Final Fluvial Geomorphological Assessment Report – Holland River Crossings

Highway 400 to Highway 404 Link (Bradford Bypass)

Ontario Ministry of Transportation

60636190

August 25, 2023

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AECOM: 2015-04-13

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Revision History

Rev #	Revision Date	Revised By:	Revision Description
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2	February 2, 2023	AECOM	Draft Fluvial Geomorphology Impact Assessment Report – Holland River Crossing
3	February 21, 2023	AECOM	Draft Fluvial Geomorphology Impact Assessment Report – Holland River Crossing
4	March 3, 2023	AECOM	Draft Fluvial Geomorphology Impact Assessment Report – Holland River Crossing
5	March 8, 2023	AECOM	Draft Fluvial Geomorphology Impact Assessment Report – Holland River Crossing
6	August 25, 2023	AECOM	Final Fluvial Geomorphology Impact Assessment Report – Holland River Crossing

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Executive Summary

The Ontario Ministry of Transportation (the Ministry) has retained AECOM Canada Ltd. (AECOM) to undertake a Preliminary Design and project-specific assessment of environmental impacts for the proposed Highway 400 to Highway 404 Link (Bradford Bypass). The Bradford Bypass (the project) is being assessed in accordance with Ontario Regulation 697/21 (the Regulation). The Ministry previously completed a route planning study for the Bradford Bypass that received subsequent approval in 2002.

The project is a new 16.3 kilometre (km) controlled access freeway. The proposed highway will extend from Highway 400 between 8th Line and 9th Line in Bradford West Gwillimbury, will cross a small portion of King Township, and will connect to Highway 404 between Queensville Sideroad and Holborn Road in East Gwillimbury. There are proposed full and partial interchanges, as well as grade separated crossings at intersecting municipal roads and watercourses, including the Holland River and Holland River East Branch. This project will also include the design integration for the replacement of the 9th Line structure on Highway 400, which will accommodate the proposed future ramps north of the Bradford Bypass corridor. The Ministry is considering an interim two-lane configuration and an ultimate four-lane design for the Bradford Bypass. The interim condition will include two general purpose lanes in each direction and the ultimate condition will include four lanes in each direction (one high-occupancy vehicle lane and three general purpose travel lanes in each direction). The interim and ultimate designs are being reviewed as the project progresses. This Report and its findings are based on the project footprint identified within this Report. Should the footprint change or be modified in any way, a review of the changes shall be undertaken, and the Report will be updated to reflect the changes, impacts, mitigation measures, and any commitments to future work.

The purpose of this Draft Fluvial Geomorphology Report (this Report) will be to characterize geomorphological baseline conditions to provide input to the Preliminary Design for: crossing design and impact assessment for the watercourses upstream and downstream of the proposed crossings, and to provide an opportunity to mitigate both future erosion risk to the structures and adverse impacts on the watercourse. The focus of this Report has been limited to the upstream and downstream extent of the Holland River and Holland River East Branch crossings, with the remainder of the crossings detailed in the *Fluvial Geomorphological Assessment Report – Bradford Bypass Crossings,* (AECOM, 2022), available under a separate cover. Recommendations for the Preliminary Design will relate to the proposed location, configuration, span, pier placement if required, and the Preliminary Design of the crossing structure for the Holland River and Holland River East Branch crossings.

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1. Overview of Undertaking

1.1 Project Overview

The Ontario Ministry of Transportation (the Ministry) has retained AECOM Canada Ltd. (AECOM) to undertake a Preliminary Design and project-specific assessment of environmental impacts for the proposed Highway 400 – Highway 404 Link (Bradford Bypass). The Bradford Bypass (the project) is being assessed in accordance with Ontario Regulation 697/21 (the Regulation).

The Bradford Bypass is part of Ontario's plan to expand highways and public transit across the Greater Golden Horseshoe to fight congestion, create jobs and prepare for the massive population growth expected in the next 30 years. Simcoe County's population is expected to increase to 416,000 by 2031, with the Regional Municipality of York growing to 1.79 million by 2041. The Bradford Bypass has been proposed as a response to this dramatic growth in population and travel demand in the area and the forecasted increase in congestion on key roadways linking Highway 400 to Highway 404.

The project is a new 16.3 kilometre controlled access freeway. The proposed highway will extend from Highway 400 between 8th Line and 9th Line in Bradford West Gwillimbury, will cross a small portion of King Township, and will connect to Highway 404 between Queensville Sideroad and Holborn Road in East Gwillimbury. There are proposed full and partial interchanges, as well as grade separated crossings at intersecting municipal roads and watercourses, including the Holland River and Holland River East Branch. This project also includes the design integration for the replacement of the 9th Line structure on Highway 400, which will accommodate the proposed future ramps north of the Bradford Bypass corridor. The Ministry is considering an interim two-lane configuration and an ultimate four-lane design for the Bradford Bypass. The interim condition will include two general purpose lanes in each direction and the ultimate condition will include four lanes in each direction (one high-occupancy vehicle lane and three general purpose travel lanes in each direction). The interim and ultimate designs are being reviewed as the project progresses. This Report and its findings are based on the project footprint identified within this Report. Should the footprint change or be modified in any way, a review of the changes shall be undertaken, and the Report will be updated to reflect the changes, impacts, mitigation measures, and any commitments to future work.

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1.2 Study Area

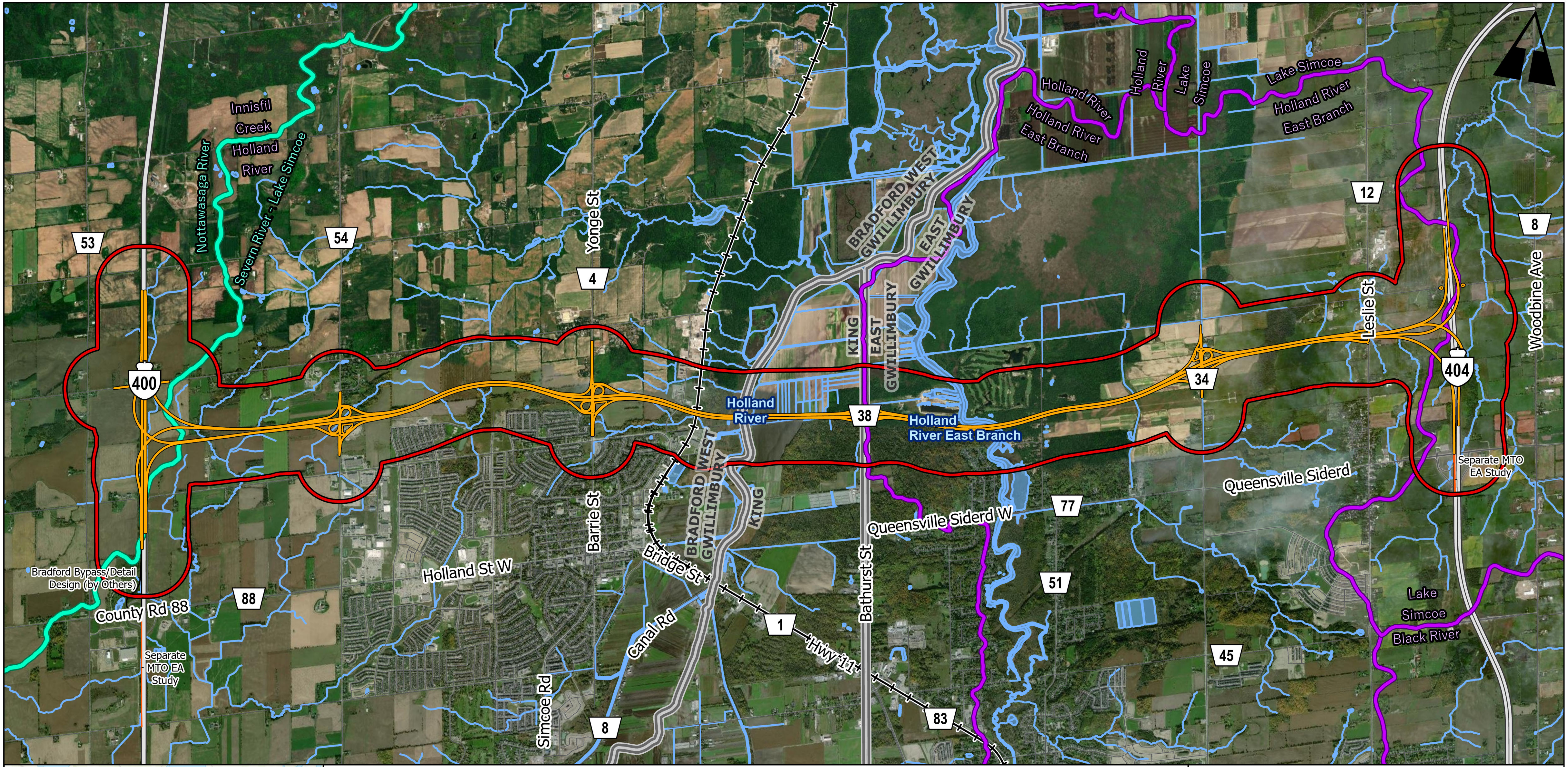
The Study Area is located within Simcoe County (Town of Bradford West Gwillimbury) and the Regional Municipality of York (Township of King and Town of East Gwillimbury). For the purposes of the project, the study area will include the reaches upstream and downstream of the proposed crossings (hereafter referred to as the Study Area). A map of the Study Area is shown in **Figure 1-1**.

