McKinnon's Creek Erosion Hazard Assessment

930 Smith Road, Navan, Ontario

Prepared for:
Hierarchy Development & Design Inc.
112 Royal Troon Lane
Dunrobin, Ontario
K0A 1T0

December 8, 2023 (Revised March 22 and June 18, 2024)
PN23106

GEO MORPHIX
Geomorphology
Earth Science
Observations

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Report Title:	McKinnon's Creek Erosion Hazard Assessment 930 Smith Road, Navan, Ontario
Report Prepared for:	Hierarchy Development & Design Inc. 112 Royal Troon Lane Dunrobin, Ontario K0A 1T0
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1 Introduction

GEO Morphix was retained by Hierarchy Development & Design Inc. to complete a fluvial geomorphological and erosion hazard assessment for a proposed development located at 930 Smith Road in the community of Navan in Ottawa, Ontario. The subject lands are approximately 5 ha in area and bounded by Smith Road to the east and south, and existing residences to the north and west. McKinnon's Creek flows from north to south and is located east of Smith Road, parallel to the subject site (**Appendix A**). Existing land uses consist of vacant greenfield and forested valley associated with McKinnon's Creek.

The City of Ottawa, as part of the pre-application consultation, requested the completion of a Fluvial Geomorphology Report. The following activities have been completed in support of our assessment:

- Reviewed available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Reviewed historical aerial photographs to ascertain changes to the watercourse and surrounding land use and cover over time
- Validated reach delineation from previous studies
- Conducted a rapid geomorphological assessment along McKinnon's Creek to document notable erosion zones, gather in-stream measurements of bankfull channel dimensions, and describe the composition and structure of the bed and bank materials
- Delineated the erosion hazard using historical and recent aerial imagery and field observations

This report summarizes the results of our desktop and field-based assessment. It identifies site constraints from a fluvial geomorphological perspective and should be considered in conjunction with studies being completed by other disciplines (i.e., geotechnical slope stability assessment) in support of the proposed development.

2 Background Review and Desktop Assessment

2.1 Background Information

McKinnon's Creek is located east of the Mer Bleue wetlands within the Bear Brook subwatershed of the South Nation River, east of the City of Ottawa. The section of the creek examined in the assessment flows through the small community of Navan. The surrounding land use is a combination of fragmented forest, low and medium density urban residential dwellings, and rural agricultural and fallow fields. An Environmental Management Plan was developed by Morrison Hershfield Limited for an area that encapsulates a length of McKinnon's Creek upstream of the present study area in 2017. The boundary of the EMP assessment area ends immediately upstream of the boundary of assessment for the present report.

2.2 Geology and Physiography

Geology and physiography act as constraints to channel development and tendency. These factors determine the nature and quantity of the availability and type of sediment. Secondary variables that affect the channel include land use and riparian vegetation. 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.

Based on published mapping, the subject area lies within the St. Lawrence-Ottawa Lowlands physiographic region, an area of low relief with elevations approaching sea-level (approximately 200 feet asl or lower) (Chapman and Putnam, 1984). There are two (2) minor physiographic regions throughout the subject area: a relatively coarse and elongate section of the Russel and Prescott sand plains (region 50) northeast of Mer Bleue, and the Ottawa Valley clay flats (region 49). Both physiographic regions were formed by drainage of the postglacial Ottawa River into the Champlain Sea with sediments sourced from Canadian Shield granite. The sand plains were deposited as deltas near the confluence, while the clay flats were deposited in the slackwaters of the Champlain Sea. Chapman and Putnam (1984) describe the clay deposits in this area as deep, fine textured, poorly drained, and very plastic. The sand is described as well-drained, depending on topography, as the best drainage is found where the region borders bluffs along the former channel margins of the postglacial Ottawa River. Published Ontario Geological Survey (OGS) mapping shows that the surficial geology throughout **Reach MC2** is characterized as high permeability medium to fine-grained sands of glaciomarine (deltaic and estuarine) origin (unit 11a; OGS, 2010).

Borehole logs recorded within the subject lands during a 2021 field investigation by GEMTEC Consulting Engineers and Scientists Limited (GEMTEC) (2024) encountered deposits in the subsurface that confirm the surficial geology shown in regional mapping, as described above. GEMTEC sampled three (3) locations in August 2021. Topsoil with a thickness ranging from 130 - 180 mm comprised the top layer of the subsurface. The next deposit encountered in only one (1) of the locations was silty sand with a thickness of approximately 150 mm. Deposits of silty clay were encountered below topsoil in all boreholes with the base terminating at 5.3 m below ground surface in one (1) borehole and extended to depths beyond 6.7 – 8.3 m in the other boreholes. The upper portion of the silty clay deposits had weathered into a stiff crust approximately 2.8 – 5.2 m in thickness comprised of 21% silt and 78% clay with water content ranging from 25 – 51%. The silty clay below the weathered crust decreased from stiff to firm consistency with depth, with water content ranging from 61 – 81%. A deposit of glacial till comprised of silt (24%), sand (44%), with some gravel (16%) and clay (16%) was encountered below the base of the silty clay at 5.3 m depth below ground surface and extended to depths beyond 6.1 m.

