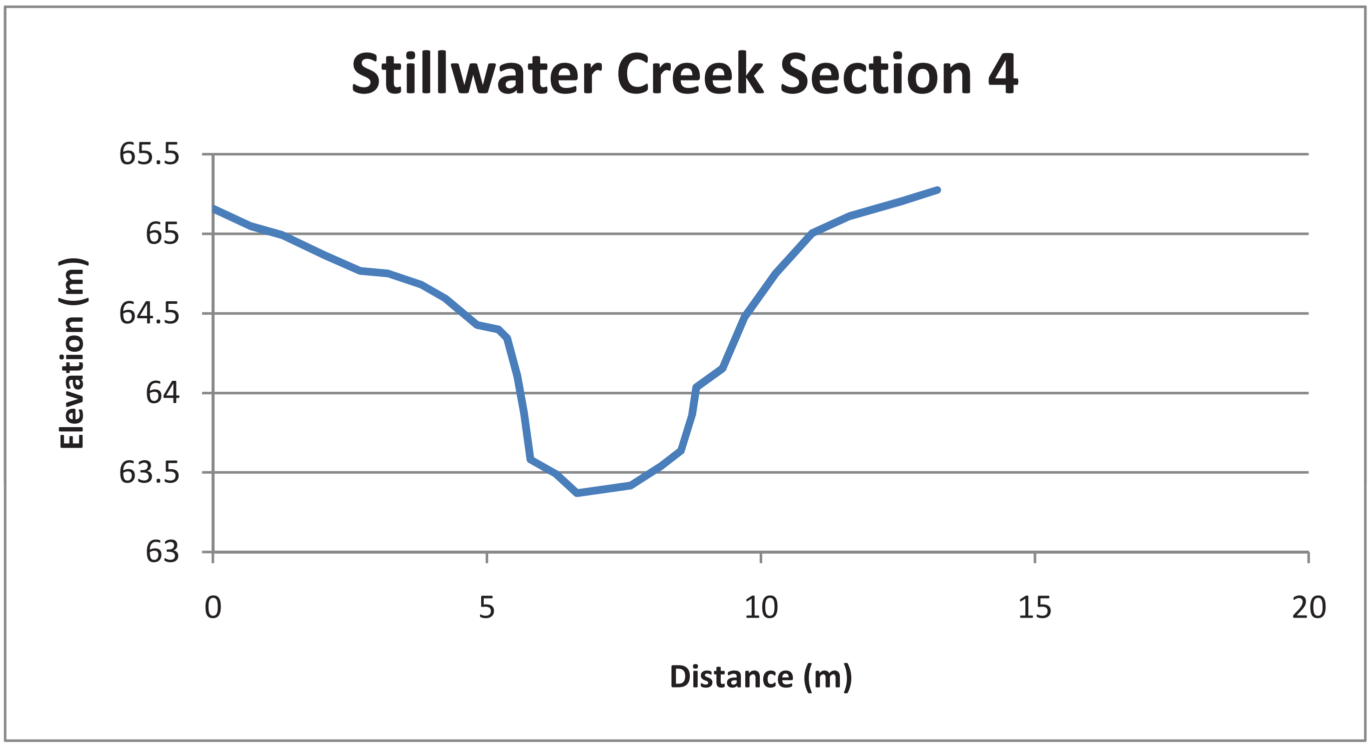
Appendix 1:

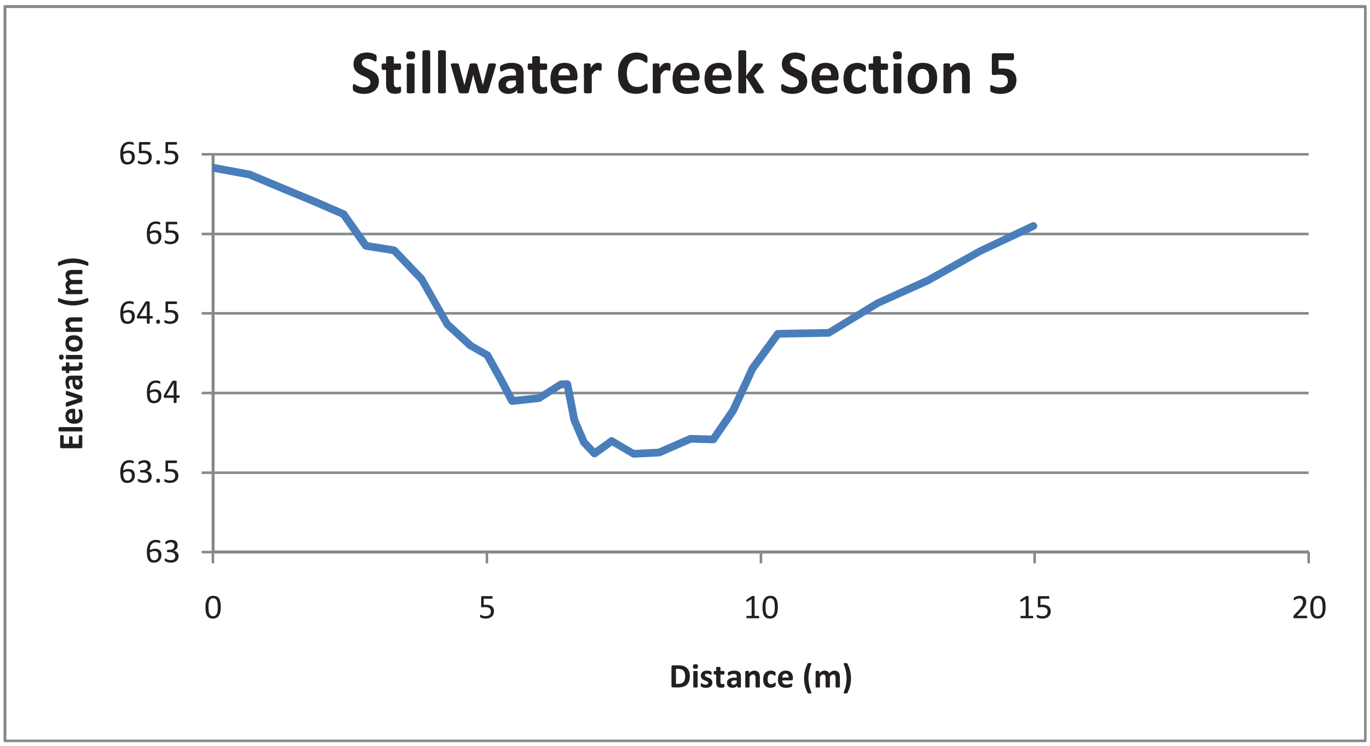
Cross-sections, Stillwater Creek


Stillwater Creek Section 1
Elevation (m)
65.5
65
64.5
64
63.5
63
0
5
10
15
20
Distance (m)

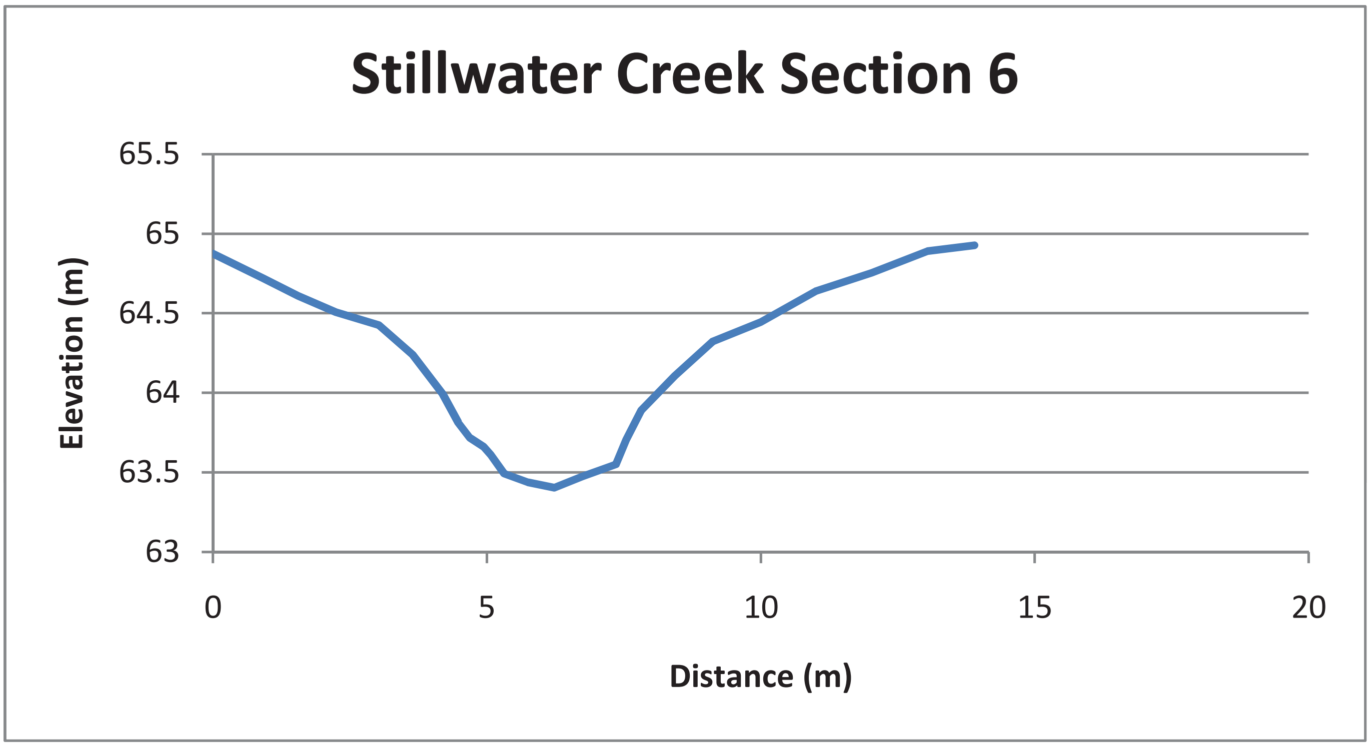

Stillwater Creek Section 2
Elevation (m)
65.5
65
64.5
64
63.5
63
0
5
10
15
20
Distance (m)


