APPENDIX C6

Geomorphology

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APPENDIX C6.1

Upper East Patterson Creek Geomorphic Assessment

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Rizmi Property
City of Vaughan, Ontario

Upper East Patterson Creek
Geomorphic Assessment

Prepared for: Rizmi Holdings Limited
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Project No.: 15080

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1 Introduction

A Municipal Class Environment Assessment is proposed by the City of Vaughan to determine the preferred alternative to extend Kirby Road to Gamble Road in the Town of Richmond, between Dufferin and Bathurst Streets. The ultimate alignment of this arterial road will be determined with consideration to numerous factors as required in the Class EA process. One consideration is East Patterson Creek, which is addressed in this report.

The east tributary of Patterson Creek originates in a wetland located near the north part of the Rizmi Stone & Aggregates property at 11333 Dufferin Street in the community of Maple. A significant portion of channel within the property limits has apparently been modified in the past. The alterations, however, do not affect fish habitat due to a significant barrier to fish passage along the southern property line. The watercourse currently conveys flows to the south property line where it terminates in a wetland. The following report provides a geomorphic assessment of East Patterson Creek to fulfill a Class EA requirement to document natural heritage features, as well as to support the decision-making process with respect to actions that affect the watercourse.

It is understood that the future of the channel within the property has yet to be determined as it is not considered to be direct fish habitat. Potential outcomes include removal, retain in its current alignment, realignment, enhancement, or a combination of these alternatives. GEO Morphix will provide appropriate support once the preferred solution has been determined in the Class EA study.

2 Historical Conditions

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Historical aerial photographs from 1946 (scale 1:20,000) and 1954 (scale 1:63,360), and orthophotography from 1970, 1999, 2002, 2005, 2007, 2011, 2012 and 2013, and Google Earth Pro satellite imagery from 2015 were reviewed to complete the historical assessment.

In 1946, the upper East Patterson Creek drainage area was largely forested, with the exception of a clearing for agriculture at the upper extent of the drainage area. At the current location of the Rizmi Stone & Aggregates field operations, there was a clearing but no apparent activity. The drainage route within the subject property could not be identified due to tree cover, but there was an intermittently-forested corridor with a watercourse that extended in a southeasterly direction from the subject property towards Bathurst Street. The channel planform could not be determine on the aerial photography. Outside of the forested area to the north beyond the drainage area, the land was used exclusively for agriculture. The area beyond the property to the south was also used for agriculture.

There were no significant changes in land use through 1954. The surrounding land to the south, however, was transformed to a golf course, Maple Downs Golf Course. By 1970, Rizmi operations extended approximately 0.4 km to the east from the previously cleared area, as suggested by the heavily disturbed landscape and the access road connecting the disturbed area to Dufferin Street. Also between 1954 and 1970, the TransCanada Pipeline was constructed along the south property boundary and across the channel. The watercourse is visible along the east side of an internal road at the eastern end of the disturbed area, but the Pipeline clearly prevents flow conveyance

beyond the property as evidenced by the ponded water at the Pipeline crossing. The lack of tree cover along the section of channel along the internal road as well as its linear alignment also suggest that it was channelized to enhance drainage function. East of the Rizmi property along the north side of the Pipeline was a private runway.

Rizmi operations appeared to have slowed by 1999. The channel alignment was the same as it was in 1970, but the pond at the Pipeline had visual characteristics of a wetland. Another notable change within the property was a linear clearing through the forest leading to the general area of the channel origin, north of the cleared aggregate extraction area. There was also limited clearing on the east side of the internal road and channel, as well as a culvert in the channel next to this recently cleared area for access the east side. Southeast of the property, the land was developed for residential use.

Surrounding land use remained generally unchanged in 2011. Between 2007 and 2011, a portion of the channel within the Rizmi property was again realigned to travel along the margin of the cleared area. The previously installed culvert was removed due to the channel realignment, and a new culvert was constructed at the new channel crossing location. Activity within the property also appears to have increased during this period. There were no notable changes in 2012 and 2013.

Overall, the portion of East Patterson Creek within the Rizmi property experienced significant changes over the period covered by historical imagery. These changes include realignment and straightening (i.e., channelization), removal of tree cover, and the disruption of channel and flow continuity as a result of the TransCanada Pipeline.

3 Existing Conditions

3.1 Watershed Characteristics

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.

East Patterson Creek is situated in the Upper East Don Subwatershed. The channel within the property limits is a headwater feature that originates from a generally linear wetland feature located mostly within the property. In total, the channel travels in a southerly direction for approximately 6 km, where it joins West Patterson Creek, then continues for another 1.5 km to the confluence with the East Don River.

The subject site is located in a southward extending lobe of the Oak Ridges Moraine physiographic region, which is bounded by the South Slope physiographic region to the west, south and east. Beyond the South Slope is the Peel Plain (Chapman and Putnam, 1984), where Patterson Creek joins the East Don River. With respect to surficial geology, the subject area is characterized by ice-contact stratified deposits consisting of sand and gravel, minor silt, clay and till (OGS, 2010). The surficial geology generally changes in the downstream direction in concert with the physiographic regions: the South Slope is comprised of clay to silt-textured till (derived from glaciolacustrine deposits or shale) and the Peel Plain is generally characterized by glaciolacustrine deposits (OGS, 2010). The predominantly sand and gravel composition of the surficial material

allows the channel to readily adjust, although the degree of adjustment would also be influenced by the flow regime as well as other factors such as vegetation control.

The catchment area for the channel within the subject property is largely forested with the exception of the area cleared for the Rizmi Stone & Aggregates operations. Downstream of the property to Bathurst Street, the channel travels through a forested corridor surrounded by low-density residential dwellings. The forested channel corridor continues beyond Bathurst Street, although housing density increases.

3.2 Reach Delineation

Rivers and streams are frequently segmented into reaches to provide meaningful lengths of channel for study. Reaches are delineated based on changes such as hydrology, channel gradient, confinement, planform (i.e., channel pattern), geology, surrounding land use and anthropogenic disturbances (e.g., crossing structures, dams, straightening/channelization, armouring). Each reach can then be studied as a unit that is expected to function in generally uniform manner throughout its length.

Within the Rizmi property, East Patterson Creek was divided into three reaches. The downstream channel reach (EPC-1) is approximately 100 m in length, the middle reach (EPC-2) is 130 m, and the upstream reach (EPC-3) is 200 m. Forest cover was one consideration when delineating the reaches: the Reach EPC-1 channel lies just within the west forest margin, while Reaches EPC-2 and EPC-3 are just outside the west forest margin. Despite the apparently limited differences between reaches, tree cover is a significant factor that governs channel form and function, and hence the two reaches. Reaches EPC-2 and EPC-3 are differentiated primarily by channel morphology. Wetland features are located downstream of Reach EPC-1 and upstream of Reach EPC-2. The reach delineation was verified in the field, as discussed below.

3.3 Reach Assessments

Site observations and channel measurements were collected on November 2, 2015. The field investigation was completed for the full length of channel between the wetland at the upstream extent of the channel and the south property limit. A photographic record of site conditions is provided in Appendix A. On the day of the site visit, the temperature was 10°C and there was no precipitation. There was, however, 7 mm of rain from October 31 to November 1.

3.3.1 General Observations

Within the Rizmi property, East Patterson Creek originates in a wetland feature located in a forested area to the north just beyond an open, disturbed area created by site activities. The channel travels along the perimeter of the clearing before entering the forested area. It continues just within the forest boundary to a wetland feature at the south limit of the property. The reaches identified in Section 3.2 were confirmed to be correct. The following is a description of each reach from upstream to downstream.

The wetland at the upstream end of the section of channel under study is comprised of a dense thicket of shrubs (red-osier dogwood). There was no define flow pattern within the wetland.

Reach EPC-3 is in a constructed valley feature containing a low-flow channel. The valley had a 'V' shape except towards the downstream end of the reach. The channel had no bankfull indicators

and there was limited evidence of a stable channel morphology. The bed was composed of mostly silt and sand, and its morphology was partly controlled by vegetation. Three knickpoints were observed, which suggests that the channel gradient is high relative to those of the two downstream reaches. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the wetland contributed to total flow. Wetted flow width varied due to the high degree of channel confinement, ranging from 0.1 to 1.5 m. The channel characteristics were largely governed by the composition of the valley materials, which was sand. The northeast embankment (left embankment viewed in the downstream direction) was comprised of exposed sand with limited woody vegetation. Due to the unstable nature of the embankments, in particular that to the northeast, the channel will likely continue to adjust according to the sediment supply. Mature trees lied beyond the sandy embankment. The southwest side of the channel was open with primarily grasses.

Reaches EPC-3 and EPC-2 were divided by a partly embedded 1200 mm CSP culvert, constructed for access across the channel. Reach EPC-2 continues as a constructed valley feature, but with appreciably different physical characteristics. Here, the valley top width was roughly 3.9 m wide and the valley depth was 1.5 to 2.0 m. The east side of the valley was populated by mature trees, while the east side was dominated by grasses within an open (i.e., cleared) area.

The Reach EPC-2 channel likely formed naturally following valley excavation. The low-flow channel is considered to be the bankfull channel, although it still may be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. There was a 0.22 m high knickpoint mid-reach that cut into till. Upstream of the knickpoint, the bed was characterized by sand, gravel and small cobbles, while downstream of the knickpoint, the bed was comprised of mostly sand, but also exposed till. This longitudinal change in bed characteristics can be explained by differences in bed gradient.

At the downstream end of Reach EPC-2, the channel turns at nearly a right angle to travel south into Reach EPC-1. There was evidence of the former channel location (before the realignment of Reaches EPC-3 and EPC-2), in the form of a linear depression across the cleared area, that aligned with Reach EPC-1. Although the former channel was decommissioned, surface runoff apparently continued to enter the Reach EPC-1 channel at the upstream end of this reach as indicated by the minor erosion and headcutting.

Reach EPC-1 travels in a southerly direction and continues as a constructed valley feature approximately 5 m wide and just over 1 m deep. Both sides of the valley was vegetated with mature trees; however, the woody riparian buffer on the west side was limited. Tree cover over the channel was dense, and there were frequent observations of woody debris within the constructed valley, mostly as broken individual tree limbs that did not significantly affect flow pattern. The low-flow channel had no riffle-pool development, and averaged 1.90 m wide and 0.15 m deep. The increase in width-to-depth ratio, relative to that of Reach EPC-2, can be explained by the decrease in channel gradient and the increase in discharge. Both the bed and banks were comprised of sand, which would be expected due to the lower gradient and the typical downstream fining found in natural watercourses.

At the downstream end of the Reach EPC-1 channel was a wetland feature. This wetland was contained in a basin (roughly 70 wide and 50 m wide) that was bounded in the downstream (south) end by a raised natural gas pipeline corridor (i.e., TransCanada Pipeline), which was essentially a large berm. The top of the Pipeline was approximately 1.5 to 2.0 m above the wetland bed, and therefore a considerable volume of water would be required for flows to spill

over the Pipeline corridor. There was no evidence of a flow path over the Pipeline, although it would clearly be located across the lowest point. The impact of the lack of surface flow continuity to the watercourse downstream (south) of the Pipeline corridor could not be assessed due to property constraints.

3.3.2 Rapid Field Assessments

Rapid field assessments were completed as reconnaissance-level evaluations to determine the condition of each reach with respect to channel stability and general stream health:

- Channel instability was semi-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.

A summary of the rapid assessments is provided in Table 1. Completed field sheets are found in Appendix B.

Table 1: Rapid field assessment summary

Reach	RGA*			RSAT**		
	Score	Condition	Dominant Form of Adjustment	Score	Condition	Limiting Feature(s)
EPC-1	0.11	In regime	Aggradation	26	Good	Physical instream habitat
EPC-2	0.12	In regime	Degradation	28	Good	Riparian habitat conditions
EPC-3	0.09	In regime	Degradation	22	Fair	Riparian habitat conditions

* Ontario Ministry of the Environment (2003)
** Galli (1996)

3.3.3 Detailed Geomorphic Assessment

Within the property limits, Reach EPC-1 was determined to be relatively natural and certainly the most aged since realignment. As such, this reach was selected for further investigation – i.e., detailed geomorphic assessment. This detailed assessment serves as the basis for any required channel modifications such as realignment or stabilization.

The detailed assessment involved temporarily setting up eight representative cross sections for the purpose of determining average bankfull channel dimensions (e.g., width, average bankfull depth, maximum depth, and bank angles). The bankfull level was determined using standard protocols and accepted field indicators. A survey of the bed profile was also completed to determine slope and compute bankfull hydraulics. A modified Wolman (1954) pebble count was completed to characterize the bed materials. A summary of measured and computed values is presented in Table 2.

Table 2: Bankfull parameters of the reference channel

Channel parameter	Results
Measured	
Average bankfull channel width (m)	1.89
Average bankfull channel depth (m)	0.15
Average width-to-depth ratio	14.7
Channel gradient (%)	0.42
D_{50} (mm)	<2
D_{84} (mm)	<2
Manning's n roughness coefficient	0.034
Computed	
Bankfull channel discharge (m^3/s) *	0.14
Average bankfull velocity (m/s)	0.53
Unit stream power at bankfull discharge (W/m^2)	3.2
Tractive force at bankfull (N/m^2)	5.98
Critical shear stress (N/m^2) **	1.46
Flow competency for D_{50} (m/s) ***	0.27
Flow competency for D_{84} (m/s) ***	0.27

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

The Reach EPC-1 reference channel has a lower width-to-depth ratio than the two upstream reaches due to the lower channel gradient. Despite the relatively low unit stream power, the bed (comprised of sand) is fully mobile under bankfull flow conditions. It is expected that the Reach EPC-1 channel length would decrease slowly over time as the bed material is transported and deposited in the wetland. The receiving wetland would consequently increase in size, but only in the upstream direction due to the raised pipeline crossing.

4 Conclusions

East Patterson Creek within the Rizmi property has been significantly altered, and impacted both directly and indirectly, over the period covered by historical imagery. It also no longer functions

as potential fish habitat as a result of the construction of the TransCanada Pipeline. In-channel flows now therefore infiltrate and contribute to groundwater.

If the preferred alternative solution, resulting from the Class EA study, is assessed to be restoration, realignment or enhancement, we would be pleased to provide design services. Concurrently or independently, we can also investigate potential hazards associated with a dynamic channel.

5 References

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Miller, M.C., McCave, I.N., and Komar, P.D. 1977. Threshold of sediment motion under unidirectional currents. Sedimentology, 24: 507-528.

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Appendix A
Photographic Record of Site Conditions

Photo 1	
	EPC-3: Near upstream extent of reach, viewed upstream. The channel was confined by sandy valley wall to the east and a vegetated valley wall to the west.
Photo 2	
	EPC-3: Mid-reach viewed upstream at a knickpoint.

Photo 3	
	EPC-3: Reach viewed upstream from downstream end of reach.
Photo 4	
	1200 mm CSP culvert between Reaches EPC-2 and 3.

Photo 5	
	ECP-2: Channel viewed in the downstream direction. Coarse substrate was found mostly in the upstream portion of the reach. Note the channel confinement.
Photo 6	
	EPC-2: Mid-reach knickpoint in exposed till.

Photo 7	
	EPC-2: Channel viewed in the downstream direction towards end of reach.
Photo 8	
	EPC-1: Mid-reach channel viewed in the downstream direction. Note the limited channel definition and lack of morphological variability, and confinement between valley walls.

Photo 9	
	ECP-1: Channel viewed downstream towards downstream end of reach. Note the absence of flow and limited channel definition.
Photo 10	
	EPC-1: Wetland at property line with raised pipeline in background (see fence line). No culvert was found.