The focus of this Report has been limited to the upstream and downstream extent of the East and West Holland River crossings. Bridges are proposed to span the Holland River and the Holland River East Branch. Therefore, fluvial recommendations will pertain to the location of the piers for the proposed bridge structures. The remaining crossings impacted by this project are covered in a separate report as part of this study (*Fluvial Geomorphological Assessment Report – Bradford Bypass Crossings).* Many of the rural areas of Bradford West Gwillimbury and East Gwillimbury adjacent to the proposed Bradford Bypass corridor have already been slated for future urban development in municipal Official Plans.

The details about the two water crossings that are the focus of this Report are presented in **Table 1-1.**

Table 1-1: Location of works

Reach ID	Crossing ID	Highway/Road	Municipality	Latitude	Longitude	Sub Watershed
HR-01	C17-A-1	Hochreiter Road	Township of King, Regional Municipality of York	44.131257°	-79.545499°	West Holland
HREB-01	C20-A-1	Bradford Bypass ROW	Town of East Gwillimbury, Regional Municipality of York	44.136164°	-79.512821°	East Holland
	C20-B-1	Bradford Bypass ROW	Town of East Gwillimbury, Regional Municipality of York	44.137107°	-79.510612°	East Holland



LEGEND

- Study Area (500 m)
- Bradford Bypass Preliminary Design
- Bradford Bypass/Detail Design (by Others)
- Separate MTO EA Study

General Features

- Municipal Boundary
- Railway
- Provincial Highway
- Other Road
- Waterbody
- Watercourse
- Tertiary Watershed Boundary
- Quaternary Watershed Boundary

0 0.5 1 2 3
Kilometers

Highway 400- Highway 404 Link (Bradford Bypass)

Study Area

Figure 1-1

Datum: NAD 1983 UTM Zone 17N
Source: MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
Scale: 1:45,000

Jan, 2023

AECOM

Project Location: C:\GIS\Projects\60636190 BBP Fluvial\PRJ-60636190-BradfordBypass.aprx Layout: FLUVGEO - Study Area
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1.3 Aims and Objectives

When crossings are placed over a watercourse without due consideration of the geomorphologic processes that are occurring within the watercourse, risks to the crossing structure and/or channel form and function may occur. Such risks could lead to the need for continual or emergency maintenance of the crossing and/or could adversely affect channel stability, fish passage potential and aquatic habitat conditions. The fluvial geomorphological assessment will characterize geomorphological baseline conditions and provide input to preliminary crossing design and impact assessment for the watercourse reaches upstream and downstream of the proposed crossings. Only the Holland River and the Holland River East Branch have been included in the fluvial geomorphological study. Refer to the *Fluvial Geomorphological Assessment Report – Bradford Bypass Crossings* (AECOM, 2022), available under a separate cover for the assessment of the remaining crossings.

This information will provide an opportunity to mitigate both future erosion risk to the structures and adverse impacts on the watercourses. The following study components are documented in this Report:

- Review of background documents
- Historical and meander belt assessment
- Field reconnaissance
- Recommendations for preliminary design of crossing structures and channel realignments (where required), and
- High-level review of hydraulic modelling results.

2. Background Review

A background review was conducted to better understand the Study Area and any previous inspections or assessment that have been undertaken prior to this study.

The following documents were reviewed, and information extracted and cited where pertinent as part of the background review:

- LSRCA, 2010b. East Holland River Subwatershed Plan – Chapter 7 Fluvial Geomorphology
- LSRCA, 2010c. West Holland River Subwatershed Management Plan – Chapter 7 Fluvial Geomorphology
- AECOM 2020. Fish and Fish Habitat Existing Conditions Report – FINAL. Highway 400 – Highway 404 Link (Bradford Bypass) W.O. #19-2001
- Ontario Ministry of Transportation, 1997. Environmental Assessment Report One - Stage Submission: Highway 400 – Highway 404 Extension Link EA Study, and
- Environmental Assessment Report One - Stage Submission: Highway 400 – Highway 404 Extension Link EA Study (Bradford Bypass) W.P. 377-90-00 (McCormick Rankin Corporation, 1997).

The following sections summarize the details obtained as part of the background review.

2.1 Previous Geomorphological Assessments

A background review of previous fluvial geomorphic assessments and other related technical reports was undertaken to ensure that the current investigation builds on previous work. The following documents provide key information relating to watershed characteristics and previous findings that form the basis for the detailed fluvial geomorphological assessment.

East Holland River Subwatershed Plan – Chapter 7 Fluvial Geomorphology (LSRCA, 2010b)

A study commissioned to Parish Geomorphic (2007) found the watershed to be stable with little land use change over the 43-yr (1959-2002) period on which the study focused. The study evaluated 23 reaches within the East Holland River subwatershed between the summer of 2005 and the fall of 2006. The report indicates that the planform of the main branch of the East Holland River remained stable and did not have substantial changes from the imagery examined (1959, 1976 and 2002). However, from the intersection of Yonge Street and Mount Albert Road to south of Davis Road, the planform of the East Holland River was straight, coinciding with Newmarket's urban centre. A meander belt assessment was also completed on two reaches of the East Holland River (immediately north and south of the proposed Bradford Bypass). North of the proposed Bradford Bypass the meander belt width was in the range of 161-310 m wide while south of the proposed road the belt width is in the range of 101-160 m. There were no details provided regarding the methodology used to generate the meander belts. The Parish Geomorphic report referenced within the Subwatershed Plan could not be located.

West Holland River Subwatershed Management Plan – Chapter 7 Fluvial Geomorphology (LSRCA, 2010c)

A study commissioned to Parish Geomorphic (2007) found the watershed to be stable with little land use change over the 43-yr (1959-2002) period on which the study focused. The study evaluated 31 reaches within the West Holland subwatershed from summer 2005 to fall 2006 and only one reach received an RGA score of "in adjustment". Thirteen reaches were determined to be "transitional" and 17 were determined to be "in regime". A list of reaches is provided, and several are located within the current Study Area. However, due to the quality of the document/reaches map (poor resolution) the ID of the reaches within the Study Area can't be determined. Channel widening was the dominant process observed and aggradation was frequently observed on the downstream section of the watershed. The report noted that several tributaries have been channelized closer to the mouth and that agricultural practices were likely the reason. Table 7-5 within the West Holland River Subwatershed Management Plan contains information of field observations and Rapid Geomorphic Assessment (RGA) and Rapid Stream Assessment Technique (RSAT) scores. A meander belt assessment was also completed on two reaches of the West Holland River (immediately north and south of the proposed Bradford Bypass). The meander belt width for the two reaches is reported in the range of 161-310 m wide. There were no details provided regarding the methodology used to generate the meander belts. The Parish Geomorphic report referenced within the Subwatershed Plan could not be located.