Stillwater Creek Section 3
65.5
65
64.5
64
63.5
63
Elevation (m)
0
5
10
15
20
Distance (m)


Stillwater Creek Section 4
65.5
65
64.5
64
63.5
63
0
5
10
15
20
Elevation (m)
Distance (m)



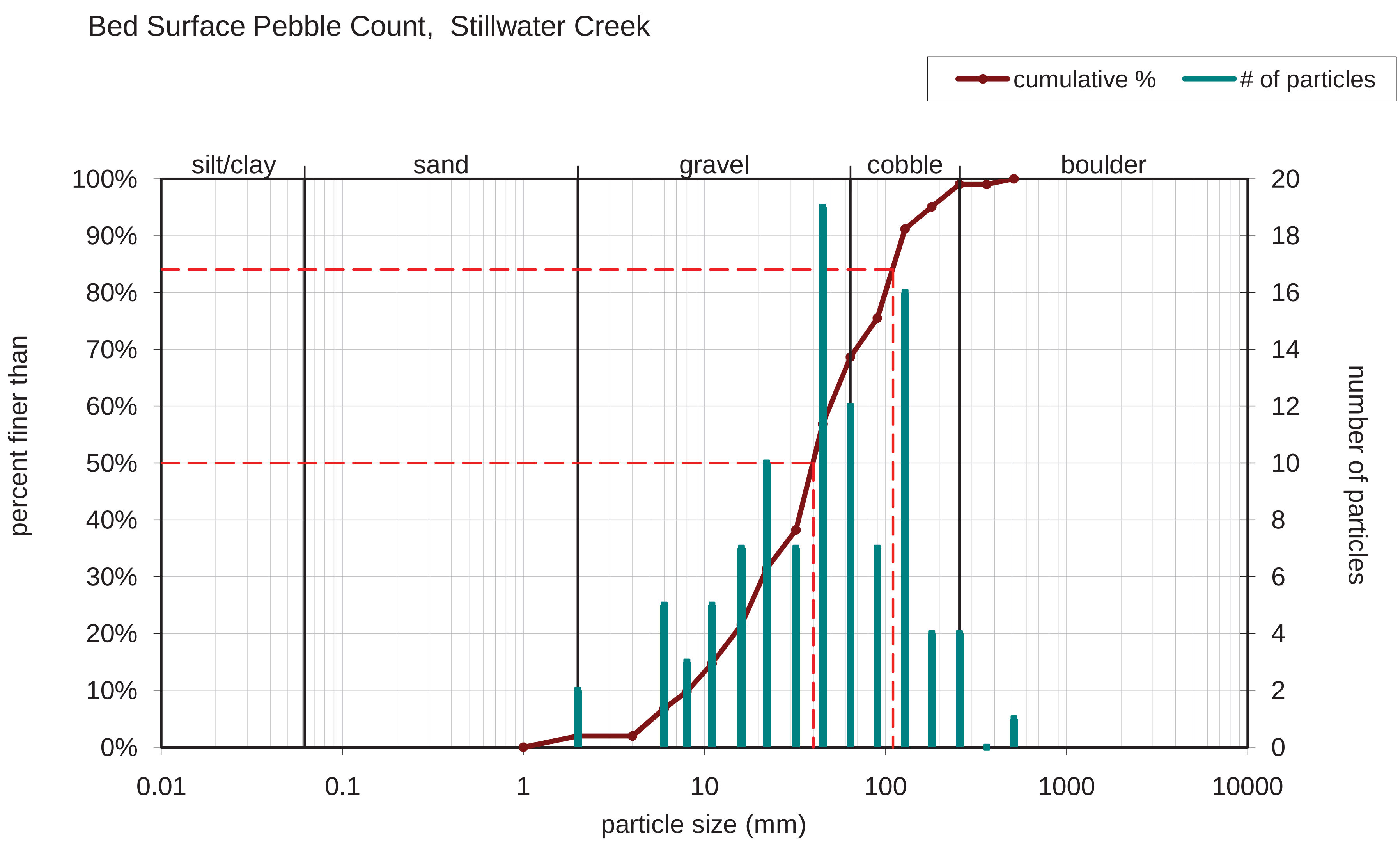
Stillwater Creek Section 5
Elevation (m)
65.5
65
64.5
64
63.5
63
0
5
10
15
20
Distance (m)



Stillwater Creek Section 6
65.5
65
64.5
64
63.5
63
Elevation (m)
0
5
10
15
20
Distance (m)

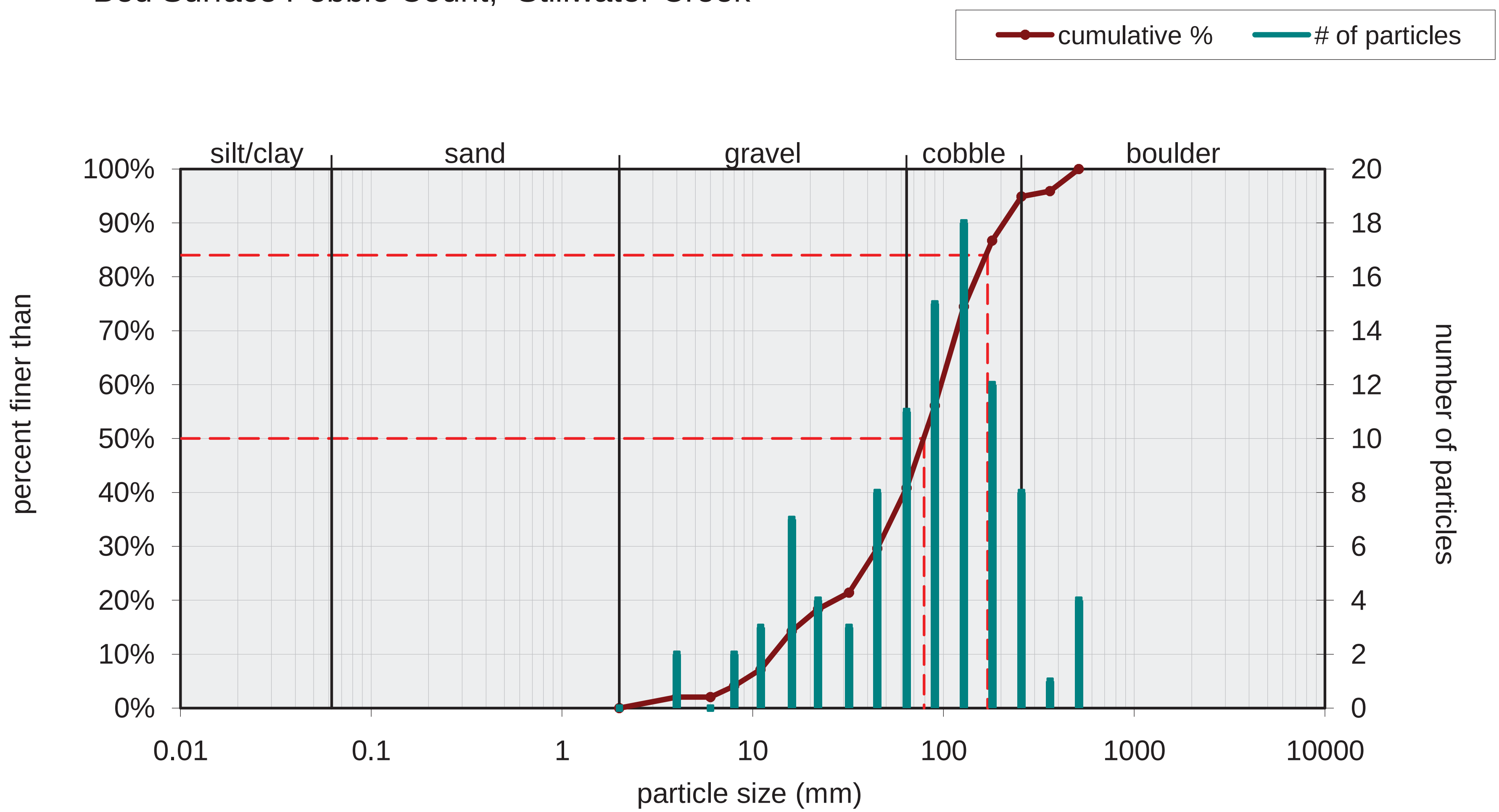
Appendix 2:

