Appendix C: Hydraulic Analysis

Culvert Analysis Report
E.C. B-1 Ex - 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	2.9800 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	2.9800 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.9800 m³/s	Bottom Elevation	303.41 m
Depth	0.67 m	Velocity	0.89 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	2.9800 m³/s	304.96 m	2.44 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Ex - 100yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	304.96	m	Discharge	2.9800	m^3/s
Inlet Control HW Elev.	304.87	m	Tailwater Elevation	304.08	m
Outlet Control HW Elev.	304.96	m	Control Type	Entrance Control	
Headwater Depth/Height	1.31				

Grades					
Upstream Invert	303.77	m	Downstream Invert	303.41	m
Length	35.00	m	Constructed Slope	0.010143	m/m

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	0.67	m
Slope Type	Steep		Normal Depth	0.51	m
Flow Regime	N/A		Critical Depth	0.65	m
Velocity Downstream	2.44	m/s	Critical Slope	0.005207	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.015	
Section Material	Concrete		Span	1.83	m
Section Size	1800 x 600 mm		Rise	0.91	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	304.96	m	Upstream Velocity Head	0.32	m
Ke	0.70		Entrance Loss	0.23	m

Inlet Control Properties					
Inlet Control HW Elev.	304.87	m	Flow Control	N/A	
Inlet Type	0° wingwall flares		Area Full	1.7	m^2
K	0.06100		HDS 5 Chart	8	
M	0.75000		HDS 5 Scale	3	
C	0.04230		Equation Form	1	
Y	0.82000				

Culvert Analysis Report
E.C. B-1 Ex - 50yr Flow

Analysis Component			
Storm Event	Design	Discharge	2.6500 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	2.6500 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.6500 m³/s	Bottom Elevation	303.41 m
Depth	0.63 m	Velocity	0.86 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	2.6500 m³/s	304.87 m	2.31 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Ex - 50yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	304.87	m	Discharge	2.6500	m³/s
Inlet Control HW Elev.	304.79	m	Tailwater Elevation	304.04	m
Outlet Control HW Elev.	304.87	m	Control Type	Entrance Control	
Headwater Depth/Height	1.21				

Grades					
Upstream Invert	303.77	m	Downstream Invert	303.41	m
Length	35.00	m	Constructed Slope	0.010143	m/m

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	0.63	m
Slope Type	Steep		Normal Depth	0.47	m
Flow Regime	N/A		Critical Depth	0.60	m
Velocity Downstream	2.31	m/s	Critical Slope	0.005123	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.015	
Section Material	Concrete		Span	1.83	m
Section Size	1800 x 600 mm		Rise	0.91	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	304.87	m	Upstream Velocity Head	0.30	m
Ke	0.70		Entrance Loss	0.21	m

Inlet Control Properties					
Inlet Control HW Elev.	304.79	m	Flow Control	N/A	
Inlet Type	0° wingwall flares		Area Full	1.7	m²
K	0.06100		HDS 5 Chart	8	
M	0.75000		HDS 5 Scale	3	
C	0.04230		Equation Form	1	
Y	0.82000				

Culvert Analysis Report
E.C. B-1 Ex - Regional Flow

Analysis Component			
Storm Event	Design	Discharge	2.5100 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	2.5100 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.5100 m³/s	Bottom Elevation	303.41 m
Depth	0.61 m	Velocity	0.85 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	2.5100 m³/s	304.83 m	2.25 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Ex - Regional Flow

Component:Culvert-1

Culvert Summary			
Computed Headwater Elevation	304.83 m	Discharge	2.5100 m^3/s
Inlet Control HW Elev.	304.75 m	Tailwater Elevation	304.02 m
Outlet Control HW Elev.	304.83 m	Control Type	Entrance Control
Headwater Depth/Height	1.17		

Grades			
Upstream Invert	303.77 m	Downstream Invert	303.41 m
Length	35.00 m	Constructed Slope	0.010143 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.61 m
Slope Type	Steep	Normal Depth	0.45 m
Flow Regime	N/A	Critical Depth	0.58 m
Velocity Downstream	2.25 m/s	Critical Slope	0.005088 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.015
Section Material	Concrete	Span	1.83 m
Section Size	1800 x 600 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	304.83 m	Upstream Velocity Head	0.29 m
Ke	0.70	Entrance Loss	0.20 m

Inlet Control Properties			
Inlet Control HW Elev.	304.75 m	Flow Control	N/A
Inlet Type	0° wingwall flares	Area Full	1.7 m^2
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	3
C	0.04230	Equation Form	1
Y	0.82000		

Culvert Analysis Report
E.C. B-1 Pr - 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	3.4700 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	3.4700 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	3.4700 m³/s	Bottom Elevation	303.41 m
Depth	0.72 m	Velocity	0.93 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	3.4700 m³/s	305.10 m	3.52 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Pr - 100yr Flow

Component:Culvert-1

Culvert Summary			
Computed Headwater Elevation	305.10 m	Discharge	3.4700 m³/s
Inlet Control HW Elev.	305.10 m	Tailwater Elevation	304.13 m
Outlet Control HW Elev.	305.09 m	Control Type	Inlet Control
Headwater Depth/Height	1.46		

Grades			
Upstream Invert	303.77 m	Downstream Invert	303.41 m
Length	35.00 m	Constructed Slope	0.010171 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.54 m
Slope Type	Steep	Normal Depth	0.51 m
Flow Regime	N/A	Critical Depth	0.72 m
Velocity Downstream	3.52 m/s	Critical Slope	0.004005 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1800 x 600 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	305.09 m	Upstream Velocity Head	0.36 m
Ke	0.70	Entrance Loss	0.25 m

Inlet Control Properties			
Inlet Control HW Elev.	305.10 m	Flow Control	N/A
Inlet Type	0° wingwall flares	Area Full	1.7 m²
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	3
C	0.04230	Equation Form	1
Y	0.82000		

Culvert Analysis Report
E.C. B-1 Pr - 50yr Flow

Analysis Component			
Storm Event	Design	Discharge	3.0700 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	3.0700 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	3.0700 m³/s	Bottom Elevation	303.47 m
Depth	0.68 m	Velocity	0.90 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	3.0700 m³/s	304.99 m	2.27 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Pr - 50yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	304.99	m	Discharge	3.0700	m³/s
Inlet Control HW Elev.	304.89	m	Tailwater Elevation	304.15	m
Outlet Control HW Elev.	304.99	m	Control Type	Entrance Control	
Headwater Depth/Height	1.34				

Grades					
Upstream Invert	303.77	m	Downstream Invert	303.41	m
Length	35.00	m	Constructed Slope	0.010171	m/m

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	0.74	m
Slope Type	Steep		Normal Depth	0.47	m
Flow Regime	N/A		Critical Depth	0.66	m
Velocity Downstream	2.27	m/s	Critical Slope	0.003928	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.83	m
Section Size	1800 x 600 mm		Rise	0.91	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	304.99	m	Upstream Velocity Head	0.33	m
Ke	0.70		Entrance Loss	0.23	m

Inlet Control Properties					
Inlet Control HW Elev.	304.89	m	Flow Control	N/A	
Inlet Type	0° wingwall flares		Area Full	1.7	m²
K	0.06100		HDS 5 Chart	8	
M	0.75000		HDS 5 Scale	3	
C	0.04230		Equation Form	1	
Y	0.82000				

Culvert Analysis Report
E.C. B-1 Pr - Regional Flow

Analysis Component			
Storm Event	Design	Discharge	2.5100 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	2.5100 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.5100 m³/s	Bottom Elevation	303.41 m
Depth	0.61 m	Velocity	0.85 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1800 x 600 mm Box	2.5100 m³/s	304.83 m	2.25 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. B-1 Pr - Regional Flow

Component:Culvert-1

Culvert Summary			
Computed Headwater Elevation	304.83 m	Discharge	2.5100 m³/s
Inlet Control HW Elev.	304.75 m	Tailwater Elevation	304.02 m
Outlet Control HW Elev.	304.83 m	Control Type	Entrance Control
Headwater Depth/Height	1.17		

Grades			
Upstream Invert	303.77 m	Downstream Invert	303.41 m
Length	35.00 m	Constructed Slope	0.010171 m/m

Hydraulic Profile			
Profile	CompositeS1S2	Depth, Downstream	0.61 m
Slope Type	Steep	Normal Depth	0.41 m
Flow Regime	N/A	Critical Depth	0.58 m
Velocity Downstream	2.25 m/s	Critical Slope	0.003822 m/m

Section			
Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.83 m
Section Size	1800 x 600 mm	Rise	0.91 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	304.83 m	Upstream Velocity Head	0.29 m
Ke	0.70	Entrance Loss	0.20 m

Inlet Control Properties			
Inlet Control HW Elev.	304.75 m	Flow Control	N/A
Inlet Type	0° wingwall flares	Area Full	1.7 m²
K	0.06100	HDS 5 Chart	8
M	0.75000	HDS 5 Scale	3
C	0.04230	Equation Form	1
Y	0.82000		

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	4.0600 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	4.0600 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	4.0600 m³/s	Bottom Elevation	290.50 m
Depth	1.00 m	Velocity	1.02 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1050 mm Circular	4.0600 m³/s	300.95 m	4.60 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) 100yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	300.95	m	Discharge	4.0600	m^3/s
Inlet Control HW Elev.	296.81	m	Tailwater Elevation	291.50	m
Outlet Control HW Elev.	300.95	m	Control Type	Outlet Control	
Headwater Depth/Height	7.93				

Grades					
Upstream Invert	292.50	m	Downstream Invert	290.50	m
Length	110.00	m	Constructed Slope	0.018182	m/m

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	1.03	m
Slope Type	Mild		Normal Depth	N/A	m
Flow Regime	Subcritical		Critical Depth	1.03	m
Velocity Downstream	4.60	m/s	Critical Slope	0.060399	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.07	m
Section Size	1050 mm		Rise	1.07	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	300.95	m	Upstream Velocity Head	1.05	m
Ke	0.70		Entrance Loss	0.74	m

Inlet Control Properties					
Inlet Control HW Elev.	296.81	m	Flow Control	Submerged	
Inlet Type	Projecting		Area Full	0.9	m^2
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) 50yr Flow

Analysis Component			
Storm Event	Design	Discharge	3.3000 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	3.3000 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	3.3000 m³/s	Bottom Elevation	290.50 m
Depth	0.91 m	Velocity	0.97 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1050 mm Circular	3.3000 m³/s	297.74 m	3.83 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) 50yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	297.74	m	Discharge	3.3000	m³/s
Inlet Control HW Elev.	295.54	m	Tailwater Elevation	291.41	m
Outlet Control HW Elev.	297.74	m	Control Type	Outlet Control	
Headwater Depth/Height	4.91				

Grades					
Upstream Invert	292.50	m	Downstream Invert	290.50	m
Length	110.00	m	Constructed Slope	0.018182	m/m

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	0.98	m
Slope Type	Mild		Normal Depth	N/A	m
Flow Regime	Subcritical		Critical Depth	0.98	m
Velocity Downstream	3.83	m/s	Critical Slope	0.039682	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.07	m
Section Size	1050 mm		Rise	1.07	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	297.74	m	Upstream Velocity Head	0.69	m
Ke	0.70		Entrance Loss	0.49	m

Inlet Control Properties					
Inlet Control HW Elev.	295.54	m	Flow Control	Submerged	
Inlet Type	Projecting		Area Full	0.9	m²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) Regional Flow

Analysis Component			
Storm Event	Design	Discharge	3.7700 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	3.7700 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	3.7700 m³/s	Bottom Elevation	290.50 m
Depth	0.97 m	Velocity	1.00 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1050 mm Circular	3.7700 m³/s	299.65 m	4.30 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Ex (202 to 105) Regional Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	299.65	m	Discharge	3.7700	m³/s
Inlet Control HW Elev.	296.29	m	Tailwater Elevation	291.47	m
Outlet Control HW Elev.	299.65	m	Control Type	Outlet Control	
Headwater Depth/Height	6.71				

Grades					
Upstream Invert	292.50	m	Downstream Invert	290.50	m
Length	110.00	m	Constructed Slope	0.018182	m/m

Hydraulic Profile					
Profile	CompositeM2PressureProfile		Depth, Downstream	1.01	m
Slope Type	Mild		Normal Depth	N/A	m
Flow Regime	Subcritical		Critical Depth	1.01	m
Velocity Downstream	4.30	m/s	Critical Slope	0.051695	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.024	
Section Material	CMP		Span	1.07	m
Section Size	1050 mm		Rise	1.07	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	299.65	m	Upstream Velocity Head	0.91	m
Ke	0.70		Entrance Loss	0.63	m