Fish and Fish Habitat Existing Conditions Report – FINAL. Highway 400 – Highway 404 Link (Bradford Bypass) W.O. #19-2001 (AECOM, 2020)

The report presented a desktop review of existing reports and documents of fish and fish habitat conditions along the area of the proposed Bradford Bypass. The report identified thirty-six (36) aquatic features (rivers, streams, and roadside/agricultural drains) along the technically preferred route for the Bradford Bypass. Many of the aquatic features identified are regulated under the *Fisheries Act (Protocol for Protecting Fish and Fish Habitat on Provincial Transportation Undertaking, Version 4 (the Protocol) (MTO, 2019).* The design of the Bradford Bypass will be subject to assessment under the Ministry of Transportation Ontario (MTO) / Fisheries and Oceans Canada (DFO) / Ministry of Natural Resources and Forestry (MNRF), and Fisheries Protocol to determine whether the project will result in harmful alteration, disruption or destruction (HADD) of fish habitat.

Environmental Assessment Report One – Stage Submission: Highway 400 – Highway 404 Extension Link EA Study (Bradford Bypass) W.P. 377-90-00 (McCormick Rankin Corporation, 1997)

The Rankin 1997 report, referred to as the 2002 Approved EA, provided a travel demand forecast analysis for the region south of Cook's Bay (Lake Simcoe). The report determined that based on the forecasted population growth in the areas adjacent to Newmarket and the Highway 400, travel demands would increase and that an east-west transportation corridor was necessary to accommodate the population growth. In Section 5.4.2 (Natural Environment) of the report, the issue of minimizing potential impacts from long-span bridges and culverts to surface water systems (physical characteristics, water quality and quantity) was brought forward by key stakeholders including the Ministry of Transportation Ontario (MTO), Ministry of Natural Resources and Forestry (MNRF), Ministry of the Environment, Conservation and Parks (MECP), Fisheries and Oceans Canada (DFO), Lake Simcoe Region Conservation Authority (LSRCA), interest groups and the general public. As an initial mitigation strategy, the report recommended that the design of bridges and culverts maintain the existing channel form and flow; that fish movement is not impeded; bridge piers are not placed within channels; that erosion and flood risk are minimized upstream and downstream of structures; that slope stability be maintained; and that open bottom culverts be used in upwelling areas.

2.2 Watershed Characteristics

From east to west, the overall Study Area spans the subwatersheds of Maskinonge River, West Holland River, East Holland River, and the Innisfil Creek. The Maskinonge and the Holland River subwatersheds are part of the larger Lake Simcoe watershed and are under the jurisdiction of the Lake Simcoe Region Conservation Authority (LSRCA), while the Innisfil Creek subwatershed is part of the larger Nottawasaga River watershed and is under the jurisdiction of the Nottawasaga Valley Conservation Authority (NVCA). Maps of the surficial geology and topography within the vicinity of the full project Study Area are illustrated in **Figure 2-1** and **Figure 2-2**, respectively).

The two crossings that are the focus of this Report (the Holland River and Holland River East Branch crossings) are located within the East Holland River and the West Holland River Subwatersheds. The following sections provide a detailed summary of the West Holland River and East Holland River subwatersheds, including a review of the physiography, surficial geology, topography, and land use information. This information provides context for consideration of fluvial geomorphology and drainage characteristics within the Study Area. The physiography and geological setting of the watercourse play an important role in shaping the channel in terms of cross-section, planform, and longitudinal profile, which controls the energy available to entrain and transport the substrate as it is eroded from the valley within the channel. In general, areas where the slope of the channel is steep can experience more transport and possibly erosion. Whereas areas with lower gradients can result in sediment deposition. Overall, the physiography and local geology surrounding the watercourse plays an important role in the susceptibility to erosion.

2.2.1 East Holland River Subwatershed

The portion of the Study Area within the East Holland subwatershed extends east from Bathurst Street to Highway 404 in the vicinity of the Study Area. The subwatershed is drained by the East Holland River, which flows generally in a northerly direction and drains into Cook's Bay (Lake Simcoe). The main branches of the East Holland River include the Main Branch, flowing westward from a point west of Musselman's Lake; the Aurora Branch; Wesley Corners Creek; and Bogart Creek (LRSCA, 2010b). The Main Branch and the Aurora Branch join north of the Town of Aurora to form the East Holland River and continue to flow north to discharge into Cook's Bay (LSRCA, 2010b). This subwatershed also has a significant number of ephemeral watercourses that dry up during the summer seasons (LRSCA, 2010b). East Holland Subwatershed has a large range of thermal regimes, contains cold to coolwater tributaries feeding a warmwater Main Branch and many watercourses have been channelized to accommodate agricultural development (many that are recognized as Municipal Drains) (LSRCA, 2010b).

The East Holland River subwatershed area is approximately 247 km^2 with approximately 31% of its area used for agricultural practices; 31% as natural heritage areas and approximately 27% urbanized (LSRCA, 2010b).

2.2.1.1 Physiography and Geology

The East Holland River subwatershed is divided between four physiographic regions: The Oak Ridges Moraine, the Simcoe Lowlands, the Schomberg Clay Plains, and the Peterborough Drumlin Fields (Chapman and Putnam, 1984; OGS, 2021b). The Study Area is located within the Simcoe Lowlands physiographic region.

The surficial geology within the Study Area varies from silt and clay with minor sand and gravel glaciolacustrine deposits to the east of the subwatershed, to coarse texture glaciolacustrine deposits of sand, gravel, with minor silt and clay on the central and west portions of the subwatershed (Chapman and Putnam, 1984; OGS, 2021a). Along the East Holland River organic deposits of peat, muck and marl are also found (Chapman and Putnam, 1984; OGS, 2021a).

It is expected that watercourses located within the areas which are dominated by coarse texture glaciolacustrine deposits (central and west portion the East Holland subwatershed) will be less resistant to fluvial activity and might experience higher rates of erosion due to the low cohesiveness of sand and gravel size materials.

2.2.1.2 Topology

The elevation of the East Holland River varies from approximately 221 mASL at Queensville Side Road, to 220 mASL at the confluence with the West Holland River. This is a relatively flat topography, which is expected to contribute to lower erosion rates within the study area.

2.2.1.3 Land Use

The land use in the East Holland River subwatershed along the proposed highway corridor is predominantly agricultural and natural forested areas with smaller areas of recreational and residential properties.

2.2.2 West Holland River Subwatershed

The portion of the Study Area located within the West Holland River subwatershed extends from just east of Highway 400 to Bathurst Street. The subwatershed is drained by the West Holland River, which flows in a northeast direction and drains into Cook's Bay (Lake Simcoe). The main tributaries of the West Holland River include: Ansnorveldt Creek, Glenville Creek, East Kettleby Creek, 400 Creek, Pottageville Creek, South Schomberg River, North Schomberg River, Fraser Creek, Scanlon Creek, William Neeley Creek, Coulson's Creek and the Holland Marsh and its extensive canal and Municipal Drain system (LSRCA, 2010c). The headwaters originate from discharge springs and seepages along the northern parts of the Oak Ridges Moraine (LSRCA, 2010c); however, tributaries to the West Holland River that do not originate on the Oak Ridges Moraine, like Fraser Creek, have different characteristics such as temperature regime and substrate, and thus fish community assemblages may differ to other Holland River Tributaries (LRSCA, 2010c).

