Geomorphological and Erosion Assessment, Tributary of Bear Brook

6160 Thunder Road and 5368 Boundary Road

City of Ottawa

Prepared for:
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1.2	Minor updates to results in response to updated hydrological simulation modeling	Kelsey Serviss, M.Sc., Kelly Macgillivray, M.Sc., Karine Smith, M.Sc., and Jan Franssen, Ph.D.	Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP	August 16, 2024

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Table of Contents

List of Tables

Appendices

1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained by Thunder Road Limited Partnership to complete a fluvial geomorphology assessment in support of a proposed development at 6160 Thunder Road and 5368 Boundary Road in Ottawa, Ontario (herein referred to as "subject land"). The subject land is located west of the intersection of Thunder Road and Boundary Road within the Bear Brook watershed and is bordered in the north by low-density, forested residential properties, and by forest to the west and south. The subject land is currently undeveloped, and the land cover is comprised of planted tree cover in the north and a fallow field in the south, with straightened drainage channels throughout. The subject land drains to a tributary of Bear Brook that flows westward along the northern border of the site through a forested area. The tributary proceeds through forest and beaver meadow towards a crossing with Thunder Road, downstream of which it drains into Bear Brook. The tributary appears to be straightened for a length of approximately 200 m along the northern border of the subject land, then downstream of this it transitions to an irregularly meandering pattern, which it maintains until its confluence with Bear Brook approximately 1.4 km downstream of the subject land. A map of the watercourse and subject land is presented in **Appendix A**.

Based on the information provided, the current design for the proposed development within the subject land includes a 12.78 ha industrial park primarily comprised of warehouses, loading bays, parking lots, a drainage swale, and three (3) stormwater management facilities, one of which (Pond 1) will discharge to the tributary of Bear Brook in the northwest corner of the subject land. Pond 1 is proposed to be located along the northwestern boundary of the subject land between the proposed building and associated outdoor shed, and a straightened section of the watercourse that flows parallel to the northwestern site boundary. It is proposed to outlet to the downstream end of this straightened section of the watercourse. It is our understanding that fluvial geomorphological services are required to inform stormwater mitigation strategies for the tributary to Bear Brook. We have developed a work plan to assess existing fluvial geomorphological conditions associated with the watercourse and conduct erosion threshold and exceedance analyses to understand potential erosive impacts downstream due to stormwater discharge.

The following activities were completed as part of the fluvial geomorphological assessment:

- Review of available background reports and mapping (i.e., watershed/subwatershed reporting, geology, topography, etc.) related to channel form and function and controlling factors related to fluvial geomorphology
- Historical site assessment using aerial photograph records to identify changes to the system due to land use and past channel modifications within the primary and extended study areas
- Delineate watercourse reaches along the receiving watercourses through a desktop exercise
- Rapid geomorphological field assessment to verify the background review and desktop assessment results and identify the most erosion-sensitive reach in the receiving watercourse
- Detailed geomorphological field assessment along the most erosion-sensitive reach to support and inform erosion threshold modelling and erosion exceedance analysis
- Erosion threshold assessment based on the detailed assessment results for the most erosion-sensitive reach to determine the limiting erosion threshold value to inform the erosion exceedance analysis
- Erosion exceedance analysis of the most erosion-sensitive reach using the previously determined erosion threshold value to compare pre- and post-development conditions to inform stormwater mitigation strategies and SWM pond sizing and release rates to address erosion mitigation requirements

2 Existing Site Conditions

2.1 Background Review

A review of pertinent background material was completed to inform and provide context regarding local hydrology and stream morphology. Material reviewed includes site plans, historical aerial photographs, publicly available surficial geological mapping, physiological region and landform mapping, and watershed reports published by SNCA.

2.2 Watershed Characteristics

The subject site is located within the Bear Brook Watershed, southeast of the City of Ottawa. The main channel of Bear Brook flows generally eastwards through agricultural lands and fragmented forest to outlet into the South Nation River and is approximately 40 kilometers long. The total Bear Brook drainage area is approximately 488 km^2 and extends south and east of Ottawa (SNCA, 2016). The Bear Brook main channel begins near the community of Edwards within the municipal boundaries of the City of Ottawa and flows generally northwards in a meandering pattern until a crossing with the railway near Russell Road north of Highway 417. Downstream of the railway crossing, the main channel alignment turns to flow generally eastwards, an alignment it maintains until its confluence with the South Nation River near the community of Ettyville within Prescott-Russell County.

The tributary adjacent to the subject land is within the headwaters of Bear Brook south of Highway 417. The tributary flows westward from a crossing under the north-south segment of Thunder Road, which curves 90° in the vicinity of the subject land to intersect the tributary twice. The tributary proceeds along the northern extent of the subject land in a straightened ditch bordered by forest to the south and an abandoned residential property to the north. It then meanders irregularly in a northwestward alignment through forest and beaver meadow before crossing again under the east-west segment of Thunder Road. Downstream of the second growing it continues to meander irregularly in a northwestward alignment but is confined by a distinct valley in this section until its confluence with Bear Brook, where it enters the confined valley in which the main channel flows.

2.3 Surficial Geology and Physiography

Surficial geology and physiography act as primary controls regarding channel development, as they greatly influence the hydrological and sediment characteristics of a given drainage system. Channel morphodynamics are largely governed by the flow regime and the availability and type of sediments within the stream corridor. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity. A map showing the surficial geology is presented in **Appendix B**.

The subject land is located within a Sand Plains physiographic region that covers much of the South Nation River watershed (Chapman and Putnam, 1984). The surficial geology of the subject land is comprised of fine- to medium-grain sands (surficial geology unit 11a), that originate from fluvial and marine processes operating in in the ancient delta and estuary environments of the Champlain Sea. These sediments are non-cohesive with high permeability. The sandy sediments are underlain by red and grey stratified clay thought to originate from weathering of local granitic rock (Chapman and Putnam, 1984).

2.4 Historical Assessment

A series of historical aerial photographs and publicly available LiDAR data were reviewed to determine changes to the channel 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 1965, 1976, 1991, 2008, and 2021 from GEO Ottawa (https://maps.ottawa.ca/geoottawa/) were reviewed. Imagery is provided in **Appendix C** for reference. Remote-sensing bare-earth digital elevation models (DEMs) derived from airborne LiDAR surveys (OMNRF, 2020) were also reviewed for a detailed, broad-scale analysis of geomorphic features along the watercourse and adjacent land. The bare-earth elevation raster dataset was used to generate a hillshade model useful for the analysis. A figure showing the hillshade model for the area surrounding the length of watercourse assessed is provided in **Appendix C** for reference.

Land cover visible in the 1965 imagery within the subject land and the surrounding area was comprised of agricultural fields and fragmented forest intersected by linear drainage ditches. Boundary Road and Thunder Road were established at this time, and a few residential and agricultural buildings were present along both roads. The upstream extent of the Bear Brook Tributary was straightened and bounded by agricultural fields. Approximately 400 m southwest of Boundary Road the watercourse transitioned to a section with low sinuosity, which continues towards Thunder Road. Riparian vegetation was sparse along the straightened portion of the tributary before transitioning to fragmented forest and fallow fields to the Thunder Road crossing. Headwater tributaries appear to have drained the forest and fallow fields in the south. An area with backwatering is visible immediately upstream of the Thunder Road crossing. The watercourse enters a confined valley downstream of the crossing, and another instance of backwatering caused by a berm that spans the valley approximately 60 m northwest of the road is visible. The tributary downstream of this appears to have been straightened in an alignment that mirrors that of the valley.

Minor changes in land use in the area surrounding the subject land occurred between 1965 and 1976. Active agriculture is visible in the 1976 imagery within the upstream portion of the tributary and several additional residential buildings were established along Thunder Road north of the subject site. Highway 417 had been constructed by this time to bisect the land north of the subject land. Although it is not possible to comment on small-scale changes to the watercourse due to the low resolution of the 1976 imagery, the watercourse alignment appears identical throughout the length of the tributary. Forest cover within riparian areas has matured and expanded since 1965. Backwatering throughout the middle section of the tributary upstream of Thunder Road is evident, likely caused by the historic beaver dams observed during field assessments. Backwatering observed upstream and downstream of Thunder Road in the 1965 imagery appears to have dissipated.

Land use surrounding the subject land underwent continued changes between 1976 and 1991 with agricultural land north of the straightened section of tributary having been developed into residential properties and a fuel station having been established at the intersection of Thunder Road and Boundary Road adjacent to the subject land. South of the straight section within the subject land, it appears a tree plantation had been established. Forest cover within riparian areas continued to mature and expand, providing a buffer along a large proportion of the tributary. Backwatering caused by historic beaver dams appears to have decreased in volume, as it covers less surface area. Areas that were previously backwatered have wide, open floodplains with forest setback from the watercourse. Low-sinuosity channels are visible in the locations previously backwatered upstream and downstream of the Thunder Road crossing. A remnant of the berm observed in the 1965 imagery is visible in the 1991 imagery and no backwatering is present upstream of it. The channel form downstream of this within the valley includes regular meanders that transition to a straightened planform as the tributary enters the wider valley of Bear Brook and drains into the larger watercourse.

Between 1991 and 2008, development continued in the area surrounding the subject land, including clearing and expansion of several commercial lots along Boundary Road east of the subject area. Land east of the Thunder Road and Boundary Road intersection was partially cleared of forest and fallow field

for the beginning stages of a warehouse facility. The tree plantation within the subject land had matured, as had the riparian buffer along the entire extent of the tributary. Backwatering through the middle section of tributary had further receded, leaving a wide floodplain. Higher resolution imagery provided in 2008 aid in observing the planform of the downstream extent which was difficult to observe in previous years. The channel exhibits a meandering planform with variable sinuosity and regularity from its middle section through to the Thunder Road crossing and towards the Bear Brook confluence, in contrast with the straighter planform visible in the same sections in the 1965 imagery. A channel crossing is now apparent at the location of the berm initially noted in the 1965 imagery, as there is a break in the visible watercourse at the same location with no backwatering upstream of this feature.

Construction of the warehouse facility located east of the subject land across Boundary Road was completed between 2008 and 2021. Other commercial properties south of the warehouse continued to expand, with two properties hosting piled fill. Riparian vegetation surrounding the entire tributary continued to mature and trees appear to have begun encroaching upon the wide floodplain left by the historic beaver dam. The channel appears wider through its downstream half, particularly downstream of the Thunder Road crossing, where some changes in meander bend shape are also observable. The culvert conducting flow below Thunder Road was replaced between 2008 and 2021. The crossing/berm noted approximately 60 m downstream of Thunder Road is somewhat obscured by maturing tree cover in the 2021 imagery. Based on sections of the watercourse that are observable upstream and downstream of its location, it does not appear to be causing a backwater effect as was observed on previous historical images.

As revealed on the bare-earth hillshade model derived from 2020 LiDAR data, the section of watercourse adjacent to the subject land is a straightened channel. A T-shaped confluence with two other straightened drainage channels is visible at the westernmost corner of the proposed development area. Forms suggesting debris piles are evident north of this confluence along the right channel bank. Downstream of this confluence there is a short section that appears to have been historically straightened within a meandering alignment and a levee or piled debris visible along the length of the northern bank. Approximately 225 m downstream of the subject site the watercourse flows into an area where the channel is poorly defined on the DEM hillshade model. Here the watercourse is situated within a wide, low-lying floodplain that leads to a backwatered pond upstream of an apparent beaver dam located approximately 395 m downstream of the subject site. The gradient marginally increases from an average of < 0.01% upstream to an average of approximately 0.2% downstream of the beaver dam. The watercourse through this section meanders irregularly in an approximately northwestward alignment through a slightly more well-defined channel with the floodplain showing some evidence of historic beaver activity. At approximately 660 m downstream of the subject lands the watercourse turns towards the southwest where both the channel and floodplain become more well-defined as the channel gradient increases to approximately 0.2%. Here the planform alternates between relatively straight and irregularly meandering sections. At approximately 950 m downstream from the subject site the form of another historic beaver dam is present on the hillshade model. Downstream of this the channel turns towards the northwest before crossing under the east-west segment of Thunder Road (1060 m downstream of the subject site). The observations made through analysis of the 2020 high-resolution bare-earth DEM Hillshade model are consistent with the conclusions of the Historical Assessment (detailed above) in which historical beaver and human modifications to the floodplain and channel were identified. Observations of beaver activity were noted upstream of the Thunder Road crossing, where the floodplain was wider and poorly defined, the gradient was less than 0.4%, and the channel was also poorly defined for approximately 25% of its length.

Downstream of Thunder Road the channel gradient increases to approximately 0.5% and the watercourse flows in an irregularly meandering planform confined by a valley until it enters the wider valley of the main Bear Brook channel approximately 215 m downstream of Thunder Road. The valley

walls from the Thunder Road crossing to that point are approximately 3 m above the channel floodplain. The location of the former crossing/berm noted in the Historical Assessment is evident in the hillshade model with the channel breaching the feature 60 m downstream from Thunder Road. The gradient both upstream and downstream of the feature is approximately 0.5%.

3 Watercourse Characterization

3.1 Reach Delineation

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

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

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), the Toronto and Region Conservation Authority (2004) and others. Several watercourse reaches were delineated within the immediate zone of impact associated with each SWM facility based on a desktop assessment of available data (e.g., MNRF stream layer, surficial geology, historical and recent aerial photographs, topographic data).

A total of eight (8) reaches were identified within the subject property, from upstream to downstream: **BBT-1**, **BBT-2**, **BBT-3**, **BBT-4**, **BBT-5**, **BBT-6**, **BBT-7**, and **BBT-8.** Reach mapping is provided in **Appendix A**, for reference.

3.2 General Reach Observations

A site visit was completed by GEO Morphix Ltd. on November 8th 2023, to document existing channel conditions. Photographs of site conditions are provided in **Appendix D** and field observations are included in **Appendix E**, 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, and channel disturbances such as crossing structures

- 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
BBT-1	5.55	1.1	Clay/Silt	Clay/Silt	Trees/Shrubs	• Straightened planform • Relatively uniform U-shaped cross-sectional morphology throughout (i.e., no pool-riffle sequence)
BBT-2	6.75	1.15	Clay/Silt/ Sand	Clay/Silt/ Sand	Trees/Herbaceous	• Evidence of historical agricultural activity along both sides of reach • Historically straightened • Woody and organic debris in channel
BBT-3	21	1.3	Clay/Silt/ Sand	Clay/Silt/ Sand	Herbaceous	• Upstream of historic beaver dam • Reach flows through drained beaver meadow with wide floodplain • Some backwatering and pool present upstream of beaver dam
BBT-4	0.6*	0.53*	Clay/Silt/ Sand	Clay/Silt/ Sand	Herbaceous	• Downstream of historic beaver dam • Flow path poorly defined and obscured by vegetation • Backwatering due to channel constrictions in some locations
BBT-5	1.43*	0.5*	Clay to Gravel	Clay to Gravel	Trees/ Herbaceous	• Riparian area transitions from wide meadow to forested area • High density of woody and organic debris • Meandering planform
BBT-6	1.28*	0.59*	Clay to Gravel	Clay to Gravel	Trees/ Herbaceous	• Upstream Thunder Rd crossing • Planform mostly straight • Forest transitions to meadow with herbaceous vegetation that heavily encroaches on channel
BBT-7	3.57	0.51	Clay to Gravel	Clay to Gravel	Trees/ Herbaceous	• Downstream Thunder Rd crossing • Confined in forested valley • Meandering planform
BBT-8	1.38*	0.63*	Clay to Gravel	Clay to Gravel	Trees/ Herbaceous	• Reach flows through herbaceous meadow • Planform mostly straight with some irregular meanders • Heavy vegetation encroachment

*Indicates measurement is representative of bank width rather than bankfull width due to poor bankfull definition or a wide floodplain

BBT-1 begins at a concrete culvert near 6146 Thunder Road. The culvert outlets to a T-shaped intersection where ditches parallel to Thunder Road meet the watercourse. Reach **BBT-1** flows approximately southwest for 220 m through a straightened channel with relatively uniform U-shaped

cross-sectional morphology throughout the reach. The reach is bordered by forest comprised of coniferous trees planted in rows along the left (south) bank and an abandoned residential property with a mix of grass, herbaceous vegetation, and tree cover along the right (north) bank. The upstream end of the reach that lacks tree cover is populated by emergent aquatic vegetation and some attached algae. Fallen trees across the channel were observed throughout the reach. The bed and bank materials are generally comprised of clay and silt-sized materials, with soft silt deposits on the bed up to 0.20 m deep in some locations. The average bankfull width and depth are 5.55 m and 1.1 m, respectively. The reach ends at another T-shaped confluence with two straightened tributary channels connecting from the north and south. There was a relatively large pool (0.56 m deep) observed at the confluence and a constriction where the watercourse continues and the next reach begins. The Bear Brook Tributary continues in an approximately westward direction downstream of this confluence.

BBT-2 begins at the channel constriction at the downstream end of **BBT-1** and continues downstream for approximately 225 m. The channel appears to have been historically straightened within a meandering alignment, as the channel corridor proceeds westward before meandering slightly north, then back towards the south before a wider bend northward. Further evidence of historical alteration included a levee built up along the right (north) bank setback approximately 5-10 m. The riparian area is comprised of forest with herbaceous vegetation along the channel banks. The average bankfull width and depth are 6.75 and 1.15 m, respectively. Channel bed and banks were comprised of clay to sand-sized particles. Rooted emergent and rooted submergent aquatic vegetation was observed throughout the reach. Woody and organic debris within the channel created a somewhat sinuous thalweg within the straightened alignment that resulted in a mix of narrow, rapid flow sections and slower, wider flow sections. The watercourse continues in an approximately northwest alignment after the wide bend northward, the downstream end of which is where the next reach begins.

BBT-3 continues to meander with low-sinuosity for approximately 170 m towards a breached beaver dam. There was no evidence of contemporary beaver activity observed during the field assessment. The majority of the reach flows through a wide floodplain with herbaceous vegetation cover and emergent aquatic vegetation. Several pools of standing water and side-channels were observed adjacent to the channel within the low-lying floodplain. The average bankfull width and depth were 21 m and 1.3 m, respectively. The channel bed and banks are comprised of clay to sand-sized substrate. Rooted submergent vegetation was observed in the pool on the upstream side of the historic beaver dam. Slumping was observed in some locations along the banks.

BBT-4 begins downstream of the breached beaver dam with a section of poorly defined channel heavily obscured by herbaceous and emergent aquatic vegetation. The channel flows towards the northwest for approximately 265 m in an irregularly meandering pattern through a wide, low-lying floodplain that narrows with distance downstream. Riparian vegetation is comprised of herbaceous species with a forested area setback from the edge of the low-lying floodplain. Channel dimensions were measured, as bankfull dimensions were not estimated due to the breadth of the floodplain. Channel bank width and depth are 0.6 m and 0.53 m, respectively. The channel bed and banks are comprised of clay to sand-sized substrate. Scour and undercuts (0.05-0.15 m) were observed along the banks throughout the reach. An area of backwatering due to a constriction in the channel was observed approximately halfway downstream within the reach. At the downstream end of the reach, the floodplain transitions to a forested area where the next reach begins.

BBT-5 continues downstream in a meandering planform for approximately 200 m. An unmaintained earthen berm, approximately 1 to 2 m height and 2 m in width, spans the floodplain perpendicular to the watercourse at the upstream end of the reach with the berm breached and eroded at the location of the channel. The watercourse continues towards the northwest at first, then approximately 30 m

downstream of the break between **BBT-4** and **BBT-5** it turns towards the southwest and continues in that alignment for the remainder of the reach. The riparian area is comprised of forest with herbaceous vegetation where there are gaps in the trees and along the channel banks. Bankfull dimensions were estimated at 11.7 m wide and 1 m in depth at one location but were otherwise poorly defined. Channel dimensions were measured instead. Bank width and depth are 1.43 m and 0.5 m, respectively. Banks are comprised of clay to sand-sized material overlying a compact red and gray mottled clay till base. The channel bed is comprised of loose clay to small gravel-sized material. Bank angles ranged from 30-90 degrees. Bank undercuts ranging from 0.06-0.20 m and basal scour were observed throughout the reach along both sides of meander bends. J-hooked and leaning trees immature to established in age were also frequently observed along the banks. Woody and organic debris were also frequently observed within the channel.

BBT-6 begins where there is a transition from a forested riparian area to an area dominated by herbaceous meadow with scattered trees and a forest setback at the margins of the low-lying floodplain. There are some straight sections with infrequent and irregular meanders through the upstream end of the reach, which continues in a southwestern alignment for approximately 70 m. The channel then turns towards the northwest and proceeds to meander for approximately 135 m until it meets another Thunder Road crossing. The channel bed elevation notably drops throughout the reach and the bank angles are steeper than the reach upstream. Channel dimensions were measured, as bankfull was poorly defined due to the breadth of the low-lying floodplain. Bank width and depth are 1.28 m and 0.59 m, respectively. Bed and bank composition are identical to reach **BBT-5** and basal scour and undercuts (0.05-0.20 m) were observed along both sides of the channel throughout the reach. J-hooked trees were observed along the banks, and woody and organic debris were observed within the channel.

BBT-7 begins downstream of the Thunder Road crossing and enters a confined valley. The channel flows for approximately 200 m through a forest primarily composed of mature trees and herbaceous vegetation. The watercourse travels westward towards the Bear Brook corridor through irregular meanders. Approximately 60 m downstream of the Thunder Road crossing there is a degraded crossing. There is a corrugated steel pipe culvert situated in the centre of the channel, which has outflanked it to the west and flows through it as well as around it. Riffles and pools were observed throughout the reach, however primarily forced due to the presence of woody debris throughout the channel. Channel dimensions were measured and bankfull width and depth were 3.57 m and 0.51 m, respectively. The channel bed substrate was composed of primarily silt-sized particles with some particles up to coarse sand-size, while small pebbles were also observed within the upstream extent, all overlying a layer of compact red and gray mottled clay. Channel bank angles ranged from 60-90° and erosion was observed along 60-100% of the reach. Bank undercuts ranging from 0.06 m - 0.12 m were observed and scour was noted along both sides of the channel. J-hooked trees and exposed tree roots were prevalent.

BBT-8 begins at a transition from the confined, forested valley of **BBT-7** towards the channel corridor of the mainstem of Bear Brook. Herbaceous vegetation heavily encroached the channel which was generally straight with exception of a few tortuous meanders immediately upstream of the confluence with Bear Brook. Channel dimensions were measured, however bankfull was poorly defined, although it was estimated at 1.38m wide and 0.63 deep. The channel bed and banks were composed of clay to sand-sixed substrate and ranged from 30-90°. Scour was prevalent along the reach and an undercut of 0.06m was recorded at one location. Bank erosion was observed along 30-60% of the reach.

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 purpose of the RGA is to produce a score, or stability index, which evaluates the degree to which a stream has departed from its equilibrium condition. A stream with a score of less than 0.20 is in regime, indicating minimal changes to its shape or processes over time. A score of 0.21 to 0.40 indicates that a stream is in transition or stress and is experiencing major changes to process and form outside the natural range of variability. A score of greater than 0.41 indicates that a stream is in extreme adjustment, exhibiting a new stream type, or in the process of adjusting to a new equilibrium (MOE, 2003; VANR, 2007).

