Bear Brook and Ramsay Creek Watersheds Fluvial Geomorphological Study

Existing Conditions Summary Report

Tewin Lands

Prepared for:
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3.1	Addressing Conservation Authority Comments	K. Woodrow	P. Villard	2024-12-12

Disclaimer

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1 Introduction

1.1 Introduction

This fluvial geomorphological report is part of a set of technical reports which have been prepared as part of Phase 1 of the Tewin study process. The Tewin Study Area ("Study Area") lands were identified as a future urban development area in the new City of Ottawa Official Plan (2022). The Study Area is located in southeast Ottawa, generally bordered by Leitrim Road to the north, Farmers Way to the east, Thunder Road to the south, and Anderson Road and Ramsayville Road to the west. The Study Area is outlined in **Figure 1** below. These technical reports are intended to establish an understanding of the existing physical, social, and ecological conditions that characterize the Study Area. Where appropriate, these reports also identify preliminary opportunities to help guide the next phase of the master planning process.

This information will be used to identify opportunities and strategic considerations that will inform the Tewin community design process going forward, as well as frame the preparation of additional site-specific technical studies and recommendation reports. Development at Tewin will explore new approaches to planning, design and development, including alternative strategies and solutions that can successfully implement the key community objectives.

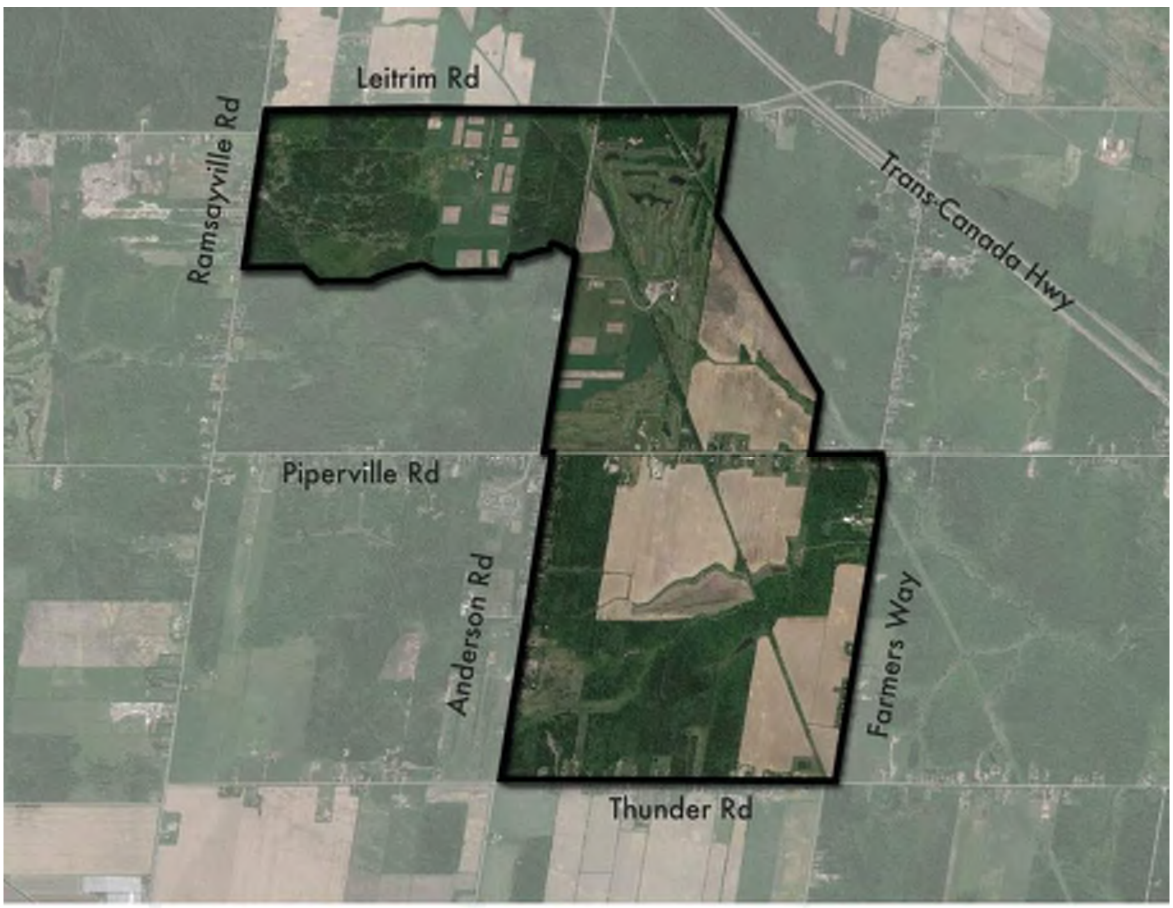

Figure 1. Tewin Study Area identified in black outline

1.2 Integrated Master Plan & Municipal Class EA Process

The ambition and scale of Tewin requires ongoing internal and external consultation. The purpose of the integrated Master Plan and Municipal Class EA process is to consolidate the various technical and community planning elements of the project to promote coordinated community engagement through streamlined and aligned decision making. This format will ensure critical partners, consultants and stakeholders are brought together at major milestones to identify and track challenges and opportunities through the development process.

The integrated Master Plan and Municipal Class EA process will include a public consultation strategy and technical study review timeline that achieves the requirements of the Master Plan and Municipal Class EA concurrently. The statutory Municipal Class EA meetings will be timed to align with the development of the community objectives, urban framework, preferred plans, and the draft secondary plan. Additional public and targeted consultations will be planned to complement the statutory consultation requirements. The development of the One Planet Action Plan (OPAP) will occur in parallel, with the final OPAP available at the time of final secondary plan Council approval. One Planet Living endorsement will follow Council approval of the secondary plan.

1.3 Tewin Overview and Community Vision

Tewin is planned to be a community of approximately 45,000 people and thousands of jobs. It will be more compact and dense than existing suburbs in Ottawa, with new urban areas integrated alongside valuable natural areas. Tewin will be an inclusive community, anchored in Algonquin wisdom and placekeeping principles, and welcoming to all. The community will have a meaningful mix of land uses and support active mobility, to achieve a complete, future ready community. The Tewin Project Team and City of Ottawa have committed to exploring appropriate options, alternatives and standards to enable Tewin to become a model of best practices in sustainable and inclusive community design in the North American context.

The integrated Master Plan and Municipal Class EA process will bring together various technical and community planning considerations.

The key objectives for Tewin are to create a community that is:

- Anchored in Algonquin wisdom, principles and placekeeping
- A benchmark for community design, demonstrating achievement of the 5 Big Moves identified in the Ottawa Official Plan
- Mobility-oriented and supportive, promoting a broad range of active forms of movement, where personal vehicles are optional
- Characterized by a meaningful mix of housing, community amenities, jobs and services in order to achieve a complete, future-ready community
- Designed to protect and integrate alongside valuable natural areas and agricultural lands; and
- Affordable, inclusive, healthy, welcoming and accessible to all

1.4 Tewin Intent: A Forward-Thinking Framework

Development at Tewin will explore new approaches to planning, design and development, finding successful options and alternatives to implement the key community objectives, in some cases likely going beyond what current development standards would allow for. The Tewin Project Team and the City of Ottawa have articulated these in the “Tewin Intent” which sets out the following:

1. Bold and Innovative Thinking:

Tewin is about creating a new kind of community, a future-focused model for smart, healthy and sustainable development. It will be a people-centred place that seeks to create the conditions for well-being. The Tewin Project Team will be open to bold ideas, innovative approaches, creative solutions, efficient use of land and resources, emerging technologies, smart city infrastructure that advances the City’s goals and objectives, and other future-forward ideas and opportunities that will enable Tewin to reach its full potential.

2. Integrating Algonquin Values and Principles:

Algonquin principles, values and teachings will guide the planning, consultation, design and development process for Tewin. The integration of Algonquin principles and design intentions will ensure the community is nature-based and sensitive to Mother Earth while creating capacity-building and economic development opportunities for the Algonquin people.

3. Sustainability and Resilience:

Tewin will be a model community that will position Ottawa as a leader in integrated sustainable design with the goal of being a resilient and holistic community. Tewin will be guided by the One Planet Living framework and Algonquin values of respect for the earth. The Community Design Plan will respond to the City's High Performance Development Standard and Climate Change Master Plan and will result in a Community Energy Plan. A Community Energy Plan and performance-based sustainability metrics that address climate mitigation and adaptation, and the other categories of the High-Performance Development Standards will be established from the start and monitored over time.

4. Systems-Based Environmental Planning

Tewin's organization and functions will be designed to respect nature and integrate natural features and landscapes into its form, character, and spirit. To that end, the Tewin Project Team is committed to pursuing a systems-based approach to natural heritage protection, environmental management, and water management in a way that is inclusive and integrated and encourages stewardship and a positive relationship with the natural world. Natural features are regarded as opportunities rather than constraints, will be woven into the fabric of the community, and will be central to its design and character.

5. Alternative Design Solutions:

Designing a community of the future requires progressive and forward-thinking infrastructure solutions. The Tewin Project Team is committed to being solutions-oriented and will consider alternative design and engineering standards that prioritize natural systems, pedestrians, cyclists and transit users, and which efficiently use available land and resources.

Surface water management strategies that achieve quality, conveyance and storage objectives will be based on the fundamentals of natural cycles, green/soft infrastructure, and multi-use opportunities that complement the human realm. Infrastructure design will consider the needs of those involved in the construction, operation and maintenance of municipal services to find opportunities to efficiently service the community and showcase sustainable practices while meeting the community's needs.

A framework for assessing alternative design standards will be established to consider and review alternatives against existing standards within the context of goals and objectives for the City and Tewin.

6. Cost-Effectiveness and Efficiency:

Tewin will demonstrate best practices in efficient and compact development. As a dense, mixed-use community of scale, Tewin will achieve a critical mass of people and jobs to support new infrastructure investments. The Tewin Project Team is committed to exploring opportunities to optimize the community's efficiency through a range of strategies, including prioritizing space-efficient modes of transportation, use of technology, green infrastructure, innovative construction practices, shared-use agreements, and mixed-use forms of development that will promote the efficient use and optimization of land; housing affordability; and supporting the long-term financial viability of the community and city resources.

7. Integrated Planning Process:

We are committed to advancing Tewin through a comprehensive and integrated planning and environmental assessment process where possible or applicable. The process will bring together various planning, environmental, transportation, urban design, infrastructure, economic, financial, social and technical considerations. The process will be underpinned by engagement with the Algonquin people, other stakeholders, and the public.

8. Collaboration and Problem Solving:

The Tewin Project Team and City of Ottawa Project Team are committed to working collaboratively together to move Tewin forward in an expedited way. We will plan with a spirit of collaboration and joint problem-solving to ensure that the development of Tewin meets the best interests of the City of Ottawa and the Algonquins of Ontario.

9. Communication and Transparency

The Tewin Project Team and the City of Ottawa Project Team commit to open and transparent communication throughout the project. This will require proactively sharing information between the groups as decisions are made and to ensure relevant communication materials are distributed in a timely manner.

The Tewin Project Team and the City of Ottawa Project Team will ensure that all parties, including City Council, residents, and other stakeholders, are provided with pertinent details. Effective information sharing will ensure the project achieves outcomes that are, to the greatest extent possible, known by all involved.

1.5 Existing Conditions Technical Reports

A range of specialized consultants have been studying the physical environment of the Study Area to support community design, servicing strategies and the future development of Tewin. This data has been collected and reported on in a set of Existing Conditions and Opportunities Reports, of which this document is one. The full suite of reports includes the following:

- **Tewin Existing Conditions and Preliminary Opportunities Report** dated September 2024 and prepared by Urban Strategies
- **Fluvial Geomorphology Study — Tewin Lands: Existing Conditions Summary Report - Bear Brook and Ramsay Creek Watersheds** dated October 2024 and prepared by GEO Morphix Ltd.
- **Tewin Lands: Existing Conditions Hydrogeological Study** dated September 2024 and prepared by Dillon Consulting
- **Existing Conditions - Geotechnical: Tewin Lands** dated September 2024 and prepared by Paterson Group
- **Tewin Lands: Natural Heritage Preliminary Existing Conditions Report** dated April 2024 and prepared by Kilgour and Associates
- **Tewin Lands: Cumulative Hydrologic Impact Assessment** dated April 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Lands: 2021-22 Field Monitoring Report** dated April 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Lands – Existing Conditions Water Budget** dated October 2024 and prepared by J.F. Sabourin and Associates
- **Tewin Mobility Existing Conditions** dated May 2024 and prepared by CGH Transportation
- **Stage 1 Archaeological Assessment Tewin Lands** dated July 14, 2023 and prepared by WSP Canada

1.6 Framework for Identifying Preliminary Opportunities

Given the unique scale, vision and project goals for Tewin, as well as the shared commitment to exploring new ways of advancing the community design process as expressed in the Tewin Intent, the Phase 1 reports for Tewin include a discussion of potential opportunities to be explored in subsequent stages of the integrated Master Plan and Municipal Class EA process. The identification of preliminary constraints and opportunities, as well as a preliminary community structure, is required in Phase 1 of the integrated Master Plan and Municipal Class EA process as per specific Terms of Reference that were established for each of the Tewin planning, environmental and transportation studies.

The opportunities introduced within these reports are based on a series of key policy directions and strategic considerations, including:

- **Ottawa's new Official Plan**, which promotes the creation of complete, transit-supportive communities
- **Algonquin values and principles**, underscored by respect for nature, integration of water, and planning the natural environment to achieve long-term vitality over many generations
- **The Tewin Intent**, which promotes innovative thinking and alternative, performance-based solutions
- **One Planet Living**, a holistic framework for achieving environmental resiliency, sustainable development, and reduced carbon emissions
- **Provincial policy** direction focused on supporting housing development and facilitating growth, in order to address the province's housing supply challenges
- **An integrated, systems-based approach** to planning at Tewin that brings together diverse planning, environmental, technical and economic considerations

1.7 Scope of Tewin Fluvial Geomorphological Assessments

The extent of fluvial geomorphic assessment activities completed to-date span several tributaries of Bear Brook and Ramsay Creek, including the Smith Gooding Municipal Drain and Johnson Municipal Drain. Both field-based and desktop-based assessments have been completed. The field-based assessments provide preliminary observations in support of future activities within the Tewin Area in the City of Ottawa, Ontario (**Figure 1**). The information provided by the field assessments informed an erosion hazard assessment and crossing assessment for several watercourses within the Tewin Study Area and adjacent lands. The field information will continue to serve and inform additional planning aspects relating to fluvial geomorphology, such as erosion thresholds for long-term erosion mitigation. As part of the Tewin Lands field-based fluvial geomorphic assessments, GEO Morphix Ltd. ("GEO Morphix") completed the following:

- Background review of all existing documents related to the Tewin Study Area and topography, physiography, and geology maps of the local watersheds and study area
- Reach delineation for all watercourses in the Study Area, including various tributaries downstream of the study area boundary
- Historical assessment of changes in land use and channel form and function using historical aerial photographs
- Site reconnaissance, including rapid geomorphological assessments and channel characterization for all reaches identified on participating lands
- Detailed geomorphological assessments of erosion-sensitive reaches identified by site reconnaissance to inform future erosion threshold analysis
- Hazard delineation and erosion setbacks for all confined and unconfined reaches in the Tewin Study Area to support the preliminary review of existing environmental constraints
- Assessment of existing drainage crossings that overlap with the proposed servicing lines route

A desktop-based geomorphological inventory and assessment was conducted by GEO Morphix along Bear Brook, downstream of the Tewin Study Area. The desktop assessment examined watercourse characteristics in a hierarchical, nested approach in terms of spatial scale. The Bear Brook watershed was assessed at the watershed/sub-watershed scale, then reach scale, then sub-reach and geomorphic unit scale. The purpose of the desktop-based analyses was to document existing conditions and the extent of potential future concerns along the Bear Brook main channel as areas within its headwaters undergo land use changes. The following tasks were completed as part of the desktop-based assessment:

- Review of cumulative hydrologic inputs of Bear Brook and select tributaries for multiple hydrological scenarios and storm conditions (JFSA, 2024)
- Review of watershed characteristics (e.g., surficial geology, topography, land cover/use)
- Division of the main channel through the assessment area into "valley segments"
- Historical aerial imagery analysis to identify historical geomorphological and anthropogenic changes along the channel and channel corridor

- An inventory of Points of Interest observed in the aerial imagery at which the Bear Brook main channel may have higher sensitivity to proposed future land use changes

The results of the field-based fluvial geomorphic assessments are presented herein. Results of the desktop-based geomorphological inventory and assessment for Bear Brook are provided in **Appendix A**.

2 Background Review

2.1 Watershed

The Tewin Study Area (8.9 km^2) is situated in the headwaters of the Bear Brook and Ramsay Creek watersheds. Bear Brook is a tributary of the South Nation River and drains an area of approximately 490 km^2. A section of the Smith Gooding and Johnson Municipal Drains (tributaries to Bear Book) also bisect the Tewin Lands. Ramsay Creek is a tributary of Green's Creek which drains an area of approximately 71.97 km^2 and 113.34 km^2 respectively; Green's Creek is a tributary of the Ottawa River. The Tewin Study Area occupies roughly 2% of the overall Bear Brook subwatershed and 5% of the overall Ramsay Creek watershed area. The tributaries and Municipal Drain extents are shown in **Appendix B**, for reference.

Landuse along the channel reaches within the Tewin Study Area is a mix of forested and agricultural lands. The headwater reaches of Ramsay creek, upstream of Leitrum Road, are straight drainage channels. The tributaries of Bear Brook which drain and traverse the Tewin Study Area are a mix of headwater drainage features, municipal drains, and relatively sinuous reaches with floodplains situated in confined valley settings.

2.1.1 Terrain Analysis

Terrain analysis of a high-resolution digital elevation model (DEM) was used to classify the channel valley type (confined; unconfined) for each of the channel reaches within the study area. A high-resolution bare-earth DEM was obtained for the study area from a publicly available LiDAR dataset maintained by OMNRF (2019/2020 data). The bare-earth elevation raster was used to generate a hillshade model of the study that was used for the interpretation and analysis of geomorphic features (e.g. stream channels and valley walls). Following from SNCA guidance documents, a reach was classed as confined where all or a portion of the channel was situated in a valley where both valley walls extended to a height of 3m or more above the floodplain, or if absent, the channel. Additional field observations were also used to verify channel and valley form. A hillshade model of the LiDAR data is provided in **Appendix B**.

A review of the longitudinal profiles along Bear Brook within the Study Area was also preformed using the LiDAR dataset. Longitudinal channel bed profiles were generated by taking samples of elevation at 1 m intervals along the channel flow path. The sampled elevations in meters were then plotted with horizontal distance downstream. Features along the watercourse, including crossings, beaver dams (observed during rapid assessments or aerial interpretation), and confluences were overlayed on the plot to provide geomorphic context. It should be noted that the long profiles are based on 2020 data, and as such, there may be differences between 2020 and present-day conditions. Given the Municipal Drain status of many of the watercourse segments within the Tewin study area, ongoing maintenance activities in these drains may also adjust specific conditions at any given time.

The length of Bear Brook was divided into Bear Brook North and Bear Brook South, which are presented below in **Figures 2** and **3**.

Overall, the longitudinal profiles along the main branch of Bear Brook exhibited the greatest change in slope around beaver dams, crossings, and tributary confluences. Generally, the areas with relatively lower gradients tended to precede beaver dams, most likely due to the deposition caused by backwatering and slower flows, as observed in the field assessments summarized in Section 3.

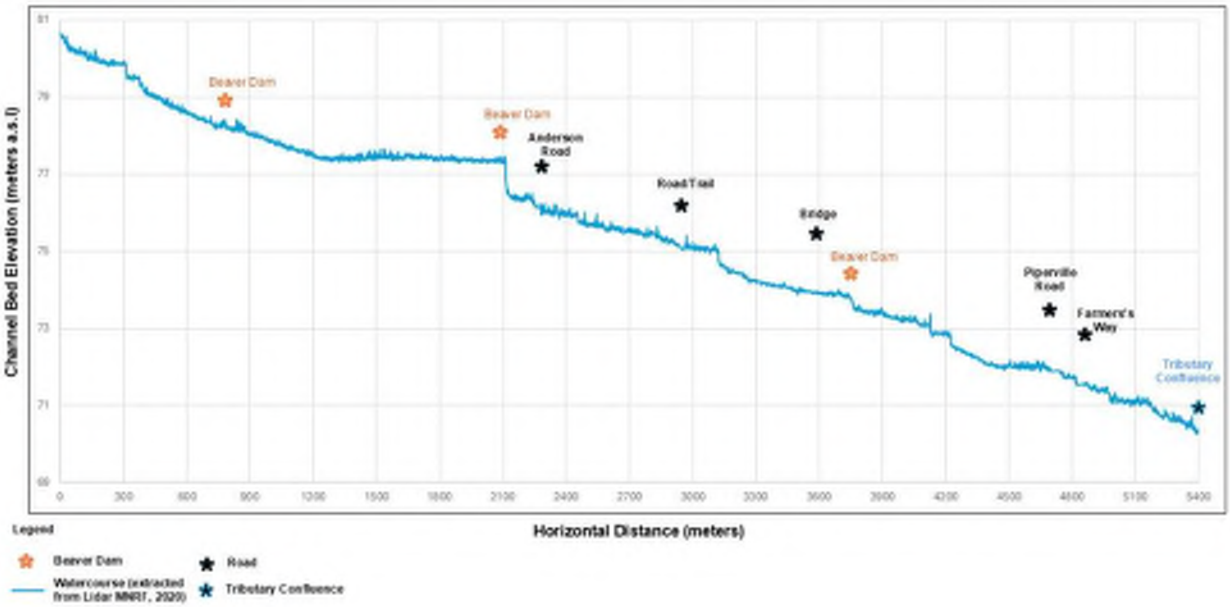

Figure 2. Longitudinal Profile of Bear Brook North Branch

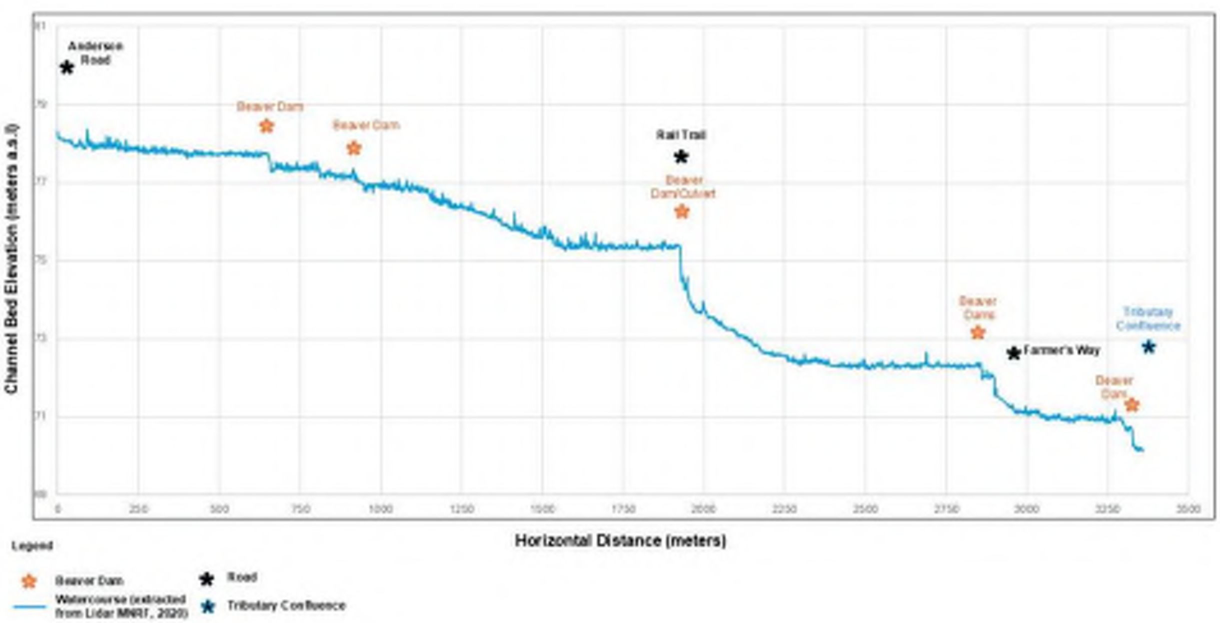

Figure 3. Longitudinal Profile of Bear Brook South Branch

2.2 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 proposed development within the stream's catchment area. A map showing the surficial geology throughout the subject lands is provided in **Appendix B**.

The Tewin Study area is located in a physiographic region known as the Russell and Prescott Sand Plains (region 50) which is adjacent to the Ottawa Valley Clay Plains (Region 49) located immediately to the north and east of the Tewin Study area (Chapman and Putnam, 1984). This region of sand plains is characterized by a relatively level surface located at approximately 80 m above sea level. The sand deposits across the study area are associated with the Champlain Sea, an inlet to the Atlantic Ocean which extended into the present-day Ottawa River Valley at the end of the most recent glacial period (c. 10,000 ago). Across the Tewin Study Area, the surficial geology is mapped as fine-to-medium-grained (nearshore deposits) along the western boundary of the area, with silt and clay (off-shore marine deposits) mapped across the central portion of the study area (OGS, 2010). The surficial deposits along the northeastern corner of the area are mapped as medium-to fine-grained sands characteristics of deltaic and estuarine deposits (OGS, 2010). The fine-grained, silt and clay deposits, mapped across most of site originated in a glaciomarine context in the brackish waters of the Champlain Sea with sediments sourced from Canadian Shield granite (Alysworth and Lawrence, 2003; Hunter, Crow, and Brooks, 2010; Chapman and Putnam, 1984). These courser-grained materials are non-cohesive and more susceptible to erosion. Whereas the finer silty and clay-sized materials that are mapped across most of the Tewin Study Area have a greater cohesive bond and are, therefore, more resistant to erosion. For a more detailed characterization of subsurface conditions, refer to the Existing Conditions - Geotechnical: Tewin Lands report prepared by Paterson Group (2024) and the Tewin Lands: Existing Conditions Hydrogeological Study prepared by Dillon Consulting (2024).

2.3 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to watercourse systems and surrounding land use/cover over time. This information partly provides an understanding of the historical factors that have contributed to current channel morphodynamics. Aerial photographs from 1965 to 2019 from the City of Ottawa (https://maps.ottawa.ca/geoottawa/) were reviewed. Historical aerial photographs are included in **Appendix C**, for reference.

Aerial photographs from 1965 only cover the upstream reaches of Ramsay Creek within the Study Area. Ramsay Creek's main branch meanders through a mix of active agricultural field and treed areas. Many of its tributaries have been historically straightened for agricultural purposes and drain the surrounding actively cultivated fields. Riparian vegetation along Ramsay Creek and its tributaries is relatively sparse and composed of grasses and herbaceous vegetation. Few rural dwellings are established along Leitrim Road, Ramsayville Road, and Anderson Road in 1965.

Little visible change occurs between 1965 and 1976 imagery for Ramsay Creek. The upstream reaches of Ramsay Creek and its tributaries within the Study Area (i.e., south of Leitrim Road) exhibit little planform development. Riparian vegetation remains sparse and active agriculture remains the dominant land use adjacent to the reaches.

Bear Brook and its tributaries within the Study Area are generally visible in the 1975 imagery. The surrounding land use is predominantly active agriculture, and several rural dwellings are located sparsely across the lands. The main branch of Bear Brook meanders through active agricultural fields. Several of the reaches along the main branch and its tributaries exhibit straightened planforms and drain the surrounding fields. Sparse parcels of land containing forested areas are concentrated with the southern portion of the Study Area and the riparian edges at these locations are wide and composed of mature trees. The riparian edges along the remaining reaches are generally narrow and sparse. Notably Highway 417 located northeast of the site is constructed between 1965 and 1976.

Historical imagery between 1976 and 1991 show little observable changes in channel planform throughout the Study Area for Bear Brook and tributaries. Land use remains predominantly active agriculture. However, many of the fields along the northern and southern border of the site, and many previously cultivated fields surrounding the Study Area appear to transition to treed areas. Several additional rural dwellings are established along the bordering roads. Riparian vegetation along the main branches of Ramsay Creek and Bear Brook matures, as well as many of the upstream Bear Brook reaches located in the southern portion of the Study Area.

Changes in channel planform between 1991 and 1999 imagery are minimally observed. Land use remains active agriculture and trees in the southern and northern portions of the Study area increasingly mature. Riparian edges along the agricultural ditches remain narrow or non-existent.

Between 1999 and 2011 major changes within the Study Area include the development of the Anderson Links Golf Course, located in the northeastern corner of the site on previously farmed land. This resulted in the incorporation of outlets to the main branch of Bear Brook through a series of constructed ponds. Several large beaver ponds are observed along upstream reaches of Bear Brook, resulting in slight changes in channel planform due to backwatering. Much of the land use remains active agriculture and forested plots increase in maturity.

Little changes occur across the Study Area between 1999 and 2019. Treed areas in the north and south are mature and many of the tributaries are not visible due to the dense canopy coverage. The large beaver ponds in the south have de-watered as of 2019 imagery, leaving large grassy floodplains. The riparian edges along many of the tributaries flowing through active agriculture remains narrow. Surrounding land use from 1965 to 2019 has transitioned from agriculture to treed areas; however, agriculture remains prominent within the Study Area.

2.4 Desktop Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are divided as such because they are expected to have similar inputs and outputs in terms of sediments and discharge. They are also expected to react similarly throughout to flow events and other stressors. They are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are delineated based on changes in the following:

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

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

A reach map is provided in **Appendix B**. Reaches within the Tewin Study Area consist of Bear Brook and Ramsay Creek Tributaries, labelled with a **BB** and **RC** prefix, respectively. Reaches are numbered downstream to upstream to provide geographic context. The extent of the Smith Gooding and Johnson Municipal Drains are also displayed on the mapping provided in **Appendix B**. Reaches situated along the drains are denoted with drain name prefix: Smith Gooding Municipal Drain (SG) and Johnson Municipal Drain (J).

Reach delineation was extended within the Tewin Study Area, while also including reaches along Ramsay Creek and Bear Brook downstream of the Study area to better identify areas sensitive to erosion. It should be noted that field assessments were generally limited to reaches on participating lands within the Tewin Study Area.

3 Field Assessments

Field investigations along Bear Brook and Ramsay Creek were completed over several months between October 2021 and December 2023. Field investigations were completed on a reach-by-reach basis on participating properties within and downstream of the Tewin Development Lands.

Field assessments were completed along each accessible reach following standard, accepted protocols. Reach-by-reach observations generally included the following:

- Confirmation of desktop reach delineation extents
- Instream estimates of bankfull channel geometry
- Bed and bank material composition and structure
- Description of riparian vegetation type and cover
- Observations of erosion, scour, or deposition

Tables 1 and **2** summarize observations and measurements for all reaches within the Study Area for Bear Brook and Ramsay Creek, respectively. **Appendix D** provides supplemental field data for other reaches within the Tewin Secondary Plan Area for reference. Representative photographs are included in **Appendix E** to supplement and support the observations.

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Table 1. General reach characteristics for Bear Brook reaches in Study Area

Reach	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
BB5-5A	11.2	-	Unknown due to backwatering		Confined	Trees, Grass, Herbaceous	Largely backwatered due to two beaver dams downstream, evidence of fluvial entrainment, fall/sloughing and minor undercutting; deep water and soft sediment prohibited depth measurement
BB5-5A-2	1.8	0.5	Clay, Silt, Sand	Clay, Silt, Sand	Confined	Trees dominant, Grasses	Woody debris jams present, bank angle 5-30% through mid to upstream extend, erosion predominant at downstream extent
BB5-5A-3	7.2	0.9	Gravel, Small Cobble, Large Cobble	Silt, Sand, Gravel	Confined	Trees	Reach modified by previous upstream beaver dam failure, evidence of undercutting, active bed and outer bank erosion
BB5-5A-3-1	5.0	1.5	Gravel, Small Cobble, Parent	Silt, Sand Gravel	Confined	Trees	Reach break moved and heavily modified due to beaver pond and activity, leaning mature trees on eroded banks,
BB5-5A-3-1A	4.7	1.4	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Trees, shrubs, grasses, herbaceous	Reach ends at beaver formed pond, channel appears stable, low entrenchment
BB5-5A-3-1A-1	4.7	1.4	Clay, Silt, Sand		Unconfined	Trees	Instream vegetation heavy, characteristic of a ditch
BB5-5A-3A	5.4	1.5	Clay, Silt, Gravel, Small Cobble	Clay, Silt	Confined	Trees, grasses, herbaceous	Reach backwatered due to large downstream beaver dam, instream logs and trees observed from bank failure, riffle-run development present
BB5-5A-3B	3.2	1.0	Clay, Silt, Sand, Gravel	Clay, Silt, Sand	Unconfined	Grasses, Herbaceous	Increased sinuosity moving downstream, massive banks and valley wall failure observed, riffle-run development present
BB5-5A-3B-1	2.7	0.5	No riffle-pool development		Unconfined	Trees, Herbaceous	Channel primarily dry and poorly defined, majority of erosion occurs in the downstream portion
BB5-5A-3C	5.6	1.9	Clay, Silt, Gravel	Clay, Silt, Sand	Unconfined	Grasses, Herbaceous	Evidence of enlarging, erosion and minor adjustment may be related to beaver activity
BB5-5A-3D	6.3	2.5	No riffle-pool development		Unconfined	Grasses	Channel backwatered from downstream beaver dam, high water levels, reach may have riffle-pool development under in absence of backwater conditions
BB5-5A-3D-1	No defined channel, and no bankfull indicators		No riffle-pool development		Unconfined	Grasses	Feature was characteristic of a ditch
BB5-5B	No defined channel, and no bankfull indicators		No riffle-pool development		Confined	Grasses, Herbaceous	Feature was characteristic of a large online pond at the time of assessment. Flows are restricted through a

Reach	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
							drain at the downstream extent prior to converging with BB5-5A
BB5-5C	7.8	1.0	Clay, Silt, Sand, Gravel	Clay, Silt, Sand	Confined	Grasses	Wide agricultural swale, entrenched, multiple flow paths, riffle-run development, no deep pools observed,
BB5-5C-1	7.9	1.3	No riffle-pool development		Unconfined	Grasses, Herbaceous	Wide agricultural swale, entrenched, modified by agricultural activities, feature 100% run.
BB5-5C-1A	7.8	1.3	No riffle-pool development		Unconfined	Grasses, Herbaceous	Wide swale, entrenched, accumulation of organics, no morphological adjustment in process
BB5-5C-1A-1	2.0	0.3	No riffle-pool development		Unconfined	Grasses, Trees	Ditch-like characteristics of swale, heavily modified and straightened, several footbridges across, input from numerous storm drains/culverts from residential lots
BB5-5C-1A-2	1.5	0.3	No riffle-pool development		Unconfined	Trees, Herbaceous	100% runs, agricultural swale. Poorly defined with little geomorphic activity
BB5-5D	2	0.3	No riffle-pool development		Unconfined	Trees, Shrubs, Herbaceous	Flows may be perennial, leaning trees and shrubs on banks, feature 100% run, some sedimentation observed, no morphological adjustment in process
BB5-5D-1	1.0	0.3	No riffle pool development		Unconfined	Trees, Shrubs, Herbaceous	Poorly defined feature flows behind residential lots.
BB7	Channel assessed from right of way, unable to complete full observations				Confined	Grasses, Trees	Limited channel access, undercutting and bank erosion observed
BB7-1	No observations – non-participating lands						
BB8	Reach outside of Tewin study area boundary but included in mapping.						
BB8-1	Reach outside of Tewin study area boundary but included in mapping.						
BB9	6.3	1.9	Silt, Sand, Gravel	Clay, Silt, Sand	Unconfined	Grasses, Trees	Nearby beaver dam causing severe backwatering and intensifying erosion, dominated by runs
BB10	4.8	2.8	No riffle	Clay, Silt, Sand	Unconfined	Grasses, Herbaceous, Trees	No true riffles observed, high valley wall above stream banks, leaning trees, bank slumping and exposed tree roots observed, enlarging observed
BB10-1	3.5	1.3	Silt, Sand, Gravel	Clay, Silt, Sand	Unconfined	Grasses, Herbaceous	Downstream of golf course, J shaped trunks, no true riffles observed, reach dominated by runs, channel entrenched
BB10-1A	1.4	0.3	Clay, Silt, Till	Clay, Silt, Till	Unconfined	Grasses, Trees	Narrow corridor of grasses through golf course, minor slumping observed, little geomorphic activity overall
BB10-1B	1.6	0.3	Clay, Silt	Clay, Silt	Unconfined	Grasses	Straight ditch, all runs observed, algae and few cattails present, minor slumping observed, little geomorphic activity overall
BB11	4..8	2.8	Silt, Sand, Till	Silt, Sand, Till	Unconfined	Grasses	Straightened ditch, little geomorphic activity
BB12	4.2	1.4	Silt, sand, gravel, small cobble	Clay, silt, sand	Unconfined	Grasses, Herbaceous	Few pools observed, predominantly riffles and runs, sediment deposits observed through reach, evidence of enlarging

Reach	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
BB13	4.7	0.8	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Grasses, Shrubs	Somewhat naturalized ditched agricultural channel, partially straightened, slumping common, several vegetated islands observed
BB14	3.8	1.0	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Grasses, Shrubs	Straight agricultural ditch, planform recovering towards sinuous, exposed till on bed and banks
BB15	4.8	1.7	Clay, Silt	Clay, Silt	Unconfined	Grasses	Straight ditched channel, heavy backwatering from large beaver dam, erosion less severe closer to downstream extent, minimal geomorphic activities
BB16	4.1	1.2	Clay, Silt, Gravel	Clay, Silt	Unconfined	Grasses	Straight ditched channel, channel morphology mostly comprised of runs

N/A – Measurements not possible either due to large channel size or lack of defined channel or poor bankfull indicators

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Table 2. General reach characteristics for Ramsay Creek reaches in Study Area

Reach	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Substrate		Valley Type	Riparian Vegetation	Notes
			Riffle	Pool			
RC4-1-1A	4.8	0.7	Clay, Silt	Clay, Silt	Unconfined	Trees, Grasses	Straight agricultural ditch, beaver dams retaining water, no flow observed, minor slumping observed, minimal geomorphic activity
RC4-1-1A-1A	5.3	0.9	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Trees, Grasses	Assessed as part of **RCA-1-1A-1**
RCA-1-1A-1	5.3	0.9	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Trees, Grasses	Former agricultural ditch, no flow observed, trees growing on channel bed, mostly stable
RCA-1-1A-2	5.0	0.8	Clay, Silt	Clay, Silt	Unconfined	Trees	Former agricultural ditch, no flow observed, trees growing on dry bed, minimal geomorphic activity
RCA-1-1A-3	5.3	0.9	Clay, Silt, Sand	Clay, Silt, Sand	Unconfined	Trees, Grasses	Assessed as a part of **RCA-1-1A**
RC5	5.1	0.7	Clay, Silt	Clay, Silt	Unconfined	Trees, Herbaceous, Grasses	Shallow pooled water but no flow observed, grasses and wetland species observed growing on semi-dry bed, minimal geomorphic activity
RC5-1	4.8	1.0	No riffle-pool development		Unconfined	Trees, Grasses	Straight agricultural ditch with some pools of water, no flow observed, some aquatic vegetation growing within channel
RC5-2	No observations due to poorly defined swale feature						
RC5-1-1	3.9	0.7	No riffle-pool development		Unconfined	Grasses	Straight agricultural ditch with some pools of water, no flow observed, extreme riparian vegetation encroachment
RC5-1-2	2.7	0.5	No riffle-pool development		Unconfined	Grasses	Straight agricultural ditch with some pools of water, no flow observed, extreme riparian vegetation encroachment
RC5-1-3	2.3	1.95	No riffle-pool development		Unconfined	Grasses	Straight agricultural ditch with some pools of water observed. Extreme riparian vegetation encroachment

3.1 Rapid Assessments

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

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health. Due to the absence of flowing water at the time of assessment, the RSAT was not applied.

A summary of RGA and RSAT scores for all the assessed reaches within and downstream the Tewin Development Block are provided in **Tables 3 and 4** below. The observations are supplemented and supported with representative photographs included in **Appendix E**.