Grain Size Analysis Results

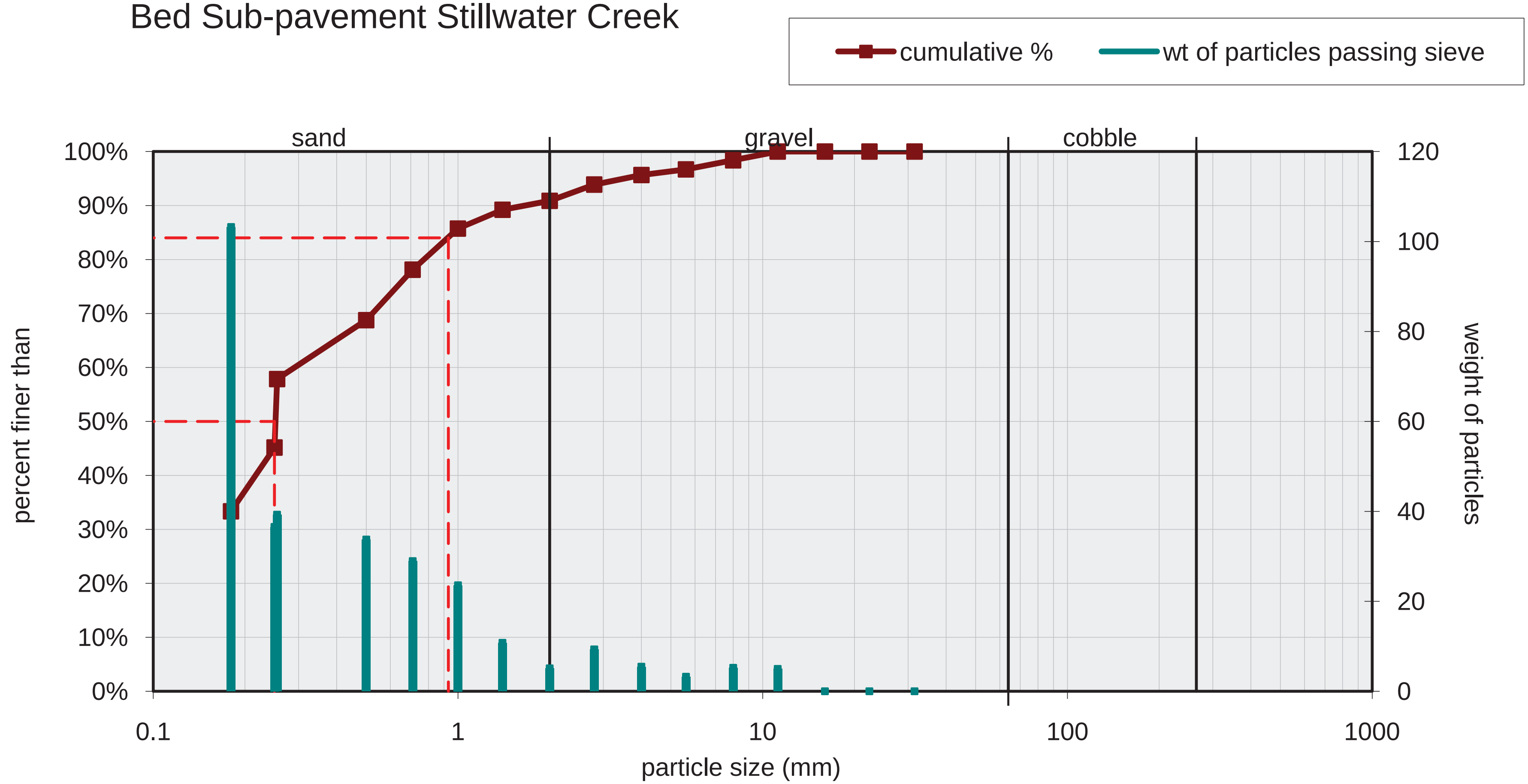


Bed Surface Pebble Count, Stillwater Creek
cumulative %
# of particles
silt/clay
sand
gravel
cobble
boulder
percent finer than
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
number of particles
20
18
16
14
12
10
8
6
4
2
0
0.01
0.1
1
10
100
1000
10000
particle size (mm)

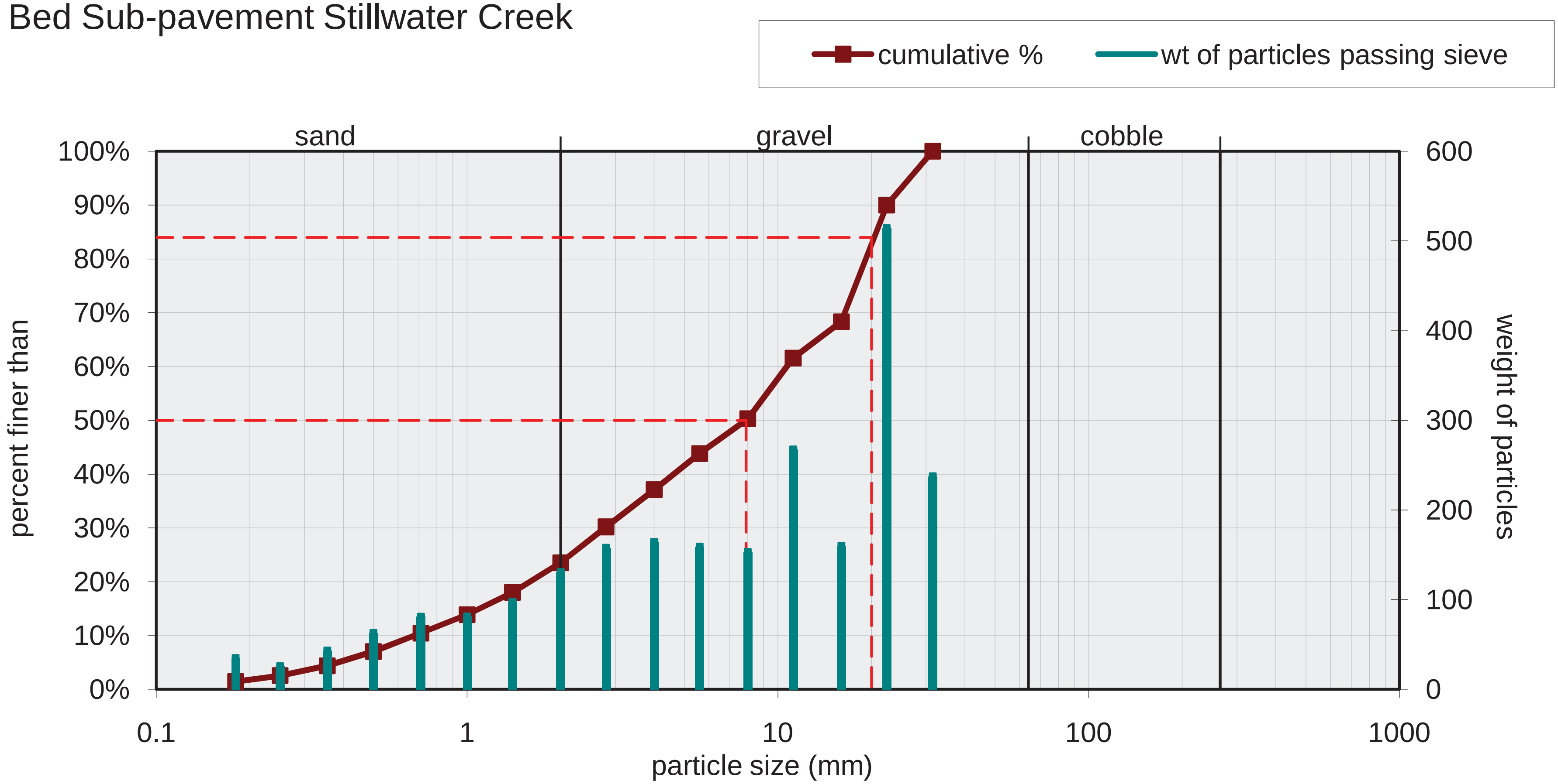
Bed Surface Pebble Count, Stillwater Creek



Bed Sub-pavement Stillwater Creek



Bed Sub-pavement Stillwater Creek



Appendix 3:

Critical Velocity Tables

Stillwater Creek Section 1

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.41	0.00	0.032	0.03	0.02	0.30	0.06
63.42	0.00	0.092	0.09	0.06	0.88	0.18
63.43	0.00	0.136	0.13	0.09	1.30	0.26
63.44	0.00	0.174	0.16	0.12	1.66	0.34
63.45	0.00	0.208	0.19	0.14	1.98	0.40
63.46	0.01	0.244	0.23	0.17	2.32	0.47
63.47	0.01	0.276	0.26	0.19	2.63	0.54
63.48	0.01	0.305	0.28	0.21	2.90	0.59
63.49	0.02	0.333	0.31	0.23	3.17	0.65
63.50	0.02	0.36	0.33	0.24	3.43	0.70
63.51	0.03	0.395	0.37	0.27	3.76	0.77
63.52	0.04	0.43	0.40	0.29	4.10	0.84
63.53	0.05	0.462	0.43	0.31	4.40	0.90
63.54	0.06	0.493	0.46	0.33	4.70	0.96
63.55	0.07	0.522	0.48	0.35	4.97	1.02
63.56	0.09	0.55	0.51	0.37	5.24	1.07
63.57	0.10	0.576	0.53	0.39	5.49	1.12
63.58	0.12	0.602	0.56	0.41	5.73	1.17
63.59	0.13	0.626	0.58	0.42	5.96	1.22
63.60	0.15	0.65	0.60	0.44	6.19	1.26
63.61	0.17	0.673	0.62	0.46	6.41	1.31
63.62	0.19	0.695	0.64	0.47	6.62	1.35
63.63	0.21	0.718	0.67	0.49	6.84	1.40
63.64	0.23	0.74	0.69	0.50	7.05	1.44
63.65	0.26	0.762	0.71	0.52	7.26	1.48
63.66	0.28	0.783	0.73	0.53	7.46	1.52
63.67	0.30	0.792	0.73	0.54	7.54	1.54
63.68	0.33	0.798	0.74	0.54	7.60	1.55
63.69	0.35	0.805	0.75	0.55	7.67	1.57
63.70	0.37	0.813	0.75	0.55	7.74	1.58
63.71	0.40	0.821	0.76	0.56	7.82	1.60
63.72	0.43	0.832	0.77	0.56	7.92	1.62
63.73	0.46	0.85	0.79	0.58	8.10	1.65
63.74	0.50	0.867	0.80	0.59	8.26	1.69
63.75	0.54	0.884	0.82	0.60	8.42	1.72
63.76	0.58	0.9	0.83	0.61	8.57	1.75
63.77	0.62	0.917	0.85	0.62	8.73	1.78
63.78	0.66	0.933	0.86	0.63	8.89	1.82
63.79	0.70	0.949	0.88	0.64	9.04	1.85
63.80	0.75	0.965	0.89	0.65	9.19	1.88
63.81	0.80	0.982	0.91	0.67	9.35	1.91
63.82	0.85	1.006	0.93	0.68	9.58	1.96
63.83	0.91	1.031	0.96	0.70	9.82	2.01
63.84	0.97	1.054	0.98	0.71	10.04	2.05
63.85	1.03	1.078	1.00	0.73	10.27	2.10
63.86	1.09	1.101	1.02	0.75	10.49	2.14
63.87	1.16	1.123	1.04	0.76	10.70	2.18
63.88	1.22	1.145	1.06	0.78	10.90	2.23
63.89	1.29	1.167	1.08	0.79	11.11	2.27
63.90	1.36	1.188	1.10	0.81	11.31	2.31
63.91	1.43	1.209	1.12	0.82	11.51	2.35
63.92	1.50	1.229	1.14	0.83	11.70	2.39
63.93	1.57	1.25	1.16	0.85	11.90	2.43
63.94	1.64	1.27	1.18	0.86	12.10	2.47
63.95	1.71	1.289	1.19	0.87	12.28	2.51
63.96	1.79	1.309	1.21	0.89	12.47	2.55
63.97	1.87	1.328	1.23	0.90	12.65	2.58
63.98	1.94	1.347	1.25	0.91	12.83	2.62
63.99	2.02	1.362	1.26	0.92	12.97	2.65
64.00	2.09	1.376	1.28	0.93	13.10	2.68
64.01	2.17	1.39	1.29	0.94	13.24	2.70
64.02	2.24	1.403	1.30	0.95	13.36	2.73
64.03	2.32	1.417	1.31	0.96	13.50	2.76
64.04	2.40	1.43	1.33	0.97	13.62	2.78