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

The reaches were also classified according to the Downs (1995) Model of Channel Evolution and a modified version of the River Styles Framework (Brierley and Fryirs, 2005). The Downs (1995) model describes successional stages of a channel as a result of a perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve or respond to an alteration to the system. The River Styles Framework is a set of procedures that are applied to describe and explain channel forms and processes and assess channel response and potential future behaviour. These procedures are integrated into our geomorphic field assessment protocol.

Rapid assessments were completed during the site visit on November 8th, 2023. Photographs of channel conditions for all reaches are provided in **Appendix D** and field observations are included in **Appendix E**, for reference. **Table 2**, below, summarizes the results of the rapid field assessments.

Table 2: Reach Classification Summary

Reach Name	RGA (MOE, 2001)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
BBT-1	0.178	In Regime	Widening	30	Good	Riparian Habitat Conditions
BBT-2	0.178	In Regime	Widening	33	Good	Physical Instream Habitat
BBT-3	0.107	In Regime	Aggradation	31	Good	Physical Instream Habitat
BBT-4	0.214	In Transition	Planimetric Adjustment	31	Good	Channel Stability
BBT-5	0.371	In Transition	Widening	29	Good	Physical Instream Habitat
BBT-6	0.363	In Transition	Widening	25	Good	Physical Instream Habitat
BBT-7	0.394	In Transition	Widening	25	Good	Physical Instream Habitat
BBT-8	0.214	In Transition	Widening	27	Good	Physical Instream Habitat

Reach **BBT-1** scored 0.178 on the RGA, indicating that the channel is in regime. The dominant systematic adjustment observed was evidence of widening, as a few fallen and leaning trees as well as occurrence of organic debris in the channel was observed. The reach received an RSAT score of 30, or good. The limiting factor was predominantly riparian habitat conditions due the lack of variation in vegetation and low canopy coverage along the riparian corridor.

Reach **BBT-2** received a score of 0.178 on the RGA, indicating that the channel is in regime. This was similarly due to the dominant systematic adjustment being evidence of widening. Occurrence of woody debris in the channel, and leaning trees contributed to the score. The reach received an RSAT score of 33, or good. The limiting feature along the reach was physical instream habitat due to the lack of riffle-pool features and variety of substrate sizes.

Reach **BBT-3** scored a 0.107 on the RGA, indicating that the channel is in regime. Occurrences of siltation in the pools and deposition along the overbank zone suggested the observed dominant systematic adjustment be evidence of aggradation. The reach received an RSAT score of 31, or good. The limiting factor was physical instream habitat due to the lack of riffle-pool features and variety in substrate sizes.

Reach **BBT-4** received a score of 0.214 on the RGA, indicating that the channel is in transition. It was determined that the dominant systematic adjustment was planform adjustment. This was due to observations of cut-off channels, islands, and the thalweg alignment out of phase. The reach received an RSAT score of 31 or good, with the limiting factor identified as poor channel stability. This was due to observations of bank failure and recent signs of slumping.

Reach **BBT-5** scored 0.371 on the RGA, indicating that the channel is in transition. The dominant systematic adjustment was channel widening, as fallen and leaning trees, exposed roots, large organic debris and basal scour throughout the reach was observed. The reach received an RSAT score of 29 or good. The limiting factor was identified as the physical instream habitat due to the lack of riffle-pool features and variety of substrate sizes.

Reach **BBT-6** was given an RGA score of 0.363, indicating that the channel is in transition. Due to observations of fallen and leaning trees, organic debris in the channel, and basal scour on both banks throughout the reach, it was determined that the dominant systematic adjustment was channel widening. The reach received an RSAT score of 25, or good. The limiting factor was identified as physical instream habitat again, due to a lack of riffles and pools, and a lack or variability in channel substrate sizes.

Reach **BBT-7** scored 0.394 on the RGA, indicating that the channel is in transition. The dominant systematic adjustment was evidence of widening as observations of leaning trees, exposed roots, organic debris in the channel and basal scour along both banks throughout the reach were made. The reach received an RSAT score of 25, or good. The limiting factor was identified as poor physical instream habitat due to shallow riffle and pool depths and channel alteration

Reach **BBT-8** received an RGA score of 0.214, indicating that the channel is in transition. The dominant systematic adjustment observed was channel widening due to observations of organic debris in the channel, fracture lines, and basal scour on both banks throughout the reach. An RSAT score of 27, or good was assigned. The limiting factor was physical instream habitat due to the lack of riffle and pool features.

3.4 Detailed Geomorphological Assessment

A detailed geomorphological assessment was completed for reach **BBT-7** on November 15th, 2023. This reach was selected for detailed assessment based on the results of the desktop assessment (see Section 2.4) and rapid field assessment (see Section 3.2) of the receiving watercourse. The results of these broader scale assessments indicated that reach **BBT-7** was the reach most susceptible to changes in erosion potential associated with the proposed development. This determination was based on multiple factors including evidence of active channel bank scour along the reach, and the reach being both confined and with a steeper channel gradient relative to upstream reaches. Consistent with this assessment were RGA scores which were higher and RSAT scores that were lower relative to the other assessed reaches along the receiving watercourse. Higher RGA scores indicate a greater degree of channel instability whereas lower RSAT scores indicate poorer quality stream conditions (i.e., RSAT includes an evaluation of ecological indicators as well as channel stability and scour).

The detailed assessment included measurements and observations of channel form (i.e., planform, bed-configuration, slope, and cross-sectional form), bed and bank materials, erosion indicators (i.e., undercutting, exposed roots, mass movement), bankfull indicators, and aquatic and riparian vegetation. Measurements of water velocity and observations of sediment transport were also made along the reach. Detailed measurements and observations were at collected at eight representative cross sections and a longitudinal survey of the channel was completed to determine reach slope.

For reference, photographs of channel conditions are provided in **Appendix D** and a comprehensive summary of the channel measurements is included in **Appendix F**. In the following section, channel characteristics relevant for the erosion threshold analysis are presented in **Table 3.**

4 Erosion Threshold Analysis

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. Erosion thresholds were modelled from detailed field observations of reach **BBT-7**. This reach was selected for the assessment, as it was determined to be the most erosion-sensitive reach within the potential zone of impact within the receiving watercourse (see details provided in preceding section). 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. Due to variability between bed and bank composition and structure, erosion thresholds are determined for both bed and bank materials. The lower of the bed and bank erosion thresholds is adopted, as it provides the more conservative and limiting estimate of erosion potential.

4.1 Methods

Erosion thresholds 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. Alternatively, a velocity-based approach can be applied. For fine grained sediments, empirically derived values such as those compiled by Fischenich (2001), Chow (1959) or Julien (1994), can be applied.

An erosion threshold, defined in terms of a critical discharge, is quantified based on the bed and bank materials and local channel geometry. 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 in slightly exceeds the critical threshold of the bed material. The velocity is determined using a Manning's approach, where the Manning's n value is visually estimated through a method described by Acrement and Schneider (1989) or calculated using the Limerino (1970) approach. The velocity is mathematically represented as:

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

where, d is depth of water, S is channel slope, and n is the 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:

$$\tau = d\rho g S_{bed} \qquad \text{[Eq. 2]}$$

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

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

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).

4.2 Results

Banks within **BBT-7** were composed of soils with particles ranging from clay to sand in size. Fresh sandy overbank deposits were observed on top of the soil comprising the banks throughout the reach. Compact clay till underlying the soil was observed to be exposed along the base of the bank at several locations where scour had occurred. Based on field observations, the bank materials were classified as silty loam using the criteria of Fischenich (2001). Using the empirically derived values from Fischenich (2001) a critical velocity of 0.53 m/s for the erosion of silty loam was used for the bank material which yielded a critical discharge estimate of 0.808 m^3/s based on the average cross-sectional area of the channel.

Bed materials within **BBT-7** were composed largely of particles ranging from silt to coarse sand in size, with the addition of small pebble-sized materials observed at 2 of the 7 surveyed cross-sections and loose clay-sized materials with cohesive properties observed at 1 of the 7 surveyed cross-sections. Compact clay till was exposed on the bed at 1 of the 7 surveyed cross-sections. Based on field observations, the bed materials were classified as silty loam (i.e., a mixture of predominantly silt sized particles with some sand and some clay). This classification was considered the most appropriate to capture the range of bed material sizes and properties observed throughout the reach. Using the empirically derived values from Fischenich (2001), a critical velocity of 0.53 m/s for the erosion of silty loam was used for the bed material, yielding a critical discharge estimate of 0.203 m^3/s based on the average cross-sectional area of the channel.

The final, modelled erosion threshold is the lesser of the bed and bank materials, and in this instance was determined to be 0.203 m3/s for the bed materials. A pre-development drainage area of 148.64 ha was provided by JFSA (2024) and used to calculate the unitary erosion threshold of 0.00136 m3/s/ha. The results of the erosion threshold assessment are provided in **Table 3** below.

Table 3: Reach BBT-7 detailed assessment and erosion threshold analysis results

Channel Parameter	BBT-7		
Channel Characteristics			
Average bankfull width (m)	3.57		
Average bankfull depth (m)	0.31		
Channel gradient (%)	0.47		
D_{50} (mm)	<2.0		
D_{84} (mm)	<2.0		
Manning's n roughness coefficient	0.04		
Average bankfull discharge (m^3/s)	0.733		
Average bankfull velocity (m/s)	0.737		
	Bed	**Banks**	
Material	Silt loam	Silt loam	Compact clay
Reference	Fischenich, 2001	Fischenich, 2001	Chow, 1959
Critical velocity at the bed (m/s)	0.53	0.53	0.54
Apparent shear stress (N/m^2)	8.28	10.74	10.77
Critical discharge (m^3/s)	0.203	0.808	0.876
Unitary threshold ($m^3/s/ha$)*	0.00136	0.00544	0.00589
Limiting critical discharge (m^3/s)	**0.203**		

* Determined using a 148.64 ha drainage area 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). An outlet is proposed to drain a SWM pond that will release flows to the upstream end of the subject tributary at **BBT-1.** Ultimately, flows drain downstream into reach **BBT-7**, which was determined through rapid assessments to be the most erosion sensitive reach downstream of the proposed outlet located within the potential zone of impact.

Using the results of the erosion threshold analysis and hydrological simulation modelling provided by JFSA (2024) for pre- and post-development conditions, an erosion exceedance analyses to evaluate the potential for changes in the amount of erosion within the watercourse were completed with our in-house Erosion Exceedance Model. The most relevant erosion exceedances indices are summarized below:

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

(CVC, 2015). 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 (TRCA, 2012).

Time of exceedance, number of exceedances, and cumulative effective discharge and volume can be calculated from the discharge record and established critical discharge value (i.e., erosion threshold). 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. Specific details about how each of these key erosion metrics are calculated is provided in the following subsection.

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 a 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 reach **BBT-7** was provided by JFSA (2024) in 5-minute increments for a 40-year period from 1968 to 2007. The hydrological modelling reflects local rainfall data from that period; with the yearly data spanning the period spring to fall. The years 2001 and 2005 are not represented in the data, however, as rainfall data for those years was not available in the historic climate record used for the hydrological simulation. The hydrological simulation data for pre- and post-development conditions 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 G**, for reference.

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 the 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:

$$Q_{T=} \sum Q_i \qquad \text{[Eq. 3]}$$

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

$$Q_i = U_i w_i d_i \qquad \text{[Eq. 4]}$$

where, w_i and d_i are width and 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 a maximum bed shear stress, $\tau_{o_{\max}}$ based on:

$$\tau_{o_{\max}} = d_{\max}\rho g S_{\text{bed}} \quad \text{[Eq. 5]}$$

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

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

$$\omega_{\text{tot}} = \sum \tau_{0_{\max}} . U_{\text{avg}} . \Delta t \quad \text{[Eq. 6]}$$

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

$$\omega_{\text{eff}} = \sum \tau - \tau_{cr} . U . \Delta t, \omega < 0 = 0 \quad \text{[Eq. 7]}$$

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

Time of exceedance t_{ex} defined as:

$$t_{\text{ex}} = \sum \Delta t \quad \text{for } (Q_T > Q_{\text{threshold}}) \quad \text{[Eq. 8]}$$

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

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

$$\text{CEV} = \sum Q \text{ (for } Q > Q_{threshold}) \quad \text{[Eq. 9]}$$

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

$$\text{CED} = \text{CEV}/t_{ex} \quad \text{[Eq. 10]}$$

5.2 Results

Modeling results indicate an insignificant post-development increase in erosion indices. We note that the cumulative effective work index (ωeff; CEWI) is considered the most relevant index with respect to erosion potential, as it reflects both the flow magnitude and exceedance duration of a given erosion event. Results indicated a 3.86% increase in post development CEWI. Results within +/-5% are not considered to be significant enough to result in a detectable change in erosion potential. Therefore, the results indicate that the erosion potential of the receiving watercourse, expressed in this case by CEWI, is maintained post-development. Of secondary relevance is the cumulative effective discharge (CED) indicator, representing the total discharge volume that exceeds the established critical discharge throughout the modelling record. The erosion exceedance modeling was completed using one set of hydrological simulation data that reflects local rainfall data spanning the years 1968 to 2007 (provided by JFSA). The pre-development and post-development hydrographs are included in **Appendix G**. **Table 4** provides the results of the assessment based on the flow data provided by JFSA (2024).

Table 4: Reach BBT-7 cumulative pre- and post-development erosion exceedance analysis results

Simulation		CED (m^3/s)	ω_{eff} (N/m^2)	t_{ex} (hrs)	# Of Exceedances
Cumulative	**(PRE)**	459,259	3,682	492	112
	(POST)	453,223	3,825	540	120
	Change (%)	**-1.31**	**3.86**	**9.70**	**7.14**

The cumulative effective discharge (CED) represents the total volume of flow exceeding the threshold during a given year. The pre-development CED estimate for all years is approximately 459,259 m^3/s, while the post-development CED estimate is approximately 453,223 m^3/s, which amounts to a negligible decrease of 1.31%. The cumulative effective work index (ω_{eff}) reflects both the duration and magnitude of erosion events. The pre-development ω_{eff} estimate summed for all years is approximately 3,682 N/m^2, while the post-development ω_{eff} estimate is approximately 3,825 N/m^2, which amounts to a slight increase of 3.86%.

The cumulative time of exceedance (t_{ex}) represents the cumulative time for which flow exceeds the established erosion threshold. The pre-development t_{ex} estimate summed for all years is approximately 492 hrs, while the post-development t_{ex} estimate is approximately 540 hrs, which amounts to 9.70% increase. The number of exceedances also increased by 7.14%, from 112 pre-development, to 120 under post-development conditions.

The percent change estimates for CED and ω_{eff} fall within the +/-5% range of variability expected in natural channels. The estimated percent change for cumulative effective work, defined as the most relevant index in terms of erosion potential, is approximately 4%. As such, the proposed stormwater management plan adequately addresses concerns relating to potential erosion impacts of the development on the receiving watercourse.

6 Summary

GEO Morphix Ltd was retained by Thunder Road Limited Partnership to complete a fluvial geomorphology assessment in support of a proposed development at 6160 Thunder Road and 5368 Boundary Road in Ottawa, Ontario. This report summarizes the existing geomorphic conditions of the channel and provides erosion threshold and exceedance analysis to understand potential erosion impacts to the receiving watercourse associated with the proposed development.

Activities completed for the assessment included a detailed desktop review of available geology, topography, drainage area characteristics and watercourse reach confirmation and delineation. General channel observations, rapid stream assessments, and a detailed geomorphological assessment along the most sensitive reach were completed on November 8th and 15th, 2023. These assessments documented existing channel characteristics and assessed relative erosion-sensitivity of each channel reach. The results of the rapid assessments informed the location of the detailed geomorphological assessment, which was completed at reach **BBT-7**.

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 **BBT-7**. An erosion threshold of 0.203 m^3/s was defined for the subject reach. Using a drainage area of 148.64 ha provided by JFSA (2024) a corresponding unitary erosion threshold was defined as 0.00136 $m^3/s/ha$. The results from a site-wide continuous hydrological simulation model were used to calculate pre- and post-development erosion exceedance indices for the site. Modeling results demonstrate that the proposed stormwater management strategy for the development is effective in mitigating potential downstream erosion impacts to the receiving watercourse.

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

Respectfully submitted,

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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 Bear Brook Erosion Threshold and Exceedance Assessment

Ottawa, Ontario

Legend

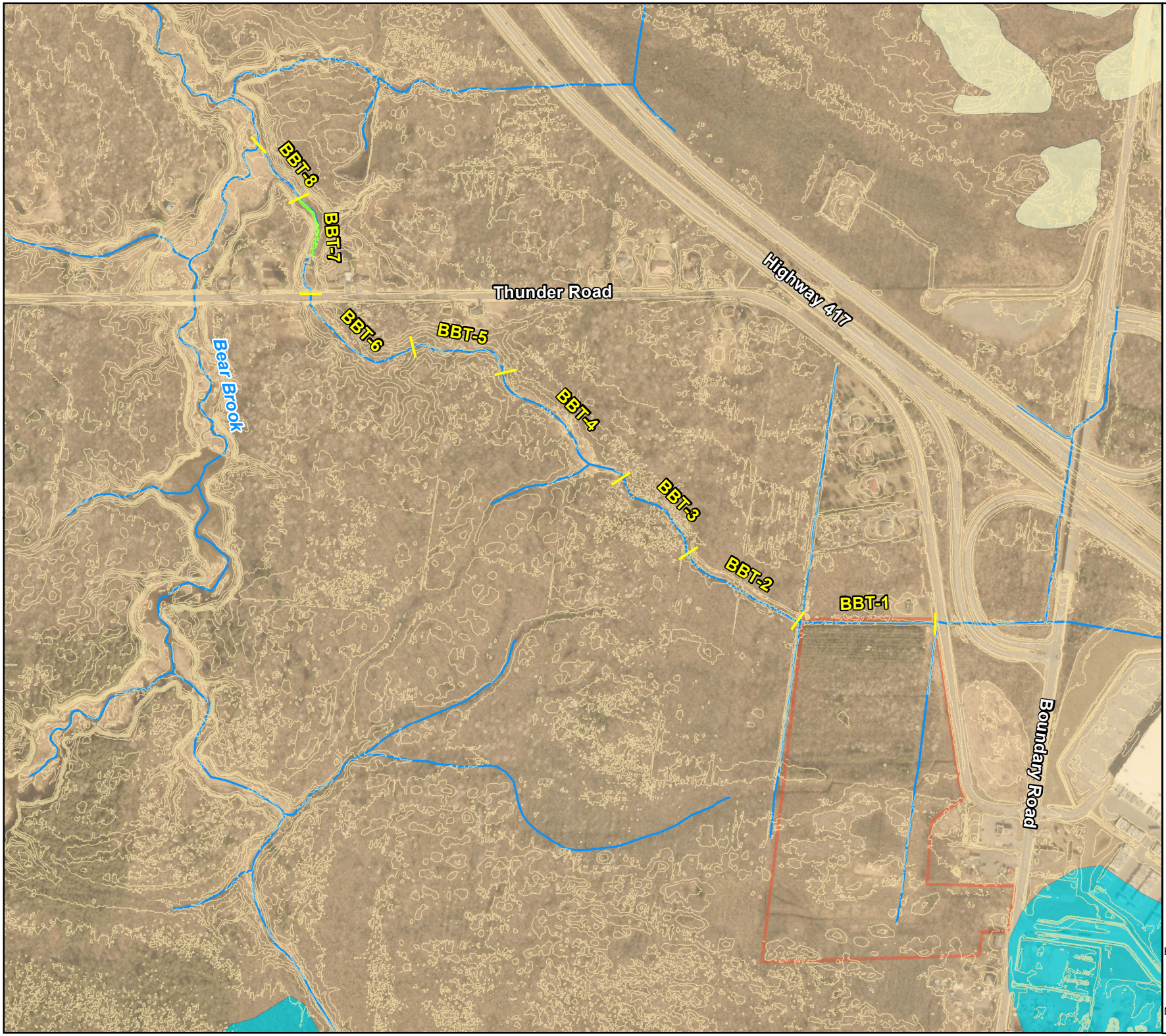
- Reach Break and ID
- Watercourse
- Detailed Assessment Location
- 0.5 m Contour
- Site Plan
- Development Boundary
- Stormwater Retention Pond

0 130 260

Metres

Imagery: City of Ottawa, 2021.
Reach Break and ID, Detailed Assessment Location: GEO Morphix Ltd., 2023.
Development Boundary and site Plan: MCROBIE Architecture + Interior Designers, 2024.
Watercourse, 0.5 m Contour: MNRF, 2019-2020.
Print Date: June 2024. PN23111. Drawn By: K.S., G.U.

Appendix B:
Surficial Geology



GEO MORPHIX™

Surficial Geology

Tributary to Bear Brook Erosion Threshold and Exceedance Assessment

Ottawa, Ontario

Legend

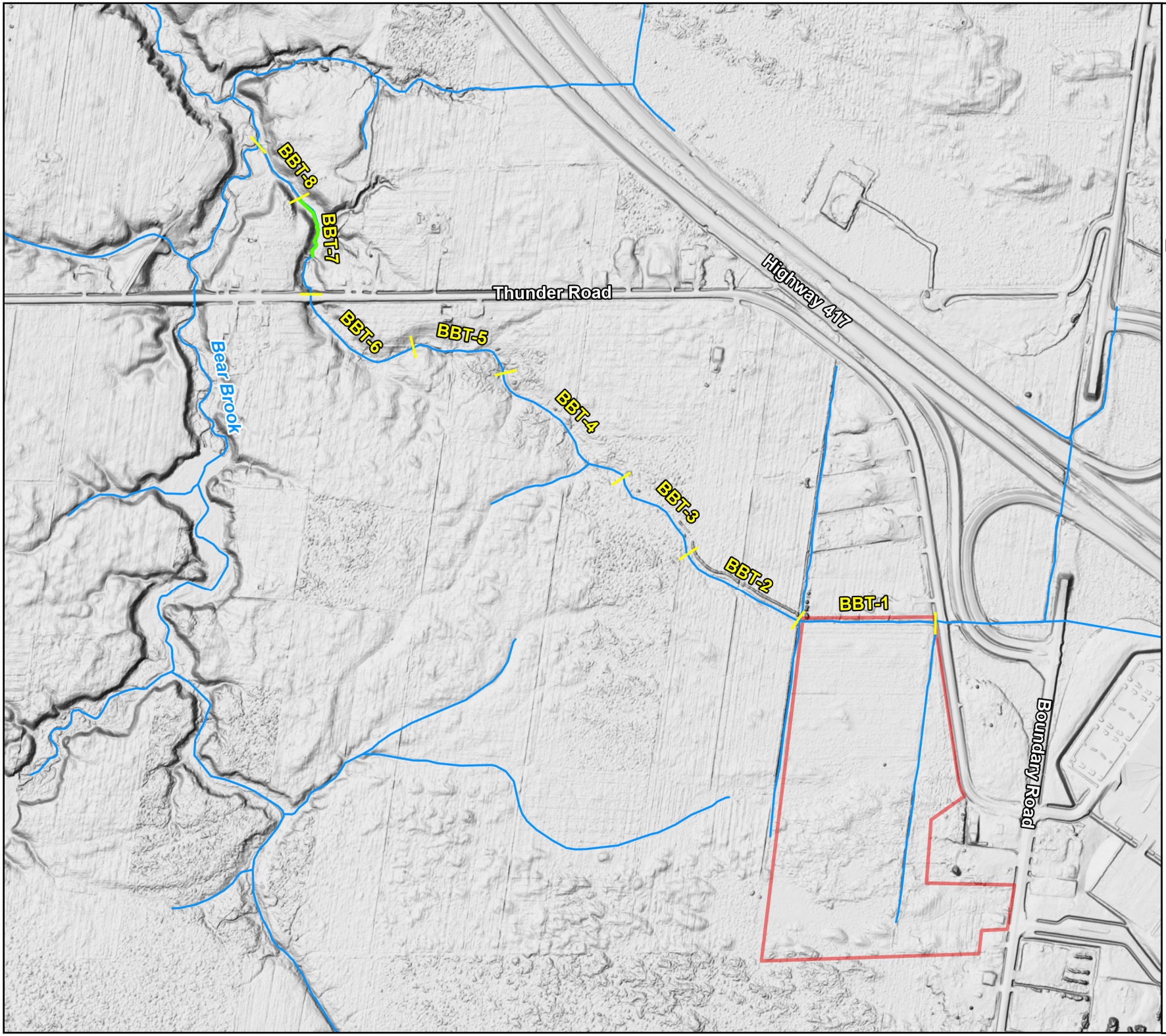
- Reach Break and ID
- 0.5 m Contour
- Watercourse
- Detailed Assessment Location
- Approximate Development Boundary
- 10a: Massive-well laminated
- 17: Eolian deposits
- 11a: Coarse-textured glaciofluvial and glaciomarine deposits

0 130 260

Metres

Imagery: City of Ottawa, 2021. Reach Break and ID,Approximate Development Boundary, Detailed Assessment Location: GEO Morphix Ltd., 2023. Watercourse: OHN, 2020. Surficial Geology: MNRF, 2010. 0.5 m Contour: MNRF, 2019-2020. Drawn By: M.O., K.S Print Date: May 2024. PN23111.

Appendix C:
Historical Aerial Photographs and Terrain Map



GEO MORPHIX™

DRAFT

Terrain Analysis

Tributary to Bear Brook Erosion Threshold and Exceedance Assessment

Ottawa, Ontario

Legend

- Reach Break and ID
- Detailed Assessment Location
- Watercourse
- Approximate Development Boundary

INTERNAL USE ONLY

0 130 260

Metres

Terrain Analysis: MNRF, 2020. Reach Break and ID, Detailed Assessment Location, Approximate Development Boundary: GEO Morphix Ltd., 2023. Watercourse: OHN, 2020. 0.5 m Contour: MNRF, 2019-2020. Print Date: May 2024. PN23111. Drawn By: M.O., K.S., G.U.

Location: 6150 Thunder Road, Ottawa, ON
Year: 1965
Source: Geo Ottawa
Red Arrow: Thunder Road crossing
Yellow Arrow: Upstream extent

Location: 6150 Thunder Road, Ottawa, ON
Year: 1976
Source: GEO Ottawa
Red Arrow: Thunder Road crossing
Yellow Arrow: Upstream extent

Location: 6150 Thunder Road, Ottawa, ON
Year: 1991
Source: GEO Ottawa
Red Arrow: Thunder Road crossing
Yellow Arrow: Upstream extent

Location: 6150 Thunder Road, Ottawa, ON
Year: 2008
Source: GEO Ottawa
Red Arrow: Thunder Road crossing
Yellow Arrow: Upstream extent

Location: 6150 Thunder Road, Ottawa, ON
Year: 2021
Source: GEO Ottawa
Red Arrow: Thunder Road crossing
Yellow Arrow: Upstream extent

Appendix D:
Photographic Record

Photo 1
Tributary of Bear Brook
Reach BBT-1

Photograph taken at the upstream extent of **BBT-1**, facing downstream. The riparian zones along the entire reach were immature hardwoods and mature softwoods as a part of a plantation along the left bank, and grasses/herbaceous vegetation and manicured grass as part of a private property along the right bank.

Photo 2
Tributary of Bear Brook
Reach BBT-1

Photograph taken facing downstream along **BBT-1.** Several down trees were observed along the reach and woody debris in the channel was common.

Photo 3
Tributary of Bear Brook
Reach BBT-1

Photograph taken facing downstream along **BBT-1.** The reach was historically straigtened and lacked pool-riffle features.

Photo 4
Tributary of Bear Brook
Reach BBT-1

Photograph taken at the downstream extent of **BBT-1**, at the confluence with a drainage ditch and **BBT-2.** A pool had formed at the confluence. Little signs of erosion were observed throughout the reach.

Photo 5 **Tributary of Bear Brook** **Reach BBT-2**	
	Photograph taken at the upstream extent of **BBT-2**, facing downstream. The riparian corridor transitions to herbaceous vegetation, grasses, and mature hardwoods.
Photo 6 **Tributary of Bear Brook** **Reach BBT-2**	
	Photograph taken facing downstream along **BBT-2.** Woody debris in the channel and down trees have created riffles and pools resulting in areas of deposition and pools.

Photo 7
Tributary of Bear Brook
Reach BBT-2

Photograph taken facing downstream along **BBT-2.** Evidence of historic agricultural activity adjacent to the channel observed. The channel slightly wandered, but was evidently historically straightened.

Photo 8
Tributary of Bear Brook
Reach BBT-2

Photograph taken at the downstream extent of **BBT-2.** The channel exhibited no riffle-pool formations and there was litter signs of erosion observed throughout the reach.

Photo 9 Tributary of Bear Brook Reach BBT-3	
	Photograph taken at the upstream extent of **BBT-3**. Riparian vegetation transitions into wetland dominated species which encroached within the channel. Field observations suggest this portion of the reach was historically backwatered by downstream beaver dam.
Photo 10 Tributary of Bear Brook Reach BBT-3	
	Photograph taken facing downstream along **BBT-3.** The channel had low sinuosity and travelled within a wide floodplain dominated by herbaceous vegetation and grasses. Bed substrate was composed of fine silt.

Photo 11 **Tributary of Bear Brook** **Reach BBT-3**	
	Photograph taken facing south from the left bank along **BBT-3.** Several dewatering zones and secondary flow paths were observed throughout the reach.
Photo 12 **Tributary of Bear Brook** **Reach BBT-3**	
	Photograph taken facing south towards the right bank. The large beaver dam (1.5 tall), on the left side of the photo had a large 5-foot gap through the middle. Vegetation was well established along the top of the dam.

Photo 13
Tributary of Bear Brook
Reach BBT-4

Photograph taken at the upstream extent of **BBT-4**, facing downstream. Field observations suggested this portion of the reach was also part of a historical beaver pond. The channel separates into multiple flow paths travelling within the wide floodplain.

Photo 14
Tributary of Bear Brook
Reach BBT-4

Photograph taken at the downstream extent of **BBT-4,** where the channel merges back into one flow path. At the downstream extent, the gradient increases, and down cuts, resulting in observed basal scour and undercutting.

Photo 15
Tributary of Bear Brook
Reach BBT-5

Photograph taken facing downstream along **BBT-5.** The channel gains defined banks and meanders through a forest composed of established trees and grasses.

Photo 16
Tributary of Bear Brook
Reach BBT-5

Photograph taken facing downstream along **BBT-5**. Woody debris was present in the channel and cutbanks throughout the reach, forming riffle-pool sequences.

Photo 17
Tributary of Bear Brook
Reach BBT-5

Photograph taken facing the left bank along **BBT-5.** Undercutting and basal scour was observed throughout the reach, concentrated along meander bends. The most severe areas were due to debris in the channel re-directing flows.

Photo 18
Tributary of Bear Brook
Reach BBT-5

Channel bed substrate along **BBT-5** was composed of coarse silt and fine sands.

Photo 19
Tributary of Bear Brook
Reach BBT-6

Photograph taken facing downstream along **BBT-6**. The riparian corridors were primarily grasses and herbaceous vegetation with establish hardwoods and shrubs.

Photo 20
Tributary of Bear Brook
Reach BBT-6

Photograph taken facing downstream along **BBT-6**. Undercutting, exposed roots and 'J' hooked trees were frequently observed throughout the reach. Most of the severe areas were due to debris in the channel redirecting flows.

Photo 21 Tributary of Bear Brook Reach BBT-6	
	Photograph taken facing downstream along **BBT-6**. The watercourse lacked pool-riffle features other then those created by instream debris. Bed substrate was composed of silt.
Photo 22 Tributary of Bear Brook Reach BBT-6	
	Photograph taken at the downstream extent of **BBT-6.** The watercourse passes through a densely vegetated section and under thunder road through a culvert.

Photo 23
Tributary of Bear Brook
Reach BBT-7

Photograph taken at the upstream extent of **BBT-7**, facing downstream. The riparian corridor transitions from predominantly herbaceous vegetation to a mix of trees and grasses.

Photo 24
Tributary of Bear Brook
Reach BBT-7

Photograph taken facing downstream along **BBT-7**. The watercourse exhibited a meandering planform within a confined valley.

Photo 25
Tributary of Bear Brook
Reach BBT-7

Photograph taken facing upstream along **BBT-7**. Undercutting, basal scour, exposed roots and 'J' hooked trees were all commonly observed throughout the reach. Woody debris in the channel and cutbank was common.

Photo 26
Tributary of Bear Brook
Reach BBT-7

Photograph taken facing the right bank along **BBT-7.** Several groundwater upwellings were observed along the channel.

Photo 27
Tributary of Bear Brook
Reach BBT-8

Photograph taken facing downstream along **BBT-8**. The channel enters the Bear Brook corridor and riparian vegetation becomes predominantly wetland vegetation species which heavily encroach into the channel.

Photo 28
Tributary of Bear Brook
Reach BBT-8

Photograph taken facing the right bank along **BBT-8.** The channel banks were well vegetated. Few signs of erosion were observed.

Appendix E:
Field Observations

GEO MORPHIX™

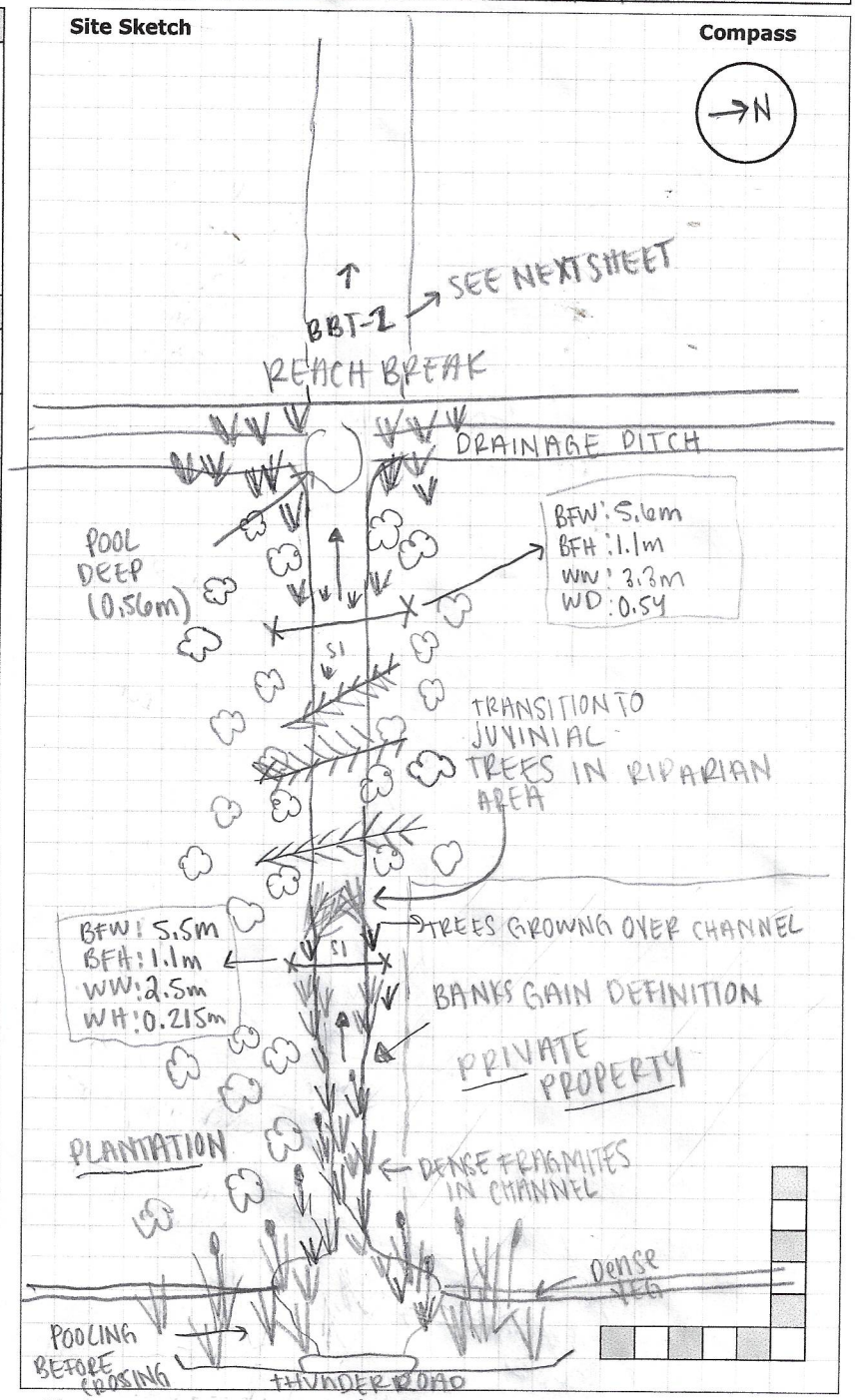
General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOKE TRIB
Time:	11:00am	**Reach:**	BBT-1
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOKE

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: (100s/coarse)

Notes: · CHANNEL BED SILTY (~0.20m) - WATER LEVELS LOW - NO RIFFLE-POOL FORMATION, HISTORICALLY STRAIGHTENED - SOFTER SED UPSTREAM, ROOTED SUBMERGENTS ON BED

V_1: 7.42(1m) V_2: 21.10 (50cm)

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	11:00	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C SUNNY	**Reach:**	BBT-1	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1,2 | **Encroachment** (Table 7): 2

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): 1,2 | **Reach Coverage %**: 20

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): N/A | **Sinuosity Degree** (Table 10): 1 | **Gradient** (Table 11): 1 | **# of Channels** (Table 12): 1 | **Entrenchment** (Table 13): 1 | **Bank Failure** (Table 14): N/A | **Down's Model** (Table 15): S | **Bankfull Indicators** (Table 18): 1,3 | **Sed Sorting** (Table 20): WS | **Sediment Transport Observed?** ☐ Yes ☒ No ☐ Not Visible | **Transport Mode** (Table 21): N/A | **% of Bed Active**: 0 | **Geomorphic Units** (Table 22): 8 | **Mass Movement** (Table 23): N/A | **Riffle-Pool Spacing (m)**: N/A | **% Riffles**: 0 | **% Pools**: 0

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)	5.5	5.6		**Wetted Width (m)**	2.5	3.3		
Bankfull Depth (m)	1.1	1.1		**Wetted Depth (m)**	0.215	0.54		
Undercuts (m)	N/A			**Velocity (m/s)**	0.135	0.024		
Pool Depth (m)	—			**Velocity Estimate Method**	WB	WB		
Riffle Length (m)	N/A			**Meander Amplitude (m)**	N/A			

Notes: CHANNEL BED COMPRISED OF SOFT SILTY DEPOSITS, UP TO 0.20 M DEEP IN SOME LOCATIONS. PLANFORM IS STRAIGHT, CROSS-SECTION IS GENERALLY U-SHAPED. NO RIFFLE-POOL FORMATION, MORPHOLOGY UNIFORM THROUGHOUT. REACH ENDS AT T-SHAPED CONFLUENCE W OTHER STRAIGHTENED CHANNELS; A LARGE DEEP POOL IS PRESENT WHERE THE 3 CHANNELS INTERSECT, WHICH THEN FEEDS INTO A SLIGHTLY NARROWER AND HIGHER GRADIENT REACH (BBT-2) IN THE SAME ALIGNMENT AS BBT-1. LAND COVER SURROUNDING BBT-1 IS RESIDENTIAL (ABANDONED SINGLE FAMILY HOME) ALONG THE RB AND REFORESTED / TREE PLANTATION ALONG THE LB.

Photos:

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	11:00 AM	**Reach:**	BBT-1
Weather:	0°C SUNNY	**Location:**	6150 THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		✓	1/7
	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 =	1	6	0.142
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	1/7
	2	Exposed sanitary / storm sewer / pipeline / etc.	✓		
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		✓	
	6	Cut face on bar forms		✓	
	7	Head cutting due to 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 =	1	6	0.142
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		2/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	2	5	0.285
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	0.142

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.177

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	11:00 AM	**Reach:**	BBT-1
Weather:	0°C SUNNY	**Location:**	6150 THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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 N/A
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:	03-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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) = 30	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

N/A

N/A

N/A

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	11:45am	**Reach:**	BBT-2
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOKE

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

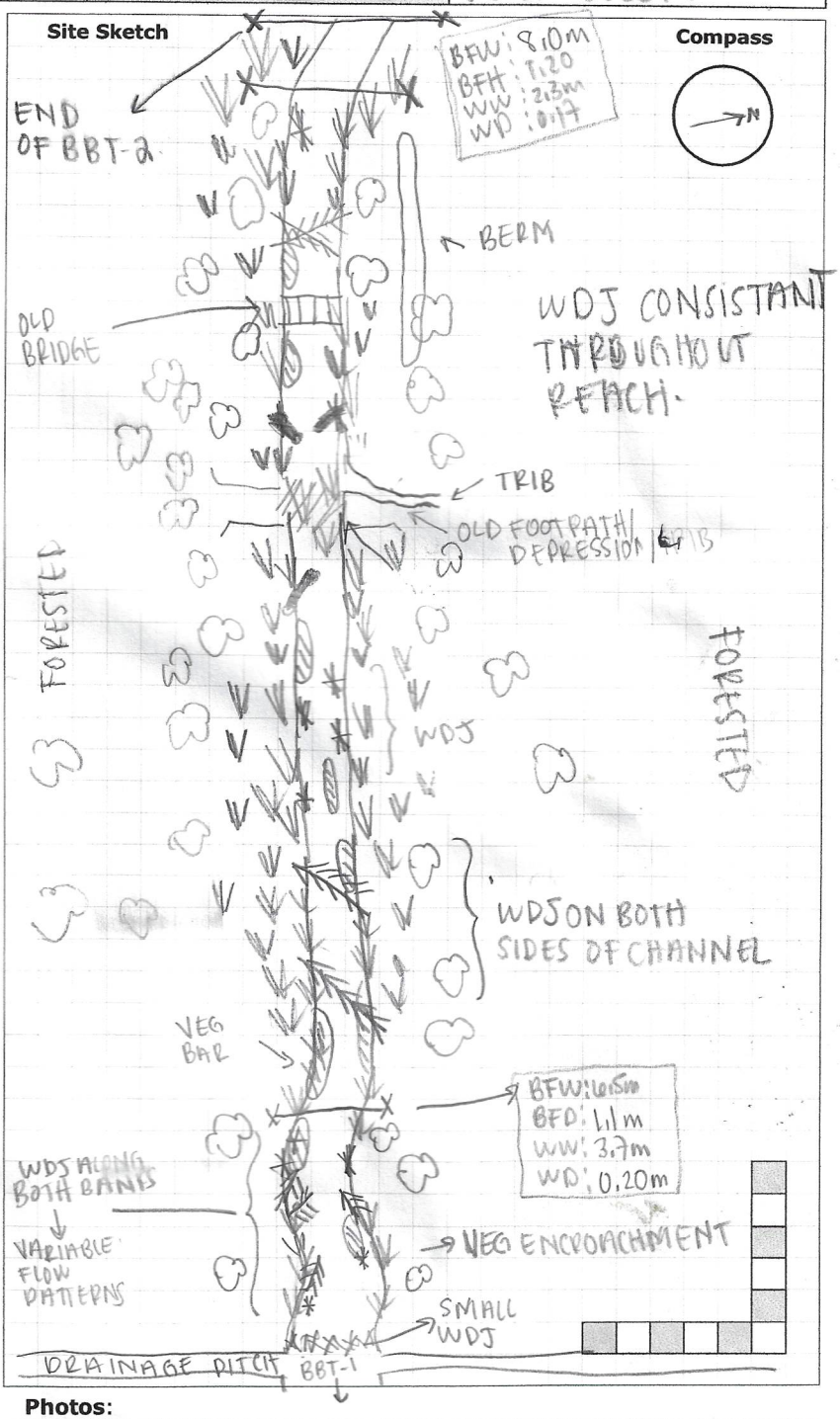
Substrate

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: ~CHANNEL STRAIGHTENED. MORE WDJ IN CHANNEL COMPARED TO BBT-1. WDJ CAUSING VARIABLE FLOW PATHS/VELOCITIES, CAUSING ZONES OF DEP; MOSTLY RUNS + POOLS

~CHANNEL BED: SAND, (COARSE) SILT

V_1: 10.07 (1m) V_2: 6.73 (1m)

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	11:30 AM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C SUNNY	**Reach:**	BBT-2	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1,4 | **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 %**: 20

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): N/A | **Sinuosity Degree** (Table 10): 1 | **Gradient** (Table 11): 1 | **# of Channels** (Table 12): 1 | **Entrenchment** (Table 13): 1 | **Bank Failure** (Table 14): N/A | **Down's Model** (Table 15): S | **Bankfull Indicators** (Table 18): 1,3 | **Sed Sorting** (Table 20): WS | **Sediment Transport Observed?** ☐ Yes ☒ No ☐ Not Visible | **Transport Mode** (Table 21): N/A | **% of Bed Active**: 0 | **Geomorphic Units** (Table 22): 5,8 | **Mass Movement** (Table 23): N/A | % RUNS: 10 | **Riffle-Pool Spacing (m)**: 20 | **% Riffles**: 10 | **% Pools**: 80

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)	6.5	8		**Wetted Width (m)**	3.7	2.3	
Bankfull Depth (m)	1.1	1.2		**Wetted Depth (m)**	0.2	0.17	
Undercuts (m)	—			**Velocity (m/s)**	0.099	0.149	
Pool Depth (m)	—			**Velocity Estimate Method**	WB	WB	
Riffle Length (m)	2			**Meander Amplitude (m)**	N/A		

Notes: CHANNEL APPEARS HISTORICALLY STRAIGHTENED, EVIDENCE OF HISTORIC AGRICULTURAL ACTIVITY ALONG BOTH SIDES THROUGHOUT W/S PORTION OF REACH. CHANNEL CORRIDOR SOMEWHAT "WANDERS" INSTEAD OF MEANDERING (I.E. IT MAY HAVE BEEN HISTORICALLY STRAIGHTENED IN ITS NATURAL MEANDERING ALIGNMENT. WOODY AND ORGANIC DEBRIS IN CHANNEL CREATE LOW SINUOSITY THALWEG W/IN STRAIGHT CHANNEL. NARROW AND RAPID FLOW ZONES (I.E. RIFFLES) ARE CAUSED BY WOODY AND ORGANIC DEBRIS. THERE APPEARS TO BE A MAN-MADE LEVEE BUILT UP ALONG THE RB THROUGHOUT THE REACH SETBACK APPROX. 5-10 M FROM CHANNEL BANK.

Photos:

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	11:30 AM	**Reach:**	BBT-2
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	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	0.285
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	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 =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	✓		2/7
	2	Occurrence of large organic debris	✓		
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		N/A	
		Sum of indices =	2	7	0.285
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	0.142

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.178

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	11:30AM	**Reach:**	BBT-2
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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:	08-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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

N/A

Total overall score (0–42) = 33	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™

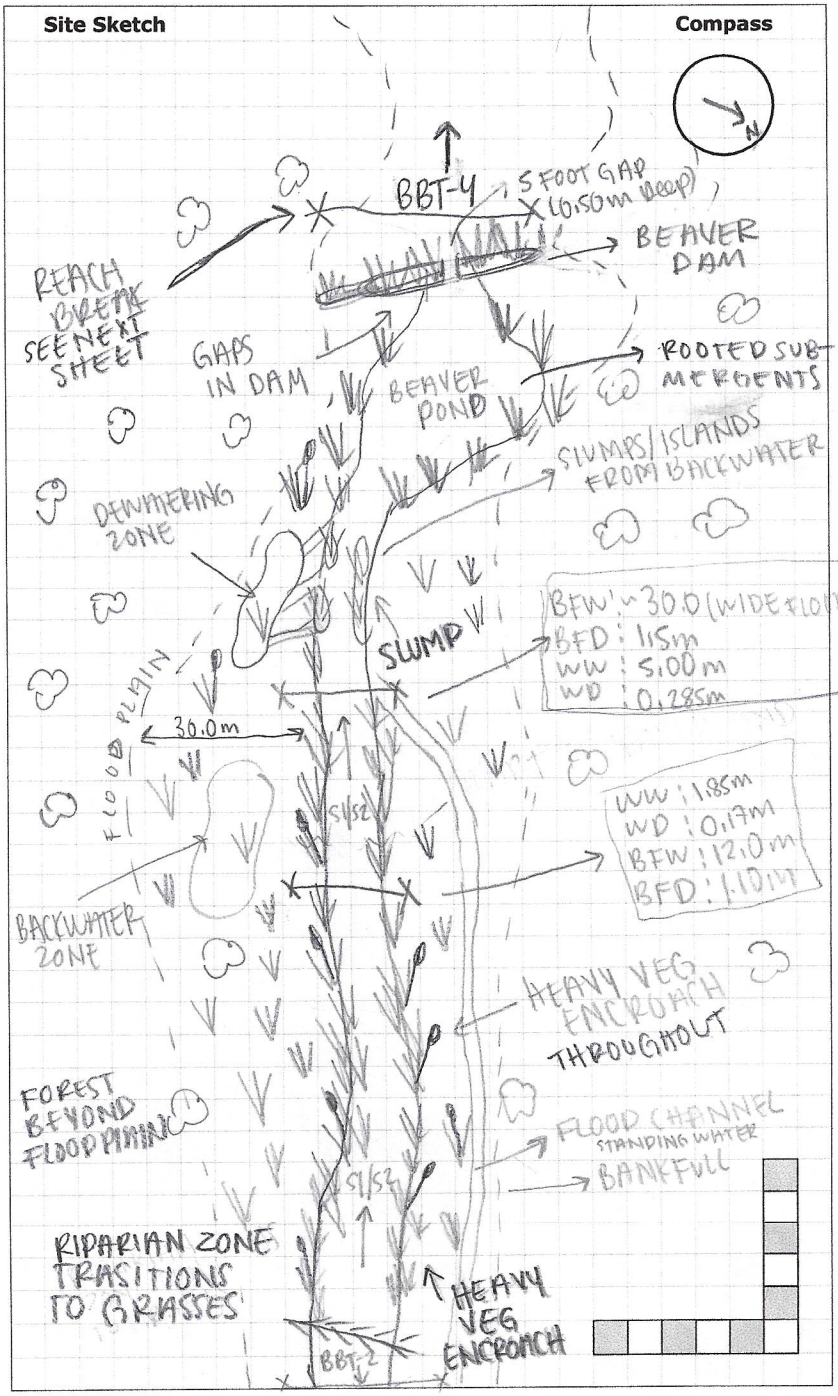
General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	TRIB OF BEAR BROOKE
Time:	12:30pm	**Reach:**	BBT-3
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOKE

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 **Compass**



Flow Type

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

Substrate

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

Other

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

Photos:

Notes: -NO RIFFLE - POOLS
- CHOSE TO BEAVER POND, VEG ENCROACHMENT BECOMES EXTREME
- EVIDENCE OF SOME DE-WATERING, LOW BANKS, SILTY BED, WIDE FLOODPLAIN

V_3: 7.15 (1m) (COARSE SILT / FINE SAND ON BED (0:20))

Version #4 V_2: 14.26 (1m)
Last edited: 21/02/2023

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

NO RIFFLE/POOLS

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	12:15 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C SUNNY	**Reach:**	BBT-3	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 4
Encroachment (Table 7): 4

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): 1,2
Reach Coverage %: 80

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

WDJ/50m: 0

Water Quality

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

Channel Characteristics

Sinuosity Type (Table 9): 2
Gradient (Table 11): 1
Entrenchment (Table 13): 1
Down's Model (Table 15): D
Sed Sorting (Table 20): WS
Transport Mode (Table 21): N/A
Geomorphic Units (Table 22): 8
Riffle-Pool Spacing (m): N/A

Sinuosity Degree (Table 10): 1
# of Channels (Table 12): 1
Bank Failure (Table 14): N/A
Bankfull Indicators (Table 18): 1,5
Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible
% of Bed Active: 6
Mass Movement (Table 23): N/A %RUNS: 100
% 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)	☒	☒	☐	☐	☐	☐	☐

				Wetted Width (m)	1.85	5	
Bankfull Width (m)	12	30		Wetted Depth (m)	0.17	0.285	
Bankfull Depth (m)	1.1	1.5		Velocity (m/s)	0.139	0.07	
Undercuts (m)	—			Velocity Estimate Method	WB	WB	
Pool Depth (m)	—			Meander Amplitude (m)	—		
Riffle Length (m)	—						

Notes: BBT-3 IS IMMEDIATELY W/S OF A HISTORIC BEAVER DAM THAT HAS BEEN BREACHED IN A PAST SEASON (I.E. NO EVIDENCE OF ONGOING BEAVER ACTIVITY, BUT EVIDENCE OF PRESENCE IS < 10 YEARS OLD). HISTORIC DAM CAUSES BACKWATERING AND FORMS POOL AT D/S END OF REACH. MOST OF REACH FLOWS THROUGH WIDE FLOODPLAIN W HERBACEOUS + SEMI-AQUATIC VEG POPULATING LAND SURFACE SUBMERGENT AQUATIC VEG MOSTLY OCCURS W/IN POOL AT DAM.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	12:15 PM	**Reach:**	BBT-3
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	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	7	0.285
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	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 =	0	5	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		\	0/7
	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 =	0	7	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		\	1/7
	2	Single thread channel to multiple channel		\	
	3	Evolution of pool-riffle form to low bed relief form		\	
	4	Cut-off channel(s)		\	
	5	Formation of island(s)	\		
	6	Thalweg alignment out of phase with meander form		\	
	7	Bar forms poorly formed / reworked / removed		\	
		Sum of indices =	1	7	0.142

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.107

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	12:15 PM	**Reach:**	BBT-3
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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: KS Completed by: KS

GEO MORPHIX™

Date:	08-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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 HERBACEOUS MEADOW
	• 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) = 31	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

N/A

N/A

N/A

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

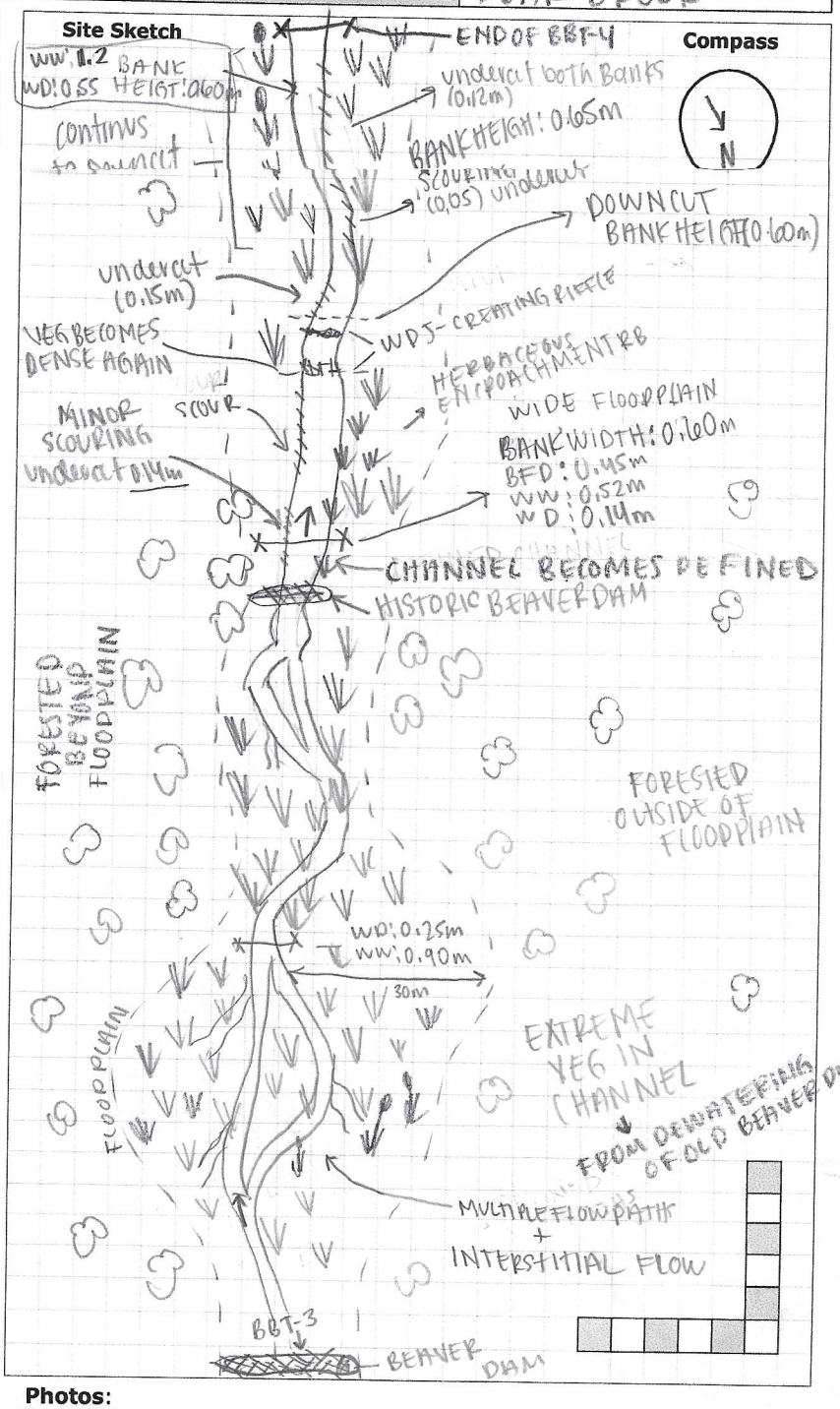
General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	1:15pm	**Reach:**	BBT-4
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Features	Monitoring
Reach break	Long-profile
Station location	Monumented XS
Cross-section	Monumented photo
Flow direction / Riffle	Monumented photo direction
Pool	Sediment sampling
Sediment bar	Erosion pins
Eroded bank/slope	Scour chains
Undercut bank	**Additional Symbols**
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: NOTE: FLOWPATHS IN DRAWING NOT EXACT

V_1: 2.92 (1m) - SAND/SILT ON CHANNEL BED (1:0.10-0.20m)

-SCOURS/UNDERCUTTING MORE PRESENT DS

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	1:00 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C SUNNY	**Reach:**	BBT-4	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 4
Encroachment (Table 7): 4

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 %: 90

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

WDJ/50m: 0

Water Quality

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

Channel Characteristics

Sinuosity Type (Table 9): 2
Gradient (Table 11): 1
Entrenchment (Table 13): 1
Down's Model (Table 15): M
Sed Sorting (Table 20): WS
Transport Mode (Table 21): N/A
Geomorphic Units (Table 22): 5, 8
Riffle-Pool Spacing (m): N/A

Sinuosity Degree (Table 10): 2
# of Channels (Table 12): 2
Bank Failure (Table 14): 2
Bankfull Indicators (Table 18): 5
Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible
% of Bed Active: 0
Mass Movement (Table 23): N/A
% Riffles: —
% Pools: 40

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)		0.6		Wetted Width (m)	0.90	0.52	1.20
Bankfull Depth (m)		0.45	0.60	Wetted Depth (m)	0.25	0.14	0.55
Undercuts (m)	0.12	0.15	0.05	Velocity (m/s)		0.342	
Pool Depth (m)	—			Velocity Estimate Method		WB	
Riffle Length (m)	—			Meander Amplitude (m)	—		

Notes: BBT-4 BEGINS IMMEDIATELY D/S OF HISTORIC BEAVER DAM W A SECTION OF UNDEFINED FLOW PATH. D/S OF THIS THE CHANNEL MEANDERS IRREGULARLY THROUGH A WIDE FLOODPLAIN W HERBACEOUS + SEMI-AQUATIC VEG BORDERED BY FOREST LIKE BBT-3. THE CHANNEL IS HEAVILY OBSCURED BY VEG ENCROACHMENT, MAKING DIMENSION MEASUREMENTS DIFFICULT. BANKFULL WIDTH WAS NOT ESTIMATED DUE TO THE LARGE WIDTH (LIKELY > 30M). GRADIENT IN THIS REACH APPEARED SLIGHTLY STEEPER THAN U/S REACHES. SOME SECTIONS OF THE REACH ARE BACKWATERED DUE TO CHANNEL CONSTRICTIONS.

Photos:

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	1:00 PM	**Reach:**	BBT-4
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	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	0.285
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	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 =	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	0.142
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		/	3/7
	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 =	3	4	0.428

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.214

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	1:45 PM	**Reach:**	BBT-4
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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

N/A

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	09-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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 HERBACEOUS MEADOW
	• 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) = 31	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

N/A

N/A

N/A

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX™

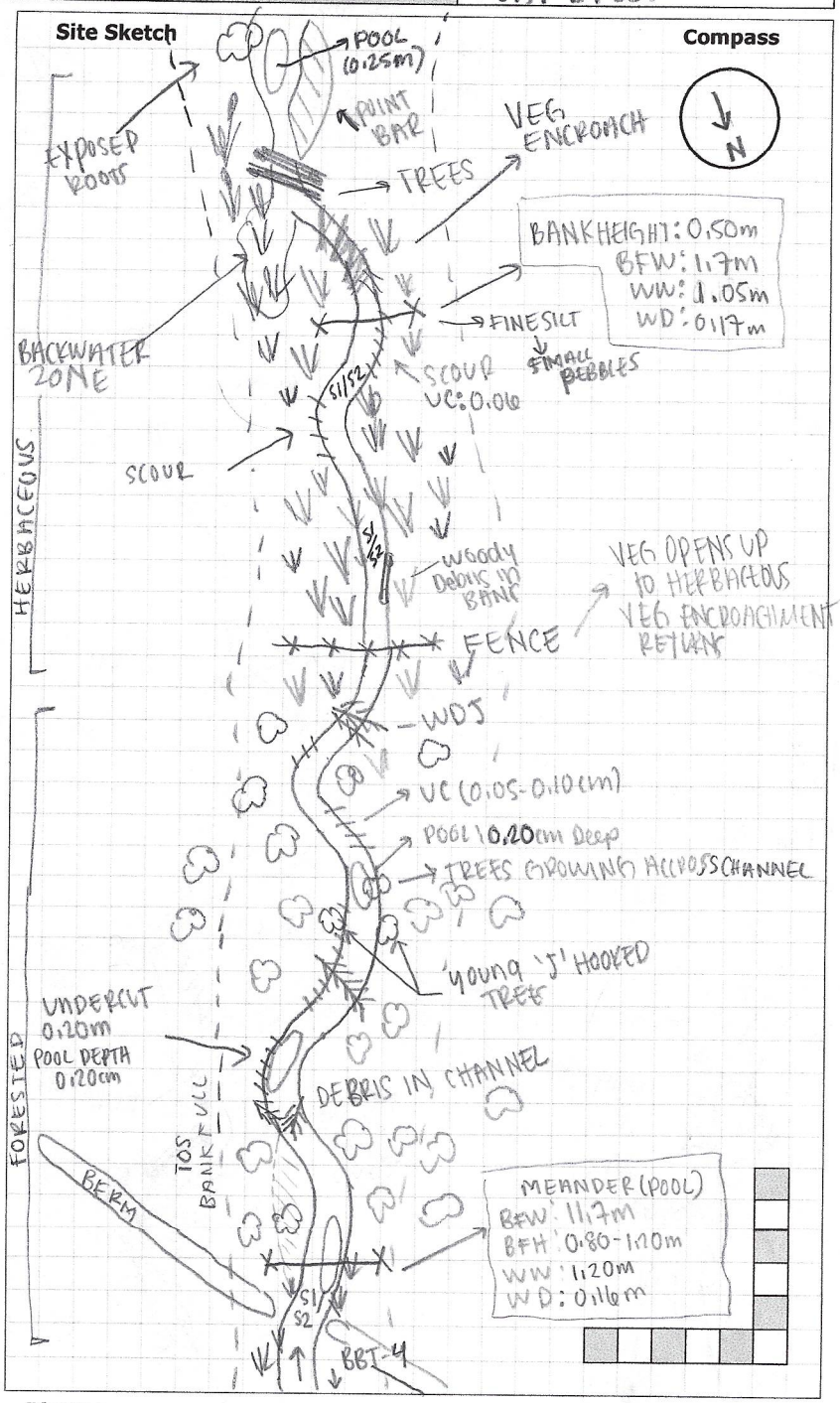
General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	2:00pm	**Reach:**	BBT-5
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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: -MORE SCOURS/UC ALONG MEANDERS → TRANSITIONS INTO DEFINED CHANNEL - BEGINS MEANDING → STILL WIDE FLOODPLAIN/BF → CHANNEL BED: COARSE SILT / FINE SAND → MAINLY RUNS + POOLS

V_1: 10.52 (1m) V_2: 3.85 (1m)

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	2:00pm	**Reach:**	BBT-5 (cont)
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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

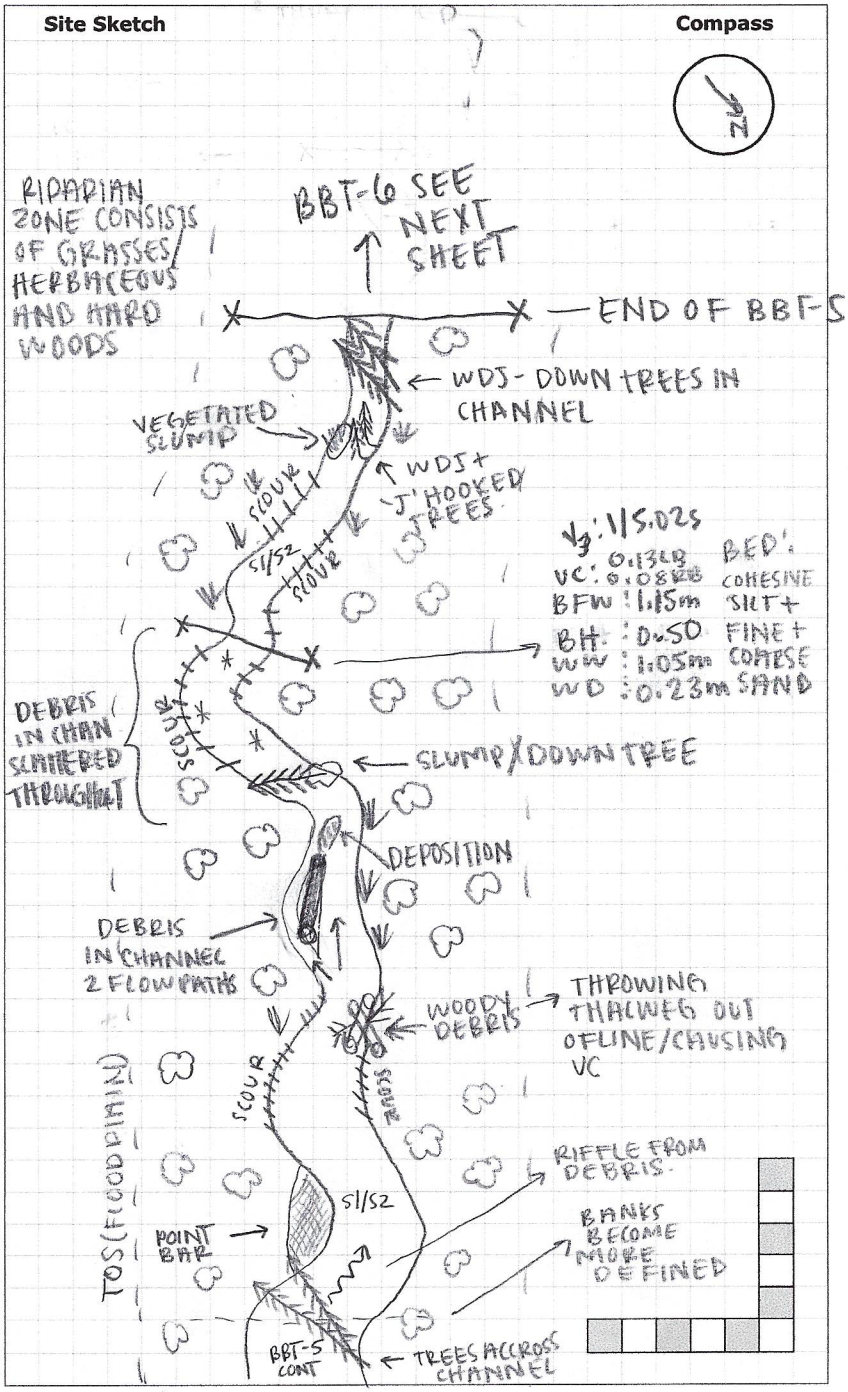
Substrate

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: -INCREASE IN SCOURS (consentrated D/S), BASAL SCOUR PRESENT ON BOTH BANKS. DEBRIS IN CHANNEL CREATING UNDERCUTS. STILL FEW RIFFLES (MOSTLY POOLS/RUNS) SOME TORTUOUS MEANDERS.

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	1:30 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0'C SUNNY	**Reach:**	BBT-5	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1,4

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 %: 20

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

Gradient (Table 11): 2

Entrenchment (Table 13): 1

Down's Model (Table 15): m

Sed Sorting (Table 20): PS

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 5,6,8

Riffle-Pool Spacing (m): 20

Sinuosity Degree (Table 10): 2

# of Channels (Table 12): 1

Bank Failure (Table 14): 2

Bankfull Indicators (Table 18): 1,3

Sediment Transport Observed?: ☐ Yes ☒ No ☐ Not Visible

% of Bed Active: 0

Mass Movement (Table 23): N/A

% Riffles: 15

% Runs: 60

% Pools: 25

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

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

		BANK DIMENSION	BANK DIMENSION
Bankfull Width (m)	11.7	1.7	1.15
Bankfull Depth (m)	1	0.5	0.5
Undercuts (m)	0.20	0.06	0.13
Pool Depth (m)	0.20	0.20	0.25
Riffle Length (m)	5		

(Table 19)

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

Wetted Width (m)	1.2	1.05	1.05
Wetted Depth (m)	0.16	0.17	0.23
Velocity (m/s)	0.095	0.259	0.199
Velocity Estimate Method	WB	WB	WB
Meander Amplitude (m)	—		

Notes: BBT-5 BEGINS AT TRANSITION FROM BROAD HERBACEOUS MEADOW TO FORESTED RIPARIAN AREA. FLOODPLAIN NARROWS SLIGHTLY AND CHANNEL MEANDERS SOMEWHAT REGULARLY FOR SHORT STRETCHES BETWEEN STRAIGHT AND IRREGULAR SECTIONS. HIGH DENSITY OF WOODY AND ORGANIC DEBRIS WAS CAUSING THALWEG TO BE OUT OF PHASE W CHANNEL IN SOME SECTIONS. VERY FREQUENT OCCURENCE OF J-HOOK TREES IMMATURE TO ESTABLISHED IN AGE. UNDERCUTTING AND BASAL SCOUR OBSV THROUGH -OUT REACH. PEACH-COLOURED CLAY OBSV ALONG BASE OF ERODED BANKS IN MANY LOCATIONS.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	1:30 PM	**Reach:**	BBT-5
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	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	0.428
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	1/5
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		N/A	
	6	Cut face on bar forms		—	
	7	Head cutting due to 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 =	1	4	0.20
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	0.714
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	0.142

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.297

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	1:30	**Reach:**	BBT-5
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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

N/A

Version #2
Last edited: 10/02/2023

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

GEO MORPHIX

Date:	08-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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

N/A

Total overall score (0–42) = 29	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™

General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	2:45pm	**Reach:**	BBT-6
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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

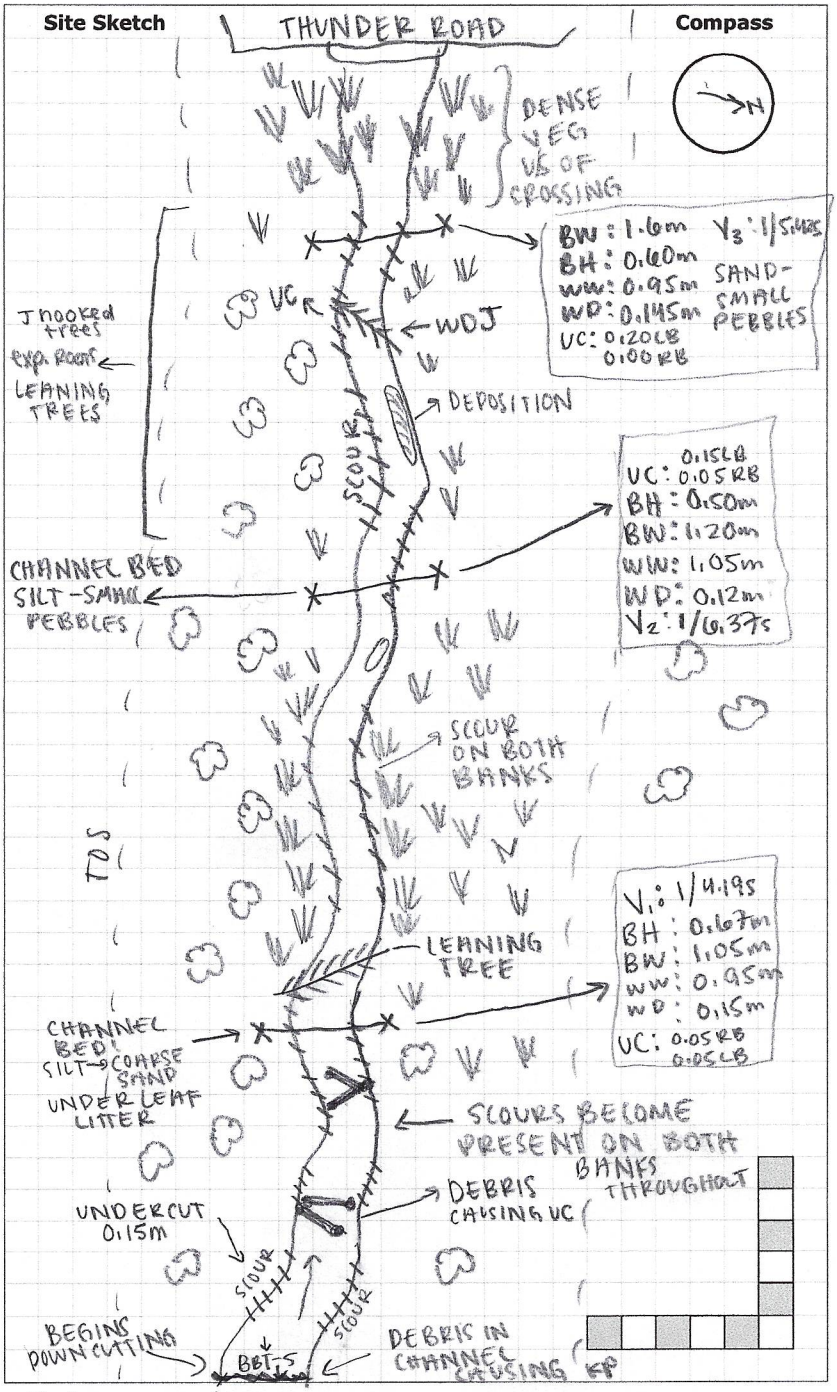
Substrate

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: BBT-5 TRANSITIONS TO THE CHANNEL EXHIBITING VERTICAL BANKS + CHANNEL BEGINS TO DOWN CUT
- SCOUR THROUGHOUT ON BOTH BANKS

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	2:15 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C SUNNY	**Reach:**	BBT-6	**UTM (Downstream):**	

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

Riparian Vegetation

Dominant Type (Table 6): 1, 4

Encroachment (Table 7): 4

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 %: 40

Woody Debris	WD Density	
☒ In Cutbank	☐ Low	WDJ/50m: 1
☒ In Channel	☒ Mod	
☐ Not Present	☐ High	

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 2

Channel Characteristics

Sinuosity Type (Table 9): 2

Gradient (Table 11): 2

Entrenchment (Table 13): 1

Down's Model (Table 15): U

Sed Sorting (Table 20): MS

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 5, 6, 8

Riffle-Pool Spacing (m): 10-20

Sinuosity Degree (Table 10): 1

# of Channels (Table 12): 1

Bank Failure (Table 14): 2, 5

Bankfull Indicators (Table 18): 3, 5

Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible

% of Bed Active: 0

Mass Movement (Table 23): N/A

% Riffles: 15 **% Pools:** 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)	1.05	1.20	1.6	**Wetted Width (m)**	0.95	1.05	0.95
Bankfull Depth (m)	0.67	0.50	0.60	**Wetted Depth (m)**	0.15	0.12	0.145
Undercuts (m)	0.15	0.05	0.20	**Velocity (m/s)**	0.239	0.157	0.185
Pool Depth (m)	—			**Velocity Estimate Method**	WB	WB	WB
Riffle Length (m)	3-5			**Meander Amplitude (m)**	—		

Notes: BBT-6 BEGINS AS THE CHANNEL TRANSITIONS FROM A MEANDERING PLANFORM TO ONE DOMINATED BY STRAIGHT SECTIONS W STEEP BANKS AND UNDERCUTS ALONG BOTH SIDES. BETWEEN THE STRAIGHT SECTIONS THERE ARE INFREQUENT MEANDERS W SCOUR ALONG BOTH BANKS. THE RIPARIAN AREA ALSO TRANSITIONS FROM FOREST TO A HERBACEOUS MEADOW W HEAVY VEG ENCROACHMENT. HIGH FREQUENCY OF YOUNG J-HOOK TREES OBSV, OFTEN W UNDERCUTS ALONG OPPOSITE BANK. BBT-6 ENDS AT THE U/S SIDE OF THE CULVERT CROSSING UNDER THUNDER ROAD.

Photos:

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

GEO MORPHIX™

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	2:15 PM	**Reach:**	BBT-6
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		/	1/7
	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 =	1	6	0.142
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	1/6
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		—	
	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 =	1	5	0.167
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	0.285

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.363

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

Date:	08-11-2023	PN:	Z3111	Location:	THUNDER ROAD

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) = 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

GEO MORPHIX

Rapid Stream Assessment Technique Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	2:15 PM	**Reach:**	BBT-6
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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 N/A
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™

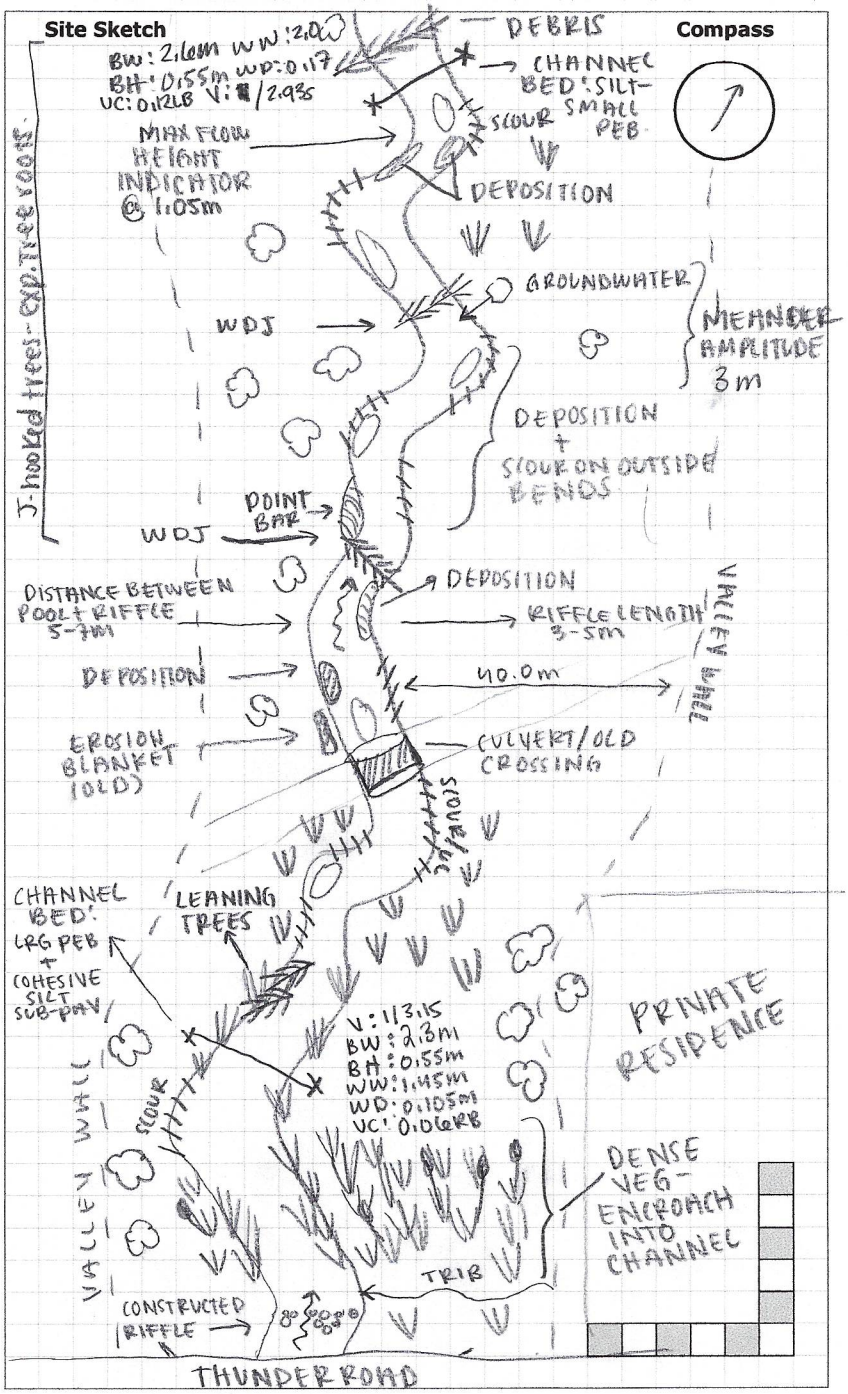
General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	3:30 pm	**Reach:**	BBT-7
Weather:	SUNNY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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: SCOUR ON MANY BENDS + DEPOSITION
- EXPOSED TREE ROOTS + WDS + 'J' HOOKED TREES COMMON.
- MEANDERING. SOME POOL-RIFFLE FORMATIONS
- MOSTLY TREES ON LB AND HERBACEOUS ON RB.

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

General Site Characteristics

Project Number: 23111

Date:	2023-11-08	**Stream:**	BEAR BROOK TRIB
Time:	3:30pm	**Reach:**	BBT-7 (cont) + BBT-8
Weather:	CLOUDY 0°C	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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

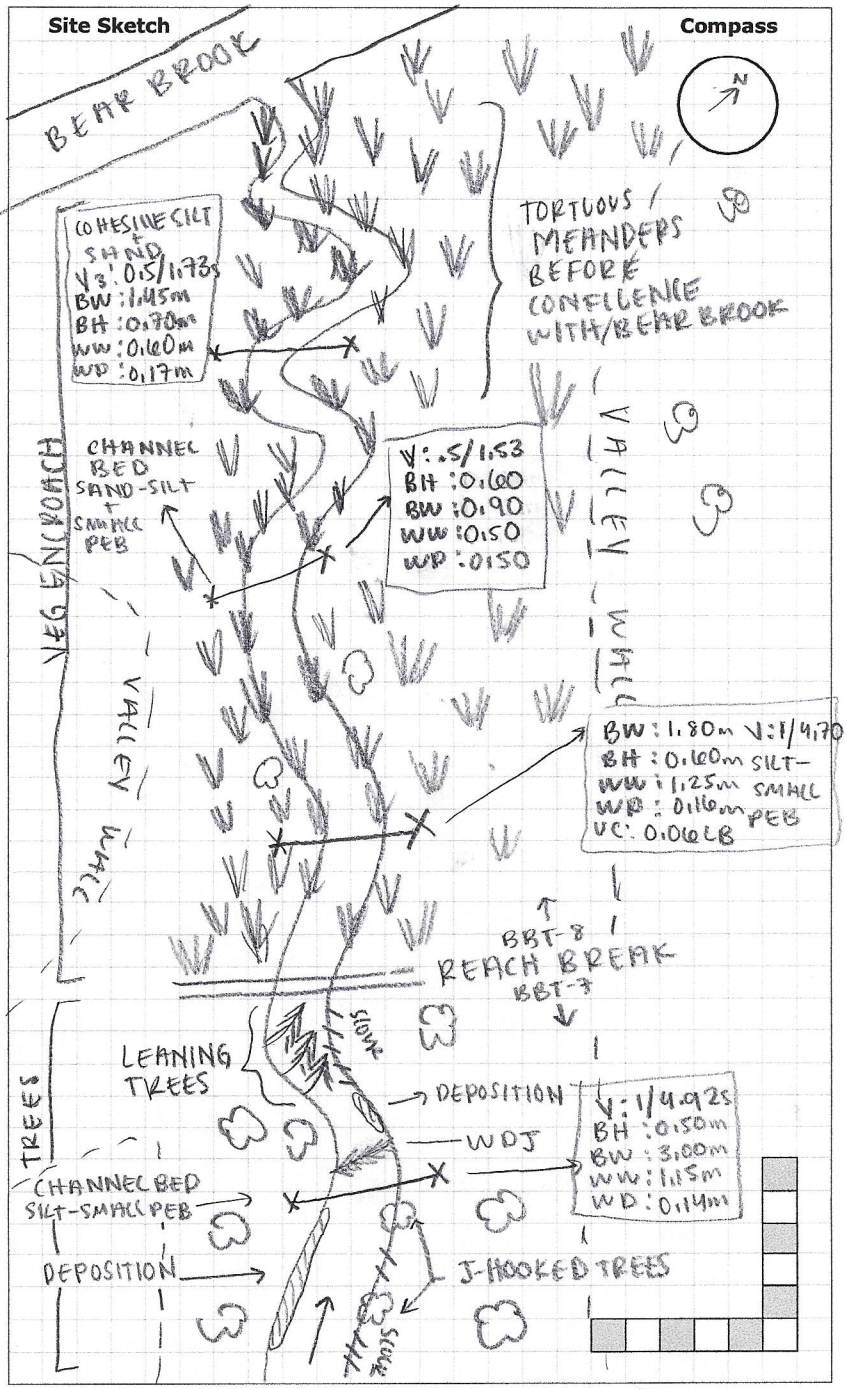
Substrate

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: -TRANSITION TO BBT-8 - HEAVY VEG ENCROACH - RIPARIAN ZONE BECOMES HERBACEOUS AS TRIB ENTERS BEAR BROOK CORRIDOR.
- RIFFLE-POOL FORMATION ABSENT IN BBT-8, LESS MEANDERING EXCEPT D/S EXTENT BEFORE CONFLUENCE WITH BEAR BROOK

Version #4
Last edited: 21/02/2023

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

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	2:45 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:		**Reach:**	BBT-7	**UTM (Downstream):**	

Land Use (Table 1): 1,7 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 8 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☒ Evidence of Groundwater Location: MULTIPLE Photo: YES

Riparian Vegetation

Dominant Type (Table 6): 1,4

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 %: 20

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): 4

Gradient (Table 11): 2

Entrenchment (Table 13): 1

Down's Model (Table 15): M

Sed Sorting (Table 20): MS

Transport Mode (Table 21): N/A

Geomorphic Units (Table 22): 5,6 8

Riffle-Pool Spacing (m): 5-7

Sinuosity Degree (Table 10): 3

# of Channels (Table 12): 1

Bank Failure (Table 14): 2

Bankfull Indicators (Table 18): 1,3

Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible

% of Bed Active: 0

Mass Movement (Table 23): N/A

% Riffles: 10 **% Pools:** 80

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

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

	Bankfull Width (m)	Bankfull Depth (m)	Undercuts (m)	Pool Depth (m)	Riffle Length (m)
	2.3	0.55	0.06	—	3-5
	2.6	0.55	0.12		
	3.0	0.50			

(Table 19)

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

	Wetted Width (m)	Wetted Depth (m)	Velocity (m/s)	Velocity Estimate Method	Meander Amplitude (m)
	1.45	0.105	0.317	WB	
	2.0	0.17	0.341	WB	3
	1.15	0.14	0.203	WB	

Notes: BBT-7 BEGINS IMMEDIATELY D/S OF THE CULVERT CROSSING UNDER THUNDER ROAD. THE VALLEY TYPE IS CONFINED UNLIKE THE REACHES U/S. RESIDENTIAL PROPERTIES BORDER THE VALLEY TOP NORTH OF THUNDER ROAD. LAND COVER IS PRIMARILY FORESTED W/IN THE VALLEY W SOME OPEN AREAS COVERED IN HERBACEOUS VEG. THE CHANNEL HAS A MEANDERING PLANFORM THROUGHOUT THE REACH. THE SAME PEACH-COLOURED CLAY WAS OBSV ALONG THE BASE OF SCOURED BANKS, AS IN BBT-5.

Photos:

Version #4
Last edited: 04/04/2023

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

GEO MORPHIX

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	2:45 PM	**Reach:**	BBT-7
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	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	0.428
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	1/9
	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 =	1	8	0.111
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. CULVERT	\		
	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	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	0.285

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.394

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	2:45 PM	**Reach:**	BBT-7
Weather:	0°C SUNNY	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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: KM Completed by: KS

GEO MORPHIX™

Date:	08-11-2023	PN:	23111	Location:	THUNDER ROAD

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
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

N/A

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

GEO MORPHIX™

Reach Characteristics Project Number: 23111

Date:	08-11-2023	**Field Staff:**	KS KM	**Watershed/Subwatershed:**	BEAR BROOK
Time:	3:20 PM	**Stream:**	BEAR BROOK TRIB	**UTM (Upstream):**	
Weather:	0°C OVERCAST	**Reach:**	BBT-8	**UTM (Downstream):**	

Land Use (Table 1): 1 | **Valley Type** (Table 2): 1,2 | **Channel Type** (Table 3): 11,12 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 1 | ☐ Evidence of Groundwater Location: \ Photo: \

Riparian Vegetation

Dominant Type (Table 6): 1,4
Encroachment (Table 7): 4

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 %: 80

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

WDJ/50m: \

Water Quality

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

Channel Characteristics

Sinuosity Type (Table 9): 1
Gradient (Table 11): 2
Entrenchment (Table 13): 1
Down's Model (Table 15): C
Sed Sorting (Table 20): MS
Transport Mode (Table 21): N/A
Geomorphic Units (Table 22): 8
Riffle-Pool Spacing (m): \

Sinuosity Degree (Table 10): 1
# of Channels (Table 12): 1
Bank Failure (Table 14): 2
Bankfull Indicators (Table 18): 3,5
Sediment Transport Observed? ☐ Yes ☒ No ☐ Not Visible
% of Bed Active: 0
Mass Movement (Table 23): N/A
% Riffles: \ **% 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)	1.8	0.90	1.45	**Wetted Width (m)**	1.25	0.50	0.60
Bankfull Depth (m)	0.160	0.160	0.170	**Wetted Depth (m)**	0.16	0.50	0.17
Undercuts (m)	0.06			**Velocity (m/s)**	0.213	0.327	0.289
Pool Depth (m)	—			**Velocity Estimate Method**	WB	WB	WB
Riffle Length (m)	—			**Meander Amplitude (m)**	—		

Notes: BBT-8 BEGINS AT A TRANSITION FROM A MEANDERING, FORESTED SECTION TO A MORE OPEN HERBACEOUS MEADOW. THE VALLEY BEGINS TO WIDEN AND THE CHANNEL ENTERS THE MUCH BROADER BEAR BROOK VALLEY HALFWAY THROUGH THE REACH. THE PLANFORM IS MOSTLY STRAIGHT W INFREQUENT AND ISOLATED BENDS. SCOUR IS PREVALENT. THE CHANNEL IS LARGELY OBSCURED BY THE HERBACEOUS AND SEMI-AQUATIC VEG DUE TO HEAVEY ENCROACHMENT. CHANNEL DIMENSIONS CHANGE AS THE CONFLUENCE W BEAR BROOK IS APPROACHED; WIDTH DECREASES WHILE DEPTH INCREASES.

Photos:

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

GEO MORPHIX

Rapid Geomorphic Assessment

Project Number: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	3:20 PM	**Reach:**	BBT-8
Weather:	0°C OVERCAST	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

Process	No.	Geomorphological Indicator	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		/	0/7
	2	Coarse materials in riffles embedded		/	
	3	Siltation in pools		/	
	4	Medial bars		/	
	5	Accretion on point bars		/	
	6	Poor longitudinal sorting of bed materials		/	
	7	Deposition in the overbank zone		/	
		Sum of indices =	0	7	0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/5
	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 =	0	5	0
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	0.714
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	0.142

Notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.214

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: 23111

Date:	08-11-2023	**Stream:**	BEAR BROOK TRIB
Time:	3:20 PM	**Reach:**	BBT-8
Weather:	0°C OVERCAST	**Location:**	THUNDER ROAD
Field Staff:	KS KM	**Watershed/Subwatershed:**	BEAR BROOK

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: _____ Completed by: _____

GEO MORPHIX™

Date:	08-11-2023	PN:	23111	Location:	THUNDER ROAD

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) = 27	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

Appendix F:
Detailed Assessment Summary

Detailed Geomorphological Assessment Summary

Reach: BBT-7

Project Number:	PN23111	**Date:**	15-11-23
Client:	Thunder Road Limited Partnership	**Length Surveyed (m):**	115.4
Location:	Bear Brook Tributary, Thunder Rd	**# of Cross-Sections:**	7

Reach Characteristics

Drainage Area:	148.65 ha	**Dominant Riparian Vegetation Type:**	Trees, shrubs
Geology/Soils:	Glaciofluvial and glaciomarine sands	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest	**Width of Riparian Cover:**	4-10 channel widths
Valley Type:	Confined	**Age Class of Riparian Vegetation:**	Established
Dominant Instream Vegetation Type:	Rooted emergent	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	5%	**Density of Woody Debris:**	High

Hydrology

Measured Discharge (m^3/s):	0.0297	**Calculated Bankfull Discharge (m^3/s):**	0.86
		Calculated Bankfull Velocity (m/s):	0.78

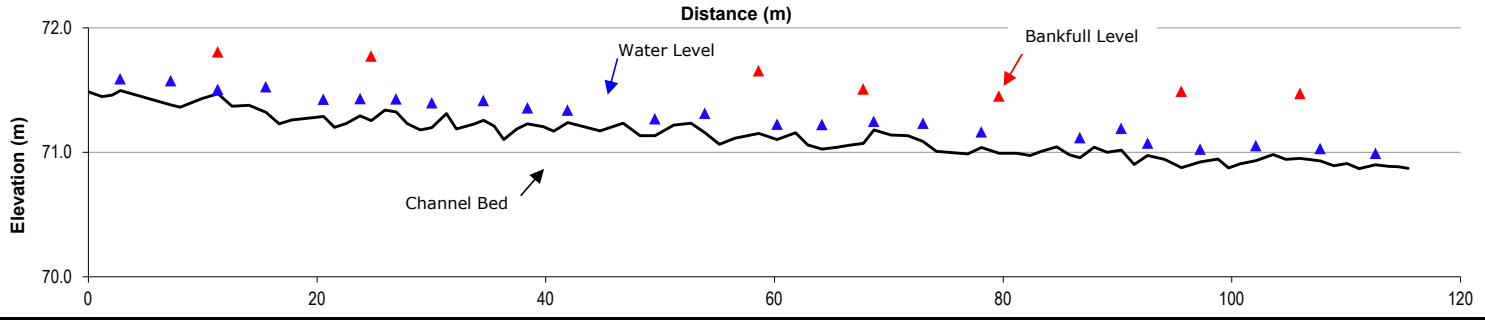
Profile Characteristics

Bankfull Gradient (%):	0.40
Channel Bed Gradient (%):	0.47
Riffle Gradient (%):	1.55
Riffle Length (m):	N/A
Riffle-Pool Spacing (m):	N/A

Planform Characteristics

Sinuosity:	1.28
Meander Belt Width (m):	N/A - Confined
Meander Amplitude (m):	3 m

Longitudinal Profile



Bank Characteristics

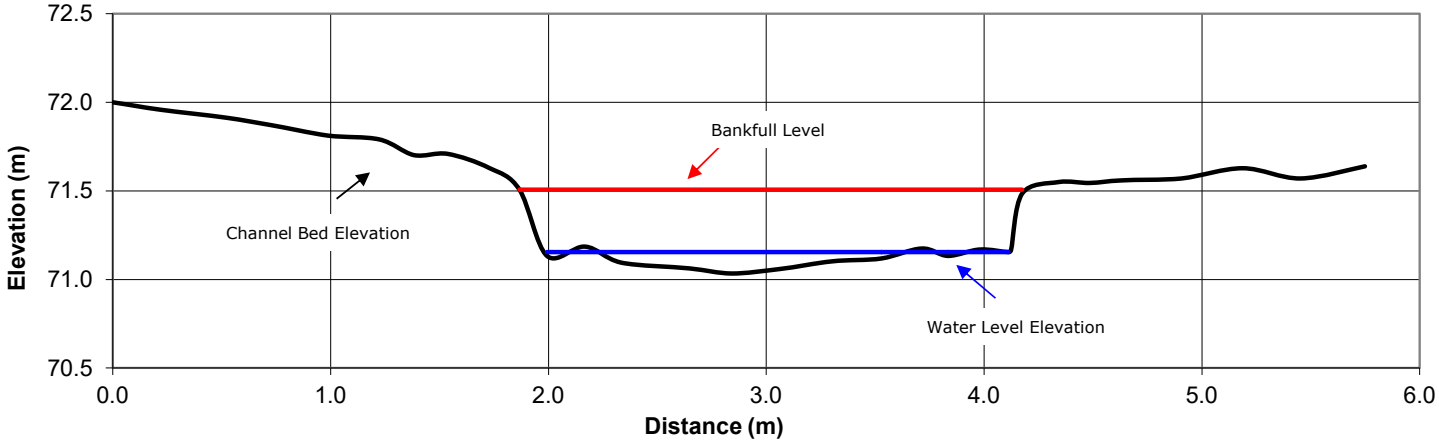
	Minimum	Maximum	Average		Average
Bank Height (m):	0.35	0.75	0.63		
Bank Angle (deg):	20	90	67	**Torvane Value (kg/cm^2):**	0.75
Root Depth (m):	0.10	0.20	0.14	**Penetrometer Value (kg/cm^3):**	1.04
Root Density (%):	20	70	47	**Bank Material (range):**	Clay to sand sized
Bank Undercut (m):	0.00	0.17	0.05		

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.31	8.89	3.57
Average Bankfull Depth (m):	0.27	0.36	0.31
Bankfull Width/Depth (m/m):	6.90	30.73	11.83
Wetted Width (m):	0.79	2.12	1.60
Average Water Depth (m):	0.05	0.13	0.09
Wetted Width/Depth (m/m):	12.59	38.89	19.47
Maximum Water Depth (m):	0.12	0.20	0.16
Manning's *n* :		0.040	

Photograph at cross section 4 (looking downstream)

Representative Cross-Section 4



Substrate Characteristics

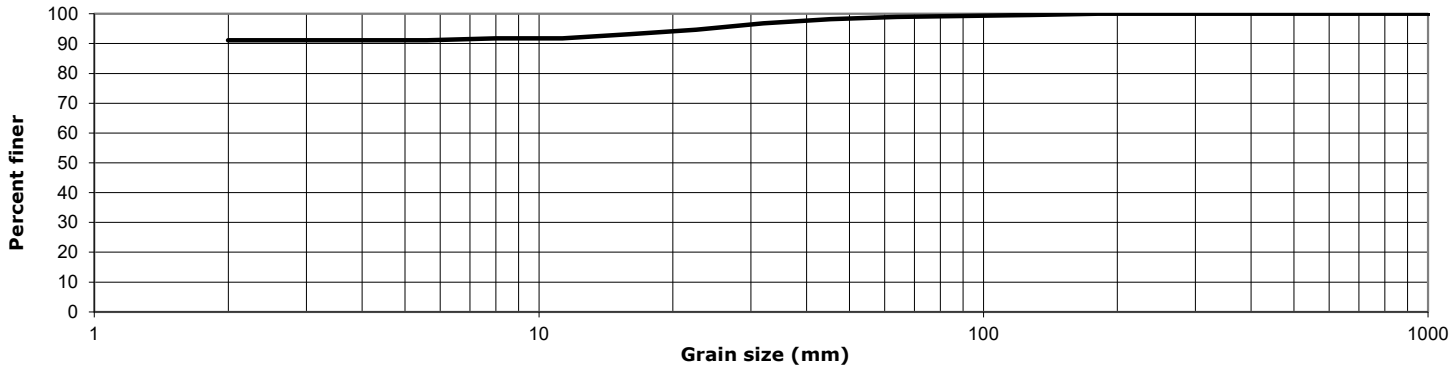
Particle Size (mm)

D_{10} :	<2.0
D_{50} :	<2.0
D_{84} :	<2.0

Subpavement: Clay

Particle shape: Sub-angular to sub-rounded

Cumulative Particle Size Distribution



Channel Thresholds			
Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	14.25
for D_{50}:	0.09	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.09	**Critical Shear Stress (D_{50}) (N/m^2):**	0.15
Unit Stream Power at Bankfull (W/m^2):	11.16		

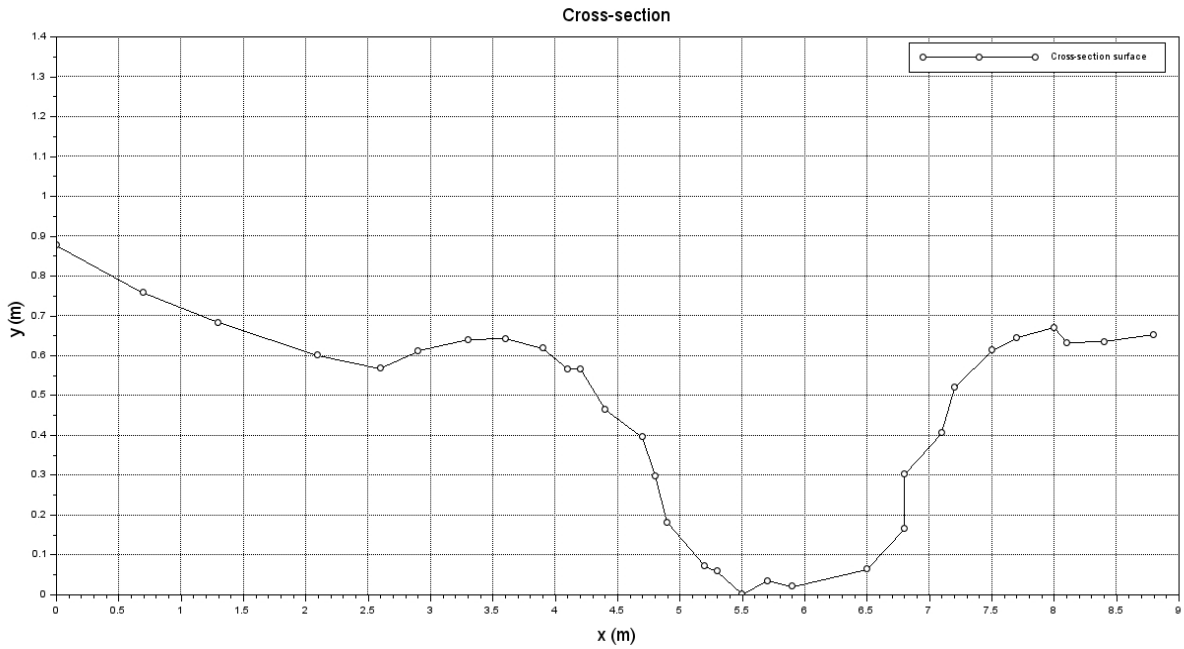
General Field Observations

Channel Description

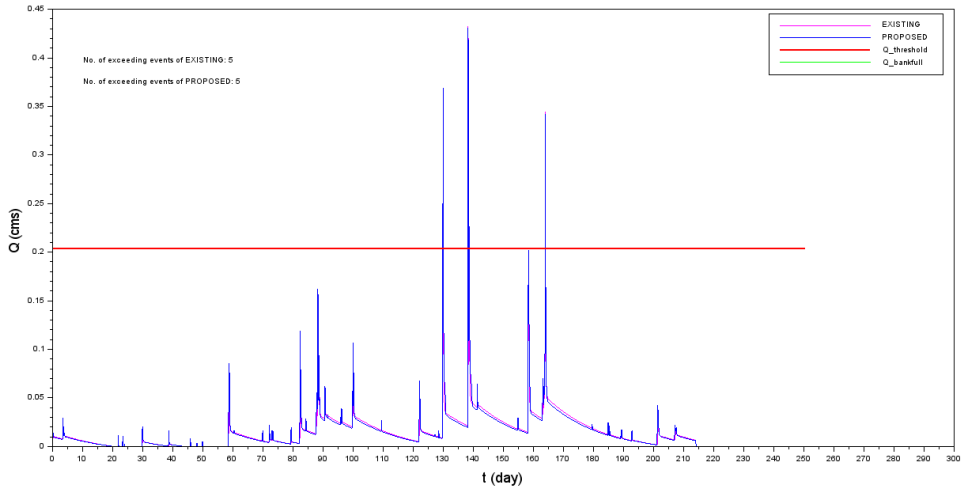
Reach BBT-7 begins downstream of a large culvert crossing under Thunder Road. The watercourse is confined in a valley through this reach and residential properties border the top of the valley slope. Land cover within the valley is primarily forested with some open areas covered in herbaceous vegetation. The channel has an irregular meandering planform through BBT-7. Exposed tree roots and hooked and leaning trees were frequently observed. Some point bar deposition combined with outside bend scour was observed along meanders. The geomorphic units were predominantly runs, with some riffles and pools. A high density of woody debris within the channel created the conditions for many of the geomorphic units observed, such as backwatering forming a pool.

Facing Downstream at cross-section 1

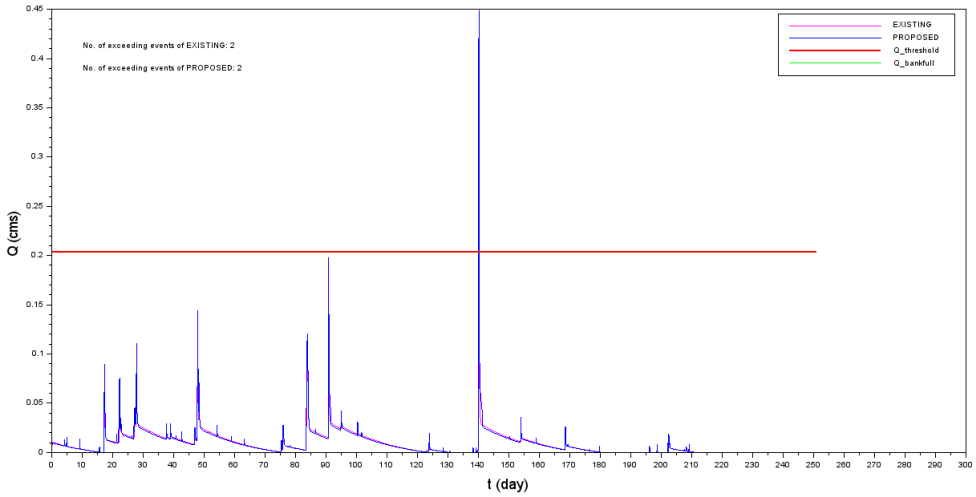
Appendix G:
Erosion Modelling Hydrographs



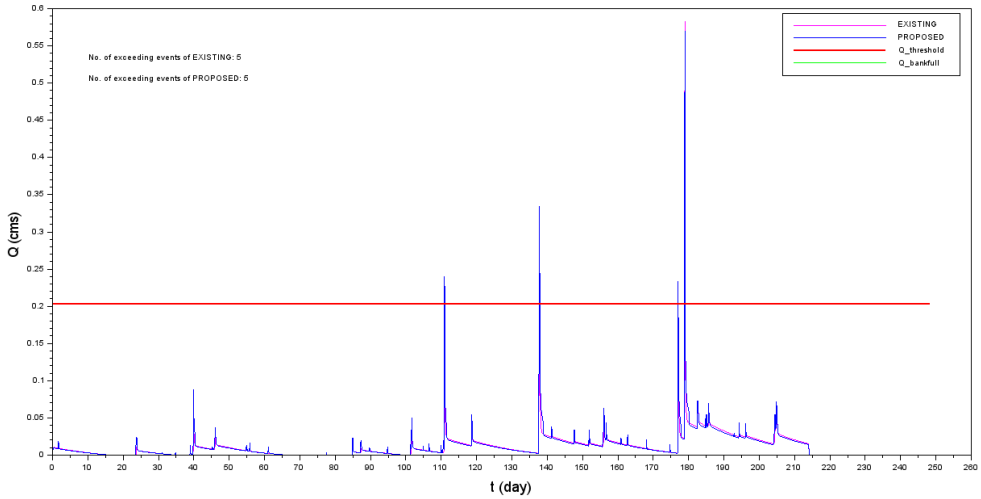
Representative cross-section used for the analysis
Reach BBT-7



1968
Reach BBT-7

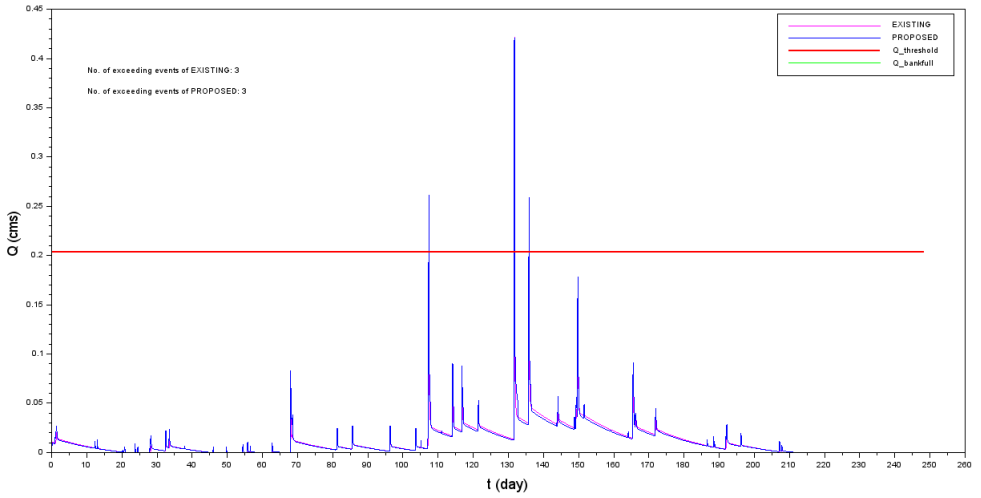


1969
Reach BBT-7



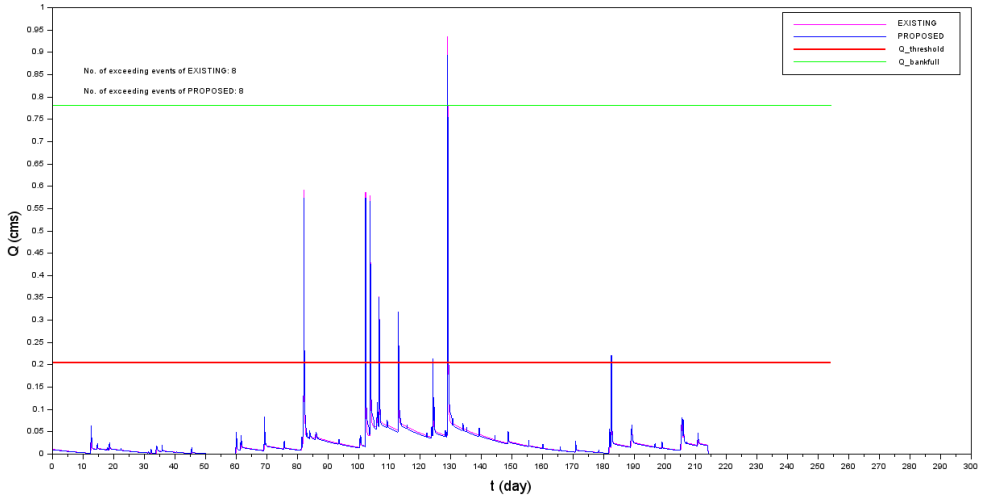
1970

Reach BBT-7



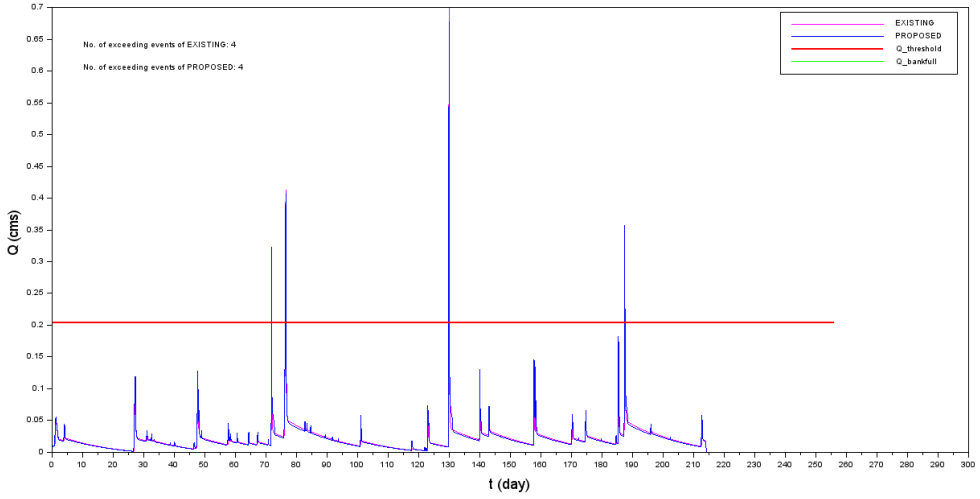
1971

Reach BBT-7



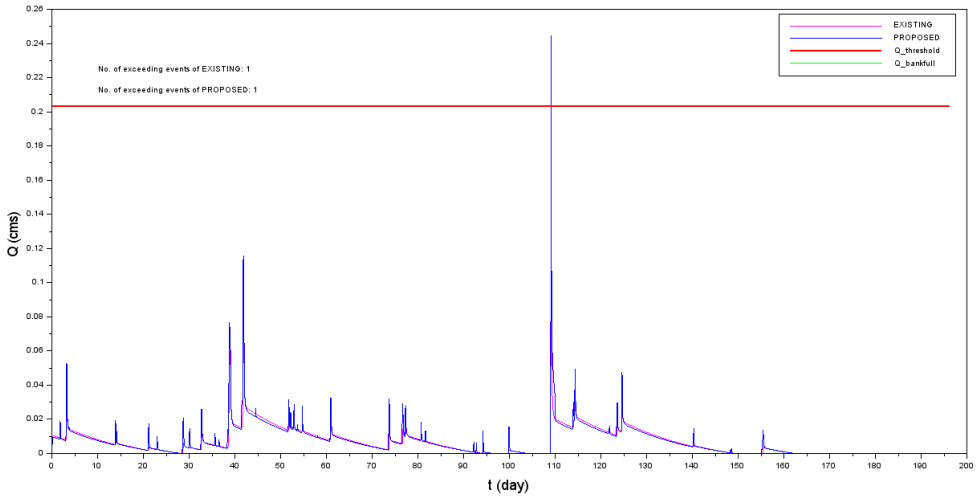
1972

Reach BBT-7



1973

Reach BBT-7



1974

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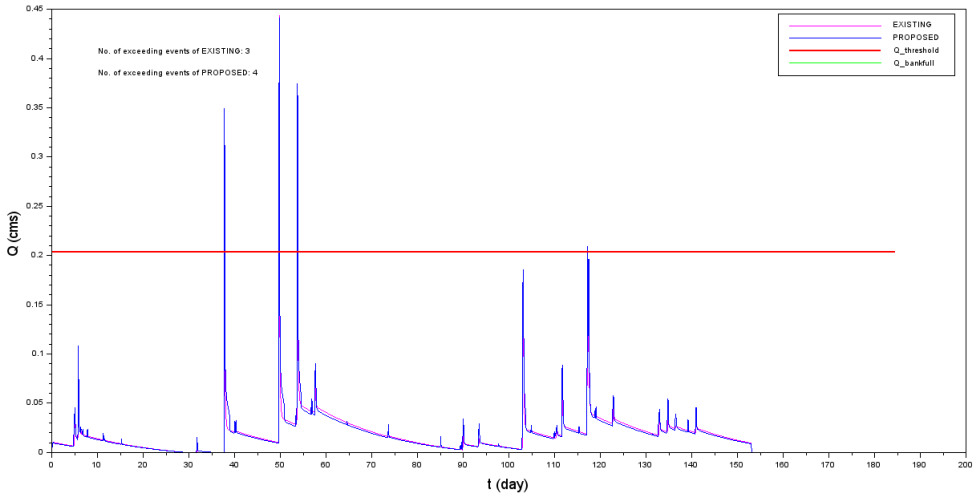

1975

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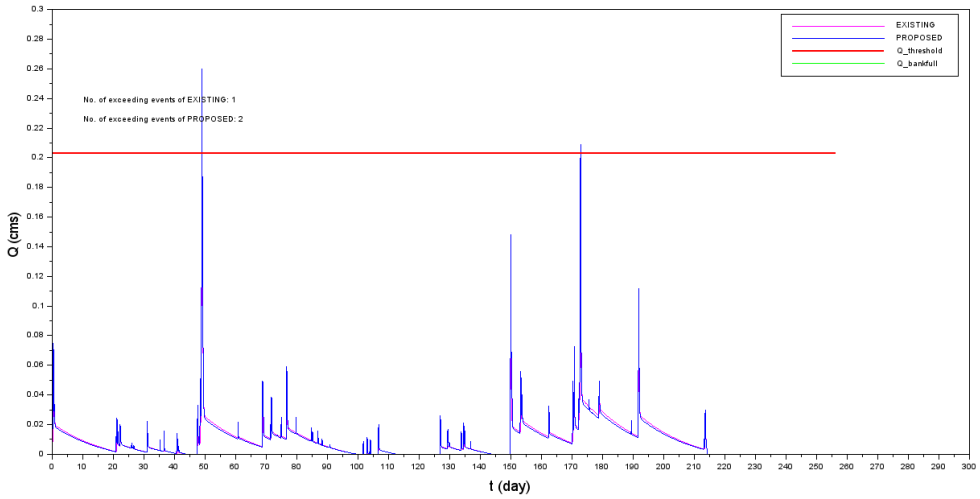

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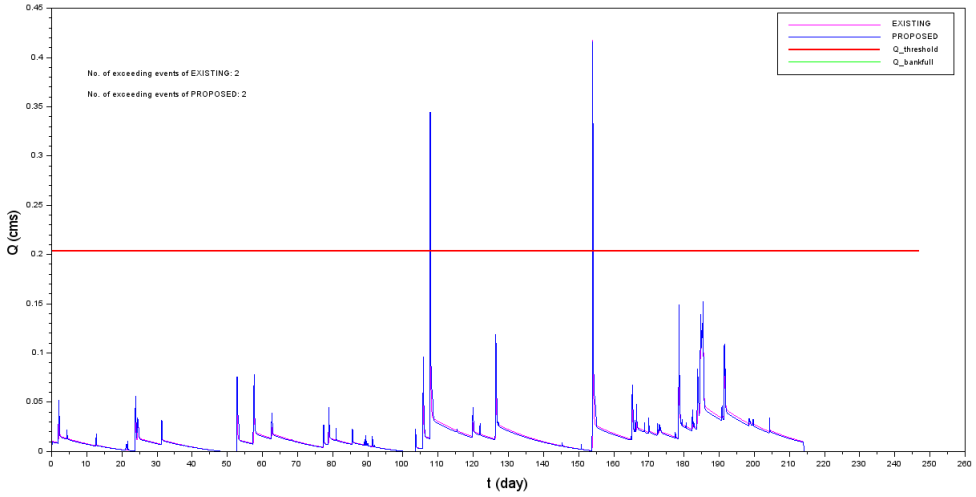

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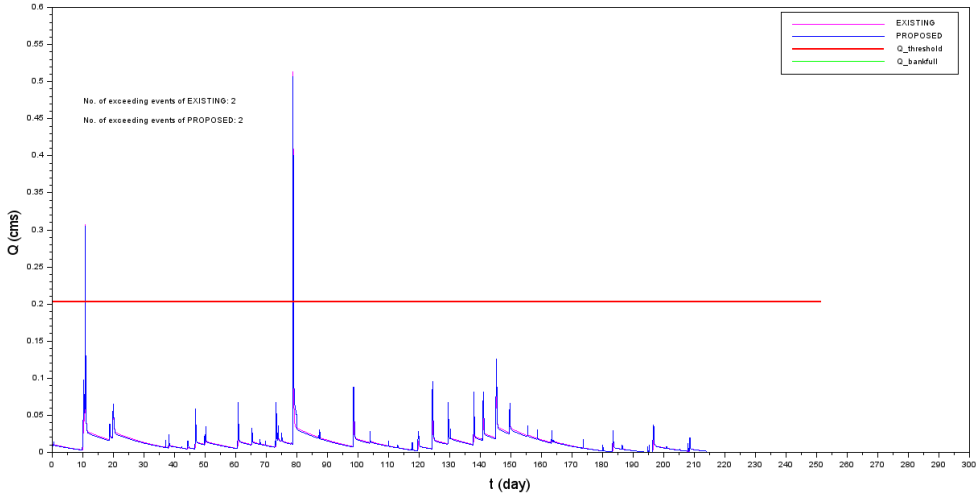

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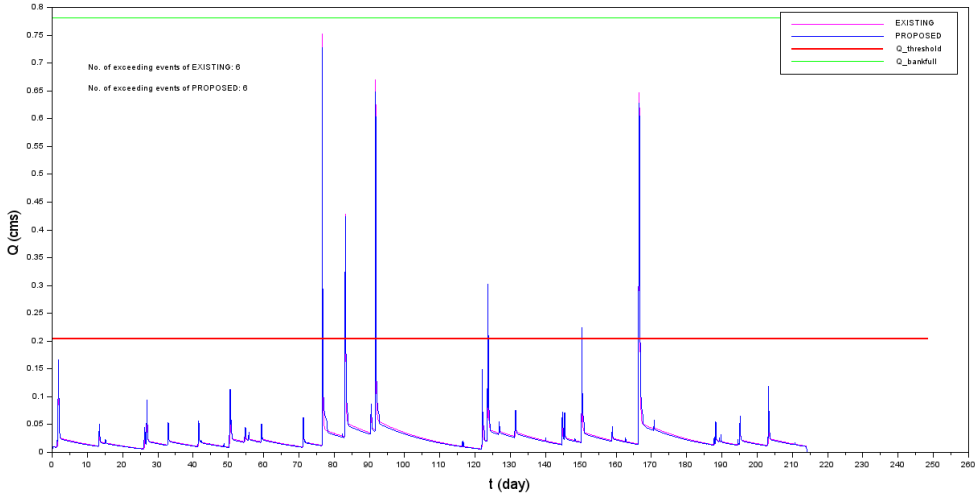

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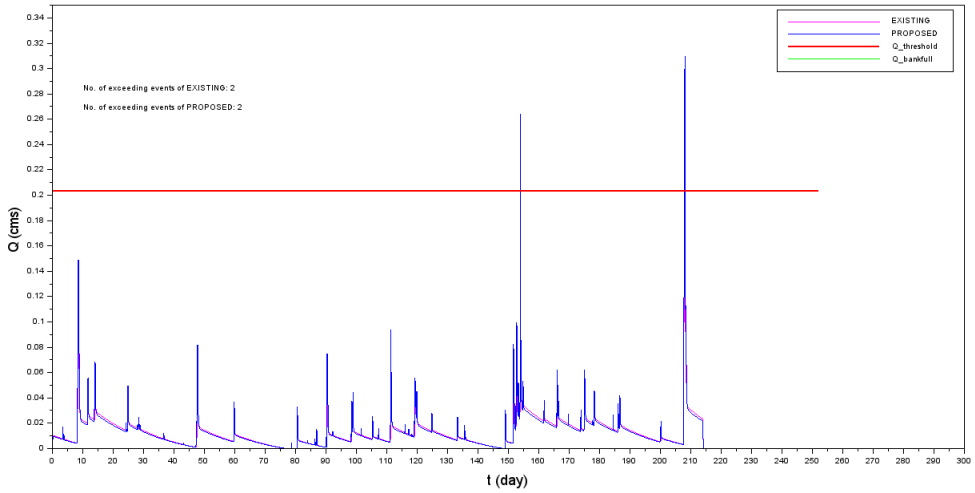

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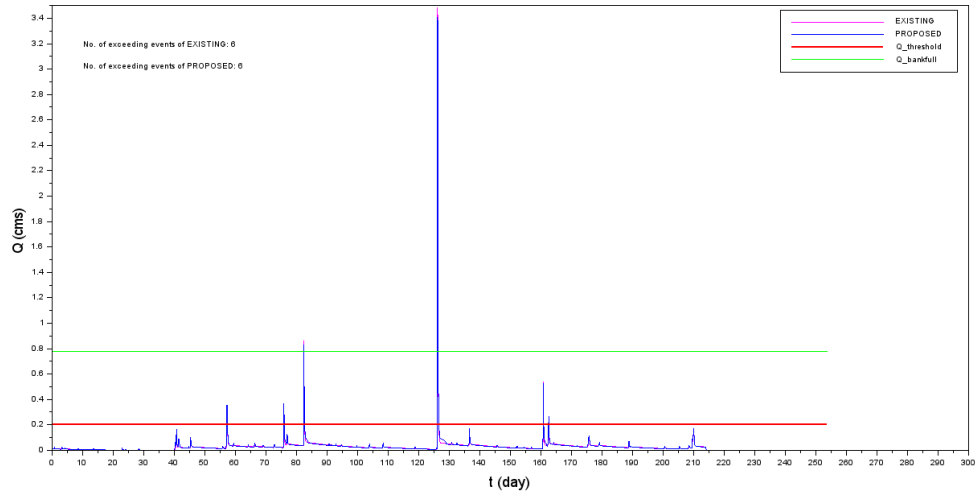

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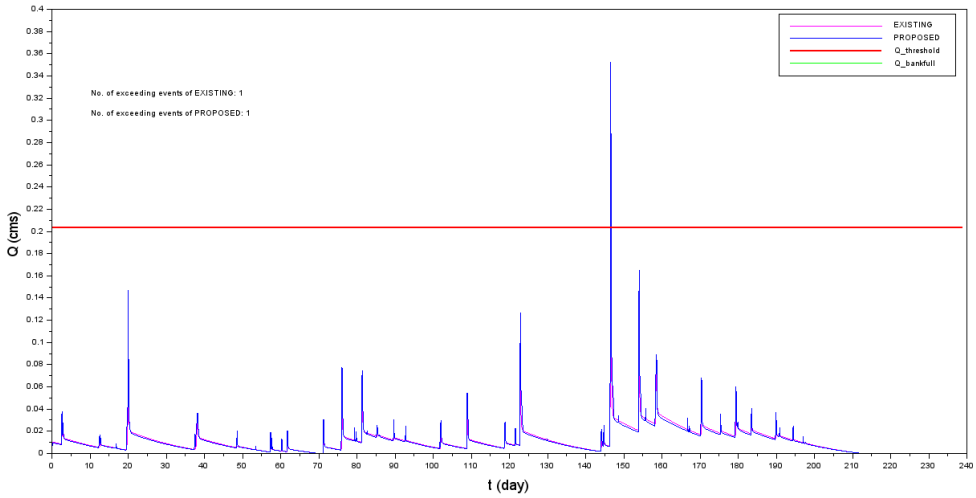

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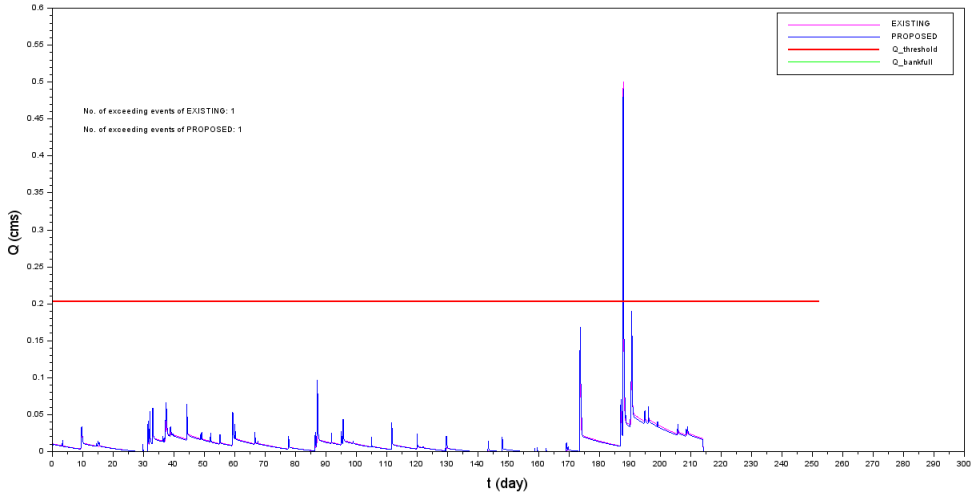

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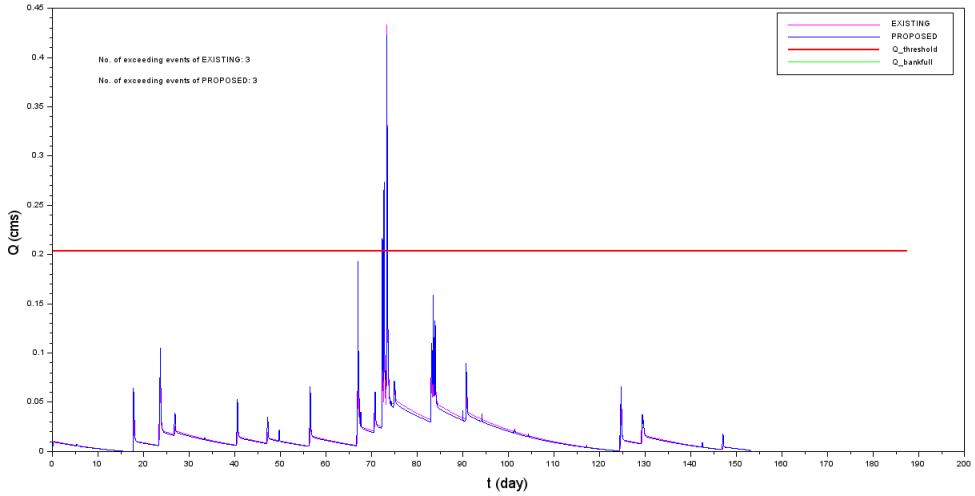

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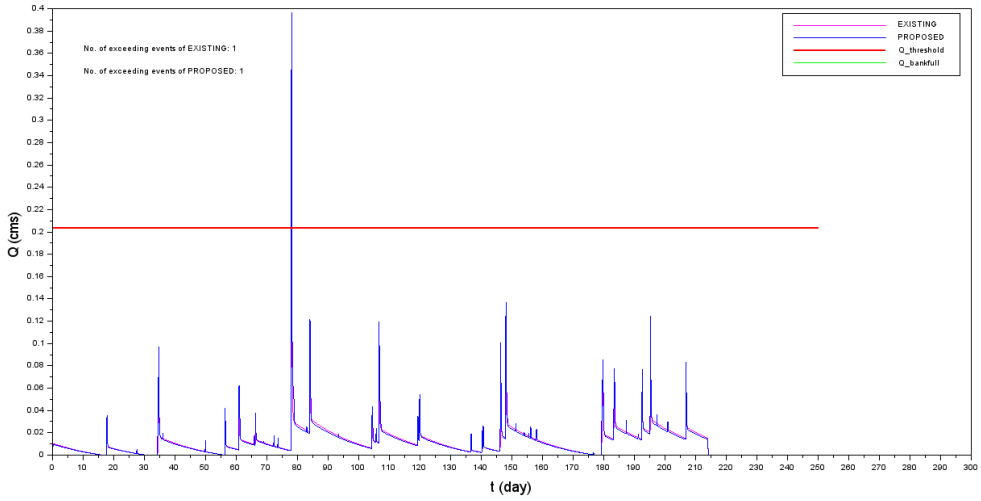

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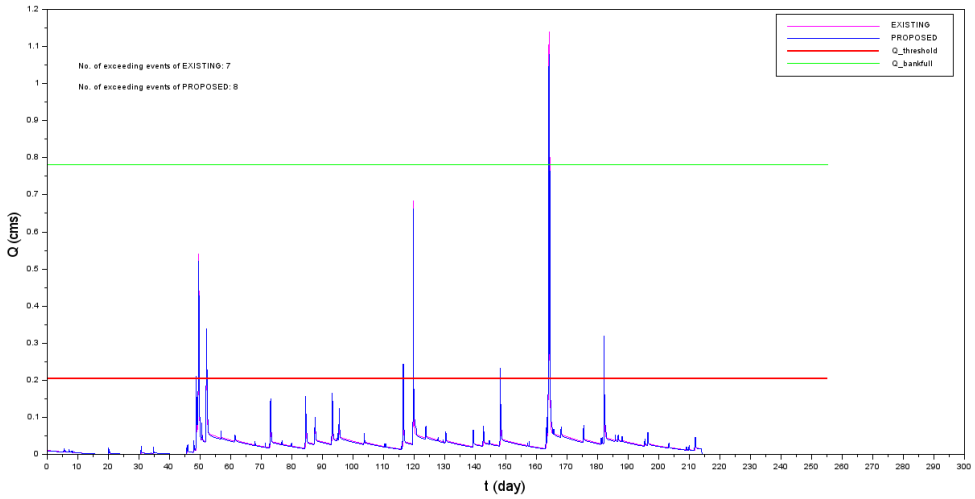

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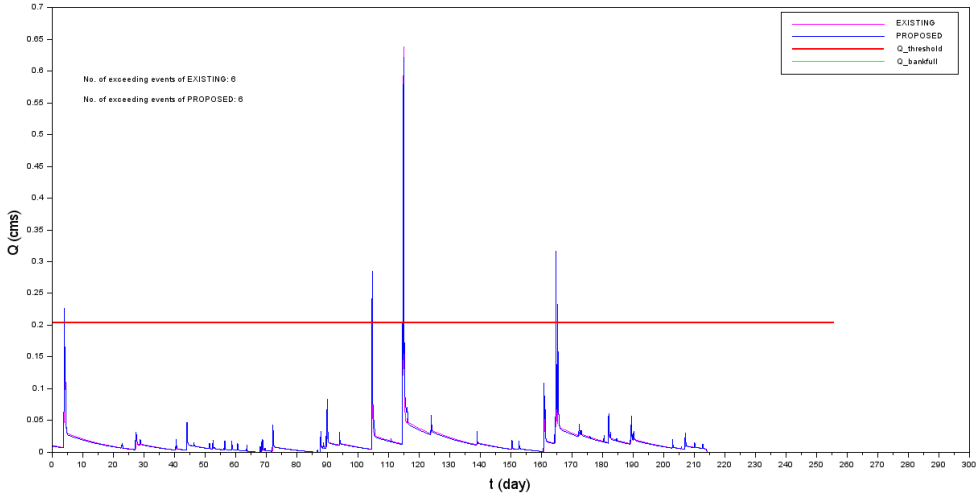

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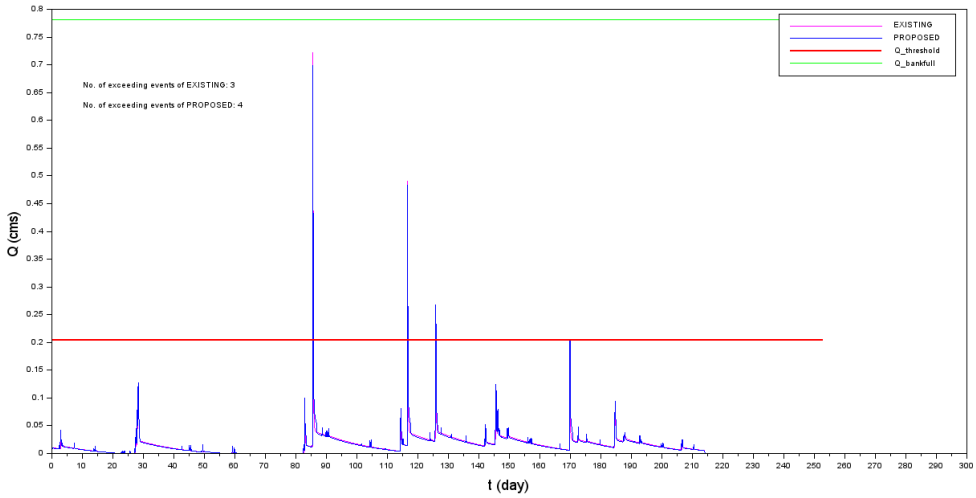

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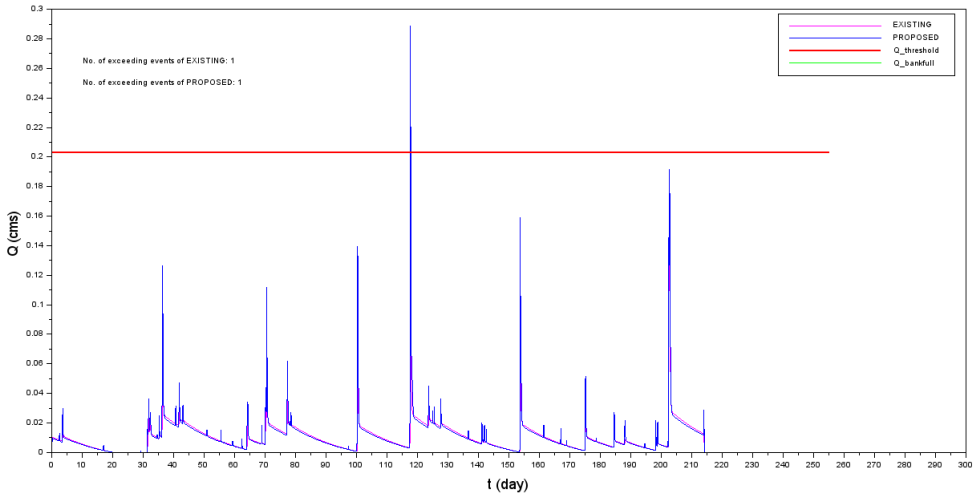

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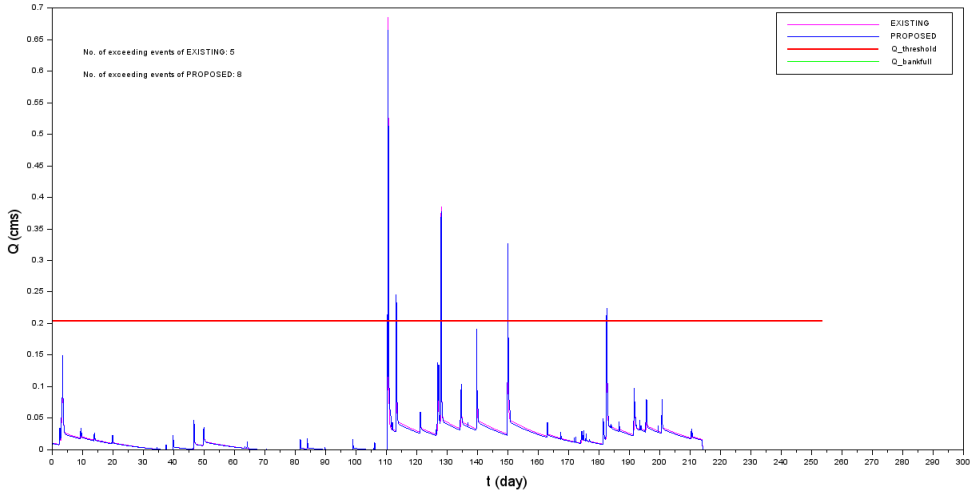

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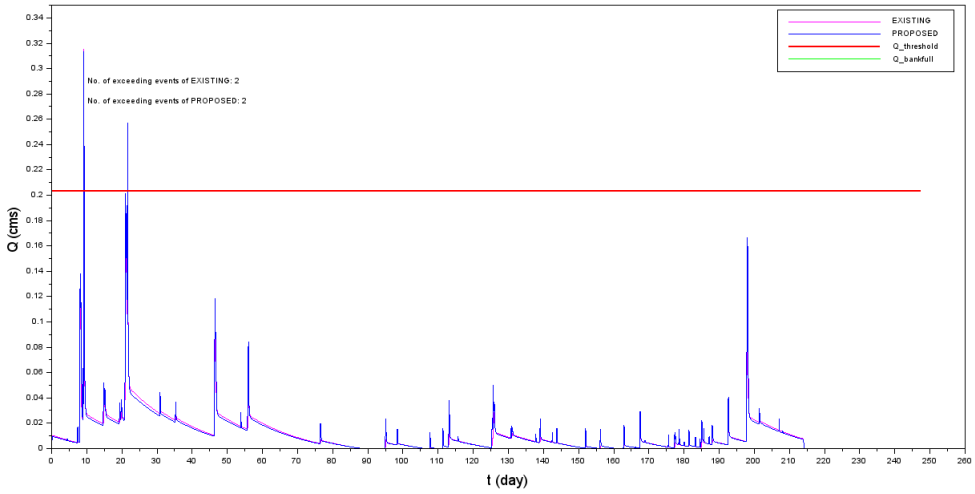

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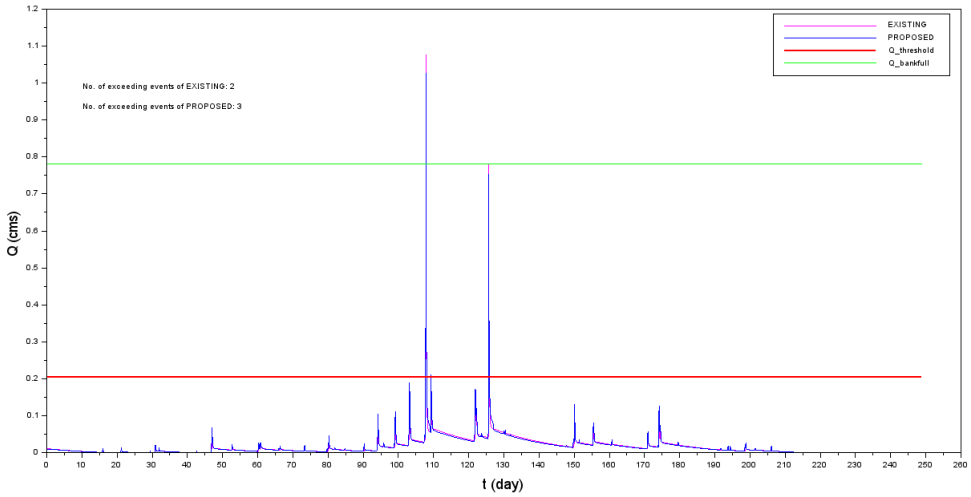

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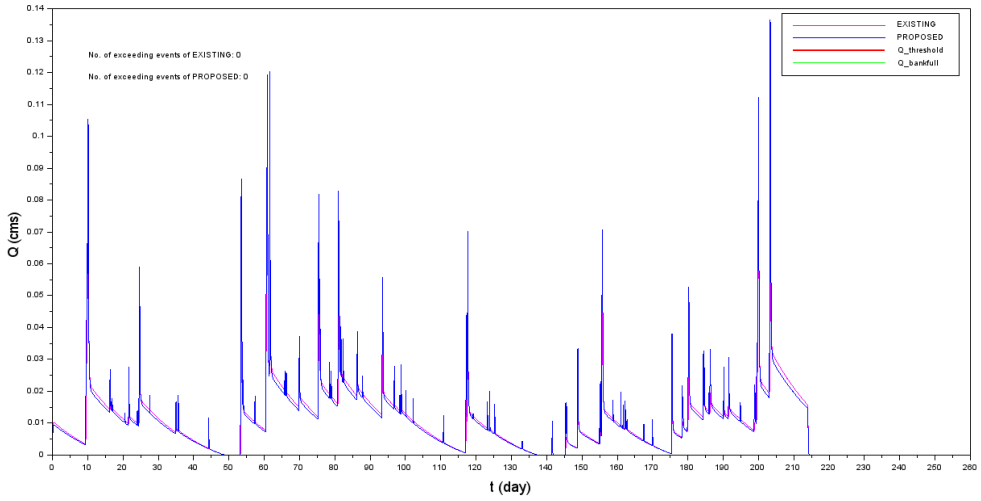

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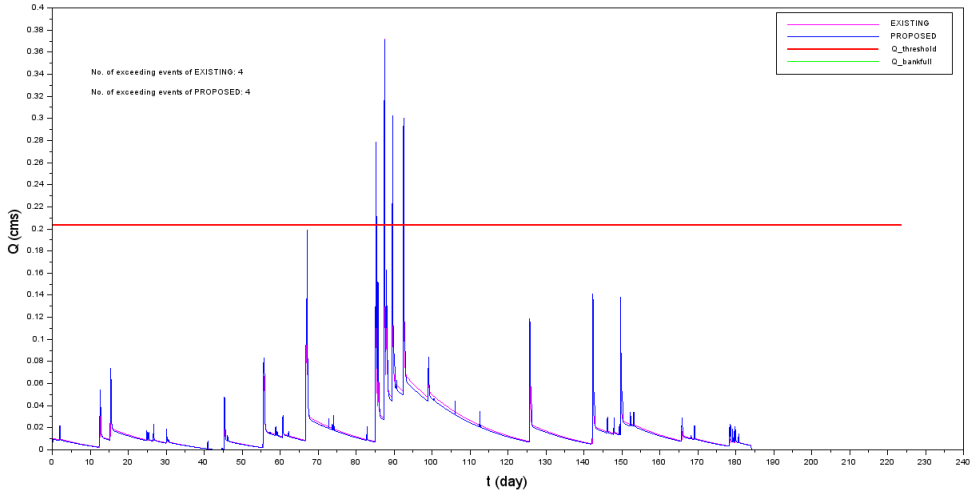

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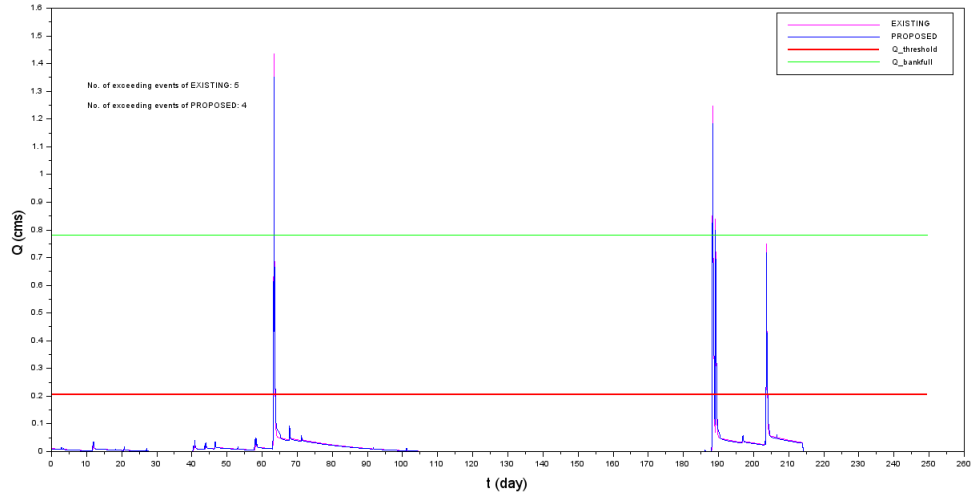

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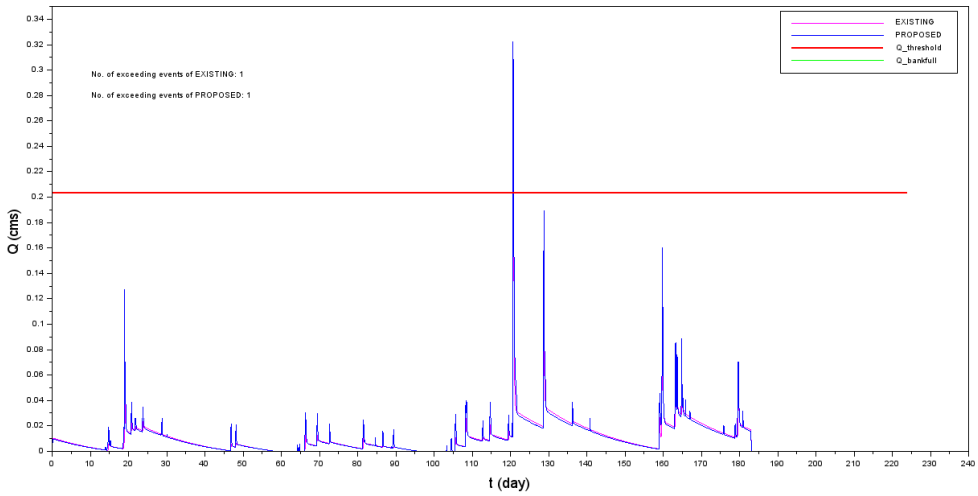

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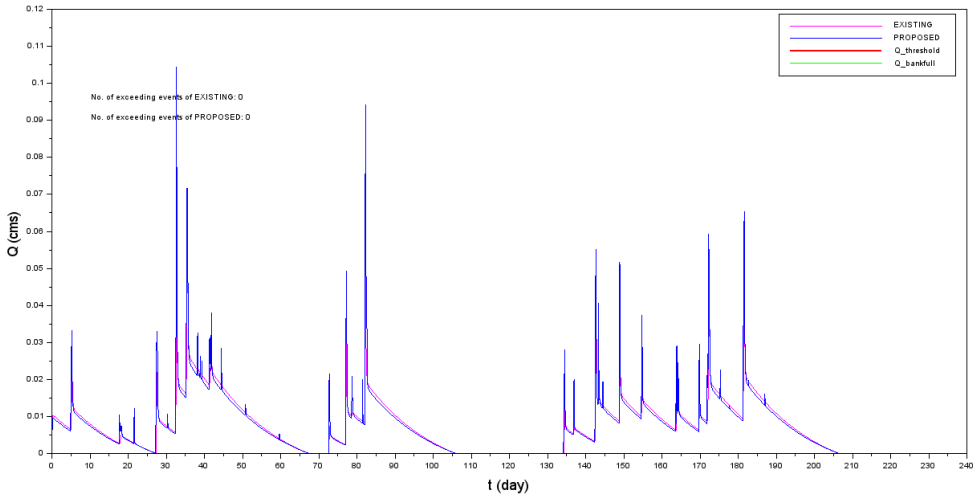

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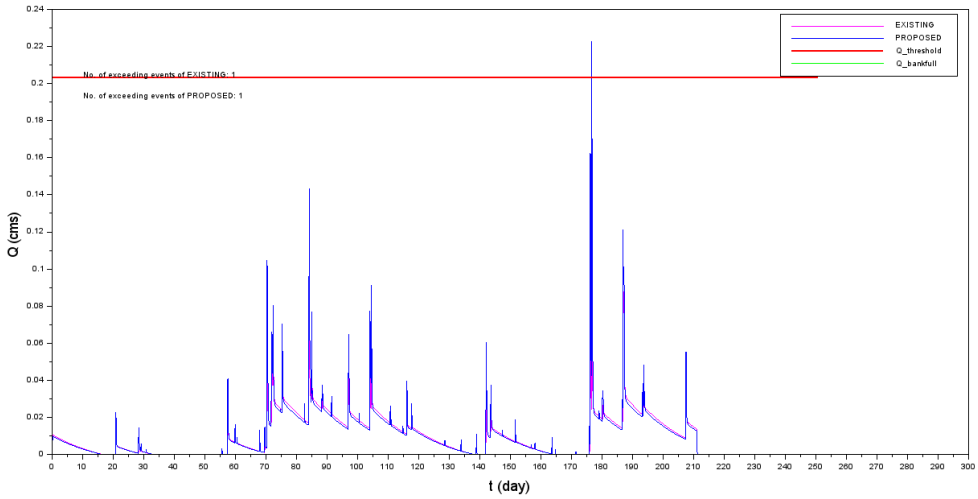

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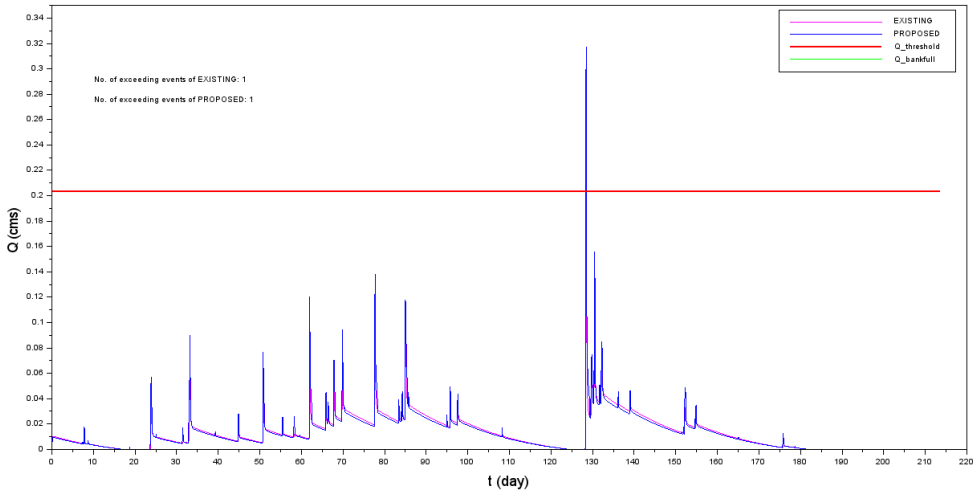

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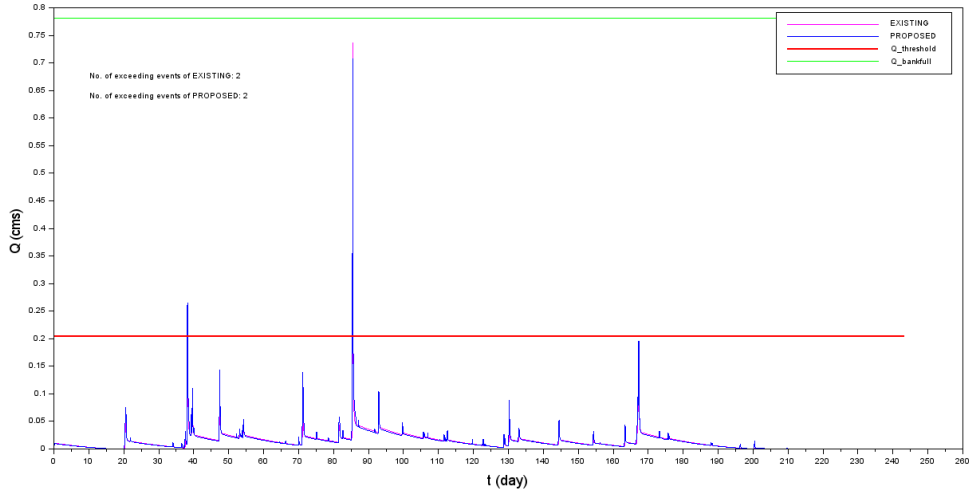

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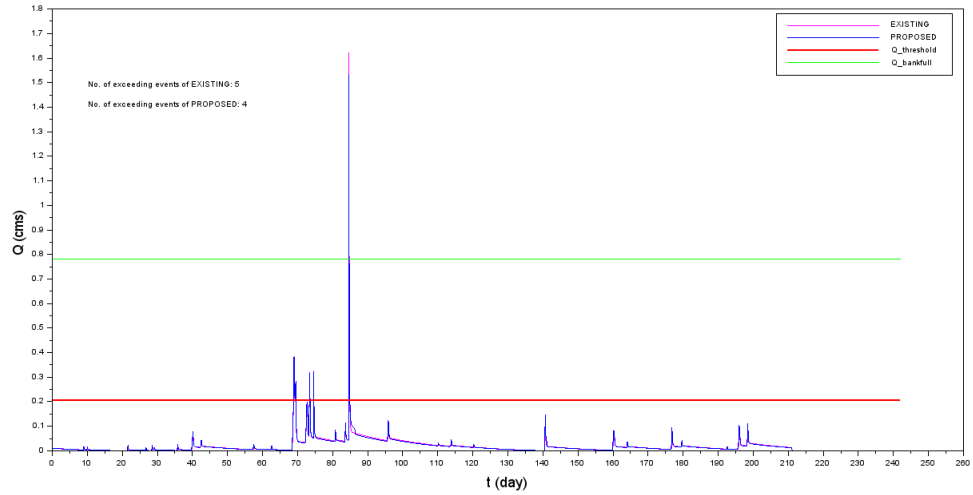

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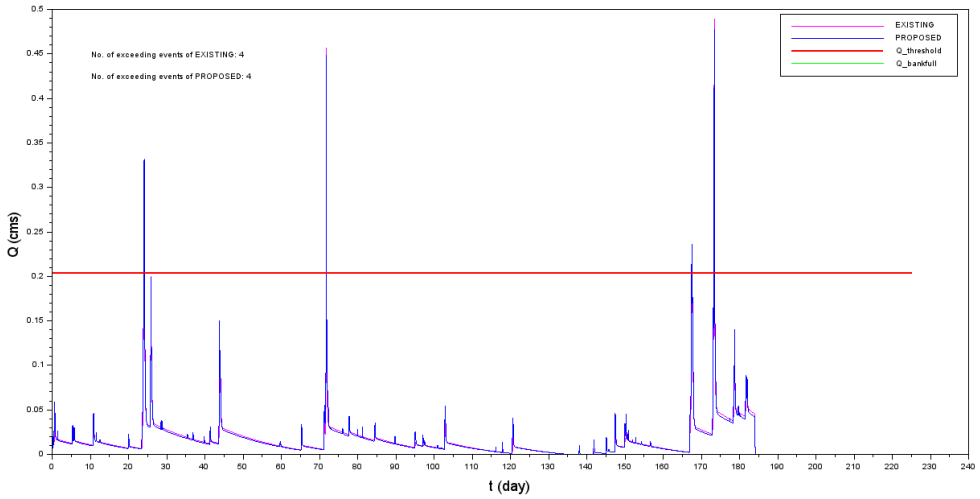

2003

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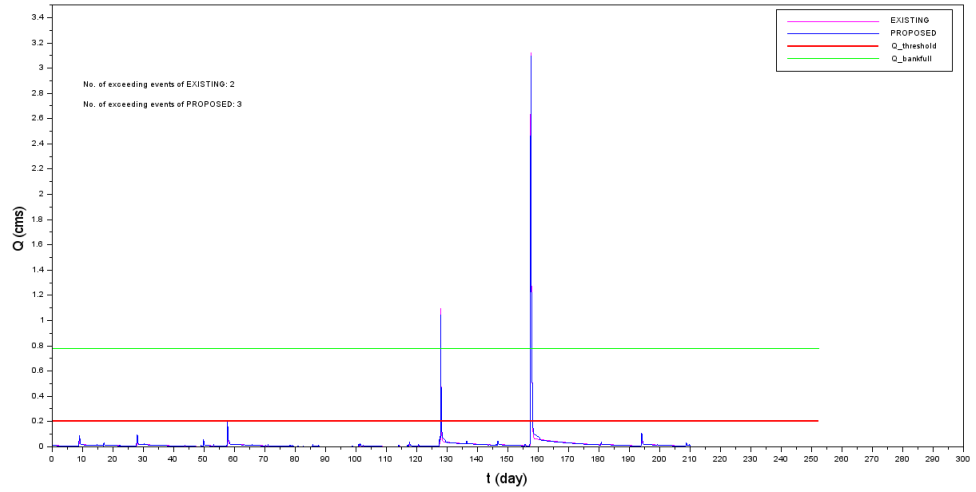

2004

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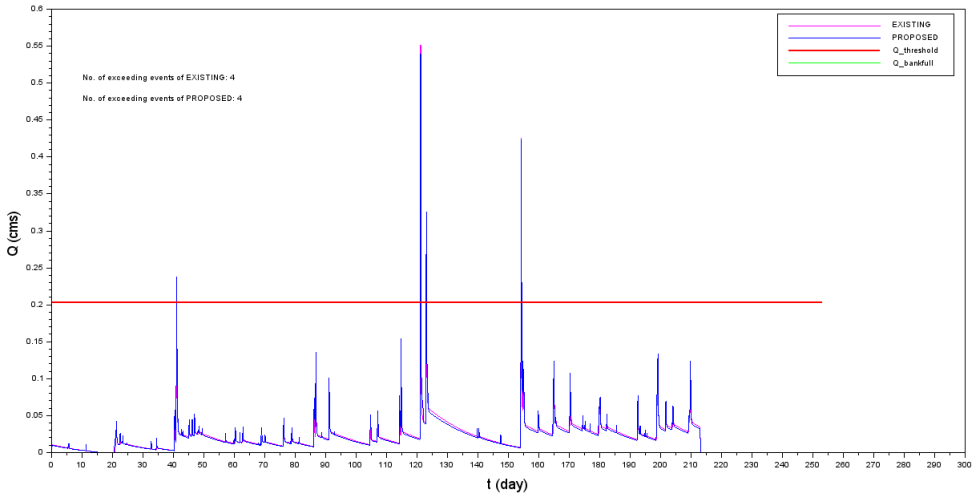

2006

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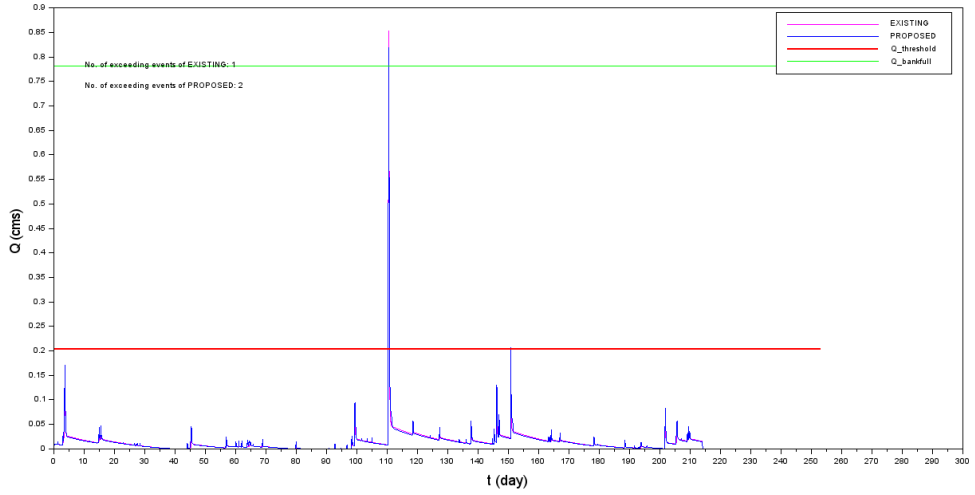

2007

Reach BBT-7