Fluvial Geomorphological and Erosion Threshold Assessment, Tributary of Cardinal Creek

1296 and 1400 Old Montreal Road

City of Ottawa, Ontario

Prepared for:
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Disclaimer

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1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained by Tamarack Developments to complete a fluvial geomorphology assessment in support of the Cardinal Creek Village South development at 1296 and 1400 Old Montreal Road Draft Plan of Subdivision in Ottawa, Ontario. The proposed development site, referred to as the 'subject lands', is bounded by Old Montreal Road to the north, Cox Country Road to the east, a tributary to Cardinal Creek aligned perpendicular to Cox Country Road to the south, and existing low-density residential properties to the west. The subject lands have a development area of approximately 46.30 ha.

The tributary to Cardinal Creek, comprising the southern border to the subject lands and aligned perpendicular to Cox Country Road, is known as the South Tributary. The South Tributary corridor is a forested, confined valley that flows towards the southwest and outlets to Cardinal Creek approximately 350 m south of the Old Montreal Road crossing over Cardinal Creek. The majority of contributing drainage to the South Tributary originates from the south and the east. A map of the subject lands is provided in **Appendix A**.

Following a review of the Cardinal Creek Village South Draft Plan of Subdivision and Zoning By-Law Amendment applications, the City of Ottawa outlined concerns regarding a specific slope failure location downstream of the proposed development area and apparent instability and deforestation/erosion impacts to the South Cardinal Creek Tributary valley. The City of Ottawa suggests that the slope failure has resulted in a change to the environmental setting compared to the conditions under which the Cardinal Creek Village Master Services Study (MSS) was completed approximately ten years ago. The City has indicated that the potential change in the environmental setting requires an addendum to the Cardinal Creek Village Master Servicing Study (MSS) and an Environmental Management Plan (EMP). Specifically, there is a need for further detailed geotechnical and geomorphological investigations.

It is noted that although the original geomorphological assessments completed are dated, they are reasonably detailed in scope. The concerns brought forward by the City are geotechnical and geomorphological in nature, and thus, the present assessment is limited to specific concerns about erosion and slope adjustment. The geomorphological study of the tributary focused on updating existing condition characterization, updating/confirming erosion hazard delineation, reviewing erosion mitigation strategies, identifying remedial measures required to stabilize the slope, and confirming and updating (where required) the stormwater management criteria. The City has stated that this work is required before the Cardinal Creek Village South development can proceed.

The work plan outlined below conforms to the Terms of Reference previously submitted to Tamarack Developments and was specifically developed to provide information that addresses the City's comments and concerns. In summary, we would complete the following activities as part of our work:

- Review available background reports and mapping (i.e., watershed/subwatershed studies, geology, topography, conceptual development plans) to inform watershed and drainage network characterization. Specific reports to be reviewed include the following:
    - Cardinal Creek Geomorphic Assessment, City of Ottawa (Geomorphic Solutions – April 2007)
    - Cardinal Creek Village Erosion Threshold Assessment of South Tributary (Parish Geomorphic Limited – January 2013)
    - Cardinal Creek Village Meander Belt Width Delineation Memo (Parish Geomorphic Limited – April 4, 2013)
    - Cardinal Creek Village Erosion Threshold Assessment of Cardinal Creek Main Branch (Parish Geomorphic Limited – May 2013)

- Preliminary Geotechnical Review for Proposed SWMP (Paterson Group – December 2, 2020)
    - Phase I Environmental Site Assessment Cardinal Creek Village South (Paterson Group May 20, 2022)
    - Geotechnical Investigation Cardinal Creek Village South (Paterson Group – November 19, 2021)
    - Preliminary Stormwater Management Plan and Stormwater Management Facility Design (JFSA – December 21, 2021)
    - Functional Servicing Report Cardinal Creek Village South (DSEL – June 2022)
- Review watercourse reach delineation and confirm/update reach delineation completed through past studies to support the characterization of existing conditions
- Develop a Terms of Reference to ensure the geomorphological component of the study addresses all requirements of the City of Ottawa
- Update the original historical assessment to include more recent aerial photographs to identify any additional slope adjustments or feature changes
- Conduct LiDAR-based assessment based on available data to identify geomorphic units, including slips, landslides, and other erosion features, to bring the assessment up to the current period
- Review the previously completed rapid geomorphological field assessments, and, where required, complete updated rapid geomorphic field assessments to document any areas of significant erosion, collect instream measurements of bankfull channel dimensions, and characterize bed and bank material composition and structure
    - Compile an erosion inventory along the South Tributary to document evidence of dynamic adjustments along channel or adjacent valley slopes
- Complete a detailed geomorphic field assessment data and field observations in the context of erosion thresholds
- Review meander belt width delineation or erosion hazard for the watercourse using historical and recent aerial imagery, field observations, or empirical modelling approaches where required
- Develop and initiate a pre-development erosion monitoring program to establish baseline conditions for comparison during post-construction
- Specifically review the identified slope failure location at 1320 Grand-Chêne Court within reach **R3** and provide recommendations for dealing with erosion concerns in that area

2 Desktop Assessment

A review of pertinent background material was completed to inform and provide context regarding local hydrology, stream morphology, and previous erosion hazard studies. Material reviewed includes site plans, historical aerial photographs, publicly available surficial geological mapping, physiological region and landform mapping, watershed reports published by RVCA, and previous assessments and reports, which are listed above. Spatial terrain datasets were also analyzed to map and interpret channel and valley geomorphic features to provide insights into the nature and rate of geomorphic change within the subject lands.

2.1 Watershed Characteristics

The subject lands are located in the Orleans suburb in the Cardinal Creek Watershed, east of Ottawa. Cardinal Creek is eight kilometres long and drains approximately 35 km^2 of land (RVCA, 2022). The creek flows in a northwestern direction from the headwaters east of the intersection of Frank Kenny Road and Innes Road until it crosses Watters Road, where it changes direction to flow north towards the Ottawa River. Land use within the watershed is primarily agricultural, particularly within the headwaters, and transitions into residential and commercial land use at the downstream extent before reaching the

Ottawa River (RVCA, 2022). The section of Cardinal Creek where the South Tributary outlets meanders within a forested, confined valley surrounded by residential properties in the adjacent tablelands.

The South Tributary corridor is a forested, confined valley that flows towards the southwest and outlets to Cardinal Creek approximately 350 m south of the Old Montreal Road crossing over Cardinal Creek. The farthest upstream extent of the South Tributary is immediately west of the intersection of Cox Country Road and Jonquille Way. This portion of the watercourse is a straightened agricultural drain, which transitions into a forested corridor with decreasing elevation and increasing width, sinuosity, and valley confinement closer to the confluence with Cardinal Creek.

The majority of contributing drainage to the South Tributary originates from the south and the east. Land use to the south is comprised of agricultural fields with forested areas occupying some of the headwater channel corridors that discharge to the South Tributary. Portions of the headwater channel corridors to the south have been deforested and straightened as recently as the 2010s. Land use to the east is comprised of low-density residential properties and a fragmented forest block. Former land use towards the east appears to have been agricultural, and the drainage features in this area were previously straightened to accommodate prior farming activities.

2.2 Surficial Geology and Physiography

Surficial geology and physiography act as primary controls regarding channel development, as they greatly influence a given drainage system's hydrological and sediment characteristics. Channel morphodynamics are primarily governed by the flow regime and the availability and type of sediments within the stream corridor. These factors are explored as they offer insight into existing conditions and potential changes that could be expected in the future as they relate to proposed development within the streams catchment area. A map showing the surficial geology throughout the subject lands is provided in **Appendix C**.

The St. Lawrence-Ottawa Lowlands physiographic region, an area of low relief with elevations approaching sea level (approximately 200 feet asl or lower), encompasses the entirety of the subject lands (Chapman and Putnam, 1984). There are two minor physiographic regions throughout the subject lands: the Ottawa Valley Clay Plains (region 49), which encompass most of the South Tributary and it's contributing watercourses flowing from the south, and an area around the farthest upstream reaches with glacial till comprised of gravel to boulder-sized substrate that is likely part of the Glengarry Till Plain (region 46) (Chapman and Putnam, 1984). The Ottawa Valley Clay Plain region is characterized by deep, silty clay plains interrupted by occasional rock and sand ridges (Chapman and Putnam, 1984). The clay deposits originated in a glaciomarine context in the brackish waters of the Champlain Sea with sediments sourced from Canadian Shield granite (Alysworth and Lawrence, 2003; Hunter, Crow, and Brooks, 2011; Chapman and Putnam, 1984). Surficial geology throughout the subject lands is thus primarily comprised of a clay and silty clay layer derived from non-clay minerals (i.e., glacial rock flour) that is generally poorly drained and very plastic (Alysworth and Lawrence, 2003; Chapman and Putnam, 1984; OGS, 2010). The native sediments that compose the channel substrate within the South Tributary are dominated by cohesive clay materials. An ancient landslide scar comprised of the native sediments is present within the lower reaches of the South Tributary and a small area where the calciferous Paleozoic bedrock outcrops at the surface. The landslide scar also overlaps with the main channel of Cardinal Creek near the confluence with the South Tributary, and there are more extensive bedrock outcrops within the main channel along the reach downstream of the confluence.

2.3 Review of Previous Studies

Studies conducted for the Greater Cardinal Creek Subwatershed Study (SWS) were reviewed to confirm preliminary erosion threshold targets and other development constraints for the subject land. The

Greater Cardinal Creek SWS was initiated to document existing conditions within the watershed and provide recommendations for development and preservation. While the SWS was ongoing, an Urban Expansion Area, Area 11, was confirmed within the watershed. The reviewed SWS studies include the Geomorphic Assessment (Geomorphic Solutions, 2007) and the Existing Conditions report (AECOM, 2009).

Studies conducted as part of the Master Servicing Study (MSS) for Cardinal Creek Village were reviewed to confirm updated erosion threshold targets and erosion hazard setbacks. The MSS was initiated to investigate the provision of servicing infrastructure to support the proposed development of Cardinal Creek Village within the City of Ottawa. The Cardinal Creek Village development area comprises 208 hectares of the Area 11 Urban Expansion Area north of the South Tributary to Cardinal Creek. Studies reviewed include the Meander Belt Width (MBW) Delineation and Erosion Threshold Assessments for the Cardinal Creek main branch and South Tributary in three (3) separate reports (Parish Geomorphic Ltd., 2013). Erosion threshold methods and results from the respective geomorphic assessments are discussed in more detail in **Section 4** below.

Studies prepared for the Planning Act development application and the Functional Servicing Study (FSS) for Cardinal Creek Village were also reviewed to confirm erosion hazard setbacks and development constraints for the subject lands. Studies conducted to establish existing conditions, assess stormwater management, and identify erosion hazards and development constraints for the Cardinal Creek Village South development were reviewed. These include the Preliminary Geotechnical Review for the proposed SWMP (Paterson Group, 2020), the Phase 1 Environmental Site Assessment (Paterson Group, May 2022), the Geotechnical Investigation for Cardinal Creek Village South (Paterson Group, November 2021), and the Preliminary SWMP (JFSA, 2021). The Geotechnical Review for the proposed SWMP and the Geotechnical investigation completed by Paterson Group (Paterson) were revised in 2023, and the most up-to-date versions of these documents were reviewed. The Geotechnical Slope Stability Assessment for the recent slope failure within the rear yard of **1320 Grand-Chêne Court** was also reviewed (Paterson, 2023).

2.3.1 Geomorphic Assessment and Existing Conditions for Cardinal Creek

The Geomorphic Assessment report examined the Cardinal Creek watershed at a "planning level" to delineate reaches, develop an understanding of system health and sensitivity to change, and provide preliminary targets for planning and baseline data for future studies (Geomorphic Solutions, 2007). Rapid and detailed geomorphic assessments were conducted along the main branch of Cardinal Creek in October and November 2006. There was no access to the South Tributary during this time, and the Geomorphic Assessment did not delineate erosion hazards or estimate an erosion threshold for that watercourse. The results for reaches along the main channel are provided for reference. The Rapid Geomorphic Assessments (RGAs) conducted along the main branch found that reach **C4** was 'In Regime' with an RGA score of 0.14, while reach **C10** was found to be 'In Regime' with an RGA score of 0.11 (MOE, 2003; VANR, 2007). Erosion thresholds were modelled for reaches **C4** and **C10** along the main branch using the results of the rapid and detailed assessments. Reach **C4** is located upstream of the South Tributary near the intersection of Frank Kenny Road and Cox Country Road, while reach **C10** is the reach into which the South Tributary discharges. For reach **C4**, a critical discharge of 1.01 m^3/s was modelled based on a permissible shear of 4.7 N/m^2 for the compact sandy clay observed along the channel bed. For reach **C10**, a critical discharge of 0.05 m^3/s was modelled using a critical velocity of 0.30 m/s based on the flow competency for the median grain size of the bed substrate.

The Existing Conditions report identified sites requiring immediate slope stabilization and where toe erosion protection is recommended, all located along the main branch of Cardinal Creek (AECOM, 2009). The Subwatershed Management Plan phase built upon the Existing Conditions report and included identification, policies for protection, and potential habitat restoration opportunities of the natural heritage system. The forested areas occupying the South Tributary corridor and its headwater channels to the south were all designated as Significant Woodland. According to the Cardinal Creek SMP, one of the headwater channel corridors near the eastern end of the South Tributary was deforested and straightened in 2009, and increased channel and bank instability were observed within the South Tributary following this deforestation.

2.3.2 Erosion and Meander Belt Width Assessments for Cardinal Creek Village and Cardinal Creek Village South

Erosion Assessment reports examined watercourses within the Cardinal Creek watershed in which the development of Cardinal Creek Village was proposed to support the associated stormwater management plan (Parish Geomorphic Ltd., 2013). Rapid and detailed assessments were conducted along the main branch of Cardinal Creek by Parish Geomorphic Ltd. (Parish) in April 2013. An erosion threshold was modelled for reach **C11-B** by Parish in May of 2013 based on the results of the rapid and detailed assessments. Reach **C11-B** is located downstream of the South Tributary, south of Old Montreal Road. The rapid assessments found that reach **C11-B** was 'In Adjustment', with a 0.44 RGA score, with widening being the dominant form of adjustment (MOE, 2003; VANR, 2007). Reach **C11** was assessed in 2007 by Geomorphic Solutions and was assessed as being 'In Transition' with an RGA score of 0.34 and widening being the dominant form of adjustment. In 2007, reach **C10** was found to be 'In Regime' with an RGA score of 0.11. The 2013 rapid assessments found reach **C10** was 'In Adjustment' with an RGA score of 0.33 with widening as the dominant form of adjustment. An erosion threshold, expressed as a critical discharge of 1.5 m^3/s, was modelled for reach **C11-B** based on a permissible shear of 12.25 N/m^2 for the compact sandy clay observed along the channel bed.

Rapid and detailed assessments and erosion threshold modelling were also completed for reaches along the South Tributary to Cardinal Creek in 2012 and 2013 by Parish (Parish Geomorphic Ltd., January 2013). Three (3) reaches were delineated within the South Tributary, **R1**, **R2**, and **R3**. **R1** comprises the farthest upstream extent with a large proportion of its length straightened and traveling through agricultural fields. **R2** begins where the watercourse enters a confining, forested valley and continues until the downstream side of a wide southeastward bend in the valley and channel. **R3** continues from there until the confluence with the main channel of Cardinal Creek. The RGA found that all three (3) reaches, **R1**, **R2**, and **R3** were 'In Adjustment' with RGA scores of 0.485, 0.55, and 0.51, respectively. Widening was the dominant form of adjustment in all cases (MOE, 2003; VANR, 2007). The erosion threshold was modelled in reach **R2** based on the permissible shear of 20.3 N/m^2 for the silty-clay bed substrate observed throughout the reach, which resulted in a critical discharge of 0.43 m^3/s (Dunn, 1959).

Meander Belt Width delineation was also completed for all reaches along the South Tributary to Cardinal Creek in 2013 (Parish Geomorphic Ltd., April 2013). An additional reach was delineated during this assessment that divided **R3** in two to create **R4**, which begins where a large contributing watercourse (reach **T4**, see **Section 3.1** below) meets the South Tributary and continues until the confluence with the main channel. MBWs were both measured and empirically derived, each with a 10% buffer applied, with the more conservative empirically derived MBWs ultimately being recommended due to the high RGA scores for the tributary. The empirical MBWs were calculated using methods outlined in Lorenz et al. (1985), Ward (2002), and Williams (1986) and then averaged to derive the final estimate. The MBWs for **R1**, **R2**, **R3**, and **R4** are 26.6 m, 26.6 m, 25.8 m, and 29.8 m, respectively. Reach **R2** was used as a surrogate for **R1**, as the latter was historically straightened.

2.3.3 Phase I Environmental Site Assessment Cardinal Creek Village South

The Phase I Environmental Site Assessment (ESA) aimed to review past land use within and adjacent to the subject lands to identify potential environmental concerns caused by previous activities (Paterson

Group, 2022). Land use within and adjacent to the subject lands was found to be historically agricultural or rural residential. A site inspection of contemporary land use within the subject lands identified a rock crushing and storage operation in the western portion of the development area, with the remainder of the development area being vacant. No environmental concerns were identified with respect to this ongoing operation within the subject lands or current land uses within properties adjacent to the subject lands. A Phase II ESA was not recommended.

2.3.4 Preliminary Stormwater Management Plan and Design

The Preliminary Stormwater Management Plan and Stormwater Management Facility Design for Cardinal Creek Village South evaluated the storage required for the proposed SWM facilities (JFSA, 2021). While two SWM facilities are proposed within Cardinal Creek South Village, only one is proposed to discharge to the South Tributary and is discussed herein. The SWMP proposed to discharge to the South Tributary would drain an area of 38.08 ha and provide quality, quantity, and erosion control up to the 100-year level. Target release rates for the pond were estimated using an XPSWMM model for the 24-hour SCS Type II design storm, and the proposed drainage area to the pond was simulated using a SWMHYMO model. The proposed pond design was determined to be of sufficient size, as quantity control requirements were met.

2.3.5 Preliminary Geotechnical Review of Proposed SWMP Cardinal Creek Village South

The geotechnical review of the proposed SWMP in Cardinal Creek Village South was undertaken to provide recommendations for construction based on the subsurface profile at the proposed pond location and slope stability adjacent to the proposed pond location (Paterson, 2023). The proposed pond location is located within the tablelands north of the South Tributary to Cardinal Creek along reach **R2**. Subsurface conditions were examined through test holes advanced at the proposed SWMP location. The subsurface was found to be comprised of a very stiff brown silty clay transitioning at 3 to 6 m below the existing surface to a stiff grey silty clay. A long-term groundwater depth of 3 to 4 m below the existing ground surface was estimated. The slope stability analysis incorporated results from the subsurface investigations to model the stable slope at two cross-sections along the north valley slope adjacent to the proposed location under a range of pond water levels. The minimum factors of safety of 1.5 under statics conditions and 1.1 under seismic conditions were met at both cross-sections and the slope was determined to be stable under long-term conditions.

2.3.6 Geotechnical Investigation for Cardinal Creek Village South

The Geotechnical Investigation for Cardinal Creek Village South examined subsurface conditions within the subject lands and slope stability along the slopes within the South Tributary valley to provide design recommendations for the development (Paterson Group, 2023). Subsurface conditions were observed using a combination of boreholes and test pits advanced throughout the subject lands between January 2009 and March 2021. Groundwater levels were monitored using piezometers fitted to boreholes. Overburden thickness within the subject lands was delineated through a probehole bedrock delineation program conducted in November 2019. The watercourse and slopes within the valley were observed between April 2012 and July 2023. Cross-sections along valley slopes derived from topographic surveys and LiDAR data were assessed as part of the slope stability analysis.

The surficial soil was found to be underlain by a weathered brown crust of stiff silty clay, which was underlain by an unweathered grey silty clay to depths greater than 9 m, with depth decreasing towards the eastern side of the subject lands. Glacial till comprised of silty clay with variable coarse contents ranging in size from sand up to boulders was also present below the unweathered grey silty clay. Depth to bedrock from the existing ground surface ranged from 0 to 25 m, decreasing in depth towards the eastern side of the subject lands. A long-term groundwater depth of 3 to 4 m below the existing ground surface was estimated. Permissible grade raise restrictions ranging from 2 to 2.5 m were proposed for the site due to the silty clay subsurface layer.

Slopes ranging from 3 to 15 m in height and 5H:1V to 1H:1V in gradient were observed throughout the South Tributary valley. Slopes were comprised of a stiff brown silty clay underlain by firm grey silty clay. Toe erosion was observed where the watercourse was in contact with the valley wall. Undercutting and shallow slips were noted as the types of erosion observed. The channel bed was observed to be comprised of a combination of glacial till and grey silty clay in the farthest upstream portion of the South Tributary and grey silty clay in the downstream portion. The Limit of Hazard Lands setback along the top of the north valley slope was delineated based on the slope stability analysis, which incorporated results from all subsurface investigations described above and was carried out in accordance with the City of Ottawa's standard guidelines. The minimum factor of safety of 1.5 was met at all cross-sections analyzed except for two, where setbacks of 4.7 and 17 m were delineated. A toe erosion allowance of 5 m, delineated from the stable top of slope, was proposed based on the observed slope composition and toe erosion.

2.3.7 Geotechnical Slope Stability Assessment of Recent Slope Failure

A slope failure along the north valley slope of the South Tributary was previously identified within the rear yard of **1320 Grand-Chêne Court** and observed in a land surface model generated from remotely sensed data (Stantec, 2021). The City of Ottawa was made aware of this slope failure and expressed concern regarding slope stability throughout the proposed development of Cardinal Creek Village South through an engineering review letter dated June 2, 2023. Additional geotechnical and geomorphological studies were undertaken to address the slope stability concerns.

Paterson Group (Paterson) initiated and conducted a geotechnical slope stability assessment in 2023. Based on interviews with the property owner of **1320 Grand-Chêne Court** conducted by Paterson, the slope failure was initially observed in April 2014, shortly after they had taken possession, and annual slope movement has been observed since then. It was also noted that the ground surface adjacent to a retaining wall along the top of the valley slope within the neighbouring property had failed at an unknown time in the past (Paterson, 2023). Based on discussions with the contractor who constructed the homes along Grand-Chêne Court, the property owner learned that the ground surface throughout that development area had been raised using soil generated from building excavations. This soil was also dumped down the valley slope of the South Tributary.

A failure surface ranging from 0.40 to 1.2 m in height was observed along the top of the valley slope in the rear yard of **1320 Grand-Chêne Court** by Paterson in July 2023. Additional slip surfaces were also noted along the base of the slope. The subsurface profile consisted of a relatively thick layer of the aforementioned fill, overlying a relatively thin layer of brown silty clay, which was overlying a saturated layer of firm to stiff grey silty clay (Paterson, 2023). Depth to bedrock was estimated to be approximately 18.2 m based on public well records. The valley slope was 14 m in height with a 3.5H:1V profile with local sections up to 1.5H:1V (Paterson, 2023).

The slope stability analysis for the valley slope at **1320 Grand-Chêne Court** found that the factor of safety was 1.1 for slope conditions prior to in-filling (Paterson, 2023). The minimum factor of safety generally recommended where slope failure would endanger permanent structures is 1.5. The report concluded that a limit of hazard lands setback should have been applied to the lot, and fill placement in the tablelands and along the valley slope should have been avoided (Paterson, 2023). The slope failure was ultimately attributed to a combination of the fill placement and ongoing erosion at the toe of the valley slope by the watercourse. Additional geotechnical studies were recommended to verify undisturbed soil characteristics and depth of the failure plane and to delineate a stable slope setback with a minimum 1.5 factor of safety.

2.4 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the South Tributary, the main channel of Cardinal Creek, where the tributary outlets, and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics and is used to inform erosion hazard assessments. Aerial photographs for the years 1976, 1991, 2002, 2011, and 2021 from GEO Ottawa (https://maps.ottawa.ca/geoottawa/) were reviewed. Imagery is provided in **Appendix B** for reference.

1976

The subject property and portions of the surrounding area were actively cultivated prior to 1976. Old Montreal Road and Cox Country Road were established by this time. Land use within the tablelands surrounding the main channel of Cardinal Creek downstream of the South Tributary confluence was comprised of residential properties. Land use north and east of the South Tributary, which is visible on the 1976 imagery, consisted primarily of agricultural fields. At this time, there were few residential dwellings located south of Old Montreal Road between the road and reaches **R3** and **R4** of the subject tributary (updated reach delineation is detailed in **Section 3.1** below, and a reach map is provided in **Appendix A**). A forested buffer separates the agricultural fields to the north of the upstream reaches from the valley. Land use south of the South Tributary outside the subject lands is largely comprised of forest interspersed with agricultural fields. Evidence of the tributaries (reaches **T1**, **T2**, **T3**, and **T4**) draining the land south of the South Tributary is largely obscured by the forest cover. However, the westernmost tributary (**T4**) is observable where it transitions from straightened agricultural drainage to a forested valley.

The South Tributary channel pattern is largely obscured by forest cover in the 1976 imagery. However, a straightened section of the channel through agricultural fields perpendicular to and immediately downstream of Cox Country Road, reach **R1**, is discernable in the imagery. Downstream of this, a backwatered area is visible within reach **R1A** before the watercourse enters the forested valley, and the channel pattern is obscured where reach **R2** begins. Also visible is a vegetative buffer surrounding the area where a branching drainage channel is noted along the northern valley wall of reach **R2**. This drainage feature extends into a field immediately east of the lot where piled fill is currently stored. In the Geotechnical Investigation for Cardinal Creek Village South, this drainage feature is recommended for infilling (Paterson, 2023). Crossings over the watercourse and valley are visible within the middle extent of the South Tributary, where there is a wide southeastward bend, delineated as reach **R2A** in the present report. The land is cleared of vegetation along an embankment supporting the road, suggesting it may have been recently graded.

1991

Land use appears to remain largely unchanged between 1976 and 1991, with the exception of the area east of Cox Country Road, upstream of the South Tributary. The area that was formerly agricultural fields east of Cox Country Road has been cleared, and grading and road building are evident, with several residential lots already occupied by homes. The channel pattern of the South Tributary and its southern contributing channels (**T1** to **T4**) remains largely obscured. Backwatering previously observed at the upstream extent in reach **R1A** has receded, and the area previously occupied by water now appears to have herbaceous meadow cover. Vegetation surrounding the branching drainage channel observed encroaching to the north from **R2**, as well as the beginning of the channel itself, are visible in the 1991 imagery. Straightened ditches are evident, draining agricultural fields north of the valley into the South Tributary. The crossings observed in the 1976 imagery within the middle extents of the watercourse appear to remain in use. New houses were built along the edge of the northern valley wall immediately downstream of the crossings in **R3** between 1976 and 1991. Construction and grading activities appear to have been recent in the 1991 imagery, as the land is cleared of vegetation.

2002

Land use within the subject lands and surrounding areas again appears largely unchanged between 1991 and 2002. Some planform change is observable within reach **C10** along the main channel, particularly in the downstream extent, where a meander bend appears to have migrated towards the Old Montreal Road embankment. An area of the embankment that was forested in 1991 is missing some tree cover in the 2002 imagery, exposed sediment is evident, and a form resembling a slump with a headscarp near the road is observable. The upstream extent of the channel in reach **R1** remains a straight ditch surrounded by agricultural fields. The channel pattern of the South Tributary and its southern contributing channels (**T1** to **T4**) remains largely obscured. Immediately downstream of the straight section, there is an irregularly meandering channel travelling through a wide floodplain vegetated with herbaceous meadow cover visible in the area, which was previously backwatered, delineated as reach **R1A** in the present report. The channel pattern is mostly obscured downstream of this as it enters the forested valley. Severe backwatering is evident upstream of the previously noted crossings in **R2A**.

2011

Land use within the subject lands again remains largely unchanged between 2002 and 2011. Additional planform changes are visible along **C10,** where changes were identified in the 2002 imagery. Substrate from the slope on the outside of the meander bend appears to have settled at the base of the slope, constricting the channel at that location. Cutoff chutes appear to have formed around mature, vegetated bars upstream of this, creating islands. A beaver dam is evident across the channel upstream of this, causing backwatering upstream. The outside of the meander bend immediately upstream of the beaver dam appears to have migrated, as the slope that was forested in the 2002 imagery is missing tree cover, and exposed sediment is evident. A second beaver dam is evident just downstream of the confluence with the South Tributary.

An area of forest has been removed in the tablelands south of the valley adjacent to the section from reach **R1** to **R2A**; reaches **T1** and **T2** are located in this area. There is evidence of **T1** and **T2** on the deforested landscape in approximately their current alignment. An area surrounding **T1,** where the channel bends westward, appears to be saturated, suggesting possible historic backwatering at that location. The area north of **T1** remained forested in the 2011 imagery. **T3** and **T4** remain largely obscured by forest cover, except **T4** is observable where it transitions from straightened agricultural drainage to a forested valley and remains in the same alignment as the 1976 imagery.

The upstream extent of the channel in **R1** remains straight, while the channel just downstream in **R1A** within the wide, vegetated floodplain no longer meanders. There is a small area with backwatering, then a relatively straight section with evidence of lateral scour beginning to form meanders. Observing the 2005 and 2008 imagery, the area is covered in a large volume of water, which likely lead to deposition over the former channel location and formation of a new channel through the freshly deposited sediments when the backwatered area drained. Vegetation surrounding the encroaching drainage channel previously observed along the north valley wall in **R2**, as well as the beginning of the channel itself, remain visible and appear to be in the same location. The formerly backwatered area upstream of the valley crossing in **R2A** has drained, and a narrow channel is visible, cutting a path through a wide floodplain likely created by sediments deposited while the area was backwatered. The crossing appears to remain in use, although part of the road has been abandoned, and a more direct path is visible, cutting across the landscape. Additional houses and pools were built along the edge of the north valley wall downstream of the crossing in **R3**. Parts of the channel are visible downstream of the crossing in

R3, meandering through a wide floodplain that lacks tree cover. Observing the 2007 imagery, this area is also backwatered, and there is extensive treefall along the margins of the valley. Thus, this area also underwent a cycle of backwatering, deposition, drainage, and new channel formation similar to the upstream section previously described.

2021

The slope along Old Montreal Road, where a headscarp was previously visible along reach **C10** in the 2002 imagery, appears to have undergone stabilization works. The location where the channel constriction occurred has adjusted, with the opposite bank having migrated away from the road. The cutoff chutes appear to have enlarged and the former main channel that flowed between the islands created by the cutoff chutes appears to be in the process of abandonment. The farthest downstream beaver dam noted in the 2011 imagery is no longer present in the 2021 imagery. The slope immediately upstream of this also appears to have undergone stabilization works. It is unclear whether the beaver dam just downstream of the confluence with the South Tributary is still present due to shadows on the aerial images.

Deforestation within the tablelands south of the valley adjacent to the section from reach **R1** to **R2A** continued between 2011 and 2021, with the previously forested area north of **T1** now cleared of trees and the fields being actively cultivated. The farthest upstream sections of **T1** and **T2** that were previously surrounded by forest are now realigned and straightened, with little buffering of **T2** from the agricultural fields, while **T1** appears to be buffered to the south. **T3** and **T4** remain largely obscured by forest cover, except **T4** is observable where it transitions from straightened agricultural drainage to a forested valley and remains in the same alignment as the 1976 imagery. The channel pattern within the upstream extent of the South Tributary in **R1** and **R1A** remains identical. Vegetation surrounding the encroaching drainage channel along **R2** remains visible and its footprint appears identical to earlier images. The storage piles of fill appeared on the tablelands north of the valley adjacent to **R2** between 2011 and 2014 and continued to expand to its current extent in the intervening period. The area upstream of the crossing in **R2A** maintains a wide floodplain with herbaceous vegetation cover. The crossing appears to have been abandoned, as vegetation along the road is overgrown. The area downstream of the crossing in **R3** is backwatered again.

2.5 Digital Terrain Analysis

Terrain analysis of two high-resolution spatial datasets was used to map, plot, and interpret channel and valley geomorphic features within the study area. Stream channels are inherently dynamic features of the natural landscape, and the detailed observation of channel and valley geomorphology using spatial datasets is useful to gain insight into how a given fluvial system has adjusted and is likely to adjust over time. In particular, the use of high-resolution bare-earth digital elevation models derived from airborne LiDAR surveys allows for detailed broad-scale mapping and analysis of geomorphic features. In cases where two or more elevation surveys are available, analyzing the detailed topographic data from these surveys can provide useful insights into the nature and rate of geomorphic adjustment during the intervening period.

2.5.1 Methods

For this study remote sensing data was used for detailed analysis of geomorphic features adjacent to and within the valley of the subject watercourse. Remote sensing data in the form of LiDAR-derived bare-earth digital elevation models (DEM) with a horizontal resolution of 1x1 m were provided by Stantec (2012 data) and also obtained from a publicly available dataset maintained by OMNRF (2019/2020 data). The bare-earth elevation raster datasets were used to generate hillshade models and longitudinal channel bed elevation profiles both useful for interpreting and analyzing geomorphic features. The following specific geomorphic features and terrain metrics were mapped, plotted, and analyzed using the high-resolution elevation data:

- Land surface changes across the study area between 2012 and 2019/2020
- Gullies along the valley walls
- Slumps and landslides feature along the valley walls
- Slope gradients within the valley
- Channel bed longitudinal profile for 2012 and 2019/2020

The 2012 and 2019/2020 DEMs were used to generate a land surface change raster, or a DEM of Difference (DoD), which is used to highlight areas of significant elevation change between the two survey periods. The DoD was generated by subtracting the elevation values recorded in the more recent 2019/2020 elevation raster from the elevation values recorded in the earlier 2012 elevation raster. The DoD was overlayed on the 2019/2020 hillshade raster to show the spatial distribution and magnitude of land surface changes over the given time period. Ground control points (n=10) were used to evaluate and correct for any systematic elevation difference between the two elevation rasters (mean difference: -0.22 m; standard deviation: 0.05). Note that the ground control elevations in the 2019/2020 dataset were all lower and ranged from -0.16 to -0.31 m of the 2012 elevations. To account for the elevation difference, an offset of 0.22 m was applied to the 2019/2020 elevation raster before generating the DoD.

Geomorphic features, including gullies, slumps, and landslides, were delineated using the hillshade model generated from the OMNRF bare-earth elevation raster. Delineation was generally accomplished by visually interpreting the morphological features and characteristics shown on the hillshade, slope gradient raster, and land surface change raster. Slumps were identifiable by their concave profile, with a steep, crescent-shaped headscarp and debris amassed at the base of the slope. More recent slumps were the most readily identifiable due to the contrast in slope gradient between the headscarp and the debris pile, while in older slumps the contrast was somewhat diminished likely due to ongoing erosion processes. Gullies were identifiable as relatively straight V-shaped features cut into the valley walls, approximately perpendicular to the length of the valley. The land surface change and geomorphic features map is provided in **Appendix D**.

The OMNRF 2019/2020 bare-earth elevation raster was also used to generate a slope raster with a slope classification scheme that highlights slopes with gradients of >3:1, >2:1, and >1:1. For reference, the minimum stable slope gradient recommended by OMNRF is 3:1 (horizontal:vertical) ratio (OMNRF, 2002). The resulting slope classification raster was overlayed on the 2019/2020 hillshade raster to show the spatial distribution of the relatively higher slope areas adjacent to the creek and within its valley. Areas shaded 'red' are those with slopes greater than 45 degrees (i.e., >1:1 slope). This analysis was undertaken to map the spatial distribution of the steepest slopes and to aid in identifying geomorphic features. The resulting slope raster and hillshade map is provided in **Appendix D**.

The 2012 and 2019/2020 DEMs were used to generate longitudinal profiles of the South Tributary channel. The longitudinal profiles were generated by sampling elevation values from both the 2012 (corrected) and 2019/2020 DEMs at intervals of 1 m along the channel flow path. The sampled elevations in meters for the respective years were then plotted with horizontal distance downstream. Reach breaks and other features along the South Tributary, including the historical crossings, beaver dams, underlying surficial geology, and the longitudinal extent of the recent slope failure, were overlayed on the plot to provide geomorphic context. The plot is presented below in **Figure 1**.

2.5.2 Slope and Land Surface Change Results

The active channel, floodplain, and valley walls are all clearly visible on the hillshade model generated from the 2019/2020 bare-earth DEM (OMNRF; 2020). Slumps, gullies, and areas of backwatering are discernable on the hillshade model as well as the land surface change and slope gradient distribution rasters. Historic landslides within tributary valleys, as mapped in Brooks (2019), are also identifiable on the hillshade model. The results of the analysis are discussed below, reach by reach. For reference, figures showing mapped geomorphic features and slope gradients are provided in **Appendix D**.

Reaches **R1** and **R1A**

Along reach **R1,** the hillshade model reveals that the watercourse is unconfined and the channel straightened. The banks in this reach have relatively steep, localized slope gradients up to approximately 50% on the slope gradient map. Here, channel banks range from 0.5 to 1.0 m in height. Minor evidence of lateral scour along the banks was observed during the field assessment (details provided in Section 3.2—General Reach Observations).

The channel planform in reach **R1A** is relatively straight with some isolated bends. A well defined valley emerges with distance downstream while the channel gradient increases, as shown on the longitudinal channel profile provided below (see **Figure 1)**. As noted in the Historical Assessment provided above, the hillshade model shows evidence of historic beaver activity within this reach. Desktop terrain analysis indicates there are no locations within **R1A** where the watercourse is in contact with the valley slopes, a finding that is consistent with the results of the field assessment (see discussion below). The valley slope gradient appears to increase with distance downstream as valley walls increase in height, with maximum local slope gradients around 50%. Floodplain widths within the emerging valley range from approximately 4-18 m.

Reach **R2**

Downstream of this in **R2**, the watercourse becomes confined within a valley characterized by alternating scalloped valley wall headlands that encroach into a relatively narrow floodplain. The watercourse meanders somewhat irregularly within its confined valley setting, making frequent contact with the toe of the valley slope. The hillshade model reveals an evident connection between the valley form and channel form within this reach, as the scalloped valley form largely follows the pattern and wavelength of the meanders. Slump scarps and gullies are a frequent feature along the scalloped valley walls. The floodplain within this reach is discontinuous due to the narrow valley and encroaching headlands. Instead, there are isolated pocket floodplains (up to 15 m wide) and terraced features, which are observable in the hillshade model and were noted during the field assessment.

There is a sharp increase in the magnitude of valley wall slope gradients entering Reach **R2** and a higher density of gradient values greater than 33%. Terrain analysis revealed valley wall slope gradients of up to 140%. Terrain slopes tend to be greater within gullies, along the face of slumping valley wall headscarps, and where the outside of meander bends are in contact with the valley wall. There are several gullies and slumps along the valley walls along this reach where elevation decreases between 1 to 3 m were detected in localized and isolated locations (i.e., land surface areas with magnitudes in the order of 10^1 m^2). Most of the gullies and slumps present along **R2** were not associated with recent land surface changes detected through land surface change analysis (i.e., DoD raster). Localized elevation decreases of the magnitude of 1 to 3 m were detected along Reach **R2** (DoD raster; 2012 vs 2019/2020 elevation datasets) at the outside of several meander bends. The watercourse is in contact with the valley slopes on the outside of many of these meander bends, some of which have slope gradients of up to 125%.

The form of the branching drainage feature extending into the fields north of the valley that was noted in the Historical Assessment is revealed more clearly on the hillshade model. The lack of recent elevation changes along this feature indicates it formed and stabilized prior to 2012 (i.e., the year of the first DEM used in this terrain assessment).

Reach **R2A**

The watercourse continues to flow within the confined valley in reach **R2A**, although scalloping along the valley walls is no longer evident. A sculpted embankment along the north valley slope supports access paths to two watercourse crossings that may have historically impacted the valley planform. The valley wall, both upstream and downstream of the embankment, ties in with the valley wall above the embankment, suggesting the embankment was built out from the valley slope and interrupted the generally southwestward trajectory of the valley planform. The curve of the southeastward bend along the south valley wall also appears to match that of the embankment. The watercourse planform through this reach meanders irregularly through a wider floodplain (7 to 19 m) upstream of the first channel crossing. The planform between the first and second crossings is straighter through a narrower floodplain (width: 4 to 6 m). Channel planform was also likely historically impacted by the channel crossings and the aforementioned embankments. Distinct from Reach **R2**, here, multiple channel flow paths are visible in the hillshade model within the much wider floodplain area upstream of the first channel crossing. These channel features were also observed during the field assessment (see Section 3.2 below).

There is a lower density of valley slope gradients steeper than 33% along the north valley slope compared to adjacent reaches, where local gradients up to 75% are observed. Limited elevation changes were detected in **R2A** upstream of the first crossing, however, there is one location along the north slope where the watercourse is in contact with the toe of a slump where elevation decrease was detected. Slope gradients along the sculpted crossing embankment and the south valley slope opposite it are identical in steepness and density to those upstream. Some localized elevation decreases between 2012 and 2019/2020 were detected along the base of the valley wall along this section. These elevation decreases comprised relatively small patches with surface areas on the order of 10^1 m^2. Valley wall slope gradients within this section increase relative to the upstream portion of this reach, with gradients up to 107% observed.

Reach **R3**

The watercourse continues to flow within a confined valley and the generally southwestward trajectory of the north valley wall continues in reach **R3**, while the south valley wall through this reach becomes more complex in its form. The south valley wall trajectory is interrupted by tributaries, relatively deep gullies, and the debris of a large landslide (Brooks, 2019). Slump scars are also present along both valley walls, and there are recent slope failures along both the north and south valley walls adjacent to the property at **1320 Grand-Chêne Court** across from the landslide debris where the watercourse is in contact with the valley slope toes. The channel planform meanders irregularly through a floodplain with variable width (2 to 26 m) along the reach. The variable floodplain widths are attributed to the channel flowing through unconsolidated sediment deposits on the upstream side of two beaver dams located within this reach, features that are visible in the hillshade model and were observed during the field assessment.

Valley wall slope gradients within the section upstream of the first beaver dam tend to be greater within gullies, along the face of slump headscarps, and where the outside of meander bends are in contact with the valley slope toe. Outside the slope failure at 1320 Grande-Chene, analysis of the LiDAR datasets indicates that the slopes of the northern valley wall along Reach **R3** have been relatively stable without slumping or the development of gully features during the period between 2012-2020. On the southern valley wall, two relatively deep gullies had formed prior to 2012. Since 2012, areas with elevation increases of up to approximately 1 and elevation decreases of up to approximately 3 m were detected along the length of one of these two larger gully features. Along the channel two areas of relatively large elevation increases show the effect of backwatering caused by the first beaver dam. Note, here elevations shown on the DEM from 2019/2020 are that of an inferred water surface elevation rather than the bare-earth elevations shown on the DEM for areas outside the wetted channel. This is a known and important limitation of bare-earth elevation models derived from LiDAR data as the near-infrared lasers used for aerial LiDAR surveys do not effectively penetrate water. This area was no longer backwatered during field assessments conducted in July 2023, and both beaver dams appear to have been breached sometime between 2019/2020 and 2021 based on surface model and aerial imagery observations.

The recent slope failure at **1320 Grande-Chene** is located immediately downstream of the location of one of the two former beaver dams. At the location of the slope failure, changes in elevation were detected in the DoD along both valley slopes, channel banks, and within the floodplain. Elevation decreases up to 2 m were detected along the top of the north valley slope at the location of the recent failure, cumulatively comprising a land surface area on the order of 10^2 m^2, and with slope gradients of up to 108% observed on the LiDAR-derived bare-earth DEM. At the toe of the slope below the recent failure, an area with elevation decreases was detected along the outside of a meander bend where local slope gradients up to 117% were measured. Elevation decreases at that location range from approximately 1 to 3 m and comprise a land surface area with a magnitude in the order of 10^1 m^2. Opposite from this along the south valley slope, a crescent-shaped area of elevation decrease was detected where local slope gradients up to 102% were observed, indicating a recent slump. Elevation decreases at this location are up to approximately 3 m and comprise a land surface area with a magnitude on the order of 10^2 m^2.

Downstream of **1320 Grande-Chene Court**, valley wall slope gradient decreases along the north valley wall, with gradients up to 57% observed, as does the density of slopes greater than 33%. There are two slumps along the south valley slope within this section with gradients up to 70% measured on the headscarp; recent and significant elevation changes were not detected at this location. Significant elevation increases in the area upstream of the second beaver dam were detected on the DoD and are likely representative of backwatering caused by the beaver dam. Evidence that this area had recently drained was observed during field assessments conducted in July 2023. This was confirmed by observing imagery dated to May 8, 2023, using Google Earth Pro, which showed that the area remained backwatered as of that date, indicating the beaver pond drained sometime between May and July 2023.

Reach **R4**

The watercourse continues to flow in a confined valley setting in reach **R4** while the general valley trajectory turns southwards. The South Tributary valley walls at the upstream end of the reach tie into the Cardinal Creek valley walls; several slumps and gullies are in this transition zone. The channel planform meanders tortuously through a floodplain. Here floodplain widths range from 2 to 15 m, with the channel making frequent contact with the toe of the valley slope along the outside of meander bends. There is evidence of recent slumping in the lower end of the reach. Elevation decreases up to approximately 2.5 m were detected in multiple slump headscarps along the valley wall adjacent to meander bends. Local slope gradients up to 115% were observed in the headscarps. There are several gullies along the south valley wall within this reach. Analysis of the DoD indicated there were no recent and significant elevation changes at this location, although a higher density of slope gradients greater than 33% were observed.

Tributary Reaches **T1** to **T4**

Land surface changes, geomorphic features, and slope gradients were mapped for the four contributing channels draining the area south of the South Tributary, reaches **T1**, **T2**, **T3**, and **T4**. The results of the digital terrain analyses for these reaches are not discussed at length in this report since they are located outside of the subject lands. However, the historic landslide attributed to the sensitivity of glaciomarine clays within **T4** was mapped to show the location relative to the South Tributary (Brooks, 2019). Observing the spatial distribution of geomorphic features, land surface changes, and slope gradients mapped within reaches **T1** to **T4** compared to those mapped within the South Tributary shows that the geomorphic processes operating in those tributaries are likely to be operating within the South Tributary.

Summary

Analysis of the hillshade model, land surface change raster (i.e., DoD), and slope gradient distribution raster revealed ongoing geomorphic processes within the South Tributary. Slope gradients tend to be greater within gullies, along the face of slump headscarps, and where the outside of meander bends are in contact with the valley slope. Slumps were more concentrated within reaches **R2** and **R3**, while the highest concentration of gullies occurs in reach **R2**. Most of the mapped slumps and gullies formed prior to 2012, and significant surface elevation changes that occurred between 2012 and 2019/2020 were identified and mapped, the most notable being the decrease in elevation along the top of the north valley slope adjacent to **1320 Grand-Chêne Court** and along the south valley slope across from it. Beaver activity was also highlighted by the land surface change analysis, particularly extensive backwatering upstream of dams within reach **R3** both upstream and downstream of the recent slope failure.

2.5.3 Longitudinal Profile Comparison Results

The comparison of longitudinal profiles from 2012 (yellow) and 2019/2020 (blue) in **Figure 1** below reveals several changes in channel bed gradient and profile during the intervening period. The locations of reach breaks, surficial geology, detailed assessment, tributary confluences, historical crossings and beaver dams, and the extent of the recent slope failure are also overlayed on the long profiles. Along the length of the subject lands, the elevation of the South tributary drops approximately 32 m over a distance of approximately 2000 m (average channel gradient 1.6%). The long profile for the South Tributary is punctuated by several prominent slope breaks with localized sub-reach scale channel gradients of up to 4%. The longitudinal profiles are generally consistent between the 2012 and 2019/2020 elevation data, with the exception of the significant (2-3m) elevation increases observed at the location of the beaver dams. Surficial geology along the watercourse is largely dominated by glaciomarine clay, with a short section of limestone bedrock outcropping at the downstream end of Reach R2A near the first historic channel crossing. The long profiles are described below reach by reach.

Reaches **R1 and R1A**

A peak in elevation visible within reach **R1** near 60 m horizontal distance in the 2012 profile represents a former crossing over the channel between agricultural fields that was no longer present in 2019/2020. A short section of relatively level elevation in both profiles within reach **R1A** between approximately 200 to 300 m horizontal distance precedes the location of a historical beaver dam noted in the Historical Assessment and field observations. Two step-like decreases in bed elevation, where short plateaus in elevation precede a sudden drop, are visible in the 2012 profile just downstream of the historic beaver dam at approximately 320 and 380 m but are not present in the 2019/2020 profile, indicating potential erosion during the intervening period.

Reaches **R2** and **R2A**

Reach-scale channel gradient increases relative to **R1**. Along **R2**, there were no significant changes in the channel profile between 2012 and 2019/2020. This section of the reach has three significant breaks in slope at 450 m, 800 m, and 900 m distance downstream. The reach-scale gradient increases with distance downstream along **R2A,** with the profile punctuated by two spikes in elevation associated with channel crossing embankments. The channel gradient of the section between the two crossings is relatively high at approximately 4%. The 2012 and 2019/2020 profiles show a relatively consistent elevation with the exception of an approximately 100 m long section, between approximately 1180 to 1280 m downstream, which lowered by as much as 50-100 cm between 2012 and 2019/2020. This section was backwatered as recently as 2002, as noted in the Historical Assessment.

Reach **R3**

Reach-scale gradient lowers relative to the section between the historical crossings in **R2A**. There are significant changes in the channel profile between 2012 and 2019/2020 associated with the location of beaver dams located at approximately 1580 m and 1840 m downstream. The 2019/2020 profile shows the flat backwatered sections upstream of where the beaver dams are located. The recent slope failure in the rear yard of **1320 Grand-Chêne Court**, approximately 1595 to 1645 m downstream, occurs along the right (north) bank of the watercourse immediately downstream of the first beaver dam. At the time of the 2023 field assessments, this area was observed to have been dewatered due to rupturing of the beaver dam.

The 2012 channel bed profile shows a step-like drop at approximately 1590 m, then a similar elevation range and gradient to the sections both upstream and downstream. The 2019/2020 profile shows a step-like decrease at around 1620 m, then greater variations in elevation than the 2012 profile. Note that this variability in slope profile is located in the area of the recent slope failure, suggesting that this channel bed variability is associated with colluvial material from the adjacent slopes eroding into the watercourse.

Downstream of the recent slope failure extent, the 2012 profile continues within a similar elevation range and gradient to the upstream sections of **R3** up to the location of a historic beaver dam around 1760 m horizontal distance, where there is another step-like drop. This area dewatered in the spring of 2023, as confirmed by aerial imagery and field observations, and is covered by deep deposits (> 1 m) of soft silty clay with a relatively low channel gradient.

Reach R4

Reach R4 begins downstream of a beaver dam. There is a slope break around 1900 m, after which the gradient decreases in both the 2012 and 2019/2020 profiles. The 2012 profile shows a backwatered section upstream of the confluence with Cardinal Creek.

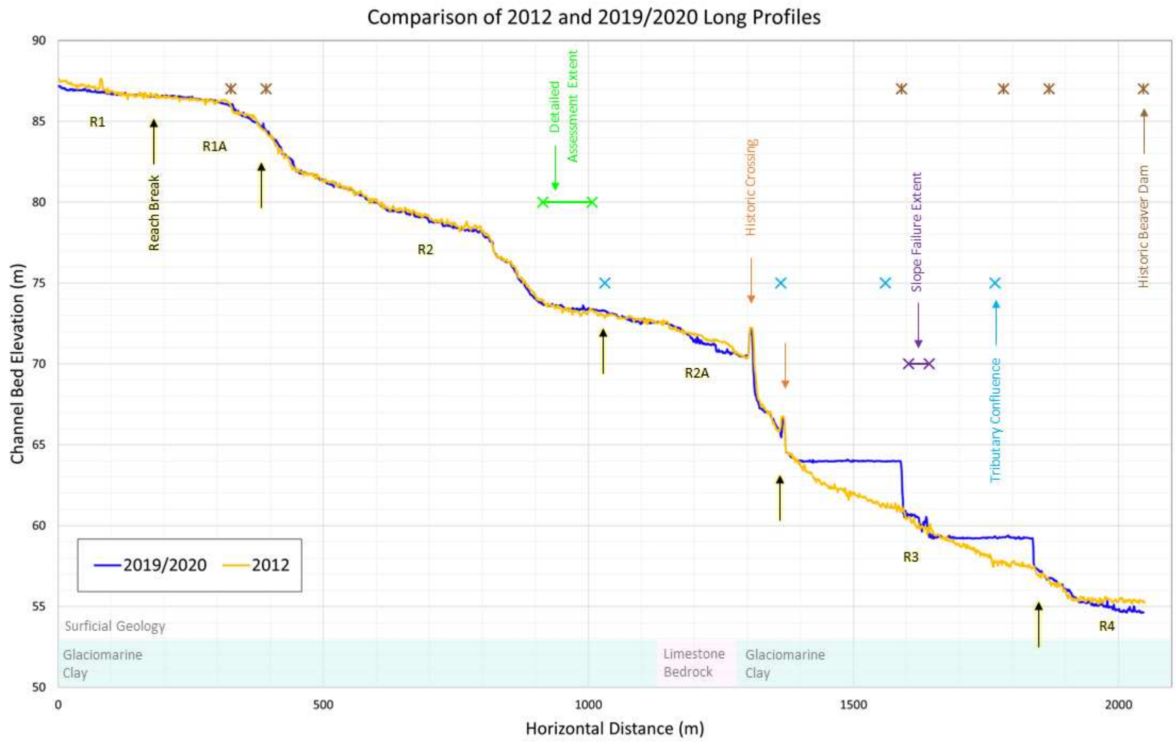

Figure 1: Comparison of 2012 and 2019/2020 South Tributary Long Profiles

Summary

Overall, the 2012 and 2019/2020 long profiles were similar, with differences notable in the vicinity of historic beaver dams and watercourse crossings. Sections with relatively lower gradients tended to precede historic beaver dams, likely due to deposition caused by backwatering and slower flows. Sections downstream of beaver dams, specifically within reaches R1A and R3, and the section upstream of the first historic crossing showed differences in the local profile pattern and elevation variance between the 2012 and 2019/2020 profiles. Particularly notable is the extent of recent backwatering due to beaver dams immediately upstream and downstream of the recent slope failure.

3 Field Assessment

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 a scientifically defensible methodology proposed by Montgomery and Buffington (1997), the Toronto and Region Conservation Authority (2004) and others. Several watercourse reaches were previously delineated by Parish Geomorphic (2013), some of which are used in the present study and some of which were amended. While reach delineation can be completed based on longitudinal profiles, the basic reach classification scheme from previous assessments was adopted in order to maintain consistency with existing reports and studies for the subject property.

A total of six reaches were identified within the subject property: **R1, R1A, R2, R2A, R3 and R4.** Reach Reaches **R3** and **R4** were adopted from Parish Geomorphic (2013) mapping, while reaches **R1**, **R1A**, **R2**, and **R2A** were amended from Parish Geomorphic (2013) mapping. Reach **R1** was divided into **R1** and **R1A,** and the reach break at the downstream end of **R1A** was moved slightly farther downstream to a location where the channel elevation distinctly begins to drop at the beginning of **R2**. Reach **R2** was divided into **R2** and **R2A**, with the reach break at the upstream end of **R2A** placed at a location where the floodplain distinctly increases in width. Reach **C10** from the Geomorphic Solutions (2007) and Parish Geomorphic (2013) mapping was also identified as the reach along the main channel of Cardinal Creek into which the South Tributary discharges. Additionally, four tributaries flowing from the south tablelands into the South Tributary were identified and assessed: **T1, T2, T3** and **T4.** Reach mapping is provided in **Appendix A** for reference.

3.2 General Reach Observations

GEO Morphix Ltd. completed visits on July 12th, 2023, and November 29th, 2023, to document existing channel conditions. **Appendix E** provides a geo-referenced photographic inventory documenting evidence of dynamic adjustment within the system. Photographs of general site conditions are provided in **Appendix F,** and field observations are included in **Appendix G** for reference.

The site visits included the following activities and reach observations:

- Habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation for the extent of each reach assessed
- Descriptions of riparian conditions
- Documentation of culvert crossing conditions
- Estimates of bankfull channel dimensions
- Bed and bank material composition and structure
- Observations of erosion, scour or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, channel disturbances such as crossing structures, and areas of erosion and/or evidence of dynamic adjustments
- Completion of rapid channel assessments following the Rapid Geomorphological Assessment (RGA) (MOE, 2003; VANR, 2007) and Rapid Stream Assessment Technique (RSAT) (Galli, 1996) methodologies

General channel characteristics for all assessed reaches are summarized below in **Table 1**.

Table 1: General reach observation summary

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Dominant Riparian Condition	Notes
R1	3.25	0.60	Clay/Silt		Grasses, Herbaceous	• No riffle pool formation, all runs • Historically straightened agricultural ditch • Dense instream vegetation • Minor basal scouring; rilling from adjacent fields
R1A	2.50	0.55	Clay/Silt		Grasses, Herbaceous	• Flows through historic beaver meadow • Heavily encroached and interstitial flow • Poorly defined bankfull; low and flat floodplain
R2	6.66	0.75	Clay/Silt-Boulders	Clay/Silt-Cobble	Trees, Herbaceous	• Develops meandering planform • Mass movement, exposed roots, down trees, undercutting observed • Channel substrate composed of clay-till, exposed along the bed • Valley wall contact observed
R2A	2.50	0.40	Clay/Silt		Herbaceous, Grasses	• Channel flows through historic beaver meadow • Multiple flow paths and interstitial flow • Channel bed compact clay • Flat and low floodplain between valley walls
R3	3.83	0.86	Clay/Silt-Cobble	Clay/Silt	Trees, Herbaceous	• Valley narrows, bank in contact with valley wall along right bank • Extreme tree fall throughout • Large breached historic beaver dam at the downstream extent
R4	3.00	0.75	Clay/Silt-Boulders	Clay/Silt-Gravel	Trees, Herbaceous	• Beaver dam located upstream and downstream end of reach • Backwatering at the downstream section • Valley wall contact observed
T1	Poorly defined- though ravine		Clay/Silt-Boulders		Trees, Herbaceous	• Tributary through ravine • High gradient • Many forced knickpoint due to debris and roots • Scour and exposed roots along both banks

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Riffle Substrate	Pool Substrate	Dominant Riparian Condition	Notes
T2	1.65	0.54	Clay/Silt-Boulders		Trees, Herbaceous	• Tributary through ravine • High gradient • Recent slump observed on slope • Many forced knickpoints due to debris and roots • Basal scour and exposed roots along both banks observed
T3	Poorly defined-through ravine		Clay/Silt	Clay/Silt	Trees, Herbaceous	• Tributary through ravine • Rotational slides and undercutting present • Many forced knickpoints due to debris and roots • Frequent down trees
T4	1.50	0.56	Clay/Silt-Boulders	Clay/Silt-Gravel	Trees, Herbaceous	• Tributary through ravine • Rotational slide, undercutting observed • Many downed trees • Channel bed flat compact clay
C10	13.32	0.72	Sand-Boulders	Clay-Cobbles	Trees, Herbaceous	• Bedrock exposed throughout, comprising bed in multiple locations • Two bedrock knickpoints • Three beaver dams backwatering upstream half of reach

3.2.1 South Tributary Reaches

Reach **R1** begins along Cox County Road, flowing under the road and in a generally westward direction towards Cardinal Creek. The channel flows through an actively cultivated agricultural field and exhibits a straightened planform with a low gradient. The channel had no pool-riffle features, and vegetation encroachment was heavy. The riparian buffer between the active field and the channel was narrow (2-3 m) and was composed of grasses and herbaceous vegetation. At the time of the assessment, emergent and submerged aquatic vegetation and floating algae were present throughout the reach. The channel bed and banks were composed of loose silt, and some large cobbles were observed along the banks. Minor basal scour was observed at few locations and rilling from the adjacent field into the channel margins was observed along the downstream extent.

Reach **R1A** extends from **R1** continuing to travel westward for approximately 130 m. The channel exits the agricultural field and flows within a historic beaver meadow, which was heavily encroached by vegetation and surrounded by a wide and flat floodplain composed of grasses. No riffle-pool features were present. The channel was poorly defined in some locations, and interstitial flows through the beaver meadow substrate were observed at several locations throughout the reach. The channel bed and banks were composed of compact silt with a clay channel substrate. A historic beaver dam outflanked to the right (north) by the existing channel and with undercutting (0.55 m) was observed within the downstream extent of the reach. Evidence of erosion was limited along the reach except near the transition to **R2**, where the channel elevation began to drop and basal scour and bank undercutting was observed.

Reach **R2** extends from **R1A** and enters a confined valley setting where the creek continues flowing westward for approximately 500 m. The channel exhibits a meandering planform along the valley floor which ranged from 10-20 m wide with slopes up to 10 m tall. The riparian zone consisted of trees and herbaceous vegetation. The bed material was composed of clay till, which was exposed along the length of the channel, as well as pebble-sized clay conglomerates, soft silt, and cobble and boulder-sized glacial till. Riffle-pool sequences were common throughout the reach, with substrates composed of clay up to boulders in some riffle locations. Exposed till up to 0.5 m in height, and small-scale mass movement was observed where the channel was in contact with the valley wall. Undercutting up to 0.60 m was observed, and bank angles were between 60° and 90°. Exposed tree roots and leaning trees of all ages and large woody debris in the channel was commonly observed. Approximately 60% to 100% of the reach exhibited signs of erosion.

Reach **R2A** extends from **R2** as the channel enters a lower gradient section with a wider floodplain. A sculpted embankment upstream of the first of two historic channel crossings protrudes from the north valley wall towards the southeast into the South Tributary valley. Land cover on the embankment was comprised of forest and meadow encroaching along the abandoned access road. The valley and watercourse trajectory mirror that of the protruding embankment with a wide southeastward bend. Access roads to the historic crossings travel down the valley slopes and cross over the channel with corrugated steel pipe culverts conducting flow below them. Reach **R2A** continues for approximately 300 m and ends at the second historic crossing located at the downstream extent of the Reach. The culverts at both crossings were in a degraded condition at the time of the assessment and both were perched above the channel (2 to 5 m height) on the downstream side. A large proportion of the flow was conducted interstitially through both crossings as the channel outflanked the culverts on their upstream side. A cascade constructed from placed cobble comprised the watercourse immediately downstream of the first crossing, and there was a scour pool eroding into the clay till downstream of the second crossing.

The land cover within the relatively wide floodplain is comprised of dense grasses and some large woody debris. There are multiple distinct channels through this section of the reach which are heavily encroached by grassy vegetation. Some streamflow is via channels located along the base of the valley walls and interstitially through the meadow. No riffle-pool features were present, and the channel bed was composed of compact clay-till. Undercutting up to 0.15 m was observed along the banks in several locations. The channel banks ranged between 30° to 90°, and bank erosion was observed along 5% to 30% of the reach. The 50 m long section of the reach between the first and second channel crossings has a significantly steeper channel gradient and narrower floodplain relative to the upstream section of the reach with a narrow floodplain.

Reach **R3** begins at the downstream end of the second of the two historic channel crossings, where a relatively large scour pool formed on the downstream side of the culvert. From here the channel continues flowing westward towards the main branch of Cardinal Creek. This reach exhibited similar characteristics to those observed along reach **R2**. The channel regained a meandering planform which was in contact with the bounding valley slopes throughout much of the reach. Riffle-pool features were observed, however, not as frequently as in reach **R2.** Channel banks slopes ranged from 60° to 90° and bank erosion was observed along 60% to 100% of the reach. A tall (3-4 m) breached beaver dam was observed approximately 150 m downstream from the beginning of the reach. Flow passed through the abandoned dam and there was a drop in channel elevation on the downstream side, as the channel upstream of the dam flowed through a thick layer of sediment deposited behind the dam. Downstream of this point the valley becomes increasingly narrow and the channel is in contact with the valley slopes in multiple locations. A recent slope failure was identified along the right bank in this section adjacent to **1320 Grand-Chêne Court**. Another tall (2-3 m) beaver dam that had recently breached was observed at the downstream extent of reach **R3**. The dewatering of the beaver pond was evidenced by relatively deep (> 1 m) loose silty clay deposits with limited vegetation growth as well as tree trunks within the floodplain were covered with dried clay residue at heights up to 1.5 m. Here an approximately 1.40 wide and 0.08 m deep channel has formed in the newly exposed beaver pond sediments, which were unconsolidated to depths greater than 1 m.

In the vicinity of the recent slope failure, extreme tree fall was noted along both valley slopes and the channel was clogged with debris. The channel bed was composed of exposed clay-till and some gravel. Undercutting up to 0.15 m was observed along the right bank. Slumping was observed along both the left and right valley slopes. The right (north) valley slope had a step-like slope profile where slope breaks separated sections with relatively lower and higher gradients. Leaning trees and exposed roots were observed along the right slope. An intact root wad that originated from the slump along the left (south) valley slope was perched across the channel supported by older woody debris.

R4 begins on the downstream side of the recently dewatered beaver dam and continues to flow westward for approximately 200 m until the confluence with Cardinal Creek. The reach break used for the field assessment was at the confluence between the South Tributary and **T4**, as in Parish (2013), and was moved downstream of this to the location of the beaver dam following the field assessment due to the disparity between characteristics of the recently dewatered area and the rest of **R4**. Downstream of the recently breached beaver dam, the channel regains its meandering planform, with several locations of valley wall contact observed. A second active beaver dam at the confluence with Cardinal Creek was observed, resulting in the stream being backwatered for most of reach R4. Exposed tree roots and leaning trees were observed along the banks and valley slopes. Due to high water levels, neither the bed substrate nor channel bedforms (e.g., riffle-pool features) were observable. The channel bank angles ranged from 60° to 90° and evidence of erosion was observed along 60% to 100% of the reach.

3.2.2 Tributaries to the South Tributary

All four watercourses contributing to the South Tributary are located to the south of the subject watercourse and drain agricultural lands. Tributary **T1** outlets to reach **R2** of the South Tributary and has a relatively straight planform through an agricultural field that transitioned to a high gradient ravine as it entered the forested valley setting along the South Tributary. The channel bed in the ravine was composed of clay to large cobbles and boulders. Fallen trees and exposed tree roots were commonly observed along the ravine slopes, and several forced knickpoints due to debris and roots were noted. Undercuts up to 0.40 m were measured, and valley wall contact and scour were observed along both banks throughout the reach. The riparian zone was composed of trees and herbaceous vegetation. The channel banks were nearly vertical and measured up to 4 m in height with signs of erosion observed along 60%-100% of the reach.

Reach **T2** is located south of the South Tributary and flows in a generally westward direction through an agricultural field, then turns northwest where it enters a forested valley of the South Tributary and flows in a high gradient ravine to outlet into reach **R3** approximately 300 m downstream of the **T1** confluence. The tributary exhibits a wandering planform with no true meanders through the ravine. Like **T1**, many fallen and leaning trees, cutbanks, and undercutting up to 0.90 m were observed. Many forced knickpoints due to debris and roots were noted. A recent slump with characteristic regressive slump blocks was observed along the southwest valley slope, located across from a historic failure resulting in a large accumulation of debris and dense tree fall in the channel (Brooks, 2019). The channel bed was composed of exposed clay tills with locations where large boulders and cobbles were present. The channel bank angles ranged from 60° to 90°, and evidence of erosion was observed along 60% to 100% of the channel.

Reach **T3** is similarly located south of the South Tributary and flows from the southwestern edge of the adjacent field through a ravine to discharge into **R3** approximately 200 meters downstream from **T2.** Similar characteristics to those observed along **T2** were noted, including fallen and leaning trees, cutbanks, and undercutting up to 0.42 m. The channel bed was similarly composed of compact clay-till with some large cobbles and boulders observed. A large knickpoint was observed halfway along the reach. Occurring within the compact clay-till, it was approximately 1 m in height and had a large scour pool on the downstream side. Several other forced knickpoints formed due to channel debris were also observed. Channel bank angles ranged from 30° to 90° and evidence of erosion was observed along 60% to 100% of the reach.

Reach **T4** is also located south of the South Tributary and flows westward from agricultural fields into a forested area, where it transitions into a ravine. The tributary through the ravine generally flows northwestern and discharges into **R4** approximately 170 m downstream of the **T3** confluence. The channel exhibits a wandering planform and high gradient. The riparian zone consisted of trees and herbaceous vegetation and the channel bed was composed of exposed clay-till with cobbles and boulders observed in some locations. Evidence of bed scour, specifically large angular conglomerates displaced from the compact clay-till bed, was observed along most of the reach. Evidence of rotational slumping was observed along with leaning trees, undercutting up to 1.50 m, and cutbanks. Forced knickpoints within the channel and scour along both banks were also observed. The channel bank angles were 60°-90°, and erosion was observed along 60% to 100% of the reach.

3.2.3 Main Channel

Reach **C10** begins where the South Tributary meets the main channel of Cardinal Creek and flows generally north for approximately 475 meters to the Old Montreal Road crossing. The channel exhibits an irregular meandering planform and a moderate gradient. The riparian zone was comprised of forested valley slopes and a narrow floodplain with grassy and herbaceous vegetative cover. The channel bed composition varied throughout the reach, with the downstream extent comprised largely of sand to boulder-sized substrate with areas of exposed bedrock and the upstream extent comprised largely of loose clay and glaciomarine clay till with some cobbles. Banks were comprised of the same variable materials, with some bedrock banks and some alluvial soil banks. Basal scour was observed along both banks throughout the reach, as were multiple bar forms and islands. Undercutting up to approximately 0.61 m was observed, primarily within the downstream half of the reach. Bank angles ranged from 10 to 80 degrees throughout the reach, averaging 45 degrees. Two bedrock steps were observed with shallow pools downstream. Three active beaver dams were observed within the upstream half of the reach, causing backwatering up to and beyond the confluence with the South Tributary.

3.3 Rapid Field Assessments

Channel stability and susceptibility to erosion were objectively assessed through the application of the Ontario Ministry of the Environment (MOE; 2003) Rapid Geomorphic Assessment (RGA) technique. The RGA evaluates degradation, aggradation, widening, and planimetric form adjustment at the reach scale. The RGA technique aims to produce a score, or stability index, which qualitatively evaluates the degree to which a stream has departed from its equilibrium condition. A stream with a score of less than 0.20 is classed as 'in regime', indicating minimal changes to channel form or processes. A score of 0.21 to 0.40 indicates that a stream is 'in transition' with the channel undergoing major changes to process and form. A score of greater than 0.41 indicates that a stream is 'in adjustment', exhibiting a new stream type, or a channel that is in the process of adjusting to a new equilibrium (MOE, 2003; VANR, 2007).

The RGA technique is useful for a qualitative reach-by-reach spatial comparison of relative channel stability. Although RGA scores provided by different practitioners for reach assessments conducted at different times can be compared, different practitioners may interpret indicators differently, and therefore, any temporal comparison is qualitative and other techniques for assessing channel stability and morphological channels derived from sources such as aerial imagery and quantitative data are best relied upon to assess temporal changes. RGA scores and reach descriptions from previous assessments were considered, and are summarized in the following paragraphs, but were not relied upon to assess whether relative channel stability had increased or decreased over the period between assessments.

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system and to consider the ecological functions 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.

Rapid assessments were completed during the site visits on July 12th, 2023, November 30th, 2023 and October 10th, 2024. Photographs of general channel conditions for all reaches are provided in **Appendix F,** and field observations are included in **Appendix G** for reference. **Table 2** below summarizes the results of the rapid field assessments.

Reach **R1** scored 0.143 on the RGA, indicating that the channel is 'in regime'. The dominant systematic adjustment was aggradation and planimetric adjustment due to the few observations of scour, rilling and re-worked bars. This suggests an increase in channel stability and a reduction in active channel widening since the 2013 rapid geomorphic assessment conducted by Parish Geomorphic in 2013. For the current study, the reach received an RSAT score of 24 or Fair due to poor riparian habitat conditions as there was a lack of riparian vegetation diversity.

Reach **R1A** also received an RGA score of 0.143, indicating that the channel is 'in regime'. The dominant systematic adjustment was aggradation due to the observation of siltation and over-bank deposition of sediments. Consistent with **R1**, the updated RGA score suggests increased channel stability and reduced erosion since 2013, when the reach was determined to be 'in adjustment' with evidence of active widening (Parish, 2013). Note that **R1A** is a portion of what was defined as reach R1 in previous studies; therefore, a direct comparison of RGA scores is not possible for this reach. An RSAT score of 27, or Good, was assigned, with the limiting factor being physical instream habitat due to the lack of diverse instream substrate and lack of riffle-pool features.

Reach **R2** scored 0.600 on the RGA, indicating that the channel is 'in adjustment'. The dominant systematic adjustment was aggradation and widening due to observations of point bars, siltation, and overbank deposition as well as leaning trees, large woody debris, and basal scour throughout the reach. This updated RGA score represents a slight increase in comparison with the 2013 score, possibly suggestive of active channel evolution and widening. The reach received an RSAT score of 22 or Fair. The limiting feature was predominantly channel stability due to unstable bends, tree roots, and scour along much of the reach.

Reach **R2A** scored 0.330 in the RGA, indicating that the channel is 'in transition'. Observations of multiple channels, island formation, and cutoff channels indicate that the dominant systematic adjustment is planimetric. This could indicate a slight increase in channel stability since 2013, when **R2** was determined to be 'in adjustment', with active widening. However, **R2A** is a new reach delineated for the current assessment and was formerly encompassed by **R2**, so a direct comparison between assessments is not possible for this reach. The reach received an RSAT score of 28 or Good. The limiting factor was the physical instream habitat due to the absence of riffle-pool features.

Table 2: Reach classification summary

Reach Name	RGA (MOE, 2001)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
R1	0.143	In Regime	Evidence of Aggradation & Evidence of Planimetric Adjustment	24	Fair	Riparian Habitat Conditions
R1A	0.143	In Regime	Evidence of Aggradation	27	Good	Physical Instream Habitat
R2	0.600	In Adjustment	Evidence of Aggradation & Evidence of Widening	22	Fair	Channel Stability
R2A	0.330	In Transition	Evidence of Planimetric Adjustment	28	Good	Physical Instream Habitat
R3	0.630	In Adjustment	Evidence of Aggradation & Evidence of Widening	23	Fair	Channel Stability
R4	0.613	In Adjustment	Evidence of Widening	26	Good	Channel Stability & Physical Instream Habitat
T1	0.336	In Transition	Evidence of Widening	22	Fair	Physical Instream Habitat
T2	0.575	In Adjustment	Evidence of Degradation	23	Fair	Channel Stability
T3	0.614	In Adjustment	Evidence of Widening	23	Fair	Physical Instream Habitat
T4	0.557	In Adjustment	Evidence of Widening	25	Good	Physical Instream Habitat
C10	0.489	In Adjustment	Evidence of Widening	26	Good	Water Quality / Channel Stability

Reach **R3** received an RGA score of 0.630, indicating that the channel is 'in adjustment'. Evidence of aggradation and channel widening were the dominant systematic adjustments. This was due to observations of bars, siltation, overbank deposition, leaning trees, exposed roots, and basal scour throughout the reach. Similar to **R2**, the RGA score for **R3** has increased since 2013, suggesting increased channel sensitivity and continued active channel widening. An RSAT score of 23 or Fair was assigned, with the limiting factor being channel stability due to the unstable banks and scour.

Reach **R4** received an RGA score of 0.613, indicating that the channel is 'in adjustment'. The dominant systematic adjustment was widening due to observations of down trees, exposed roots, and basal scour along most of the reach. Although **R4** was adopted from the 2013 assessment, this portion of the subject channel was included within **R3** for the 2013 RGA. An RSAT score of 26 or Good was assigned. The limiting factor was the physical instream habitat due to the lack of riffle-pool features and little variability in substrate sizes.

Reach **T1** received an RGA score of 0.336, indicating that the channel is 'in transition'. Channel widening was defined as the dominant systematic adjustment due to observations of leaning trees, exposed roots, and basal scour. The reach received an RSAT score of 22, or Fair, with physical instream habitat being the limiting factor due to the lack of variability in instream features.

Reach **T2** scored 0.575 on the RGA, indicating that the channel is 'in adjustment'. The dominant systematic adjustment was degradation due to observations of cut faces on bar forms, exposed tile drains, and head cutting due to knickpoint migration. An RSAT score of 23 or Fair was received. The limiting factor was channel stability due to observations of scour and exposed roots.

Reach **T3** received an RGA score of 0.614, indicating that the channel is 'in adjustment'. Due to observations of leaning trees, exposed roots, and basal scour, the dominant systematic adjustment was widening. The reach was assigned an RSAT score of 23 or Fair. The limiting factor was the physical instream habitat due to a lack of variability of channel bed substrate and features.

Reach **T4** scored 0.557 on the RGA, indicating that the channel is 'in adjustment'. The dominant systematic adjustment was identified as widening due to observations of leaning trees, exposed roots, and basal scour throughout the reach. The reach received an RSAT score of 25, or Good, with the limiting factor being physical instream habitat due to the lack of channel bed substrate variability and no diversity in riffle-pool features.

Reach **C10** received an RGA score of 0.489, indicating that the channel is 'in adjustment'. The dominant systematic adjustment was widening due to observations of down trees, exposed roots, the occurrence of large organic debris, and basal scour along most of the reach. The updated RGA score for **C10** from the current assessment is greater than that from the 2013 assessment, indicating potentially increased sensitivity and continued adjustment within the system. An RSAT score of 26 or Good was assigned. The limiting factors were water quality due to the opaque water, likely caused by fine clay particles in suspension, as well as channel stability.

3.4 Detailed Geomorphological Assessment

Detailed geomorphological assessments were completed for reach **R3** along the South Tributary and reach **C10** along Cardinal Creek during site visits on August 7th, 2024 and October 10th, 2024, respectively. This assessment provided bankfull channel characteristics, including cross-sectional geometry and hydraulics, for the purpose of defining the erosion threshold. Reach **R3** was selected based on field observations, as confirmed by both the RGA and RSAT, which showed this reach was the most susceptible to erosion in the potential zone of impact downstream of the proposed SWMP, which will discharge to reach **R2** upstream. The South Tributary discharges to the upstream end of reach **C10** along the main channel of Cardinal Creek. Representative cross sections were surveyed within representative sections of both reaches. Composite sediment samples for bed and bank materials were collected and analyzed at accredited laboratories. Longitudinal surveys of the channel bed were completed to determine channel slope and planform. Photographs of general channel conditions are provided in **Appendix F,** and a comprehensive summary of the channel measurements is included in **Appendix H** for reference. A tabular summary of channel measurements is also presented in **Table 3**, within **Section 4.1**.

4 Erosion Threshold Assessment

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank material (Garcia, 2008; Villard and Parish, 2003). As such, they are used to inform erosion mitigation strategies in channels influenced by conceptual flow and stormwater management plans. The erosion threshold is the theoretical point, typically expressed as a critical discharge or shear stress, at which entrainment of sediment would occur based on the morphology of the channel and characteristics of the bed and bank materials. Bed and bank materials typically exhibit distinct composition and structure, and therefore erosion thresholds are determined for both bed and bank materials. The lower of the bed and bank erosion thresholds is adopted, as it provides a more conservative and limiting estimate of erosion potential.

Erosion thresholds are generally determined using a range of methods that are dependent on channel and sediment characteristics. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied. For cohesive materials, a method such as that described by Komar (1987) or empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1994) could be applied. An erosion threshold, in the form of a critical discharge, is estimated based on the bed and bank material sizes (D_{crit}) and channel geometry in the assessed reach. Theoretically, above this discharge, the flow produces sufficient force to entrain and transport the bed and/or bank sediments.

The approach described above results in the definition of an inherently conservative, or lower-bound, estimate of the erosion threshold for any given stream channel. There are several factors that contribute to the conservative nature of the approach. Firstly, The erosion threshold is defined for what is determined to be, through a detailed geomorphic assessment of the stream channel, the most erosion-sensitive reach within the subject channel. Secondly, for the most erosion-sensitive reach a distinct erosion threshold is defined for both the bed and the bank materials and the lower of the two values is adopted as the erosion threshold. Thirdly, the approach does not account for channel forms and structures that contribute flow resistance (e.g., vegetation, surface roughness, channel bedforms, channel sinuosity) and which dissipate some of the force available for entrainment of the channel sediments.

4.1 Previous Erosion Threshold Assessments

Previously completed erosion threshold assessments provide a range of critical discharges and critical shear stresses for both Cardinal Creek and the South Tributary. As requested by the City of Ottawa, the previous erosion thresholds are reviewed and summarized below.

4.1.1 2007 Erosion Threshold Assessment

Geomorphic Solutions conducted Field assessments along the main branch of Cardinal Creek in October and November 2006. Channel and sediment characteristic results observed during these assessments are summarized in **Table 3** below. Erosion thresholds were modelled for reaches **C4** and **C10**. The bankfull geometry results in reach **C4** include an average bankfull width of 7.6 m, an average bankfull depth of 0.65 m, and a bankfull gradient of 0.09%. Sediments observed within this reach included alluvial silts overlaying a clay till substrate. A Manning's n value of 0.033 was applied. A critical velocity of 0.49 m/s was based on the permissible shear for the compact clay till, which provided a critical discharge of 1.01 m^3/s.

Observations for reach **C10** include an average bankfull width of 7.47 m, an average bankfull depth of 0.69 m, and a bankfull gradient of 0.27%. Sediment distributions produced from Wolman (1954) pebble counts produced a median grain size (D_{50}) of 3.0 mm and a D_{84} of 70.0 mm. A Manning's n value of 0.035 was applied. A critical velocity of 0.30 m/s was based on the permissible shear for the median grain size, which provided a critical discharge of 0.05 m^3/s. There was no access to the South Tributary during this time. The Geomorphic Assessment did not delineate erosion hazards or estimate an erosion threshold for that watercourse.

The methods applied to estimate the critical discharge are those of Chow (1959), Fischenich (2001), and Komar (1987). The equations used to complete calculations were not provided in the Cardinal Creek Geomorphic Assessment report (Geomorphic Solutions, 2007). It is noted that the threshold for reach **C4** was estimated using methods for cohesive clay substrate due to the clay till substrate and the threshold for reach **C10** was estimated using methods for non-cohesive sediments.

4.1.2 January 2013 Erosion Threshold Assessment

Parish conducted Field assessments along the South Tributary of Cardinal Creek in December 2012. (Parish Geomorphic Ltd., January 2013). Erosion thresholds were modelled for reach **R2** using channel and sediment characteristics that are summarized in **Table 3** below. The bankfull geometry observed in **R2** include an average bankfull width of 3.57 m, an average bankfull depth of 0.37 m, and a bankfull gradient of 1%. Sediment distributions produced from Wolman (1954) pebble counts were noted to be bimodal since sediment sizes that were observed included clay as well as pebble to cobble sized materials. The median particle size derived from these distributions was, therefore, theoretical (i.e., it was not observed in the channel), and thus, the results were not used for the erosion threshold assessment. Instead, the clay till substrate observed throughout the watercourse was used to determine the erosion threshold. A Manning's n value of 0.035 was applied in this assessment.

The method applied to estimate the critical discharge is that of Dunn (1959). The equation used to complete the calculations was not provided in the Cardinal Creek Village Erosion Threshold Assessment of South Tributary; the equation below is from the provided source and is assumed to be the method that was applied (Parish Geomorphic Ltd., January 2013). Dunn (1959) and others developed relations through which critical shear stress could be estimated using the proportion of fine sediments. It is mathematically represented as:

$$\tau_c = 0.1 + 0.1179SC + 0.0028SC^2 - 2.34E^{-5}SC^3 \qquad \text{[Eq. 1]}$$

where τ_c is the critical shear stress and SC is the proportion of silt and clay.

The proportion of substrate that was silt-clay-sized within **R2** was estimated at 80%. The critical shear stress resulting from this estimate is 20.3 N/m^3. This critical shear stress was then used to calculate the critical discharge, which was estimated to be 0.43 m^3/s. The equation used to calculate this value was not provided in the earlier 2013 report (Parish Geomorphic Ltd., January 2013). The later 2013 Erosion Threshold Assessment of Cardinal Creek Main Branch report outlines that the shear stresses estimated using sediment characteristics and methods outlined in Chow (1959) were used as an input in an entrainment equation to calculate the critical shear stress (Fischenich, 2001; Parish Geomorphic Ltd., May 2013). Dunn (1959) also used critical shear stress in the excess shear stress equation to estimate erosion rates, expressed as a critical discharge. The excess shear stress equation is mathematically represented as:

$$\varepsilon T = k_d\,(\tau_b - \tau_c)^m \quad \text{[Eq. 2]}$$

where εT is the erosion rate in m^3/s, k_d is an erodibility coefficient in m^3/Ns, τ_b is hydraulic boundary shear stress, τ_c is critical shear stress, and m is an empirical exponent.

4.1.3 May 2013 Erosion Threshold Assessment

Parish conducted field assessments along the main branch of Cardinal Creek in April 2013. Erosion thresholds were modelled for reach **C11-B**; observed channel and sediment characteristics are summarized in **Table 3** below. The bankfull geometry results for reach **C11-B** include an average bankfull width of 7.20 m, an average bankfull depth of 0.75 m, and a bankfull gradient of 0.36%. Sediment distributions produced from Wolman (1954) pebble counts produced a D_{50} of 29.5 mm and a D_{84} of 73 mm. The particle sizes derived from these distributions were not used in the erosion threshold assessment. Instead, the clay till substrate observed throughout the watercourse was used in determining the erosion threshold. A Manning's n value of 0.034 was applied in this assessment.

Two methods were applied to estimate critical discharges, which were then compared to determine the limiting discharge. Based on the clay till substrate that was observed exposed along the bed throughout the reach, both Chow (1959) and Dunn (1959), which account for the cohesive nature of that material, were used to estimate critical shear stresses. For Chow (1959), a shear stress of 15.3 N/m^2 was estimated based on a voids ratio of 0.4, which was lowered to 12.25 N/m^2 due to the sinuous channel planform. This value was used as input in an entrainment equation from Fischenich (2001) to derive the critical discharge estimate of 1.5 m^3/s. For Dunn (1959), a shear stress of 21.1 N/m^2 was estimated based on a silt-clay percentage of 85%. This value resulted in a critical discharge estimate of 3.9 m^3/s. Comparing these two estimates, the lower estimate of 1.5 m^3/s was chosen as the limiting critical discharge.

Table 3: Comparison of erosion threshold analysis results

Channel Parameter	Geomorphic Solutions (2007)		Parish Geomorphic Ltd. (2013)	
	C4	C10	C11-B	R2
Bankfull Conditions				
Average bankfull width (m)	7.6	7.47	7.2	3.57
Average bankfull depth (m)	0.65	0.69	0.75	0.37
Channel gradient (%)	0.09	0.27	0.36	1
D_{50} (mm)	< 2.0	3	29.5	Not provided
D_{84} (mm)	< 2.0	70	73	Not provided
Manning's n roughness coefficient	0.033	0.035	0.034	0.035
Average bankfull discharge (m^3/s)	4.89	7.3	8.55	2.21
Average bankfull velocity (m/s)	0.57	1.4	1.33	1.34
Channel Bed Erosion Threshold				
Method	Critical velocity for clay till substrate	Critical shear stress for D_{50}	Critical shear stress for clay till substrate (Chow, 1959)	Critical shear stress for clay till substrate (Dunn, 1959)
Bed material	Alluvial silt, clay till	Clay to cobble	Clay till	Clay till

Channel Parameter	Geomorphic Solutions (2007)		Parish Geomorphic Ltd. (2013)	
	C4	C10	C11-B	R2
Critical depth (m)	0.4	0.13	0.72	0.17
Critical velocity (m/s)	0.49	0.3	0.8	0.82
Critical shear stress (N/m^2)	4.7	2.19	12.25	20.3
Critical discharge (m^3/s)	1.01	0.05	1.5	0.43
Critical Parameters Compared to Bankfull Conditions				
Critical depth as a % of bankfull	61.54	18.84	96.00	45.95
Critical velocity as a % of bankfull	85.96	21.43	60.15	61.19
Critical discharge as a % of bankfull	20.65	0.68	17.54	19.46

4.2 Methodology

Erosion thresholds were modelled from detailed field observations of reach **R3** within the South Tributary. This reach was selected for the assessment, as it was determined to be the most erosion-sensitive reach within the potential zone of impact downstream of the proposed SWM outlet. It is understood that the current concept plan proposes to include a SWM Pond, denoted as Pond 2 within the concept plan, along the northern perimeter of the South Tributary valley corridor. The proposed outlet would discharge into the downstream portion of **R2**. Erosion thresholds were also modelled from detailed field observations of reach **C10** within the main channel of Cardinal Creek, which is downstream of the confluence with the South Tributary.

Threshold targets are determined using different methods that are dependent on channel and sediment characteristics. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied. For cohesive materials, a method such as that described by Komar (1987) or empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1994) could be applied.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry in the form of a critical discharge. Theoretically, above this discharge, entrainment and transport of sediment can occur. To determine this discharge, the velocity, U, or Shear Stress, t is calculated at various depths for a representative cross-section until the average velocity or shear stress slightly exceeds the critical threshold of the bed material. The velocity is determined using Manning's approach, where Manning's n value is visually estimated through a method described by Acrement and Schneider (1989) or calculated using the Limerino (1970) approach. A Manning's n value of 0.05 was used for the assessment. The velocity is mathematically represented as:

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

where d is the water depth, S is the channel slope, and n is Manning's roughness.

The shear stress is determined using the depth-slope product, which can be applied to the bed of open channels containing fluid undergoing steady flows. The shear stress is mathematically represented as:

$$t = d\rho g S_{bed} \qquad \text{[Eq. 4]}$$

Where t is shear stress, d is the water depth, ρ is water density, g is the acceleration due to gravity, and S_{bed} is the channel bed slope.

Because only 75% of bed shear stress and velocities apply to channel banks in uniform cross sections (Chow, 1959), the erosion threshold is scaled appropriately for these materials.

4.3 Results

Reach R3

The bed material within reach **R3** was comprised of thick, loose clay that originated as deposits in a backwater area upstream of a beaver dam that has since dewatered. The loose clay comprised the largest proportion of bed sediment and was chosen as the critical parameter with which to model the erosion threshold discharge. A channel gradient of 0.76% derived from the longitudinal profile plotted using the Detailed Assessment data was used to model the erosion threshold. Based on the type of material observed, a critical velocity approach was taken using the criteria of Julien (1994) for the alluvial mud bed material, as this most closely matched the bed sediments observed within the reach. This material is estimated to have a critical velocity of 0.61 m/s, which was used to determine a threshold discharge, the point at which sediment entrainment begins to occur. In this instance, the critical discharge for the bank materials was predicted to be 0.184 m^3/s. A Manning's roughness value of 0.040 was adopted for the critical discharge calculations based on the framework described by Acrement and Schneider (1989). The banks within reach **R3** comprised the same thick, loose clay deposits. The same critical velocity approach applied to the bed material was applied to the bank material. The resulting critical discharge estimate is 0.504 m^3/s.

The results of the erosion threshold assessment are provided in **Table 4** below. The final, modelled erosion threshold is the lesser of the bed and bank materials. For reach **R3** the erosion threshold was determined to be 0.184 m^3/s for the alluvial mud bed materials. A pre-development drainage area of 211.28 ha, provided by JFSA (2024), was used to calculate the unitary erosion threshold of 0.00087 $m^3/s/ha$.

Reach C10

The bed material within reach **C10** was comprised of a wide range of materials from clay to boulder-sized sediments. Sand to boulder-sized sediments overlying the local calciferous bedrock comprised a large proportion of the bed in the downstream half of the reach, which also included areas where exposed calciferous bedrock comprised the channel bed material. The upstream half of the reach included thick loose clay deposits, generally located immediately upstream of the three active beaver dams within that section, as well as areas of exposed glaciomarine clay till and sand to boulder-sized sediments. Sediment samples were taken from the channel bed and banks at one cross-section in the upstream section and one cross-section in the downstream section. Sediment size analysis results are provided in **Appendix H**. The erosion threshold was modelled for the downstream half of the reach, as the upstream half of the reach was considered less erosion sensitive due to the thick alluvial deposits, ongoing beaver activity, and a lower channel gradient of 0.41%.

The coarse sediments comprised the largest proportion of bed sediments within the downstream half of the reach and these materials were chosen as the critical parameter with which to model the erosion threshold discharge for the bed. A channel gradient of 1.01% for the downstream half of the reach was derived from the longitudinal profile plotted using the Detailed Assessment data. Based on the type of material observed, a critical velocity approach was taken using the criteria of Komar (1987) for the D50 of the bed sediments, as determined through Wolman (1954) pebble counts. This material is estimated to have a critical velocity of 1.14 m/s, which was used to determine a threshold discharge, the point at which sediment entrainment begins to occur. In this instance, the critical discharge for the bed materials was predicted to be 2.664 m^3/s. A Manning's roughness value of 0.040 was adopted for the critical discharge calculations based on the framework described by Acrement and Schneider (1989).

The banks within reach **C10** were primarily clayey soils that included coarser materials up to sand and gravel sized sediments. Based on the type of material observed, a critical velocity approach based on the criteria of Julien (1994) was applied to the bank material, which was classified as fine sandy loamy clay, as this most closely matched the soil observed. This material has an estimated range of critical velocities from 0.45-0.91 m/s (Julien, 1994). Based on flow conditions observed during the field assessment, a critical velocity of 0.76 m/s was selected from that range and used to determine a threshold discharge, the point at which sediment entrainment begins to occur. There was no evidence of sediment entrainment or transport during the field assessment, so velocities within the given range that resulted in flows lower than those observed were considered lower than the likely critical threshold. A critical velocity of 0.76 m/s was selected through an iterative process where the velocity input to the model was incrementally increased until the observed flow conditions were exceeded in all cross-sections represented in the model. In this instance, the critical discharge for the bed materials was predicted to be 1.77 m^3/s.

The results of the erosion threshold assessment are provided in **Table 4** below. The final, modelled erosion threshold is the lesser of the bed and bank materials. For reach **C10** the erosion threshold was determined to be 1.77 m^3/s for the alluvial mud bed materials. A pre-development drainage area of 3,279.64 ha, provided by JFSA (2024), was used to calculate the unitary erosion threshold of 0.00055 $m^3/s/ha$.

An erosion threshold of 0.184 m^3/s was determined for reach **R3**. Given the geomorphic characteristics of the site, a conservative approach was adopted for defining the erosion threshold, which is lower than the threshold of 0.43 m^3/s previously defined for reach **R2** upstream through the 2013 Parish Geomorphic assessment, but which is more consistent with the previously defined erosion thresholds for reaches with fine-grained cohesive sediments elsewhere in the Cardinal Creek watershed. An erosion threshold of 1.77 m^3/s was determined for **C10**. This is greater than both previously defined erosion thresholds along this section of the main channel of Cardinal Creek. The previous erosion threshold of 0.05 m^3/s defined for reach **C10** through the Geomorphic Solutions (2007) assessment was based on a critical velocity approach for transient fine-grained bed materials. These materials were also observed during the current field assessment but were not considered the dominant bed material nor the most sensitive characteristic in the reach. The coarse materials and exposed bedrock make the channel bed more resistant to erosion than the channel banks through this reach. The active mode of adjustment observed in **C10** during the current assessment, as well as the 2007 assessment, was widening, indicating that the channel banks are adjusting. Thus, the soils comprised of fine materials along the banks were considered more sensitive to erosion than the bed. The previous erosion threshold of 1.5 m^3/s was defined for reach **C11-B** through the Parish Geomorphic (2013) assessment based on a shear stress approach for the compact sandy-clay bed materials. The active mode of adjustment observed during the 2013 assessment was also widening, indicating that the channel banks in the reaches downstream of Old Montreal Road were likely sensitive to adjustment at that time as well. The continued sensitivity of the channel banks, based on the dominant mode of adjustment identified as widening through all previous and current assessments and an erosion threshold based on channel bank materials, is a conservative approach appropriate for the main channel.

Table 4: Detailed assessment and erosion threshold analysis results

Channel Parameter	Results by Reach	
	R3	C10
Bankfull Conditions		
Average bankfull width (m)	3.62	13.4
Average bankfull depth (m)	0.37	0.68
Channel gradient (%)	0.76	1.01
D_{50} (mm)	<2.0	45
D_{84} (mm)	<2.0	120
Manning's n roughness coefficient	0.040	0.040
Modelled bankfull discharge (m^3/s)	1.75	16.85
Modelled bankfull velocity (m/s)	0.99	2.00
Modelled bankfull shear stress (N/m^2)	29.46	69.34
Pre-development drainage area (ha)	211.28*	3,280
Channel Bed Erosion Threshold		
Bed material	Alluvial mud	D50
Reference	Julien, 1994	Komar, 1987
Critical velocity at the bed (m/s)	0.61	1.14
Critical depth (m)	0.26	0.47
Apparent shear stress acting on the bed (N/m^2)	11.06	28.29
Critical discharge (m^3/s)	0.184	2.66
Channel Banks Erosion Threshold		
Bank material	Alluvial mud	Alluvial loamy clay
Reference	Julien, 1994	Julien, 1994
Critical velocity at the banks (m/s)	0.61	0.76
Critical depth (m)	0.41	0.39
Critical shear stress acting on banks (N/m^2)	13.59	17.86
Critical discharge (m^3/s)	0.504	1.77
Final Erosion Threshold		
Limiting critical discharge (m^3/s)	**0.184**	**1.77**
Unitary erosion threshold* ($m^3/s/ha$)	**0.00087**	**0.00055**

* Provided by JFSA (2024)

5 Pre- to Post-Development Erosion Exceedance Analysis

In support of the proposed Stormwater Management (SWM) plan, an erosion exceedance analysis was completed for the receiving watercourse (CVC, 2015; TRCA, 2012). Our understanding is that runoff from the proposed development will be directed to a SWM Pond that will outlet to the downstream portion of **reach R2,** which is located immediately upstream of reach **R3**. As detailed above, reach **R3** was determined to be the most erosion-sensitive reach downstream of the proposed outlet. The South Tributary then discharges to the main channel of Cardinal Creek at the upstream end of reach **C10**.

An erosion exceedance analysis was completed using the threshold determined for reach **R3**, which was identified as the most erosion-sensitive reach within the receiving watercourse to assess potential changes in downstream erosion processes.

To support the definition of erosion control criteria for the proposed outlet, an erosion threshold assessment was completed for reach **R3** along the South Tributary and for reach **C10** along the mainstem of Cardinal Creek.

Using the results of the erosion threshold assessment and hydrological modelling provided by JFSA (2024) for pre- and post-development conditions, analyses of erosion potential within the receiving watercourse was completed with our in-house Erosion Exceedance Model based on four erosion exceedance indices:

1) Cumulative time of exceedance
2) Number of exceedance events
3) Cumulative effective discharge and volume
4) Cumulative effective work index (i.e. cumulative effective stream power)

These indices have been applied elsewhere in numerous jurisdictions, such as Conservation Halton and Toronto and Region Conservation Authority and have been widely accepted by Ontario Conservation Authorities. They provide an evaluation of the number, duration, and magnitude of exceedance events. We note that the most relevant indicator is the cumulative effective work index, as this value reflects both the duration and magnitude of erosion exceedance events.

Time of exceedance, number of exceedances, and cumulative effective discharge and volume can be calculated from the discharge record and established critical discharge. The cumulative time of exceedance is simply the summed duration of time where discharge exceeds the established erosion threshold, and the number of exceedances is the count of erosion exceedance events throughout the discharge record. The cumulative effective discharge represents the average magnitude of discharge exceeding the erosion threshold during a given erosion event, whereas the cumulative effective volume represents the total discharge volume that exceeds the erosion threshold throughout the modelled discharge record.

For more relevant indicators, namely the cumulative effective work index, hydraulic information is required. Our model applies the discharge to a characteristic cross-section. Using Manning's approach, the discharge at each time step in the continuous hydrological model is converted into a velocity, depth of flow, shear stress, and/or stream power. These parameters are calculated based on field measurements of slope, cross-section, and channel roughness. This provides analysis that is appropriate to the specific site conditions.

Flow data for nodes within reaches **R3** and **C10** were provided by JFSA (2024) in 10-minute increments for a 36-year period from 1967 to 2003 (excluding 2001). The flow nodes are located at the downstream end of the respective reaches in which they are located. A map showing the flow-node locations is provided in **Appendix I** for reference. The hydrological modelling reflects local rainfall data from that period. The hydrological modelling was analyzed to calculate the aforementioned erosion indices. The pre- and post-development hydrographs, overlain with the respective erosion threshold and bankfull discharge, are provided in **Appendix I** for reference.

The simulation used an erosion threshold value of 0.184 m^3/s for reach **R3** and 1.77 m^3/s for reach **C10**. These erosion thresholds were determined through the Erosion Threshold Assessment detailed above (**Table 4**).

5.1 Methods

To calculate erosion indices, both velocity and shear stress were calculated at each time step. Through an iterative process, water depth and velocity were calculated for each discharge passing through a representative cross-section. The cross-section is divided into floodplain and bankfull sections. The cross-section is further broken into panels. Velocity, U, is calculated for each panel using Manning's approach. This is a conservative approach as it allows dissipation of flood energy in the floodplain.

The total discharge, $Q_{T,}$ at each time step is based on the summation of the discharge of all panels, Q_i, such that:

$$Q_{T=} \sum Q_i \qquad \text{[Eq. 5]}$$

Q_i is discharge through a panel (which is set at 10 percent of the cross-section). Q_i is defined as:

$$Q_i = U_i w_i d_i \qquad \text{[Eq. 6]}$$

where, w_i and d_i are the width and the depth for each panel. The discharge for each panel was then summed to give a total discharge. This is more accurate than using average cross-sectional dimensions of a simple trapezoidal channel, as the bed is usually irregular, and a panel approach more accurately represents the true cross-sectional area.

For each event, the discharge is converted into a maximum depth and average velocity. The maximum depth is used to calculate the maximum bed shear stress, $\tau_{o_{\max}}$ based on:

$$\tau_{o_{\max}} = d_{\max} \rho g S_{\text{bed}} \qquad \text{[Eq. 7]}$$

where $d_{\max}$ is the maximum water depth, ρ is water density, g is the acceleration due to gravity, and S_{bed} is the channel bed slope.

Cumulative total work, ϖ_{tot} is defined as:

$$\varpi_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \qquad \text{[Eq. 8]}$$

where, U_{avg} is average velocity (Q_{tot}/A_{tot}, where A_{tot} is wetted area), while cumulative effective work index (ϖ_{eff}) is defined by:

$$\varpi_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \varpi < 0 = 0 \qquad \text{[Eq. 9]}$$

where, τ_{cr} is the critical shear stress.

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \quad \text{for } (Q_T > Q_{\text{threshold}}) \qquad \text{[Eq. 10]}$$

where, $Q_{\text{threshold}}$ is the discharge at the erosion threshold.

The cumulative effective discharge volume (CEV) is defined as:

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \qquad \text{[Eq. 11]}$$

Similarly, the cumulative effective discharge (CED) is defined as:

$$\text{CED} = \text{CEV}/t_{ex} \qquad \text{[Eq. 12]}$$

5.2 Results

Modeling results indicate a post-development decrease in erosion potential for the receiving watercourse. Specifically, results show a 4.58% reduction in post-development Cumulative Effective Work Index (ωeff; CEWI). CEWI is considered the most relevant index with respect to erosion potential, as it reflects both the magnitude and duration of a given erosion event. The cumulative effective discharge volume (CEV) represents the total volume of flow exceeding the erosion threshold. In this instance, the cumulative pre-development CEV for **R3** decreases by 8.20% from 568,078 m^3 to 521,517 m^3. The duration and number of exceedances are expected to increase by 4.65% and 5.49%, respectively. **Table 5** summarizes the results for the key erosion exceedance metrics from the modeling conducted using the hydrological simulation data provided by JFSA (2024).

Table 5: Reach R3 erosion exceedance assessment results

Simulation		CEV (m^3)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
Cumulative (1967-2003)	**(PRE)**	568,078	5,349	624	237
	(POST)	521,517	5,104	653	250
	Change	**-8.20%**	**-4.58%**	**4.65%**	**5.49%**

Hydrograph analysis indicates that under post-development conditions, peak flows are reduced, and recession curves are extended for several days following peak flows. Overall, modeling results showed a 5.8% increase in cumulative discharge for the receiving watercourse, with most of the modelled increase in streamflow occurring at discharges below the erosion threshold. These results indicate that the proposed stormwater management plan for the site effectively mitigates any increases in downstream erosion potential for the South Tributary.

For reference, a year-by-year breakdown of pre- to post-development changes in erosion indices from 1967-2003 is provided in **Appendix H**, and pre- and post-development hydrographs are provided in **Appendix I**.

For the mainstem of Cardinal Creek (**Reach C10**), modeling results indicate an insignificant increase in post-development erosion potential. Specifically, results show a 0.4% increase in post-development CEV and a 1.2% increase in CEWI. Similarly, both the duration and the number of exceedances were not significantly different between pre- and post-development conditions with increases of 2.2% and 0.9%, respectively. **Table 6** summarizes the results for the key erosion exceedance metrics for the subject reach.

Table 6: Reach C10 erosion exceedance assessment results

Simulation		CEV (m^3)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
Cumulative (1967-2003)	**(PRE)**	9,596,301	88,298	1,474	216
	(POST)	9,636,289	89,397	1,506	218
	Change	0.42%	1.24%	2.16%	**0.93%**

Analysis of the pre-to post-development hydrographs for **Reach C10** demonstrates near identical plots for both existing and proposed conditions. These results indicate that the proposed development will not have a detectable impact on erosion rates with the mainstem of Cardinal Creek.

6 Erosion hazard assessment and recommendations

Numerous slumps and gully features were mapped through both field assessment and desktop terrain analysis of the South Tributary, as described in the sections above. The results of the terrain analysis showed that with few exceptions slumps and gully features along the receiving watercourse are relatively stable. For example, along Reach **R2** which borders the subject lands 9 of 11 mapped gully features showed no significant elevation changes which would indicate a recent widening, deepening, or an upslope progression of the gully. The remaining 2 of 11 gullies showed localized elevation decreases consistent with erosion and gully expansion. While further gully expansion into the tableland may occur under existing conditions, under proposed conditions surface runoff from most of the contributing areas to existing gullies will be redirected to the main channel via the stormwater management pond. This will result in significantly oversized gully features relative to their post-development contributing areas. Gully growth predominantly depends on the size of the contributing area conveying runoff to the feature (Burkard and Kostachuk, 1997; Morgan 2005). Furthermore, under existing conditions, the mapped gullies along the South Tributary, particularly those along the north valley wall, are well-vegetated, indicating a degree of relatively long-term stability. Therefore, any potential risk of future gully expansion onto the subject lands is considered negligible and effectively managed by the proposed stormwater management plan.

From a geomorphic perspective, gullies along the South Tributary were observed to contribute some sediments to the channel. Therefore, infilling or flow alterations to the gullies adjacent to the subject site could reduce sediment loading to the channel. However, results from field and desktop assessments indicate that the gullies adjacent to the subject site are unlikely to contribute a significant volume of sediment to the channel. Rather, assessment results indicate that the most significant sediment contributions are from upstream channel banks, valley wall slopes, and from tributaries draining lands to the south. Therefore, any reductions in long-term sediment contributions to the South Tributary due to the development of the subject lands is not anticipated to pose any measurable or significant impact on sediment supply to the South Tributary.

Valley-wall slope failures due to slumping have also been identified as a potential erosion hazard risk along the South Tributary. Numerous slumps were mapped along the receiving water course, upstream and downstream of the proposed SWM Pond outlet location. However, with the exception of the slope failure at **1320 Grand-Chêne Court**, none of the slumps appear to have occurred since 2012. The cause of the aforementioned slope failure was attributed to a combination of top of slope fill placement and ongoing erosion at the toe of the valley slope at this location (Paterson 2023). To address slope stability issues along the receiving watercourse, the Paterson Group conducted a slope stability assessment to determine a geotechnical hazard setback along the north bank of the subject tributary. The assessment included a two-dimensional slope stability analysis of 23 slope cross-sections and was undertaken in accordance with the City of Ottawa's standard guidelines for slope stability assessments. A limit of hazard lands and setbacks were defined for the South Tributary and included both a 6 m erosion access allowance, a stable slope allowance (where required), and a 5 m toe erosion allowance. The toe erosion allowance of 5 m was determined in consultation between the Paterson Group and GEO Morphix and was based on an evaluation of the composition and configuration of the valley wall slopes along the subject watercourse.

Specifically, to address the erosion hazard at **1320 Grand-Chêne Court,** the primary recommended design element is a robust yet fish-friendly erosion protection measure along the slope toe. A bioengineered feature such as a vegetated rock revetment would provide the necessary mass (assuming stones are appropriately sized) and "hardness" for toe stability and improve near-bank cover with woody vegetation. Root wads and other similar structures installed at the embankment toe would also offer similar benefits. Such features should be installed along the full length of slope toe whether or not it is currently in contact with flows. Moreover, the existing channel and flow alignments should be maintained to limit the area of disturbance. Extensive toe protection would address risks to the embankment due to future channel adjustments and changing contact points along the embankment toe.

Aggressive livestaking is proposed along the bank treatments to augment the long-term stability of the banks and to reduce erosion potential, as vegetation establishes. Livestaking will enhance near-bank aquatic habitat by providing shade, thereby helping to regulate water temperature. through shading. This shaded area will also provide refuge for fish. As a result of the design, flow velocity will be reduced during higher flows, and therefore, they can also provide refuge for fish during storms. Furthermore, the shrubs are a source of small organic debris and terrestrial insects and, therefore, provide foraging opportunities to fish and serve as an important food source for many aquatic organisms.

Additional design elements are recommended to address the erosion hazard along the valley slope above the vegetated rock revetment and below the slip. The remediation design would mitigate erosion potential along the slope by capturing and directing runoff to a stable outlet downslope while improving slope stability by incorporating bioengineering and a high density of woody plantings. The design would seek to limit any disturbance to the existing slope and avoid impacts to nearby trees to the maximum extent possible. Machinery access would be limited to the top of the slope, and some manual labor would be required along the lower portion of the slope.

Considering these constraints, installing a series of siltsocks (Filtrexx® SiltsocksTM, or equivalent) along the portion of the slope below the failure location is recommended. The slope below the failure location would be regraded by removal of the previously dumped fill originating from excavations during the development of the properties along Grand-Chêne Court, where feasible, back to original condition to create a level slope which ties into the existing adjacent valley walls. The silt socks will be sized to a specific diameter and staked in place with shade-tolerant live woody plantings, which will be spaced apart at a specified distance along each silt sock. The siltsocks will be filled with Growing MediaTM, or equivalent, to promote vegetation establishment. The siltsocks are to be embedded beneath the surface of the topsoil to help capture and distribute subsurface flow/runoff. Finally, the slope will be topped by a layer of compost spray with a specified thickness with MicroBlend® (or equivalent) and a woodland seed mix.

The proposed restoration activities will help alleviate pressure along the valley wall, control erosion along the slope face, and lower siltation levels in the watercourse through increased stabilization. The combination of slope and bank treatments will also benefit local fish communities.

7 Pre-Development Baseline Monitoring

Erosion monitoring is being undertaken to characterize existing conditions within the South Tributary to establish a baseline for comparison to post-development conditions. Changes in channel geometry captured by seasonally surveying monumented cross-sections are being used to determine the natural variability of geomorphic adjustments within a system. This approach will also document any existing erosion concerns and inform potential stabilization and restoration activities.

Monumented channel cross-sections have be installed and are being monitored annually during both fall and spring (following freshet conditions). Cross-section installations and re-surveying nclude the following tasks:

- Establish and survey monumented cross-sections to assess changes in channel and bankfull geometry over time

- Install and measure erosion pins at each cross-section (one in each bank) to assess erosion/deposition rates over time
- Characterize bank materials and stability at each cross-section
- Complete grain size analysis using the modified Wolman (1954) pebble count or a bed material sample at each monumented cross-section to assess changes in substrate composition over time
- Collect monumented photographs at each cross-section location

It is recommended that erosion monitoring activities be conducted for two years prior to initiation of development within the subject lands. Monitoring is schedule to occur twice a year, once during the spring and once during the fall during each monitoring season. Monitoring sites are dispersed within the reaches of the South Tributary, both upstream and downstream of the proposed development, to capture the variability of existing conditions and geomorphic adjustments within the system to be used as a reference for future monitoring efforts.

8 Summary and Conclusions

GEO Morphix Ltd. was retained by Tamarack Developments to complete a fluvial geomorphic and erosion threshold assessment in support of the proposed development at Cardinal Creek South Village, Ontario. This report summarizes the existing geomorphic conditions of the receiving system and provides recommendations to address the recent slope failure at **1320 Grand-Chêne Court**, an erosion threshold for the most erosion-sensitive channel reach, and recommendations for pre-development baseline monitoring.

The geomorphology of the South Tributary and the recent slope failure were assessed using a combination of desktop and field assessments. Previous studies on the South Tributary were reviewed to provide context for the current assessment. A desktop assessment, which included the analysis of two sets of high-resolution bare-earth digital elevation models, revealed the location of valley wall slumps and valley wall gullies within the study area. With the exception of the slope failure at **1320 Grand-Chene Court,** our assessment indicates that most of these features have developed at a time scale greater than that evaluated here through terrain analysis (i.e., approximately 10 years). The frequency of valley wall contacts with evidence of erosion and lateral migration was found to be higher in reach **R2** and **R3,** relative to **R2A,** which had a wider and more continuous floodplain along the valley. The density of valley wall slumps was also greater in reach **R2** and **R3**, indicating the potential link between channel and valley processes in valley wall slumps. Beaver activity within the South Tributary has historically impacted the geomorphology of the system and continues to impact contemporary geomorphology as well. The field assessment identified and confirmed features such as abandoned beaver dams, degraded watercourse crossings, and slumping along the valley slopes.

Both desktop and field assessments identified and confirmed evidence of a recent slope failure adjacent to **1320 Grand-Chêne Court** and documented channel and slope geomorphology at that location. Ongoing valley slope toe erosion throughout the South Tributary and at the location of the recent slope failure, in particular, was noted. Recommendations were provided to mitigate the impact that toe erosion may have on slope processes adjacent to the subject property.

The results of the detailed geomorphological assessment provided information relevant to the erosion threshold analysis. An erosion threshold, expressed as a critical discharge was determined for both the bed and bank materials within reach **R3** along the South Tributary and reach **C10** along the main channel of Cardinal Creek. Reach **R3** was selected based on field observations indicating the reach was the most susceptible to erosion along the receiving watercourse downstream of the proposed SWM outlet; an erosion threshold of 0.184 m^3/s was determined for this reach. An erosion threshold was determined for both the bank and bed materials within reach **C10,** and the lesser of the two values was chosen as the limiting discharge (i.e., 1.77 m^3/s). This reach was assessed as it is the first reach on the main channel downstream of the confluence with the South Tributary.

Analysis of the pre-to post-development hydrographs for reach **R3** demonstrate decreases in all erosion indicators, suggesting a reduction of erosion potential within the South Tributary under post-development conditions. Analysis of the pre- and post-development hydrographs for reach **C10** demonstrate negligible changes in all erosion indicators, suggesting limited changes in erosion potential within the main channel under post-development conditions. The stormwater management plan is thus not expected to exacerbate erosion within the South Tributary or the main channel of Cardinal Creek.

This assessment was developed and undertaken to provide guidance in the development of an appropriate SWM and erosion mitigation strategy for the proposed development located on the tableland to the north of the South Tributary and adjacent to reaches **R1**, **R1A**, and **R2**. Pre-development monitoring within the South Tributary was also initiated. Future reports will further summarize the results of ongoing baseline monitoring being conducted along the South Tributary.

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

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., CAN-CISEC Director, Principal Geomorphologist	Jan Franssen, Ph.D Senior Watershed Scientist

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Appendix A:
Reach Delineation

GEO MORPHIX™
Study Area and Reach Delineation
Tributary to Cardinal Creek
City of Ottawa
Legend
Reach Break and ID
Detailed Assessment
Watercourse
2 m Contour
Approximate Boundary of 1320 Grand-Chene Court
Approximate Development Area
N
0 100 200
Metres
Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Detailed Assessment: GEO Morphix Ltd., 2023. 2.0 m Contour: MNRF, 2019. Approximate Development Area: DSEL, 2022. Print Date: October 2024. PN23076. Drawn By: J.F., M.O., K.S., G.U.
Cardinal Creek Dr.
Ch. Old Montreal Rd.
Cox Country Rd.
South Tributary
Cardinal Creek
Limit of 2023 Assessment
C11-B
C11-A
C10
C9
R1
R1A
R2
R2A
R3
R4
T1
T2
T3
T4

Appendix B:
Historical Aerial Photographs

Location: Cardinal Creek South Tributary
Year: 1976
Source: GEO Ottawa
Yellow dot indicates tributary crossing at Cox Country Rd.

Location: Cardinal Creek South Tributary
Year: 1991
Source: GEO Ottawa

Location: Cardinal Creek South Tributary
Year: 2002
Source: GEO Ottawa

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Location: Cardinal Creek South Tributary
Year: 2005
Source: GEO Ottawa

Location: Cardinal Creek South Tributary
Year: 2008
Source: GEO Ottawa

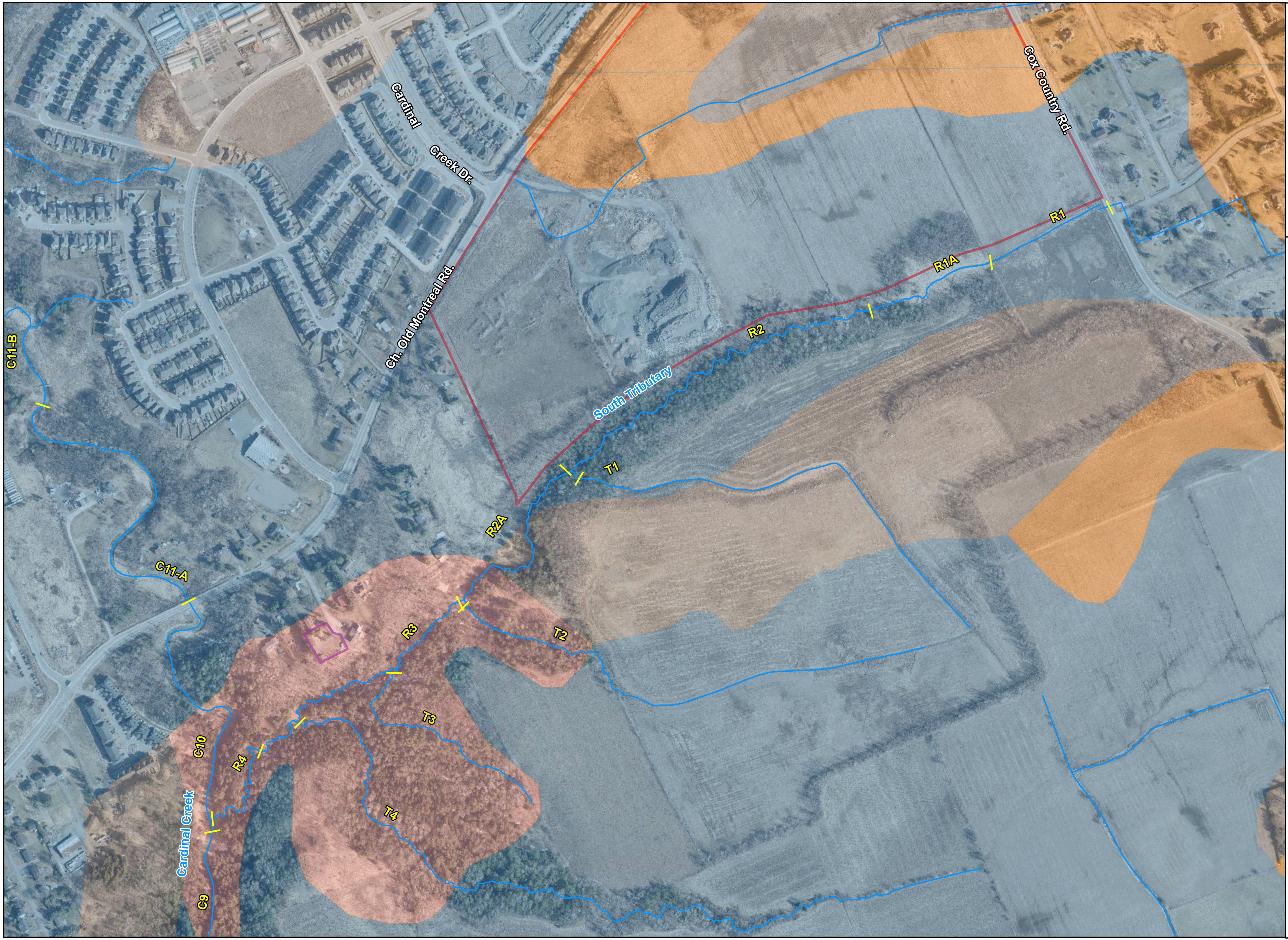
Location: Cardinal Creek South Tributary
Year: 2011
Source: GEO Ottawa

Location: Cardinal Creek South Tributary
Year: 2014
Source: GEO Ottawa

GEO MORPHIX™

Location: Cardinal Creek South Tributary
Year: 2021
Source: GEO Ottawa

Appendix C:
Surficial Geology



GEO MORPHIX™

Surficial Geology

Tributary to Cardinal Creek

City of Ottawa

Legend

- Reach Break and ID
- Watercourse
- Approximate Boundary of 1320 Grand-Chene Court
- Approximate Development Area

Surficial Geology

- 10a,clay, silt
- 18,diamicton
- 3,Paleozoic Bedrock
- 5b,diamicton

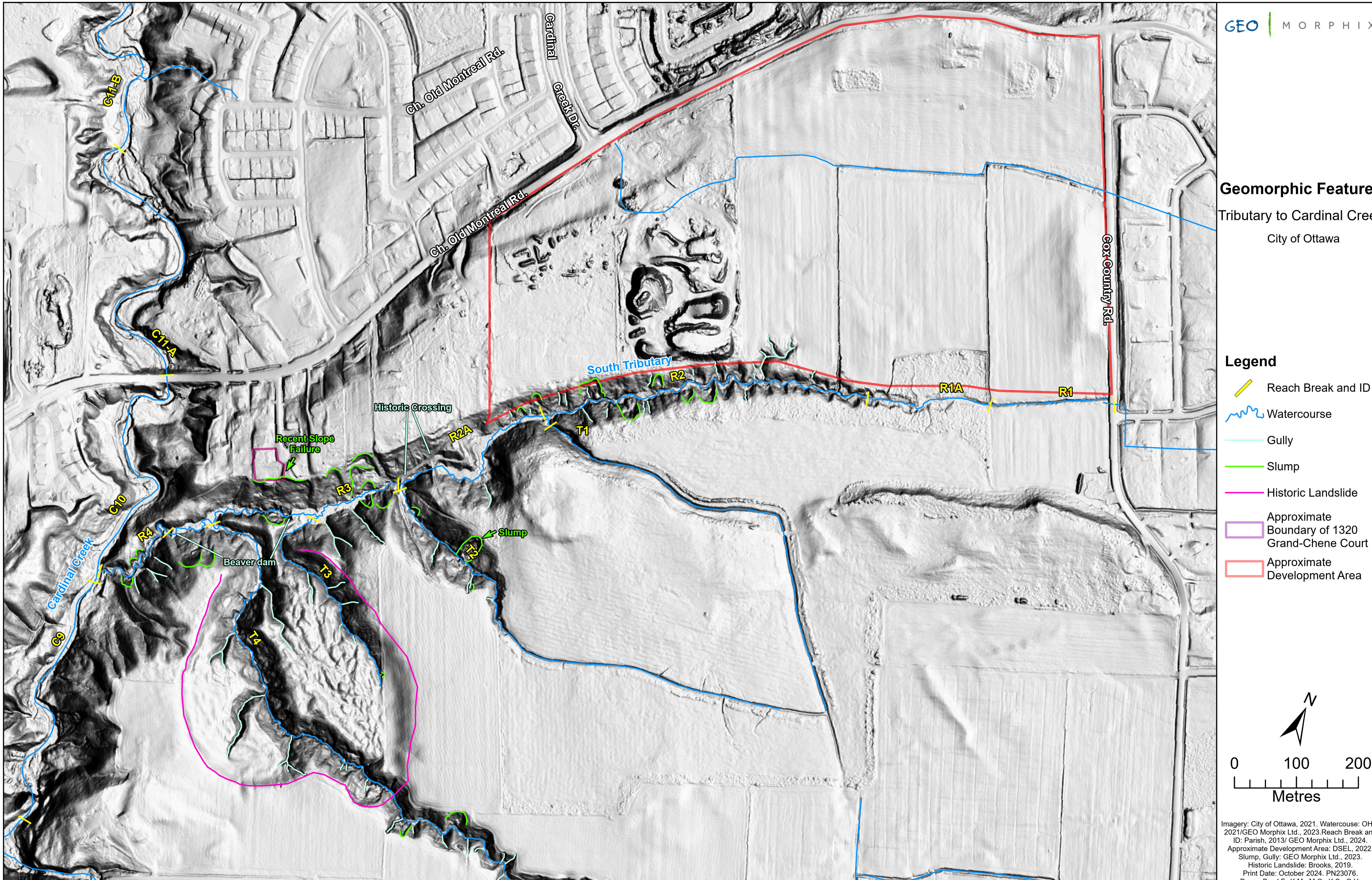
N

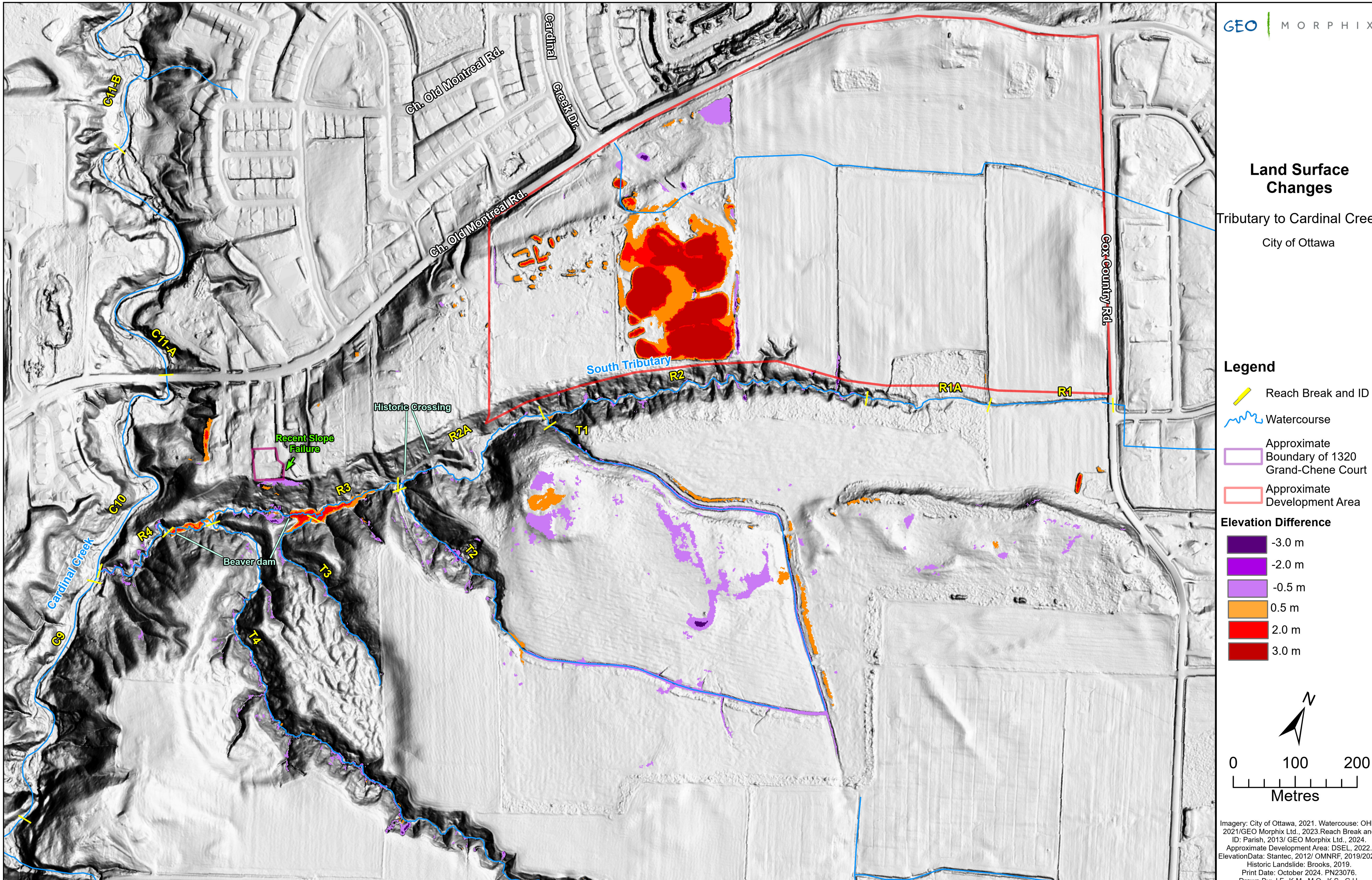
0 100 200

Metres

Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Approximate Development Area: DSEL, 2022. Print Date: January 2024. PN23076. Drawn By: J.F., K.M., M.O., K.S.

Appendix D:
Digital Terrain Analysis


GEO MORPHIX™
Geomorphic Features
Tributary to Cardinal Creek
City of Ottawa
Legend
Reach Break and ID
Watercourse
Gully
Slump
Historic Landslide
Approximate Boundary of 1320 Grand-Chene Court
Approximate Development Area
N
0 100 200
Metres
Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Approximate Development Area: DSEL, 2022. Slump, Gully: GEO Morphix Ltd., 2023. Historic Landslide: Brooks, 2019. Print Date: October 2024. PN23076. Drawn By: J.F., K.M., M.O., K.S., G.U.
Ch. Old Montreal Rd.
Ch. Old Montreal Rd.
Cardinal Creek Dr.
Cox Country Rd.
South Tributary
Cardinal Creek
C11-B
C11-A
C10
C9
R1
R1A
R2
R2A
R3
R4
T1
T2
T3
T4
Historic Crossing
Recent Slope Failure
Slump
Beaver dam


GEO MORPHIX™
Land Surface Changes
Tributary to Cardinal Creek
City of Ottawa
Legend
Reach Break and ID
Watercourse
Approximate Boundary of 1320 Grand-Chene Court
Approximate Development Area
Elevation Difference
-3.0 m
-2.0 m
-0.5 m
0.5 m
2.0 m
3.0 m
N
0
100
200
Metres
Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024.
Approximate Development Area: DSEL, 2022.
ElevationData: Stantec, 2012/ OMNRF, 2019/2020.
Historic Landslide: Brooks, 2019.
Print Date: October 2024. PN23076.
Drawn By: J.F., K.M., M.O., K.S., G.U.
Ch. Old Montreal Rd.
Cardinal Creek Dr.
Cox Country Rd.
South Tributary
Cardinal Creek
Historic Crossing
Recent Slope Failure
Beaver dam
C11-B
C11-A
C10
C9
R1
R1A
R2
R2A
R3
R4
T1
T2
T3
T4

GEO MORPHIX™

DRAFT INTERNAL USE ONLY

Slope Gradient

Tributary to Cardinal Creek

City of Ottawa

Legend

- Reach Break and ID
- Watercourse
- Approximate Boundary of 1320 Grand-Chene Court
- Approximate Development Area

Slope %

- 33 - 55
- 55 - 100
- 100 - 150

N

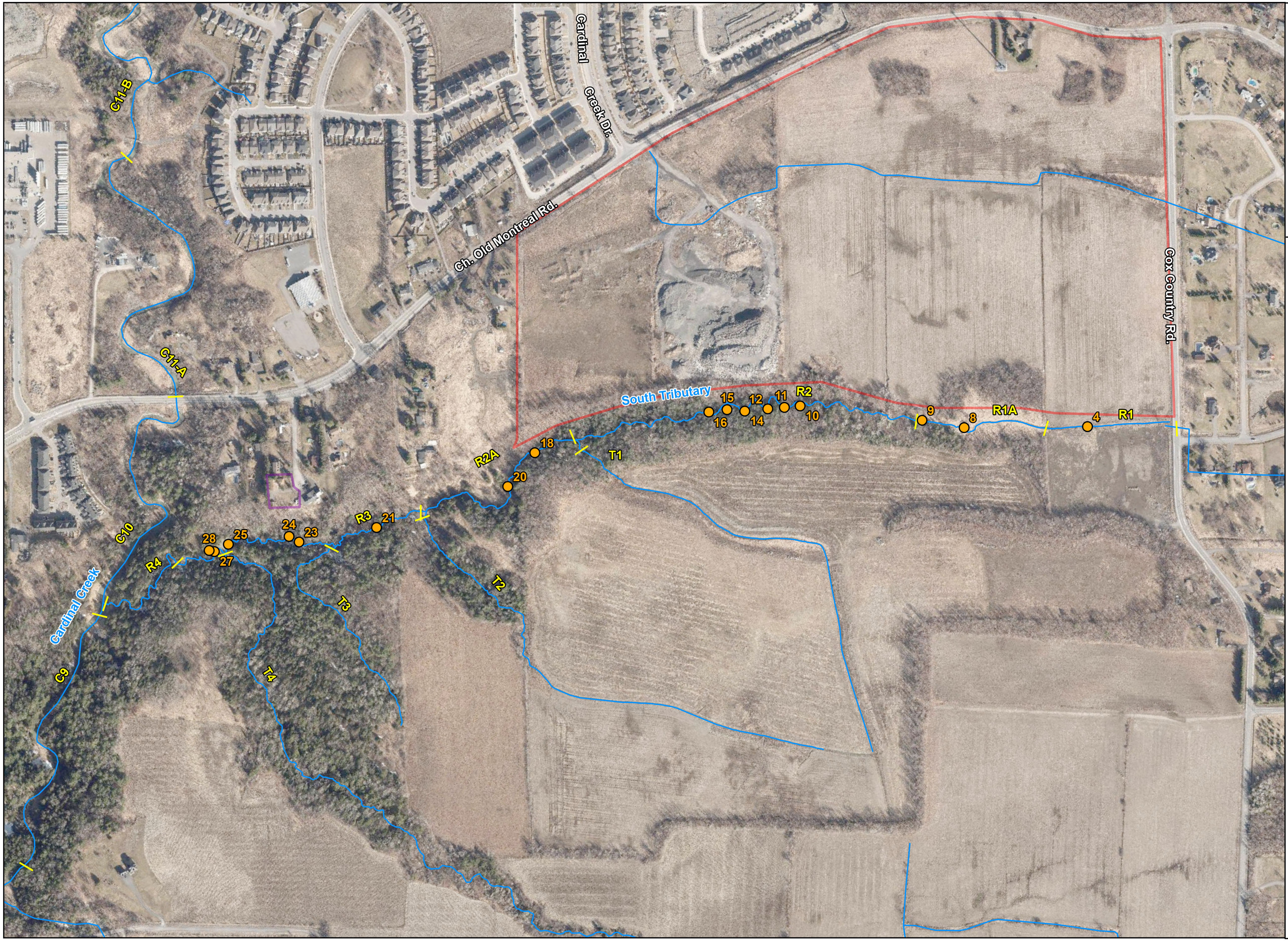
0 100 200

Metres

NOT TO BE DISTRIBUTED

Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Slope Percent: GEO Morphix Ltd., 2023. Elevation Data: MNRF, 2019-2020. Approximate Development Area: DSEL, 2022. Print Date: January 2024. PN23076. Drawn By: J.F., K.M., M.O., K.S.

Appendix E:
Georeferenced Photographic Inventory



GEO MORPHIX™

Photo Locations

Tributary to Cardinal Creek

City of Ottawa

Legend

- Reach Break and ID
- Photo Locations
- Watercourse
- Approximate Boundary of 1320 Grand-Chene Court
- Approximate Development Area

N

0 100 200

Metres

Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Approximate Development Area: DSEL, 2022. Print Date: January 2024. PN23076. Drawn By: J.F., K.M., M.O., K.S.

Appendix F: Photographic Record

Photo 1
Tributary of Cardinal Creek
Reach: R1

Phototgraph taken facing downstream at the most upstream extent of **R1.** The straigtened channel flows through an active agricultural field.

Photo 2
Tributary of Cardinal Creek
Reach: R1

Photograph taken facing downstream along **R1.** The riparian buffer between the fields and the channel was narrow and composed of grasses and herbaceous vegetation. Vegetation encroachment was major.

Photo 3 Tributary of Cardinal Creek Reach: R1	 Photograph taken facing the channel bed at **R1.** The bed and banks were composed of compact silt. Instream vegetation covered approximatly 60-80% of the reach.
Photo 4 Tributary of Cardinal Creek Reach: R1	 Photograph taken facing the left bank at the downstream extent of **R1.** Minor scour was observed along both banks.

Photo 5 **Tributary of Cardinal Creek** **Reach: R1A**	 Photograph taken facing downstream along **R1A.** The channel was poorly defined and flowed through a historic beaver meadow.
Photo 6 **Tributary of Cardinal Creek** **Reach: R1A**	 Photograph taken facing downstream along **R1A.** Along the downstream extent, the channel gains definition. The riparian vegetation was prefominantly grasses and trees along the border of the floodplain.

Photo 7
Tributary of Cardinal Creek
Reach: R1A

Photograph taken facing the channel bed along reach **R1A.** The channel was heavily encroched throughtout the reach. Bed substrates were composed of compact silt.

Photo 8
Tributary of Cardinal Creek
Reach: R1A

Photograph taken at the downstream extent of **R1A.** An old historic beaver dam was indentified on the left bank and was undercut (0.55m).

Photo 9 Tributary of Cardinal Creek Reach: R2	 Photograph taken facing downstream at the upstream extent of reach **R2** (Fall 2023). Valley wall contact was observed throughout the reach.
Photo 10 Tributary of Cardinal Creek Reach: R2	 Photograoh taken facing downstream along reach **R2**. An additional location where valley wall contact was observed. Leaning trees and instream woody debris was commonly observed.

Photo 11 Tributary of Cardinal Creek Reach: R2	 Photograph taken facing upstream along reach **R2.** An additional location where valley wall contact was observed. At several locations, exposed laminated clay-till at the base of the banks were observed (up to 1.5 m)
Photo 12 Tributary of Cardinal Creek Reach: R2	 Photograph taken facing downstream along reach **R2.** Riparian vegetation was composed of mature trees and shrubs, and herbaceous vegetation. An additional valley wall contact located along the centre of the reach.

Photo 13
Tributary of Cardinal Creek
Reach: R2

Photograph taken facing downstream along **R2.** Channel bed substrate ranged from fine silt and clay-till (pebble shaped clay conglomerates were commonly observed) in the runs and pools, and cobble to boulders in the riffles.

Photo 14
Tributary of Cardinal Creek
Reach: R2

Photograph taken facing the left bank along **R2.** Exposed tree roots and undercutting was commonly observed. An additional location with valley wall contact. Note the exposed clay-till at the base of the bank.

Photo 15 Tributary of Cardinal Creek Reach: R2	 Photograph taken facing downstream along reach **R2**, at an additional location where valley wall contact was observed.
Photo 16 Tributary of Cardinal Creek Reach: R2	 Photograph taken facing downstream along reach **R2**, where valley wall contact was observed.

Photo 17 Tributary of Cardinal Creek Reach: R2A	 Photograph taken facing downstream along **R2A**. The channel travels through a historic beaver meadow, which is heavily encroached with grasses.
Photo 18 Tributary of Cardinal Creek Reach: R2A	 Photograph taken facing the left bank along **R2A**. Multiple flow paths (2-3) travelled within the valley walls and through the historic beaver meadow.

Photo 19
Tributary of Cardinal Creek
Reach: R2A

Photograph taken facing downstream along **R2A**. Formation of islands, cut off channels as well as minor undercutting was observed along the reach.

Photo 20
Tributary of Cardinal Creek
Reach: R2A

Photograph taken facing upstream along **R2A**. a knickpoint (0.65m) was observed.

Photo 21 Tributary of Cardinal Creek Reach: R3	
	Photograph taken facing downstream at the upstream extent of **R3** Riparain vegtation was primarily composed of mature trees and herbacious vegetaion. Instream woody debris jams were extreme and frequently observed.
Photo 22 Tributary of Cardinal Creek Reach: R3	
	Photograph taken facing the channel bed along **R3.** Substrate was composed of exposed clay-till and pebble sized clay conglomerates.

Photo 23 Tributary of Cardal Creek Reach: R3	 Photograph taken facing the left bank at the downstream extent of **R3.** A large (3-4 m) beaver dam was observed, with flow travelling interstitially through the dam.
Photo 24 Tributary of Cardinal Creek Reach: R3	 Photograph taken at the downstream extent of **R3** facing the top of a large slump**.** The slump was located on the right bank and carried debris over the channel.

Photo 25 Tributary of Cardinal Creek Reach: R3	
	Photograph taken facing the right bank. Bank materials were composed of thick and loose clay deposits. Undercutting of up to 15 cm was observed along the right bank.
Photo 26 Tributary of Cardinal Creek Reach: R3	
	Photograph taken facing downstream. Fallen trees and woody debris were observed throughout the reach, in particularly high densities near the slope failure.

Photo 27 Tributary of Cardinal Creek Reach: R4	
	Photograph taken facing downstream along **R4** (summer 2023)**.** The upstream portion of the reach exhibited signs of recent de-watering including dry cracked sediments and the channel carving a path through exposed sediments.
Photo 28 Tributary of Cardinal Creek Reach: R4	
	Photograph taken facing downstream along **R4** (fall 2023). A large beaver pond was still observed directly upstream of the beaver dam.

Photo 29 Tributary of Cardinal Creek Reach: R4	
	Photograph taken facing the right bank along **R4**. The large (2-3m) beaver dam was still in tacked and partially breached as flows were traveling through the dam.
Photo 30 Tributary of Cardinal Creek Reach: R4	
	Photograph taken facing the left bank along the upstream extent of **R4**. Valley wall contact was observed. Scour, undercutting and woody debris in the channel were commonly observed. The downstream extent of the reach was backwatered due to a second dam at the confluence with Cardinal Creek.

Photo 31
Tributary of Cardinal Creek
Reach: T1

Photograph taken facing downstream from the upstream extent of **T1.** The channel had a high gradient as it travelled through a ravine. Riparian vegetation was composed of trees.

Photo 32
Tributary of Cardin6l Creek
Reach: T1

Photograph taken facing the right bank along **T1**. Undercutting, exposed roots and woody debris jams were commonly observed.

Photo 33 Tributary of Cardinal Creek Reach: T2	
	Photograph taken facing downstream along **T2.** The channel travelled through a ravine. Channel substrate ranged from exposed clay-till to boulders.
Photo 34 Tributary of Cardinal Creek Reach: T2	
	Photograph taken facing upstream along **T2**. Undercutting, exposed roots and rotational slumps were commonly observed.

Photo 35 Tributary of Cardinal Creek Reach: T3	 Photograph taken facing upstream along **T3**. The channel travels through a ravine feature with frequent tree fall observed. Riparian vegetation was predominantly trees.
Photo 36 Tributary of Cardinal Creek Reach: T3	 Photograph taken facing upstream along **T3.** Multiple forced knickpoints were observed throughout the reach.

Photo 37 **Tributary of Cardl Creek** **Reach: T4**	 Photograph taken facing downstream along **T4**. The channel exhibits a high gradient as it travels towards the confluence with the Cardinal Creek tributary. The riparian vegetation was predominantly tree. Exposed roots and undercutting was commonly observed.
Photo 38 **Tributary of Cardinal Creek** **Reach: T4**	 Photograph taken facing upstream along **T4**. Several forced knickpoints were observed as well as knickpoints in exposed clay-till.

Photo 39 Tributary of Cardinal Creek Reach: C10		
	Photograph taken facing downstream at cross-section 2, downstream of the first beaver dam near the confluence. Reach C10 is a relatively large and deep channel, receiving flow from the South Tributary at its confluence with Reach R4.	
Photo 40 Tributary of Cardinal Creek Reach: C10		
	Photograph taken facing downstream at cross-section 3. Woody debris was observed in moderate densities along both banks throughout the reach.	

Photo 41 **Tributary of Cardinal Creek** **Reach: C10**	 Photograph taken facing upstream at cross-section 5; located upstream of one of three beaver dams observed. Slope stabilization works comprise the right bank around the meander bend for erosion protection.
Photo 42 **Tributary of Cardinal Creek** **Reach: C10**	 Photograph taken facing the left bank near cross-section 6. Bank materials consisted of clayey and sandy soils containing gravel deposits, with exposed local calciferous bedrock.

Photo 43 **Tributary of Cardinal Creek** **Reach: C10**	 Photograph taken facing upstream near cross-section 7. A bedrock knickpoint was observed in the middle section of C10, corresponding with a local change in channel bed gradient.
Photo 44 **Tributary of Cardinal Creek** **Reach: C10**	 Coarse bed sediments were observed throughout the downstream half of C10.

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Photo 45
Tributary of Cardinal Creek
Reach: C10

Photograph taken facing upstream. Riffle-pool sequences characterized the downstream half of C10.

Photo 46
Tributary of Cardinal Creek
Reach: C10

Photograph taken facing upstream at cross-section 10. Slope stabilization works are evident along the left bank, which comprised the embankment of Old Montreal Road.

Appendix G:
Field Observations

GEO MORPHIX™

Reach Characteristics **Project Number:** 230716

Date:	2023-11-28	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	—	**Stream:**	CARDINAL CREEK TRIB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	R1	**UTM (Downstream):**	

Land Use (Table 1)	**Valley Type** (Table 2)	**Channel Type** (Table 3)	**Channel Zone** (Table 4)	**Flow Type** (Table 5)
3	1	6	1	1

☐ Evidence of Groundwater Location: — Photo: —

Riparian Vegetation

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

Aquatic & Instream Vegetation

		Woody Debris	WD Density	WDJ/50m:
Type (Table 8)	1/2	☐ In Cutbank	☒ Low	/
		☐ In Channel	☐ Mod	
Reach Coverage %	80	☒ Not Present	☐ High	

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9)	1	**Sinuosity Degree** (Table 10)	1
Gradient (Table 11)	1	**# of Channels** (Table 12)	1
Entrenchment (Table 13)	1	**Bank Failure** (Table 14)	5
Down's Model (Table 15)	E	**Bankfull Indicators** (Table 18)	1,5
Sed Sorting (Table 20)	WS	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	\	**% of Bed Active**	0
Geomorphic Units (Table 22)	10	**Mass Movement** (Table 23)	N/A
Riffle-Pool Spacing (m):	N/A	**% Riffles:**	N/A
		% Pools:	N/A

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

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

Bankfull Width (m)	2.5	4.0	/
Bankfull Depth (m)	0.40	0.80	/
Undercuts (m)	/	/	/
Pool Depth (m)	ALL RUNS	ALL RUNS	ALL RUNS
Riffle Length (m)	ALL RUNS	ALL RUNS	ALL RUNS

Wetted Width (m)	1.65	3.10	/
Wetted Depth (m)	0.11	0.14	/
Velocity (m/s)	0.175	0.144	/
Velocity Estimate Method	WIFFLE BALL	WIFFLE BALL	/
Meander Amplitude (m)	STRAIGHT	STRAIGHT	STRAIGHT

Notes:

- NO RIFFLE + POOL FEATURES
- STRAIGHT AG. DITCH
- SOFT SILTY BED
- IN STREAM VEG (SUBMERGENT + EMERGENT) DENSE
- MINOR BASAL SCOUR OBSERVED AT THE D/S EXTENT
- RILLS FROM ADJACENT AG. FIELD AND SLUMPING OBSERVED THROUGHOUT
- THIN VEG BUFFER BETWEEN AG FIELD + WATERCOURSE

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	–	**Reach:**	R1
Weather:	SUN+CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREE

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Flow Type

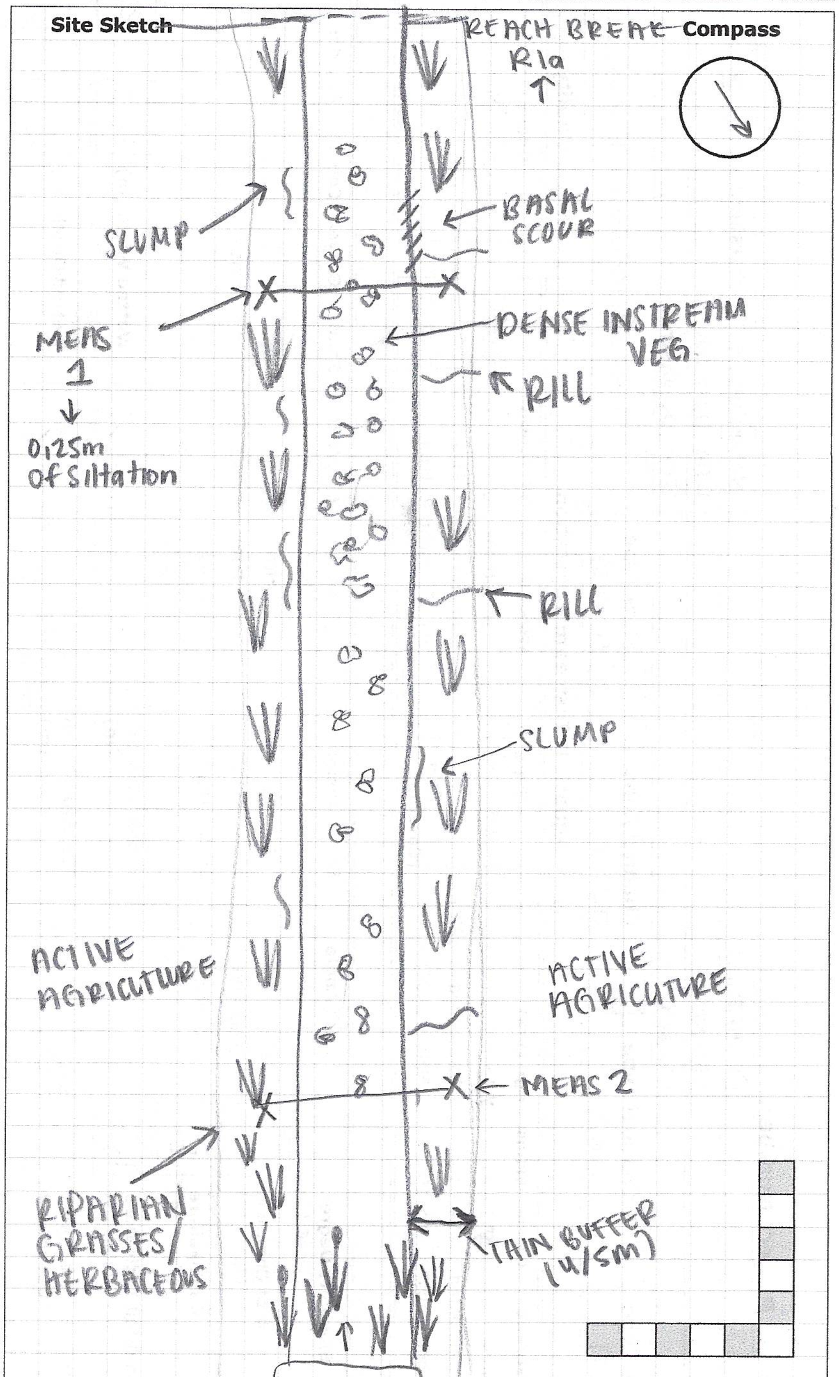
H1	Standing water	H1A	Back water
H2	Scarcely perceptible flow		
H3	Smooth surface flow		
H4	Upwelling		
H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

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:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Rapid Geomorphic Assessment **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	11:15 AM	**Reach:**	R1
Weather:	OVERCAST -7°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Geomorphological Indicator – Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	2/7
	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 =	2	5	0.286
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		↓	
	3	Elevated storm sewer outfall(s)		↓	
	4	Undermined gabion baskets / concrete aprons / etc.		↓	
	5	Scour pools downstream of culverts / storm sewer outlets		↓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knickpoint migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	0/8
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		✓	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	0	8	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	2/7
	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 with meander form		✓	
	7	Bar forms poorly formed / reworked / removed	✓		
		Sum of indices =	2	5	0.286

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.143
In Regime	**In Transition/Stress**	**In Adjustment**
☒ **0.00 - 0.20**	☐ **0.21 - 0.40**	☐ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	11:15 AM	**Reach:**	R1
Weather:	OVERCAST -7'C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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) 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
	• 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	N/A
	• 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	N/A
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 < 0.15m 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) = 2A	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Reach Characteristics — Project Number: 23076

Date:	28-11-23	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:		**Stream:**	SOUTH TRIB CARDINAL CREEK	**UTM (Upstream):**	
Weather:	SUN-CLOUD -2°C	**Reach:**	R1A	**UTM (Downstream):**	

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)	☐ Evidence of Groundwater Location: / Photo: /
1,3	3	12	2	1	

Riparian Vegetation

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

Aquatic & Instream Vegetation

- **Type** (Table 8): 1
- **Reach Coverage %**: 60
- **Woody Debris**: ☐ In Cutbank ☒ In Channel ☐ Not Present
- **WD Density**: ☒ Low ☐ Mod ☐ High
- **WDJ/50m**: \

Water Quality

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

Channel Characteristics

- **Sinuosity Type** (Table 9): 2
- **Sinuosity Degree** (Table 10): 1
- **Gradient** (Table 11): 1
- **# of Channels** (Table 12): 1
- **Entrenchment** (Table 13): 1
- **Bank Failure** (Table 14): 2,5
- **Down's Model** (Table 15): U
- **Bankfull Indicators** (Table 18): 1
- **Sed Sorting** (Table 20): WS
- **Sediment Transport Observed?** ☐ Yes ☐ No ☒ Not Visible — VEG ENCROACH
- **Transport Mode** (Table 21): \
- **% of Bed Active**: 0
- **Geomorphic Units** (Table 22): 4
- **Mass Movement** (Table 23):
- RUNS 100%
- **Riffle-Pool Spacing (m)**: /
- **% Riffles**: /
- **% Pools**: /
- **Bank Angle**: ☒ 0 – 30 ☐ 30 – 60 ☐ 60 – 90 ☐ Undercut
- **Bank Erosion**: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

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

Bankfull Width (m)	10.0	20.0	2.5
Bankfull Depth (m)	1.0	1.0	0.55
Undercuts (m)	0.30	/	/
Pool Depth (m)	/	/	/
Riffle Length (m)	/	/	/

Wetted Width (m)	1.4	0.80	1.80
Wetted Depth (m)	0.27 (0.50)	0.35	0.13
Velocity (m/s)	3.82	2.65	0.88
Velocity Estimate Method			
Meander Amplitude (m)	/	/	/

Notes: CHANNEL FLOWS THROUGH OPEN MEADOW W HERBACEOUS VEG COVER. SOME IRREGULAR MEANDERS. BANKFULL NOT WELL-DEFINED, FLOODPLAIN IS FLAT AND LOW ON EITHER SIDE OF CHANNEL W/IN U/S END OF REACH. U/S END OF REACH BEGINS AT HISTORIC BEAVER DAM THAT HAS BEEN ERODED AND UNDERCUT. ELEVATION DROPS AND CONFINEMENT INCREASES W DISTANCE D/S UNTIL THE WATERCOURSE ENTERS A CONIFEROUS FOREST VALLEY WHERE R2 BEGINS.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics — Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	R1A
Weather:	SUN + CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

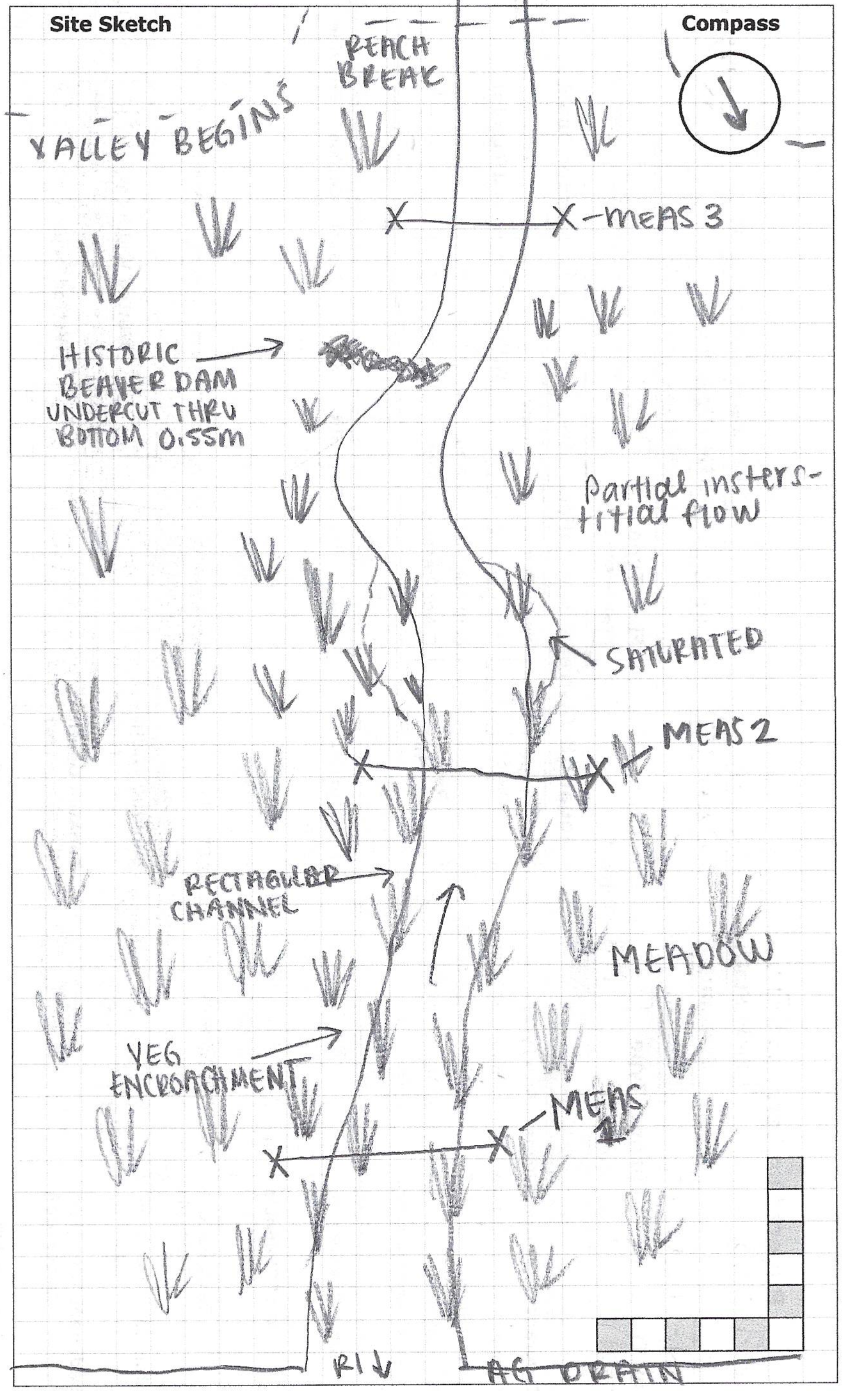
Substrate

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

Site Sketch — **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO
MORPHIX™

Rapid Geomorphic Assessment   Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	11:30 AM	**Reach:**	R1A
Weather:	OVERCAST -5°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	2/7
	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 =	2	5	0.286
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		↓	
	3	Elevated storm sewer outfall(s)		↓	
	4	Undermined gabion baskets / concrete aprons / etc.		↓	
	5	Scour pools downstream of culverts / storm sewer outlets		↓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to knickpoint migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	1/7
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	1	6	0.143
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 with meander form		✓	
	7	Bar forms poorly formed / reworked / removed	✓		
		Sum of indices =	1	6	0.143

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.143
In Regime	**In Transition/Stress**	**In Adjustment**
☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	11:30 AM	**Reach:**	R1A
Weather:	OVERCAST -5°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
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%)	N/A
	• 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	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	

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

Version #2
Last edited: 10/02/2023

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

GEO
MORPHIX™

Reach Characteristics   Project Number: 23076

Date:	2023-11-28	**Field Staff:**	KS + KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	—	**Stream:**	Cardinal Creek Trib	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°	**Reach:**	R2	**UTM (Downstream):**	

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)	
1,3	2	8	2	1	☒ Evidence of Groundwater Location: THROUGHOUT Photo: ______

Riparian Vegetation

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

Aquatic & Instream Vegetation

Type (Table 8)	Reach Coverage %	Woody Debris	WD Density	WDJ/50m:
N/A	0	☒ In Cutbank ☒ In Channel ☐ Not Present	☐ Low ☐ Mod ☒ High	1-2

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9)	2,3	Sinuosity Degree (Table 10)	3
Gradient (Table 11)	2	# of Channels (Table 12)	1
Entrenchment (Table 13)	1-2	Bank Failure (Table 14)	1,2 5,6
Down's Model (Table 15)	M	Bankfull Indicators (Table 18)	1,3 5,7
Sed Sorting (Table 20)	PS	Sediment Transport Observed?	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	—	% of Bed Active	—
Geomorphic Units (Table 22)	5,6 8	Mass Movement (Table 23)	4
Riffle-Pool Spacing (m):	15.0	% Riffles:	30
% Pools:	30	% RUNS	30

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

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

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

Bankfull Width (m)	5.00	10.0	5.00
Bankfull Depth (m)	0.77	0.70	0.75
Undercuts (m)	0.30	0.60	0.26
Pool Depth (m)	0.19	0.21	0.23
Riffle Length (m)	15.0	6.00	10.0

Wetted Width (m)	1.25	1.15	2.60
Wetted Depth (m)	0.08	0.08	0.11
Velocity (m/s)	0.41(1)	.55(1)	0.39(1)
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	8.8	8.7	

Notes:

WAVELENGTH: 8.00m, 12.0m

- MOVED U/S REACH BREAK DOWNSTREAM -MANY BOULDERS/COBBLES IN STREAM BED
- SILTATION IN POOLS - CLAY + SILT + PEBS -VWC FREQUENT - EXPOSED TREE ROOTS (ALL AGES) FREQUENT
- FREQUENT TREE FALLS + LEANING TREES - CLAY TILL EXPOSED ALONG FULL LENGTH OF BED
- CLAY CONGLOMERATES, LOOSE CLAY, GLACIAL TILL (COBBLES - BOULDERS) + COMPACT CLAY TILL COMPRISE BED
- SMALL SCALE MASS MOVEMENT (ROTATIONAL SLIDE) OBSV IN SOME LOCATIONS WHERE CHANNEL IS IN CONTACT W VALLEY WALL

* SEE 12-07-23 FIELD NOTES FOR RGA/RSAT * D/S HALF OF REACH WAS ASSESSED ON

Photos: THAT DATE, OBSERVATIONS ON THIS SHEET PERTAIN TO U/S HALF FROM R1A TO T1 CONFLUENCE

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics **Project Number:** 230760

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	R2
Weather:	SUN + CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features		**Monitoring**	
	Reach break		Long-profile
	Station location		Monumented XS
	Cross-section		Monumented photo
	Flow direction		Monumented photo direction
	Riffle		Sediment sampling
	Pool		Erosion pins
	Sediment bar		Scour chains
	Eroded bank/slope	**Additional Symbols**	
	Undercut bank		
	Bank stabilization		
	Leaning tree		
	Fence		
	Culvert/outfall		
	Swamp/wetland		
	Grasses		
	Tree		
	Instream log/tree		
	Woody debris		
	Beaver dam		
	Vegetated island		

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

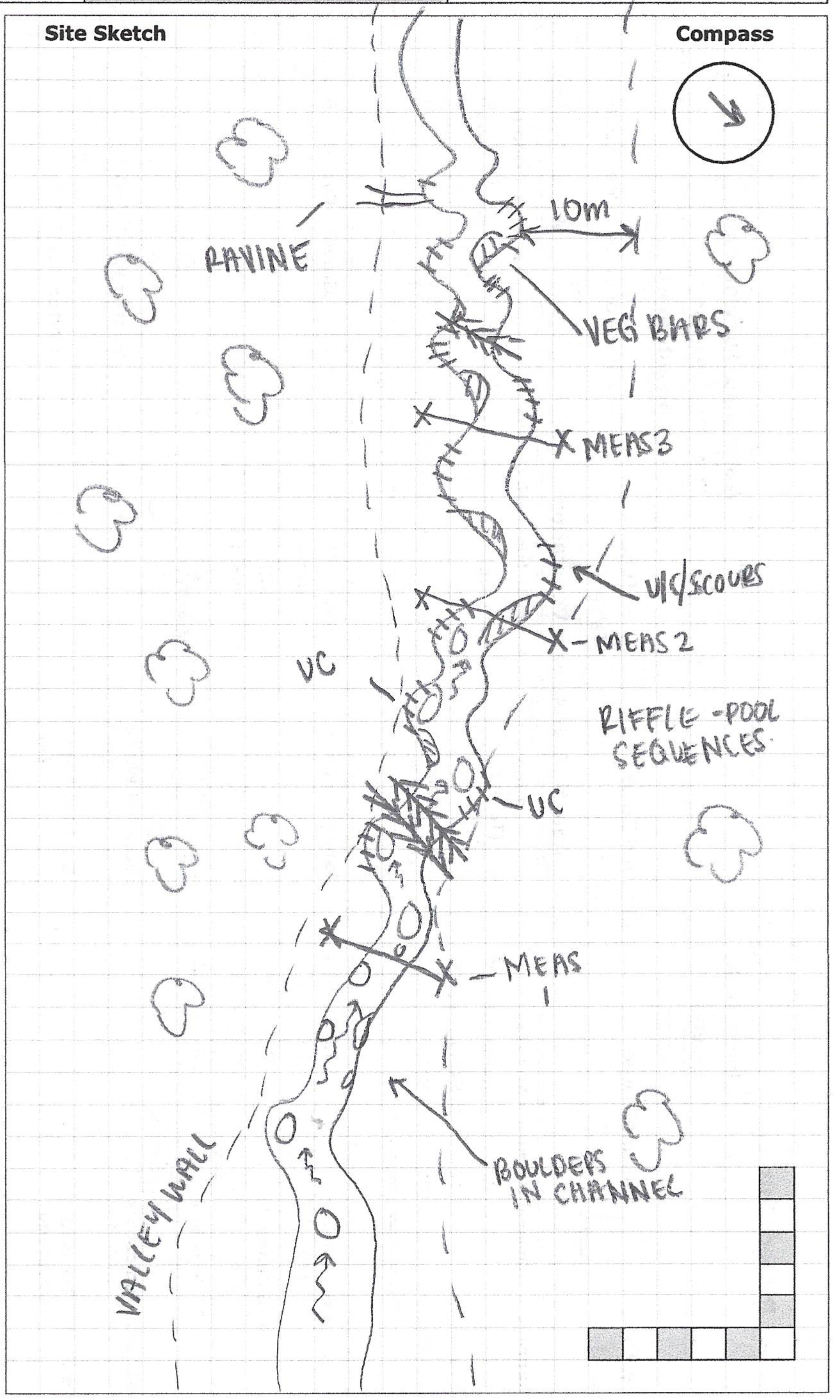
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Reach Characteristics **Project Number:** 23076

Date:	2023-07-12	**Field Staff:**	KM / KS	**Watershed/Subwatershed:**	Cardinal creek
Time:	10:15 AM	**Stream:**	cardinal creek-trib	**UTM (Upstream):**	45.497946, 75.453293
Weather:	Sunny, 27°C	**Reach:**	R2	**UTM (Downstream):**	

Land Use (Table 1)	1	**Valley Type** (Table 2)	2	**Channel Type** (Table 3)	8	**Channel Zone** (Table 4)	3	**Flow Type** (Table 5)	1

☐ Evidence of Groundwater Location:__________ Photo:______

Riparian Vegetation

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

Aquatic & Instream Vegetation

Type (Table 8)	1	**Woody Debris**: ☒ In Cutbank; ☒ In Channel; ☐ Not Present	**WD Density**: ☐ Low; ☒ Mod; ☐ High	WDJ/50m: 2-3
Reach Coverage %	<5			

Water Quality

Odour (Table 16)	**Turbidity** (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9)	5/2	**Sinuosity Degree** (Table 10)	2
Gradient (Table 11)	2	**# of Channels** (Table 12)	1
Entrenchment (Table 13)	1	**Bank Failure** (Table 14)	6/2
Down's Model (Table 15)	d/u	**Bankfull Indicators** (Table 18)	1/5/7
Sed Sorting (Table 20)	4	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	3	**% of Bed Active**	N/A
Geomorphic Units (Table 22)	5/6/8	**Mass Movement** (Table 23)	1
Riffle-Pool Spacing (m):	3-10	**% Riffles:**	30
		% Pools:	60

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

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

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

	XS1	XS2	XS3
Bankfull Width (m)	14.57	5	3
Bankfull Depth (m)	0.56	0.75	0.69
Undercuts (m)	0.43	0.13	NA
Pool Depth (m)	0.18	DS XS1 0.183	NA
Riffle Length (m)	5	NA	2

	XS1	XS2	XS3
Wetted Width (m)	2.17	1.25	0.75
Wetted Depth (m)	0.036	0.183	0.12
Velocity (m/s)	0.19	0.27	0.07
Velocity Estimate Method	WIFFLE BALL	" "	" "
Meander Amplitude (m)	7.8	NA	~10

Notes: MULTIPLE VWC THROUGHOUT, FINELY LAMINATED CLAY EXPOSED AT SLOPE TOE. MULTIPLE SECTIONS W BOULDERS ALONG BED

V_1: D_1 = 1M
T_1 = 5.26s

V_2: D_2 = 1M
T_2 = 3.65s

V_3 D_3 = 1M
T_3 = 13.54s

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 23076

Date:	2023-07-12	**Stream:**	Cardinal Creek Trib
Time:		**Reach:**	R2
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Date:	2023-07-12	PN:	23076	Location:	Orleans

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 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
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 < 0.15m 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) = 22	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23076

Date:	2023-07-12	**Stream:**	Cardinal creek - Trib
Time:		**Reach:**	R2
Weather:	Sunny 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal Creek

Process	No.	Geomorphological Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar	X		0.857
	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 =	6	1	
Evidence of Degradation (DI)	1	Exposed bridge footing(s) N/A			0.400
	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 =	2	3	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		0.857
	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	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0.286
	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 =	2	5	

Notes: See general reach characteristics

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.60
In Regime	**In Transition/Stress**	**In Adjustment**
☐ 0.00 - 0.20	☐ 0.21 - 0.40	☒ 0.41

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 230016

Date:	2023-07-12	**Stream:**	Cardinal creek
Time:	10:15 AM	**Reach:**	R2
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal creek

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

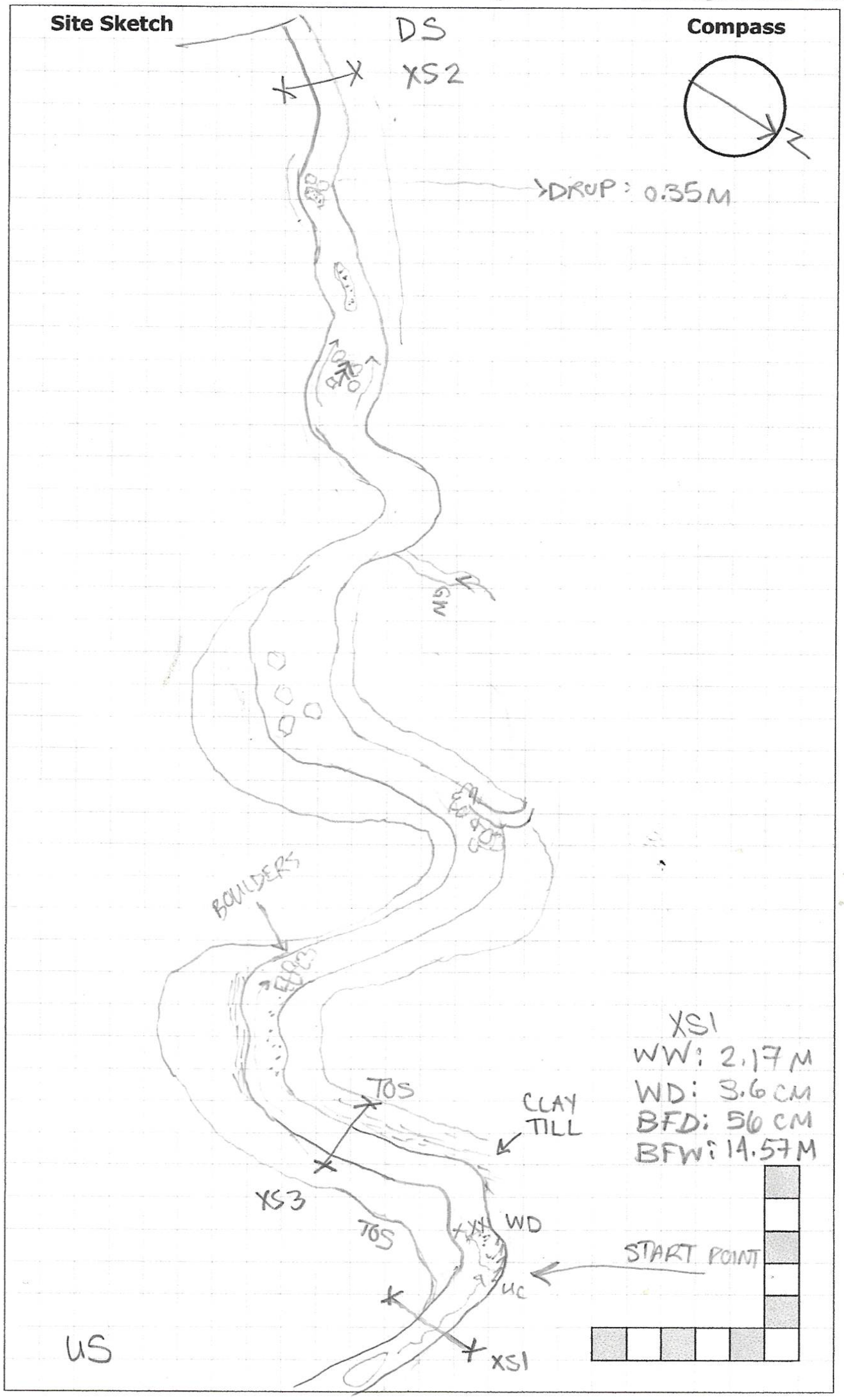
Substrate

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

Site Sketch



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-30	**Stream:**	CARDINAL CREEK TRIB
Time:	-	**Reach:**	R2a
Weather:	CLOUDY -2°C	**Location:**	ORLEANS, ON
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

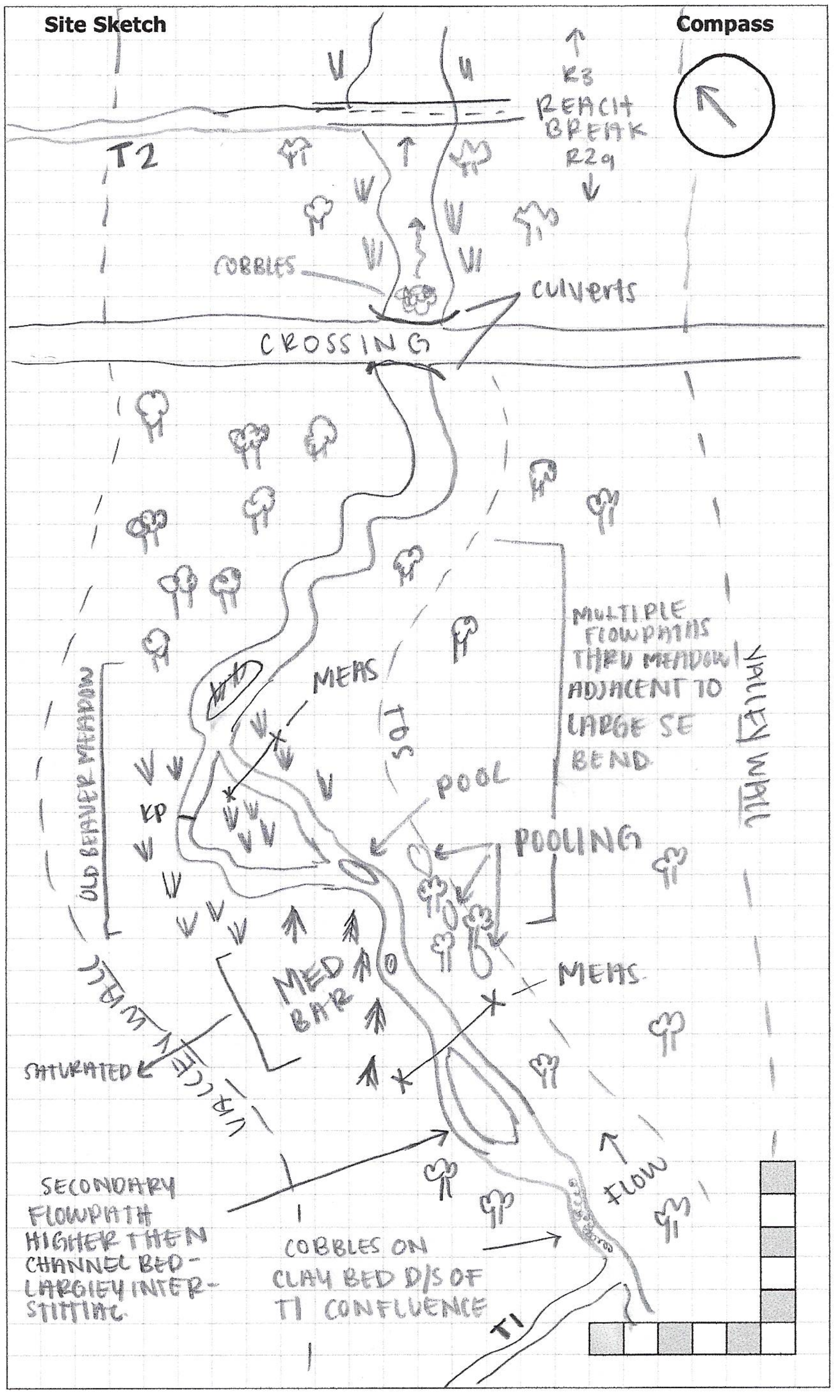
Substrate

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

Site Sketch



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Reach Characteristics **Project Number:** 230?6

Date:	2023-11-30	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	–	**Stream:**	SOUTH CARDINAL TRIB	**UTM (Upstream):**	
Weather:	CLOUDY -2°C	**Reach:**	R2a	**UTM (Downstream):**	

Land Use (Table 1)	1	**Valley Type** (Table 2)	2	**Channel Type** (Table 3)	12	**Channel Zone** (Table 4)	2	**Flow Type** (Table 5)	1

☐ Evidence of Groundwater Location:______ Photo:______

Riparian Vegetation

Dominant Type (Table 6): 3/4

Encroachment (Table 7): 3

Coverage: ☐ None; ☐ Fragmented; ☒ Continuous

Channel Widths: ☐ 1 - 4; ☐ 4 - 10; ☒ > 10

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

Aquatic & Instream Vegetation

Type (Table 8): 1/2

Reach Coverage %: 60-80

Woody Debris: ☒ In Cutbank; ☒ In Channel; ☐ Not Present

WD Density: ☒ Low; ☐ Mod; ☐ High

WDJ/50m: <1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

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

RUNS: 100 **% Pools:** /

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

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

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

Bankfull Width (m)	2.0	3.0	/
Bankfull Depth (m)	0.75	0.45	/
Undercuts (m)	0.15	/	/
Pool Depth (m)	/	/	/
Riffle Length (m)	/	/	/

Wetted Width (m)	0.78	1.30	/
Wetted Depth (m)	0.08	0.08	/
Velocity (m/s)	0.34	0.23	/
Velocity Estimate Method	WB	WB	/
Meander Amplitude (m)	/	/	/

Notes:

→ CHANNEL FLOWS UNDER CROSSING INTO OLD BEAVER MEADOW
→ MULTIPLE FLOW PATHS/INTERSTITIAL FLOW THROUGHOUT REACH
→ FLOW PATHS AT TOE OF VALLEY SLOPE ON BOTH SIDES AND THRU MIDDLE
→ DEBRIS IN CHANNEL NOT COMMON
→ CHANNEL BED COMPACT CLAY+SILT.
→ UNDERCUTTIN OBSERVED
→ LARGE SECTIONS OF SATURATED SOIL IN SPOTS/OLD FLOW PATHS.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment **Project Number:** 230716

Date:	2023-11-30	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	R2a
Weather:	CLOUDY -2°C	**Location:**	ORLEANS, ON
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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	X		
	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 =	2	4	0.333
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 =	2	5	0.286
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 =	4	3	0.571

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.33
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☒ **0.21 - 0.40**	☐ **0.41**

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

Version #3
Last edited: 10/02/2023

GEO MORPHIX™

Rapid Stream Assessment Technique   Project Number: 23076

Date:	2023-11-30	**Stream:**	CARDINAL CREEK TRIB
Time:	~	**Reach:**	R2a
Weather:	CLOUDY -2°C	**Location:**	ORLEANS, ON
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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

Category	Poor	Fair	Good	Excellent
NO RIFFLES 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

Version #2
Last edited: 10/02/2023

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

Date:	2023-11-30	PN:	23076	Location:	ORLEANS, ON

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)
NO RIFFLES	• 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
NO RIFFLES	• 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 < 0.15m 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) =	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

General Site Characteristics **Project Number:** 23076

Date:	2023-07-12	**Stream:**	Cardinal creek
Time:	11:15	**Reach:**	R2A
Weather:	SUNNY, 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal creek

Features	**Monitoring**
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	SUMAC
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

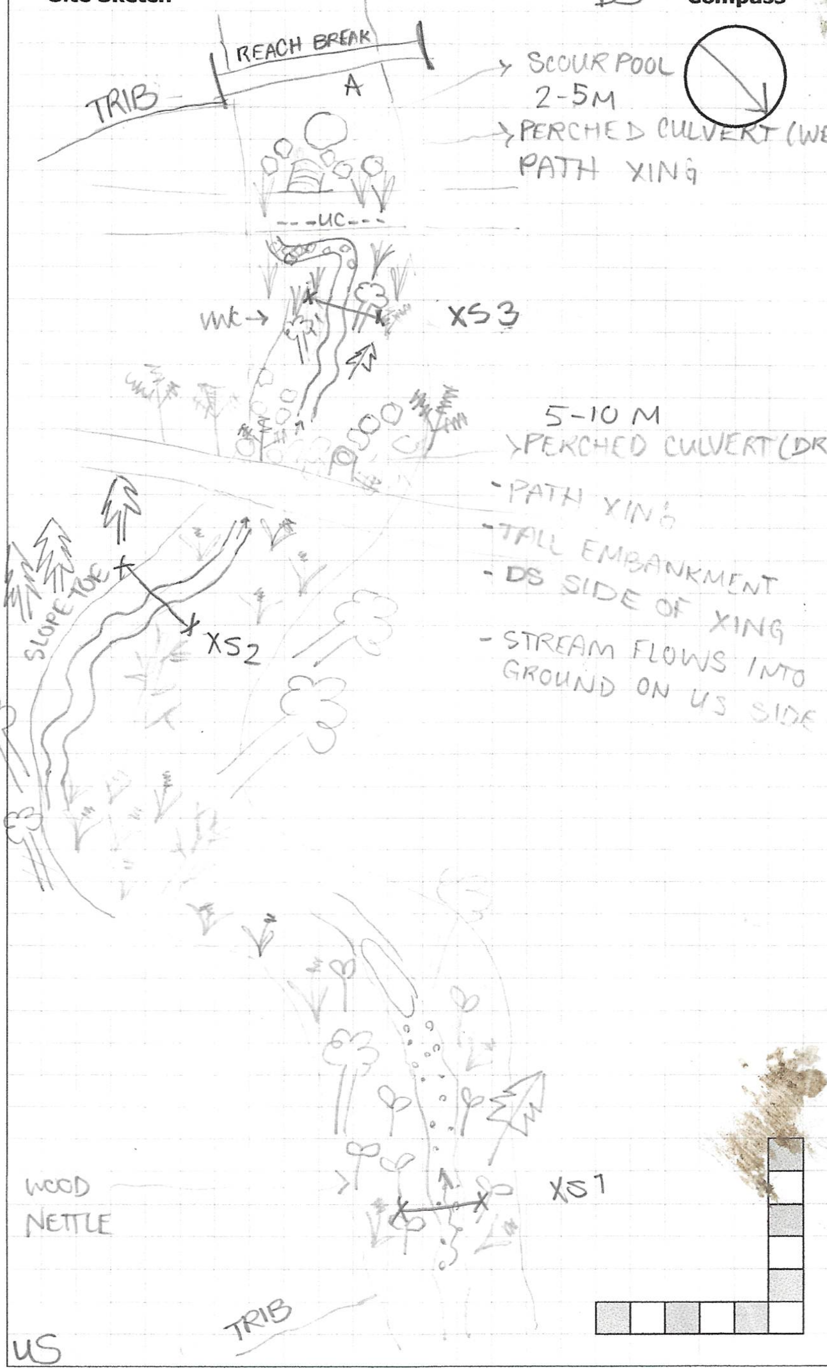
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

PT A WL ELEVATION 63 M

GEO MORPHIX™

Reach Characteristics

Project Number: 23076

Date:	2023-07-12	**Field Staff:**	KM/KS	**Watershed/Subwatershed:**	Cardinal Creek
Time:	11:15 AM	**Stream:**	Cardinal Creek-trib	**UTM (Upstream):**	
Weather:	SUNNY, 28°C	**Reach:**	R2A	**UTM (Downstream):**	

Land Use (Table 1)	Valley Type (Table 2)	Channel Type (Table 3)	Channel Zone (Table 4)	Flow Type (Table 5)
1	2	8	3	1

☐ Evidence of Groundwater Location:_________ Photo:______

Riparian Vegetation

Dominant Type (Table 6)	1/3/4
Encroachment (Table 7)	3

Coverage	Channel Widths	Age (yrs)
☐ None	☐ 1 - 4	☐ Immature (<5)
☐ Fragmented	☒ 4 - 10	☒ Established (5-30)
☒ Continuous	☒ > 10	☒ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8)	1
Reach Coverage %	<5

Woody Debris	WD Density
☐ In Cutbank	☐ Low
☒ In Channel	☒ Mod
☐ Not Present	☐ High

WDJ/50m: 1-2

Water Quality

Odour (Table 16)	Turbidity (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9)	7	Sinuosity Degree (Table 10)	2
Gradient (Table 11)	2	# of Channels (Table 12)	1
Entrenchment (Table 13)	2	Bank Failure (Table 14)	6/2
Down's Model (Table 15)	d/U	Bankfull Indicators (Table 18)	1/5/7
Sed Sorting (Table 20)	4	Sediment Transport Observed?	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	3	% of Bed Active	N/A
Geomorphic Units (Table 22)	5/6/8	Mass Movement (Table 23)	1
Riffle-Pool Spacing (m):	3-10	% Riffles:	25

% Pools: 50

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

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

	XS1	XS2	XS3
Bankfull Width (m)	2	3	2.5
Bankfull Depth (m)	0.50	0.66	0.48
Undercuts (m)	NA	NA	NA
Pool Depth (m)	0.185	0.095	0.29 (DS XS3)
Riffle Length (m)	10	NA	3

	XS1	XS2	XS3
Wetted Width (m)	1.12	0.675	0.44
Wetted Depth (m)	0.04	0.072	0.028
Velocity (m/s)	0.32	0.16	0.05
Velocity Estimate Method	WIFFLE BALL	" "	" "
Meander Amplitude (m)	NA	2	1

Notes: TWO HISTORIC PATH XINGS W/IN R2A, W̄ OUTFLANKED/UNDERMINED CULVERTS, FLOW SEEMS TO TRAVEL INTERSTITIALLY IN XING EMBANKMENT SUBSTRATE (NO POOLING US). VALLEY BOTTOM IS APPROX 10-15M WIDE, FLAT W̄ MEANDERING CHANNEL + GRASSY VEG MARGINS. MULTIPLE VWC THROUGHOUT REACH. SLOPE FAILURE 1 (US) LOCATED W/IN THIS REACH.

V_3 D_3 0.5M V_2 D_2= 1M V_1 D_1=1M

T_3 19.28s T_2 = 6.65s T_1 = 3.05s

Photos:

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

Version #4
Last edited: 04/04/2023

GEO MORPHIX™

Rapid Stream Assessment Technique Project Number: 23076

Date:	2023-07-12	**Stream:**	Cardinal creek - Trib
Time:		**Reach:**	R2A
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM | KS	**Watershed/Subwatershed:**	Cardinal 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): ________ Checked by: ________ Completed by: KM/KS

GEO MORPHIX™

Date:	2023-07-12	PN:	23076	Location:	Orleans

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 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
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 < 0.15m 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) = 23	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 230716

Date:	2023-07-12	**Stream:**	Cardinal creek-trib
Time:		**Reach:**	R2A
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal Creek

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar	X		0.857
	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 =	6	1	
Evidence of Degradation (DI)	1	Exposed bridge footing(s) N/A			0.500
	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	X		
	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 =	3	3	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		0.857
	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	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0.286
	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 =	2	5	0.623

Notes: See General reach characteristics

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

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

Version #3
Last edited: 10/02/2023

GEO MORPHIX™

Reach Characteristics

Project Number: 23076

Date:	2023-07-12	**Field Staff:**	KM/KS	**Watershed/Subwatershed:**	Cardinal creek
Time:	12:00	**Stream:**	Cardinal creek-Trib	**UTM (Upstream):**	
Weather:	SUNNY, 28°C	**Reach:**	R3	**UTM (Downstream):**	

Land Use (Table 1): 1 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 8 | **Channel Zone** (Table 4): 3 | **Flow Type** (Table 5): 1 | ☒ Evidence of Groundwater Location:______ Photo:______

Riparian Vegetation

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

Aquatic & Instream Vegetation

Type (Table 8)	1	**Woody Debris**	**WD Density**	**WDJ/50m:**
		☒ In Cutbank	☐ Low	1-2
Reach Coverage %	<5	☒ In Channel	☒ Mod	
		☐ Not Present	☐ High	

Water Quality

Odour (Table 16)	**Turbidity** (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9)	S/2	**Sinuosity Degree** (Table 10)	2	
Gradient (Table 11)	2	**# of Channels** (Table 12)	1	
Entrenchment (Table 13)	1	**Bank Failure** (Table 14)	6/2	
Down's Model (Table 15)	d/v	**Bankfull Indicators** (Table 18)	1/5/7	
Sed Sorting (Table 20)	4	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible	
Transport Mode (Table 21)	3	**% of Bed Active**	N/A	
Geomorphic Units (Table 22)	5/6/8	**Mass Movement** (Table 23)	1	
Riffle-Pool Spacing (m):	3-10m	**% Riffles:**	25	**% Pools:** 50

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

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

	XS1	XS2	XS3
Bankfull Width (m)	3	5	3.5
Bankfull Depth (m)	0.53	1.3	0.75
Undercuts (m)	NA	0.15	0.06
Pool Depth (m)	0.42 US XS1	0.175	0.26 DS XS3
Riffle Length (m)	3.5 XS1	NA	2

	XS1	XS2	XS3
Wetted Width (m)	0.80	0.87	1
Wetted Depth (m)	0.04	0.175	0.07
Velocity (m/s)	0.465	0.237	0.27
Velocity Estimate Method	WIFFLE BALL	"	"
Meander Amplitude (m)			7

Notes:

V_1 D_1=1M V_2 D_2=1M V_3 D_3=1M
T_1=2.15s T_2=4.22s T_3=3.75s

RECENTLY DRAINED BEAVER POND AT DS EXTENT OF REACH WHERE R3 MEETS T4. VALLEY BOTTOM FLAT APPROX. 20M WIDE W SOFT SATURATED CLAY CREEK CUTTING MEANDERING PATH THROUGH RECENTLY EXPOSED SUBSTRATE SLOPE FAILURE 2 (DS) LOCATED W/IN R3. AROUND SLOPE FAILURE 2 VALLEY IS NARROW + BANK IS IN CONTACT W VW ON RIGHT SIDE. EXTREME TREE FALL ACROSS CHANNEL US + DS AROUND SF2. VALLEY BOTTOM EXTREMELY DIFFICULT TO TRAVERSE. BED IS MAJORITY CLAY W SOME GRAVEL (80/20)

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 230760

Date:	2023-07-12	**Stream:**	Cardinal Creek - Trib
Time:		**Reach:**	R3
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM/KS	**Watershed/Subwatershed:**	Cardinal 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

Version #2
Last edited: 10/02/2023

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

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Date: 2023-	PN: 230716	Location: Cardinal Creek

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 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
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 < 0.15m 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) = 23	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

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Rapid Geomorphic Assessment **Project Number:** 23076

Date:	2023-07-12	**Stream:**	Caraunal creek-trib
Time:		**Reach:**	R3
Weather:	Sunny 28°C	**Location:**	Orleans
Field Staff:	KM / KS	**Watershed/Subwatershed:**	Caraunal creek

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar	X		0.857
	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 =	6	1	
Evidence of Degradation (DI)	1	Exposed bridge footing(s) N/A			0.400
	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 =	2	3	
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		0.857
	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	
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0.286
	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 =	2	5	

Notes: See General reach characteristics

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.60
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☒ **0.41**

Version #3
Last edited: 10/02/2023

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

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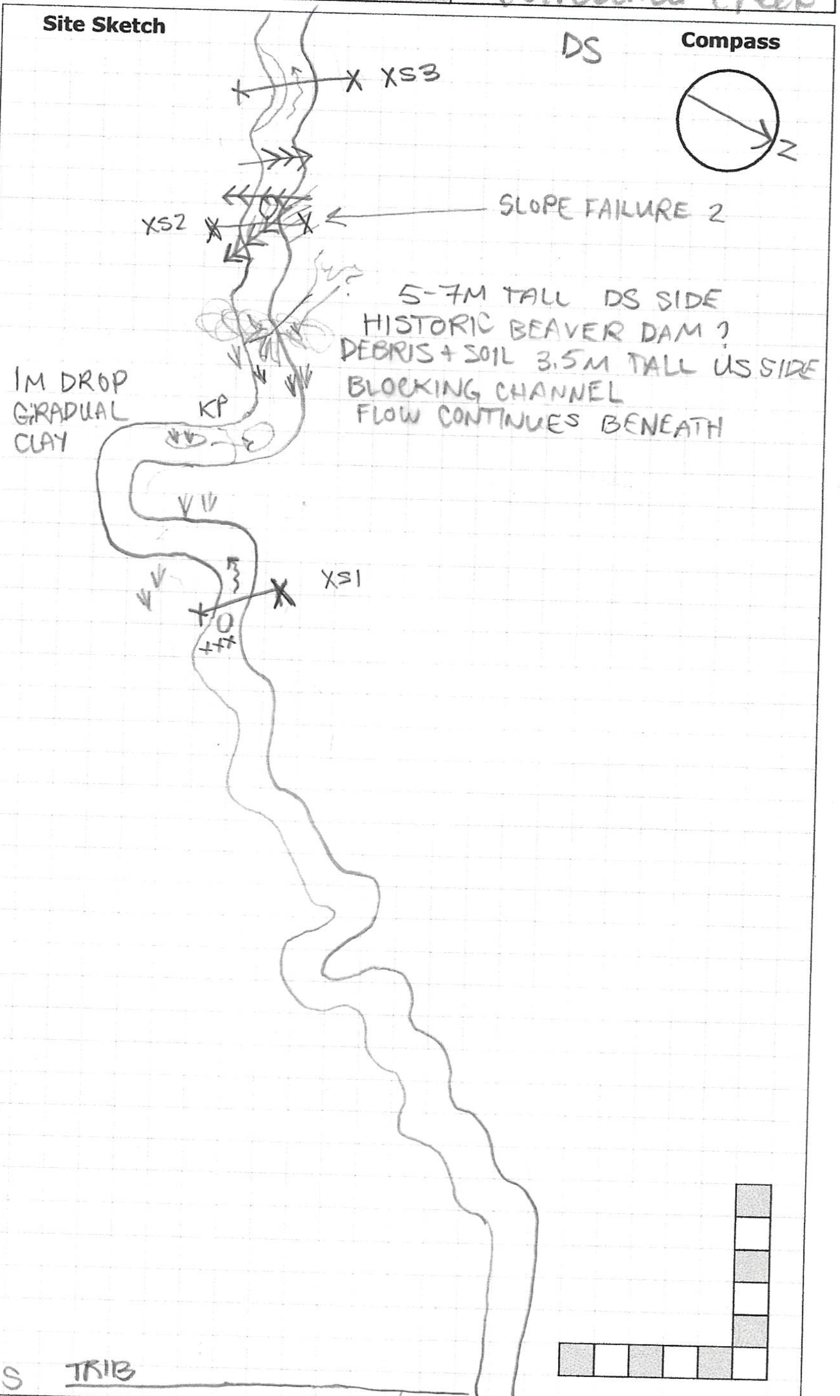
General Site Characteristics

Project Number: 23096

Date:	2023-07-12	**Stream:**	Cardinal Creek
Time:	12:00	**Reach:**	R3
Weather:	Sunny, 28°C	**Location:**	Orleans
Field Staff:	KM/FS	**Watershed/Subwatershed:**	Cardinal Creek

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

Site Sketch



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:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

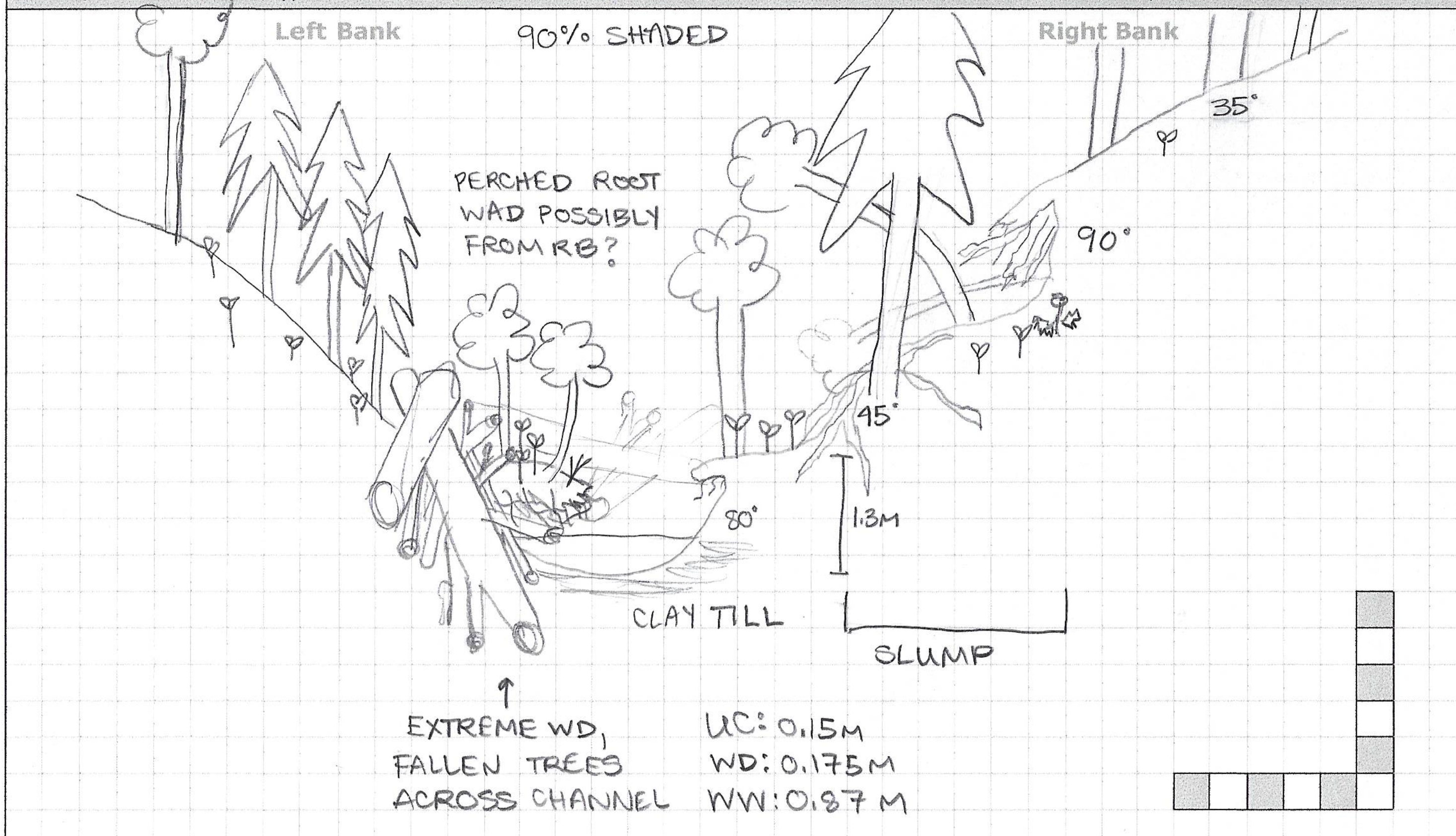
Meander Bend Erosion Risk Modeling Data Collection

Project Number: 23076

Date:	12-07-23	**Field Staff:**	KS KM	**Bend ID:**	—
Time:	12:30 PM	**Stream:**	TRIB # CARDINAL CREEK	**Subwatershed:**	CARDINAL CREEK
Weather:	SUNNY, HUMID, 25°C	**Reach:**	R3	**Watershed:**	OTTAWA RIVER

RB or LB? (Outside bank)	Bankfull Width (m)	Bankfull Height (m)	Bank Height (m)	Root Depth (m)	Root Density (%)	Surface Protection (%)	Bank Angle (°)	Bank Material (Table 19)		
RB	5	1.3	1.3	0.25	30	20	(SEE SKETCH) 35-90	☒ Till ☒ Clay ☒ Silt	☐ Sand ☐ Gravel ☐ Small Cobble	☐ Large Cobble ☐ Small Boulder ☐ Large Boulder ☐ Bedrock

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Geomorphic Unit (Table 22)

☐ Riffle ☐ Run ☒ Pool ☐ None

Type of Bank Failure (Table 14)

- ☐ Fluvial entrainment
- ☐ Fall/slough
- ☐ Undercutting
- ☐ Parallel slide
- ☐ Slab failure
- ☒ Rotation slip and slump

Adjacent Infrastructure

- ☐ Utilities
- ☐ Parking lot
- ☒ Building
- ☐ Pathway
- ☐ Road
- ☐ Bridge footing
- ☐ Other: ____________

Distance from TOB (m): ________

Notes: HOUSE ON TABLE LAND ADJACENT TO RB VALLEY WALL
NO ALLUVIAL STRATA OBS.
BED CLAY TILL
BANK BASE CLAY TILL
MANY EXPOSED ROOTS, FALLEN + LEANING TREES

Photos: W/IN SLUMP

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Reach Characteristics **Project Number:** 23076

Date:	2023-11-28	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	–	**Stream:**	CARDINAL CREEK TRIB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	R4	**UTM (Downstream):**	

Land Use (Table 1): 1	**Valley Type** (Table 2): 2	**Channel Type** (Table 3): 8	**Channel Zone** (Table 4): 2	**Flow Type** (Table 5): 1

☐ Evidence of Groundwater Location:__________ Photo:______

Riparian Vegetation

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

Aquatic & Instream Vegetation

Type (Table 8): 2	**Woody Debris**	**WD Density**	WDJ/50m: 1
	☒ In Cutbank	☒ Low	
	☒ In Channel	☐ Mod	
Reach Coverage %: <5	☐ Not Present	☐ High	

Water Quality

Odour (Table 16)	**Turbidity** (Table 17)
1	2

Channel Characteristics

Sinuosity Type (Table 9): 2	**Sinuosity Degree** (Table 10): 3	**Bank Angle**	**Bank Erosion**
		☐ 0 – 30	☐ < 5%
Gradient (Table 11): 3	**# of Channels** (Table 12): 1	☒ 30 – 60	☐ 5 – 30%
		☒ 60 – 90	☐ 30 – 60%
Entrenchment (Table 13): 1	**Bank Failure** (Table 14): 1/2	☒ Undercut	☒ 60 – 100%

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

Down's Model (Table 15)	E	**Bankfull Indicators** (Table 18)	1/3/5	**Bankfull Width (m)**	1.70	3.00	/	**Wetted Width (m)**	1.40 / 1.75 / /
Sed Sorting (Table 20)	PS	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible	**Bankfull Depth (m)**	0.50	0.75	/	**Wetted Depth (m)**	0.08 / 0.10 / /
Transport Mode (Table 21)	3	**% of Bed Active**	0	**Undercuts (m)**	0.10	0.24	/	**Velocity (m/s)**	0.29 / 0.78 / /
Geomorphic Units (Table 22)	5/6/8	**Mass Movement** (Table 23)	1/3 RUNS%: 30	**Pool Depth (m)**	0.24	FROZEN	FROZEN	**Velocity Estimate Method**	WIFFLE BALL / WIFFLE BALL / /
Riffle-Pool Spacing (m):	10	**% Riffles:**	30 % Pools: 30	**Riffle Length (m)**	3	/	/	**Meander Amplitude (m)**	7 / 5 / 10

Notes:
- 2nd HALF OF CHANNEL BACKWATERED DUE TO BEAVER DAM @ DS EXTENT OF REACH
- LARGE (1m tall) DAM AT THE CENTER OF THE REACH CAUSING A LARGE (FROZEN) POOL U/S.
- EVIDENCE OF DEWATERING FROM EXPOSED/SILTY/BARE BANKS AT U/S EXTENT
- RIFFLE POOL SEQUENCES OBSERVED (where not Frozen) D/S OF BEAVER DAM.
- VWC THROUGHOUT REACH
- EVIDENCE OF RECENT BEAVER ACTION OBSERVED
- FINE SILT STUCK TO TREE TRUNKS AT U/S EXTENT SUGGEST SEDIMENTS WERE 1m DEEP BEFORE

Photos: DEWATERING

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	–	**Reach:**	R4
Weather:	SUN + CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS + KM	**Watershed/Subwatershed:**	CARDINAL 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
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H3	Smooth surface flow		
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H5	Rippled		
H6	Unbroken standing wave		
H7	Broken standing wave		
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

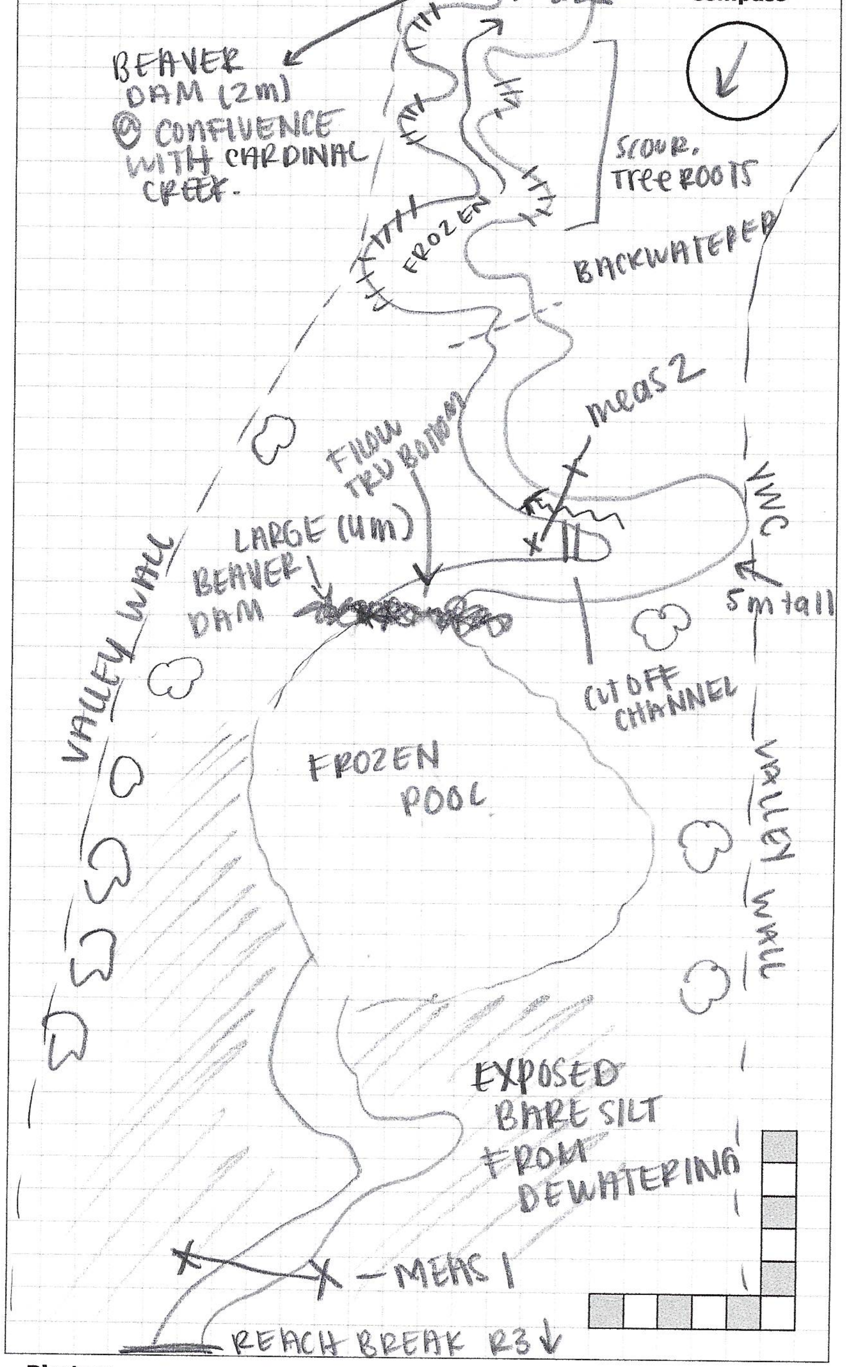
Substrate

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

Site Sketch



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Rapid Geomorphic Assessment **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	3:30 PM	**Reach:**	R4
Weather:	CLOUDY -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Geomorphological Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		\	4/7
	2	Coarse materials in riffles embedded		\	
	3	Siltation in pools	\		
	4	Medial bars	\		
	5	Accretion on point bars	\		
	6	Poor longitudinal sorting of bed materials	\		
	7	Deposition in the overbank zone		\	
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	3/5
	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 knickpoint 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 =	3	2	0.6
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	\		5/7
	2	Occurrence of large organic debris	\		
	3	Exposed tree roots	\		
	4	Basal scour on inside meander bends	\		
	5	Basal scour on both sides of channel through riffle		\	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach	\		
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		\	
	10	Exposed building foundation		N/A	
		Sum of indices =	5	2	0.71
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	4/7
	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 with meander form	\		
	7	Bar forms poorly formed / reworked / removed	\		
		Sum of indices =	4	3	0.57

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.613
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☒ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:		**Reach:**	R4
Weather:	OVERCAST -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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 COBBLE	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
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 < 0.15m 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	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	

Total overall score (0-42) = 26	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

Senior staff sign-off (if required): ________ Checked by: ICM Completed by: KS

GEO MORPHIX™

Reach Characteristics **Project Number:** 23076

Date:	2023-11-28	**Field Staff:**	KS + KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	–	**Stream:**	CARDINAL CREEK TRIB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	T1	**UTM (Downstream):**	

Land Use (Table 1): 3/1 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 7 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater Location:______ Photo:______

Riparian Vegetation

Dominant Type (Table 6): 1/2

Encroachment (Table 7): 1

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel Widths: ☐ 1 - 4 ☒ 4 - 10 ☒ > 10

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

Aquatic & Instream Vegetation

Type (Table 8): 5

Reach Coverage %: <5

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

WD Density: ☐ Low ☐ Mod ☒ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 2 | **Sinuosity Degree** (Table 10): 2

Gradient (Table 11): 3 | **# of Channels** (Table 12): 1

Entrenchment (Table 13): 3 | RAVINE **Bank Failure** (Table 14): 1,2, 5,6

Down's Model (Table 15): E,C | **Bankfull Indicators** (Table 18): 1/3/6

Sed Sorting (Table 20): MS | **Sediment Transport Observed?** ☐ Yes ☒ No ☐ Not Visible

Transport Mode (Table 21): 3 | **% of Bed Active**: 0

Geomorphic Units (Table 22): 6/8 | **Mass Movement** (Table 23): 4 | /

Riffle-Pool Spacing (m): / | **% Riffles:** / | **% Pools:** /

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

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

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

Bankfull Width (m)	POORLY DEFINED	POORLY DEFINED	POORLY DEFINED
Bankfull Depth (m)	" "	" "	" "
Undercuts (m)	0.40	0.23	0.32
Pool Depth (m)	/	/	/
Riffle Length (m)	/	/	/

Wetted Width (m)	1.5	1.75	/
Wetted Depth (m)	0.04	0.06	/
Velocity (m/s)	/	/	/
Velocity Estimate Method	/	/	/
Meander Amplitude (m)	/	/	/

Notes:
- RAVINE FLOWED FROM AG FIELD HIGH GRADIENT
- DEBRIS IN CHANNEL COMMON - HIGH CONCENTRATION DEBRIS BEFORE CONFLUENCE WITH MAIN TRIB
- MANY COBBLES + BOULDERS THROUGHOUT
- KNICKPOINTS FORCED BY DEBRIS/ROOTS OBSERVED THROUGHOUT - FORCED CHANGES IN FLOW DIRECTION
- SCOUR ON BOTH BANKS
- U/C AND EXSPOSED ROOTS/LEANING TREES COMMON

☆ REACH WAS A RAVINE FEATURE ☆

Photos:

Version #4
Last edited: 04/04/2023

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

GEO
MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	T1
Weather:	SUN + CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

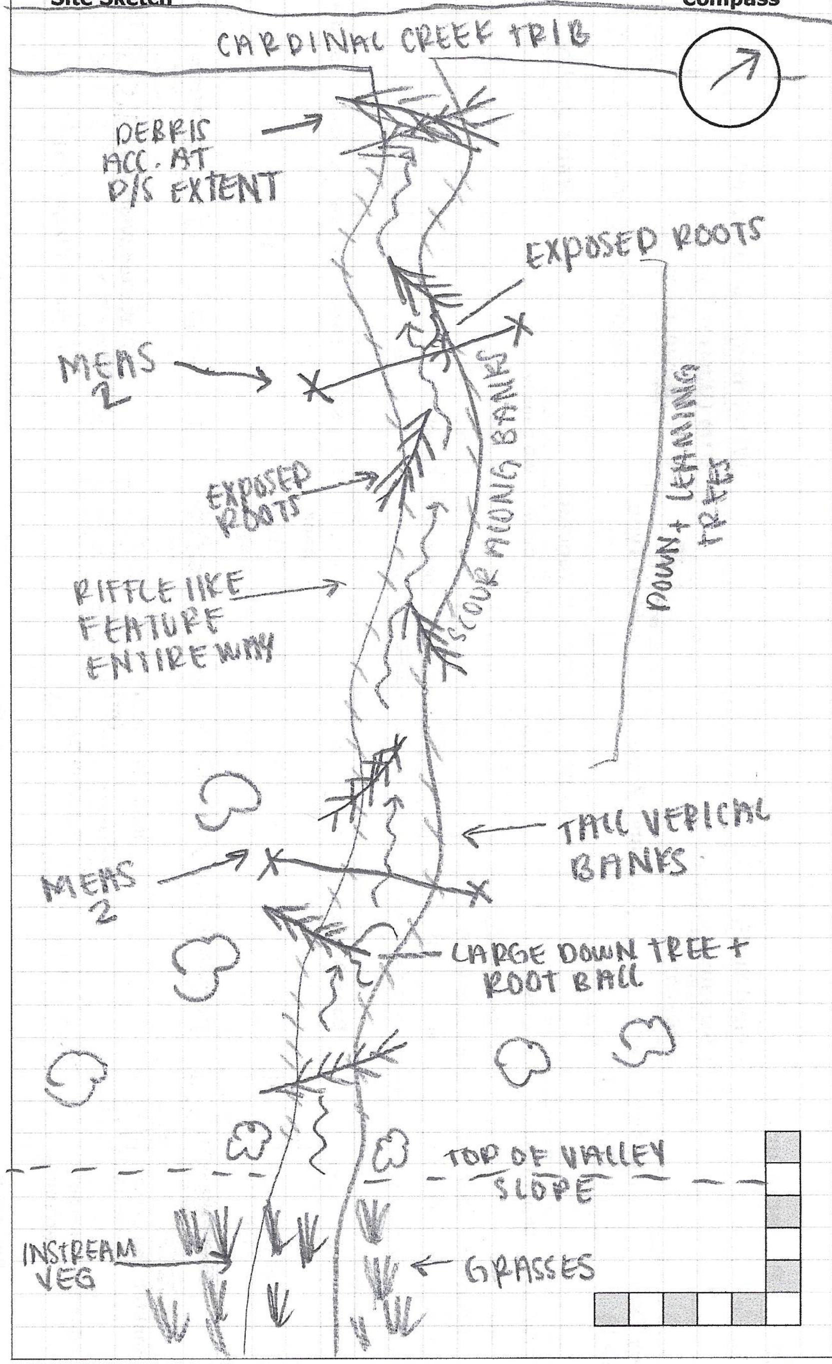
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Rapid Geomorphic Assessment Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	12:55 PM	**Reach:**	TRIB 1
Weather:	OVERCAST -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Geomorphological Indicator – Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		\	2/7
	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 =	2	5	0.286
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	2/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		N/A	
	6	Cut face on bar forms		\	
	7	Head cutting due to knickpoint 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	3	0.40
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	\		4/7
	2	Occurrence of large organic debris	\		
	3	Exposed tree roots	\		
	4	Basal scour on inside meander bends		\	
	5	Basal scour on both sides of channel through riffle		\	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach	\		
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		\	
	10	Exposed building foundation		N/A	
		Sum of indices =	4	3	0.57
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	2/7
	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 with meander form	\		
	7	Bar forms poorly formed / reworked / removed	\		
		Sum of indices =	2	5	0.286

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.386
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☒ **0.21 - 0.40**	☐ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique   Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	12:55 PM	**Reach:**	TRIB 1
Weather:	OVERCAST -5 °C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
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 < 0.15m 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	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	

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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Reach Characteristics **Project Number:** 23076

Date:	2023-11-28	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	–	**Stream:**	CARDINAL CREEK TRB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	T2	**UTM (Downstream):**	

Land Use (Table 1)	**Valley Type** (Table 2)	**Channel Type** (Table 3)	**Channel Zone** (Table 4)	**Flow Type** (Table 5)
1/3	2	13	2	1

☐ Evidence of Groundwater Location:__________ Photo:______

Riparian Vegetation

Dominant Type (Table 6): 1/2

Encroachment (Table 7): 1

Coverage	**Channel Widths**	**Age (yrs)**
☐ None	☐ 1 - 4	☐ Immature (<5)
☐ Fragmented	☒ 4 - 10	☒ Established (5-30)
☒ Continuous	☒ > 10	☒ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 5

Reach Coverage %: >5

Woody Debris	**WD Density**
☒ In Cutbank	☐ Low
☒ In Channel	☐ Mod
☐ Not Present	☒ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9)	2	**Sinuosity Degree** (Table 10)	3
Gradient (Table 11)	3	**# of Channels** (Table 12)	1
Entrenchment (Table 13)	3	**Bank Failure** (Table 14) RAVINE	2
Down's Model (Table 15)	E/e	**Bankfull Indicators** (Table 18)	1/3/5
Sed Sorting (Table 20)	VP	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	3	**% of Bed Active**	0
Geomorphic Units (Table 22)	5/6	**Mass Movement** (Table 23)	1/4
Riffle-Pool Spacing (m):	/	**% Riffles:**	100

% Pools: /

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

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

Bankfull Width (m)	1.08	1.63	POORLY DEFINED
Bankfull Depth (m)	0.53	0.55	POORLY DEFINED
Undercuts (m)	0.90	0.85	0.15
Pool Depth (m)	0.15	0.90	/
Riffle Length (m) ENTIRE REACH	/	/	/

Wetted Width (m)	0.48	0.93	1.20
Wetted Depth (m)	0.025	0.08	0.90
Velocity (m/s)	/	/	/
Velocity Estimate Method	/	/	/
Meander Amplitude (m)	2.00	/	/

Notes:

- RAVINE FROM AG FIELD DOWN TO MAIN TRIBUTARY
- LARGE ACCUMULATION OF DEBRIS IN CHANNLE, LEANING TREES/ EXPOSED ROOTS/ UNDERCUTTING COMONLY OBSERVED
- CHANNEL BED COMPOSED OF CLAY SUBPAVEMENT + COBBLES + BOULDERS
- MANY FORCED KNICK POINTS FROM ROOTS/ DEBRIS
- OBSERVED RECENT REGRESSIONAL SLMP ACROSS FROM HISTORIC SLUMP → EVIDENCE OF MINOR ONES ASWELL
- RILLS FROM FIELD ENTERING THE RAVINE OBSERVED
- MANY CUT FACES

Photos:

Version #4
Last edited: 04/04/2023

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GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	T2
Weather:	SUN + CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS + KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction	Monumented photo direction
Riffle	Sediment sampling
Pool	Erosion pins
Sediment bar	Scour chains
Eroded bank/slope	**Additional Symbols**
Undercut bank	
Bank stabilization	
Leaning tree	
Fence	
Culvert/outfall	
Swamp/wetland	
Grasses	
Tree	
Instream log/tree	
Woody debris	
Beaver dam	
Vegetated island	

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

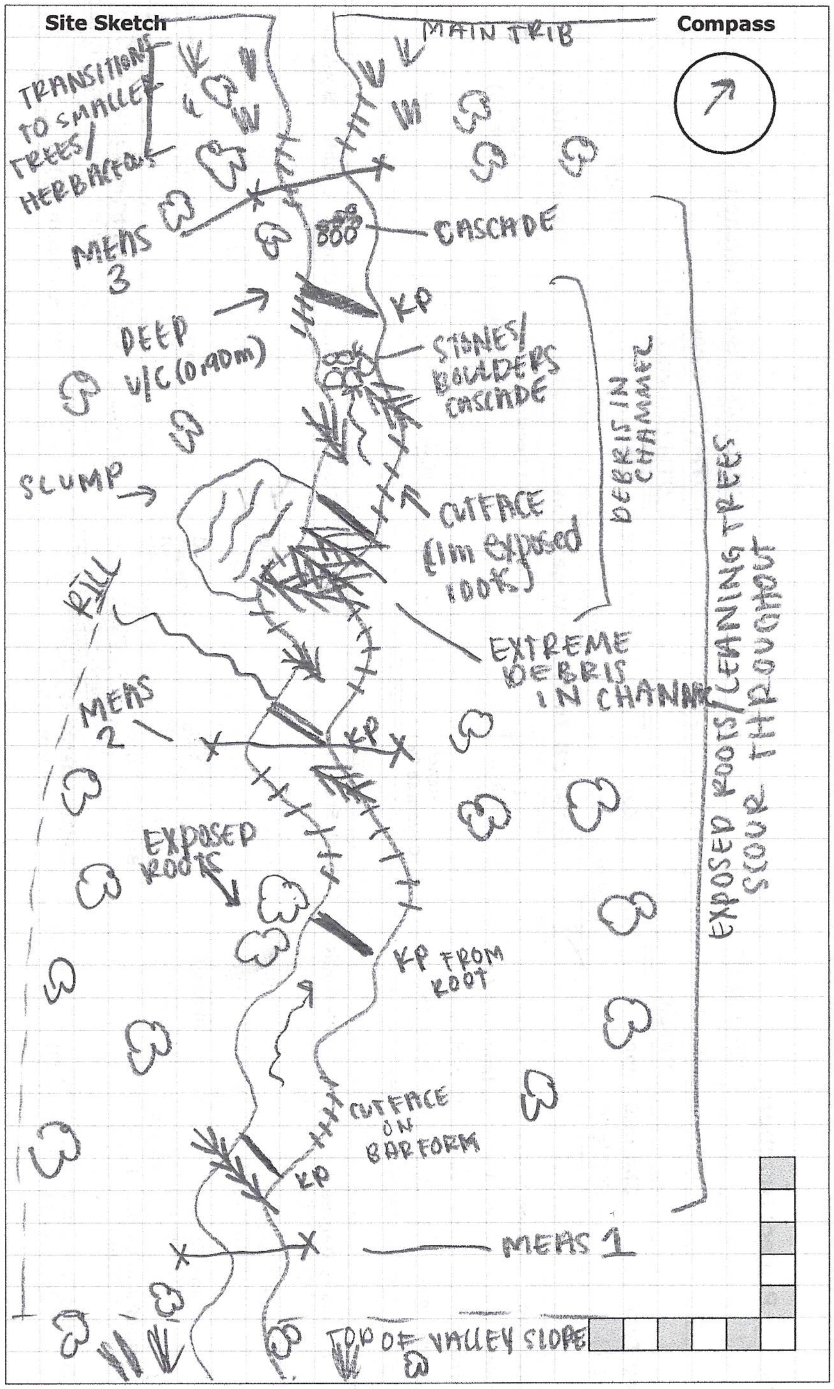
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

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GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	1:20 PM	**Reach:**	TRIB 2
Weather:	CLOUDY WITH SUN -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Geomorphological Indicator Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		\	3/7
	2	Coarse materials in riffles embedded		\	
	3	Siltation in pools	\		
	4	Medial bars		\	
	5	Accretion on point bars	\		
	6	Poor longitudinal sorting of bed materials	\		
	7	Deposition in the overbank zone		\	
		Sum of indices =	3	4	0.429
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	5/6
	2	Exposed sanitary / storm sewer / pipeline / etc. TILE DRAIN	\		
	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 knickpoint 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 =	5	1	0.833
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	\		6/8
	2	Occurrence of large organic debris	\		
	3	Exposed tree roots	\		
	4	Basal scour on inside meander bends		\	
	5	Basal scour on both sides of channel through riffle		\	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach	\		
	8	Exposed length of previously buried pipe / cable / etc. TILE DRAIN	\		
	9	Fracture lines along top of bank	\		
	10	Exposed building foundation		N/A	
		Sum of indices =	6	2	0.75
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	2/7
	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 with meander form	\		
	7	Bar forms poorly formed / reworked / removed	\		
		Sum of indices =	2	5	0.286

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.575
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☒ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique   Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	1:20 PM	**Reach:**	TRIB 2
Weather:	CLOUDY W SUN	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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

Version #2   Senior staff sign-off (if required): ________ Checked by: KM Completed by: KS

Last edited: 10/02/2023

GEO
MORPHIX

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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 N/A
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 < 0.15m 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) = 23	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Reach Characteristics **Project Number:** 23076

Date:	2023-11-28	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	—	**Stream:**	CARDINAL CREEK TRIB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	T3	**UTM (Downstream):**	

Land Use (Table 1): 1,3 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 6-7 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater Location: / Photo: /

Riparian Vegetation

Dominant Type (Table 6): 1

Encroachment (Table 7): 3

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel Widths: ☐ 1 - 4 ☒ 4 - 10 ☒ > 10

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

Aquatic & Instream Vegetation

Type (Table 8): \

Reach Coverage %: \

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

WD Density: ☐ Low ☐ Mod ☒ High

WDJ/50m: 1-2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 2 | **Sinuosity Degree** (Table 10): 2

Gradient (Table 11): 3 | **# of Channels** (Table 12): 1

Entrenchment (Table 13): 2 | **Bank Failure** (Table 14): 1,2 5,6

Down's Model (Table 15): e,c | **Bankfull Indicators** (Table 18): \

Sed Sorting (Table 20): PS | **Sediment Transport Observed?** ☐ Yes ☒ No ☐ Not Visible

Transport Mode (Table 21): \ | **% of Bed Active**: 0

Geomorphic Units (Table 22): 4,5 | **Mass Movement** (Table 23): 4

Riffle-Pool Spacing (m): \ | **% Riffles:** \ | **% Pools:** \

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

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

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

Bankfull Width (m)	POORLY DEFINED	POORLY DEFINED	POORLY DEFINED
Bankfull Depth (m)	" "	" "	" "
Undercuts (m)	0.30	0.42	0.15
Pool Depth (m)	0.12	0.25	0.21
Riffle Length (m)	/	/	/

Wetted Width (m)	0.55	0.50	0.62
Wetted Depth (m)	0.05	0.15	0.04
Velocity (m/s)	/	/	/
Velocity Estimate Method	/	/	/
Meander Amplitude (m)	/	/	/

Notes: HIGH GRADIENT TRIBUTARY FLOWING THROUGH RAVINE. UNDERCUTTING ROTATIONAL SLIDES FREQUENT ALONG BANKS. FALLEN TREES ACROSS CHANNEL FREQUENT MAKING TRAVEL ALONG WATERCOURSE DIFFICULT KNICKPOINT IN COMPACT CLAY TILL >1M TALL W SCOUR POOL ON D/S SIDE HALFWAY ALONG REACH SECOND LARGE KNICKPOINT IN TOPSOIL AND CLAY TILL ~0.80M TALL AT U/S EXTENT OF REACH, ADJACENT TO GULLY ORIGINATING FROM AG FIELD TO THE EAST

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	T3
Weather:	SUN+CLOUD -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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		
H8	Chute		
H9	Free fall	**H9A**	Dissipates below free fall

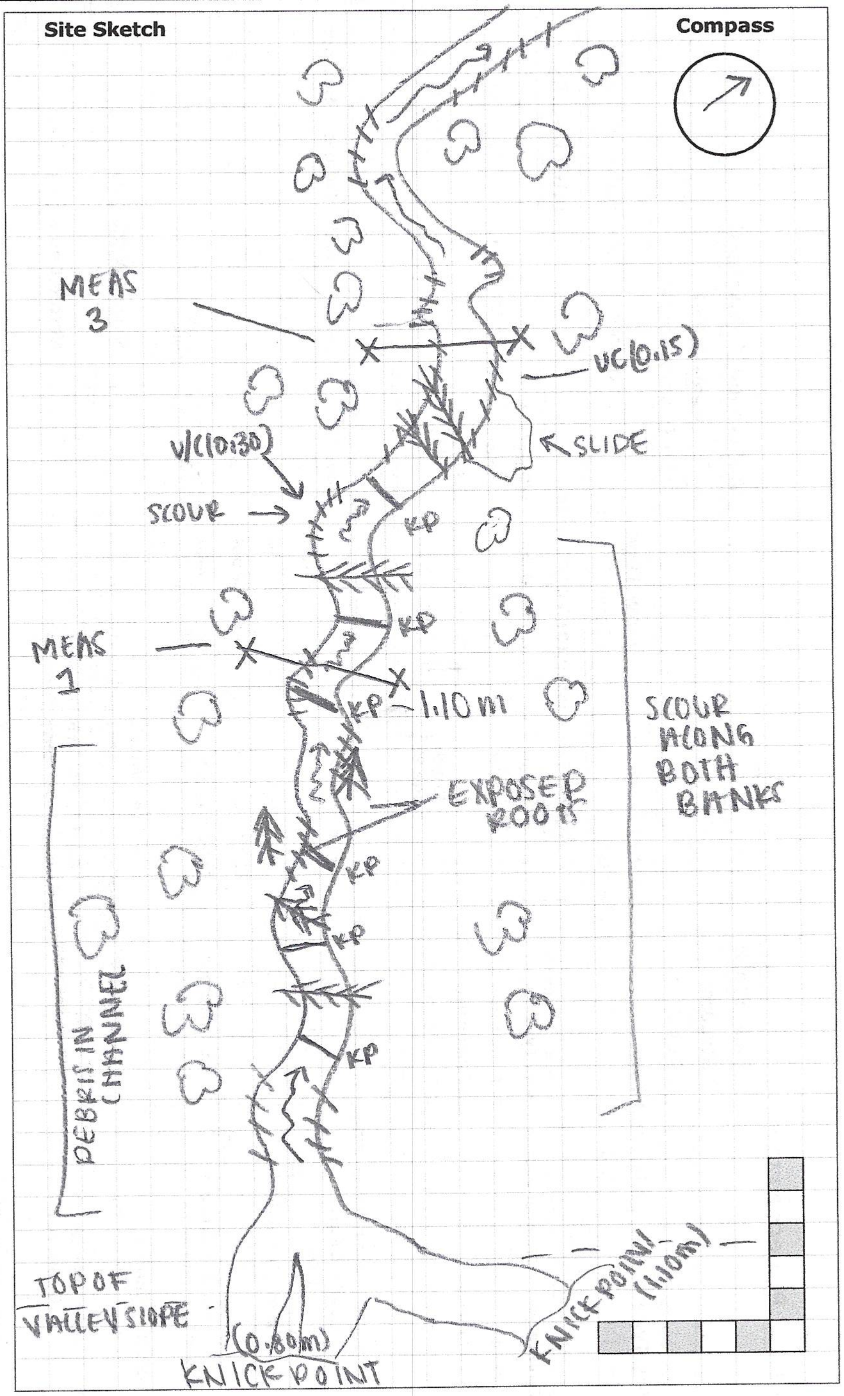
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	2:15 PM	**Reach:**	TRIB 3
Weather:	OVERCAST -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	5/7
	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 =	2	5	0.714
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	3/5
	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 knickpoint 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 =	3	2	0.6
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		6/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends	✓		
	5	Basal scour on both sides of channel through riffle	✓		
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach	✓		
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	6	1	0.857
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	2/7
	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 with meander form	✓		
	7	Bar forms poorly formed / reworked / removed	✓		
		Sum of indices =	2	5	0.286

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.614
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☑ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX™

Rapid Stream Assessment Technique **Project Number:** 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	2:15 PM	**Reach:**	TRIB 3
Weather:	OVERCAST - 2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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

Version #2
Last edited: 10/02/2023

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

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
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 < 0.15m 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	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	

Total overall score (0–42) = 23	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Reach Characteristics

Project Number: 23076

Date:	2023-11-28	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK
Time:	—	**Stream:**	CARDINAL CREEK TRIB	**UTM (Upstream):**	
Weather:	SUN + CLOUD -2°C	**Reach:**	T4	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1/3

Encroachment (Table 7): 1

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel Widths: ☐ 1 - 4 ☒ 4 - 10 ☒ > 10

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

Aquatic & Instream Vegetation

Type (Table 8): /

Reach Coverage %: 0

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

WD Density: ☐ Low ☐ Mod ☒ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 2

Sinuosity Degree (Table 10): 3

Gradient (Table 11): 3 — RAVINE

# of Channels (Table 12): 1

Entrenchment (Table 13): 2

Bank Failure (Table 14): 1, 2, 5, 6

Down's Model (Table 15): E, C

Bankfull Indicators (Table 18): \

Sed Sorting (Table 20): PS

Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible

Transport Mode (Table 21): \

% of Bed Active: 0

Geomorphic Units (Table 22): 4, 5

Mass Movement (Table 23): 4

Riffle-Pool Spacing (m): \

% Riffles: 90 **% Pools:** 10

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

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

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

Bankfull Width (m)	2.03	POORLY DEFINED	0.50
Bankfull Depth (m)	0.58	POORLY DEFINED	0.55
Undercuts (m)	0.50	1.50	0.15
Pool Depth (m)	0.17	0.16	0.21
Riffle Length (m)	/	/	/

Wetted Width (m)	1.42	1.05	0.85
Wetted Depth (m)	0.13	0.12	0.07
Velocity (m/s)	0.06	0.10	0.15
Velocity Estimate Method	WIFFLE BALL	WIFFLE BALL	WIFFLE BALL
Meander Amplitude (m)	3.00	3.50	5.00

Notes:

- RAVINE FLOW FROM AG FIELD - HIGH GRADIENT
- UNDERCUTTING, LARGE ROTATIONAL SLIDE OBSERVED
- FALLEN TREES ACROSS CHANNEL COMMON
- FORCED KNICK POINTS COMMON, SEVERAL CASCADE FEATURES @ D/S EXTENT
- CHANNEL BED FLAT COMPACT CLAY - EVIDENCE OF BED SCOUR DUE TO CHUNKS REMOVED
- EXPOSED ROOTS / LEANING TREES COMMON
- SCOUR ON BOTH BANKS

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 230760

Date:	2023-11-28	**Stream:**	CARDINAL CREEK TRIB
Time:	—	**Reach:**	T4
Weather:	CLOUDY + SUN -2°C	**Location:**	ORLEANS
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Features		Monitoring	
	Reach break		Long-profile
	Station location		Monumented XS
	Cross-section		Monumented photo
	Flow direction		Monumented photo direction
	Riffle		Sediment sampling
	Pool		Erosion pins
	Sediment bar		Scour chains
	Eroded bank/slope	**Additional Symbols**	
	Undercut bank		
	Bank stabilization		
	Leaning tree		
	Fence		
	Culvert/outfall		
	Swamp/wetland		
	Grasses		
	Tree		
	Instream log/tree		
	Woody debris		
	Beaver dam		
	Vegetated island		

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

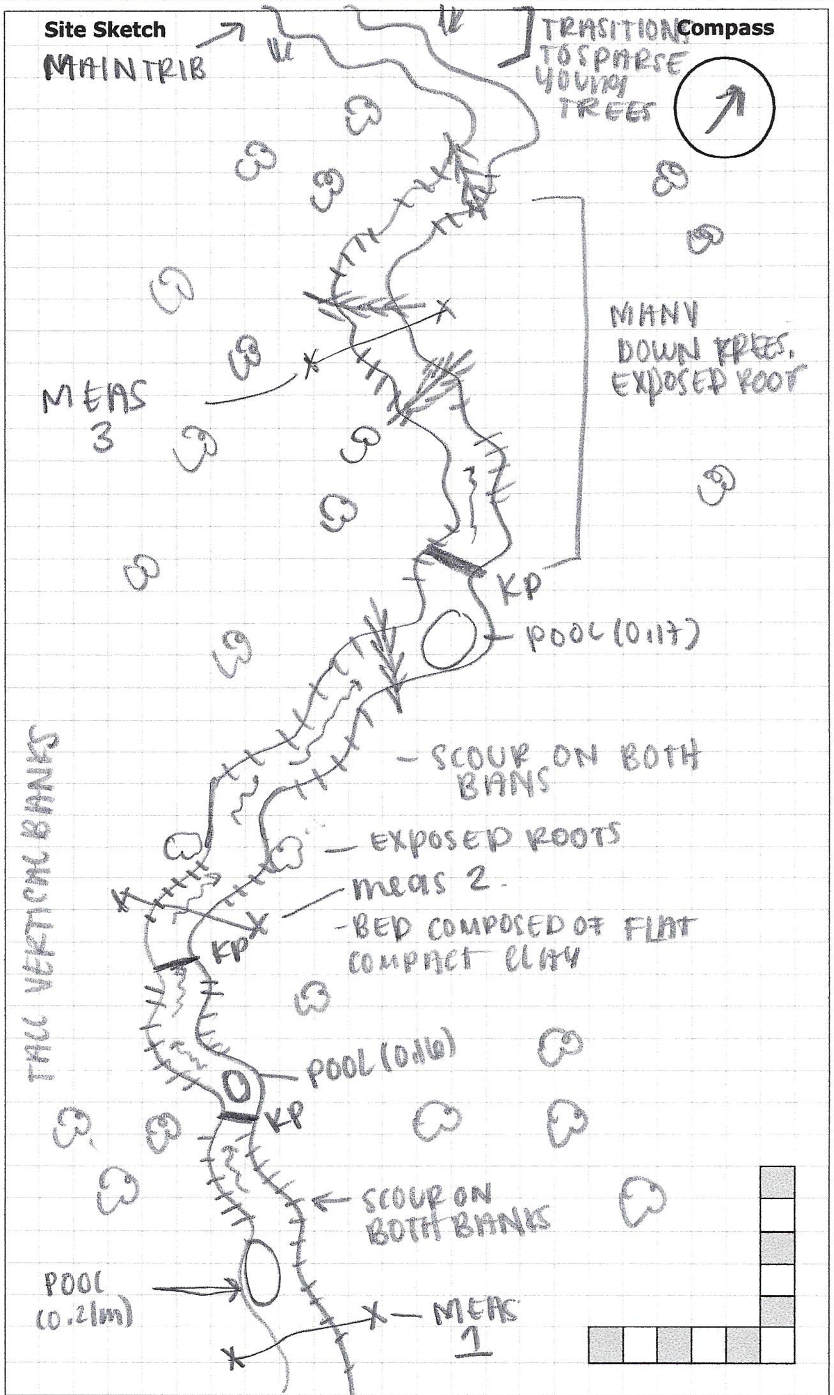
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Version #4
Last edited: 21/02/2023

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

Page ____ of ____

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	2:45 PM	**Reach:**	TRIB 4 (FARTHEST DIS)
Weather:	OVERCAST, -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL CREEK

Process	No.	Description	Yes	No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		\	2/7
	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 =	2	5	0.286
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	4/5
	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 knickpoint 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 =	4	1	0.80
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	\		6/7
	2	Occurrence of large organic debris	\		
	3	Exposed tree roots	\		
	4	Basal scour on inside meander bends	\		
	5	Basal scour on both sides of channel through riffle	\		
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach	\		
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		\	
	10	Exposed building foundation		N/A	
		Sum of indices =	6	1	0.857
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	2/7
	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 with meander form	\		
	7	Bar forms poorly formed / reworked / removed	\		
		Sum of indices =	2	5	0.286

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.557
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☒ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO
MORPHIX™

Rapid Stream Assessment Technique   Project Number: 23076

Date:	28-11-23	**Stream:**	SOUTH TRIB CARDINAL CREEK
Time:	2:45	**Reach:**	T4 (FARTHEST D/S TRIB)
Weather:	OVERCAST -2°C	**Location:**	CARDINAL CREEK VILLAGE
Field Staff:	KS KM	**Watershed/Subwatershed:**	CARDINAL 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 N/A
	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	28-11-23	PN:	23076	Location:	SOUTH TRIB CARDINAL

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 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	N/A
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 < 0.15m 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	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	

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

Version #2
Last edited: 10/02/2023

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

Reach Characteristics

Project Number: 23076

GEO MORPHIX™

Date:	10-10-24	**Field Staff:**	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER
Time:	10:30	**Stream:**	CARDINAL CREEK	**UTM (Upstream):**	
Weather:	10°C SUN/CLOUD	**Reach:**	C10	**UTM (Downstream):**	

Land Use (Table 1): 1 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 9 | **Channel Zone** (Table 4): 2/3 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater Location:______ Photo:______

Riparian Vegetation

Dominant Type (Table 6): 1/4

Encroachment (Table 7): 2

- **Coverage:** ☐ None ☐ Fragmented ☒ Continuous
- **Channel Widths:** ☐ 1 - 4 ☐ 4 - 10 ☒ > 10
- **Age (yrs):** ☐ Immature (<5) ☒ Established (5-30) ☒ Mature (>30)

Aquatic & Instream Vegetation

Type (Table 8): 1, 2, 6

Reach Coverage %: 10

- **Woody Debris:** ☒ In Cutbank ☒ In Channel ☐ Not Present
- **WD Density:** ☐ Low ☒ Mod ☐ High
- **WDJ/50m:** BEAVER DAMS

Water Quality

Odour (Table 16): 2

Turbidity (Table 17): 3

Channel Characteristics

Sinuosity Type (Table 9)	2	**Sinuosity Degree** (Table 10)	3
Gradient (Table 11)	3	**# of Channels** (Table 12)	2
Entrenchment (Table 13)	1	**Bank Failure** (Table 14)	2/5
Down's Model (Table 15)	m	**Bankfull Indicators** (Table 18)	1, 3, 5
Sed Sorting (Table 20)	MS	**Sediment Transport Observed?**	☐ Yes ☒ No ☐ Not Visible
Transport Mode (Table 21)	N/A	**% of Bed Active**	0
Geomorphic Units (Table 22)	ALL	**Mass Movement** (Table 23)	N/A
Riffle-Pool Spacing (m):	10-20	**% Riffles:**	25
		% Pools:	75

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

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

Bankfull Width (m)	SEE	DETAILED	ASSESS.
Bankfull Depth (m)			
Undercuts (m)	0.61	0.21	0.55
Pool Depth (m)	0.33	0.32	0.93
Riffle Length (m)	10-30		

Wetted Width (m)	SEE	DETAILED	ASSESS.
Wetted Depth (m)			
Velocity (m/s)			
Velocity Estimate Method			
Meander Amplitude (m)	7	10.8	9.5

Notes: DETAILED ASSESSMENT COMPLETED CONCURRENTLY W RAPID ASSESSMENT — NO BF OR WW MEASUREMENTS TAKEN USING ANALOG METHODS

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment **Project Number:** 23076

Date:	10-10-24	**Stream:**	CARDINAL CREEK
Time:	10:30	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	ORLEANS
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Process	No.	Description	Yes	No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar	X		3/7
	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 =	3	4	0.428
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.		X	
	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 =	2	4	0.333
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		5/8
	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.		X	
	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 =	5	3	0.625
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	4/7
	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 =	4	3	0.57

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 =		0.49
In Regime	**In Transition/Stress**	**In Adjustment**
☐ **0.00 - 0.20**	☐ **0.21 - 0.40**	☑ **0.41**

Version #3
Last edited: 10/02/2023

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

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 23076

Date:	10-10-24	**Stream:**	CARDINAL CREEK
Time:	10:30	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	ORLEANS
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

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 N/A
	• 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

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Date:	10-10-24	PN:	23076	Location:	C10 CARDINAL CREEK

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 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 N/A
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 < 0.15m 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) = 26	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

Detailed Assessment Long Profile (Total Station) — Project Code: 23076

Date:	2024-08-06	**Reach:**	R3
Time:	10:34am	**Location:**	ORLEANS
Weather:	SUN 25°C	**Watershed/Subwatershed:**	CARDINAL CREEK
Field Staff:	KM HM	**Rain in last 24 hours:**	☐ None ☐ Yes: Amount ______ mm

Point No.		Code	Notes
		TOTAL STATION	

Survey Direction

☐ Upstream to Downstream
☒ Downstream to Upstream

Cross-sections

No. of Cross-sections Surveyed: 8
Monitoring Cross-sections: ☐ No ☒ Yes
XS ID: 5 / ______ / ______
Erosion Pin Installed: ☐ No ☒ Yes
XS ID: 5 / ______ / ______

Velocity & Sediment Transport

☒ Velocity 0.40 m/s **Method:**
☐ Discharge ______ m³/s WIFFLE BALL
Sed. Transport (Table 21): ☐ Suspended ☐ Saltation ☐ Sliding ☐ Rolling
Percentage of Bed Active: 0 %

Valley Type

☒ Confined ☐ Partially ☐ Unconfined

Channel Zone

☐ Headwater ☒ Transfer ☐ Deposition

Land Use

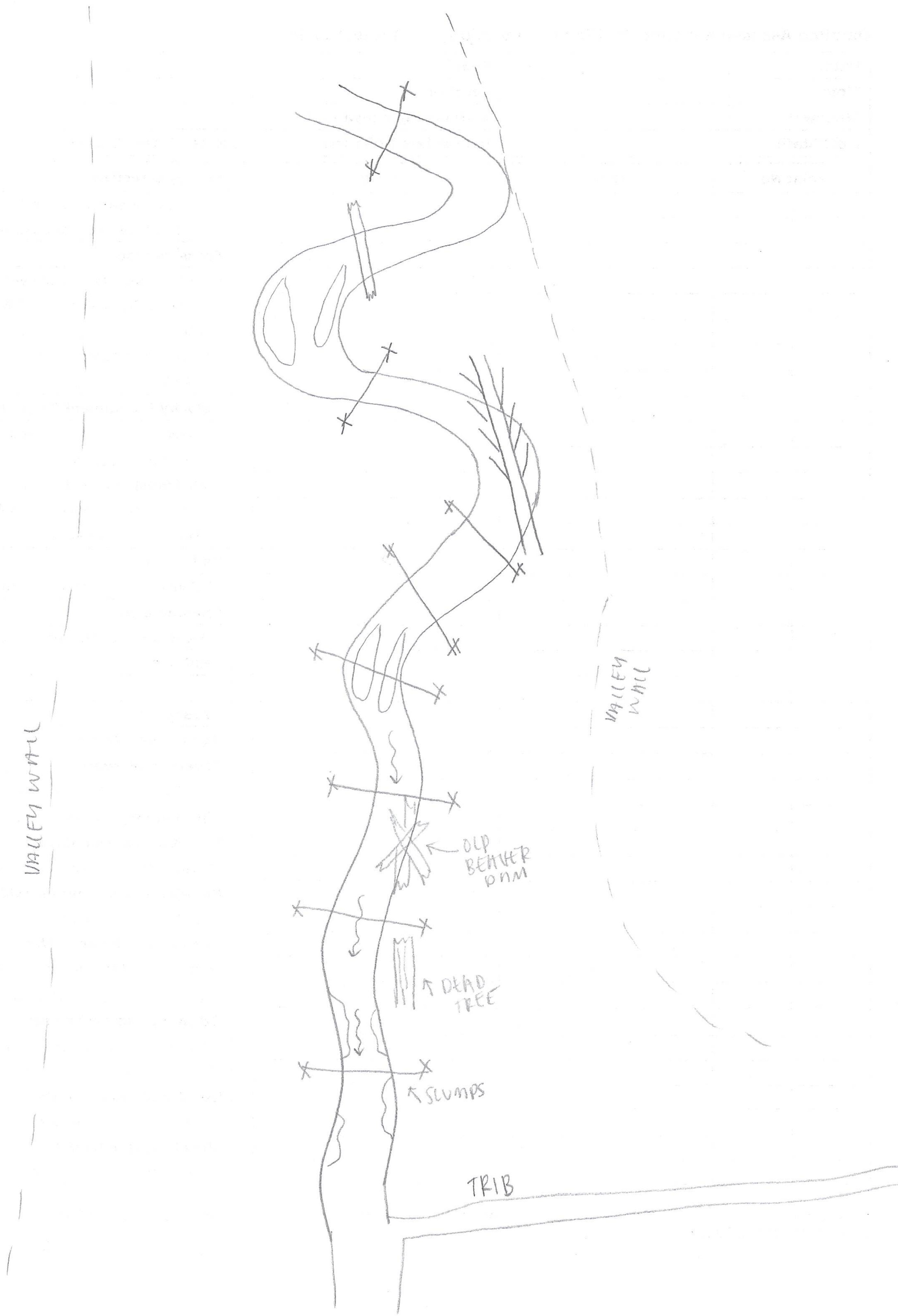
FOREST / FLOODPLAIN (MARSH)

Vegetation

Aquatic Vegetation: ALGAE
Coverage of Reach: 5 %
☒ In Stream ☐ Margins ☐ On Bank
Riparian Vegetation: ☐ No ☒ Yes
Extent of Riparian Cover:
☐ Fragment ☐ None ☒ Continuous
Riparian Cover (channel widths):
☐ 1-4 ☐ 4-10 ☒ >10
Age Class of Riparian Vegetation:
Immature ☒ (<5 yrs) Established ☐ (5-30 yrs) Mature ☒ (>30 yrs)
Extent of Encroachment:
☐ None ☒ Minimal ☐ Moderate ☐ Heavy ☐ Extreme
Density of Woody Debris:
☒ Low ☐ Moderate ☐ High
Blockage(s) in Channel:
☐ Infrastructure ☐ Dam ☒ LWD

Version #3
Last edited: 21/02/2023

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



VALLEY WALL
VALLEY WALL
OLD BEAVER DAM
DEAD TREE
SLUMPS
TRIB

General Site Characteristics

Project Number: 23076

Date:	2024-08-06	**Stream:**	CARDINAL CREEK S.TRIB
Time:	10:34am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL 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		
H8	Chute		
H9	Free fall	H9A	Dissipates below free fall

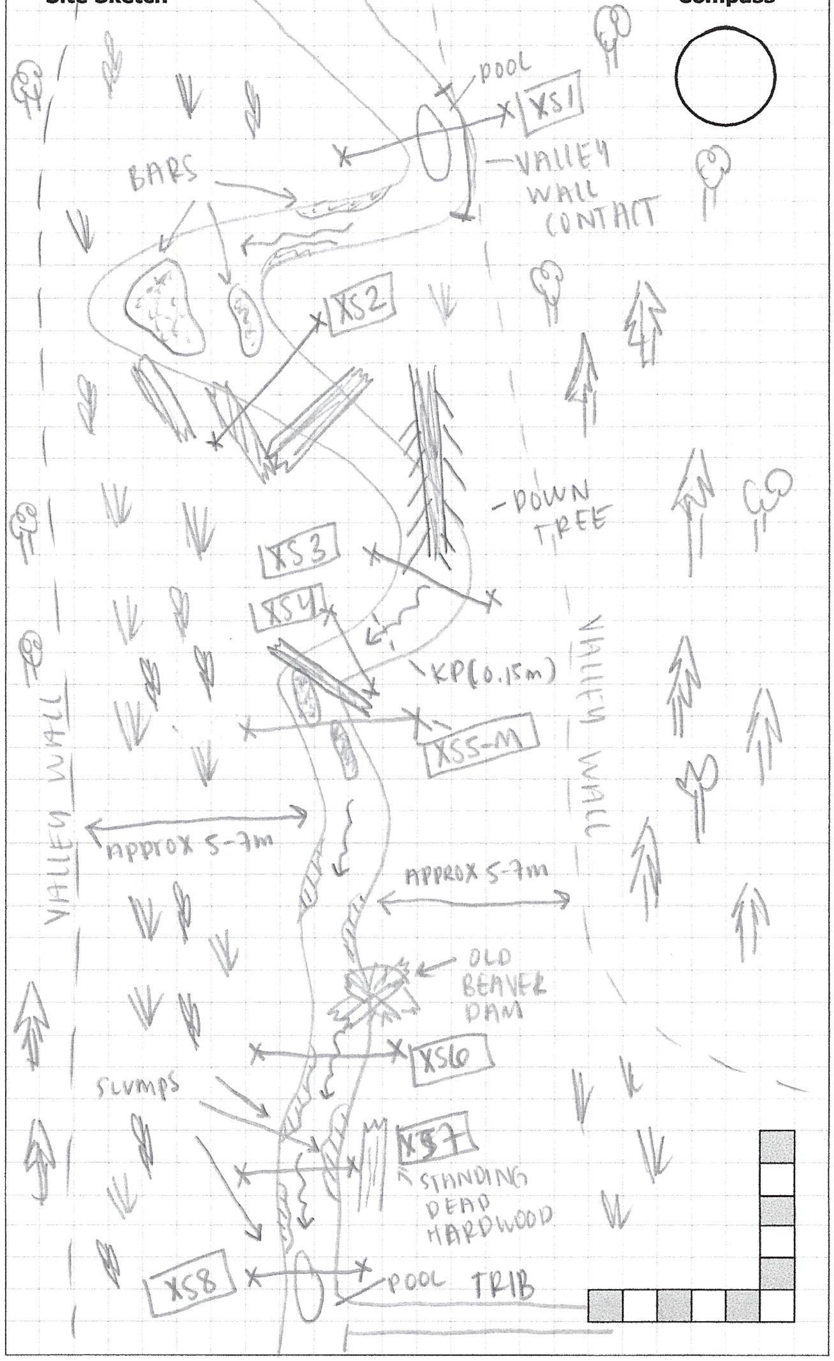
Substrate

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

Site Sketch **Compass**



Photos:

Notes:

Detailed Cross-Section Characteristics **Project Number:** 23076

GEO MORPHIX™

Date:	2024-08-06	**Cross-section:**	XS1
Time:	11:13am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM MM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS → PN23076-XS1				

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

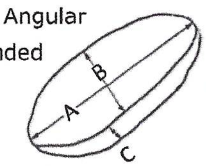
Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	FINES			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



Embedededness: ________ %

Subpavement: ________________

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: __________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity

☐ Measured ________ m/s Method: WB

☒ Estimated 0.13 m/s XS ID: XS1

Distance 0.5 m Time 4.75 s V 0.10 m/s

Distance 0.5 m Time 2.85 s V 0.17 m/s

Distance 0.5 m Time 4.06 s V 0.12 m/s

Discharge

☐ Estimated ________ m^3/s Method: ________

☐ Measured ________ m^3/s XS ID: ________

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

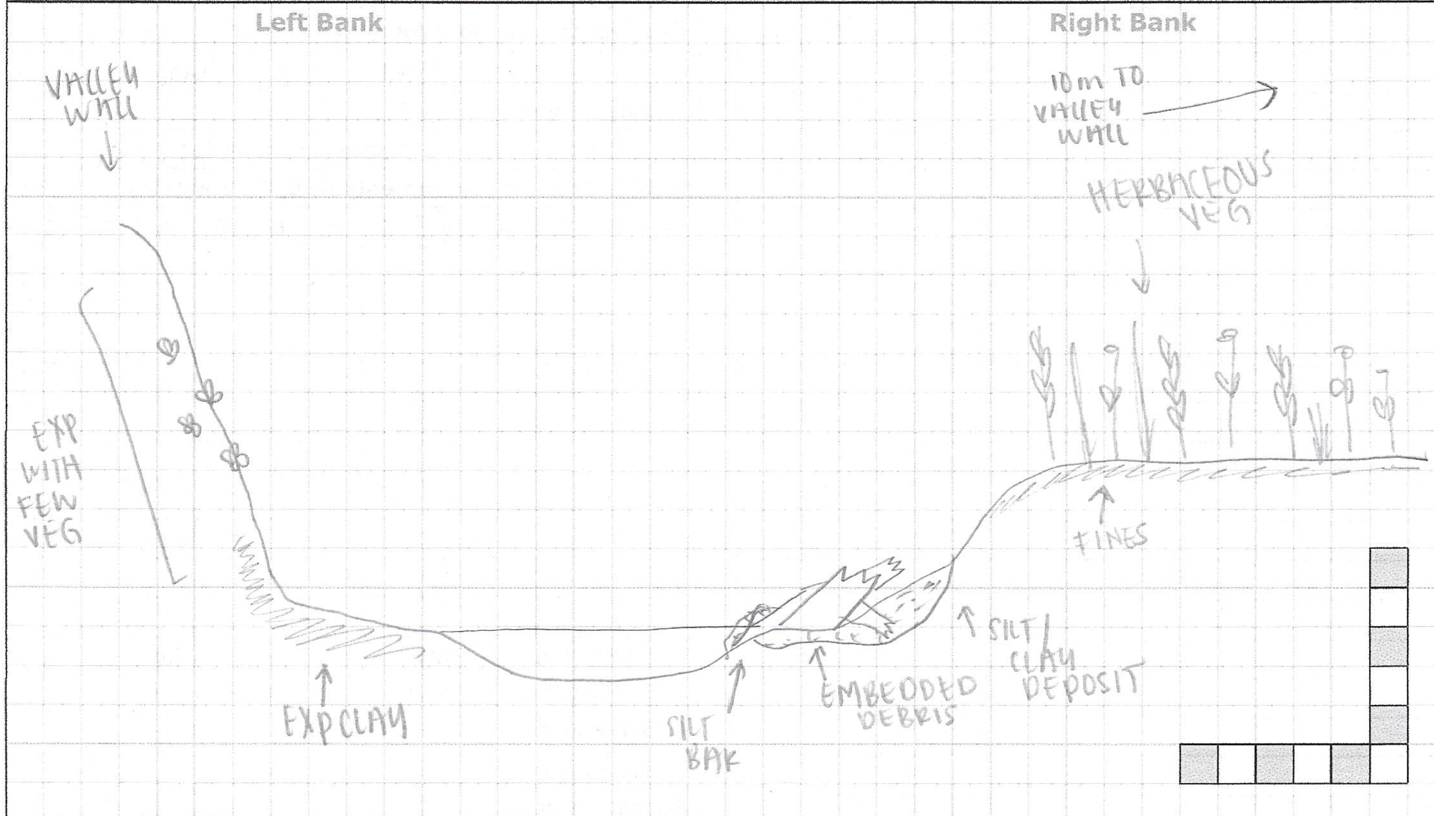
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS1
Time:	11:13am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.85	m
Bank Angle:	30	°
Root Depth:	0.16	m
Root Density:	5	%
Undercut:	NO	m
Erosion Pin:	N/A	m
Torvane:	1.5	kg/cm^2
Penetrometer:	1.5	kg/cm^2
Foot Used:	☐ Yes ☒ No	

Features

- Station location
- Monumented XS
- Monumented photo
- Undercut bank
- Eroded bank/slope
- Bank stabilization
- Fence
- Grasses
- Leaning tree
- Tree
- Woody Debris
- Sediment sample
- Erosion pin
- Scour/bed chain

Right Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.55	m
Bank Angle:	40	°
Root Depth:	0.07	m
Root Density:	20	%
Undercut:	NO	m
Erosion Pin:	N/A	m
Torvane:	0.5	kg/cm^2
Penetrometer:	0.75	kg/cm^2
Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics   Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS2
Time:	11:35am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS → PN23076-XS2				

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

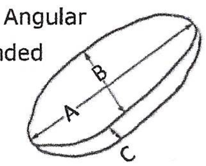
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES	1			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular
☐ Sub-angular ☐ Angular ☐ Rounded
☐ Sub-Rounded ☐ Well Rounded

Embedness: ________ %

Subpavement: ________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity

☐ Measured ________ m/s Method: WIFFLE BALL

☒ Estimated 0.40 m/s XS ID: XS2

Distance 1 m Time 2.75 s V 0.36 m/s

Distance 1 m Time 2.40 s V 0.41 m/s

Distance 1 m Time 2.21 s V 0.45 m/s

Discharge

☐ Estimated ________ m^3/s Method: ____________

☐ Measured ________ m^3/s XS ID: ____________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

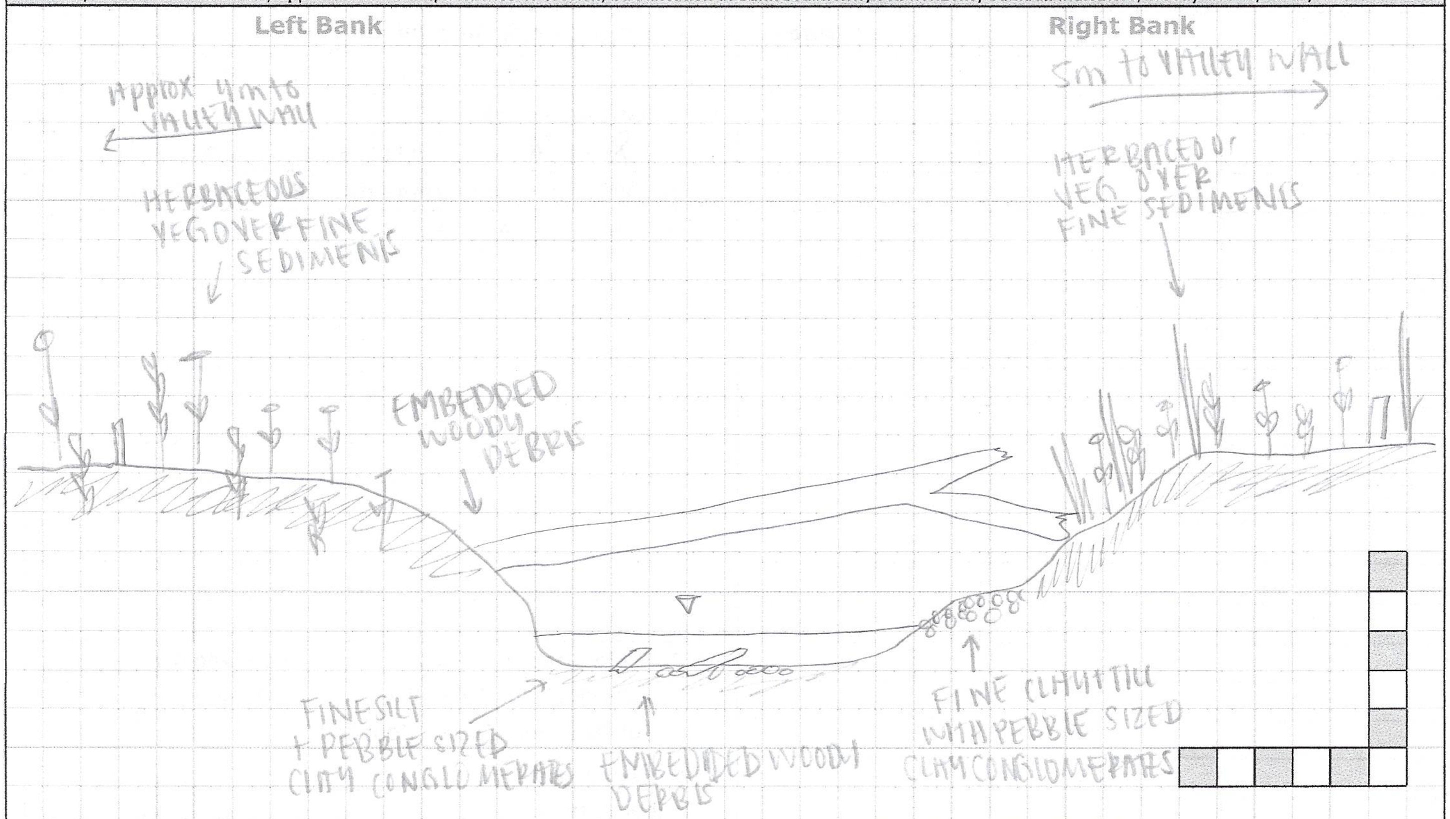
GEO MORPHIX™

Bank Characteristics

Project Number: 230716

Date:	2024-08-06	**Cross-section:**	XS2
Time:	11:35am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.70	m
Bank Angle:	45	°
Root Depth:	0.11	m
Root Density:	35	%
Undercut:	0.05	m
Erosion Pin:	NO	m
Torvane:	0.150	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
x x x	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.45	m
Bank Angle:	25	°
Root Depth:	0.10	m
Root Density:	15	%
Undercut:	NO	m
Erosion Pin:	N/A	m
Torvane:	1.0	kg/cm²
Penetrometer:	1.0	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number:

Date:	2024-08-06	**Cross-section:**	XS3
Time:	11:46am	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS → PN230716-XS3				

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

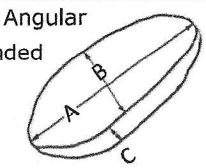
Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES 1				11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular
☐ Sub-angular ☐ Angular ☐ Rounded
☐ Sub-Rounded ☐ Well Rounded



Embededness: ________ %

Subpavement: ____________________ [Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________________ %

Velocity

☐ Measured ________ m/s Method: WIFFLE BALL

☒ Estimated 0.60 m/s XS ID: XS3

Distance 1 m Time 1.70 s V 0.58 m/s

Distance 1 m Time 1.63 s V 0.61 m/s

Distance 1 m Time 1.61 s V 0.62 m/s

Discharge

☐ Estimated ________ m^3/s Method: ____________

☐ Measured ________ m^3/s XS ID: ____________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

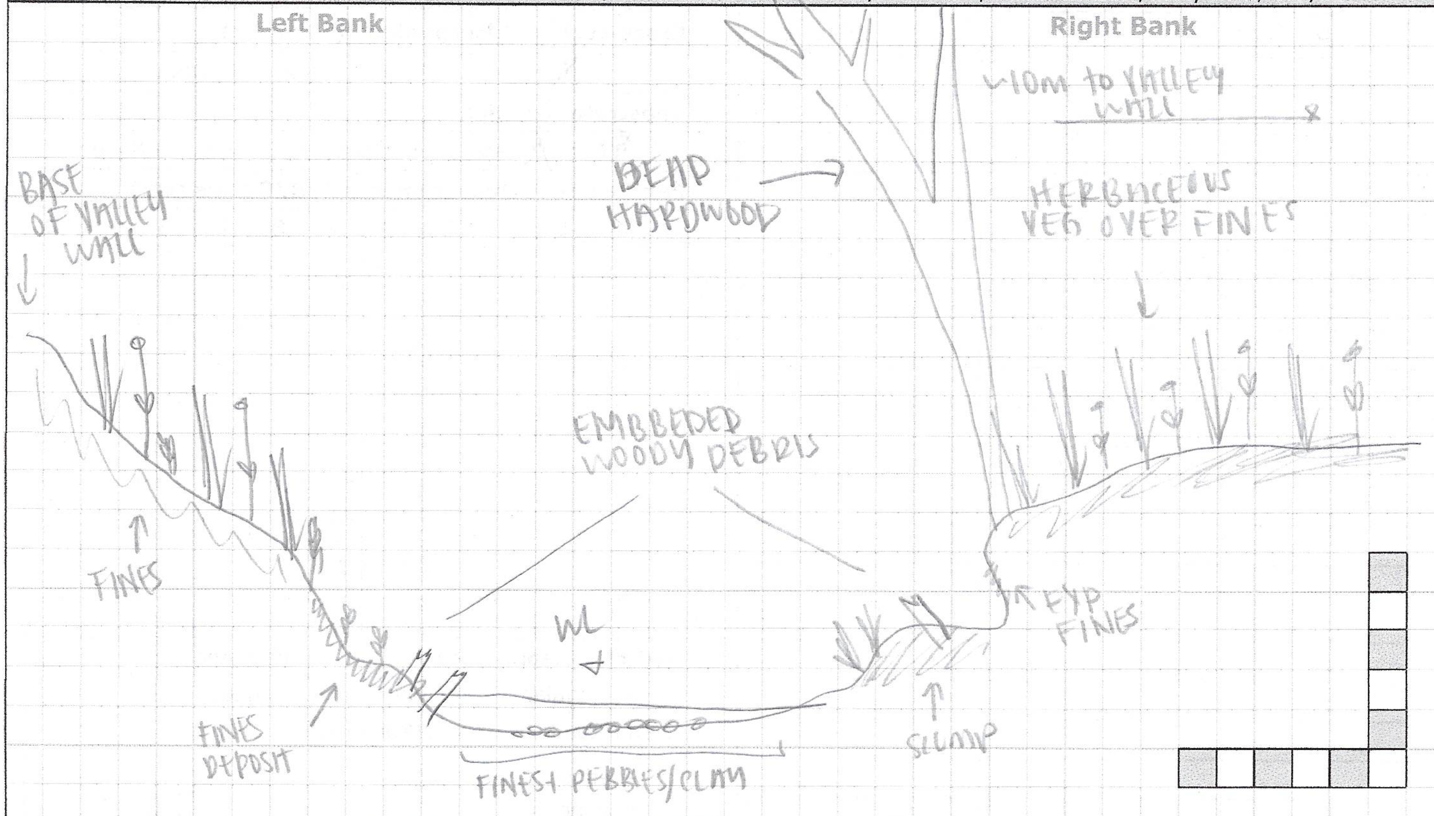
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS3
Time:	11:46am	**Reach:**	R2
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			
☐ Bedrock	☐ Gravel		
☐ Till	☐ Small Cobble		
☒ Clay	☐ Large Cobble		
☐ Silt	☐ Small Boulder		
☐ Sand	☐ Large Boulder		
Bank Height:	0.85	m	
Bank Angle:	30	°	
Root Depth:	0.07	m	
Root Density:	10	%	
Undercut:	NO	m	
Erosion Pin:	N/A	m	
Torvane:	0.50	kg/cm²	
Penetrometer:	0.75	kg/cm²	
Foot Used:	☐ Yes ☒ No		

Features	
	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
x x x	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble	
☐ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	0.55	m
Bank Angle:	25	°
Root Depth:	0.11	m
Root Density:	30	%
Undercut:	0.28	m
Erosion Pin:	N/A	m
Torvane:	0	kg/cm²
Penetrometer:		kg/cm²
Foot Used:	☐ Yes ☐ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS4
Time:	12:01pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
		TS →	PN23076 →	XS4	

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

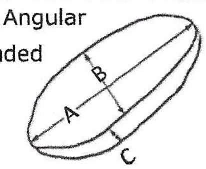
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES	1			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embedededness: ________ %

Subpavement: ________________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________________ %

Velocity

☐ Measured ________ m/s Method: WIFFLE BALL

☒ Estimated 0.31 m/s XS ID: XS4

Distance 1 m Time 2.88 s V 0.34 m/s

Distance 1 m Time 3.71 s V 0.26 m/s

Distance 1 m Time 3.03 s V 0.33 m/s

Discharge

☐ Estimated ________ m^3/s Method: ____________

☐ Measured ________ m^3/s XS ID: ____________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

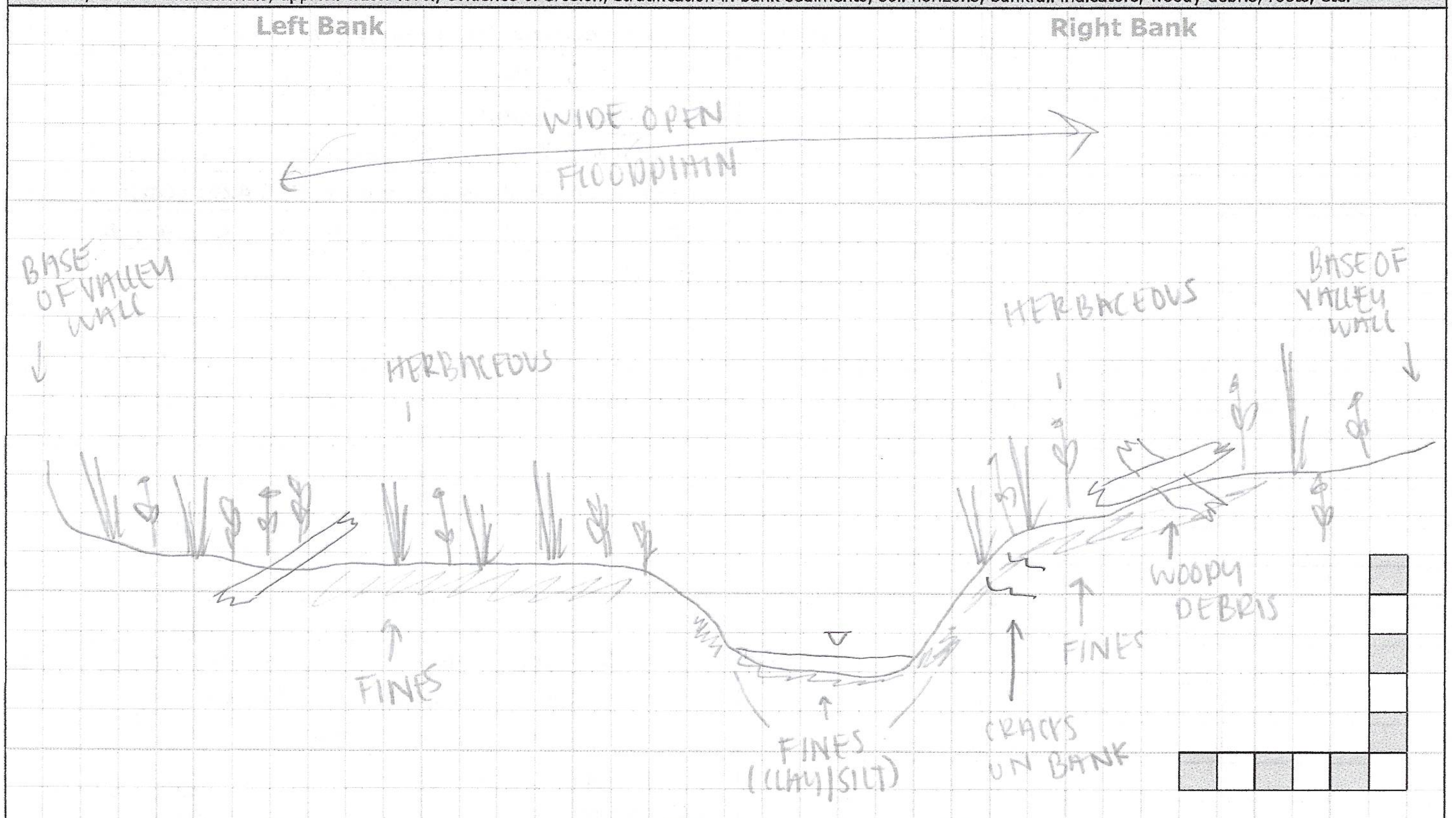
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS4
Time:	12:01 pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.55	m
Bank Angle:	35	°
Root Depth:	0.12	m
Root Density:	10	%
Undercut:	0.05	m
Erosion Pin:	N/A	m
Torvane:	0.5	kg/cm²
Penetrometer:	0.5	kg/cm²
Foot Used:	☐ Yes ☐ No	

Features

	Station location
	Monumented XS
	Monumented photo
	Undercut bank
	Eroded bank/slope
	Bank stabilization
	Fence
	Grasses
	Leaning tree
	Tree
	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.50	m
Bank Angle:	45	°
Root Depth:	0.06	m
Root Density:	20	%
Undercut:	0.07	m
Erosion Pin:	NO	m
Torvane:	1.0	kg/cm²
Penetrometer:	0.25	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS5-M
Time:	12:09 pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
TS → PN 23076 - XS5-M					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

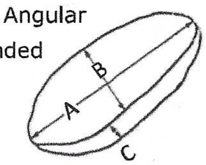
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	FINES			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embedededness: ________ %

Subpavement: ____________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☒ Obsv ☐ Not Obsv ☐ Not Visible - Reason:________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☒ Rolling ☐ Saltation

Percentage of Bed Active: 75 %

Velocity

☐ Measured ________m/s Method: WIFFLE BALL

☒ Estimated 0.23 m/s XS ID: XS5-M

Distance 1 m Time 4.31 s V 0.23 m/s

Distance 1 m Time 4.26 s V 0.23 m/s

Distance 1 m Time 4.03 s V 0.24 m/s

Discharge

☐ Estimated ________m^3/s Method: ________

☐ Measured ________m^3/s XS ID: ________

Depth ______m Width ______m V_{60} ______m/s

Depth ______m Width ______m V_{60} ______m/s

Depth ______m Width ______m V_{60} ______m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

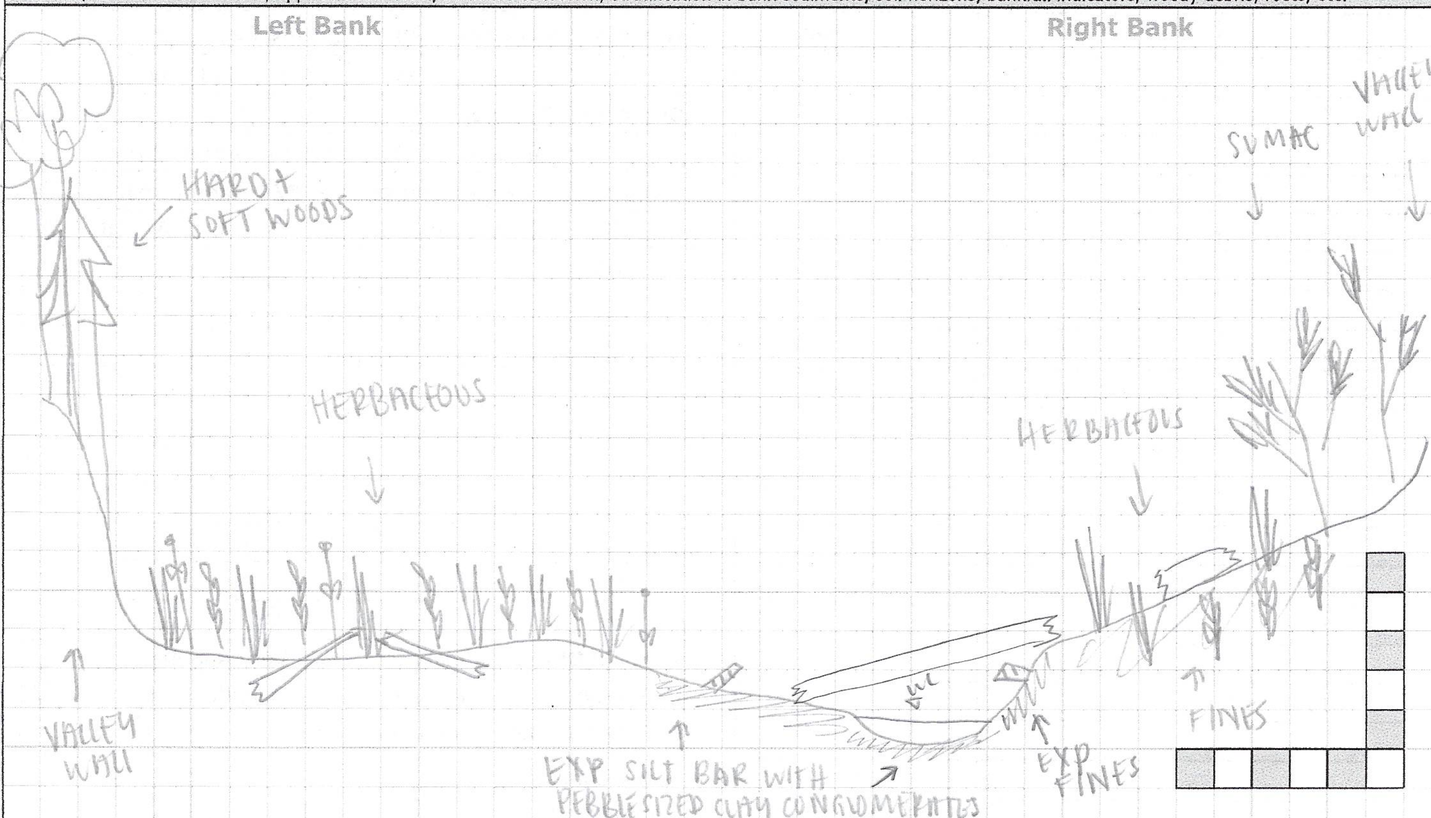
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS5-M
Time:	12:09 pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials	
☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.62	m
Bank Angle:	15	°
Root Depth:	0.06	m
Root Density:	20	%
Undercut:	0.03	m
Erosion Pin:	0.28	m
Torvane:	0.75	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features	
	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
×--×--×	Fence
	Grasses
	Leaning tree
	Tree
✳ ✳ ✳	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials	
☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.52	m
Bank Angle:	40	°
Root Depth:	0.16	m
Root Density:	20	%
Undercut:	0.12	m
Erosion Pin:	0.26	m
Torvane:	0.25	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

XS IS ALSO LABELLED XS-7 IN LARGER MONITORING NETWORK.

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS6
Time:	12:35pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS → PN23076 → XS6				

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None → COMP WITH XS6 XS7 XS8

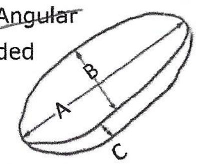
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES	1			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embedness: ________ %

Subpavement: ____________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity

☐ Measured ______ m/s Method: WIFFLE BALL

☒ Estimated 0.47 m/s XS ID: XS6

Distance 1 m Time 2.01 s V 0.49 m/s

Distance 1 m Time 2.28 s V 0.43 m/s

Distance 1 m Time 1.96 s V 0.51 m/s

Discharge

☐ Estimated ______ m^3/s Method: ________

☐ Measured ______ m^3/s XS ID: ________

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

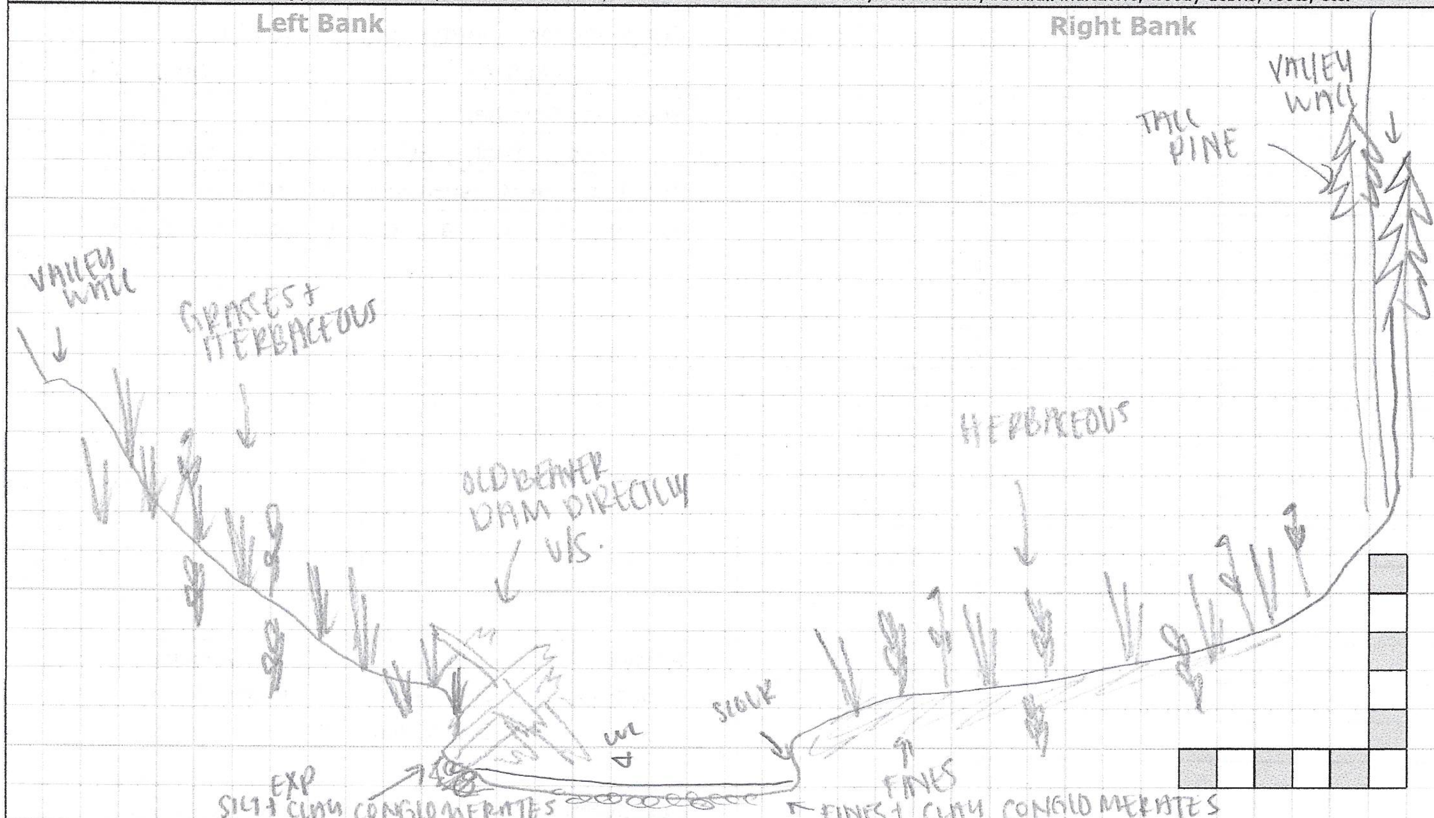
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS6
Time:	12:25pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☒ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	0.60	m
Bank Angle:	50	°
Root Depth:	0.09	m
Root Density:	10	%
Undercut:	0.05	m
Erosion Pin:	N/A	m
Torvane:	0	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features	
(symbol)	Station location
(symbol)	Monumented XS
(symbol)	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
(symbol)	Bank stabilization
x--x--x	Fence
(symbol)	Grasses
(symbol)	Leaning tree
(symbol)	Tree
x x x	Woody Debris
(symbol)	Sediment sample
(symbol)	Erosion pin
(symbol)	Scour/bed chain

Right Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☒ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	0.50	m
Bank Angle:	45	°
Root Depth:	0.13	m
Root Density:	10	%
Undercut:	0.02	m
Erosion Pin:	N/A	m
Torvane:	1.00	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS7
Time:	12:41pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS →	PN23076 →	XS7		

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

COMP WITH XS6 XS7 XS8

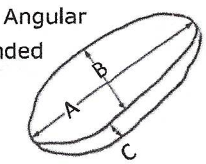
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES	1			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ____________________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ____________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity

☐ Measured ________ m/s Method: WIFFLE BALL

☒ Estimated 0.70 m/s XS ID: XS7

Distance 0.5 m Time 1.05 s V 0.95 m/s

Distance 0.5 m Time 1.91 s V 0.52 m/s

Distance 0.5 m Time 1.56 s V 0.64 m/s

Discharge

☐ Estimated ________ m^3/s Method: ____________

☐ Measured ________ m^3/s XS ID: ____________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

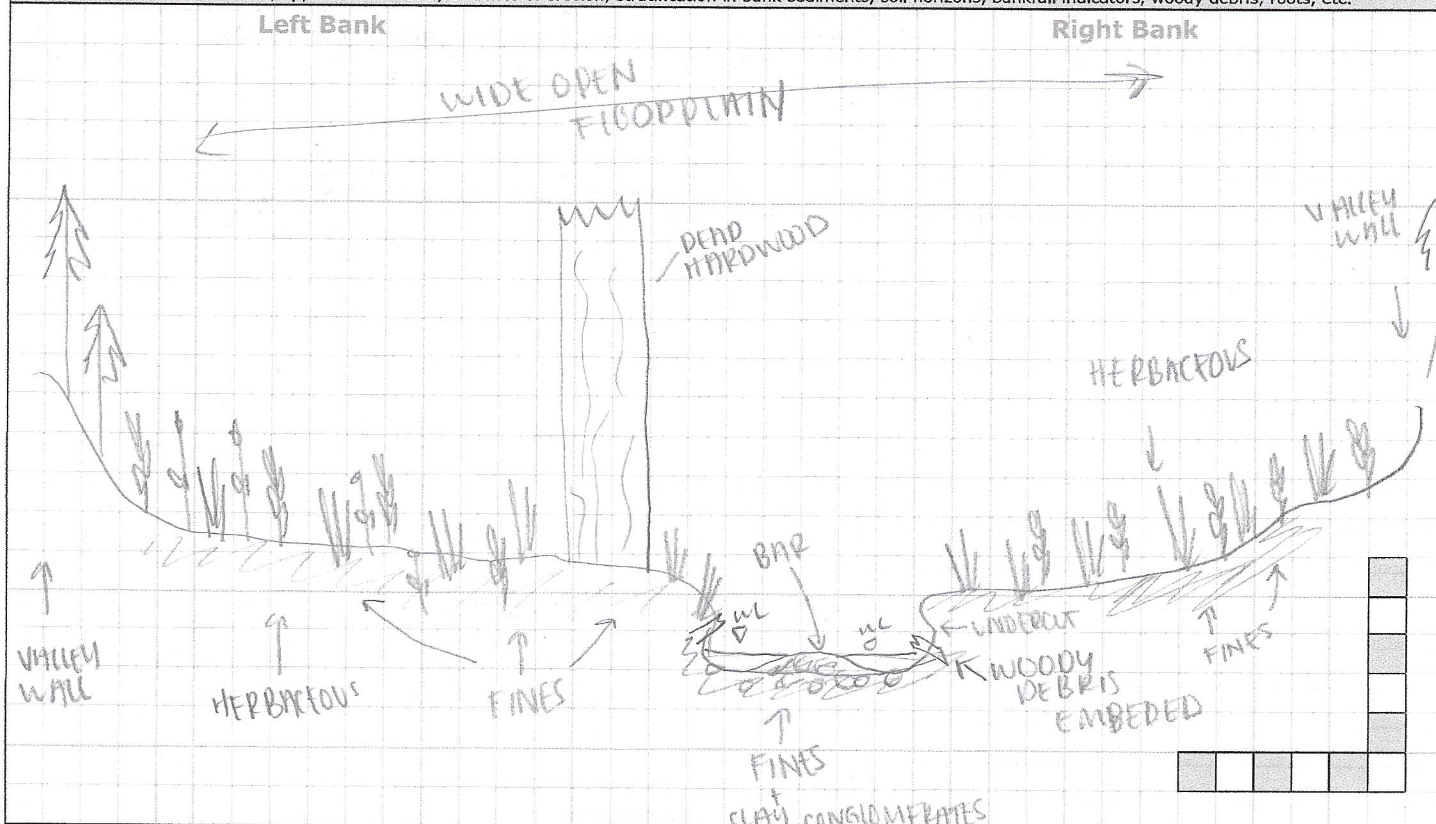
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS 7
Time:	12:41pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☒ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	0.60	m
Bank Angle:	25	°
Root Depth:	0.16	m
Root Density:	15	%
Undercut:	NO	m
Erosion Pin:	N/A	m
Torvane:	0.50	kg/cm²
Penetrometer:	0.50	kg/cm²
Foot Used:	☐ Yes ☐ No	

Features

- Station location
- Monumented XS
- Monumented photo
- Undercut bank
- Eroded bank/slope
- Bank stabilization
- Fence
- Grasses
- Leaning tree
- Tree
- Woody Debris
- Sediment sample
- Erosion pin
- Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☒ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	0.55	m
Bank Angle:	90	°
Root Depth:	0.15	m
Root Density:	30	%
Undercut:	0.29	m
Erosion Pin:	N/A	m
Torvane:	1.00	kg/cm²
Penetrometer:	0.56	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS8
Time:	12:49	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

					Notes
	TS →	PN23076 →	XS8		

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

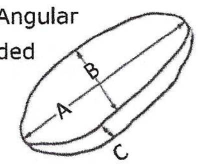
☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

comp with XS6 XS7 XS8

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
FINES				11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



Embededness: ________ %

Subpavement: ____________________ [Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ____________ %

Velocity

☐ Measured ________ m/s Method: WIFFLE BALL

☒ Estimated ________ m/s XS ID: XS8

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Distance ________ m Time ________ s V ________ m/s

Discharge

☐ Estimated ________ m^3/s Method: ________

☐ Measured ________ m^3/s XS ID: ________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

GEO MORPHIX™

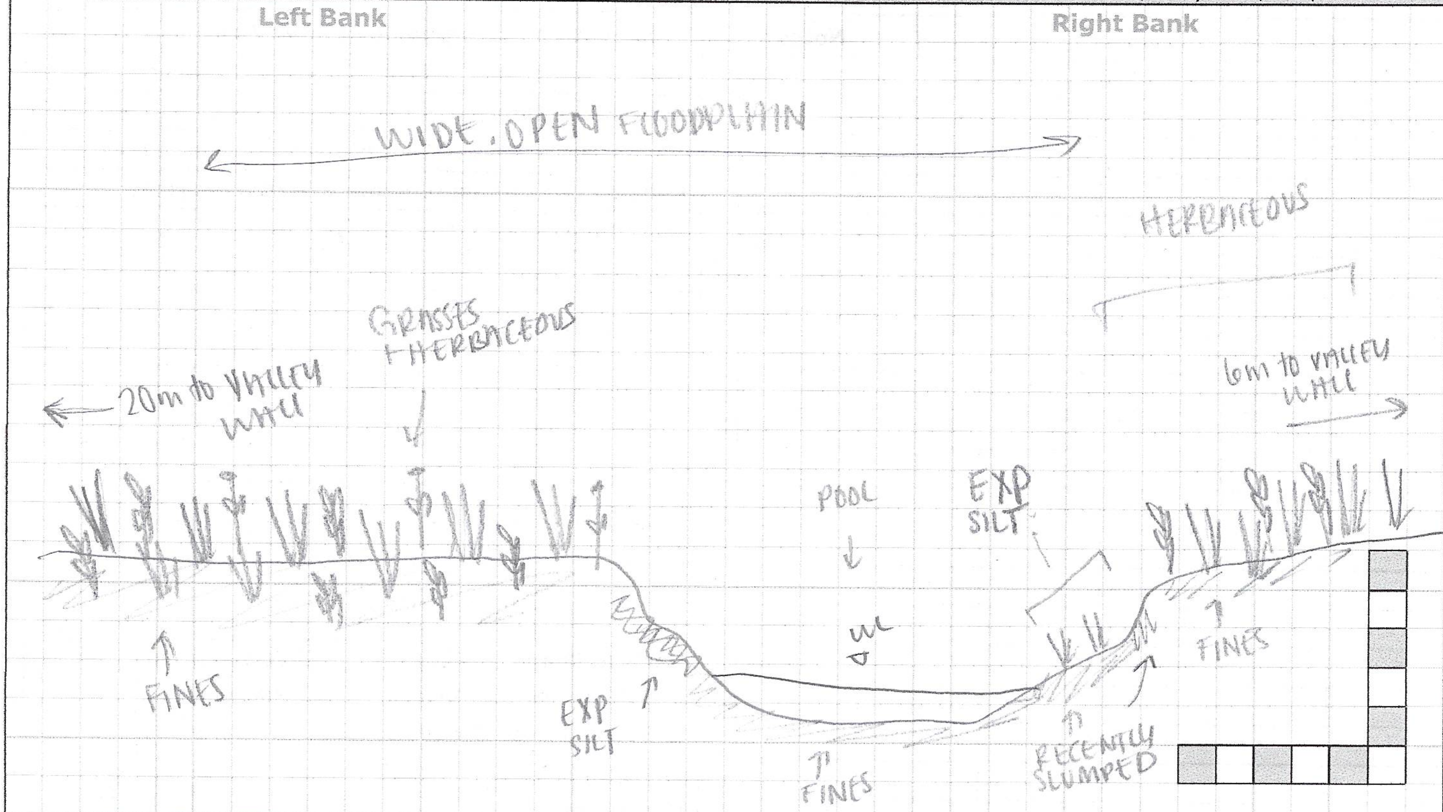
Bank Characteristics

Project Number: 23076

Date:	2024-08-06	**Cross-section:**	XS 8
Time:	12:49pm	**Reach:**	R3
Weather:	SUN 25°C	**Location:**	ORLEANS
Field Staff:	KM HM	**Watershed/Subwatershed:**	CARDINAL CREEK

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.

Left Bank | Right Bank



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☒ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	0.70	m
Bank Angle:	45	°
Root Depth:	0.05	m
Root Density:	20	%
Undercut:	0.02	m
Erosion Pin:	N/A	m
Torvane:	1.25	kg/cm²
Penetrometer:	1.00	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

⌖	Station location
├─┤	Monumented XS
⊡	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
XXXXX	Bank stabilization
x-x-x	Fence
VVV	Grasses
⋙	Leaning tree
☁	Tree
✱✱✱	Woody Debris
▭	Sediment sample
▭▭▭	Erosion pin
8	Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☒ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	0.60	m
Bank Angle:	35	°
Root Depth:	0.08	m
Root Density:	20	%
Undercut:	0.12 (FROM SLUMP)	m
Erosion Pin:	N/A	m
Torvane:	1.00	kg/cm²
Penetrometer:	1.50	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Assessment Long Profile ~~(Total Station)~~ **Project Code:** 23076

Date:	10-10-24	**Reach:**	C10
Time:	10:30	**Location:**	CARDINAL CREEK
Weather:	10°C SUN/CLOUD	**Watershed/Subwatershed:**	OTTAWA RIVER
Field Staff:	KS CM MK	**Rain in last 24 hours:**	[x] None ☐ Yes: Amount ____ mm

Point No.	Code	Notes
9000	BSSTN-1	
9001	WL, BED, DAM	WATER LEVEL,
↓		CHANNEL BED,
9433		BEAVER DAM
10000	ISLAND-WL	WATER LEVEL,
↓	ISLAND-BED	CHANNEL BED ALONG
10057		SIDE CHANNEL
* RTK4 → 23076-101024 *		

Survey Direction
☐ Upstream to Downstream
[x] Downstream to Upstream

Cross-sections
No. of Cross-sections Surveyed: 10
Monitoring Cross-sections: ☐ No [x] Yes
XS ID: ____ / ____ / ____
Erosion Pin Installed: ☐ No [x] Yes
XS ID: ____ / ____ / ____

Velocity & Sediment Transport
[x] Velocity ____ m/s **Method:**
☐ Discharge ____ m^3/s WB
Sed. Transport (Table 21): ☐ Suspended ☐ Saltation ☐ Sliding ☐ Rolling
Percentage of Bed Active: 0 %

Valley Type
[x] Confined ☐ Partially ☐ Unconfined

Channel Zone
☐ Headwater [x] Transfer [x] Deposition

Land Use
FOREST

Vegetation
Aquatic Vegetation: SUB/EMERGENT
Coverage of Reach: 10 %
[x] In Stream [x] Margins ☐ On Bank
Riparian Vegetation: ☐ No [x] Yes
Extent of Riparian Cover:
☐ Fragment ☐ None [x] Continuous
Riparian Cover (channel widths):
☐ 1-4 ☐ 4-10 [x] >10
Age Class of Riparian Vegetation:
Immature ☐ (<5 yrs) Established [x] (5-30 yrs) Mature [x] (>30 yrs)
Extent of Encroachment:
☐ None [x] Minimal ☐ Moderate ☐ Heavy ☐ Extreme
Density of Woody Debris:
☐ Low [x] Moderate ☐ High
Blockage(s) in Channel:
☐ Infrastructure [x] Dam ☐ LWD

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23076

Date:	10-10-24	**Stream:**	CARDINAL CREEK
Time:	10:30	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	ORLEANS
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

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

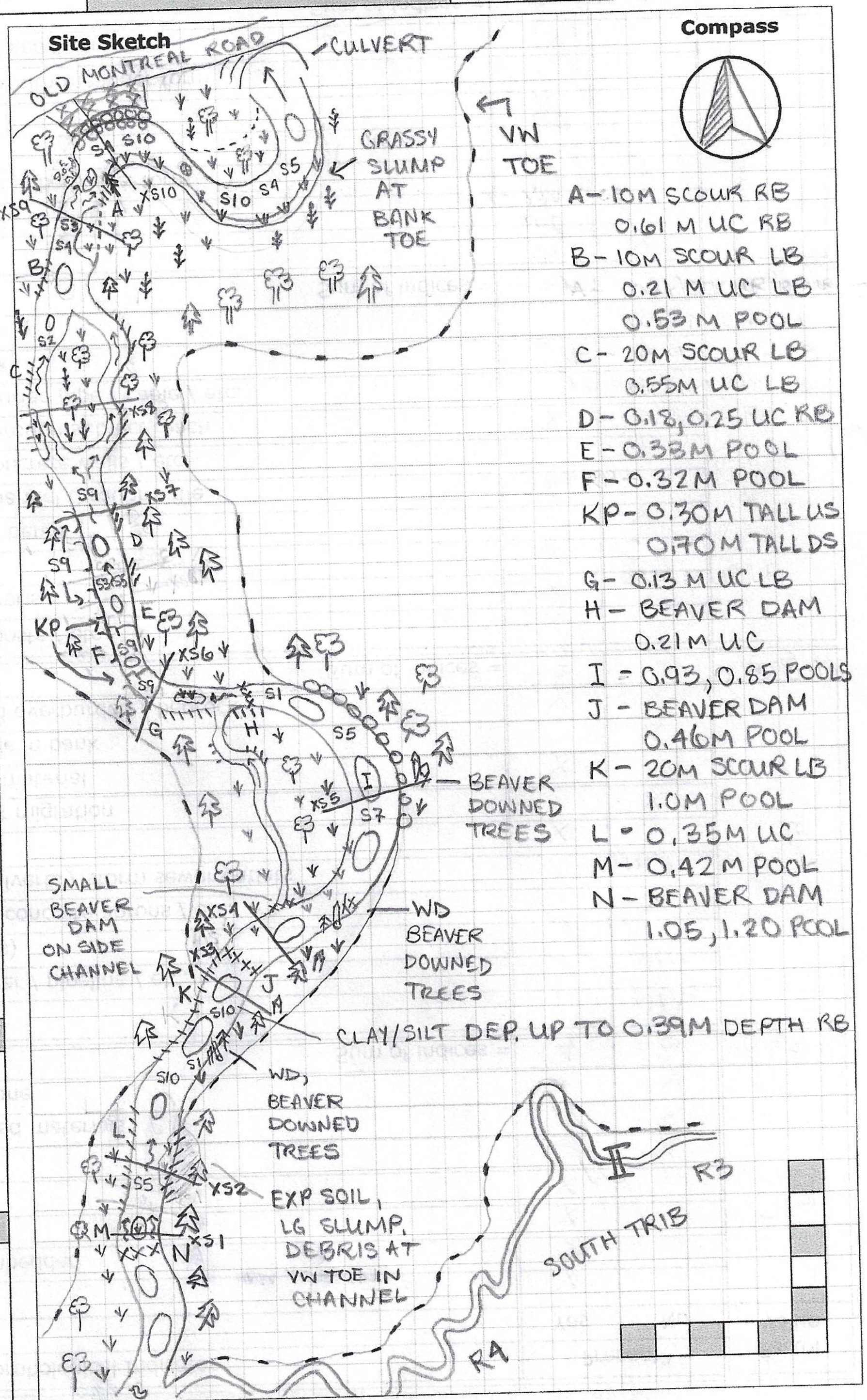
- Long-profile
- Monumented XS
- Monumented photo
- Monumented photo direction
- Sediment sampling
- Erosion pins
- Scour chains

Additional Symbols

- HERBACEOUS VEG
- IN-STREAM GUAGE ?
- GRASSY ISLAND
- JOINTED BEDROCK
- BEAVER DOWNED TREES

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	S10	CLAY TILL

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: ISLANDS W/ TREES IN 2 LOCATONS, ISLANDS /MATURE BARS W/ GRASS THROUGHOUT REACH, 3 BEAVER DAMS ACROSS MAIN CHANNEL W/IN US EXTENT OF REACH

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS1
Time:	12:00	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076 - 101024					
PT ID → 100					
PT CODE → XS1					
		XS1BF			
		XS1WE			
		XS1P — CENTER BAR			
		XS1PE — "			
		LVW — LB VW			

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

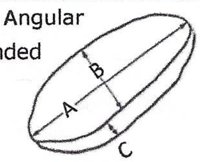
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	8.2			10.5			8.3			9.5	
	11			3.3			10			10	
	4.9			16.5			27			30.5	
11	9	4.8	1.7	1.0	0.3	1.7	1.4	0.5	8.5	5.8	5.6
	3.8			7.5			12.3			11	
	4			13.4			19.6			11.5	
	5.6			10			8.8			9.2	
7.2	4.5	3.9	2.4	1.2	0.5	15	14.8	8.5	7	5.4	3
	4.3			18			12			7.9	
	11.4			11.4			7			3	

Particle Shape: ☒ Platy ☐ Very Angular
☒ Sub-angular ☒ Angular ☐ Rounded
☒ Sub-Rounded ☐ Well Rounded

Embededness: 10 %

Subpavement: CLAY TILL



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated ______ m/s XS ID: 1

Distance 1 m Time 1.16 s V 0.86 m/s

Distance 1 m Time 1.12 s V 0.89 m/s

Distance 1 m Time 1.06 s V 0.94 m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

GEO MORPHIX™

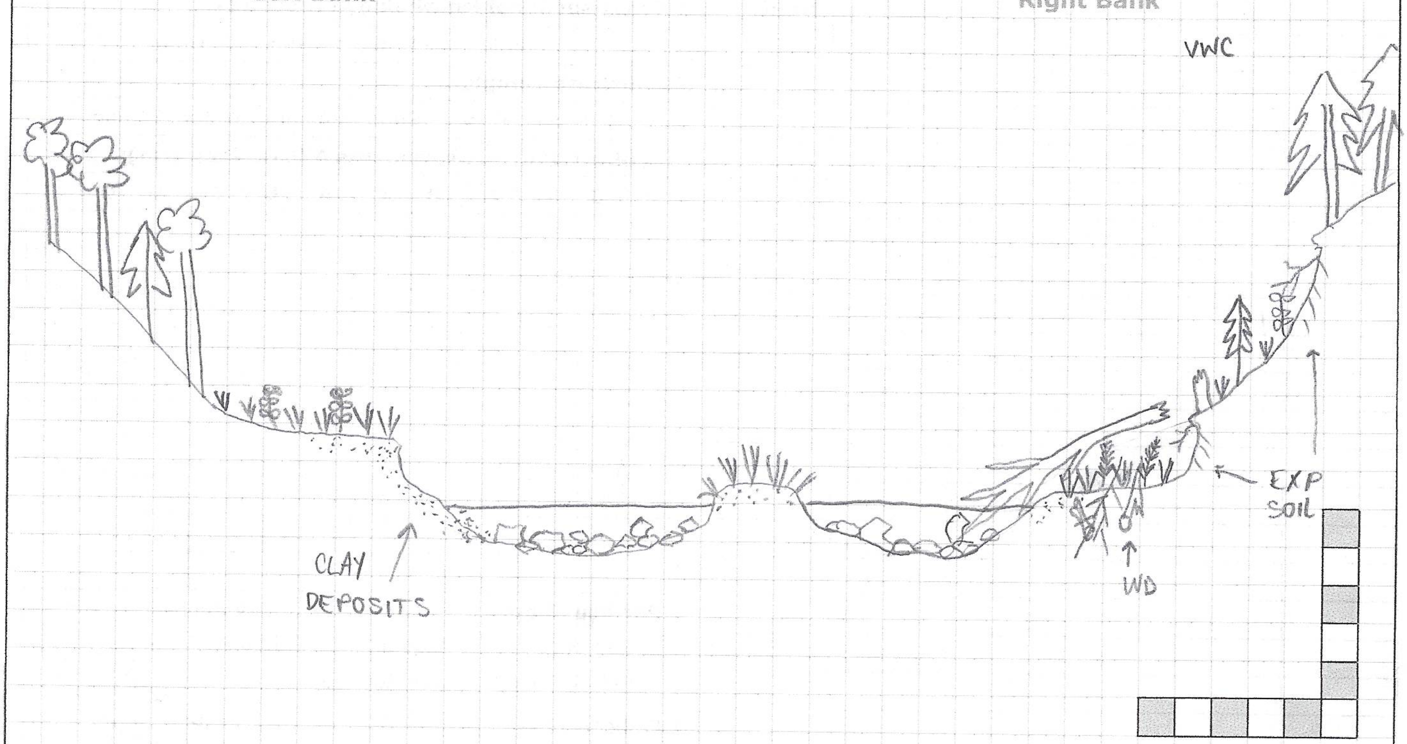
Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS1
Time:	12:00	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.

Left Bank | Right Bank



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	0.75	m
Bank Angle:	55	°
Root Depth:	0.20	m
Root Density:	10	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	1.0	kg/cm^2
Penetrometer:	0.75	kg/cm^2
Foot Used:	☐ Yes ☒ No	

Features

- Station location
- Monumented XS
- Monumented photo
- Undercut bank
- Eroded bank/slope
- Bank stabilization
- Fence
- Grasses
- Leaning tree
- Tree
- Woody Debris
- Sediment sample
- Erosion pin
- Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☐ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	1.0	m
Bank Angle:	60	°
Root Depth:	1.0	m
Root Density:	10	%
Undercut:	0.16	m
Erosion Pin:	—	m
Torvane:	3.0	kg/cm^2
Penetrometer:	1.75	kg/cm^2
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS2
Time:	12:45	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK 4 → 23076-101024					
PT ID → 200					
PT CODE →		XS2			
		XS2 BF			
		XS2 WE			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	FINES			11			21			31	
	2			12			22			32	
	3			13			23			33	
4	4	4	14	14	14	24	24	24	34	34	34
	5			15			25			35	
	6			16			26			36	
	7			17			27			37	
8	8	8	18	18	18	28	28	28	38	38	38
	9			19			29			39	
	10			20			30			40	

Particle Shape: ☐ Platy ☐ Very Angular ☐ Sub-angular ☐ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ______ %

Subpavement: ______

A B C [Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: ______

☐ Estimated ______ m/s XS ID: ______

Distance ______ m Time ______ s V ______ m/s

STAGNANT

Distance ______ m Time ______ s V ______ m/s

Distance ______ m Time ______ s V ______ m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

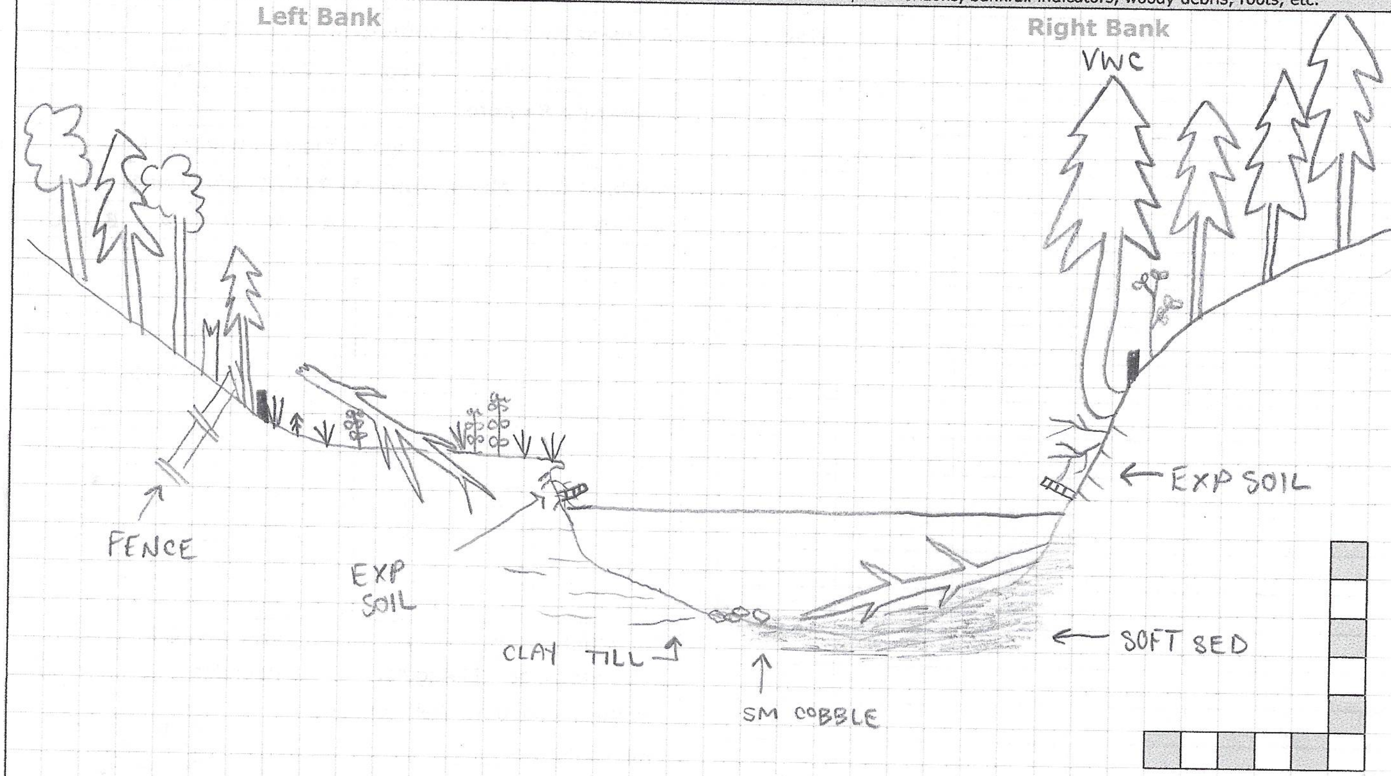
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS 2-M
Time:	12:45	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	1.75	m
Bank Angle:	50	°
Root Depth:	0.55	m
Root Density:	15	%
Undercut:	0.06	m
Erosion Pin:	0.26	m
Torvane:	0.5	kg/cm²
Penetrometer:	0.75	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
* * *	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	2.5	m
Bank Angle:	50	°
Root Depth:	1.5	m
Root Density:	20	%
Undercut:	0	m
Erosion Pin:	0.25	m
Torvane:	0.5	kg/cm²
Penetrometer:	1.0	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

XS BTW 2 BEAVER DAMS

Photos:

Version #4
Last edited: 21/02/2023

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

GEO
MORPHIX™

Detailed Cross-Section Characteristics　　Project Number:

Date:	10-10-24	**Cross-section:**	XS3
Time:	13:15	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PT ID → 300					
PT CODE → XS3					
		XS3BF			
		XS3WE			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

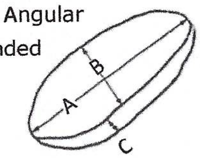
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	14.9			19			15.3			11.6	
	15.4			11.4			6			19.8	
	8.4			0.2			15			1.6	
9.4	6	3.5	10	9.4	3.9	11.5	7.3	6.4	6.8	4.5	2.9
	5.2			0.2			7			5.9	
	13			0.2			8.9			3.5	
	18			0.2			20			2.8	
16	14.5	4.8	19.5	14	3.8	8.9	7.5	3.9	6	5	4
	18			0.2			14			12.8	
	17.4			0.2			7.8			1.3	

Particle Shape: ☒ Platy ☐ Very Angular
☒ Sub-angular ☒ Angular ☐ Rounded
☒ Sub-Rounded ☐ Well Rounded

Embededness: 35 %

Subpavement: CLAY TILL



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.06 m/s XS ID: 3

Distance 0.5 m Time 11.89 s V 0.04 m/s

Distance 0.5 m Time 8.20 s V 0.06 m/s

Distance 0.5 m Time 7.40 s V 0.07 m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

GEO MORPHIX™

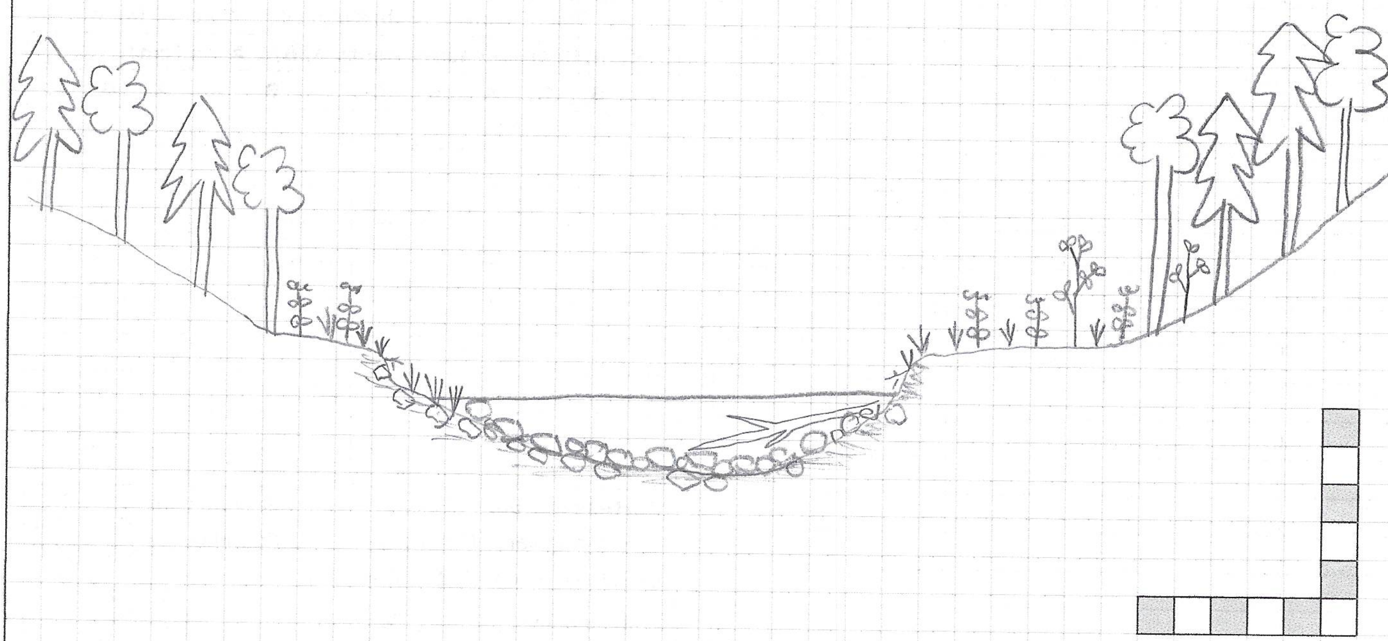
Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS3
Time:	13:15	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.

Left Bank | Right Bank



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☒ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	1.2	m
Bank Angle:	60	°
Root Depth:	0.35	m
Root Density:	20	%
Undercut:	0.16	m
Erosion Pin:	—	m
Torvane:	0.5	kg/cm²
Penetrometer:	1.75	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

- Station location
- Monumented XS
- Monumented photo
- Undercut bank
- Eroded bank/slope
- Bank stabilization
- Fence
- Grasses
- Leaning tree
- Tree
- Woody Debris
- Sediment sample
- Erosion pin
- Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	1.2	m
Bank Angle:	80	°
Root Depth:	0.45	m
Root Density:	15	%
Undercut:	0.19	m
Erosion Pin:	—	m
Torvane:	0.25	kg/cm²
Penetrometer:	1.0	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

BED CLAY DEPOSITS + COBBLE

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS4
Time:	13:45	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK 4 → 23076-101024					
PT ID → 400					
PT CODE → XS4					
		XS4BF			
		XS4WE			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

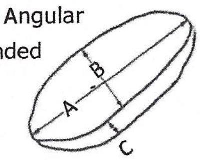
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	0.2			0.2			6.3			9	
	0.2			0.2			8.8			8.5	
	0.2			0.2			3.3			28.3	
6.5	4	1.1	23	17	4	5.4	5	2.5	6	4.3	1.2
	0.2			0.2			8.1			5	
	0.2			0.2			6.3			11.4	
	0.2			24.8			1.8			12.9	
7.5	5	0.5	11	10.1	1	4.5	4	1.5	7	4.3	1.8
	0.2			8.3			13.3			10	
	0.2			9			14			4.5	

Particle Shape: ☒ Platy ☐ Very Angular ☒ Sub-angular ☒ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: ________ %

Subpavement: ________



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________ %

Velocity

☐ Measured ________ m/s Method: WB

☒ Estimated 0.04 m/s XS ID: 4

Distance 0.5 m Time 14.25 s V 0.03 m/s

Distance 0.5 m Time 9.52 s V 0.05 m/s

Distance 0.5 m Time 10.91 s V 0.04 m/s

Discharge

☐ Estimated ________ m^3/s Method: ________

☐ Measured ________ m^3/s XS ID: ________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

Version #3
Last edited: 21/02/2023

GEO MORPHIX™

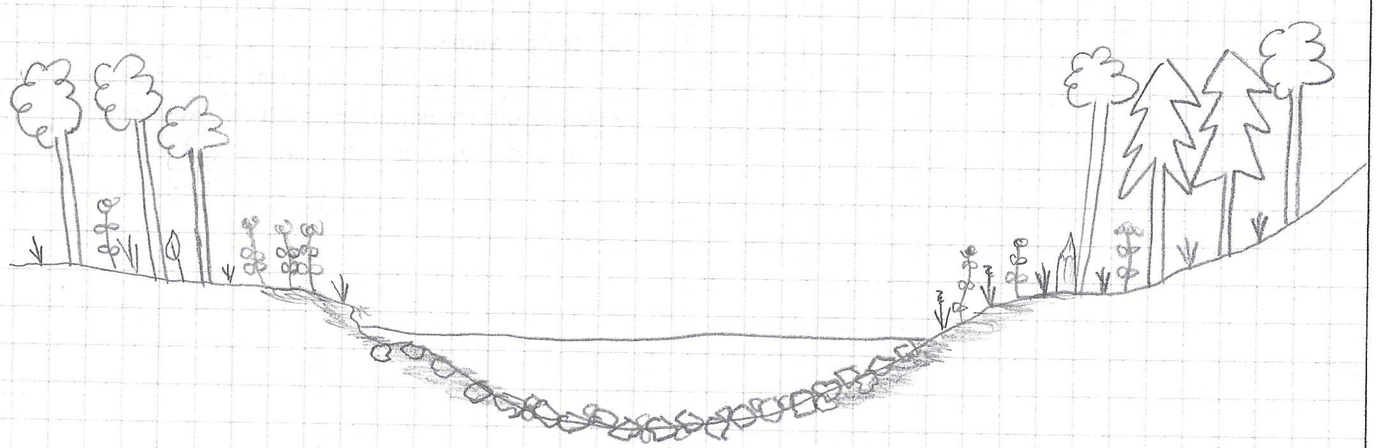
Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS4
Time:	13:45	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.

Left Bank | Right Bank



Left Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☐ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	1.2	m
Bank Angle:	30	°
Root Depth:	0.25	m
Root Density:	5	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	0.25	kg/cm²
Penetrometer:	1.0	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☐ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	1.25	m
Bank Angle:	26	°
Root Depth:	0.15	m
Root Density:	5	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	0.25	kg/cm²
Penetrometer:	0.75	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

BED COBBLE + BOULDER W CLAY DEPOSITS ALONG BANK MARGINS
LB IS INSIDE LG MEANDER BEND

Photos: UDLR

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number:

Date:	10-10-24	**Cross-section:**	XS5
Time:	14:15	**Reach:**	C10
Weather:	10°C CLOUDY	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PTID → 500					
PT CODE → XS5					
		XS5 BF			
		XS5 WE			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

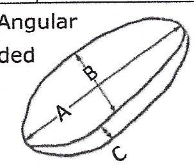
Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	0.2			48			12			0.6	
	0.2			49			16.1			0.8	
	0.2			26.1			26.4			1	
8	4.8	3	15.2	10.1	6				3	0.5	0.8
	0.2			10.6			26			2	
	0.2			3.2			33			1	
	0.2			32			8			1.3	
10	6.5	2	12	12	2.9				2	1.5	0.4
	2.6			10			15.6			1.8	
	7.4			16			32			1.4	

Particle Shape: ☐ Platy ☐ Very Angular
☒ Sub-angular ☒ Angular ☐ Rounded
☒ Sub-Rounded ☐ Well Rounded



Embededness: 10 %

Subpavement: BEDROCK

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☐ Moderate ☒ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ________

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ________ %

Velocity

☐ Measured ________ m/s Method: WB

☒ Estimated 0.04 m/s XS ID: 5

Distance 0.5 m Time 16.10 s V 0.03 m/s

Distance 0.5 m Time 14.01 s V 0.04 m/s

Distance 0.5 m Time 10.31 s V 0.05 m/s

Discharge

☐ Estimated ________ m^3/s Method: ________

☐ Measured ________ m^3/s XS ID: ________

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Depth ________ m Width ________ m V_{60} ________ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

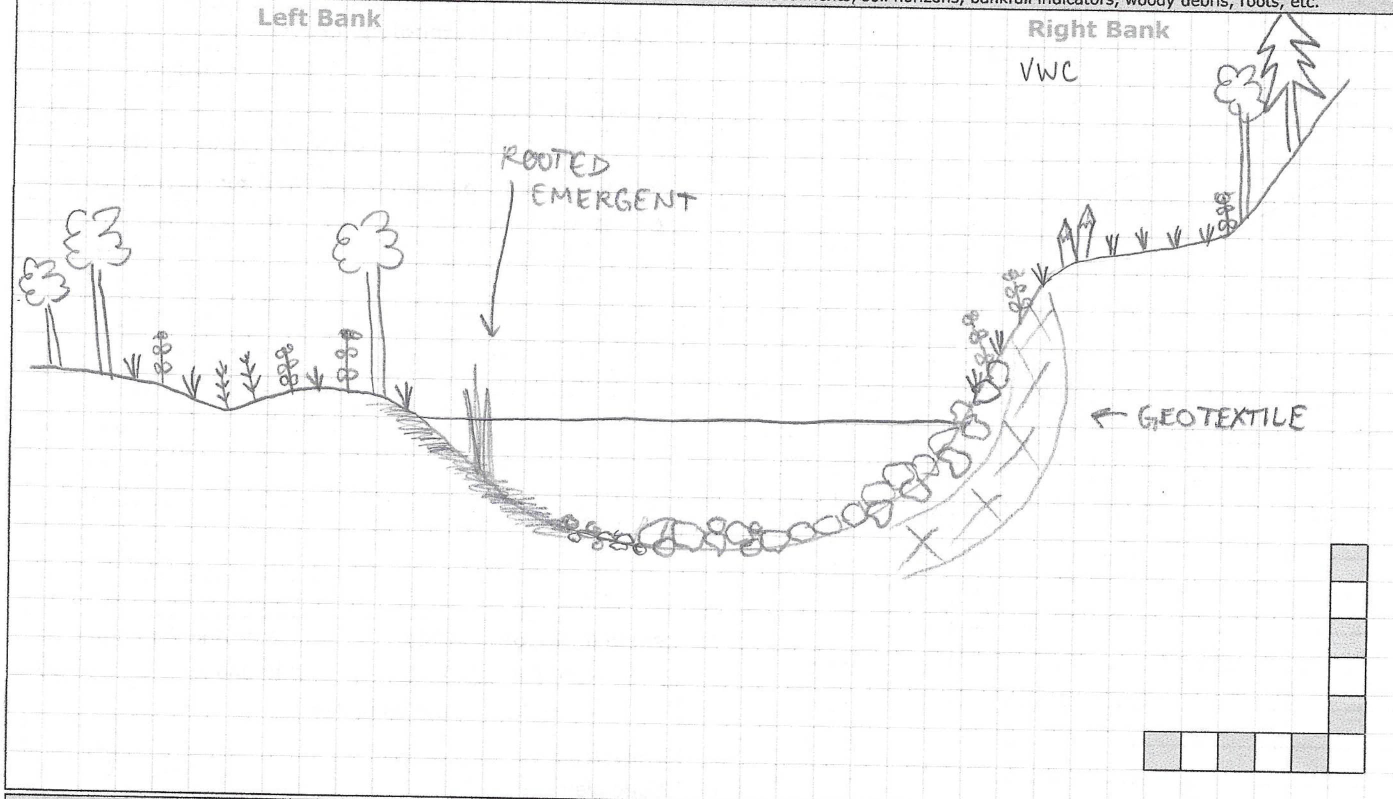
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS 5
Time:	14:15	**Reach:**	C10
Weather:	10°C CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

- ☐ Bedrock
- ☐ Till
- ☒ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☐ Large Cobble
- ☐ Small Boulder
- ☐ Large Boulder

Bank Height:	1.15	m
Bank Angle:	15	°
Root Depth:	0.20	m
Root Density:	15	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	2.5	kg/cm²
Penetrometer:	1.0	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
* * *	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

- ☐ Bedrock
- ☐ Till
- ☐ Clay
- ☐ Silt
- ☐ Sand
- ☐ Gravel
- ☐ Small Cobble
- ☒ Large Cobble
- ☒ Small Boulder
- ☐ Large Boulder

Bank Height:	4.0	m
Bank Angle:	45	°
Root Depth:	0.30	m
Root Density:	15	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	N/A	kg/cm²
Penetrometer:	1.5	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

LB ISLAND ON INSIDE LG MEANDER BEND
COBBLES + BOULDERS ALONG RB PART OF BANK PROTECTION ALONG OUTSIDE BEND OF LG MEANDER IMMEDIATELY US OF BEAVER DAM

Photos: UDLR

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS6
Time:	14:45	**Reach:**	C10
Weather:	10°C CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PT ID → 600					
PT CODE →		XS6			
		XS6 WE			
		XS6 BF			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☐ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

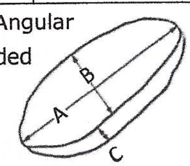
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	5			BEDROCK			BEDROCK			BEDROCK	
	6			12			22			32	
	4.3			13			23			33	
8.5	7.4	2.3	5	3	1.8	24	24	24	34	34	34
	5			15			25			35	
	10			16			26			36	
	17			17			27			37	
3	2.6	0.8	18	18	18	28	28	28	38	38	38
	6			19			29			39	
	2.9			20			30			40	

Particle Shape: ☒ Platy ☐ Very Angular ☐ Sub-angular ☒ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: 0 %

Subpavement: BEDROCK



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.33 m/s XS ID: 6

Distance 1.0 m Time 3.41 s V 0.29 m/s

Distance 1.0 m Time 3.76 s V 0.26 m/s

Distance 1.0 m Time 2.31 s V 0.43 m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

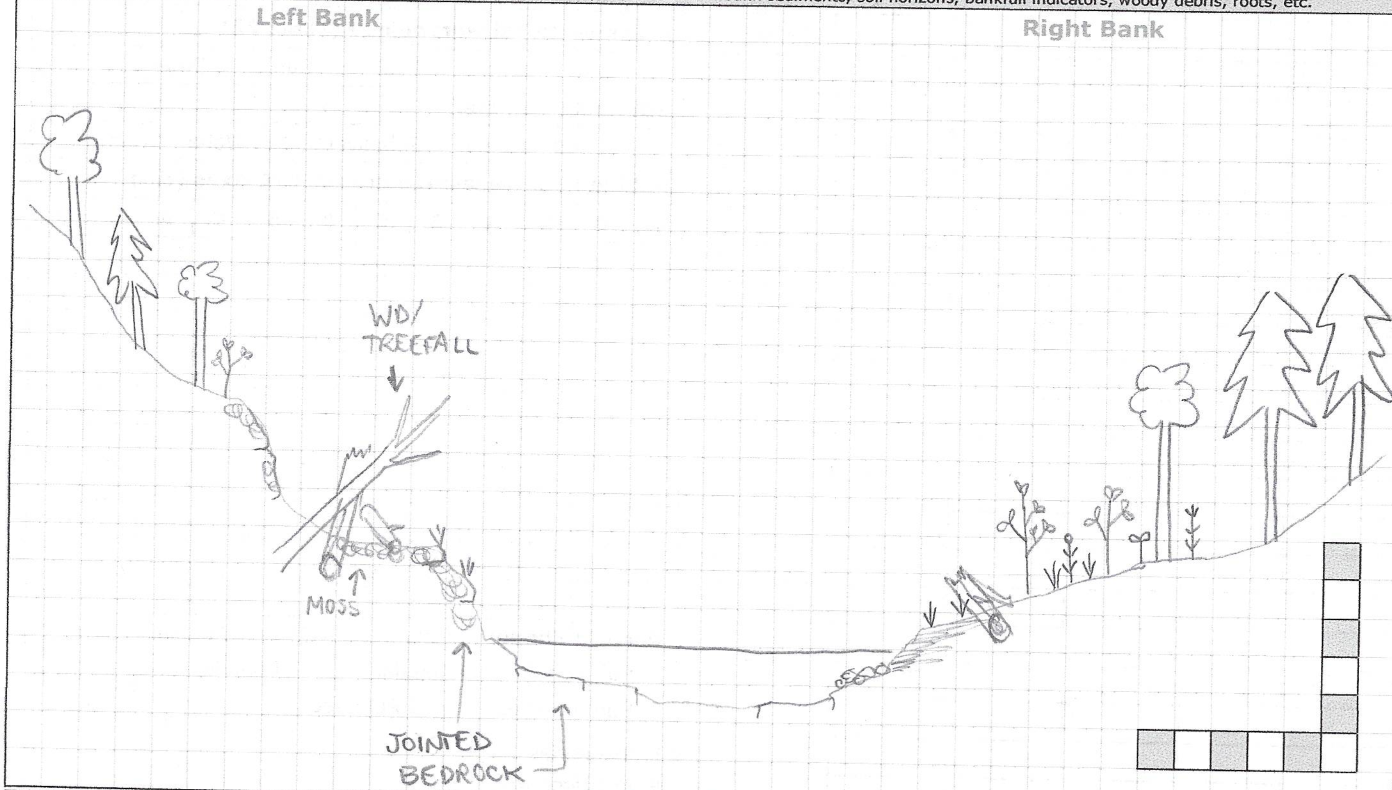
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS6
Time:	14:45	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials		
☒ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☐ Clay	☐ Large Cobble	
☐ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	1.3	m
Bank Angle:	45	°
Root Depth:	N/A	m
Root Density:	N/A	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	N/A	kg/cm²
Penetrometer:	N/A	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features	
	Station location
	Monumented XS
	Monumented photo
	Undercut bank
	Eroded bank/slope
	Bank stabilization
	Fence
	Grasses
	Leaning tree
	Tree
	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☒ Clay	☐ Large Cobble	
☐ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	0.80	m
Bank Angle:	20	°
Root Depth:	0.25	m
Root Density:	15	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	0.25	kg/cm²
Penetrometer:	1.5	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

XS IMMEDIATELY DS KNICKPOINT IN BEDROCK

Photos:

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS7
Time:	15:00	**Reach:**	C10
Weather:	10°C CLOUDY	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PT ID → 700					
PT CODE → XS7					
		XS7WE			
		XS7 BF			

Cross-sectional Morphology (Table 22)

☐ Riffle ☒ Pool ☒ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

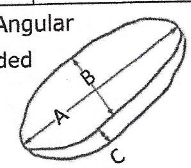
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
3.5			7			BEDROCK			BEDROCK		
5.4			11.3								
3.8			10.4								
42	38	36	15	14	4.2						
11			13.3								
8			2								
9.4			7.4								
19	13	7.8	4.4	3.4	2.3						
9			2.2								
12.2			3.9								

Particle Shape: ☒ Platy ☐ Very Angular ☐ Sub-angular ☒ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded

Embededness: 0 %

Subpavement: BEDROCK



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.20 m/s XS ID: 7

Distance 1 m Time 6.01 s V 0.17 m/s

Distance 1 m Time 4.29 s V 0.23 m/s

Distance 1 m Time 4.83 s V 0.21 m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

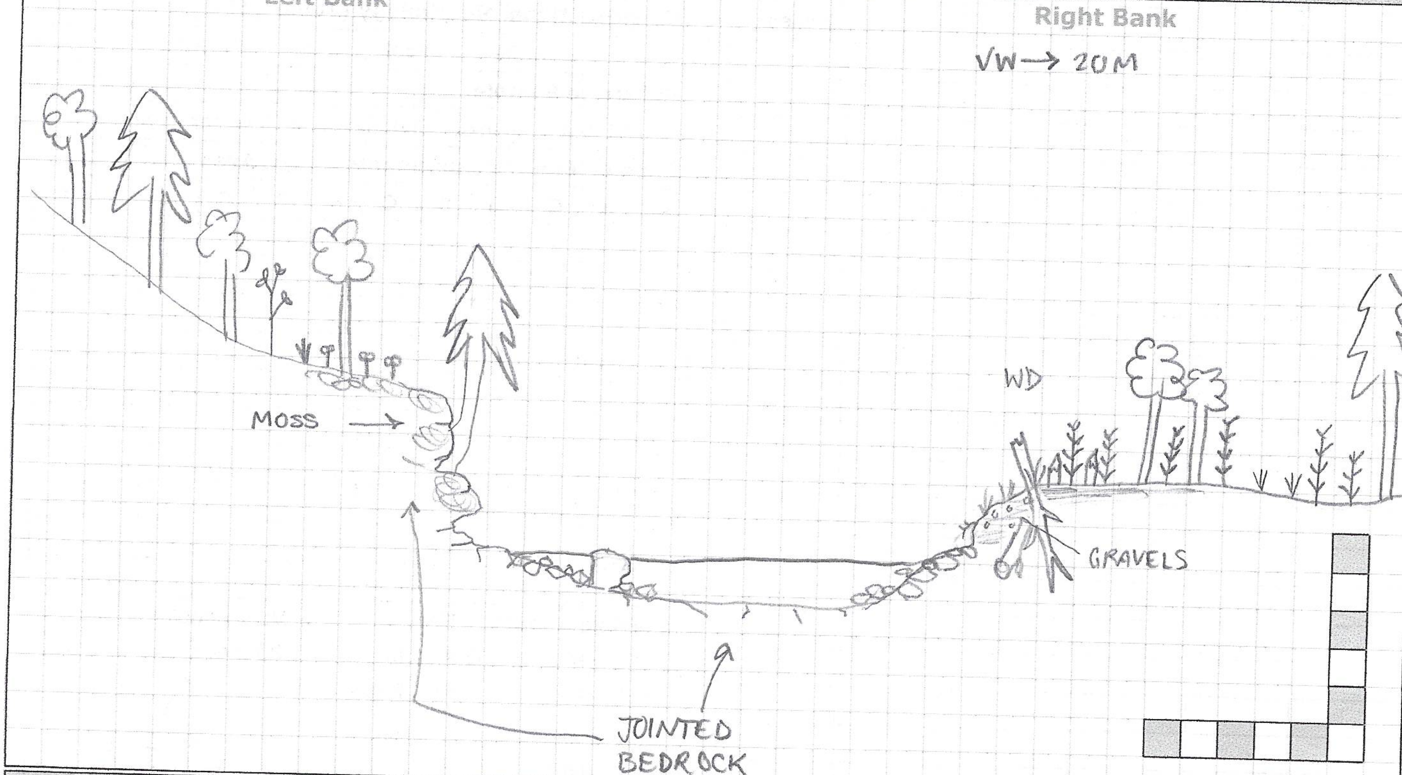
GEO MORPHIX™

Bank Characteristics

Project Number:

Date:	10-10-24	**Cross-section:**	XS7
Time:	15:00	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials

☒ Bedrock ☐ Gravel
☐ Till ☐ Small Cobble
☐ Clay ☐ Large Cobble
☐ Silt ☐ Small Boulder
☐ Sand ☐ Large Boulder

Bank Height:	1.4	m
Bank Angle:	85	°
Root Depth:	N/A	m
Root Density:	N/A	%
Undercut:	N/A	m
Erosion Pin:	—	m
Torvane:	N/A	kg/cm²
Penetrometer:	N/A	kg/cm²

Foot Used: ☐ Yes ☒ No

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
/////	Eroded bank/slope
	Bank stabilization
x-x-x	Fence
	Grasses
	Leaning tree
	Tree
x x x	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

☐ Bedrock ☒ Gravel
☐ Till ☐ Small Cobble
☒ Clay ☐ Large Cobble
☐ Silt ☐ Small Boulder
☐ Sand ☐ Large Boulder

Bank Height:	0.75	m
Bank Angle:	30	°
Root Depth:	0.4	m
Root Density:	20	%
Undercut:	0.15	m
Erosion Pin:	—	m
Torvane:	0.25	kg/cm²
Penetrometer:	1.0	kg/cm²

Foot Used: ☐ Yes ☒ No

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS8
Time:	15:30	**Reach:**	C10
Weather:	10°C CLOUD/SUN	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PT ID → 800					
PT CODE → XS8					

VELOCITY XS 8 RIGHT CHANNEL

	D(M)	T(S)	V(M/S)	AVG V (M/S)
R	1	2.43	0.41	0.39
	1	2.70	0.37	

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

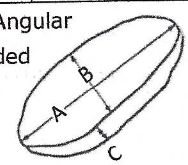
Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	6			10.4			5			3.8	
	3.4			6.8			1.5			6.4	
	14.5			5.8			4.8			11.5	
18	13	9.9	28	21	4	6	4	1.2	4	3.4	1.4
	12.5			3.7			6.3			10.4	
	9.8			12			1.4			10.1	
	8			10			6			7.8	
15	12.4	3	15	12	3.5	6.3	3.5	2.8	2	1.8	1.2
	9.5			10.5			5.5			8	
	7.5			7.6			3			13	

Particle Shape: ☒ Platy ☐ Very Angular ☒ Sub-angular ☒ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



Embededness: 5 %

Subpavement: BEDROCK

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.345 m/s XS ID: 8 LEFT CHANNEL

L Distance 1 m Time 2.85 s V 0.35 m/s

Distance 1 m Time 2.92 s V 0.34 m/s

Distance ______ m Time ______ s V ______ m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

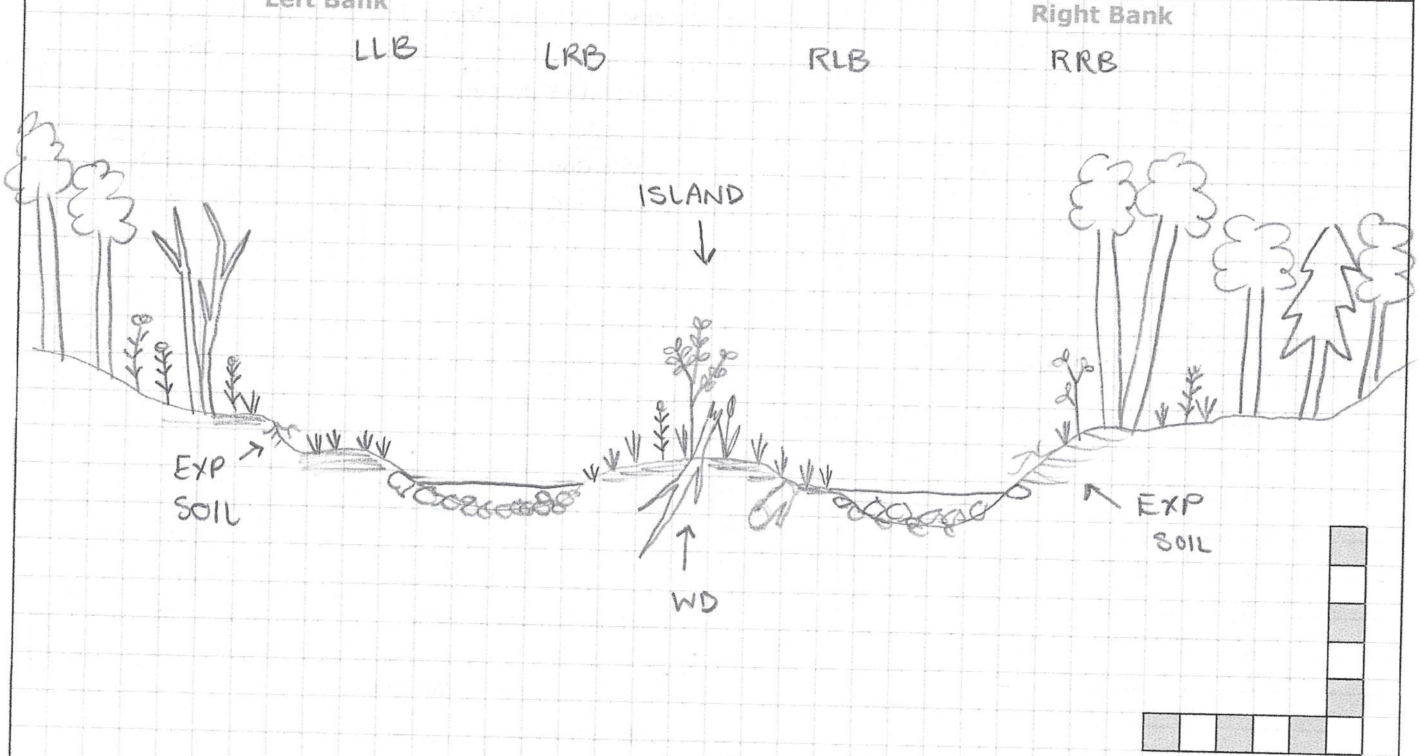
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS8
Time:	15:30	**Reach:**	C10
Weather:	10°C CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials			
☐ Bedrock	☐ Gravel		
☐ Till	☐ Small Cobble		
☒ Clay	☐ Large Cobble		
☐ Silt	☐ Small Boulder		
☐ Sand	☐ Large Boulder		
Bank Height:	0.85 / 0.50	m	
Bank Angle:	50 / 50	°	
Root Depth:	0.25 / 0.30	m	
Root Density:	10 / 25	%	
Undercut:	0 / 0	m	
Erosion Pin:	—	m	
Torvane:	1.75 / 0.25	kg/cm²	
Penetrometer:	2 / 0.75	kg/cm²	
Foot Used:	☐ Yes ☒ No		

Features	
	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials			
☐ Bedrock	☐ Gravel		
☐ Till	☐ Small Cobble		
☒ Clay	☐ Large Cobble		
☐ Silt	☐ Small Boulder		
☐ Sand	☐ Large Boulder		
Bank Height:	0.40 / 0.80	m	
Bank Angle:	10 / 75	°	
Root Depth:	0.15 / 0.60	m	
Root Density:	10 / 25	%	
Undercut:	0 / 0.42	m	
Erosion Pin:	—	m	
Torvane:	0.25 / 1.0	kg/cm²	
Penetrometer:	0.5 / 1.5	kg/cm²	
Foot Used:	☐ Yes ☒ No		

Additional Notes

TREE + HERBACEOUS + GRASSY VEG ON ISLAND

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS9-M
Time:	15:45	**Reach:**	C10
Weather:	10°C CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTK4 → 23076-101024					
PT ID → 900					
PT CODE →		XS9			
		XS9WL			
		XS9BF			

Cross-sectional Morphology (Table 22)

☒ Riffle ☐ Pool ☐ Run ☐ Other

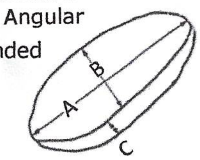
Substrate Sample:

☒ Bed ☒ Bank ☐ Subpavement ☐ Water ☐ None

Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	7.6			3.6			2.6		1.8		
	2.8				4.4		2.5		2.2		
	1.4		3.1				1.1			2.9	
2.4	1.8	1.2	7.6	4	0.4	1.1	0.8	0.4	3.6	2.8	1.6
	3.1			2.6			3.4			5.0	
	2.4			2.2			1.06			1.8	
	2.9			1.1			1.4			2.4	
2	1.4	0.4	1.6	1.4	0.6	1.4	1.1	0.4	6.4	3.6	3.6
	1.1			0.8			1.4			14.2	
	0.4			0.8			3.9			9.4	

Particle Shape: ☒ Platy ☐ Very Angular ☒ Sub-angular ☒ Angular ☐ Rounded ☐ Sub-Rounded ☐ Well Rounded



Embededness: ______ %

Subpavement: ______

[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.89 m/s XS ID: 9

Distance 1 m Time 1.19 s V 0.84 m/s

Distance 1 m Time 1.13 s V 0.88 m/s

Distance 1 m Time 1.06 s V 0.94 m/s

Discharge

☐ Estimated ______ m^3/s Method: ______

☐ Measured ______ m^3/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

Version #3
Last edited: 21/02/2023

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

GEO MORPHIX™

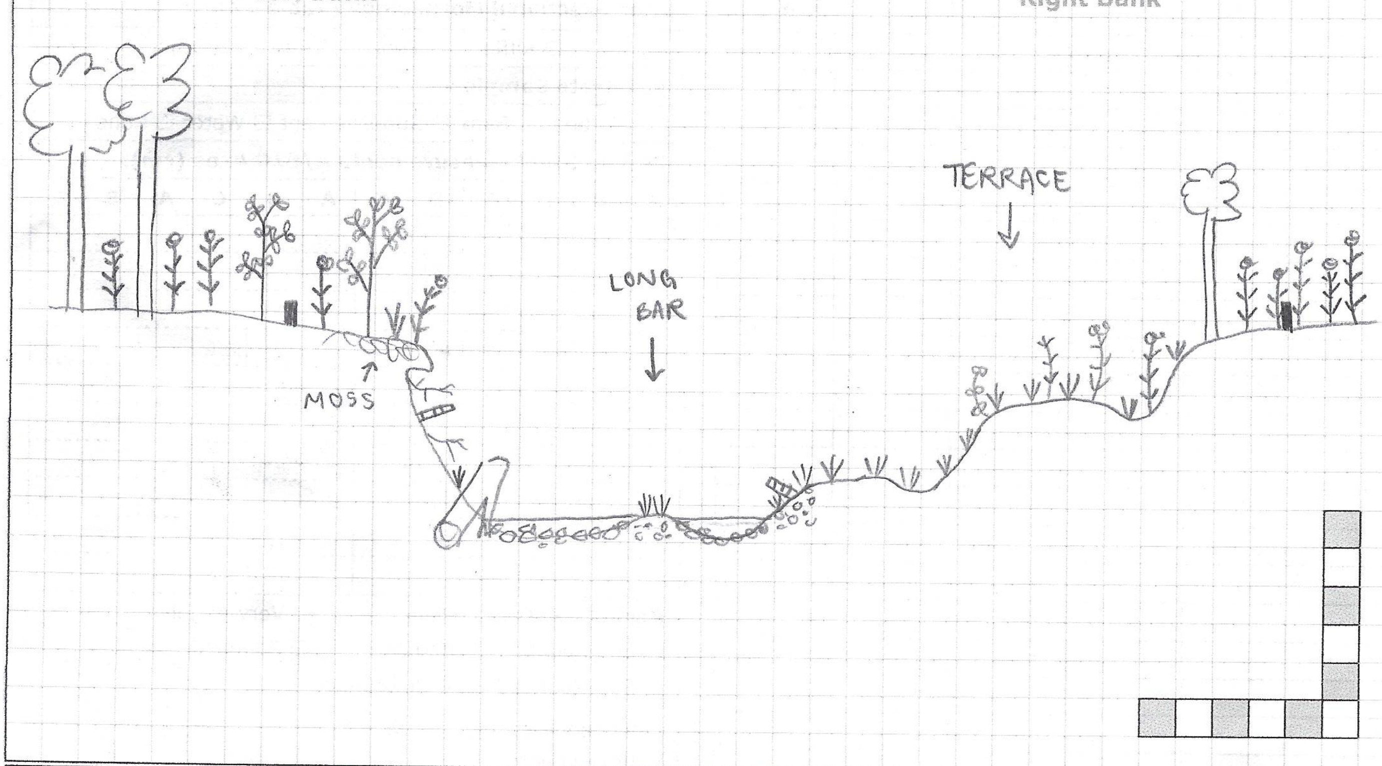
Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS9-M
Time:	15:45	**Reach:**	C10
Weather:	10°c CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.

Left Bank Right Bank



Left Bank Materials

☐ Bedrock	☒ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☐ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	1.57	m
Bank Angle:	60	°
Root Depth:	1.57	m
Root Density:	10	%
Undercut:	0.08	m
Erosion Pin:	0.20	m
Torvane:	1.8	kg/cm²
Penetrometer:	0.5	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features

	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
×-×-×	Fence
	Grasses
	Leaning tree
	Tree
×××	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials

☐ Bedrock	☐ Gravel
☐ Till	☐ Small Cobble
☒ Clay	☐ Large Cobble
☒ Silt	☐ Small Boulder
☐ Sand	☐ Large Boulder

Bank Height:	0.46	m
Bank Angle:	20	°
Root Depth:	0.10	m
Root Density:	10	%
Undercut:	0	m
Erosion Pin:	0.20	m
Torvane:	1.0	kg/cm²
Penetrometer:	0.25	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

Photos:

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Detailed Cross-Section Characteristics

Project Number:

Date:	10-10-24	**Cross-section:**	XS10
Time:	14:15	**Reach:**	C10
Weather:	10°C SUN/CLOUD	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

					Notes
RTKA → 23076-101024					
PTID → 1000					
PT CODE → XS10					

Cross-sectional Morphology (Table 22)

☐ Riffle ☐ Pool ☒ Run ☐ Other

Substrate Sample:

☐ Bed ☐ Bank ☐ Subpavement ☐ Water ☒ None

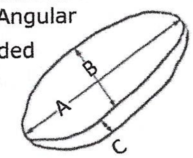
Pebble Count Measurements A/B/C Axes (cm):

A	B	C	A	B	C	A	B	C	A	B	C
	16.8			6.0			10.4			0.2	
	8.6			4.4			10.2				
	6.6			1.8			4.8				
14.8	10.8	6.0	3.4	2.6	0.2	11.4	6.8	5.2			
	8.6			1.4			8.1				
	8.9			1.8			5.8				
	4			1.8			1.8				
23	12.2	8.4	2.6	1.1	0.2	4.8	3.8	1.1			
	8.1			2.1			2.1				
	5.4			8.4			3.5				

Particle Shape: ☐ Platy ☐ Very Angular
☒ Sub-angular ☐ Angular ☐ Rounded
☒ Sub-Rounded ☐ Well Rounded

Embededness: 50 %

Subpavement: CLAY TILL



[Pebble ABC axis guide]

Sorting (Table 20): ☐ Well ☒ Moderate ☐ Poor ☐ Very poor

Sediment Transport

☐ Obsv ☒ Not Obsv ☐ Not Visible - Reason: ______

If Observed (Table 21):

☐ Suspended ☐ Sliding ☐ Rolling ☐ Saltation

Percentage of Bed Active: ______ %

Velocity

☐ Measured ______ m/s Method: WB

☒ Estimated 0.54 m/s XS ID: 10

Distance 1 m Time 2.12 s V 0.47 m/s

Distance 1 m Time 1.73 s V 0.58 m/s

Distance 1 m Time 1.72 s V 0.58 m/s

Discharge

☐ Estimated ______ m³/s Method: ______

☐ Measured ______ m³/s XS ID: ______

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Depth ______ m Width ______ m V_{60} ______ m/s

Use V_{60} if Depth < 0.75 m and V_{20} / V_{80} if Depth > 0.75 m

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

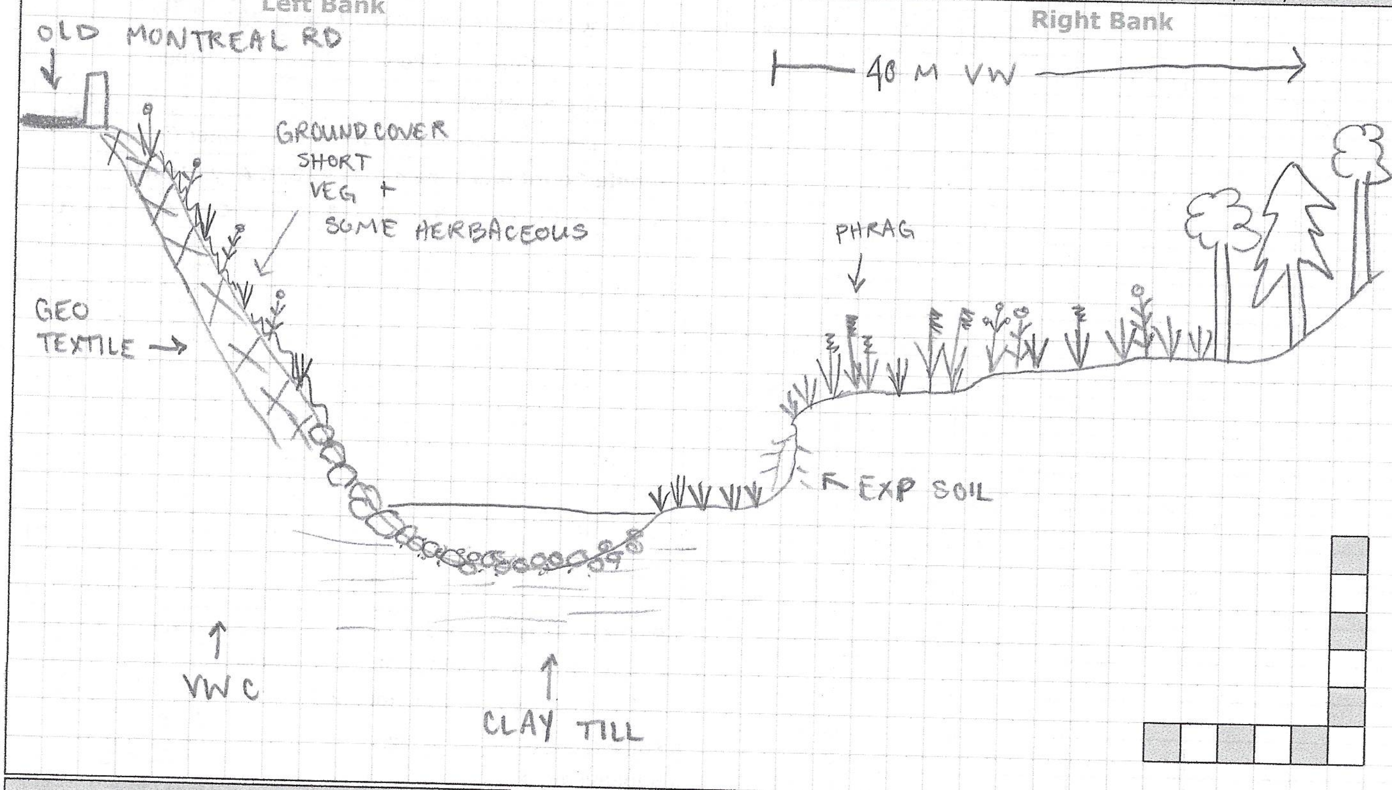
GEO MORPHIX™

Bank Characteristics

Project Number: 23076

Date:	10-10-24	**Cross-section:**	XS10
Time:	16:15	**Reach:**	C10
Weather:	10 °C CLOUD/SUN	**Location:**	CARDINAL CREEK
Field Staff:	KS CM MK	**Watershed/Subwatershed:**	OTTAWA RIVER

Sketch (Viewed Downstream) Include: measurements, bank slope, evidence of geomorphic processes/adjustments, geomorphic/bedform units, vegetation type & location, bed & bank materials, approx. water level, evidence of erosion, stratification in bank sediments, soil horizons, bankfull indicators, woody debris, roots, etc.



Left Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☒ Small Cobble	
☐ Clay	☒ Large Cobble	
☐ Silt	☒ Small Boulder	
☐ Sand	☒ Large Boulder	
Bank Height:	10	m
Bank Angle:	50	°
Root Depth:	N/A	m
Root Density:	N/A	%
Undercut:	0	m
Erosion Pin:	—	m
Torvane:	N/A	kg/cm²
Penetrometer:	N/A	kg/cm²
Foot Used:	☐ Yes ☒ No	

Features	
	Station location
	Monumented XS
	Monumented photo
------	Undercut bank
//////	Eroded bank/slope
	Bank stabilization
x--x--x	Fence
	Grasses
	Leaning tree
	Tree
	Woody Debris
	Sediment sample
	Erosion pin
	Scour/bed chain

Right Bank Materials		
☐ Bedrock	☐ Gravel	
☐ Till	☐ Small Cobble	
☒ Clay	☐ Large Cobble	
☒ Silt	☐ Small Boulder	
☐ Sand	☐ Large Boulder	
Bank Height:	1.55	m
Bank Angle:	37	°
Root Depth:	0.15	m
Root Density:	20	%
Undercut:	0.10	m
Erosion Pin:	—	m
Torvane:	1.0	kg/cm²
Penetrometer:	0.25	kg/cm²
Foot Used:	☐ Yes ☒ No	

Additional Notes

LB OUTSIDE LG MEANDER BEND PROTECTED W BOULDER/COBBLE AT TOE + GEO TEXTILE + PLANTING UP TO ROAD LEVEL

Photos:

Version #4
Last edited: 21/02/2023

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

Appendix H:
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach R3

Project Number:	PN23076	**Date:**	2024-08-07
Client:	Tamarack Developments	**Length Surveyed (m):**	88.5
Location:	Cardinal Creek South Tributary	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area:	1.9 km^2	**Dominant Riparian Vegetation Type:**	Herbaceous, Grasses
Geology/Soils:	Ottawa Valley Clay Plains	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forested valley	**Width of Riparian Cover:**	>10 channel widths
Valley Type:	Confined	**Age Class of Riparian Vegetation:**	Immature to Established
Dominant Instream Vegetation Type:	Algae	**Extent of Encroachment into Channel:**	Moderate
Portion of Reach with Vegetation:	5%	**Density of Woody Debris:**	Moderate

Hydrology

Estimated Discharge (m^3/s):	0.03	**Estimated Bankfull Discharge (m^3/s):**	1.27	*
Modelled 2-year Discharge (m^3/s):		**Estimated Bankfull Velocity (m/s):**	0.95	*
Modelled 2-year Velocity (m/s):		* Bankfull parameters affected by beaver dam activity		

Profile Characteristics

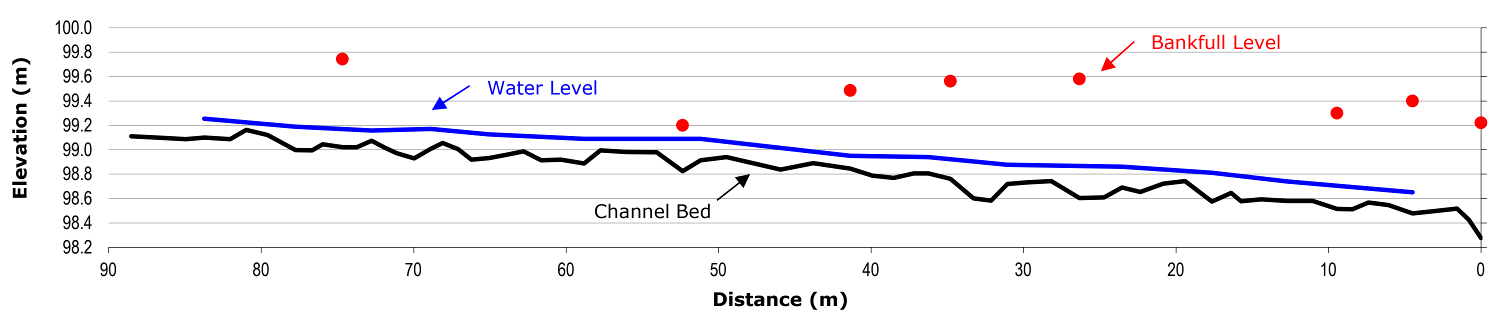
Bankfull Gradient (%):	0.41
Channel Bed Gradient (%):	0.76
Riffle Gradient (%):	4.61
Riffle Length (m):	4.29
Riffle-Pool Spacing (m):	0.00

Planform Characteristics

Sinuosity:	1.33	
Meander Belt Width (m):	25.8	*
Radius of Curvature (m):	15	
Meander Amplitude (m):	10	
Meander Wavelength (m):	15	

*Parish Geomorphic Ltd., 2013

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.45	0.85	0.61
Bank Angle (deg):	15	90	39
Root Depth (m):	0.05	0.16	0.11
Root Density (%):	5	30	18
Bank Undercut (m):	0.00	0.29	0.07

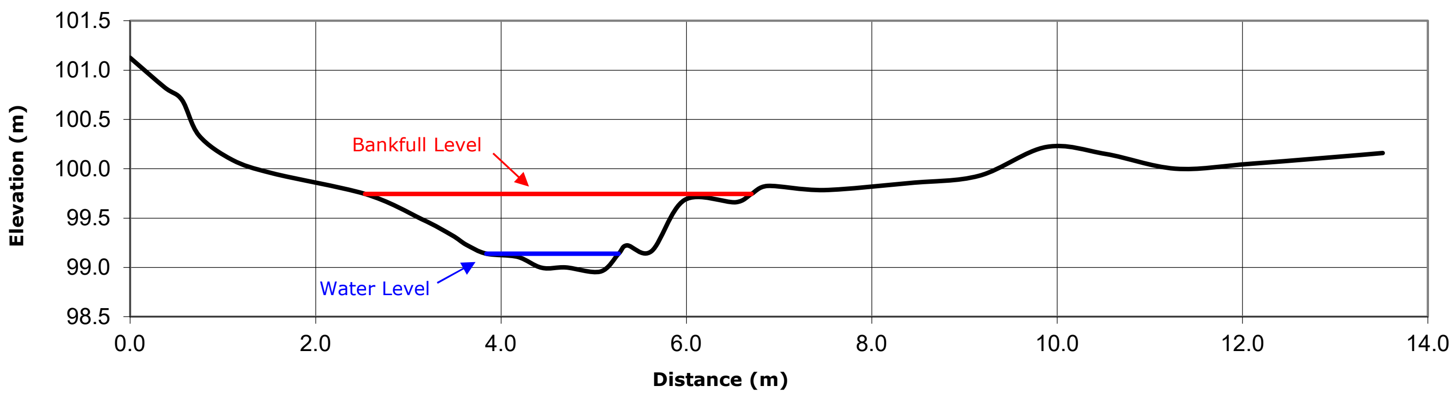
	Minimum	Maximum	Average
Penetrometer Value (kg/cm3):	0	1.5	0.7
Bank Material (range):	Clay/silt to pebble sized clay conglomerates		

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.10	4.71	3.62
Average Bankfull Depth (m):	0.16	0.46	0.37
Bankfull Width/Depth (m/m):	7	13	10
Wetted Width (m):	0.92	1.87	1.31
Average Water Depth (m):	0.02	0.14	0.05
Wetted Width/Depth (m/m):	14	75	33
Entrenchment Ratio (m/m):	>2.2 (Slight/Low Entrenchment)		
Maximum Water Depth (m):	0.04	0.19	0.11
Manning's *n*:		0.040	

Photograph at cross section 1 (looking downstream)

Representative Cross-Section #1



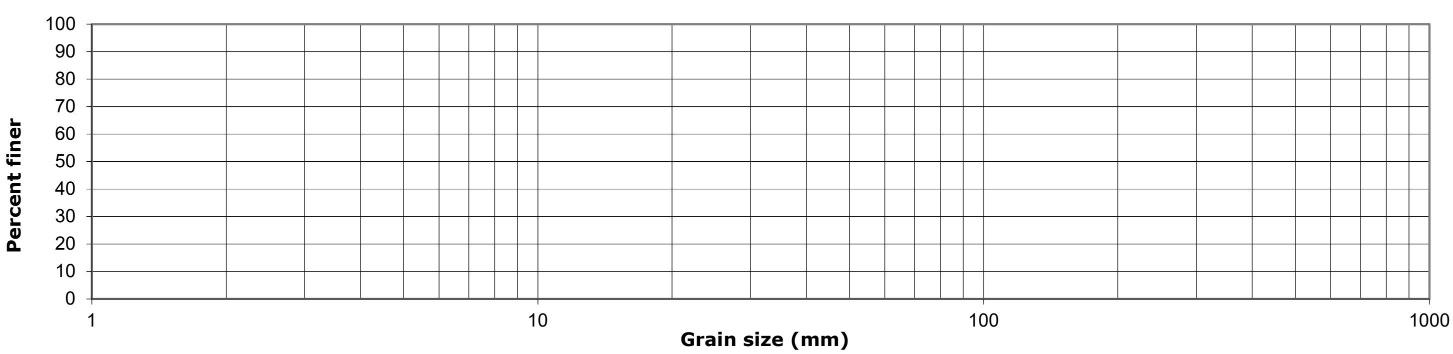
Substrate Characteristics

Particle Size (mm)

D_{10} :	2.0
D_{50} :	2.0
D_{84} :	2.0

Subpavement:	Clay
Particle Shape:	Round
Embeddedness (%):	<5
Particle Range (riffle):	Silt-pebble sized clay conglomerates
Particle Range (pool):	Silt

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	15.05
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	N/A
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	14		

General Field Observations

Channel Description

Reach **R3** was characterized by a sinuous channel set within a confined, wooded valley. The valley floor was previously inundated due to beaver activity and had since drained to reveal accumulated fine sediment deposits (e.g. clay to sand sized particles). Short grasses and herbaceous vegetation are populating the deposits, forming a beaver meadow. At the time of inspection, a channel was forming within the meadow and actively reworking the deposits of fine sediments. The channel bed morphology consisted of alternating riffle-pool sequences comprised primarily of fine sediments. A small proportion of the channel sediments were gravel sized and were generally limited to riffle features. The channel banks were vegetated but were relatively soft in composition and thus sensitive to erosion (e.g. slumping). The channel exhibited evidence of systematic aggradation and widening. For example, channel banks were generally unstable and in-channel bars/fine sediment deposits were common.

Cross Section 5 - Facing Downstream

Detailed Geomorphological Assessment Summary

Reach C10

Project Number:	PN23076	**Date:**	10-10-24
Client:	Tamarack Developments	**Length Surveyed (m):**	459.0
Location:	Cardinal Creek	**# of Cross-Sections:**	10

Reach Characteristics

Drainage Area:	3280 ha	**Dominant Riparian Vegetation Type:**	Forest
Geology/Soils:	Glaciomarine clay till; bedrock	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest, Residential	**Width of Riparian Cover:**	4 to 10 Channel Widths
Valley Type:	Confined	**Age Class of Riparian Vegetation:**	Established and Mature
Dominant Instream Vegetation Type:	Attached algae	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	10%	**Density of Woody Debris:**	Moderate

Hydrology

Estimated Discharge (m^3/s):	0.50	**Estimated Bankfull Discharge (m^3/s):**	16.85
		Estimated Bankfull Velocity (m/s):	2.00

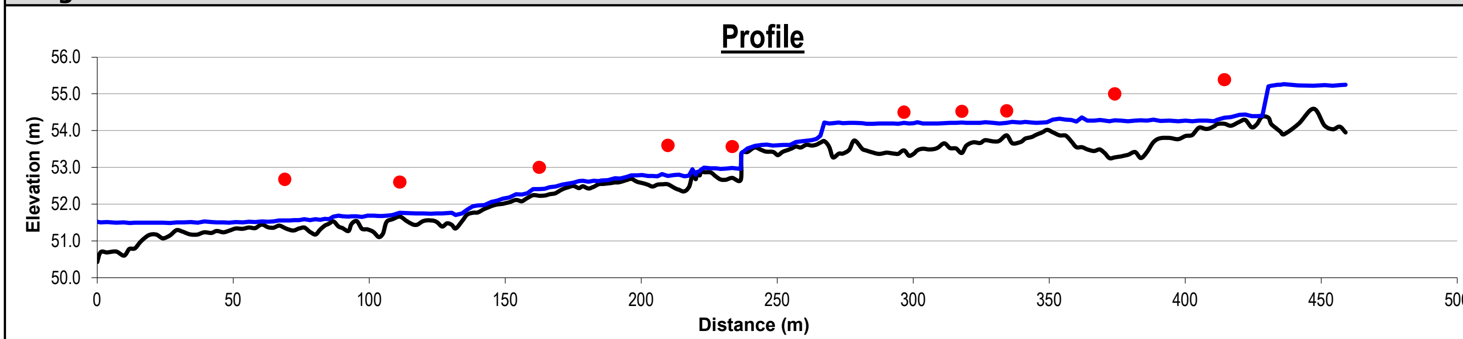
Profile Characteristics

Bankfull Gradient (%):	0.85
Channel Bed Gradient (%):	0.81
Riffle Gradient (%):	1.75
Riffle Length (m):	0.74
Riffle-Pool Spacing (m):	0.55

Planform Characteristics

Sinuosity:	1.49
Meander Belt Width (m):	Confined system, N/A
Radius of Curvature (m):	15.0
Meander Amplitude (m):	20.0
Meander Wavelength (m):	32.0

Longitudinal Profile



Bank Characteristics

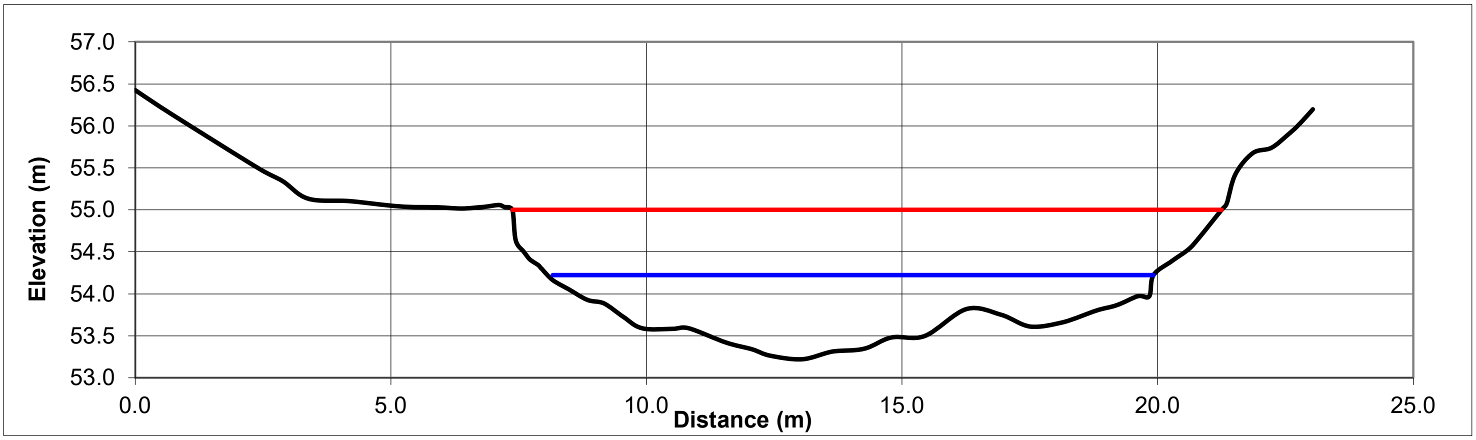
	Minimum	Maximum	Average		Minimum	Maximum	Average
Bank Height (m):	0.40	10.00	1.65	**Penetrometer Value (kg/cm3):**	0.25	3.00	1.00
Bank Angle (deg):	10	85	45	**Bank Material (range):**	Bedrock, clay, silt, gravel, cobble		
Root Depth (m):	0.10	1.57	0.46				
Root Density (%):	5	25	14				
Bank Undercut (m):	0.00	0.42	0.06				

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	8.90	23.21	13.32
Average Bankfull Depth (m):	0.50	1.05	0.72
Bankfull Width/Depth (m/m):	11	41	20
Wetted Width (m):	4.12	17.93	9.01
Average Water Depth (m):	0.09	0.54	0.28
Wetted Width/Depth (m/m):	19	81	39
Entrenchment Ratio (m/m):	>2.2 (Slight/Low Entrenchment)		
Maximum Water Depth (m):	0.21	1.00	0.51
Manning's *n*:		0.040	

Photograph at cross section 2 facing the left bank

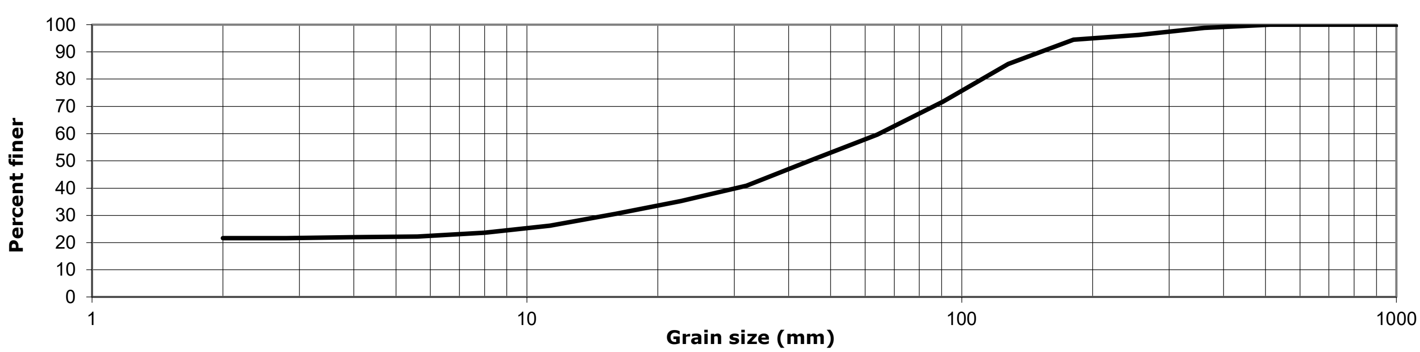
Representative Cross-Section 2



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Bedrock, clay till
D_{10} :	2.0	**Particle Shape:**	Platy, sub-angular, sub-rounded
D_{50} :	45.0	**Embeddedness (%):**	5 to 50
D_{84} :	120.0	**Particle Range (riffle):**	Sand to boulder
		Particle Range (pool):	Clay to cobble

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	59.72
for D_{50}:	1.14		
for D_{84}:	1.79	**Critical Shear Stress (D_{50}) (N/m^2):**	32.78
Unit Stream Power at Bankfull (W/m^2):	126		

General Field Observations

Channel Description

The subject reach was characterized by a meandering channel set within a confined wooded valley. Dominant riparian vegetation consisted of trees and grasses, which provided limited cover over the channel. Channel bed morphology was characterized by alternating riffle-pool sequences. The channel exhibited evidence of systematic widening. For example, leaning trees, accumulation of organic debris in the channel and basal scour throughout the reach was observed. Additionally, evidence of planimetric adjustment was noted due to multiple channels, the formation of two islands, and cutoff channels were noted. The channel also displayed multiple indicators associated with "good" channel health. For example, the channel was characterized by a variable bed morphology with diverse flow conditions and habitat refuge potential. Notably, extensive beaver activity was observed, including the establishment of three beaver dams towards the upstream extent of the assessed reach, resulting in the formation of several cutoff channels and scour pools. The channel flowed over bedrock along the center of the reach while exposed till, gravel and cobbles were noted along the up and downstream extents. Valley wall contact was observed at two locations, and large armour stones and geotextile were in place for protection.

Cross Section 8 - Facing Downstream

Appendix I: Hydrographs

GEO MORPHIX™

Erosion Mitigation Assessment

South Tributary
to Cardinal Creek

Ottawa, Ontario

Legend

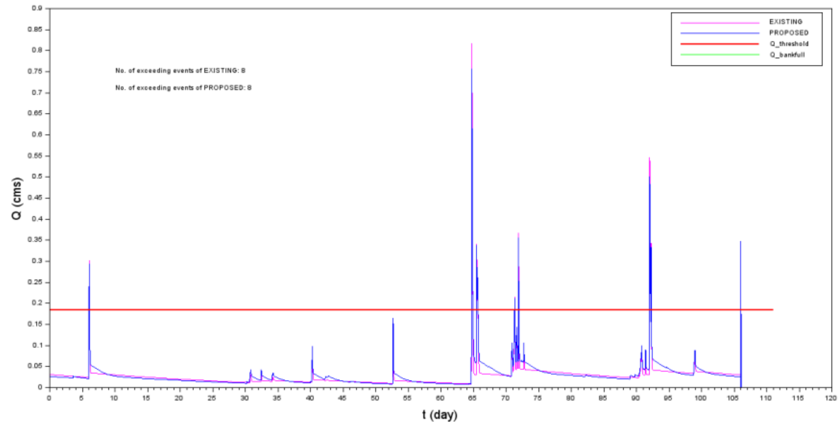
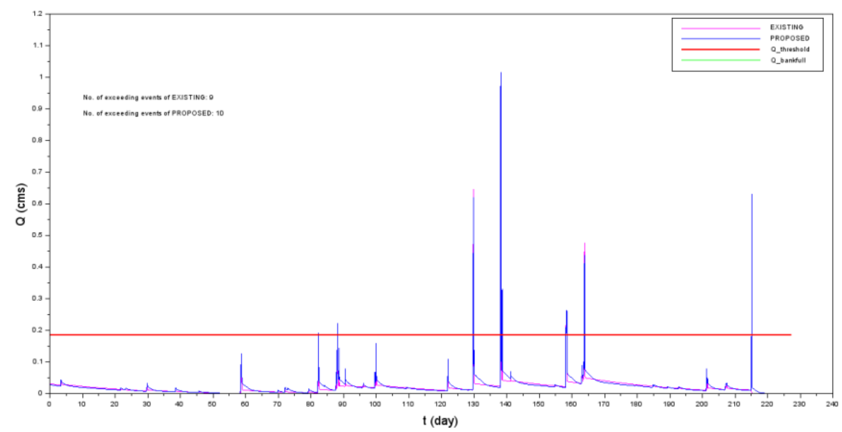
- Reach Break and ID
- Flow Modelling Node
- Watercourse
- 2024 Detailed Assessment
- 0.5 m Contour
- Approximate SWM Pond Location
- Approximate Boundary of 1320 Grand-Chene Court
- Approximate Subject Lands

N

0 80 160

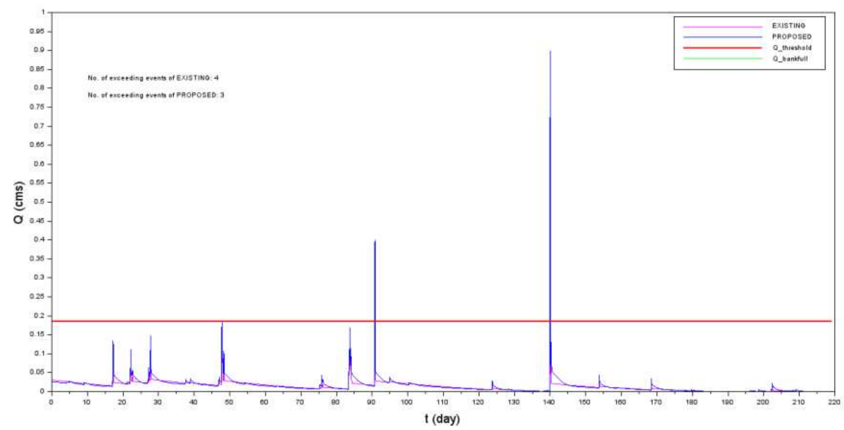
Metres

Imagery: City of Ottawa, 2021. Watercouse: OHN, 2021/GEO Morphix Ltd., 2023.Reach Break and ID: Parish, 2013/ GEO Morphix Ltd., 2024. Detailed Assessment: GEO Morphix Ltd., 2023. 0.5 m Contour: DSEL, 2023. Approximate SWM Pond and Node Location: GEO Morphix Ltd., 2024. Print Date: October, 2024. PN23076. Drawn By: K.Se., M.O., G.U.

Reach 3 **1967**	
Reach 3 **1968**	

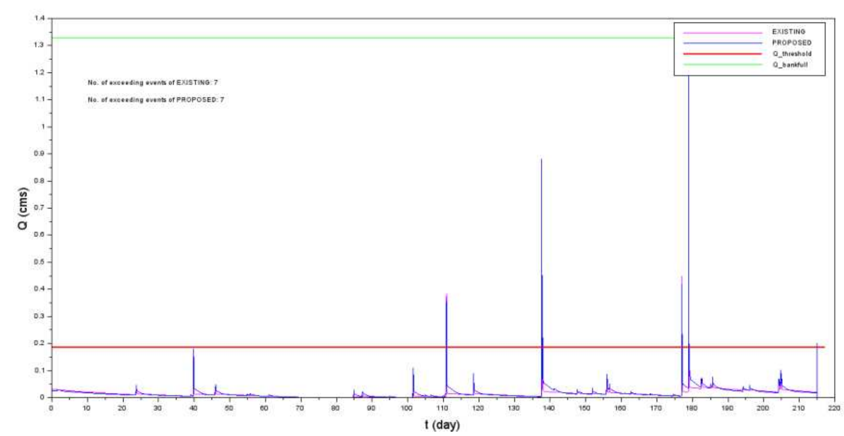
Reach 3

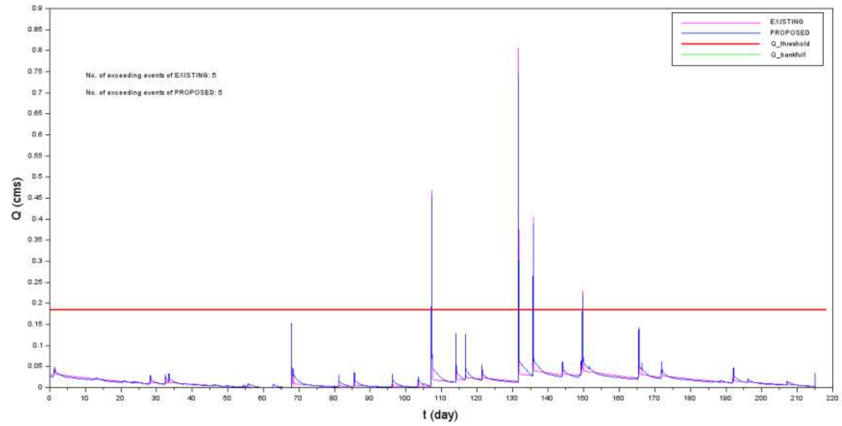
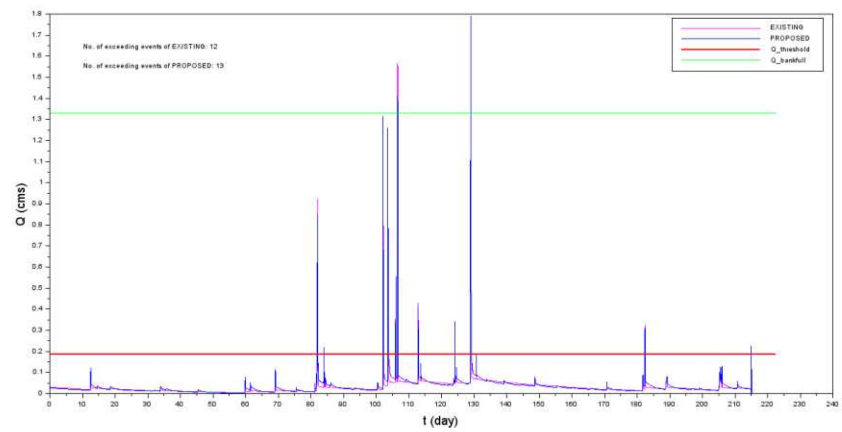
1969

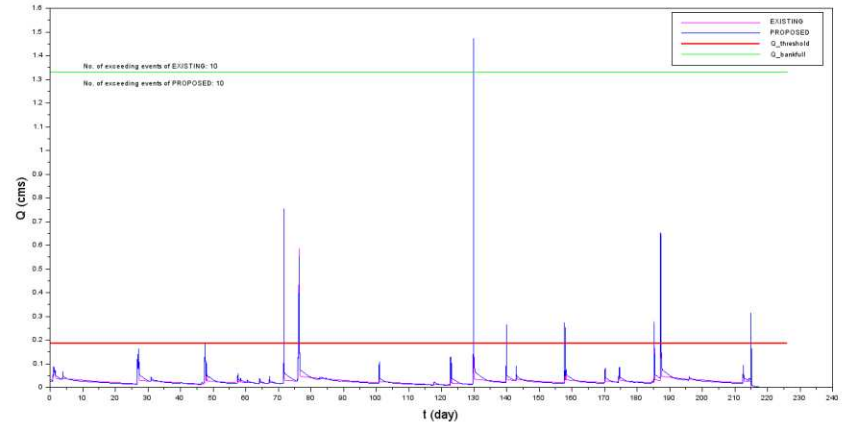
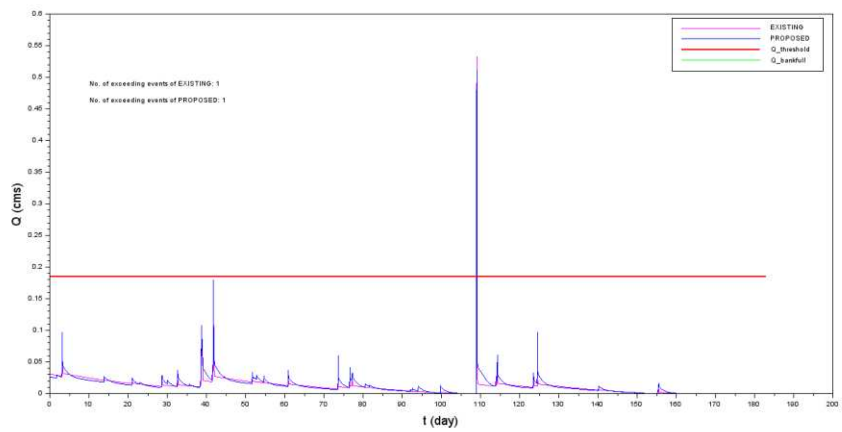


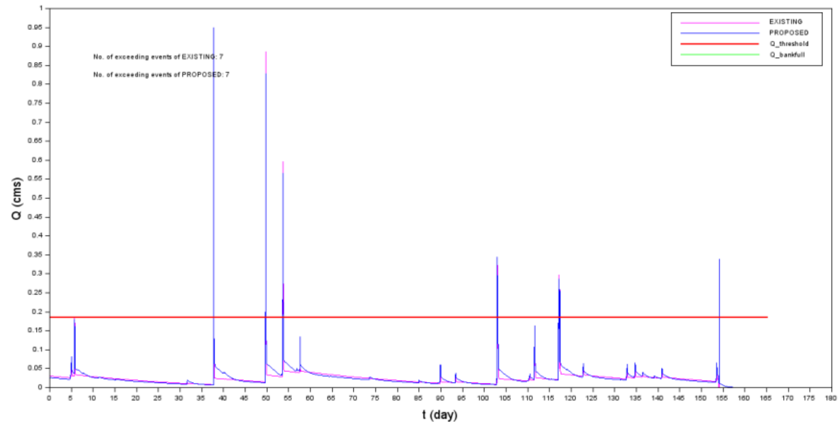
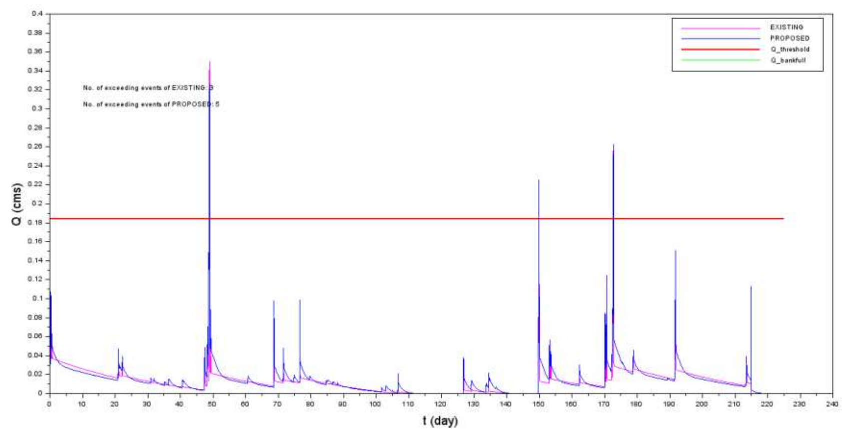
Reach 3

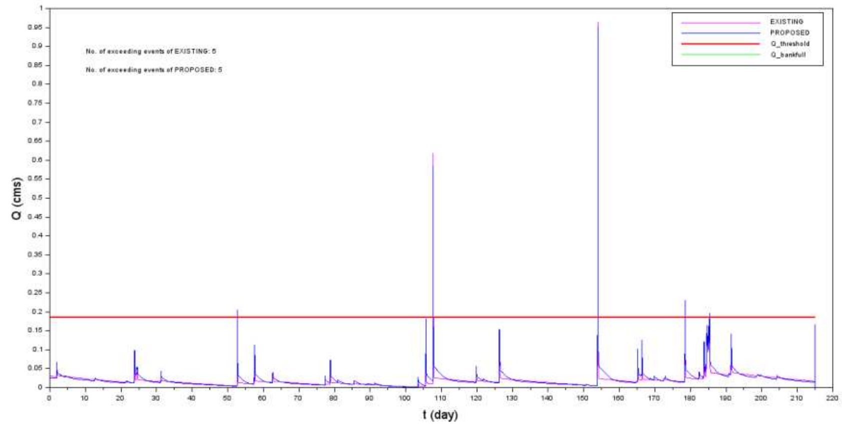
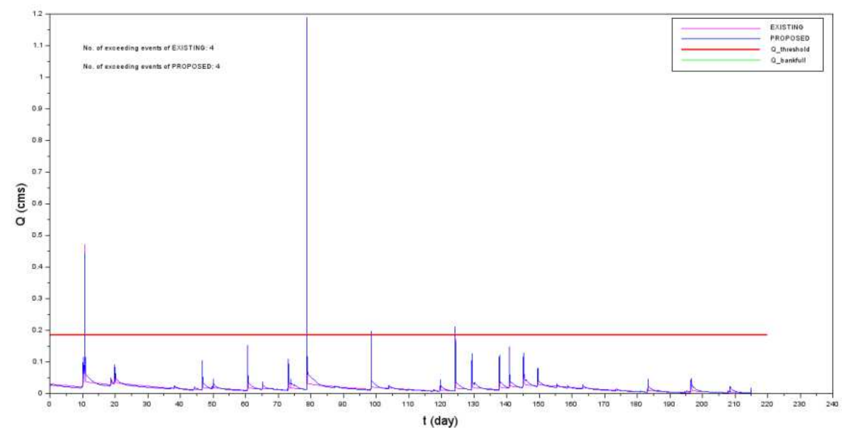
1970



Reach 3 **1971**	
Reach 3 **1972**	

Reach 3 **1973**	
Reach 3 **1974**	

Reach 3 **1975**	
Reach 3 **1976**	

Reach 3 **1977**	
Reach 3 **1978**	

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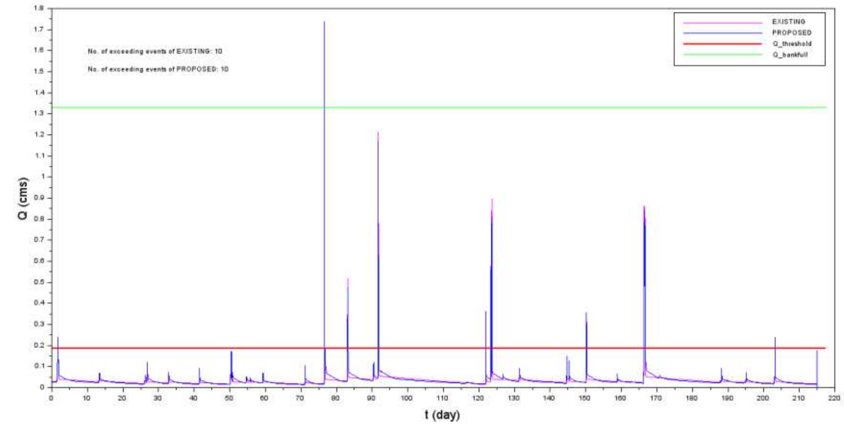
1979</td><td>
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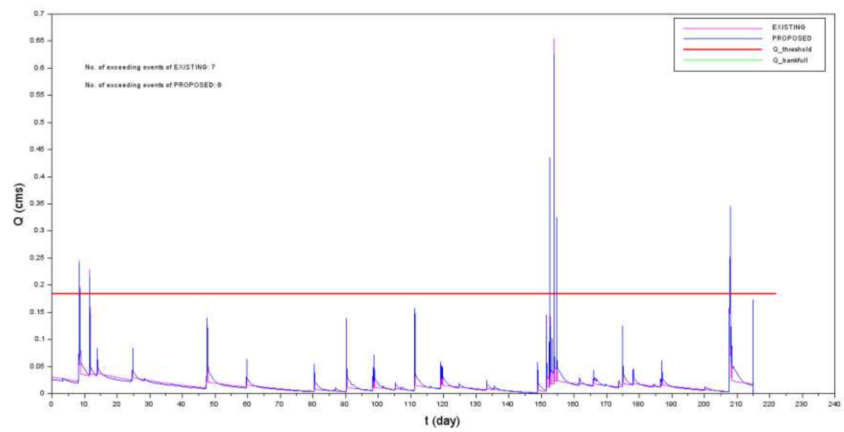
1980</td><td>
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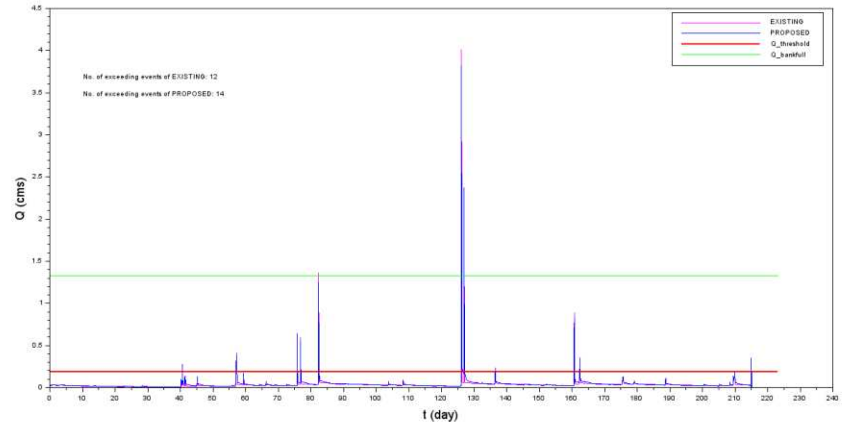
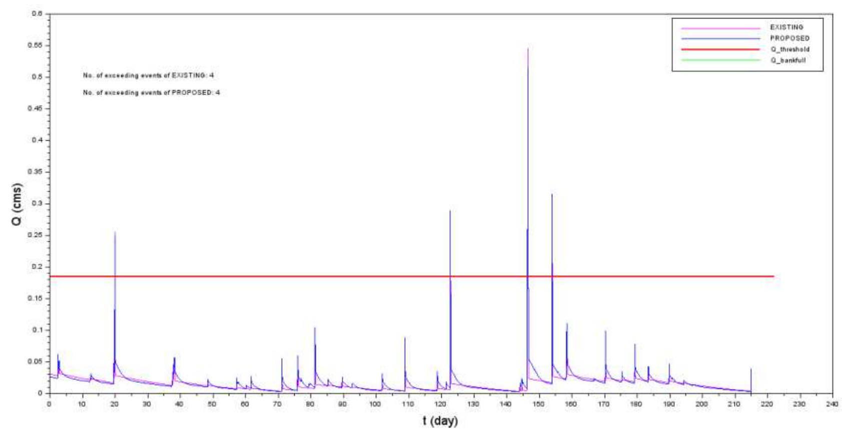
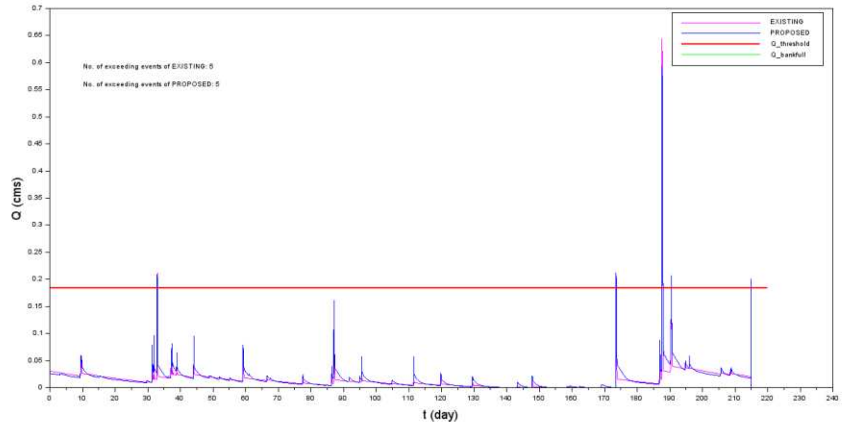
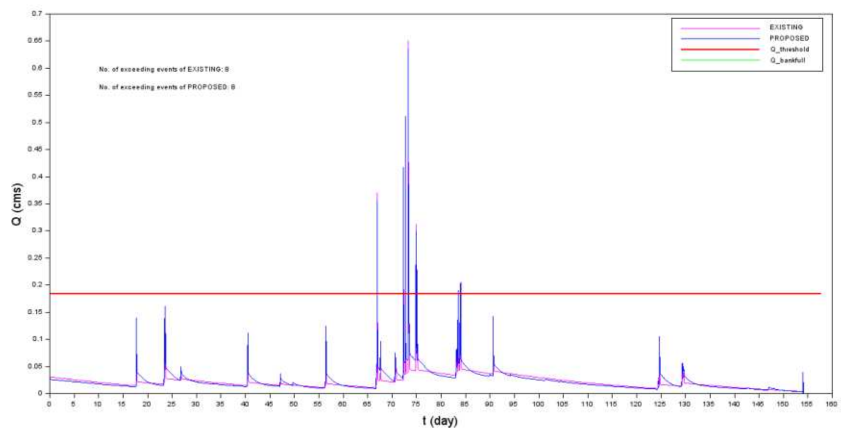
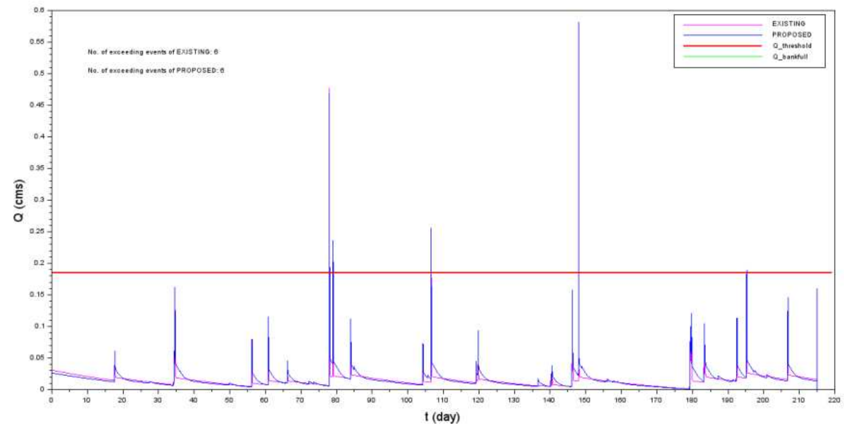
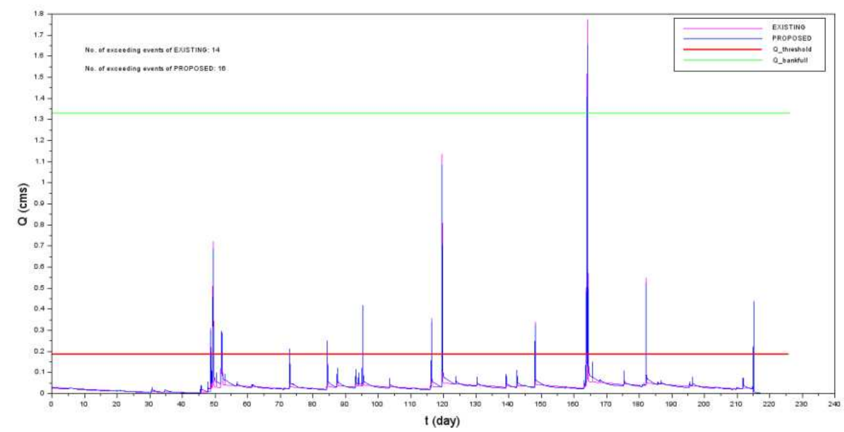
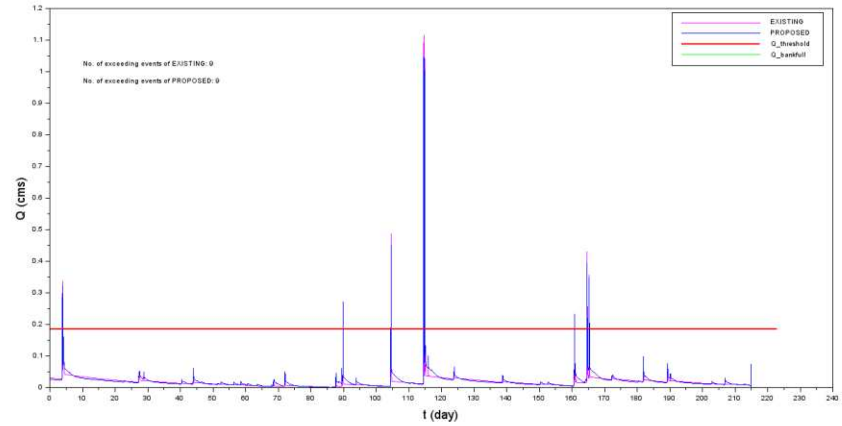
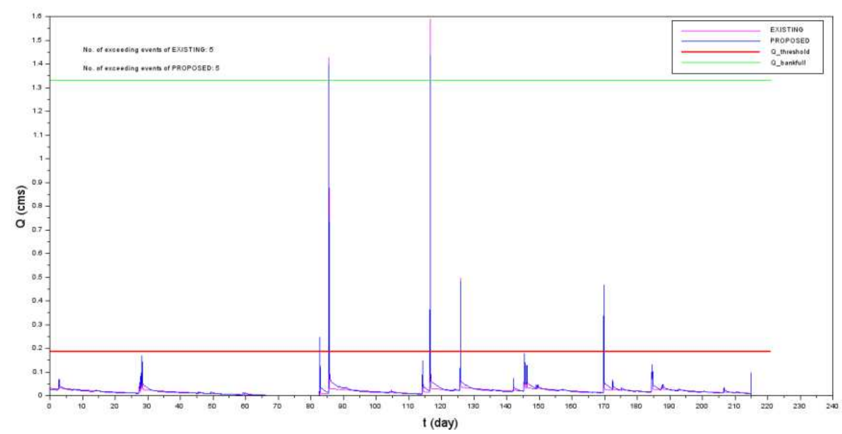
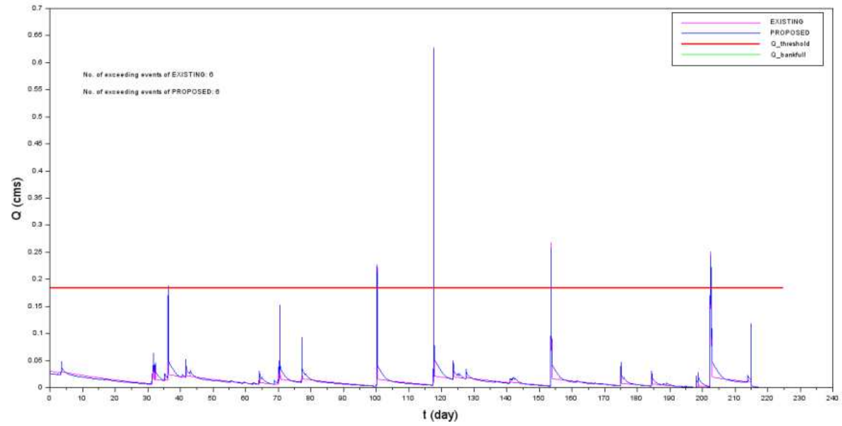
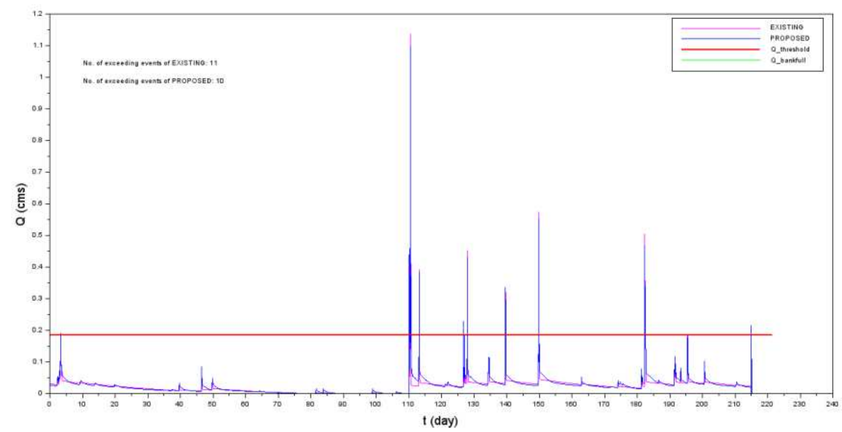
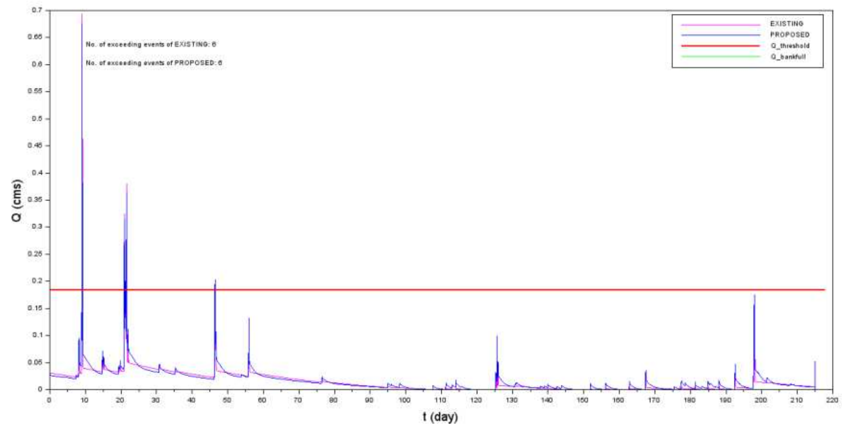
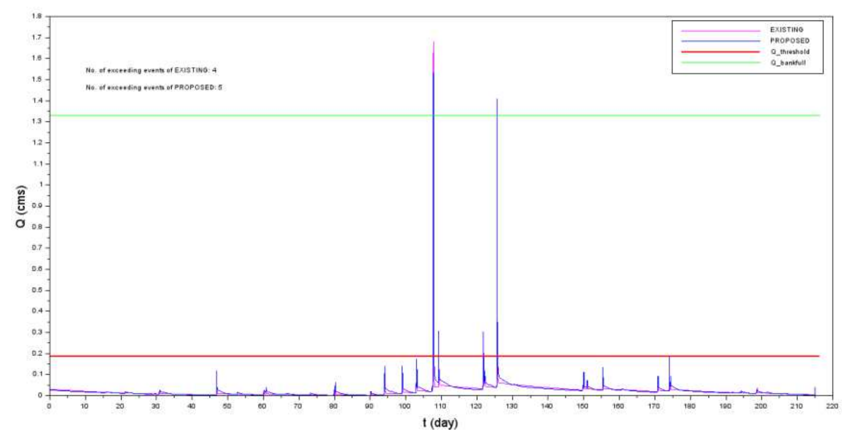
Reach 3 **1981**	
Reach 3 **1982**	

Reach 3 **1983**	
Reach 3 **1984**	

Reach 3 **1985**	
Reach 3 **1986**	

Reach 3 **1987**	
Reach 3 **1988**	

Reach 3 **1989**	
Reach 3 **1990**	

Reach 3 **1991**	
Reach 3 **1992**	

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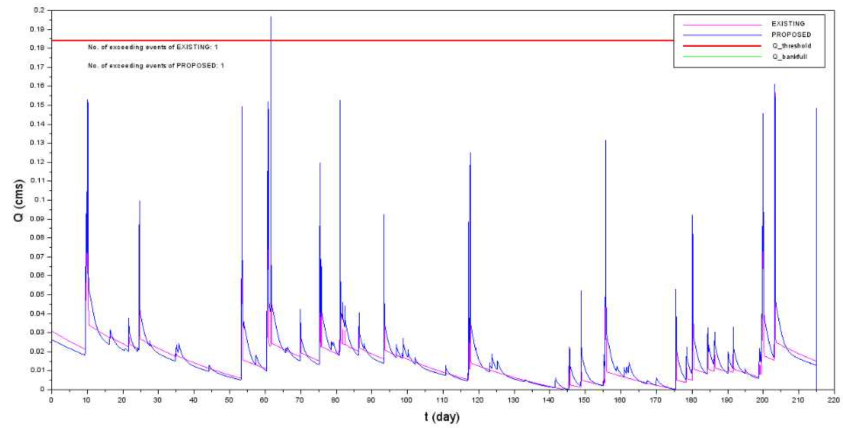
1993</td><td>
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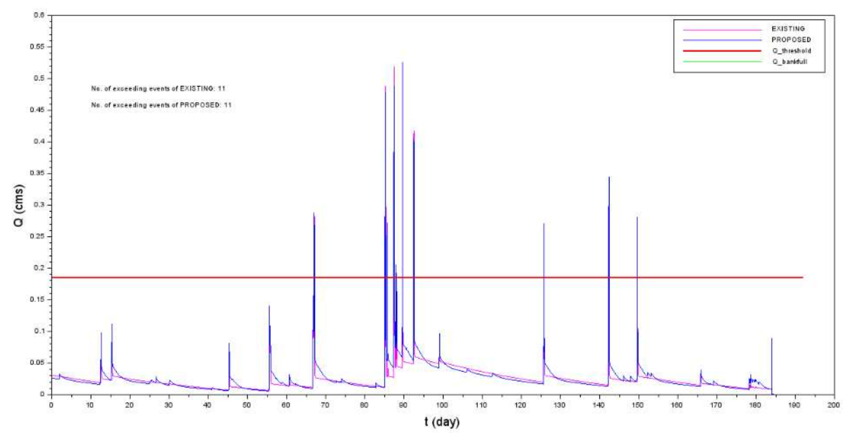
1994</td><td>
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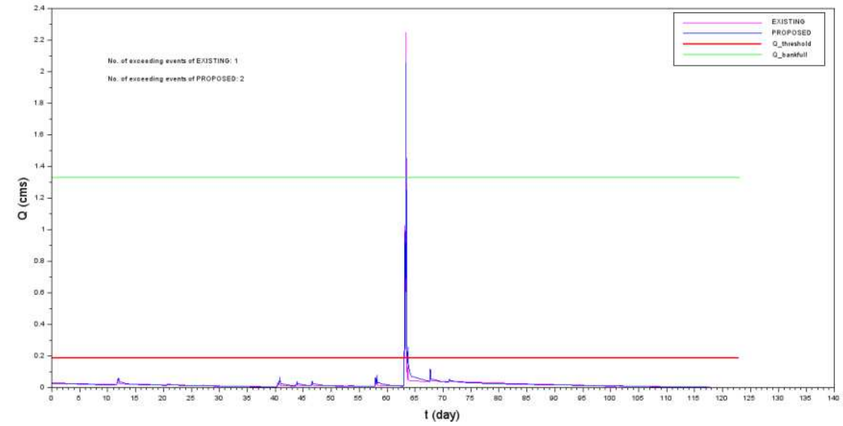
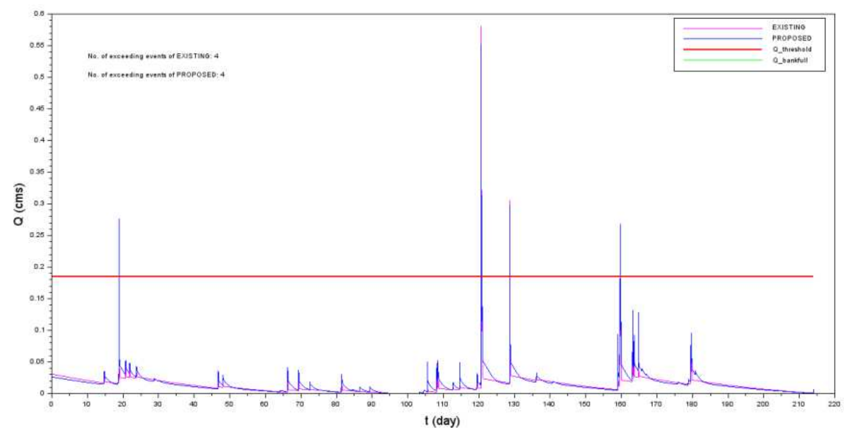
Reach 3 **1995**	
Reach 3 **1996**	

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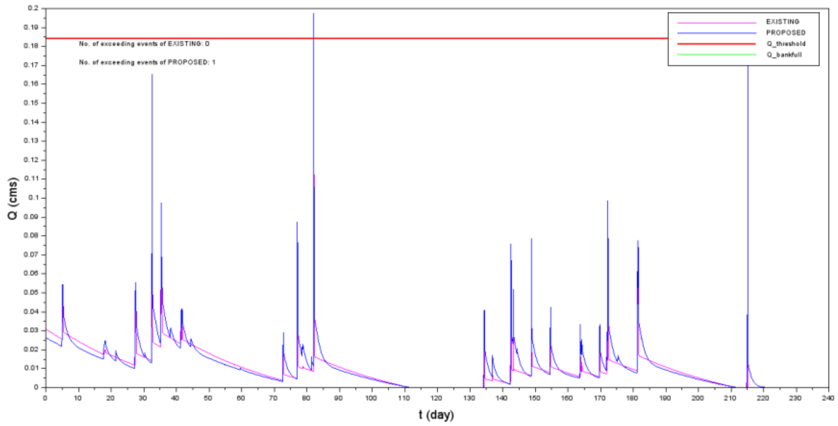
1997</td><td>
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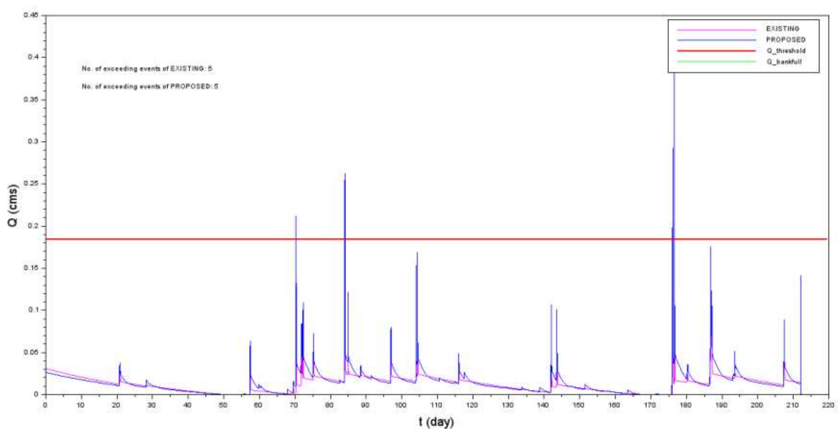
1998</td><td>
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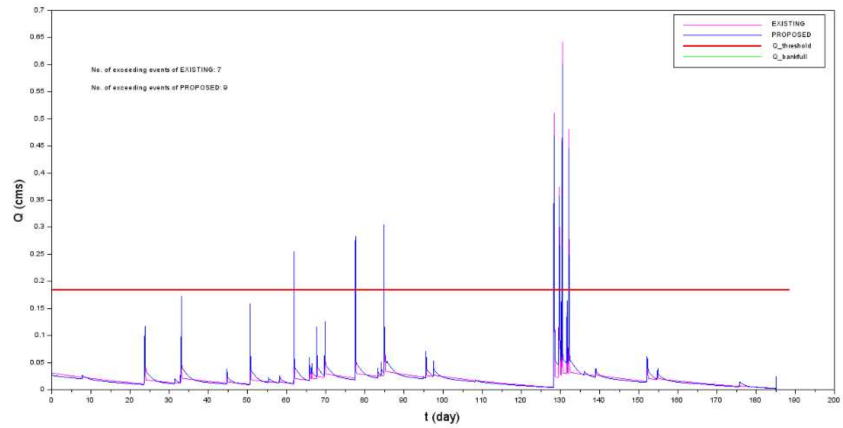
1999</td><td>
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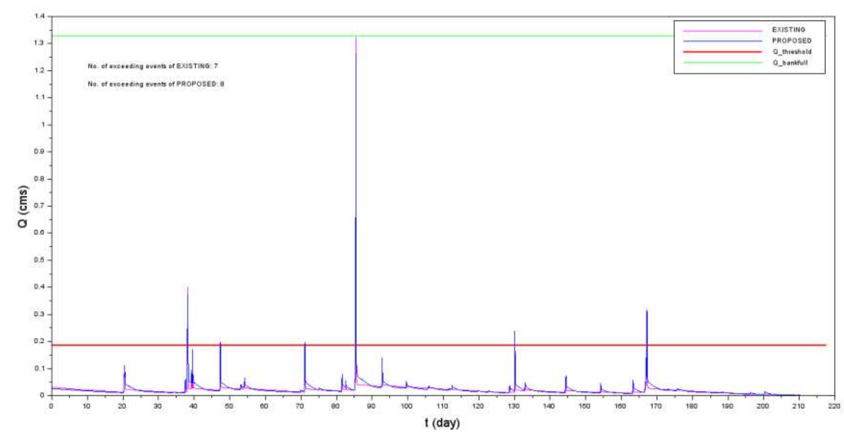
2000</td><td>
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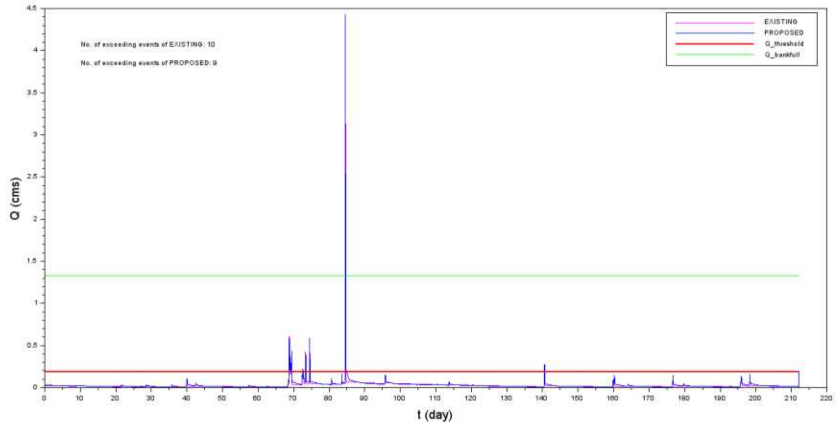
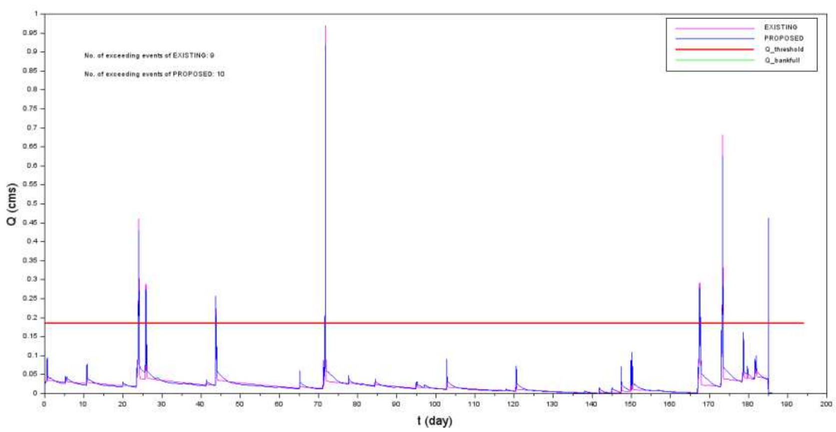
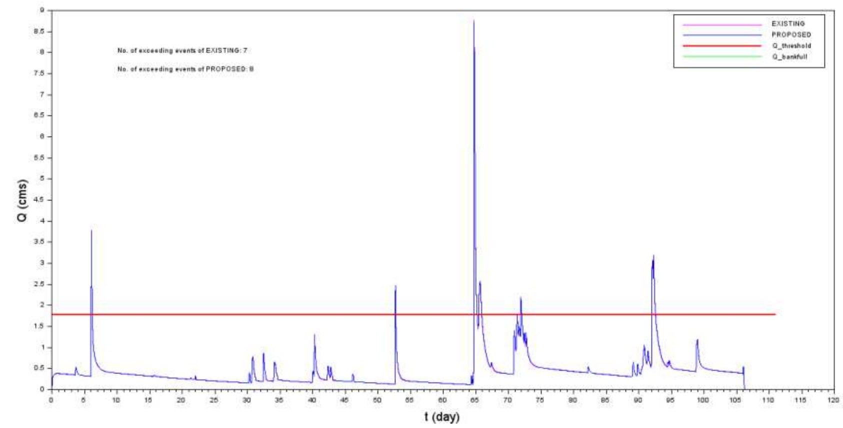
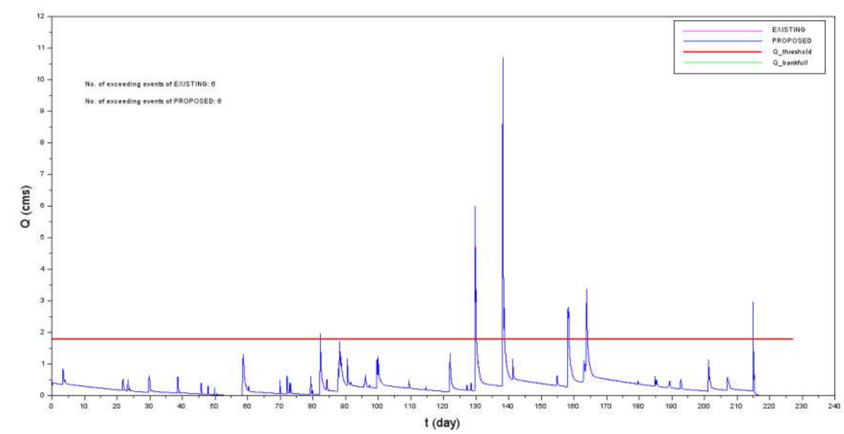
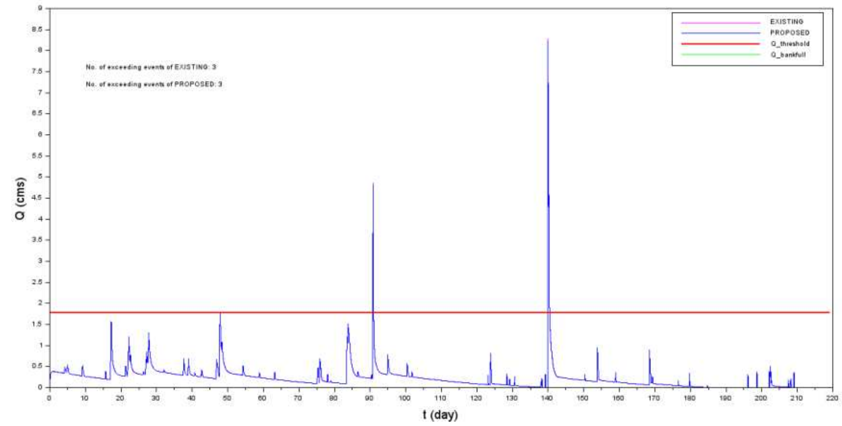
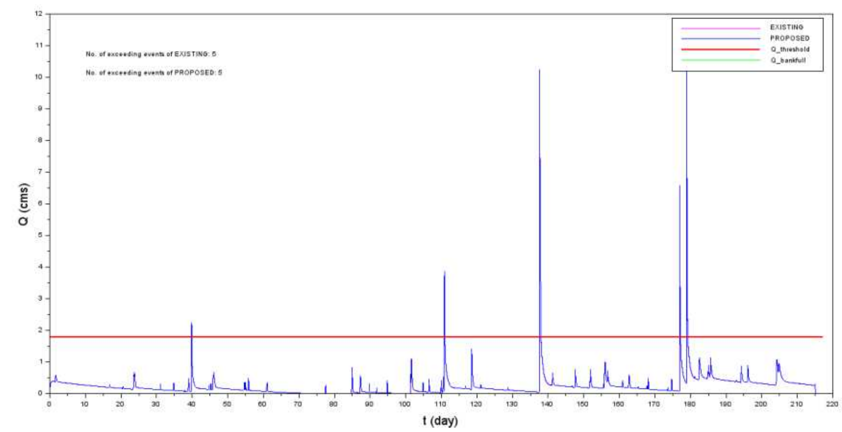
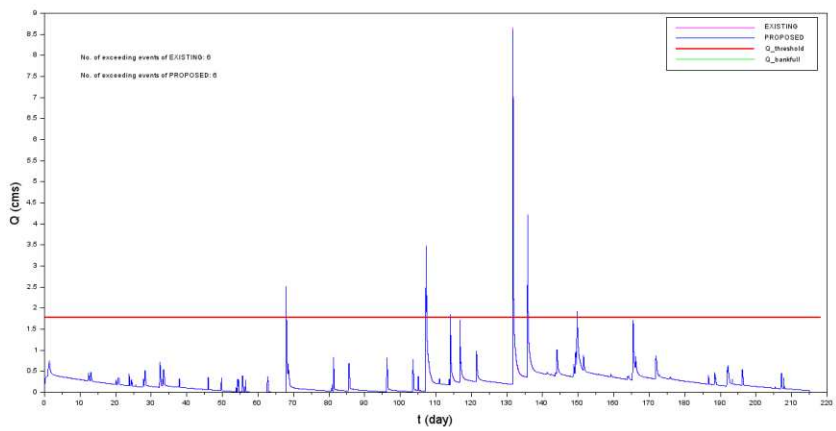
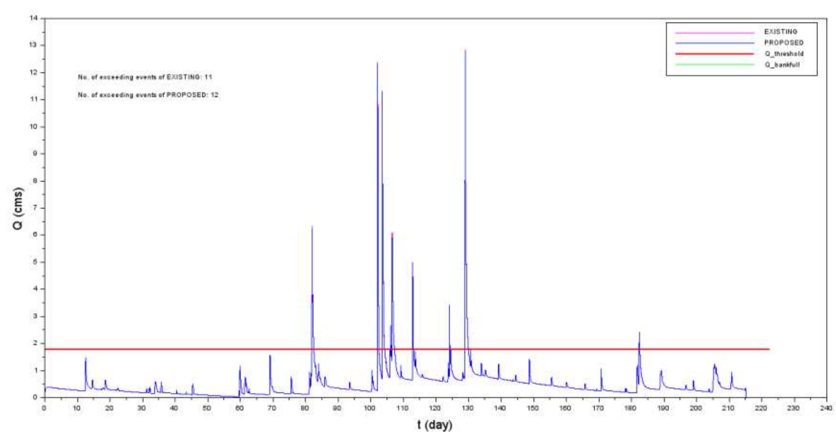
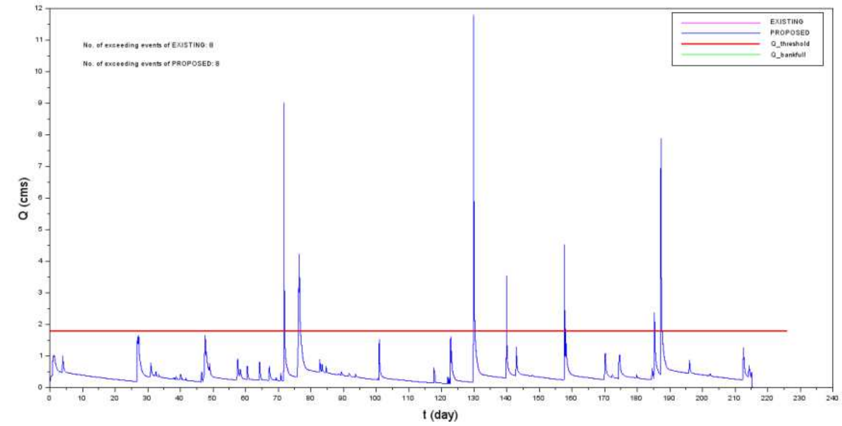
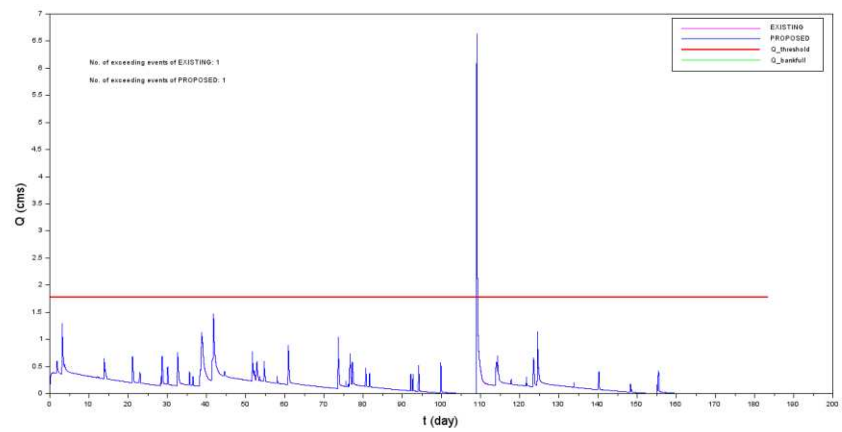
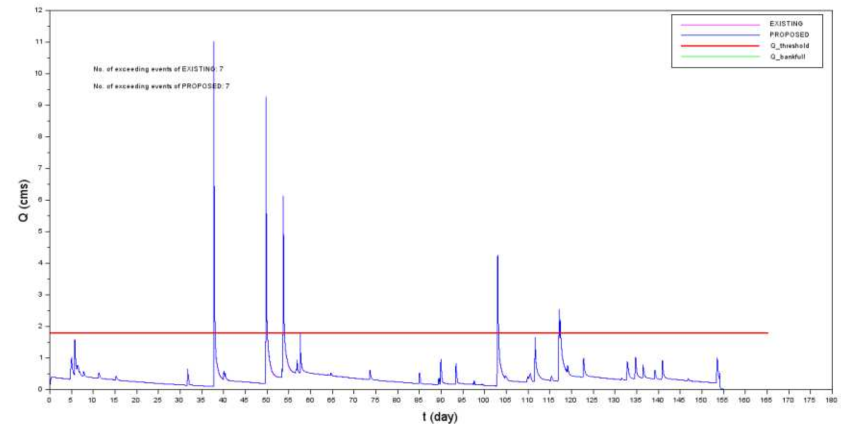
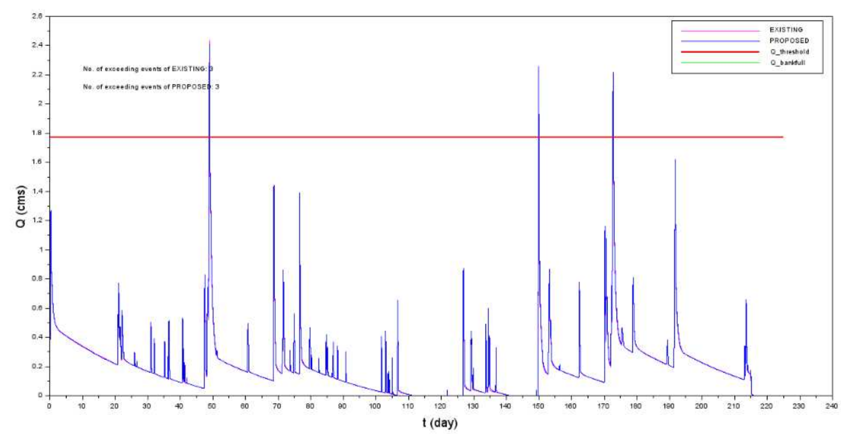
Reach 3 **2002**	
Reach 3 **2003**	

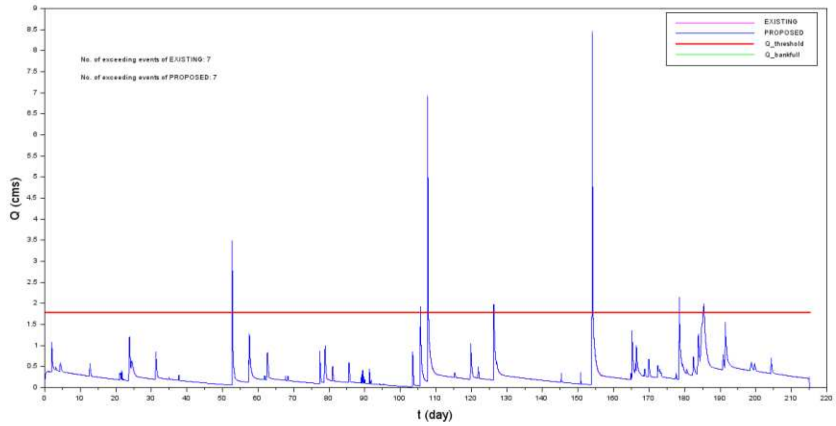
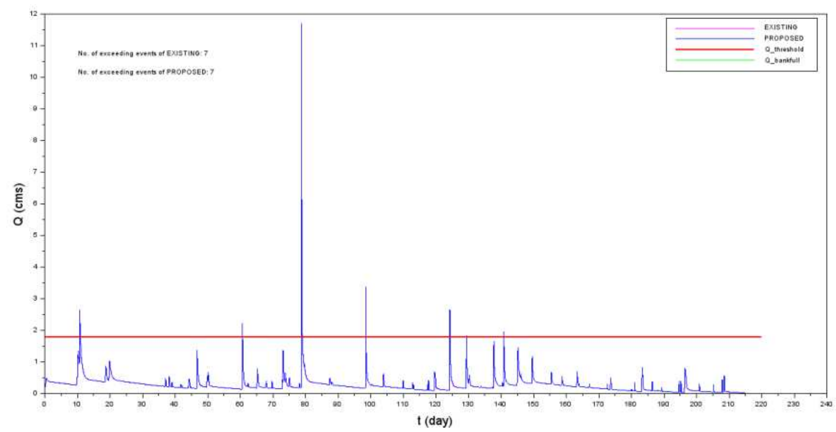
Reach C10 **1967**	
Reach C10 **1968**	

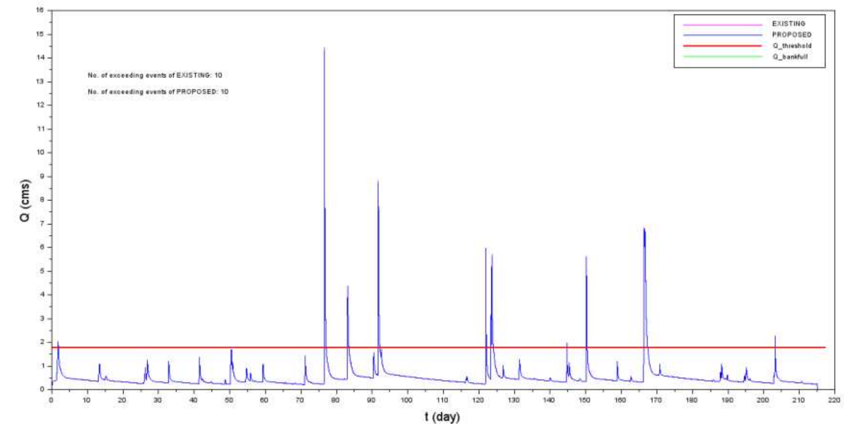
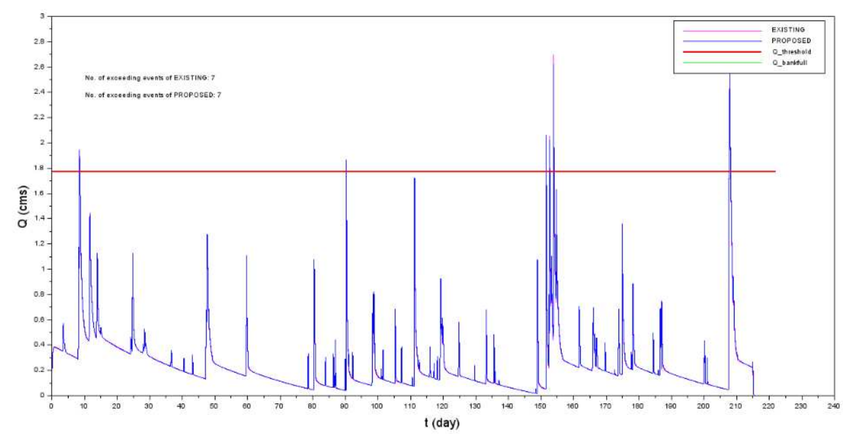
Reach C10 **1969**	
Reach C10 **1970**	

Reach C10 **1971**	
Reach C10 **1972**	

Reach C10 **1973**	
Reach C10 **1974**	

Reach C10 **1975**	
Reach C10 **1976**	

Reach C10 **1977**	
Reach C10 **1978**	

Reach C10 **1979**	
Reach C10 **1980**	

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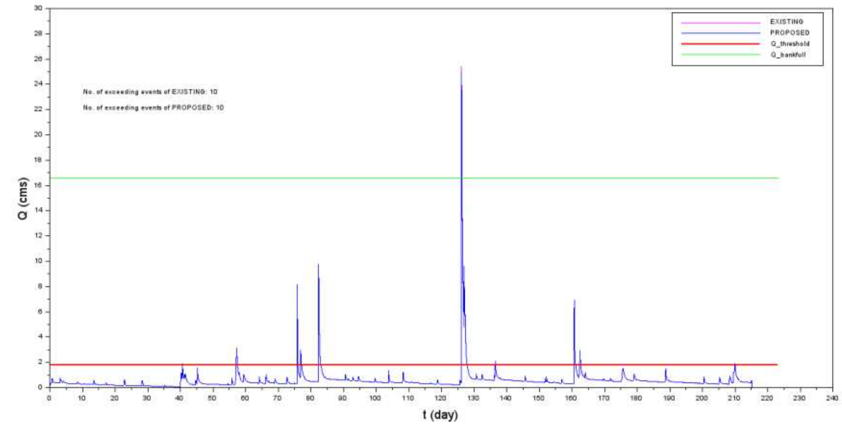
1981</td><td>
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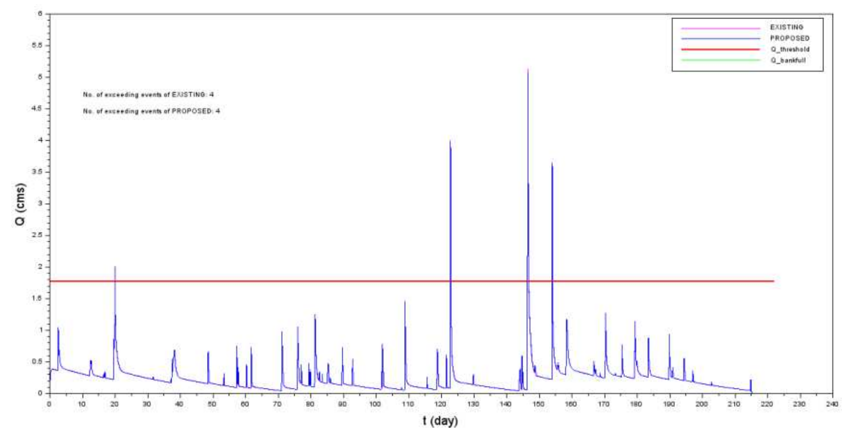
1982</td><td>
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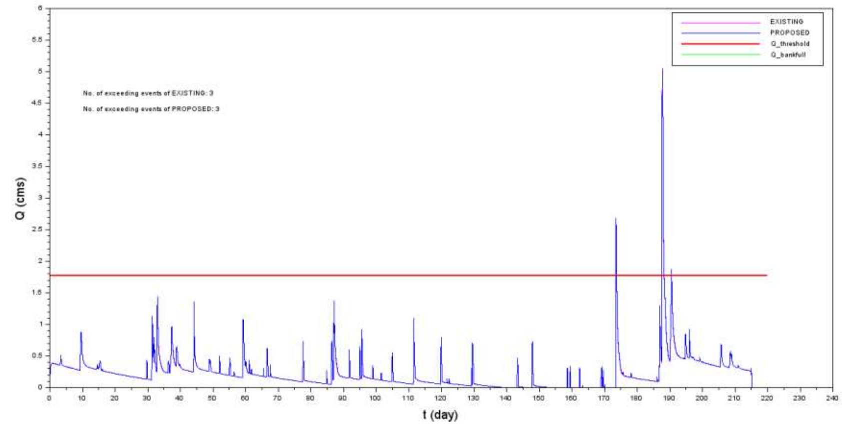
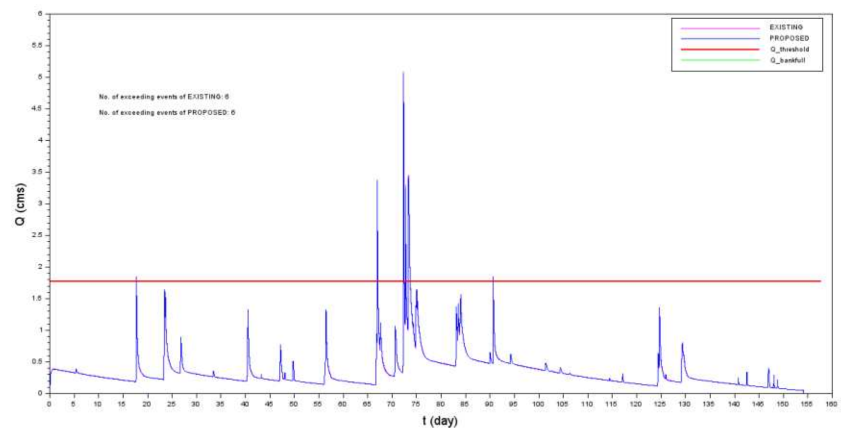
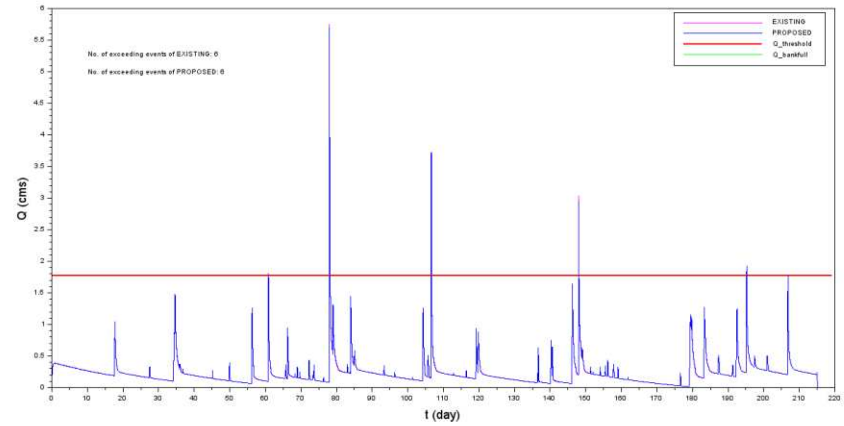
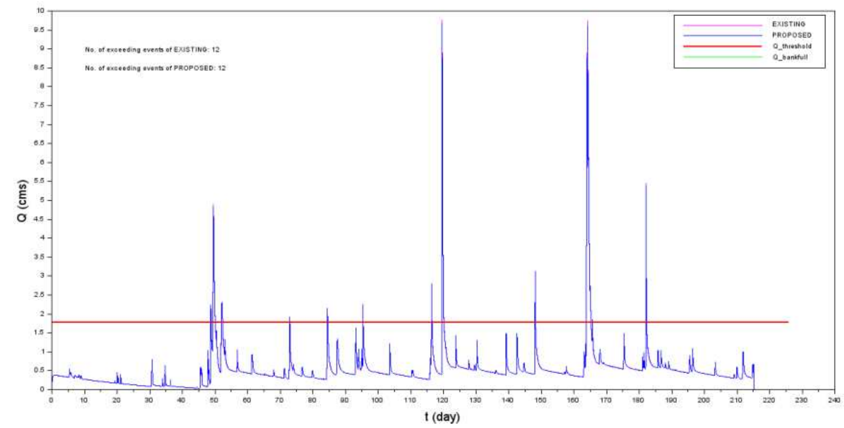
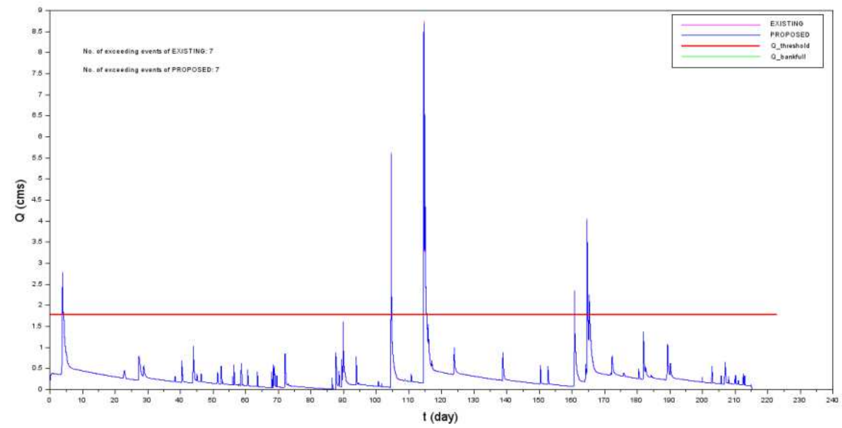
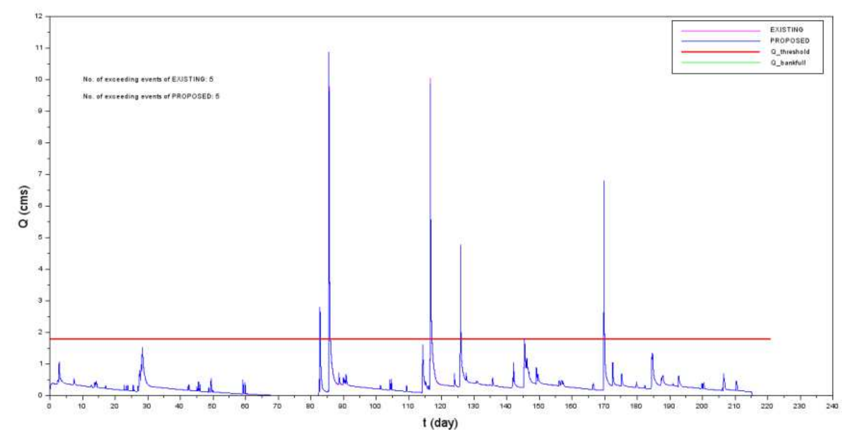
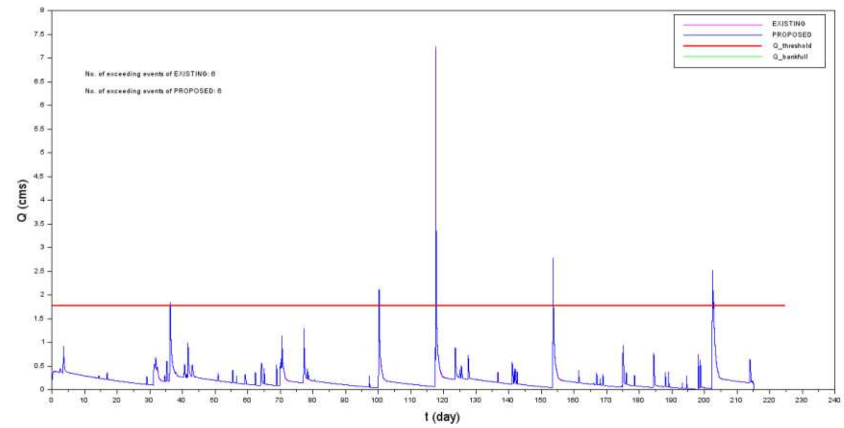
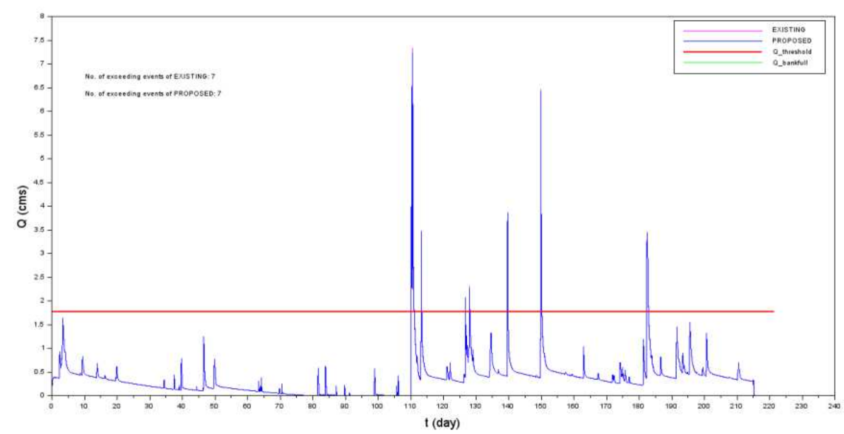
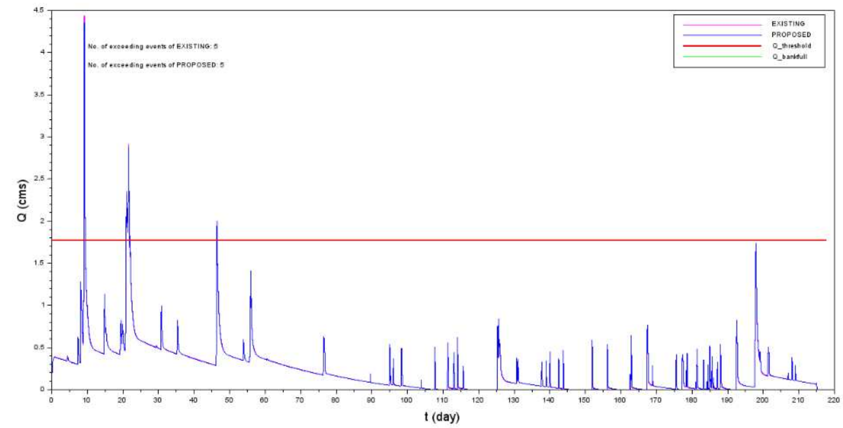
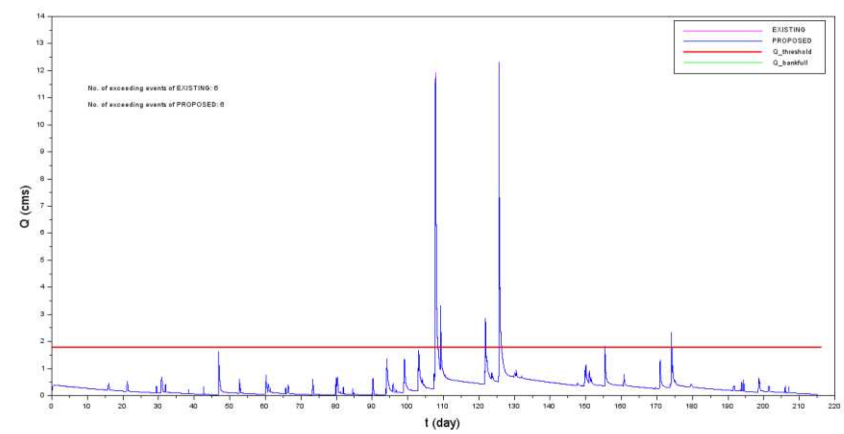
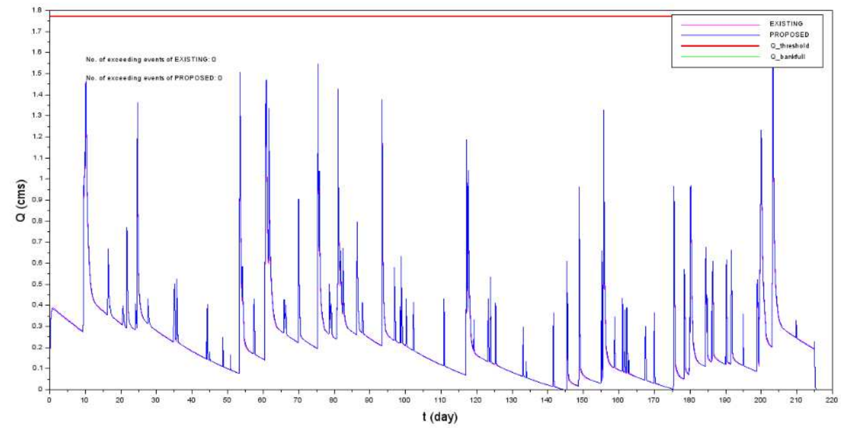
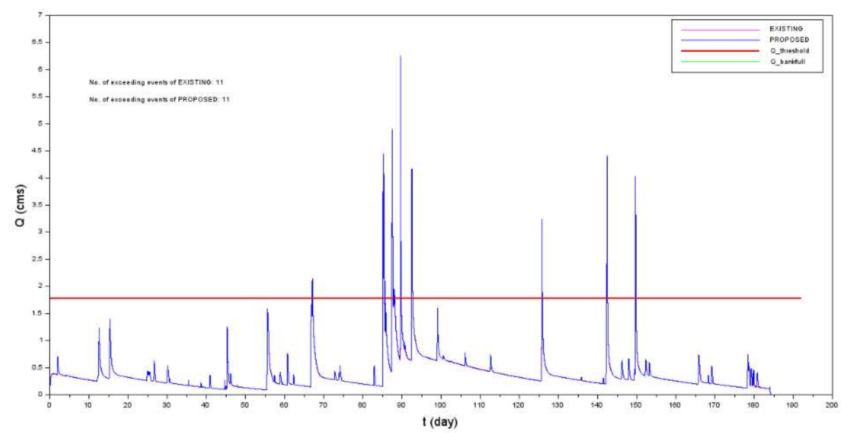
Reach C10 **1983**	
Reach C10 **1984**	

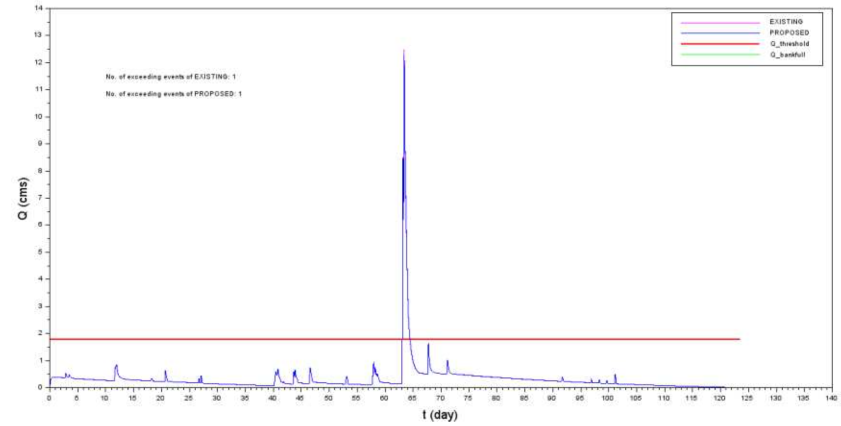
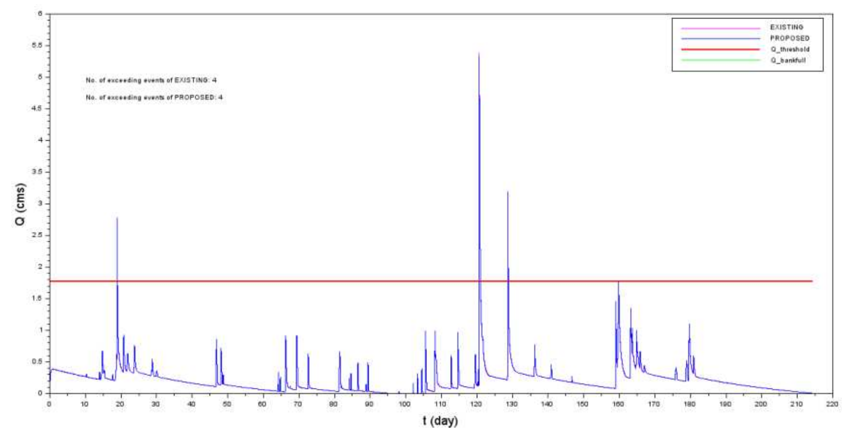
Reach C10 **1985**	
Reach C10 **1986**	

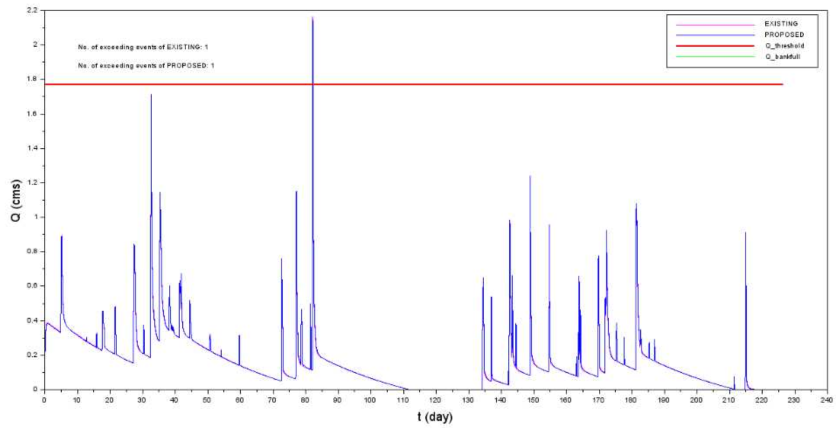
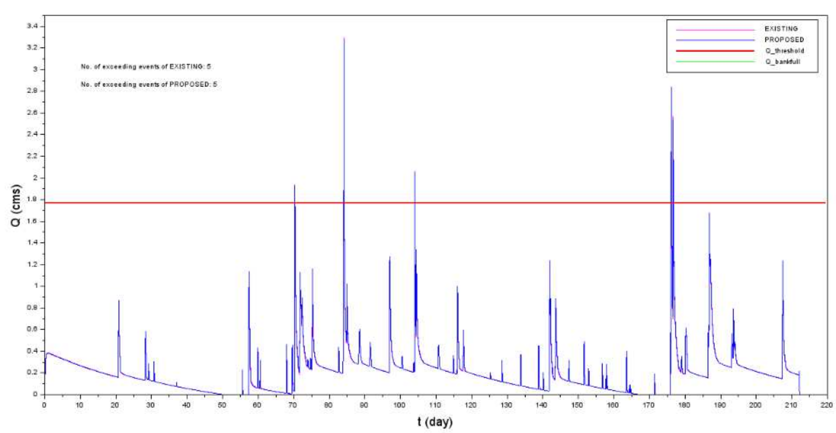
Reach C10 **1987**	
Reach C10 **1988**	

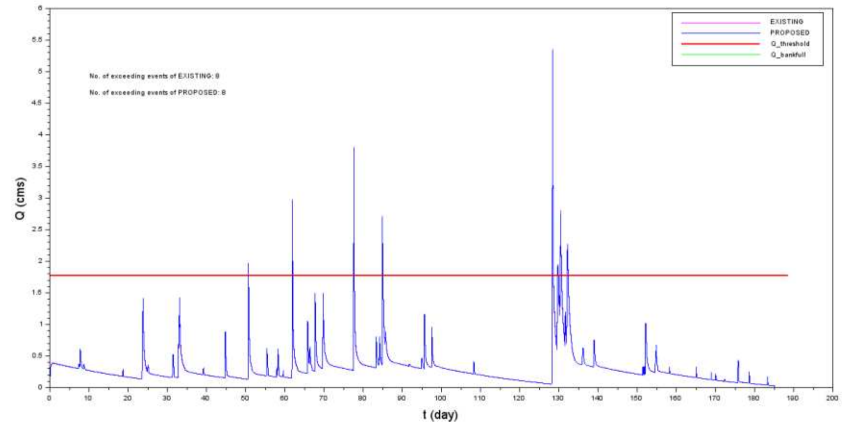
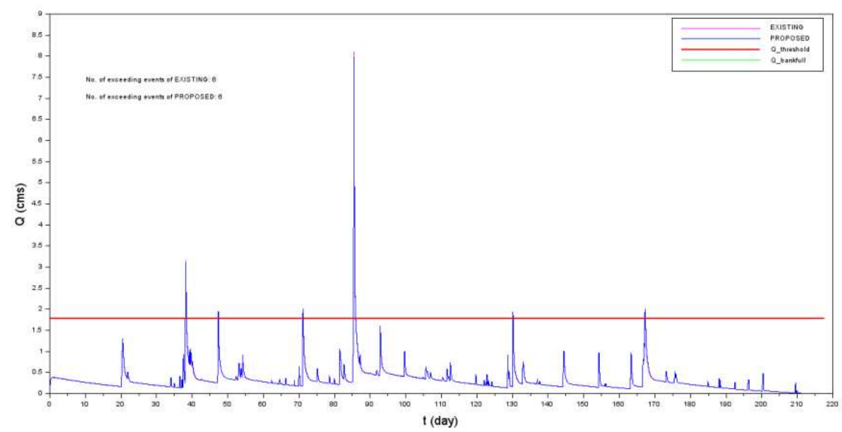
Reach C10 **1989**	
Reach C10 **1990**	

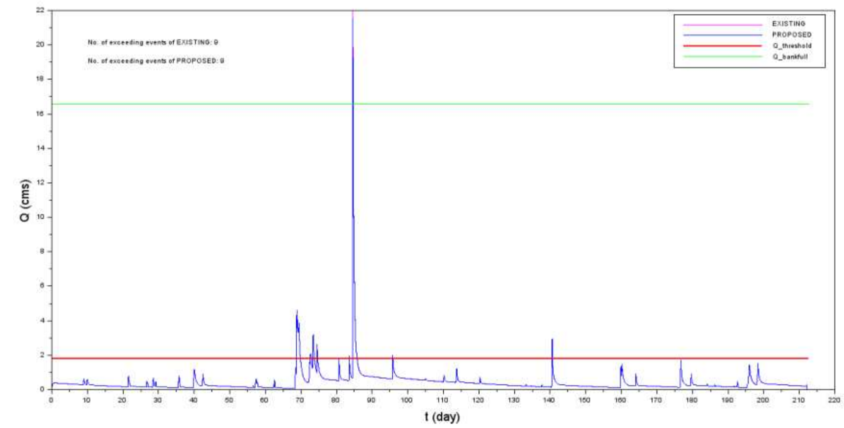
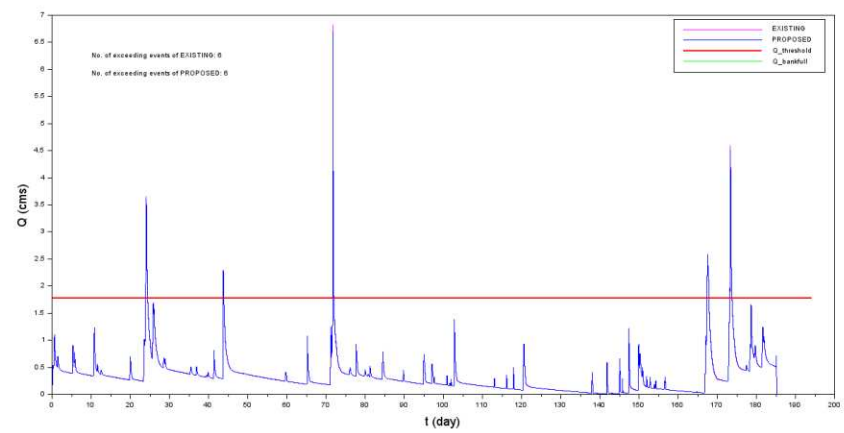
Reach C10 **1991**	
Reach C10 **1992**	

Reach C10 **1993**	
Reach C10 **1994**	

Reach C10 **1995**	
Reach C10 **1996**	

Reach C10 **1997**	
Reach C10 **1998**	

Reach C10 **1999**	
Reach C10 **2000**	

Reach C10 **2002**	
Reach C10 **2003**	

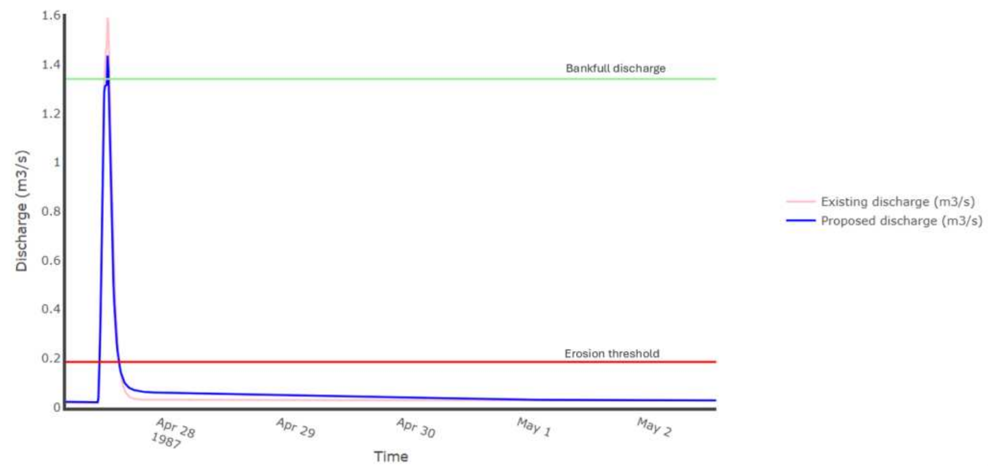
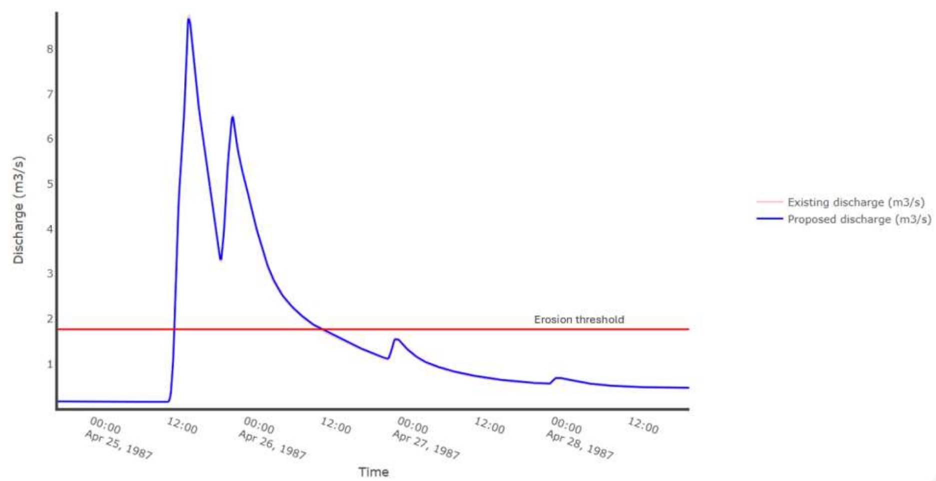
Reach 3 **Representative Event Hydrograph**	
Reach C10 **Representative Event Hydrograph**	

Table H.1: Annual breakdown of erosion exceedance assessment for R3.

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
1967	**(PRE)**	12,945	145	24	8
	(POST)	11,781	138	24	8
	Change	**-8.99%**	**-5.29%**	**1.39%**	**0.00%**
1968	**(PRE)**	11,968	136	23	9
	(POST)	11,108	131	24	10
	Change	**-7.19%**	**-3.56%**	**2.92%**	**11.11%**
1969	**(PRE)**	6,258	60	7	4
	(POST)	5,927	57	7	3
	Change	**-5.29%**	**-5.15%**	**-4.76%**	**-25.00%**
1970	**(PRE)**	11,451	112	14	7
	(POST)	11,213	111	14	7
	Change	**-2.08%**	**-0.32%**	**4.94%**	**0.00%**
1971	**(PRE)**	6,538	70	11	5
	(POST)	5,780	65	11	5
	Change	**-11.59%**	**-7.83%**	**0.00%**	**0.00%**
1972	**(PRE)**	52,781	468	41	12
	(POST)	49,639	450	43	13
	Change	**-5.95%**	**-3.76%**	**5.28%**	**8.33%**
1973	**(PRE)**	19,824	198	25	10
	(POST)	18,406	188	26	10
	Change	**-7.15%**	**-4.80%**	**1.32%**	**0.00%**
1974	**(PRE)**	1,644	17	3	1
	(POST)	1,458	16	2	1
	Change	**-11.32%**	**-9.84%**	**-6.67%**	**0.00%**
1975	**(PRE)**	12,405	128	18	7
	(POST)	11,186	118	17	7
	Change	**-9.83%**	**-7.99%**	**-3.74%**	**0.00%**
1976	**(PRE)**	2,142	36	9	3
	(POST)	1,854	33	9	5
	Change	**-13.43%**	**-6.89%**	**-1.79%**	**66.67%**
1977	**(PRE)**	6,392	63	8	5
	(POST)	5,792	59	8	5
	Change	**-9.39%**	**-6.32%**	**2.13%**	**0.00%**
1978	**(PRE)**	6,097	58	6	4
	(POST)	5,699	56	7	4
	Change	**-6.54%**	**-2.55%**	**10.53%**	**0.00%**
1979	**(PRE)**	42,835	387	36	10
	(POST)	39,014	362	37	10
	Change	**-8.92%**	**-6.44%**	**3.23%**	**0.00%**
1981	**(PRE)**	90,500	690	45	12

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
	(POST)	83,672	687	57	14
	Change	**-7.54%**	**-0.39%**	**26.47%**	**16.67%**
1982	**(PRE)**	4,622	54	10	4
	(POST)	4,096	50	9	4
	Change	**-11.37%**	**-7.71%**	**-1.75%**	**0.00%**
1983	**(PRE)**	8,805	95	15	5
	(POST)	7,818	88	15	5
	Change	**-11.21%**	**-6.76%**	**2.30%**	**0.00%**
1984	**(PRE)**	7,496	85	14	8
	(POST)	6,814	81	15	8
	Change	**-9.10%**	**-5.00%**	**2.35%**	**0.00%**
1985	**(PRE)**	2,785	34	6	6
	(POST)	2,545	31	6	6
	Change	**-8.60%**	**-7.26%**	**-5.26%**	**0.00%**
1986	**(PRE)**	48,678	440	42	14
	(POST)	44,194	413	44	16
	Change	**-9.21%**	**-6.28%**	**4.35%**	**14.29%**
1987	**(PRE)**	18,010	179	23	9
	(POST)	16,386	168	23	9
	Change	**-9.02%**	**-6.32%**	**0.74%**	**0.00%**
1988	**(PRE)**	19,501	168	13	5
	(POST)	17,513	153	13	5
	Change	**-10.20%**	**-8.75%**	**-2.56%**	**0.00%**
1989	**(PRE)**	3,598	52	12	6
	(POST)	3,157	48	12	6
	Change	**-12.24%**	**-6.94%**	**-1.39%**	**0.00%**
1990	**(PRE)**	18,196	191	28	11
	(POST)	16,236	175	27	10
	Change	**-10.77%**	**-8.33%**	**-3.03%**	**-9.09%**
1991	**(PRE)**	5,115	63	12	6
	(POST)	4,429	58	12	6
	Change	**-13.41%**	**-9.02%**	**-2.74%**	**0.00%**
1992	**(PRE)**	22,763	195	15	4
	(POST)	21,863	192	17	5
	Change	**-3.95%**	**-1.25%**	**11.24%**	**25.00%**
1993	**(PRE)**	1	0	0	1
	(POST)	16	1	1	1
	Change	**2067.95%**	**227.40%**	**200.00%**	**0.00%**
1994	**(PRE)**	9,408	112	20	11
	(POST)	8,757	110	22	11
	Change	**-6.92%**	**-1.71%**	**6.61%**	**0.00%**
1995	**(PRE)**	28,116	223	11	1

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
	(POST)	26,418	219	14	2
	Change	**-6.04%**	**-1.81%**	**30.30%**	**100.00%**
1996	**(PRE)**	3,758	47	9	4
	(POST)	3,262	44	10	4
	Change	**-13.19%**	**-6.90%**	**1.79%**	**0.00%**
1997	**(PRE)**	0	0	0	0
	(POST)	15	1	1	1
	Change	**N/A**	**N/A**	**N/A**	**N/A**
1998	**(PRE)**	1,516	24	6	5
	(POST)	1,418	23	6	5
	Change	**-6.49%**	**-3.01%**	**0.00%**	**0.00%**
1999	**(PRE)**	10,274	118	20	7
	(POST)	8,862	107	20	9
	Change	**-13.74%**	**-8.97%**	**-0.83%**	**28.57%**
2000	**(PRE)**	10,438	112	17	7
	(POST)	9,305	104	17	8
	Change	**-10.85%**	**-7.25%**	**0.00%**	**14.29%**
2002	**(PRE)**	40,681	343	36	10
	(POST)	38,106	341	41	9
	Change	**-6.33%**	**-0.64%**	**14.49%**	**-10.00%**
2003	**(PRE)**	14,779	171	30	9
	(POST)	12,780	156	30	10
	Change	**-13.53%**	**-8.53%**	**0.00%**	**11.11%**

Table H.2: Annual breakdown of erosion exceedance assessment for C10.

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
1967	**(PRE)**	203,225	2,371	48	7
	(POST)	203,821	2,417	49	8
	Change	**0.29%**	**1.95%**	**3.14%**	**14.29%**
1968	**(PRE)**	242,214	2,595	49	6
	(POST)	242,769	2,621	50	6
	Change	**0.23%**	**1.03%**	**1.71%**	**0.00%**
1969	**(PRE)**	154,337	1,282	18	3
	(POST)	155,155	1,292	18	3
	Change	**0.53%**	**0.72%**	**0.92%**	**0.00%**
1970	**(PRE)**	297,915	2,415	34	5
	(POST)	300,174	2,455	35	5
	Change	**0.76%**	**1.66%**	**2.96%**	**0.00%**
1971	**(PRE)**	135,453	1,463	28	6
	(POST)	135,373	1,472	28	6
	Change	**-0.06%**	**0.64%**	**1.20%**	**0.00%**

Simulation		CEV (m³/s)	ω_{eff} (N/m²)	t_{ex} (hrs)	# Of Exceedances
1972	(PRE)	842,902	7,279	112	11
	(POST)	849,589	7,366	114	12
	Change	0.79%	1.20%	1.64%	9.09%
1973	(PRE)	401,077	3,594	57	8
	(POST)	403,033	3,638	58	8
	Change	0.49%	1.22%	2.05%	0.00%
1974	(PRE)	47,959	401	6	1
	(POST)	47,945	411	6	1
	Change	-0.03%	2.33%	5.88%	0.00%
1975	(PRE)	298,134	2,622	41	7
	(POST)	298,558	2,663	42	7
	Change	0.14%	1.56%	3.27%	0.00%
1976	(PRE)	14,791	495	15	3
	(POST)	14,566	503	15	3
	Change	-1.52%	1.67%	2.25%	0.00%
1977	(PRE)	151,246	1,667	32	7
	(POST)	151,748	1,689	33	7
	Change	0.33%	1.32%	2.06%	0.00%
1978	(PRE)	139,062	1,281	22	7
	(POST)	139,625	1,298	22	7
	Change	0.41%	1.34%	2.33%	0.00%
1979	(PRE)	711,457	6,237	96	10
	(POST)	714,009	6,317	99	10
	Change	0.36%	1.30%	2.43%	0.00%
1981	(PRE)	1,488,881	9,983	118	10
	(POST)	1,496,436	10,054	120	10
	Change	0.51%	0.71%	1.84%	0.00%
1982	(PRE)	81,917	926	18	4
	(POST)	81,756	940	18	4
	Change	-0.20%	1.45%	2.80%	0.00%
1983	(PRE)	108,441	1,249	25	3
	(POST)	108,624	1,265	25	3
	Change	0.17%	1.23%	2.04%	0.00%
1984	(PRE)	88,231	1,177	26	6
	(POST)	88,329	1,202	26	6
	Change	0.11%	2.07%	3.27%	0.00%
1985	(PRE)	62,390	749	15	6
	(POST)	62,133	757	16	6
	Change	-0.41%	1.06%	2.20%	0.00%
1986	(PRE)	714,283	6,439	103	12
	(POST)	716,402	6,513	105	12
	Change	0.30%	1.14%	2.10%	0.00%

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
1987	**(PRE)**	284,474	2,976	55	7
	(POST)	285,780	3,022	56	7
	Change	**0.46%**	**1.52%**	**2.44%**	**0.00%**
1988	**(PRE)**	353,897	2,838	39	5
	(POST)	354,782	2,868	40	5
	Change	**0.25%**	**1.06%**	**2.13%**	**0.00%**
1989	**(PRE)**	83,055	1,082	24	6
	(POST)	82,904	1,105	24	6
	Change	**-0.18%**	**2.13%**	**3.55%**	**0.00%**
1990	**(PRE)**	287,109	3,112	59	7
	(POST)	287,829	3,154	60	7
	Change	**0.25%**	**1.35%**	**2.28%**	**0.00%**
1991	**(PRE)**	65,587	1,309	34	5
	(POST)	65,758	1,324	35	5
	Change	**0.26%**	**1.16%**	**1.46%**	**0.00%**
1992	**(PRE)**	430,641	3,434	48	6
	(POST)	434,300	3,491	50	6
	Change	**0.85%**	**1.67%**	**2.76%**	**0.00%**
1993	**(PRE)**	0	0	0	0
	(POST)	0	0	0	0
	Change	**N/A**	**N/A**	**N/A**	**N/A**
1994	**(PRE)**	208,435	2,537	52	11
	(POST)	209,398	2,608	54	11
	Change	**0.46%**	**2.81%**	**4.50%**	**0.00%**
1995	**(PRE)**	478,847	3,212	33	1
	(POST)	481,704	3,236	33	1
	Change	**0.60%**	**0.75%**	**1.01%**	**0.00%**
1996	**(PRE)**	65,024	797	16	4
	(POST)	64,687	795	16	4
	Change	**-0.52%**	**-0.21%**	**0.00%**	**0.00%**
1997	**(PRE)**	1,773	66	2	1
	(POST)	1,769	66	2	1
	Change	**-0.23%**	**-0.10%**	**0.00%**	**0.00%**
1998	**(PRE)**	26,011	526	14	5
	(POST)	25,823	534	14	5
	Change	**-0.72%**	**1.61%**	**2.41%**	**0.00%**
1999	**(PRE)**	102,465	1,643	40	8
	(POST)	101,675	1,658	40	8
	Change	**-0.77%**	**0.92%**	**1.69%**	**0.00%**
2000	**(PRE)**	139,039	1,648	34	6
	(POST)	139,403	1,659	34	6
	Change	**0.26%**	**0.71%**	**0.99%**	**0.00%**

Simulation		CEV (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
2002	**(PRE)**	681,511	5,731	90	9
	(POST)	686,527	5,815	92	9
	Change	**0.74%**	**1.46%**	**2.04%**	**0.00%**
2003	**(PRE)**	174,647	2,345	51	6
	(POST)	174,545	2,374	52	6
	Change	**-0.06%**	**1.21%**	**1.95%**	**0.00%**