GEMTEC (2024) notes that surficial geology maps of the Ottawa area indicate that the subject lands are underlain by thick deposits of sensitive silty clay. As noted above, silty clay deposits were encountered in all boreholes with the base terminating at 5.3 m below ground surface in one (1) borehole and extended to depths beyond 6.7 – 8.3 m in the other boreholes. A brief summary of sediment characteristics is included below. For specific details related to the suite of tests used to characterize the silty clay deposit, refer to the report prepared by GEMTEC (2024).

The upper portion of the silty clay was weathered to a grey brown crust ranging in thickness from 2.8 m to 5.2 m and had a stiff to very stiff consistency and medium plasticity. The water content of the weathered silty clay deposit ranged from 25% to 51%, which was noted be below the liquid limit (GEMTEC, 2024). The weathered layer was underlain by grey silty clay. Two (2) of the boreholes terminated in this deposit, at depths ranging from 6.7 to 8.3 m. The deposit was characterized as having a firm to stiff consistency and medium plasticity. The silty clay had a sensitivity ranging from approximately 5 to 14 and was considered to have a low to medium sensitivity (i.e. sensitivity less than 30) (GEMTEC, 2024). The water content ranged from approximately 61% to 81%, which is above the liquid limit.

It is understood that the City of Ottawa has provided high-level screening criteria to assess where there is potential for retrogressive earth flow slides along the western valley slope of McKinnon's Creek (GEMTEC, 2024). The following specific criteria were provided by the City:

- the height slope must be greater than 8 m
- the top and bottom of slope are to be determined where the slope has a gradient of less than 14% over a distance of greater than 15 m
- at least 35 to 40% of the slope height above the critical failure surface must consist of sensitive marine clay

If one of the above criteria are not met, the slope is not considered to be at risk of retrogressive earth flow slide. Test pits at previously studied cross-sections excavated by GEMTEC (2024) indicate that the silty clay deposit ranges in thickness from approximately 3.5 m to 7.3 m. GEMTEC (2024) also assessed slope height and gradients along McKinnon's Creek using 2019 LiDAR data from the City of Ottawa. None of the slope heights were greater than 8 m. Given two of the three criteria provided by the City were not met, the west valley slope of McKinnon's Creek was evaluated to be at a low risk of retrogressive landslide failure (GEMTEC, 2024).

2.3 Site History

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. Aerial photographs from 1976, 1991, 1999, 2011, and 2021 available online through the GEO Ottawa web mapping application were reviewed. Refer to **Appendix B** for copies of select imagery.

The earliest imagery available on the GEO Ottawa web mapping application shows the creek in 1976. There were already residential properties and roads within the tablelands surrounding the creek valley at this time, with the other predominant land use being agriculture. The land cover within the valley is comprised of trees. East of **Reach MC2**, the tablelands were also covered in a forested area, with some residential properties along Smith Road. Smith Road crosses the creek at the northern extent of **Reach MC2** then bends 90° southwards to travel along the western edge of the creek valley. Beyond Smith Road west of **Reach MC2**, there was a fallow field with residential properties along its northern edge. The details of the creek planform are obscured by trees in the 1976 imagery.

Land cover in 1991 remained the same west of the creek with the fallow field still present and the creek valley remained forested. The forested area east of the creek valley had been fragmented by this time, as a new residential subdivision had been constructed. More residential subdivisions had also been constructed within tablelands upstream of **Reach MC2**. Some time between 1976 and 1999, it appears as though stabilization work was completed along the right (west) bank immediately downstream of the Smith Road crossing, as some of the trees in that location were removed and the application of a rock bank treatment is evident in the 1999 imagery. The location of this bank treatment was confirmed in the field.

Land cover remained the same between 1999 and 2011. The channel planform between the 1999 and 2011 imagery is largely obscured by forest vegetation but appears to be similar with the exception of the channel near the second bend downstream of the Smith Road crossing, where the channel appears to have widened, particularly towards the northeast. Land cover also remained the same between 2011 and 2021, with no observable changes in the overall channel planform.

3 Watercourse Characteristics

3.1 Reach Delineation

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

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

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

A single reach, **MC2,** which was previously delineated by GEO Morphix Ltd. (2023), was assessed for the present study. The reach travels parallel to Smith Road which is located east of the subject site. Refer to **Appendix A** for a reach map.

3.2 General Reach Observations

Field investigations were first completed on November 24, 2022 for a previous study and confirmed on October 24, 2023. The rapid field assessment included the following activities:

- Complete reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation
- Describe riparian conditions
- Estimate bankfull channel dimensions
- Characterize bed and bank material composition and structure
- Observe areas of erosion, scour, or deposition
- Collect photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

These observations and measurements are summarized below and are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including reach summaries, habitat sketch maps and rapid assessments, are provided in **Appendix D**.