Inlet Control Properties					
Inlet Control HW Elev.	296.29	m	Flow Control	Submerged	
Inlet Type	Projecting		Area Full	0.9	m²
K	0.03400		HDS 5 Chart	2	
M	1.50000		HDS 5 Scale	3	
C	0.05530		Equation Form	1	
Y	0.54000				

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	4.3100 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	4.3100 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	4.3100 m³/s	Bottom Elevation	290.80 m
Depth	1.02 m	Velocity	1.03 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1650 mm Circular	4.3100 m³/s	293.96 m	4.50 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) 100yr Flow

Component:Culvert-1

Culvert Summary			
Computed Headwater Elevation	293.96 m	Discharge	4.3100 m³/s
Inlet Control HW Elev.	293.76 m	Tailwater Elevation	291.82 m
Outlet Control HW Elev.	293.96 m	Control Type	Entrance Control
Headwater Depth/Height	1.08		

Grades			
Upstream Invert	292.15 m	Downstream Invert	290.80 m
Length	110.00 m	Constructed Slope	0.012273 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.75 m
Slope Type	Steep	Normal Depth	0.75 m
Flow Regime	Supercritical	Critical Depth	1.05 m
Velocity Downstream	4.50 m/s	Critical Slope	0.004007 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.68 m
Section Size	1650 mm	Rise	1.68 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	293.96 m	Upstream Velocity Head	0.45 m
Ke	0.70	Entrance Loss	0.31 m

Inlet Control Properties			
Inlet Control HW Elev.	293.76 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.2 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) 50 yr Flow

Analysis Component			
Storm Event	Design	Discharge	3.4900 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	3.4900 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	3.4900 m³/s	Bottom Elevation	290.80 m
Depth	0.94 m	Velocity	0.98 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1650 mm Circular	3.4900 m³/s	293.74 m	4.28 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) 50 yr Flow

Component:Culvert-1

Culvert Summary			
Computed Headwater Elevation	293.74 m	Discharge	3.4900 m^3/s
Inlet Control HW Elev.	293.54 m	Tailwater Elevation	291.74 m
Outlet Control HW Elev.	293.74 m	Control Type	Entrance Control
Headwater Depth/Height	0.95		

Grades			
Upstream Invert	292.15 m	Downstream Invert	290.80 m
Length	110.00 m	Constructed Slope	0.012273 m/m

Hydraulic Profile			
Profile	S2	Depth, Downstream	0.66 m
Slope Type	Steep	Normal Depth	0.66 m
Flow Regime	Supercritical	Critical Depth	0.94 m
Velocity Downstream	4.28 m/s	Critical Slope	0.003690 m/m

Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.68 m
Section Size	1650 mm	Rise	1.68 m
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	293.74 m	Upstream Velocity Head	0.38 m
Ke	0.70	Entrance Loss	0.27 m

Inlet Control Properties			
Inlet Control HW Elev.	293.54 m	Flow Control	N/A
Inlet Type	Square edge w/headwall	Area Full	2.2 m^2
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) Regional Flow

Analysis Component			
Storm Event	Design	Discharge	4.2900 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	4.2900 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	4.2900 m³/s	Bottom Elevation	290.80 m
Depth	1.02 m	Velocity	1.03 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1650 mm Circular	4.2900 m³/s	293.96 m	4.49 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
E.C. W-1 Pr (202 to 105) Regional Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	293.96	m	Discharge	4.2900	m^3/s
Inlet Control HW Elev.	293.75	m	Tailwater Elevation	291.82	m
Outlet Control HW Elev.	293.96	m	Control Type	Entrance Control	
Headwater Depth/Height	1.08				

Grades					
Upstream Invert	292.15	m	Downstream Invert	290.80	m
Length	110.00	m	Constructed Slope	0.012273	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.75	m
Slope Type	Steep		Normal Depth	0.74	m
Flow Regime	Supercritical		Critical Depth	1.05	m
Velocity Downstream	4.49	m/s	Critical Slope	0.003998	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.68	m
Section Size	1650 mm		Rise	1.68	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	293.96	m	Upstream Velocity Head	0.45	m
Ke	0.70		Entrance Loss	0.31	m

Inlet Control Properties					
Inlet Control HW Elev.	293.75	m	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	2.2	m^2
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	1.8500 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	1.8500 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	1.8500 m³/s	Bottom Elevation	299.60 m
Depth	0.48 m	Velocity	0.71 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1200 x 900 mm Box	1.8500 m³/s	301.15 m	3.16 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) 100yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	301.15	m	Discharge	1.8500	m^3/s
Inlet Control HW Elev.	300.98	m	Tailwater Elevation	300.08	m
Outlet Control HW Elev.	301.15	m	Control Type	Entrance Control	
Headwater Depth/Height	1.28				

Grades					
Upstream Invert	300.00	m	Downstream Invert	299.60	m
Length	40.00	m	Constructed Slope	0.010000	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.49	m
Slope Type	Steep		Normal Depth	0.48	m
Flow Regime	Supercritical		Critical Depth	0.62	m
Velocity Downstream	3.16	m/s	Critical Slope	0.005016	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.20	m
Section Size	1200 x 900 mm		Rise	0.90	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	301.15	m	Upstream Velocity Head	0.31	m
Ke	0.70		Entrance Loss	0.22	m

Inlet Control Properties					
Inlet Control HW Elev.	300.98	m	Flow Control	N/A	
Inlet Type	90° headwall w 45° bevels		Area Full	1.1	m^2
K	0.49500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	2	
C	0.03140		Equation Form	2	
Y	0.82000				

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) 50yr Flow

Analysis Component			
Storm Event	Design	Discharge	1.0900 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	1.0900 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	1.0900 m³/s	Bottom Elevation	299.60 m
Depth	0.37 m	Velocity	0.61 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1200 x 900 mm Box	1.0900 m³/s	300.81 m	2.74 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) 50yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	300.81	m	Discharge	1.0900	m^3/s
Inlet Control HW Elev.	300.69	m	Tailwater Elevation	299.97	m
Outlet Control HW Elev.	300.81	m	Control Type	Entrance Control	
Headwater Depth/Height	0.90				

Grades					
Upstream Invert	300.00	m	Downstream Invert	299.60	m
Length	40.00	m	Constructed Slope	0.010000	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.33	m
Slope Type	Steep		Normal Depth	0.33	m
Flow Regime	Supercritical		Critical Depth	0.44	m
Velocity Downstream	2.74	m/s	Critical Slope	0.004533	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.20	m
Section Size	1200 x 900 mm		Rise	0.90	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	300.81	m	Upstream Velocity Head	0.22	m
Ke	0.70		Entrance Loss	0.15	m

Inlet Control Properties					
Inlet Control HW Elev.	300.69	m	Flow Control	N/A	
Inlet Type	90° headwall w 45° bevels		Area Full	1.1	m^2
K	0.49500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	2	
C	0.03140		Equation Form	2	
Y	0.82000				

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) Regional Flow

Analysis Component			
Storm Event	Design	Discharge	2.1200 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	2.1200 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	2.1200 m³/s	Bottom Elevation	299.60 m
Depth	0.52 m	Velocity	0.74 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-1200 x 900 mm Box	2.1200 m³/s	301.26 m	3.27 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. L-2 Pr (@ Bryne Dr) Regional Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	301.26	m	Discharge	2.1200	m³/s
Inlet Control HW Elev.	301.11	m	Tailwater Elevation	300.12	m
Outlet Control HW Elev.	301.26	m	Control Type	Entrance Control	
Headwater Depth/Height	1.40				

Grades					
Upstream Invert	300.00	m	Downstream Invert	299.60	m
Length	40.00	m	Constructed Slope	0.010000	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.54	m
Slope Type	Steep		Normal Depth	0.53	m
Flow Regime	Supercritical		Critical Depth	0.68	m
Velocity Downstream	3.27	m/s	Critical Slope	0.005184	m/m

Section					
Section Shape	Box		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.20	m
Section Size	1200 x 900 mm		Rise	0.90	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	301.26	m	Upstream Velocity Head	0.34	m
Ke	0.70		Entrance Loss	0.24	m

Inlet Control Properties					
Inlet Control HW Elev.	301.11	m	Flow Control	N/A	
Inlet Type	90° headwall w 45° bevels		Area Full	1.1	m²
K	0.49500		HDS 5 Chart	10	
M	0.66700		HDS 5 Scale	2	
C	0.03140		Equation Form	2	
Y	0.82000				

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) 100yr Flow

Analysis Component			
Storm Event	Design	Discharge	0.2600 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	0.2600 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	0.2600 m³/s	Bottom Elevation	290.10 m
Depth	0.25 m	Velocity	0.47 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-750 mm Circular	0.2600 m³/s	290.75 m	1.51 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) 100yr Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	290.75	m	Discharge	0.2600	m^3/s
Inlet Control HW Elev.	290.68	m	Tailwater Elevation	290.35	m
Outlet Control HW Elev.	290.75	m	Control Type	Entrance Control	
Headwater Depth/Height	0.66				

Grades					
Upstream Invert	290.25	m	Downstream Invert	290.10	m
Length	35.00	m	Constructed Slope	0.004286	m/m

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.31	m
Slope Type	Steep		Normal Depth	0.31	m
Flow Regime	Supercritical		Critical Depth	0.31	m
Velocity Downstream	1.51	m/s	Critical Slope	0.004247	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	0.76	m
Section Size	750 mm		Rise	0.76	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	290.75	m	Upstream Velocity Head	0.12	m
Ke	0.70		Entrance Loss	0.08	m

Inlet Control Properties					
Inlet Control HW Elev.	290.68	m	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.5	m^2
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) 50yr Flow

Analysis Component			
Storm Event	Design	Discharge	0.2100 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	0.2100 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	0.2100 m³/s	Bottom Elevation	290.10 m
Depth	0.22 m	Velocity	0.45 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-750 mm Circular	0.2100 m³/s	290.70 m	1.42 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) 50yr Flow

Component:Culvert-1

Culvert Summary

Computed Headwater Elevation	290.70	m	Discharge	0.2100	m³/s
Inlet Control HW Elev.	290.63	m	Tailwater Elevation	290.32	m
Outlet Control HW Elev.	290.70	m	Control Type	Entrance Control	
Headwater Depth/Height	0.59				

Grades

Upstream Invert	290.25	m	Downstream Invert	290.10	m
Length	35.00	m	Constructed Slope	0.004286	m/m

Hydraulic Profile

Profile	S2		Depth, Downstream	0.27	m
Slope Type	Steep		Normal Depth	0.27	m
Flow Regime	Supercritical		Critical Depth	0.28	m
Velocity Downstream	1.42	m/s	Critical Slope	0.004177	m/m

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	0.76	m
Section Size	750 mm		Rise	0.76	m
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	290.70	m	Upstream Velocity Head	0.10	m
Ke	0.70		Entrance Loss	0.07	m

Inlet Control Properties

Inlet Control HW Elev.	290.63	m	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.5	m²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) Regional Flow

Analysis Component			
Storm Event	Design	Discharge	0.4200 m³/s

Peak Discharge Method: User-Specified			
Design Discharge	0.4200 m³/s	Check Discharge	0.0000 m³/s

Tailwater properties: Trapezoidal Channel

Tailwater conditions for Design Storm.			
Discharge	0.4200 m³/s	Bottom Elevation	290.10 m
Depth	0.32 m	Velocity	0.54 m/s

Name	Description	Discharge	HW Elev.	Velocity
Culvert-1	1-750 mm Circular	0.4200 m³/s	290.91 m	1.76 m/s
Weir	Not Considered	N/A	N/A	N/A

Culvert Analysis Report
P.C. W-1 Pr (2051 to 2052) Regional Flow

Component:Culvert-1

Culvert Summary					
Computed Headwater Elevation	290.91	m	Discharge	0.4200	m³/s
Inlet Control HW Elev.	290.81	m	Tailwater Elevation	290.42	m
Outlet Control HW Elev.	290.91	m	Control Type	Outlet Control	
Headwater Depth/Height	0.86				

Grades					
Upstream Invert	290.25	m	Downstream Invert	290.10	m
Length	35.00	m	Constructed Slope	0.004286	m/m