Stillwater Creek Section 1

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample: Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
64.05	2.48	1.444	1.34	0.98	13.75	2.81
64.06	2.56	1.457	1.35	0.99	13.88	2.83
64.07	2.65	1.469	1.36	1.00	13.99	2.86
64.08	2.73	1.481	1.37	1.00	14.10	2.88
64.09	2.82	1.497	1.39	1.01	14.26	2.91
64.10	2.91	1.513	1.40	1.03	14.41	2.94
64.11	3.01	1.529	1.42	1.04	14.56	2.97
64.12	3.11	1.544	1.43	1.05	14.70	3.00
64.13	3.20	1.56	1.45	1.06	14.86	3.04
64.14	3.30	1.575	1.46	1.07	15.00	3.06
64.15	3.40	1.59	1.47	1.08	15.14	3.09
64.16	3.51	1.605	1.49	1.09	15.29	3.12
64.17	3.61	1.62	1.50	1.10	15.43	3.15
64.18	3.72	1.635	1.52	1.11	15.57	3.18
64.19	3.82	1.649	1.53	1.12	15.70	3.21
64.20	3.93	1.664	1.54	1.13	15.85	3.24
64.21	4.04	1.678	1.56	1.14	15.98	3.26
64.22	4.15	1.692	1.57	1.15	16.11	3.29
64.23	4.26	1.706	1.58	1.16	16.25	3.32
64.24	4.37	1.72	1.59	1.17	16.38	3.35
64.25	4.49	1.734	1.61	1.18	16.51	3.37
64.26	4.60	1.748	1.62	1.19	16.65	3.40
64.27	4.72	1.76	1.63	1.19	16.76	3.42
64.28	4.83	1.773	1.64	1.20	16.89	3.45
64.29	4.95	1.785	1.65	1.21	17.00	3.47
64.30	5.07	1.798	1.67	1.22	17.12	3.50
64.31	5.19	1.81	1.68	1.23	17.24	3.52
64.32	5.31	1.823	1.69	1.24	17.36	3.55
64.33	5.43	1.835	1.70	1.24	17.48	3.57
64.34	5.56	1.847	1.71	1.25	17.59	3.59
64.35	5.68	1.859	1.72	1.26	17.70	3.62
64.36	5.81	1.871	1.73	1.27	17.82	3.64
64.37	5.94	1.883	1.75	1.28	17.93	3.66
64.38	6.07	1.895	1.76	1.28	18.05	3.69
64.39	6.20	1.906	1.77	1.29	18.15	3.71
64.40	6.33	1.918	1.78	1.30	18.27	3.73
64.41	6.47	1.93	1.79	1.31	18.38	3.75
64.42	6.60	1.941	1.80	1.32	18.49	3.78
64.43	6.74	1.953	1.81	1.32	18.60	3.80
64.44	6.88	1.964	1.82	1.33	18.70	3.82
64.45	7.01	1.973	1.83	1.34	18.79	3.84
64.46	7.14	1.981	1.84	1.34	18.87	3.85
64.47	7.27	1.988	1.84	1.35	18.93	3.87
64.48	7.41	1.996	1.85	1.35	19.01	3.88
64.49	7.50	1.994	1.85	1.35	18.99	3.88
64.50	7.56	1.981	1.84	1.34	18.87	3.85
64.51	7.62	1.968	1.82	1.33	18.74	3.83
64.52	7.68	1.957	1.81	1.33	18.64	3.81
64.53	7.75	1.946	1.80	1.32	18.53	3.79
64.54	7.82	1.936	1.79	1.31	18.44	3.77
64.55	7.89	1.927	1.79	1.31	18.35	3.75
64.56	7.97	1.918	1.78	1.30	18.27	3.73
64.57	8.05	1.91	1.77	1.29	18.19	3.72
64.58	8.13	1.902	1.76	1.29	18.11	3.70
64.59	8.16	1.882	1.74	1.28	17.92	3.66
64.60	8.16	1.858	1.72	1.26	17.70	3.61
64.61	8.18	1.835	1.70	1.24	17.48	3.57
64.62	8.20	1.814	1.68	1.23	17.28	3.53
64.63	8.23	1.795	1.66	1.22	17.10	3.49
64.64	8.27	1.776	1.65	1.20	16.91	3.46
64.65	8.31	1.76	1.63	1.19	16.76	3.42
64.66	8.36	1.744	1.62	1.18	16.61	3.39
64.67	8.41	1.73	1.60	1.17	16.48	3.37

Stillwater Creek Section 2

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample: Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.36	0.000	0.000	0.00	0.00	0.00	0.00
63.37	0.000	0.072	0.07	0.05	0.69	0.14
63.38	0.000	0.119	0.11	0.08	1.13	0.23
63.39	0.001	0.115	0.11	0.08	1.10	0.22
63.40	0.002	0.166	0.15	0.11	1.58	0.32
63.41	0.005	0.215	0.20	0.15	2.05	0.42
63.42	0.009	0.256	0.24	0.17	2.44	0.50
63.43	0.013	0.292	0.27	0.20	2.78	0.57
63.44	0.019	0.324	0.30	0.22	3.09	0.63
63.45	0.027	0.363	0.34	0.25	3.46	0.71
63.46	0.036	0.402	0.37	0.27	3.83	0.78
63.47	0.046	0.438	0.41	0.30	4.17	0.85
63.48	0.057	0.472	0.44	0.32	4.50	0.92
63.49	0.069	0.504	0.47	0.34	4.80	0.98
63.50	0.082	0.534	0.49	0.36	5.09	1.04
63.51	0.096	0.563	0.52	0.38	5.36	1.10
63.52	0.111	0.590	0.55	0.40	5.62	1.15
63.53	0.127	0.616	0.57	0.42	5.87	1.20
63.54	0.144	0.642	0.59	0.44	6.11	1.25
63.55	0.162	0.666	0.62	0.45	6.34	1.30
63.56	0.182	0.690	0.64	0.47	6.57	1.34
63.57	0.202	0.712	0.66	0.48	6.78	1.39
63.58	0.223	0.735	0.68	0.50	7.00	1.43
63.59	0.245	0.756	0.70	0.51	7.20	1.47
63.60	0.269	0.777	0.72	0.53	7.40	1.51
63.61	0.294	0.799	0.74	0.54	7.61	1.55
63.62	0.320	0.820	0.76	0.56	7.81	1.60
63.63	0.347	0.841	0.78	0.57	8.01	1.64
63.64	0.375	0.861	0.80	0.58	8.20	1.68
63.65	0.404	0.881	0.82	0.60	8.39	1.71
63.66	0.435	0.900	0.83	0.61	8.57	1.75
63.67	0.466	0.919	0.85	0.62	8.75	1.79
63.68	0.499	0.938	0.87	0.64	8.93	1.82
63.69	0.532	0.956	0.89	0.65	9.10	1.86
63.70	0.567	0.974	0.90	0.66	9.28	1.89
63.71	0.603	0.992	0.92	0.67	9.45	1.93
63.72	0.640	1.010	0.94	0.68	9.62	1.96
63.73	0.680	1.029	0.95	0.70	9.80	2.00
63.74	0.722	1.051	0.97	0.71	10.01	2.04
63.75	0.766	1.073	0.99	0.73	10.22	2.09
63.76	0.811	1.095	1.01	0.74	10.43	2.13
63.77	0.856	1.116	1.03	0.76	10.63	2.17
63.78	0.902	1.136	1.05	0.77	10.82	2.21
63.79	0.949	1.156	1.07	0.78	11.01	2.25
63.80	0.997	1.176	1.09	0.80	11.20	2.29
63.81	1.046	1.195	1.11	0.81	11.38	2.32
63.82	1.096	1.214	1.13	0.82	11.56	2.36
63.83	1.146	1.233	1.14	0.84	11.74	2.40
63.84	1.197	1.251	1.16	0.85	11.91	2.43
63.85	1.249	1.269	1.18	0.86	12.09	2.47
63.86	1.302	1.287	1.19	0.87	12.26	2.50
63.87	1.355	1.304	1.21	0.88	12.42	2.54
63.88	1.409	1.322	1.23	0.90	12.59	2.57
63.89	1.464	1.338	1.24	0.91	12.74	2.60
63.90	1.519	1.355	1.26	0.92	12.90	2.64
63.91	1.575	1.371	1.27	0.93	13.06	2.67
63.92	1.632	1.387	1.29	0.94	13.21	2.70
63.93	1.690	1.403	1.30	0.95	13.36	2.73
63.94	1.748	1.418	1.31	0.96	13.50	2.76
63.95	1.807	1.434	1.33	0.97	13.66	2.79
63.96	1.866	1.449	1.34	0.98	13.80	2.82
63.97	1.926	1.464	1.36	0.99	13.94	2.85
63.98	1.987	1.478	1.37	1.00	14.08	2.88