Bankfull channel dimensions and channel characteristics such as substrate composition, channel form and the presence of undercut channel banks are measured during rapid field reconnaissance as these elements provide an indication of channel adjustments such as degradation, aggradation, migration or widening. Bankfull channel dimensions and channel bank undercuts were measured along the reach during site visits conducted in November 2022 and October 2023. Measurements are provided in the reach description below.

Reach MC2 extends from Meteor Avenue to Smith Road, flowing approximately 310 m from the northern to southern extent. The reach was characterised as confined with a perennial flow regime. Published surficial geology mapping indicates that this section of McKinnon's Creek is comprised of high permeability medium to fine-grained sands of glaciomarine (deltaic and estuarine) origin. The channel throughout this reach exhibited low sinuosity and both pool and riffle features were present and were approximately 10 - 15 m apart. Within the riparian zone, a continuous buffer of mature trees was present, with no encroachment into the channel. Downed trees were frequently observed within the valley, most likely due to a combination of recent storms and soil saturation. Bankfull width ranged from 8.0 - 10.9 m and bankfull depth was approximately 1.20 m. At the time of the October 2023 site visit, wetted width and depth measurements ranged from 5.00 - 6.35 m and 0.11 - 0.40 m, respectively.

Bank materials were composed of fine-grained substrate and included cobbles and boulders in some locations. A treatment on the right (west) bank along the first 75 m of the reach, composed of angular cobble to boulder sized riprap, was observed. Bed materials ranged from sand up to cobbles (0.05 - 0.15 m diameter) in pools, and from sand to boulders (up to 0.45 m diameter) in riffles. Substrate was generally sub-angular and not embedded.

Evidence of channel adjustment was observed throughout the reach. Three occurrences of valley wall contact were noted, with cut banks ranging from 2 - 7 m in height and 10 - 25 m in length. Basal scouring was observed along the outside bends, resulting in undercutting (concentrated at the downstream extent) ranging from 0.23 - 1.05 m. J-hooked trees and exposed roots were also commonly observed. Large woody debris was extensive throughout the reach, both in the channel and the cutbank, and was present every 50 - 100m. Channel bank angles ranged from 30 - 90°, and erosion was observed along 60 - 100% of the reach.

3.3 Rapid Assessments

Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether a 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 as it considers the ecological function 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.

Reach MC2 was assigned an RGA score of 0.36, indicating the reach was in transition. The dominant geomorphological indicator was evidence of widening, shown by occurrences of large organic debris and exposed roots. **Reach MC2** was evaluated to be in good condition, with an RSAT score of 30. The limiting factor was channel stability due to observations of unstable banks.

4 Erosion Hazard Delineation

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

When defining the meander belt width for a creek system, the TRCA (2004) and MNR (2002) protocols treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or slopes well-outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contact is possible. The reach of McKinnon's Creek parallel to the subject site is a confined system.

In confined systems where the channel is less than 15 m from the toe of the valley slope, the erosion hazard can be delineated using a toe erosion allowance, stable slope allowance, and an erosion access allowance. This is in keeping with the Provincial Policy Statement (PPS, 2020) on defining erosion hazards. Following MNR (2002) guidelines, the toe erosion allowance can be determined by:

1) calculating the average annual recession rate based on a minimum of 25 years of record
2) applying a 15 m toe erosion allowance measured inland horizontally and perpendicular to the toe of the watercourse slope
3) based on soil types and hydraulic processes

4) use of a study that applies accepted geotechnical and engineering principles based on a minimum of 25 years of record

It is understood that the City requested the erosion setback be based on the approach that utilizes a 100-year meander migration rate. GEO Morphix agrees that this is the preferred approach when the channel planform is visible in aerial imagery and the historical aerials can be adequately georeferenced to minimize measurement error. As noted elsewhere in this report (refer to **Section 2.3**), this approach is not possible along **Reach MC2** given the significant level of tree cover obscuring the channel planform in aerial photographs.

As meander migration rates could not be determined in aerial imagery along **Reach MC2** due to forest vegetation, approach no. 3 described above was followed. Table 3 in the MNR (2002) guidelines provides recommendations for an appropriate toe erosion allowance based on evidence of erosion, channel bank composition and bankfull channel width. Using MNR (2002) guidelines and selecting the upper or lower range of setback values based on evidence of erosion is an acceptable method for establishing the 100-year erosion setback, particularly when the bankfull channel is not visible in aerial photographs.

GEMTEC (2024) has completed a geotechnical slope stability assessment along **Reach MC2** and included a toe erosion allowance in their analysis. Following MNR (2002) guidelines for soft/firm cohesive soils, a 15 m toe erosion allowance was assigned where the channel was within 15 m of the valley slope toe. GEO Morphix has reviewed meander migration rates along sections of McKinnon's Creek upstream of **Reach MC2** as part of a previous study, resulting in 100-year meander migration rates in the range of approximately 2.5 to 10 m. The 15 m toe erosion allowance is considered a conservative approach and is the maximum toe erosion allowance recommendation following Table 3 of the MNR (2002) guidelines.