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Table 3. Rapid geomorphological assessment results for Bear Brook reaches in Study Area

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
BB5-5A	0.18	In Regime	Widening	27	Good	Physical instream habitat
BB5-5A-2	0.30	In Transition	Widening	20	Fair	Physical instream habitat
BB5-5A-3	0.61	In Adjustment	Degradation	23	Fair	Channel scouring/ Sediment deposition
BB5-5A-3-1	0.41	In Adjustment	Degradation	24	Fair	Channel souring/sediment deposition, Channel stability
BB5-5A-3-1A	0.08	In Regime	Widening	31	Good	Physical instream habitat/riparian habitat conditions
BB5-5A-3-1A-1	N/A feature characterized as swale					
BB5-5A-3A	0.26	In Transition	Widening	23	Fair	Channel scouring/sediment deposition
BB5-5A-3B	0.29	In Transition	Widening	17	Fair	Physical instream habitat
BB5-5A-3B-1	N/A feature characterized as swale					
BB5-5A-3C	0.17	In Regime	Widening	22	Fair	Riparian habitat conditions
BB5-5A-3D	0.20	In Regime	Widening	25	Good	Riparian habitat condition
BB5-5A-3D-1	N/A feature characterized as swale					
BB5-5B	N/A feature characterized as swale					
BB5-5C	0.11	In Regime	Planimetric adjustment	24	Fair	Riparian habitat conditions
BB5-5C-1	N/A feature characterized as swale					
BB5-5C-1A	N/A feature characterized as swale					
BB5-5C-1A-1	N/A feature characterized as swale					
BB5-5C-1A-2	N/A feature characterized as swale					
BB5-5D	0.17	In Regime	Planimetric adjustment	30	Good	Physical instream conditions
BB5-5D-1	N/A feature characterized as swale					
BB7	0.26	In Transition	Widening	25	Good	Channel stability
BB7-1	No observations. Non-participating lands					
BB8	Reach out of Tewin study area boundary but included in mapping					
BB8-1	Reach out of Tewin study area boundary but included in mapping					
BB9	0.31	In Transition	Degradation	17	Fair	Riparian habitat conditions
BB11	0.23	In Transition	Widening	25	Good	Riparian habitat conditions
BB10	0.26	In Transition	Widening	20	Fair	Riparian habitat conditions
BB10-1	0.19	In Regime	Widening	19	Fair	Riparian habitat conditions
BB10-1A	0.23	In Transition	Degradation	27	Good	Riparian habitat conditions
BB10-1B	0.18	In Regime	Aggradation	23	Fair	Riparian habitat conditions
BB12	0.29	In Transition	Widening	21	Fair	Riparian habitat conditions

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
BB13	0.21	In Transition	Widening	25	Good	Riparian habitat conditions
BB14	0.32	In Transition	Widening	23	Fair	Channel stability
BB15	0.19	In Regime	Aggradation	24	Fair	Physical instream habitat/Riparian habitat conditions
BB16	0.29	In Transition	Widening	22	Fair	Channel stability

Table 4. Rapid geomorphological assessment results for Ramsay Creek reaches in Study Area

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
RC4-1-1A	0.12	In Regime	Widening	28	Good	Physical instream habitat/water quality
RC4-1-1A-1A	0.09	In Regime	Widening	25	Good	Physical instream habitat
RC4-1-1A-1	0.09	In Regime	Widening	25	Good	Physical instream habitat
RC4-1-1A-2	0.09	In Regime	Widening	26	Good	Physical instream habitat
RC4-1-1A-3	0.09	In Regime	Widening	25	Good	Physical instream habitat
RC5	0.09	In Regime	Widening	30	Good	Physical instream habitat
RC5-1	0.04	In Regime	Planimetric Adjustment	19	Fair	Physical instream habitat/Riparian habitat conditions
RC5-2	N/A feature characterized as a swale					
RC5-1-1	0.04	In Regime	Planimetric Adjustment	19	Fair	Physical instream habitat/Riparian habitat conditions
RC5-1-2	0.04	In Regime	Planimetric Adjustment	19	Fair	Physical instream habitat/Riparian habitat conditions
RC5-1-3	N/A feature characterized as a swale					

3.2 Detailed Geomorphological Assessment

Following the rapid field assessments, detailed geomorphological assessments were completed on seven reaches within the Tewin Study area and along downstream reaches within both the Bear Brook and Ramsay Creek watersheds. Detailed assessment locations were selected based on those reaches identified as most sensitive to erosion through a review of RGA scores and reach-level observations of current channel conditions.

Detailed assessments were completed on the following reaches: **BB5, BB5-5, BB5-5A-3,** and **BB-6** in October 2021. Additionally, detailed assessments were completed along the most sensitive downstream reaches of Ramsay Creek and Bear Brook at **BB1, RC1** and **RCB** in the summer of 2022 and winter of 2023. The locations of these sites are indicated in **Appendix B.**

For each assessment, the following activities were completed along an approximately 100 m length of the reach:

- Long profile of the channel bed, water level, and bankfull channel extent to determine channel bed and bankfull gradients, as well as water surface slope on the given day
- 8-10 detailed cross-sectional surveys of the channel to document average bankfull channel geometry
- Detailed instream measurements at each cross-section location including bankfull channel geometry, riparian vegetation type and cover conditions, bank material composition and structure, bank height/angle, presence of undercutting, and bank root density
- Bed material sampling at each cross-section location following a modified Wolman's (1954) Pebble Count Technique or substrate sample for laboratory grain size analysis

The detailed assessments' results are summarized below in **Table 5**. Summaries of the detailed assessments are available in **Appendix F**.

Table 5. Average channel parameters for detailed assessment sites

Channel parameter	Reach						
	BB1	BB5	BB5-5	BB5-5A-3	BB6	RC1	RCB
Measured							
Average bankfull channel width (m)	9.63	5.97	4.34	6.22	4.73	6.30	5.85
Average bankfull channel depth (m)	1.22	0.82	0.59	0.37	0.94	0.79	0.80
Bed gradient (%)	0.04	0.09	0.22	0.56	0.23	0.03	0.26
Bankfull gradient (%)	0.03	0.02	0.20	0.47	0.21	0.20	0.27
D_{50} (mm)	<2	<2	<2	7.5	<2	<2	<2
D^{84} (mm)	<2	<2	<2	17	<2	<2	<2
Manning's n roughness coefficient	0.055	0.040	0.040	0.040	0.040	0.045	0.045
Computed							
Bankfull Discharge (m^3/s)*	4.88	3.20	1.99	2.23	2.23	4.87	4.67
Average bankfull velocity (m/s)*	0.42	0.66	0.78	0.97	0.88	1.10	1.00
Bankfull shear stress (N/m^2)	4.79	7.22	11.51	20.39	19.34	13.90	21.23

**Based on Manning's Equation*

4 Erosion Hazard Assessment

4.1 Methodology

River and stream systems are dynamic in nature, changing and evolving due to erosional forces associated with flowing water and local slope composition and structure. Defining an erosion hazard for a given watercourse is useful for determining potential impacts or hazards to proposed activities adjacent to a given watercourse. It should be noted that unconfined and confined valley systems are assessed differently when defining the erosion hazard for a creek system. The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for establishing the erosion hazard in both unconfined and confined systems.

The erosion hazard is delineated as a meander belt width in unconfined systems. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. Unconfined systems are generally found within glaciated plains with flat or gently rolling topography. The meander belt width can be applied in unconfined systems based on 20 times the bankfull channel width. Alternatively, the meander belt width can be determined through a detailed geomorphological study that examines the largest channel meanders observed through historical and recent aerial photograph interpretation. The meander belt width can then be graphically defined using orthorectified aerial imagery by determining the channel centerline and central tendency (i.e., meander belt axis). In cases where the channel is not discernible in aerial photographs or has been substantially modified, empirical models can be used to estimate the meander belt width.

Confined systems are those where the watercourse is contained within a defined valley, where contact between the watercourse and a valley wall is possible. The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for establishing the erosion hazard where watercourses are confined by valley walls. In confined systems, the erosion hazard is based on a combination of a toe erosion allowance and stable slope allowance. This approach defines an appropriate erosion setback or toe erosion allowance from a channel bank where the creek is within 15 m of the toe of the valley slope. A toe erosion allowance can be determined in several ways: use of an average annual recession rate; application of a 15 m toe erosion allowance in areas where the channel is within 15 m of the toe of slope; or use of soil information and field observations of geomorphic processes (MNRF, 2002). The stable slope allowance is determined through a valid geotechnical slope stability study.

It should be noted that South Nation Conservation considers confined systems as those with valley walls equal to or greater than 3 m in height (Ontario Regulation 170/06). Valley wall height can be confirmed through a combination of field observations and a desktop assessment of detailed topographic data. Ultimately, the final erosion hazard in confined systems is based on an appropriate toe erosion allowance (where the channel is within 15 m of the valley toe) and the stable slope allowance, as determined by a valid geotechnical study. Valley confinement and overall erosion hazards for confined systems have been identified by Paterson Group (2024).

4.2 Results

4.2.1 Unconfined Valley Reaches

When limited information is available, meander belt widths can be applied based on 20 times the bankfull channel width. A more detailed approach would include an assessment of the largest channel meanders observed through historical and recent aerial photography. In cases where the channel is not discernible in aerial photographs or the channel has been substantially modified, empirical models are also used to estimate the meander belt width.

A review of recent and historical aerial imagery was completed. Still, it did not indicate the presence of significant meanders along any of the reaches, either due to poor aerial coverage or the frequent presence of historically modified (i.e., straightened) drainage networks. Based on our review through the historical aerial record and our field observations, unconfined reaches within the Study Area are generally small and straightened. As such, measuring meander amplitudes through a formal overlay analysis of historic and recent aerial imagery was not possible. Given the limitations associated with the aerial imagery and existing conditions of the creeks, definition of the erosion hazard for reaches within the Tewin Study Area was based on an empirical modelling approach to determine a range of potential meander belt widths.

The empirical relation from Williams (1986) was applied using average bankfull channel dimensions measured in the field by GEO Morphix to estimate the meander belt width (B_w) for each reach such that:

$$B_w = 4.3{W_b}^{1.12} + W_b \quad \text{[Eq. 1]}$$

where W_b is average bankfull channel width (m). An additional 20 percent factor of safety was also applied.

A meander belt width was also calculated based on the Toronto Region Conservation Authority (TRCA) (2004) empirical model:

$$B_w = -14.827 + 8.319\ln\left(\rho g Q S * DA\right) \quad \text{[Eq. 2]}$$

where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2). The parameters used for the TRCA meander belt width values are provided in **Appendix G**, for reference. It is anticipated that review and refinement of existing meander belt widths may be carried out during future detailed studies, which will include more site-specific hydrological input data.

Note that one standard error was also applied to the TRCA meander belt width calculation. Two standard errors are applied to large channels and where hydrological regime changes are anticipated. In this case, the reaches throughout the Study Area are relatively small, straight, and have shown limited to no change in cross-sectional geometry over the extent of our historical review. It is also anticipated that any future changes in hydrology will be addressed through adequate stormwater management. As such, one standard error is considered appropriate for all reaches.

Results of the empirical modelling exercise and preliminary recommendations for meander belt widths are outlined in **Table 6**. The preliminary meander belt widths are also mapped in **Appendix B**, for reference. The preliminary meander belt widths are provided for informational purposes.

Table 6. Preliminary meander belt widths for unconfined reaches in Study Area

Reach	**TRCA (2004) Meander Belt Width (m)	**Modified Williams Width (1986) Meander Belt Width with Factor of Safety (m)	Preliminary Meander Belt Width Proposed (m)
BB5-5A-3-1A	*	37	37
BB5-5A-3-1A-1	*	35	35
BB5-5A-3B	20	23	48
BB5-5A-3B-1	*	19	19
BB5-5A-3C	20	42	48
BB5-5A-3D	20	48	48
BB5-5A-3D-1	*	17	17
BB5-5C-1	30	62	30
BB5-5C-1A	30	61	30
BB5-5C-1A-1	*	14	14
BB5-5C-1A-2	*	10	10
BB5-5D	*	14	14
BB5-5D-1	*	6	6
BB9	48	48	48
BB10	48	36	48
BB10-1	23	25	25
BB10-1A	*	9	9
BB10-1B	9	11	11
BB11	48	36	48
BB12	48	31	48
BB13	44	35	44
BB14	44	28	44
BB15	42	36	42
BB16	42	30	42
RC5	*	38	38

** Indicates negative values*
*** Includes 20% Buffer/Factor of Safety to account for potential under prediction; or 1 standard error for TRCA*

It should be noted that the TRCA model is largely governed by drainage area and, as such, has difficulty predicting meander belt widths for small, low-order features. This can often result in negative values for the final predicted meander belt width. These values are non-sensical. As such, we recommend applying the meander belt widths determined based on Williams (1986), especially for small, low order streams. The William's equation was developed based on a dataset from natural channels, but it still provides an approach for erosion hazard delineation in modified systems. There is limited channel planform development on these reaches due to previous modifications (i.e., channel straightening), and the bankfull channel size is likely exaggerated because of ditching activities. As such, the meander belt widths are likely conservative based on the exaggerated field bankfull channel geometries. Furthermore, a modified version of the Williams equation has been used, which includes an additional bankfull channel width and additional factor of safety.

Note that meander belt widths are only provided on participating properties within the Tewin Study Area. The meander belt widths are considered preliminary and are subject to refinement following further field and desktop data review/analysis to be undertaken as part of more detailed planning studies. In cases where enhancement or restoration activities are proposed, meander belt widths or erosion hazards would be refined for those features through future design stages.

4.2.2 Confined Valley Reaches

The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for defining an appropriate erosion setback or toe erosion allowance either through use of an average annual recession rate; application of a minimum 15 m toe erosion allowance; or use of soil information and field observations of geomorphic processes (MNRF, Table 3, 2002).

Given the lack of visible channel definition and meanders through aerial photographs, an average annual recession rate could not be determined for confined reaches. A toe erosion allowance was ultimately applied based on field observations of geomorphic processes and local surficial geology, as per the MNRF Table 3 (2002). Results of the desktop assessment and field observations documented by the geotechnical consultant were also considered in the recommendation for toe erosion allowances.

Based on field observations of stiff clays and silts along channel banks and areas of modest, discontinuous erosion, we recommend a toe erosion allowance in the range of 5-8 m for all confined reaches where the channel is within 15 m of the valley slope. This recommendation also considers field observations made by the geotechnical consultant that identify "stiff, brown silty clay, which was underlain by firm, grey silty clay" as the material comprising the majority of slopes along the channels observed (Patterson, 2024). The 5-8 m range is also appropriate given the general stability of the watercourses, with little to no channel adjustment evident in aerial photographs or LiDAR data. Confined reaches where the erosion hazard is addressed by the toe erosion allowance are shown in the mapping provided under **Appendix B**. Note that confined reaches were determined based on a combination of field observations and a review of detailed topographic data for the Study Area (e.g., LiDAR).

Notably, the toe erosion allowance is one component of the erosion hazard delineation required for confined systems where the channel is situated within 15 m of the valley wall (MNRF, 2002). In addition to the toe erosion allowance, a stable slope allowance and erosion access allowance is also required. A slope stability assessment has been completed by Paterson Group and is summarized under separate cover (*Existing Conditions - Geotechnical: Tewin Lands dated September 2024*).

Meander belt widths have been provided for several reaches that were classified as confined by Paterson Group (2024). In these cases, adjacent slopes are close to SNC's 3 m slope height threshold for confinement. The meander belt widths for these reaches are provided for information and for situations where a reach may be found to be partially confined or where the SNC's 3 m height threshold is not met. Given that valley confinement is ultimately a geotechnical slope stability matter, the final erosion hazard extent for confined systems is based on the work completed by Paterson Group (2024).

5 Crossing Assessment

An assessment of existing drainage crossings that overlap with the potential servicing lines was completed in November and December 2022. This preliminary assessment aimed to provide information on potential crossing locations for future servicing infrastructure. Data gathered from this assessment are for information purposes and greater review will be required once the servicing strategy is better understood.

The proposed servicing lines run along specific existing roadways within and adjacent to the Tewin Study Area boundaries; a map of the proposed servicing lines is provided in **Appendix H**. The assessment involved identifying and documenting all crossing structures along the proposed route and observing the drainage ditches and watercourses upstream and downstream of the crossing structures. In total, 36 crossings were identified. Streams cross the proposed route at 16 of the 36 crossings. The other 20 crossings are either roadside ditches or agricultural ditches. Bankfull width and depth, plus any erosion and/or deposition observed near the stream crossings, was documented. A summary of the assessment is provided in **Appendix H.**

6 Summary of Preliminary Opportunities

Based on the information provided in this report, the strategic planning and community design objectives for Tewin, and the commitment to exploring bold and innovative strategies for Tewin, the following section identifies a series of preliminary opportunities for consideration. These preliminary opportunities may help inform the next phase of the integrated master planning and EA process and can be used to frame community design options and technical solutions.

The main activities relating to fluvial geomorphology completed to date include a large-scale characterization of the existing watercourses within the Tewin Lands, detailed geomorphological assessments at erosion-sensitive locations, determination of preliminary meander belt widths and toe erosion setbacks, and a high-level analysis of potential future impacts to Bear Brook downstream of the Study area.

Standard rapid geomorphological assessments (RGA/RSAT) were completed to document the existing conditions and characterize the dominant channel-forming processes of all watercourses within the study area. Through this, preliminary erosion hazard setbacks were delineated, and a baseline inventory of channel conditions and sensitive channel reaches was developed, which can serve, in part, as reference material moving forward. The identified sensitive channel locations were subject to further study by application of detailed geomorphological field assessments. Through this, detailed information relating to channel geometry, gradient, substrate, and bank conditions was obtained. This information will serve as a basis for the determination of erosion thresholds and erosion mitigation criteria for future stormwater management planning. The desktop-based analyses (**Appendix A**) provide high-level inference regarding potential impacts to the downstream channel and proximal infrastructure as a consequence of the proposed Tewin Study Area. This information, in part, can inform appropriate mitigation strategies.

Field characterizations indicate that the watercourse features within the Tewin Lands are generally degraded, largely from past and present agricultural activities. Many channel corridors have been evidently straightened, leading to the re-development of sinuous low-flow channels within the corridor and causing significant bank erosion. Riparian conditions across many of the major channels are often compromised, reducing stability and erosion resistance within the channel banks. Bed substrate is predominantly sand with observations of clay and silt also commonly noted throughout the study area, indicating potential excess sedimentation due to agricultural activities, as well as generally sensitive channel conditions.

Considering the aforementioned field characterizations, there exist many potential opportunities to improve existing channel conditions through future mitigation and enhancement activities. Opportunities generally relate to improving long-term channel stability, water quality, and overall stream health, as many watercourses within the study area are evidently degraded and negatively impacted by prior modification. Potential opportunities relating to fluvial geomorphology within and downstream of the Tewin Lands include, but are not limited to the following:

- Localized erosion mitigation and stabilization works within existing channels can address existing erosion issues
- Potential realignment of certain watercourse features following natural channel design can accommodate modifications to hydrological regimes in an appropriate manner
- Enhancements can be made to existing channel corridors to help reconnect watercourse features with the surrounding floodplain, and subsequently improve floodplain conditions
- Determination and field-validation of erosion thresholds at erosion-sensitive watercourse reaches, and the application of continuous hydrological and long-term erosion models can determine appropriate erosion mitigation criteria for stormwater management facilities
- Improvements to water quality and stream health can be achieved through stormwater management facility and outfall designs, including local landscape restoration plans
- General reference to this existing conditions report can assist in facilitating future related studies, and in providing a baseline characterization from which to ensure the integrity of the watercourses within and downstream of the Tewin Lands is maintained or improved upon following any hydrological modification

7 Conclusion

The aim of this existing conditions report was to synthesize all geomorphological observations collected to date for the tributaries of Bear Brook and Ramsay Creek within the Tewin Study Area in the City of Ottawa, Ontario.

Various fluvial geomorphic assessments have been completed to date to characterize the existing conditions of the watercourse and drainage features. This included a detailed desktop review of available geology, topography, and drainage area characteristics, watercourse reach delineation, rapid and detailed geomorphological assessments, as well as a preliminary erosion hazard assessment in support of constraint delineation. In addition to the existing conditions characterization, a desktop-based geomorphological inventory and assessment (**Appendix A**) was also completed.

Preliminary opportunities for watercourse-related enhancements have been explored based on the existing conditions characterizations. This information provides a baseline reference geomorphological characterization that will, in part, support future environmental and related studies for the Tewin Study Area.

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

Respectfully submitted,

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Appendix A
Desktop Geomorphological Assessment of Bear Brook

Bear Brook Desktop Geomorphological Inventory and Assessment

Highway 417 to South Nation River

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Submitted:
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GEO Morphix Project No. 22024

Ver.	Purpose/Change	Authored by	Approved by	Date
1.0		K. Woodrow	P. Villard	2023-06-30
1.1	Updated reference date for JFSA study (2024)	K. Woodrow	P. Villard	2024-09-18

Disclaimer

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1 Introduction

This report provides a summary of the desktop-based geomorphological inventory and assessment conducted by GEO Morphix Ltd. (GEO Morphix) along Bear Brook, downstream of the Tewin Lands. The main Tewin Lands Study Area is located in southeast Ottawa, generally bordered by Leitrim Road to the north, Farmers Way to the east, Thunder Road to the south, and Anderson Road and Ramsayville Road to the west. The main Tewin Lands Study Area is outlined in **Figure 1** below.

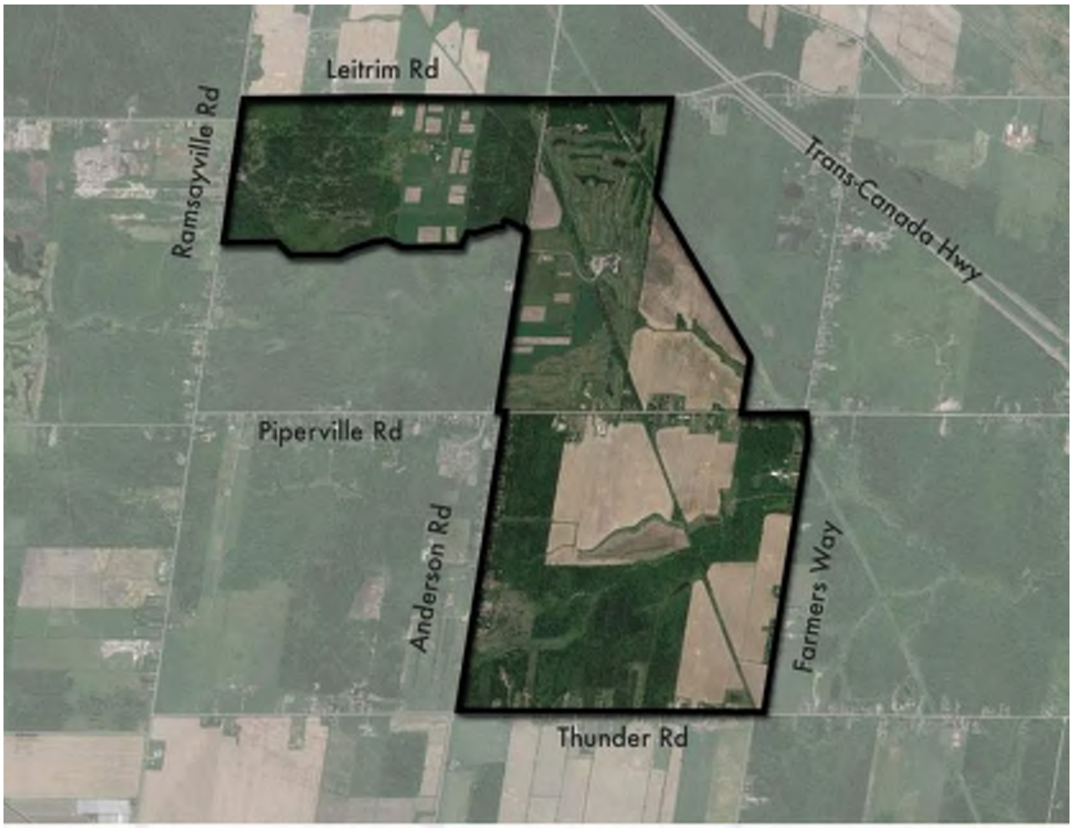

Figure 1. The Tewin Study Area is identified in black outline

Bear Brook, which drains a significant portion of the Tewin Lands, is a tributary of the South Nation River and drains a total area of approximately 490 km^2 on the east side of the City of Ottawa. The study area associated with the desktop and hydrologic assessments extends along the main channel from Highway 417 to its confluence with South Nation River. A map of the desktop geomorphological inventory and assessment study area is provided in **Appendix A.1**. GEO Morphix would like to highlight that the purpose of the desktop geomorphological assessment is not to encourage intervention at any identified Point of Interest. Rather, the purpose of these assessments was to document existing conditions and the extent of potential future concerns along the Bear Brook main channel as areas within its headwaters undergo land use changes. Ultimately, the content of the geomorphological inventory will help contextualize and facilitate future studies upstream, as well as help inform the potential requirement for localized downstream erosion mitigation measures, where necessary.

The assessments described in this report examined characteristics in a hierarchical, nested approach in terms of spatial scale. The Bear Brook watershed was assessed at the watershed/sub-watershed scale, then reach scale, then sub-reach and geomorphic unit scale. The following are the tasks completed for analysis:

- Review of watershed characteristics (e.g., surficial geology, topography, land cover/use);
- Division of the main channel through the study area into "valley segments";

- Historical aerial imagery analysis to identify historical geomorphological and anthropogenic changes along the channel and channel corridor;
- An inventory of Points of Interest observed in the aerial imagery at which the Bear Brook main channel may have higher sensitivity to proposed future land use changes;
- Cumulative hydrologic impact assessment of Bear Brook and select tributaries for multiple hydrological scenarios and storm conditions (JFSA, 2024).

The following sections expand upon and provide context for these tasks. The results are presented in tabular format in the appropriate sections below, and supporting maps and other materials are provided in the appendices.

2 Background

2.1 Study Context and Objectives

The Desktop geomorphological assessment examined approximately 40 kilometers of the Bear Brook main channel downstream of the Tewin Lands. The study area extends along the main channel from Highway 417 to its confluence with South Nation River. A map of the study area is provided in **Appendix A.1**. The purpose of this analysis was to observe the Bear Brook main channel to document existing geomorphological conditions and locations that may be more sensitive to changes in the watershed where potential future concerns are most likely to arise within the channel corridor and riparian area. These locations, referred to as "Points of Interest", include locations where notable geomorphological activity, adjacent infrastructure, and past river modifications were observed in historic and contemporary aerial imagery of the study area.

Channel morphology and planform are largely governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within a stream corridor. Physiography, topography, riparian vegetation, and land use also physically influence the channel. These factors provide insight into existing conditions and sensitivity to potential land use changes. The sensitivity of watercourse features, from a geomorphological perspective, is a function of driving and resisting forces and the controls that influence these forces. Driving forces are a product of drainage area, discharge, and slope (including channel and valley gradient). Resisting forces are a product of physiography and surficial geology (including parent materials and substrate). It is important to note that modifications to driving and resisting forces also impact channel sensitivity. These modifications may include riparian vegetation and historical modifications to channel form and function.

Conducting this analysis as a desktop exercise allowed a nested approach with observations at multiple spatial scales at which watershed/sub-watershed characteristics, reaches (i.e., "valley segments"), sub-reaches/geomorphic units, and Points of Interest were observable. This was done with the intent of identifying potential future concerns. The results from this desktop geomorphological assessment could be used to inform future, smaller scale analyses within the study area if they are warranted. We note that this assessment was completed solely as a desktop exercise using the highest resolution aerial imagery we could obtain, and that no associated fieldwork has been completed to verify results.

2.2 Study Extent

In terms of identifying an appropriate geographical extent of analysis for determining potential geomorphological impacts from changes to hydrology, the Toronto and Region Conservation Authority (TRCA) suggests that the limit of significant downstream impacts is associated with the capacity of the downstream watercourse to assimilate changes in hydrology (TRCA, 2012). Further, smaller streams and smaller drainage areas have less assimilation capacity are more sensitive than larger streams and drainage areas. This is due to the size of the features. The simplest method of identifying the potential capacity of a watercourse to assimilate changes in hydrology is to assess the relative scales of modified drainage area to the receiving watercourse's drainage area, or compare 2-year flows (TRCA, 2012). Specific to the relationship between drainage area and impact of land use changes, the Credit Valley Conservation Authority (CVC) recommends that calculations for downstream impact assessment must be provided up to a downstream confluence point, or by assessing the impact of land use changes downstream to a point where the area of land use changes is 10% of the total drainage area (CVC, 2012). The extent of the study area for the Desktop geomorphological assessment was determined considering the above information. Thus, the study area extends from the headwaters to the confluence between Bear Brook and South Nation River. Upstream of this confluence along Bear Brook, approximately 3% of the total drainage area is associated with the Tewin Study Area. As such, the study area sufficiently captures the extent of the potential geomorphological impacts associated with future changes to hydrology.

3 Geomorphological Assessment Methods

3.1 Watershed Characteristics

To inform and provide context to the assessment, watershed characteristics were observed through a GIS mapping and spatial data review exercise. Watershed and sub-watershed boundaries (JFSA, 2024) were mapped along with the Bear Brook main channel and tributaries. Physiography, surficial geology, and topography layers were mapped as well to examine the relative changes in these characteristics along the main channel corridor. A map showing the course of the main channel and the surficial geology underlying it is provided in **Appendix A.3**. Aerial imagery was also analyzed to identify land use/cover.

Data reviewed as part of this analysis include the following:

- Surficial Geology – Ministry of Northern Development and Mines (2010);
- Physiography of Southern Ontario – Chapman and Putnam (1984);
- Watersheds Minor – City of Ottawa (2021);
- Sub-watersheds – City of Ottawa (2021);
- Ottawa High Resolution Digital Elevation Model – Natural Resources Canada (2020).

3.2 Historical Aerial Image Analysis

Aerial imagery from readily available sources was examined to determine the extent of historical changes within the channel and its corridor due to anthropogenic and natural influences. The aerial imagery was also used in dividing the main channel into valley segments and identifying points of interest. Open source basemap imagery is available through the City of Ottawa open data website, which includes years 1965, 1976, 1991, 1999, 2005, 2010, 2011, 2014, 2015, 2017, and 2019. Each year was examined to determine qualitative historical channel adjustment and past modifications. At this time, channel migration rates were not explicitly calculated to quantitatively assess historical channel adjustment. Orthorectified imagery from the years 1965, 1976, and 2018 was used as the base imagery for maps presented in the appendices. Aerial imagery from the City of Ottawa occasionally did not extend to the downstream sections of Bear Brook, given its distance from the Ottawa city center. Where City of Ottawa datasets were unavailable, ArcGIS basemap imagery (2019), Google Earth, and other open-source aerial images were used to supplement City of Ottawa datasets.

3.3 Valley Segment Delineation

Characteristics of the main channel and adjacent landscape through the study area were observed throughout the review of watershed characteristics and historical aerial imagery analysis. The main channel was subsequently divided into “valley segments” based on observations made throughout those respective analyses. Valley segments are similar to reach breaks, which are sections of homogenous channel dominated by similar geomorphological qualities and processes, such as channel planform, gradient, physiography, and land cover. However, valley segments differ from reaches in that they are typically longer and have more flexibility in geomorphological qualities. The main features used to define valley segments in this desktop analysis are historical processes, underlying geology, channel form, anthropogenic channel modifications, surrounding land use, and riparian cover. For example, a break between valley segments was delineated at a location corresponding with a marked change in channel planform from relatively low-amplitude meanders to high-amplitude, tortuous meanders.

3.4 Context of Hydrological Inputs

The results of the Cumulative Hydrologic Impact Assessment (JFSA, 2024) were reviewed to inform anticipated geomorphological impacts along Bear Brook. The purpose of the cumulative hydrological impact review was to characterize the capacity of Bear Brook assimilate changes in hydrology associated with land-use changes within the Tewin Study Area, ultimately providing additional context to the overall geomorphological assessment. A total of six (6) hydrological scenarios produced by JFSA (2024) were reviewed for the assessment. Q_2 flows and contributing drainage areas were analyzed across the scenarios at six (6) different model nodes along Bear Brook and other tributaries, downstream of the Tewin Lands. Cross-scenario comparison of contributing flows at each node location allowed for inference regarding high-level hydrological (and consequently, potential geomorphological) impacts and the mitigating effects of SWM controls.

3.5 Point of Interest Inventory

Points of Interest (POIs) are locations at the sub-reach or geomorphic unit scale where the Bear Brook main channel may have higher sensitivity to future land use changes upstream due to historical human modification or ongoing geomorphological adjustments, for example. POIs were identified using aerial imagery available from the City of Ottawa. POIs observed in the imagery were assigned a category: Geomorphological Feature, Infrastructure, and Past Alterations (described below). A subcategory was assigned to each POI as well to provide a greater level of detail in the results. **Table 1** contains descriptions of each subcategory.

Geomorphological Features: Areas with aerial image evidence of channel adjustment.

Infrastructure: Areas of infrastructure adjacent to the channel, within approximately 20 m.

Past Alteration: Areas which, through historical imagery analysis, show signs of previous alterations by anthropogenic influences within the channel.

Table 1: Subcategories for Points of Interest

Geomorphological Features	
Subcategory	**Outside Meander Bend:** A meander bend which exhibits signs of active erosion greater than a typical meander bend.
	Point Bar: Areas with point bar formation, visible in aerial images. Notable especially if the point bar is in areas where point bars are not typical (i.e. outside meander bend)
	Widening: Areas where the bank is showing signs of active erosion, such as gullies or rills. Or historical photograph analysis shows clear signs of channel widening.
	Large Woody Debris: Woody debris or leaning trees.
	Planimetric Adjustment: Any signs visible in the aerial image which could indicate that the creek is adjusting planimetrically. Examples include remnant channels, cutoff channels, medial bars, islands, or multi-channel formation.
	Uncharacterized Channel Adjustment: Creek adjustment is occurring and visible in aerial imagery, but the type is undefinable.
	Saturated Conditions/Impoundment: Saturated/impounded areas that affect the stream, such as backwatering or vegetation encroachment.*
	Aggradation: Evidence of aggradation such as sediment lobes, sandy streaks, or point bar accretion.
Infrastructure	
Subcategory	**Property:** Locations where noticeable private or public property is adjacent to a location of possible increased erosion due to the channel. Distance to the channel is measured from nearest adjacent buildings or fence.
	Road: Any location where a road either crosses the creek or is adjacent to an area of possible increased erosion due to the channel.
	Pedestrian Bridge: Locations of pedestrian bridge crossings across the channel.
Past Alterations	
Subcategory	**Weirs or Dams:** Based on aerial image analysis, locations of possible weirs or dams. Status is unknown until structures can be verified in field.
	Straightening: Based on historical aerial images analysis available, locations of possible historical creek straightening.
	Bank Protection: Any locations of bank protection visible in aerial images. From the desktop analysis, a majority of treatments appear to be rip-rap.

* Not in technical sense; not evaluated.

4 Geomorphological Assessment Results

4.1 Watershed Characteristics and Historical Aerial Imagery Analysis

Bear Brook flows through a range of physiographic units and glacial and alluvial surficial geology deposits within the study area. A map showing the course of the main channel, the valley segments delineated for this assessment (denoted below in brackets as 'dBB#'), and the underlying surficial geology is provided in **Appendix A.3**. Upstream of the Highway 417 crossing (dBB1), the physiography varies between sand plains, till plains, and clay plains. Within the farthest upstream headwaters area streamflow is almost entirely through straightened and widened channels. The underlying surficial geology in this area is fine- to medium-grain sands that are glaciofluvial and glaciomarine in origin (surficial geology unit 11c). These materials are non-cohesive and more susceptible to erosion than cohesive materials (i.e., clays/till).

There is a distinct change in surficial geology as the headwaters approach Hwy 417; this area is underlain by silt and clay glaciomarine deposits (unit 10a). This surficial geology unit underlies the largest proportion of the main channel throughout the study area. The relatively straight, single-thread channels in this section flow through well-defined floodplains. Downstream of this, as Bear Brook approaches its crossing with Hwy 417, stream channels with irregular and partially confined meanders traverse deltaic deposits of medium- to fine-grain sand (unit 11a). Node J32 is located in this area. Downstream of the Hwy 417 crossing, the surficial geology once again transitions to the glaciomarine clay deposits (unit 10a), and the trajectory of Bear Brook switches from northwest to easterly immediately downstream of the railway crossing south of Russell Road.

Downstream of the Hwy 417 crossing, the physiography is entirely clay plains, expect for one short section of kame moraine, comprised of sand and gravel. In the vicinity of Boundary Road (dBB2), the channel flows for several hundred meters across sand deposits associated with abandoned floodplain sediments (unit 12). Downstream of this point (dBB3), and until the Frank Kenny Road crossing, the stream flows almost entirely in a channel that has incised into the clay glaciomarine deposits described above (unit 10a). Node MK_DN5 is located in this area. Between Frank Kenny Road and Dunning Road (dBB4-dBB5), Bear Brook alternates between flowing through a compact sandy and silty glacial deposit (unit 5b) and the clay glaciomarine deposit (unit 10a). Node J23 is located near Frank Kenny Road in this section. The channel briefly flows through coarser, poorly sorted sand to boulder sized deposits that are glaciofluvial in origin (unit 7) in the vicinity of the Dunning Road crossing (dBB5).

Downstream of the Dunning Road crossing (dBB5-dBB6) it flows through the compact sandy and silty deposit (unit 5b) until just upstream of its crossing with Russell Road in the vicinity of the intersection with Saumure Road (dBB7-dBB8), at which point the underlying surficial geology returns to the clay glaciomarine deposits (unit 10a). Node J13 is located in this area. Between Indian Creek Road and Drouin Road (dBB9), a short section of Bear Brook flows through sand deposits associated with abandoned floodplain sediments again (unit 12). The watercourse flows through the clay glaciomarine deposits (unit 10a) (dBB10) again until the Bouvier Road crossing. Node J9 is located in this area. Here the surficial geology becomes dominated by modern alluvial deposits (unit 19) and the meander amplitudes progressively increase as Bear Brook approaches its confluence with the South Nation River (dBB11-dBB12). Node Sink-1 is located in this final section in valley segment dBB11.

The area surrounding Bear Brook is dominated by agricultural land uses with some residential properties as well. Bear Brook appears to have been straightened for a majority of the length examined, likely to accommodate agriculture. Most of the work occurred prior to 1965, which is the earliest imagery date examined. Prior to historical straightening, Bear Brook was sinuous with compound meandering form, oxbow lakes, wetlands, and a wide floodplain, as evidenced by channel remnants and geomorphological scars visible in the imagery. Contemporary Bear Brook is a straightened, single channel with narrow riparian zones and limited wetlands. Aerial photographs in 1965 indicate the land use was primarily agricultural with extremely limited riparian cover. In aerial imagery from 1976, areas of previously tilled agriculture begin to ‘naturalize’, as riparian cover appears to increase and more wetlands are apparent compared to the 1965 imagery. There is limited evidence of bank protection structures, although in-field verification would be required to confirm this.

4.2 Valley Segment Delineation

The Bear Brook main channel through the study area was divided into 12 valley segments to facilitate more detailed observations within localized geomorphological context. Valley segments are labelled sequentially from upstream to downstream. A map of the valley segments is provided along with the study area map in **Appendix A.1**. Descriptions of valley segments are provided below in **Table 2**. The extent of historical aerial imagery examined is provided in **Appendix A.4**.

Table 2: Valley Segment Descriptions

Name	Description
dBB1	dBB1 is sinuous and the location where the watercourse changes direction from flowing generally north to flowing generally east is within this segment, which is perhaps part of an original compound meander. There is evidence of older, more sinuous channels in the aerial imagery such as meander scars along this segment. Land use has varied greatly throughout the years, from open field, forest, wetland, and hedge row. The railway and Russell Road area constrain the movement of the creek here. There is also a property occupied by a lumber operation north of Russell Road and east of Spring Street just upstream of the segment break between dBB1 and dBB2. Based on aerial photographs, the site was constructed between the years 2005 and 2017 and owners have artificially adjusted the creek, creating a cutoff channel to straighten the channel away from their buildings. A vehicle crossing over the watercourse was constructed on this property between 2008 and 2011 to expand the area of operation.
dBB2	The valley segment dBB2 is a single channel section of Bear Brook, straightened prior to 1965 to accommodate agriculture and the Boundary Road crossing. Between the years 1965 and 2019, the land surrounding the creek was permitted to naturalize. Today, it appears as shrubby wetland with grassy vegetation encroachment into the channel. Pockets of agriculture still exist along the south bank, but tilling is not as extensive as in 1965.
dBB3	dBB3 is the longest valley segment delineated and is defined by its form and agricultural field land cover throughout the years. The confluence with McKinnons Creek is within this segment. The creek is straight throughout this segment with occasional meanders. There is little riparian cover through this segment, with tilled agriculture along most of the channel. Based on aerial imagery analysis, these conditions have remained the same since at least 1965. There is a fragmented forest stand near Milton Road and this area could be considered its own segment in a more localized assessment. Downstream of Milton Road, a remnant bed is visible in aerial imagery. However, the remnant bed must have formed before 1965, as there has been no change in the channel form between the years 1965 and 2019. Location iv for the drainage characterization is within this segment.
dBB4	The riparian zone of dBB4 is agricultural land cover with little riparian cover. The valley segment dBB4 differs from other segments with its more sinuous form. There are signs the creek has been straightened downstream of Rockdale Road. Evidence of its previously sinuous channel form can be seen in the remnant bed, which is situated in a small pocket of 'naturalized' forest. This remnant channel bed is visible in aerial imagery prior to 2011. The confluence with Shaw Creek and location v for the drainage characterization are within this segment.
dBB5	The valley segment dBB5 is defined by a heterogenous land cover and channel forms. A mix of private property, agricultural fields, and a golf course comprise the land use. The riparian cover varies between lawns and tilled agriculture. The planform is single channel with high amplitude meanders that flow into a golf course.
dBB6	There is abundant evidence of previous straightening by human influence within the valley segment dBB6. In aerial images as recent as 1976, dBB6 is multi-channel, with islands, and oxbow wetlands. There is historical evidence of a large tributary discharging into this segment, which is not visible in modern aerial imagery.
dBB7	Unlike other sections of Bear Brook, the valley segment dBB7 is highly sinuous and does not show signs of historical straightening. The meander of greatest amplitude along dBB7 is highly active with evidence of bank degradation, point bars, and compound meander formation. Widening, rills, and gullies can be seen in the aerial imagery, even along the inner bank of the meander bend. Other dynamic geomorphological processes such as backwatering and wetland formation is visible in aerial imagery from 2019.
dBB8	The valley segment dBB8 is a long and homogenous section of creek with forested riparian cover and single channel form. The current riparian cover is modern, as it is only visible in imagery after 1976. There is planimetric adjustment in the valley segment dBB8 evidenced by an island forming in the upstream sections.
dBB9	Valley segment dBB9 is single channel with meandering form. The meander amplitude in this segment is larger than dBB8 and is dominated by different geomorphological processes; there is no evidence of planimetric adjustment such as island formation in the aerial imagery. The riparian cover of this valley segment is forest and there is little evidence of historical straightening. The meanders are asymmetrical in shape and are unique to this segment. South Indian Creek discharges into Bear Brook within this segment.

