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Appendix D

Sheldon Creek – East Branch Assessment Report

AECOM

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April 23, 2012

Teodor Kochmar, P.Eng., PMP
Project Manager - Water Design & Construction
Public Works Department
Regional Municipality of Halton

Dear Teodor:

Project No:

Regarding: **Sheldon Creek East Branch Assessment, Burloak Water Purification plant Expansion (Phase 2) Environmental Assessment Support, Supporting Creek Assessment flows.**

Further to our recently completed Creek assessment report in relation to the above reference project, we are in receipt of additional information with regard to the proposed flows that are expected to be discharged to Sheldon Creek east Branch as a result of the proposed expansion. The flow values used in the analysis of the report are in the following table:

Plant Capacity	Discharge Flows (Average, 95% recovery)	Discharge Flows (Peak, 90% recovery)
55 ML/d (current)	-	-
165 ML/d (Phase 2 and 3)	100 L/s	200 L/s
220 ML/d (Phase 4)	135 L/s	270 L/s
440 ML/d (Ultimate Site Capacity)	270 L/s	540 L/s

Due to refinement of the calculation of plant discharge, the following values are presented:

Plant Capacity	Discharge Flows (Average, 95% recovery)	Discharge Flows (Peak, 90% recovery)
55 ML/d (current)	-	-
165 ML/d (Phase 2 and 3)	101 L/s	212 L/s
220 ML/d (Phase 4)	134 L/s	283 L/s
440 ML/d (Ultimate Site Capacity)	268 L/s	566 L/s

Based on the comparison between the originally assessed flows and the refined values, there appears to be an increase of 4.8% to 6.0% across the proposed expansion scenarios.

The approach utilized for the assessment of flows in the Creek Assessment Report dated February 2012 reflect a range of flows that can be experienced by the watercourse. The approach is based on the variability of the hydrology in the watershed since a continuous flow hydrologic model is not available.

The report describes the augmented flow in relation to a sensitivity analysis which includes increases in flows that account for the flow value refinements recently provided. Since the 5% to 6% incremental flows fall within the sensitivity range, a re-assessment of the impact is not necessary, and as a result, do not change the recommendations made in the report.

If you have any questions, or required further elaboration of the items contained in the report, please contact me at your convenience.

Sincerely,
AECOM Canada Ltd.

Wolfgang Wolter
Water Resources Lead, Central Canada
wolfgang.wolter@aecom.com

Region of Halton

Sheldon Creek, East Branch - Assessment

Burloak Water Purification Plant Expansion (Phase 2) Environmental Assessment Support

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February 24, 2012

Teodor Kochmar, P.Eng., PMP
Project Manager - Water Design & Construction
Public Works Department
Regional Municipality of Halton

Dear Teodor:

Project No:

Regarding: **Sheldon Creek East Branch Assessment, Burloak Water Purification plant Expansion (Phase 2) Environmental Assessment Support**

We are pleased to present to you the findings of the assessment concerning the above referenced creek in connection with the Burloak Plant Expansion EA. We note that the report focuses on the integrity of Sheldon creek using discharge values obtained from the Region of Halton at varying levels of expansion.

If you have any questions, or required further elaboration of the items contained in the report, please contact me at your convenience.

Sincerely,
AECOM Canada Ltd.

Wolfgang Wolter
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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	WW/MP/DA	6-Dec-2011	Draft for agency review
2	WW/DA	24-Feb-2012	Final report
3	WW/JD	23-April-/2012	ESR Revision

AECOM Signatures

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1. Introduction

The Region of Halton is undertaking an Environmental Assessment for the expansion of the existing water treatment plant located at Rebecca St. and Great Lakes Blvd. in the Town of Oakville. The EA study proposes several alternatives that examine the plant expansion options to serve demand for various stages of development. The alternatives being examined require that a specific investigation be carried out in connection with the discharge of water resulting from the membrane purification process. The option to discharge water into the east branch of Sheldon Creek is the subject of this assessment report.

When presented with the prospect of discharging any volume of water into an existing watercourse, it is prudent to take into consideration the possible impacts that could be imposed on the receiving watercourse environment. Given that Sheldon Creek is comprised of several components that may be affected by increased flows, AECOM has focused on analysis of the following primary elements:

- Channel Integrity, bed and bank (hydraulic based);
- Erosion susceptibility, predominant soil characteristics (laboratory gradation analysis);
- Geomorphology, channel condition; and
- Hydraulic Conditions, variable water levels, flow shear force and flow velocity (Geomorphology combined with technical model results).

In addition, the report provides information on Vegetative and Aquatic Ecology Impacts.

2. Approach

The approach taken to assess the stability of Sheldon Creek involved the establishment of its existing conditions within the affected reaches. The site was traversed by engineering staff, a fluvial geomorphologist and a terrestrial biologist to collect pertinent information that allows for the development of a condition assessment.

The site reconnaissance included the establishment of six detailed geomorphic channel cross sections to determine the section characteristics and includes the collection of soil samples from the bed and banks at five of the section locations.

Further analysis of the channel involved the review and documentation of the existing HEC-RAS hydraulic model provided to AECOM by Conservation Halton. Information in connection with the proposed discharge flows from the plant expansion was provided through information developed for the project alternatives of the plant expansion.

The assessment of the east branch of Sheldon Creek is intended to focus on the initial phase of the plant expansion (Phase 2/3) in conjunction with the scope of the Environmental Assessment being undertaken under a separate process.

The report outlines two methodologies in ascertaining either erosion thresholds, or evaluation of the creek condition. This includes a technical approach, using observed and model data that describes channel composition and corresponding hydraulic forces, as well as a geomorphic approach which examines channel form and function on a reach wide basis.

3. Hydraulic Assessment

3.1 Existing Hydraulic Conditions

The existing hydraulic conditions for the East Branch of Sheldon Creek are characterized in the existing HEC-RAS hydraulic model provided by Conservation Halton. The section of creek evaluated in this study flows from Creek Path Ave., downstream of Rebecca St., to the confluence with the Main Branch of Sheldon Creek, upstream of Great Lakes Blvd. This section of creek has been divided into four reaches based on geomorphic characteristics (described in section 5). In addition, six cross-sections were surveyed for the geomorphic characterization; the hydraulic analysis provides results at locations close to these cross-sections (using existing HEC-RAS sections) to maintain consistency with other parts of this study. Figure 3.1.1 illustrates the hydraulic study area and cross-section locations established in the field.

Figure 3.1.1 - Reach and Cross Section Locations in the Study Area

Although the HEC-RAS data provides hydraulic information for typical storm events, there are no flow values in the model that represent base flow. Given that the majority of the duration whereby the proposed plant expansion discharge flow will be active is during base flow conditions, it is necessary to determine a base flow value to properly assess the impact of the plant expansion. The low-flow conditions in the creek were assessed during a site visit on November 8, 2011. Based on the measured water levels at each cross-section and the average gradient of the study area obtained from the hydraulic model (calculated as approximately 0.69%), a flow of approximately 0.139m^3/s was estimated, averaged from the values for each cross-section. This flow is considered appropriate for use as a typical low flow in this section of creek, based on observed geomorphic characteristics. A range of low flows were derived from this flow to perform a sensitivity analysis on low flow conditions in the creek, ranging from 75% below to 75% above the estimated flow. The flows used to characterize existing low flow conditions are shown in Table 3.1.1.

The HEC-RAS profile shown in Figure 3.1.2 shows that the creek has a relatively consistent bed gradient to the point of confluence with the main branch of Sheldon Creek at 0.69% with minor undulations at crossings. The 2 year event flow, also shown, is noted to pass below deck soffits at crossings. The HEC-RAS model data summary is included in Appendix B-1.

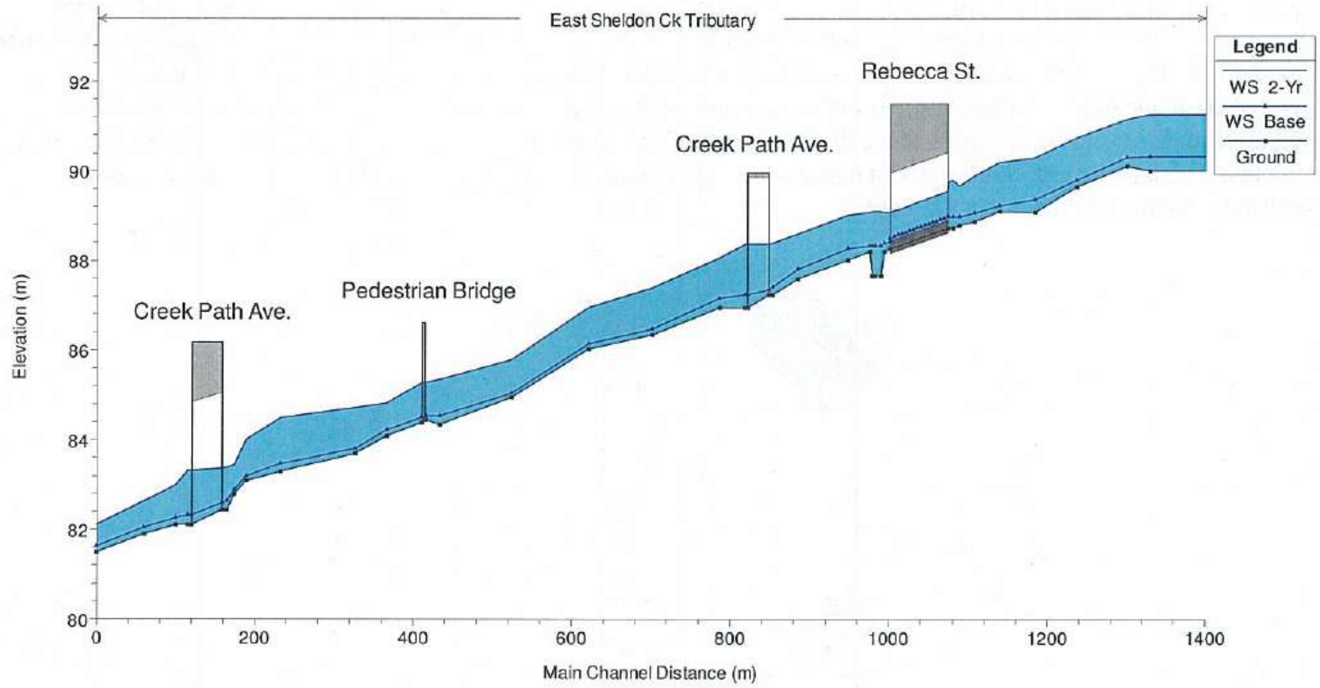


Figure 3.1.2 - Existing HEC-RAS Model Profile of East Branch Study Area

Table 3.1.1 - Existing Low Flows used for Hydraulic Analysis

Low Flow Profile	Flow (m^3/s)
Estimated -75%	0.035
Estimated -50%	0.070
Estimated -25%	0.104
Estimated	0.139
Estimated +25%	0.174
Estimated +50%	0.209
Estimated +75%	0.243

3.2 Existing Soil Conditions

The site reconnaissance included tasks to collect soil samples of the bank and bed at five of the six cross-sections along the study reach at regular intervals to characterize the soil structure. The samples were collected at the surface of the bed and banks with a spade shovel and delivered to a Geotechnical lab for a gradation analysis. From a general perspective, there was some difficulty in collecting the bed samples due to the shale fragment layer overlaying the bed surface. Difficulty was also encountered collecting bank samples due to the significant array of root mass imposed by the bank vegetative cover. We note that some of sample results from the gradation analysis do not adequately represent either the shale fragment bed cover, or the gravel nature of the bank material. Due to technical reasons, fine particle quantification was also not conducted. For these reasons, we have removed selected sample results from consideration in the analysis. Table 3.2.1 is a summary of the soil gradation analysis results. The red italicized text is considered to be 'not representative' of actual conditions. The gradation analysis graphs are included in Appendix B-2.

Table 3.2.1 - Soil Characteristics at Creek Cross Sections

Section	Location	Soil Description	D50 (mm)	D75 (mm)	Allowable Velocity (m/s) D50	Allowable Velocity (m/s) D75
XS1	Bed	Sandy gravel, trace silt, occasional cobble	11	22	1.3	1.75
XS1	*Bank (NA)*	*Silt, some sand*	*0.001*		*0.8*	
XS2	Bed	Gravel, some sand, some silt	28	60	1.5	2.3
XS2	*Bank (NA)*	*Silt and sand, some gravel*	*0.075*		*0.6*	
XS3	*Bed (NA)*	*Silty gravelly sand*	*1*		*0.8*	
XS3	Bank	Gravel, some sand, trace silt, occasional cobbles	20	40	1.4	2.0
XS4	Bank	Gravel, trace sand	36	50	1.6	2.2
Bridge	*Creek Path Ave South (NA) sediment*	*Gravelly sand, some silt*	*2.5*		*0.9*	
XS5	Bed	Sandy gravel, trace silt	10	25	1.25	1.85
XS5	*Bank(NA)*	*Gravelly sand and silt*	*0.3*		*0.6*	
Average	All areas	(bed average and bank average combined)	**22.15**	**40.5**		

The existing soil characteristics were compared against standard 'allowable velocity' tables to determine the flow velocity at which particles would become entrained, using the 'D50' particle size. Observations of the results indicate that the average D50 competency of bed and bank materials is approximately 1.3m/s, and for D75, competency would be approximately 2.0 m/s.

If using a 'general' soil type classification, the bed can be classified as soft shale and the bank sand and gravel with observed areas of clay material. In accordance with MTO design chart 2.17, the maximum permissible velocities for shale and coarse gravel ranges between 1.2 and 1.8 m/s. Maximum velocities for the bank material, alluvial silts, graded loam and coarse gravel can range between 1.15 and 1.2 m/s. These values coincide somewhat with the applicable particles size analysis from Table 3.2.1. The MTO design chart 2.17 is included in Appendix B-3.

4. Proposed Conditions and Analysis

4.1 Proposed Treatment Plant Discharge Flows

The treatment plant expansion is proposed to occur in several phases. As additional membrane filtration capacity is installed, the discharge of membrane waste water will increase. The anticipated waste discharges for the phases of plant expansion are shown in Table 4.1.1. Both an average flow and peak flow are included, corresponding to 95% and 90% membrane recovery rates respectively, with average flows representing typical operation and peak flows representing operation during periods of high turbidity in the source water, anticipated to occur during the spring melt.

Table 4.1.1 - Proposed Treatment Plant Discharge Flows

Plant Capacity	Discharge Flows (Average, 95% recovery)	Discharge Flows (Peak, 90% recovery)
55 ML/d (current)	-	-
165 ML/d (Phase 2 and 3)	100 L/s	200 L/s
220 ML/d (Phase 4)	135 L/s	270 L/s
440 ML/d (Ultimate Site Capacity)	270 L/s	540 L/s

From an operational standpoint, it is suggested that peak effects of the discharge be attenuated and the sustained additional flows proposed would be represented by the Average flow values.

4.2 Proposed Hydraulic Conditions

To assess the impact of the proposed treatment plant discharge, the flows shown in Table 4.1.1 were added to the estimated existing low flows shown in Table 3.1.1. The resultant flows used to evaluate the proposed hydraulic conditions are shown in Table 4.2.1.

Table 4.2.1 - Proposed Flows for Hydraulic Analysis

Low Flow Profile	Base/Low Flows (m^3/s)	Phase 2/3 Avg (m^3/s)	Phase 2/3 Peak (m^3/s)	Phase 4 Peak (m^3/s)	Ultimate Peak (m^3/s)
-75%	0.035	0.135	0.235	0.305	0.575
-50%	0.070	0.170	0.270	0.340	0.610
-25%	0.104	0.204	0.304	0.374	0.644
Base	0.139	0.239	0.339	0.409	0.679
+25%	0.174	0.274	0.374	0.444	0.714
+50%	0.209	0.309	0.409	0.479	0.749
+75%	0.243	0.343	0.443	0.513	0.783

The Phase 4 Average and Ultimate Capacity Average flows were not explicitly evaluated in this study. However, the Phase 4 average flows are below those of the Phase 2/3 Peak flows, and the Ultimate Capacity Average flows are equivalent to the Phase 4 Peak flows, indicating that the analysis encompasses the full range of expected plant flows.

The 2-year flow of $9.80m^3/s$, as obtained from the existing hydraulic model, was also used in the analysis to demonstrate the volume of flow that resides within the channel sections in relation to the base flows and proposed discharge flows. In some cross sections along the channel reach, the two year event flow can access the floodplain, while in other sections the 2 year event flow is retained within. The modelled results show the differential in water levels at this flood stage to quantify water level changes during theoretical frequent flood events.

4.3 Analysis of Proposed Conditions

The existing HEC-RAS model was revised to include the flow profiles shown in Table 4.2.1. The results were analysed for potential impacts on the hydraulic function and stability of the study area as a result of the proposed treatment plant discharge flows. The results were observed for changes in shear force, flow velocity and water levels.

4.3.1 Impact on Water Levels

The increase in water levels from the proposed plant flows are shown in Table 4.3.1.1. These figures represent the maximum, minimum and average water level increases at the study area cross-sections, obtained from the HEC-RAS model results using the revised flow profiles. Only the base case flow profiles (i.e., estimated low flow +/- 0%) are shown in the tables for comparison purposes.

Table 4.3.1.1 - Water Level Impacts in Study Area from Proposed Plant Flows

XS	Low Flow (m)	Phase 2/3 Avg (m)	Δ Low Flow to Phase 2/3 (m)	Ultimate Peak (m)	Δ Low Flow to Ult Peak (m)
1	87.151	87.201	0.050	87.330	0.179
2	86.130	86.171	0.041	86.268	0.138
3	84.215	84.222	0.007	84.301	0.086
4	83.188	83.230	0.042	83.321	0.133
5	82.039	82.067	0.028	82.159	0.120
6	81.617	81.652	0.035	81.715	0.098

The first phase of plant expansion (Phase 2/3) that would result in discharge of water to the creek is expected to cause an average water level increase of 0.034m in the study cross-sections. At the ultimate plant capacity peak flows, the water level increase over the average low flow is estimated at 0.126m. The extent of these impacts on channel stability is assessed in the following sections with respect to shear and velocity increases (as well as in the geomorphic analysis section).

It is noted that at the 2-year flow, selected to represent the bankfull condition context (due to coincidental bank overtopping event in some cross sections), the ultimate plant capacity peak flow value would be expected to increase water levels by a maximum of 0.027m. In consideration of flood level changes, this results in minimal top width increases and hence would not have a distinguishable impact. Figure 4.3.1.1 and 4.3.1.2 show graphically the water level of the model 2 year event and the combined 2 year event with the ultimate peak discharge flow volume. These two cross sections were selected since they reflect similar geometry as depicted in the model coding at their respective locations.

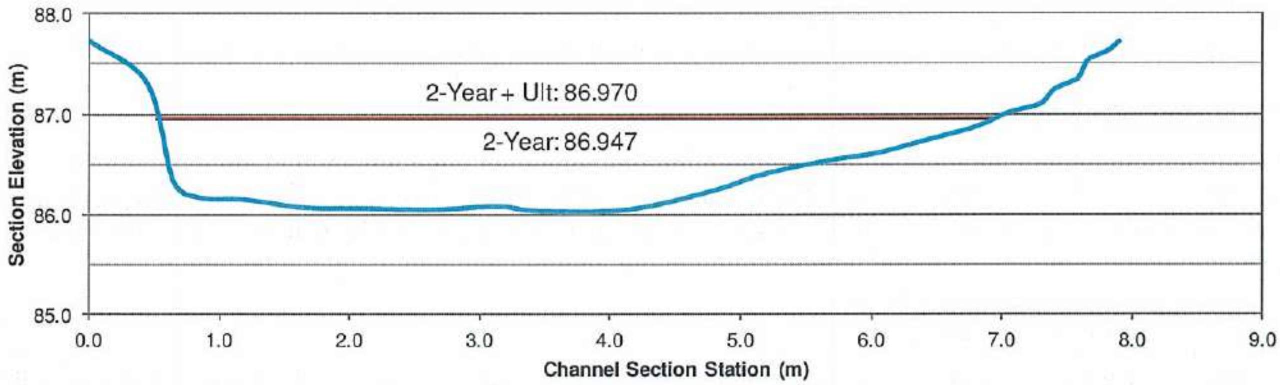


Figure 4.3.1.1 - 2-Year Flow Water Level Impact at XS 2

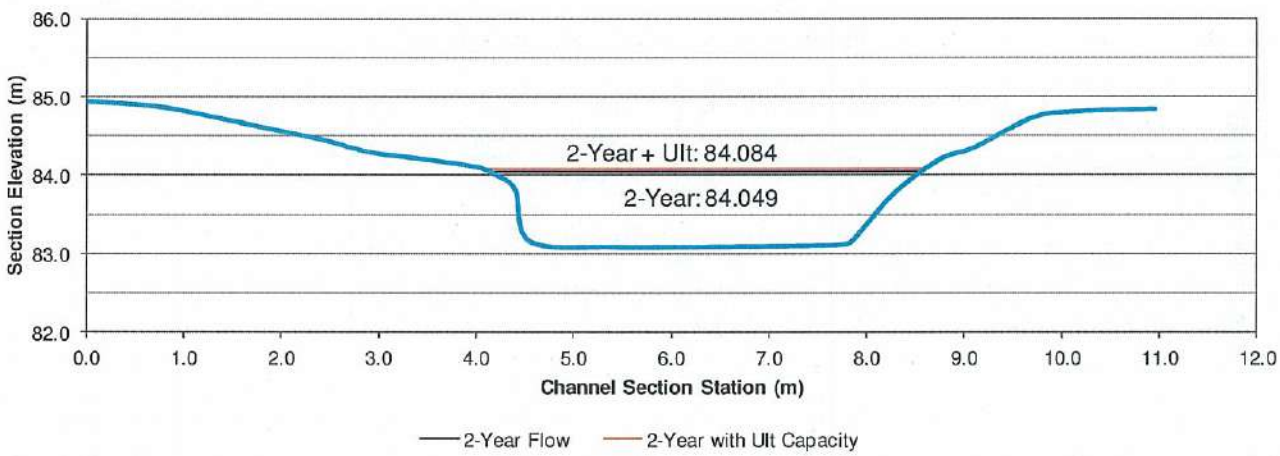


Figure 4.3.1.2 - 2-Year Flow Water Level Impact at XS 4

4.3.2 Impact on Channel Velocity

The increase in channel velocity from the proposed plant flows are shown in Table 4.3.2.1. These figures represent the maximum, minimum and average channel velocity increases at the study area cross-sections, obtained from the HEC-RAS model using the revised flow profiles. Only the base case flow profiles are shown in the tables for comparison purposes. Additional figures are included with this report that illustrates the channel velocity changes for each cross-section for all flow profiles (Figure 4.3.2.1 to Figure 4.3.2.6 in Appendix B-4).