Appendix B
Rapid Assessment Field Sheets

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Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-1
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St.
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

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

Riparian Vegetation

Dominant Type: (Table 6) 1
Species: ______

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): / | Coverage of Reach (%): /

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

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

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

see detailed assessment

Bankfull Width (m)				**Wetted Width (m)**			
Bankfull Depth (m)				**Wetted Depth (m)**			

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

Pool Depth (m): NA | **Riffle Length (m):** NA | **Undercuts (m):** None

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

Comments: No riffle - pools, poor BF indicators

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

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

Notes:

Completed by: CH   Checked by: ______

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code/Phase:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

Process	No.	Geomorphic Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	1/4
	2	Coarse materials in riffles embedded	NA		
	3	Siltation in pools	NA		
	4	Medial bars		✓	
	5	Accretion on point bars	NA		
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone		✓	
		Sum of indices =	1	3	0.25
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA		0/3
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA		
	3	Elevated storm sewer outfall(s)	NA		
	4	Undermined gabion baskets / concrete aprons / etc.	NA		
	5	Scour pools downstream of culverts / storm sewer outlets	NA		
	6	Cut face on bar forms	NA		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material	NA		
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	3	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	1/5
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	NA		
	5	Basal scour on both sides of channel through riffle	NA		
	6	Outflanked gabion baskets / concrete walls / etc.	NA		
	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	4	0.2
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/6
	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	NA		
		Sum of indices =	0	6	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.11			
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: CH Checked by: ________

Rapid Stream Assessment Technique **Project Number:** PK15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

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 NA
	• 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) NA
	• 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 N/A
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	NA
	• 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	NA
	• 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	NA
	• 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	NA
	• ~~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	NA
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) =				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			26	

Completed by: CL Checked by: ________

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Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-2
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | ☒ Groundwater | Evidence: iron staining

Riparian Vegetation

Dominant Type: (Table 6) 3
Species: ____

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 | Coverage of Reach (%): <5

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

Density of WD: ☐ Low ☐ Moderate ☐ High | WDJ/50m:

Water Quality

Odour (Table 16): 1
Turbidity (Table 17): 1

Channel Characteristics

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

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

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	☐	☒	☒	☒ small	☐	☒ till	☐
~~Pool Substrate~~	☐	☐	☐	☐	☐	☐	☐
Bank Material	☒ silt	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	1.3	1.0		**Wetted Width (m)**	0.3	0.25	
Bankfull Depth (m)	0.4	0.45		**Wetted Depth (m)**	0.1	0.15	

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

Pool Depth (m): NA | **Riffle Length (m):** NA | **Undercuts (m):** /

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

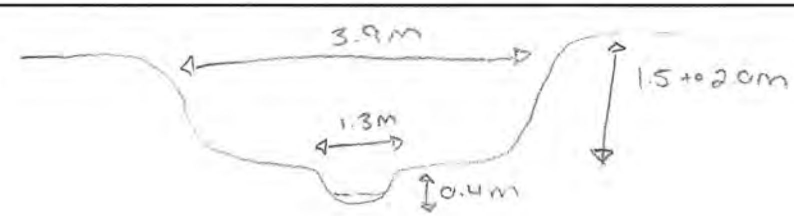
Comments: KP + exposed till
coarse bed material u/s of KP

Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☐ < 5% ☐ 5 – 30% ☒ 30 – 60% ☐ 60 – 100%

Notes:
CSP @ crossing = 1.2m

Valley feature



Completed by: CH Checked by: ________

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Rapid Geomorphic Assessment

Project Code/Phase: DN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	East Patterson

Process	No.	Geomorphic Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/5
	2	Coarse materials in riffles embedded	N/A		
	3	Siltation in pools	N/A		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	0	5	0.0
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.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N/A		
	5	Basal scour on both sides of channel through riffle	N/A		
	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 =	0	5	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/6
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form	N/A		
	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 =	1	5	0.17

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.13

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

Additional notes:

Completed by: KT/ER Checked by: ________

Rapid Stream Assessment Technique **Project Number:** DN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

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)	N/A
	• 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	

EPC-2
PN15080

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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	NA
	• 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	NA
	• 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	NA
	• 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 N/A
	• 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)
			✓	

Completed by: KT/ER Checked by: ________

Reach Characteristics

Project Code/Phase: PH15080

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Geomorphology Earth Science Observations

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-3
Weather:	sun + 10°C	**Location:**	Kirby Rd
Field staff:	CH / ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | ☒ Groundwater | Evidence: watercress

Riparian Vegetation

Dominant Type:	Coverage:	Channel widths	Age Class (yrs):	Encroachment:
(Table 6) ☐	☐ None	☐ 1-4	☐ Immature (<5)	(Table 7)
Species:	☐ Fragmented	☒ 4-10	☒ Established (5-30)	3
______	☒ Continuous	☐ > 10	☐ Mature (>30)	

Aquatic/Instream Vegetation

Type (Table8): 2 | Coverage of Reach (%): 40

Woody Debris	Density of WD:	
☐ Present in Cutbank	☐ Low	WDJ/50m: NA
☐ Present in Channel	☐ Moderate	
☒ Not Present	☐ High	

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

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

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

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	☐	☒	☒ some	☐	☐	☐	☐
~~Pool Substrate~~	☐	☐	☐	☐	☐	☐	☐
Bank Material	☐	☒	☐	☐	☐	☐	☒

Bankfull Width (m)	1.4			**Wetted Width (m)**	0.8		
Bankfull Depth (m)	0.35			**Wetted Depth (m)**	0.1		

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

Pool Depth (m) D/S of KP: 0.3 | **Riffle Length (m)**: NA | **Undercuts (m)**: /

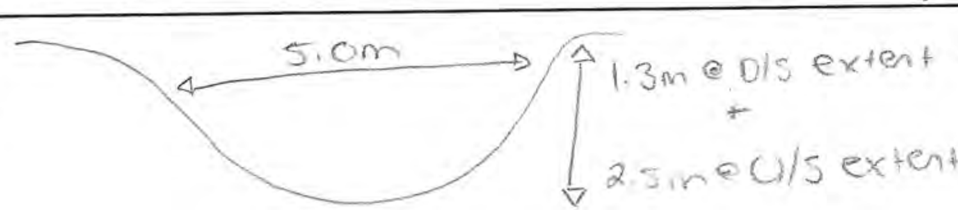
Velocity (m/s): / | / | / | **Wiffle ball / ADV / Estimated**

Bank Angle	Bank Erosion
☐ 0 – 30	☐ < 5%
☐ 30 – 60	☐ 5 – 30%
☒ 60 – 90	☐ 30 – 60%
☐ Undercut	☒ 60 – 100%

Comments: 3 knickpoints, no riffle - pool development

Notes: sandy VWC along LB; saplings in channel @ D/S extent; wetland u/s of VWC

valley feature



Completed by: CH

Checked by: ______

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Rapid Geomorphic Assessment **Project Code/Phase:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/7
	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 =	0	7	0.0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N	A	1/5
	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 =	1	4	0.20
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N	A	
	5	Basal scour on both sides of channel through riffle	N	A	
	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 =	0	5	0.0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	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 =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.09

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

Completed by: KI/ER Checked by: ________

Rapid Stream Assessment Technique **Project Number:** pn15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	East Patterson

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
N/A	• 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
N/A	• 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

EPC-3
PN 15080

GEO | MORPHIX

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) = 22				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
		✓		

Completed by: KT/ER Checked by: ________

APPENDIX C6.2

Planning Level Meander Belt Width Delineation, 100-Year Erosion Limits, and Preliminary Crossing Recommendations

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June 4, 2018

Schaeffers Consulting Engineers
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Attention: Mr. Leonid Groysman, Class EA Lead

Re: Planning Level Meander Belt Width Delineation, 100-Year Erosion Limits, and Preliminary Crossing Recommendations for the Kirby Road Extension Environmental Assessment
Upper East Patterson Creek, Vaughan, Ontario
GEO Morphix Project No. 15080

A geomorphological assessment was previously completed by GEO Morphix Ltd. (2016) for the Upper East Patterson Creek in the vicinity of the proposed Kirby Road Extension in Vaughan, Ontario. Our 2016 assessment involved both desktop and field activities including reach delineation, reach-by-reach rapid assessments, and a detailed geomorphological assessment.

Our understanding is that the Toronto and Region Conservation Authority (TRCA) has requested additional information including meander belt widths, 100-year erosion limits, and preliminary recommendations regarding the potential crossing location (Scott Smith, email dated May 3, 2018).

To address this request we completed additional desktop analysis to: supplement the findings of our original report; provide planning level meander belt widths; calculate 100-year erosion limits; and develop crossing recommendations.

General Reach Characteristics

Our previous work identified three reaches. A reach map is included in **Appendix A**. Reaches **EPC-1**, **EPC-2**, and **EPC-3** of Upper East Patterson Creek were assessed in Fall 2015 (GEO Morphix Ltd., 2016). Reach **EPC-1** was forested, while Reaches **EPC-2** and **EPC-3** flowed just outside the forest margin, along the perimeter of a disturbed area. An additional reach, **EPC-4**, was considered in the present desktop analysis to address all potential road alignment options and possible crossing locations. Reach **EPC-4** was identified as a wetland feature in a forested area upstream of Reach **EPC-3**. No significant tributaries were observed flowing into the main channel within the study area.

According to our observations in Fall 2015, the majority of the channel was at least partially confined or fully realigned. Reach **EPC-1** was a constructed valley feature, approximately 5 m wide and just over 1 m deep. The low-flow channel had no riffle-pool development, and averaged 1.89 m wide and 0.15 m deep. Reach **EPC-2** was also within a constructed valley feature, whose channel was likely formed naturally following valley excavation. The low-flow channel was considered to be the bankfull channel, although it may still be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. Reach **EPC-3** continued as a low-flow channel within a constructed valley feature, but with appreciably different physical characteristics than Reach **EPC-2**. The Reach **EPC-3** channel had no bankfull indicators and limited evidence of a stable channel morphology. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the upstream wetland (Reach **EPC-4**) contributed to total flow. Further reach descriptions and observations are provided in our previous report, which has been included as **Appendix B**.

Planning Level Meander Belt Width Delineation and 100-Year Erosion Limits

In support of crossing recommendations and to provide context, meander belt widths and 100-year erosion limits were calculated for the four reaches within the study area.

Meander belt widths for Reaches **EPC-1**, **EPC-2**, **EPC-3** and **EPC-4** were estimated using two methods.

The first method used two modified Williams (1986) models with the addition of a 20% factor of safety.

Modified Williams (1986) Area, $B_w = 18A^{0.65} + W_b$ ....(Eq.1)

Modified Williams (1986) Width, $B_w = 4.3W_b^{1.12} + W_b$ ....(Eq.2)

Where B_w is meander belt width (m), A is cross-sectional area (m^2), and W_b is bankfull channel width (m).

Previous clearing and other historical site activities have resulted in a disturbed study area with few natural references. Reach **EPC-1** was determined to have the most natural characteristics and was the most aged since realignment (GEO Morphix, 2016). As such, this reach was selected for detailed assessment to determine average bankfull channel dimensions (Fall 2015) and was used as a reference reach to model a representative meander belt width for all reaches in the present analysis. The average bankfull channel width for Reach **EPC-1** was 1.89 m, and the average bankfull channel depth was 0.15 m.

The modelled meander belt widths (including a 20% factor of safety) based on the detailed assessment were 11.8 m (Eq.1) and 12.8 m (Eq.2).

The second method for determining meander belt widths required measuring the largest meander amplitude observed within each reach. Again, previous site activities and watercourse realignments had erased any previously natural meanders from the planforms of Reaches **EPC-2** and **EPC-3**. The forest cover of Reaches **EPC-1** and **EPC-4** also prevented us from identifying drainage routes and channel planforms using aerial photography.

As a surrogate, we measured the largest meander amplitude within the study extent, as observed along the Ontario Hydro Network (MNR) watercourse. This was the most accurate delineation of the watercourse available for the present study. A 20% factor of safety was added to the measured value to determine a meander belt width of 20.6 m, which was applied for all reaches. This meander belt width was delineated along the observed central tendency of the watercourse within the study extent, and is illustrated in **Appendix C**.

The calculated meander belt widths are conservative, given that the studied reaches are in confined, or partially-confined systems. These meander belt widths can be further refined at detailed design, if required.

A 100-year erosion limit was estimated for all the reaches in the study area based on geology, level of erosion, and channel size according to the MNR's erosion hazard technical guidelines (MNR, 2001).

Where the reaches were not controlled by the presence of vegetation, the bank materials were a mix of clay, silt, and sand, with only limited evidence of active erosion. As such, based on MNR guidance we suggest an erosion limit of 5 m be applied to delineate the lateral erosion hazard.

Geomorphological Crossing Recommendations

Our preferences with regards to road alignment are based solely on geomorphological and erosion considerations. We have also considered TRCA's Crossing Guideline for Valley and Stream Corridors (2015), which recommends using siting and design to avoid damage to the infrastructure and minimizing channel contact with the crossing infrastructure to reducing erosion hazards.

We recommend that the sizing and location of the proposed crossing consider potential future channel erosion and/or migration. We suggest that the crossing be located at a fair distance from any upstream meanders. The crossing should also maintain velocity differentials and sediment transport processes for frequent storm events through and adjacent to the crossing. The installed structure should have an open bottom and be positioned within a reasonably stable length of channel.

Road Alignment Options 4 and 5 are not preferred as they both could potentially result in disturbance of well-established riparian cover. Clearing the riparian cover would negatively influence creek function. If this crossing location is proposed, we recommend spanning the meander belt width and limiting vegetation removal/impact. In that case, the potential impacts can likely be mitigated.

Road Alignment Options 6 and 6A are preferred as they cross the existing watercourse at a perpendicular angle through a previously disturbed area where the reach has been realigned and channelized. Erosion was noted along the valley walls in the crossing location associated with Road Alignment Options 6 and 6A. A crossing at this location would likely provide an opportunity for stabilization.

We recommend two possible approaches to crossing sizing at 6 or 6A. The first is calculated as three times the bankfull channel width. The second is calculated as bankfull width plus two times the erosion limit. Based on the average bankfull channel width of 1.9 m, these approaches provide crossing sizes of 5.7 m and 11.9 m, respectively. Note these values are a significant portion of the modelled meander belt width estimates.

If disturbance of riparian vegetation is anticipated, we also advocate installation of a channel reinforced with hydraulically sized materials to stabilize the channel under the crossing allowing for fish passage across a wide range of conditions. With regards to hydraulic sizing, MTO Highway Drainage Design Standards (2008) would suggest 100-year event scour protection per standards WC-1/WC-3 for 'local road' conditions with FS=1. Detailed design HEC-RAS results can be utilized for the 100-year event velocity determination.

These recommendations reflect the geomorphological considerations. Other disciplines will also need to be considered including terrestrial and aquatic biology, ecology, hydrogeology, and hydrology.

We trust this memo meets your requirements.

Respectfully submitted,

Cara Hutton

Paul Villard, Ph.D., P.Geo., Can-CISEC
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Senior Environmental Technician

References

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Ontario Ministry of Natural Resources (MNR). 2001. Technical Guide–River & Stream Systems: Erosion Hazard Limit.

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Appendix A

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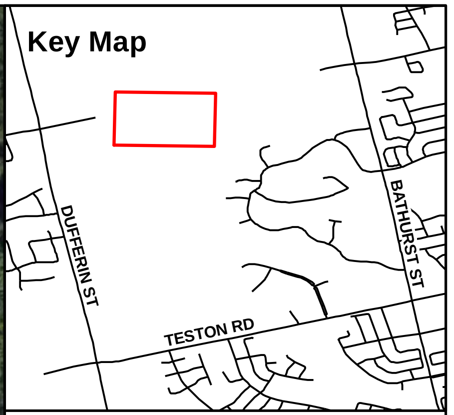

Legend

Reach break

Centreline of watercourse

N

0 50
Metres

Reach break: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018, and GEO Morphix Ltd., 2018.
Imagery: York Region, 2017.

