BLACK CREEK

HIGHWAY 407 STATION - 10% DESIGN SUBMISSION

- GEOMORPHOLOGICAL COMPONENT –

JUNE 2009

PARISH geomorphic

Introduction

In response to the proposed TTC subway alignment and station within the Black Creek Valley, the need to realign a portion of the channel in vicinity of Jane Street has been identified. As a result of the proposed station location and channel realignment, a fluvial geomorphic study was undertaken to document existing conditions and determine the potential implications of the proposed works on the creek and valley system at a sufficient level of detail to achieve 'approval in principle' from Toronto and Region Conservation Authority. The findings of this assessment were presented in the *Black Creek – Highway 407 Station – Phase I Memo* (PARISH, 2009). Subsequent to this initial assessment, design concepts were developed in support of the Phase 2 detailed design and approvals process. This report constitutes the 10% design submission for the geomorphic component of the Black Creek channel realignment associated with the Highway 407 Station. The purpose of this design submission is to outline the design objectives and justification for a channel realignment, as well as identify opportunities and constraints considered in the design process. Finally, an overview of the proposed channel design elements for Black Creek will be presented from a geomorphic perspective.

Design Overview

The proposed Highway 407 TTC Station will require construction of the transit tunnel underneath the channel within the stream corridor, as well as fill within the valley in order to accommodate infrastructure such as the transit station itself. Upon assessing the extent to which the valley would require modifications in order to support the proposed design, it was determined that a realignment of Black Creek downstream of Jane Street would be required in order to mitigate risk to the proposed infrastructure and support the proposed footprint of the station itself. The main objective of the design is to develop a dynamically stable channel that maintains, to the greatest extent feasible within established design constraints, existing stream lengths while minimizing maintenance requirements due to erosion to the proposed infrastructure. An effort was also made to enhance geomorphic diversity and aquatic habitat elements within the realigned channel.

Design Considerations and Constraints

In the development of a functional channel design, existing and proposed land use and local infrastructure presented various constraints that required consideration. The following points summarize the various considerations and constraints incorporated into the Black Creek natural channel design:

- *Urban Flow Regime* – the study area is located within an intensely urbanized portion of Toronto; as such, it is subject to a flashier flow regime in which peak events of a larger magnitude occur at a higher frequency.
- *Existing Conditions* - The channel itself is presently showing indications of geomorphic instability in the form of widening, planform adjustment and aggradation. These adjustments are a direct response to the urbanized flow regime, as the cross-sectional capacity of the channel attempts to increase its capacity.
- *Valley Setting* – Within the study area, Black Creek flows within a well-defined valley. From a design perspective, it represents a major lateral constraint with respect to planform realignment opportunities.
- *Bridge* – A stream road crossing is being designed over Black Creek to connect the station with the existing road network in the area. The bridge represents a localized constraint to the realigned channel in order to ensure that the proposed design does not pose a maintenance risk to the structure in the long-term.
- *Station Footprint and Associated Grading* – In order to accommodate the future station, filling of the existing valley will be required. The extent of this fill and associated grading represent a lateral constraint to the proposed realignment.
- *Matching Invert Elevations* – the upstream and downstream realignment tie-ins at Jane Street and the rail crossing (CSPs) represent vertical constraints and control the proposed channel gradient.

Design Opportunities

While the aforementioned considerations did represent constraints to the design process, opportunities for enhancement also exist. The following points summarize the various improvements that could be incorporated into the Black Creek natural channel design:

- *Removal of Existing CSPs* – presently, twin CSP culverts represent the downstream tie-in for the natural channel design. Removal of these CSPs would not only afford a greater degree of freedom with respect to the proposed channel planform which could achieve an overall gain in stream length, but also a benefit to the channel in general due to the fact that they are undersized and poorly suited to accommodate the existing flow regime.
- *Enhanced Morphology* – While the existing channel does display a riffle-pool morphology, the channel is in a somewhat degraded state. The proposed natural design will enhance the local bed morphology to provide high-quality riffles and pools that are dynamically stable over a range of flows.
- *Increased Cross-sectional Area* – In response to the on-going evidence of widening, the proposed natural channel design involves increasing the cross-sectional area such that it can accommodate the existing urbanized flow regime. This increase in cross-sectional area represents an optimization of available aquatic habitat.
- *Enhanced Riparian Corridor* – The exiting riparian zone is dominated by scrub meadow, with minimal tree coverage. The proposed channel works can incorporate an enhanced planting plan to improve the overall quality of riparian conditions and terrestrial habitat within the valley.
- *Mitigate Erosion and Instability* – The natural design will enhance the geomorphic stability and stream health to a point where the system can accommodate high flow events and maintain base flow. The channel will be less susceptible to erosion and overall degradation.