The ultimate erosion hazard limit for confined valley systems is based on the combined influence of the toe erosion allowance, the stable slope allowance and the 6 m erosion access allowance. GEO Morphix agrees with the slope stability assessment completed by GEMTEC given the conservative 15 m toe erosion allowance. The erosion hazard as been adequately addressed from a fluvial geomorphologic perspective.

5 Summary

GEO Morphix was retained to complete a fluvial geomorphological assessment of a section of McKinnon's Creek located in Ottawa. The desktop assessment included a review of available reporting and surficial geology and topographic mapping, as well as reach delineation. A historical assessment was also completed using imagery available from the geoOttawa web mapping application. The historical assessment revealed that the channel planform is not visible in imagery spanning the period of available record (1976 to 2022) due to substantive tree cover.

The desktop assessment was confirmed through the completion of reach-based field reconnaissance on October 24, 2023. **Reach MC2** was evaluated to be in transition, with an RGA score of 0.36. The RSAT score of 30 indicated that the reach was in good condition. Evidence of adjustment was observed throughout the reach during field reconnaissance, including undercutting, exposed tree roots, and valley wall contacts. However, no significant planform migration was observed in the historical assessment in parts of the channel that were not entirely obscured by tree cover between the years 1999 and 2021.

Where channel systems are confined, the erosion hazard can be defined using the 100-year erosion limit or through the selection of an appropriate toe erosion allowance based on MNR (2002) guidelines. For this study, channel migration rates could not be measured along **Reach MC2** due to tree cover within the creek valley, which obscured a clear view of the channel planform. GEMTEC recommended a 15 m toe erosion allowance following Table 3 of the MNR (2002) guidelines. This is the maximum value outlined in MNR (2002), is greater than the 100-year meander migration rates measured along McKinnon's Creek upstream of the subject site as part of a previous study, and is considered a conservative approach. The ultimate erosion hazard limit includes the toe erosion allowance, stable slope allowance and a 6 m erosion access allowance as outlined by GEMTEC (2024). The erosion hazard has been adequately addressed from a fluvial geomorphological perspective.

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

Respectfully submitted,

2024/06/18

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Senior Environmental Scientist

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Appendix A
Reach Delineation

GEO MORPHIX™

Study Area

McKinnon's Creek

930 Smith Road
Navan, Ontario

Legend

- Reach Break and ID (MC-1)
- 0.5 m Contour
- Watercourse
- Approximate Study Area

N

0 30 60
Metres

Imagery: City of Ottawa, 2021. Watercourse: MNRF, 2021/GEO Morphix Ltd., 2022. Reach Break and ID: GEO Morphix Ltd., 2022. 0.5 m Contour: MNRF, 2019 (Derived from LiDAR). Approximate Study Area: Gemtec, 2023. PN23106. Print Date: December 2023. Drawn By: M.O., S.S.O.

Appendix B
Historical Aerial Photographs

Location: Navan, ON
Reach: MC2
Year: 1976
Source: geoOttawa

Location: Navan, ON
Reach: MC2
Year: 1999
Source: geoOttawa

Location: Navan, ON
Reach: MC2
Year: 2005
Source: geoOttawa

Location: Navan, ON
Reach: MC2
Year: 2014
Source: geoOttawa

Location: Navan, ON
Reach: MC2
Year: 2021
Source: geoOttawa

Appendix C
Photographic Record

Photo 1 **McKinnon' s Creek** **930 Smith Road, Navan**	 Photograph taken facing east towards Smith Road from the center of the subject site. No established drainage features were observed within the site.
Photo 2 **McKinnon' s Creek** **930 Smith Road, Navan**	 Photograph taken facing north at the most upstream extent of **MC-2**. For approximately 75 m along the right bank from the crossing, placed angular riprap covered the bank.

Photo 3 McKinnon´ s Creek 930 Smith Road, Navan	 Photograph taken facing southwest at the right bank. A large cutface in the valley wall (approximately 5-7 m tall, 10-15 m long) was observed. Young J-hooked trees and exposed roots were present.
Photo 4 McKinnon´ s Creek 930 Smith Road, Navan	 Photograph taken facing north at the upstream extent of the reach. Large woody debris was frequently observed along the reach (approx. every 50-100m).

Photo 5 McKinnon´ s Creek 930 Smith Road, Navan	
	Photograph taken facing the left bank along the center of the reach. Exposed roots were commonly observed. Large boulders and cobbles were observed along the channel banks.
Photo 6 McKinnon´ s Creek 930 Smith Road, Navan	
	Photograph taken facing north along the center of the reach. Basal scour, exposed roots and J-hooked trees were observed along the outside bends of the channel.