Table 4.3.2.1 - Channel Velocity Change in Study Area from Proposed Plant Flows

XS	Low Flow (m/s)	Phase 2/3 Avg (m/s)	Δ Low Flow to Phase 2/3 (m/s)	Ultimate Peak (m/s)	Δ Low Flow to Ult Peak (m/s)
1	0.99	1.10	0.11	1.36	0.37
2	0.49	0.58	0.09	0.88	0.39
3	0.56	0.87	0.31	1.13	0.57
4	0.78	0.87	0.09	1.30	0.52
5	0.36	0.47	0.11	0.69	0.33
6	0.75	0.73	-0.02	1.00	0.25

The first phase of plant expansion (Phase 2/3) that would result in discharge of water to the creek is expected to cause an average channel velocity increase of 0.12m/s in the study cross-sections. This would be expected to have a low impact on the creek hydraulic performance, but may have localized effects depending on bed and bank soil characteristics. At the ultimate plant capacity peak flows, the channel velocity increase over the average low flow is estimated to be an average of 0.41m/s. In comparison with the competent mean velocities determined in the Section 3.2, the increased velocities resulting from the discharge flow remain within the velocity thresholds provided in Table 3.2.1.

4.3.3 Impact on Channel Shear

The increase in channel shear from the proposed plant flows are shown in Table 4.3.2.1. These figures represent the maximum, minimum and average channel shear increases at the study area cross-sections, obtained from the HEC-RAS model using the revised flow profiles. Only the base case flow profiles are shown in the tables for comparison purposes. Additional figures are included with this submission that illustrates the channel shear changes for each cross-section for all flow profiles (Figure 4.3.3.1 to 4.3.3.6 in Appendix B-5).

Table 4.3.3.1 - Channel Shear Impacts in Study Area from Proposed Plant Flows

XS	Low Flow (N/m^2)	Phase 2/3 Avg (N/m^2)	Δ Low Flow to Phase 2/3 (N/m^2)	Ultimate Peak (N/m^2)	Δ Low Flow to Ult Peak (N/m^2)
1	18.98	21.76	2.78	28.72	9.74
2	4.81	5.98	1.17	11.88	7.07
3	6.71	15.66	8.95	22.38	15.67
4	16.74	18.84	2.10	36.62	19.88
5	2.55	3.91	1.36	7.15	4.60
6	13.11	11.46	-1.65	19.02	5.91

The first phase of plant expansion (Phase 2/3) that would result in discharge of water to the creek is expected to cause an average channel shear increase of 2.45N/m^2 in the study cross-sections. This would be expected to have a minimal impact on creek stability based on soil type. At the ultimate plant capacity peak flows, the channel shear increase over the average low flow is estimated to be an average of 10.48 N/m^2.

4.3.4 Calculation of Allowable Shear

The soil particle gradation results indicate varying particle diameters depending on where the samples were collected and whether they were source from bed or bank soil. Since the model shear value is expressed in terms of 'channel shear' (i.e., bed or bank shear is not individually identified) the particle shear resistance (based on particle size) is averaged across the study area representing both bed and bank composition. The applied shear stress is compared to allowable shear stress using an empirically derived relationship (Shields parameter and Reynolds grain number). The critical shear is calculated by the equation:

$$\tau_c = \tau^* (\gamma_s - \gamma) D$$

where:
τ^* = Shields parameter, dimensionless
R^* = grain Reynolds number = u^*d/ν, dimensionless
τ_c = critical shear stress (lb/ft^2 or N/m^2)
γ_s = specific weight of sediment (lb/ft^3 or N/m^3)
γ = specific weight of water (lb/ft^3 or N/m^3)
D = particle diameter (ft or m)

The Shields parameter (τ^*) represents particles within a specified Reynolds number range. The curve 'flat-lines' after the 'Boundary Reynolds' number for larger particle sizes, such as the particles encountered in the study area. This number, determined to be *0.0642,* represents the 'Dimensionless Shields parameter'. The resulting critical shear is calculated to be 16.0 N/m^2 for the average particle size in the study area. Tables developed for shear/average particle size determination have also been referenced in assessing the average threshold values (see Appendix B-6). The analysis provides a comparison of the average particle shear resistance with the average model shear from each of the six sections measured in the field (see Appendix B-7).

Shear profiles for all flow discharge scenarios are provided in figures: 4.3.3.1 to 4.3.3.6 in Appendix B-5, based on channel shear model results. These profiles demonstrate the change in shear along the varying flow values. In addition, since the EA (under separate cover - not yet completed) focuses on the Phase 2/3 expansion, shear profiles are also provided only for the Phase 2/3 discharge results. The shear profiles are based on the 95% average recovery flows for the average bank shear. The graphed profiles demonstrate that under controlled peak flows, the discharge curves lay within the current flow fluctuation scenario curves (see Appendix B-8).

It is noted that some areas along the channel may have localized particle entrainment even at current base flows, and some areas will have far greater resistance to entrainment even at ultimate expansion discharge flows. The 'average' approach is used since it can provide an assessment of the channel as a whole. The following section focuses on the fluvial aspects of the reach. The observations of the physical composition of the channel bed are reflected therein, and give some impression that the technical shear analysis for the channel as a whole may be considered conservative.

5. Fluvial Geomorphology

Existing conditions and characteristics of the east branch of Sheldon Creek and the creek corridor south of Rebecca Street were ascertained through a review of background information and through reconnaissance-level field investigations. The analyses focused primarily on the approximately 900 m length of channel from Rebecca Street to the confluence with the main branch of Sheldon Creek. Analyses were extended to a broader spatial area and temporal perspective to provide a context for observations and to inform analyses intended to examine impacts for future proposed discharge into the east tributary channel. A summary of existing conditions is presented by discipline in the following sections.

5.1 Historic Change and Implications to Channel Form and Process

Originating in the City of Burlington, upstream of Upper Middle Rd., the east branch of Sheldon Creek flows through a varying landscape that includes open fields, residential, industrial, and commercial developed areas. While the Petro Canada Refinery, in the north east quadrant of Rebecca St. and Burloak Dr., was present in the late 1980s, the remainder of the watershed was largely undeveloped at that time. Development adjacent to the study area, downstream of Rebecca St., began in the early 2000s.

Review of aerial photography and mapping of the east branch of Sheldon Creek indicates that the watercourse was previously straightened, potentially in conjunction with historic agricultural land uses. Immediately upstream of Rebecca St., an approximately 250 m length of the watercourse was realigned following the principles of natural channel design as documented in the Parish Geomorphic design brief (2002). In conjunction with land development south of Rebecca Street, an online plunge pool was created, downstream of which the east branch of Sheldon Creek is contained within a narrow corridor that is flanked by a pedestrian trail and residential homes to the west and Great Lakes Blvd. to the east. The creek emerges into a large wooded open space near Milkweed Way which extends to the main branch of Sheldon Creek.

Changes in the land use within a watershed affect the hydrologic regime of the drainage network. Specifically, even with stormwater management controls, urbanization leads to an increase in flow frequencies and a higher volume of flow that is conveyed through the watercourse. In response, watercourses may enlarge their cross-sectional area. Further, the frequent discharge of water, presumably under a critical threshold for sediment movement, may affect micro-scale channel forms and impact the lower bank area.

5.2 Reaches

During the reconnaissance level field investigation, numerous photos and field observations were recorded, leading to the definition of four reaches along the east branch of Sheldon Creek, beginning at the northerly Creek Path Ave. crossing and extending to its confluence with the main channel of Sheldon Creek. A description of reach characteristics is provided within the following sections. A photo record of stream features in included in Appendix A.

5.2.1 Reach 1: Creek Path Avenue to Milkweed Way

Emerging from the arch shaped, open bottom culvert at Creek Path Ave., Reach 1 extends approximately 270 m downstream. Accumulation of shale fragments under and immediately downstream of the culvert was evident (Photo R1-1). Overall, the channel appeared to have been historically straightened and therefore had a relatively straight planform configuration. A slight sinuosity was developing within the channel corridor (e.g., alternating lateral bars). Evidence of previous channel works/vegetation restoration was evident through exposed filter cloth and planting supports of trees in addition to tree maintenance (i.e., cut tree trunks close to bank edge).

Channel banks were well vegetated with dense scrub-like vegetation, shrubs and vines (Photo R1-2), and often had a mossy cover on the middle to lower bank. Channel banks were often well-reinforced with the rooting networks of the riparian vegetation. In several locations, the roots created a mat on the channel bed and contributed to the formation of a knickpoint (Photo R1-3 and R1-4), downstream of which a deep (~ 1 m) scour pool had formed. Trees along the bank showed evidence of slope adjustments (e.g., leaning or pistol butt trunks that had self-corrected after initial slope and channel widening). Bank materials were clayey (e.g., weathered, hydrated clay) and often undercut, shale was exposed along the bank toe in several locations. Roots extended from the bank.

Bed morphology consisted of relatively shallow pools and short riffles. Substrate materials were mostly characterized as shale fragments with some larger platey and blocky limestone/siltstone forms. In addition to depositions on the channel bed (pools and riffles), medial bars had also formed where larger rocks were imbricated. Shale bedrock was exposed on the channel bed, in the pools within this reach. Bed materials tended to be somewhat imbricated on the lateral bars.

The cross-section was typically u-shaped and some evidence of long term incision was evident in subtle or minor terracing along the channel banks (Photo R1-5) and/or as defined changes in cross-section profile (e.g., smaller channel set within a larger channel). Review of the cross-section configuration suggested that the channel would be able to access the floodplain during periods of high flow. Several dry overland flow swales were evident in the floodplain, directing flow into the channel. Two cross-section profiles were created in this reach, which revealed a 3.5 m wide channel set within a wider (~ 7 m) channel. Channel depth varied from 0.5 to 0.70 m. A typical Reach 1 cross section is illustrated in figure 5.2.1.1.

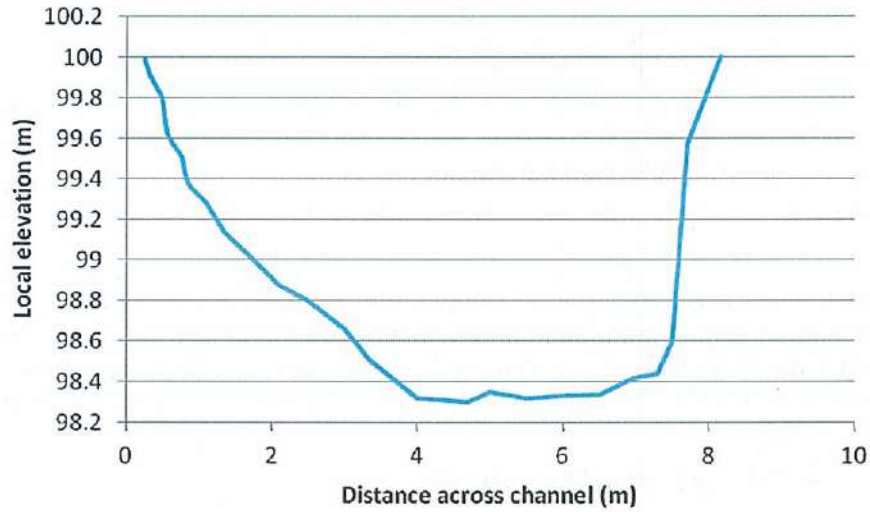


Figure 5.2.1.1 - Reach 1 cross-section

Overall, the channel appeared to be stable but showed evidence of incision and minor planform development.

5.2.2 Reach 2: Milkweed Way to Raspberry Bush Trail

From Milkweed Way to downstream of the trail crossing at Timeless Dr. (distance of ~ 260 m), vegetation in the riparian zone changed and channel characteristics varied, becoming transitional to the dominant characteristics of Reach 2.

Reach 2 varied from Reach 1 primarily as follows:

- Channel width was wider
- Overall, a more 'natural' channel form and surrounding condition
- Floodplain vegetation changed to a woodlot, including a less dense riparian cover (Photo R2-1)
- Increase in exposed shale on the channel bed
- Lateral bars of sediment were present along the banks
- A sinuous planform with developed meander bends was present, including erosion along outside meander bend

Bank vegetation consisted primarily of trees, of which tree roots were often exposed, indicative of channel widening. Fallen trees across or within the channel were also evident and noticeable (Photo R2-2). The banks were often characterized by a lower layer of exposed shale (broken, blocky materials) that was overlain by alluvial materials. Most banks were vertical and banks along the outside of meander bends were often undercut.

The channel cross-sectional configuration tended to be u-shaped, with asymmetry occurring along the more well-developed bends. Channel width was approximately 6 m and depth was ~ 0.70 m. Floodplain access appeared to be variable due to differences in bank height. Evidence of long term channel bed incision and migration across the floodplain were evident through terraces along the channel banks and evidence of a smaller channel set within a larger channel. A typical Reach 2 cross-section is shown in Figure 5.2.2.1.

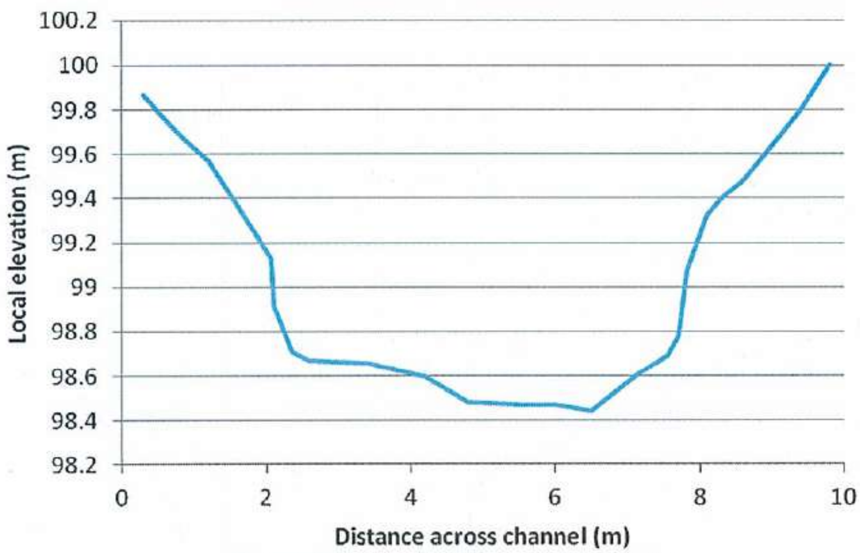


Figure 5.2.2.1 - Reach 2 cross-section

Several dry channels/swales were present in the floodplain, enabling a conveyance of overland flow to the channel (Photo R2-3).

Accumulation of sediment as lateral bars and point bars was common (Photo R2-4 and R2-5); these materials typically consisted of shale fragments (less than 3 cm along the y-axis) that were weathering. In several locations, the occurrence of long lateral bars were causing the low-flow channel to shift towards the opposite bank, contributing to the undercutting of those banks. In some locations, wedges or 'slugs' of sediment were present along the channel bed.

Bed morphology within Reach 2 continued to have riffle-pool forms. Pools tended to be deeper than Reach 1, and riffles more pronounced. Substrate materials typically consisted of shale along the pool bottoms and gravels in riffles typically exposed in pools. A wedge of sediment had accumulated on the channel bed, effectively creating a small knickpoint in the channel profile.

Overall, this reach was relatively stable, but exhibited evidence of planform development and channel widening.

5.2.3 Reach 3: Raspberry Bush Trail to Creek Path Avenue

Reach 3, was defined by a change in riparian vegetation and an increase in bedrock exposure on the channel bed. The reach length was approximately 150 m. Riparian vegetation species and density began to resemble that which was present along the upstream portion of Reach 2 (i.e., shrubs), but contained more grasses (Photo R3-1 and R3-2).

Reach 3 varied from Reaches 2 and 1 as follows:

- Shale bedrock was more exposed along the channel bed (Photo R3-3), at both pool and riffle-like forms; accumulations of shale fragments and some coarser gravel did occur at some riffles.
- Shale was exposed (sub aerial) on the channel bed, at the bank toe.
- The bed morphology consisted of pool-riffle/run sequences, pools and riffles both tended to be longer than upstream.
- Undercuts were more prevalent, reaching depths of 0.75 m.

- Channel width was narrower (~ 4.7 m, with a depth of ~ 1m).

Similar to the upstream reaches, banks were typically near vertical but also were vegetated with shrubs, grasses, and trees. Tree trunks were bent and/or leaning, indicative of bank adjustment processes (Photo R3-4).
The overall channel configuration appeared to have been straightened and the cross-section was u-shaped. The cross-section profile suggests that the active (bankfull) channel is set within a larger cross-section. A typical Reach 3 cross-section is shown in Figure 5.2.3.1.

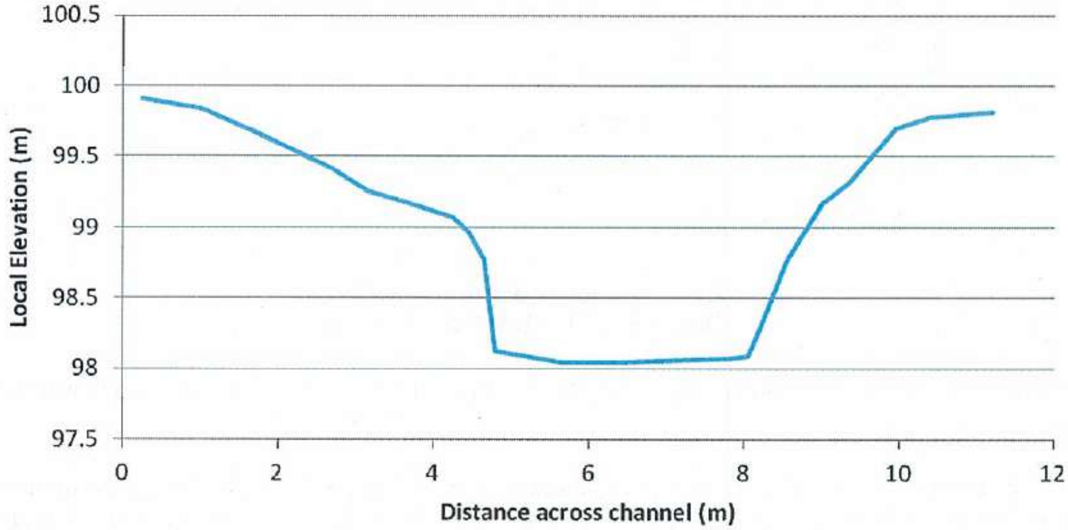


Figure 5.2.3.1 - Reach 3 cross-section

In addition to the increased shale exposure along the channel bed, shale was also exposed as ledges along the toe of bank, extending into the channel (Photo R3-5). The shale tended to be cracked, both on the channel bed and along the bank toe.

Overall, the channel exhibited evidence of widening and downcutting.

5.2.4 Reach 4: Creek Path Avenue to Sheldon Creek Confluence

Reach 4 emerges from underneath Creek Path Ave. where it is contained in a small defined channel that begins to lose definition towards the downstream end. From the culvert, the channel flows ~ 180 m before joining the main branch of Sheldon Creek. This reach was defined by a change in overall channel process, change in riparian channel control, and subtle channel form.