Stillwater Creek Section 2

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.99	2.049	1.493	1.38	1.01	14.22	2.90
64.00	2.111	1.507	1.40	1.02	14.35	2.93
64.01	2.173	1.521	1.41	1.03	14.49	2.96
64.02	2.237	1.535	1.42	1.04	14.62	2.99
64.03	2.300	1.549	1.44	1.05	14.75	3.01
64.04	2.365	1.562	1.45	1.06	14.88	3.04
64.05	2.430	1.575	1.46	1.07	15.00	3.06
64.06	2.496	1.589	1.47	1.08	15.13	3.09
64.07	2.562	1.602	1.48	1.09	15.26	3.12
64.08	2.629	1.614	1.50	1.09	15.37	3.14
64.09	2.696	1.627	1.51	1.10	15.50	3.17
64.10	2.764	1.640	1.52	1.11	15.62	3.19
64.11	2.833	1.652	1.53	1.12	15.73	3.21
64.12	2.902	1.664	1.54	1.13	15.85	3.24
64.13	2.971	1.676	1.55	1.14	15.96	3.26
64.14	3.041	1.688	1.56	1.14	16.08	3.28
64.15	3.112	1.700	1.58	1.15	16.19	3.31
64.16	3.183	1.712	1.59	1.16	16.30	3.33
64.17	3.255	1.723	1.60	1.17	16.41	3.35
64.18	3.328	1.734	1.61	1.18	16.51	3.37
64.19	3.400	1.746	1.62	1.18	16.63	3.40
64.20	3.474	1.757	1.63	1.19	16.73	3.42
64.21	3.548	1.768	1.64	1.20	16.84	3.44
64.22	3.622	1.779	1.65	1.21	16.94	3.46
64.23	3.697	1.790	1.66	1.21	17.05	3.48
64.24	3.771	1.800	1.67	1.22	17.14	3.50
64.25	3.838	1.806	1.67	1.22	17.20	3.51
64.26	3.905	1.811	1.68	1.23	17.25	3.52
64.27	3.972	1.817	1.68	1.23	17.30	3.54
64.28	4.041	1.823	1.69	1.24	17.36	3.55
64.29	4.111	1.829	1.70	1.24	17.42	3.56
64.30	4.182	1.835	1.70	1.24	17.48	3.57
64.31	4.253	1.841	1.71	1.25	17.53	3.58
64.32	4.326	1.847	1.71	1.25	17.59	3.59
64.33	4.399	1.853	1.72	1.26	17.65	3.61
64.34	4.470	1.858	1.72	1.26	17.70	3.61
64.35	4.534	1.859	1.72	1.26	17.70	3.62
64.36	4.601	1.861	1.72	1.26	17.72	3.62
64.37	4.669	1.863	1.73	1.26	17.74	3.62
64.38	4.738	1.866	1.73	1.27	17.77	3.63
64.39	4.809	1.868	1.73	1.27	17.79	3.63
64.40	4.882	1.871	1.73	1.27	17.82	3.64
64.41	4.960	1.875	1.74	1.27	17.86	3.65
64.42	5.040	1.880	1.74	1.27	17.90	3.66
64.43	5.122	1.885	1.75	1.28	17.95	3.67
64.44	5.205	1.890	1.75	1.28	18.00	3.68
64.45	5.289	1.895	1.76	1.28	18.05	3.69
64.46	5.375	1.900	1.76	1.29	18.10	3.70
64.47	5.462	1.905	1.77	1.29	18.14	3.71
64.48	5.551	1.910	1.77	1.29	18.19	3.72
64.49	5.641	1.915	1.77	1.30	18.24	3.73
64.50	5.732	1.921	1.78	1.30	18.30	3.74
64.51	5.825	1.926	1.78	1.31	18.34	3.75
64.52	5.920	1.932	1.79	1.31	18.40	3.76
64.53	6.015	1.937	1.80	1.31	18.45	3.77
64.54	6.062	1.927	1.79	1.31	18.35	3.75
64.55	5.897	1.849	1.71	1.25	17.61	3.60
64.56	5.759	1.781	1.65	1.21	16.96	3.46
64.57	5.642	1.721	1.59	1.17	16.39	3.35
64.58	5.547	1.667	1.54	1.13	15.88	3.24
64.59	5.447	1.613	1.49	1.09	15.36	3.14
64.60	5.359	1.563	1.45	1.06	14.89	3.04
64.61	5.289	1.518	1.41	1.03	14.46	2.95
64.62	5.298	1.496	1.39	1.01	14.25	2.91

Stillwater Creek Section 3

WSE	Q	Vel	Exceedence as a Percent of D50 for Sample			
(m)	(cms)	(m/sec)	Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.39	0.000	0.009	0.01	0.01	0.09	0.02
63.40	0.000	0.082	0.08	0.06	0.78	0.16
63.41	0.001	0.129	0.12	0.09	1.23	0.25
63.42	0.002	0.180	0.17	0.12	1.71	0.35
63.43	0.004	0.231	0.21	0.16	2.20	0.45
63.44	0.007	0.274	0.25	0.19	2.61	0.53
63.45	0.010	0.312	0.29	0.21	2.97	0.61
63.46	0.014	0.346	0.32	0.23	3.30	0.67
63.47	0.019	0.377	0.35	0.26	3.59	0.73
63.48	0.025	0.406	0.38	0.28	3.87	0.79
63.49	0.031	0.433	0.40	0.29	4.12	0.84
63.50	0.038	0.459	0.43	0.31	4.37	0.89
63.51	0.046	0.484	0.45	0.33	4.61	0.94
63.52	0.055	0.508	0.47	0.34	4.84	0.99
63.53	0.063	0.515	0.48	0.35	4.90	1.00
63.54	0.066	0.477	0.44	0.32	4.54	0.93
63.55	0.080	0.503	0.47	0.34	4.79	0.98
63.56	0.094	0.527	0.49	0.36	5.02	1.03
63.57	0.110	0.551	0.51	0.37	5.25	1.07
63.58	0.128	0.573	0.53	0.39	5.46	1.11
63.59	0.147	0.595	0.55	0.40	5.67	1.16
63.60	0.167	0.617	0.57	0.42	5.88	1.20
63.61	0.189	0.639	0.59	0.43	6.09	1.24
63.62	0.214	0.663	0.61	0.45	6.31	1.29
63.63	0.240	0.686	0.64	0.47	6.53	1.33
63.64	0.268	0.709	0.66	0.48	6.75	1.38
63.65	0.297	0.731	0.68	0.50	6.96	1.42
63.66	0.329	0.756	0.70	0.51	7.20	1.47
63.67	0.364	0.783	0.73	0.53	7.46	1.52
63.68	0.401	0.810	0.75	0.55	7.71	1.58
63.69	0.440	0.837	0.78	0.57	7.97	1.63
63.70	0.480	0.863	0.80	0.59	8.22	1.68
63.71	0.521	0.888	0.82	0.60	8.46	1.73
63.72	0.564	0.913	0.85	0.62	8.70	1.78
63.73	0.608	0.937	0.87	0.64	8.92	1.82
63.74	0.653	0.961	0.89	0.65	9.15	1.87
63.75	0.700	0.984	0.91	0.67	9.37	1.91
63.76	0.749	1.007	0.93	0.68	9.59	1.96
63.77	0.800	1.031	0.96	0.70	9.82	2.01
63.78	0.852	1.055	0.98	0.72	10.05	2.05
63.79	0.905	1.078	1.00	0.73	10.27	2.10
63.80	0.959	1.100	1.02	0.75	10.48	2.14
63.81	1.015	1.122	1.04	0.76	10.69	2.18
63.82	1.071	1.144	1.06	0.78	10.90	2.23
63.83	1.129	1.165	1.08	0.79	11.10	2.27
63.84	1.188	1.186	1.10	0.80	11.30	2.31
63.85	1.248	1.206	1.12	0.82	11.49	2.35
63.86	1.309	1.226	1.14	0.83	11.68	2.39
63.87	1.371	1.246	1.15	0.84	11.87	2.42
63.88	1.434	1.265	1.17	0.86	12.05	2.46
63.89	1.499	1.284	1.19	0.87	12.23	2.50
63.90	1.564	1.303	1.21	0.88	12.41	2.54
63.91	1.630	1.322	1.23	0.90	12.59	2.57
63.92	1.698	1.340	1.24	0.91	12.76	2.61
63.93	1.766	1.358	1.26	0.92	12.93	2.64
63.94	1.836	1.376	1.28	0.93	13.10	2.68
63.95	1.906	1.393	1.29	0.94	13.27	2.71
63.96	1.978	1.410	1.31	0.96	13.43	2.74
63.97	2.050	1.427	1.32	0.97	13.59	2.78
63.98	2.123	1.444	1.34	0.98	13.75	2.81
63.99	2.198	1.461	1.35	0.99	13.91	2.84
64.00	2.273	1.477	1.37	1.00	14.07	2.87

tillwater Creek Section 3

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
64.01	2.349	1.493	1.38	1.01	14.22	2.90
64.02	2.426	1.509	1.40	1.02	14.37	2.94
64.03	2.505	1.524	1.41	1.03	14.51	2.96
64.04	2.584	1.540	1.43	1.04	14.67	3.00
64.05	2.664	1.555	1.44	1.05	14.81	3.03
64.06	2.745	1.570	1.46	1.06	14.95	3.05
64.07	2.826	1.585	1.47	1.07	15.10	3.08
64.08	2.909	1.600	1.48	1.08	15.24	3.11
64.09	2.993	1.615	1.50	1.09	15.38	3.14
64.10	3.077	1.629	1.51	1.10	15.51	3.17
64.11	3.163	1.643	1.52	1.11	15.65	3.20
64.12	3.249	1.657	1.54	1.12	15.78	3.22
64.13	3.336	1.671	1.55	1.13	15.91	3.25
64.14	3.424	1.685	1.56	1.14	16.05	3.28
64.15	3.513	1.699	1.57	1.15	16.18	3.31
64.16	3.603	1.712	1.59	1.16	16.30	3.33
64.17	3.694	1.726	1.60	1.17	16.44	3.36
64.18	3.785	1.739	1.61	1.18	16.56	3.38
64.19	3.878	1.752	1.62	1.19	16.69	3.41
64.20	3.971	1.765	1.64	1.20	16.81	3.43