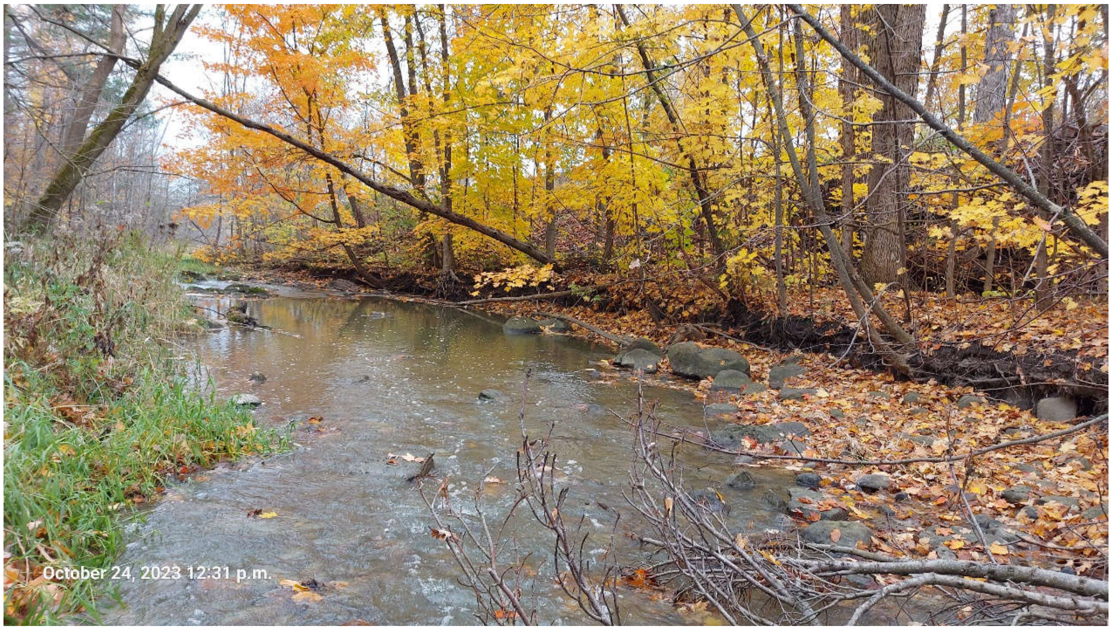
Photo 7
McKinnon' s Creek
930 Smith Road, Navan

Photograph taken facing west along the right bank of the reach. Valley wall contact was observed at 3 occurrences throughout the reach, exposing tree roots and soil.

Photo 8
McKinnon' s Creek
930 Smith Road, Navan

Photograph taken facing the right bank at the downstream extent of the reach. Undercutting was not commonly observed with exception to the outside bend along the downstream extent of the reach where undercutting was measured up to 1.05 m.

Photo 9
McKinnon´ s Creek
930 Smith Road, Navan



Photograph taken facing south at the most downstream extent of the reach. Basal scour was observed along the outside bend, and vegetated bars along the inside bend.

Photo 10
McKinnon´ s Creek
930 Smith Road, Navan

Photographs of the channel bed and banks. Instream substrate ranged from sand, gravel and cobbles in the pools and runs, and up to boulders in the riffles. Bank materials ranged from fine materials to gravel and cobbles.

Appendix D
Field Assessment Sheets

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Reach Characteristics

Project Number: 23106

Date:	2023-10-24	**Field Staff:**	KM / KS	**Watershed/Subwatershed:**	MCKINNON'S CREEK
Time:	10:45	**Stream:**	MCKINNON'S CREEK	**UTM (Upstream):**	465984.53 5029574.91
Weather:	Cloudy 15°C	**Reach:**	MC-2	**UTM (Downstream):**	466060.92 5029326.04

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)
1/7	2	7	2	1

☐ Evidence of Groundwater Location:________ Photo:_____

Riparian Vegetation

Dominant Type (Table 6)	1	**Coverage**	**Channel Widths**	**Age (yrs)**	
		☐ None	☐ 1 - 4	☒ Immature (<5)	
		☐ Fragmented	☒ 4 - 10	☒ Established (5-30)	
Encroachment (Table 7)	2	☒ Continuous	☐ > 10	☒ Mature (>30)	

Aquatic & Instream Vegetation

Type (Table 8)	2	**Woody Debris**	**WD Density**	WDJ/50m:	
		☒ In Cutbank	☐ Low	2/3	
		☒ In Channel	☐ Mod		
Reach Coverage %	>5	☐ Not Present	☒ High		

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	3

Channel Characteristics

Sinuosity Type (Table 9)	5	Sinuosity Degree (Table 10)	2	**Bank Angle**	**Bank Erosion**
Gradient (Table 11)	1	# of Channels (Table 12)	1	☐ 0 - 30	☐ < 5%
Entrenchment (Table 13)	1	Bank Failure (Table 14)	1/2	☒ 30 - 60	☐ 5 - 30%
Down's Model (Table 15)	M/U	Bankfull Indicators (Table 18)	1/3/5	☒ 60 - 90	☐ 30 - 60%
Sed Sorting (Table 20)	WS	Sediment Transport Observed?	☐ Yes ☒ No ☐ Not Visible	☒ Undercut	☒ 60 - 100%
Transport Mode (Table 21)	3	% of Bed Active	<5		
Geomorphic Units (Table 22)	5/6/8	Mass Movement (Table 23)	1	RUNS%	20
Riffle-Pool Spacing (m):	10-15	% Riffles:	50	% Pools:	30