Hydraulic Profile					
Profile	M2		Depth, Downstream	0.40	m
Slope Type	Mild		Normal Depth	0.40	m
Flow Regime	Subcritical		Critical Depth	0.40	m
Velocity Downstream	1.76	m/s	Critical Slope	0.004603	m/m

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	0.76	m
Section Size	750 mm		Rise	0.76	m
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	290.91	m	Upstream Velocity Head	0.15	m
Ke	0.70		Entrance Loss	0.10	m

Inlet Control Properties					
Inlet Control HW Elev.	290.81	m	Flow Control	N/A	
Inlet Type	Groove end projecting		Area Full	0.5	m²
K	0.00450		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	3	
C	0.03170		Equation Form	1	
Y	0.69000				

Appendix D: Storm Sewer Sizing

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
H-1106				0.70	0.912	0.638	0.638	10.000	108.922	0.193						
H-1104	MH 1	MH 2	89	0.25	0.673	0.168	0.806	10.432	106.531	0.239	525	2.98	0.743	3.433	0.432	32%
H-1107				0.93	0.755	0.703	0.703	10.000	108.922	0.213						
H-1103	MH 2	MH 3	98.7	0.27	0.725	0.196	1.704	10.822	104.473	0.495	525	4.49	0.912	4.214	0.390	54%
H-1108				0.59	0.485	0.286	0.286	10.000	108.922	0.087						
H-1102	MH 3	MH 4	82.8	0.25	0.657	0.164	2.155	11.142	102.856	0.616	600	3.95	1.222	4.320	0.319	50%
H-1109				0.52	0.755	0.392	0.392	10.000	108.922	0.119						
H-1101	MH 4	MH 5	73.8	0.24	0.690	0.166	2.713	11.444	101.378	0.764	675	3	1.457	4.073	0.302	52%
Ext	MH 36	MH 5	78	9.01	0.817	7.364	7.364	11.855	99.444	2.034	1350	0.5	3.778	2.639	0.493	54%
	MH 5	HT06 Pond Inlet	72				10.077	11.899	99.244	2.778	1350	0.5	3.778	2.639	0.455	74%
H-2105	MH 6	MH 7	65	0.61	0.559	0.341	0.341	10.000	108.922	0.103	300	4.58	0.207	2.931	0.370	50%
H-2104	MH 7	MH 8	72	0.17	0.705	0.120	0.461	10.378	106.826	0.137	375	4	0.351	3.178	0.378	39%
H-2103	MH 8	MH 9	75	0.29	0.807	0.234	0.695	10.776	104.714	0.202	375	3.9	0.347	3.138	0.398	58%
H-3				0.89	0.757	0.674	0.674	10.000	108.922	0.204						
H-2101				0.07	0.730	0.051	0.051	10.000	108.922	0.015						
H-2102	MH 9	MH 10	51	0.21	0.708	0.149	1.568	10.936	103.891	0.453	600	1.5	0.753	5.305	0.160	60%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	***A***	***B***	***C***
Return Period Storm	**5**	853.61	4.70	0.77
[Optional] User Defined				

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
H-1106				0.61	0.912	0.556	0.556	10.000	108.922	0.168						
H-1104	MH 1	MH 2	89	0.39	0.912	0.355	0.912	10.432	106.531	0.270	525	2.98	0.743	3.433	0.432	36%
H-1107				0.86	0.772	0.664	0.664	10.000	108.922	0.201						
H-1103	MH 2	MH 3	98.7	0.48	0.912	0.438	2.013	10.822	104.473	0.584	525	4.49	0.912	4.214	0.390	64%
H-1108				0.51	0.497	0.254	0.254	10.000	108.922	0.077						
H-1102	MH 3	MH 4	82.8	0.43	0.912	0.392	2.658	11.142	102.856	0.760	600	3.95	1.222	4.320	0.319	62%
H-1109				0.43	0.763	0.328	0.328	10.000	108.922	0.099						
H-1101	MH 4	MH 5	73.8	0.38	0.912	0.346	3.333	11.444	101.378	0.939	675	3	1.457	4.073	0.302	64%
Ext	MH 36	MH 5	78	8.64	0.804	6.944	6.944	11.855	99.444	1.918	1350	0.5	3.778	2.639	0.493	51%
	MH 5	HT06 Pond Inlet	72				10.277	11.899	99.244	2.833	1350	0.5	3.778	2.639	0.455	75%
H-2105	MH 6	MH 7	65	0.75	0.912	0.684	0.684	10.000	108.922	0.207	300	4.58	0.207	2.931	0.370	100%
H-2104	MH 7	MH 8	72	0.24	0.912	0.219	0.902	10.378	106.826	0.268	375	4	0.351	3.178	0.378	76%
H-2103	MH 8	MH 9	75	0.37	0.912	0.337	1.240	10.776	104.714	0.361	375	3.9	0.347	3.138	0.398	104%
H-3				0.84	0.766	0.644	0.644	10.000	108.922	0.195						
H-2101				0.09	0.912	0.082	0.082	10.000	108.922	0.025						
H-2102	MH 9	MH 10	51	0.26	0.912	0.237	2.202	10.936	103.891	0.636	600	1.5	0.753	5.305	0.160	84%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				
	100	1426.406	5.273	0.759

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
H-1106				0.61	0.912	0.556	0.556	10.000	108.922	0.168						
H-1104	MH 1	MH 2	89	0.39	0.912	0.355	0.912	10.432	106.531	0.270	525	2.98	0.743	3.433	0.432	36%
H-1107				0.86	0.772	0.664	0.664	10.000	108.922	0.201						
H-1103	MH 2	MH 3	98.7	0.48	0.912	0.438	2.013	10.822	104.473	0.584	525	4.49	0.912	4.214	0.390	64%
H-1108				0.51	0.497	0.254	0.254	10.000	108.922	0.077						
H-1102	MH 3	MH 4	82.8	0.43	0.912	0.392	2.658	11.142	102.856	0.760	600	3.95	1.222	4.320	0.319	62%
H-1109				0.43	0.763	0.328	0.328	10.000	108.922	0.099						
H-1101	MH 4	MH 5	73.8	0.38	0.912	0.346	3.333	11.444	101.378	0.939	675	3	1.457	4.073	0.302	64%
Ext	MH 36	MH 5	78	8.64	0.804	6.944	6.944	11.855	99.444	1.918	1350	0.5	3.778	2.639	0.493	51%
	MH 5	HT06 Pond Inlet	72				10.277	11.842	165.241	4.717	1650	0.5	6.451	3.017	0.398	73%
H-2105	MH 6	MH 7	65	0.75	0.912	0.684	0.684	10.000	108.922	0.207	375	4.58	0.376	3.401	0.319	55%
H-2104	MH 7	MH 8	72	0.24	0.912	0.219	0.902	10.378	106.826	0.268	375	4	0.351	3.178	0.378	76%
H-2103	MH 8	MH 9	75	0.37	0.912	0.337	1.240	10.730	104.951	0.361	450	3.9	0.564	3.544	0.353	64%
H-3				0.84	0.766	0.644	0.644	10.000	108.922	0.195						
H-2101				0.09	0.912	0.082	0.082	10.000	108.922	0.025						
H-2102	MH 9	MH 10	51	0.26	0.912	0.237	2.202	10.891	104.123	0.637	600	1.5	0.753	5.305	0.160	85%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
P208			60	0.210	0.950	0.200	0.200	10.000	108.922	0.060						
	MH2081	MH2082	70	0.245	0.950	0.233	0.432	10.000	108.922	0.131	450	0.75	0.247	1.554	0.751	53%
	MH2082	MH2083	100	0.350	1.950	0.683	1.115	11.000	103.567	0.321	525	3	0.746	3.444	0.484	43%
	MH2083	MH2084	100	0.350	1.950	0.683	1.797	11.000	103.567	0.517	525	3	0.746	3.444	0.484	69%
	MH2084	Pond	20	0.070	0.950	0.067	1.181	10.751	104.844	0.344	600	0.85	0.567	2.004	0.166	61%
P209			41.2	0.144	0.950	0.137	0.137	10.000	108.922	0.041						
	MH2091	MH2092	100	0.350	0.950	0.333	0.469	10.856	104.299	0.136	375	1.5	0.215	1.946	0.856	63%
	MH2092	MH2093	100	0.350	1.950	0.683	1.152	11.565	100.801	0.323	525	1.4	0.509	2.353	0.708	63%
	MH2093	Pond	20	0.070	0.950	0.067	1.218	11.073	103.198	0.349	600	0.5	0.435	1.537	0.217	80%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	Pipe Time [min]	V_Full [cms]	Capacity [%]
L-100				0.193	0.739	0.143	0.143	10.0	108.922	0.043						
L-200	EXCBMH-20	EXMH-21	24.4	0.133	0.747	0.099	0.099	10.3	107.097	0.073	300	0.82	0.088	0.328	1.240	83%
L-101				1.030	0.818	0.842	0.842	10.0	108.922	0.119						
L-201	EXMH-21	EXMH-22	106	0.351	0.785	0.275	0.275	11.6	100.483	0.269	450	0.57	0.215	1.304	1.355	125%
L-102				0.262	0.856	0.224	0.224	10.0	108.922	0.068						
L-202	EXMH-22	EXMH-23	76	0.202	0.610	0.123	0.123	12.4	96.938	0.370	525	0.66	0.350	0.784	1.616	106%
L-103				0.682	0.606	0.413	0.413	10.0	108.922	0.088						
L-203 South of MH24	EXMH-23	EXMH-24	63.4	0.210	0.663	0.139	0.139	13.0	94.540	0.495	600	0.73	0.525	0.569	1.857	94%
L-106				0.168	0.835	0.140	0.140	10.0	108.922	0.042						
L-108				0.783	0.594	0.465	0.465	28.2	58.728	0.076						
L-207	EXMH-25	EXMH-26	39.4	0.127	0.620	0.079	0.079	28.7	58.120	0.131	450	0.66	0.232	0.450	1.458	57%
L-206	EXMH-26	EXMH-27	73.7	0.098	0.624	0.061	0.140	30.1	56.342	0.153	525	0.2	0.193	1.381	0.889	79%
L-205				0.075	0.701	0.052	0.052	30.1	56.342	0.008						
L-104				1.159	0.835	0.967	0.967	10.0	108.922	0.122						
L-105				0.460	0.835	0.384	0.384	10.0	108.922	0.116						
L-204	EXMH-27	EXMH-24	95.3	0.113	0.663	0.075	0.075	31.3	54.855	0.410	750	0.26	0.568	1.235	1.286	72%
L-203 South of MH24				0.219	0.663	0.145	0.145	10.0	108.922	0.692						
L-109				2.003	0.867	1.736	1.736	10.2	107.968	0.127						
	EXMH-24	24-1	100				0.145	32.4	53.547	1.053	1050	0.21	1.253	1.152	1.447	84%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	Pipe Time [min]	V_Full [cms]	Capacity [%]
L-100				0.193	0.739	0.143	0.143	10.0	108.922	0.043						
L-200	EXCBMH-20	EXMH-21	24.4	0.133	0.912	0.121	0.121	10.3	107.097	0.079	300	0.82	0.088	0.328	1.240	90%
L-101				1.010	0.783	0.791	0.791	10.0	108.922	0.114						
L-201	EXMH-21	EXMH-22	106	0.430	0.912	0.392	0.392	11.6	100.483	0.303	450	0.57	0.215	1.304	1.355	141%
L-102				0.260	0.828	0.215	0.215	10.0	108.922	0.065						
L-202	EXMH-22	EXMH-14	76	0.250	0.912	0.228	0.228	12.4	96.938	0.429	525	0.66	0.350	0.784	1.616	123%
L-103				0.530	0.663	0.351	0.351	10.0	108.922	0.097						
P403 South of PMH2	EXMH-14	EXMH-24	63.4	0.330	0.870	0.287	0.287	10.0	108.922	0.613	600	0.73	0.525	0.569	1.857	117%
L-106				0.210	0.835	0.175	0.175	10.0	108.922	0.053						
L-507				0.560	0.780	0.437	0.175	18.4	77.075	0.038						
L-108				0.783	0.594	0.465	0.465	28.2	58.728	0.076						
L-207	EXMH-27	EXMH-26	39.4	0.190	0.796	0.151	0.151	28.7	58.120	0.191	450	0.66	0.232	0.450	1.458	82%
L-206	EXMH-26	EXMH-25	73.7	0.090	0.796	0.072	0.072	30.1	56.342	0.202	525	0.2	0.193	1.381	0.889	105%
L-205				0.075	0.796	0.059	0.059	30.1	56.342	0.009						
L-105				0.500	0.835	0.417	0.417	10.0	108.922	0.122						
L-204	EXMH-25	EXMH-24	95.3	0.090	0.796	0.072	0.072	31.3	54.855	0.344	750	0.26	0.568	1.235	1.286	61%
L-1042				0.610	0.835	0.509	0.509	10.0	108.922	0.122						
L-203				0.270	0.796	0.215	0.215	10.0	108.922	0.065						
L-109				1.920	0.850	1.632	1.632	10.2	107.968	0.124						
	EXMH-24	PMH2	50					31.9	54.192	1.268	1050	0.21	1.253	0.576	1.447	101%
P403 North of PMH2	PMH1	PMH2	80	0.350	0.870	0.305	0.305	10.0	108.922	0.092	600	0.21	0.282	1.338	0.996	33%
	PMH2	EXMH24-1	50					32.4	53.547	1.360	1050	0.21	1.253	0.576	1.447	109%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	Pipe Time [min]	V_Full [cms]	Capacity [%]
L-100				0.193	0.739	0.143	0.143	10.0	108.922	0.043						
L-200	EXCBMH-20	EXMH-21	24.4	0.133	0.912	0.121	0.121	10.3	107.345	0.079	375	0.82	0.159	0.283	1.439	50%
L-101				1.010	0.783	0.791	0.791	10.0	108.922	0.114						
L-201	EXMH-21	EXMH-22	106	0.430	0.912	0.392	0.392	11.4	101.788	0.304	600	0.57	0.464	1.076	1.641	66%
L-102				0.260	0.828	0.215	0.215	10.0	108.922	0.065						
L-202	EXMH-22	EXMH-14	76	0.250	0.912	0.228	0.228	12.0	98.682	0.432	675	0.66	0.684	0.663	1.910	63%
L-103				0.530	0.663	0.351	0.351	10.0	108.922	0.097						
P403 South of PMH2	EXMH-14	EXMH-24	63.4	0.330	0.870	0.287	0.287	10.0	108.922	0.616	750	0.73	0.952	0.490	2.155	65%
L-106				0.210	0.835	0.175	0.175	10.0	108.922	0.053						
L-507				0.560	0.780	0.437	0.175	18.4	77.075	0.038						
L-108				0.783	0.594	0.465	0.465	28.2	58.728	0.076						
L-207	EXMH-27	EXMH-26	39.4	0.190	0.796	0.151	0.151	28.7	58.120	0.191	450	0.66	0.232	0.450	1.458	82%
L-206	EXMH-26	EXMH-25	73.7	0.090	0.796	0.072	0.072	29.9	56.489	0.202	600	0.2	0.275	1.264	0.972	74%
L-205				0.075	0.796	0.059	0.059	29.9	56.489	0.009						
L-105				0.500	0.835	0.417	0.417	10.0	108.922	0.122						
L-204	EXMH-25	EXMH-24	95.3	0.090	0.796	0.072	0.072	31.2	54.993	0.344	750	0.26	0.568	1.235	1.286	61%
L-1042				0.610	0.835	0.509	0.509	10.0	108.922	0.122						
L-203				0.270	0.796	0.215	0.215	10.0	108.922	0.065						
L-109				1.920	0.850	1.632	1.632	10.2	107.968	0.124						
	EXMH-24	PMH2	50					31.7	54.382	1.271	1200	0.21	1.788	0.527	1.581	71%
P403 North of PMH2	PMH1	PMH2	80	0.350	0.870	0.305	0.305	10.0	108.922	0.092	600	0.21	0.282	1.338	0.996	33%
	PMH2	EXMH24-1	50					32.2	53.787	1.363	1200	0.21	1.788	0.527	1.581	76%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				
	100	1426.406	5.273	0.76