Name	Description
dBB10	The valley segment dBB10 is a single channel with straightened form. There are several confluences with tributaries within this segment. There is more limited aerial imagery available this distant from the Ottawa City center, so only modern coverage was available. his segment is homogenous with forested riparian cover. The surficial geology of dBB10 is classified as modern floodplain alluvial deposits, unlike any other segment upstream. This indicates Bear Brook was once large enough within this segment to form a floodplain and deposit enough sediment to influence surficial deposits.
dBB11	The valley segment dBB11 is sinuous with single channel form. The surficial geology is also modern alluvial sediment, and the riparian cover is dominated by forest. Major land use remains agriculture. Schnupp Road constrains any lateral movement of the meander in the downstream section. North Indian Creek discharges into Bear Brook within this segment.
dBB12	The most recognizable valley segment, dBB12, is distinct in its meandering form. This segment is highly sinuous and forms the most downstream section of Bear Brook before its confluence with South Nation River. An oxbow feature can be observed in modern aerial imagery. Also unique to dBB12, Ettyville Road and Boileau Road were built to mirror the curves of the channel, but now possibly restrict and limit the movement of adjacent meanders.

4.3 Cumulative Hydrologic Impact Review

The Cumulative Hydrologic Impact Assessment (JFSA, 2024) assessed the potential discharge contributions of different subcatchments within the Bear Brook watershed for multiple hydrological scenarios and storm conditions. The study area extends from just upstream of Hwy 417 to a few kilometers upstream of the confluence with the South Nation River near the town of Bourget.

Flow and drainage area information was extracted at six (6) hydrological model nodes. A map of the node locations within the study area is provided in **Appendix A.2** and a description of the node locations and their respective drainage areas is provided below in **Table 4**. Of particular significance, Node J32 resides near the downstream extent of Bear Brook within the Tewin Study Area, and consequently best captures the drainage contributions from within. We note that Node J32 has a drainage area of 49.98 km^2, of which, no more than 14.2 km^2 are attributable to the Tewin Study Area. As such, the results stated in this review are conservative with regards to the actual drainage contributions from the Tewin Lands.

Table 3: Node Locations and Drainage Areas (JFSA, 2024)

Location*	Node	Upstream Drainage Area (km^2)	J32 Proportion of Downstream Drainage Areas
On Bear Brook south (upstream) of Hwy 417 adjacent to Hall Road (upstream of dBB1)	J32	49.98	1.00
On McKinnons Creek east of Mer Bleue near the confluence with Bear Brook (dBB3)	MK_DNS	33.61	1.49
On Bear Brook adjacent to Frank Kenny Road (dBB3)	J23	175.88	0.28
On Bear Brook east of Ruissellet Road (dBB7)	J13	232.74	0.21
On Bear Brook east of Drouin Road (dBB10)	J6	372.39	0.13
Near Champlain Road on Bear Brook main channel (dBB11)	Sink-1	447.20	0.11

*The respective Valley Segment where each flow node is located is indicated in brackets

The HEC-HMS software, developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE) was employed by JFSA to provide drainage area and discharge estimates for six nodes within the watershed: one along a channel within a subcatchments to Bear Brook and five along the main channel of Bear Brook. The HEC-HMS model prepared by JFSA is based a HEC-HMS originally prepared by South Nation Conservation (SNC) in the scope of the Bear Brook and Tributaries Flood

Hazard Mapping Report (2022). Sub-catchment boundaries and hydrologic parameters (e.g., proposed imperviousness) of the original SNC model were revised for the purposes of this assessment to capture the respective contributions and alterations of proposed land-use scenarios. The design storm volume used for JFSA revised HEC-HMS (48.47 mm 2-year 24-hour SCS) was derived from the IDF curves in the City of Ottawa Storm Sewer Design Guidelines.

A total of six (6) scenarios, based on the SNC "summer" hydrologic model, were assessed and modelled in HEC-HMS. Negligible differences noted for a number of scenarios, and as such, only the Existing Conditions (Scenario 1), Uncontrolled (Scenario 2) and Controlled (Scenario 3) scenarios are presented. The Uncontrolled scenario reflects urbanized or high-runoff conditions without SWM controls in the sub-catchment where Tewin Lands are located, whereas the Controlled scenario reflects urbanized/high-runoff conditions with SWM controls implemented.

Summarized results from the Cumulative Hydrological Impact Assessment conducted by JFSA (2024) are provided below. The Q_2 discharge metric refers to the flood discharge with a theoretical return period of two years (i.e., exceedance probability of 50% in any given year) and is shown in **Table 5**. In a geomorphological context, the Q_2 flood discharge estimate provides a reasonable approximation of the bankfull discharge in alluvial stream channels. The Q_2 fractions are also presented in **Table 5** and show the relative proportion of Q_2 flows originating from sub-catchment area J32 (i.e. at the downstream extent of the Tewin Lands) at each sub-catchment area downstream along Bear Brook, until the terminal Sink-1 node.

Table 4: Modelled 2-Year 24-Hour SCS Peak Flows (JFSA, 2024) and Estimated J32 Sub-Catchment Q2 Fractions

Node	Existing Conditions		Uncontrolled Scenario		Controlled Scenario	
	Q_2 Flow (m^3/s)	Q_2 Fraction	Q_2 Flow (m^3/s)	Q_2 Fraction	Q_2 Flow (m^3/s)	Q_2 Fraction
J32	3.7	1.00	7.3	1.00	3.58	1.00
MK_DNS	18.4	0.20	18.40	0.40	18.38	0.19
J23	28.9	0.13	33.00	0.22	28.70	0.12
J13	43.2	0.09	46.50	0.16	42.65	0.08
J6	53.6	0.07	56.20	0.13	52.77	0.07
Sink-1	62.5	0.06	64.90	0.11	61.63	0.06

The net discharge outputs from the sub-catchment represented by node J32 are estimated to range between 3.52 to 3.90 m^3/s for all scenarios besides the Uncontrolled Scenario, which has an estimated Q_2 output of 7.30 m^3/s. In the Existing Conditions and Controlled scenarios, the Q_2 contribution fraction of node J32 drops below 13% upon reaching node J23, approximately 13 km downstream. In the uncontrolled scenario, the Q_2 fraction at J23 is 22%. Q_2 fractions continue to decrease moving downstream. Flow contributions associated with node J32 in the Controlled and Existing Conditions scenarios account for approximately 6% of the discharge at the Sink-1 Node, which captures most of the Bear Brook watershed. The Uncontrolled Scenario estimate accounts for approximately 11% of the discharge at the Sink-1 node.

Overall, the results show that the proportion of urban flows originating from the Tewin Lands represent a small fraction of the total flows within the downstream sections Bear Brook relative to the respective drainage areas. For instance, node J32 only accounts for 6% of the Q_2 flows at node Sink-1, despite occupying approximately 11% of the Sink-1 drainage area. This suggests that with appropriate SWM controls, the urban flows from the Tewin Lands are not expected to adversely affect the downstream sections of Bear Brook, and in particular, the points of interest identified in Section 1. We note that these results are conservative given the fact that Node J32 captures drainage from additional lands, external to the Tewin Lands and Subject Area. As such, Q_2 fractions at Sink-1 that are purely associated with the Tewin Lands are likely to range from 0.02 – 0.04.

4.4 Point of Interest Inventory

An inventory of points of interest was compiled through this preliminary desktop analysis, including geomorphological features, infrastructure, and past alterations along Bear Brook. A total of 117 locations of interest were found. A breakdown of POIs into the categories and subcategories is presented in **Table 3**.

Table 5: Point of Interest Inventory Breakdown

Geomorphological Features			
Subcategory	Outside Meander Bend	3	**Total:** 54
	Point Bar	5	
	Widening	9	
	Large Woody Debris	21	
	Planimetric Adjustment	6	
	Uncharacterized Channel Adjustment	2	
	Saturated Conditions/Impoundment	4	
	Aggradation	4	
Infrastructure			
Subcategory	Property	15	**Total:** 52
	Road	29	
	Pedestrian Bridge	8	
Past Alterations			
Subcategory	Weir or Dam	3	**Total:** 11
	Straightening	6	
	Bank Protection	2	

The most common geomorphological feature observed was large woody debris, which is typically associated with channel widening processes. Point bars, channel widening processes, and planimetric adjustment processes were observed in relatively moderate frequencies, indicating some level of ongoing channel adjustment along Bear Brook. Road crossings and channel encroachment in proximity to roads was commonly observed throughout the study extent. Encroachment onto properties was also frequently observed. In total, infrastructure-related points of interest were most common, indicating locations that are sensitive to changes in hydrology and may consequently requires some level of mitigation activities to address the associated risks. Past alterations were typically associated with agricultural activities, such as channel straightening. Several weirs and dams, and occasional bank protection measures were identified within the study extent.

Detailed maps of the locations of all points of interest are provided in **Appendix A.5**. Accompanying descriptions of each POI are provided within **Appendix A.5** as well. This inventory is to inform decision making with regards to requirements for future studies, and provide a baseline characterization of Bear

Brook from which to facilitate potential mitigation activities associated with changes to the hydrological regime.

5 Conclusion

GEO Morphix conducted a desktop-based geomorphological inventory and assessment along Bear Brook on the east side of the City of Ottawa, summarized herein. Results from the Cumulative Hydrological Impact Assessment completed by JFSA (2024) were summarized to provide context and further exemplify the relatively minor (from a geomorphological perspective) drainage contributions from the Tewin Lands. The purpose of this desktop analysis was to document existing conditions and the extent of potential future concerns along the Bear Brook main channel as areas within its headwaters undergo land use changes. Existing geomorphological conditions are documented through the review of watershed characteristics, the historical aerial image analysis, and valley segment delineation. The Points of Interest inventory documents the extent of potential future concerns along Bear Brook. GEO Morphix does not encourage intervention at any identified Points of Interest. Rather, the outcome of this desktop analysis is intended as documentation for areas of potential concern that may be identified by other stakeholders. This inventory, in part, will serve to facilitate future land use changes in the Tewin Subject Lands upstream.

We trust this memo meets your current requirements. Should you have any questions, please contact us.

Respectfully submitted,

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

Kat Woodrow, M.Sc.
Manager of Watershed Studies

6 References

Chapman, L.J., and Putnam, D.F. (1984). Physiography of Southern Ontario; Ontario Geological Survey, Map P.2715. Scale 1:600 000.

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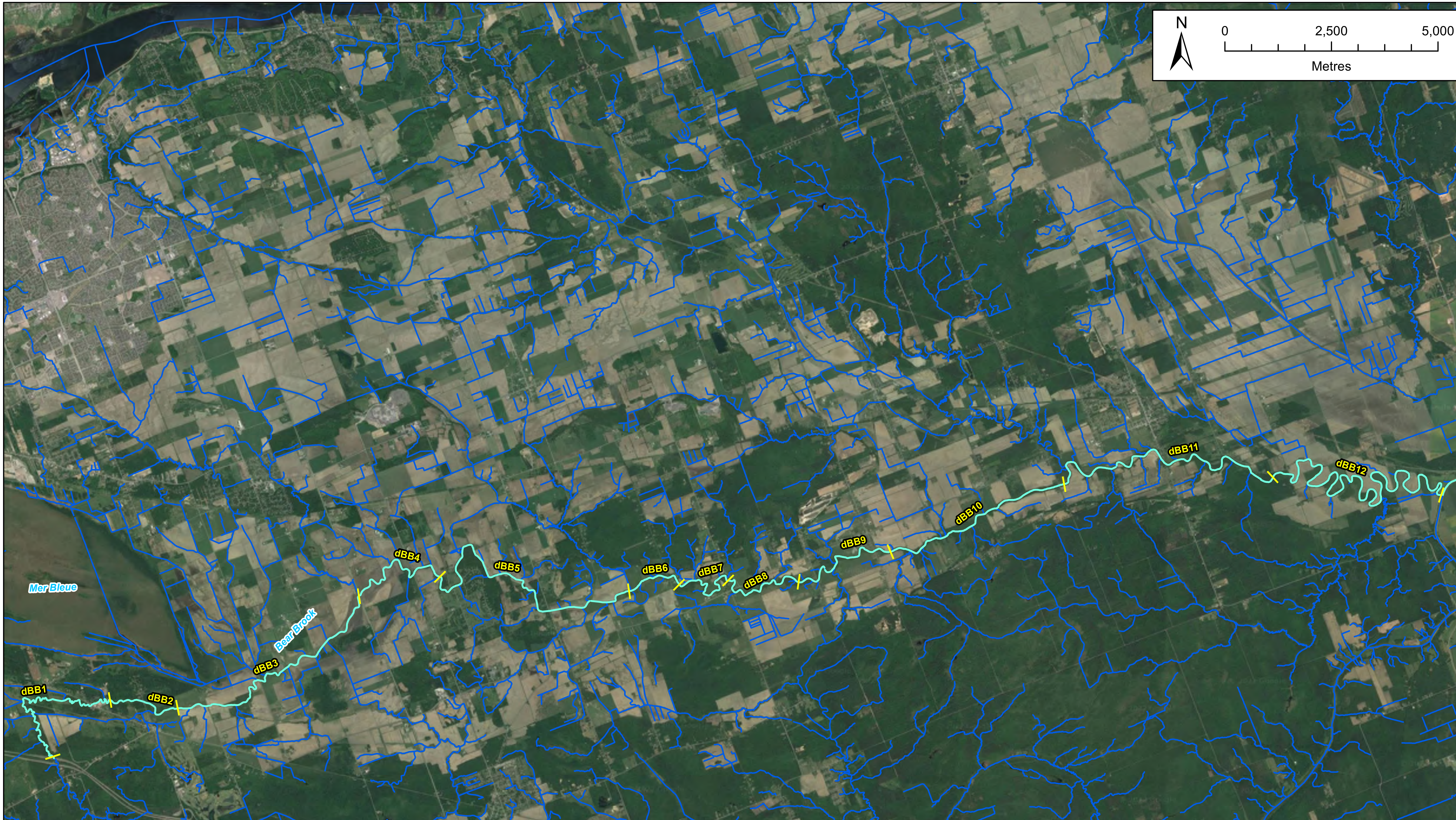
Toronto and Region Conservation Authority (TRCA). 2012. Stormwater Management Criteria.

Appendix A.1:
Study Area Mapping



Legend

- Valley Segment Delineation
- Main Branches
- Watercourse

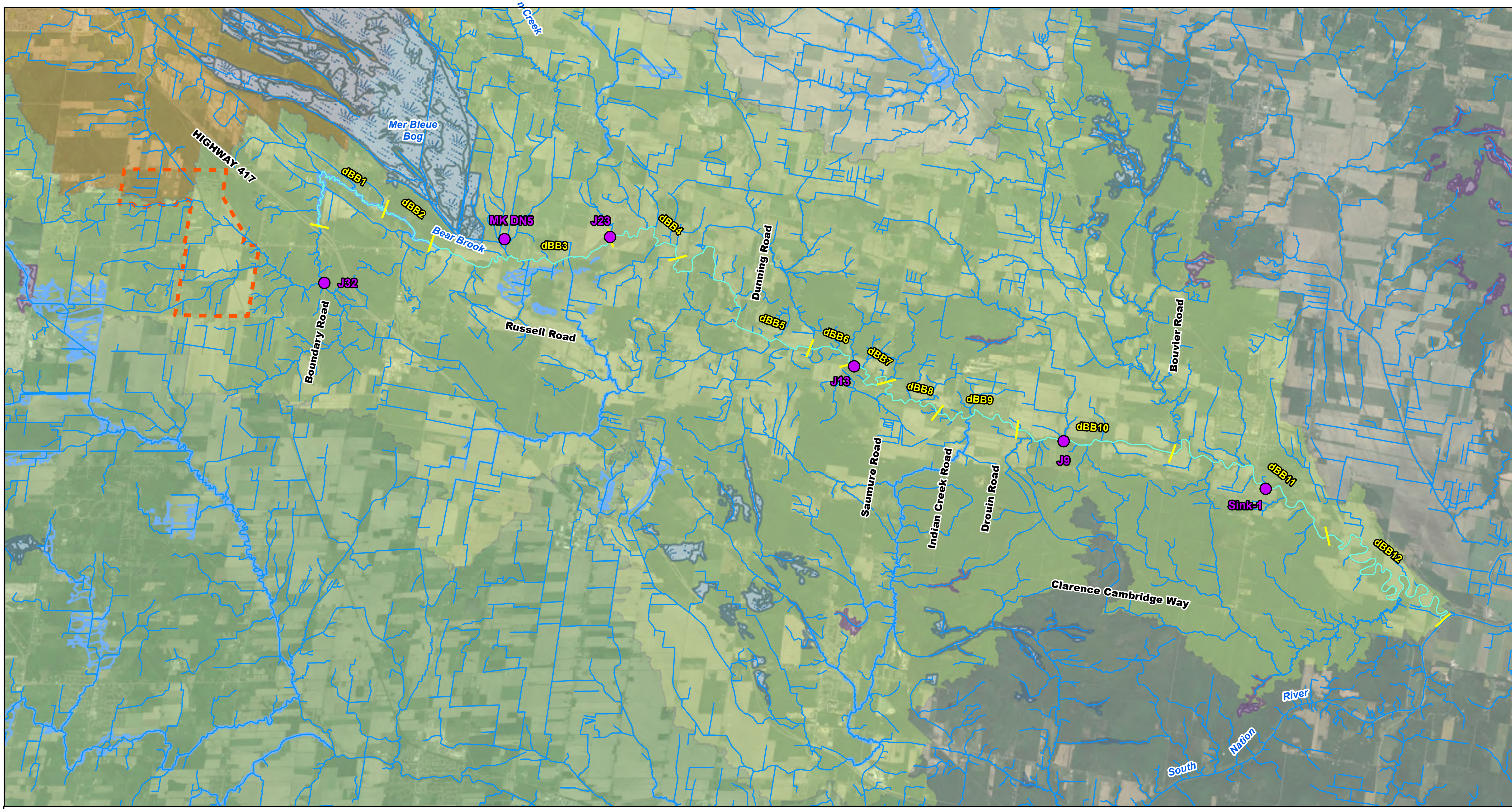
Bear Brook Main Branch

Valley Segment Delineation

Ottawa, Ontario

Imagery: Google Earth, 2018.
Watercourse: MNRF, 2021.
Main Branch/Valley Segment Delineation: GEO Morphix Ltd., 2022.
Print Date: March 2023. PN22024. Drawn By: L.L., M.O.

Appendix A.2:
Hydrological Node Locations



Legend

- Node
- Valley Segment Delineation
- Bear Brook Main Branch
- Watercourse
- Tewin Study Area
- Bear Brook Watershed
- Green's Creek Watershed
- Castor Watershed

Cumulative Hydrologic Impact Assessment

Bear Brook Main Channel

Ottawa, Ontario

N

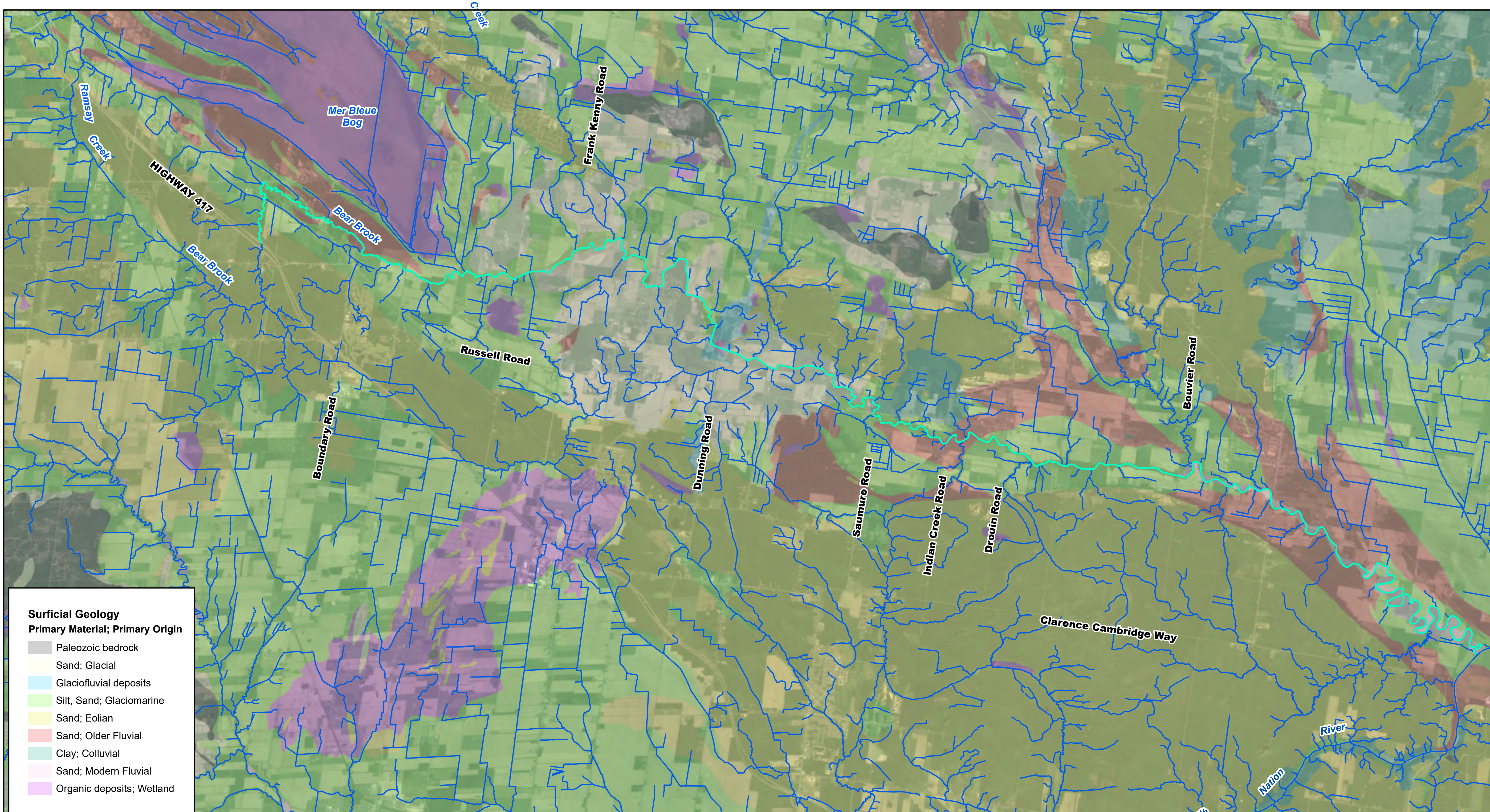
0 2 4

Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Boundary Areas: Algonquins of Ontario/Taggart, 2021., GEO Morphix Ltd., 2021. Watercourse: MNRF, 2021. Watershed: City of Ottawa, 2021. Valley Segment Delineation: GEO Morphix Ltd., 2021. Bear Brook, South Nation Main Branch: MNRF/GEO. Minor Watersheds: City of Ottawa, 2011. Morphix June 2023. PN22024. Drawn By: L.L., M.O., K.S.

Appendix A.3:
Surficial Geology Mapping



Legend

Watercourse

Bear Brook Main Branch

Tewin Secondary Plan Subwatershed Study

Tewin Lands (Surficial Geology)

Ottawa, Ontario

N

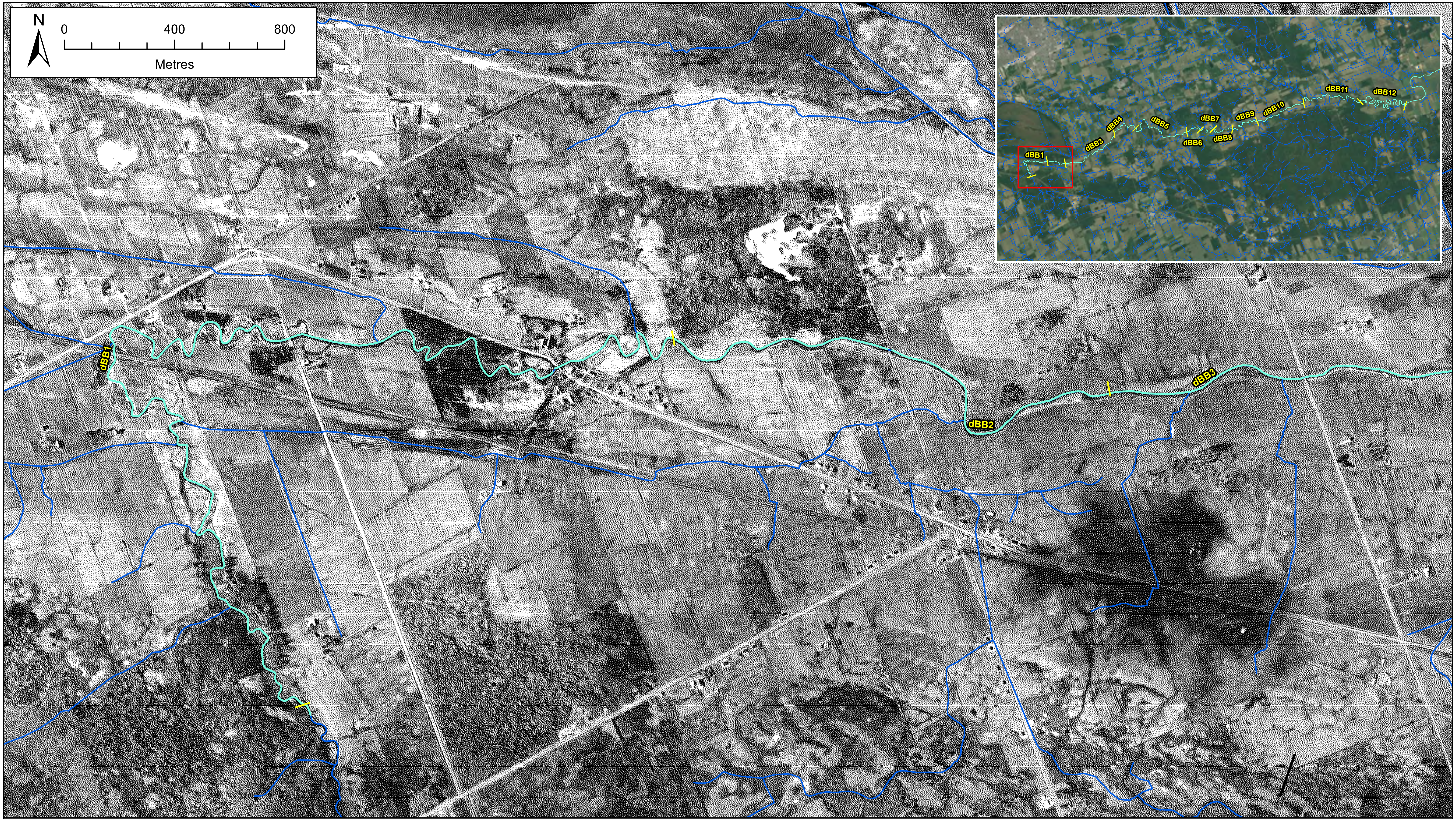
0 2 4

Kilometers

GEO MORPHIX™

Imagery: Google Earth, 2018.
0.5 Contours: NRCan, May, 2020.
Watercourse: JFSA Inc., 2021.
Surficial Geology: MNRF, 2020.
Main Branch: MNRF/GEO Morphix Ltd., 2022.
Printed: March 2023. PN22024. Drawn By: M.O., K.S.

Appendix A.4:
Historical Aerial Imagery



Legend

Valley Segment Delineation

Main Branches

Watercourse

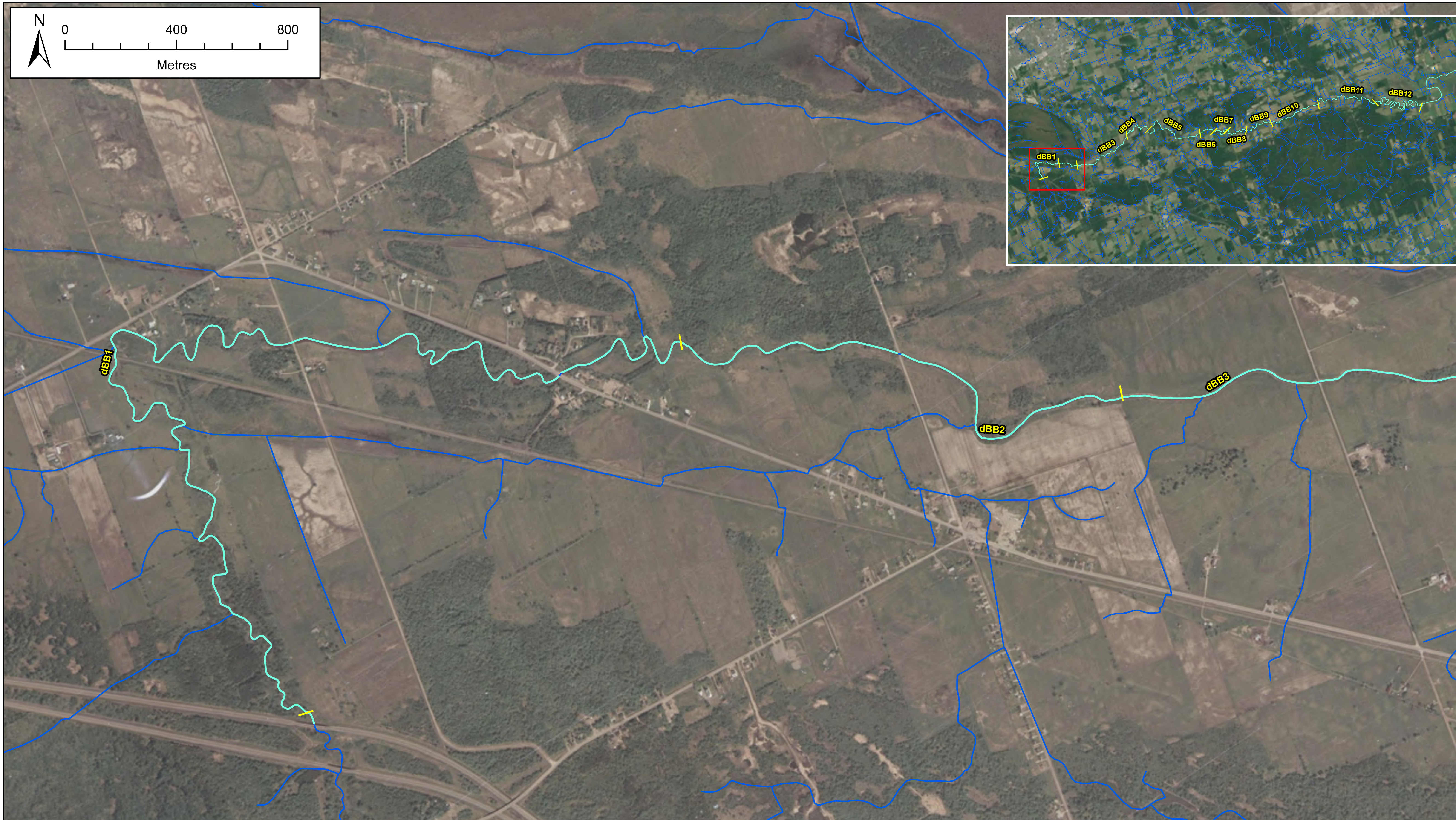
Bear Brook Main Branch

Valley Segments - 1965 Aerial Imagery

Ottawa, Ontario

GEO MORPHIX™

Imagery: Google Earth, 2018/City of Ottawa,1965,1976.
Watercourse: MNRF, 2021.
Main Branch/Valley Segment Delineation: GEO Morphix Ltd., 2022.
Print Date: March 2023. PN22024. Drawn By: L.L., M.O.



Legend

Valley Segment Delineation

Main Branches

Watercourse

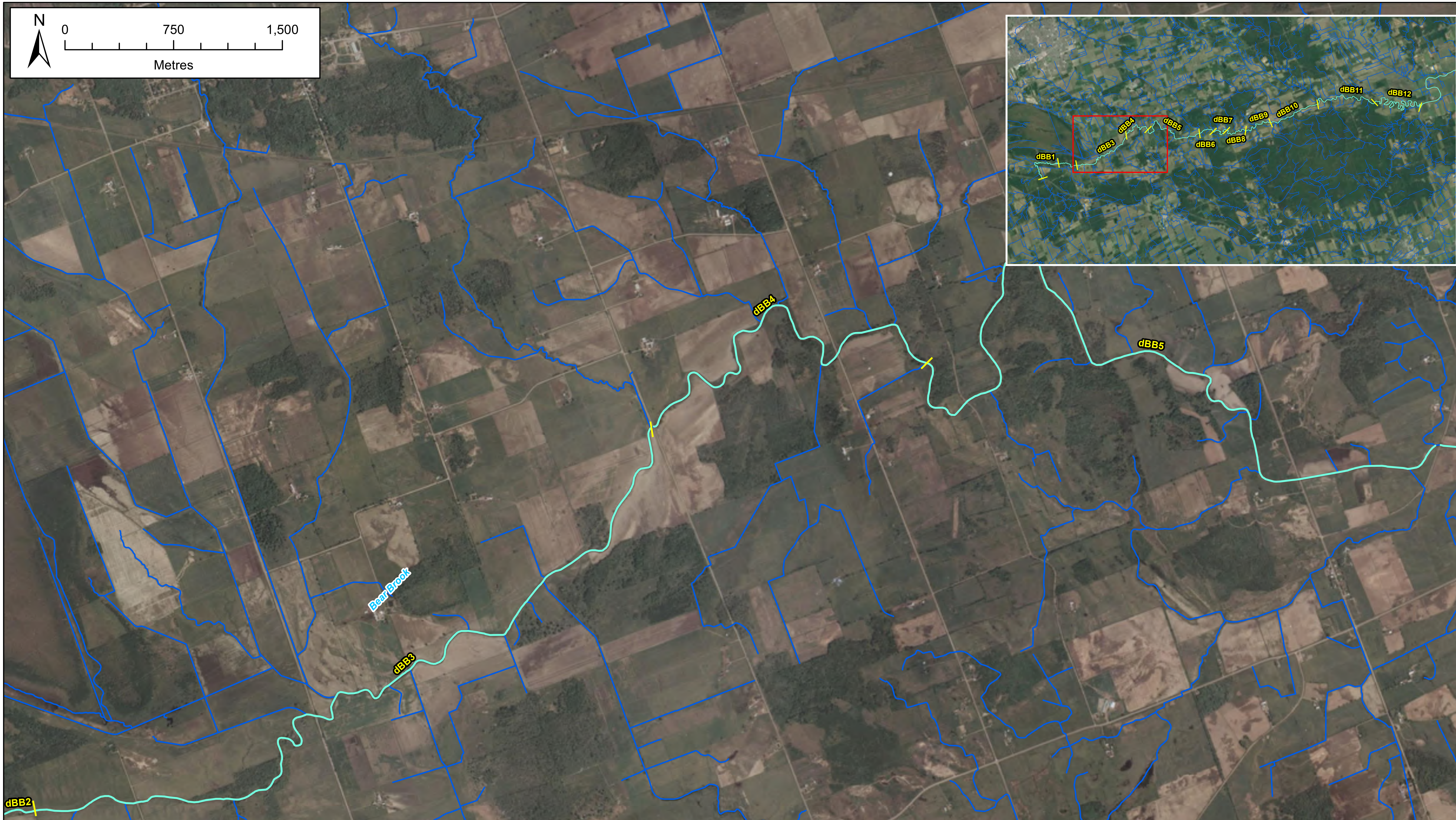
Bear Brook Main Branch

Valley Segments - 1976 Aerial Imagery

Ottawa, Ontario

GEO MORPHIX™

Imagery: Google Earth, 2018/City of Ottawa,1965,1976.
Watercourse: MNRF, 2021.
Main Branch/Valley Segment Delineation: GEO Morphix Ltd.,2022.
Print Date: March 2023. PN22024. Drawn By: L.L.,M.O.



Legend

- Valley Segment Delineation
- Main Branches
- Watercourse

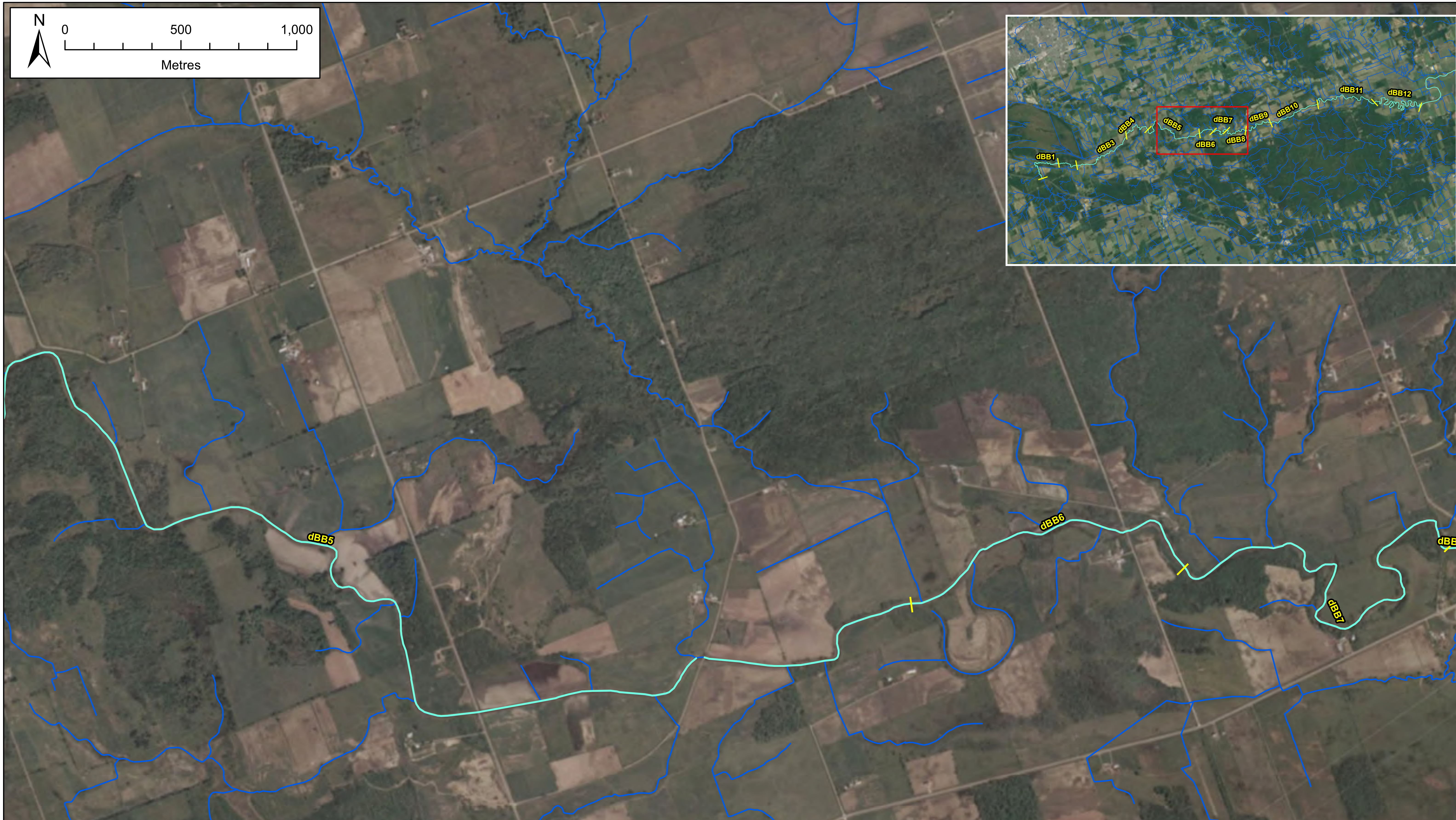
Bear Brook Main Branch

Valley Segments - 1976 Aerial Imagery

Ottawa, Ontario

GEO MORPHIX™

Imagery: Google Earth, 2018/City of Ottawa,1965,1976.
Watercourse: MNRF, 2021.
Main Branch/Valley Segment Delineation: GEO Morphix Ltd.,2022.
Print Date: March 2023. PN22024. Drawn By: L.L.,M.O.