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Reach Delineation

Upper East Patterson Creek

Vaughan, Ontario

Appendix B

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Rizmi Property
City of Vaughan, Ontario

Upper East Patterson Creek
Geomorphic Assessment

Prepared for:	Rizmi Holdings Limited 11333 Dufferin Street PO Box 663 Maple, Ontario L6A 1S5
Prepared by:	GEO Morphix Ltd.
Project No.:	15080
Date:	January 18, 2016

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Appendices

1 Introduction

A Municipal Class Environment Assessment is proposed by the City of Vaughan to determine the preferred alternative to extend Kirby Road to Gamble Road in the Town of Richmond, between Dufferin and Bathurst Streets. The ultimate alignment of this arterial road will be determined with consideration to numerous factors as required in the Class EA process. One consideration is East Patterson Creek, which is addressed in this report.

The east tributary of Patterson Creek originates in a wetland located near the north part of the Rizmi Stone & Aggregates property at 11333 Dufferin Street in the community of Maple. A significant portion of channel within the property limits has apparently been modified in the past. The alterations, however, do not affect fish habitat due to a significant barrier to fish passage along the southern property line. The watercourse currently conveys flows to the south property line where it terminates in a wetland. The following report provides a geomorphic assessment of East Patterson Creek to fulfill a Class EA requirement to document natural heritage features, as well as to support the decision-making process with respect to actions that affect the watercourse.

It is understood that the future of the channel within the property has yet to be determined as it is not considered to be direct fish habitat. Potential outcomes include removal, retain in its current alignment, realignment, enhancement, or a combination of these alternatives. GEO Morphix will provide appropriate support once the preferred solution has been determined in the Class EA study.

2 Historical Conditions

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Historical aerial photographs from 1946 (scale 1:20,000) and 1954 (scale 1:63,360), and orthophotography from 1970, 1999, 2002, 2005, 2007, 2011, 2012 and 2013, and Google Earth Pro satellite imagery from 2015 were reviewed to complete the historical assessment.

In 1946, the upper East Patterson Creek drainage area was largely forested, with the exception of a clearing for agriculture at the upper extent of the drainage area. At the current location of the Rizmi Stone & Aggregates field operations, there was a clearing but no apparent activity. The drainage route within the subject property could not be identified due to tree cover, but there was an intermittently-forested corridor with a watercourse that extended in a southeasterly direction from the subject property towards Bathurst Street. The channel planform could not be determine on the aerial photography. Outside of the forested area to the north beyond the drainage area, the land was used exclusively for agriculture. The area beyond the property to the south was also used for agriculture.

There were no significant changes in land use through 1954. The surrounding land to the south, however, was transformed to a golf course, Maple Downs Golf Course. By 1970, Rizmi operations extended approximately 0.4 km to the east from the previously cleared area, as suggested by the heavily disturbed landscape and the access road connecting the disturbed area to Dufferin Street. Also between 1954 and 1970, the TransCanada Pipeline was constructed along the south property boundary and across the channel. The watercourse is visible along the east side of an internal road at the eastern end of the disturbed area, but the Pipeline clearly prevents flow conveyance

beyond the property as evidenced by the ponded water at the Pipeline crossing. The lack of tree cover along the section of channel along the internal road as well as its linear alignment also suggest that it was channelized to enhance drainage function. East of the Rizmi property along the north side of the Pipeline was a private runway.

Rizmi operations appeared to have slowed by 1999. The channel alignment was the same as it was in 1970, but the pond at the Pipeline had visual characteristics of a wetland. Another notable change within the property was a linear clearing through the forest leading to the general area of the channel origin, north of the cleared aggregate extraction area. There was also limited clearing on the east side of the internal road and channel, as well as a culvert in the channel next to this recently cleared area for access the east side. Southeast of the property, the land was developed for residential use.

Surrounding land use remained generally unchanged in 2011. Between 2007 and 2011, a portion of the channel within the Rizmi property was again realigned to travel along the margin of the cleared area. The previously installed culvert was removed due to the channel realignment, and a new culvert was constructed at the new channel crossing location. Activity within the property also appears to have increased during this period. There were no notable changes in 2012 and 2013.

Overall, the portion of East Patterson Creek within the Rizmi property experienced significant changes over the period covered by historical imagery. These changes include realignment and straightening (i.e., channelization), removal of tree cover, and the disruption of channel and flow continuity as a result of the TransCanada Pipeline.

3 Existing Conditions

3.1 Watershed Characteristics

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.

East Patterson Creek is situated in the Upper East Don Subwatershed. The channel within the property limits is a headwater feature that originates from a generally linear wetland feature located mostly within the property. In total, the channel travels in a southerly direction for approximately 6 km, where it joins West Patterson Creek, then continues for another 1.5 km to the confluence with the East Don River.

The subject site is located in a southward extending lobe of the Oak Ridges Moraine physiographic region, which is bounded by the South Slope physiographic region to the west, south and east. Beyond the South Slope is the Peel Plain (Chapman and Putnam, 1984), where Patterson Creek joins the East Don River. With respect to surficial geology, the subject area is characterized by ice-contact stratified deposits consisting of sand and gravel, minor silt, clay and till (OGS, 2010). The surficial geology generally changes in the downstream direction in concert with the physiographic regions: the South Slope is comprised of clay to silt-textured till (derived from glaciolacustrine deposits or shale) and the Peel Plain is generally characterized by glaciolacustrine deposits (OGS, 2010). The predominantly sand and gravel composition of the surficial material

allows the channel to readily adjust, although the degree of adjustment would also be influenced by the flow regime as well as other factors such as vegetation control.

The catchment area for the channel within the subject property is largely forested with the exception of the area cleared for the Rizmi Stone & Aggregates operations. Downstream of the property to Bathurst Street, the channel travels through a forested corridor surrounded by low-density residential dwellings. The forested channel corridor continues beyond Bathurst Street, although housing density increases.

3.2 Reach Delineation

Rivers and streams are frequently segmented into reaches to provide meaningful lengths of channel for study. Reaches are delineated based on changes such as hydrology, channel gradient, confinement, planform (i.e., channel pattern), geology, surrounding land use and anthropogenic disturbances (e.g., crossing structures, dams, straightening/channelization, armouring). Each reach can then be studied as a unit that is expected to function in generally uniform manner throughout its length.

Within the Rizmi property, East Patterson Creek was divided into three reaches. The downstream channel reach (EPC-1) is approximately 100 m in length, the middle reach (EPC-2) is 130 m, and the upstream reach (EPC-3) is 200 m. Forest cover was one consideration when delineating the reaches: the Reach EPC-1 channel lies just within the west forest margin, while Reaches EPC-2 and EPC-3 are just outside the west forest margin. Despite the apparently limited differences between reaches, tree cover is a significant factor that governs channel form and function, and hence the two reaches. Reaches EPC-2 and EPC-3 are differentiated primarily by channel morphology. Wetland features are located downstream of Reach EPC-1 and upstream of Reach EPC-2. The reach delineation was verified in the field, as discussed below.

3.3 Reach Assessments

Site observations and channel measurements were collected on November 2, 2015. The field investigation was completed for the full length of channel between the wetland at the upstream extent of the channel and the south property limit. A photographic record of site conditions is provided in Appendix A. On the day of the site visit, the temperature was 10°C and there was no precipitation. There was, however, 7 mm of rain from October 31 to November 1.

3.3.1 General Observations

Within the Rizmi property, East Patterson Creek originates in a wetland feature located in a forested area to the north just beyond an open, disturbed area created by site activities. The channel travels along the perimeter of the clearing before entering the forested area. It continues just within the forest boundary to a wetland feature at the south limit of the property. The reaches identified in Section 3.2 were confirmed to be correct. The following is a description of each reach from upstream to downstream.

The wetland at the upstream end of the section of channel under study is comprised of a dense thicket of shrubs (red-osier dogwood). There was no define flow pattern within the wetland.

Reach EPC-3 is in a constructed valley feature containing a low-flow channel. The valley had a 'V' shape except towards the downstream end of the reach. The channel had no bankfull indicators

and there was limited evidence of a stable channel morphology. The bed was composed of mostly silt and sand, and its morphology was partly controlled by vegetation. Three knickpoints were observed, which suggests that the channel gradient is high relative to those of the two downstream reaches. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the wetland contributed to total flow. Wetted flow width varied due to the high degree of channel confinement, ranging from 0.1 to 1.5 m. The channel characteristics were largely governed by the composition of the valley materials, which was sand. The northeast embankment (left embankment viewed in the downstream direction) was comprised of exposed sand with limited woody vegetation. Due to the unstable nature of the embankments, in particular that to the northeast, the channel will likely continue to adjust according to the sediment supply. Mature trees lied beyond the sandy embankment. The southwest side of the channel was open with primarily grasses.

Reaches EPC-3 and EPC-2 were divided by a partly embedded 1200 mm CSP culvert, constructed for access across the channel. Reach EPC-2 continues as a constructed valley feature, but with appreciably different physical characteristics. Here, the valley top width was roughly 3.9 m wide and the valley depth was 1.5 to 2.0 m. The east side of the valley was populated by mature trees, while the east side was dominated by grasses within an open (i.e., cleared) area.

The Reach EPC-2 channel likely formed naturally following valley excavation. The low-flow channel is considered to be the bankfull channel, although it still may be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. There was a 0.22 m high knickpoint mid-reach that cut into till. Upstream of the knickpoint, the bed was characterized by sand, gravel and small cobbles, while downstream of the knickpoint, the bed was comprised of mostly sand, but also exposed till. This longitudinal change in bed characteristics can be explained by differences in bed gradient.

At the downstream end of Reach EPC-2, the channel turns at nearly a right angle to travel south into Reach EPC-1. There was evidence of the former channel location (before the realignment of Reaches EPC-3 and EPC-2), in the form of a linear depression across the cleared area, that aligned with Reach EPC-1. Although the former channel was decommissioned, surface runoff apparently continued to enter the Reach EPC-1 channel at the upstream end of this reach as indicated by the minor erosion and headcutting.

Reach EPC-1 travels in a southerly direction and continues as a constructed valley feature approximately 5 m wide and just over 1 m deep. Both sides of the valley was vegetated with mature trees; however, the woody riparian buffer on the west side was limited. Tree cover over the channel was dense, and there were frequent observations of woody debris within the constructed valley, mostly as broken individual tree limbs that did not significantly affect flow pattern. The low-flow channel had no riffle-pool development, and averaged 1.90 m wide and 0.15 m deep. The increase in width-to-depth ratio, relative to that of Reach EPC-2, can be explained by the decrease in channel gradient and the increase in discharge. Both the bed and banks were comprised of sand, which would be expected due to the lower gradient and the typical downstream fining found in natural watercourses.

At the downstream end of the Reach EPC-1 channel was a wetland feature. This wetland was contained in a basin (roughly 70 wide and 50 m wide) that was bounded in the downstream (south) end by a raised natural gas pipeline corridor (i.e., TransCanada Pipeline), which was essentially a large berm. The top of the Pipeline was approximately 1.5 to 2.0 m above the wetland bed, and therefore a considerable volume of water would be required for flows to spill

over the Pipeline corridor. There was no evidence of a flow path over the Pipeline, although it would clearly be located across the lowest point. The impact of the lack of surface flow continuity to the watercourse downstream (south) of the Pipeline corridor could not be assessed due to property constraints.

3.3.2 Rapid Field Assessments

Rapid field assessments were completed as reconnaissance-level evaluations to determine the condition of each reach with respect to channel stability and general stream health:

- Channel instability was semi-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.

A summary of the rapid assessments is provided in Table 1. Completed field sheets are found in Appendix B.

Table 1: Rapid field assessment summary

Reach	RGA*			RSAT**		
	Score	Condition	Dominant Form of Adjustment	Score	Condition	Limiting Feature(s)
EPC-1	0.11	In regime	Aggradation	26	Good	Physical instream habitat
EPC-2	0.12	In regime	Degradation	28	Good	Riparian habitat conditions
EPC-3	0.09	In regime	Degradation	22	Fair	Riparian habitat conditions

* Ontario Ministry of the Environment (2003)
** Galli (1996)

3.3.3 Detailed Geomorphic Assessment

Within the property limits, Reach EPC-1 was determined to be relatively natural and certainly the most aged since realignment. As such, this reach was selected for further investigation – i.e., detailed geomorphic assessment. This detailed assessment serves as the basis for any required channel modifications such as realignment or stabilization.

The detailed assessment involved temporarily setting up eight representative cross sections for the purpose of determining average bankfull channel dimensions (e.g., width, average bankfull depth, maximum depth, and bank angles). The bankfull level was determined using standard protocols and accepted field indicators. A survey of the bed profile was also completed to determine slope and compute bankfull hydraulics. A modified Wolman (1954) pebble count was completed to characterize the bed materials. A summary of measured and computed values is presented in Table 2.

Table 2: Bankfull parameters of the reference channel

Channel parameter	Results
Measured	
Average bankfull channel width (m)	1.89
Average bankfull channel depth (m)	0.15
Average width-to-depth ratio	14.7
Channel gradient (%)	0.42
D_{50} (mm)	<2
D_{84} (mm)	<2
Manning's n roughness coefficient	0.034
Computed	
Bankfull channel discharge (m^3/s) *	0.14
Average bankfull velocity (m/s)	0.53
Unit stream power at bankfull discharge (W/m^2)	3.2
Tractive force at bankfull (N/m^2)	5.98
Critical shear stress (N/m^2) **	1.46
Flow competency for D_{50} (m/s) ***	0.27
Flow competency for D_{84} (m/s) ***	0.27

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

The Reach EPC-1 reference channel has a lower width-to-depth ratio than the two upstream reaches due to the lower channel gradient. Despite the relatively low unit stream power, the bed (comprised of sand) is fully mobile under bankfull flow conditions. It is expected that the Reach EPC-1 channel length would decrease slowly over time as the bed material is transported and deposited in the wetland. The receiving wetland would consequently increase in size, but only in the upstream direction due to the raised pipeline crossing.

4 Conclusions

East Patterson Creek within the Rizmi property has been significantly altered, and impacted both directly and indirectly, over the period covered by historical imagery. It also no longer functions

as potential fish habitat as a result of the construction of the TransCanada Pipeline. In-channel flows now therefore infiltrate and contribute to groundwater.

If the preferred alternative solution, resulting from the Class EA study, is assessed to be restoration, realignment or enhancement, we would be pleased to provide design services. Concurrently or independently, we can also investigate potential hazards associated with a dynamic channel.

5 References

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Appendix A
Photographic Record of Site Conditions

Photo 1	
	EPC-3: Near upstream extent of reach, viewed upstream. The channel was confined by sandy valley wall to the east and a vegetated valley wall to the west.
Photo 2	
	EPC-3: Mid-reach viewed upstream at a knickpoint.

Photo 3	
	EPC-3: Reach viewed upstream from downstream end of reach.
Photo 4	
	1200 mm CSP culvert between Reaches EPC-2 and 3.

Photo 5	
	ECP-2: Channel viewed in the downstream direction. Coarse substrate was found mostly in the upstream portion of the reach. Note the channel confinement.
Photo 6	
	EPC-2: Mid-reach knickpoint in exposed till.

Photo 7	
	EPC-2: Channel viewed in the downstream direction towards end of reach.
Photo 8	
	EPC-1: Mid-reach channel viewed in the downstream direction. Note the limited channel definition and lack of morphological variability, and confinement between valley walls.

Photo 9	
	ECP-1: Channel viewed downstream towards downstream end of reach. Note the absence of flow and limited channel definition.
Photo 10	
	EPC-1: Wetland at property line with raised pipeline in background (see fence line). No culvert was found.