Stillwater Creek Section 4

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.37	0.000	0.000	0.00	0.00	0.00	0.00
63.38	0.000	0.080	0.07	0.05	0.76	0.16
63.39	0.001	0.127	0.12	0.09	1.21	0.25
63.40	0.002	0.168	0.16	0.11	1.60	0.33
63.41	0.004	0.204	0.19	0.14	1.94	0.40
63.42	0.007	0.239	0.22	0.16	2.28	0.46
63.43	0.012	0.286	0.27	0.19	2.72	0.56
63.44	0.018	0.328	0.30	0.22	3.12	0.64
63.45	0.025	0.366	0.34	0.25	3.49	0.71
63.46	0.033	0.400	0.37	0.27	3.81	0.78
63.47	0.042	0.432	0.40	0.29	4.11	0.84
63.48	0.052	0.462	0.43	0.31	4.40	0.90
63.49	0.063	0.490	0.45	0.33	4.67	0.95
63.50	0.075	0.514	0.48	0.35	4.90	1.00
63.51	0.088	0.536	0.50	0.36	5.10	1.04
63.52	0.103	0.558	0.52	0.38	5.31	1.09
63.53	0.118	0.580	0.54	0.39	5.52	1.13
63.54	0.135	0.600	0.56	0.41	5.71	1.17
63.55	0.154	0.622	0.58	0.42	5.92	1.21
63.56	0.174	0.643	0.60	0.44	6.12	1.25
63.57	0.196	0.664	0.62	0.45	6.32	1.29
63.58	0.219	0.684	0.63	0.46	6.51	1.33
63.59	0.246	0.711	0.66	0.48	6.77	1.38
63.60	0.274	0.737	0.68	0.50	7.02	1.43
63.61	0.303	0.762	0.71	0.52	7.26	1.48
63.62	0.334	0.787	0.73	0.53	7.50	1.53
63.63	0.366	0.811	0.75	0.55	7.72	1.58
63.64	0.400	0.836	0.77	0.57	7.96	1.63
63.65	0.437	0.863	0.80	0.59	8.22	1.68
63.66	0.476	0.889	0.82	0.60	8.47	1.73
63.67	0.515	0.915	0.85	0.62	8.71	1.78
63.68	0.556	0.940	0.87	0.64	8.95	1.83
63.69	0.597	0.964	0.89	0.65	9.18	1.88
63.70	0.640	0.988	0.92	0.67	9.41	1.92
63.71	0.684	1.012	0.94	0.69	9.64	1.97
63.72	0.729	1.034	0.96	0.70	9.85	2.01
63.73	0.776	1.057	0.98	0.72	10.07	2.06
63.74	0.823	1.079	1.00	0.73	10.28	2.10
63.75	0.872	1.100	1.02	0.75	10.48	2.14
63.76	0.921	1.121	1.04	0.76	10.68	2.18
63.77	0.972	1.142	1.06	0.77	10.88	2.22
63.78	1.023	1.162	1.08	0.79	11.07	2.26
63.79	1.076	1.182	1.10	0.80	11.26	2.30
63.80	1.129	1.202	1.11	0.81	11.45	2.34
63.81	1.184	1.221	1.13	0.83	11.63	2.38
63.82	1.240	1.240	1.15	0.84	11.81	2.41
63.83	1.296	1.259	1.17	0.85	11.99	2.45
63.84	1.354	1.277	1.18	0.87	12.16	2.48
63.85	1.412	1.295	1.20	0.88	12.33	2.52
63.86	1.472	1.313	1.22	0.89	12.50	2.55
63.87	1.533	1.331	1.23	0.90	12.68	2.59
63.88	1.595	1.349	1.25	0.91	12.85	2.62
63.89	1.658	1.366	1.27	0.93	13.01	2.66
63.90	1.721	1.384	1.28	0.94	13.18	2.69
63.91	1.786	1.401	1.30	0.95	13.34	2.73
63.92	1.851	1.417	1.31	0.96	13.50	2.76
63.93	1.918	1.434	1.33	0.97	13.66	2.79
63.94	1.985	1.450	1.34	0.98	13.81	2.82
63.95	2.053	1.466	1.36	0.99	13.96	2.85
63.96	2.122	1.482	1.37	1.00	14.11	2.88
63.97	2.192	1.498	1.39	1.02	14.27	2.91
63.98	2.262	1.513	1.40	1.03	14.41	2.94
63.99	2.334	1.528	1.42	1.04	14.55	2.97
64.00	2.406	1.543	1.43	1.05	14.70	3.00

Stillwater Creek Section 5

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.620	0.000	0.034	0.03	0.02	0.32	0.07
63.630	0.001	0.102	0.09	0.07	0.97	0.20
63.640	0.002	0.162	0.15	0.11	1.54	0.32
63.650	0.004	0.206	0.19	0.14	1.96	0.40
63.660	0.008	0.243	0.23	0.16	2.31	0.47
63.670	0.012	0.276	0.26	0.19	2.63	0.54
63.680	0.018	0.307	0.28	0.21	2.92	0.60
63.690	0.025	0.335	0.31	0.23	3.19	0.65
63.700	0.034	0.366	0.34	0.25	3.49	0.71
63.710	0.043	0.382	0.35	0.26	3.64	0.74
63.720	0.054	0.398	0.37	0.27	3.79	0.77
63.730	0.070	0.440	0.41	0.30	4.19	0.86
63.740	0.088	0.479	0.44	0.32	4.56	0.93
63.750	0.108	0.516	0.48	0.35	4.91	1.00
63.760	0.130	0.552	0.51	0.37	5.26	1.07
63.770	0.152	0.585	0.54	0.40	5.57	1.14
63.780	0.177	0.618	0.57	0.42	5.89	1.20
63.790	0.203	0.649	0.60	0.44	6.18	1.26
63.800	0.230	0.679	0.63	0.46	6.47	1.32
63.810	0.259	0.708	0.66	0.48	6.74	1.38
63.820	0.289	0.736	0.68	0.50	7.01	1.43
63.830	0.321	0.763	0.71	0.52	7.27	1.48
63.840	0.354	0.790	0.73	0.54	7.52	1.54
63.850	0.389	0.816	0.76	0.55	7.77	1.59
63.860	0.425	0.842	0.78	0.57	8.02	1.64
63.870	0.463	0.867	0.80	0.59	8.26	1.69
63.880	0.502	0.891	0.83	0.60	8.49	1.73
63.890	0.542	0.915	0.85	0.62	8.71	1.78
63.900	0.584	0.939	0.87	0.64	8.94	1.83
63.910	0.627	0.963	0.89	0.65	9.17	1.87
63.920	0.671	0.986	0.91	0.67	9.39	1.92
63.930	0.717	1.009	0.94	0.68	9.61	1.96
63.940	0.764	1.031	0.96	0.70	9.82	2.01
63.950	0.812	1.053	0.98	0.71	10.03	2.05
63.960	0.816	1.017	0.94	0.69	9.69	1.98
63.970	0.834	0.996	0.92	0.68	9.49	1.94
63.980	0.881	1.008	0.93	0.68	9.60	1.96
63.990	0.930	1.021	0.95	0.69	9.72	1.99
64.000	0.981	1.033	0.96	0.70	9.84	2.01
64.010	1.034	1.045	0.97	0.71	9.95	2.03
64.020	1.088	1.058	0.98	0.72	10.08	2.06
64.030	1.144	1.070	0.99	0.73	10.19	2.08
64.040	1.202	1.082	1.00	0.73	10.30	2.11
64.050	1.261	1.094	1.01	0.74	10.42	2.13
64.060	1.308	1.094	1.01	0.74	10.42	2.13
64.070	1.384	1.115	1.03	0.76	10.62	2.17
64.080	1.460	1.136	1.05	0.77	10.82	2.21
64.090	1.539	1.157	1.07	0.78	11.02	2.25
64.100	1.620	1.178	1.09	0.80	11.22	2.29
64.110	1.702	1.198	1.11	0.81	11.41	2.33
64.120	1.785	1.217	1.13	0.83	11.59	2.37
64.130	1.871	1.237	1.15	0.84	11.78	2.41
64.140	1.958	1.256	1.16	0.85	11.96	2.44
64.150	2.047	1.275	1.18	0.86	12.14	2.48
64.160	2.137	1.293	1.20	0.88	12.31	2.52
64.170	2.228	1.310	1.21	0.89	12.48	2.55
64.180	2.321	1.327	1.23	0.90	12.64	2.58
64.190	2.415	1.344	1.25	0.91	12.80	2.61
64.200	2.511	1.361	1.26	0.92	12.96	2.65
64.210	2.609	1.378	1.28	0.93	13.12	2.68
64.220	2.709	1.394	1.29	0.95	13.28	2.71
64.230	2.811	1.410	1.31	0.96	13.43	2.74
64.240	2.910	1.424	1.32	0.97	13.56	2.77
64.250	3.004	1.435	1.33	0.97	13.67	2.79