Legend

Valley Segment Delineation

Main Branches

Watercourse

Bear Brook Main Branch

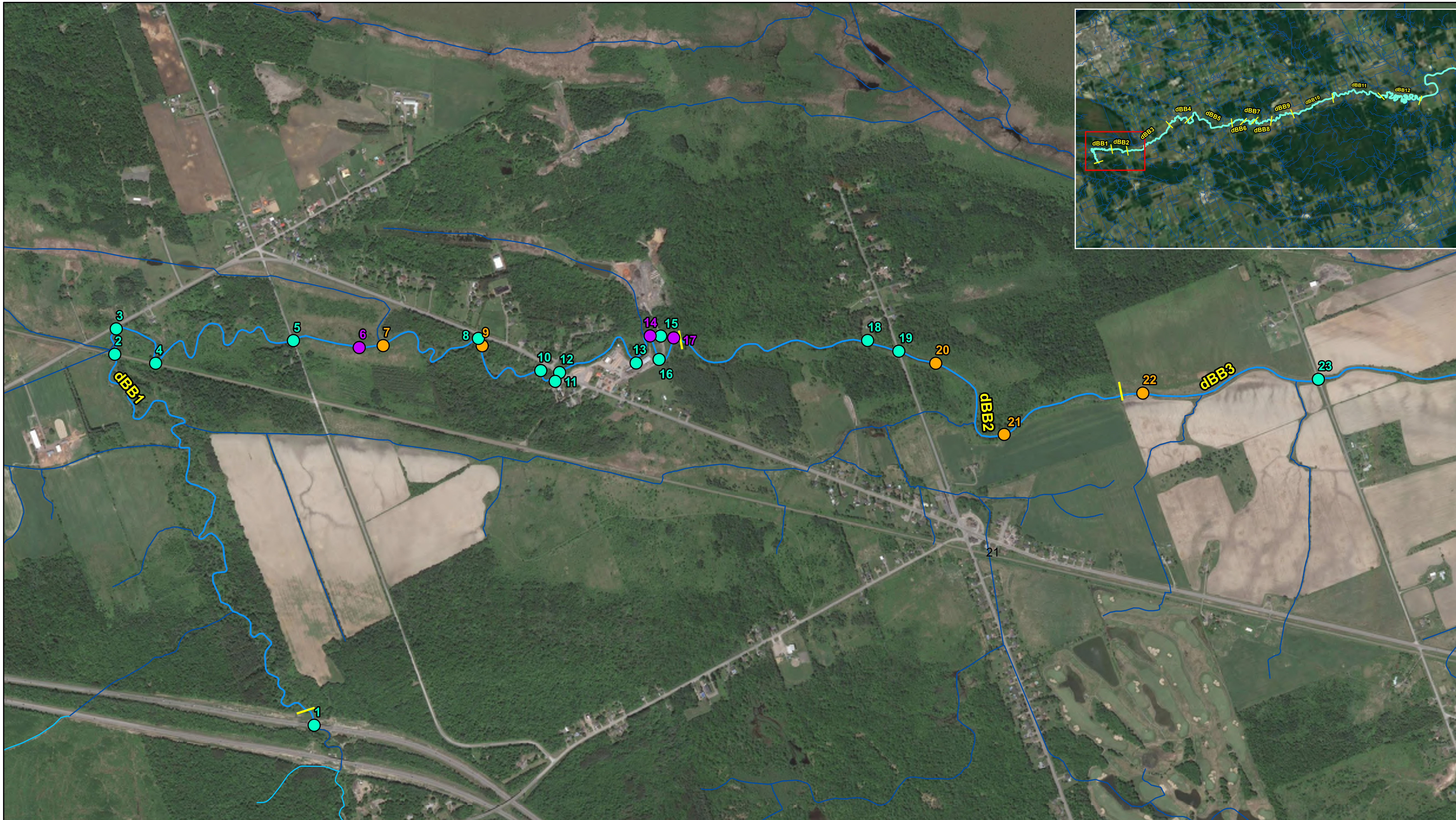
Valley Segments - 1976 Aerial Imagery

Ottawa, Ontario

GEO MORPHIX™

Imagery: Google Earth, 2018/City of Ottawa,1965,1976.
Watercourse: MNRF, 2021.
Main Branch/Valley Segment Delineation: GEO Morphix Ltd.,2022.
Print Date: March 2023. PN22024. Drawn By: L.L.,M.O.

Appendix A.5:
Geomorphological Points of Interest Locations



Legend

Valley Segment Delineation

Watercourse

Main Branch

Points of Interest

Geomorphological Feature

Infrastructure

Past Alteration

Bear Brook Main Branch

Points of Interest

Ottawa, Ontario

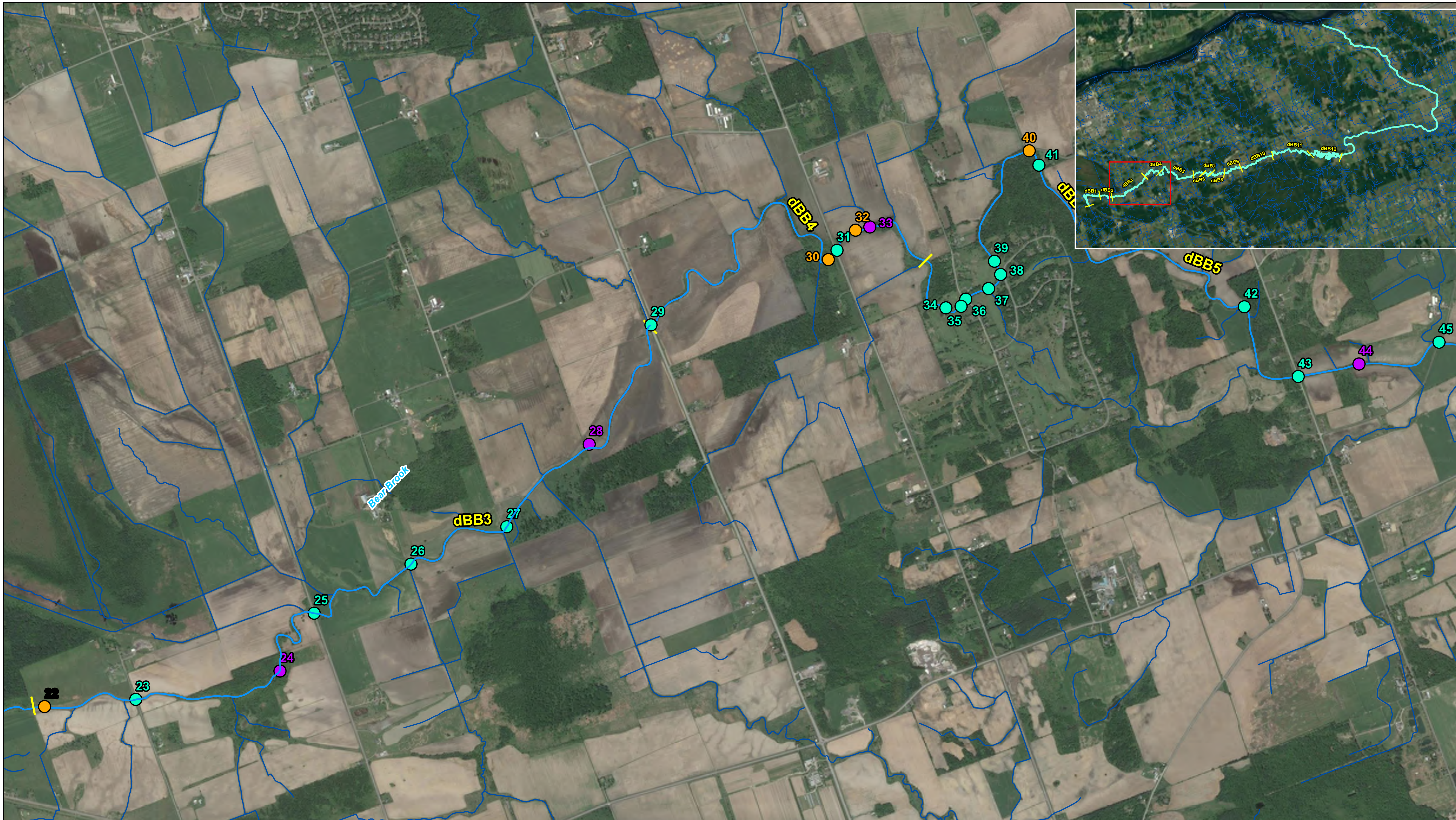
N

0 0.25 0.5

Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Watercourse: OHN, 2020. Main Branches, Valley Segment Delineation, Points of Interest: GEO Morphix Ltd., 2022. Print Date: June 2023. PN22024. Drawn By: M.O., L.L.



Legend

Valley Segment Delineation
Watercourse
Main Branch

Points of Interest

Geomorphological Feature
Infrastructure
Past Alteration

Bear Brook Main Branch

Points of Interest

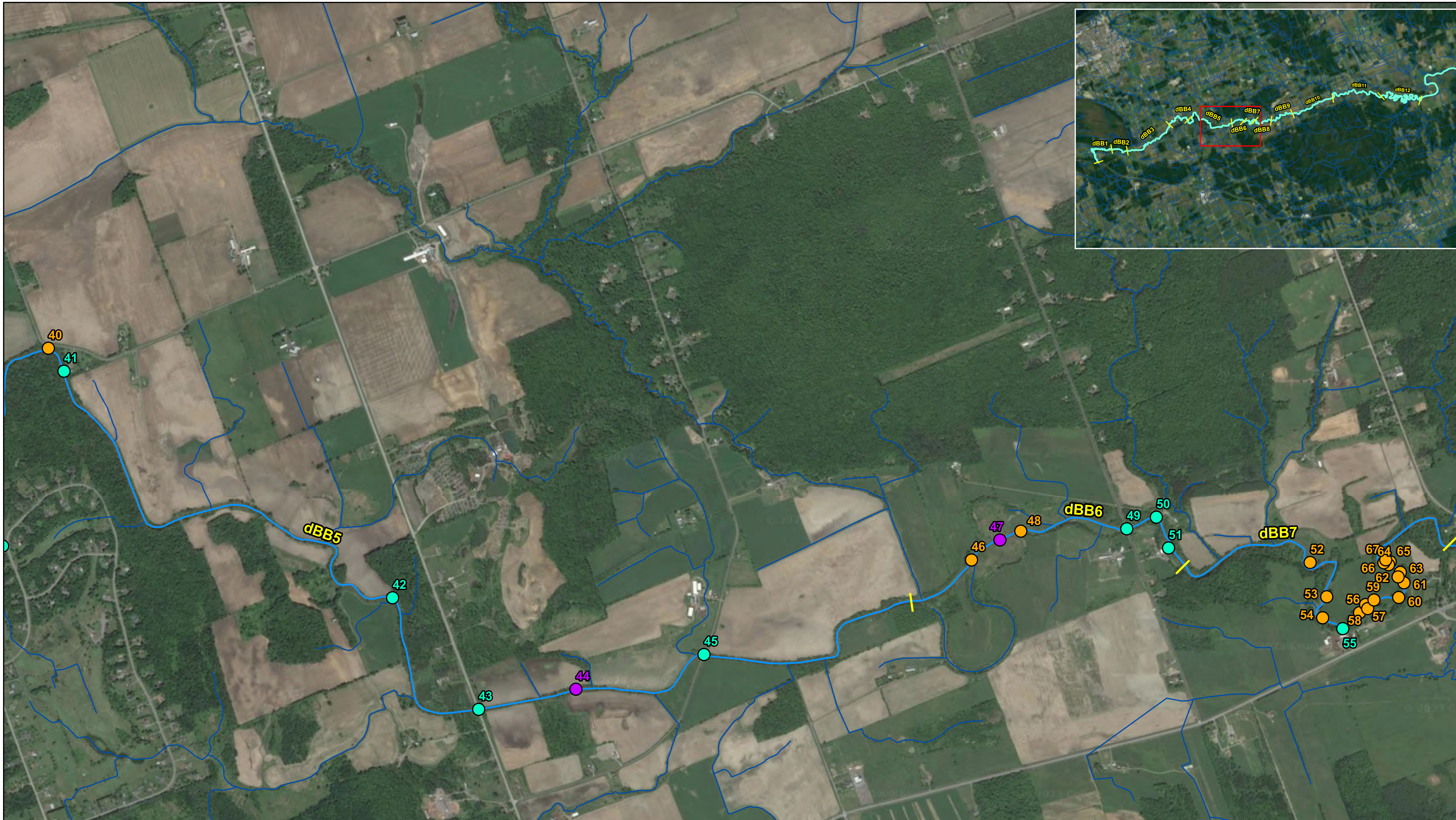
Ottawa, Ontario

N

0 0.5 1
Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Watercourse: OHN, 2020. Main Branches, Valley Segment Delineation, Points of Interest: GEO Morphix Ltd., 2022.
Print Date: June 2023. PN22024. Drawn By: M.O., L.L.



Legend

Valley Segment Delineation

Watercourse

Main Branch

Points of Interest

Geomorphological Feature

Infrastructure

Past Alteration

Bear Brook Main Branch

Points of Interest

Ottawa, Ontario

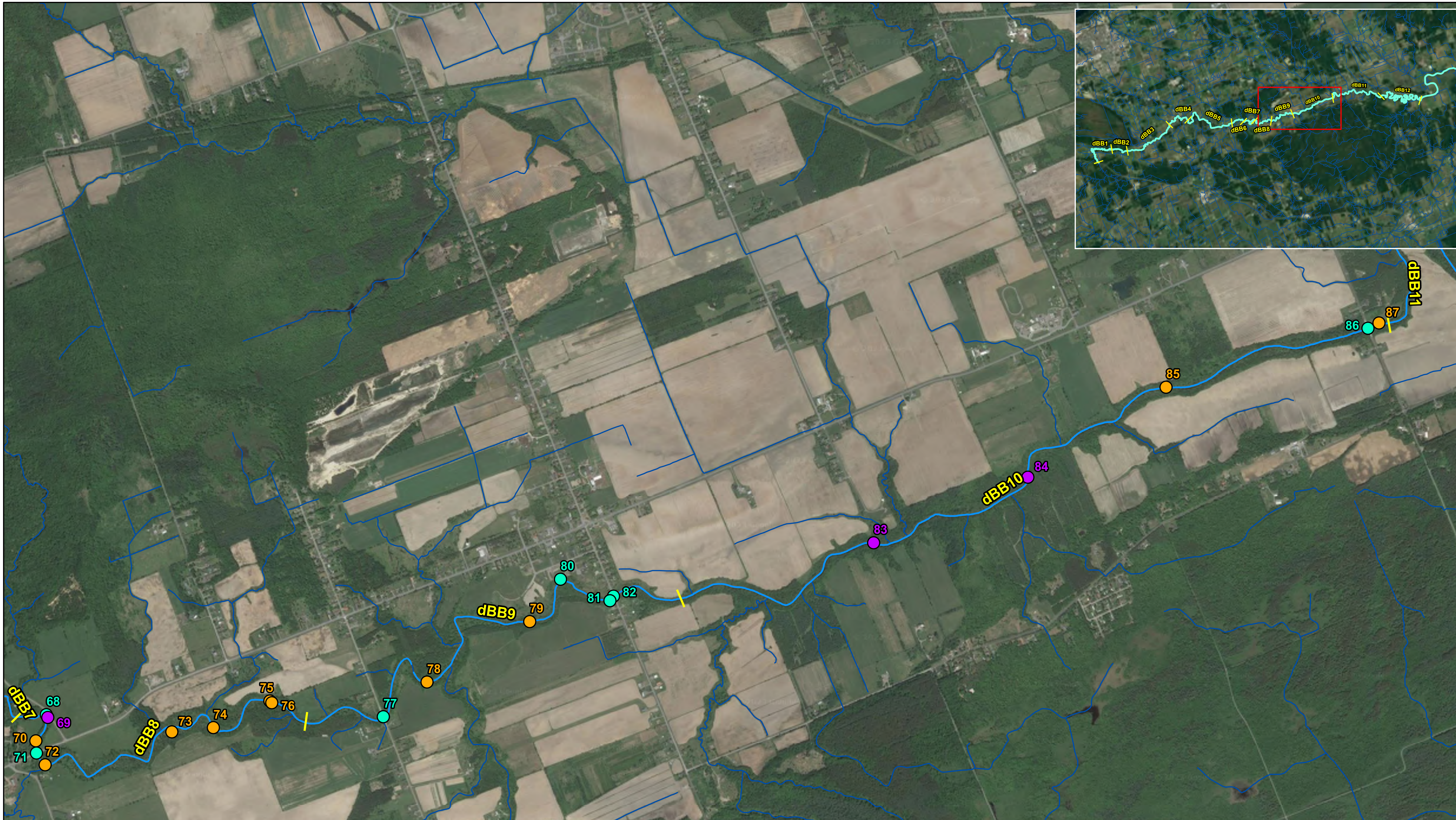
N

0 0.25 0.5

Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Watercourse: OHN, 2020. Main Branches, Valley Segment Delineation, Points of Interest: GEO Morphix Ltd., 2022.
Print Date: June 2023. PN22024. Drawn By: M.O., L.L.



Legend

Valley Segment Delineation

Watercourse

Main Branch

Points of Interest

Geomorphological Feature

Infrastructure

Past Alteration

Bear Brook Main Branch

Points of Interest

Ottawa, Ontario

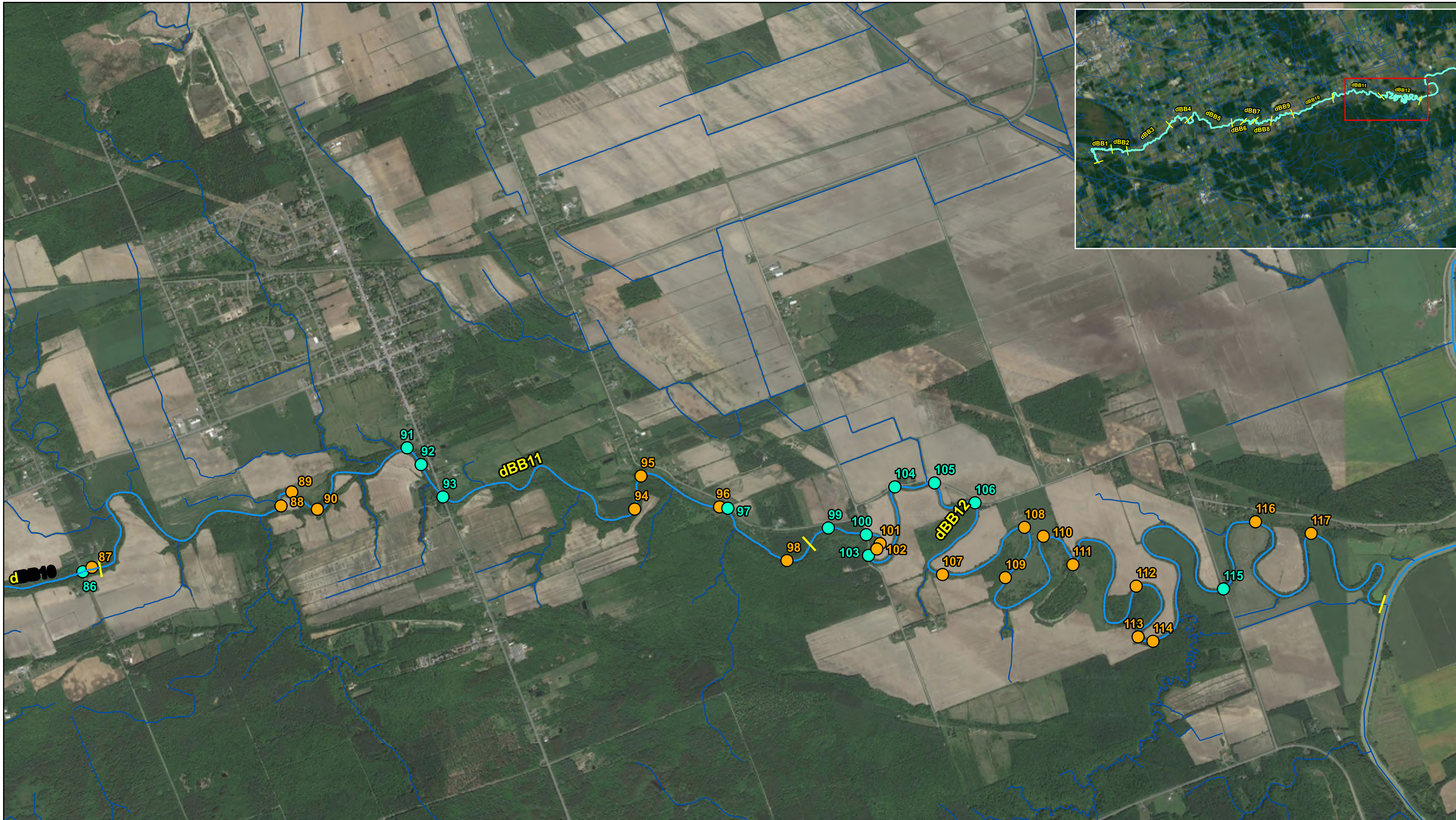
N

0 0.5 1

Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Watercourse: OHN, 2020.
Main Branches, Valley Segment Delineation, Points of
Interest: GEO Morphix Ltd., 2022.
Print Date: June 2023. PN22024. Drawn By: M.O., L.L.



Legend

- Valley Segment Delineation
- Watercourse
- Main Branch

Points of Interest

- Geomorphological Feature
- Infrastructure
- Past Alteration

Bear Brook Main Branch

Points of Interest

Ottawa, Ontario

N

0 0.5 1

Kilometres

GEO MORPHIX™

Imagery: Google Earth, 2018. Watercourse: OHN, 2020. Main Branches, Valley Segment Delineation, Points of Interest: GEO Morphix Ltd., 2022.
Print Date: June 2023. PN22024. Drawn By: M.O., L.L.

#	Valley Segment	Category	Sub-category	Notes
1	dBB1	Infrastructure	Road	Highway 417 Crossing
2	dBB1	Infrastructure	Property	VIA Rail crossing over Bear Brook
3	dBB1	Infrastructure	Road	Russell Road approximately ~10 m from channel
4	dBB1	Infrastructure	Property	VIA Rail ~10 m from the outer bank of meander bend
5	dBB1	Infrastructure	Road	Hall Road crossing and likely straightened section Bear Brook
6	dBB1	Past Alteration	Straightening	Previous channel straightened before 1965 (remnants of previous sinuous channel can be seen in 1965 aerial imagery)
7	dBB1	Geomorphological Feature	Saturated Conditions	Isolated saturated conditions with vegetation encroachment, creek remains well defined
8	dBB1	Infrastructure	Road	Russell Road is ~10 m from the creek along an outer meander bend
9	dBB1	Geomorphological Feature	Large Woody Debris	Large woody debris across active channel
10	dBB1	Infrastructure	Property	Building of Carlsbad Springs Bath House at the outer meander bend, ~ 10 m from bank
11	dBB1	Infrastructure	Property	Building along the bank of Bear Brook
12	dBB1	Infrastructure	Road	Russell Road bridge
13	dBB1	Infrastructure	Property	Commercial lot at the outer meander bend, buildings ~10 m from top of bank
14	dBB1	Past Alteration	Weirs or Dams	Dam or diversion structure placed to maintain artificial cutoff channel, placed between 2005 and 2011
15	dBB1	Infrastructure	Pedestrian Bridge	Bridge over artificial cutoff channel
16	dBB1	Infrastructure	Pedestrian Bridge	Commercial road bridge over Bear Brook
17	dBB2	Past Alteration	Weirs or Dams	Weir or dam isolating artificially dugout cutoff channel
18	dBB2	Infrastructure	Property	Property adjacent to creek with loss of riparian vegetation
19	dBB2	Infrastructure	Road	Boundary Road bridge
20	dBB2	Geomorphological Feature	Aggradation	Medial bar formation between 1976 and 2019
21	dBB2	Geomorphological Feature	Aggradation	Medial bar formation between 1976 and 2019
22	dBB2	Geomorphological Feature	Saturated Conditions	Isolated saturated conditions, creek remains defined
23	dBB3	Infrastructure	Road	Carlsbad Lane Road bridge
24	dBB3	Past Alteration	Weirs or Dams	Structure perpendicular to active channel, crossing type not discernable, possibly beaver dam
25	dBB3	Infrastructure	Road	Milton Road bridge

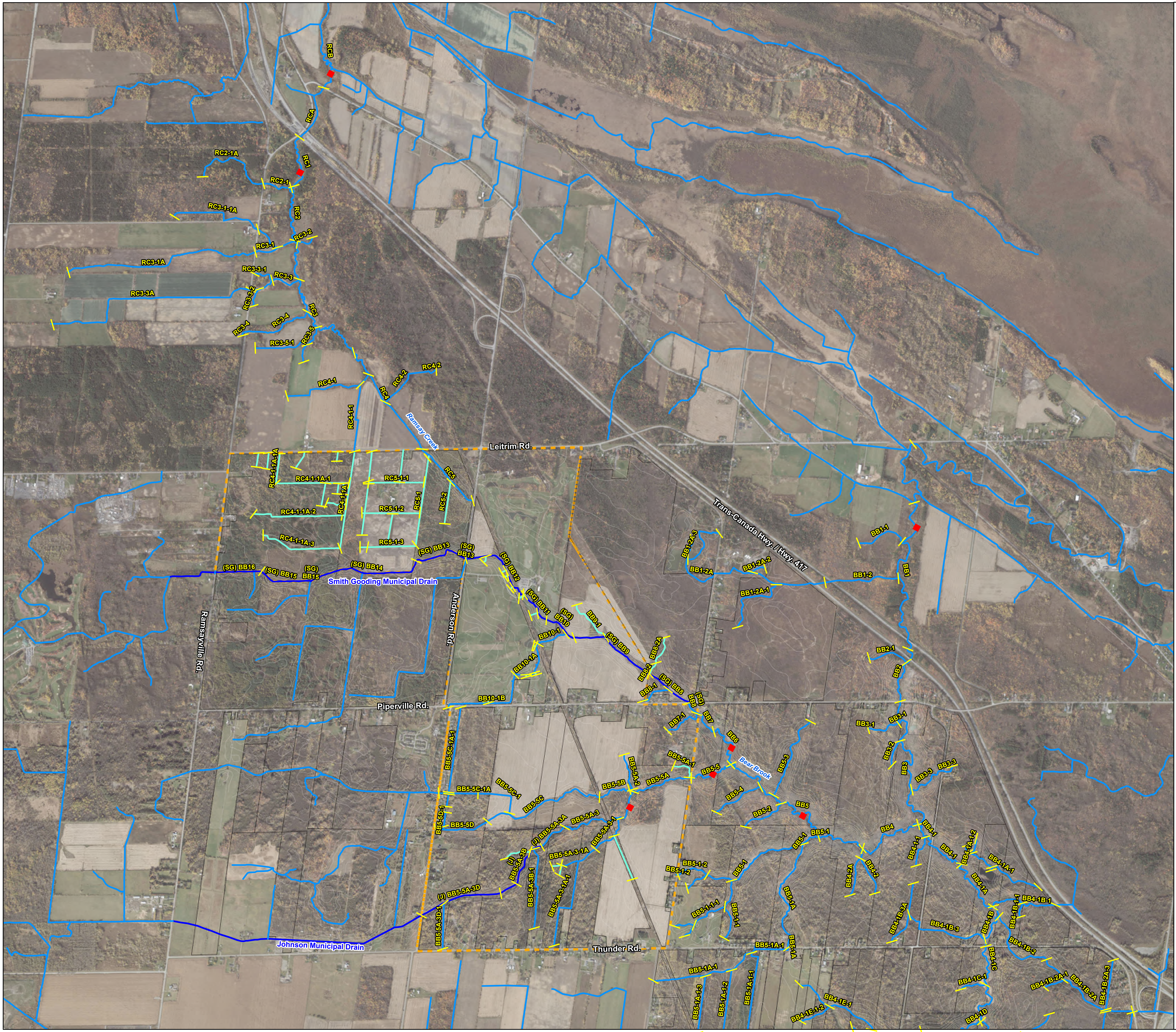
#	Valley Segment	Category	Sub-category	Notes
26	dBB3	Infrastructure	Pedestrian Bridge	Farm crossing, status unknown
27	dBB3	Infrastructure	Pedestrian Bridge	Crossing for agricultural uses, must be field verified
28	dBB3	Past Alteration	Straightening	Channel has been intermittently straightened for ~2.5 km (likely agricultural activities)
29	dBB4	Infrastructure	Road	Road culvert for Frank Kenny Road
30	dBB4	Geomorphological Feature	Large Woody Debris	Debris jam in centre of active channel, possibly a beaver dam
31	dBB4	Infrastructure	Road	Rockdale Road culvert
32	dBB4	Geomorphological Feature	Large Woody Debris	Debris jam in centre of active channel, possibly a beaver dam
33	dBB4	Past Alteration	Straightening	Channel straightening completed prior to 1976
34	dBB5	Infrastructure	Pedestrian Bridge	Pedestrian bridge on golf course
35	dBB5	Infrastructure	Property	Building ~15 m from channel
36	dBB5	Infrastructure	Road	McNeely Road culvert
37	dBB5	Infrastructure	Pedestrian Bridge	Pedestrian bridge
38	dBB5	Infrastructure	Road	Whispering Willow Drive along outer meander bend, ~15 m from bank
39	dBB5	Infrastructure	Pedestrian Bridge	Pedestrian bridge on golf course
40	dBB5	Geomorphological Feature	Meander Bend	Outside meander bend <20 m from Magladry Rd
41	dBB5	Infrastructure	Property	Building off Madladry Rd is ~5 m from river bank
42	dBB5	Infrastructure	Pedestrian Bridge	Pedestrian bridge for either trail or golf course
43	dBB5	Infrastructure	Road	Road culvert for Dunning Road
44	dBB5	Past Alteration	Straightening	Straightened section of channel through agricultural fields (occurred prior to 1965)
45	dBB5	Infrastructure	Road	Road culvert for Sarsfield Road
46	dBB6	Geomorphological Feature	Planimetric Adjustment	Channel previously more sinuous (formation of cutoff channel)
47	dBB6	Past Alteration	Straightening	Aerial imagery suggests remnants of previous channel, channel likely previously straightened
48	dBB6	Geomorphological Feature	Saturated Conditions	Impoundment causing backwatering in channel and saturated conditions in riparian zone
49	dBB6	Infrastructure	Road	Road culvert for Ruissellet Road
50	dBB6	Infrastructure	Property	Property loss on outside meander bend
51	dBB6	Infrastructure	Property	Building ~30 m from banks of a straight portion of the creek

#	Valley Segment	Category	Sub-category	Notes
52	dBB7	Geomorphological Feature	Saturated Conditions	Backwatering due to impoundment within portion of the creek
53	dBB7	Geomorphological Feature	Planimetric Adjustment	Bank erosion or valley wall contact, evidence of rills and overland flow erosion on both banks, possibly indicating planimetric adjustment
54	dBB7	Geomorphological Feature	Point Bar	Large point bar formation
55	dBB7	Infrastructure	Property	Farm buildings ~20 m of active meander bend
56	dBB7	Geomorphological Feature	Widening	Bank erosion, evidence of gullies and rills
57	dBB7	Geomorphological Feature	Widening	General bank erosion, fracture line and slumping
58	dBB7	Geomorphological Feature	Point Bar	Large point bar formation and slope erosion on opposite bank
59	dBB7	Geomorphological Feature	Widening	Evidence of bank erosion (creek adjustment)
60	dBB7	Geomorphological Feature	Planimetric Adjustment	Island formation and possible medial bar, indicates planimetric adjustment
61	dBB7	Geomorphological Feature	Large Woody Debris	Large woody debris, likely result of fallen trees potentially from bank erosion
62	dBB7	Geomorphological Feature	Uncharacterized	General bank erosion
63	dBB7	Geomorphological Feature	Planimetric Adjustment	Medial bars or islands, evidence of planimetric adjustment
64	dBB7	Geomorphological Feature	Point Bar	Point bar formation at valley wall contact
65	dBB7	Geomorphological Feature	Widening	Evidence of bank erosion, with formation of rills and gullies
66	dBB7	Geomorphological Feature	Aggradation	Sediment accumulation in centre of channel, possible medial bar
67	dBB7	Geomorphological Feature	Widening	Bank erosion, evidence of gullies and rills
68	dBB8	Infrastructure	Road	Birchgrove Road runs parallel to outside meander bend (bank is ~10 m from road)
69	dBB8	Past Alteration	Bank Protection	Boulder or riprap treatment along the bank (road protection)
70	dBB8	Geomorphological Feature	Large Woody Debris	Large woody debris
71	dBB8	Infrastructure	Road	Russell Road bridge and road culvert
72	dBB8	Geomorphological Feature	Large Woody Debris	Large woody debris, deposition in channel is evidence of island or bar formation
73	dBB9	Geomorphological Feature	Planimetric Adjustment	Possible island formation (evident through historical aerial imagery)
74	dBB9	Geomorphological Feature	Large Woody Debris	Large woody debris in creek
75	dBB9	Geomorphological Feature	Large Woody Debris	Large woody debris in area
76	dBB9	Geomorphological Feature	Point Bar	Large point bar

#	Valley Segment	Category	Sub-category	Notes
77	dBB9	Infrastructure	Road	Road culvert for Indian Creek Road
78	dBB9	Geomorphological Feature	Large Woody Debris	Series of large woody debris blockages
79	dBB9	Geomorphological Feature	Large Woody Debris	Large woody debris extends across active channel
80	dBB9	Infrastructure	Property	Stormwater management pond and outfall adjacent to outside meander bend
81	dBB9	Infrastructure	Property	Buildings of private property sits ~30 m away from bank, outer bend is constricted by road bridge
82	dBB9	Infrastructure	Road	Drouin Road bridge
83	dBB10	Past Alteration	Bank Protection	Bank protection, status unknown
84	dBB10	Past Alteration	Straightening	Possible straightened section of creek through agricultural land, ~4 km long
85	dBB10	Geomorphological Feature	Large Woody Debris	Large woody debris extends across active channel
86	dBB10	Infrastructure	Road	Bouvier Road bridge
87	dBB10	Geomorphological Feature	Uncharacterized	Bank slump (tree loss)
88	dBB11	Geomorphological Feature	Widening	Bank has slumped, erosion and rills are evident
89	dBB11	Geomorphological Feature	Widening	Bank erosion, erosion, and rills evident
90	dBB11	Geomorphological Feature	Large Woody Debris	Large woody debris (likely man-made)
91	dBB11	Infrastructure	Property	Property adjacent to outer meander bend
92	dBB11	Infrastructure	Property	Three buildings ~10 m to channel
93	dBB11	Infrastructure	Road	Champlain Street Road bridge, oblique to creek
94	dBB11	Geomorphological Feature	Point Bar	Large point bar formation along inside meander bend
95	dBB11	Geomorphological Feature	Widening	Isolated erosion along outside meander bend
96	dBB11	Geomorphological Feature	Large Woody Debris	Blockage in channel - possibly farm weir, needs to be field verified
97	dBB11	Infrastructure	Road	Schnupp Road 15 m to the outer meander bend
98	dBB11	Geomorphological Feature	Large Woody Debris	Large woody debris
99	dBB12	Infrastructure	Road	Schnupp Road 15 m to the outer meander bend
100	dBB12	Infrastructure	Road	Road bridge for Boileau Road
101	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris (along outer meander bend)
102	dBB13	Geomorphological Feature	Widening	Bank erosion and slumping

#	Valley Segment	Category	Sub-category	Notes
103	dBB12	Infrastructure	Road	Road is along outside meander bend, and ~13 m away from bank
104	dBB12	Infrastructure	Road	Outside meander bend along Ettyville Road ~10 m from bank
105	dBB12	Infrastructure	Road	Ettyville Road is ~10 m from top of bank along an outside meander bend
106	dBB12	Infrastructure	Road	Ettyville Road is ~10 m from the outside of a meander bend
107	dBB12	Geomorphological Feature	Large Woody Debris	Series of large woody debris blockages
108	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris blockages
109	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris pile along one bank
110	dBB12	Geomorphological Feature	Meander Bend	Meander bend is showing signs of active erosion along outer bend (cutoff channel may eventually form)
111	dBB12	Geomorphological Feature	Planimetric Adjustment	Remnants of previous channel (cutoff from the main channel)
112	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris extending from one bank across channel, diverting flows towards opposite bank, where erosion is evident
113	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris along a high sinuosity segment of Bear Brook and outer meander bend
114	dBB12	Geomorphological Feature	Aggradation	Lobate bar forming at the confluence of Bear Brook with a small tributary
115	dBB12	Infrastructure	Road	Robillard Road bridge
116	dBB12	Geomorphological Feature	Large Woody Debris	Large woody debris (possibly man-made)
117	dBB12	Geomorphological Feature	Meander Bend	Outer meander bend erosion with potential impacts to private property

Appendix B
Study Area Mapping



GEO MORPHIX™

Study Area

Figure 1

Tewin Lands

Ottawa, Ontario

Legend

Reach Break and ID

Detailed Assessment Location

50 cm Contour

Watercourse

Municipal Drain

Headwater Drainage Feature

Participating Properties

Tewin Study Area

0 600 1,200

Metres

Imagery: City of Ottawa, 2019.
Watercourse: MNRF, 2020/GEO Morphix Ltd., 2022.
Reach Break and ID, Detailed Assessment Location:
GEO Morphix Ltd., 2022. Headwater Drainage Feature
Extent: Kilgour, 2022. 50 cm Contour: MNRF, 2019.
Study Area: Algonquins of Ontario/Taggart, 2021.
Print Date: October 2024. PN 22024.
Drawn By: M.O., K.W., G.U., K.M.