Reach 4 varied from Reach 3 as follows:

- Change in bed material composition and depth of accumulation towards a reduction in extent of exposed bedrock, and increase in shale fragments
- Increase in grassy bank vegetation control on channel form

The channel planform in Reach 4 contained both straightened and meandering channel sections (Photo R4-1). Where meandering, active point bar development was evident, and terracing along the inside bend was observed. Terracing was also observed along straighter channel sections (Photo R4-2).

The cross-section of the channel was typically 'u-shaped' and appeared to be better-connected to the floodplain than upstream reaches, but did exhibit evidence of incision. Figure 5.2.4.1 illustrates a typical Reach 4 cross-section.

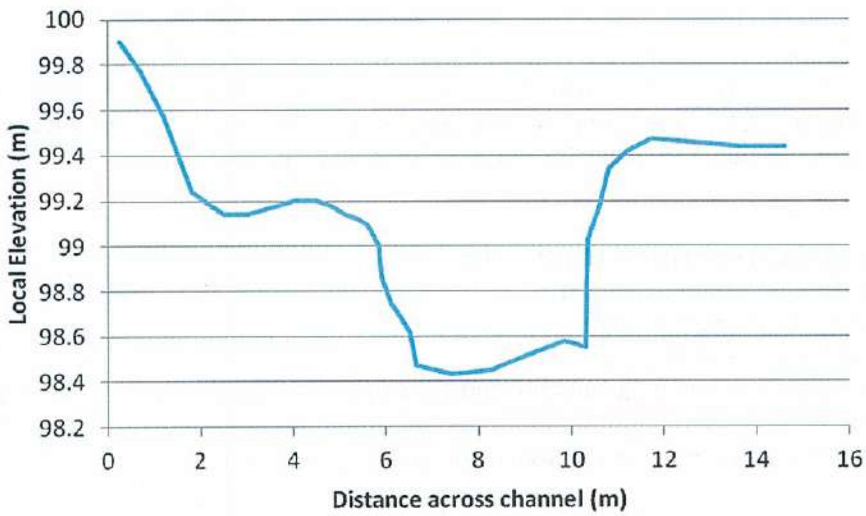


Figure 5.2.4.1 - Reach 4 cross-section

Similar to Reaches 1 and 2, evidence of vegetation maintenance activities was observed along the channel through cut trunks (Photo R4-3). Further, disturbance of the floodplain was observed (rip-rap on floodplain, exposed filter cloth along banks), which upon review of air photos was found to be in the vicinity of two stormwater management ponds.

Channel banks were diverse throughout the reach. Banks were variably vegetated with a low profile or near vertical and undercut with exposed roots. Trees on banks often exhibited bent trunks, attesting to previous bank processes to which the trees have adjusted. Bank materials consisted of clayey material or exposed shale at the bank toe, above which fragmented shale was overlain by soils (Photo R4-4).

The channel bed configuration consisted of pool-riffle sequences. Bed materials consisted of clay fragment and larger gravel/small cobbles. Sandy materials were also observed. Deposition of materials occurred as lateral and point bars within the channel.

Accumulation of large woody debris within the channel has contributed to a debris jam, upstream of which deposition of sediment has occurred (Photo R4-5).

The outlet of the tributary into the main branch of Sheldon Creek was elevated ~ 10 cm above the bed of the main branch. Boulders situated at the outlet create a blockage and trap sediment, contributing to the elevated condition. Adjacent to the outlet, field observations suggest that high flows are reworking the mouth of the creek, which may eventually lead to a new location of the mouth (i.e., a few metres downstream). This would be accompanied by downcutting at the outlet, towards a similar elevation as the main branch of Sheldon Creek.

Overall, this reach appeared to be a sediment transport deposit zone (Photo R4-6), which is typical for downstream reaches that discharge into another watercourse. In addition, the dominant trend appeared to be planform development and channel bed lowering in the long term.

5.3 Impact of Proposed Conditions on Creek Geomorphology

5.3.1 Geomorphology

As noted, the east tributary of Sheldon Creek is a rock controlled channel type. This means that processes and channel responses that occur by the channel in response to a change in one or more of its controlling parameters will differ from that of an alluvial channel. Further, processes other than shear stresses also play an important role in channel development. Dominant processes that affect the erosion/degradation of a bedrock channel include, but are not limited to:

- Abrasion by sediment entrained/transported by flow;
- Plucking by hydraulic action and/or ice;
- Gouging/scour – by periodic debris;
- Upstream knickpoint regression;
- Physical and chemical weathering: wet-dry and freeze-thaw cycles; hydration of the shale, altering its state to a clay; and
- Flow regime – movement of sediment from bank toe.

Enlargement of a cross-section in a bedrock controlled channel can occur in one of four zones, as defined by Allen *et al.* (2002):

- Soil zone;
- Slake zone (exposed bedrock in lower bank);
- Rock zone (exposed bedrock on channel bed); and
- Bed material zone.

Allen *et al.* (2002) suggest that where a channel has downcut into underlying bedrock, similar to the condition at the east branch of Sheldon Creek, then widening of the channel occurs through scour of alluvial material and weathering (slaking) and removal of exposed rock material. This occurs in the zone from the "mean flow line of the channel taken as the riffle height to the soil/rock interface is termed the slake zone...channel losses range from 0.4 to 2 inches a year (*in Texas*), depending on the number of wet-dry cycles per year and flood frequency" (pg. 1486, Allen *et al.*, 2002; *italics ours*).

When considering impacts of the proposed discharge into the east branch of Sheldon Creek, it is important to consider that the existing channel has been impacted and is responding to the recent urban hydro-modification (i.e., change in hydrologic regime as a direct result of urban development).

As part of the reconnaissance field investigation, six cross-section profiles were collected in the field using a fibre-glass tape. This was intended to confirm general cross-section shape and dimensions as represented in the HEC-RAS model and for review of channel geometry. In general, the modeled cross-sections (in HEC-RAS) were a reasonable approximation of the actual channel configuration.

Review of the channel geometry, primarily through the HEC-RAS models and substantiated through the field collected cross-section Profile, demonstrated that the channel was incised. That is, field observations suggested that the observed 'bankfull' channel was set within a larger channel. Review of the HEC RAS models demonstrated that larger channel which contained the bankfull channel could typically contain a minimum of the 20 year return period flow, and most often contained the 50 or 100 year flow. This signifies that the energy associated with higher than bankfull flow remains in the channel, rather than dissipating energy onto the adjacent floodplain. As such, they affect the channel form that develops within the channel and the erosional processes that occur therein.

Examination of the width:depth ratio associated with the 2 year flow event hydraulic parameters suggests that Reach 1 is narrowest (w:d ratio is typically 13 – 14). The ratio varies most widely for Reach 4 (ratio: 10 – 54) and has relatively similar ranges between reaches 2 and 3 (ratio: 12 – 20).

Preliminary review of the stream power of flows that are conveyed through the channel suggests that while relatively low overall, in each defined Reach there are sections in the HEC-RAS model where stream power becomes high. This is likely due to local variations in channel slope. Stream power was relatively high for most of Reach 4. However, the highest stream power defined by the HEC-RAS model occurs in Reaches 2 and 3. This supports the notion that Reach 3 is the more sensitive channel.

Analysis of the HEC-RAS data was undertaken to determine the potential grain size that could be entrained, as a function of in-channel shear stress. Results of the analyses suggest that the largest potential grain size that could be entrainment (e.g., 0.12 m) occurs in both Reaches 2 and 3. In Reaches 1 and 4, the largest potential grain size that could be entrained is 0.08 m and 0.09 m respectively. Based on field observations and measurements, while large particles (e.g., measured up to 0.27 m) certainly occur within the channel, many particles that constituted lateral bars and bed materials were much smaller (i.e., < 5 cm).

5.3.2 Bank Stability

Accurately predicting the effect of the proposed discharge scenarios on the banks of the east branch of Sheldon Creek is difficult given the complexity of processes and factors that affect bank retreat, especially of a shale bedrock controlled channel. The mechanism for shale bedrock bank retreat include, but are not limited to, weathering and spalling of bedrock materials, freeze-thaw weathering, removal of loose sediment during flow events, and abrasion during flow events. Erosion of the upper alluvial layers occurs, but is limited to gradual winnowing and removal of loose sediment during flow events and slumping due to undercuts.

The existing channel banks are well reinforced by the rooting network of bankside vegetation. This control is reduced in those areas where bedrock is exposed at the bank toe. The existing high level of vegetative control on the upper channel banks within the study area is advantageous in minimizing bank retreat. Indeed, Allen and Narramore (1985) suggest that vegetation plays a significant role in influencing channel adjustments to new flow regimes brought on by urbanization. This is due to the sediment binding benefit of roots which increase the structural strength of bank materials. As such, even when undercuts occur, it may be some time until the overhanging bank fails.

Fischenich (2001) has assembled a table of permissible velocity and shear for various boundary materials. For shale, the threshold values are 1.83 m/s and 32.08 N/m^2 respectively; for alluvial silt (colloidal), the values are 1.14 m/s and 12.45 N/m^2 (note: these values do not take into account the effect of root binding, which increases the shear strength beyond these thresholds). Review of permissible velocity values indicate that flow velocity thresholds for shale materials and alluvial silt (in general) would not be exceeded by any of the flow scenarios. Table 5.3.2.1 quantifies the bank shear stresses corresponding to the low flow, Phase 2/3 average and Ultimate peak scenarios; all values are well below the Fischenich threshold for shale materials and alluvial silt, except for section 6. At that location the root binding effects increase the thresholds and, as such, the close match between proposed plant flow bank shear and shear thresholds is not considered to be an indication of likely channel impacts.

Table 5.3.2.1 - Channel Bank Shear in Study Area from Proposed Plant Flows

XS	Low Flow (N/m^2)	Phase 2/3 Avg (N/m^2)	Ultimate Peak (N/m^2)
1	2.50	4.14	8.57
2	1.36	2.59	6.23
3	6.32	6.94	8.21
4	2.64	4.64	8.98
5	3.2	4.29	7.37
6	9.54	13.28	12.85

Besides the hydraulic effect of the proposed plant flows, the effect within the slake zone (i.e., lower bank) needs to be further considered, given the other processes identified above. Where the lower bank is in contact with the flow, hydration of the bedrock into a cohesive clayey unit has occurred that, in conjunction with fine sediment deposition, has largely protected the bedrock in the lower bank from direct physical weathering and plucking action, thereby reducing the contact between flow and bedrock in this zone. Where bedrock is exposed in undercut banks, the turbulence and reduced flow rates within the undercut banks reduces the plucking action of the shale. Where bedrock is present at the bed-bank interface, then it is in direct contact with the flows and subject to erosion.

Review of Table 4.3.1.1 reveals that the change in water level from existing low flow conditions to the Phase 2/3 scenario is ≤ 5 cm. A more substantial change in water level would occur in the ultimate peak scenario (i.e., 9 - 18 cm). Given the accumulation of fine sediment at the base of most banks, the maximum 5 cm change in water level would likely have minimal impacts on channel bank processes. In those areas where bedrock is exposed at the channel bed - bank toe interface (e.g., Reach 3), the 5 cm increase would contribute to some increase in wetting-drying of this lower layer. The magnitude of effect will be affected by the duration and frequency of the proposed discharge events. It is difficult, however, to quantify an actual rate, but qualitatively, it is expected that the effect would be minimal.

The 9 - 18 cm increase in water level that would be anticipated with the ultimate peak flow scenario would have greater potential to come into contact with the shale bank (i.e., may be higher than the deposits at the bank toe) and, over time, could contribute to retreat of the shale bedrock layer. Where bedrock is not exposed at the bank toe, then the increase in water levels may contribute to the gradual winnowing of bank materials from amongst roots. Further field investigations to examine the channel bank profile and stratigraphy would be beneficial for the purpose of better defining impacts resulting from each of the proposed flow scenarios.

Evidence from other shale bedded watercourses suggests that removal of sediment accumulations at the bank toe (e.g., through sediment entrainment), and continual fluctuations in water level may begin to cause gradual bank toe erosion. Typically, this rate is very gradual and occurs less quickly than channel bed lowering. As long as the shale upper bank materials are reasonably protected from fluvial, sub-aerial, groundwater and frost action by overlying alluvial materials (especially when reinforced with vegetation), then actual retreat of the top of bank is a gradual process. That is, the stable inclination of a shale bank can be near vertical, even when somewhat undercut. Upon failure of an overhanging bank, the failed bank block often sits at the base of the bank, providing protection of the bank, and redirecting flow away from the bank, thereby limiting contact with flow, until the slumped bank block is removed.

In addition to the actual increase in water level and change in bank shear exerted by flows, and flow velocities, the effect of flow fluctuations may in fact be the more important characteristic of the proposed flow discharge that affects bank processes. This includes the duration of the peak flow and frequency of fluctuations. That is, short duration and low frequency events would be expected to have a lesser impact than frequent and long duration events on the slake zone. Currently, both widening and channel migration are active, albeit very gradual, processes in the existing watercourse. Based on the analyses described above, it would appear that the Phase 2/3 flow would have minimal impact. Some impact from the Ultimate flow scenario may be expected, given the increase in flow depth and effect on non-hydraulic bank erosion processes. The magnitude of this effect can be better quantified in conjunction with the effectiveness of the methods that would be contemplated in attenuation of the discharge peaks at the plant and within the conduit leading to the discharge point.

5.3.3 Bed Stability

As noted above, there are various processes that affect the erosion of bedrock on a channel bed. While some of these are hydraulically driven, others are a function of weathering (wetting-drying), ice conditions, periodic scour due to in-flow objects, and also of the jointing of shale stratigraphic layers.

Both the cross-section and sediment data collected in the field were used to determine a preliminary erosion threshold. The analyses assumed an average 0.69% channel grade (see Section 3.1) and assumed that the grain size distribution determined through laboratory analyses was a reasonable approximation of the actual bed materials. It is important to note that the sediment samples included both surface and sub-pavement materials. Typically, coarser sediments are supported by a matrix of finer sediment. Therefore, the median grain size as presented in Table 5.3.3.1 is likely somewhat finer than what is exposed on the channel bed and in direct contact with the flow. Results of the analyses are provided in Table 5.3.3.1.

Table 5.3.3.1 - Critical thresholds of sediment movement (Geomorphic Derivation)

Cross-Section	Reach	D50 (mm)	Critical Shear (N/m2)	Corresponding flow depth (m)	Critical discharge (cms)
1	1	11	8.01	0.14	0.36
2	1	28	20.39	0.26	2.36
3	2	Bedrock and gravels[1]			
4	3	Bedrock[2]			
5	4	10	6.19	0.10	0.26

Notes: [1)] laboratory results do not appear to be representative of the actual bed material distribution and were not carried through; [2)] critical shear analyses were not completed for bedrock material

Comparison of the critical flows defined in Table 5.3.3.1 with the various flow scenarios presented in Table 5.3.2.2 suggests that the critical flow for sections 1 and 2 would not be exceeded until the Phase 4 ultimate peak flow scenarios. This potential condition provides direction to carry out a future analysis to examine alternatives that attenuate peaks.

The effect of increased flow on in-channel shear stresses is perhaps a more robust measure to examine the implications on sediment entrainment potential. That is, the grain size that may be expected to be entrained due to the in-channel shear stresses corresponding to each of the flow scenarios is presented in Table 5.3.2.2; the difference in grain size between the flow scenarios is also tabulated. Review of Table 5.3.2.2 suggests that, except for Section 3, a ≤ 4 mm increase in entrainable grain size is expected from the existing low-flow conditions to the Phase 2/3 scenario. This small grain size increase (average of 3 mm for all cross-sections) does not result in a change in grain size classification (e.g. coarse gravel). Further, the small grain size differences may well be within the range of error associated with the methods.

Table 5.3.2.2 – Entrainable Grain Size Impacts in Study Area from Proposed Plant Flows

XS	Low Flow (m)	Phase 2/3 Avg (m)	Δ Low Flow to Phase 2/3 (m)	Ultimate Peak (m)	Δ Low Flow to Ult Peak (m)
1	0.026	0.030	0.004	0.039	0.013
2	0.007	0.008	0.002	0.016	0.010
3	0.009	0.022	0.012	0.031	0.022
4	0.023	0.026	0.003	0.050	0.027
5	0.004	0.005	0.002	0.010	0.006
6	0.018	0.016	-0.002	0.026	0.008
average	0.014	0.018	0.003	0.029	0.014

Further review suggests that the increase in potential entrainable grain size ranges from 6 to 27 mm between the low flow and ultimate flow scenarios, with an average of 14 mm. These changes do cause a shift in the grain size classes for most cross-sections. Further, the most marked increase occurs in Reach 3, which was identified as the more sensitive channel reach due to the increase in bedrock exposure.

An increase in flow depth during periods of low flow may be advantageous to the more sensitive reaches defined in this study. Specifically, this will keep the bedrock that is exposed along the channel bank/bed interface moist, decreasing the bedrock's susceptibility to physical weathering processes that are due to sub-aerial exposure. In Reach 3, bedrock was exposed on the channel bed and also at the toe of slope, within the slake zone. The increase in flow depth, as summarized in Table 4.3.1.1 (section 4 occurs in Reach 3), would be sufficient to submerge the exposed bedrock lip at the base of the bank.

6. Vegetative Assessment

The existing terrestrial conditions along the east branch of Sheldon Creek were assessed through a field investigation on November 8, 2011. Communities were delineated according to the Ontario Ministry of Natural Resources' Ecological Land Classification (ELC) system (Lee *et al.*, 1998). All floral species observed were noted along with a photographic record of the communities in relation to the Creek.

The terrestrial communities along Sheldon Creek range from early successional to mature forest. Starting at the confluence, plant species are comprised of Manitoba maple (*Acer negundoi),* Norway maple (*Acer platanoides*), willow (*Salix sp.*), and black walnut (*Juglans nigra*). There is a prevalence of Norway maple, especially in the area upstream of Nautical Blvd, where trees completely cover Sheldon Creek. Tree species are young ranging in height between 10 and 15 metres. Beyond this stand of Norway maple, the terrestrial conditions reflect a more natural state where a mature upland sugar maple (*Acer saccharum*) forest with white ash (*Fraxinus americana*), red oak (*Quercus rubra*), American beech (*Fagus grandifolia*) and shagbark hickory (*Carya ovata*) associates occur. Tree height within the forest community ranges between 20 and 25 metres. Shrub cover is low as well as herb cover. Between Milkweed Way and Nautical Boulevard, the terrestrial conditions narrow to a thin strip of vegetation along the Creek. Tree species are similar to that found within the forest, however, tree cover is less and shrub cover is increased, especially that of the invasive common buckthorn (*Rhamnus cathartica*). Beyond Nautical Boulevard, the creek widens with fringe cattail marsh communities along its banks and planted landscape trees along the slope.

These conditions can be delineated into the following Ecological Land Classification vegetation communities:

- CUW1 - Mineral Cultural Woodland Ecosite
- FOD5-8: Dry-Fresh Sugar Maple - White Ash Deciduous Forest Type
- MAS 2-1: Cattail Mineral Shallow Marsh Type

Appendix C presents a plant species list.

The conditions of the vegetation within proximity of the creek are a mixture of invasive (Norway maple, Manitoba maple, common buckthorn) and common (sugar maple, red oak, American beech) plants typical of upland communities. Most of the terrestrial environment along the east branch of Sheldon creek is comprised of species that are typical of disturbed areas that have a relatively high tolerance for varying conditions, particularly water level fluctuations. The area where species are less tolerant of water level fluctuations is populated by a mature sugar maple forest (in particular between Springflower Way and Milkweed Way). Both red oak and sugar maple, the dominant trees along the creek within this portion, would be prone to mortality with a substantial rise of water levels, especially should water levels rise to a level which creates waterlogged soils, resulting in poor gas exchange and depleting the soil of oxygen. However, considering that water level rise is estimated to be a maximum of 126 mm, these types of conditions along this stretch of creek is not anticipated and thereby an effect to the woodland would not be expected.

7. Aquatic Ecology Evaluation

An aquatic assessment investigation was not completed as part of the field work for this specific assessment report. Aquatic information has been derived from the 2003 Environmental Assessment carried out by TSH for the main branch of Sheldon Creek from New St. to Spruce St. as well as from the 2007 Bronte Creek EA and the Supplemental Monitoring program published by Conservation Halton (dated October 2009). The intent of the review is to ascertain, at a general level, if the impacts of additional base flow would impact the aquatic species present in the creek.

The data resulting from the 2003 Sheldon Creek EA revealed the following species that were either identified or had the potential to exist in the creek system:

Blacknose Dace	White Sucker
Brook Stickleback	Rainbow Darter
Common Shiner	Longnose Dace
Creek Chub	Fathead Monnow
Rainbow Trout	Brown Trout
Fantail Darter	

Given the connection of the main branch to the east branch, these species are considered to be common to the study reach of both branches despite a series of passage impediments at the confluence and along the branch at low flow. These species are not expected to be negatively impacted by the proposed increases in base flow discharge.