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics					
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
	27	155	60	0.676	0.89	0.604	5.457	17.549	79.292	1.202	1050	0.5	1.933	2.232	0.448	62%
	155	OGS	49.9	0.183	0.85	0.156	5.613	17.997	78.091	1.218	1050	0.48	1.894	2.187	0.380	64%
	OGS	Outfall	13	0.192	0.85	0.163	5.776	18.377	77.104	1.237	1050	0.54	2.009	2.320	0.093	62%
P106			60	0.210	0.950	0.200	0.200									
	MH1061	MH1062	100	0.350	0.950	0.333	0.532	10.000	108.922	0.161	450	1.5	0.350	2.198	0.758	46%
	MH1062	MH1063	100	0.350	0.950	0.333	0.865	10.484	106.253	0.255	525	3	0.746	3.444	0.484	34%
	DICB1061	MH1063	30	3.120	0.220	0.686	0.686	10.839	104.386	0.199	525	0.5	0.304	1.406	0.356	65%
	MH1063	MH1064	60	0.210	0.950	0.200	1.750	10.601	105.627	0.514	675	0.5	0.595	1.663	0.601	86%
	MH1064	Pond A	30	0.105	0.950	0.100	1.850	10.752	173.697	0.893	800	0.5	0.936	1.862	0.269	95%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	5	853.61	4.70	0.77
[Optional] User Defined				

Sewer	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

MH Location			Runoff Calculations							Designed Pipe Characteristics					
From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	Slope [%]	Q_Full [cms]	Pipe Time [min]	V_Full [cms]	Capacity [%]
PMH1	PMH2	97.84	0.333	0.900	0.299	0.299	10.0	108.922	0.091	375	1.00	0.176	1.026	1.589	52%
PMH2	PMH3	100	0.340	0.900	0.306	0.605	10.0	108.922	0.183	450	1.00	0.285	0.929	1.794	64%
PMH3	PMH4	100	0.340	0.900	0.306	0.911	10.0	108.922	0.276	450	2.50	0.451	0.587	2.837	61%
PMH4	PMH5	100	0.340	0.900	0.306	1.217	10.0	108.922	0.368	525	2.50	0.681	0.530	3.144	54%
PMH5	PMH6	100	0.340	0.900	0.306	1.523	10.0	108.922	0.461	600	0.89	0.580	0.813	2.051	79%
PMH6	PMH7	100	0.340	0.900	0.306	1.829	10.0	108.922	0.554	675	0.60	0.652	0.915	1.821	85%
PMH7	Pond	20	0.068	0.900	0.061	1.891	10.0	108.922	0.572	675	0.50	0.595	0.200	1.663	96%
PMH8	PMH9	100							0.790	750	1.00	1.114	0.661	2.522	71%
PMH9	U/S E.C. B-1	100	0.340	0.900	0.306	0.275	10.0	108.922	0.790	750	1.00	1.114	0.661	2.522	71%
PMH10	PMH11	100	0.550	0.900	0.495	0.446	10.000	108.922	0.135	450	0.5	0.202	1.314	1.269	67%
PMH11	PMH12	37.7							0.135	450	0.5	0.202	0.495	1.269	67%
PMH12	D/S E.C. B-1	10							0.135	450	0.5	0.202	0.131	1.269	67%

Storm sewer sizing and capacity assessment to convey flows from sub-catchments

A. Input Data (Apply for A <10 ha)

Specify "Design Storm" using drop-down (see "Rainfall Data" sheet for reference data) or manual IDF input; Set maximum inlet time and manning's roughness for pipe

Design Storm	IDF Coeff			
	Year	*A*	*B*	*C*
Return Period Storm	10	975.87	4.70	0.76
[Optional] User Defined				

Sewer Characteristics	Input Value	
Inlet Time [min]	10	*City of Barrie Drainage and Stormwater Management Guidelines*
Manning's "n"	0.013	*Concrete Pipe*

B. Storm Sewer Calculation Sheet

At minimum, input "Length", "Diameter" and "Slope" of pipe

Sub-Catchment ID	MH Location			Runoff Calculations							Designed Pipe Characteristics							
	From	To	Distance [m]	A [ha]	C	A x C	Total AxC	Tin [min]	i [mm/hr]	Q [cms]	Diameter [mm]	U/S Invert [m]	D/S Invert [m]	Slope [%]	Q_Full [cms]	V_Full [cms]	Pipe Time [min]	Capacity [%]
	92	97	100	0.101	0.73	0.074	0.074	10.000	126.547	0.026	300	312	310.82	1.2	0.105	1.488	1.120	25%
Townhouse	97	107	91.3	0.653	0.59	0.383	0.457	11.120	119.676	0.152	375	310.82	309.67	1.3	0.197	1.783	0.853	77%
	107	117	98.6	0.216	0.91	0.197	0.655	11.974	114.992	0.209	450	309.67	307.97	1.7	0.375	2.356	0.697	56%
Veterans	117	122	98.6	0.409	0.64	0.260	0.915	12.671	111.466	0.283	450	307.97	305.91	2.1	0.413	2.594	0.634	69%
	122	127	98.4	0.690	0.92	0.634	1.549	13.305	108.472	0.467	600	305.91	304.72	1.2	0.676	2.391	0.686	69%
	127	137	100	0.310	0.84	0.259	1.808	13.991	105.432	0.529	600	304.72	303.19	1.5	0.760	2.689	0.620	70%
154 -148	137	142	99.4	1.432	0.42	0.597	2.405	14.611	102.850	0.687	600	303.19	301.25	2.0	0.859	3.037	0.546	80%
	142	152	94.4	0.289	0.88	0.255	2.660	15.156	100.695	0.744	675	301.25	299.78	1.6	1.050	2.934	0.536	71%
146	152	11	97.7	0.871	0.48	0.420	3.080	15.692	98.676	0.844	675	299.78	298.45	1.4	0.982	2.743	0.594	86%
HEB	11	21	95.6	0.301	0.83	0.249	3.329	16.286	96.548	0.893	750	298.45	296.35	2.2	1.652	3.739	0.426	54%
	21	24	84	0.315	0.79	0.250	3.579	16.712	95.084	0.945	750	296.35	295.5	1.0	1.121	2.537	0.552	84%
	24	27	36	0.295	0.85	0.250	3.829	17.264	93.263	0.992	825	295.6	295.38	0.6	1.123	2.101	0.286	88%

Appendix E: Fluvial Geomorphological Report

water's edge
ENVIRONMENTAL SOLUTIONS TEAM LTD.

Transportation Improvements for Bryne Drive, Essa Road, Harvie Road Class EA

Fluvial Geomorphological and Meander Beltwidth Assessment

June 16, 2017

June 16, 2017
WE 17008

Ms. Melissa Alexander, B.Sc., MCIP, RPP
Environmental Planner
Hatch Infrastructure
5035 South Service Road, Sixth Floor
Burlington, Ontario
L7L 6M9

Dear Ms. Alexander:

RE: Transportation Improvements for Bryne Dr., Harvie Rd and Essa Rd Class EA – Whiskey, Lovers and Bear Creeks, Barrie, ON - Fluvial Geomorphological and Meander Beltwidth Assessments

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Water's Edge was authorized by the City of Barrie and Hatch to complete a fluvial geomorphological and meander beltwidth assessments in conjunction with the Transportation Improvements for Bryne Drive, Harvie Road and Essa Road Class EA being undertaken in Barrie, Ontario. The purpose of this undertaking is to assess the channel crossings within the environmental assessment study area. This report will focus on two crossings associated with the Whiskey Creek subwatershed, one crossing for the Lovers Creek subwatershed and one crossing for the Bear Creek subwatershed. The study will review data if available from previous reports.

We have completed our assessment of the creek in accordance with the approved project Terms of Reference. Data sources for the analysis include:

- 1954, 1978, 1991, 1995, 2012 and 2013 Aerial Photos, (City of Barrie);
- Barrie Creeks, Lovers Creek and Hewitt's Creek Subwatershed Plan, (LSRCA 2012);
- Physiography of Southern Ontario by Chapman & Putnam (digital data from Ministry of Northern Development and Mines (MNDM));
- Ontario Flow Assessment Tools III (OFAT III) (from MNRF) and;
- Site Inspections and Surveys by Water's Edge staff.

Site inspections and geomorphic surveys of multiple sites were completed by Water's Edge staff in December 2015 as well as Summer 2016. The initial site inspection was undertaken after review of the mapping and available literature was completed in order to confirm site and general system characteristics. A background review which focused on the subwatersheds of Lovers Creek, Hewitt's Creek and Sandy Cove Creek of the 2013 Barrie Annexation Study was also completed.

1.0 BACKGROUND REVIEW

Previous studies have been conducted on the streams and reaches throughout the Bryne, Harvie and Essa study area. The information outlined below includes; geology, channel characteristics, subwatershed details, assessment scores and meander beltwidths.