The West Holland River subwatershed area is approximately 354 km^2 and the primary land use is agricultural at approximately 57%. Approximately 31% of the watershed remains as natural heritage areas and 3% is occupied by urban areas that are projected to expand (LSCA, 2010c).

2.2.2.1 Physiography and Geology

The West Holland River subwatershed is divided into four physiographic regions: The Oak Ridges Moraine, the Simcoe Lowlands, the Schomberg Clay Plains and the Peterborough Drumlin Field (Chapman and Putnam, 1984; OGS, 2021b). The portion of the Study Area located within the West Holland subwatershed sits within the Simcoe Lowlands to the east of the subwatershed, and to the west on the Peterborough Drumlin Field and the Schomberg Clay Plains (Chapman and Putnam, 1984; OGS, 2021b).

The surficial geology of the Study Area within the east portion of the West Holland subwatershed varies from glaciolacustrine deposits of silt and clay with minor sand and gravel to coarse-texture deposits of sand, gravel, with minor silt and clay. The west portion of the subwatershed is characterized by a combination of glaciolacustrine deposits of stone-poor, sandy silt to silty sand tills and silt and clay with minor sand and gravel. Along the West Holland River organic deposits of peat, muck and marl are found (Chapman and Putnam, 1984; OGS, 2021a).

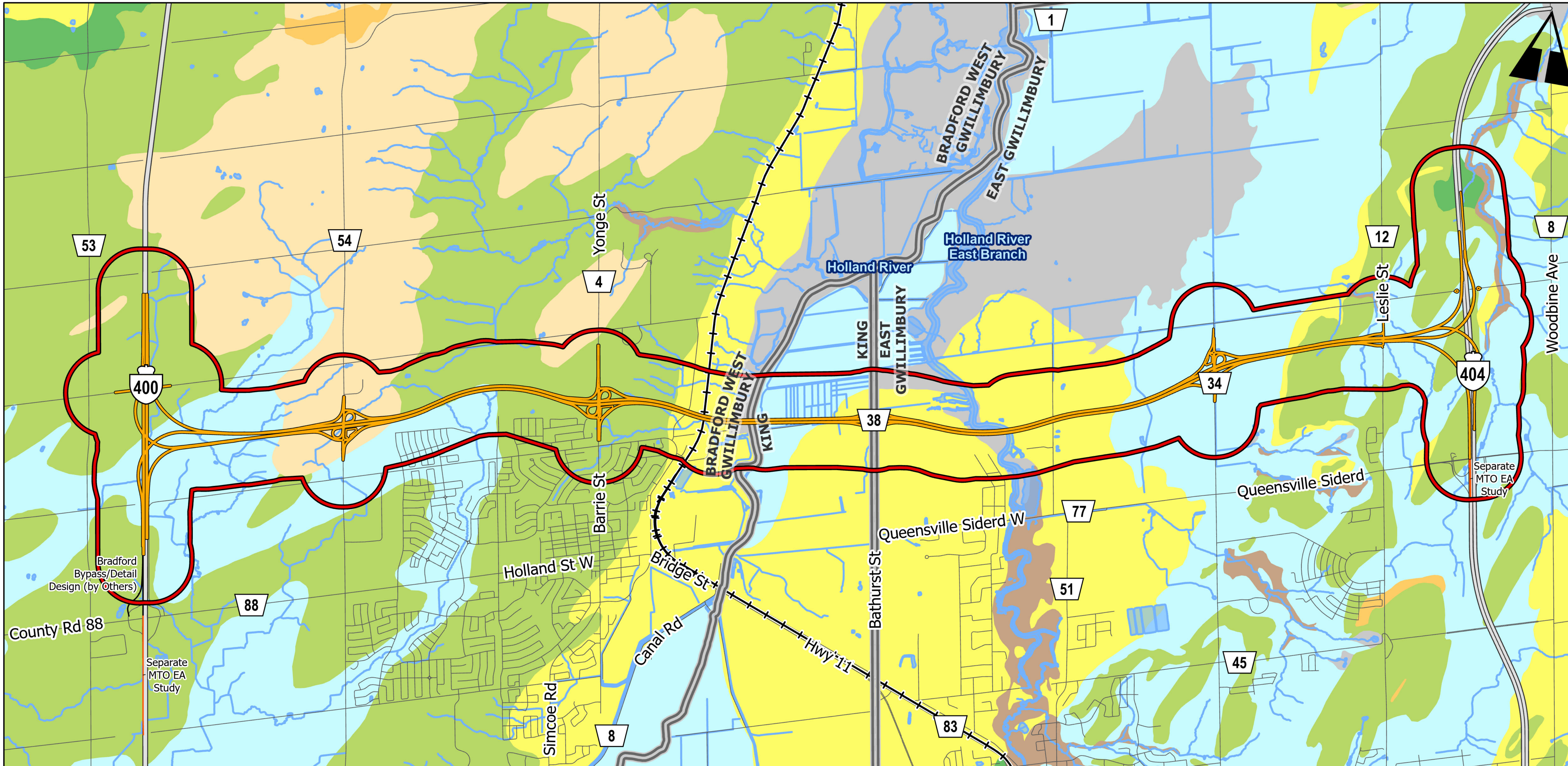
Areas of the subwatershed located within the Schomberg Clay Plains are expected to be more resistant to fluvial eroding forces due to the greater cohesion of clay and silt dominant deposits, except for localized areas where coarse-textured deposits are dominant. Nonetheless, recent increase in impermeable urban areas (residential and roads) within the West Holland River subwatershed can increase the rates of erosion as time of concentration for runoff are reduced within the subwatershed.

2.2.2.2 Topology

The elevation along West Holland River remains relatively flat from Bridge Street (south of the Study Area) to the confluence with the East Holland River branch, is approximately 220 mASL.

2.2.2.3 Land Use

The land use within the West Holland River subwatershed along the proposed highway corridor is predominantly agricultural and residential with smaller natural forested areas and industrial/commercial properties.



LEGEND

- Study Area (500 m)
- Bradford Bypass Preliminary Design
- Bradford Bypass/ Detail Design (by Others)
- Separate MTO EA Study

Surficial Geology

- 5b: Stone-poor, carbonate-derived silty to sandy till
- 5d: Glaciolacustrine-derived silty to clayey till
- 6: Ice-contact stratified deposits
- 7: Glaciofluvial deposits
- 8a: Massive-well laminated
- 9b: Littoral-foreshore deposits
- 9c: Foreshore-basinal deposits
- 12: Older alluvial deposits
- 17: Eolian deposits
- 19: Modern alluvial deposits
- 20: Organic deposits

General Features

- Municipal Boundary
- Railway
- Provincial Highway
- Other Road
- Waterbody
- Watercourse

0 0.5 1 2 3
Kilometers

Highway 400- Highway 404 Link (Bradford Bypass)

Surficial Geology

Figure 2-1

Datum: NAD 1983 UTM Zone 17N
Source: MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
Scale: 1:45,000