Appendix B
Rapid Assessment Field Sheets

GEO | MORPHIX

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-1
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

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

Riparian Vegetation

Dominant Type: (Table 6) 1

Species: ______

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): / | Coverage of Reach (%): /

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

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

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

see detailed assessment

Bankfull Width (m)				**Wetted Width (m)**			
Bankfull Depth (m)				**Wetted Depth (m)**			

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

Pool Depth (m) NA | **Riffle Length (m)** NA | **Undercuts (m)** None

Velocity (m/s) ∅ | / | / | Wiffle ball / ADV / Estimated

Comments: No riffle-pools, poor BF indicators

Bank Angle: ☒ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Notes:

Completed by: CH   Checked by: ______

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code/Phase:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	1/4
	2	Coarse materials in riffles embedded	NA		
	3	Siltation in pools	NA		
	4	Medial bars		✓	
	5	Accretion on point bars	NA		
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone		✓	
		Sum of indices =	1	3	0.25
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA		0/3
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA		
	3	Elevated storm sewer outfall(s)	NA		
	4	Undermined gabion baskets / concrete aprons / etc.	NA		
	5	Scour pools downstream of culverts / storm sewer outlets	NA		
	6	Cut face on bar forms	NA		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material	NA		
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	3	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	1/5
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	NA		
	5	Basal scour on both sides of channel through riffle	NA		
	6	Outflanked gabion baskets / concrete walls / etc.	NA		
	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	4	0.2
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/6
	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	NA		
		Sum of indices =	0	6	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.11			
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: CH Checked by: ________

Rapid Stream Assessment Technique **Project Number:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

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 NA
	• 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) NA
	• 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 NA
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	NA
	• 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	NA
	• 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	NA
	• 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	NA
	• 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	NA
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) =				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			26	

Completed by: CH Checked by: ________

GEO | MORPHIX

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-2
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | ☒ Groundwater | Evidence: iron staining

Riparian Vegetation

- Dominant Type: (Table 6) 3
- Species: ____
- 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
- Coverage of Reach (%): <5
- Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☒ Not Present
- Density of WD: ☐ Low ☐ Moderate ☐ High
- WDJ/50m:

Water Quality

- Odour (Table 16): 1
- Turbidity (Table 17): 1

Channel Characteristics

- Sinuosity (Type) (Table 9): 1
- Sinuosity (Degree) (Table 10): 1
- Gradient (Table 11): 2
- Number of Channels (Table 12): 1
- Entrenchment (Table 13): 2
- Type of Bank Failure (Table 14): 1
- Downs's Classification (Table 15): E

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	☐	☒	☒	☒ small	☐	☒ till	☐
~~Pool Substrate~~	☐	☐	☐	☐	☐	☐	☐
Bank Material	☒ silt	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	1.3	1.0		**Wetted Width (m)**	0.3	0.25	
Bankfull Depth (m)	0.4	0.45		**Wetted Depth (m)**	0.1	0.15	

- **Riffle/Pool Spacing (m)**: NA | **% Riffles:** NA | **% Pools:** NA | **Meander Amplitude:** N/A
- **Pool Depth (m)**: NA | **Riffle Length (m)**: NA | **Undercuts (m)**: /
- **Velocity (m/s)**: / | / | / **Wiffle ball / ADV / Estimated**

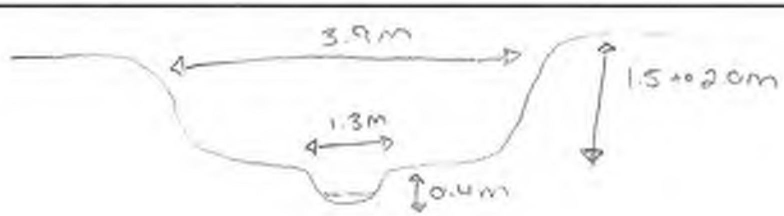
Comments: KP + exposed till
coarse bed material u/s of KP

Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☐ < 5% ☐ 5 – 30% ☒ 30 – 60% ☐ 60 – 100%

Notes:
CSP @ crossing = 1.2m

Valley feature



Completed by: CH

Checked by: ____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code/Phase: DN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	East Patterson

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/5
	2	Coarse materials in riffles embedded	N/A		
	3	Siltation in pools	N/A		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	0	5	0.0
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.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N/A		
	5	Basal scour on both sides of channel through riffle	N/A		
	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 =	0	5	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/6
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form	N/A		
	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 =	1	5	0.17

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.13

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

Completed by: KT/ER Checked by: ________

Rapid Stream Assessment Technique **Project Number:** pn15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

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)	N/A
	• 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	

EPC-2
PN15080

GEO | MORPHIX

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	NA
	• 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	NA
	• 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	NA
	• 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 N/A
	• 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)
			✓	

Completed by: KT/ER Checked by: ________

Reach Characteristics

Project Code/Phase: PH15080

GEO | MORPHIX

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-3
Weather:	sun + 10°C	**Location:**	Kirby Rd
Field staff:	CH / ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 **Valley Type** (Table 2): 2 **Channel Type** (Table 3): 6 **Channel Zone** (Table 4): 1 **Flow Type** (Table 5): 2 [x] Groundwater **Evidence:** watercress

Riparian Vegetation

- **Dominant Type:** (Table 6):
- Species: ________
- **Coverage:** [ ] None [ ] Fragmented [x] Continuous
- **Channel widths:** [ ] 1-4 [x] 4-10 [ ] > 10
- **Age Class (yrs):** [ ] Immature (<5) [x] Established (5-30) [ ] Mature (>30)
- **Encroachment:** (Table 7): 3

Aquatic/Instream Vegetation

- **Type** (Table8): 2 Coverage of Reach (%): 40
- **Woody Debris:** [ ] Present in Cutbank [ ] Present in Channel [x] Not Present
- **Density of WD:** [ ] Low [ ] Moderate [ ] High WDJ/50m:

Water Quality

- **Odour** (Table 16): 1
- **Turbidity** (Table 17): 1

Channel Characteristics

- **Sinuosity (Type)** (Table 9): 1
- **Sinuosity (Degree)** (Table 10): 1
- **Gradient** (Table 11): 2
- **Number of Channels** (Table 12): 1
- **Entrenchment** (Table 13): 2
- **Type of Bank Failure** (Table 14): 1
- **Downs's Classification** (Table 15): e

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	[ ]	[x]	[x] some	[ ]	[ ]	[ ]	[ ]
~~Pool Substrate~~	~~[ ]~~	~~[ ]~~	~~[ ]~~	~~[ ]~~	~~[ ]~~	~~[ ]~~	~~[ ]~~
Bank Material	[ ]	[x]	[ ]	[ ]	[ ]	[ ]	[x]

Bankfull Width (m)	1.4		
Wetted Width (m)	0.8		
Bankfull Depth (m)	0.35		
Wetted Depth (m)	0.1		

Riffle/Pool Spacing (m) NA **% Riffles:** NA **% Pools:** NA **Meander Amplitude:** NA

Pool Depth (m) D/S of KP: 0.3 **Riffle Length (m)** NA **Undercuts (m)** /

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

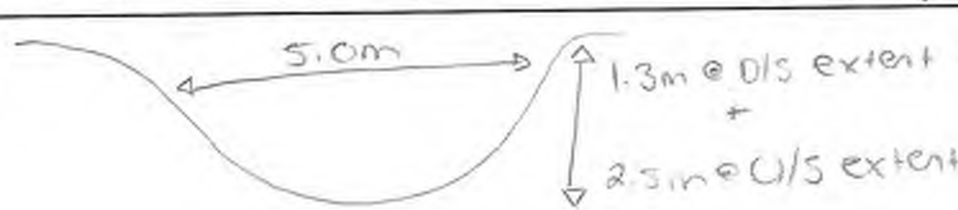
Bank Angle: [ ] 0 – 30 [ ] 30 – 60 [x] 60 – 90 [ ] Undercut

Bank Erosion: [ ] < 5% [ ] 5 – 30% [ ] 30 – 60% [x] 60 – 100%

Comments: 3 knickpoints, no riffle-pool development

Notes: sandy VWR along LB; saplings in channel @ D/S extent; wetland U/S of VWC

valley feature



Completed by: CH **Checked by:** ________

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code/Phase:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/7
	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 =	0	7	0.0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		1/5
	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 =	1	4	0.20
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N/A		
	5	Basal scour on both sides of channel through riffle	N/A		
	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 =	0	5	0.0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	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 =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.09			
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: KT/ER Checked by: ________

Rapid Stream Assessment Technique **Project Number:** pn15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

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
N/A	• 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
N/A	• 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

EPC-3
PN 15080

GEO | MORPHIX

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

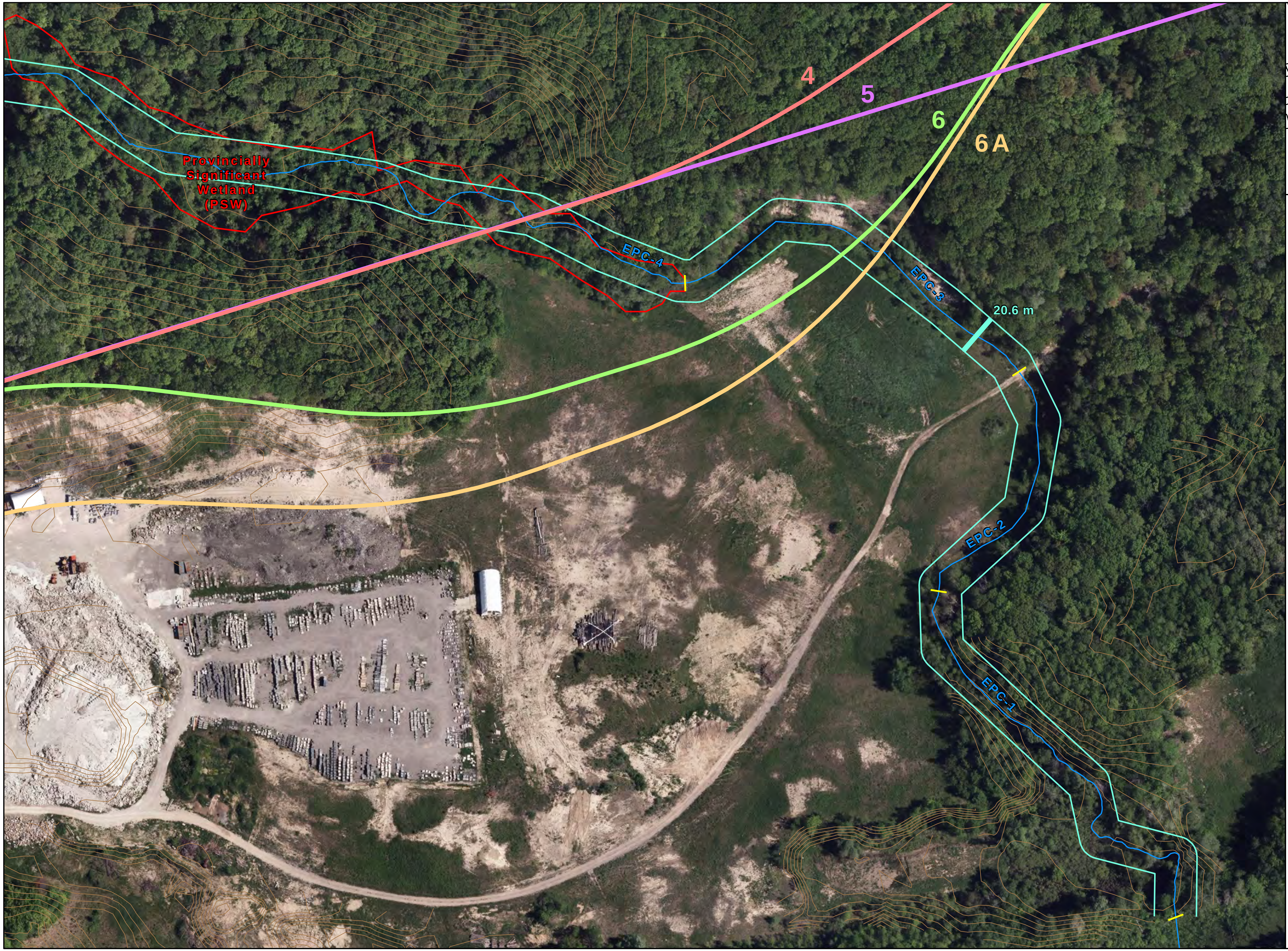
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: < 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:

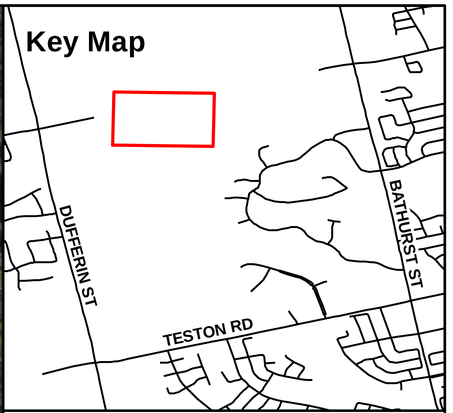
Total overall score (0 - 42) = 22				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
		✓		

Completed by: KT/ER Checked by: ________

Appendix C



Key Map



Legend

- Reach break
- Centreline of watercourse
- Meander belt width (20.6 m)
- 1 m Contour

Road Alignment Options

- 4
- 6
- 5
- 6A

N

0 50
Metres

Reach break and Meander belt width: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018, and GEO Morphix Ltd., 2018.
Contours, Road Alignment Options, and PSW: Schaeffers Consulting Engineers, 2018.
Imagery: York Region, 2017.

GEO MORPHIX

Planning Level Meander Belt Width Delineation

Upper East Patterson Creek

Vaughan, Ontario

APPENDIX C6.3

Reponse to TRCA Comments dated September 12, 2018

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GEO Morphix Ltd.

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November 28, 2018

Schaeffers Consulting Engineers
6 Ronrose Drive
Vaughan, ON
L4K 4R3

Attention: Leonid Groysman

Re: Kirby Road Extension Crossing for East Patterson Creek
Response to TRCA Comments dated September 12, 2018
City of Vaughan, Ontario
GEO Morphix Project No. PN15080

This letter is in response to several comments received from the Toronto Region Conservation Authority (TRCA, September 12, 2018) regarding the Kirby Road Extension between Dufferin and Bathurst Streets in the City of Vaughan. Specifically, we address comments related to the geomorphic assessment completed by GEO Morphix (report dated January 18, 2016 and letter dated June 4, 2018). We have provided each comment in italics below as well as a subsequent written response. Supporting materials have also been included as attachments.

Response to TRCA Comments

- *Comment #4 – For example: S3.2.3.2:*
    - *a) Please provide a drawing showing the location of the different reaches.*

A reach map was included under the GEO Morphix letter dated June 4, 2018. Reaches are also outlined on the new figure included in this letter (**Attachment A**).

- *b) Please provide a figure showing the location of the observed watercress in the channel.*
- *c) Please identify all wetland features on a figure with their size in hectares.*
- *d) Please provide a figure showing the location of observed groundwater staining and the area described as "basin-like".*

The locations of watercress, wetlands, and iron staining were not specifically mapped as part of the geomorphological assessment. These were general, reach level observations collected during the field reconnaissance. The exact locations were not mapped, as they were not significant with respect to the geomorphological assessment.

- *Comment #18 – Please provide a location map.*

A location map was included under the GEO Morphix letter dated June 4, 2018. The location is also outlined on the new figure included in this letter (**Attachment A**).

- *Comment #19 – Please provide a figure showing the location of all observations: e.g. barrier to fish passage and referenced wetlands, knick points, culverts and pipeline. Historical photos are recommended to improve clarity.*

The new figure included in this letter (**Attachment A**) shows the location of knick points and one (1) observed culvert. It should be noted that knick points in this case are small in scale and, as such, are not a relevant constraint with respect to proposed crossing locations. The locations of fish barriers were not specifically mapped as part of the geomorphological assessment. These were general observations collected during the field reconnaissance. Although these items may be of interest to other disciplines, they are not significant from a geomorphological perspective. The term wetland was used to indicate wet areas without a defined channel/vegetation controlled. Further, the location of the pipeline was not specifically mapped as it was located immediately downstream of the study site. As requested, historical photographs of the site have been included under **Attachment B**.