Barrie Creeks, Lovers Creek and Hewitt's Creek Subwatershed Plan, (LSRCA 2012)

The subwatershed plan was developed by the Lake Simcoe and Region Conservation Authority (LSRCA) and is a general overview of the current conditions of the Barrie Creeks, Lovers Creek and Hewitt's Creek subwatersheds. The plan provides recommendations on stormwater management, hydrological and hydrogeological functions, water quality, conservation of wetlands and woodlands, fish habitat, natural features and corridors and land-use planning. The report includes two of the three creeks (Lovers and Whiskey) that are included in this assessment and from a fluvial geomorphological perspective, the report discusses the following:

- Lovers Creek is a 4th order stream with a drainage area of 58.60 km^2 and total stream length of 93.11 km while Whiskey Creek is a 3rd order stream with a drainage area of 6.15 km^2 and total stream length of 12.14 km;
- Lovers Creek and Whiskey Creek subwatersheds land use are both primarily natural heritage features and non-intensive agriculture;
- The general surficial geology is stone-poor, carbonate-derived silty to sandy till but along the stream corridors the geology is alluvial deposits;
- Prior to the 2012 report no specific fluvial geomorphology studies had been completed on the Barrie Creeks, Lovers Creek or Hewitt's Creek subwatersheds;
- Fourteen sites were randomly chosen on Lovers Creek for a stream bank stability assessment; 9 sites had higher percentage of stable stream banks, 2 had a higher percentage of unstable stream banks and 3 had higher moderate stability stream banks and;
- Six sites were randomly chosen on Whiskey Creek where the results showed an even split between stable, moderately stable and unstable creek banks.

2.0 EXISTING CONDITIONS

Geology & Physiography

Reviewing the site area's surficial materials is important to evaluate active channel processes. Stream channel form and sediment supply are controlled by the region's physiography and underlying surficial geology. Figure 1 shows the local physiography in the study area.

The study area, as shown in Figure 1, is located within the Peterborough Drumlin field physiographic region and within the Drumlinized Till Plain landforms. The glacial deposits of this region are typically sands of varying sizes and some silts. Many of the creeks in this area have heavy sand loads throughout many of their reaches. Drumlins and eskers are characteristic to the Peterborough Drumlin Field. Also of note is the presence of underlying tills that were found in some reaches of this study area. North of the study area, is the Simcoe Lowlands physiographic region which Whiskey and Lovers Creeks flow through before flowing into Lake Simcoe.

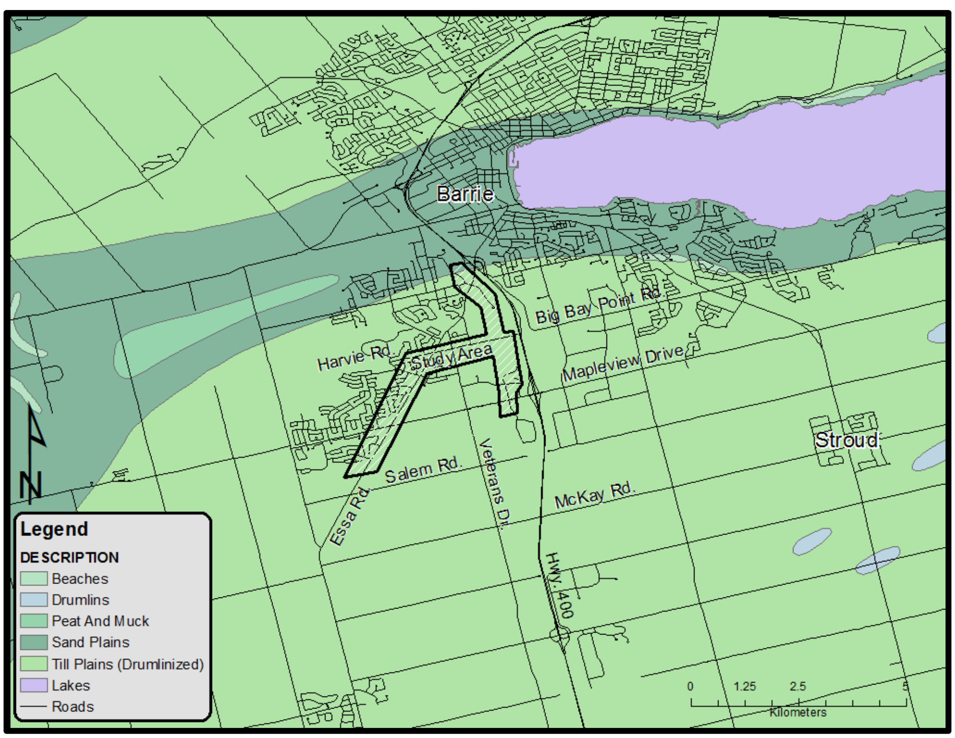

Figure 1: Local Physiography (data Ontario Geological Survey)

General Watershed Characteristics
The following data was acquired using the Ontario Flow Assessment Tool III (OFAT III). The data closely resembles the data from the LSRCA subwatershed report. The landcover percentages are based only on the delineated subwatershed seen in Figure 2.

Whiskey Creek is a 3rd order stream that has a total drainage area of roughly 6.15 km^2 but only 1.6 km^2 of it is included in this assessment's study area. It originates west of Highway 400 in what is predominantly community/infrastructure (68%). The southwest branch of Whiskey Creek originates from a SWM pond while the northwest originates in forested areas north of Harvie Rd. Remaining land use of the site is 13% agricultural lands, 14% forested areas and 4% swamp. After flowing through the study area, the channel flows east under Highway 400 and then through industrial, forested and residential areas before out letting to Kempenfelt Bay.

Lovers Creek is a 4th order stream which originates south of the City of Barrie and flows through the city before draining into the Kempenfelt Bay of Lake Simcoe. The total Lovers Creek watershed is 59 km^2 in size while the area for this study is only small portion of that at 0.6 km^2. The general slope of Lovers Creek is 3.81% while in the study area it is only 1.5%. The study area subwatershed as shown in Figure 2 is primarily community/infrastructure (63%) with the remaining areas being agricultural (20%), forested (14%), and marsh (3%).

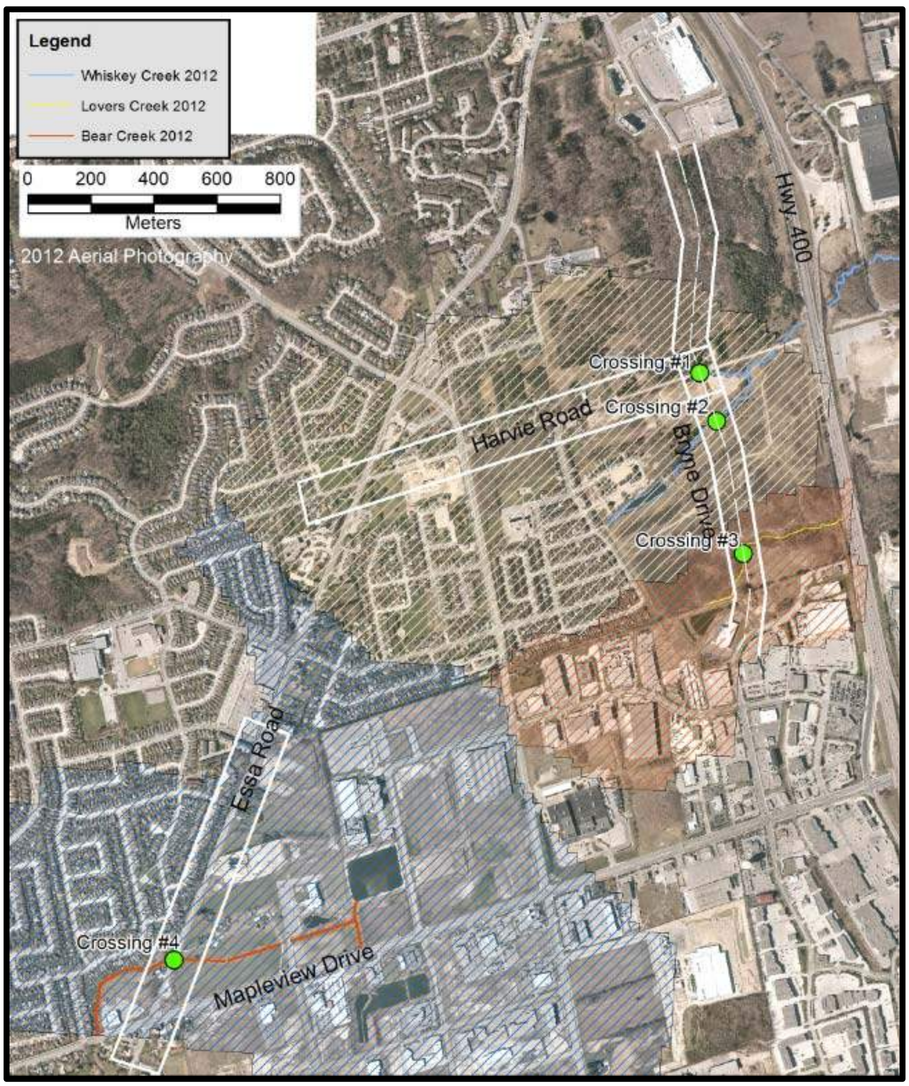

Figure 2: Subwatersheds and Crossing Locations ((from OFAT III), (2012 Air Photo, Barrie))

Bear Creek falls within the Nottawasaga Valley Conservation Authority (NVCA) because it flows west towards the Nottawasaga River. Bear Creek is likely a 5th order stream which originates on the southwest side of the City of Barrie and flows west through primarily forested and agricultural lands before out letting to the Nottawasaga River in the Town of Angus. The total Bear Creek watershed is approximately 89 km^2 in size but only 2.5 km^2 of that are within this study area. The headwaters for this portion of Bear Creek come from SWM ponds east of the site that drain industrial areas. The landuse for this area is 82% community/infrastructure and 15% agricultural. The general slope for the entirety of Bear Creek is 3.03% while the study area is roughly 1.47%.

Reach Delineation and Crossing Numbering

Channel morphology and substrate characteristics can change along a watercourse. Hence, it becomes important to account for these changes by delineating lengths of a watercourse that exhibit similar planform, sediment substrate, land use, local geology, valley confinement, hydrology and slope. In this study, the different reaches were delineated to account for change in valley trends and planform geometry, specifically, changes in meander axes. The reaches delineated for the geomorphic assessment will not however be the same as the ones delineated for the meander beltwidth assessment as they do not align well.

The crossings associated with this study have each been given a number which can be seen in Figure 2. From a geomorphic perspective, each of the crossing's creeks have different features that separate them into separate reaches, these will be discussed in Channel Characterization but the reaches will not be given specific designations as it is not applicable to this study. Some of the crossings also have more than one meander axis in proximity to the existing/future crossing. The additional reaches will be numbered in Table 7 of the meander belt assessment section. The crossing numbers will be referred to from here on.

Table 1: Study Crossings and Associated Road

Crossing #	Creek	Road
1	Whiskey Creek	Harvie Road
2	Whiskey Creek	Bryne Drive
3	Lovers Creek	Bryne Drive
4	Bear Creek	Essa Road

Channel Characterization

Site visits were conducted on all creek crossings within the study boundaries that intersected with the roadways of Essa Road, Harvie Road and Bryne Drive as part of the Transportation Improvements Class EA. Geomorphic data was collected so that site conditions could be confirmed and so each reach could be characterized properly. The characteristics of each of the applicable reaches are detailed below.

Rosgen Channel Classification

In order to quickly and easily convey the general characteristics of a creek or portion of a creek it can be helpful to have an established classification system that can do this. A commonly accepted stream classification system is the Rosgen system which was first outlined in *A Classification of Natural Rivers,* (Rosgen, 1994) and further discussed in multiple other papers.

Rosgen's system breaks classification into two levels. Level 1 is a broad characterization of geomorphic conditions such as longitudinal profiles, valley and channel cross-sections and planview patterns. Figure 5 (Appendix C) shows the steps taken to classify a channel at Level 1.

Level II goes further into detail and more specific characterization is made by using data that has been collected from the field. The components of Level 2 are bed material, entrenchment, width/depth ratio, sinuosity and slope. Figure 6 (Appendix C) shows the steps taken to classify a channel at Level 2. The crossings assessed for this report have each been given a Rosgen classification based on the data collected in the field.