The Conservation Halton report provided information in regard to the quality of the benthic community. Sampling began in 2007 within Shell Park and has shown the station to be 'impaired.' The report suggests that the 'EPT' value is '*very low*' with only four species identified. The text also suggests that the shale conditions paired with the presence of debris and concrete blocks does not provide for good conditions.

Activities in the vicinity of Sheldon Creek will need to consider the impacts to the aquatic species and benthic community. There are two benefits to fish habitat that are envisioned in the event that additional base flow is provided in the creek:

1. Potential exists that the increase in base flow can function to improve pollutant dilution in the channel and provide an improvement in the water environment for benthic quality. Moreover, the slight increase in flow velocity could improve benthic communities in creek substrate that is comprised of shale fragments, cobble and coarse gravel base (assuming a sustained base flow average increase). Reduced benefit due to velocity increases would be experienced in areas of smooth shale bed exposure. To definitively assess this potential, further study would be required.
2. The hydraulic modeling indicates that increased depth occurs over the study reach under all flow scenarios; however, the benefit is best defined in the lower reach near the confluence with the main branch. The increased depth improves passage potential over the creek bed where sporadic widened sections yield low water depths.

8. Conclusions and Recommendations

As noted previously, Sheldon Creek is in a state of transition. Development has impacted the channel and it is currently in the process of response to these impacts. The response has resulted in bed incision and channel widening. The overall intent of the assessment is to determine through qualitative means if the rate of change would be altered in response to additional base flow.

The preceding information suggests that initial phase plant expansion (Phase 2/3) would not have a significant adverse effect to the creek channel integrity, with the understanding that controls would be implemented to manage the peak discharge values. Under 'ultimate' scenarios, for some sections of channel, it could be concluded that adverse impacts would not be significant, and for other sections, additional study would be needed, particularly in characterizing the creek bed and bank soil conditions. It is envisioned that prior to full expansion, conditions in the creek would be re-evaluated with the benefit of the proposed monitoring work which would be undertaken as part of the initial phase.

The capacity of the channel is assessed in two ways since it is comprised of both cohesive and non-cohesive materials. The extent of the soil gradation tests did not account for the quantity by weight of particles which would be classified as clay or fine material; hence the degree to which the material is cohesive could not be measured. For channels lined by grass, earth or sand, the 'competent velocity' method is used to determine the channel resistance to flow velocity. Model results indicate that the channel would not reach maximum (average) permissible velocity thresholds under the majority of discharge scenarios resulting from the plant expansion, with only a minimal exceedance in cross-section 1 at the ultimate plant capacity peak flow (see Appendix B-9).

The channel was also assessed using the 'allowable shear stress' method which determines allowable stresses for channels with a lining of rock, cobbles or granular materials. This method takes into account the reach observations of the bed shale fragments and granular material. However, it is considered to provide a conservative approach, since it does not take into account the binding mechanism of the small particles (not measured in the soil sieve analysis) with the larger particles or the root mass comprising the majority of the channel banks that help to retain material integrity.

The shear force analysis shows that the average shear resistance is exceeded at the flow volume of approximately 0.45 cms. This value is coincidental with the Phase 4 expansion value of 270 l/s peak flow discharge added to the average base flow discharge of 0.139 cms (409 l/s or 0.409 cms). This suggests that from a conservative perspective, the plant can expand to 'Phase 4' levels within average particle shear thresholds, and that since the 'Ultimate' expansion average discharge is equivalent to the peak discharge of the phase 4 level peak discharge, some attenuation of the peaks will be required for the ultimate expansion (see Appendix B-7).

8.1 Flow Attenuation from Plant

Peak flows under any expansion scenario should be attenuated prior to discharge so that the wetting and drying effect on the channel banks is minimized. Smoothing of the peaks can be achieved using temporary detention either at the plant or within the conduit prior to the point of discharge. A hydraulic analysis would need to be carried out to determine the optimal alternative to produce continuous flow and minimization of surge effects. It is noted that the peak discharge in the 'Ultimate' scenario is the same as the average discharge flow (95% recovery) for the Phase 4 discharge (270 l/s). This value is slightly under the calculated average threshold value using the 'Shear Stress' method in the study. Though this method is conservative given the observations, attenuation of flow is recommended during all discharge stages.

8.2 Discharge Attenuation – Outlet Structure

The proposed discharge structure has been proposed to be located at or near the Sheldon Creek East Branch channel bank immediately south or north of Nautical Blvd. The structure is proposed to receive flow from the plant via pump action (i.e., gravitational flow of the conduit is not required). The structure should incorporate a primary energy dissipation chamber that can function to maximize the weir effect at discharge to achieve a well distributed outflow. In addition, a flow dispersion structure should be considered to minimize local erosion or flow concentrations. The discharge location is proposed to be located in an area where local trees or vegetation loss will be minimally affected.

8.3 Monitoring – Adaptive Management

Monitoring of the channel flows and channel integrity are recommended to take place for the establishment of detailed design parameters. Monitoring devices should be installed for a period of at least nine months to develop a baseline that captures existing base flows as well as impacts of storm event flows. In concert with flow monitors, we recommend that erosion pins be installed at critical areas to measure the change in bed and bank geometry and characteristics. This information will aid in the design of appropriate discharge elements. Monitoring would continue post-implementation to ascertain the impacts and enact changes if required.

8.4 External Impacts

This report focuses on the impacts of the channel in regard to its anticipated response with the proposed treatment plant discharge flows. The geomorphic sections in this report refer to the general processes in this area (section 5). To ascertain impacts to public areas, roadway, crossings, etc., two sources of information are used: the geomorphic context and hydraulic model sections. From a geomorphic perspective, the channel is in transition and will continue to be in transition as it responds to historic urbanization of the watershed. The proposed discharge flows are identified to be below the channel threshold and are not expected to adversely impact the channel progression; the channel will continue to widen and downcut in certain areas as is occurring currently.

From a flood perspective (i.e., crossing capacity or frequent flooding), the model cross sections demonstrate that overtopping elevations will not significantly change, (i.e. 0.03m above the 2 year event).

AECOM

Appendix A

Photograph R1-1 ↑
Accumulation of shale fragments at Creek Path Avenue

Photograph R1-2 ↑
Well vegetated channel banks in Reach 1

Photograph R1-3 ↑
Knick point formation in Reach 1

Photograph R1-4 ↑
Knick point formation in Reach 1

Photograph R1-5 ↑

Minor terracing of channel banks in Reach 1

Photograph R2-1 ↑
Floodplain vegetation in Reach 2

Photograph R2-2 ↑
Fallen trees across channel in Reach 2

Photograph R2-3 ↑
Overland flow channel in floodplain

Photograph R2-4 ↑
Accumulation of sediment as lateral bars in channel

Photograph R2-5 ↑
Accumulation of sediment as lateral bars in channel

Photograph R3-1 ↑
Riparian vegetation in Reach 3

Photograph R3-2 ↑
Riparian vegetation in Reach 3

Photograph R3-3 ↑
Exposed shale bedrock on channel bed

Photograph R3-4 ↑
Leaning trees on bank

Photograph R2-5 ↑
Exposed shale along toe of bank in Reach 3

Photograph R4-1 ↑
Typical channel section in Reach 4

Photograph R4-2 ↑
Bank terracing noted in Reach 4

Photograph R4-3 ↑

Photograph R4-4 ↑

Evidence of vegetation maintenance in Reach 4

Photograph R4-5 ↑
Debris jam in Reach 4

Fragmented shale overlain by soil on bank

Photograph R4-6 ↑
Boulders at confluence with main branch

AECOM

Appendix B-1

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
East Sheldon Ck	Tributary	1086		Culvert	(Rebecca Street)								
East Sheldon Ck	Tributary	1050	2-Yr	9.9	88.260	89.077	88.800	89.140	0.001957	1.10	9.02	17.89	0.44
East Sheldon Ck	Tributary	1050	Base	0.14	88.260	88.412	88.360	88.430	0.005271	0.54	0.26	2.37	0.53
East Sheldon Ck	Tributary	1050	P23Avg	0.24	88.260	88.486	88.400	88.490	0.004804	0.32	0.74	14.16	0.45
East Sheldon Ck	Tributary	1050	P23Peak	0.34	88.260	88.495	88.470	88.500	0.005692	0.39	0.86	14.22	0.50
East Sheldon Ck	Tributary	1050	P4Peak	0.41	88.260	88.504	88.480	88.510	0.005137	0.41	1.00	14.28	0.49
East Sheldon Ck	Tributary	1050	UltPeak	0.68	88.260	88.512	88.500	88.530	0.009785	0.61	1.11	14.33	0.69
East Sheldon Ck	Tributary	1043	2-Yr	9.9	88.200	89.086		89.120	0.001123	0.82	12.14	19.14	0.33
East Sheldon Ck	Tributary	1043	Base	0.14	88.200	88.387	88.390	88.400	0.002971	0.48	0.29	2.12	0.41
East Sheldon Ck	Tributary	1043	P23Avg	0.24	88.200	88.410	88.410	88.420	0.023206	0.50	0.48	15.36	0.91
East Sheldon Ck	Tributary	1043	P23Peak	0.34	88.200	88.416	88.420	88.430	0.026253	0.60	0.57	15.39	0.99
East Sheldon Ck	Tributary	1043	P4Peak	0.41	88.200	88.418	88.420	88.440	0.032544	0.69	0.60	15.40	1.11
East Sheldon Ck	Tributary	1043	UltPeak	0.68	88.200	88.479		88.490	0.003874	0.44	1.54	15.74	0.45
East Sheldon Ck	Tributary	1039	2-Yr	9.8	87.650	89.102		89.110	0.000112	0.41	25.32	24.26	0.12
East Sheldon Ck	Tributary	1039	Base	0.14	87.650	88.329		88.330	0.000001	0.02	8.80	17.95	0.01
East Sheldon Ck	Tributary	1039	P23Avg	0.24	87.650	88.374		88.370	0.000001	0.02	9.63	18.62	0.01
East Sheldon Ck	Tributary	1039	P23Peak	0.34	87.650	88.408		88.410	0.000002	0.03	10.28	19.06	0.01
East Sheldon Ck	Tributary	1039	P4Peak	0.41	87.650	88.427		88.430	0.000003	0.04	10.65	19.21	0.02
East Sheldon Ck	Tributary	1039	UltPeak	0.68	87.650	88.485		88.490	0.000006	0.06	11.78	19.64	0.02
East Sheldon Ck	Tributary	1032	2-Yr	9.8	87.650	89.105		89.110	0.000051	0.29	35.01	30.99	0.08
East Sheldon Ck	Tributary	1032	Base	0.14	87.650	88.329		88.330	0.000000	0.01	14.03	23.26	0.00
East Sheldon Ck	Tributary	1032	P23Avg	0.24	87.650	88.374		88.370	0.000000	0.02	15.09	23.60	0.01
East Sheldon Ck	Tributary	1032	P23Peak	0.34	87.650	88.408		88.410	0.000001	0.02	15.91	23.89	0.01
East Sheldon Ck	Tributary	1032	P4Peak	0.41	87.650	88.428		88.430	0.000001	0.02	16.37	24.08	0.01
East Sheldon Ck	Tributary	1032	UltPeak	0.68	87.650	88.486		88.490	0.000002	0.04	17.78	24.67	0.01
East Sheldon Ck	Tributary	1028	2-Yr	9.8	87.650	89.100		89.110	0.000090	0.40	25.75	20.50	0.11
East Sheldon Ck	Tributary	1028	Base	0.14	87.650	88.329		88.330	0.000000	0.01	10.92	17.31	0.01
East Sheldon Ck	Tributary	1028	P23Avg	0.24	87.650	88.374		88.370	0.000001	0.02	11.73	18.13	0.01
East Sheldon Ck	Tributary	1028	P23Peak	0.34	87.650	88.408		88.410	0.000001	0.03	12.35	18.23	0.01
East Sheldon Ck	Tributary	1028	P4Peak	0.41	87.650	88.427		88.430	0.000001	0.03	12.70	18.29	0.01
East Sheldon Ck	Tributary	1028	UltPeak	0.68	87.650	88.485		88.490	0.000003	0.05	13.77	18.48	0.02
East Sheldon Ck	Tributary	1024	2-Yr	9.8	88.200	89.082		89.110	0.000722	0.79	14.63	22.35	0.28
East Sheldon Ck	Tributary	1024	Base	0.14	88.200	88.324		88.330	0.001623	0.30	0.47	4.46	0.29
East Sheldon Ck	Tributary	1024	P23Avg	0.24	88.200	88.367		88.370	0.001659	0.36	0.67	4.93	0.31
East Sheldon Ck	Tributary	1024	P23Peak	0.34	88.200	88.399		88.410	0.001756	0.41	0.84	5.29	0.33
East Sheldon Ck	Tributary	1024	P4Peak	0.41	88.200	88.417		88.430	0.001779	0.44	0.96	8.45	0.33
East Sheldon Ck	Tributary	1024	UltPeak	0.68	88.200	88.473		88.480	0.001611	0.50	1.66	16.55	0.33
East Sheldon Ck	Tributary	996	2-Yr	9.8	88.010	89.022		89.070	0.001933	1.02	9.67	16.91	0.42
East Sheldon Ck	Tributary	996	Base	0.14	88.010	88.270		88.280	0.003226	0.36	0.38	4.52	0.40
East Sheldon Ck	Tributary	996	P23Avg	0.24	88.010	88.310		88.320	0.003025	0.41	0.59	5.51	0.40
East Sheldon Ck	Tributary	996	P23Peak	0.34	88.010	88.339		88.350	0.003058	0.45	0.76	6.22	0.41
East Sheldon Ck	Tributary	996	P4Peak	0.41	88.010	88.357		88.370	0.003007	0.47	0.87	6.67	0.41
East Sheldon Ck	Tributary	996	UltPeak	0.68	88.010	88.417		88.430	0.002741	0.51	1.32	8.15	0.41
East Sheldon Ck	Tributary	931	2-Yr	9.8	87.600	88.603	88.600	88.820	0.009679	2.34	5.55	12.81	0.93
East Sheldon Ck	Tributary	931	Base	0.14	87.600	87.800	87.800	87.850	0.020780	1.00	0.14	1.39	1.01
East Sheldon Ck	Tributary	931	P23Avg	0.24	87.600	87.850	87.850	87.910	0.018655	1.10	0.22	1.73	1.00
East Sheldon Ck	Tributary	931	P23Peak	0.34	87.600	87.888	87.890	87.960	0.017810	1.18	0.29	1.99	1.00
East Sheldon Ck	Tributary	931	P4Peak	0.41	87.600	87.910	87.910	87.990	0.017521	1.23	0.33	2.15	1.00
East Sheldon Ck	Tributary	931	UltPeak	0.68	87.600	87.980	87.980	88.070	0.016208	1.36	0.50	2.63	0.99
East Sheldon Ck	Tributary	899	2-Yr	9.8	87.250	88.381	87.800	88.390	0.000275	0.49	20.06	29.30	0.17
East Sheldon Ck	Tributary	899	Base	0.14	87.250	87.404	87.340	87.420	0.003647	0.49	0.28	2.27	0.45
East Sheldon Ck	Tributary	899	P23Avg	0.24	87.250	87.450	87.380	87.470	0.004151	0.61	0.39	2.53	0.49
East Sheldon Ck	Tributary	899	P23Peak	0.34	87.250	87.488	87.410	87.510	0.004426	0.69	0.49	2.75	0.52
East Sheldon Ck	Tributary	899	P4Peak	0.41	87.250	87.511	87.430	87.540	0.004521	0.73	0.56	2.88	0.53
East Sheldon Ck	Tributary	899	UltPeak	0.68	87.250	87.618	87.490	87.630	0.004494	0.39	1.75	24.12	0.46
East Sheldon Ck	Tributary	882		Bridge	(Creek Path Ave - North Crossing)								

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
East Sheldon Ck	Tributary	865	2-Yr	9.8	86.950	88.362	87.500	88.370	0.000100	0.36	27.35	30.22	0.11
East Sheldon Ck	Tributary	865	Base	0.14	86.950	87.242	87.040	87.240	0.000344	0.21	0.65	3.05	0.15
East Sheldon Ck	Tributary	865	P23Avg	0.24	86.950	87.319	87.080	87.320	0.000515	0.13	1.80	24.61	0.16
East Sheldon Ck	Tributary	865	P23Peak	0.34	86.950	87.348	87.110	87.350	0.000347	0.14	2.51	24.76	0.13
East Sheldon Ck	Tributary	865	P4Peak	0.41	86.950	87.370	87.130	87.370	0.000264	0.13	3.04	24.88	0.12
East Sheldon Ck	Tributary	865	UltPeak	0.68	86.950	87.449	87.190	87.450	0.000142	0.14	4.97	25.30	0.10
East Sheldon Ck	Tributary	833	2-Yr	9.8	86.950	88.049	88.050	88.330	0.011675	2.35	4.17	7.59	1.01
East Sheldon Ck	Tributary	833	Base	0.14	86.950	87.151	87.150	87.200	0.020015	0.99	0.14	1.39	1.00
East Sheldon Ck	Tributary	833	P23Avg	0.24	86.950	87.201	87.200	87.260	0.018444	1.10	0.22	1.73	0.99
East Sheldon Ck	Tributary	833	P23Peak	0.34	86.950	87.236	87.240	87.310	0.018237	1.20	0.28	1.98	1.01
East Sheldon Ck	Tributary	833	P4Peak	0.41	86.950	87.256	87.260	87.340	0.018493	1.26	0.32	2.11	1.03
East Sheldon Ck	Tributary	833	UltPeak	0.68	86.950	87.330	87.330	87.420	0.016031	1.36	0.50	2.63	0.99
East Sheldon Ck	Tributary	748	2-Yr	9.8	86.350	87.396	87.150	87.520	0.003065	1.56	6.57	9.98	0.56
East Sheldon Ck	Tributary	748	Base	0.14	86.350	86.478	86.430	86.490	0.003358	0.43	0.32	3.09	0.42
East Sheldon Ck	Tributary	748	P23Avg	0.24	86.350	86.519	86.450	86.530	0.003612	0.52	0.46	3.44	0.45
East Sheldon Ck	Tributary	748	P23Peak	0.34	86.350	86.558	86.480	86.570	0.003389	0.56	0.60	3.77	0.45
East Sheldon Ck	Tributary	748	P4Peak	0.41	86.350	86.586	86.490	86.600	0.003076	0.58	0.71	4.01	0.44
East Sheldon Ck	Tributary	748	UltPeak	0.68	86.350	86.648	86.550	86.670	0.003462	0.70	0.98	4.54	0.48
East Sheldon Ck	Tributary	668	2-Yr	9.8	86.030	86.939	86.860	87.140	0.007753	2.01	4.87	8.22	0.83
East Sheldon Ck	Tributary	668	Base	0.14	86.030	86.130		86.140	0.005510	0.49	0.28	3.13	0.52
East Sheldon Ck	Tributary	668	P23Avg	0.24	86.030	86.171		86.190	0.005071	0.58	0.41	3.39	0.53
East Sheldon Ck	Tributary	668	P23Peak	0.34	86.030	86.193		86.220	0.006044	0.69	0.49	3.53	0.59
East Sheldon Ck	Tributary	668	P4Peak	0.41	86.030	86.203		86.230	0.007215	0.78	0.53	3.59	0.65
East Sheldon Ck	Tributary	668	UltPeak	0.68	86.030	86.268		86.310	0.006413	0.88	0.77	4.00	0.64
East Sheldon Ck	Tributary	570	2-Yr	9.8	84.940	85.782	85.780	86.080	0.015725	2.42	4.05	6.90	1.01
East Sheldon Ck	Tributary	570	Base	0.14	84.940	85.027	85.030	85.060	0.032839	0.75	0.19	3.34	1.02
East Sheldon Ck	Tributary	570	P23Avg	0.24	84.940	85.044	85.040	85.090	0.040529	0.98	0.24	3.42	1.17
East Sheldon Ck	Tributary	570	P23Peak	0.34	84.940	85.074	85.070	85.120	0.026544	0.98	0.35	3.56	1.00
East Sheldon Ck	Tributary	570	P4Peak	0.41	84.940	85.099	85.100	85.140	0.018918	0.94	0.44	3.67	0.87
East Sheldon Ck	Tributary	570	UltPeak	0.68	84.940	85.132	85.130	85.210	0.024029	1.21	0.56	3.83	1.01
East Sheldon Ck	Tributary	480	2-Yr	9.8	84.340	85.342		85.440	0.002631	1.37	7.15	9.54	0.51
East Sheldon Ck	Tributary	480	Base	0.14	84.340	84.538		84.540	0.000196	0.14	0.98	5.81	0.11
East Sheldon Ck	Tributary	480	P23Avg	0.24	84.340	84.572		84.570	0.000328	0.20	1.18	5.97	0.15
East Sheldon Ck	Tributary	480	P23Peak	0.34	84.340	84.602		84.600	0.000422	0.25	1.36	6.11	0.17
East Sheldon Ck	Tributary	480	P4Peak	0.41	84.340	84.621		84.630	0.000473	0.28	1.48	6.20	0.18
East Sheldon Ck	Tributary	480	UltPeak	0.68	84.340	84.683		84.690	0.000640	0.36	1.87	6.48	0.22
East Sheldon Ck	Tributary	462	2-Yr	9.8	84.440	85.273	85.110	85.380	0.003603	1.64	7.58	14.25	0.58
East Sheldon Ck	Tributary	462	Base	0.14	84.440	84.519	84.490	84.530	0.005450	0.41	0.34	4.98	0.50
East Sheldon Ck	Tributary	462	P23Avg	0.24	84.440	84.541	84.510	84.560	0.006363	0.53	0.45	5.01	0.56
East Sheldon Ck	Tributary	462	P23Peak	0.34	84.440	84.567	84.530	84.580	0.005679	0.58	0.58	5.04	0.55
East Sheldon Ck	Tributary	462	P4Peak	0.41	84.440	84.584	84.540	84.600	0.005227	0.61	0.67	5.06	0.54
East Sheldon Ck	Tributary	462	UltPeak	0.68	84.440	84.635	84.570	84.660	0.005028	0.73	0.93	5.13	0.55
East Sheldon Ck	Tributary	459.5		Bridge	(Pedestrian Bridge)								