(Table 19)	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Bank	☐	☒	☒	☒	☒	☐	☐
Riffle	☐	☐	☒	☒	☒	☐	☐
Pool	☐	☒	☒	☒	☐	☐	☐
Bed (if no riffle-pool morphology)	☐	☐	☐	☐	☐	☐	☐

Bankfull Width (m)	9.35	8.00	10.90
Bankfull Depth (m)	1.20	1.20	1.20
Undercuts (m)	0.57	0.48	0.23
Pool Depth (m)	0.45	0.37	0.40
Riffle Length (m)	2	5	10

Wetted Width (m)	6.35	5.00	5.70
Wetted Depth (m)	0.13	0.40	11.50
Velocity (m/s)	0.14	0.33	0.29
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	~25	/	/

Notes:

→ CHANNEL CONFINED WITHIN VALLEY, VWC AT US EXTENT SIGNS OF SIG. EROSION (TALL CUTBANKS, EXPOSED TREE ROOTS, VERTICAL BANKS). CUTBANKS BETWEEN 5-7m TALL AND 10-25m LONG.

→ VEGETATED BARS LOCATED AT SEVERAL LOCATIONS ESP. ALONG THE LB OF THE DS EXTENT (AREAS OF DEPOSITION, BUT WELL VEGETATED)

→ WATER DEPTH INDICATORS SUGGEST WATER REACHES UP TO 1.2/1.3m, EVIDENCE AT HIGH FLOWS WATER BREACHES THE BANKS + HAS CONTACT WITH THE VALLEY WALL (UNDERCUTTING + SCOUR AT THAT HEIGHT OBSERVED).

→ CHANNEL BED COMPOSED OF 10-20cm COBBLE, POOLS COMPOSED OF 10cm COBBLE AND GRAVEL. POOL/

Photos: RIFFLE FORMATIONS COMMON

→ MAIN AREAS OF EROSION CONCERN ALONG OUTSIDE BEND @ US EXTENT

→ JUVINIAL 'J' HOOKED TREES OBSERVED THROUGHOUT

Senior staff sign-off (if required): SS Checked by: ________ Completed by: KM

GEO MORPHIX™

General Site Characteristics

Project Number: 23106

Date:	2023-10-24	**Stream:**	MCKINNON'S CREEK
Time:	10:45	**Reach:**	MC-2
Weather:	CLOUDY 15°C	**Location:**	SMITH RD, NAVAN
Field Staff:	KS | KM	**Watershed/Subwatershed:**	MCKINNON'S CREEK

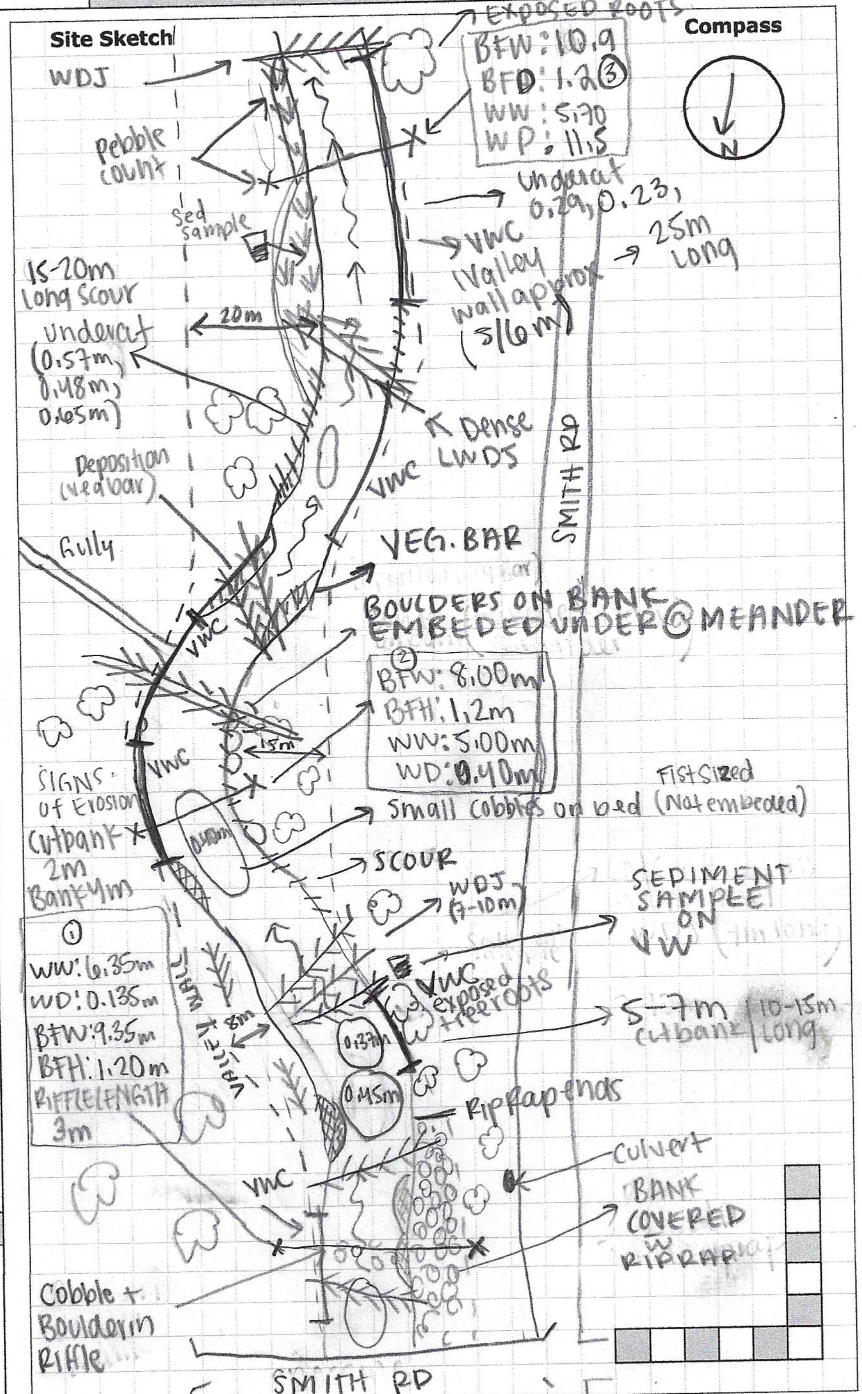
Features
- Reach break
- Station location
- Cross-section
- Flow direction
- Riffle
- Pool
- Sediment bar
- Eroded bank/slope
- Undercut bank
- Bank stabilization
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Beaver dam
- Vegetated island