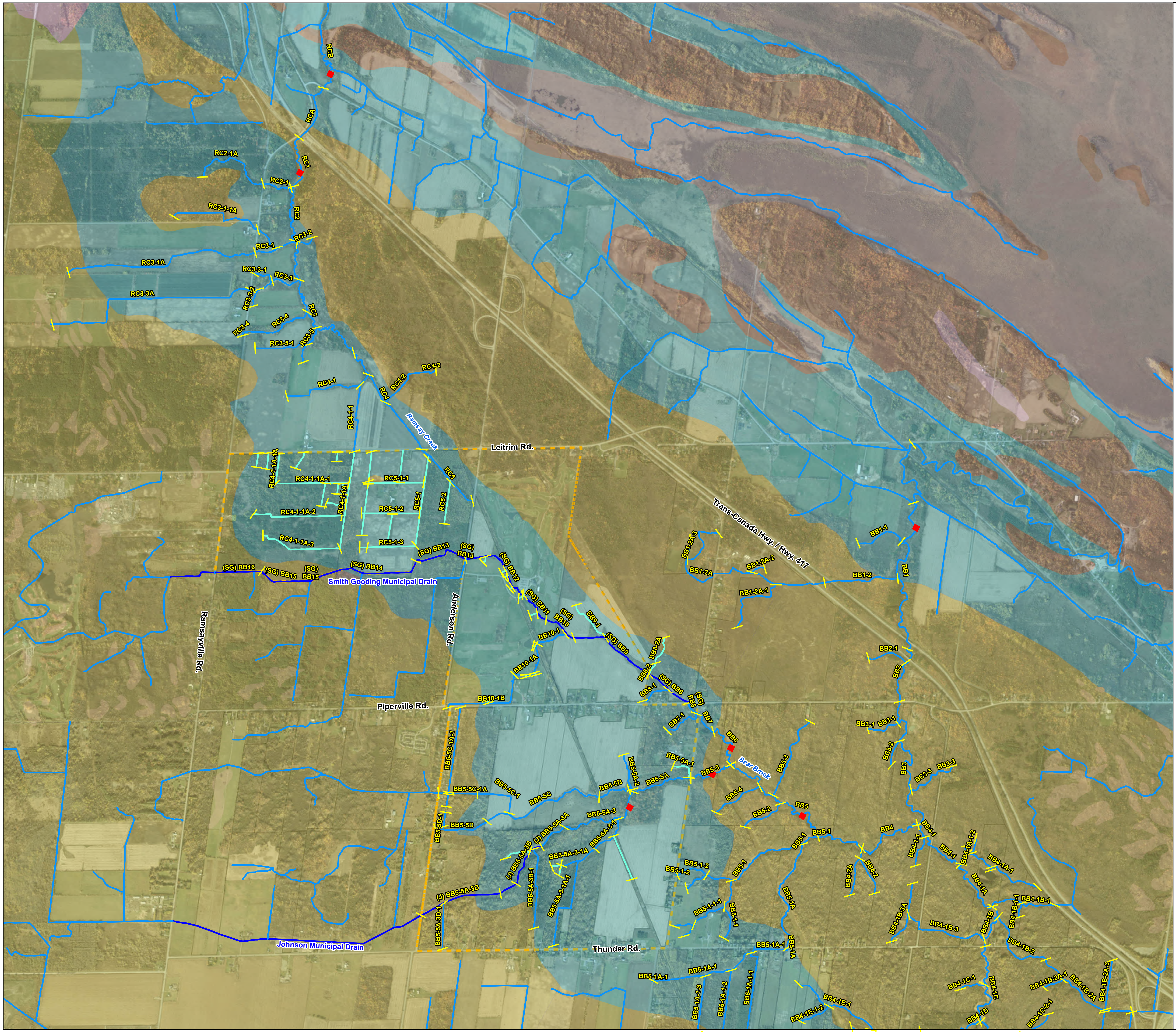
GEO MORPHIX™

Surficial Geology

Figure 2

Tewin Lands

Ottawa, Ontario



Legend

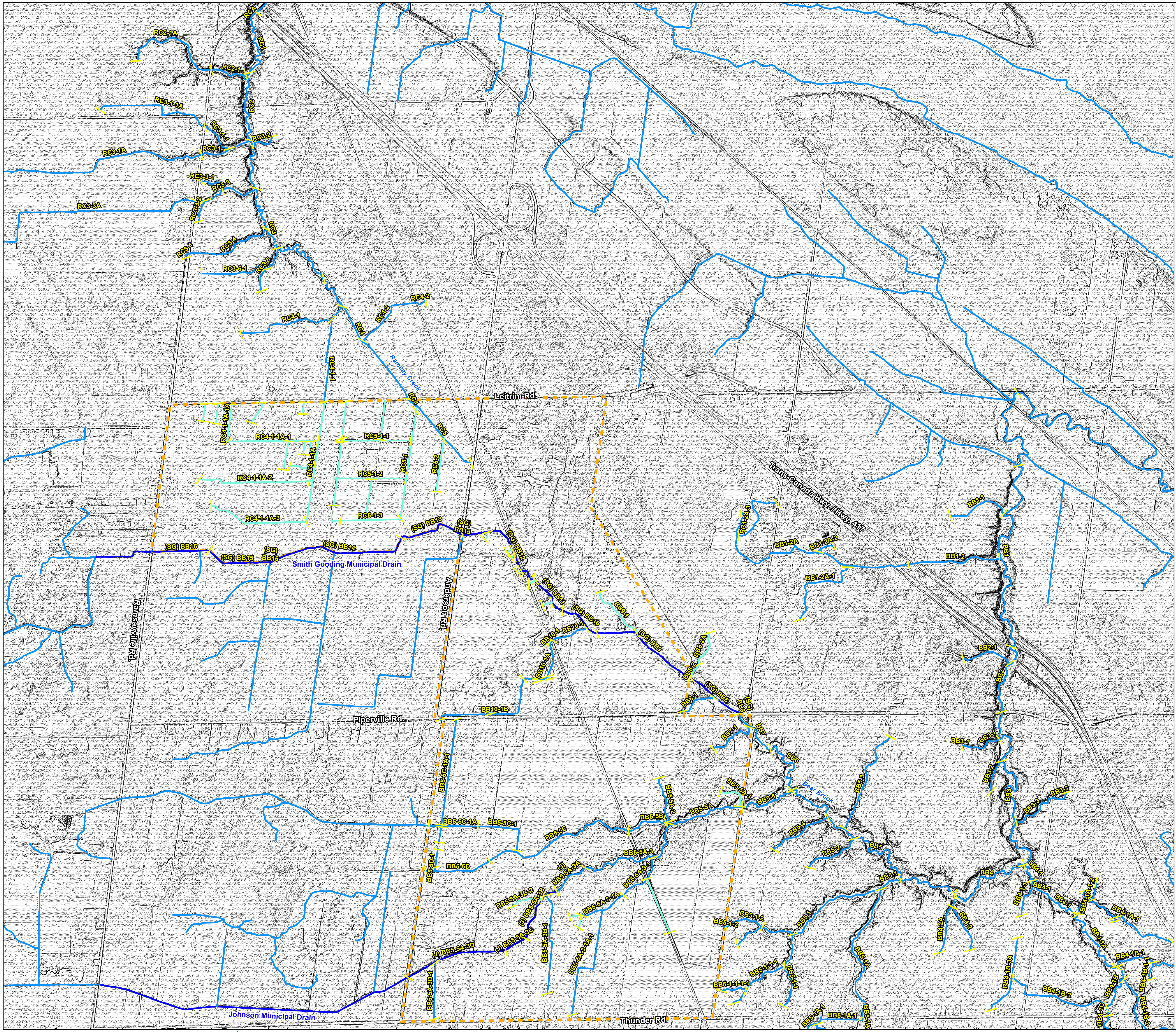
- Reach Break and ID
- Detailed Assessment Location
- Participating Properties
- Tewin Study
- 3: Paleozoic bedrock
- 5b: Stone-poor, carbonate-derived silty to sandy till
- 10a: Massive-well laminated
- 11a/c: Deltaic and foreshore-basinal deposits
- 12: Older alluvial deposits
- 17: Eolian deposits
- 20: Organic deposits

N

0 600 1,200

Metres

Imagery: City of Ottawa, 2019.
Watercourse: MNRF, 2020/GEO Morphix Ltd., 2022.
Reach Break and ID, Detailed Assessment Location: GEO Morphix Ltd., 2022. Surficial Geology: MNRF, 2024.
Headwater Drainage Feature Extent: Kilgour, 2022.
Study Area, Tewin Lands: Algonquins of Ontario/Taggart, 2021. PN 22024. Print Date: October 2024.
Drawn By: M.O., K.W., G.U., K.M.



GEO MORPHIX™

Study Area Terrain

Figure 3

Tewin Lands

Ottawa, Ontario

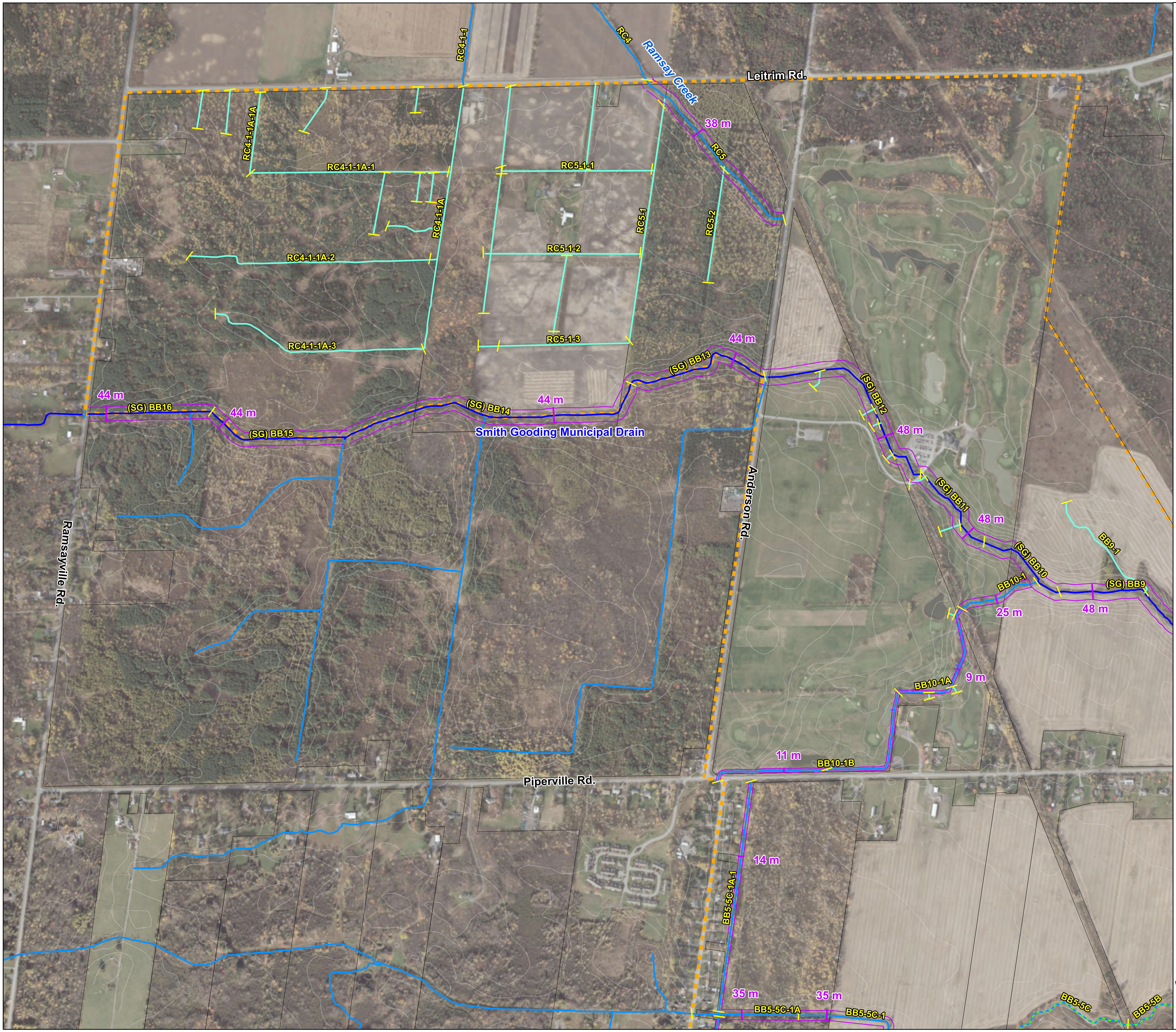
Legend

- Reach Break and ID
- Watercourse
- Municipal Drain
- Headwater Drainage Feature
- Tewin Study Area

0 500 1,000

Metres

Terrain: MNRF, 2020. Watercourse: MNRF, 2020/ GEO Morphix Ltd., 2022. Reach Break and ID: GEO Morphix Ltd., 2022. Headwater Drainage Feature Extent: Kilgour, 2022. Study Area: Algonquins of Ontario/Taggart, 2021. PN 22024. Print Date: October 2024. Drawn By: M.O., K.W., G.U.



GEO MORPHIX™

Preliminary Erosion Hazard Mapping

Figure 4a

Tewin Lands

Ottawa, Ontario

Legend

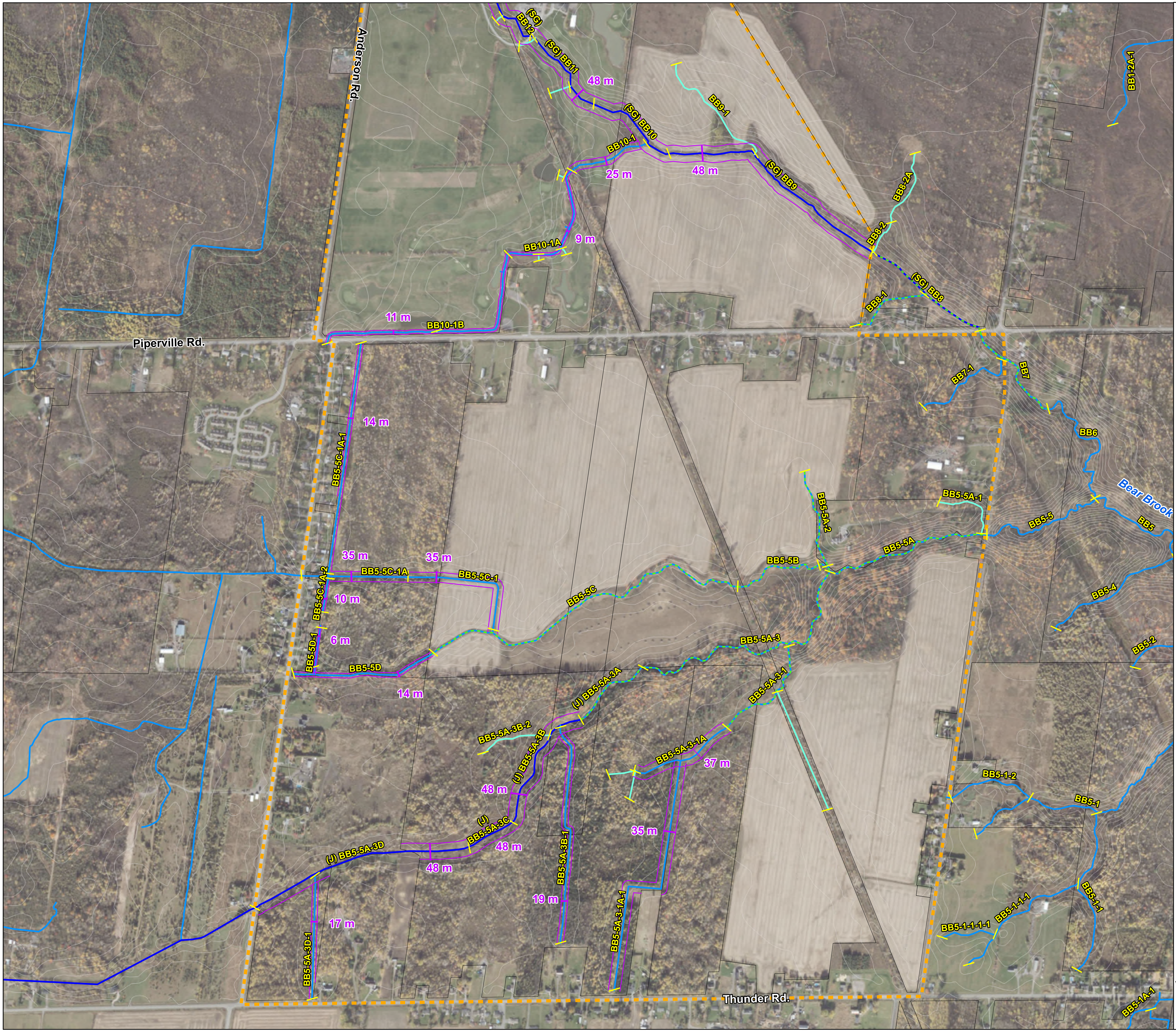
- Reach Break and ID
- Watercourse
- Municipal Drain
- Headwater Drainage Feature
- Confined Valley System
- Meander Belt Width
- Participating Properties
- Tewin Study Area

N

0 230 460

Metres

Imagery: City of Ottaway, 2019.
Watercourse: MNRF, 2020/GEO Morphix Ltd., 2022. Reach Break and ID, MBW, Confined Valley: GEO Morphix Ltd., 2022/2024.
Headwater Drainage Feature, Extent: Kilgour, 2022. 50 cm Contour: MNRF, 2019. Study Area, Tewin Lands: Algonquins of Ontario/Taggart, 2021. PN 21063.
Print Date: October 2024. Drawn By: M.O., K.W.



GEO MORPHIX™

Preliminary Erosion Hazard Mapping

Figure 4b

Tewin Lands

Ottawa, Ontario

Legend

- Reach Break and ID
- Watercourse
- Municipal Drain
- Headwater Drainage Feature
- Confined Valley System
- Meander Belt Width
- Participating Properties
- Tewin Study Area

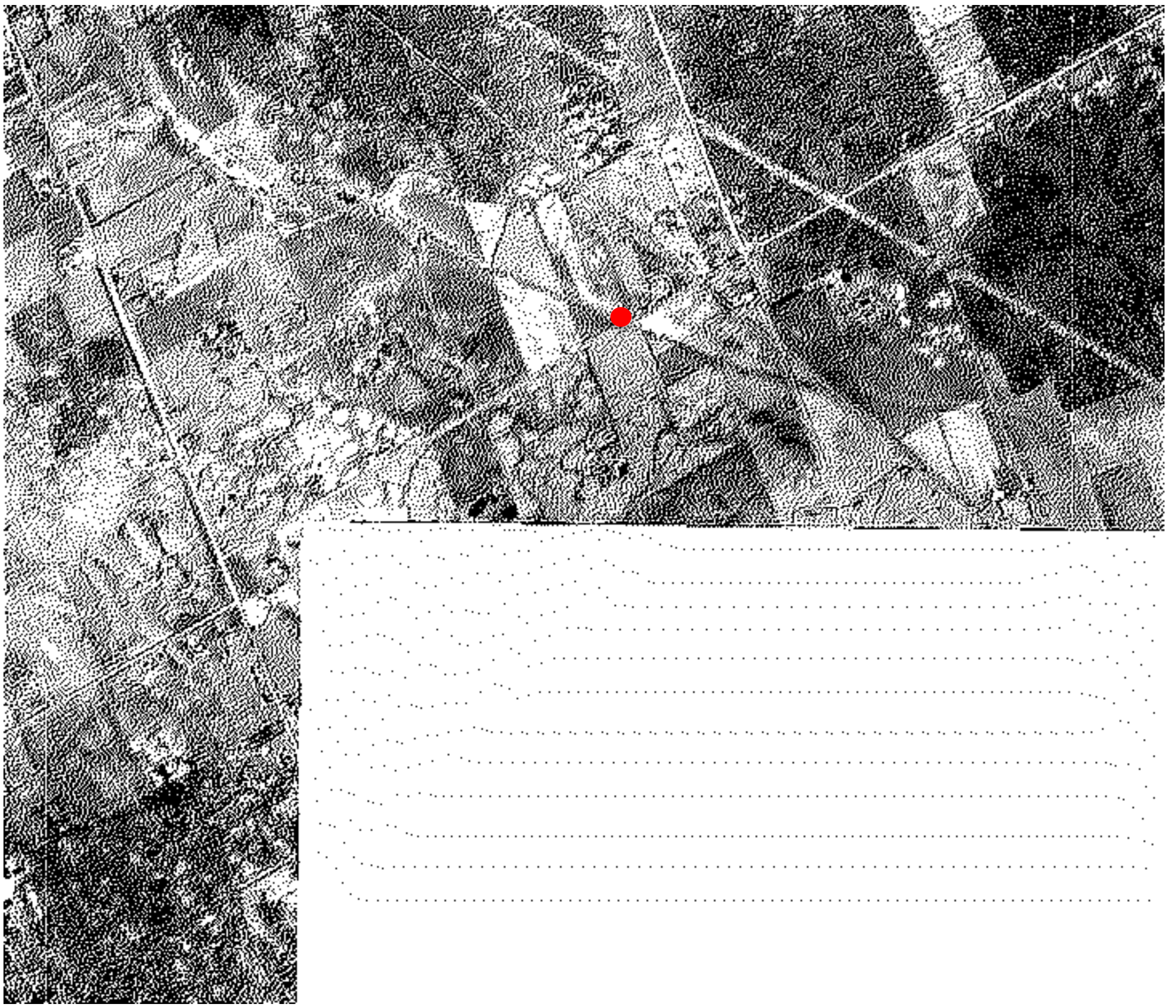
N

0 230 460

Metres

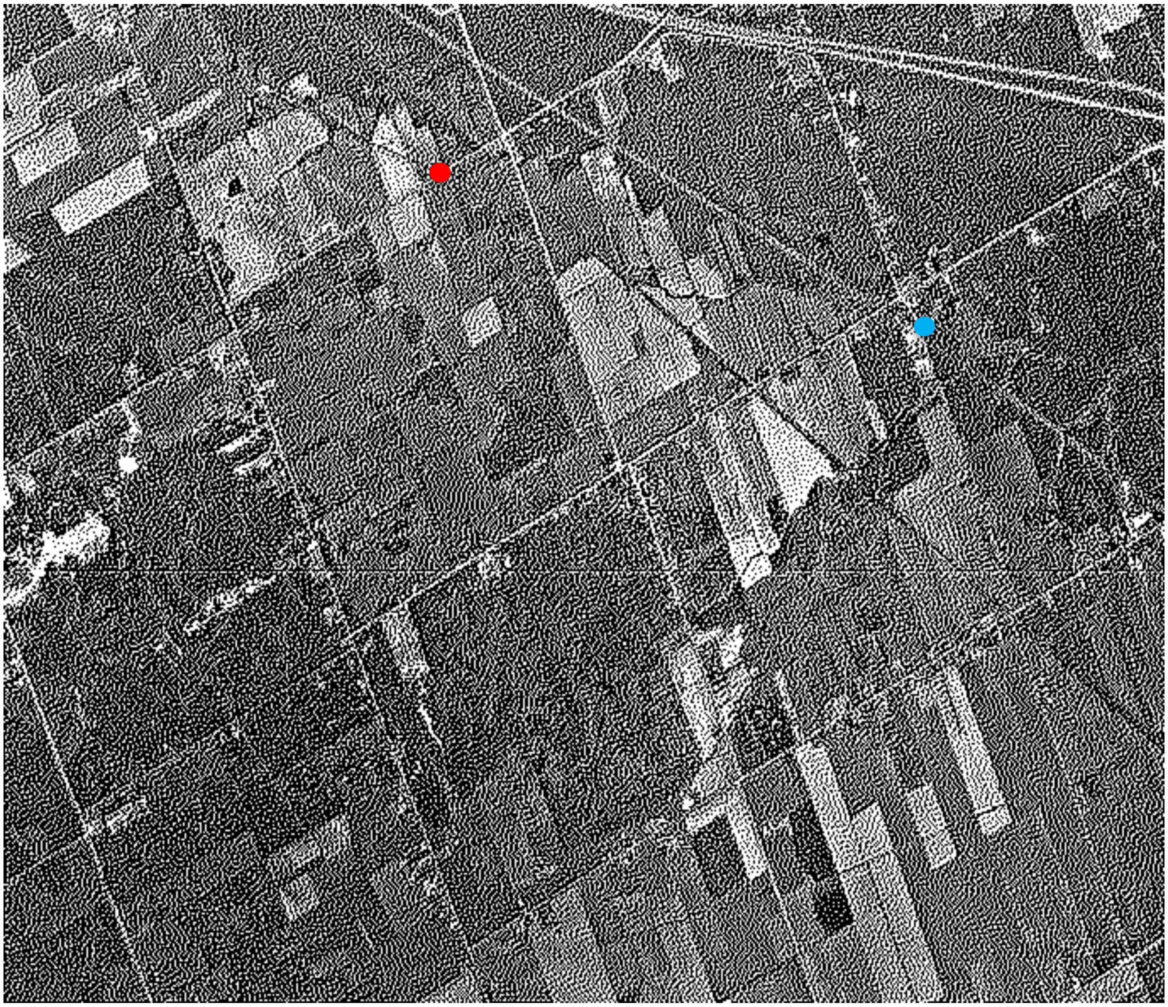
Imagery: City of Ottawa, 2019.
Watercourse: MNRF, 2020/GEO Morphix Ltd., 2022. Reach Break and ID, MBW, Confined Valley: GEO Morphix Ltd., 2022/2024.
Headwater Drainage Feature, Extent: Kilgour, 2022. 50 cm
Contour: MNRF, 2019. Study Area, Tewin Lands: Algonquins of Ontario/Taggart, 2021. PN 21063.
Print Date: October 2024. Drawn By: M.O., K.W.

Appendix C
Historical Aerial Photographs



Location: Ottawa, ON
Year: 1965
Source: GEO Ottawa
Red dot: intersection of Ramsay Creek Main Branch with Tewin Study Area Boundary
Blue dot: intersection of Bear Brook Main Branch with Tewin Study Area Boundary

Location: Ottawa, ON
Year: 1976
Source: GEO Ottawa
Red dot: intersection of Ramsay Creek Main Branch with Tewin Study Area Boundary
Blue dot: intersection of Bear Brook Main Branch with Tewin Study Area Boundary



Location: Ottawa, ON
Year: 1999
Source: GEO Ottawa
Red dot: intersection of Ramsay Creek Main Branch with Tewin Study Area Boundary
Blue dot: intersection of Bear Brook Main Branch with Tewin Study Area Boundary

Location: Ottawa, ON
Year: 2011
Source: GEO Ottawa
Red dot: intersection of Ramsay Creek Main Branch with Tewin Study Area Boundary
Blue dot: intersection of Bear Brook Main Branch with Tewin Study Area Boundary

Location: Ottawa, ON
Year: 2022
Source: GEO Ottawa
Red dot: intersection of Ramsay Creek Main Branch with Tewin Study Area Boundary
Blue dot: intersection of Bear Brook Main Branch with Tewin Study Area Boundary

Appendix D
Reach Characteristics Summary Table

Date Assessed	Reach	Bed Substrate	Bank Substrate	Evidence of Erosion	Valley Type	RGA Score	RGA Classification	RGA Limiting Factor(s)	RSAT Score	RSAT Classification	RSAT Limiting Factor(s)	Avg Bankfull Width (m)	Avg Bankfull Depth (m)	Bank Angle	Erosion Percent	Riparian Vegetation	Aquatic Vegetation	Notes
2022-06-29	**BB1**	Clay, silt, sand, gravel	Clay, silt, sand	Undercutting, bank slumping	Unconfined	0.41	In Adjustment	WI	21	Fair	Channel stability	10.63	1.97	60-90	60-100%	Trees, shrubs, grasses	Rooted submergent, rooted floating	Bank failure observed
2022-06-29	**BB2**	Clay, silt, sand, gravel	Clay, silt, sand	Undercutting, banks slumping	Unconfined	0.41	In Adjustment	WI	22	Fair	Channel stability	9.11	2.11	60-90	60-100%	Trees, shrubs, grasses	Rooted emergent, rooted floating	Many down trees, low gradient, pool-riffle formations observed, evidence of erosion
2021-11-02	**BB3**	Sand, clay	Clay, sand	Banks slumping	Unconfined	0.377	In Transition	WI	27	Good	Channel stability	8.73	1.68	60-90	5-30%	Trees, grasses	Rooted emergent	Several debris jams from beaver dams, no true riffles observed
2021-11-03	**BB3-1**	Clay, silt, sand	Clay, silt, sand	Undercutting	Confined	0.321	In Transition	WI	28	Good	Channel stability, physical instream habitat	1.20	0.29	60-90	5-30%	Trees, grasses	Rooted emergent	Valley wall contact, erosion observed along portions of the reach
2021-11-02	**BB3-2**	Silt, sand	Sand, silt	Minimal, generally stable	Confined	0.214	In Transition	PI	31	Good	Channel stability, physical instream habitat	1.07	0.17	30-60	<5%	Ttrees, grasses, shrubs	Rooted emergent	Poorly defined swale type channel near BB3 confluence
2021-11-02	**BB3-3**	Silt, sand	Clay, silt, sand	Undercutting	Confined	0.339	In Transition	DI	32	Good	Channel stability, physical instream habitat	0.97	0.34	60-90	5-30%	Trees, shrubs	Rooted emergent	More confined at DS extent, v-shaped valley
2021-11-02	**BB4**	Clay, sand	Clay, sand	Banks slumping	Unconfined	0.399	In Adjustment	WI	30	Good	Water quality	7.73	1.54	60-90	5-30%	Trees, grasses	Rooted emergent	Several debris jams from beaver dams, chutes observed, entrenched
2021-11-01	**BB4-2**	Clay, silt, sand, cobble	Silt, sand, clay	Undercutting	Unconfined	0.304	In Adjustment	DI	32	Good	Physical instream habitat, channel scouring, sediment deposition	0.87	0.30	60-90	30-60%	Trees, grasses	Rooted emergent	Evidence of groundwater inputs, undercutting common, exposed till noted, lack of clear geomorphic units
2021-11-01	**BB4-2A**	Clay, silt, sand, gravel	Silt, sand, clay	Undercutting	Unconfined	0.279	In Adjustment	DI	31	Good	Physical instream habitat, channel scouring, sediment deposition	0.77	0.31	60-90	5-30%	Trees, grasses	Rooted emergent	Exposed till noted, lack of clear geomorphic units
2021-11-01	**BB5**	Sand, clay	Clay, sand	Banks slumping	Unconfined	0.402	In Adjustment	WI	26	Good	Channel stability	6.60	1.42	60-90	5-30%	Trees, grasses	Rooted emergent	Several debris jams associated with beaver activity, entrenched, no true riffles, slumping and undercutting common
2021-11-03	**BB5-1**	Silt, clay, sand	Silt, clay, sand	Minimal, generally stable	Unconfined	0.256	In Transition	PI	34	Excellent	Physical instream habitat, channel scouring, sediment deposition	0.93	0.22	60-90	<5%	Trees, grasses	Rooted emergent	Entire reach is essentially a swale/wetland feature. Very large beaver pond in middle
2021-11-03	**BB5-1-1**	Silt, clay	Silt, clay	Fluvial entrainment	Unconfined	0.155	In Regime	PI	35	Excellent	Physical instream habitat, channel scouring, sediment deposition	1.32	0.20	0-30	<5%	Grasses, shrubs	Rooted emergent	Characteristic of an anatomosing swale, poorly defined, lack of geomorphic activity
2021-11-03	**BB5-1-2**	Silt, clay	Silt, clay	Fluvial entrainment	Unconfined	0.77	In Regime	AI	30	Good	Physical instream habitat	2.75	0.10	0-30	<5%	Grasses, shrubs	Rooted emergent	Poorly defined in sections, a saturated swale, lack of geomorphic activity
2021-11-04	**BB5-2**	Silt, clay, sand	Silt, clay	Fluvial entrainment	Confined	0.25	In Transition	AI	32	Good	Physical instream habitat	1.51	0.74	30-60	<5%	Grasses, trees	Rooted emergent	Multiple threaded channels as it enters BB5 floodplain
2021-11-03	**BB5-3**	Sand, clay	Sand, clay	Undercutting	Confined	0.201	In Transition	WI	31	Good	Channel stability, physical instream habitat	1.40	0.28	30-90	5-30%	Trees	Rooted emergent	Beaver dam and ponds present, occasional poorly defined/swale type channel
2021-11-03	**BB5-4**	Sand, clay	Sand, clay	Fluvial entrainment	Confined	0.179	In Regime	AI, PI	30	Good	Channel scouring, sediment deposition, phsyical instream habitat	1.80	0.37	30-60	5-30%	Grasses, trees	Rooted emergent	Poorly defined swale feature in upstream half of reach, only defined ~200 upstream of BB5 confluence
2021-11-01	**BB5-5**	Sand, clay	Sand, clay	Undercutting	Confined	0.333	In Transition	WI	28	Good	Channel stability	4.08	1.28	60-90	30-60%	Grasses, trees	Rooted emergent	Only accessed DS of hydrocorridor. Beaver dam at DS extent causing scour DS
2021-10-29	**BB5-5A**	N/A	Silt, clay, sand	Banks slumping	Confined	0.18	In Regime	WI	27	Good	Physical instream habitat	11.17	N/A	30-90	60-100%	Trees, grasses	Rooted emergent	Significant channel alteration and backwatering from downstream beaver dams. Observations restricted.
2021-10-29	**BB5-5A-2**	Clay, silt, sand, gravel	Clay, silt, sand	Banks slumping	Confined	0.304	In Transition	WI	20	Fair	Physical instream habitat	3.43	0.50	30-60	30-60%	Trees, grasses	Rooted emergent	Feature originates from HDF in agricultural field, unconfined at US extent, transition to partial, confined at DS extent
2021-10-27	**BB5-5A-3**	Clay, silt, sand, gravel	Clay, silt, sand	Undercutting	Confined	0.61	In Adjustment	AI	23	Fair	Channel scouring, sediment deposition	7.27	1.00	30-90	60-100%	Trees	Rooted submergent	Reach modified by previous upstream beaver dam failure, evidence of undercutting, active bed and outer bank erosion
2021-10-29	**BB5-5A-3-1**	Parent, clay, silt, sand, gravel, small cobble	Clay, silt, sand	Undercutting	Confined	0.41	In Adjustment	AI	24	Fair	Channel scouring, sediment deposition	5.00	1.53	30-90	60-100%	Trees	Rooted submergent	Upstream reach break at rail trail, large beaver pond and dam upstream of trail
2021-10-29	**BB5-5A-3-1A**	clay, silt and sand	Clay, silt, sand	Fluvial entrainment	Confined	0.085	In Regime	WI	31	Good	Riparian habitat conditions	4.73	1.41	30-60	5-30%	Trees, shrubs, grasses	Rooted emergent	Reach ends at beaver formed pond, channel appears stable, low entrenchment
2021-10-28	**BB5-5A-3A**	Clay, silt, gravel, small cobble	Clay, silt	Banks slumping	Confined	0.26	In Transition	WI	23	Fair	Riparian habitat conditions	5.60	1.55	60-90	60-100%	Trees, grasses, herbaceous	Rooted emergent	Proposed downstream reach break/split slightly downstream of BB5-5A-3A-1 confluence. Increasing sinuosity moving downstream, massive bank and valley wall failure observed.
2021-10-28	**BB5-5A-3B**	Clay, silt, sand, gravel	Clay, silt	Banks slumping	Unconfined	0.29	In Transition	WI	17	Fair	Channel stability, physical instream habitat, riparian habitat	3.50	0.93	60-90	60-100%	Grasses, herbaceous	Rooted emergent	Proposed downstream reach break/split slightly downstream of BB5-5A-3A-1 confluence. Increasing sinuosity moving downstream, massive bank and valley wall failure observed.
2021-10-28	**BB5-5A-3B-1**	Clay, silt, sand, gravel	Clay, silt, sand	Fluvial entrainment	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	2.69	0.54	30-60	<5%	Trees	Rooted emergent	Watercourse primarily dry
2021-10-28	**BB5-5A-3B-2**	Clay, silt, sand, gravel	Clay, silt	Fluvial entrainment	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	2.12	0.67	30-60	<5%	Grasses, herbaceous	Rooted emergent	Wetland at upstream extent
2021-10-28	**BB5-5A-3C**	Clay, silt, gravel	Clay, silt	Banks slumping	Unconfined	0.17	In Regime	WI	22	Fair	Riparian habitat conditions	6.25	1.88	60-90	60-100%	Grasses, herbaceous	Rooted emergent	Erosion observed intensified by beaver activity/proposed reach break to move ~200m ds to beaver dam
2021-10-28	**BB5-5A-3D**	NA	Clay, silt	Banks slumping	Unconfined	0.2	In Regime	WI	25	Good	Riparian habitat conditions	6.25	2.50	60-90	60-100%	Grasses, herbaceous, trees	Rooted emergent	Channel backwatered from downstream beaver dam, steep banks, entrenched channel. Proposed reach break to move ~200 m DS to existing beaver dam
2021-10-27	**BB5-5B**	Clay, silt	Unknown due to ponding	Banks slumping	Confined	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30-60	30-60%	Grasses, herbaceous	Rooted emergent	Feature was characteristic of a large online pond at the time of assessment. Flows are restricted through a drain at the downstream extent prior to converging with BB5-5A
2021-10-27	**BB5-5C**	Clay, silt, sand	Clay, silt	Banks slumping	Confined	0.11	In Regime	PI	24	Fair	Riparian habitat conditions	7.78	1.06	60-90	30-60%	Grasses	Rooted emergent	Wide agricultural swale, entrenched, multiple flow paths, riffle-run development, no deep pools observed,
2021-10-26	**BB5-5C-1**	Clay, silt, sand, gravel	Clay, silt, sand	Banks slumping	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	7.90	1.32	60-90	30-60%	Grasses, herbaceous	Rooted emergent	Wide agricultural swale, entrenched, modified by agricultural activities, feature 100% run.