- *Comment #20 – Please note that TRCA has not yet concluded that this channel does not constitute fish habitat.*

Noted.

- *Comment #21 – Please provide a figure showing the breakdown of reaches within the watercourse.*

A reach map was included under the GEO Morphix letter dated June 4, 2018. Reaches are also outlined on the new figure included in this letter (**Attachment A**).

- *Comment #22 – In the second last paragraph, please revise the text to clarify the meaning of "fining".*

Fining is a common term used in geomorphological assessments. We have not revised the report text, but instead provide a description here to clarify. Downstream fining of sediment is observed in most creek systems as a result of collective sediment sorting (i.e. smaller grains are transported farther downstream while larger grains are deposited preferentially upstream). The finer sediments observed along reach EPC-1 were therefore expected given that it was the farthest downstream reach.

- *Comment #23 – Please provide a figure identifying the location of the referenced 8 cross sections.*

The new figure included in this letter (**Attachment A**) shows the location of the eight (8) cross-sections.

- *Comment #24 – Please note that the construction of the Trans Canada Pipeline doesn't necessarily preclude the possibility that the channel constitutes fish habitat.*

Noted.

- *Comment #25 – Please note that TRCA's Crossing Guideline for Valley and Stream Corridors recommends that new crossings are designed to span the meander belt width or the 100-year channel migration limit. These limits must be identified to support an assessment of crossing alternatives.*

The new figure included in **Attachment A** shows the extent of the meander belt width and/or erosion hazard setback in relation to the proposed crossing locations.

Additional field work was completed on November 16, 2018 to verify the location of the channel centreline in the vicinity of each crossing location. Specifically, a RTK and Total Station survey was completed to field-truth the MNRF stream layer (see figure in **Attachment A**).

We understand that crossing Option 5 has been selected as the preferred approach. It should be noted that in the vicinity of the Option 5 crossing, a channel centreline could not be mapped by Total Station or RTK GPS survey. The existing MNRF stream layer shown near Option 5 (**Attachment A**) also does not accurately characterize this particular section. Based on our field observations, the area is vegetation controlled with a low-gradient, evidence of aggradation, and no defined low-flow channel. As such, there is limited erosion potential.

From a geomorphological perspective, there is no future concern of erosion in the vicinity of crossing Option 5. Still, we have provided a meander belt width in this area based on the largest channel meander amplitude measured upstream of the Option 5 crossing using the MNRF stream layer. Given that the feature is vegetation controlled and lacks defined bed and banks in this section, the meander belt width is an extremely conservative estimate of the erosion hazard. For further discussion on the application of the meander belt width and erosion hazard, please refer to our June 4, 2018 memo.

Option 5 is an appropriate approach for the future road crossing. If required at detailed design, a low-flow channel could be created as part of the crossing design.

If you have any questions or concerns, please contact the undersigned.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., CAN-CISEC
Director, Principal Geomorphologist

Attachment A

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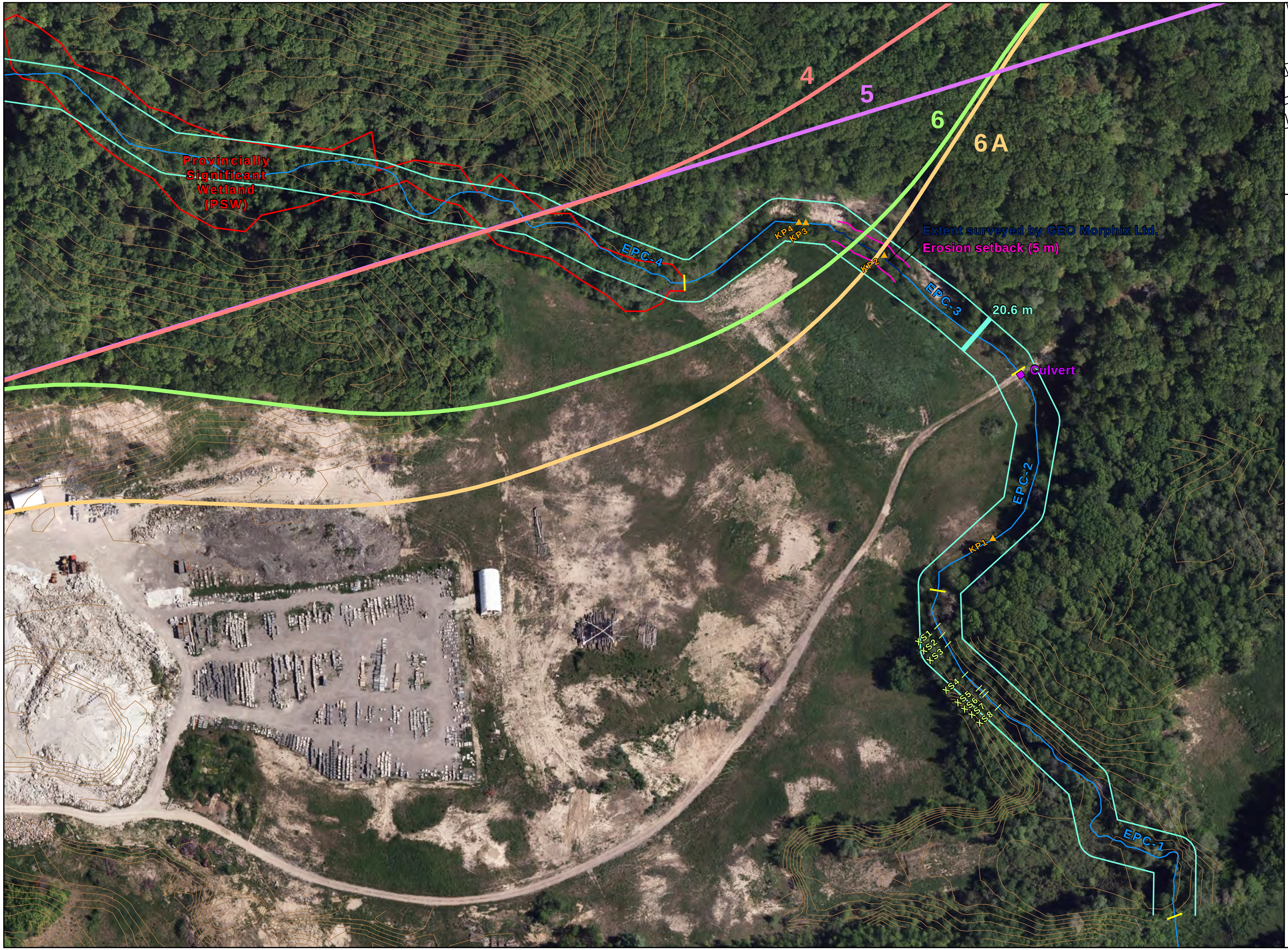

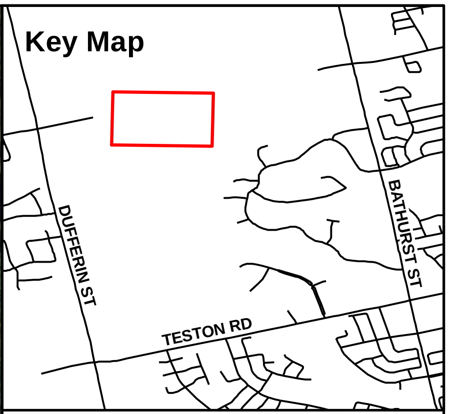

Legend

- Knick point
- Cross section
- Reach break
- Centreline of watercourse
- Meander belt width (20.6 m)
- 1 m Contour

Road Alignment Options

- 4
- 5
- 6
- 6A

N

0 50
Metres

Knick point, Cross section, Reach break
and Meander belt width: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018,
and GEO Morphix Ltd., 2018.
Contours, Road Alignment Options, and PSW:
Schaeffers Consulting Engineers, 2018.
Imagery: York Region, 2017.

GEO MORPHIX

Planning Level Meander Belt Width Delineation

Upper East Patterson Creek

Vaughan, Ontario

Attachment B

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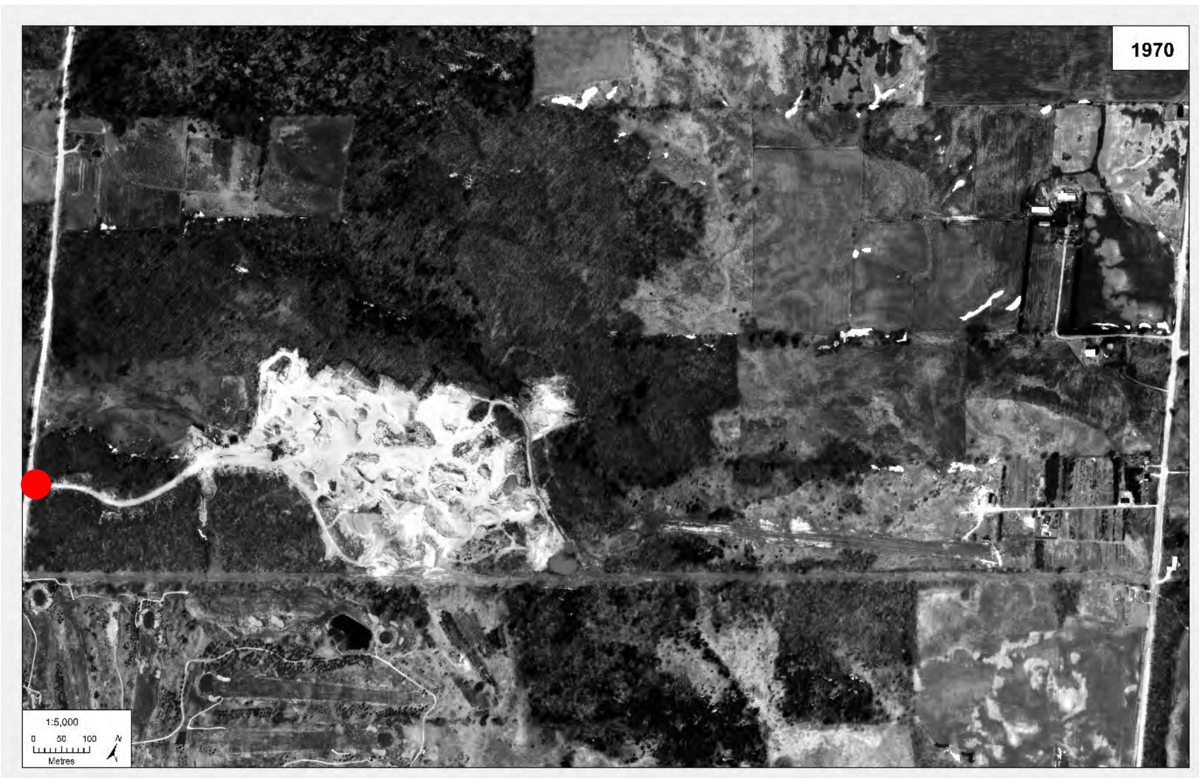
Location: 11333 Dufferin Street, Maple, ON
Year: 1946
Scale: 1:20,000
Source: NAPL

Location: 11333 Dufferin Street, Maple, ON
Year: 1954
Scale: 1:63,360
Source: Hunting Survey Corporation Limited



Location: 11333 Dufferin Street, Maple, ON
Year: 1970
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 1999
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2002
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2005
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2007
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2011
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2012
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2013
Scale: Orthoimagery
Source: York Region

Location: 11333 Dufferin Street, Maple, ON
Year: 2015
Scale: N/A
Source: Google Earth Pro

APPENDIX C6.4

Recommendations for Alignment 5A

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April 15, 2019

Schaeffers Consulting Engineers
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Attention: Mr. Leonid Groysman, Class EA Lead

Re: Recommendations for the Kirby Road Extension Environmental Assessment
Proposed Crossing Alignment 5A
Upper East Patterson Creek, Vaughan, Ontario
GEO Morphix Project No. 15080

A geomorphological assessment was previously completed by GEO Morphix Ltd. for Upper East Patterson Creek in the vicinity of the proposed Kirby Road extension in the City of Vaughan, Ontario. The geomorphological assessment included both desktop and field activities including reach delineation and reach-by-reach rapid assessments. The Toronto and Region Conservation Authority (TRCA) also requested additional information related to meander belt widths, 100-year erosion limits, and preliminary recommendations for the potential Kirby Road crossing location. As such, additional desktop analysis was completed to support planning level meander belt width delineation and determination of a 100-year erosion limit for the creek.

Several alignments have been proposed for the Kirby Road extension. The current alignment proposed for the road crossing (Option 5A) is outlined on the map provided in **Appendix A**. This letter provides a summary of the geomorphological assessment completed in support of the Kirby Road extension and outlines recommendations with regards to crossing design and implementation in the context of the preferred Option 5A alignment.

General Reach Characteristics

Three watercourse reaches were identified for East Patterson Creek in the vicinity of the proposed road crossing. A reach map is included in **Appendix A**. Reaches **EPC-1**, **EPC-2**, and **EPC-3** of Upper East Patterson Creek were assessed in Fall 2015. Reach **EPC-1** was forested, while Reaches **EPC-2** and **EPC-3** flowed just outside the forest margin, along the perimeter of a disturbed area. An additional reach, **EPC-4**, was considered in the desktop analysis to address all potential road alignment options and possible crossing locations. Reach **EPC-4** was identified as a wetland feature in a forested area upstream of Reach **EPC-3**. No significant tributaries were observed flowing into the main channel within the study area.

Based on our 2015 field observations, the majority of the channel was at least partially confined or fully realigned. Reach **EPC-1** was a constructed valley feature, approximately 5 m wide and just over 1 m deep. The low-flow channel had no riffle-pool development and averaged 1.89 m wide and 0.15 m deep. Reach **EPC-2** was also within a constructed valley feature, whose channel was likely formed naturally following valley excavation. The low-flow channel was considered to be the bankfull channel, although it may still be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. Reach **EPC-3** continued as a low-flow channel within a constructed valley feature, but with appreciably different physical characteristics than Reach **EPC-2**. The Reach **EPC-3** channel had no bankfull indicators and limited evidence of channel morphology. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the upstream wetland (Reach **EPC-4**) contributed to total flow. Given that Reach **EPC-3** is located immediately downstream of the wetland, it can also be characterized as a reasonably low-energy system. This is supported by the lack of definition and limited evidence of a defined bankfull channel. However, minor evidence of erosion was noted along the straightened section of Reach EPC-3 in the area associated with the proposed road and watercourse crossing.

Planning Level Meander Belt Width Delineation and 100-Year Erosion Limits

In support of crossing recommendations and to provide context, meander belt widths and 100-year erosion limits were calculated for the four reaches within the study area. Meander belt widths for Reaches **EPC-1**, **EPC-2**, **EPC-3** and **EPC-4** were estimated using a combination of empirical models, historical aerial photographs, and the Ontario Base Mapping stream layer. A full summary of our methodology and approach is outlined in our June 4, 2018 letter included in **Appendix B**: *Planning Level Meander Belt Width Delineation, 100-Year Erosion Limits, and Preliminary Crossing Recommendations for the Kirby Road Extension Environmental Assessment*.

A meander belt width of 20.6 m was determined for the four reaches of East Patterson Creek and included a 20% factor of safety. This meander belt width was delineated along the observed central tendency of the watercourse within the study extent, and is illustrated in **Appendix A**. The meander belt width is conservative, given that the studied reaches are in confined, or partially-confined systems. As such, the meander belt width can be further refined at detailed design, if required.