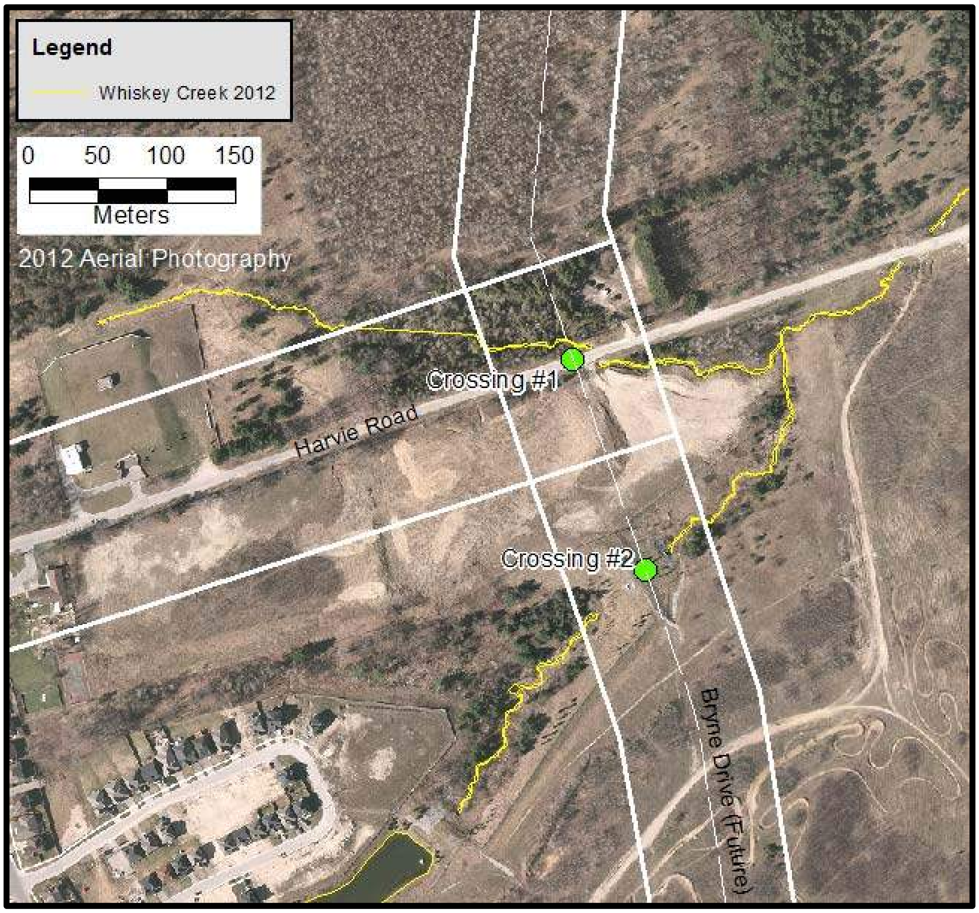

Figure 3: Whiskey Creek - Crossing Locations 1 and 2

Crossing 1 – Whiskey Creek (North Branch)
The study reach for Crossing 1 extends 50 m upstream of Harvie Road and 150m downstream, to the confluence with the South Branch. The reach begins in a cedar forested area that provides a steady supply of woody debris for the creek. The channel banks are generally easily erodible loams and sands held together by tree roots. During site inspections, it was noted that sections downstream of Harvie Rd. have been altered by development of the nearby site. This includes potential adjustment or channel realignment in some areas. A longitudinal profile and 12 cross sections were surveyed to characterize the creek. Bankfull width has been determined to be 1.41m while the average maximum bankfull depth is 0.35m. The width depth ratio is low while the channel is only slightly entrenched within its floodplain (Entrenchment Ratio > 2.2). The average bankfull slope at this site is 0.026 m/m. The substrate within the reach ranges from sands to gravels. In general, this reach shows the characteristics of a Rosgen E5 channel. A summary of the geomorphic parameters can be seen in Table 2.

Crossing 2 – Whiskey Creek (South Branch) (Bryne Drive)
The study reach for Crossing 2 begins at the outlet from a SWM pond and ends at the confluence with the North Branch. The proposed road crossing locations is near a flood control structure that bisects the study reach, downstream of two SWM areas. The study reach is 450 metres in length and 6 cross sections and a profile were surveyed to determine the channel characteristics. The channel banks are well vegetated with grasses and in some slower moving areas there are cattails

in the channel. The channel has a wide and easily accessible floodplain. At the downstream end, just before the confluence with the North Branch the channel has cut down into undisturbed tills, however the dominant substrate is sands. Bankfull width is averaged to be 1.27m while the average maximum bankfull depth is 0.46m. The width depth ratio is low while the channel is only slightly entrenched within its floodplain (Entrenchment Ratio > 2.2). The average bankfull slope at this site is 0.012 m/m. In general, this reach shows the characteristics of a Rosgen E5 channel. A summary of the geomorphic parameters can be seen in Table 2.

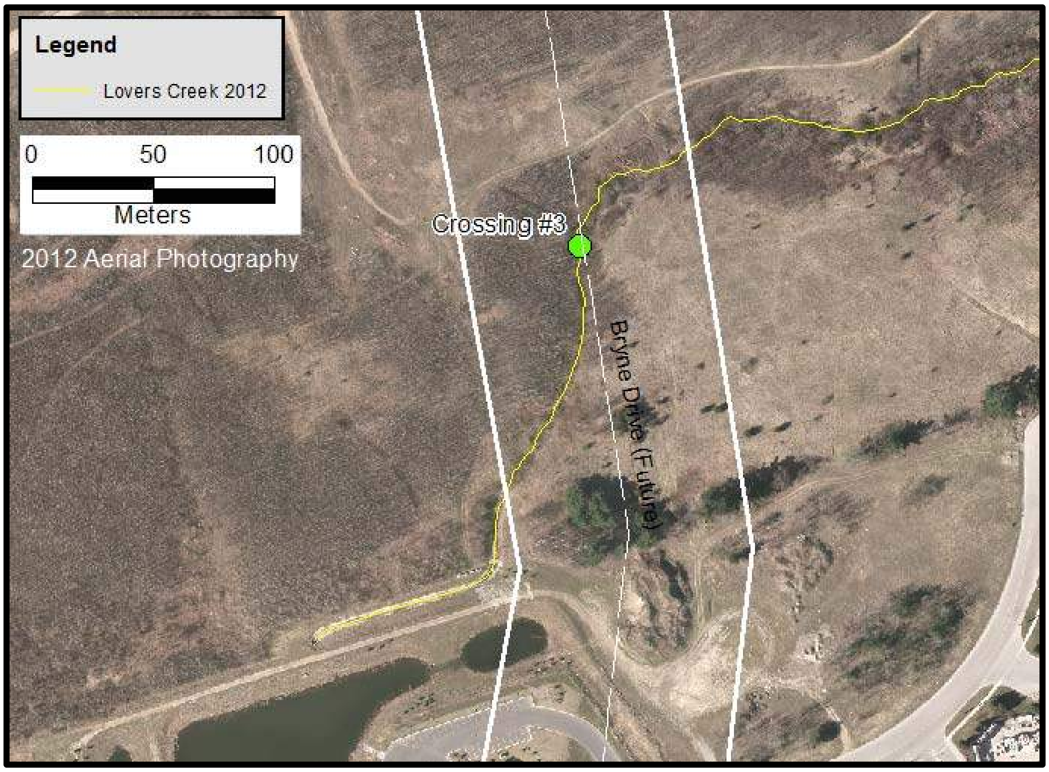

Figure 4: Lovers Creek - Crossing Location 3

Crossing 3 – Lovers Creek (Bryne Drive)

Crossing 3 is associated with Lovers Creek and the future alignment of Bryne Drive. The channel at the approximate location of the future crossing location varies in its geomorphic parameters from the upstream end of the study reaches to the downstream end. The study area begins west of the right of way at the exit to a SWM pond and the study reach ends at Hwy. 400. Roughly 550 metres of channel was surveyed and analyzed for this crossing. Multiple cross sections were also surveyed to determine the typical geomorphic characteristics of the channel. Lovers Creek at Crossing 3 is typically a single thread channel, however there are sections where it becomes braided. Some areas of the creek exhibit similar characteristics with wide flat floodplains, embedded riffles and highly erodible bank materials. Downstream areas, east of the right of way, differ from much of the upstream area as it has a well defined channel with grassy banks and gravel riffles. Much of the channel is very well vegetated and all the reaches have copious amounts of woody debris. Slope is consistent throughout the reaches at 0.0166 m/m. Bankfull dimensions for each of the reaches are similar and have been grouped together. Bankfull width is 1.01m while maximum bankfull depth is averaged to be 0.23m. The substrate within the reaches is primarily sands however gravels do occur in reach 3. The channel is only slightly entrenched within the floodplain (Entrenchment Ratio >4.0) and shows a low width to depth ratio. In general, this reach shows the characteristics of a Rosgen E5 channel. A summary of the geomorphic parameters can be seen in Table 2.

Crossing 4 – Bear Creek (Essa Road)
Crossing 4 is located near the intersection of Essa Road and Mapleview Drive. The channel is a drainage channel that has been constructed between 1991 and 1995. The channel drains at least two SWM ponds east of the Essa Road crossing. The channel is a wide trapezoidal channel that has no discernable bankfull characteristics. The channel has silted in overtime and is now over grown with cattails. From a fluvial geomorphological perspective, the channel is stable because of a number of factors including that the channel was constructed using gabion matts and it also has a low slope. No evidence of degradation can be seen from the site or from air photos. The only channel characteristics that would be helpful for this assessment would be the top of bank width, the bottom width, and the slope. The top of bank has a width of 13 metres while the bottom width is approximately 5 metres. The slope is very low at 0.004 m/m. No Rosgen classification is given for this study reach. A summary of the geomorphic parameters can be seen in Table 2.

Figure 5: Bear Creek - Crossing Location 4

Table 2: Existing Geomorphic Parameters

Crossing #	Road	Avg Bkf Width (m)	Avg Bkf Depth (m)	Avg W/D	Slope	Substrate	Rosgen Class
1	Harvie Road	1.41	0.35	7.21	0.026 m/m	Sand/Gravel	E5
2	Bryne Drive	1.27	0.46	5.36	0.012 m/m	Sand	E5
3	Bryne Drive	1.01	0.23	7.93	0.016 m/m	Sand/Gravel	E5
4	Essa Road	N/A	N/A	N/A	0.004 m/m	Muck/Sand	N/A

3.0 STREAM ASSESSMENT SCORES

In addition to classification of a stream system, various techniques for geomorphic assessments are used to better understand general stream conditions (stability, habitat, erosion/degradation, riparian, etc.). In our assessment of Whiskey, Lovers and Bear Creeks, we used Rapid Geomorphic Assessment and Rapid Stream Assessment Technique.

Rapid Geomorphic Assessment (RGA)

Creek stability was assessed using a Rapid Geomorphic Assessment (MOE, 2003). The RGA assessment focuses entirely on the geomorphic component of a river system. The RGA method consists of four factors that summarize various components of channel adjustment, specifically: aggradation, degradation, channel widening and plan form adjustment. Each factor is assessed separately and the total score indicates the overall stability of the system. This methodology has been applied to numerous streams and rivers and the following table details the ranking criteria (see Table 4).

Table 3 presents the results of the RGA assessments. Generally, the lower the score the more stable the channel is. Crossing 1 are very similar as they show signs of widening with falling trees, basal scour and fracture lines on the banks. Crossing 3 shows signs of aggradation in many areas as well as planform adjustment. The two are linked in that aggradation in sections of the channel can cause realignment and adjustment. Crossing 4 receives a good score and shows to be 'In Regime' but this is due to its artificial stability.

Table 3: RGA Scores and Ranking

Crossing #	Score	Verbal Ranking
1	0.21	Transitional/Stressed
2	0.16	In Regime
3	0.37	Transitional/Stressed
4	0.18	In Regime

Table 4: Interpretation of RGA Score

Stability Index (SI) Value	Classification	Interpretation
SI ≤ 0.20	In Regime	The channel morphology is within a range of variance for rivers of similar hydrographic characteristics and evidence of instability is isolated or associated with normal river meander processes.
0.21 ≤ SI ≤0.40	Transitional/Stressed	Channel morphology is within a range of variance for rivers of similar hydrographic characteristics but the evidence of instability is frequent.
SI ≥ 0.40	In Adjustment	Channel morphology is not within the range of variance and evidence of instability is wide spread.