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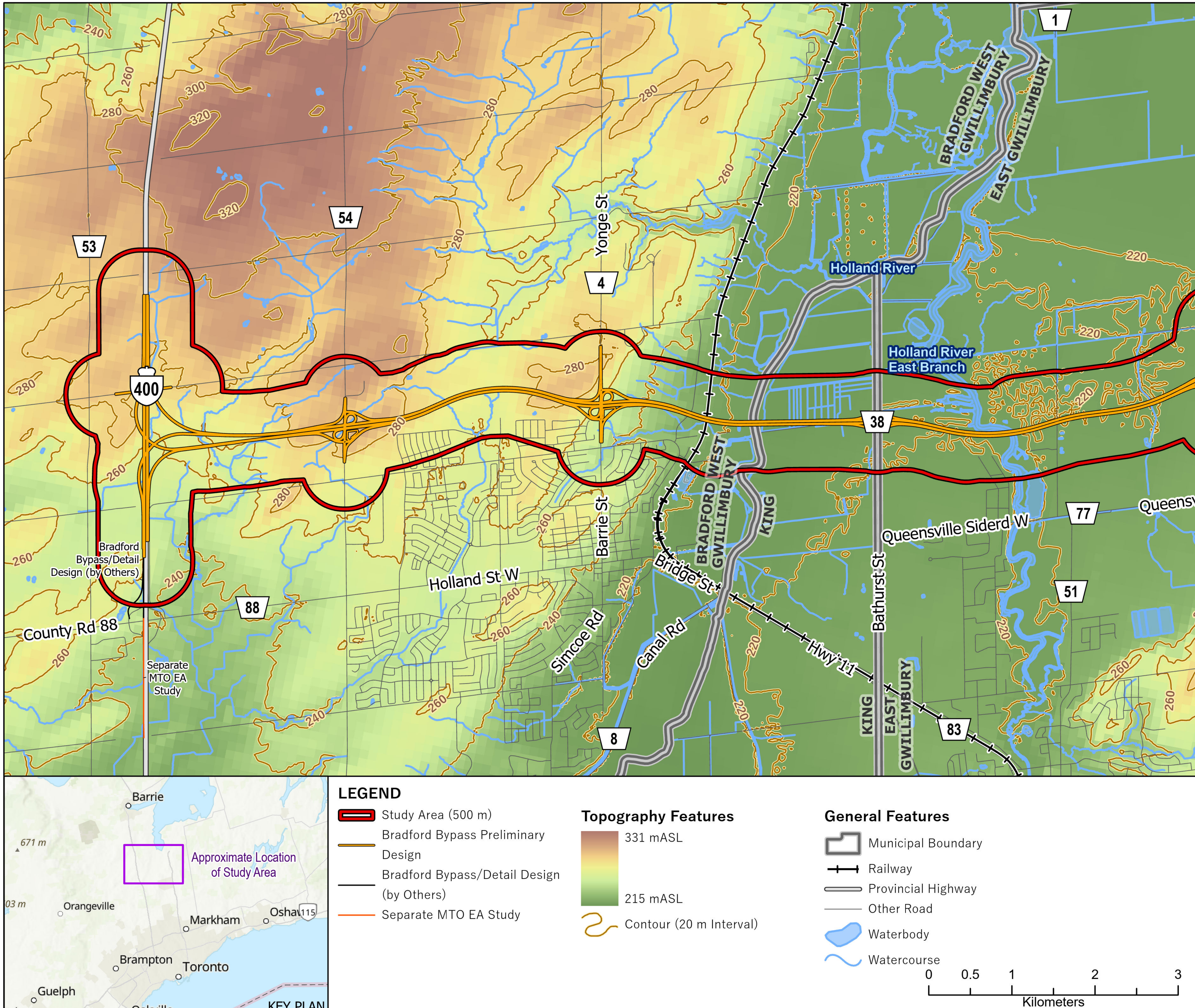

Highway 400- Highway 404 Link (Bradford Bypass)

Topography

Figure 2-2

Datum: NAD 1983 UTM Zone 17N
Source: MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
Scale: 1:45,000

Jan, 2023

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3. Desk Based Assessment

3.1 Reach Delineation

Reaches can be defined as lengths of the channel that display similar physical characteristics and have a setting that remains nearly constant along their length. Reaches display relative homogeneity in channel form, functions and process and are influenced by similar controlling (discharge, slope) and modifying factors (vegetation) to which the channel has become adjusted or will become adjusted to in the future.

Reach breaks within the Study Area were first delineated through a desktop assessment of tributary locations, channel gradient, geology, valley setting, sinuosity and riparian vegetation using Geographic information System (GIS) layers. The reaches were subsequently confirmed in the field. Reach names were assigned using a watercourse identifier (HR = Holland River, HREB = Holland River East Branch), followed by a number to create a unique reach ID.

The location and rationale of the reach breaks within the Study Area is stated in **Table 3-1** and displayed in **Figure 3-1**.

Table 3-1: Reach Selection Justification

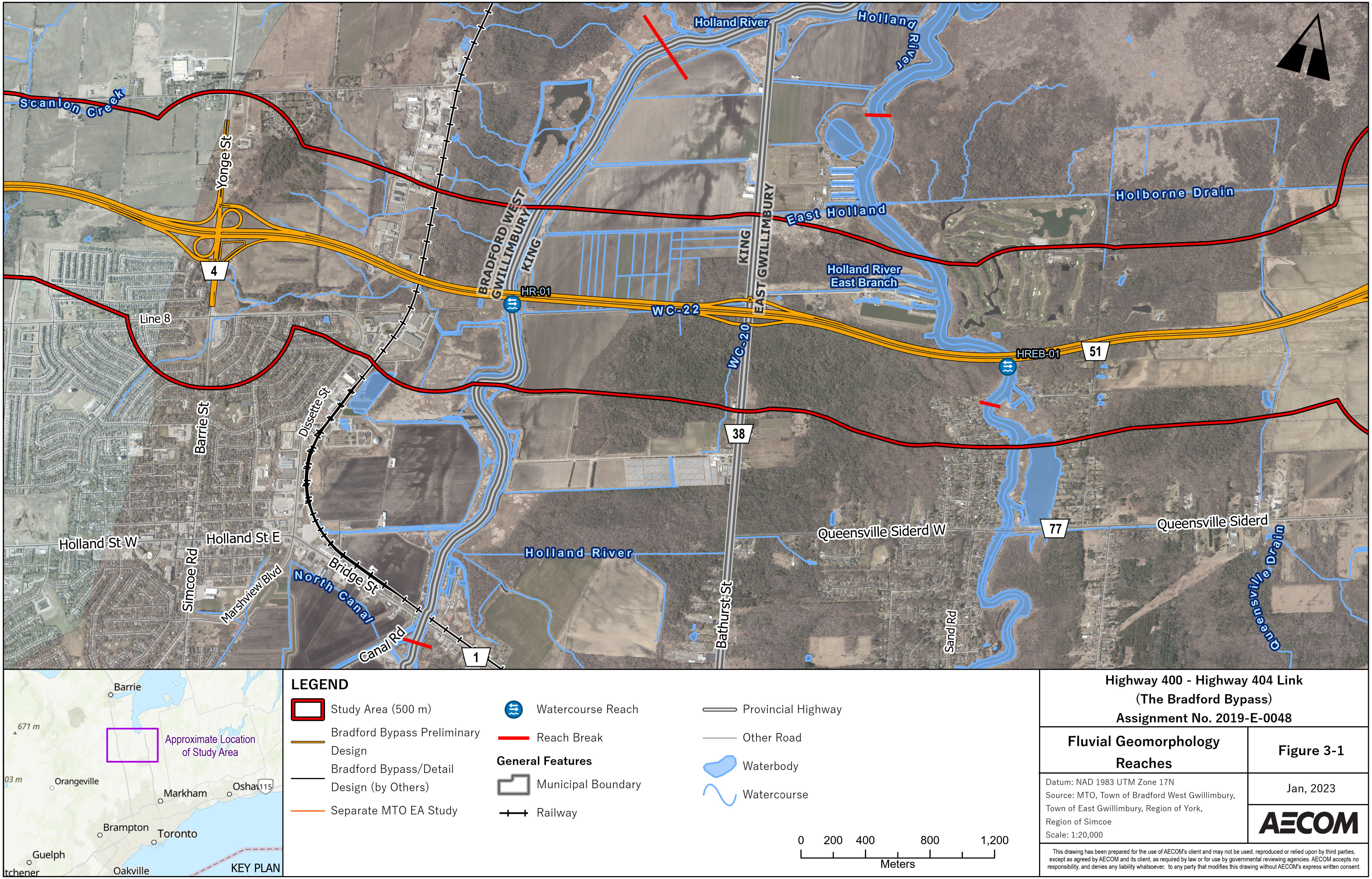
Reach	Crossing ID	Upstream Boundary Reason	Upstream Boundary Coordinates	Downstream Boundary Reason	Downstream Boundary Coordinates	Hydraulic Regime
HR-01	C17-A-1	Confluence between two watercourses (South Canal and North Canal Tributaries)	44.1121 -79.5461	Confluence present downstream and change from relatively straight planform to more meandering planform	44.1479 -79.5394	Permanent
HREB-01	C20-A-1 C20-B-1	Change in adjacent land use and riparian vegetation. From residential to woodlot type	44.1332 -79.5077	Change in riparian vegetation from mix of woodlot and recreational to agricultural and meadow type	44.1472 -79.5220	Permanent

3.2 Historical Assessment

Historical aerial photographs showing each of the reaches in the vicinity of the Study Area taken in 1969, 1981, and 2018 were reviewed to analyze changes in local land use and channel planform in the vicinity of the proposed crossing structures. The historical channel configurations were digitized and analyzed using Geographic Information Systems (GIS) software to identify changes between 1969 and 2019. Results are summarized in **Table 3-2**. The study by Parish Geomorphic (2007) also found that the Holland River East Branch was stable with only minor changes in the aerial imagery examined (1959, 1976, 2002).

Table 3-2: Historical Assessment of Reaches within the Study Area

Reach	Crossing ID	1969	1981	2018
HR-01	C17-A-1	Holland River branch, natural meandering planform. Agricultural activities adjacent to right bank present prior to 1969.	No significant changes in channel planform since 1969	No major changes in channel planform. Residential developments appear on left bank prior to 2018. Evidence of erosion along right bank of the inner meander upstream of the proposed crossing.
HREB-01	C20-A-1 C20-B-1	Holland River East Branch. A residential development on the left bank of the feature (north and south of Queensville Sideroad West) is present prior to 1969. Also prior to 1969, a boat marina is present on the left bank, east of Bathurst St. and a second marina is present on the right bank, at the end of Morgans Rd.	Boat marina on the left bank, off Bathurst St. substantially increased in size since 1969. Further downstream, also on the left bank and north, a large boat marina has been carved on the feature's left bank.	Prior to 2018, a large golf course development took place on the right bank of the feature (north of Morgans Rd.). Despite changes in land use on the feature’s banks and floodplain, its meandering planform relatively remains unchanged. The only visible evidence of erosion is recession of the outer meanders downstream of the proposed crossing.



Highway 400 - Highway 404 Link
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Fluvial Geomorphology Reaches

Figure 3-1

Datum: NAD 1983 UTM Zone 17N
Source: MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
Scale: 1:20,000

Jan, 2023

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4. Field Based Assessment

Field reconnaissance was completed between September 22 and October 1, 2020, and again between May 24 and May 26, 2022, to assess identified reaches within the Study Area. Fieldwork was performed to identify existing geomorphological form and processes located within the Study Area and to verify the results of the desktop assessment.

4.1 Geomorphological Reach Characterization

During field reconnaissance, geomorphological reach breaks were assessed, as detailed in **Table 4-2**. A photographic record (**Appendix A**) was also completed to document channel dimensions, bank and bed materials, riparian vegetation, valley walls, and floodplain dynamics. Locations of geomorphological importance were also photographed including bank erosion sites, channel modifications, and woody material within the watercourse. An overview of site observations and interpretations are provided in the following sections.

Table 4-1: Geomorphological Reach Characterization

Reach Name	Crossing ID	Description
HR-01	C17-A-1	The reach is part of the Holland River and it is a defined alluvial channel with a meandering planform of moderate gradient, and unconfined with access to the floodplain. The reach is approximately 4,520 m in length. Its upstream reach break is approximately 140 m east of Peterman Lane and 130 south of Bridge Street. The estimated bankfull width and depth are 100 to 120 m and 1.5 to 2 m, respectively. The feature did not have a visible riffle-pool morphology due to the high-water levels and the wetted width was estimated at approximately 90 m (wetted depth could not be collected safely). The bed substrate could not be safely investigated, and the bank materials consisted of clay, silt, and sand. The surrounding vegetation was herbaceous along the right bank (east) and woodlot type along the left bank (west). Exposed bridge footings and fallen/leaning trees/fence posts/etc. were noted during the assessment. Woody debris was observed however, not all of it could be attributed to fluvial processes.
HREB-01	C20-A-1 C20-B-1	The reach is part of the Holland River East Branch, it is a defined alluvial channel with a meandering planform, permanent hydrological regime, moderate gradient, and unconfined with access to the floodplain. The banks of the channel are well protected by wetland type vegetation and there is no erosion reported along the outer bends. The reach is approximately 2,460 m in length. Its upstream reach break is approximately 620 m west of Yonge Street and 780 m north of Queensville Sideroad West. Field measurements were not collected due to safety concerns. The feature did not have a visible riffle-pool morphology due to the high-water levels and the wetted width was estimated at approximately 83 m (wetted depth could not be collected safely). The bed substrate could not be safely investigated, and the bank materials consisted of clay, silt, and sand. The surrounding vegetation was herbaceous and woodlot type. A marina located on the west bank of the reach is a potential source of channel disturbance. No evidence of erosion was noted on the day of the assessment. Woody debris was observed however, not all of it could be attributed to fluvial processes.

4.2 Rapid Geomorphic Assessment

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of the Environment, Conservation and Parks (MECP) (1999) to assess reaches in urban channels. This technique uses visual indicators to document evidence of channel instabilities using presence/absence methodology. Stability is determined by adjustments in slope, either an increase (aggradation) due to sediment deposition or a decrease (degradation) due to bed erosion. It also considers an increase in the bank-to-bank width (widening) and by any evidence indicating adjustment in the planimetric form regime. Each of the geomorphic indicators is documented throughout the reach and upon completion is tallied by category. These data are then used to calculate an overall reach stability index which classifies the reach as 'stable', 'transitional', or 'in-adjustment' corresponding to their relative sensitivity to altered sediment and flow regimes. The classification and interpolation as defined by the factor value (total score) are identified in **Table 4-2** (taken from the MECP, 2003).

Results of the Rapid Geomorphological Assessment for the Holland River East Branch (Reach HREB-01) and the Holland River (HR-01) are summarized in **Table 4-3**. The RGA classified both reaches HR-01 and HREB-01 as 'In Regime' indicating that channel morphology is stable and with little evidence of changes to the planform, bed, or banks.

Table 4-2: Rapid Geomorphic Assessment Criterion

Factor Value	Classification	Interpretation
≤0.20	In Regime or Stable Least Sensitive)	Channel morphology is within a range of variance for streams of similar hydrographic characteristics – evidence of instability is isolated or associated with normal river propagation processes.
0.21- 0.40	Transitional or Stressed (Moderately Sensitive)	Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent.
≥0.41	In Adjustment (Most Sensitive)	Channel morphology is not within a range of variance and evidence of instability is widespread.

Table 4-3: Rapid Geomorphic Assessment Results

Reach	Crossing ID	Factor Value Aggradation	Factor Value Degradation	Factor Value Widening	Factor Value Planimetric Form Adjustment	Stability Index	Condition
HR-01	C17-A-1	0.14	0	0.13	0.14	0.1	In Regime
HREB-01	C20-A-1 C20-B-1	0.14	0	0.00	0.14	0.07	In Regime

Throughout the reach along HR-01 and HREB-01, there was minor evidence of aggradation, widening (for HR-01), and planimetric form adjustment.

Minor evidence of channel widening included fallen and leaning trees along the banks. This can be localized instability or a result of the channel attempting to enlarge its cross-section due to changes in flow regime, such as those resulting from increased urbanization (i.e., increased stormwater flows due to higher impervious surfaces and therefore elevated runoff). Instability within the watercourse often occurs due to increased run-off patterns which can alter the flow and sediment regime as a result.

Aggradation is influenced by discharge, sediment load, morphological characteristics such as slope, and changes in flow regime due to human activity. Both watercourse slopes were observed to be relatively flat during the field investigations (**Section 4.1)** and analysis of the topography from mapping resources (**Sections 2.2.1.2 and 2.2.2.2**). The minor instability noted along the reach, in the form of fallen and leaning trees, can increase sediment load within the channel resulting in depositional areas if the flow cannot entrain and transport it.

4.3 Photographic Record

A photographic record was completed to document channel dimensions, bank and bed materials, riparian vegetation, valley walls, and floodplain dynamics. Locations of geomorphological importance were also photographed and included areas of bank erosion and channel modification. The complete photographic record can be found in **Appendix A**.

5. Meander Belt Width Assessment

Watercourses are dynamic features and therefore undergo movement within the floodplain. The associated erosion and deposition that occurs as a result of meander development and migration processes can cause loss or damage to private property and/or infrastructure. For this reason, it is desirable to delineate a corridor that contains the natural meander and migration tendencies of the channel. Outside this corridor, it is assumed that private property and structures are beyond the area at risk from fluvial erosion. The space in which the meandering watercourse occupies its floodplain, and in which all associated natural channel processes occur, is commonly referred to as the meander belt. It is typical to consider the meander belt width when adding a new river crossing structures as they can impact hydraulic connectivity and sediment transport within the watercourse, leading to increased maintenance and future fluvial geomorphological issues.

The guidance publications "Watershed Development Guidelines (for the Implementation of Ontario Regulation 179/06)" (LSRCA, 2020) and "Belt Width Delineation Procedures" (TRCA, 2004) provide protocols for defining appropriate meander belt widths for unconfined and confined systems. The preferred approach involves drawing tangential lines parallel to the meander belt axis (i.e., valley axis), along the outside of the meanders that are situated at the edge of the floodplain. The perpendicular distance between these two lines represents the meander belt width. Approaches to defining the meander belt widths vary depending on whether the reach is unconfined, partially confined or confined by valley walls:

- Unconfined watercourses have no limits on spatial occupation of the floodplain
- Partially confined watercourses come into contact with the valley wall on one side of the channel which restricts the meander migration, and
- Confined watercourses come into contact with the valley wall on both sides of the channel which restricts channel migration. Thus, valley walls restrict the channel from occupying its potential meander belt (TRCA, 2004).

The current meander belt width assessment only analyzed reaches HR-01 and HREB-01, whose hydrological regime was categorized as permanent. Both watercourses are also classified as "unconfined".

It should be mentioned that background materials reviewed in **Section 2.2** *Watershed Characteristics,* indicated that meander belt analyses have been completed for the branches of the Holland River, however, there was no access to the methodology used and the analyses were completed prior to the existence of the current LSRCA Watershed Development Guidelines (2020). The meander belt widths calculated for reaches delineated to the north and south of the proposed crossings within the Holland River and Holland River East Branch range from 161 to 310 m.

5.1 Preliminary Meander Belt

The preliminary meander belt width was predicted in accordance with the available guidelines from LSRCA. The assessment was conducted in accordance with these guidance documents, using digital aerial photography, topographic mapping, and historic channel positions in a GIS. The LSRCA guidelines recommend that for unconfined systems the bankfull width be multiplied 20 times and confined systems require that the average annual erosion rate be determined.

Empirical analyses were also undertaken to calculate the meander belt width using a range of published models, based on channel and drainage metrics. Empirical Meander belt width calculations were based a range of published models using the following input variables: bankfull width (W), bankfull depth (D), and discharge (Qbf and Bbf). The results of each model are weighted equally to arrive at an average preliminary meander belt width. The values used in the empirical analysis were calculated based on the averages taken from rapid cross-sections and are presented in **Table 5-1**.

The results of the empirical analyses (**Table 5-2**) were subsequently compared with the results from the preliminary meander belt width calculated in accordance with the methods suggested by LSRCA (twenty times the bankfull width). The values produced by empirical analysis are a second form of reliability when conducting the meander belt assessment. It should be noted that the results calculated using empirical analysis are much less than those determined by the 20 times the bankfull method. The empirical calculations are likely more accurate as they take into account more variables than the 20 times method.

The meander belt widths defined for each reach are summarized in **Table 5-3.** It should be noted that these meander belt widths do not take into account geotechnical or slope stability issues.

Table 5-1: Meander Belt Width Input Variables for Empirical Calculations

Channel Parameters (Input for Empirical Assessment)	Notation	Units	Value (m)	
			HR-01	HREB-01
Bankfull Width	Wbf	m	120	130
Bankfull Depth	Dbf	m	2	2
Bankfull Area	Abf = Wbf * Dbf	m2	240	260

Table 5-2: Empirically Calculated Preliminary Meander Belt Width Results

Source	Conditions/ Applications	Input Variable	Equation	Estimated Meander Belt Width (m)	
				HR-01	HREB-01
Ward et al. (2002)	W_{bf} in feet - no factor of safety	Bankfull Width (ft)	$4.8 * W_{bf}^{1.08}$	929.0	1012.9
Ward et al. (2002)	W_{bf} in feet - with factor of safety	Bankfull Width (ft)	$6 * W_{bf}^{1.12}$	1474.9	1613.2
Williams (1986)	$W_{bf} > 1.5$ m	Bankfull Width (m)	$4.3 * W_{bf}^{1.12}$	916.5	1002.5
Piegay et al. (2005) and Bravard et al. (1999)	Average	Bankfull Width (m)	$10 * W_{bf}$	1200.0	1300.0
NRCS manual TS14S (2007)		Bankfull Width (m)	$6 * W_{bf}$	720.0	780.0
Lorenz and Heinze (1985)		Bankfull Width (m)	$7.53 * W_{bf}^{1.01}$	947.9	1027.7
Malavoi et al. (1998)		Bankfull Width (m)	$10 * W_{bf}$	1200.0	1300.0
Kline and Dolan (2008)	Vermont - general guidance	Bankfull Width (m)	$6 * W_{bf} + 1\ W_{bf}$ on either side = $8 * W_{bf}$	960.0	1040.0
Mean				1043.5	1134.5

Source	Conditions/ Applications	Input Variable	Equation	Estimated Meander Belt Width (m)	
				HR-01	HREB-01
Williams (1986)		Bankfull Depth (m)	$148 * D_{bf}^{1.52}$	424.5	424.5
Bridge and Mackey (1993)		Bankfull Depth (m)	$59.9 * D_{bf}^{1.8}$	208.6	208.6
Mean				211.0	211.0
Williams (1986)	Bankfull area > 0.04 m^2	Bankfull area (m^2)	$18 * A_{bf}^{0.65}$	634.5	668.4
TOTAL AVERAGE				874.2	943.4

Table 5-3: Preliminary Meander Belt Width Results

Reach	Crossing ID	Hydrological Regime	Floodplain Characteristic	Conservation Authority	Bankfull Width (m)*	20 times Bankfull Width Preliminary Meander Belt Width (m) **	Empirical Preliminary Meander Belt Width
HR-01	C17-A-1	Permanent	Unconfined	LSRCA	120	2,400 m	874.2 m
HREB-01	C20-A-1 C20-B-1	Permanent	Unconfined	LSRCA	130	2,600 m	943.4 m

* Bankfull widths are approximate based on aerial imagery mapping.
**LSRCA uses twenty times the bankfull width to determine the meander belt for unconfined systems as established in the OMNR Technical Guide – River and Stream Systems: Erosion Hazard Limit, 2002.