Monitoring
- Long-profile
- Monumented XS
- Monumented photo
- Monumented photo direction
- Sediment sampling
- Erosion pins
- Scour chains

Additional Symbols

Site Sketch

Compass



Flow Type

H1	Standing water	H1A	Back water
H2	Scarcely perceptible flow		
H3	Smooth surface flow		
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

Substrate

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

Other

BM	Benchmark	EP	Erosion pin
BS	Backsight	RB	Rebar
DS	Downstream	US	Upstream
WDJ	Woody debris jam	TR	Terrace
VWC	Valley wall contact	FC	Flood chute
BOS	Bottom of slope	FP	Flood plain
TOS	Top of slope	KP	Knick point

Photos:

Notes: WH indicators + 2m from current depth.
Riffle/pool spacing: 10-15m   Juvinile J hooks observed
meander amplitude: 25m
RIFFLE LENGTH: 2-5m

V2: (1m) 8.21, 10.84, 10.35 | V3: (1m) 2.04, 1.92, 6.14
V1: 3.80, 2.75, 2.42 (1m) | P1: 1.5 | T1: 0.75
P2: 1.10 | T1: 1.15

Senior staff sign-off (if required): SS   Checked by: ______   Completed by: KM

Version #4
Last edited: 21/02/2023

GEO MORPHIX™

General Site Characteristics

Project Number: 23106

Date:	2023-10-24	**Stream:**	MCKINNON'S CREEK
Time:	10:45	**Reach:**	MC-2 CONT.
Weather:	CLOUDY 15°C	**Location:**	SMITH RD, NAVAN
Field Staff:	KS / KM	**Watershed/Subwatershed:**	MCKINNON'S CREEK

Features

- Reach break
- Station location
- Cross-section
- Flow direction
- Riffle
- Pool
- Sediment bar
- Eroded bank/slope
- Undercut bank
- Bank stabilization
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Beaver dam
- Vegetated island

Monitoring

- Long-profile
- Monumented XS
- Monumented photo
- Monumented photo direction
- Sediment sampling
- Erosion pins
- Scour chains

Additional Symbols

Flow Type

H1	Standing water	**H1A**	Back water
H2	Scarcely perceptible flow		
H3	Smooth surface flow		
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
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H9	Free fall	**H9A**	Dissipates below free fall