Rapid Stream Assessment Technique (RSAT)

Rapid Stream Assessment Technique was developed by John Galli and other staff of the Metropolitan Washington (DC) Council of Governments (Galli et al, 1996). The RSAT systematically focuses on conditions reflecting aquatic-system response to watershed urbanization. It groups responses into six categories, presumed to adequately evaluate the conditions of the river system at the time of measurement on a reach-by-reach basis. The six categories are:

1. Channel stability;
2. Channel scouring and sediment deposition;
3. Physical in-stream habitat;
4. Water quality;
5. Riparian habitat conditions; and
6. Biological conditions.

River channel stability and cross-sectional characterization is a critical component of RSAT. The entire channel was inspected for signs of instability (such as bank sloughing, recently exposed non-woody tree roots, general absence of vegetation within bottom third of the bank, recent tree falls, etc.) and channel degradation or downcutting (such as high banks in small headwater streams and erosion around man-made structures). Observations were noted and cross-section measurements were made.

A rapid assessment of soil conditions along the river banks is also conducted to determine soil texture and potential erodibility of the watercourse bank. Qualitative water quality measurements were also made (temperature, turbidity, colour and odour) along with an indication of substrate fouling (i.e., the unwanted accumulation of sediment).

RSAT also typically involves a quantitative sampling and evaluation of benthic organisms. As no benthic sampling was undertaken, the score was based on site conditions and general observations of water quality.

Each category was assigned a value which was then summed to provide an overall score and ranking. Table 6 details the range of scores and rankings with a higher score suggesting a healthier system.

Within these broad categories, we evaluated each crossing and determined RSAT scores for each one. These scores are outlined in Table 5. Crossings 1 and 2 received 'Good' rankings which is attributed to their habitat, biological assessments because of their diversity of flow and good riparian zones among other things. Crossing 3 received a 'Fair' ranking which is likely due to its fine substrate and low bank stability. Crossing 4 even though it has great stability is extremely poor in its biological indicators, as well as having basically no riparian zone.

Table 5: RSAT Scores and Ranking

Crossing #	Score	Verbal Ranking
1	31	Good
2	33	Good
3	28	Fair
4	17	Poor

Table 6: Interpretation of RSAT Score

RSAT Score	Ranking
41-50	Excellent
31-40	Good
21-30	Fair
11-20	Poor
0-10	Degraded

4.0 MEANDER BELTWIDTH ASSESSMENT

Assessment of the meander beltwidth is undertaken in accordance with commonly accepted standard meander beltwidth delineation procedures which are established for watercourses with well defined, meandering bankfull channels. Each site was reviewed on a case by case basis to determine the final meander beltwidth nearest the future crossing location.

The methodology involves determining a preliminary beltwidth using aerial photographs. First, parallel lines are drawn on either side of the subject reach at the outermost edge of the meanders. These parallel lines follow the meander axis of the reach. Then the distance between the parallel lines is measured and a 100-year erosion rate is applied. In the absence of quality air photos where erosion rates can be observed, alternate methods can be used. When no erosion rate calculation is possible, a factor of safety, usually 10%, is applied to both sides of the preliminary beltwidths. The factor of safety can be higher if the study reach is deemed unstable, possibly by way of the RGA assessments. Table 7 details the results of the meander beltwidth assessment.

Aerial Photography Analysis
Air photos from 1954, 1995 and 2012 were used to determine the meander belts and were analyzed using GIS mapping. The photos are used to trace the bankfull limits of the channel or centreline from each of the crossings which the meander axis and beltwidths are based on. The same method as explained above will be used in the determination of each crossing except for Bear Creek. These beltwidths are detailed in Table 7 and can be seen in Figures 6 - 8 in Appendix A.

Final Meander Beltwidths
Based on the calculated meander beltwidths using aerial photographs, we have determined the final meander beltwidths of Crossing 1-3 on Whiskey and Lovers Creek. The final beltwidths were calculated to be the sum of the preliminary beltwidth and a 10% or 15% factor of safety added to each bank as no 100-year migration rates were calculated. The determination behind which factor of safety is applied results from the scores of the RGA assessments, where a good assessment receives 10% and a Fair receives 15%. The LSRCA has additionally established setback requirements which are 15 metres on both sides of the channel. This 15 metre buffer is added on top of the final beltwidth. Bear Creek crossing Essa Road is a stabilized channel that has not had any change in alignment since its construction. No meander belt is necessary in this type of channel because if the channel was to ever meander it would be a structural failure that would need to be repaired. The current top of bank width is given for the Bear Creek beltwidth in Table 7. Table 7 presents a summary of the preliminary beltwidths, the factor of safety, the erosion access allowance, the final beltwidths and the final corridor widths. Figures 6 - 8 show the preliminary and final beltwidths for the channels.

Table 7: Summary of Beltwidths (m) at the Proposed Culvert Locations

Crossing #	Meander Axis	Preliminary Meander Beltwidth(s) (m)	Erosion Setback (m) (% Both Sides)	Final Meander Beltwidth (m)	Erosion Access Allowance	Final Corridor Width (m)
1	1	11.1	1.11 (10%)	13.3	30	43.3
1	2	8.3	0.8 (10%)	9.9	30	39.9
1	3	7.6	0.8 (10%)	9.2	30	39.2
2	1	17.5	1.8 (10%)	21.1	30	51.1
3	1	10.4	1.6 (15%)	13.6	30	43.6
3	2	12.0	1.8 (15%)	15.6	30	45.6
3	3	10.5	1.6 (15%)	13.7	30	43.7
4	1	11	0	11	0	11

5.0 SUMMARY

Based on our field work and desktop analyses, we conclude the following:

1. There are 4 crossing locations within the study area for Whiskey Creek, Lovers Creek and Bear Creek;
2. Two of the watercourses (Whiskey and Lovers) are well-defined channels with definable bankfull parameters;

3. Bear Creek is a constructed drainage channel that is unlikely to meander out of its current alignment;
4. The watercourses along these locations were studied to determine typical stream characteristics, the details of which are outlined in Table 2;
5. All study reaches were assessed using field forms and all reaches received either a 'Transitional/Stressed' or 'In Regime' verbal ranking for the RGA and either a 'Fair' or 'Good' ranking using the RSAT, and;
6. Background documentation and aerial photo analyses were used in the determination of the final meander beltwidths at each crossing location as outlined in Table 7 and shown in Figures 6 – 8.

6.0 RECOMMENDATIONS

The following recommendations should be considered during any channel modification and culvert installation:

1. All proposed channel dimensions should closely resemble existing geomorphic parameters laid out in Table 2, specifically bankfull width, depth and slope;
2. Pool/riffle sequences should be laid with pools generally on the outside bend of a meander and riffles through the transitions;
3. Stone sizing should take into account the existing substrate of each reach while at the same time protecting the road embankments and culverts;
4. Channel realignment should properly observe the final meander beltwidths as shown in Table 7;
5. Low flow channels should be created through culverts using riverstone to form the banks, and;
6. Bio-engineering is the preferred bank stabilization technique where infrastructure is not at risk.

Respectfully submitted,

Ed Gazendam, Ph.D., P.Eng.,
President, Sr. Geomorphologist
Water's Edge Environmental Solutions Team Ltd.

Attachments:
Appendix A: Photographs
Appendix B: Meander Beltwidth Figures
Appendix C: Rosgen Classification Figures

References

Galli, J. 1996, *Rapid Stream Assessment Technique (RSAT) field methods*. 36 pp. Metropolitan Washington Council of Governments, Department of Environmental Programs, Washington, DC.

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APPENDIX A:

Photographs

CROSSING NUMBER: 1
FROM: Roadway
LOOKING: Upstream of Harvie Road
COMMENT: Stream meanders through forest

CROSSING NUMBER: 1
FROM: Roadway
LOOKING: Downstream of Harvie Road
COMMENT: Stream flows downstream to the left

CROSSING NUMBER: 1
FROM: Left Bank
LOOKING: Upstream
COMMENT: Typical channel upstream of Harvie Rd.

CROSSING NUMBER: 1
FROM: Right Bank
LOOKING: Downstream
COMMENT: Typical channel downstream of Harvie Road.

CROSSING NUMBER: 1
FROM: Right Bank
LOOKING: Downstream towards future Bryne Drive crossing
COMMENT: Typical channel conditions on downstream side of Crossing 1

CROSSING NUMBER: 1
FROM: Right Bank
LOOKING: Downstream at channel
COMMENT: Typical channel conditions near Crossing 1

CROSSING NUMBER: 2
FROM: Right Bank
LOOKING: Across valley in SWM area
COMMENT: Typical conditions upstream of Crossing 2

CROSSING NUMBER: 2
FROM: On top of upstream headwall
LOOKING: Upstream at channel
COMMENT: Typical channel conditions on upstream side of Crossing 2

CROSSING NUMBER: 2
FROM: Channel
LOOKING: Upstream towards SWM outlet
COMMENT: Typical channel conditions downstream of flood berm at Crossing 2

CROSSING NUMBER: 2
FROM: In channel
LOOKING: Downstream at channel
COMMENT: Typical channel conditions downstream of Crossing 2

CROSSING NUMBER: 2
FROM: Left bank
LOOKING: Downstream
COMMENT: Typical channel conditions downstream of Crossing 2

CROSSING NUMBER: 2
FROM: Left Bank
LOOKING: South across channel
COMMENT: Typical channel conditions on downstream of Crossing 2

CROSSING NUMBER: 3
FROM: Right Bank
LOOKING: West/Upstream towards SWM Pond
COMMENT: Riprap lined channel

CROSSING NUMBER: 3
FROM: Right Bank
LOOKING: Upstream
COMMENT: Stream is channelized here

CROSSING NUMBER: 3
FROM: Left Bank
LOOKING: Downstream at channel
COMMENT: Typical channel conditions at Crossing 3

CROSSING NUMBER: 3
FROM: Channel
LOOKING: Downstream
COMMENT: Typical channel conditions near Crossing 3

CROSSING NUMBER: 3
FROM: Right Bank
LOOKING: Upstream at Channel
COMMENT: Typical channel conditions downstream of Crossing 3

CROSSING NUMBER: 3
FROM: Right Bank
LOOKING: Upstream at channel
COMMENT: Typical channel conditions downstream of Crossing 3 near Hwy. 400

CROSSING NUMBER: 4
FROM: From Essa Road
LOOKING: Upstream at channel
COMMENT:

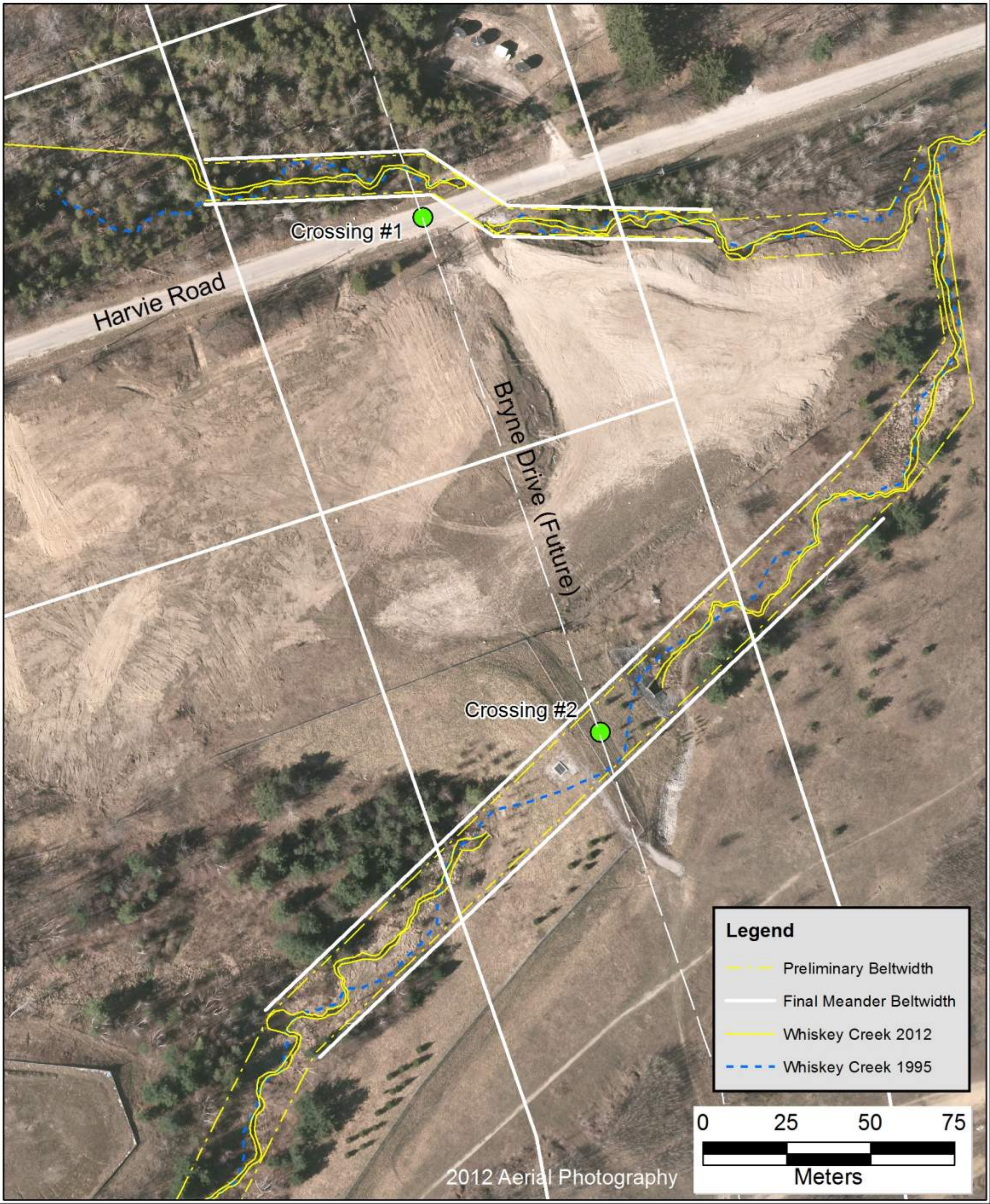
CROSSING NUMBER: 4
FROM: Right Bank
LOOKING: Downstream at channel and Essa Road
COMMENT:

CROSSING NUMBER: 4
FROM: Road embankment
LOOKING: Downstream at channel and culvert
COMMENT:

CROSSING NUMBER: 4
FROM: Left Bank
LOOKING: Upstream at channel and Essa Rd.
COMMENT:

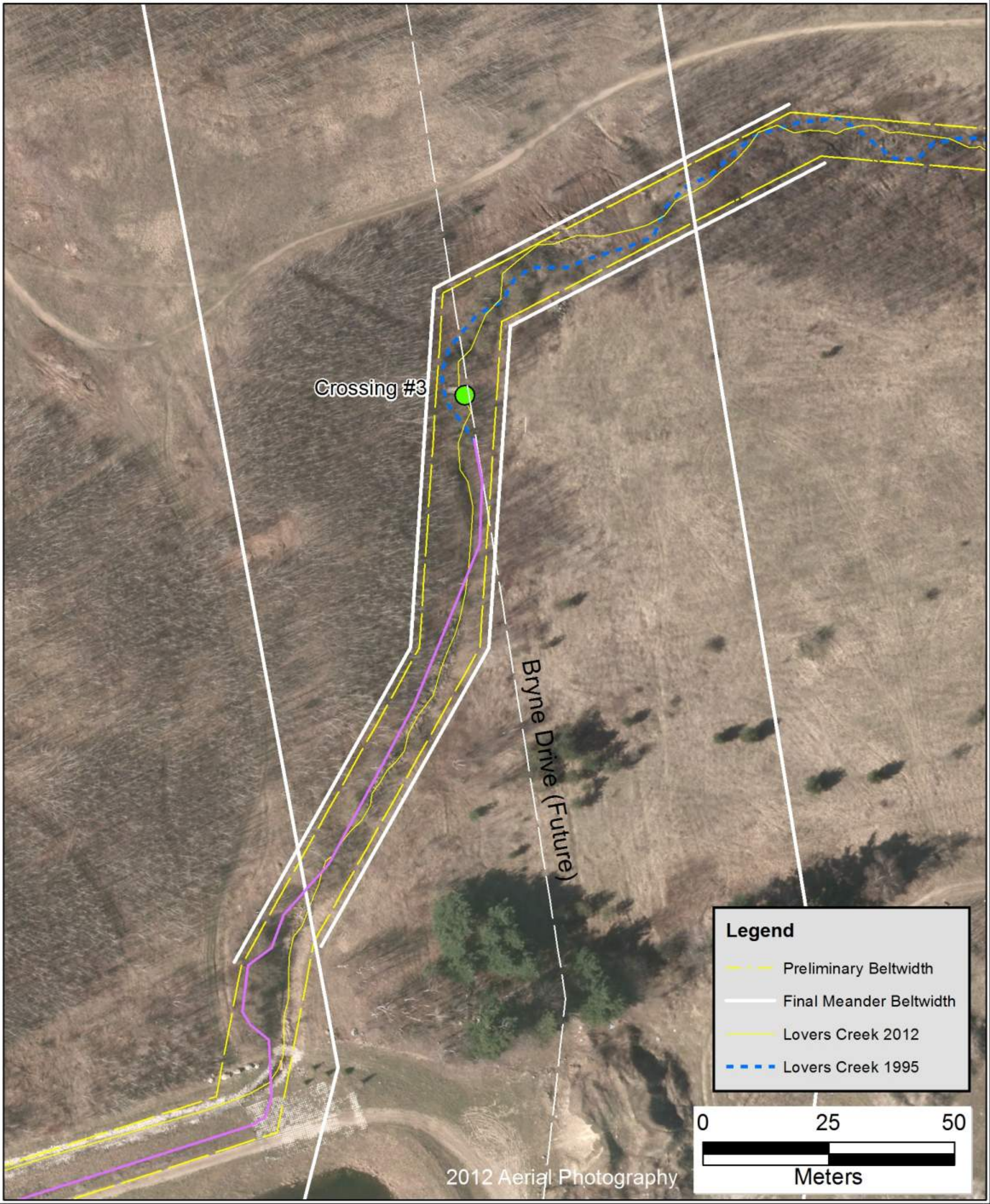
APPENDIX B:

Meander Beltwidth Figures 6 - 8



water's edge ENVIRONMENTAL SOLUTIONS TEAM LTD.

City of Barrie Bryne, Harvie and Essa Road EA	Figure No.: 6	Date: June 15, 2017
Whiskey Creek Crossings 1 and 2	Checked By: EG	Drawn By: NG



water's edge ENVIRONMENTAL SOLUTIONS TEAM LTD.	City of Barrie Bryne, Harvie and Essa Road EA	Figure No.: 7	Date: June 15, 2017
	Lovers Creek Crossing 3	Checked By: EG	Drawn By: NG

water's edge ENVIRONMENTAL SOLUTIONS TEAM LTD.

City of Barrie Bryne, Harvie and Essa Road EA	Figure No.: 8	Date: June 15, 2017
Bear Creek Crossing 4	Checked By: EG	Drawn By: NG

APPENDIX C:

Rosgen Classification Figures

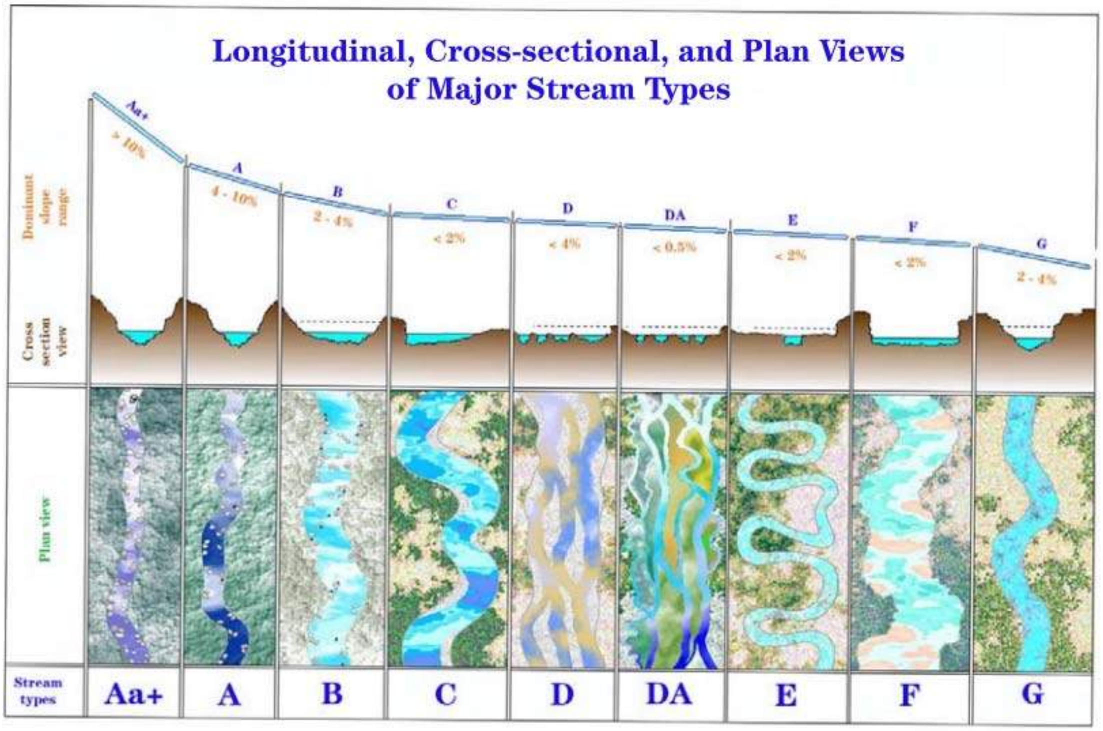


Figure 6: **Rosgen Level 1 Stream Classification (Rosgen, 2006)**

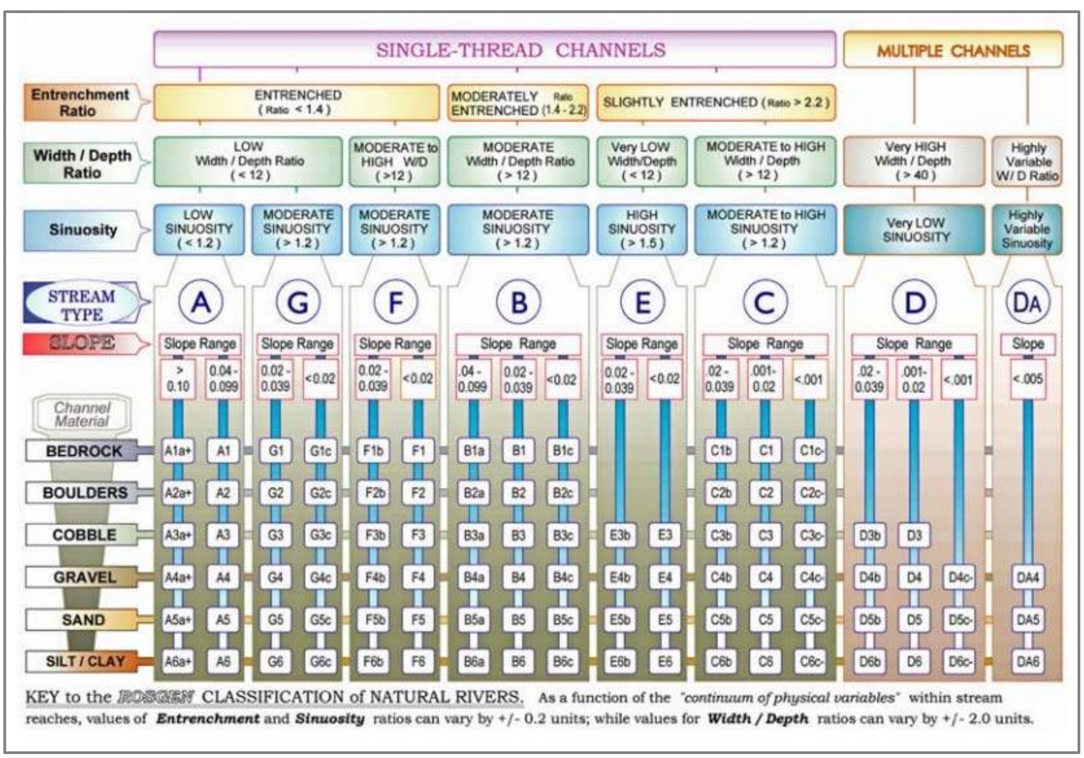


Figure 7: **Rosgen Level 2 Stream Classification (Rosgen, 2006)**