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
East Sheldon Ck	Tributary	457	2-Yr	9.8	84.380	85.255	85.090	85.360	0.003355	1.61	7.71	14.25	0.56
East Sheldon Ck	Tributary	457	Base	0.14	84.380	84.478	84.440	84.480	0.003722	0.36	0.38	4.96	0.42
East Sheldon Ck	Tributary	457	P23Avg	0.24	84.380	84.516	84.460	84.530	0.002899	0.42	0.57	5.01	0.39
East Sheldon Ck	Tributary	457	P23Peak	0.34	84.380	84.546	84.480	84.560	0.002740	0.47	0.72	5.04	0.39
East Sheldon Ck	Tributary	457	P4Peak	0.41	84.380	84.565	84.490	84.580	0.002651	0.50	0.82	5.07	0.39
East Sheldon Ck	Tributary	457	UltPeak	0.68	84.380	84.615	84.530	84.640	0.003069	0.63	1.08	5.13	0.44
East Sheldon Ck	Tributary	425	2-Yr	9.8	84.100	84.820	84.820	85.080	0.010248	2.28	4.44	8.94	0.97
East Sheldon Ck	Tributary	425	Base	0.14	84.100	84.215	84.210	84.230	0.009600	0.56	0.25	3.46	0.67
East Sheldon Ck	Tributary	425	P23Avg	0.24	84.100	84.222	84.220	84.260	0.020816	0.87	0.28	3.57	1.00
East Sheldon Ck	Tributary	425	P23Peak	0.34	84.100	84.244	84.240	84.290	0.019681	0.95	0.36	3.88	1.00
East Sheldon Ck	Tributary	425	P4Peak	0.41	84.100	84.254	84.250	84.310	0.021539	1.04	0.39	4.02	1.06
East Sheldon Ck	Tributary	425	UltPeak	0.68	84.100	84.301	84.300	84.370	0.017919	1.13	0.60	4.69	1.01
East Sheldon Ck	Tributary	385	2-Yr	9.8	83.700	84.712		84.790	0.001885	1.37	9.72	14.45	0.45
East Sheldon Ck	Tributary	385	Base	0.14	83.700	83.803		83.810	0.005049	0.41	0.34	4.62	0.49
East Sheldon Ck	Tributary	385	P23Avg	0.24	83.700	83.832		83.850	0.005142	0.50	0.47	4.88	0.52
East Sheldon Ck	Tributary	385	P23Peak	0.34	83.700	83.858		83.870	0.004893	0.56	0.61	5.11	0.52
East Sheldon Ck	Tributary	385	P4Peak	0.41	83.700	83.872		83.890	0.005078	0.60	0.68	5.24	0.54
East Sheldon Ck	Tributary	385	UltPeak	0.68	83.700	83.931		83.950	0.004298	0.68	1.00	5.77	0.52
East Sheldon Ck	Tributary	290	2-Yr	9.8	83.300	84.481	84.100	84.570	0.003074	1.30	7.54	9.69	0.47
East Sheldon Ck	Tributary	290	Base	0.14	83.300	83.458	83.400	83.460	0.002707	0.32	0.43	4.21	0.32
East Sheldon Ck	Tributary	290	P23Avg	0.24	83.300	83.501	83.420	83.510	0.002631	0.39	0.62	4.44	0.33
East Sheldon Ck	Tributary	290	P23Peak	0.34	83.300	83.536	83.450	83.550	0.002620	0.44	0.77	4.63	0.34
East Sheldon Ck	Tributary	290	P4Peak	0.41	83.300	83.566	83.450	83.580	0.002276	0.45	0.92	4.79	0.33
East Sheldon Ck	Tributary	290	UltPeak	0.68	83.300	83.638	83.490	83.650	0.002330	0.53	1.27	5.17	0.34
East Sheldon Ck	Tributary	249	2-Yr	9.8	83.090	84.006	84.010	84.300	0.014663	2.39	4.15	7.51	0.99
East Sheldon Ck	Tributary	249	Base	0.14	83.090	83.188	83.180	83.220	0.020819	0.78	0.18	2.15	0.86
East Sheldon Ck	Tributary	249	P23Avg	0.24	83.090	83.230	83.210	83.270	0.017254	0.87	0.28	2.43	0.82
East Sheldon Ck	Tributary	249	P23Peak	0.34	83.090	83.263	83.260	83.310	0.016281	0.95	0.36	2.64	0.82
East Sheldon Ck	Tributary	249	P4Peak	0.41	83.090	83.259	83.260	83.330	0.025837	1.18	0.35	2.62	1.03
East Sheldon Ck	Tributary	249	UltPeak	0.68	83.090	83.321	83.320	83.410	0.022136	1.30	0.52	3.03	1.00
East Sheldon Ck	Tributary	234	2-Yr	9.8	82.800	83.442	83.440	83.680	0.014777	2.40	5.31	11.65	1.01
East Sheldon Ck	Tributary	234	Base	0.14	82.800	82.879	82.880	82.900	0.020847	0.65	0.21	3.39	0.83
East Sheldon Ck	Tributary	234	P23Avg	0.24	82.800	82.898	82.900	82.940	0.028478	0.86	0.28	3.71	1.00
East Sheldon Ck	Tributary	234	P23Peak	0.34	82.800	82.912	82.910	82.960	0.034713	1.02	0.33	3.96	1.12
East Sheldon Ck	Tributary	234	P4Peak	0.41	82.800	82.943	82.940	82.980	0.019652	0.88	0.47	4.50	0.87
East Sheldon Ck	Tributary	234	UltPeak	0.68	82.800	82.973	82.970	83.040	0.026072	1.12	0.60	5.02	1.03
East Sheldon Ck	Tributary	224	2-Yr	9.8	82.450	83.372	83.110	83.460	0.002395	1.28	7.66	12.09	0.49
East Sheldon Ck	Tributary	224	Base	0.14	82.450	82.638	82.580	82.640	0.002677	0.31	0.45	6.10	0.36
East Sheldon Ck	Tributary	224	P23Avg	0.24	82.450	82.675	82.620	82.680	0.002124	0.35	0.68	6.30	0.34
East Sheldon Ck	Tributary	224	P23Peak	0.34	82.450	82.696	82.630	82.710	0.002437	0.42	0.81	6.41	0.37
East Sheldon Ck	Tributary	224	P4Peak	0.41	82.450	82.710	82.640	82.720	0.002552	0.46	0.90	6.49	0.39
East Sheldon Ck	Tributary	224	UltPeak	0.68	82.450	82.750	82.670	82.770	0.003133	0.59	1.15	6.71	0.44
East Sheldon Ck	Tributary	198		Bridge	(Creek Path Ave - South Crossing)								

River	Reach	River Sta	Profile	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
East Sheldon Ck	Tributary	175	2-Yr	9.8	82.100	83.320	82.770	83.360	0.000704	0.95	12.11	16.06	0.28
East Sheldon Ck	Tributary	175	Base	0.14	82.100	82.312	82.180	82.310	0.000425	0.20	0.68	4.13	0.16
East Sheldon Ck	Tributary	175	P23Avg	0.24	82.100	82.360	82.210	82.360	0.000564	0.27	0.89	4.38	0.19
East Sheldon Ck	Tributary	175	P23Peak	0.34	82.100	82.400	82.230	82.410	0.000657	0.32	1.07	4.63	0.21
East Sheldon Ck	Tributary	175	P4Peak	0.41	82.100	82.421	82.240	82.430	0.000716	0.35	1.19	7.38	0.22
East Sheldon Ck	Tributary	175	UltPeak	0.68	82.100	82.490	82.280	82.500	0.000766	0.42	1.91	13.59	0.24
East Sheldon Ck	Tributary	160	2-Yr	9.8	82.100	82.986	82.990	83.300	0.009603	2.52	4.08	6.76	0.97
East Sheldon Ck	Tributary	160	Base	0.14	82.100	82.259	82.250	82.290	0.017369	0.80	0.17	2.18	0.91
East Sheldon Ck	Tributary	160	P23Avg	0.24	82.100	82.300	82.300	82.340	0.014863	0.87	0.27	2.75	0.88
East Sheldon Ck	Tributary	160	P23Peak	0.34	82.100	82.318	82.320	82.370	0.018883	1.04	0.33	3.00	1.00
East Sheldon Ck	Tributary	160	P4Peak	0.41	82.100	82.348	82.330	82.400	0.013826	0.97	0.42	3.41	0.88
East Sheldon Ck	Tributary	160	UltPeak	0.68	82.100	82.389	82.390	82.460	0.016910	1.18	0.57	3.97	1.00
East Sheldon Ck	Tributary	120	2-Yr	9.8	81.900	82.625	82.600	82.820	0.007658	2.24	5.76	13.39	0.87
East Sheldon Ck	Tributary	120	Base	0.14	81.900	82.039		82.050	0.002914	0.36	0.39	4.87	0.38
East Sheldon Ck	Tributary	120	P23Avg	0.24	81.900	82.067		82.080	0.003422	0.47	0.53	5.28	0.43
East Sheldon Ck	Tributary	120	P23Peak	0.34	81.900	82.098		82.110	0.002989	0.51	0.71	5.74	0.42
East Sheldon Ck	Tributary	120	P4Peak	0.41	81.900	82.105		82.120	0.003679	0.58	0.75	5.84	0.47
East Sheldon Ck	Tributary	120	UltPeak	0.68	81.900	82.159		82.180	0.003497	0.69	1.08	6.62	0.48
East Sheldon Ck	Tributary	60	2-Yr	9.8	81.510	82.104	82.100	82.270	0.010746	1.81	5.79	20.35	0.94
East Sheldon Ck	Tributary	60	Base	0.14	81.510	81.617	81.620	81.650	0.024930	0.75	0.19	3.46	1.03
East Sheldon Ck	Tributary	60	P23Avg	0.24	81.510	81.652	81.650	81.680	0.016457	0.73	0.33	4.58	0.88
East Sheldon Ck	Tributary	60	P23Peak	0.34	81.510	81.660	81.660	81.700	0.025145	0.94	0.36	4.82	1.09
East Sheldon Ck	Tributary	60	P4Peak	0.41	81.510	81.686	81.690	81.720	0.015330	0.82	0.50	5.68	0.88
East Sheldon Ck	Tributary	60	UltPeak	0.68	81.510	81.715	81.710	81.770	0.018966	1.00	0.68	6.60	1.00

Appendix B-2

LVM inc.

353 Bridge Street East
Kitchener (Ontario) Canada N2K 2Y5
Telephone: 519.741.1313
Fax: 519.741.5422
www.lvm.ca
kitchener@lvm.ca

EMAIL TRANSMISSION

November 15, 2011

AECOM
50 Sportsworld Crossing Road, Suite 290
Kitchener, Ontario N2P 0A4

Attention: Mr. David Arseneau, P.Eng.

Subject: Laboratory Gradation Results
Miscellaneaous Lab Testing for AECOM
160-P044018-0500-IM-L001-00

Dear Sir:

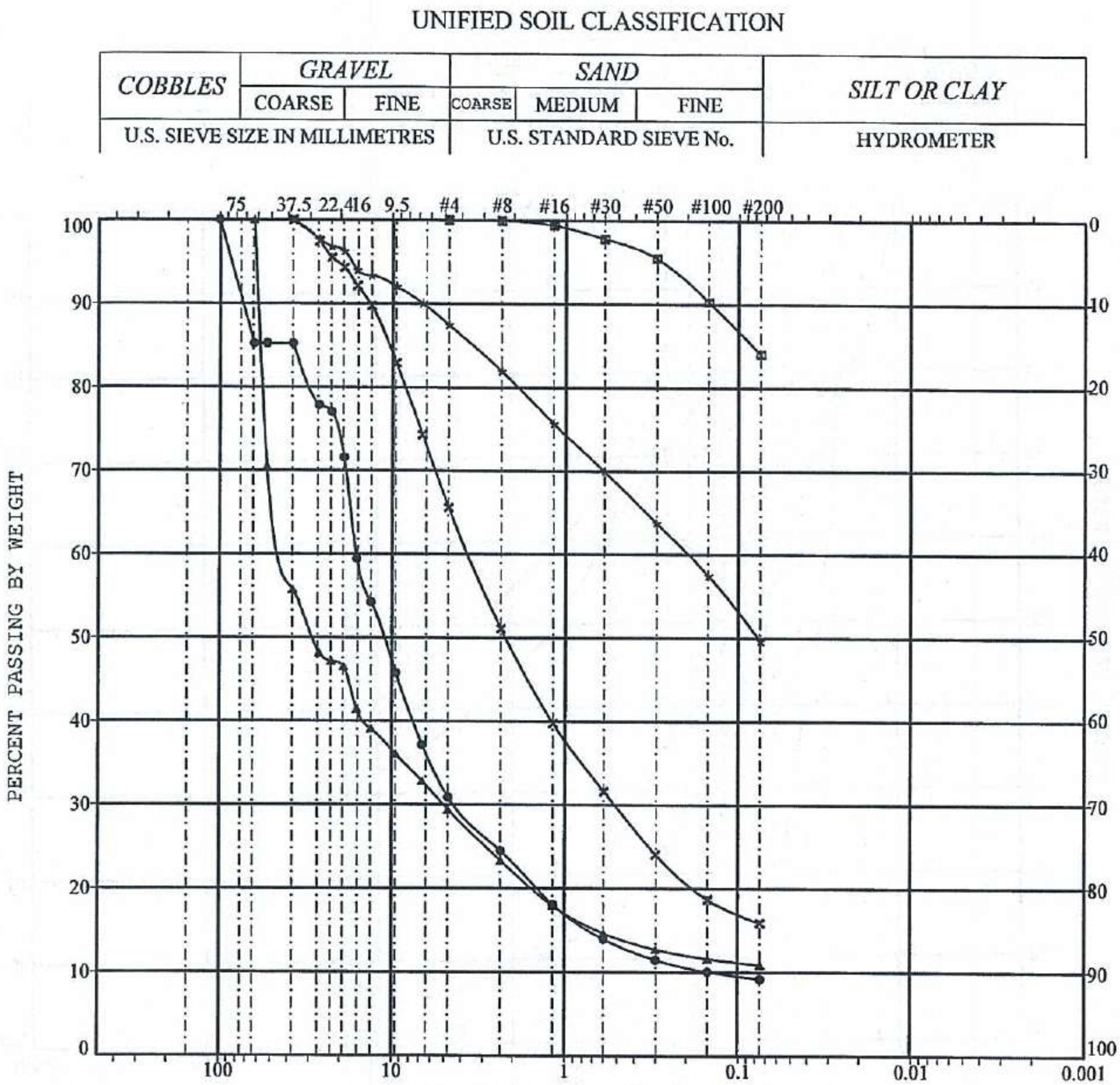
Please find attached on Figures 1 and 2 the results of laboratory gradation tests conducted on ten (10) soil samples delivered to our office on November 9, 2011. The figures include soil descriptions based on the gradation results. We note that the amount of clay could not be estimated as hydrometer testing was not conducted on the samples.

I trust that this information meets your present requirements. If you have any questions, please do not hesitate to contact our office.

Yours very truly,

Jeff Dietz, P.Eng.
Consulting Engineer
lm

Encl. Figures 1 and 2 – Laboratory Gradation Results



GRAIN SIZE IN MILLIMETRES

PROJECT Miscellaneous Testing for AECOM

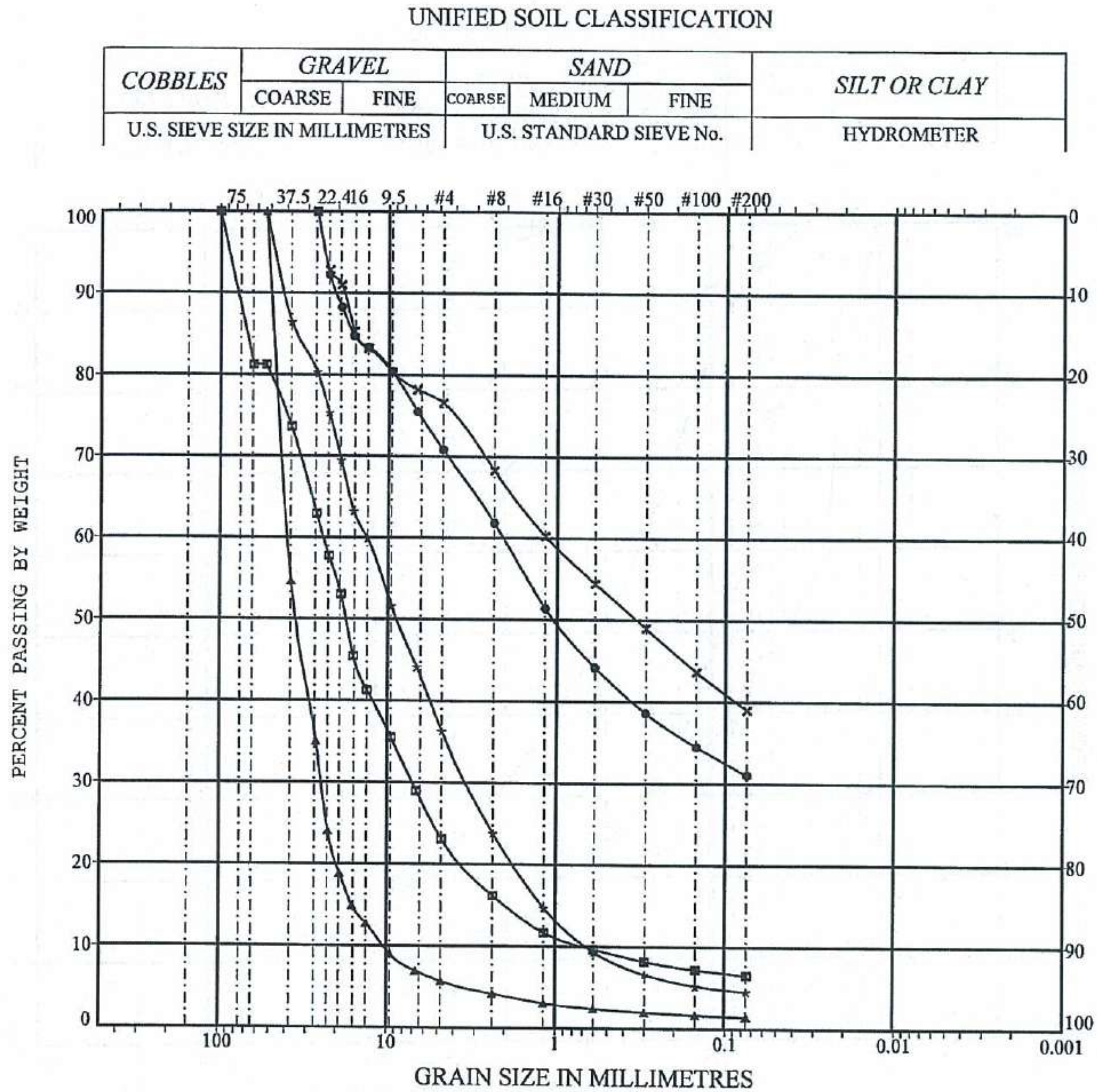
LOCATION Sheldon Creek, Ontario JOB NO. P044018-0500

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	Section 1	Bed		Sandy GRAVEL, trace Silt, occasional cobbles
⊠	Section 1	Bank		SILT, some Sand
▲	Section 2	Bed		GRAVEL, some Sand and Silt
★	Section 2	Bank		SILT AND SAND, some Gravel
✖	Bridge			Gravelly SAND, some Silt

REMARKS

LVM

Figure No. 1



PROJECT Miscellaneous Testing for AECOM

LOCATION Sheldon Creek, Ontario JOB NO. P044018-0500

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	Section 3	Bed		Silty Gravelly SAND
⊠	Section 3	Bank		GRAVEL, some Sand, trace Silt, occasional cobbles
▲	Section 4	Bank		GRAVEL, trace Sand
★	Section 5	Bed		Sandy GRAVEL, trace Silt
✕	Section 5	Bank		Gravelly SAND AND SILT

REMARKS

LVM

Figure No. 2

Appendix B-3

Design Chart 2.17: Maximum Permissive Flow Velocities - Native Material/Linings

Material	Velocity: Clear water (m/s)	Velocity: Water carrying fine silts (m/s)	Velocity: Water carrying sand and gravel (m/s)
Fine sand (noncolloidal)	0.45	0.75	0.50
Sandy loam (noncolloidal)	0.50	0.75	0.60
Silt loam (noncolloidal)	0.60	0.90	0.60
Ordinary firm loam	0.75	1.10	0.70
Volcanic ash	0.75	1.10	0.60
Fine gravel	0.75	1.50	1.15
Stiff clay (very colloidal)	1.15	1.50	0.90
Graded, loam to cobbles (noncolloidal)	1.15	1.50	0.50
Graded, silt to cobbles (colloidal)	1.20	1.70	1.50
Alluvial silts (noncolloidal)	0.60	1.10	1.60
Alluvial silts (collodial)	1.15	1.50	0.90
Coarse gravel (noncolloidal)	1.20	1.85	2.00
Cobbles and Shingles	1.50	1.70	2.00
Shales and hard plans	1.85	1.85	1.50

For sinuous channels multiply allowable velocity by 0.95 for slightly sinuous, by 0.9 for moderately sinuous channels, and by 0.8 for highly sinuous channels.
Source: American Society of Civil Engineers - ASCE (1926)

- Vegetal Linings

Cover	Slope range (%)	Velocity: Erosion resistant soils (m/s)	Velocity: Easily eroded soils (m/s)
Bermuda grass	0-5	2.4	1.8
	5-10	2.1	1.5
	over 10	1.8	1.2
Buffalo grass	0-5	2.1	1.5
Kentucky Bluegrass	5-10	1.8	1.2
Smooth Brome	over 10	1.5	0.9
Grass mixture	0-5[3]	1.5	1.2
	1-10[3]	1.2	0.9
Lespedeza Sericea	0-5[4]	1.1	0.8
Common Lespedeza[5] Sudan grass[5]	0-5[4]	1.1	0.8

Use flow velocities over 1.5 m/s only where good cover and proper maintenance can be obtained.
Do not use on slopes steeper than 10 percent.
Use on slopes steeper than 5 percent is not recommended.
Annuals, used on mild slopes or as temporary protection until permanent covers are established.
Note: Permissible average flow velocities should be based on local experience whenever possible.