tillwater Creek Section 5

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
64.260	3.100	1.445	1.34	0.98	13.76	2.81
64.270	3.198	1.455	1.35	0.99	13.86	2.83
64.280	3.298	1.466	1.36	0.99	13.96	2.85
64.290	3.400	1.476	1.37	1.00	14.06	2.87
64.300	3.507	1.487	1.38	1.01	14.16	2.89
64.310	3.621	1.501	1.39	1.02	14.30	2.92
64.320	3.738	1.514	1.40	1.03	14.42	2.95
64.330	3.856	1.527	1.42	1.04	14.54	2.97
64.340	3.977	1.541	1.43	1.04	14.68	3.00
64.350	4.099	1.554	1.44	1.05	14.80	3.02
64.360	4.224	1.567	1.45	1.06	14.92	3.05
64.370	4.351	1.580	1.46	1.07	15.05	3.07
64.380	4.104	1.457	1.35	0.99	13.88	2.83
64.390	4.213	1.460	1.35	0.99	13.90	2.84
64.400	4.324	1.463	1.36	0.99	13.93	2.85
64.410	4.437	1.467	1.36	0.99	13.97	2.85
64.420	4.553	1.471	1.36	1.00	14.01	2.86
64.430	4.670	1.474	1.37	1.00	14.04	2.87
64.440	4.785	1.477	1.37	1.00	14.07	2.87
64.450	4.901	1.479	1.37	1.00	14.09	2.88
64.460	5.018	1.482	1.37	1.00	14.11	2.88
64.470	5.137	1.485	1.38	1.01	14.14	2.89
64.480	5.259	1.487	1.38	1.01	14.16	2.89
64.490	5.381	1.490	1.38	1.01	14.19	2.90
64.500	5.506	1.493	1.38	1.01	14.22	2.90
64.510	5.632	1.496	1.39	1.01	14.25	2.91
64.520	5.760	1.499	1.39	1.02	14.28	2.92
64.530	5.890	1.503	1.39	1.02	14.31	2.92
64.540	6.022	1.506	1.40	1.02	14.34	2.93
64.550	6.155	1.509	1.40	1.02	14.37	2.94
64.560	6.290	1.513	1.40	1.03	14.41	2.94
64.570	6.419	1.514	1.40	1.03	14.42	2.95
64.580	6.542	1.514	1.40	1.03	14.42	2.95
64.590	6.668	1.514	1.40	1.03	14.42	2.95
64.600	6.796	1.515	1.40	1.03	14.43	2.95
64.610	6.926	1.515	1.40	1.03	14.43	2.95
64.620	7.058	1.516	1.41	1.03	14.44	2.95
64.630	7.192	1.517	1.41	1.03	14.45	2.95
64.640	7.329	1.518	1.41	1.03	14.46	2.95
64.650	7.467	1.519	1.41	1.03	14.47	2.96
64.660	7.608	1.521	1.41	1.03	14.49	2.96
64.670	7.751	1.522	1.41	1.03	14.50	2.96
64.680	7.896	1.524	1.41	1.03	14.51	2.96
64.690	8.043	1.526	1.41	1.03	14.53	2.97
64.700	8.193	1.528	1.42	1.04	14.55	2.97
64.710	8.347	1.530	1.42	1.04	14.57	2.98
64.720	8.510	1.534	1.42	1.04	14.61	2.98
64.730	8.667	1.536	1.42	1.04	14.63	2.99
64.740	8.827	1.539	1.43	1.04	14.66	2.99
64.750	8.989	1.542	1.43	1.05	14.69	3.00
64.760	9.153	1.544	1.43	1.05	14.70	3.00
64.770	9.319	1.547	1.43	1.05	14.73	3.01
64.780	9.488	1.550	1.44	1.05	14.76	3.02
64.790	9.658	1.553	1.44	1.05	14.79	3.02
64.800	9.831	1.556	1.44	1.05	14.82	3.03
64.810	10.006	1.559	1.44	1.06	14.85	3.03
64.820	10.184	1.562	1.45	1.06	14.88	3.04
64.830	10.363	1.565	1.45	1.06	14.90	3.04
64.840	10.545	1.569	1.45	1.06	14.94	3.05
64.850	10.729	1.572	1.46	1.07	14.97	3.06
64.860	10.915	1.575	1.46	1.07	15.00	3.06
64.870	11.104	1.578	1.46	1.07	15.03	3.07
64.880	11.295	1.582	1.47	1.07	15.07	3.08
64.890	11.488	1.585	1.47	1.07	15.10	3.08

Stillwater Creek Section 6

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
63.40	0.000	0.000	0.00	0.00	0.00	0.00
63.41	0.000	0.059	0.05	0.04	0.56	0.11
63.42	0.000	0.111	0.10	0.08	1.06	0.22
63.43	0.001	0.153	0.14	0.10	1.46	0.30
63.44	0.003	0.192	0.18	0.13	1.83	0.37
63.45	0.005	0.233	0.22	0.16	2.22	0.45
63.46	0.009	0.268	0.25	0.18	2.55	0.52
63.47	0.013	0.300	0.28	0.20	2.86	0.58
63.48	0.019	0.329	0.30	0.22	3.13	0.64
63.49	0.026	0.356	0.33	0.24	3.39	0.69
63.50	0.034	0.388	0.36	0.26	3.70	0.75
63.51	0.044	0.419	0.39	0.28	3.99	0.82
63.52	0.055	0.448	0.42	0.30	4.27	0.87
63.53	0.068	0.476	0.44	0.32	4.53	0.93
63.54	0.081	0.502	0.47	0.34	4.78	0.98
63.55	0.097	0.528	0.49	0.36	5.03	1.03
63.56	0.115	0.561	0.52	0.38	5.34	1.09
63.57	0.135	0.594	0.55	0.40	5.66	1.16
63.58	0.156	0.625	0.58	0.42	5.95	1.22
63.59	0.178	0.656	0.61	0.44	6.25	1.28
63.60	0.202	0.685	0.63	0.46	6.52	1.33
63.61	0.227	0.713	0.66	0.48	6.79	1.39
63.62	0.253	0.739	0.68	0.50	7.04	1.44
63.63	0.280	0.764	0.71	0.52	7.28	1.49
63.64	0.308	0.789	0.73	0.53	7.51	1.54
63.65	0.338	0.812	0.75	0.55	7.73	1.58
63.66	0.368	0.836	0.77	0.57	7.96	1.63
63.67	0.399	0.855	0.79	0.58	8.14	1.66
63.68	0.431	0.874	0.81	0.59	8.32	1.70
63.69	0.464	0.892	0.83	0.60	8.50	1.74
63.70	0.498	0.910	0.84	0.62	8.67	1.77
63.71	0.534	0.928	0.86	0.63	8.84	1.81
63.72	0.571	0.946	0.88	0.64	9.01	1.84
63.73	0.612	0.967	0.90	0.66	9.21	1.88
63.74	0.654	0.987	0.91	0.67	9.40	1.92
63.75	0.697	1.008	0.93	0.68	9.60	1.96
63.76	0.742	1.027	0.95	0.70	9.78	2.00
63.77	0.788	1.047	0.97	0.71	9.97	2.04
63.78	0.835	1.066	0.99	0.72	10.15	2.07
63.79	0.883	1.084	1.00	0.73	10.32	2.11
63.80	0.933	1.103	1.02	0.75	10.50	2.15
63.81	0.985	1.121	1.04	0.76	10.68	2.18
63.82	1.038	1.140	1.06	0.77	10.86	2.22
63.83	1.093	1.159	1.07	0.79	11.04	2.25
63.84	1.149	1.177	1.09	0.80	11.21	2.29
63.85	1.207	1.196	1.11	0.81	11.39	2.33
63.86	1.266	1.214	1.13	0.82	11.56	2.36
63.87	1.326	1.231	1.14	0.83	11.72	2.39
63.88	1.388	1.249	1.16	0.85	11.90	2.43
63.89	1.451	1.266	1.17	0.86	12.06	2.46
63.90	1.512	1.281	1.19	0.87	12.20	2.49
63.91	1.574	1.295	1.20	0.88	12.33	2.52
63.92	1.638	1.309	1.21	0.89	12.47	2.55
63.93	1.703	1.323	1.23	0.90	12.60	2.57
63.94	1.770	1.337	1.24	0.91	12.73	2.60
63.95	1.838	1.350	1.25	0.92	12.86	2.63
63.96	1.908	1.364	1.26	0.92	12.99	2.65
63.97	1.979	1.377	1.28	0.93	13.11	2.68
63.98	2.051	1.391	1.29	0.94	13.25	2.71
63.99	2.125	1.404	1.30	0.95	13.37	2.73
64.00	2.199	1.416	1.31	0.96	13.49	2.75
64.01	2.274	1.428	1.32	0.97	13.60	2.78
64.02	2.351	1.440	1.33	0.98	13.71	2.80
64.03	2.429	1.451	1.34	0.98	13.82	2.82

Stillwater Creek Section 6

WSE (m)	Q (cms)	Vel (m/sec)	Exceedence as a Percent of D50 for Sample			
			Upstream Riffle	Downstream Riffle	Downstream Surface	Downstream Subpavement
64.04	2.509	1.463	1.36	0.99	13.93	2.85
64.05	2.591	1.475	1.37	1.00	14.05	2.87
64.06	2.674	1.486	1.38	1.01	14.15	2.89
64.07	2.759	1.498	1.39	1.02	14.27	2.91
64.08	2.845	1.509	1.40	1.02	14.37	2.94
64.09	2.933	1.521	1.41	1.03	14.49	2.96
64.10	3.023	1.532	1.42	1.04	14.59	2.98
64.11	3.114	1.543	1.43	1.05	14.70	3.00
64.12	3.206	1.554	1.44	1.05	14.80	3.02
64.13	3.299	1.564	1.45	1.06	14.90	3.04
64.14	3.395	1.575	1.46	1.07	15.00	3.06
64.15	3.492	1.585	1.47	1.07	15.10	3.08
64.16	3.591	1.596	1.48	1.08	15.20	3.11
64.17	3.691	1.606	1.49	1.09	15.30	3.12
64.18	3.794	1.617	1.50	1.10	15.40	3.15
64.19	3.898	1.627	1.51	1.10	15.50	3.17
64.20	4.005	1.637	1.52	1.11	15.59	3.18

APPENDIX C

MICRO-POOL/FILTER STRIP SUPPORT CALCULATIONS

West Transitway SWM Design

Outlet Location	Flow (L/S)								Flow Depth over Berm (m)							
	10 mm Storm	25 mm Storm	2 year	5 year	10 year	25 year	50 year	100 year	10 mm Storm	25 mm Storm	2 year	5 year	10 year	25 year	50 year	100 year
11+680	21	74	152	202	234	276	307	337	0.01	0.03	0.05	0.06	0.06	0.07	0.07	0.08
11+740			108	143	166	196	218	239			0.04	0.04	0.05	0.05	0.06	0.06
11+845			122	162	187	221	246	269			0.04	0.05	0.05	0.06	0.06	0.07
11+980			147	195	225	266	296	324			0.05	0.05	0.06	0.07	0.07	0.08
12+065			108	143	166	196	218	239			0.04	0.04	0.05	0.05	0.06	0.06