A 100-year erosion limit was also estimated for all the reaches in the study area based on geology, level of erosion, and channel size according to the MNRF's erosion hazard technical guidelines (MNR, 2001). Where the reaches were not controlled by the presence of vegetation, the bank materials were a mix of clay, silt, and sand, with only limited evidence of active erosion. As such, based on MNR guidance an erosion limit of 5 m was applied to delineate the lateral erosion hazard.

Geomorphological Crossing Recommendations

Our recommendations with regards to the proposed road alignment are based solely on geomorphological and erosion considerations. We have also considered TRCA's Crossing Guideline for Valley and Stream Corridors (2015), which recommends using siting and design to avoid damage to the infrastructure and minimizing channel contact with the crossing infrastructure to reducing erosion hazards.

We recommend that the sizing and location of the proposed crossing consider potential future channel erosion and/or migration. As such, we suggest that the road be aligned perpendicular to the channel. Also, the crossing should also maintain velocity differentials and sediment transport processes for frequent storm events through and adjacent to the crossing. The installed structure should have an open bottom and be positioned within a reasonably stable length of channel.

Road alignment Option 5A is appropriate, given that it will cross the existing watercourse at a nearly perpendicular angle through a previously disturbed area where the reach has been realigned and channelized. Minor erosion was noted along the valley walls in the watercourse crossing location associated with Option 5A; however, a crossing at this location would likely provide an opportunity for stabilization.

We recommend two possible approaches to crossing span sizing at 5A. The first is calculated as three times the bankfull channel width. The second is calculated as bankfull width plus two times the erosion limit. Based on the average bankfull channel width of 1.9 m, these approaches provide crossing sizes of 5.7 m and 11.9 m, respectively. Note these values are a significant portion of the meander belt width estimate.

If disturbance of riparian vegetation is anticipated, we also advocate installation of a channel reinforced with hydraulically sized materials to stabilize the channel under the crossing allowing for fish passage across a wide range of conditions. With regards to hydraulic sizing, MTO Highway Drainage Design Standards (2008) would suggest 100-year event scour protection per standards WC-1/WC-3 for 'local road' conditions with FS=1. Detailed design HEC-RAS results can be utilized for the 100-year event velocity determination.

The Option 5A alignment also includes a retaining wall on the north side of the road. On the west side of the creek, the retaining wall is adjacent to a meander bend that separates Reach **EPC-3** and **EPC-4**. As documented through our field assessment, this section of channel is in a transition area between the upstream wetland the defined channel downstream. As such, it is a low-energy and stable location with limited channel definition and no evidence of erosion. Most of the erosion associated with Reach **EPC-3** is located along the straight section farther downstream. The retaining wall sits approximately 1 to 1.5 m outside of the meander belt width in this area. Given the limited potential for erosion in this area and the factor of safety included in the meander belt width delineation, we suggest that the proposed retaining wall location is appropriate. For additional erosion protection, we recommend minor bioengineering treatments or offset protection be installed.

These recommendations only reflect geomorphological considerations for the proposed Kirby Road extension alignment Option 5A. Other disciplines will also need to be considered including terrestrial and aquatic biology, ecology, hydrogeology, and hydrology.

We trust this memo meets your requirements.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., Can-CISEC
Director, Principal Geomorphologist

Kat Woodrow, M.Sc.
Environmental Scientist

References

Ontario Ministry of Natural Resources (MNR). 2001. Technical Guide–River & Stream Systems: Erosion Hazard Limit.

Ontario Ministry of Transportation (MTO). 2008. Highway Drainage Design Standards.

Toronto and Region Conservation Authority. 2015. Crossings Guideline for Valley and Stream Corridors.

Appendix A

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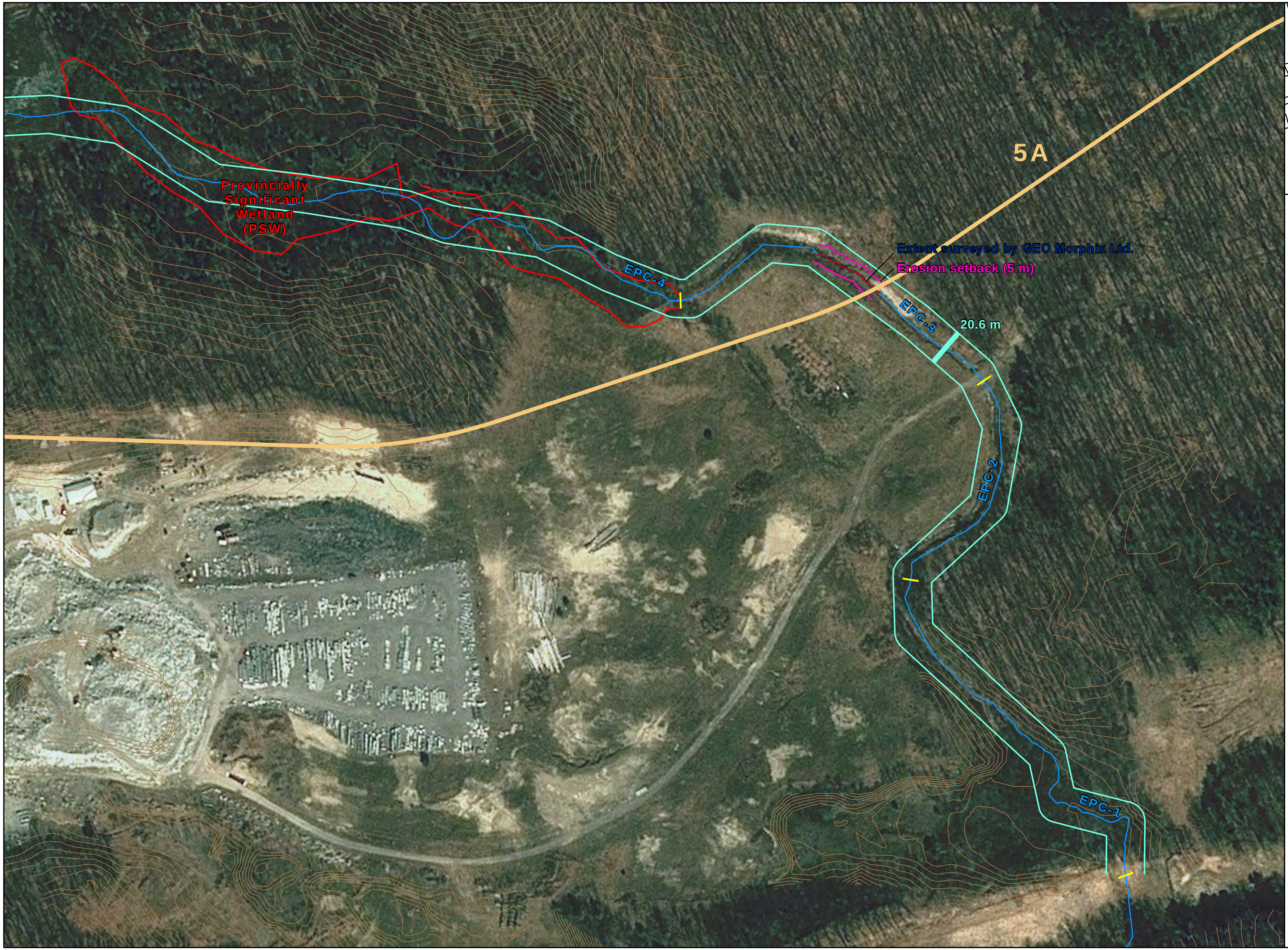
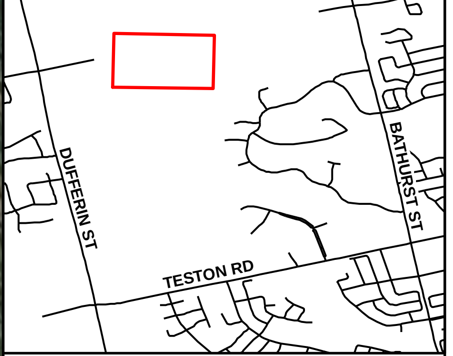


Key Map



Legend

Reach break

Centreline of watercourse

Meander belt width (20.6 m)

1 m Contour

Road Alignment Option

5A

N

0 50
Metres

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community Imagery: ~ 2014.
Reach break and Meander belt width: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018, and GEO Morphix Ltd., 2018.
Contours, Road Alignment Options, and PSW: Schaeffers Consulting Engineers, 2018/2019.
Print Date: April 2019. PN15080. Drawn By: W.B., K.W.

GEO MORPHIX

Planning Level Meander Belt Width Delineation

Upper East Patterson Creek

Vaughan, Ontario

Appendix B

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June 4, 2018

Schaeffers Consulting Engineers
6 Ronrose Drive
Concord, Ontario
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Attention: Mr. Leonid Groysman, Class EA Lead

Re: Planning Level Meander Belt Width Delineation, 100-Year Erosion Limits, and Preliminary Crossing Recommendations for the Kirby Road Extension Environmental Assessment
Upper East Patterson Creek, Vaughan, Ontario
GEO Morphix Project No. 15080

A geomorphological assessment was previously completed by GEO Morphix Ltd. (2016) for the Upper East Patterson Creek in the vicinity of the proposed Kirby Road Extension in Vaughan, Ontario. Our 2016 assessment involved both desktop and field activities including reach delineation, reach-by-reach rapid assessments, and a detailed geomorphological assessment.

Our understanding is that the Toronto and Region Conservation Authority (TRCA) has requested additional information including meander belt widths, 100-year erosion limits, and preliminary recommendations regarding the potential crossing location (Scott Smith, email dated May 3, 2018).

To address this request we completed additional desktop analysis to: supplement the findings of our original report; provide planning level meander belt widths; calculate 100-year erosion limits; and develop crossing recommendations.

General Reach Characteristics

Our previous work identified three reaches. A reach map is included in **Appendix A**. Reaches **EPC-1**, **EPC-2**, and **EPC-3** of Upper East Patterson Creek were assessed in Fall 2015 (GEO Morphix Ltd., 2016). Reach **EPC-1** was forested, while Reaches **EPC-2** and **EPC-3** flowed just outside the forest margin, along the perimeter of a disturbed area. An additional reach, **EPC-4**, was considered in the present desktop analysis to address all potential road alignment options and possible crossing locations. Reach **EPC-4** was identified as a wetland feature in a forested area upstream of Reach **EPC-3**. No significant tributaries were observed flowing into the main channel within the study area.

According to our observations in Fall 2015, the majority of the channel was at least partially confined or fully realigned. Reach **EPC-1** was a constructed valley feature, approximately 5 m wide and just over 1 m deep. The low-flow channel had no riffle-pool development, and averaged 1.89 m wide and 0.15 m deep. Reach **EPC-2** was also within a constructed valley feature, whose channel was likely formed naturally following valley excavation. The low-flow channel was considered to be the bankfull channel, although it may still be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. Reach **EPC-3** continued as a low-flow channel within a constructed valley feature, but with appreciably different physical characteristics than Reach **EPC-2**. The Reach **EPC-3** channel had no bankfull indicators and limited evidence of a stable channel morphology. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the upstream wetland (Reach **EPC-4**) contributed to total flow. Further reach descriptions and observations are provided in our previous report, which has been included as **Appendix B**.

Planning Level Meander Belt Width Delineation and 100-Year Erosion Limits

In support of crossing recommendations and to provide context, meander belt widths and 100-year erosion limits were calculated for the four reaches within the study area.

Meander belt widths for Reaches **EPC-1**, **EPC-2**, **EPC-3** and **EPC-4** were estimated using two methods.

The first method used two modified Williams (1986) models with the addition of a 20% factor of safety.

Modified Williams (1986) Area, $B_w = 18A^{0.65} + W_b$ ……………………………………………………………(Eq.1)

Modified Williams (1986) Width, $B_w = 4.3W_b^{1.12} + W_b$ ……………………………………………………………(Eq.2)

Where B_w is meander belt width (m), A is cross-sectional area (m^2), and W_b is bankfull channel width (m).

Previous clearing and other historical site activities have resulted in a disturbed study area with few natural references. Reach **EPC-1** was determined to have the most natural characteristics and was the most aged since realignment (GEO Morphix, 2016). As such, this reach was selected for detailed assessment to determine average bankfull channel dimensions (Fall 2015) and was used as a reference reach to model a representative meander belt width for all reaches in the present analysis. The average bankfull channel width for Reach **EPC-1** was 1.89 m, and the average bankfull channel depth was 0.15 m.

The modelled meander belt widths (including a 20% factor of safety) based on the detailed assessment were 11.8 m (Eq.1) and 12.8 m (Eq.2).

The second method for determining meander belt widths required measuring the largest meander amplitude observed within each reach. Again, previous site activities and watercourse realignments had erased any previously natural meanders from the planforms of Reaches **EPC-2** and **EPC-3**. The forest cover of Reaches **EPC-1** and **EPC-4** also prevented us from identifying drainage routes and channel planforms using aerial photography.

As a surrogate, we measured the largest meander amplitude within the study extent, as observed along the Ontario Hydro Network (MNR) watercourse. This was the most accurate delineation of the watercourse available for the present study. A 20% factor of safety was added to the measured value to determine a meander belt width of 20.6 m, which was applied for all reaches. This meander belt width was delineated along the observed central tendency of the watercourse within the study extent, and is illustrated in **Appendix C**.

The calculated meander belt widths are conservative, given that the studied reaches are in confined, or partially-confined systems. These meander belt widths can be further refined at detailed design, if required.

A 100-year erosion limit was estimated for all the reaches in the study area based on geology, level of erosion, and channel size according to the MNR's erosion hazard technical guidelines (MNR, 2001).

Where the reaches were not controlled by the presence of vegetation, the bank materials were a mix of clay, silt, and sand, with only limited evidence of active erosion. As such, based on MNR guidance we suggest an erosion limit of 5 m be applied to delineate the lateral erosion hazard.

Geomorphological Crossing Recommendations

Our preferences with regards to road alignment are based solely on geomorphological and erosion considerations. We have also considered TRCA's Crossing Guideline for Valley and Stream Corridors (2015), which recommends using siting and design to avoid damage to the infrastructure and minimizing channel contact with the crossing infrastructure to reducing erosion hazards.

We recommend that the sizing and location of the proposed crossing consider potential future channel erosion and/or migration. We suggest that the crossing be located at a fair distance from any upstream meanders. The crossing should also maintain velocity differentials and sediment transport processes for frequent storm events through and adjacent to the crossing. The installed structure should have an open bottom and be positioned within a reasonably stable length of channel.

Road Alignment Options 4 and 5 are not preferred as they both could potentially result in disturbance of well-established riparian cover. Clearing the riparian cover would negatively influence creek function. If this crossing location is proposed, we recommend spanning the meander belt width and limiting vegetation removal/impact. In that case, the potential impacts can likely be mitigated.

Road Alignment Options 6 and 6A are preferred as they cross the existing watercourse at a perpendicular angle through a previously disturbed area where the reach has been realigned and channelized. Erosion was noted along the valley walls in the crossing location associated with Road Alignment Options 6 and 6A. A crossing at this location would likely provide an opportunity for stabilization.

We recommend two possible approaches to crossing sizing at 6 or 6A. The first is calculated as three times the bankfull channel width. The second is calculated as bankfull width plus two times the erosion limit. Based on the average bankfull channel width of 1.9 m, these approaches provide crossing sizes of 5.7 m and 11.9 m, respectively. Note these values are a significant portion of the modelled meander belt width estimates.

If disturbance of riparian vegetation is anticipated, we also advocate installation of a channel reinforced with hydraulically sized materials to stabilize the channel under the crossing allowing for fish passage across a wide range of conditions. With regards to hydraulic sizing, MTO Highway Drainage Design Standards (2008) would suggest 100-year event scour protection per standards WC-1/WC-3 for 'local road' conditions with FS=1. Detailed design HEC-RAS results can be utilized for the 100-year event velocity determination.

These recommendations reflect the geomorphological considerations. Other disciplines will also need to be considered including terrestrial and aquatic biology, ecology, hydrogeology, and hydrology.

We trust this memo meets your requirements.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., Can-CISEC
Director, Principal Geomorphologist

Cara Hutton, M.Sc.
Senior Environmental Technician

References

GEO Morphix Ltd. 2016. Upper East Patterson Creek Geomorphic Assessment, Rizmi Property, City of Vaughan, Ontario. Rizmi Holdings Limited. January 18, 2016.

Ontario Ministry of Natural Resources (MNR). 2001. Technical Guide–River & Stream Systems: Erosion Hazard Limit.

Ontario Ministry of Transportation (MTO). 2008. Highway Drainage Design Standards.

Toronto and Region Conservation Authority. 2015. Crossings Guideline for Valley and Stream Corridors.

Williams, G.P. 1986. River meanders and channel size. Journal of Hydrology, 88 (1-2): 147-164.

Appendix A

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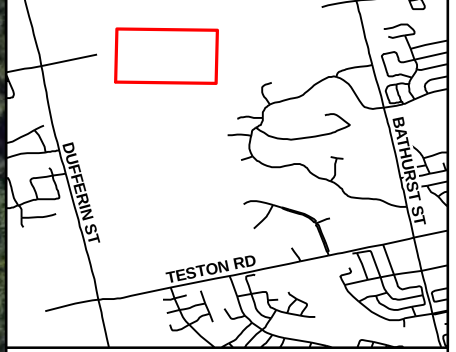
Key Map



Legend

Reach break

Centreline of watercourse

N

0 50
Metres

Reach break: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018, and GEO Morphix Ltd., 2018.
Imagery: York Region, 2017.

GEO MORPHIX

Reach Delineation

Upper East Patterson Creek

Vaughan, Ontario

Appendix B

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Rizmi Property
City of Vaughan, Ontario

Upper East Patterson Creek
Geomorphic Assessment

Prepared for:	Rizmi Holdings Limited 11333 Dufferin Street PO Box 663 Maple, Ontario L6A 1S5
Prepared by:	GEO Morphix Ltd.
Project No.:	15080
Date:	January 18, 2016

Table of Contents

List of Tables

Appendices

1 Introduction

A Municipal Class Environment Assessment is proposed by the City of Vaughan to determine the preferred alternative to extend Kirby Road to Gamble Road in the Town of Richmond, between Dufferin and Bathurst Streets. The ultimate alignment of this arterial road will be determined with consideration to numerous factors as required in the Class EA process. One consideration is East Patterson Creek, which is addressed in this report.

The east tributary of Patterson Creek originates in a wetland located near the north part of the Rizmi Stone & Aggregates property at 11333 Dufferin Street in the community of Maple. A significant portion of channel within the property limits has apparently been modified in the past. The alterations, however, do not affect fish habitat due to a significant barrier to fish passage along the southern property line. The watercourse currently conveys flows to the south property line where it terminates in a wetland. The following report provides a geomorphic assessment of East Patterson Creek to fulfill a Class EA requirement to document natural heritage features, as well as to support the decision-making process with respect to actions that affect the watercourse.

It is understood that the future of the channel within the property has yet to be determined as it is not considered to be direct fish habitat. Potential outcomes include removal, retain in its current alignment, realignment, enhancement, or a combination of these alternatives. GEO Morphix will provide appropriate support once the preferred solution has been determined in the Class EA study.

2 Historical Conditions

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Historical aerial photographs from 1946 (scale 1:20,000) and 1954 (scale 1:63,360), and orthophotography from 1970, 1999, 2002, 2005, 2007, 2011, 2012 and 2013, and Google Earth Pro satellite imagery from 2015 were reviewed to complete the historical assessment.

In 1946, the upper East Patterson Creek drainage area was largely forested, with the exception of a clearing for agriculture at the upper extent of the drainage area. At the current location of the Rizmi Stone & Aggregates field operations, there was a clearing but no apparent activity. The drainage route within the subject property could not be identified due to tree cover, but there was an intermittently-forested corridor with a watercourse that extended in a southeasterly direction from the subject property towards Bathurst Street. The channel planform could not be determine on the aerial photography. Outside of the forested area to the north beyond the drainage area, the land was used exclusively for agriculture. The area beyond the property to the south was also used for agriculture.

There were no significant changes in land use through 1954. The surrounding land to the south, however, was transformed to a golf course, Maple Downs Golf Course. By 1970, Rizmi operations extended approximately 0.4 km to the east from the previously cleared area, as suggested by the heavily disturbed landscape and the access road connecting the disturbed area to Dufferin Street. Also between 1954 and 1970, the TransCanada Pipeline was constructed along the south property boundary and across the channel. The watercourse is visible along the east side of an internal road at the eastern end of the disturbed area, but the Pipeline clearly prevents flow conveyance

beyond the property as evidenced by the ponded water at the Pipeline crossing. The lack of tree cover along the section of channel along the internal road as well as its linear alignment also suggest that it was channelized to enhance drainage function. East of the Rizmi property along the north side of the Pipeline was a private runway.

Rizmi operations appeared to have slowed by 1999. The channel alignment was the same as it was in 1970, but the pond at the Pipeline had visual characteristics of a wetland. Another notable change within the property was a linear clearing through the forest leading to the general area of the channel origin, north of the cleared aggregate extraction area. There was also limited clearing on the east side of the internal road and channel, as well as a culvert in the channel next to this recently cleared area for access the east side. Southeast of the property, the land was developed for residential use.

Surrounding land use remained generally unchanged in 2011. Between 2007 and 2011, a portion of the channel within the Rizmi property was again realigned to travel along the margin of the cleared area. The previously installed culvert was removed due to the channel realignment, and a new culvert was constructed at the new channel crossing location. Activity within the property also appears to have increased during this period. There were no notable changes in 2012 and 2013.

Overall, the portion of East Patterson Creek within the Rizmi property experienced significant changes over the period covered by historical imagery. These changes include realignment and straightening (i.e., channelization), removal of tree cover, and the disruption of channel and flow continuity as a result of the TransCanada Pipeline.

3 Existing Conditions

3.1 Watershed Characteristics

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.

East Patterson Creek is situated in the Upper East Don Subwatershed. The channel within the property limits is a headwater feature that originates from a generally linear wetland feature located mostly within the property. In total, the channel travels in a southerly direction for approximately 6 km, where it joins West Patterson Creek, then continues for another 1.5 km to the confluence with the East Don River.

The subject site is located in a southward extending lobe of the Oak Ridges Moraine physiographic region, which is bounded by the South Slope physiographic region to the west, south and east. Beyond the South Slope is the Peel Plain (Chapman and Putnam, 1984), where Patterson Creek joins the East Don River. With respect to surficial geology, the subject area is characterized by ice-contact stratified deposits consisting of sand and gravel, minor silt, clay and till (OGS, 2010). The surficial geology generally changes in the downstream direction in concert with the physiographic regions: the South Slope is comprised of clay to silt-textured till (derived from glaciolacustrine deposits or shale) and the Peel Plain is generally characterized by glaciolacustrine deposits (OGS, 2010). The predominantly sand and gravel composition of the surficial material

allows the channel to readily adjust, although the degree of adjustment would also be influenced by the flow regime as well as other factors such as vegetation control.

The catchment area for the channel within the subject property is largely forested with the exception of the area cleared for the Rizmi Stone & Aggregates operations. Downstream of the property to Bathurst Street, the channel travels through a forested corridor surrounded by low-density residential dwellings. The forested channel corridor continues beyond Bathurst Street, although housing density increases.

3.2 Reach Delineation

Rivers and streams are frequently segmented into reaches to provide meaningful lengths of channel for study. Reaches are delineated based on changes such as hydrology, channel gradient, confinement, planform (i.e., channel pattern), geology, surrounding land use and anthropogenic disturbances (e.g., crossing structures, dams, straightening/channelization, armouring). Each reach can then be studied as a unit that is expected to function in generally uniform manner throughout its length.

Within the Rizmi property, East Patterson Creek was divided into three reaches. The downstream channel reach (EPC-1) is approximately 100 m in length, the middle reach (EPC-2) is 130 m, and the upstream reach (EPC-3) is 200 m. Forest cover was one consideration when delineating the reaches: the Reach EPC-1 channel lies just within the west forest margin, while Reaches EPC-2 and EPC-3 are just outside the west forest margin. Despite the apparently limited differences between reaches, tree cover is a significant factor that governs channel form and function, and hence the two reaches. Reaches EPC-2 and EPC-3 are differentiated primarily by channel morphology. Wetland features are located downstream of Reach EPC-1 and upstream of Reach EPC-2. The reach delineation was verified in the field, as discussed below.

3.3 Reach Assessments

Site observations and channel measurements were collected on November 2, 2015. The field investigation was completed for the full length of channel between the wetland at the upstream extent of the channel and the south property limit. A photographic record of site conditions is provided in Appendix A. On the day of the site visit, the temperature was 10°C and there was no precipitation. There was, however, 7 mm of rain from October 31 to November 1.

3.3.1 General Observations

Within the Rizmi property, East Patterson Creek originates in a wetland feature located in a forested area to the north just beyond an open, disturbed area created by site activities. The channel travels along the perimeter of the clearing before entering the forested area. It continues just within the forest boundary to a wetland feature at the south limit of the property. The reaches identified in Section 3.2 were confirmed to be correct. The following is a description of each reach from upstream to downstream.

The wetland at the upstream end of the section of channel under study is comprised of a dense thicket of shrubs (red-osier dogwood). There was no define flow pattern within the wetland.

Reach EPC-3 is in a constructed valley feature containing a low-flow channel. The valley had a 'V' shape except towards the downstream end of the reach. The channel had no bankfull indicators

and there was limited evidence of a stable channel morphology. The bed was composed of mostly silt and sand, and its morphology was partly controlled by vegetation. Three knickpoints were observed, which suggests that the channel gradient is high relative to those of the two downstream reaches. Groundwater input, evidenced by the watercress towards the upstream end of the reach, as well as water from the wetland contributed to total flow. Wetted flow width varied due to the high degree of channel confinement, ranging from 0.1 to 1.5 m. The channel characteristics were largely governed by the composition of the valley materials, which was sand. The northeast embankment (left embankment viewed in the downstream direction) was comprised of exposed sand with limited woody vegetation. Due to the unstable nature of the embankments, in particular that to the northeast, the channel will likely continue to adjust according to the sediment supply. Mature trees lied beyond the sandy embankment. The southwest side of the channel was open with primarily grasses.

Reaches EPC-3 and EPC-2 were divided by a partly embedded 1200 mm CSP culvert, constructed for access across the channel. Reach EPC-2 continues as a constructed valley feature, but with appreciably different physical characteristics. Here, the valley top width was roughly 3.9 m wide and the valley depth was 1.5 to 2.0 m. The east side of the valley was populated by mature trees, while the east side was dominated by grasses within an open (i.e., cleared) area.

The Reach EPC-2 channel likely formed naturally following valley excavation. The low-flow channel is considered to be the bankfull channel, although it still may be adjusting to the annual range of flows given that the valley was constructed between 2007 and 2011. The bankfull channel was on average 1.15 m wide and 0.42 m deep. There was a 0.22 m high knickpoint mid-reach that cut into till. Upstream of the knickpoint, the bed was characterized by sand, gravel and small cobbles, while downstream of the knickpoint, the bed was comprised of mostly sand, but also exposed till. This longitudinal change in bed characteristics can be explained by differences in bed gradient.

At the downstream end of Reach EPC-2, the channel turns at nearly a right angle to travel south into Reach EPC-1. There was evidence of the former channel location (before the realignment of Reaches EPC-3 and EPC-2), in the form of a linear depression across the cleared area, that aligned with Reach EPC-1. Although the former channel was decommissioned, surface runoff apparently continued to enter the Reach EPC-1 channel at the upstream end of this reach as indicated by the minor erosion and headcutting.

Reach EPC-1 travels in a southerly direction and continues as a constructed valley feature approximately 5 m wide and just over 1 m deep. Both sides of the valley was vegetated with mature trees; however, the woody riparian buffer on the west side was limited. Tree cover over the channel was dense, and there were frequent observations of woody debris within the constructed valley, mostly as broken individual tree limbs that did not significantly affect flow pattern. The low-flow channel had no riffle-pool development, and averaged 1.90 m wide and 0.15 m deep. The increase in width-to-depth ratio, relative to that of Reach EPC-2, can be explained by the decrease in channel gradient and the increase in discharge. Both the bed and banks were comprised of sand, which would be expected due to the lower gradient and the typical downstream fining found in natural watercourses.

At the downstream end of the Reach EPC-1 channel was a wetland feature. This wetland was contained in a basin (roughly 70 wide and 50 m wide) that was bounded in the downstream (south) end by a raised natural gas pipeline corridor (i.e., TransCanada Pipeline), which was essentially a large berm. The top of the Pipeline was approximately 1.5 to 2.0 m above the wetland bed, and therefore a considerable volume of water would be required for flows to spill

over the Pipeline corridor. There was no evidence of a flow path over the Pipeline, although it would clearly be located across the lowest point. The impact of the lack of surface flow continuity to the watercourse downstream (south) of the Pipeline corridor could not be assessed due to property constraints.

3.3.2 Rapid Field Assessments

Rapid field assessments were completed as reconnaissance-level evaluations to determine the condition of each reach with respect to channel stability and general stream health:

- Channel instability was semi-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.

A summary of the rapid assessments is provided in Table 1. Completed field sheets are found in Appendix B.

Table 1: Rapid field assessment summary

Reach	RGA*			RSAT**		
	Score	Condition	Dominant Form of Adjustment	Score	Condition	Limiting Feature(s)
EPC-1	0.11	In regime	Aggradation	26	Good	Physical instream habitat
EPC-2	0.12	In regime	Degradation	28	Good	Riparian habitat conditions
EPC-3	0.09	In regime	Degradation	22	Fair	Riparian habitat conditions

* Ontario Ministry of the Environment (2003)
** Galli (1996)

3.3.3 Detailed Geomorphic Assessment

Within the property limits, Reach EPC-1 was determined to be relatively natural and certainly the most aged since realignment. As such, this reach was selected for further investigation – i.e., detailed geomorphic assessment. This detailed assessment serves as the basis for any required channel modifications such as realignment or stabilization.

The detailed assessment involved temporarily setting up eight representative cross sections for the purpose of determining average bankfull channel dimensions (e.g., width, average bankfull depth, maximum depth, and bank angles). The bankfull level was determined using standard protocols and accepted field indicators. A survey of the bed profile was also completed to determine slope and compute bankfull hydraulics. A modified Wolman (1954) pebble count was completed to characterize the bed materials. A summary of measured and computed values is presented in Table 2.

Table 2: Bankfull parameters of the reference channel

Channel parameter	Results
Measured	
Average bankfull channel width (m)	1.89
Average bankfull channel depth (m)	0.15
Average width-to-depth ratio	14.7
Channel gradient (%)	0.42
D_{50} (mm)	<2
D_{84} (mm)	<2
Manning's n roughness coefficient	0.034
Computed	
Bankfull channel discharge (m^3/s) *	0.14
Average bankfull velocity (m/s)	0.53
Unit stream power at bankfull discharge (W/m^2)	3.2
Tractive force at bankfull (N/m^2)	5.98
Critical shear stress (N/m^2) **	1.46
Flow competency for D_{50} (m/s) ***	0.27
Flow competency for D_{84} (m/s) ***	0.27

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

The Reach EPC-1 reference channel has a lower width-to-depth ratio than the two upstream reaches due to the lower channel gradient. Despite the relatively low unit stream power, the bed (comprised of sand) is fully mobile under bankfull flow conditions. It is expected that the Reach EPC-1 channel length would decrease slowly over time as the bed material is transported and deposited in the wetland. The receiving wetland would consequently increase in size, but only in the upstream direction due to the raised pipeline crossing.

4 Conclusions

East Patterson Creek within the Rizmi property has been significantly altered, and impacted both directly and indirectly, over the period covered by historical imagery. It also no longer functions

as potential fish habitat as a result of the construction of the TransCanada Pipeline. In-channel flows now therefore infiltrate and contribute to groundwater.

If the preferred alternative solution, resulting from the Class EA study, is assessed to be restoration, realignment or enhancement, we would be pleased to provide design services. Concurrently or independently, we can also investigate potential hazards associated with a dynamic channel.

5 References

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Appendix A
Photographic Record of Site Conditions

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for 2-sided printing purposes

Photo 1	
	EPC-3: Near upstream extent of reach, viewed upstream. The channel was confined by sandy valley wall to the east and a vegetated valley wall to the west.
Photo 2	
	EPC-3: Mid-reach viewed upstream at a knickpoint.

Photo 3	
	EPC-3: Reach viewed upstream from downstream end of reach.
Photo 4	
	1200 mm CSP culvert between Reaches EPC-2 and 3.

Photo 5	
	ECP-2: Channel viewed in the downstream direction. Coarse substrate was found mostly in the upstream portion of the reach. Note the channel confinement.
Photo 6	
	EPC-2: Mid-reach knickpoint in exposed till.

Photo 7	
	EPC-2: Channel viewed in the downstream direction towards end of reach.
Photo 8	
	EPC-1: Mid-reach channel viewed in the downstream direction. Note the limited channel definition and lack of morphological variability, and confinement between valley walls.

Photo 9	
	ECP-1: Channel viewed downstream towards downstream end of reach. Note the absence of flow and limited channel definition.
Photo 10	
	EPC-1: Wetland at property line with raised pipeline in background (see fence line). No culvert was found.

Appendix B
Rapid Assessment Field Sheets

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for 2-sided printing purposes

GEO | MORPHIX

Geomorphology · Earth Science · Observations

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-1
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St.
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

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

Riparian Vegetation

Dominant Type: (Table 6) 1

Species: ______

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): / | Coverage of Reach (%): /

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

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

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

see detailed assessment

Bankfull Width (m) | | | | **Wetted Width (m)** | | |

Bankfull Depth (m) | | | | **Wetted Depth (m)** | | |

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

Pool Depth (m) NA | **Riffle Length (m)** NA | **Undercuts (m)** None

Velocity (m/s) Ø | / | / | Wiffle ball / ADV / Estimated

Comments: No riffle - pools, poor BF indicators

Bank Angle: ☒ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Notes:

Completed by: CH   Checked by: ______

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code/Phase:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

Process	No.	Geomorphic Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	1/4
	2	Coarse materials in riffles embedded	NA		
	3	Siltation in pools	NA		
	4	Medial bars		✓	
	5	Accretion on point bars	NA		
	6	Poor longitudinal sorting of bed materials	✓		
	7	Deposition in the overbank zone		✓	
		Sum of indices =	1	3	0.25
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA		0/3
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA		
	3	Elevated storm sewer outfall(s)	NA		
	4	Undermined gabion baskets / concrete aprons / etc.	NA		
	5	Scour pools downstream of culverts / storm sewer outlets	NA		
	6	Cut face on bar forms	NA		
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material	NA		
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	3	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	1/5
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	NA		
	5	Basal scour on both sides of channel through riffle	NA		
	6	Outflanked gabion baskets / concrete walls / etc.	NA		
	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	4	0.2
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/6
	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	NA		
		Sum of indices =	0	6	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.11			
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: CH Checked by: ________

Rapid Stream Assessment Technique **Project Number:** PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-1
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	E. Patterson Crk

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	NA
	• 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)	NA
	• 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	NA
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	NA
	• 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	NA
	• 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	NA
	• 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	NA
	• 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	NA
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) =				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
			26	

Completed by: CH Checked by: ________

GEO MORPHIX

Reach Characteristics

Project Code/Phase: PN15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-2
Weather:	sun + 10°C	**Location:**	Kirby Rd + Dufferin St
Field staff:	CH/ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | ☒ Groundwater | Evidence: iron staining

Riparian Vegetation

Dominant Type: (Table 6) 3
Species: ______

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 | Coverage of Reach (%): <5

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

Density of WD: ☐ Low ☐ Moderate ☐ High

WDJ/50m:

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

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

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

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☒	☒	☒ small	☐	☒ till	☐
~~Pool Substrate~~	☐	☐	☐	☐	☐	☐	☐
Bank Material	☒ silt	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	1.3	1.0		Wetted Width (m)	0.3	0.25	
Bankfull Depth (m)	0.4	0.45		Wetted Depth (m)	0.1	0.15	

Riffle/Pool Spacing (m): NA | % Riffles: NA | % Pools: NA | Meander Amplitude: N/A

Pool Depth (m): NA | Riffle Length (m): NA | Undercuts (m): /

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

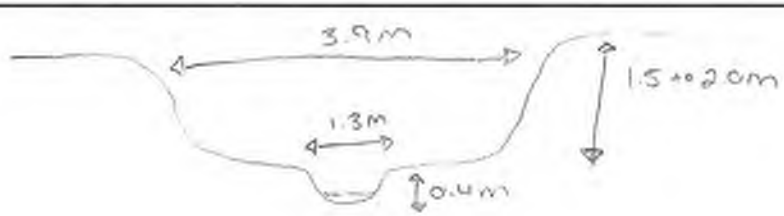
Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☐ < 5% ☐ 5 – 30% ☒ 30 – 60% ☐ 60 – 100%

Comments: KP + exposed till
coarse bed material u/s of KP

Notes:
CSP @ crossing = 1.2m

Valley feature



Completed by: CH

Checked by: ______

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Rapid Geomorphic Assessment **Project Code/Phase:** DN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH / ER	Watershed/Subwatershed:	East Patterson

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/5
	2	Coarse materials in riffles embedded	N/A		
	3	Siltation in pools	N/A		
	4	Medial bars		✓	
	5	Accretion on point bars		✓	
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	0	5	0.0
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.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N/A		
	5	Basal scour on both sides of channel through riffle	N/A		
	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 =	0	5	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/6
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form	N/A		
	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 =	1	5	0.17

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.13

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

Completed by: KT/ER Checked by: ________

Rapid Stream Assessment Technique **Project Number:** DN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-2
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

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)	N/A
	• 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	

EPC-2
PN 15080

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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	NA
	• 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	NA
	• 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	NA
	• 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	

Evaluation Category	Poor	Fair	Good	Excellent
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 N/A
	• 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

Evaluation Category	Poor	Fair	Good	Excellent
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)
			√	

Completed by: KT/ER Checked by: ________

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Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: PH15080

Date:	Nov 2, 2015	**Stream/Reach:**	EPC-3
Weather:	sun + 10°C	**Location:**	Kirby Rd
Field staff:	CH / ER	**Watershed/Subwatershed:**	East Patterson Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 4 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2 | [x] Groundwater | Evidence: watercress

Riparian Vegetation

- Dominant Type: (Table 6) [ ]
- Species: ______
- Coverage: [ ] None [ ] Fragmented [x] Continuous
- Channel widths: [ ] 1-4 [x] 4-10 [ ] > 10
- Age Class (yrs): [ ] Immature (<5) [x] Established (5-30) [ ] Mature (>30)
- Encroachment: (Table 7) 3

Aquatic/Instream Vegetation

- Type (Table8): 2
- Coverage of Reach (%): 40
- Woody Debris: [ ] Present in Cutbank [ ] Present in Channel [x] Not Present
- Density of WD: [ ] Low [ ] Moderate [ ] High
- WDJ/50m: /

Water Quality

- Odour (Table 16): 1
- Turbidity (Table 17): 1

Channel Characteristics

- Sinuosity (Type) (Table 9): 1
- Sinuosity (Degree) (Table 10): 1
- Gradient (Table 11): 2
- Number of Channels (Table 12): 1
- Entrenchment (Table 13): 2
- Type of Bank Failure (Table 14): 1
- Downs's Classification (Table 15): e

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
~~Riffle~~ Substrate	[ ]	[x]	[x] some	[ ]	[ ]	[ ]	[ ]
~~Pool Substrate~~	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Bank Material	[ ]	[x]	[ ]	[ ]	[ ]	[ ]	[x]

Bankfull Width (m)	1.4		
Bankfull Depth (m)	0.35		
Wetted Width (m)	0.8		
Wetted Depth (m)	0.1		

- **Riffle/Pool Spacing (m):** NA
- **% Riffles:** NA
- **% Pools:** NA
- **Meander Amplitude:** NA
- **Pool Depth (m)** D/S of KP: 0.3
- **Riffle Length (m):** NA
- **Undercuts (m):** /
- **Velocity (m/s):** / / /
- **Wiffle ball / ADV / Estimated**

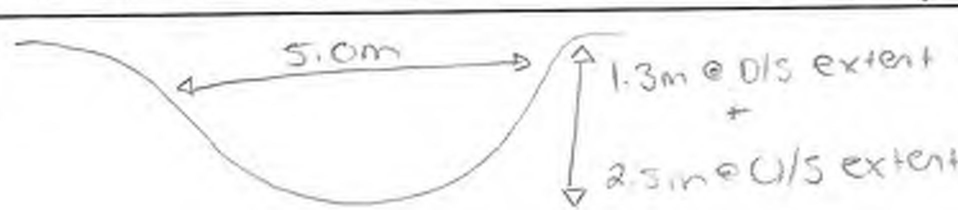
Bank Angle: [ ] 0 – 30 [ ] 30 – 60 [x] 60 – 90 [ ] Undercut

Bank Erosion: [ ] < 5% [ ] 5 – 30% [ ] 30 – 60% [x] 60 – 100%

Comments: 3 knickpoints, no riffle - pool development

Notes: sandy VLW along LB; saplings in channel @ D/S extent; wetland U/S of VLW

valley feature



Completed by: CH **Checked by:** ______

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Rapid Geomorphic Assessment

Project Code/Phase: PN15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	Sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	0/7
	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 =	0	7	0.0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		1/5
	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 =	1	4	0.20
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	0/5
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends	N/A		
	5	Basal scour on both sides of channel through riffle	N/A		
	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 =	0	5	0.0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	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 =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.09			
Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: KI/ER Checked by: ______

Rapid Stream Assessment Technique **Project Number:** pn15080

Date:	Nov 2, 2015	Stream/Reach:	EPC-3
Weather:	sun + 10°C	Location:	Kirby Rd
Field Staff:	CH/ER	Watershed/Subwatershed:	East Patterson

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
N/A	• 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
N/A	• 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

EPC-3
PN 15080

GEO | MORPHIX

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) = 22				
Ranking	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)
		✓		

Completed by: KT/ER Checked by: ______

Appendix C

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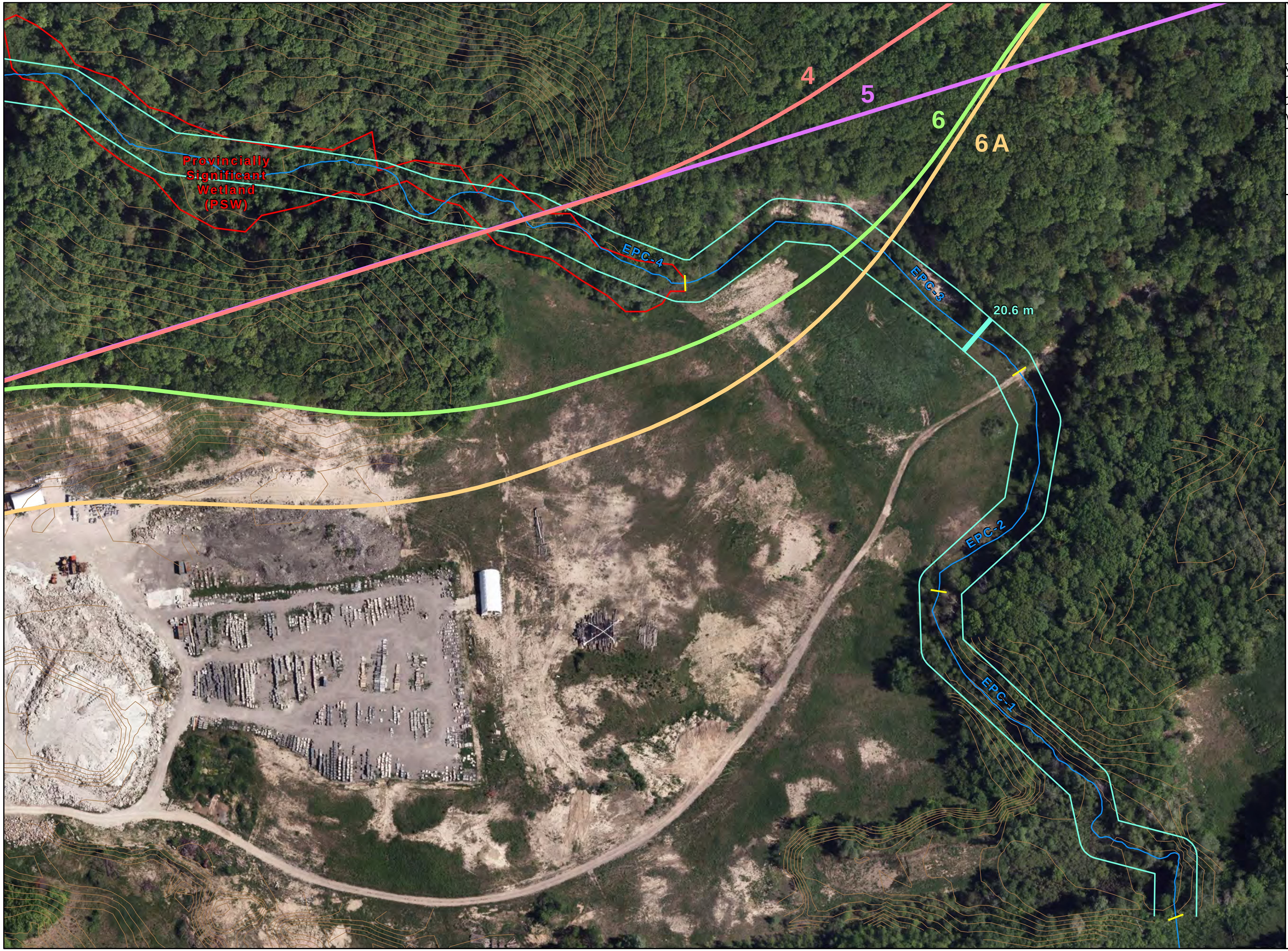
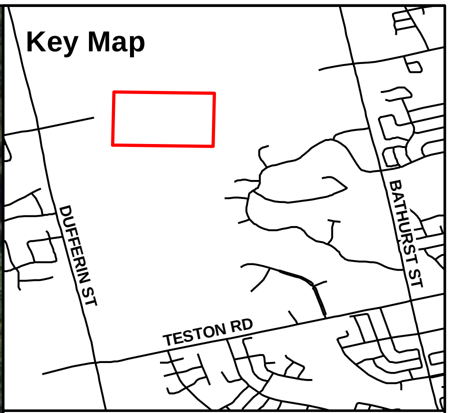
for 2-sided printing purposes





Legend

- Reach break
- Centreline of watercourse
- Meander belt width (20.6 m)
- 1 m Contour

Road Alignment Options

- 4
- 5
- 6
- 6A

N

0 50
Metres

Reach break and Meander belt width: GEO Morphix Ltd., 2018.
Watercourse: MNR, 2010, Schaeffers Consulting Engineers, 2018, and GEO Morphix Ltd., 2018.
Contours, Road Alignment Options, and PSW: Schaeffers Consulting Engineers, 2018.
Imagery: York Region, 2017.

GEO MORPHIX

Planning Level Meander Belt Width Delineation

Upper East Patterson Creek

Vaughan, Ontario