Source: U.S. Department of Agriculture (1954)

AECOM

Appendix B-4

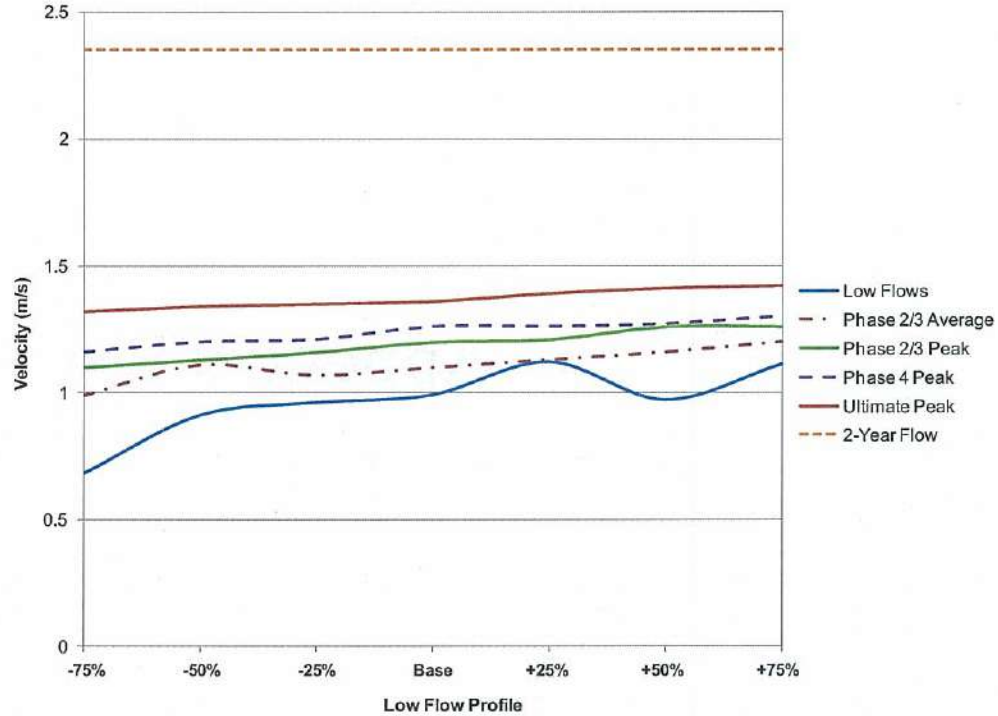


Figure 4.3.2.1 - Channel Velocity at XS 1

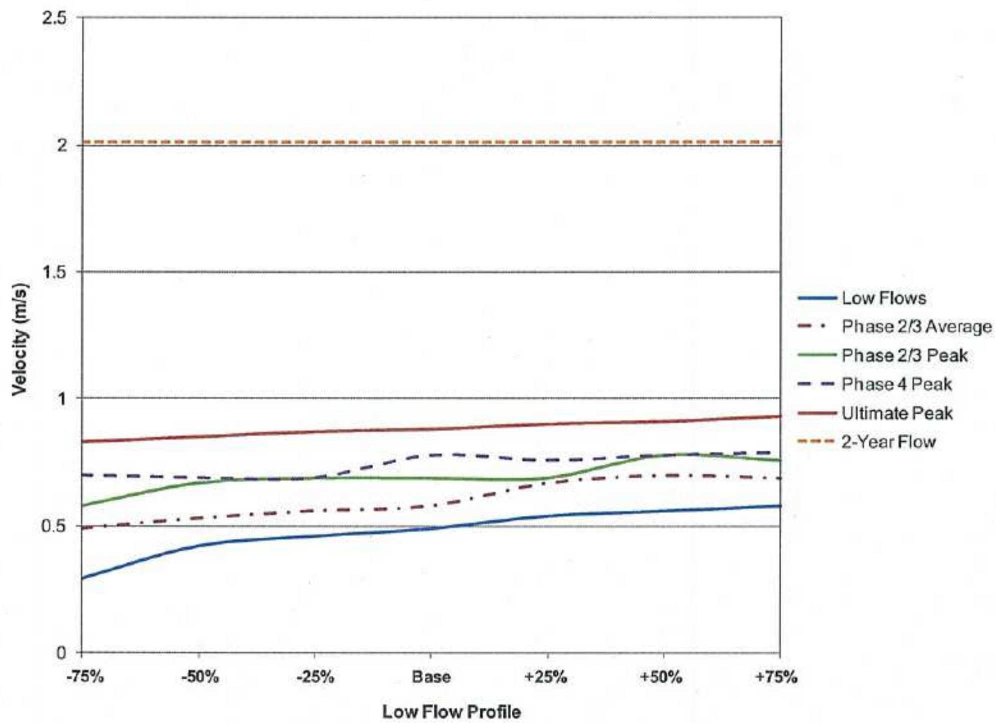


Figure 4.3.2.2 - Channel Velocity at XS 2

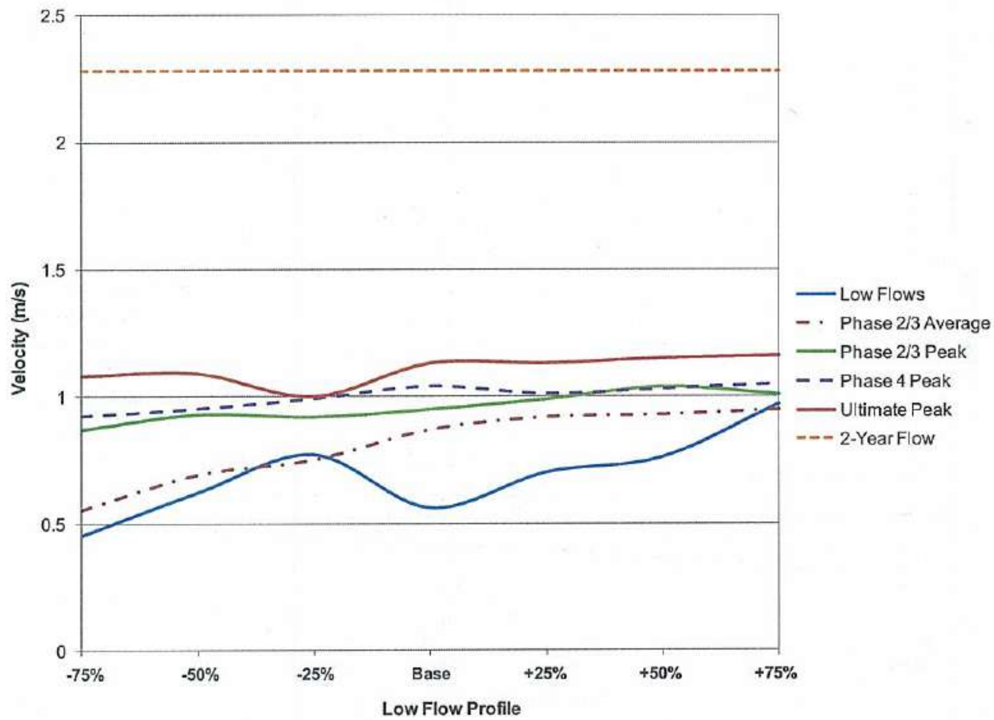


Figure 4.3.2.3 - Channel Velocity at XS 3

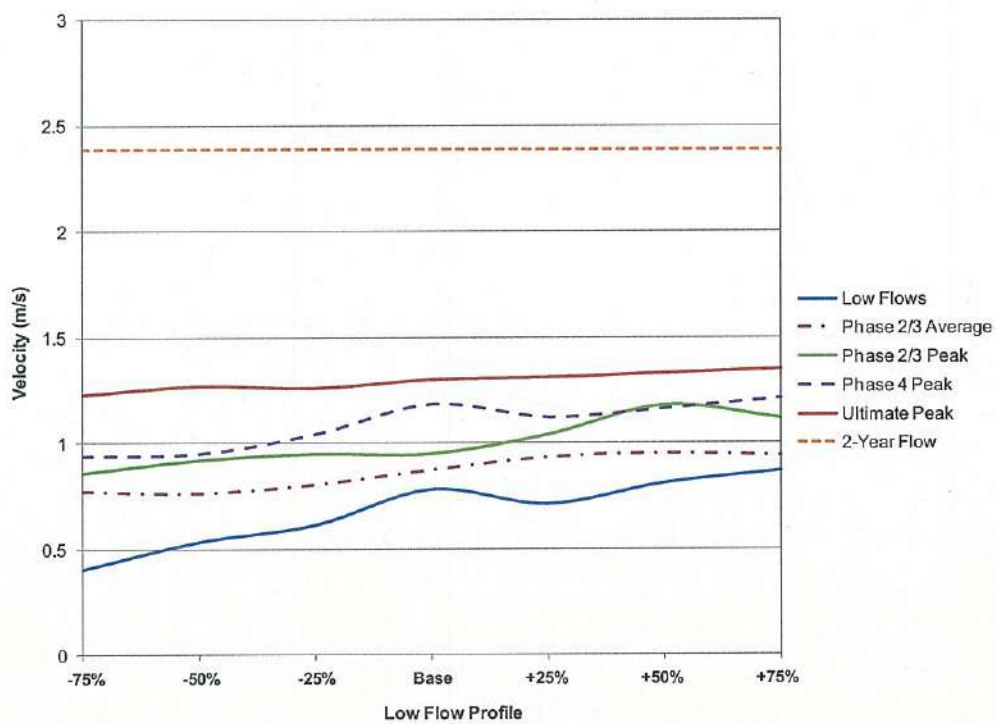


Figure 4.3.2.4 - Channel Velocity at XS 4

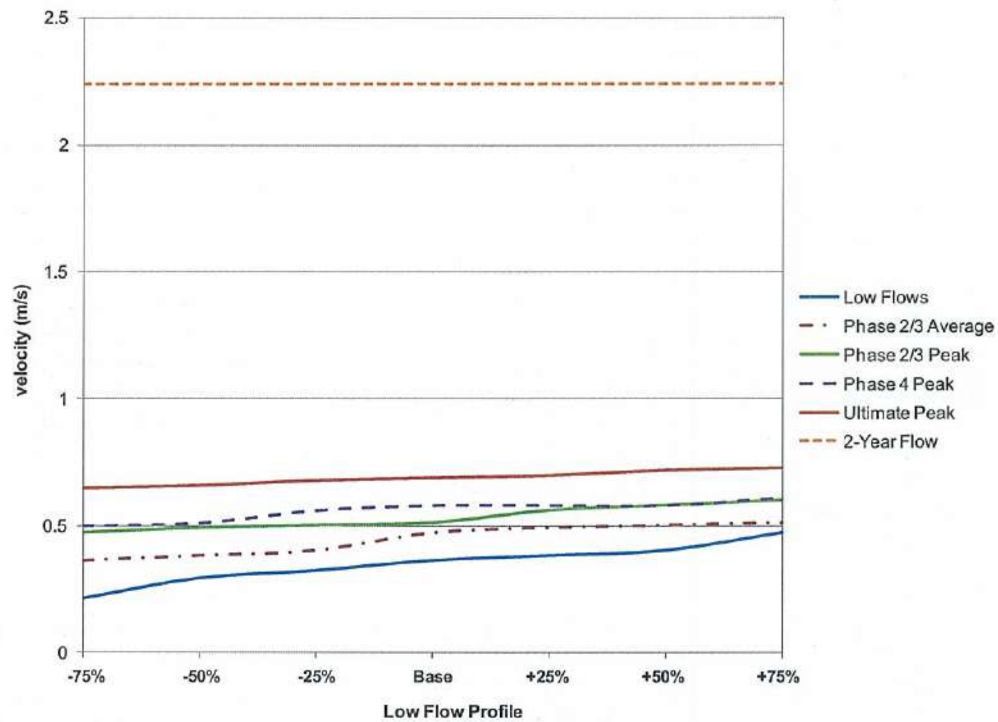


Figure 4.3.2.5 - Channel Velocity at XS 5

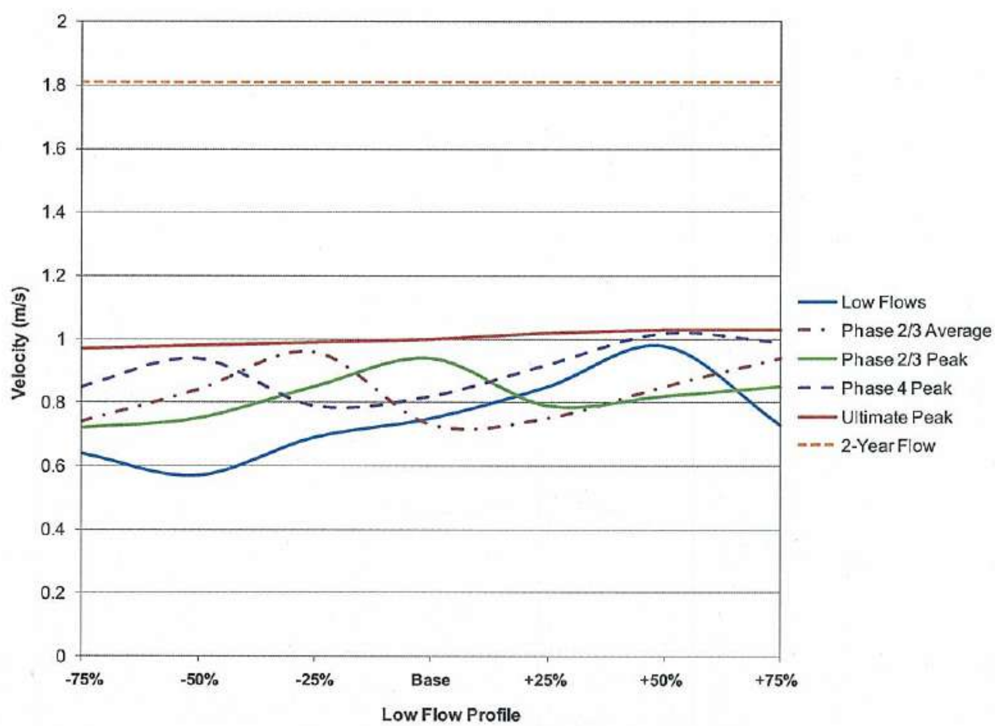


Figure 4.3.2.6 - Channel Velocity at XS 6

AECOM

Appendix B-5

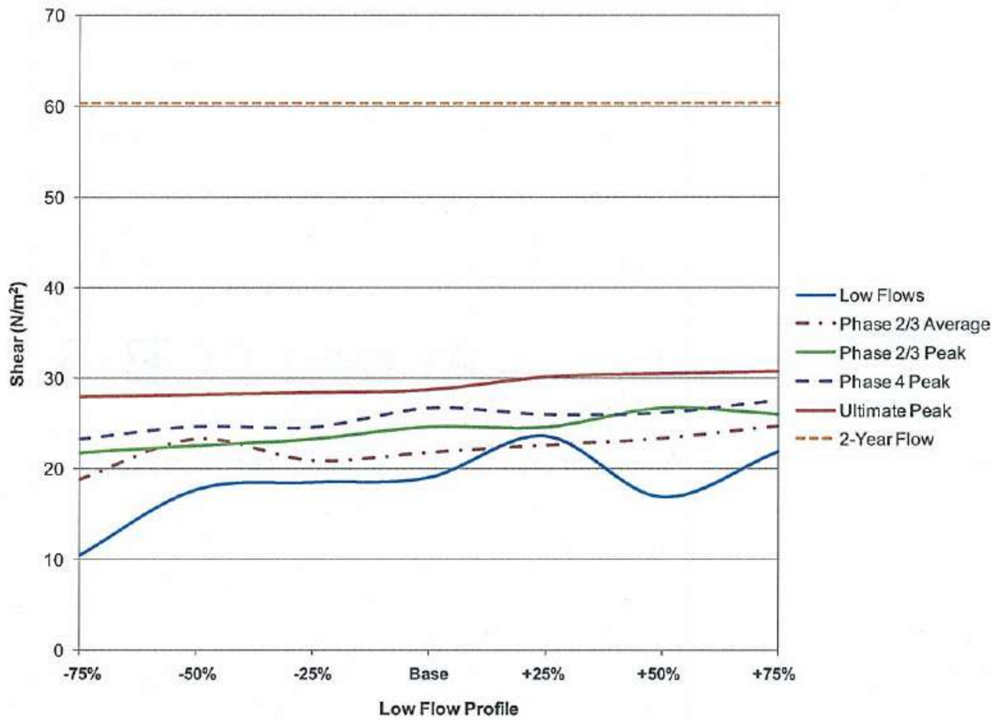


Figure 4.3.3.1 - Channel Shear at XS 1

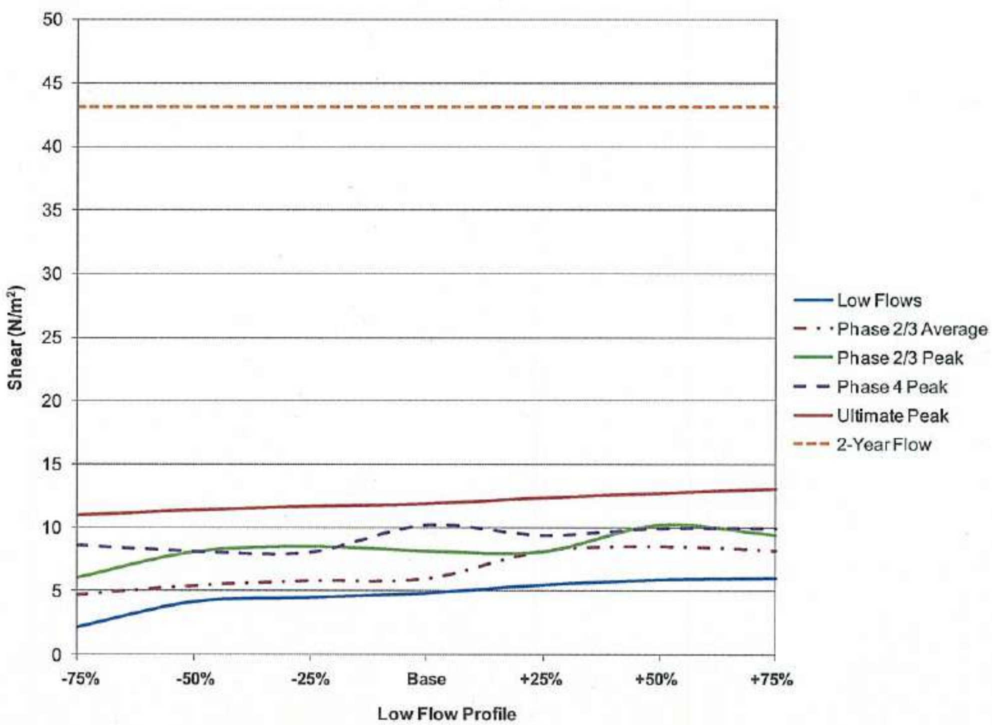


Figure 4.3.3.2 - Channel Shear at XS 2

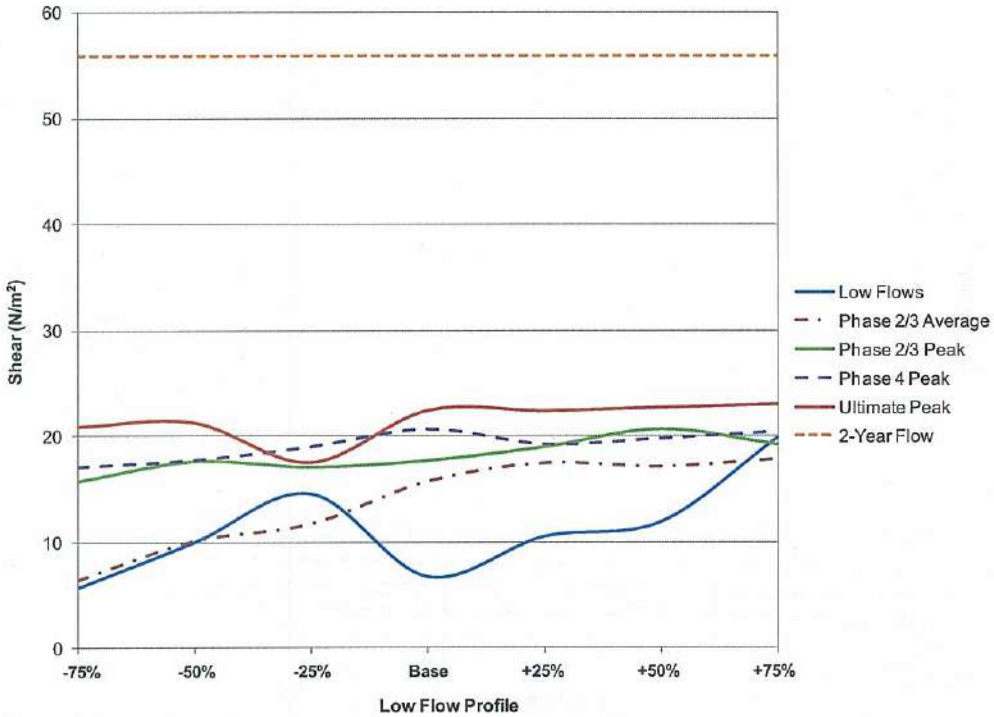


Figure 4.3.3.3 - Channel Shear at XS 3

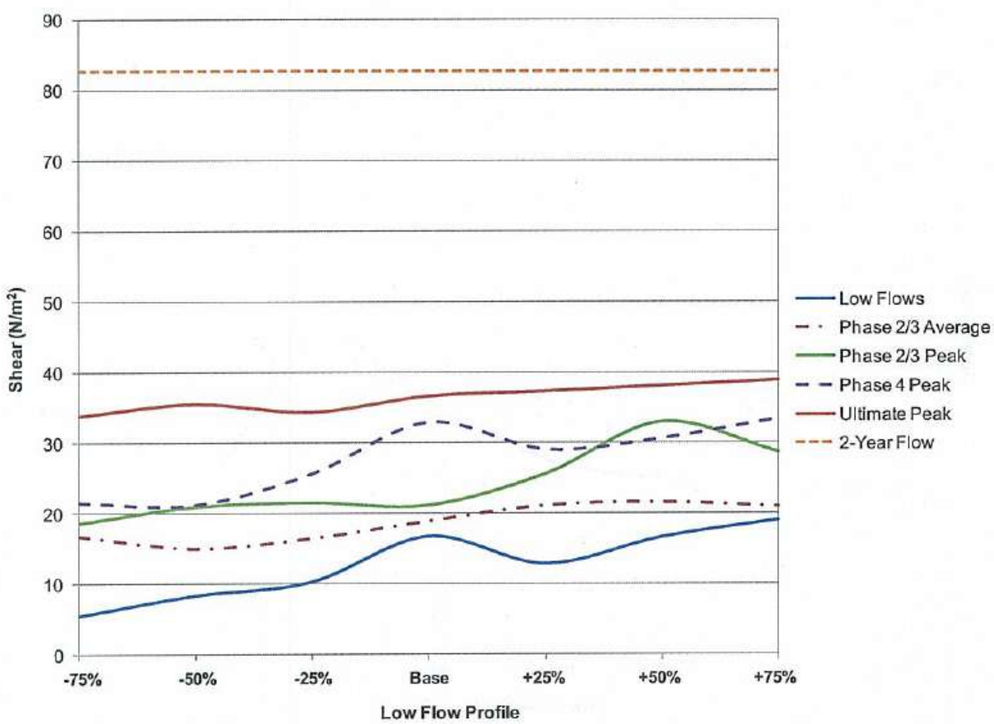