Design Approach

The design features added sinuosity to help maintain channel length, increased channel dimensions to address the channel's desire for increased cross-sectional area and pools and riffles. The pools and riffles are meant to mimic what would naturally be found in this system and offer greater channel diversity, while providing for increased stability. In addition to the channel realignment, the twin CSPs associated with the existing farm lane crossing could also be removed and the channel locally rehabilitated. In essence, the overall design

approach of this work is to leave the valley in a better, more diverse state than what currently exists.

Design Discharge

Based on the results of the detailed geomorphic field investigation (**Appendix A**), the design discharge (i.e., bankfull flow) for Black Creek was determined to be 5.4 m^3/s. This flow was based on channel dimensions and gradients measured in the field.

Cross-section

The final design will incorporate channel dimensions that are larger than the existing cross-section in order to increase the capacity of the system, as well as reduce the erosive nature of the channel. The differential depth between pools and riffles facilitates the creation of a low flow channel within the bankfull cross-section that will provide additional capacity for these backwater zones, as well as refugia habitat during low flow conditions. The increase in width and decrease in depth relative to existing channel dimension achieves and increase in cross-sectional capacity while decreasing velocities and associated erosive forces within the channel. To avoid entrenchment, the design has ensured that the creek is well-connected to the floodplain. **Table 1** provides a summary of the proposed channel dimensions for Black Creek.

Table 1. Cross sectional design characteristics on a chainage basis.

Design Element	Riffles	Pools
Bankfull Width (m)	6.0	6.0
Bankfull Depth (m)	0.75	0.95
Side Slope	1.5:1	1:1, 3:1

Planform

Working within the context of the aforementioned design constraints, the proposed planform maintains a meander geometry (amplitude and wavelength) that is consistent with the existing natural section of channel. Moreover, the channel realignment essentially achieves a match in channel length relative to the existing system. In order to mitigate the risk of bed incision to the subway tunnel, a riffle feature has been located overtop of this

infrastructure. As riffles represent grade control features within a channel, these sections of channel offer the greatest level of protection to the subway. The original field investigation identified the presence of hairpin meanders along Black Creek; the proposed planform will mitigate these issues to facilitate a more stable alignment.

Bank Treatments

The design drawings for Black Creek identify three bank protection treatments. The following section describes each treatment, their implementation on a chainage basis and the justification for their implementation from a geomorphic perspective:

1. Vegetated Stone Bank Treatment

In order to maximize the proposed channel length, while ensuring that channel erosion and migration does not pose a maintenance risk to the station in the long term, a vegetated stone bank treatment (**Figure 1**) has been proposed along the outside meanders of two bends that are located in close proximity to the station. This type of treatment will be able to absorb and re-direct the force of flows exiting the Jane Street crossing, thus protecting the station block.

2. Bio-engineering (e.g., brush mattress)

At the outlet of Jane Street, a brush mattress treatment (**Figure 2**) has been proposed along the inside bank of the meander bend. This treatment allows for a softer approach to bank stabilization while still achieving an additional level of resistance to erosive forces caused by flow constriction at the crossing.

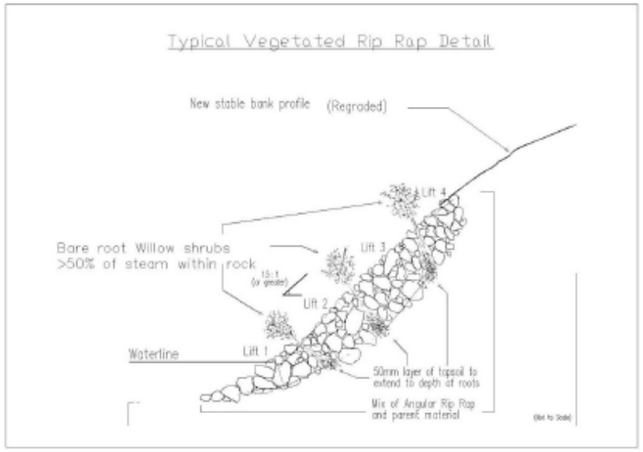

Figure 1. Vegetated stone bank treatment.

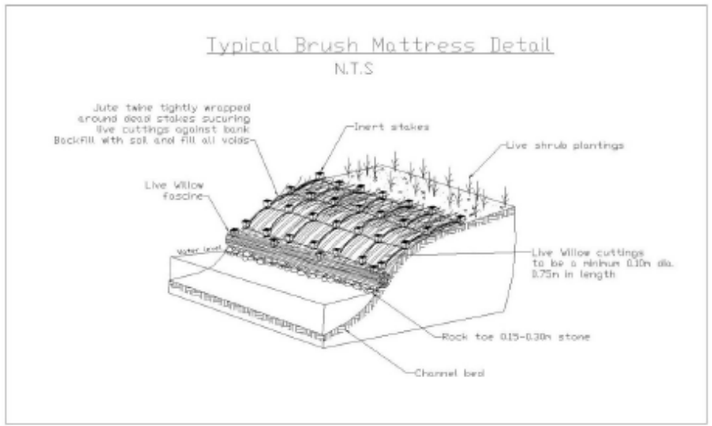

Figure 2. Typical brush mattress detail.

3. Coir Cloth and Live Staking

For the remaining sections of channel, a combination of coir cloth and live staking (**Figure 3**) has been proposed. This treatment facilitates both short and long term bank stability by providing a bio-degradable cloth covering of the bank during the initial recruitment period until rooting depths and densities from the live stakes are sufficient to ensure the long-term stability of the banks.

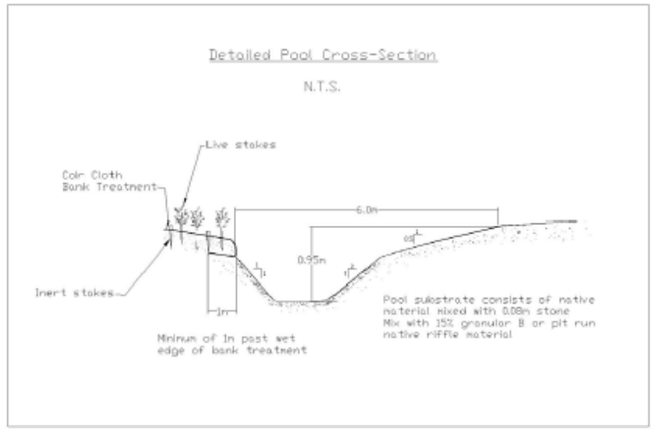

Figure 3. Coir cloth and live stake treatment.

Summary

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for the geomorphic component of the Black Creek channel realignment associated with the Highway 407 Station. This design submission outlined the design objectives, as well as identified opportunities and constraints considered in the design process. Finally, an overview of the proposed channel design elements for Black Creek was presented from a geomorphic perspective.

APPENDIX A

FLUVIAL GEOMORPHOLOGY SUMMARY

Black Creek

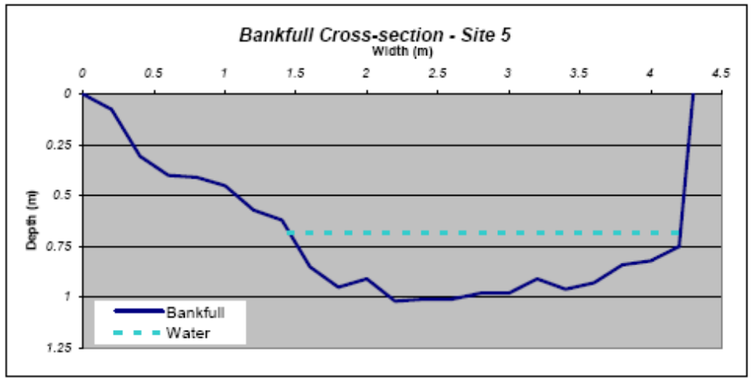
Site Location:	Jane Street south of Highway 407
Length surveyed:	460.83 m
Number of cross-sections:	10
Date of Survey:	26-Nov-08

Modifying Factors

Surrounding Land Use:	Scrub land
General Riparian Vegetation:	Tall grasses and herbs, scattered shrubs and trees
Existing Channel Disturbances:	Jane Street culvert and lane crossing double with hydro corridor between xs3 and 4
Woody Debris:	minor in channel and on banks

Cross-Sectional Characteristics

	Range	Average
Bankfull Width (m)	3.47 - 7.17	4.86
Bankfull Depth (m)	0.41 - 0.72	0.56
Width / Depth	5.61 - 13.83	8.98
Wetted Width (m)	2.58 - 3.90	3.08
Water Depth (m)	0.09 - 0.27	0.18
Width / Depth	9.69 - 35.50	20.24
Entrenchment (m)	27.00 - 105.68	61.96
Entrenchment Ratio	5.40 - 26.94	13.71
Manning's n		0.035



FLUVIAL GEOMORPHOLOGY SUMMARY

Black Creek

Bank Characteristics

	Range	Average
Bank Height (m)	0.7 - 3	1.10
Bank Angle (degrees)	27 - 64	41.83
Root Depth (cm)	8.0 - 16	11.8
Root Density *(1=Low - 5=High)*	2 - 3	2.4
Protected by vegetation (%)	25 - 70	51.4
Amount of undercut (cm)	25.0 - 38	29.50
Banks with undercuts (%)	5	25%

Bank Materials	**Torvane values (kg/cm2)**
si/ms/fs **	0.21
si/cl/fs	0.19
si/ms	0.21
si/cl/vfs	0.20
ms/fs	0.2
ms/si/cl	0.1
ms/cl/si	0.15
si/fs/cl	0.1
cl/si/ms	0.1
cl/si/vfs	0.22
cl/si/fs	0.18
ms/si	0.13
cl/vfs/si	0.23
cl/fs/si	0.1

* - Dominant Material

Planform Characteristics

Long Profile (avg)

Bankfull Gradient:	0.76	%
Inter-Pool Gradient:	0.68	%
Inter-Riffle Gradient:	0.81	%
Riffle Gradient:	2.29	%
Riffle Length:	7.98	m
Riffle-Pool Spacing:	15.82	m
Max Pool Depth:	1.62	m

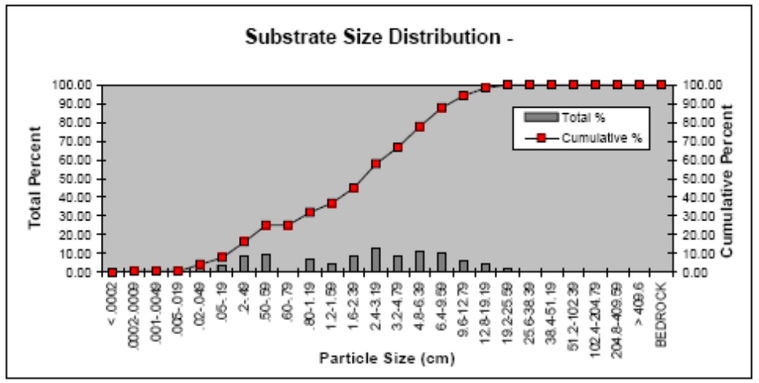
Black Creek

Substrate Characteristics

Particle Shape (cm)		Range	Average
	X	5 - 30	15.7
	Y	3.5 - 28	10.6
	Z	2 - 27	6.7
Hydraulic Roughness (cm)			
	Maximum	4 - 22	11.2
	Median	1 - 8	3.5
	Minimum	0.05 - 2	0.6
Embeddedness (%)		0.05 - 0.5	0.2

Grain Size Analysis
Pebble Counts

Particle Sizes (cm)	Site Average
D10:	0.049
D50:	2.625
D90:	11.274



Black Creek

Field Observations

At **XS1** there is cedar trees on the LB with mainly sumac on the RB. The LB is a floodplain area that contacts with the valley wall approximately 18m beyond bankfull.
XS2 is the monitoring cross section with a slumping LB and an undercut at the RB. It is also 20m downstream of a tributary coming in on the LB at the meander of the hairpin turn.
The LB is also higher than the RB.
EP1: 5m DSRB of EP2 = 13 cm (GPS of EP1: 0618893 4848572)
EP2: 6m DSLB = 12.5 cm
EP3: 5m DS xsRB = 13 cm
EP4: RB at XS = 17 cm
EP5: LB at XS = 10.5 cm
LP GPS (0618911 4848579)
RP GPS (0618912 4848578)
XS3 is located 20m downstream of culverted lane crossing and 6m upstream of the hairpin turn. There is a medial bar at the xs with 5-8cm material deposited. There is shrubs overhanging on LB.
XS4 has basal scour and undercutting on both banks. There is a medial bar 6m US and DS 5m on the LB is slumping with sections fallen into channel.
At **XS5** the bankfulls are higher than the upstream sections creating a more confined channel. Starting 4m upstream there is overhanging shrubs and major debris jams and continues beyond xs6. There is also a medial bar at this section with materials 15-20cm deposited.
At **XS6** there is slumping on the LB with a bar formation DS 1m on the RB composed of gravel material.
XS7 has pooling upstream and downstream at meander bends with clumps of slumping material in the channel likely from the RB.
At **XS8** there is an undercut RB with basal scour and valley wall 8m from bankfull pin.
Cross section located at the DS end of a meander at top of riffle. Upstream 2m on the RB is a vertical bank and undercutting located in an open scrub area.
XS9 is located mid riffle with trees on both banks and slumping on the LB.
XS10 is located at the upstream end of a meander and downstream of Jane street approximately 30m. There is basal scour and undercutting on both banks. There is dense scrub vegetation on both banks. There is also a chute formation at top of RB with slumping sections upstream 5m.