2021-10-26	**BB5-5C-1A**	Clay, silt, sand	Clay, silt, sand	Banks slumping	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	7.80	1.29	60-90	30-60%	Grasses, herbaceous	Rooted emergent	Wide swale, entrenched, accumulation of organics, no morphological adjustment in process
2021-10-26	**BB5-5C-1A-1**	Clay, silt	Clay, silt	Fluvial entrainment	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	2.00	0.30	0-30	<5%	Grasses, trees	Rooted emergent	Ditch-like characteristics of swale, heavily modified and straightened, several footbridges across, input from numerous storm drains/culverts from residential lots
2021-10-26	**BB5-5C-1A-2**	Clay, silt	Clay, silt	Fluvial entrainment	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	4.25	0.58	0-30	<5%	Trees, shrubs, herbaceous	Rooted emergent	100% runs, agricultural swale. Poorly defined with little geomorphic activity
2021-10-26	**BB5-5D**	Clay, silt, sand	Clay, silt	Fluvial entrainment	Unconfined	0.17	In Regime	PI	30	Good	Physical instream habitat	4.86	0.84	30-60	5-30%	Trees, shrubs, herbaceous	Rooted emergent	Flows may be perennial, leaning trees and shrubs on banks, feature 100% run, some sedimentation observed, no morphological adjustment in process
2021-10-26	**BB5-5D-1**	Clay, silt	Clay, silt	Fluvial entrainment	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	4.50	0.66	0-30	<5%	Trees, shrubs, herbaceous	Rooted emergent	Poorly defined feature flows behind residentials lots.
2021-11-01	**BB6**	Sand, clay	Sand, clay	Banks slumping	Confined	0.264	In Transition	WI	22	Fair	Channel stability	4.30	1.16	60-90	30-60%	Grasses, trees	Rooted emergent	Partially confined by valley wall contact
2021-11-04	**BB7**	Likely sand, clay	Likely sand, clay	Banks slumping	Confined	0.264	In Transition	WI	25	Good	Channel stability	N/A	N/A	60-90	30-60%	Trees, grasses	Rooted emergent	Observations only completed within right of way, no reach access
	BB8	Included in mapping but not assessed; outside of Tewin Study area. Confined																
2021-10-21	**BB8-1**	Clay, silt, sand	Clay, silt	Fluvial entrainment	Confined	0.424	In Adjustment	WI	19	Fair	Channel scouring, physical instream habitat	2.53	0.85	60-90	60-100%	Trees, grasses	NA	Less confined at upstream extent, several leaning trees, significant bank erosion observed, knickpoint in reach from willow
2021-10-25	**BB9**	Clay, silt, sand, gravel	Clay, silt, sand	Banks slumping, exposed roots	Unconfined	0.311	In Transition	DI	17	Fair	Riparian habitat conditions	5.80	1.45	30-90	60-100%	Grasses, trees	Rooted emergent	Nearby beaver dam causing severe backwatering and intensifying erosion, dominated by runs
2021-10-25	**BB9-1**	Clay, silt, sand	Clay, silt, sand	None <5%	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		<5%	Herbaceous, trees	Rooted submergent	Dry at upstream extent, low flow drainage throughout downstream extent, no evidence of
2021-10-25	**BB10**	Clay, silt, sand	Clay, silt, sand	Undercutting, banks slumping, exposed roots	Unconfined	0.26	In Transition	WI	20	Fair	Riparian habitat conditions	4.80	2.85	30-90	60-100%	Grasses, herbaceous, trees	Rooted emergent	morphological adjustment observed
2021-10-25	**BB10-1**	Clay, silt, sand, gravel	Clay, silt, sand	Exposed roots, banks slumping	Unconfined	0.19	In Regime	WI	19	Fair	Riparian habitat conditions	3.53	1.25	30-90	30-60%	Grasses, herbaceous	Rooted emergent	No true riffles observed, high valley wall above stream banks, leaning trees, bank slumping and exposed tree roots observed, enlarging observed
2021-10-21	**BB10-1A**	Clay, silt, till	Clay, silt	Banks slumping	Unconfined	0.233	In Transition	DI	27	Good	Riparian habitat conditions, channel stability	1.41	0.33	30-60	5-30%	Grasses	Rooted emergent	Downstream of golf course, J shaped trunks, no true riffles observed, reach dominated by runs, channel entrenched
2021-10-21	**BB10-1B**	Clay, silt	Clay, silt	Banks slumping	Unconfined	0.18	In Regime	AI	23	Fair	Riparian habitat conditions	1.60	0.35	30-60	<5%	Grasses	Attached algae, rooted emergent	Straight ditch, all runs observed, algae and few cattails present, minor slumping observed, little geomorphic activity overall
2021-10-11	**BB11**	Clay, Silt, Till	Clay, Silt, till	Banks slumping	Unconfined	0.23	In Transition	DI	27	Good	Riaprain habitat conditions	1.40	0.32	30-60	5-30%	Grasses, few trees	Rooted emergent	Little geomrophic activity
2021-10-25	**BB12**	Clay, silt, sand, gravel, small cobble	Clay, silt, sand	Banks slumping	Unconfined	0.29	In Transition	AI, WI	21	Fair	Riparian habitat conditions	4.23	1.36	60-90	30-60%	Grasses, herbaceous	Rooted emergent	Culvert at Anderson Rd. 3.8 diameter
2021-10-28	**BB12-1**	Clay, silt	Clay, silt, till	Banks slumping	Confined	0.103	In Regime	AI, DI	23	Fair	Riparian habitat conditions, physical instream habitat	1.49	0.36	60-90	5-30%	Grasses, trees	Rooted emergent	Roadside ditch, nearly uniform channel geometry throughout, some undercutting and exposed till noted
2021-10-20	**BB13**	Clay, silt	Clay, silt	Banks slumping	Unconfined	0.21	In Transition	AI, WI	25	Good	Channel stability	1.60	0.35	30-60	<5%	Grasses	Attached algae, rooted emergent	Somewhat naturalized ditched agricultural channel, partially straightened, slumping common, several vegetated islands observed
2021-10-20	**BB14**	Clay, silt, sand	Clay, silt, sand	Banks slumping	Unconfined	0.32	In Transition	WI	23	Fair	Channel stability	3.60	0.88	60-90	60-100%	Grasses, shrubs	Rooted emergent	Straight ditched channel, recovering planform
2021-10-20	**BB15**	Clay, silt	Clay, silt	Banks slumping	Unconfined	0.19	In Regime	AI	24	Fair	Channel stability, phsyical instream habitat	4.80	1.68	30-60	5-30%	Grasses	Rooted emergent	Heavy backwatering from large beaver dam
2021-10-20	**BB16**	Clay, silt, gravel	Clay, silt	Banks slumping	Unconfined	0.29	In Transition	WI	22	Fair	Channel stability	4.17	1.23	60-90	60-100%	Grasses	Rooted emergent	Straight ditched channel, recovering planform
2022-06-28	**RC1**	Clay, silt, sand, gravel, cobble	Clay, silt, sand	Undercutting, banks slumping	Unconfined	0.28	In Transition	WI	16	Fair	Riparian habitat conditions, channel stability	2.17	2.08	60-90	60-100%	Grasses	Rooted floating	Heavy vegetation encroachment
2022-06-28	**RC2**	Clay, silt, sand, gravel, cobble	Clay, silt, sand	Undercutting, slab failure, rotational slip and slump	Unconfined	0.38	In Transition	WI	15	Fair	Riparian habitat conditions, channel stability	7.09	1.45	60-90	60-100%	Grasses	Rooted floating	Entrenched channel, high banks with tall grasses
2022-06-28	**RC3**	Clay, silt, gravel, sand, cobble	Clay, silt, parent	Fluvial entrainment	Unconfined	0.4	In Transition	PI	20	Fair	Channel stability	N/A	1.78	60-90	5-30%	Grasses, trees	Rooted floating	Heavy vegetation encroachment
2022-06-28	**RC4**	Clay, silt, sand	Clay, silt, sand, gravel	Fluvial entrainment	Unconfined	0.34	In Transition	WI	26	Good	Phsycial instream habitat, water quality	N/A	1.78	30-60	5-30%	Shrubs	Rooted floating	Heavy vegetation encroachment
2022-06-28	**RC4-1-1**	Clay, silt	Clay, silt	Fluvial entrainment	Unconfined	0.179	In Regime	WI, AI	19	Fair	Phsycial instream habitat, water quality	3.83	2.20	60-90	<5%	Grasses	Rooted emergent	Straight shot agriculture ditch
2021-10-19	**RC4-1-1A**	Clay, silt	Clay, silt	Minor slumping <5%	Unconfined	0.129	In Regime	WI	28	Good	Phsycial instream habitat, water quality	4.80	0.74	30-60	<5%	Trees, grasses	Rooted emergent	Straight agricultural ditch
2021-10-20	**RC5-1A-1A**	Assessed as a part of **RC-1-1A-1**																
2021-10-20	**RC4-1-1A-1**	Clay, silt, sand	Clay, silt, sand	Falling/sloughing	Unconfined	0.098	In Regime	WI	25	Good	Phsycial instream habitat, water quality	5.35	0.95	0-30	<5%	Trees, grasses	Rooted emergent	Straight agricultural ditch, beaver dams retaining water, no flow observed, minor slumping observed, minimal geomorphic activity
2021-10-19	**RC4-1-1A-2**	Clay, silt	Clay, silt	Undercutting, banks slumping <5%	Unconfined	0.098	In Regime	WI	26	Good	Phsycial instream habitat, water quality	4.98	0.83	30-60	<5%	Trees	Rooted emergent	Former agricultural ditch, no flow observed, trees growing on channel bed, mostly stable
2021-10-20	**RC4-1-1A-3**	Assessed as a part of **RC4-1-1A-1**																
2021-10-19	**RC5**	Clay, silt	Clay, silt, sand	None <5%	Unconfined	0.098	In Regime	WI	30	Good	Physical instream habitat	5.18	0.69	0-30	<5%	Trees, herbaceous, grasses	Rooted emergent	Shallow pooled water but no flow observed, grasses and wetland species observed growing on semi-dry bed, minimal geomorphic activity
2022-07-13	**RC5-1**	N/A	Clay, silt, sand	N/A	Unconfined	0.04	In Regime	PI	19	Fair	Riparian habitat conditions, water quality, physical instream habitat	4.77	1.03	0-30	<5%	Grasses, trees	Rooted emergent	Straight agricultural ditch
2022-07-13	**RC5-2**	Poorly defined feature, no observations																
2022-07-14	**RC5-1-1**	N/A	Sand	N/A	Unconfined	0.04	In Regime	PI	19	Fair	Phsycial instream habitat, water quality	3.93	0.73	60-90	<5%	Grasses	Rooted emergent	Straight agricultural ditch, extreme vegetation encroachment
2022-07-15	**RC5-1-2**	N/A	Clay, silt, sand	N/A	Unconfined	0.04	In Regime	PI	19	Fair	Riparian habitat conditions, water quality, physical instream habitat	2.68	0.52	60-90	<5%	Grasses	Rooted emergent	Straight agricultural ditch, extreme vegetation encroachment
2022-07-15	**RC5-1-3**	Clay, silt	Clay, silt	N/A	Unconfined	N/A	N/A	N/A	N/A	N/A	N/A	2.30	1.95	60-90	<5%	Grasses	Rooted Emergent	Straight agricultural ditch, extreme vegetation encroachment
2023-12-12	**RCA**	Clay/Silt-Boulder	Clay/Silt	Banks slumping, exposed roots, undercutting	Unconfined	0.3	In Transition	WI	20	Fair	Riparian Habitat Conditions	5.60	1.77	60-90	60-100%	Grasses	Rooted emergent	Pool-riffle formations, scour on both banks

2023-12-12	**RCB**	Clay, silt, sand	Clay, silt, sand	Banks slumping, fracture lines, exposed roots	Unconfined	0.43	In Transition	WI	18	Fair	Riparian Habitat Conditions	8.20	1.88	60-90	60-100%	Grasses	Rooted Emergent	Large cutfaces along several locations, many slumps and fractures

Appendix E
Photographic Record

Photo 1 Bear Brook: BB1	
	The feature was well defined with multiple large woody debris jams and fallen trees in the channel, most likely due to a recent storm. Riparian vegetation composed of mature hardwoods and shrubs.
Photo 2 Bear Brook: BB2	
	The feature was well defined with riparian vegetation consisting of ferns, grasses, and mature hardwoods. Instream vegetation was common.

Photo 3
Bear Brook: BB3

The feature channel contained several debris jams associated with old beaver dams. Riparian vegetation consisted of mature trees.

Photo 4
Bear Brook: BB3-1

The feature was defined with multiple culverts throughout the reach. Riparian vegetation consisted of grasses and small hardwoods.

Photo 5
Bear Brook: BB3-2

Feature lacked definition and was dry in some areas. Riparian vegetation consisted of grasses and hardwoods.

Photo 6
Bear Brook: BB3-3

Feature was narrow and defined with riparian vegetation consisting of grasses and immature hardwoods.

Photo 7
Bear Brook: BB4

Riparian vegetation consisted of grasses and hardwoods; several debris jams associated with beaver dam.

Photo 8
Bear Brook: BB4-2

Channel was well defined. Undercutting was common and riparian vegetation consisted of grasses and hardwoods.

Photo 9 Bear Brook: BB4-2A	
	Channel flows through unconfined valley. Riparian vegetation consisted primarily of mature hardwoods and immature grasses.
Photo 10 Bear Brook: BB5	
	The feature was well defined, and several debris jams were present. Undercutting and slumping was common.

Photo 11
Bear Brook: BB5-1

Feature was poorly defined with riparian vegetation consisting of grasses and shrubs.

Photo 12
Bear Brook: BB5-1-1

Channel was poorly defined, riparian vegetation primarily mature shrubs and immature grasses.

Photo 13
Bear Brook: BB5-1-2

Channel was poorly defined; water was present in the channel however no flows were observed. Riparian vegetation was primarily mature shrubs and immature grasses.

Photo 14
Bear Brook: BB5-2

Channel develops multiple threads as it enters the main branch **BB5** floodplain. Riparian vegetation consists of mature hardwoods and immature grasses.

Photo 15 Bear Brook: BB5-3	
	Channel had poor definition and several beaver dams were present. Cattails and grasses where present in the channel adjacent to beaver dams.
Photo 16 Bear Brook: BB5-4	
	Channel was a poorly defined swale, with mature trees and immature grasses in the riparian zone.

Photo 17
Bear Brook: BB5-5

The featured conveyed flows through a woodlot, riparian vegetation consisted of mature trees. Slumping, undercutting and scour common.

Photo: 18
Bear Brook: BB5-5A

The featured lacked definition due to backwater from an upstream beaver dam. Riparian vegetation consisted of mature trees.

Photo: 19 Bear Brook: BB5-5A-3	
	
	Woody debris jams present, bank angle 5-30% through mid to upstream extend, erosion predominant at downstream extent
	
	Reach modified by historic beaver dam, undercutting, active bed and banks observed

Photo: 20 **Bear Brook: BB5-5A-3-1**	 Feature characteristic of a large pond due to back watering from a beaver dam.
Photo: 21 **Bear Brook: BB5-5A-3-1A**	 Riparian vegetation consisting of grasses and shrubs, low entrenchment identified.

Photo: 22 Bear Brook: BB5-5A-3A	
	Reach backwatered due to large downstream beaver dam, instream logs and trees observed due to bank failure.
Photo: 23 Bear Brook; BB5-5A-3B	
	Conveyed flows through entrenched channel with large banks. Riparian vegetation consisting of grasses and hardwoods.

Photo: 24 **Bear Brook: BB5-5A-3B-1**	 	
	The feature was primarily dry during visit, and channel lacked definition. Flows conveyed through a woodlot.	
Photo 25 **Bear Brook: BB5-5A-3B-2**	 	
	The feature conveyed flows through an online wetland and lacked bank definition.	

Photo 26 **Bear Brook: BB5-5A-3C**	
	Evidence of enlarging, erosion and minor adjustment may be related to beaver activity
Photo 27 **Bear Brook: BB5-5A-3D**	
	Channel backwatered from downstream beaver dam, high water levels, reach may have riffle-pool development under in absence of backwater conditions

Photo 28
Bear Brook: BB5-5B

Feature was characteristic of a large online pond at the time of assessment. Flows are restricted through a drain at the downstream extent prior to converging with **BB5-5A**

Photo 29
Bear Brook: BB5-5C

Feature was characteristics of a large agricultural swale with multiple flow paths along the reach.

Photo 30 Bear Brook: BB5-5C-1	 Feature was characteristic of a large agricultural swale along the reach and was modified due to agricultural activities. Lacked defined banks and flow paths along the reach.
Photo 31 Bear Brook: BB5-5C-1A	 The reach was characteristic of a large swale, with accumulation of organics in the channel. Riparian vegetation consisted of grasses and shrubs.

Photo 32 **Bear Brook: BB5-5C-1A-1**	 The feature was ditch-like with many foot bridge crossings. The channel appeared to be straightened and received flows from several storm drains/culverts connected to residential homes
Photo 33 **Bear Brook: BB5-5C-1A-2**	 100% runs, agricultural swale. Poorly defined with little geomorphic activity

Photo 34 Bear Brook: BB5-5D	
	The feature showed signs of perennial flows, riparian vegetation consisted of trees and shrubs.
Photo 35 Bear Brook: BB5-5D-1	
	Poorly defined feature travelling behind residential lots. Trees and shrubs were found in the channel and herbaceous materials on the banks.

Photo 36 Bear Brook: BB6	
	The feature was well defined, slumping and undercutting was common. Riparian vegetation composed of grasses.
Photo 37 Bear Brook: BB7	
	Limited channel access. Reach appeared to have some undercutting and riparian vegetation consisted primarily of hardwoods.

Photo 38 Bear Brook: BB8-1	
	Channel travels through partially confined valley. Leaning trees and erosion was common throughout the reach.
Photo 41 Bear Brook: BB9	
	The feature was backwatered due to an upstream beaver dam. Riparian vegetation was composed of grasses. The feature runs parallel to agricultural fields.

Photo 42 Bear Brook: BB9-1	 The feature was poorly defined and lacking banks. Feature runs through an agricultural field.
Photo 43 Bear Brook: BB10	 The feature was located downstream from a golf course. Channel was well defined and entrenched.

Photo 44 **Bear Brook: BB10-1**	 The feature was well defined, and conveyed flows through an agricultural field and the southeastern corner of a golf course.
Photo 45 **Bear Brook: BB10-1A**	 Narrow channel conveying flows through an active golf course. Riparian vegetation primarily landscaped grass.

Photo 46 Bear Brook: BB10-1B		
	Reach identified as a straight ditch with little geomorphologic activity. Some minor slumping observed. Riparian vegetation consisted primarily of grasses.	
Photo 47 Bear Brook: BB11		
	Reach was a straight ditch with limited geomorphic activity.	

Photo 48 Bear Brook: BB12	 Conveyed flows tranverse through grassland. Channel was defined and riparian vegetation consisted of grasses.
Photo 49 Bear Brook: BB12-1	 Channel identified as a roadside ditch with near uniform channel geometry. Riparian vegetation consisted of grasses and hardwoods.

Photo 50 Bear Brook: BB13	 Partially straightened throughout the reach. Slumping and vegetated islands common along the reach. Riparian vegetation was primarily grasses.
Photo 51 Bear Brook: BB14	 Channel was observed as a straight ditch. Riparian vegetation primarily grasses.

Photo 52
Bear Brook: BB15

Straight ditched channel with mostly runs. Riparian vegetation was primarily grasses.

Photo 53
Bear Brook:BB16

Straight ditched channel with mostly runs. Riparian vegetation was primarily grasses.

Photo 54 **Ramsay Creek: RC1**	
	Conveyed flows through large grassland. Channel entrenchment and bank slumping were evident. The yellow arrow indicates the direction of flow where possible
Photo 55 **Ramsay Creek: RC2**	
	Channel was entrenched. Riparian zone consisted primarily of tall grasses. Bank slumping was evident.

Photo 56 **Ramsay Creek: RC3**	 Conveyed flows through entrenched channel. Many downed trees due to recent storm.
Photo 57 **Ramsay Creek: RC4**	 Conveyed flows through a straigtened channel, travelling though active agricultural fields.

Photo 58 Ramsay Creek: RC4-1-1	
	Straight agricultural ditch, riparian zone consisting of grasses. Situated between agitucltral fields
Photo 59 Ramsay Creek: RC4-1-1A	
	The above feature was a defined, straight channel with beaver dams retaining water along the reach. Runs parallel to woodlot.

Photo 60
Ramsay Creek: RC4-1-1A-1

Former agricultural ditch with no flows at the time of visit.

Photo 61
Ramsay Creek: RC4-1-1A-1A

Small poorly defined feature. Photo taken during spring 2022 HDFA assessments.

Photo 62 **Ramsay Creek: Rc4-1-1A-2**	
	The above feature lacked defined banks and ran through a woodlot. Channel was saturated during visit.
Photo 63 **Ramsay Creek: Rc4-1-1A-3**	
	Former agricultural ditch, no flow observed, trees growing on channel bed, mostly stable

Photo 64 Ramsay Creek: RC5	 Channel lacked defined banks; water was shallow/absent during visit.
Photo 65 Ramsay Creek: RC5-1	 Agricultural swale, vegetation encroachment was heavy. Channel was dry.

Photo 66 **Ramsay Creek: RC5-1-1**	 Agricultural ditch, some water present. Riparian vegetation primarily grasses.
Photo 67 **Ramsay Creek: RC5-1-2**	 Agricultural ditch, some water present. Riparian vegetation primarily grasses.

Photo 68 Ramsay Creek: RC5-1-3	
	Straightened agricultural ditch. Little water was in the feature at the time of the assessment. Vegetation encroachment was heavy.
Photo 69 Ramsay Creek: RCA	
	Channel flowed adjacent to a road. Riffle-pool formations were observed. Channel bed composed of fines up to cobbles. Erosion was observed,

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Photo 70 Ramsay Creek: RCB	 Channel meandered through agricultural fields. No riffle-pool formations. Slumping and undercutting was common.
Photo 71 Ramsay Creek: RCC	 Channel meandered through agricultural fields. Signs of enlarging observed. Riparian vegetation was predominantly grasses and herbaceous vegetation.

Photo 72 **Ramsay Creek: RCD**	
	Channel transitions to a woody riparian edge. No riffle-pool formations observed. Slumping and scour observed.
Photo 73 **Ramsay Creek: RCE**	
	Channel meanders through historic farm fields. Several tall scours were observed along the length of the channel. Riparian vegetation predominantly grasses and herbaceous vegetation.

Photo 74 Ramsay Creek: RCF	 The channel passes under highway 417 twice along the reach. Channel banks were well vegetated and generally stable.
Photo 75 Ramsay Creek: RCG	 Channel meanders through a forested valley setting. Valley wall contacts and evidence of widening observed. Riparian vegetation composed of trees and herbaceous vegetation.

Appendix F
Detailed Assessment Summaries

Detailed Geomorphological Assessment Summary

Reach BB1

Project Number:	PN22024	**Date:**	2022-07-14
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	112.5
Location:	Tewin Lands	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area (km^2):	53.8	**Dominant Riparian Vegetation Type:**	Grasses, Trees
Geology/Soils:	Offshore glaciomarine deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Agricultural, Forest	**Width of Riparian Cover:**	>10 (channel widths)
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Mature (>30 yrs)
Dominant Instream Vegetation Type:	Floating, Emergent	**Extent of Encroachment into Channel:**	None
Portion of Reach with Vegetation:	70%	**Density of Woody Debris:**	High

Hydrology

Measured Discharge (m^3/s):	N/A	**Calculated Bankfull Discharge (m^3/s):**	4.88
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.42
Modelled 2-year Velocity (m/s):	Not modelled		

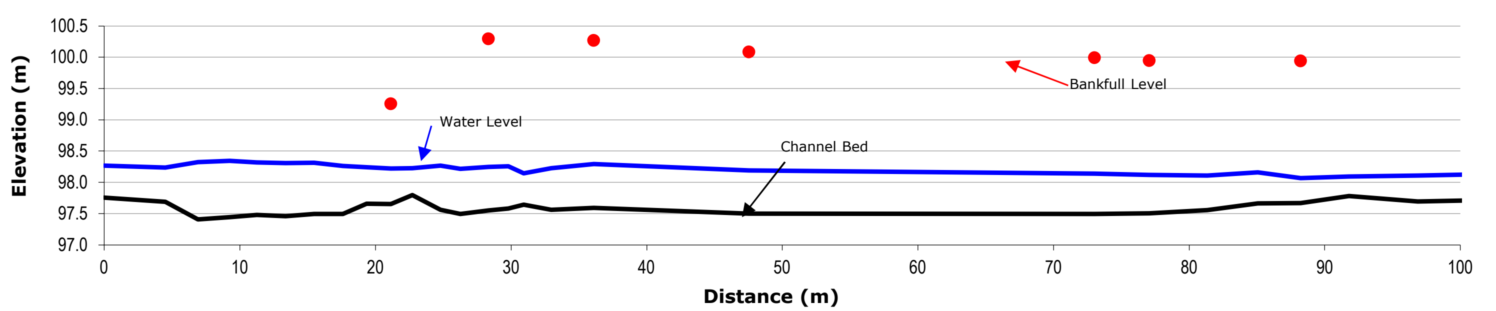
Profile Characteristics

Bankfull Gradient (%):	0.03
Channel Bed Gradient (%):	0.04
Riffle Gradient (%):	1.98
Riffle Length (m):	11.52
Riffle-Pool Spacing (m):	34.59

Planform Characteristics

Sinuosity:	3.84
Meander Belt Width (m):	N/A
Radius of Curvature (m):	25
Meander Amplitude (m):	70
Meander wavelength (m):	85

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	1.50	2.90	2.18
Bank Angle (deg):	45	90	73
Root Depth (m):	0.15	0.40	0.26
Root Density (%):	20	50	39
Bank Undercut (m):	0.02	0.35	0.17

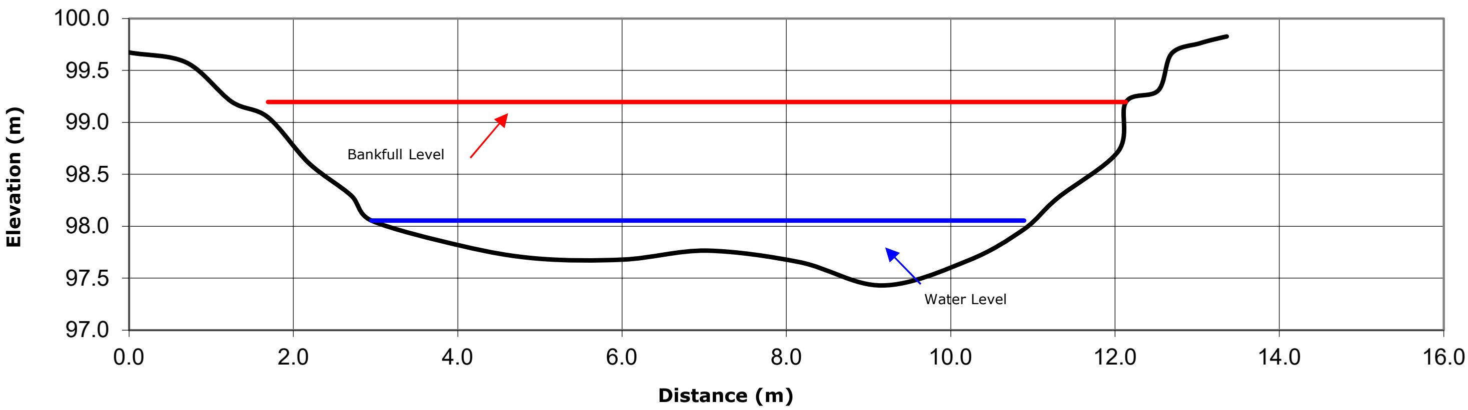
Bank Material (range): Silt-Clay

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	5.61	12.50	9.63
Average Bankfull Depth (m):	0.94	1.76	1.22
Bankfull Width/Depth (m/m):	6	10	8
Wetted Width (m):	4.78	7.94	6.15
Average Water Depth (m):	0.20	0.41	0.33
Wetted Width/Depth (m/m):	14	31	19
Entrenchment Ratio (m/m):		Low (>2.2)	
Maximum Water Depth (m):	0.43	0.72	0.60
Manning's *n*:		0.055	

Photograph at cross section 1 (looking downstream)

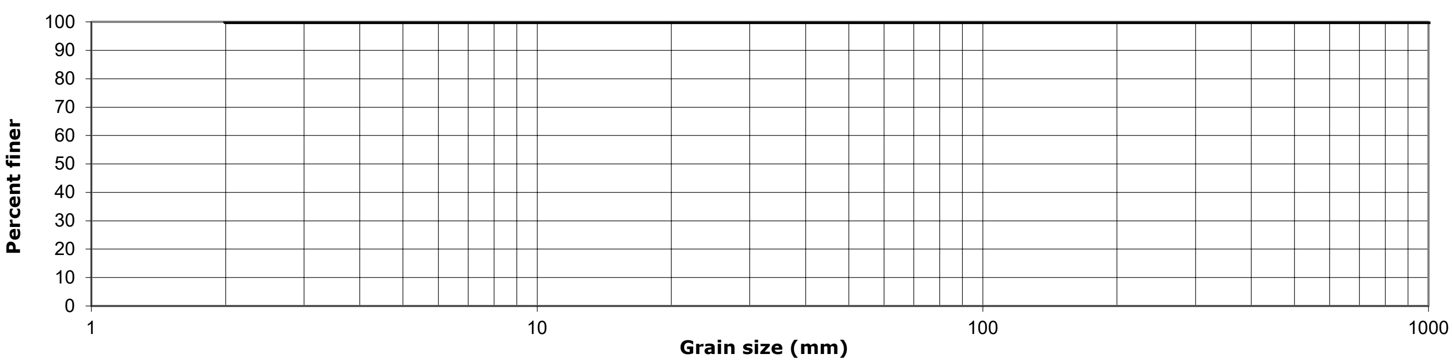
Representative Cross-Section 1



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Clay
D_{10} :	2.0	**Particle shape:**	N/A (Clay/sand)
D_{50} :	2.0	**Embeddedness (%):**	N/A (Clay/sand)
D_{84} :	2.0	**Particle range (riffle):**	Clay-Sand
		Particle Range (pool):	Clay-Sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tactive Force at Bankfull (N/m^2):**	4.79
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	1.99		

General Field Observations

Channel Description

Reach BB1 is a low gradient channel that passes through an unconfined valley. Riparian vegetation was characterized by grasses and some mature trees. Rooted submergent and emmergent vegetation was common along the reach, however vegetation encroachment was minimal. Substrate consisted of clay to sand in both the pools and the riffles. Average bankfull width and depth were 9.63 m and 1.22 m, respectivly. Some undercutting was observed, up to 0.35 m and bank slumping was present.

Cross Section 4 - Facing Downstream

Detailed Geomorphological Assessment Summary

Reach BB5

Project Number:	PN21063	**Date:**	2021/11/11
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	183.6
Location:	Tewin Lands Ottawa	**# of Cross-Sections:**	10

Reach Characteristics

Drainage Area (km^2):	31.7	**Dominant Riparian Vegetation Type:**	Grass/Herbaceous Veg.
Geology/Soils:	Offshore glaciomarine deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Grassland/Forest	**Width of Riparian Cover:**	>10 Channel Widths
Valley Type:	Partially Confined	**Age Class of Riparian Vegetation:**	Established
Dominant Instream Vegetation Type:	None observed	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	N/A	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.21	**Calculated Bankfull Discharge (m^3/s):**	3.20
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.66
Modelled 2-year Velocity (m/s):	Not modelled		

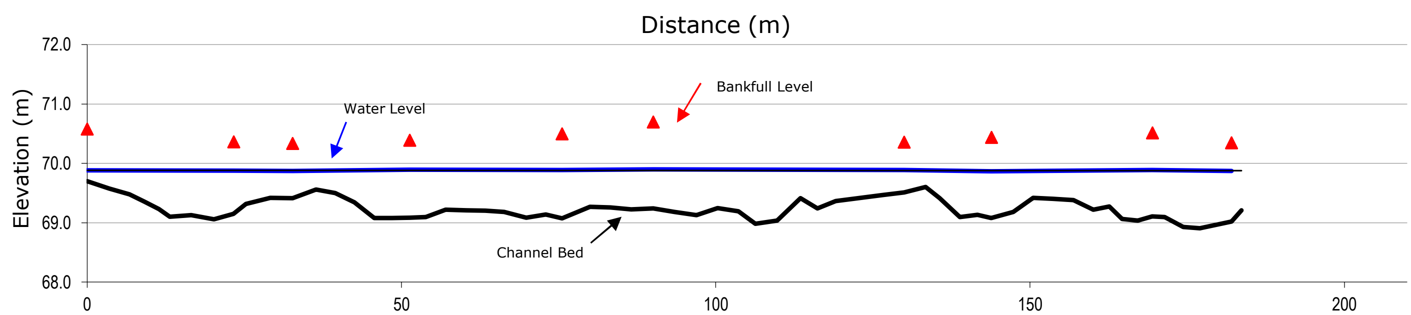
Profile Characteristics

Bankfull Gradient (%):	0.02
Channel Bed Gradient (%):	0.09
Riffle Gradient (%):	1.27
Riffle Length (m):	17.83
Riffle-Pool Spacing (m):	26.64

Planform Characteristics

Sinuosity:	1.21
Meander Belt Width (m):	N/A
Radius of Curvature (m):	15
Meander Amplitude (m):	30
Meander wavelength (m):	45

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	2.25	3.85	3.00
Bank Angle (deg):	55	85	70
Root Depth (m):	0.20	0.30	0.23
Root Density (%):	20	80	73
Bank Undercut (m):	0.00	0.12	0.02

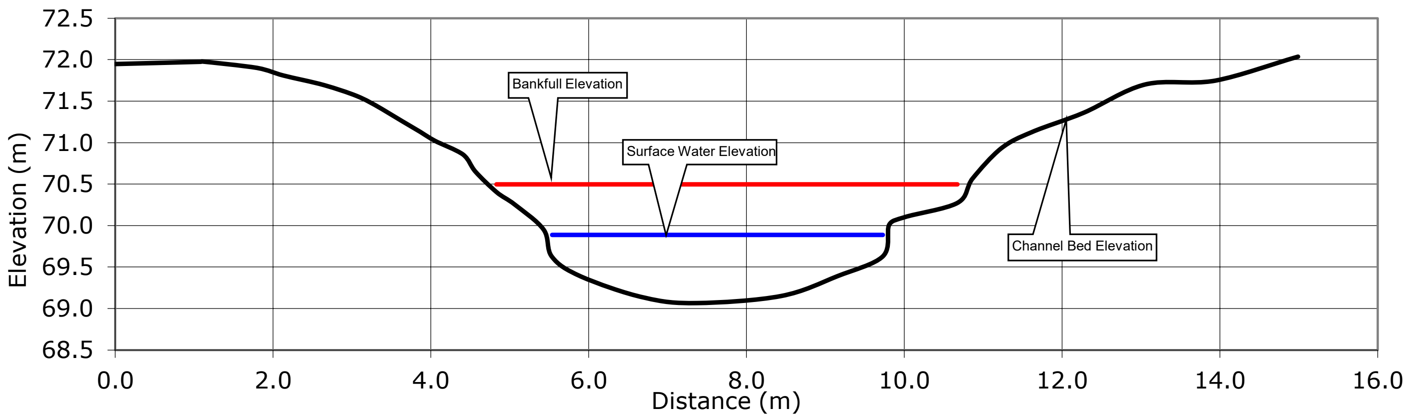
Bank Material (range): Clay-Sand

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	5.10	7.38	5.97
Average Bankfull Depth (m):	0.57	1.06	0.82
Bankfull Width/Depth (m/m):	5	13	8
Wetted Width (m):	3.61	5.61	4.39
Average Water Depth (m):	0.22	0.55	0.41
Wetted Width/Depth (m/m):	7	18	12
Entrenchment Ratio (m/m):		Low (>2.2)	
Maximum Water Depth (m):	0.37	0.96	0.68
Manning's *n* :		0.040	

Photograph at cross section 7 (looking downstream)

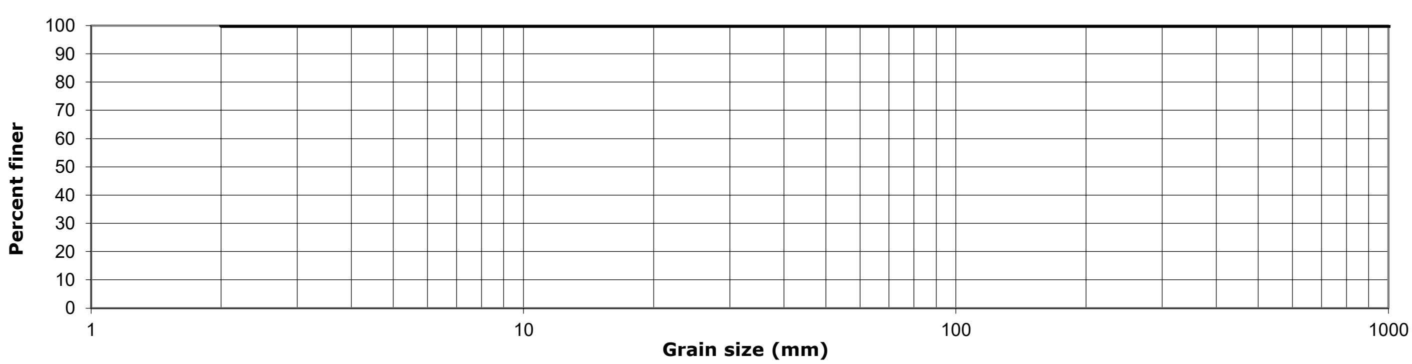
Representative Cross-Section #6



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Till
D_{10} :	2.0	**Particle shape:**	N/A
D_{50} :	2.0	**Embeddedness (%):**	N/A
D_{84} :	2.0	**Particle range (riffle):**	Clay-Sand
		Particle Range (pool):	Clay-Sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	7.22
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	4.73		

General Field Observations

Channel Description

Reach BB5 was a low gradient, meandering channel that passed through a partially confined valley. Riparian vegetation was characterized by grasses in the floodplain and on the valley slopes. There was minimal encrochment of vegetation to the channel and some reeds were found in th channel. Substrate consisted of clay to Sand in riffles and pools. Average bankfull width and depth were 5.97 m and 0.82 m, repsectively. Undercutting was minimal and was measured up to a maximum of 0.12 m.

Cross Section 3 - Facing Upstream

Detailed Geomorphological Assessment Summary

Reach BB5-5

Project Number:	PN21063	**Date:**	2021-11-08
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	201.6
Location:	Tewin Lands, Ottawa	**# of Cross-Sections:**	10

Reach Characteristics

Drainage Area (km^2):	31.7	**Dominant Riparian Vegetation Type:**	Grass/Herbaceous/Trees
Geology/Soils:	Nearshore + offshore glaciomarine deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest/Grassland	**Width of Riparian Cover:**	>10 Channel Widths
Valley Type:	Partially Confined	**Age Class of Riparian Vegetation:**	Established (5-30 Years)
Dominant Instream Vegetation Type:	Reeds	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	5%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.11	**Calculated Bankfull Discharge (m^3/s):**	1.99
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.78
Modelled 2-year Velocity (m/s):	Not modelled		

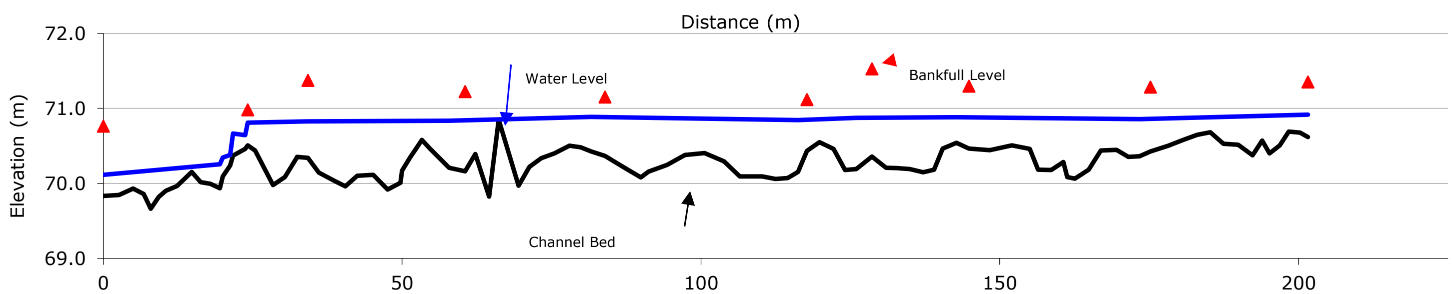
Profile Characteristics

Bankfull Gradient (%):	0.20
Channel Bed Gradient (%):	0.22
Riffle Gradient (%):	1.04
Riffle Length (m):	11.34
Riffle-Pool Spacing (m):	14.28

Planform Characteristics

Sinuosity:	1.29
Meander Belt Width (m):	N/A
Radius of Curvature (m):	7
Meander Amplitude (m):	20
Meander wavelength (m):	30

Longitudinal Profile



Bank Characteristics

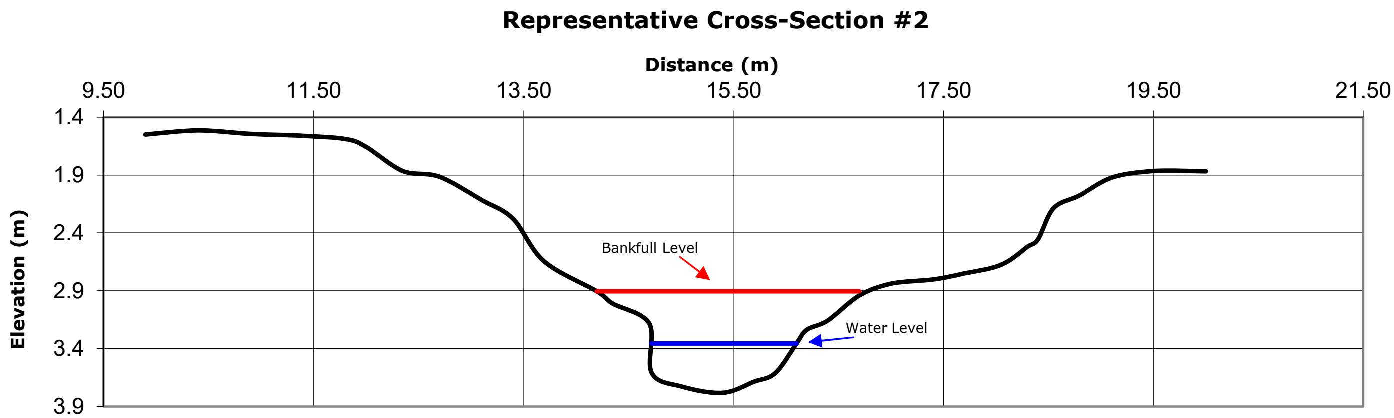
	Minimum	Maximum	Average
Bank Height (m):	1.52	2.70	2.14
Bank Angle (deg):	30	85	64
Root Depth (m):	0.20	0.50	0.22
Root Density (%):	25	70	45
Bank Undercut (m):	0	0.45	0.07

Bank Material (range): Clay-Sand

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	2.50	6.40	4.34
Average Bankfull Depth (m):	0.43	0.72	0.59
Bankfull Width/Depth (m/m):	5	14	8
Wetted Width (m):	1.20	3.20	2.25
Average Water Depth (m):	0.11	0.41	0.28
Wetted Width/Depth (m/m):	5	16	9
Entrenchment Ratio (m/m):		Low (>2.2)	
Maximum Water Depth (m):	0.21	0.69	0.47
Manning's *n* :		0.040	

Photograph at cross section 2 (looking downstream)

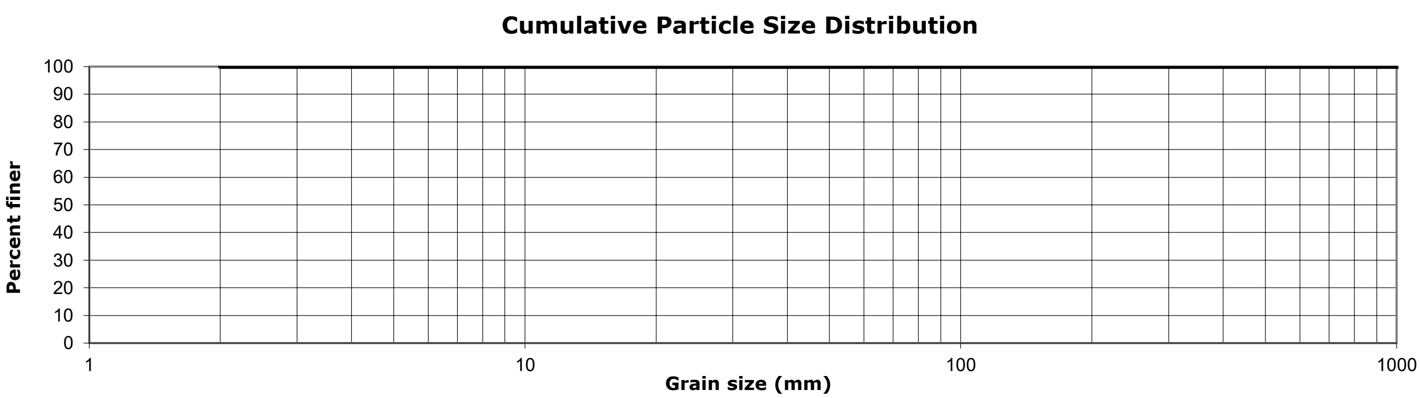


Substrate Characteristics

Particle Size (mm)

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

Subpavement:	Till
Particle shape:	N/A (sands)
Embeddedness (%):	0
Particle range (riffle):	Clay-Sand
Particle Range (pool):	Clay-Sand



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	11.51
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	9.01		

General Field Observations

Channel Description

Reach BB5-5 was a minimal gradient, meandering channel that passed through a partially confined valley. Riparian vegetation was characterized by grasses in the floodplain and on the valley slopes. There was minimal encrochment of vegetation to the channel and some reeds were found in th channel. Substrate consisted of clay to sand in riffles and pools. Average bankfull width and depth were 4.34m and 0.59 m, repsectively. Undercutting frequency was minimal and was measured up to a maximum of 0.45 m.