Outlet Location	Flow Velocity over 9 m Berm (m/s)							
	10 mm Storm	25 mm Storm	2 year	5 year	10 year	25 year	50 year	100 year
11+680	0.19	0.29	0.37	0.40	0.42	0.45	0.46	0.48
11+740			0.33	0.36	0.38	0.40	0.41	0.43
11+845			0.34	0.37	0.39	0.41	0.43	0.44
11+980			0.36	0.40	0.42	0.44	0.46	0.47
12+065			0.33	0.36	0.38	0.40	0.41	0.43

Overland Flow Velocities *							
10 mm Storm	25 mm Storm	2 year	5 year	10 year	25 year	50 year	100 year
Flow Depth (m)							
0.015	0.032	0.049	0.058	0.063	0.070	0.074	0.079
Overland Flow Velocity (m/s)							
0.07	0.12	0.16	0.18	0.19	0.20	0.21	0.22

* Using Manning's Equation - $Q=1/n\ A\ R^{2/3}\ S^{1/2}$

Assuming a "rectangular" channel, flow depth varies based on flow

Manning's n = 0.06

Slope 0.5%

APPENDIX E: MOODIE STATION PHOTOGRAPHS

Photograph 1 Looking along the Corkstown Road with the open bottom box culvert below

Photograph 2 Looking upstream (north) from upstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

Photograph 3 Looking upstream (north) at downstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

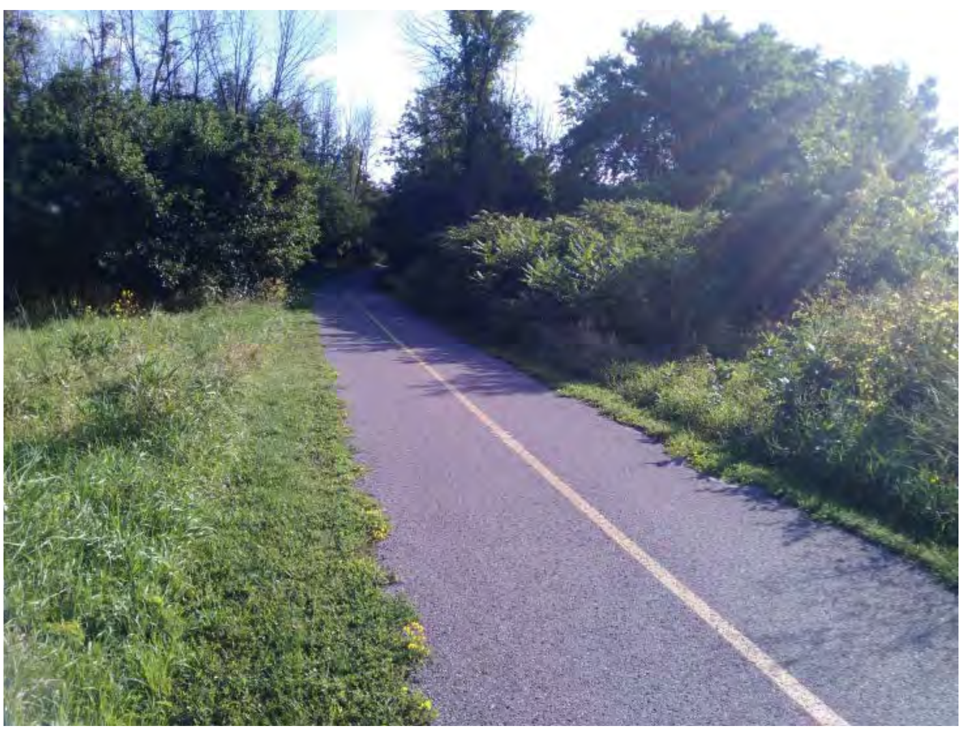
Photograph 4 Looking north at downstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

Photograph 5 Looking north at downstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

Photograph 6 Looking south at upstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

Photograph 7 Looking south at upstream face of the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert

Photograph 8 Looking downstream (south) from the Corkstown Road 3.6 meter span by 2.1 meter rise open bottom box culvert



Photograph 9 Looking along the Watts Creek Pathway (Multi-Use Path) with the 1500 mm corrugated metal pipe below

Photograph 10 Looking upstream (north) from the 1500 mm corrugated metal pipe under the Watts Creek Pathway (Multi-Use Path)

Photograph 11 Looking upstream (north) from the 1500 mm corrugated metal pipe under the Watts Creek Pathway (Multi-Use Path)

Photograph 12 Looking upstream (north) at the downstream face of the 1500 mm corrugated metal pipe under the Watts Creek Pathway

Photograph 13 Looking upstream (north) at the downstream face of the 1500 mm corrugated metal pipe under the Watts Creek Pathway

Photograph 14 Looking downstream (south) at the upstream face of the 1500 mm corrugated metal pipe under the Watts Creek Pathway

Photograph 15 Looking downstream (south) from the 1500 mm corrugated metal pipe under the Watts Creek Pathway

Photograph 16 Looking upstream (north) from 60 meters north of Corkstown Road

Photograph 17 Looking upstream (north) from 60 meters north of Corkstown Road

Photograph 18 Looking downstream (south) from 60 meters north of Corkstown Road

Photograph 19 Looking downstream (south) from 60 meters north of Corkstown Road

Photograph 20 Looking east at the confluence with the culvert under Highway OR 417 from Stillwater Creek Area 1

Photograph 21 Looking east at the confluence with the culvert under Highway OR 417 from Stillwater Creek Area 1 (Area 3 in the distance)

Photograph 22 Looking east along the Area 3 portion of Stillwater Creek towards Bayshore and parallel to Highway OR 417

Photograph 23 Looking west at the confluence and the culvert under Highway OR 417 from Stillwater Creek Area 1 (Moodie Drive in the distance)

Photograph 24 Looking north from the confluence towards the 1500 mm corrugated metal pipe under the Trans Canada Trail (Multi-Use Path)

APPENDIX F: HEC-RAS RIVER ANALYSIS SYSTEM “HYDRAULIC REFERENCE MANUAL” EXCERPTS

Table 3-1 Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
A. *Natural Streams*			
1. **Main Channels**			
a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. **Flood Plains**			
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above, but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above, but with flow into branches	0.100	0.120	0.160
5. Dense willows, summer, straight	0.110	0.150	0.200
3. **Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged**			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
b. Bottom: cobbles with large boulders	0.040	0.050	0.070

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
B. *Lined or Built-Up Channels*			
1. **Concrete**			
a. Trowel finish	0.011	0.013	0.015
b. Float Finish	0.013	0.015	0.016
c. Finished, with gravel bottom	0.015	0.017	0.020
d. Unfinished	0.014	0.017	0.020
e. Gunite, good section	0.016	0.019	0.023
f. Gunite, wavy section	0.018	0.022	0.025
g. On good excavated rock	0.017	0.020	
h. On irregular excavated rock	0.022	0.027	
2. **Concrete bottom float finished with sides of:**			
a. Dressed stone in mortar	0.015	0.017	0.020
b. Random stone in mortar	0.017	0.020	0.024
c. Cement rubble masonry, plastered	0.016	0.020	0.024
d. Cement rubble masonry	0.020	0.025	0.030
e. Dry rubble on riprap	0.020	0.030	0.035
3. **Gravel bottom with sides of:**			
a. Formed concrete	0.017	0.020	0.025
b. Random stone in mortar	0.020	0.023	0.026
c. Dry rubble or riprap	0.023	0.033	0.036
4. **Brick**			
a. Glazed	0.011	0.013	0.015
b. In cement mortar	0.012	0.015	0.018
5. **Metal**			
a. Smooth steel surfaces	0.011	0.012	0.014
b. Corrugated metal	0.021	0.025	0.030
6. **Asphalt**			
a. Smooth	0.013	0.013	
b. Rough	0.016	0.016	
7. **Vegetal lining**	0.030		0.500

Table 3-1 (Continued) Manning's 'n' Values

Type of Channel and Description	Minimum	Normal	Maximum
C. *Excavated or Dredged Channels*			
1. **Earth, straight and uniform**			
a. Clean, recently completed	0.016	0.018	0.020
b. Clean, after weathering	0.018	0.022	0.025
c. Gravel, uniform section, clean	0.022	0.025	0.030
d. With short grass, few weeds	0.022	0.027	0.033
2. **Earth, winding and sluggish**			
a. No vegetation	0.023	0.025	0.030
b. Grass, some weeds	0.025	0.030	0.033
c. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
d. Earth bottom and rubble side	0.028	0.030	0.035
e. Stony bottom and weedy banks	0.025	0.035	0.040
f. Cobble bottom and clean sides	0.030	0.040	0.050
3. **Dragline-excavated or dredged**			
a. No vegetation	0.025	0.028	0.033
b. Light brush on banks	0.035	0.050	0.060
4. **Rock cuts**			
a. Smooth and uniform	0.025	0.035	0.040
b. Jagged and irregular	0.035	0.040	0.050
5. **Channels not maintained, weeds and brush**			
a. Clean bottom, brush on sides	0.040	0.050	0.080
b. Same as above, highest stage of flow	0.045	0.070	0.110
c. Dense weeds, high as flow depth	0.050	0.080	0.120
d. Dense brush, high stage	0.080	0.100	0.140

Other sources that include pictures of selected streams as a guide to n value determination are available (Fasken, 1963; Barnes, 1967; and Hicks and Mason, 1991). In general, these references provide color photos with tables of calibrated n values for a range of flows.

Although there are many factors that affect the selection of the n value for the channel, some of the most important factors are the type and size of materials that compose the bed and banks of a channel, and the shape of the channel. Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of Manning's n of a channel. In Cowan's procedure, the value of n is computed by the following equation: