Kanata West Development Area Meander Belt Width Assessment and Erosion Analysis

Feedmill Creek

Draft Report

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GEO MORPHIX
Geomorphology
Earth Science
Observations

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1 Introduction

GEO Morphix Ltd. was retained by 2325483 Ontario Inc. to delineate the meander belt width and to assess and mitigate erosion potential within Feedmill Creek in the Kanata West Development Area. We understand that the valley corridor along the western boundary of the property may eventually be realigned to accommodate development activities. As such, the findings of this assessment will also inform the corridor design requirements in the case where natural corridor design is required.

The primary goal of this assessment was to determine meander belt, which may be used as the limit of development.

This assessment included the following components:

- Review available background reports and mapping (geology, topography, etc.);
- Desktop reach delineation;
- Completion of a rapid geomorphological field assessment to document channel conditions and verify the desktop assessment; and
- Review historical and recent aerial photographs to determine the limits of the meander belt width and to calculate channel migration rates, or estimate the meander belt width using models if the channel is not visible in the aerial imagery or is to be realigned.

With regards to future erosion potential, an assessment of channel sensitivity along with determination of an erosion threshold for the receiving watercourse. The goal of this component of the assessment was to characterize erosion potential in Feedmill Creek in order to help mitigate future impacts and support development of a suitable SWM plan as part of the mitigation strategy.

This component of the assessment included the following tasks:

- A desktop analysis for determining the potential zone of impact;
- Apply rapid geomorphic assessments to determine the overall stability of the receiving watercourse and to identify areas of erosion concern or at risk drainage feature based on field observations;
- A detailed geomorphic assessment of a sensitive reach, the primary objective of which is to determine the critical flow or erosion threshold; and
- Support appropriate strategies to address erosion concerns.

2 Background Review

2.1 Watershed Characteristics

Feedmill Creek originates southwest of the study area, within the Carp Valley. The creek generally flows northeast through agricultural fields, bending to the northwest and flowing along the western boundary of the subject property. It continues across Highway 417 and then flows northeast through a mix of industrial, forested and agricultural areas to its outlet at Carp River in Kanata. The study area contains a mix of the aforementioned land use types. Portions of the channel have been historically or recently straightened and others retain more natural features. Reach delineation was refined through field observation.

Channel morphology and planform are largely governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. Physiography, riparian vegetation and land use also physically influence the channel. These factors are explored as they

not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

Physiographically, the majority of Feedmill Creek within the Kanata West Development Area project site overlies fine-textured glaciomarine deposits containing silt and clay with minor sand and gravel, associated with the former marine bed of the Champlain Sea. Upstream reaches of Feedmill Creek, including the northwest reach along the subject property overlies organic deposits containing peat, muck and marl. Underlying Paleozoic bedrock is exposed in localized areas and acts as a topographic control through the area (OGS, 2010).

Monthly precipitation averages at Ottawa MacDonald-Cartier Int'l A (Climate ID 6106000) range from a low of 54.3 mm in February to a high of 92.8 mm in July. During the winter months, most of the precipitation is in the form of snow. During spring, snowmelt and rain-on-snow events likely generate long-duration high flows in watercourses, which result in the most significant flows with respect to shaping the channel. Convective storms during the summer are also likely to have a role in shaping the channel, but are less significant due to the short duration of high flows.

2.2 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. They are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are delineated based on changes in the following:

- Channel planform;
- Channel gradient;
- Physiography;
- Land cover (land use or vegetation);
- Flow, due to tributary inputs;
- Soil type and surficial geology; and
- Certain types of channel modifications by humans.

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997) and the Toronto and Region Conservation Authority (2004) as well as others.

Reaches were first delineated as a desktop exercise using available data and information, such as aerial photography, topographic maps, geology information, and physiography maps. These results were then verified in the field.

Five (5) reaches were delineated for Feedmill Creek including one reach (**Reach 5**) along the boundary of the subject property. Four additional reaches were defined within the length of stream downstream that was investigated as part of the assessment. These reaches were defined based on the location of road crossings as well as changes in land use, planform and gradient. Reaches were numbered from downstream to upstream to provide a geographic context. A reach map is provided in **Appendix A**.

2.3 Historical Assessment

3 Field Observations

Reach observations and channel measurements were collected on July 5th and 6th, 2016. Photographs are provided in **Appendix B** and field observations are provided in **Appendix C** for reference. Rapid geomorphological assessments for each reach were completed on July 5th, 2016. A detailed assessment for one reach was completed on July 6th, 2016.

3.1 Rapid Geomorphological Assessments

The rapid geomorphological assessments included the following reach observations:

- Characterization of stream form, process, and evolution using the Rapid Geomorphological Assessment (RGA) (MOE, 2003, VANR, 2007);
- Assessment of the ecological function of the watercourse using the Rapid Stream Assessment Technique (RSAT) (Galli, 1996);
- Stream classification following a modified Downs (1995) and a modified Brierley and Fryirs (2005) River Styles Classification approach;
- Reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow behaviour, geomorphological units, and riparian vegetation on the day;
- Instream estimates of bankfull channel dimensions;
- Bed and bank material composition and structure; and
- Georeferenced photographs to document the location of all observed erosion and infrastructure.

Five (5) reaches were defined within the study area. **Table 3.1** and **Table 3.2**, below, outline field observations for the observed reaches.

Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40) or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and consider the ecological functioning of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34) or excellent (35-42) degree of stream health.

The tributary was classified according to a modified Downs (1995) Channel Evolution Model, which describes successional stages of a channel as a result of a perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve, or respond to an alteration to the system.

The River Styles Framework (Brierley and Fryirs, 2005) provides a geomorphic approach to examining river character, behaviour, condition and recovery potential through the identification of the Geomorphic Process Zone. Geomorphic attributes are assessed, larger scale interactions between zones are analyzed, and historical data are studies in order to understand the historical evolution and future trajectories of those reaches. This ultimately provides a physical template

for river management. A modified classification approach was applied to the study reaches. **Table 1** below summarizes the results of the rapid geomorphological assessments.

Table 3.1. Rapid Assessment results by reach

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)			Downs' Channel Evolution Model (1995)	River Styles Framework (Brierley and Fryirs, 2005)
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Features		
1	0.25	In Transition/ Stress	Aggradation	27	Good	Riparian Habitat Conditions	d - Selective deposition resulting in reduced channel width	Meandering, relatively stable, suspended load dominated, low to moderate stream power
2	0.28	In Transition/ Stress	Aggradation	29	Good	Riparian Habitat Conditions	d - Selective deposition resulting in reduced channel width	Meandering, relatively stable, suspended load dominated, low to moderate stream power
3	0.30	In Transition/ Stress	Aggradation, Widening	34	Good	Scouring /Sediment Deposition	d - Selective deposition resulting in reduced channel width	Meandering, relatively stable, suspended load dominated, moderate stream power
4	0.19	In Regime	Widening	27	Good	Riparian Habitat Conditions	d - Selective deposition resulting in reduced channel width	Meandering, relatively stable, suspended load dominated, low stream power
5	0.19	In Regime	Aggradation	23	Good	Riparian Habitat Conditions	d - Selective deposition resulting in reduced channel width	Straight, relatively stable, suspended load dominated, low stream power

Reach 1 was classified according to the River Styles framework as a suspended load channel with a low to moderate gradient and stream power. The creek exists as a single channel and follows a meandering pattern, partially confined by valley sides both historically occurring and associated with recent development activities. A portion of the channel, mid-reach, has been recently straightened and realigned along the south valley wall; historically the entire reach has been meandering, with some meanders contacting the valley wall. A new crossing has been established along the straightened portion of the reach. Aggradation was noted throughout a substantial portion of the reach, including large sand deposits along bars, on the bed and sand deposits on top of banks. Erosion was less prominent (approximately 5-30%) and consisted mainly of undercutting, measured up to 0.33 m. Generally, bank angles ranged 30° to 90°. Riparian vegetation consisted mainly of dense grasses with shrubs along limited sections, both providing stability to channel bank material. Bank material was composed of clay to sand. Bed material ranged from clay to cobbles in riffles and from clay to silt in pools. Riffles comprised approximately 30% and pools / run features comprised approximately 70% of the length of the reach. Average

bankfull width and depth were 3.83 m and 0.89 m, respectfully. Woody debris was present in the channel and cutbank at a moderate density. The stream was clear and odourless.

According to the Downs' Model of Channel Evolution (1995), **Reach 1** was classified as "d – depositional" due to selective deposition resulting in reduced channel width. The Rapid Geomorphic Assessment produced a score of 0.25 or, "In Transition/Stress" with the dominant process being "Evidence of Aggradation" as shown by embedded riffle materials, siltation in pools, accretion of point bars and deposition in the overbank zone. The Rapid Stream Assessment Technique produced a score of 27, or "Good" with riparian habitat conditions as the limiting factor.

Reach 2 exists as a sinuous single channel. It follows an irregularly meandering pattern, partially confined by valley sides. The meanders are smaller and less-regular than in Reach 1. Similar to Reach 1, it was classified as a suspended load channel with low to moderate gradient and stream power. Aggradation, however notable, was somewhat less-dominant a feature in this reach. Further defining this reach was exposed till along the stream bed through a large portion at the downstream end. Bank erosion and bank conditions were similar to Reach 1 with erosion approximately 5-30%, bank angles generally ranging 60° to 90° and undercuts averaging 0.28 m. Bank composition was also similar, ranging from clay to sand. Bed material ranged from clay to cobbles in riffles and clay to silt in pools with exposed till in both types of geomorphic unit. Riffles were present through approximately 20% of the reach and pools or run features were present through approximately 80% of the reach. Average bankfull width and depth were 2.83 m and 1.05 m, respectfully. Riparian vegetation consisted of dense grasses and shrubs through a limited extent of the reach. Woody debris was less commonly present in the channel and cutbank than it was in Reach 1, as was woody vegetation. Upstream of Reach 2 lie two sections running through culverts beneath on and off-ramps of Highway 417. The stream was clear and odourless.

Rapid assessment techniques produced similar results in **Reach 2** as in **Reach 1**. According to the Downs' Model of Channel Evolution (1995), Reach 2 was classified as "d – depositional" due to selective deposition resulting in reduced channel width. The Rapid Geomorphic Assessment produced a score of 0.28 or, "In Transition/Stress" with slightly less dominance on "Evidence of Aggradation" and a greater amount of "Evidence of Degradation" than Reach 1. The Rapid Stream Assessment Technique produced a score of 29, or "Good" with riparian habitat conditions as the limiting factor.

Reach 3 was classified according to the River Styles Framework as a suspended load channel with a moderate gradient and moderate stream power. This reach flowed as a single, well-defined, meandering channel. The valley setting and meanders were generally wider than in other reaches observed however the channel still exhibited partial confinement. The channel flowed through a dense cedar forest. As such, bank material was comprised of a greater fraction of mineral soil and was stabilized by a greater proportion of tree roots as compared to other observed reaches. Also resulting from the forested surroundings was a greater amount of woody debris in the channel and on banks. Evidence of both erosion and deposition were noted throughout the reach. Bank erosion ranged approximately 30-60% with bank angles ranging 60° to 90° and undercuts ranging 0.2 to 0.5 m. Exposed roots and leaning trees were common. Bank composition ranged from clay to sand. Sand deposits were noted on outer bends, tops of banks and in pools. Bed material ranged from gravel to cobbles in riffles and from clay to sand in pools. Geomorphic units were well-developed, with riffles present along approximately 70% of the reach and pools approximately 30% of the reach. Average bankfull width and depth were 4.40 m and 0.80 m, respectfully. A length of the downstream portion flows over exposed Paleozoic bedrock. One informal farm crossing was noted. Reach 3 was the most sensitive reach observed in the study. The stream was clear and odourless.

According to the Downs' Model of Channel Evolution (1995), **Reach 3** was classified as "d – depositional" due to selective deposition resulting in reduced channel width. The Rapid Geomorphic Assessment produced a score of 0.30 or, "In Transition/Stress" with the dominant processes being "Evidence of Aggradation" and "Evidence of Widening". The Rapid Stream Assessment Technique produced a score of 34, on the high end of ranking "Good" with channel scouring / sediment deposition as the limiting factor.

Reach 4 was classified as a suspended load channel with a low to moderate gradient and stream power according to the River Styles Framework. The observed length of reach flows through an unconfined grassy floodplain with a history of beaver activity and localized ponding. Dead trees were noted throughout the flood plain on the bank or in the channel in several locations. This reach exists as a single, well-defined channel with moderate sinuosity and irregular meanders. Average bankfull width and depth were 2.23 m and 0.88 m, respectfully. Bed and bank material ranged from clay to sand with notable sand deposits in pools. Geomorphic units were less-well developed than in downstream reaches with riffles comprising just 10% of the stream length and pools/run features the remaining 90%. Deposition in pools was noted but generally less dominant than in downstream reaches. Bank erosion was similar in extent to reaches 1 and 2, at approximately 5-30%, with bank angles ranging 60° to 90° and undercuts up to 0.33 m. The stream was clear and odourless.

According to the Downs' Model of Channel Evolution (1995), **Reach 4** was classified as "d – depositional" due to selective deposition resulting in reduced channel width. The Rapid Geomorphic Assessment produced a score of 0.19 or, "In Regime" with the dominant processes being "Evidence of Widening". The Rapid Stream Assessment Technique produced a score of 27, or "Good" with riparian habitat conditions as the limiting factor.

Reach 5 exists as a straight single channel having been previously channelized and maintained as such. It flows along the western border of the subject property, though a predominantly grassy, unconfined, agricultural/wooded setting. According to the River Styles Framework, it was classified as a suspended load channel with low gradient and low stream power. Average bankfull width and depth were 2.30 m and 0.52 m, respectfully. Geomorphic units were nearly absent through this reach; a single riffle was noted downstream of an informal farm crossing in a short shrubby section of the channel. The remainder of the channel exists as a run feature. Bed material ranged from clay to gravel in runs and from clay to cobbles in riffles with a high degree of embeddedness. Rooted emergent vegetation and rootlets were present along a substantial extent of the reach. This reach exists within an area dominated by wetlands and organic soils. Bank erosion was under 5% in this reach with undercutting up to 0.12 m observed but generally quite low. Bank angles ranged from 60° to 90°. Deposition was noted in the channel and on top of banks.

According to the Downs' Model of Channel Evolution (1995), **Reach 5** was classified as "d – depositional" due to selective deposition resulting in reduced channel width. The Rapid Geomorphic Assessment produced a score of 0.19 or, "In Regime" with the dominant processes being "Evidence of Aggradation". The Rapid Stream Assessment Technique produced a score of 23, or "Good" with riparian habitat conditions as the limiting factor.

Table 3.2. General channel characteristics by reach

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
1	3.83	0.89	Clay to sand, cobble	Clay to silt	Partially confined	Shrubs and grasses	Straightened section mid-reach with new crossing; over-bank and bar sand deposits common
2	2.83	1.05	Cobble, till	Clay to silt, till	Partially confined	Shrubs and grasses	Undercut along entire reach length; till exposed along bed
3	4.4	0.8	Sand to cobble, bedrock	Clay to sand, cobble	Partially confined	Continuous cedar forest	Well developed riffles and pools; reach in natural state; bedrock exposure along bed
4	2.23	0.88	Clay to silt	Clay to sand, cobble	Partially confined	Mainly grasses, forested areas	Geomorphic units not as well defined as downstream reaches; previous flooding in area; upstream portion not observed
5	2.3	0.52	Clay to cobble, rootlets	Clay to fine gravel, rootlets	Unconfined	Mainly grasses	Previously straightened channel dominated by run feature

3.2 Detailed Geomorphological Assessments

Following the initial rapid assessments, **Reach 3** was identified for detailed assessment. This reach was selected because it is most sensitive reaches downstream of the reach that flows along the western boundary of the subject property that may eventually be realigned to accommodate development activities. **Reach 3** was identified as 'In Transition' as a result of aggradation and widening and as such was deemed suitable for determining an appropriate erosion threshold for the upstream subject reach.

The detailed assessment was completed on July 6th, 2016 and included the following:

- Long-profile, level survey of the channel centre line;
- 8 detailed cross-sectional surveys of the watercourse;
- Detailed instream measurements at each cross-section location including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density;
- Bed material sampling at each cross-section following a modified Wolman's (1954) Pebble Count Technique or substrate sample; and
- Velocity, discharge and observations of active/inactive sediment transport at select representative cross-sections.

A summary of the detailed assessment results is provided in **Appendix D**.

Table 3.3. Bankfull parameters of the sensitive reach

Channel parameter	Results
Measured	
Average bankfull channel width (m)	3.79
Average bankfull channel depth (m)	0.41
Bankfull channel gradient (%)	0.33
D_{50} (mm)	< 2
D_{84} (mm)	50.8
Manning's n roughness coefficient	0.030
Computed	
Bankfull discharge (m^3/s) *	0.45
Average bankfull velocity (m/s)	0.60
Unit stream power at bankfull discharge (W/m^2)	13.96
Tractive force at bankfull (N/m^2)	13.24
Critical shear stress (N/m^2) **	7.02
Flow competency for D_{50} (m/s) ***	N/A
Flow competency for D_{84} (m/s) ***	1.20

* Based on Manning's equation
** Based on Shields diagram from Miller et al. (1997)
*** Based on Komar (1987)

Bank pins were installed on the tops of banks and erosion pins were installed for bank erosion monitoring at two representative cross sections (one riffle and one pool). Detailed measurements were taken at these two cross sections in order to establish a baseline should future monitoring activities be required. Velocity was measured at select cross sections (typically monitoring cross-sections or riffles) to provide an estimate of stream flow at the time of observations.

4 Meander Belt Width Assessment

4.1 Methodology

Most watercourses in Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a stream.

When defining the meander belt width for a creek system, unconfined and confined systems are treated differently. Unconfined systems are those with poorly defined valleys or slopes well-outside where the channel could realistically migrate. Confined systems are those where the watercourse in contained within a defined valley, where valley wall contact is possible.

In unconfined systems, the meander belt width can be graphically defined using orthorectified aerial imagery or through survey by determining the channel centreline and the channel's central tendency (i.e. meander belt axis).

When watercourses are fully confined within a valley, an erosion setback is employed along with delineation of a stable top of slope. Stability of the valley wall should be assessed by a qualified geotechnical engineer.

Meander belt widths were estimated for two channel reaches. **Reach 5** is the reach that flows along the western boundary of the subject property and which may eventually require realignment to accommodate development activities. This reach was unconfined and previously straightened. **Reach 3** represents a reference reach located downstream exhibiting natural meandering features, indicators of sensitivity and partial confinement within a wide valley system. Both reaches exhibited defined channel banks.

Reach 3 lies mainly within a forested area containing a high density of evergreen vegetation and as such, banks are not clearly visible in aerial photographs. **Reach 5**, as mentioned, was previously straightened. As such, empirical models were used to provide estimates of the meander belt width.

The empirical relations from Williams (1986) were modified to include channel area and width, and applied using the bankfull channel dimensions such that:

$$B_w = (18A^{0.65} + W_b) \times 1.2 \quad \text{[Eq. 1]}$$

$$B_w = (4.3{W_b}^{1.12} + W_b) \times 1.2 \quad \text{[Eq. 2]}$$

where *Bw* is meander belt width (m), *A* is bankfull cross-sectional area (m^2), and *Wb* is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction and provides a factor of safety.

The results of these empirical models were compared with field-measured values of meander amplitude, for a reference meander within the immediate vicinity of the study area. In order to account for the active channel, the average bankfull width, as well as a 20% factor of safety was applied to this meander amplitude, similar to the empirical modelling approach.

Results of the meander belt width assessment, including the empirical modelling and desktop-based approaches are presented in **Table 4.1**.

Table 4.1. Meander belt width estimates for subject and reference reaches.

	Meander Belt Width Method			
	*Williams – Area (1986) (m)	*Williams – Width (1986) (m)	Reference Meander Amplitude Approach (m)	Recommended Meander Belt Width (m)
Reach 3	33	28	23	23
Reach 5	27	16	N/A	27

4.2 Results and Discussion

Meander belt width calculations completed in the Carp River Watershed Study (CRWS) take a very conservative approach of 20 to 40 times the bankfull width. This is substantially higher than recommended by the MNRF under their Guidelines (MNRF, 2001). To provide a more site appropriate meander belt width, a detailed assessment of the reach adjacent to the development and a downstream reference reach was completed. The assessment suggests the meander belt

widths range from 16 to 33 m (based on the reference reach). We suggest 27 m provides an adequate meander belt width for **Reach 5** adjacent to the development. This is greater than the measured meander belt width from **Reach 3** (23 m). We note that the area approach from Williams (1984) is more conservative than the width method that we usually employ, due to the uncertainty regarding a potential channel realignment. If a realignment is proposed, this can have an impact on the meander belt width, and should be refined based on the design geometry of the restored bankfull channel.

5 Erosion Analysis

5.1 Erosion Threshold Analysis

An erosion threshold can be defined as the magnitude of flow required to potentially entrain and transport channel bed and/or bank materials. Threshold targets are therefore provided to guide the design of the proposed SWMFs to ensure that natural erosion rates in the receiving watercourse are not accelerated.

The erosion threshold analysis provides a depth, velocity, or discharge at which sediments of a particular size may potentially be entrained. The results of the detailed geomorphic assessments for **Reach 3** (**Table 3.3**Error! Reference source not found.) were used to inform the erosion threshold analysis. We note that, due to natural variability of channel morphology and sediment characteristics within the reach, the computed flow characteristics only provide first approximations of erosion thresholds.

Erosion thresholds are determined using different methods that are dependent on channel and sediment characteristics. An erosion threshold, in the form of a critical discharge, was calculated based on the bed and bank materials and local channel geometry, as determined in the detailed geomorphological assessments. Theoretically, above this discharge, entrainment and transport of sediment can occur. Erosion thresholds for non-cohesive sediments may be estimated using either a shear stress or a velocity approach.

One such velocity approach follows that of Komar (1987), which is based on a velocity approach, whereby:

$$Vcr = 57D^{0.46} \quad \text{[Eq. 5]}$$

where *Vcr* is the critical velocity (cm/s) required to entrain a grain size of *D* (cm).

The velocity in an average channel cross section, *U*, is calculated at various depths, until the average velocity in the cross section exceeds the critical velocity of the bed materials. The velocity in the typical cross section is determined using a Manning's approach, where the Manning's *n* value is visually estimated, or by using the Limerinos (1970) equation:

$$n = \frac{(0.1129)\, R^{1/6}}{1.16+2.0\, \log\left(\frac{R}{D_{84}}\right)} \quad \text{[Eq. 6]}$$

where *R* is the hydraulic radius (m) and D_{84} is the grain size at which 84% of the material is finer (m). Mathematically, the velocity, *U*, is calculated as:

$$U = \frac{1}{n} d^{2/3} S^{1/2} \quad \text{[Eq. 7]}$$

where *n* is the Manning's roughness coefficient, *d* is the depth (m), and *S* is the channel gradient. The critical discharge is then calculated using the flow area of the cross section at the depth where the average velocity in the cross section exceeds the critical velocity of the bed materials.

Determining the erosive resistance of cohesive and/or vegetated bank materials depends on a number of factors, including particle size, cohesion of bank materials, and vegetation effects due to rooting. A typical approach to determine thresholds for the banks is to use empirically derived values for various materials, such as those by Julien (1995). To estimate the erosion threshold of the channel banks, it is assumed that 75% of the bed shear stress and velocity act on the banks in a simplified cross section, following Chow (1959). In this case, as for the bed materials, flow depth is increased until the average velocity in the cross section acting on the banks exceeds the permissible velocity of the bank materials, as outlined by Julien (1995).

The results of the erosion threshold analyses are provided in **Table 5.1**.

Table 5.1. Erosion thresholds of bed and bank materials

Erosion Thresholds (Reach 3)	
Bankfull Conditions	
Bankfull width (m)	3.79
Maximum bankfull depth (m)	0.59
Average bankfull depth (m)	0.41
Slope (%)	0.33
Bankfull Manning's n	0.030
Manning's n applied for erosion thresholds	0.033
Bankfull discharge (m^3/s)	1.64
Bankfull velocity (m/s)	1.05
Bankfull shear stress (N/m^2)	13.24
D50 (m)†	0.01130
Erosion Threshold - Bed Materials	
Critical discharge (m^3/s)	0.45
Critical velocity (m/s)*	0.60
Apparent shear stress (N/m^2)	7.02
Water depth at critical discharge (m)	0.24
Erosion Threshold - Bank Materials	
Critical discharge (m^3/s)	0.71
Critical velocity (m/s)**	0.53
Apparent shear stress (N/m^2)	9.38
Water depth at critical discharge (m)	0.32

* Based on Komar (1987)
** Based on Julien (1995)
† Average grain size excluding fine materials in pools to eliminate bias

The critical discharge needed to entrain the bed materials in **Reach 3** was determined to be 0.45 m^3/s, based on a critical velocity of 0.60 m/s determined using Komar's (1987) method. As the bank materials in this reach consisted of a sandy loam, a permissible velocity of 0.53 m/s was used (Julien, 1995). The critical discharge for the bank materials, based on this velocity, was determined to be 0.71 m^3/s. The critical discharge for the bank materials, of 0.45 m^3/s, was determined to be appropriate for the reach, as it provides a conservative estimate.

It should be noted that the modelling approach applied to determine the erosion thresholds has the potential to underestimate the erosion threshold. As such, field verification is recommended. While the erosion thresholds are based on surveyed cross sections, field verification beyond the water depths on the day of the surveys have not been completed.

6 Summary and Recommendations

The subject reach of Feedmill Creek within the subject lands, **Reach 5**, is not confined. As such the channel can naturally migrate within its valley setting. Given this, Williams (1986) meander belt width protocol was employed. The assessment was based on a measurement of the bankfull width, and was modified to accommodate cross-sectional area. This resulted in recommendations for the meander belt width for Reach 5 of 16 m based on existing conditions, and 30 m in the event that the channel is realigned.

Rapid field assessments identified a reach of potential erosion sensitivity downstream of the proposed development. The detailed assessments were completed in one reach that was identified as sensitive and indicative of natural channel conditions. An erosion threshold was defined for the bed and banks of **Reach 3**, and a critical discharge of 0.45 m^3/s was defined. We note a DRC approach is recommended in the subwatershed study to address erosion concerns. The erosion threshold can be employed in several ways to assess erosion mitigation strategies.

We trust this report meets your requirements. Should you have any questions please contact the undersigned.

Respectfully submitted,

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Environmental Scientist

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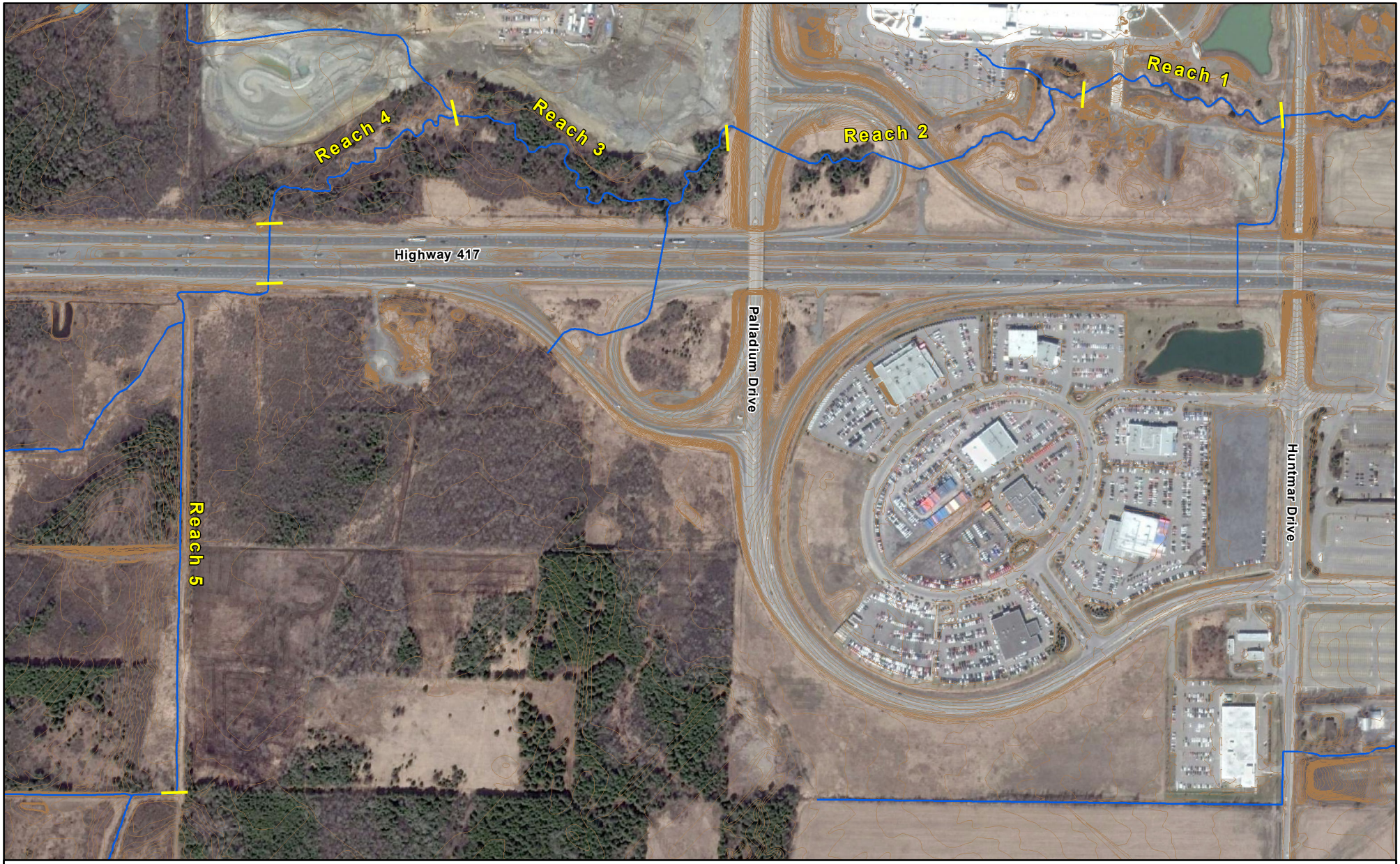
Appendix A
Reach Map



Legend

- Reach break
- Watercourse
- 25 cm Contour

Reach Delineation
Feedmill Creek

Cavanagh Kanata West

GEO MORPHIX

0 100
Metres

Imagery: Google Earth Pro, 2016.
Reach break: GEO Morphix Ltd., 2016.
Watercourse: MNR (2010). 25 cm Contour: DSEL (2016).

Appendix B
Photographic Record

Photo 1	
	Reach 1 – upstream facing to run feature; grassy banks, partial confinement, undercutting on inner bank, sandy deposit out outer bank
Photo 2	
	Reach 1 – upstream facing upstream of new crossing; large sandy deposit with cut face on bank

Photo 3	
	Reach 2 – till on stream bed
Photo 4	
	Reach 2 – upstream facing – wooded section of reach; undercut banks, woody debris; riffle feature with cobbles; embedded cobbles at downstream end; sand on bank

Photo 5	
	Reach 3 – upstream facing downstream end of reach; large undercut, large sandy deposit, exposed tree roots and woody debris
Photo 6	
	Reach 3 – upstream facing at downstream end of reach; riffle over exposed bedrock on bed

Photo 7	
	Reach 3 – upstream facing at surveyed cross section 3 (mid-reach) - riffle feature; bed material mainly cobbles
Photo 8	
	Reach 3 – downstream facing at surveyed cross-section 5 (mid-reach) – pool feature; bed material clay to sand with embedded cobbles; sand on inner bank, undercut outer bank

Photo 9	
	Reach 4 - upstream facing; grassy undercut banks; silt to cobbles on bed
Photo 10	
	Reach 4 - upstream facing; run feature with undercut banks and large woody debris; dead trees throughout floodplain

Photo 11	
	Reach 5 - upstream facing; grassy undercut banks; run feature; clay to silt bed with rooted submergent vegetation
Photo 12	
	Reach 5 – upstream facing in scrubby wooded section of reach showing bankfull dimensions and straight nature of reach; clay to cobble bed material, embeddedness

Appendix C
Field Observations

General Site Characteristics

Project Code/Phase: PN 16059

Date:	July 5 2016	Stream/Reach:	Reach 1
Weather:	Sun/clouds 33°C	Location:	Feedmill Creek
Field Staff:	AD/ER	Watershed/Subwatershed:	Carp River

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Island/bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization
- Instream log/tree
- Fence
- Culvert
- Swamp
- Grasses
- Tree

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

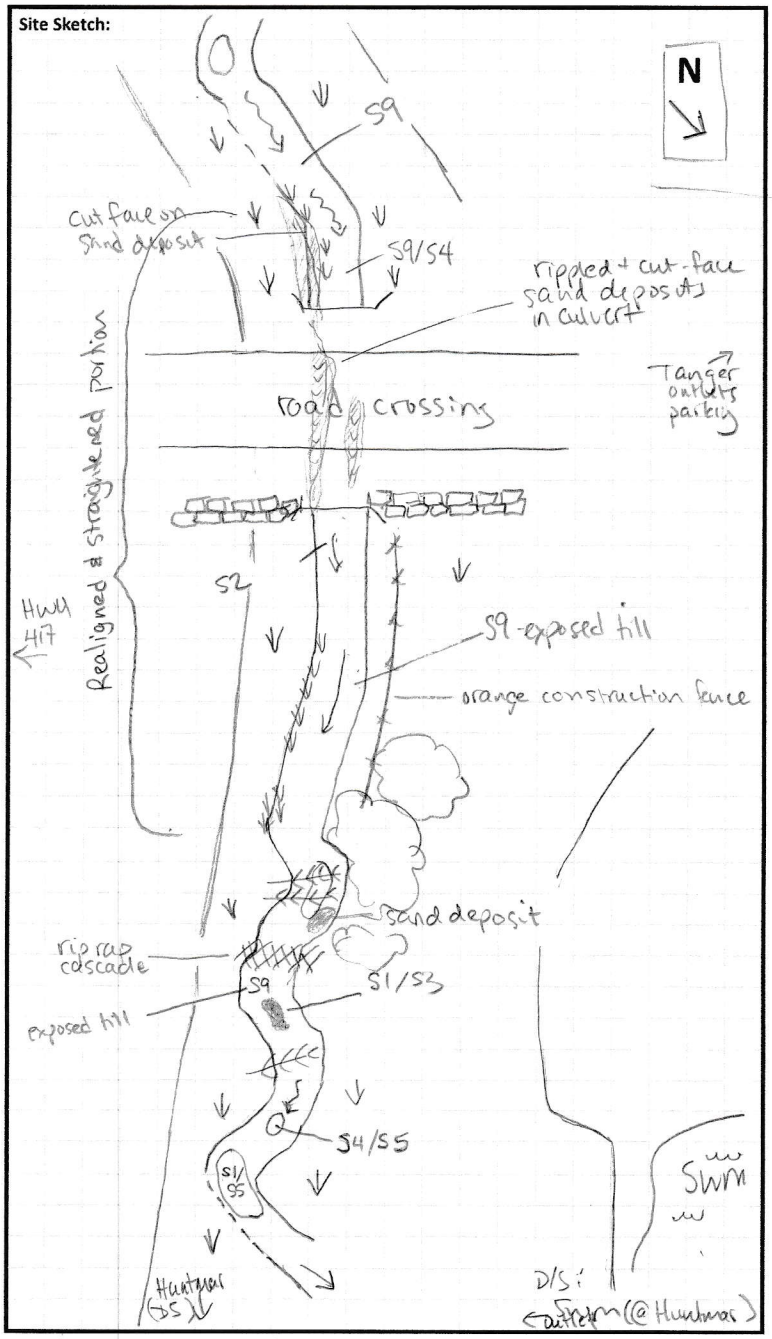
Substrate

S1	Silt
S2	Sand
S3	Gravel
S4	Small cobble
S5	Large cobble
S6	Small boulder
S7	Large boulder
S8	Bimodal
S9	Bedrock/till

Other

BM	Benchmark	TR	Terrace
FC	Flood chute	BOS	Bottom of slope
FP	Floodplain	TOS	Top of slope
GC	Grade control	VWC	Valley wall contact
KP	Knick point	WDJ	Woody debris jam

Site Sketch:



Additional notes: beaver cut wood in creek. Siltation in pools overbank sand deposits common rooted submergent and emergent.

- realigned (straightened portion extends u/s & d/s of new crossing (2014).

GEO MORPHIX

Completed by: ER Checked by: AD

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: pn16059

Date:	July 5, 2016	**Stream/Reach:**	Reach 1
Weather:	33°C, sunny	**Location:**	Feedmill Creek
Field staff:	ER/AD	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)	426642.13 mE, 5016410.23 mN	**UTM (Downstream)**	426842.80 mE, 5016548.96 mN

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 13 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 2/3
Species: unknown

Coverage:
- ☐ None
- ☑ Fragmented
- ☐ Continuous

Channel widths
- ☐ 1-4
- ☑ 4-10
- ☐ > 10

Age Class (yrs) :
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1/2 | **Coverage of Reach (%):** 10

Woody Debris
- ☑ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☑ Moderate
- ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1 very clear

Turbidity (Table 17): 1 cool

no substrate fouling

Channel Characteristics

Sinuosity (Type) (Table 9): 2 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 1/2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☑	☐	☑	☑	☐	☐	☐
Pool Substrate	☑	☐	☐	☐	☐	☐	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

	Pool	Cascade	Riffle
Bankfull Width (m)	3.50	3.70	4.30
Bankfull Depth (m)	1.30	0.70	0.67
Wetted Width (m)	2.50	3.0	2.30
Wetted Depth (m)	0.61	0.30	0.15

Riffle/Pool Spacing (m): 30 | **% Riffles:** 30 | **% Pools:** 70 | **Meander Amplitude:**

Pool Depth (m) (BF): 1.6 | 1.30 | 0.60 | 0.61

Riffle Length (m): 3-4 | **Undercuts (m):** 6.33

Velocity (m/s): Not measured.

Wiffle ball / ADV / Estimated

Bank Angle
- ☐ 0 – 30
- ☑ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☐ < 5%
- ☑ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments: overbank + bar deposits common

Notes:

Completed by: ER | Checked by: AD

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 1
Weather:	33°C Sun/clouds	Location:	Feedmill Creek
Field Staff:	AD, ER	Watershed/Subwatershed:	Canoe River

Process	No.	Geomorphic Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	4/7
	2	Coarse materials in riffles embedded	✓		
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone	✓		
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		✓	1/8
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		✓	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms	✓		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	1	7	0.125
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		2/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	2	5	0.29
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.25

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: AD, ER Checked by: _____

Rapid Stream Assessment Technique **Project Number:** PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 1
Weather:	Sunclouds 33°C	Location:	Feedmill Creek
Field Staff:	AD ER	Watershed/Subwatershed:	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☒ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☒ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☒ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☒ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 27

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			27	

Completed by: AD, ER Checked by: _____

General Site Characteristics

Project Code/Phase: PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 2
Weather:	Sun/clouds 33°C	Location:	Feedmill Creek
Field Staff:	AD, ER	Watershed/Subwatershed:	Carp River

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Island/bar
- Eroded bank
- Undercut bank
- XXXXXX Rip rap/stabilization
- Instream log/tree
- Fence
- Culvert
- Swamp
- Grasses
- Tree

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

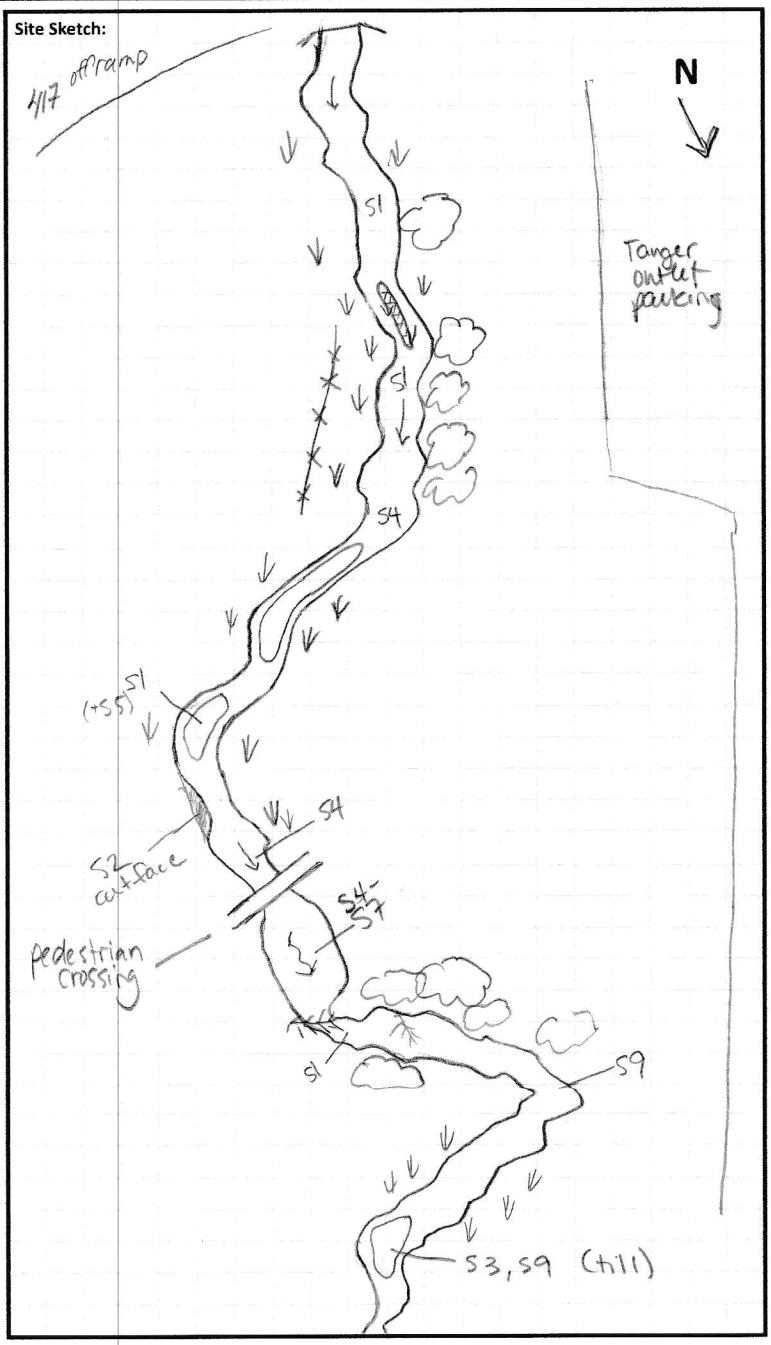
Substrate

S1	Silt
S2	Sand
S3	Gravel
S4	Small cobble
S5	Large cobble
S6	Small boulder
S7	Large boulder
S8	Bimodal
S9	Bedrock/till

Other

BM	Benchmark	TR	Terrace
FC	Flood chute	BOS	Bottom of slope
FP	Floodplain	TOS	Top of slope
GC	Grade control	VWC	Valley wall contact
KP	Knick point	WDJ	Woody debris jam

Site Sketch:



Additional notes: undercut along entire reach

till exposed on bed extensively, esp through d/s end of reach

GEO MORPHIX Geomorphology Earth Science Observations

Completed by: ER Checked by: AD

Reach Characteristics

GEO MORPHIX — Geomorphology Earth Science Observations

Project Code/Phase: phl16059

Date:	July 5, 2016	**Stream/Reach:**	Reach 2
Weather:	sun/clouds 33°C	**Location:**	Feedmill Creek
Field staff:	AD, ER	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)	426581.47 mE, 5016248.45 mN	**UTM (Downstream)**	426 642.13 mE, 5016410.23 mN

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 13 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 2/3
Species: Unknown

Coverage:
- ☐ None
- ☑ Fragmented
- ☐ Continuous

Channel widths
- ☐ 1-4
- ☑ 4-10
- ☐ > 10

Age Class (yrs) :
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1/6 | Coverage of Reach (%): 15

Woody Debris
- ☐ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 1/2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☐	☑	☐	☑	☐
Pool Substrate	☑	☐	☐	☐	☐	☑	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

	Pool	Pool		Pool	Pool	
Bankfull Width (m)	3.0	2.65		**Wetted Width (m)**	2.30	2.20	
Bankfull Depth (m)	1.05	1.05		**Wetted Depth (m)**	6.50	6.48	

Riffle/Pool Spacing (m): 50 | **% Riffles:** 20 | **% Pools:** 80 | **Meander Amplitude:**

Pool Depth (m): 0.50 | **Riffle Length (m):** 3.4 | **Undercuts (m):** 6.30, 6.25 | **Comments:**

Velocity (m/s): Not measured | **Wiffle ball / ADV / Estimated**

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☐ < 5%
- ☑ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes:

Completed by: ER | Checked by: AD

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Rapid Geomorphic Assessment

Project Code/Phase: PN160594

Date:	July 5, 2016	Stream/Reach:	Reach 2
Weather:	Sun, clouds 33°C	Location:	Feedmill Creek
Field Staff:	AD, ER	Watershed/Subwatershed:	Carp River

Process	No.	Geomorphic Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	3/4
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone	✓		
		Sum of indices =	3	4	0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	2/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		N/A	
	6	Cut face on bar forms	✓		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock (till)	✓		
		Sum of indices =	2	3	0.40
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		2/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	2	5	0.29
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.28

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: AD, ER Checked by: _____

Rapid Stream Assessment Technique **Project Number:** PN 160059

Date:	July 5, 2016	Stream/Reach:	Reach 2
Weather:	Sun/clouds 33C	Location:	Feedmill Creek
Field Staff:	ADER	Watershed/Subwatershed:	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☒ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☒ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 29

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			29	

Completed by: AD, ER Checked by: _____

General Site Characteristics

Project Code/Phase: PIV 160059

Date:	July 5, 2016	Stream/Reach:	Reach 3
Weather:	mainly sunny 33°C	Location:	Feedmill Creek
Field Staff:	AD/ER	Watershed/Subwatershed:	Carp River

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Island/bar
- Eroded bank
- Undercut bank
- XXXXXX Rip rap/stabilization
- Instream log/tree
- Fence
- Culvert
- Swamp
- Grasses
- Tree

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

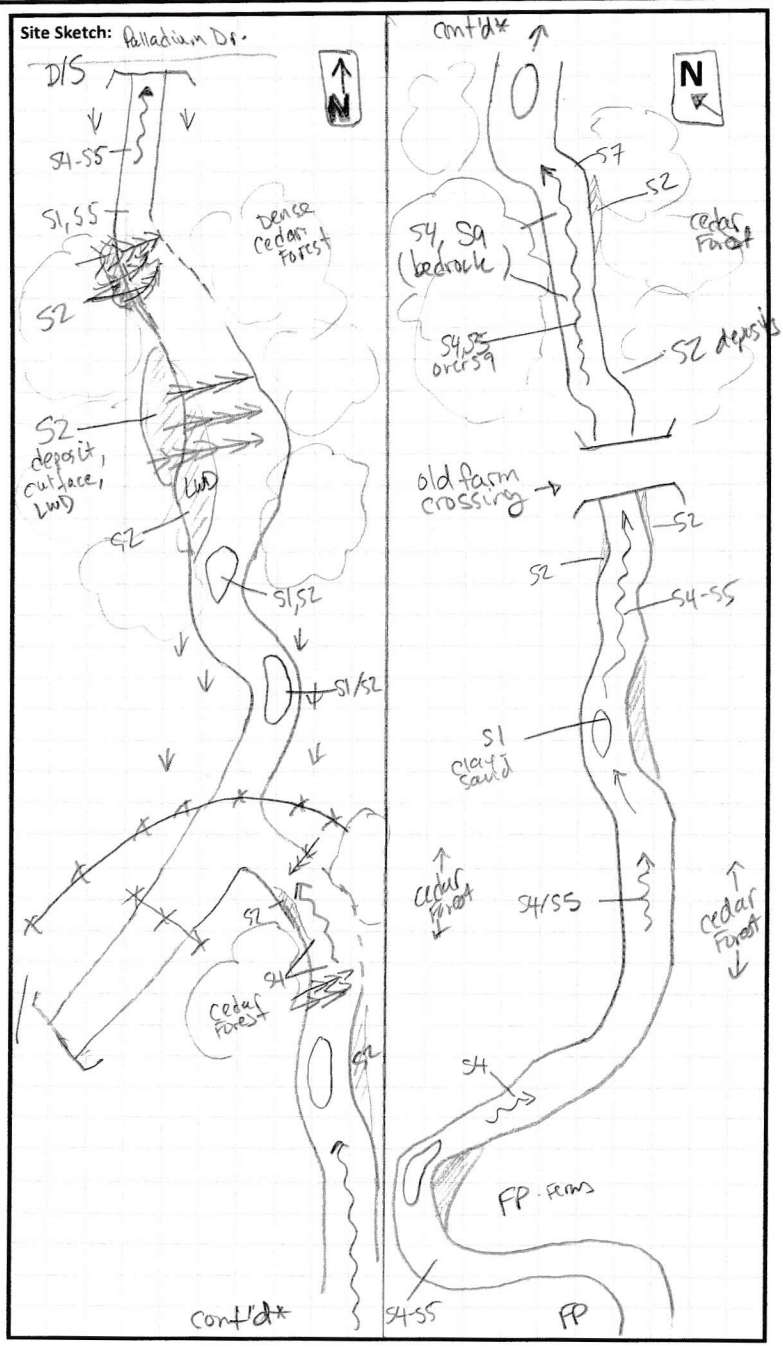
Substrate

S1	Silt
S2	Sand
S3	Gravel
S4	Small cobble
S5	Large cobble
S6	Small boulder
S7	Large boulder
S8	Bimodal
S9	Bedrock/till

Other

BM	Benchmark	TR	Terrace
FC	Flood chute	BOS	Bottom of slope
FP	Floodplain	TOS	Top of slope
GC	Grade control	VWC	Valley wall contact
KP	Knick point	WDJ	Woody debris jam

Site Sketch: Palladium Dr.



Additional notes:

GEO MORPHIX

Completed by: AD/ER Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: pn16059

Date:	July 5, 2016	**Stream/Reach:**	Reach 3
Weather:	mainly Sunny 33°C	**Location:**	Feedmill Creek
Field staff:	AD/ER	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)	426100.42 mE, 5015886.35 mN	**UTM (Downstream)**	426344 mE, 5016093.89 mN

Land Use (Table 1): 1/4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 13 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1
Species: cedar

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☐ 1-4
- ☐ 4-10
- ☒ > 10

Age Class (yrs) :
- ☐ Immature (<5)
- ☐ Established (5-30)
- ☒ Mature (>30)

Encroachment: (Table 7): 1

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 10

Woody Debris
- ☒ Present in Cutbank
- ☒ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☒ Moderate
- ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 1 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☑	☑	☐	☑	☐
Pool Substrate	☑	☑	☐	☑	☐	☐	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

	POOL	RIFF	RUN
Bankfull Width (m)	5.4	3.8	4.0
Bankfull Depth (m)	1.25	0.52	0.64
Wetted Width (m)	2.80	2.5	2.13
Wetted Depth (m)	0.60	0.11	0.19

Riffle/Pool Spacing (m): 20-30 | **% Riffles:** 70 | **% Pools:** 30 | **Meander Amplitude:** 15

Pool Depth (m): | **Riffle Length (m):** 15/20 | **Undercuts (m):** 0.20, 0.50

Velocity (m/s): | | | **Wiffle ball / ADV / Estimated**

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☑ 30 – 60%
- ☐ 60 – 100%

Comments:

Notes:

Completed by: ER | Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: PN 160559

Date:	July 5, 2016	Stream/Reach:	Reach 3
Weather:	Sun/clouds 33°C	Location:	Feedmill Creek
Field Staff:	AD, ER	Watershed/Subwatershed:	Carp River

Process	No.	Geomorphic Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	3/7
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone	✓		
		Sum of indices =	3	4	0.43
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N	A	2/6
	2	Exposed sanitary / storm sewer / pipeline / etc.	N	A	
	3	Elevated storm sewer outfall(s)	N	A	
	4	Undermined gabion baskets / concrete aprons / etc.	N	A	
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms	✓		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock	✓		
		Sum of indices =	2	4	0.33
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		3/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.	N/A		
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation	N/A		
		Sum of indices =	3	4	0.43
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.30

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: AD/ER Checked by: _____

Rapid Stream Assessment Technique **Project Number:** PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 3
Weather:	Sun/clouds 33°C	Location:	Feedmill Creek
Field Staff:	ADER	Watershed/Subwatershed:	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☑ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☑ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☑ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☑ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☑ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 34

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			34	

Completed by: AD/ER Checked by: _____

General Site Characteristics

Project Code/Phase: PN 16059

Date:	July 5 2016	Stream/Reach:	Reach 4
Weather:	Sun/clouds 33°C	Location:	Feedmill Creek
Field Staff:	AD EJR	Watershed/Subwatershed:	Carp River

Features

	Reach break
×——×	Cross-section
——→	Flow direction
~→	Riffle
⬭	Pool
⬭	Island/bar
//////////	Eroded bank
- - - - -	Undercut bank
XXXXXX	Rip rap/stabilization
⇝	Instream log/tree
×···×···×	Fence
⌊⌋	Culvert
⬭	Swamp
ѰѰѰ	Grasses
⬭	Tree

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

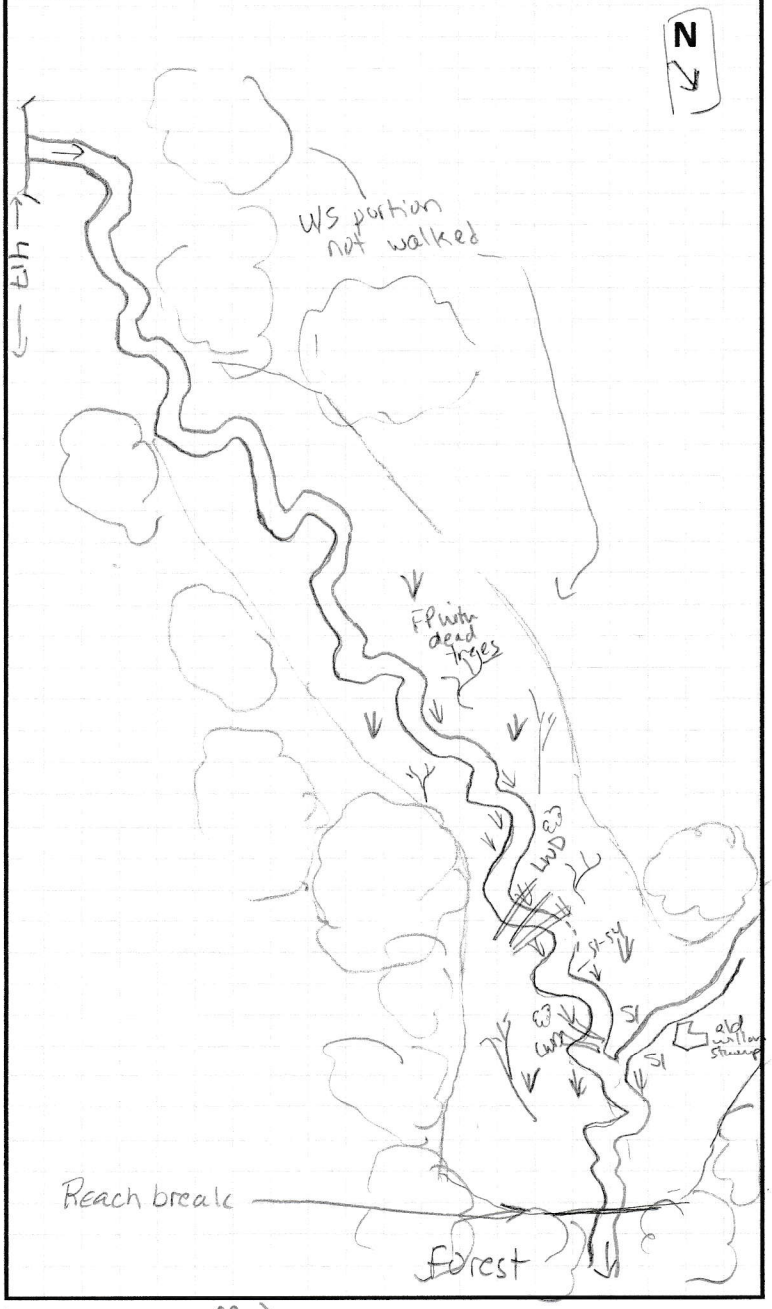
Substrate

S1	Silt
S2	Sand
S3	Gravel
S4	Small cobble
S5	Large cobble
S6	Small boulder
S7	Large boulder
S8	Bimodal
S9	Bedrock/till

Other

BM	Benchmark	**TR**	Terrace
FC	Flood chute	**BOS**	Bottom of slope
FP	Floodplain	**TOS**	Top of slope
GC	Grade control	**VWC**	Valley wall contact
KP	Knick point	**WDJ**	Woody debris jam

Site Sketch:



Additional notes: Tributary almost dry (some cut off)
Floodplain occupied by grasses, few shrubs and dead trees - Former Beaver dam d/s end of reach likely cause. Cedar fence d/s of reach and outside FP. U/S extent not observed.

GEO MORPHIX

Completed by: AD Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PN 16059

Date:	June 5, 2016	**Stream/Reach:**	Reach 4
Weather:	Sun/clouds 33°C	**Location:**	Feedmill Creek
Field staff:	AD, ER	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)	425995.12mE, 5015614.83mN	**UTM (Downstream)**	426100.42mE, 5015886.35mN

Land Use (Table 1): 1/4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 3
Species: _____
dead trees – none alive

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths
- ☐ 1-4
- ☑ 4-10
- ☐ > 10

Age Class (yrs) :
- ☑ Immature (<5)
- ☐ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 5

Woody Debris
- ☑ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☑ Moderate
- ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 1

Sinuosity (Degree) (Table 10): 2

Gradient (Table 11): 1/2

Number of Channels (Table 12): 1

Entrenchment (Table 13): 1

Type of Bank Failure (Table 14): 2

Downs's Classification (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☑	☐	☐	☐	☐	☐	☐
Pool Substrate	☑	☑	☐	☐	☐	☐	☐
Bank Material	☑	☐	☐	☐	☐	☐	☐

	RUN	POOL			RUN	POOL	
Bankfull Width (m)	2.35	2.10		**Wetted Width (m)**	1.70	1.78	
Bankfull Depth (m)	0.83	0.92		**Wetted Depth (m)**	0.29	0.18	

Riffle/Pool Spacing (m): | **% Riffles:** 10 | **% Pools:** 90 | **Meander Amplitude:**

Pool Depth (m): | **Riffle Length (m):** 4 | **Undercuts (m):** 6.05, 0.26

Velocity (m/s): not measured | **Wiffle ball / ADV / Estimated** 0.33

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☐ < 5%
- ☑ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments: beaver chewed wood
geomorph units not as present

Notes:
Stream flowing

Completed by: ER | Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: AV160S9

Date:	July 5, 2016	Stream/Reach:	Reach 4
Weather:	Sun/clouds 33C	Location:	Feedmill Creek
Field Staff:	AD, ER	Watershed/Subwatershed:	Carp River

Process	No.	Geomorphic Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	2/6
	2	Coarse materials in riffles embedded		N/A	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone		✓	
		Sum of indices =	2	4	0.33
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	9/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		N/A	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		3/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	3	4	0.43
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.19

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: AD/ER Checked by: _____

Rapid Stream Assessment Technique **Project Number:** PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 4
Weather:	Sun/clouds 33°C	Location:	Feedmill creek
Field Staff:	AO, ER	Watershed/Subwatershed:	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☒ 10 ☐ 11

Channel Scouring/ Sediment Deposition	NA • > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
NA	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☒ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☒ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 27

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			27	

Completed by: AD/ER Checked by: _____

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☒ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☒ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 27

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			27	

Completed by: MD/ER Checked by: _____

General Site Characteristics

Project Code/Phase: PN160059

Date:	July 5, 2016	Stream/Reach:	Reach 5
Weather:	Sunny 33°C	Location:	Feedmill Creek
Field Staff:	AD ER	Watershed/Subwatershed:	Carp River

Features

	Reach break
×——×	Cross-section
——→	Flow direction
~~→	Riffle
	Pool
	Island/bar
//////////	Eroded bank
- - - - -	Undercut bank
XXXXXX	Rip rap/stabilization
	Instream log/tree
×···×···×	Fence
	Culvert
	Swamp
	Grasses
	Tree

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

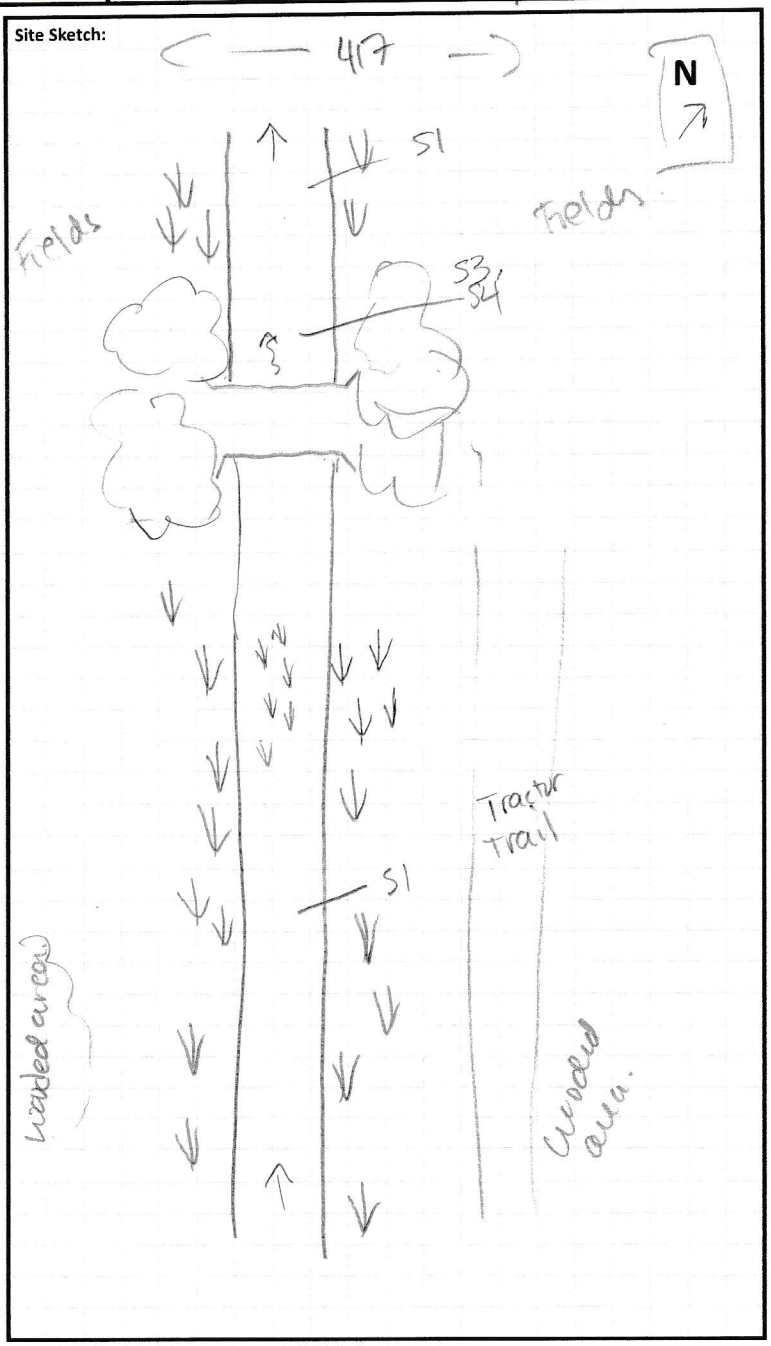
Substrate

S1	Silt
S2	Sand
S3	Gravel
S4	Small cobble
S5	Large cobble
S6	Small boulder
S7	Large boulder
S8	Bimodal
S9	Bedrock/till

Other

BM	Benchmark	**TR**	Terrace
FC	Flood chute	**BOS**	Bottom of slope
FP	Floodplain	**TOS**	Top of slope
GC	Grade control	**VWC**	Valley wall contact
KP	Knick point	**WDJ**	Woody debris jam

Site Sketch:



Additional notes: straightened channel

more encroachment than d/s reaches

GEO MORPHIX

Completed by: AD, ER Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: pnt6059

Date:	July 5, 2016	**Stream/Reach:**	Reach 5
Weather:	mainly sunny, 33°C	**Location:**	Feedmill Creek
Field staff:	AD ER	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)	426383.46mE, 5015021.22mN	**UTM (Downstream)**	425980.34 mE, 5015484.58 mN

Land Use (Table 1): 2/4 | **Valley Type** (Table 2): 1 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 3
Species: mixed/unknown

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☐ 1-4
- ☒ 4-10
- ☐ > 10

Age Class (yrs) :
- ☒ Immature (<5)
- ☐ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 50

Woody Debris
- ☐ Present in Cutbank
- ☐ Present in Channel
- ☑ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): /

Sinuosity (Degree) (Table 10): 1

Gradient (Table 11): 1

Number of Channels (Table 12): 1

Entrenchment (Table 13): 1

Type of Bank Failure (Table 14): 2

Downs's Classification (Table 15): d

	Clay/Silt	Sand (coarse)	Gravel (fine)	Cobble	Boulder	Parent	Rootlets
Riffle Substrate (RUN)	☑	☑	☑	☑	☐	☐	☑
~~Pool~~ Substrate	☑	☑	☑	☐	☐	☐	☑
Bank Material	☑	☐	☐	☐	☐	☐	☑

	RUN	RUN	RUN		RUN	RUN	RUN
Bankfull Width (m)	2.0	2.40	2.50	**Wetted Width (m)**	1.6	1.80	1.65
Bankfull Depth (m)	0.54	0.61	0.42	**Wetted Depth (m)**	0.17	0.28	0.27

Riffle/Pool Spacing (m): N/A | **% Riffles:** 5 | **% Pools:** (RUN) 95 | **Meander Amplitude:**

Pool Depth (m) wetted not BF: 0.28 | **Riffle Length (m)** | **Undercuts (m)** 0.12,

Velocity (m/s) Not measured | **Wiffle ball / ADV / Estimated**

Bank Angle
- ☐ 0 – 30
- ☐ 30 – 60
- ☑ 60 – 90
- ☑ Undercut

Bank Erosion
- ☑ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Comments:
- all runs (one small riffle)
- embedded

Notes:
- straightened
- flowing

Completed by: ER | Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: PN 16059

Date:	July 5, 2016	Stream/Reach:	Reach 5
Weather:	Mainly Sunny 33°C	Location:	Feedmill Creek
Field Staff:	AO, ER	Watershed/Subwatershed:	Carp River

Process	No.	Geomorphic Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	4/7
	2	Coarse materials in riffles embedded	✓		
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone	✓		
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/8
	2	Exposed sanitary / storm sewer / pipeline / etc.		✓	
	3	Elevated storm sewer outfall(s)		✓	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	8	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	1/6
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		NA	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		NA	
		Sum of indices =	1	6	0.17
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.19

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: AO/ER Checked by: _____

Rapid Stream Assessment Technique

Project Number: PN 160 59

Date:	July 5 2016	Stream/Reach:	Reach 5
Weather:	Sunny 33°C	Location:	Feedmill Creek
Field Staff:	ADER.	Watershed/Subwatershed:	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9 m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☒ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition: > 81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition: 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition: 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition: < 30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☒ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high percentage of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ≤ ; ≥ 1.51:1	• Riffle/Pool ratio 0.5-0.69:1; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
NA	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☒ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15 m below surface	• Objects visible to depth 0.15-0.5 m below surface	• Objects visible to depth 0.5-1.0 m below surface	• Objects visible to depth > 1.0 m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8

Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: > 80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Additional notes:

Total overall score (0 - 42) = 23

Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			23	

Completed by: AO/ER Checked by: _____

Appendix D
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Project Number:	PN16059	**Date:**	July 6, 2016
Client:	DSEL	**Length Surveyed (m):**	104.1
Location:	Feedmill Creek	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Cedar forest
Geology/Soils:	Glaciolacustrine	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Industrial/forest	**Width of Riparian Cover:**	> 10 channel widths
Valley Type:	Partially confined	**Age Class of Riparian Vegetation:**	Mature (>30 years)
Dominant Instream Vegetation Type:	Rooted submergent	**Extent of Encroachment into Channel:**	No encroachment
Portion of Reach with Vegetation:	10%	**Density of Woody Debris:**	Moderate

Hydrology

Measured Discharge (m^3/s):	#DIV/0!	**Calculated Bankfull Discharge (m^3/s):**	1.64
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	1.05
Modelled 2-year Velocity (m/s):	Not modelled		

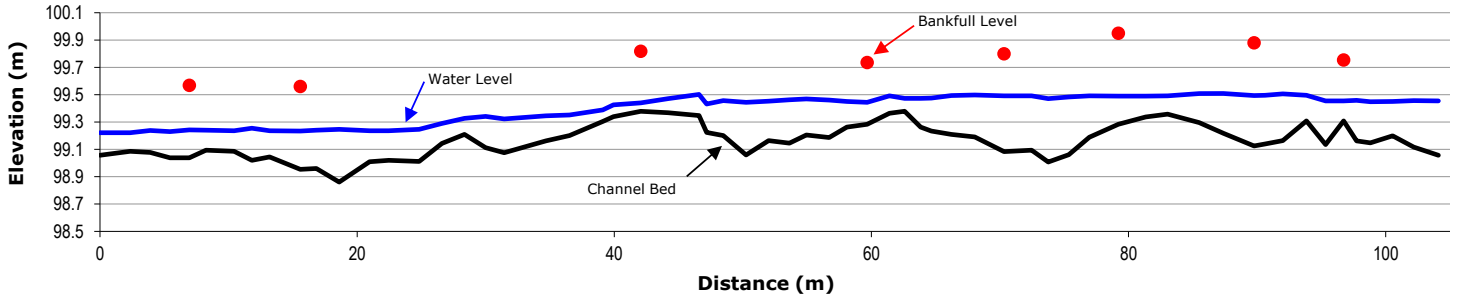
Profile Characteristics

Bankfull Gradient (%):	0.33
Channel Bed Gradient (%):	0.17
Riffle Gradient (%):	2.63
Riffle Length (m):	8.13
Riffle-Pool Spacing (m):	17.54

Planform Characteristics

Sinuosity:	1.83
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.25	0.65	0.38
Bank Angle (deg):	30	90	65
Root Depth (m):	0.05	0.30	0.18
Root Density (%):	4	35	17
Bank Undercut (m):	0.00	0.28	0.04

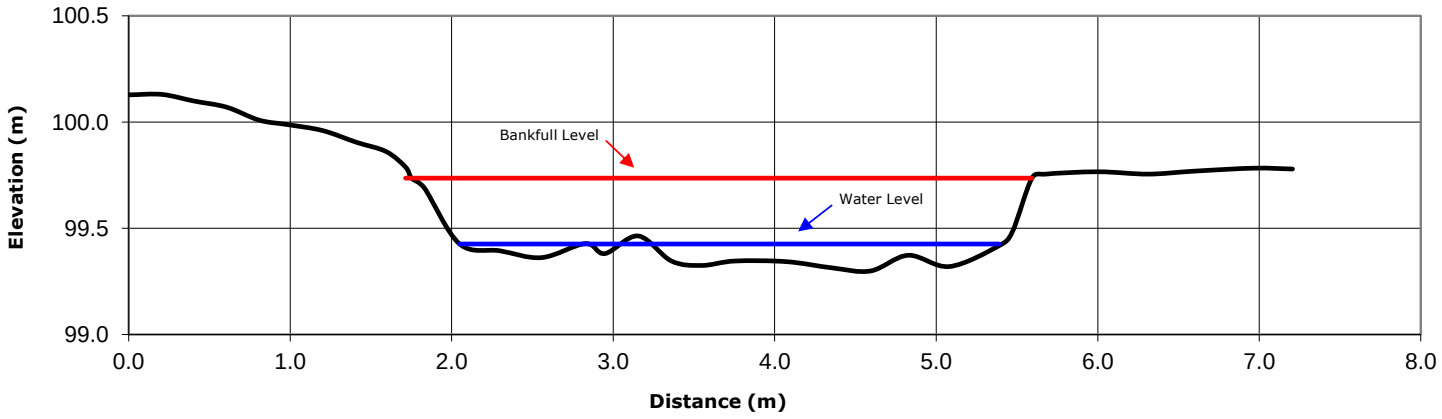
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay to sand	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.33	4.69	3.79
Average Bankfull Depth (m):	0.32	0.54	0.41
Bankfull Width/Depth (m/m):	6	13	10
Wetted Width (m):	2.05	3.34	2.59
Average Water Depth (m):	0.06	0.32	0.15
Wetted Width/Depth (m/m):	6	52	24
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.08	0.40	0.22
Manning's *n*:		0.030	

Photograph at cross section 4 (looking downstream)

Representative Cross-Section # 4



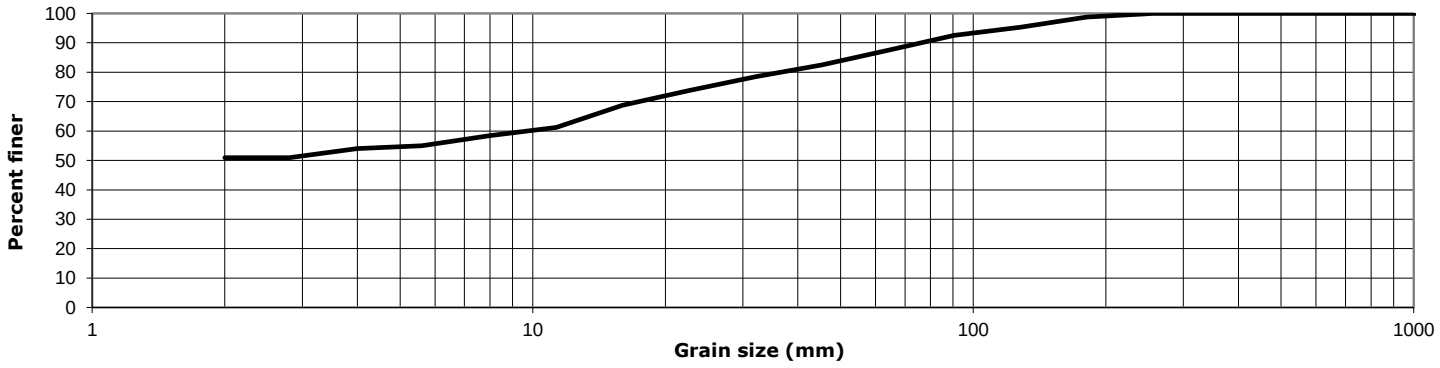
Substrate Characteristics

Particle Size (mm)

D_{10} :	<2
D_{50} :	<2
D_{84} :	50.8

Subpavement:	Gravel, cobble
Particle shape:	Subangular
Embeddedness (%):	10 - 100%
Particle range (riffle):	Sand to cobble
Particle Range (pool):	Clay to cobble

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	13.24
for D_{50}:	N/A	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	1.20	**Critical Shear Stress (D_{50}) (N/m^2):**	N/A
Unit Stream Power at Bankfull (W/m^2):	13.96		

General Field Observations

Channel Description

Reach 3 follows a meandering path within a continuous cedar forest. The reach is partially confined, has a moderate gradient and a meander amplitude of approximately 15 m. Riffles and pools are well-developed. Some riffles within the reach but outside of the surveyed extent were much longer than those surveyed. Bed substrate ranged from clay to large cobbles. Sand deposits were noted on meander bends. Bank angles ranged from 60 to 90° with undercuts up to 0.5 m but typically in the range of 0.20 m. Bank erosion was 30-60%. Most banks were well supported by both fine and large woody root matrix. Woody debris was frequently encountered in the channel.

Cross Section 6 - Looking Downstream