Detailed Geomorphological Assessment Summary

Reach BB5-5A-3

Project Number:	PN21063	**Date:**	2021/11/11
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	99.6
Location:	Tewin Lands, Ottawa	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area (km^2):	6.8	**Dominant Riparian Vegetation Type:**	Treed and Herbaceous
Geology/Soils:	ore glaciomarine deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest	**Width of Riparian Cover:**	>10 Channel Widths
Valley Type:	Partially Confined	**Age Class of Riparian Vegetation:**	Established (5-30 yrs)
Dominant Instream Vegetation Type:	None present	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	0%	**Density of Woody Debris:**	Moderate

Hydrology

Measured Discharge (m^3/s):	0.08	**Calculated Bankfull Discharge (m^3/s):**	2.23
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.97
Modelled 2-year Velocity (m/s):	Not modelled		

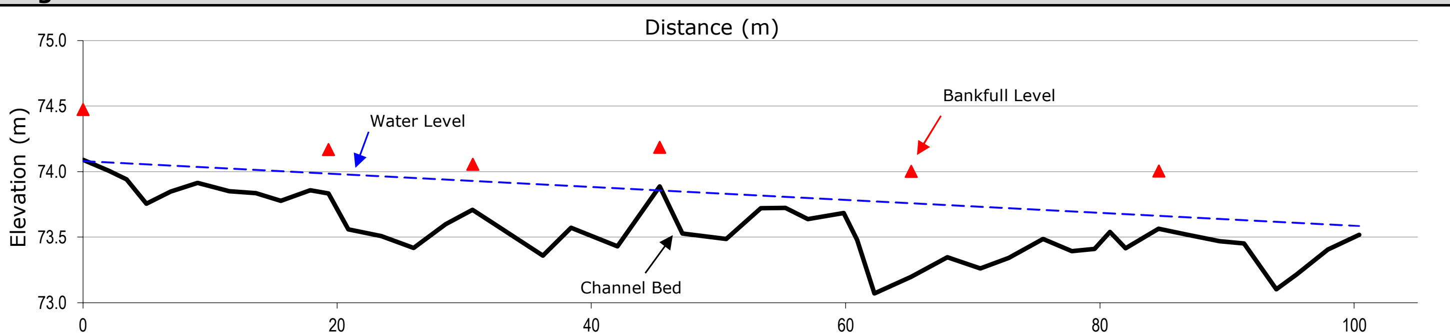
Profile Characteristics

Bankfull Gradient (%):	0.47
Channel Bed Gradient (%):	0.56
Riffle Gradient (%):	1.87
Riffle Length (m):	9.20
Riffle-Pool Spacing (m):	11.40

Planform Characteristics

Sinuosity:	1.82
Meander Belt Width (m):	N/A
Radius of Curvature (m):	10
Meander Amplitude (m):	20
Meander wavelength (m):	30

Longitudinal Profile



Bank Characteristics

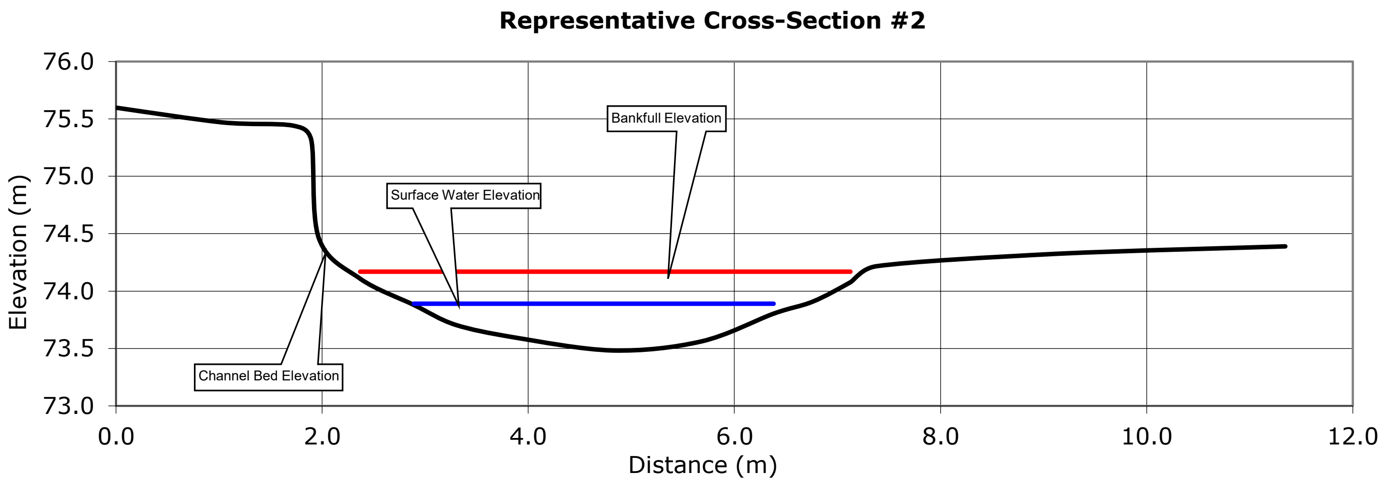
	Minimum	Maximum	Average
Bank Height (m):	0.41	3.90	1.48
Bank Angle (deg):	20	90	54
Root Depth (m):	0.10	0.90	0.35
Root Density (%):	10	80	47
Bank Undercut (m):	0.00	0.93	0.16

Bank Material (range): Clay-Sand

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.06	12.93	6.22
Average Bankfull Depth (m):	0.25	0.51	0.37
Bankfull Width/Depth (m/m):	10	52	19
Wetted Width (m):	1.55	6.81	3.72
Average Water Depth (m):	0.06	0.34	0.18
Wetted Width/Depth (m/m):	12	79	26
Entrenchment Ratio:		Low (>2.2)	
Maximum Water Depth (m):	0.10	0.55	0.30
Manning's *n*:		0.040	

Photograph at cross section 2 (looking upstream)

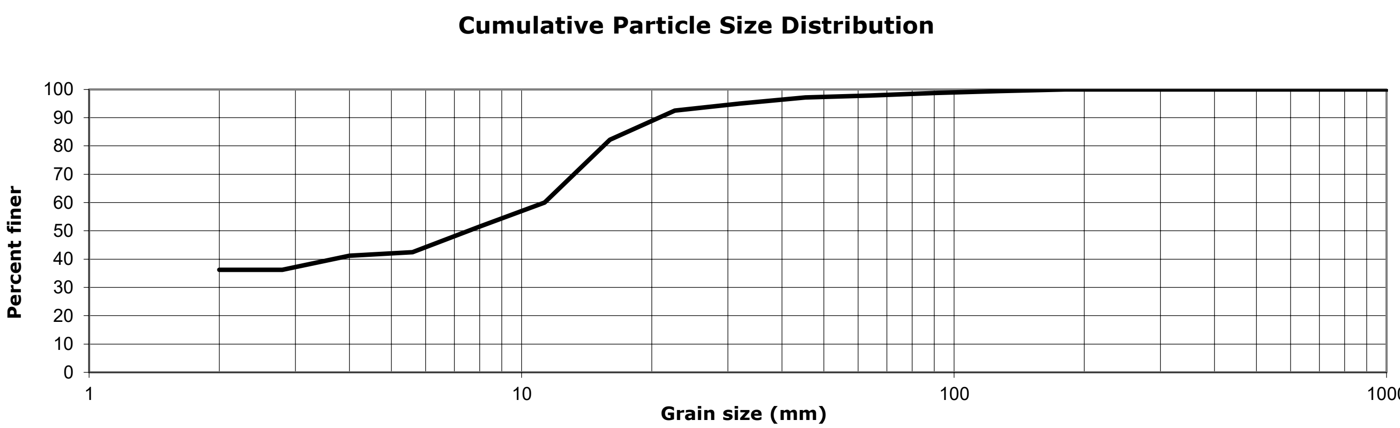


Substrate Characteristics

Particle Size (mm)

D_{10} :	2.0
D_{50} :	7.5
D_{84} :	17.0

Subpavement:	Clay, Till
Particle shape:	Angular, Sub-rounded
Embeddedness (%):	0-20
Particle range (riffle):	Clay-Cobble
Particle Range (pool):	Clay-Cobble



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	20.39
for D_{50}:	0.50	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.73	**Critical Shear Stress (D_{50}) (N/m^2):**	5.46
Unit Stream Power at Bankfull (W/m^2):	19.69		

General Field Observations

Channel Description

Reach BB5-5A-3 was a moderate gradient, meandering channel that passed through a partially confined valley. Riparian vegetation was characterized by grasses in the floodplain and trees on the valley slopes. Substrate consisted of clay to cobbles in riffles and pools. Average bankfull width and depth were 6.31 m and 0.39 m, repsectively. Undercutting was fairly common and was measured up to a maximum of 0.93 m.

Cross Section 6 - Facing Downstream

Detailed Geomorphological Assessment Summary

Reach BB6

Project Number:	PN21063	**Date:**	2021/11/09
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	170.7
Location:	Tewin Lands, Ottawa	**# of Cross-Sections:**	10

Reach Characteristics

Drainage Area (km^2):	20.7	**Dominant Riparian Vegetation Type:**	Grass/Herbaceuous/Trees
Geology/Soils:	Nearshore + offshore glaciomarine deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest	**Width of Riparian Cover:**	>10 Channel Widths
Valley Type:	Partially Confined	**Age Class of Riparian Vegetation:**	Established (5-30 Years)
Dominant Instream Vegetation Type:	Reeds	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	5%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.07	**Calculated Bankfull Discharge (m^3/s):**	2.23
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.88
Modelled 2-year Velocity (m/s):	Not modelled		

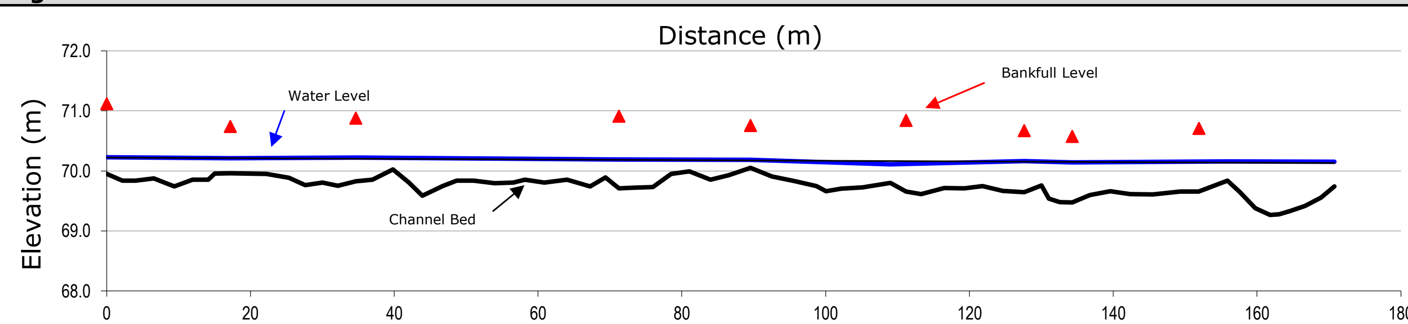
Profile Characteristics

Bankfull Gradient (%):	0.21
Channel Bed Gradient (%):	0.23
Riffle Gradient (%):	0.55
Riffle Length (m):	9.68
Riffle-Pool Spacing (m):	11.28

Planform Characteristics

Sinuosity:	1.42
Meander Belt Width (m):	N/A
Radius of Curvature (m):	10
Meander Amplitude (m):	20
Meander wavelength (m):	30

Longitudinal Profile



Bank Characteristics

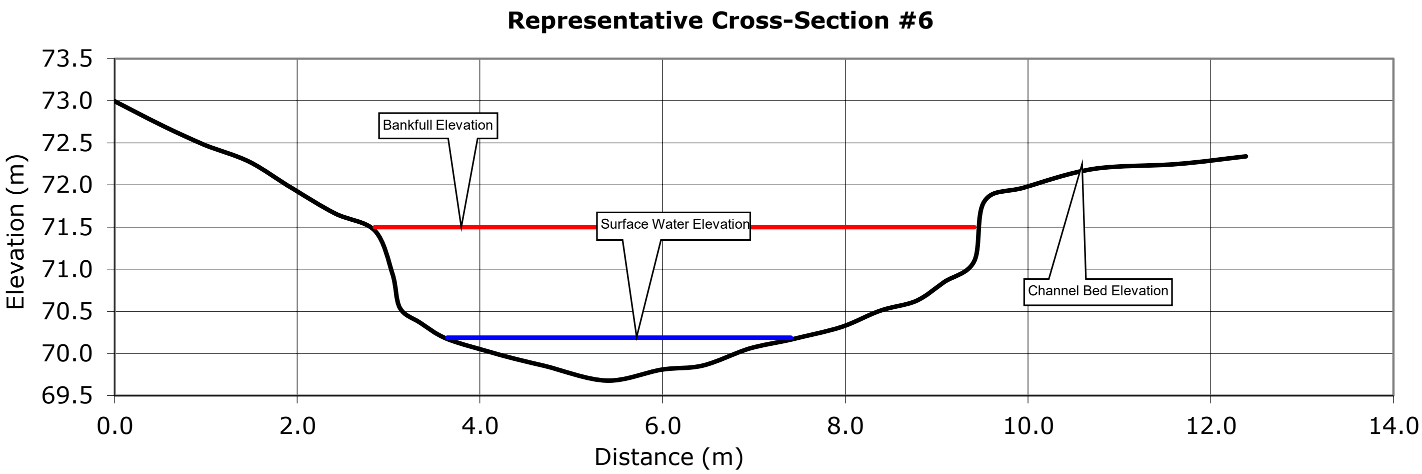
	Minimum	Maximum	Average
Bank Height (m):	2.00	3.30	2.94
Bank Angle (deg):	45	90	69
Root Depth (m):	0.15	0.30	0.18
Root Density (%):	70	80	79
Bank Undercut (m):	0.00	0.23	0.06

Bank Material (range): Clay-Sand

Cross-Sectional Characteristics

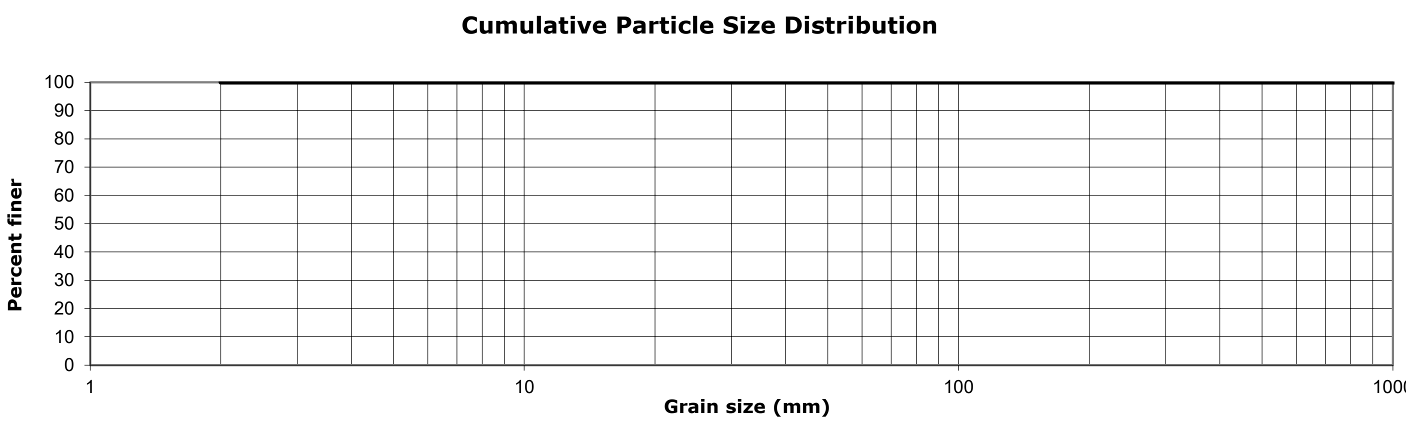
	Minimum	Maximum	Average
Bankfull Width (m):	2.63	7.35	4.67
Average Bankfull Depth (m):	0.56	1.23	0.93
Bankfull Width/Depth (m/m):	3	6	5
Wetted Width (m):	2.04	3.76	2.68
Average Water Depth (m):	0.18	0.45	0.25
Wetted Width/Depth (m/m):	5	16	11
Entrenchment Ratio (m/m):		Moderate (1.4 - 2.2)	
Maximum Water Depth (m):	0.29	0.62	0.40
Manning's *n*:		0.040	

Photograph at cross section 6 (looking downstream)



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Till
D_{10} :	2.0	**Particle shape:**	N/A (sand)
D_{50} :	2.0	**Embeddedness (%):**	0
D_{84} :	2.0	**Particle range (riffle):**	Clay-Sand
		Particle Range (pool):	Clay-Sand



Channel Thresholds			
Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	19.34
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelle
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	21.03		

General Field Observations

Channel Description

Reach BB6 was a minimal gradient, meandering channel that passed through a partially confined valley. Riparian vegetation was characterized by grasses in the floodplain and on the valley slopes. There was minimal encrochment of vegetation to the channel and some reeds were found in the channel. Substrate consisted of Clay to Sand in riffles and pools. Average bankfull width and depth were 4.73 m and 0.94 m, repsectively. Undercutting frequency was minimal and was measured up to a maximum of 0.45 m.

Cross Section 9 - Facing Upstream

Detailed Geomorphological Assessment Summary

Reach RC1

Project Number:	PN21063	**Date:**	2022-06-29
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	108.8
Location:	Tewin Lands, Ontario	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area (km²):	11.52	**Dominant Riparian Vegetation Type:**	Grasses
Geology/Soils:	Nearshore + offshore glaciomarine deposits	**Extent of Riparian Cover:**	Fragmented
Surrounding Land Use:	Agricultural/Grassland	**Width of Riparian Cover:**	4-10 channel widths
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	5-30 yrs
Dominant Instream Vegetation Type:	Emergent species	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	5%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.04	**Calculated Bankfull Discharge (m^3/s):**	4.87
Modelled 2-year Discharge (m^3/s):	4.58 (JFSA modelled)	**Calculated Bankfull Velocity (m/s):**	1.10
Modelled 2-year Velocity (m/s):	Not modelled		

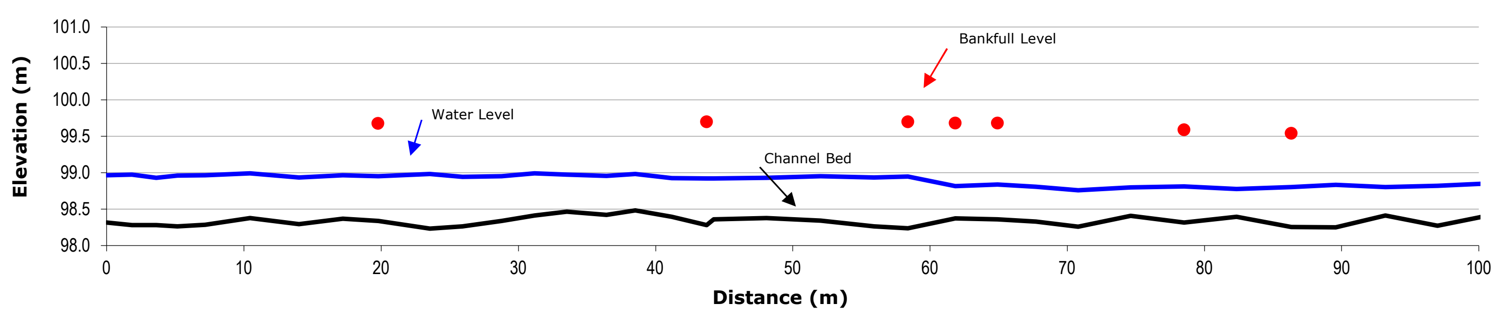
Profile Characteristics

Bankfull Gradient (%):	0.20
Channel Bed Gradient (%):	0.03
Riffle Gradient (%):	0.40
Riffle Length (m):	13
Riffle-Pool Spacing (m):	21

Planform Characteristics

Sinuosity:	1.42
Meander Belt Width (m):	N/A
Radius of Curvature (m):	7.5
Meander Amplitude (m):	20
Meander wavelength (m):	35

Longitudinal Profile



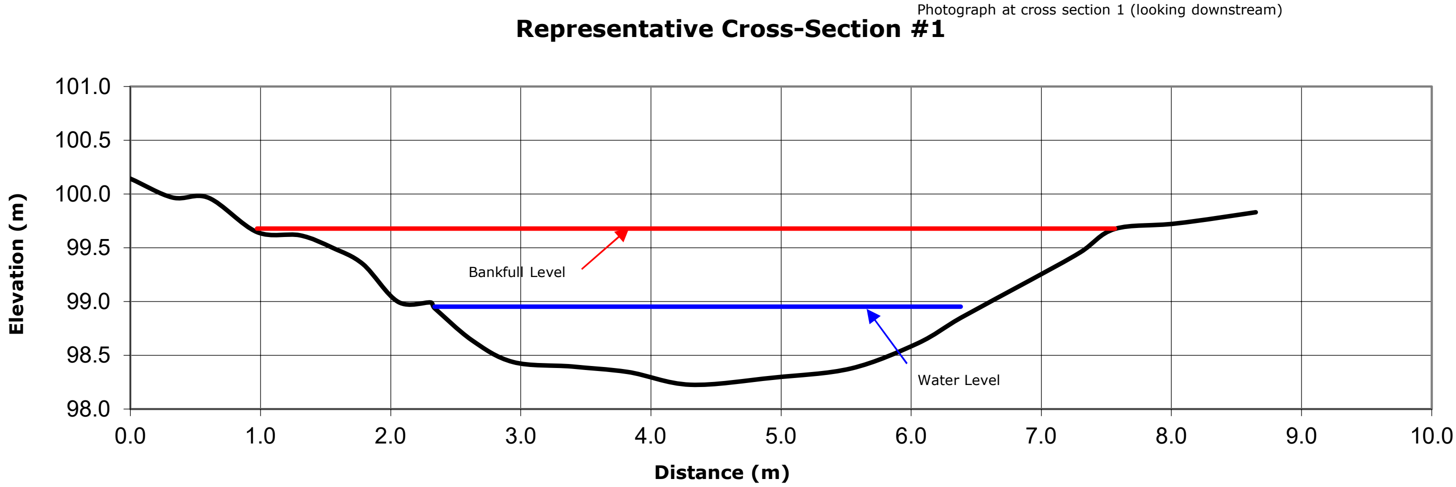
Bank Characteristics

	Minimum	**Maximum**	**Average**		
Bank Height (m):	1.40	2.00	1.68	**Bank Material (range):**	Clay to sand
Bank Angle (deg):	40	90	72		
Root Depth (m):	0.15	10.00	0.82		
Root Density (%):	20	45	37		
Bank Undercut (m):	0.00	0.30	0.10		

Cross-Sectional Characteristics

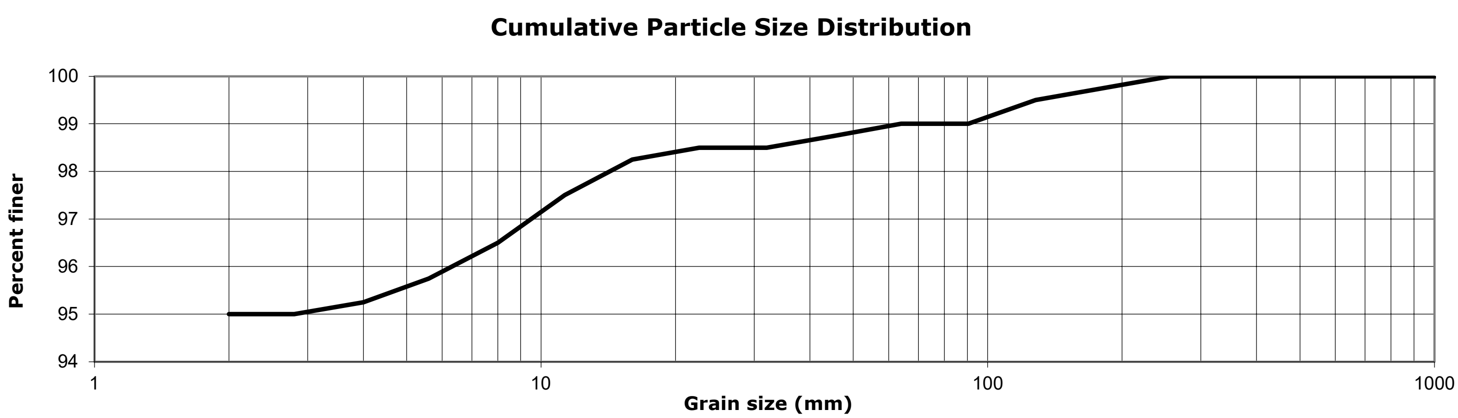
	Minimum	Maximum	Average
Bankfull Width (m):	4.90	8.09	6.30
Average Bankfull Depth (m):	0.72	0.87	0.79
Bankfull Width/Depth (m/m):	6	11	8
Wetted Width (m):	2.56	5.92	3.63
Average Water Depth (m):	0.19	0.44	0.34
Wetted Width/Depth (m/m):	8	16	11
Entrenchment Ratio (m/m):		Low (>2.2)	
Maximum Water Depth (m):	0.33	0.73	0.54
Manning's *n*:		0.045	

Photograph at cross section 1 (looking downstream)



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Clay
D_{10} :	2.0	**Particle shape:**	Platy, sub-rounded, sub-angular
D_{50} :	2.0	**Embeddedness (%):**	50
D_{84} :	2.0	**Particle range (riffle):**	Clay-Sand
		Particle Range (pool):	Clay-Sand



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	13.9
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):	11.2		

General Field Observations

Channel Description

Reach RC1 was a low gradient meandering channel that flowed through an unconfined valley. Riparian vegetation was predominantly characterized by grasses and small shrubs. There was minor encroachment of emergent-type vegetation into the channel. Channel substrates consisted mainly of clays and sands. Although, some gravel and cobbles were found in riffles. Average bankfull width and depth were 6.30 m and 0.79 m, repsectively. Bank undercutting was observed up to a maximum of 0.30 m. In addition, bank slumping was common throughout the reach.

Cross Section 6 - Facing Downstream

Detailed Geomorphological Assessment Summary

Reach RCB

Project Number:	PN21063	**Date:**	2023-12-14
Client:	Taggart Investments and Algonquins of Ontario	**Length Surveyed (m):**	141.4
Location:	Tewin Lands, Ontario	**# of Cross-Sections:**	8

Reach Characteristics

Drainage Area (km^2):	11.8	**Dominant Riparian Vegetation Type:**	Grasses
Geology/Soils:	Sandy glaciofluvial deposits	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Agricultural	**Width of Riparian Cover:**	>10 channel widths
Valley Type:	Unconfined	**Age Class of Riparian Vegetation:**	Mature
Dominant Instream Vegetation Type:	Rooted Emergent	**Extent of Encroachment into Channel:**	Moderate
Portion of Reach with Vegetation:	50%	**Density of Woody Debris:**	Low

Hydrology

Measured Discharge (m^3/s):	0.36	**Calculated Bankfull Discharge (m^3/s):**	4.67
Modelled 2-year Discharge (m3/s):	5.23 (JFSA modelled)	**Calculated Bankfull Velocity (m/s):**	1.00

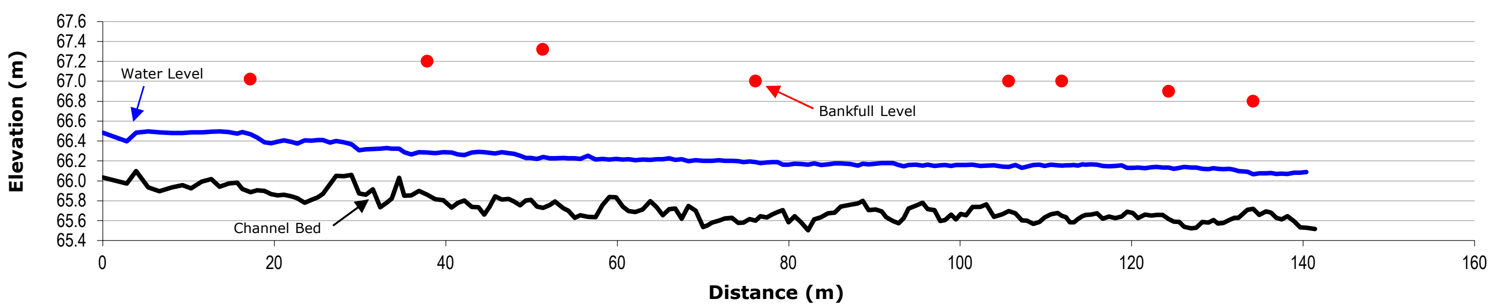
Profile Characteristics

Bankfull Gradient (%):	0.27
Channel Bed Gradient (%):	0.26
Riffle Gradient (%):	N/A no riffles
Riffle Length (m):	N/A no riffles
Riffle-Pool Spacing (m):	N/A no riffles

Planform Characteristics

Sinuosity:	1.51
Meander Amplitude (m):	12
Meander wavelength (m):	23
Radius of curvature (m):	9

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	1.40	2.80	1.88
Bank Angle (deg):	45	90	74
Root Depth (m):	0.15	50.00	20.02
Root Density (%):	20	60	43
Bank Undercut (m):	0.00	0.35	0.11

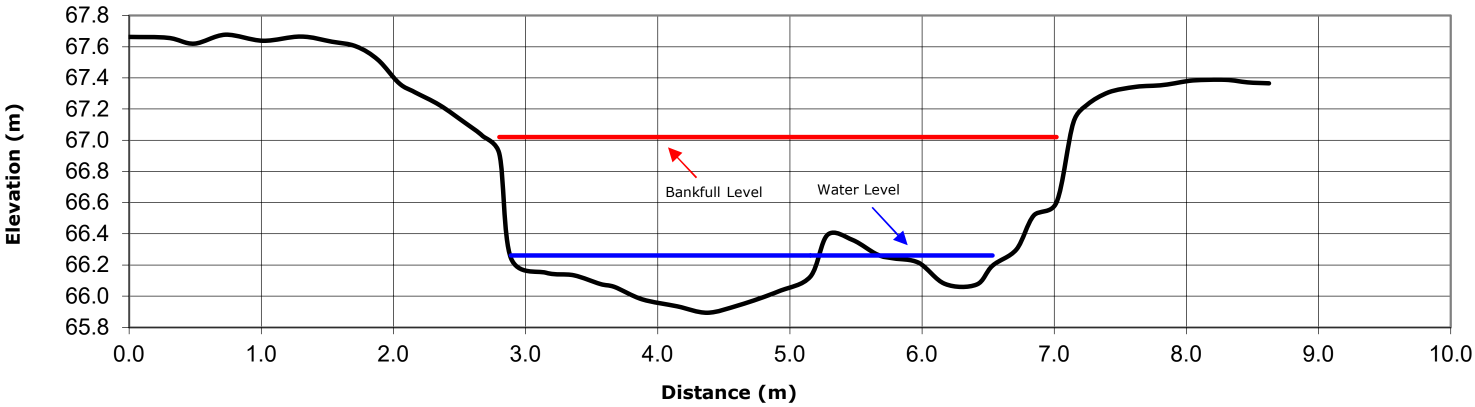
Bank Material (range): Clay, Silt, Sand

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	3.82	9.72	5.85
Average Bankfull Depth (m):	0.66	0.98	0.80
Bankfull Width/Depth (m/m):	5	14	7
Wetted Width (m):	1.73	3.64	2.73
Average Water Depth (m):	0.17	0.41	0.31
Wetted Width/Depth (m/m):	5	21	10
Maximum Water Depth (m):	0.35	0.56	0.46
Entrenchment Ratio:		Low (>2.2)	
Manning's *n* :		0.045	

Photograph at cross section 1 (looking downstream)

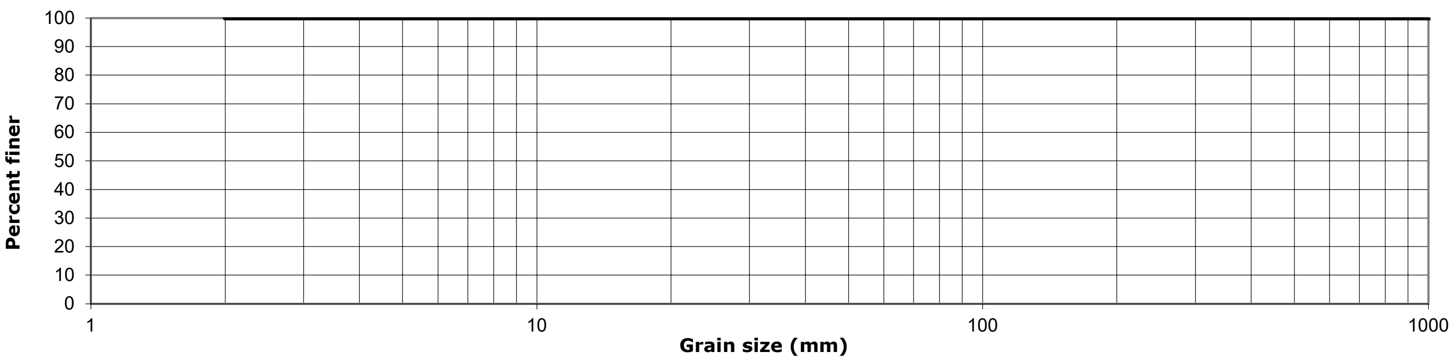
Representative Cross-Section #1



Substrate Characteristics

Particle Size (mm)		**Subpavement:**	Clay Till
D_{10} :	2.0	**Particle shape:**	Clay, Silt, Sand
D_{50} :	2.0	**Particle range (riffle):**	Clay, Silt, Sand
D_{84} :	2.0	**Particle Range (pool):**	Clay, Silt, Sand

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	21.23
for D_{50}:	0.27	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.27	**Critical Shear Stress (D_{50}) (N/m^2):**	1.46
Unit Stream Power at Bankfull (W/m^2):	21.14		

General Field Observations

Channel Description

Reach RCB meanders through active agriculture with a grassy buffer between the channel and the cultivated lands. There was no riffle formations, and was mostly composed of runs and pools. The riparian vegetation encroaches the channel and instream rooted emergent vegetation was well established. Channel slumps, fracture lines and undercutting was observed throughout the reach. The channel bed was composed of soft silt and sand over a compact clay-till subpavement. Some sections of the reach exhibited exposed compact clay-till on the bed. During the time of the assessment, the channel was iced over, however the average bankfull width and depth was 5.85 m and 0.80 m respectivley, and wetted with and depth at 2.73 m and 0.31 m , respectivly.

Cross Section 3 - Facing Downstream

Appendix G
TRCA Meander Belt Width Values

Reach	Drainage Area (km²)	Discharge (m³/s)	Gradient (m/m)
BB5-5A-3-1A	0.25	0.14	0.005
BB5-5A-3-1A-1	0.20	0.12	0.004
BB5-5A-3B	5.41	0.40*	0.001
BB5-5A-3B-1	0.30	0.17	0.003
BB5-5A-3C	5.41	0.40*	0.001
BB5-5A-3D	5.41	0.40*	0.001
BB5-5A-3D-1	0.12	0.08	0.005
BB5-5C-1	2.93	0.19*	0.002
BB5-5C-1A	2.85	1.30	0.002
BB5-5C-1A-1	0.18	0.11	0.004
BB5-5C-1A-2	0.02	0.01	0.001
BB5-5D	0.16	0.10	0.006
BB5-5D-1	0.02	0.02	0.001
BB9	18.57	2.09*	0.002
BB10	18.57	2.09*	0.002
BB10-1	0.72	0.38	0.012
BB10-1A	0.68	0.36	0.001
BB10-1B	0.55	0.30	0.004
BB11	18.57	2.09*	0.002
BB12	17.28	2.09*	0.002
BB13	14.40	1.43*	0.002
BB14	14.40	1.43*	0.002
BB15	12.26	1.43*	0.002
BB16	12.26	1.43*	0.002
RC5	0.30	0.06	0.001

*Interpolated 2-year flow provided by JFSA based on SNC Bear Brook and tributary flood hazard mapping

Appendix H
Utility Crossing Assessment

Figure 1	 	
	Existing conditions at **Crossing 1** on the north side of Piperville Road. Left photo is facing southwest at the box culvert; right photo is facing northeast at the roadside ditch.	
Figure 2	 	
	Existing conditions at **Crossing 1** on the south side of Piperville Road. Left photo is facing down at the box culvert opening; right photo is facing southwest at the roadside ditch.	

Figure 3

Existing conditions at **Crossing 2** on the north side of Piperville Road. Left photo is facing down at the culvert opening; right photo is facing southwest at the roadside ditch towards Crossing 1.

Figure 4

Existing conditions at **Crossing 2** on the south side of Piperville Road. Left photo is facing southeast at a drainage ditch flowing into the culvert from properties south of Piperville Road; right photo is facing northeast at the roadside ditch.

Figure 5

Existing conditions at **Crossing 3** on the north side of Piperville Road. Left photo is facing north from the culvert opening; right photo is facing northeast at the roadside ditch.

Figure 6

Existing conditions at **Crossing 3** on the south side of Piperville Road. Left photo is facing southeast at the culvert opening; right photo is facing southeast at a concrete structure situated immediately east of the culvert outlet.

Figure 7

Existing conditions at **Crossing 4** on the north side of Piperville Road. Left photo is facing southeast at the box culvert; right photo is facing northeast at the roadside ditch.

Figure 8

Existing conditions at **Crossing 4** on the south side of Piperville Road. Left photo is facing southeast from behind the culvert; right photo is facing north at the culvert opening.

Figure 9	
	 
	Existing conditions at **Crossing 5** on the north side of Piperville Road. Left photo is facing southeast towards Crossing 4; right photo is facing northeast at the roadside ditch draining from the culvert.

Figure 10	
	 
	Existing conditions at **Crossing 5** on the south side of Piperville Road. Left photo is facing southeast; right photo is facing northwest at the roadside ditch.

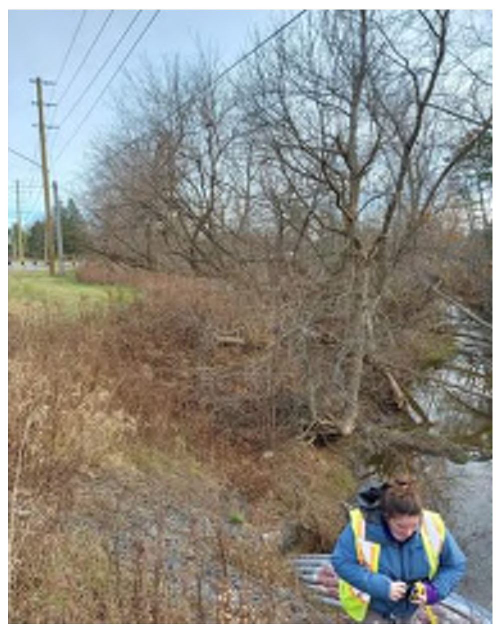
Figure 11	 
	Existing conditions at **Crossing 6** on the north side of Piperville Road. Left photo is facing northeast from the road; right photo is facing northwest. Some slumping was observed along the banks.
Figure 12	 
	Existing conditions at **Crossing 6** on the south side of Piperville Road. Left photo is facing southeast; right photo is facing east along Piperville Road. Some erosion scars and fallen trees were observed.

Figure 13


Existing conditions at **Crossing 7** on the west side of Farmer's Way. Left photograph is taken facing northwest along the roadside ditch; right photograph is taken facing east at the mouth of the culvert.

Figure 14


Existing conditions at **Crossing 7** on the east side of Farmer's Way. Left photograph is taken facing northeast along the roadside ditch; right photograph is taken facing west at the mouth of the culvert.

Figure 15

Existing conditions at **Crossing 8** on the west side of Ramsayville Road. Left photo is facing down at the mouth of the culvert; right photo is facing west.

Figure 16

Existing conditions at **Crossing 8** on the east side of Ramsayville Road. Left photo is facing east; right photo is facing west into the mouth of the culvert.

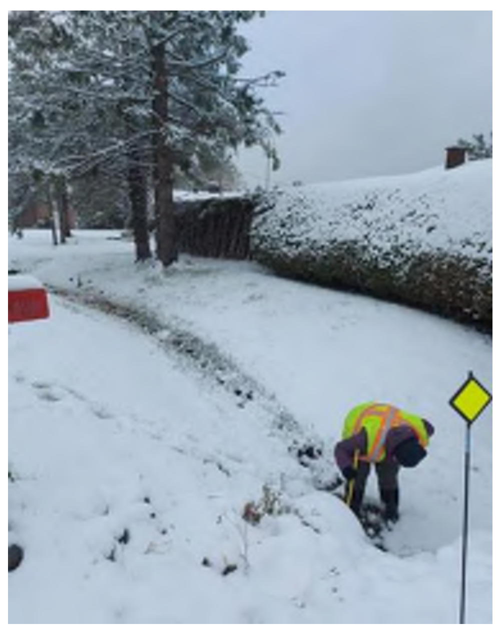
Figure 17	 
	Existing conditions at **Crossing 9** on the north side of Farmer's Way. Left photo is facing north; right photo is taken facing northeast; no defined channel was observed.
Figure 18	 
	Existing conditions of **Crossing 9** on the south side of Farmer's Way. Left photograph is taken facing southwest towards the output of the roadside ditch; right photograph is taken facing southeast.