Figure 4.3.3.4 - Channel Shear at XS 4

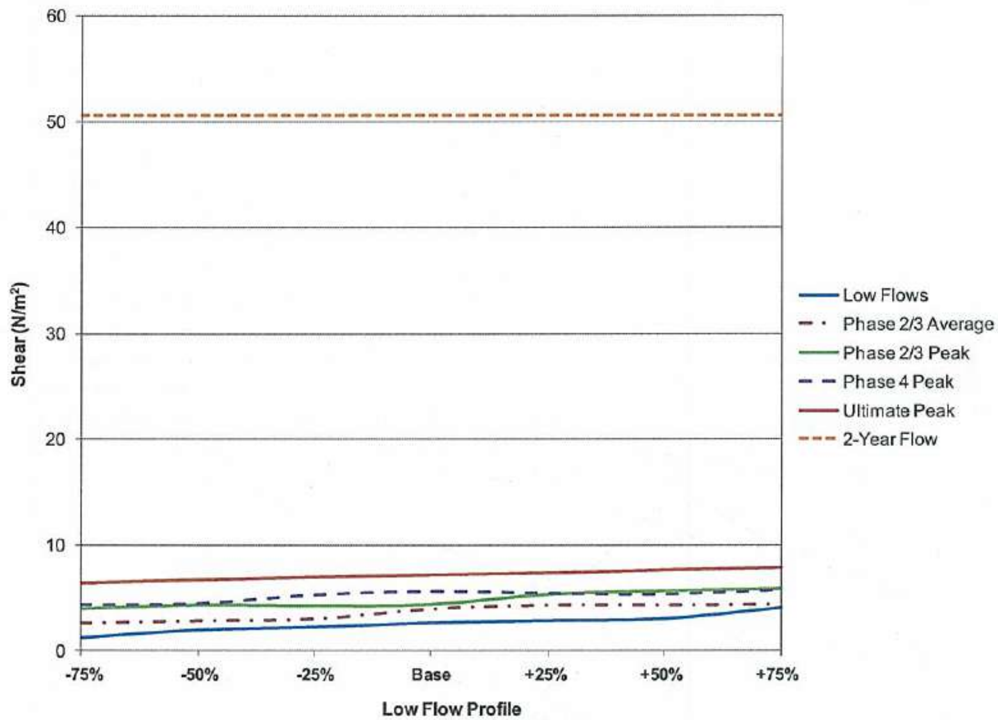


Figure 4.3.3.5 - Channel Shear at XS 5

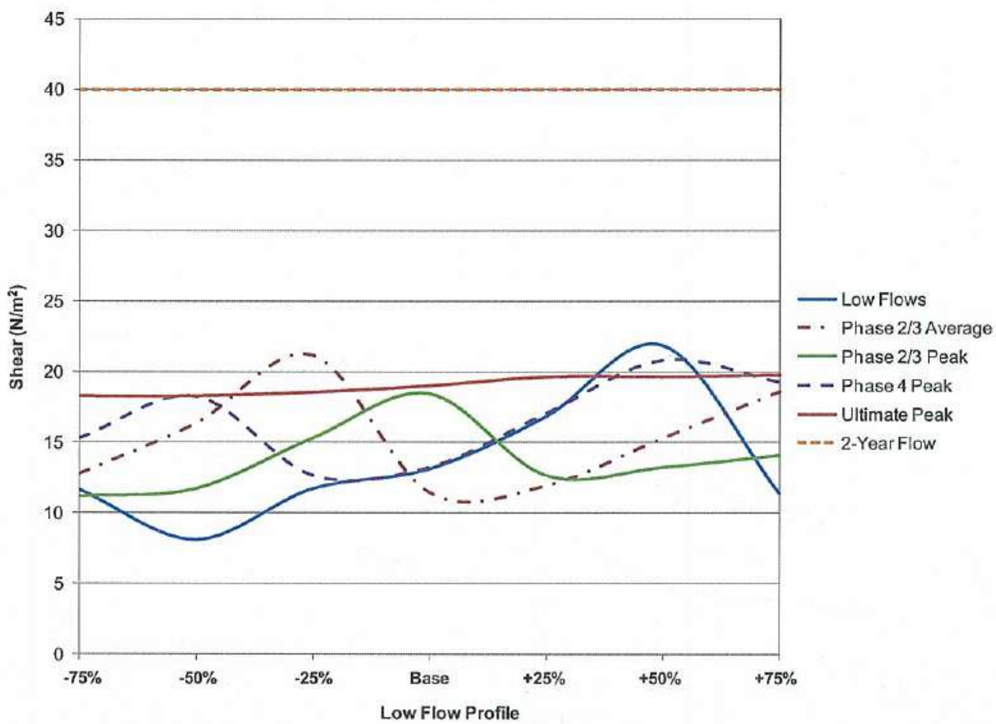
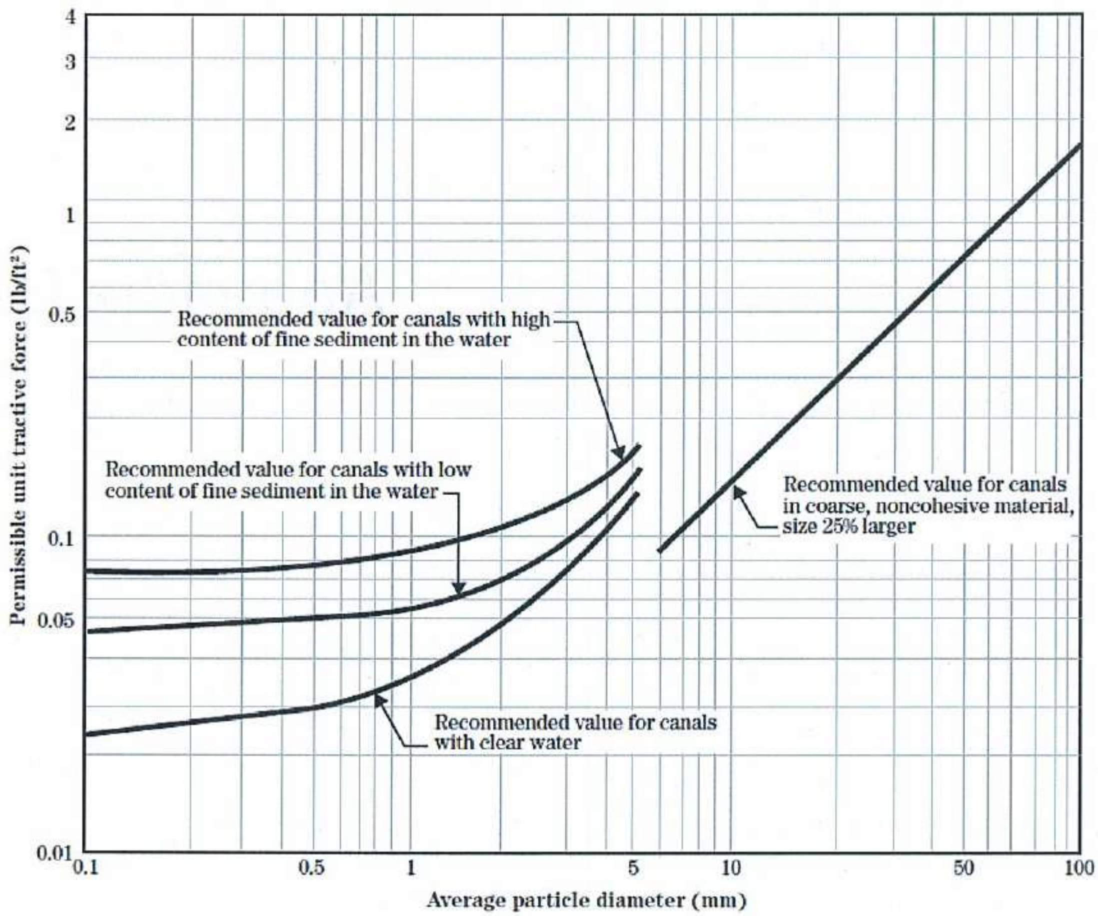


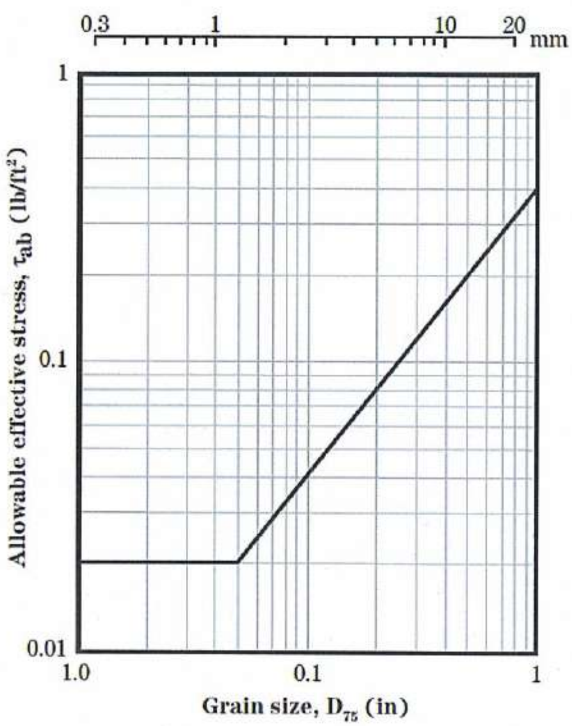
Figure 4.3.3.6 - Channel Shear at XS 6

Appendix B-6

Allowable shear stress for granular material in straight trapezoidal channels

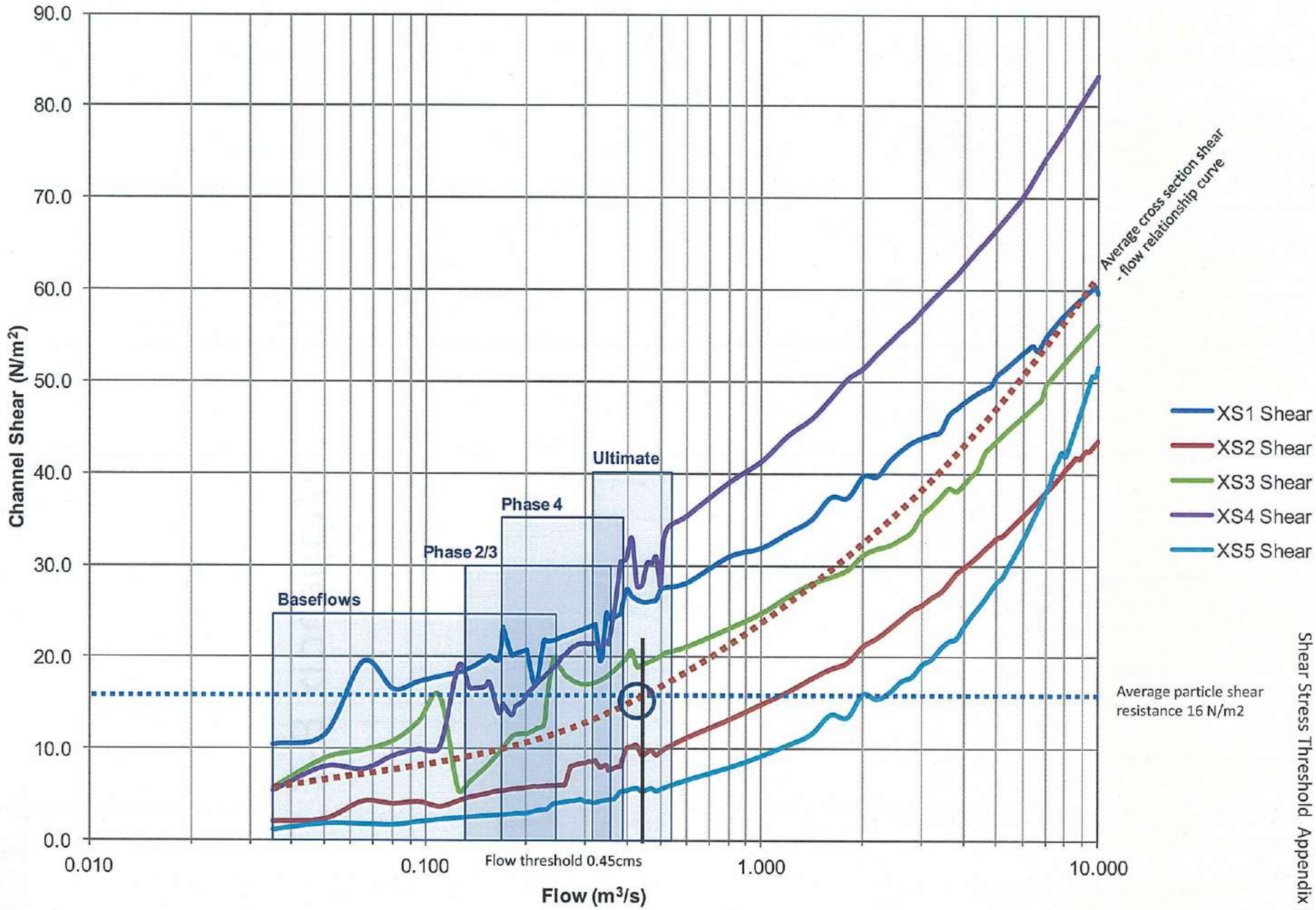


Allowable shear stress for noncohesive soils



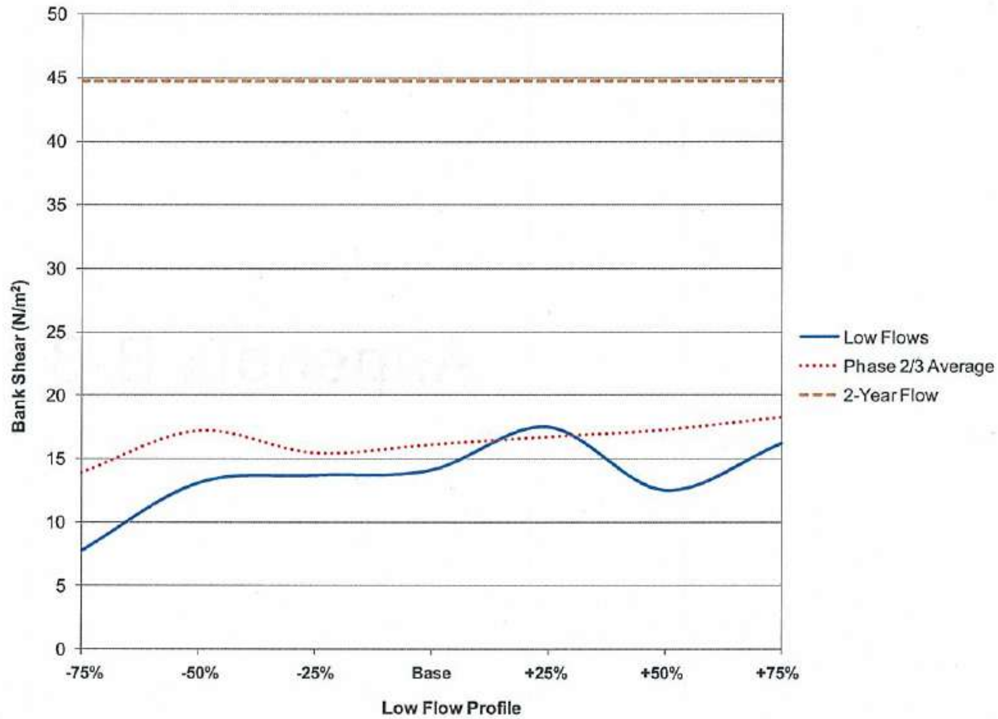
AECOM

Appendix B-7

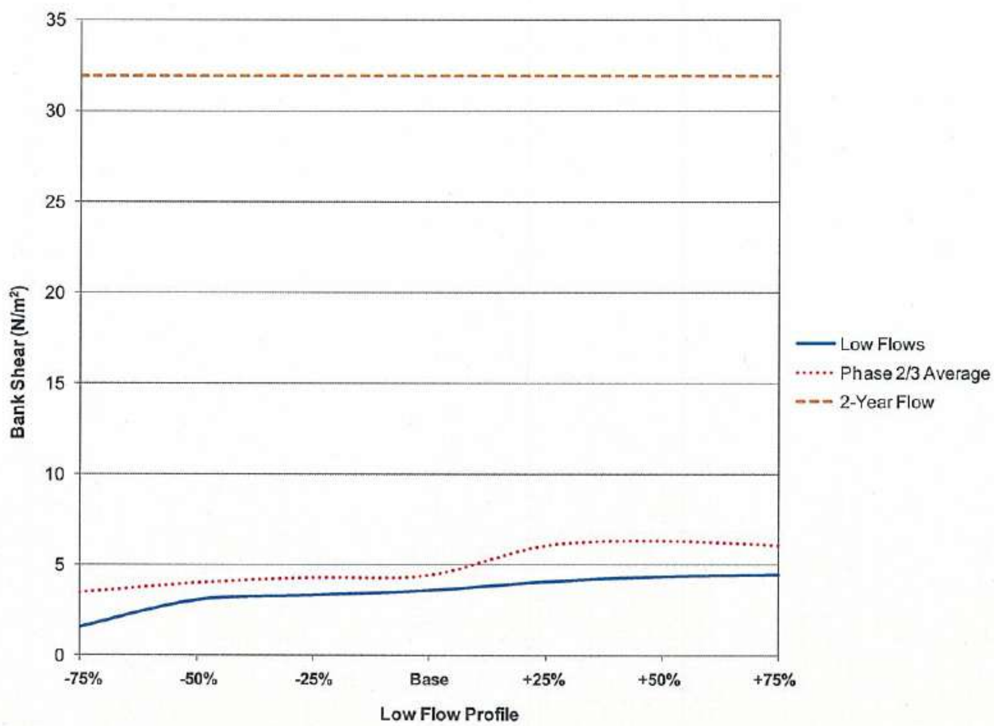

Channel Shear (N/m2)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.010
0.100
1.000
10.000
Flow (m3/s)
Baseflows
Phase 2/3
Phase 4
Ultimate
Flow threshold 0.45cms
Average cross section shear - flow relationship curve
Average particle shear resistance 16 N/m2
XS1 Shear
XS2 Shear
XS3 Shear
XS4 Shear
XS5 Shear