Substrate

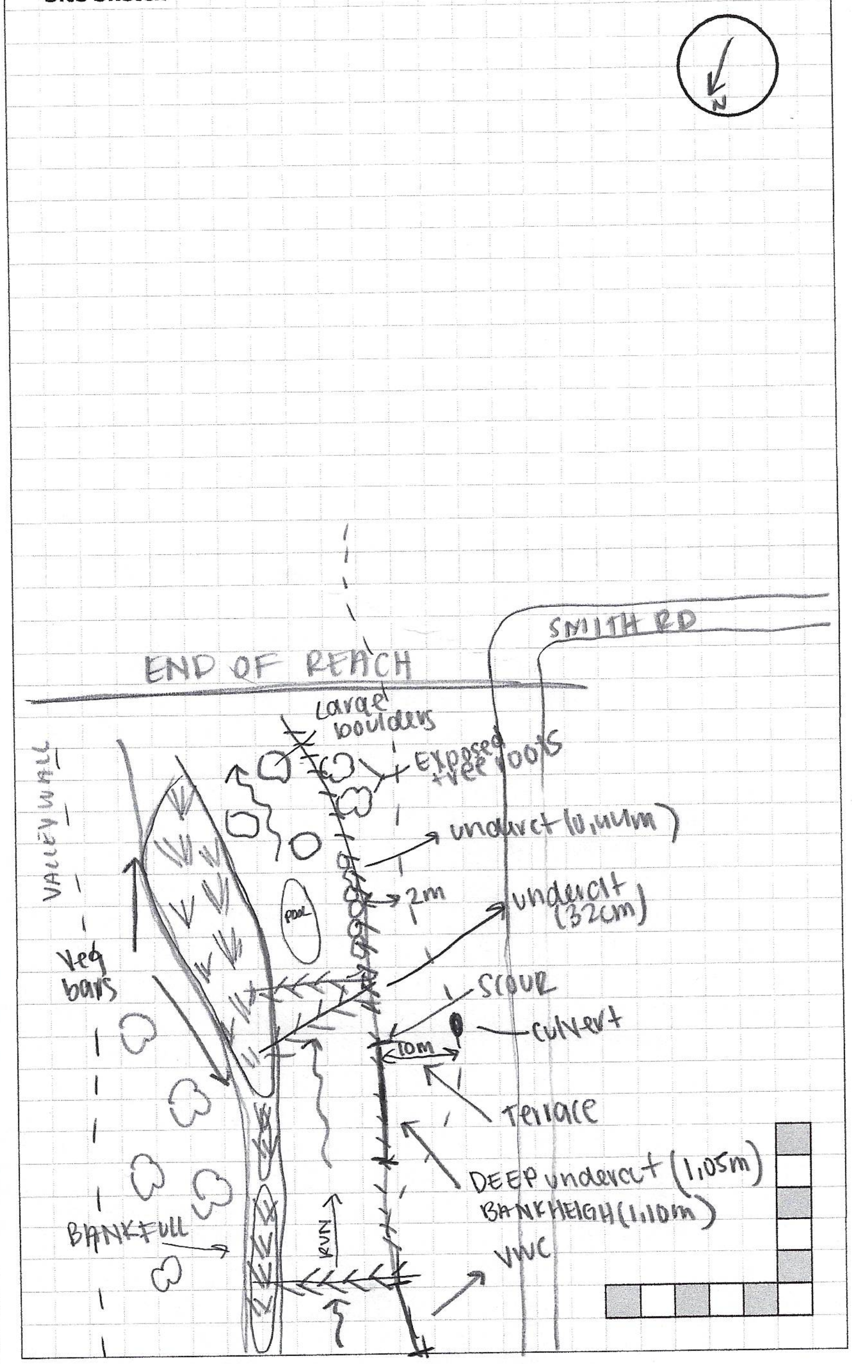
S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch

Compass



Photos:

Notes:

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23106

Date:	2023-10-24	**Stream:**	MCKINNON CREEK
Time:	10:45am	**Reach:**	MC-2
Weather:	CLOUDY 15°C	**Location:**	NAVAN, ON
Field Staff:	KM KS	**Watershed/Subwatershed:**	MCKINNON CREEK

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars	X		
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	1	6	0.143
Evidence of Degradation (DI)	1	Exposed bridge footing(s) N/A			
	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		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		
	2	Occurrence of large organic debris	X		
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends	X		
	5	Basal scour on both sides of channel through riffle	X		
	6	Outflanked gabion baskets / concrete walls / etc. N/A			
	7	Length of basal scour >50% through subject reach	X		
	8	Exposed length of previously buried pipe / cable / etc. N/A			
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation N/A			
		Sum of indices =	6	1	0.857
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	
	2	Single thread channel to multiple channel	X		
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)	X		
	6	Thalweg alignment out of phase with meander form	X		
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	3	4	0.429

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.36
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☒ **0.21 - 0.40**	☐ **0.41**

Senior staff sign-off (if required): SSD Checked by: SSD Completed by: KM

GEO MORPHIX™

Rapid Stream Assessment Technique Project Number: 23106

Date:	2023-10-24	**Stream:**	MCKINNON CREEK
Time:	10:45am	**Reach:**	MC-2
Weather:	CLOUDY 15°C	**Location:**	NAVAN, ON
Field Staff:	KS KM	**Watershed/Subwatershed:**	MCKINNON CREEK

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 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☒ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8

Senior staff sign-off (if required): SSO Checked by: SSO Completed by: KM

GEO MORPHIX™

Date: 2023-10-24	PN: 23106	Location: NAVAN, ON

Category	Poor	Fair	Good	Excellent
Physical Instream Habitat (N/A)	• 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 amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☑ 5 ☐ 6	☐ 7 ☐ 8
Water Quality (N/A)	• 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 < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m 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

Total overall score (0–42) = 30	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Senior staff sign-off (if required): SSD Checked by: SSD Completed by: KM