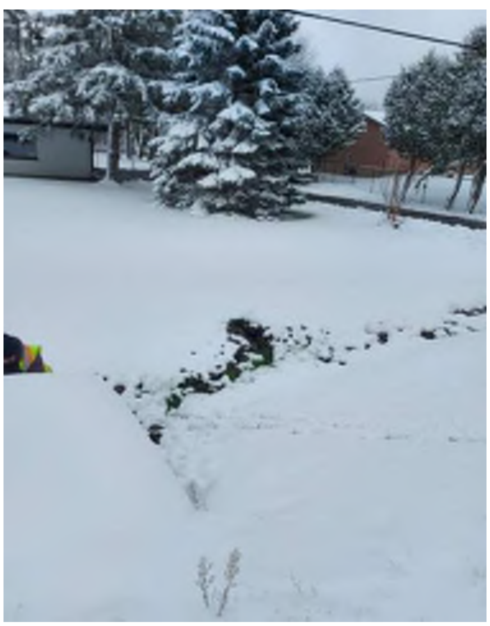
Figure	
Figure 19	 
	Existing conditions at **Crossing 10** on the north side of Leitrim Road. Left photograph is facing northeast along the roadside ditch; right photograph is facing southeast towards the culvert.
Figure 20	 
	Existing conditions at **Crossing 10** on the south side of Leitrim Road. Left photograph is facing southwest along the roadside ditch; right photograph is facing southeast.

Figure 21

Existing conditions at **Crossing 11** on the north side of Leitrim Road. Left photo is taken facing northwest; right photograph is taken facing south at the mouth of the culvert.

Figure 22

Existing conditions at **Crossing 11** on the south side of Leitrim Road. Left photograph is facing south, downstream; right photograph is taken facing southwest towards the mouth of the culvert.

Figure 23

Existing conditions at **Crossing 12** on the north side of Russell Road. Left photo is facing northeast parallel to Russell Road; right photo is facing north.

Figure 24

Existing conditions at **Crossing 12** on the south side of Russell Road. Left photo is facing west down Russell Road; right photo is facing south.

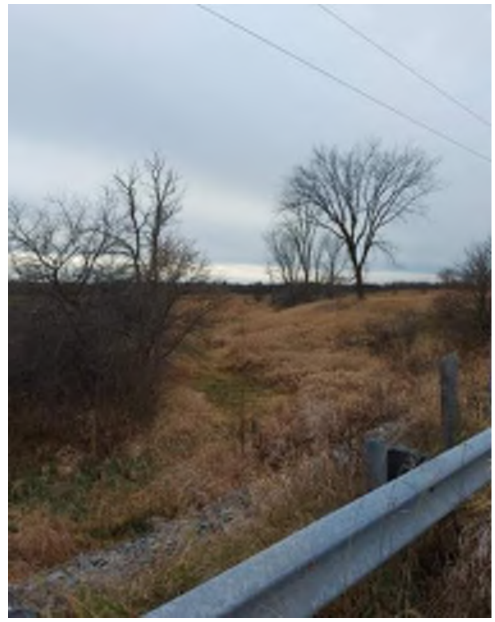
Figure 25	
	 
	Existing conditions at **Crossing 13** on the north side of Russell Road. Left photograph is facing east; the right photograph is facing northeast, downstream.
Figure 26	 
	Existing conditions at **Crossing 13** on the south side of Russell Road. Left photograph is facing northeast; right photograph is facing south towards the culvert.

Figure	
Figure 27	 
	Existing Conditions at **Crossing 14** on the north side of Russell Road. Left photograph is facing northeast; right photograph is facing south towards the mouth of the culvert.
Figure 28	 
	Existing conditions at **Crossing 14** on the south side of Russell Road. Left photo is facing south, upstream; right photograph is facing southwest, channel was dry.

Figure 29	 
	Existing conditions at **Crossing 15** on the north side of Russell Road. Left photograph is facing northwest; right photograph is facing north..
Figure 30	 
	Existing conditions at **Crossing 15** on the south side of Russell Road. Left photograph is facing south along the channel; right photograph is facing north towards the mouth of the culvert.

Figure 31	 
	Existing conditions at **Crossing 16** on the north side of Russell Road. Left photograph is facing north, downstream; right photograph is facing south, into the culvert. Some slumping was observed.
Figure 32	 
	Existing conditions at **Crossing 16** on the south side of Russell Road. Left photo is facing south, upstream; right photo is facing southeast. Some slumping was observed..

Figure 33	  Existing conditions at **Crossing 17** on the west side of Ramsayville Road. Left photo is facing southwest along the roadside ditch; right photo is facing down at the culvert.
Figure 34	 Existing conditions at **Crossing 17** on the east side of Ramsayville Road. Photo is facing southeast along the roadside ditch.

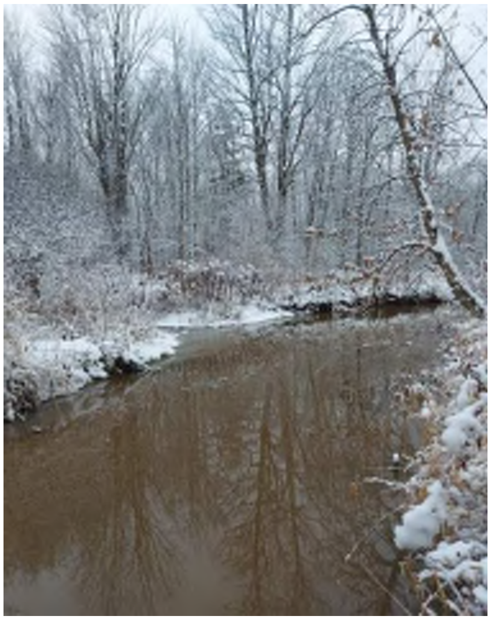
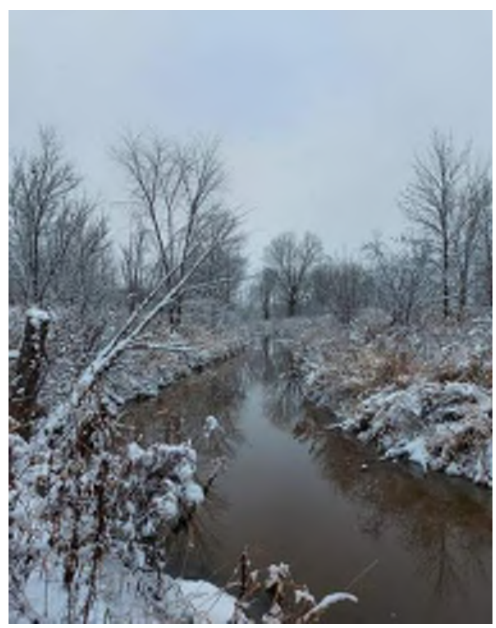
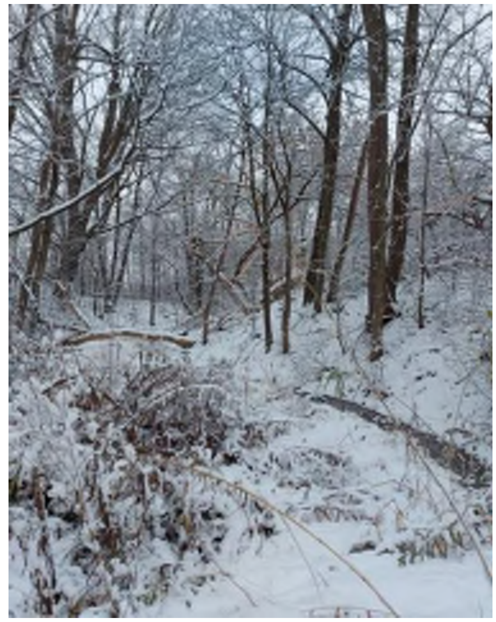
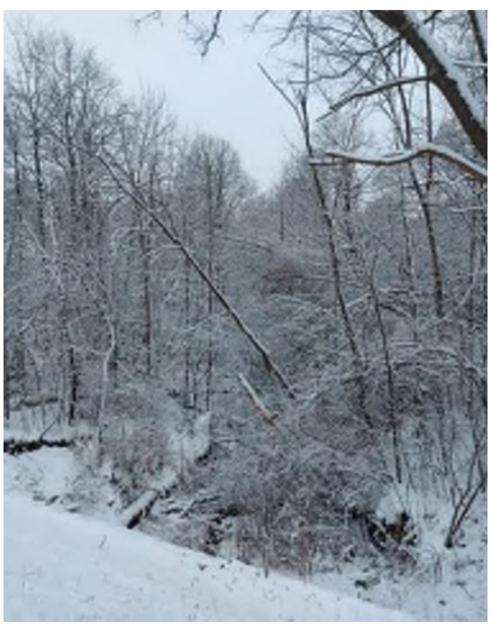
Figure 35	 
	Existing conditions at **Crossing 18** on the west side of Ramsayville Road. Left photo is facing west, upstream; right photo is facing south. Some slumping and undercutting was observed.
Figure 36	 
	Existing conditions at **Crossing 18** on the east side of Ramsayville Road. Left photo is facing northwest towards the crossing structure; right photo is facing east, downstream. Some undercutting and slumping was observed.

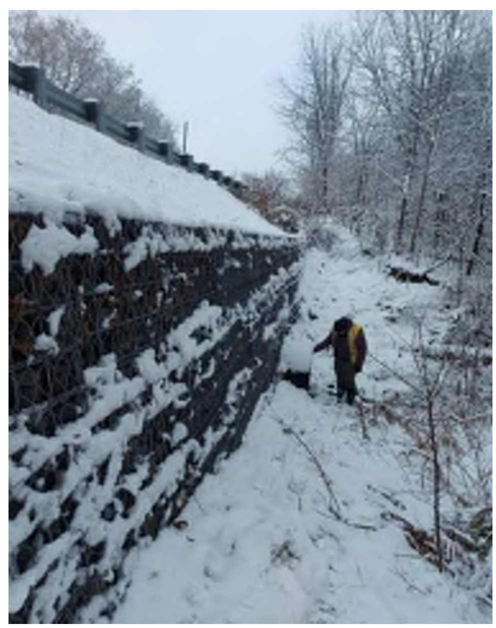
Figure 37



Existing conditions at **Crossing 19** on the west side of Ramsayville Road. Left photograph is facing north along Ramsayville Road; left photo is facing west, downstream.

Figure 38





Existing conditions at **Crossing 19** on the east side of Ramsayville Road. Left photo is facing east; right phot is facing north along Ramsayville Road. Some minor erosion scars were observed.

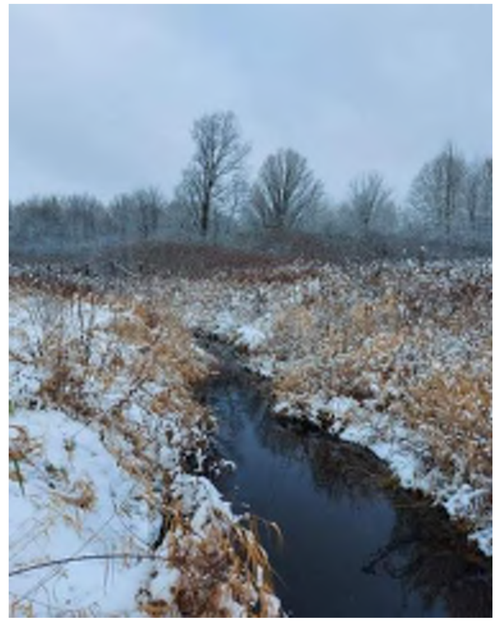
Figure 39


Existing conditions at **Crossing 20** on the west side of Ramsayville Road. Both photographs are facing west. Some minor slumping was observed.

Figure 40

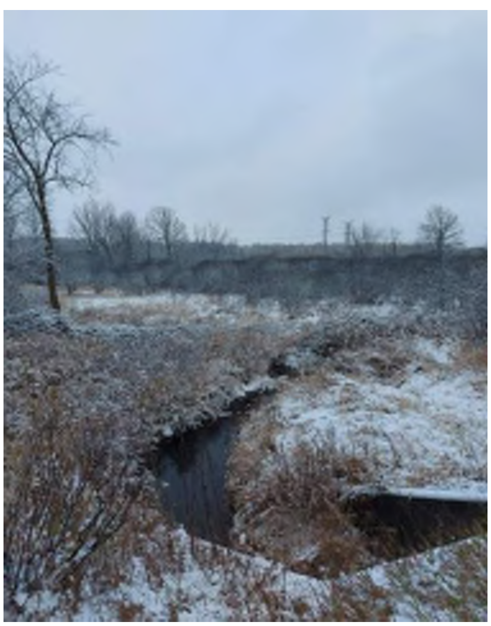

Existing conditions at **Crossing 20** on the east side of Ramsayville Road. Left phot is taken facing west; right photo is taken facing northeast. Some slumping was observed.

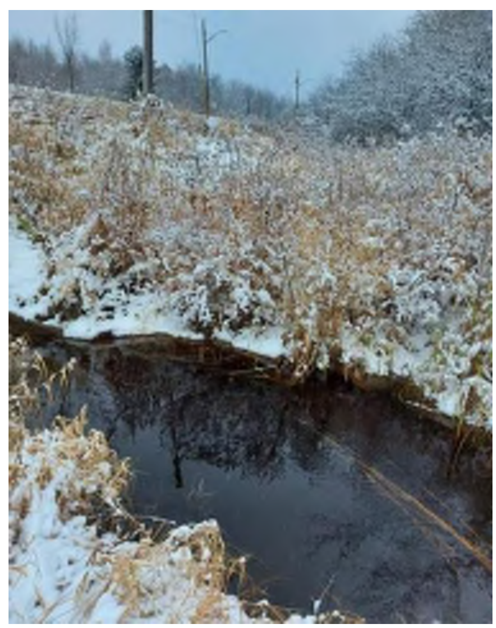
Figure 41



Existing conditions at **Crossing 21** on the north side of Walkley Road. Left photograph is taken facing northeast; right photograph is taken facing north. Some minor slumping was observed.

Figure 42





Existing conditions at **Crossing 21** on the south side of Walkley Road. Left photo is facing south; right photo is facing east. Some minor slumping was observed.

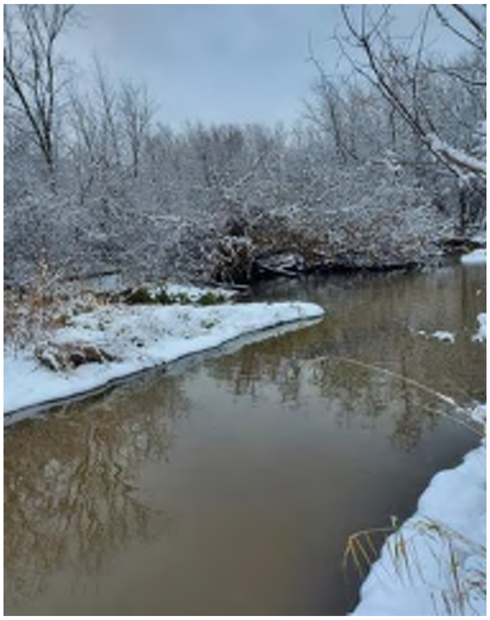
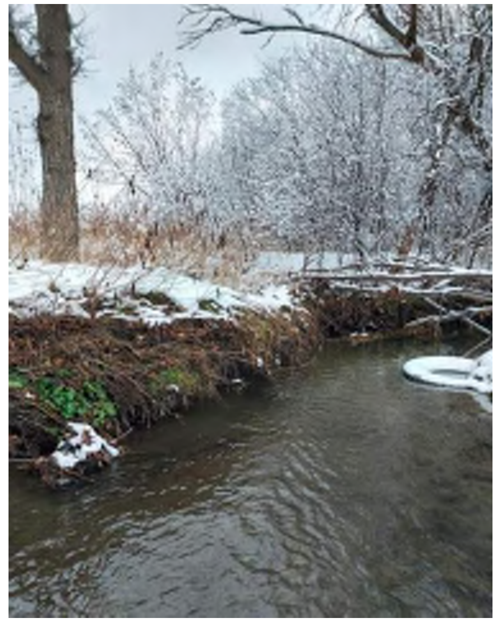
Figure 43	
	 
	Existing conditions at **Crossing 22** on the north side of Walkley Road. Left photograph is facing northwest; left photograph is facing southwest at the dual culverts. Undercutting was observed.
Figure 44	 
	Existing conditions at **Crossing 22** on the south side of Walkley Road. The left photograph is facing south; the right photograph was taken during a second visit and is facing east. Slumping was observed.

Figure 45

Existing conditions at **Crossing 24** on the north side of Russell Road. Left photograph is facing northwest along Russell Road; right photograph is facing north were undercutting and erosion scars were observed.

Figure 46

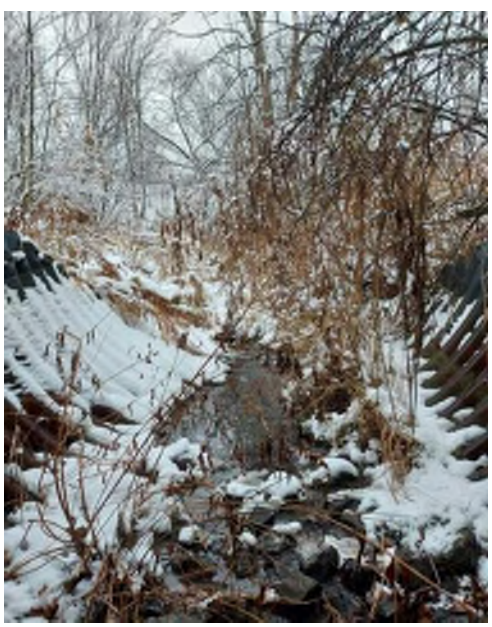
 

Existing conditions at **Crossing 24** on the south side of Russell Road. Left phot is facing south along the bank where erosion scars and slumping was observed; right photo is facing southeast.

Figure 47

Existing conditions at **Crossing 25** on the north side of Russell Road. Left photograph is taken facing north; right photograph is taken facing south towards the mouth of the culvert.

Figure 48



Existing conditions at **Crossing 25** on the south side of Russell Road. Left photo is taken facing south from within the culvert; right photograph is taken facing southwest.

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Figure 49

Existing conditions at **Crossing 26** on the north side of Russell Road. Left photograph is taken facing northwest along the roadside ditch; right photograph is taken facing southwest towards the mouth of the culvert.

Fig50e 66

Existing conditions at **Crossing 26** on the south side of Russell Road. Left photograph if facing southeast along the roadside ditch; right photograph is facing north at the mouth of the culvert.

Figure 51

Existing conditions at **Crossing 27** on the east side of Ramsayville Road. Left photo is facing east, upstream; right photograph is facing northeast, down towards the mouth of the culvert. Channel lacked definition.

Figure 52

Existing conditions at **Crossing 27** on the west side of Ramsayville Road. Left photo is facing west; the right photo is facing northwest down towards the mouth of the culvert.

Figure 53	 
	Existing conditions at **Crossing 28** on the west side of Ramsayville Road. Left photograph is facing west down towards the culvert; right photograph is facing west.
Figure 54	 
	Existing conditions at **Crossing 28** on the east side of Ramsayville road. Left photo is facing east, downstream; right photograph is facing west at the culvert. Some erosion scars and slumping was observed downstream.

Figure 55	
	 
	Existing conditions at **Crossing 29** on the west side of Ramsayville Road. Left photo is facing down at the mouth of the culvert; right photo is facing west.
Figure 56	 
	Existing conditions at **Crossing 29** on the east side of Ramsayville Road. Left photo is facing east; right photo is facing west into the mouth of the culvert.

Figure 57

Existing conditions at **Crossing 30** on the west side of Ramsayville Road. Left photo is facing northwest along the roadside ditch; right photo is facing down at the mouth of the culvert.

Figure 58

Existing conditions at **Crossing 30** on the east side of Ramsayville Road. Left photo is facing southeast; right photo is facing south.

Figure 59

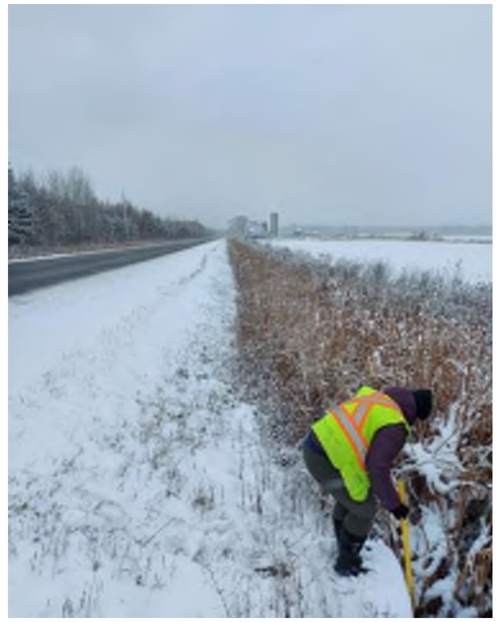

Existing conditions at **Crossing 31** on the west side of Ramsayville Road. Left photograph is taken facing west, upstream; right photograph is taken facing down at the mouth of the culvert.

Figure 60


Existing conditions at **Crossing 31** on the west side of Ramsayville Road. Left photo is taken facing west; right photo is taken facing downwards at the mouth of the culvert.

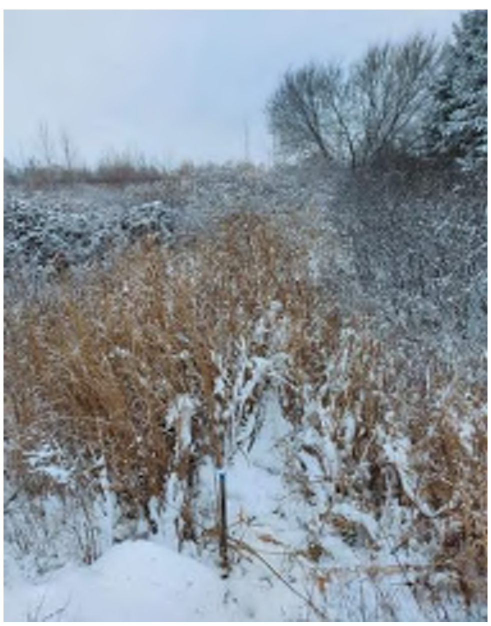
Figure 61	 
	Existing conditions at **Crossing 32** on the west side of Ramsayville Road. Left photo is facing west, a large number of down trees from recent storm are present in the channel; right photo is facing down at the mouth of the culvert. An erosion scar was observed on the left bank.
Figure 62	 
	Existing conditions at **Crossing 32** on the east side of Ramsayville Road. Left photo is facing east, downstream; right photo is facing downwards. Erosion scars were observed.

Figure 63



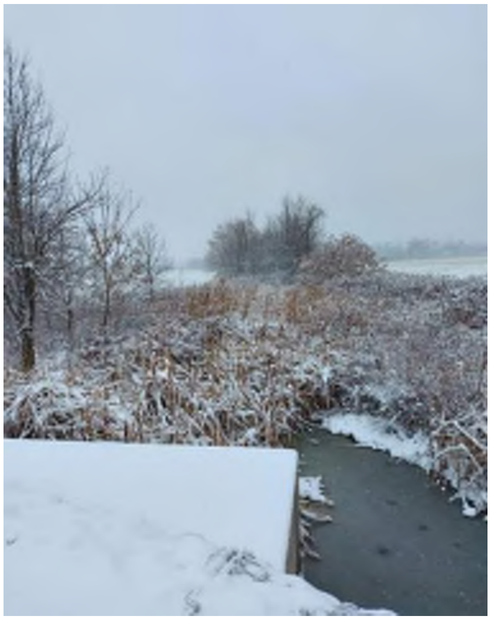
Existing conditions at **Crossing 33** on the north side of Leitrim Road. Left photograph is taken facing north, upstream; left photograph is taken facing southwest along the roadside ditch.

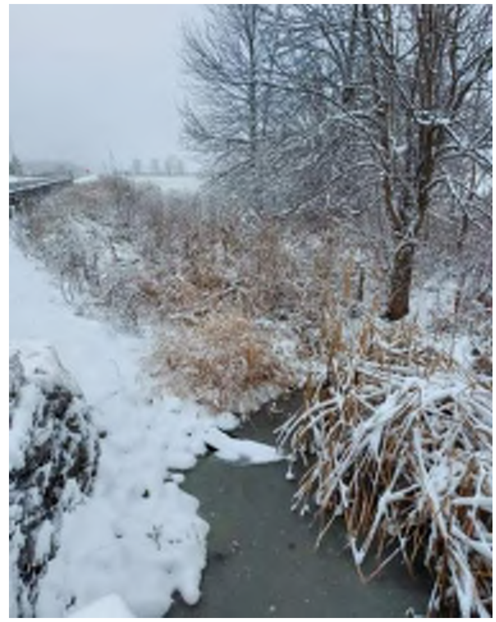
Figure 64



Existing conditions at **Crossing 33** on the south side of Leitrim Road. Left photo is taken facing southeast towards Crossing 17 along the roadside ditch; right photograph is taken facing southwest along the roadside.

Figure 65





Existing conditions at **Crossing 34** on the north side of Leitrim Road. Left photo is taken facing northwest; right photograph is taken facing west along Leitrim Road.

Figure 66

Existing conditions at **Crossing 34** on the south side of Leitrim Road. Left photograph is facing southwest along the roadside ditch; right photograph is taken facing southeast towards downstream.

Figure 67

Existing conditions at **Crossing 35** on the west side of Ramsayville Road. Left photograph is taken facing west, upstream; right photograph is taken facing southwest at the roadside ditch. Some slumping was observed.

Figure 68

Existing conditions at **Crossing 35** on the east side of Ramsayville Road. Left photograph is facing southeast at the output from the roadside ditch; right photograph is facing east, downstream. Some slumping was observed.

Figure 69

Existing conditions at **Crossing 36** on the west side of Ramsayville Road. Left photo is taken facing north at the input from the roadside ditch; right photograph is taken facing south along the roadside ditch.

Figure 70

Existing conditions at **Crossing 36** on the southeast corner of Ramsayville and Piperville Roads. Left photograph is taken facing southeast; right photograph is taken facing northeast along the roadside ditch.

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
001N	Concrete box	Agricultural/residential ditch	0.90	0.17	2.10	-	-	
001S	Concrete box	Agricultural/residential ditch	0.90	0.15	2.10	-	-	
002N	Corrugated steel	Agricultural/residential ditch	0.68	0.38	0.76	-	-	
002S	Corrugated steel	Agricultural/residential ditch	0.77	0.15	0.81	-	-	
003N	Corrugated steel	Agricultural/residential ditch	0.60	0.00	0.61	-	-	
003S	Corrugated steel	Agricultural/residential ditch	0.61	0.14	0.61	-	-	
004N	Concrete box	Agricultural/residential ditch	1.50	0.50	3.00	-	-	
004S	Concrete box	Agricultural/residential ditch	1.75	0.27	3.00	-	-	
005N	Corrugated steel	Agricultural/residential ditch	0.72	0.19	0.72	-	-	
005S	Corrugated steel	Agricultural/residential ditch	0.72	0.01	0.72	-	-	
006N	Corrugated steel	Stream	5.00	0.46	5.00	5.94	2.25	A stream meander is present immediately upstream of the culvert. Some slumping was observed on both banks.
006S	Corrugated steel	Stream	5.00	0.46	5.00	6.81	2.25	Many fallen and leaning trees due to bank slumping observed. Exposed roots and soil present. Bed substrate is composed of fine materials.
007E	Corrugated steel	Roadside ditch	0.60	0.06	0.60	-	-	

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
007W	Corrugated steel	Roadside ditch	0.60	0.13	0.60	-	-	
008N	Corrugated steel	Roadside ditch	1.00	0.27	1.00	-	-	
008S	Corrugated steel	Roadside ditch	1.00	0.20	1.00	-	-	
009N	Corrugated steel	Roadside ditch	0.55	0.07	0.60	-	-	
009S	Corrugated steel	Roadside ditch	0.55	0.04	0.60	-	-	
010N	Concrete cylinder	Roadside ditch	1.20	0.12	2.00	-	-	
010S	Concrete cylinder	Roadside ditch	1.20	0.00	2.00	-	-	
011E	Corrugated steel, wings	Roadside ditch	0.78	0.28	0.72	-	-	
011W	Corrugated steel, wings	Roadside ditch	0.78	0.18	0.72	-	-	
012N	Concrete cylinder	Agricultural/roadside ditch	0.83	0.02	0.83	-	-	
012S	Concrete cylinder	Agricultural/roadside ditch	0.83	0.02	0.83	-	-	
013N	Concrete cylinder	Agricultural ditch	1.50	0.18	1.50	-	-	
013S	Concrete cylinder	Agricultural ditch	1.50	0.11	1.50	-	-	
014N	Concrete cylinder	Agricultural ditch	0.84	0.00	0.82	-	-	
014S	Concrete cylinder	Agricultural ditch	0.84	0.27	0.82	-	-	

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
015N	Concrete cylinder	Agricultural ditch	1.10	0.01	1.10	-	-	
015S	Concrete cylinder	Agricultural ditch	1.10	0.02	1.10	-	-	
016N	Concrete box, wings	Stream	2.25	0.14	4.20	-	-	
016S	Concrete box, wings	Stream	2.25	0.40	4.20	-	-	
017E	Corrugated steel	Roadside ditch	0.55	0.04	0.50	-	-	
017W	Corrugated steel	Roadside ditch	0.55	0.00	0.50	-	-	
018E	Bridge	Stream	N/A	N/A	N/A	6.64	1.50	Channel flows below right side of bridge, while sediment deposition occupies the left side. The right bank approximately 10 meters upstream of the bridge is nearly vertical with some slumping and exposed tree roots.
018W	Bridge	Stream	N/A	N/A	N/A	6.36	1.75	Sediment deposition on left side of channel forms lower terrace in narrow stream valley downstream of bridge. Right bank is slightly less vertical than it is upstream.
019E	Corrugated steel	Stream	1.00	0.01	1.00	5.79	1.75	Meandering stream flowing along relatively flat bottom of small valley (approximately 5 meter tall valley walls and 5-10 meters wide). The base of the right valley wall has a vertical scour and

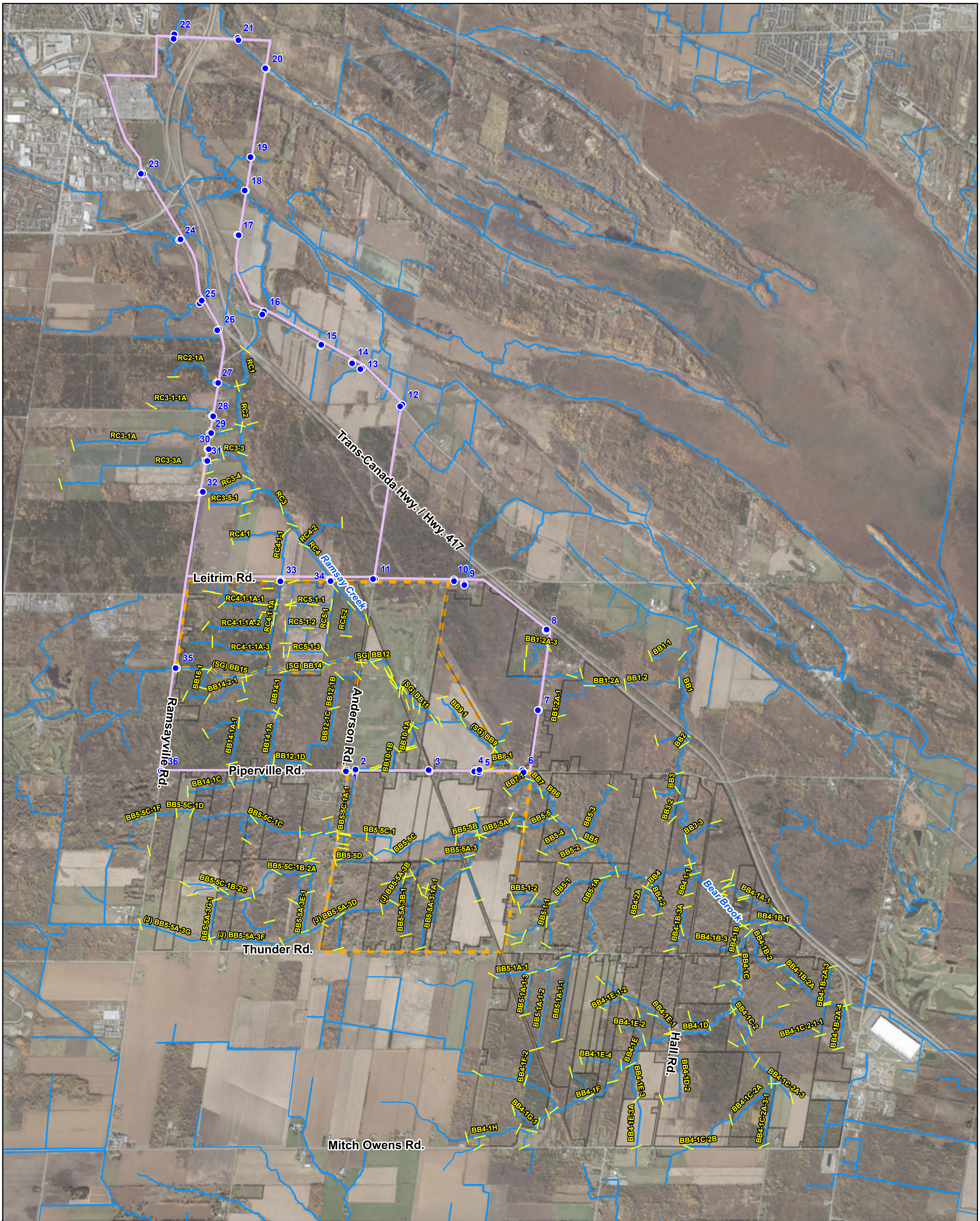
Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
								undercut approximately 0.80 m deep.
019W	Corrugated steel	Stream	1.00	0.01	1.00	6.37	2.00	Meandering stream flowing along relatively flat bottom of small valley (approximately 5 meter tall valley walls and 5-10 meters wide). Valley floor is vegetated by grasses while valley wall slopes are vegetated by sapling and mature trees.
020E	Concrete box	Stream	0.90	0.22	5.20	4.35	0.85	Relatively straight stream with grassy vegetation on both banks. Vegetated sediment deposit along the left bank immediately upstream of culvert opening.
020W	Concrete box	Stream	0.90	0.20	5.20	3.58	1.00	Relatively straight stream with grassy vegetation on both banks and some aquatic vegetation growing within the channel. Vegetated sediment deposit along the right bank immediately downstream of culvert opening.
021N	Concrete box, wings	Stream	2.00	0.33	3.00	4.27	1.00	No concerning channel erosion observed
021S	Concrete box, wings	Stream	2.00	0.33	3.00	4.80	0.70	No concerning channel erosion observed
022N	Corrugated steel, double	Stream	4.00	0.00	4.00	8.46	2.75	Valley continues on downstream side of crossing. Sparsely vegetated sediment deposit throughout left (west) culvert continues downstream as well.

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
								Right bank is nearly vertical, some slumping with exposed roots.
022S	Corrugated steel, double	Stream	4.00	0.00	4.00	9.40	1.50	Channel flows within valley. Left (west) culvert in pair of corrugated steel culverts is occupied by silt sediment deposit which extends upstream of the crossing as a medial bar with sparse vegetation. Flow is primarily through right (east) culvert. Right bank is nearly vertical, slumping with exposed roots.
023E	Concrete box	Stream	N/A	N/A	N/A	-	-	Unable to get measurements due to construction
023W	Concrete box	Stream	N/A	N/A	N/A	-	-	Unable to get measurements due to construction
024N	Concrete box	Stream	1.95	0.34	5.20	5.66	2.40	Undercut (0.20 m deep) along tall left bank. Terraced right bank has minor slumping along the top of bank.
024S	Concrete box	Stream	1.95	0.17	5.20	6.80	1.15	Undercut (0.35 m deep) along tall left bank. Terraced right bank; higher bank has some exposed roots and soil along its base. Some downed trees downstream of crossing.
025N	Corrugated steel	Stream	2.50	0.04	2.50	-	-	Unable to get measurements due to construction
025S	Corrugated steel	Stream	2.50	0.08	2.50	-	-	Unable to get measurements due to construction

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
026N	Corrugated steel	Roadside ditch	0.72	0.05	1.00	-	-	
026S	Corrugated steel	Roadside ditch	0.70	0.00	0.70	-	-	
027E	Concrete cylinder	Stream/wetland	1.30	0.26	1.60	6.87	1.00	Channel downstream of culvert is entrenched with 1 m height banks with undercuts ranging from 0.10-0.20 m. Channel bed is lined with angular cobble stones, banks are comprised of silt and sand sized sediment.
027W	Concrete cylinder	Stream/wetland	1.30	0.10	1.60	3.72	1.00	Upstream of culvert channel is undefined and flows through a saturated wetland within a wide valley vegetated with a mix of native and invasive wetland species.
028E	Corrugated steel	Stream	N/A	N/A	N/A	2.77	0.4	No concerning erosion observed.
028W	Corrugated steel	Stream	N/A	N/A	N/A	3.3	1.1	No concerning erosion observed.
029E	Corrugated steel	Stream	1.10	0.23	1.30	5.23	1.50	No concerning channel erosion observed. Banks are composed of grasses and bed was comprised of fine sediments. Concrete around culvert is degrading.
029W	Corrugated steel	Stream	1.10	0.31	1.30	4.63	2.00	No concerning channel erosion observed. Very little flow observed.
030E	Corrugated steel	Agricultural ditch	1.3	0.05	1.75	-	-	

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
030W	Corrugated steel	Agricultural ditch	1.3	0.2	1.75	-	-	
031E	Corrugated steel	Stream	1.80	0.20	2.00	3.44	2.50	Slumping and exposed soil was observed approx. 5m downstream of the culvert. Grasses were present in the channel, very little flow was observed.
031W	Corrugated steel	Stream	1.80	0.10	2.00	4.22	2.00	Channel flowing within a 2m deep valley. Banks were composed of cobble with established grasses growing overtop. No major signs of erosion observed.
032E	Concrete cylinder	Roadside ditch	2.50	0.15	2.50	4.24	1.00	Due to a recent storm, many trees were down in the channel. Some exposed soil and roots were observed upstream of the culvert. Bed materials composed of silt, sand and cobbles.
032W	Concrete cylinder	Stream	2.50	0.12	2.50	3.93	2.25	Several down trees due to recent storm. Some exposed soil sand tree roots observed.
033N	Corrugated steel	Agricultural ditch	0.74	0.24	0.85	-	-	
033S	Corrugated steel	Agricultural ditch	0.74	0.08	0.85	-	-	
034N	Concrete box	Stream	1.05	0.32	3.50	8.73	0.50	Backwater wider than culvert opening with cattails growing in silty bed sediments upstream of culvert.

Crossing ID	Culvert Type	Watercourse Type	Culvert Height	Water Depth	Culvert Depth	Bankfull Width	Bankfull Depth	Description
034S	Concrete box	Stream	1.05	0.58	3.50	5.79	0.30	Backwater wider than culvert opening, poorly defined banks,
035E	Concrete box	Stream	3.00	0.35	2.50	6.95	2.00	Some slumping and exposed soil observed on both banks downstream of the culvert. Banks were composed of grasses and bed was silt, sand and cobbles.
035W	Concrete box	Stream	3.00	0.35	2.50	5.02	1.40	Exposed soils and roots observed upstream of the culvert. Right bank composed of a manicured lawn and cobbles. Bed is composed of primarily cobbles.
036E	Concrete cylinder	Roadside ditch	1.20	0.13	1.20	-	-	
036W	Concrete cylinder	Roadside ditch	1.20	0.11	1.20	-	-	



Legend

- Reach Break and ID
- Crossing Locations and ID
- Watercourse
- Servicing Lines
- Participating Property Boundaries
- Tewin Study Area

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Tewin Secondary Plan Subwatershed Study

Potential Future Crossing Locations

Ottawa, Ontario

0 850 1,700

Metres

Imagery: City of Ottawa, 2019. Watercourse: MNRF, 2021
Boundary Areas: Algonquins of Ontario/
Taggart, 2021., GEO Morphix Ltd., 2021.
Reach Break and ID, Crossing Location: GEO Morphix Ltd., 2021.
Servicing Lines: JFSA, 2022.
Print Date: June 2023. PN22024. Drawn By: M.O. K.W.