AECOM

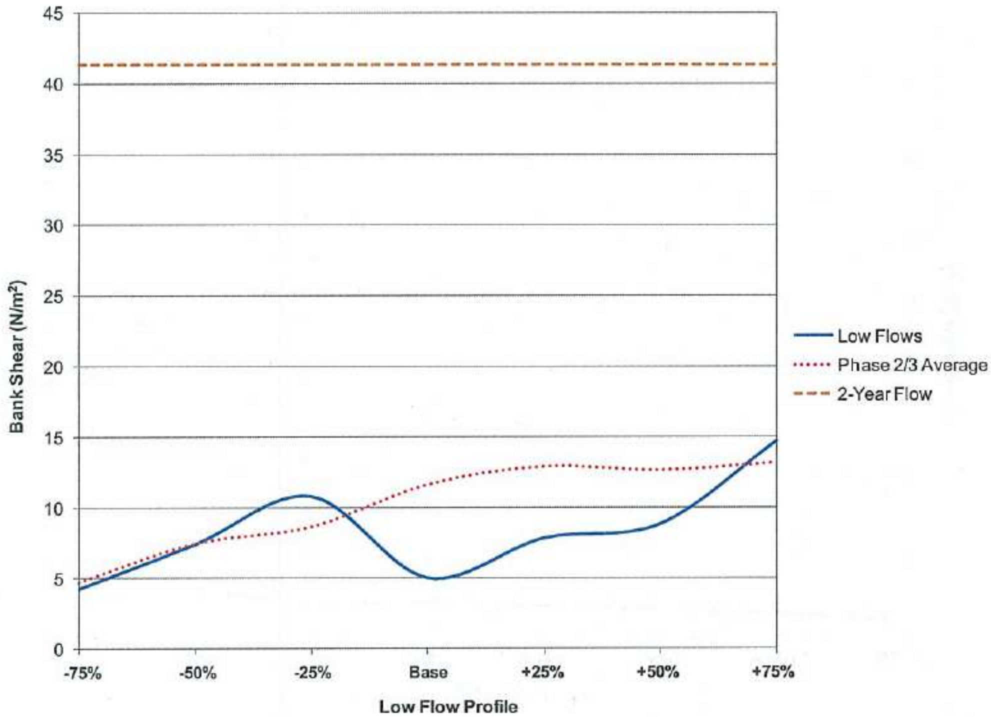
Appendix B-8


50
45
40
35
30
25
20
15
10
5
0
Bank Shear (N/m²)
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

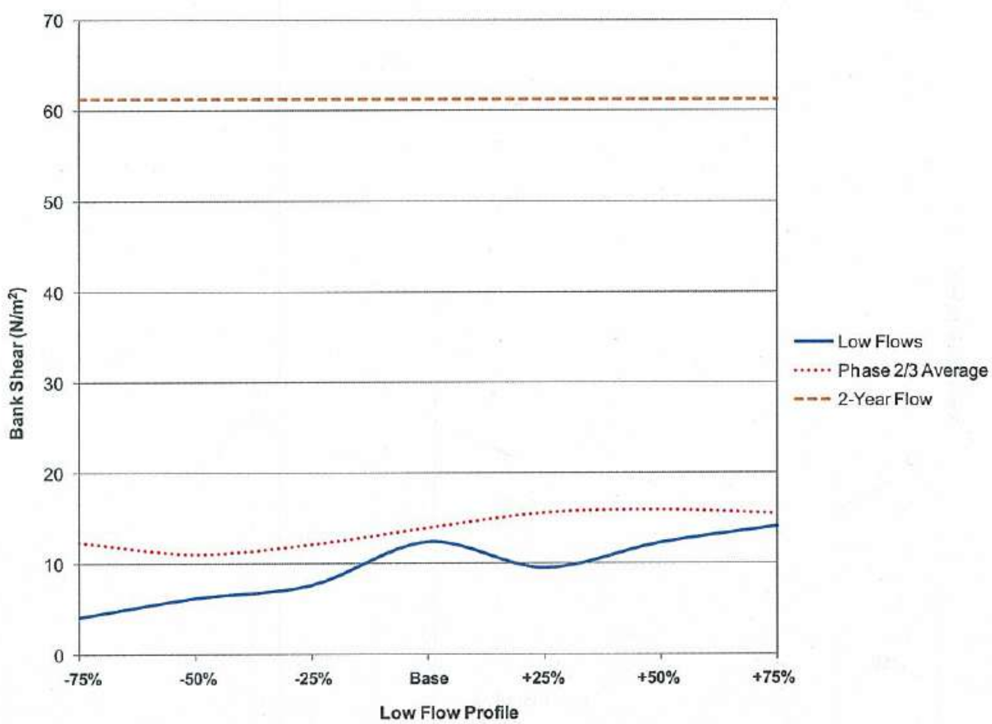
XS1


35
30
25
20
15
10
5
0
Bank Shear (N/m²)
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

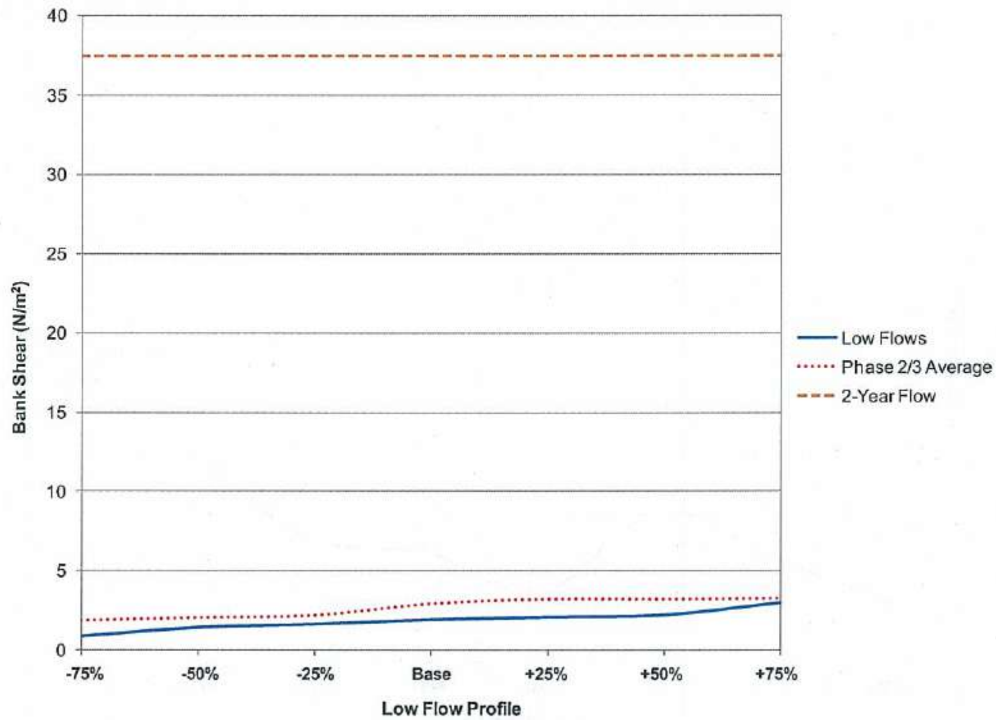
XS2


45
40
35
30
25
20
15
10
5
0
Bank Shear (N/m²)
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

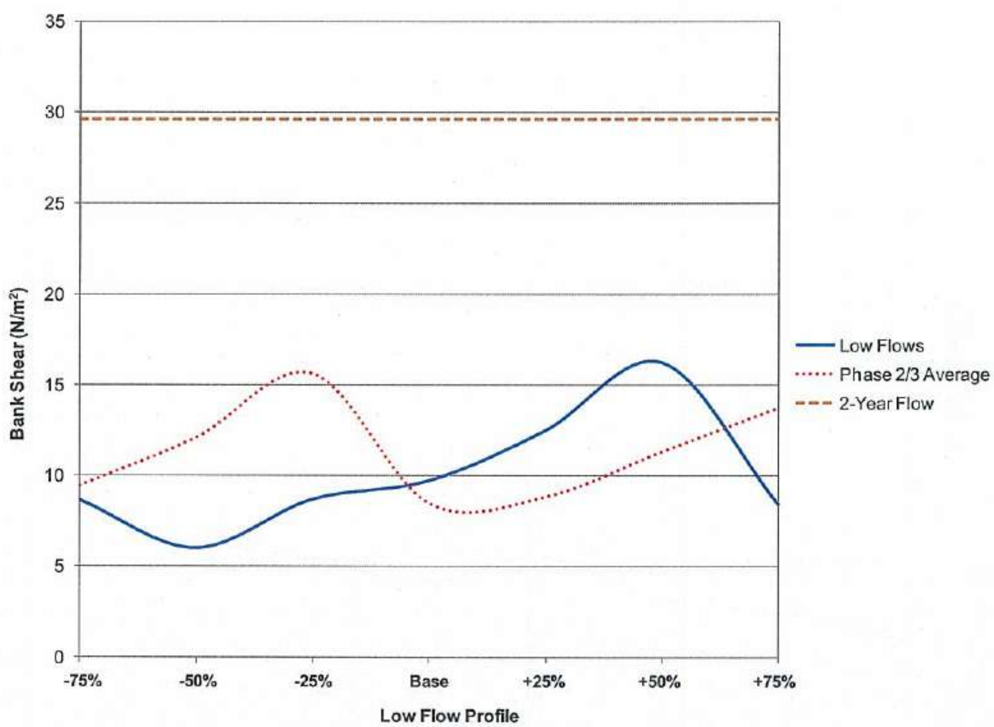
XS3


70
60
50
40
30
20
10
0
Bank Shear (N/m²)
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

XS4


Bank Shear (N/m²)
40
35
30
25
20
15
10
5
0
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

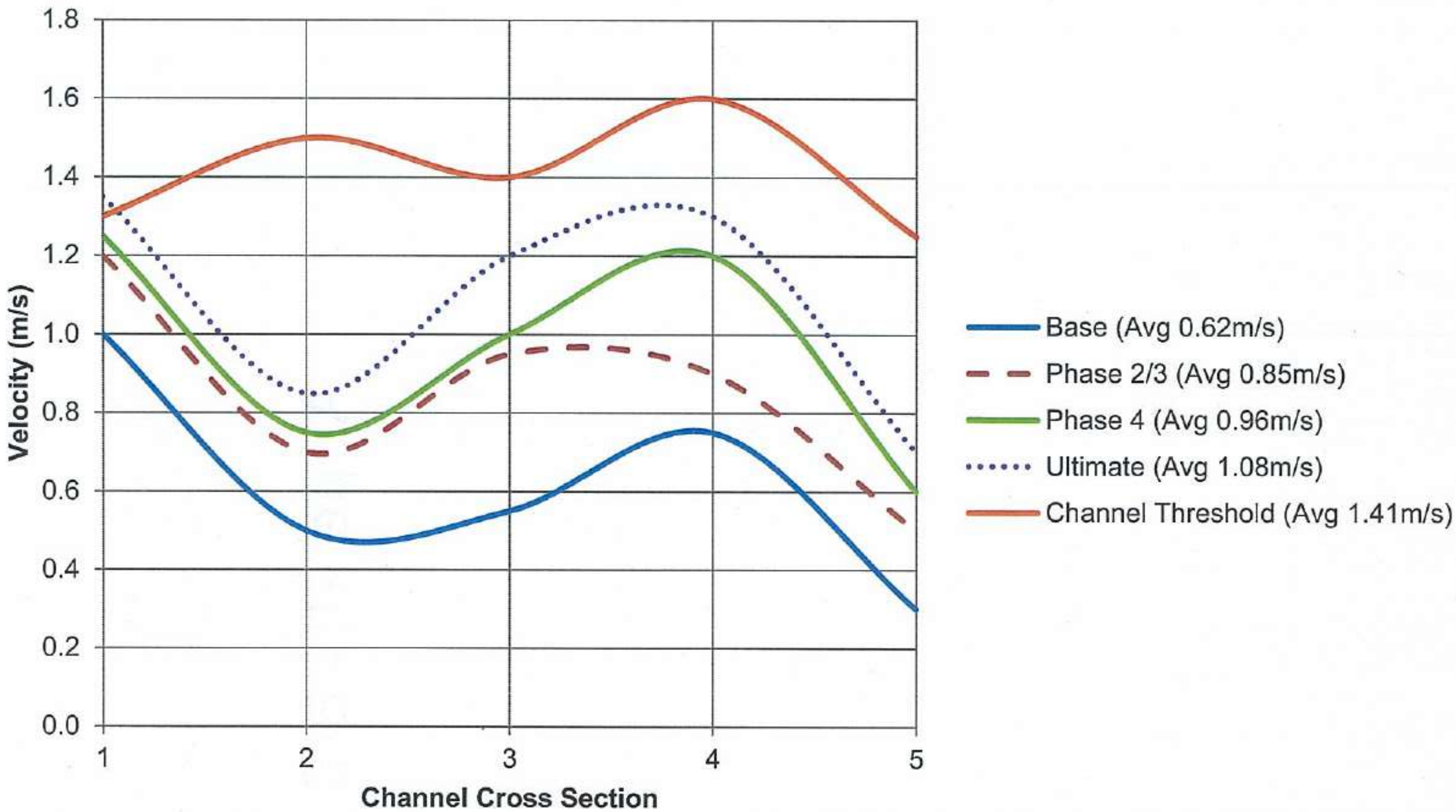
XS5


Bank Shear (N/m²)
35
30
25
20
15
10
5
0
-75%
-50%
-25%
Base
+25%
+50%
+75%
Low Flow Profile
Low Flows
Phase 2/3 Average
2-Year Flow

XS6

AECOM

Appendix B-9



Velocity (m/s)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
2
3
4
5
Channel Cross Section
Base (Avg 0.62m/s)
Phase 2/3 (Avg 0.85m/s)
Phase 4 (Avg 0.96m/s)
Ultimate (Avg 1.08m/s)
Channel Threshold (Avg 1.41m/s)

AECOM

Appendix C

BOTANICAL NAME		COMMON NAME	COEFFICIENT OF CONSERVATISM	WETNESS INDEX	WEEDINESS INDEX	PROVINCIAL STATUS	GLOBAL STATUS	LOCAL STATUS HALT
	SOURCE		OLDHAM ET AL	OLDHAM ET AL	OLDHAM ET AL	NEWMASTER	NEWMASTER	VARGA 2000
GYMNOSPERMS		**CONIFERS**						
Pinaceae		**Pine Family**						
Picea	*abies*	Norway Spruce		5	-1	SE3	G?	XSR
Picea	*glauca*	White Spruce	6	3		S5	G5	U
Pinus	*strobus*	Eastern White Pine	4	3		S5	G5	X
DICOTYLEDONS		**DICOTS**						
Aceraceae		**Maple Family**						
Acer	*negundo*	Manitoba Maple	0	-2		S5	G5	X
Acer	*saccharum*	Sugar Maple	4	3		S5	G5T?	X
Acer	*platanoides*	Norway Maple		5	-3	SE5	G?	X
Anacardiaceae		**Sumac or Cashew Family**						
Rhus	*aromatica*	Fragrant Sumac	8	5		S5	G5	R3
Apiaceae		**Carrot or Parsley Family**						
Daucus	*carota*	Wild Carrot		5	-2	SE5	G?	X
Asteraceae		**Composite or Aster Family**						
Symphyotrichum	*novae-angliae*	New England Aster	2	-3		S5	G5	X
Solidago	*canadensis*	Canada Goldenrod	1	3		S5	G5	X
Cornaceae		**Dogwood Family**						
Cornus	*sericea*	Red-osier Dogwood	2	-3		S5	G5	X
Dipsacaceae		**Teasel Family**						
Dipsacus	*fullonum ssp. sylvestris*	Wild Teasel		5	-1	SE5	G?T?	X
Ericaceae		**Heath Family**						
Gaultheria	*hispidula*	Creeping Snowberry	8	-3		S5	G5	U
Fagaceae		**Beech Family**						
Quercus	*rubra*	Red Oak	6	3		S5	G5	X
Fagus	*grandifolia*	American Beech	6	3		S5	G5	X
Juglandaceae		**Walnut Family**						
Carya	*ovata var. ovata*	Shagbark Hickory	6	3		S5	G5	U
Juglans	*nigra*	Black Walnut	5	3		S4	G5	X
Oleaceae		**Olive Family**						
Fraxinus	*americana*	White Ash	4	3		S5	G5	X
Fraxinus	*pennsylvanica*	Red Ash	3	-3		S5	G5	X
Polygonaceae		**Smartweed Family**						
Rumex	*crispus*	Curly-leaf Dock		-1	-2	SE5	G?	X
Rhamnaceae		**Buckthorn Family**						
Rhamnus	*cathartica*	Common Buckthorn		3	-3	SE5	G?	X
Rosaceae		**Rose Family**						
Rubus	*idaeus ssp. melanolasius*	Wild Red Raspberry	0	-2		S5	G5T	X
Salicaceae		**Willow Family**						
Salix	*species*	Willow species						
Tiliaceae		**Linden Family**						
Tilia	*americana*	American Basswood	4	3		S5	G5	X
MONOCOTYLEDONS		**MONOCOTS**						
Poaceae		**Grass Family**						
Phalaris	*arundinacea*	Reed Canary Grass	0	-4		S5	G5	X
Typhaceae		**Cattail Family**						
Typha	*latifolia*	Broad-leaved Cattail	3	-5		S5	G5	X

BOTANICAL NAME	COMMON NAME	COEFFICIENT OF CONSERVATISM	WETNESS INDEX	WEEDINESS INDEX	PROVINCIAL STATUS	GLOBAL STATUS	LOCAL STATUS HALT

FLORISTIC SUMMARY & ASSESSMENT

Species Diversity			
Total Species:		**19**	
Native Species:		**14**	73.68%
Exotic Species		**5**	26.32%
Total Taxa in Region (List Region, Source)		10000	
% Regional Taxa Recorded		0.19%	
Regionally Significant Species		enter manually	
S1-S3 Species		enter manually	
S4 Species		1	
S5 Species		14	
Co-efficient of Conservatism and Floral Quality Index			
Co-efficient of Conservatism (CC) (average)		**3.93**	
CC 0 to 3	*lowest sensitivity*	6	42.86%
CC 4 to 6	*moderate sensitivity*	6	42.86%
CC 7 to 8	*high sensitivity*	2	14.29%
CC 9 to 10	*highest sensitivity*	0	0.00%
Floral Quality Index (FQI)		**14.70**	
Presence of Weedy & Invasive Species			
mean weediness		**-2.00**	
weediness = -1	*low potential invasiveness*	1	20.00%
weediness = -2	*moderate potential invasivenes*	2	40.00%
weediness = -3	*high potential invasiveness*	2	40.00%
Presence of Wetland Species			
average wetness value		**1.11**	
upland		4	21.05%
facultative upland		8	42.11%
facultative		1	5.26%
facultative wetland		7	36.84%
obligate wetland		0	0.00%