5.2 Erosion Allowance – Average Annual Recession Rate (100-Year Erosion Rate)

Further to the preliminary meander belt width, an additional erosion allowance was completed to account for the 100-year erosion potential (**Table 5-4**). A minimum of 25-years of historical data are required to provide a measure of reliability when determining the average annual recession rate extended over 100-years (TRCA, 2004).

The average annual recession rate was calculated for Reach HR-01 (west branch) and HREB-01 (east branch) at 8 points per reach where meander migration or movement was observed based on historical aerial imagery from 1989 and 2018. The points were measured on two upstream meander bends and two downstream meander bends on each reach. Overall, an average 100-year erosion rate or 24.5 m or 0.25 m/year was calculated for Reach HR-01 and 21.9 m or 0.22 m/year for Reach HREB-01.

It should be noted that results are subject to error inherently associated with any historic erosion rate analysis, due to variable, and occasionally poor image quality and resolution with aerial photographs which may inhibit precise delimitation of back bank positions. For this reason, +/- 3 m is a conservative estimate of the standard error and was added to the 100-year erosion rate for a final rate of 25 m +/-3 m for Reach HR-01 and 22 m +/-3 m Reach HREB-01.

Table 5-4: Erosion Allowance Calculations

Reach	Cross Section	Erosion Rate (m/yr)	100-year Erosion Rate (m/100-yrs)
Holland River			
HR-01	1	0.18	17.64
HR-01	2	0.12	11.83
HR-01	3	0.52	52.50
HR-01	4	0.20	20.39
HR-01	5	0.14	13.76
HR-01	6	0.14	13.82
HR-01	7	0.38	37.75
HR-01	8	0.28	28.47
Holland River Erosion Allowance Average: 24.52			
Holland River East Branch			
HREB-01	1	0.29	28.52
HREB-01	2	0.18	17.57
HREB-01	3	0.22	22.16
HREB-01	4	0.16	16.31
HREB-01	5	0.21	20.90
HREB-01	6	0.29	28.75
HREB-01	7	0.16	16.28
HREB-01	8	0.25	25.03
Holland River East Branch Erosion Allowance Average: 21.94			

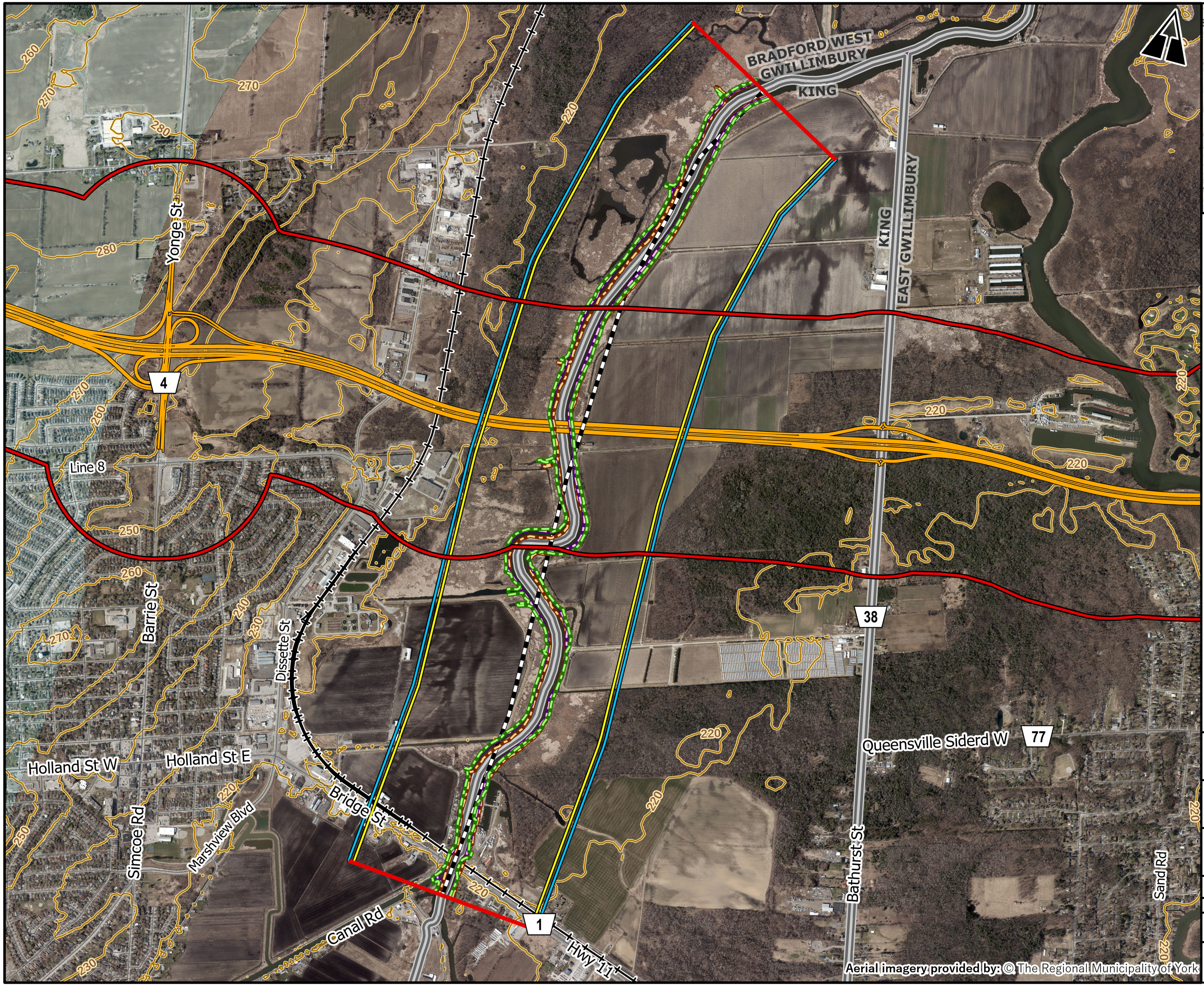
5.3 Final Meander Belt Width

The preliminary belt width and final meander belt widths were calculated for reaches HR-01 and HREB-01 in the vicinity of the proposed crossing and are presented in **Table 5-5, Figure 5-1** and **Figure 5-2**. It should be noted that these are values that represent the contemporary channel conditions along the reaches and are based on the preliminary empirical meander belt and geomorphic assessment.

The final meander belt width predicted for the Holland River (HR-01) is approximately 923.2 m while the meander belt width predicted for the Holland River East Branch (HREB-01) is 987.3 m. These values are considerably higher than the meander belts reported by Parish Geomorphic (2007) as outlined in the West Holland River Subwatershed Management Plan (LSRCA, 2010c) and the East Holland River Subwatershed Plan (LSRCA,2010b). The meander belt width reported for both the Holland River ranged from 161-310 m for two reaches analyzed immediately north and south of the proposed Bradford Bypass and the meander belt width ranged from 161-310 m north of the Bradford Bypass and 101-160 m south of the proposed road for the Holland River East Branch. However, there were no details provided regarding the methodology used to generate the meander belts for these reports and the report referenced could not be located.

Table 5-5: Final Meander Belt Calculations

Reach	Crossing ID	Floodplain Characteristics	Average Channel Width (m)*	100-year Erosion Rate (mapping)	Empirical Preliminary Meander Belt (m)	Final Meander Belt Width (m)	Justification
HR-01	C17-A-1	Unconfined	120	24.5 +/- 3 m	874.2	923.2	Preliminary Meander Belt + Erosion Rate
HREB-01	C20-A-1 C20-B-1	Unconfined	130	21.9 +/- 3 m	943.4	987.2	Preliminary Meander Belt + Erosion Rate



LEGEND

- Study Area (500 m)
- Bradford Bypass Works (Highway 400-404)

Meander Belt Type

- Empirical Preliminary Meander Belt
- Final Meander Belt
- Meander Belt Index
- Reach Break

Historical Watercourses

- 2018
- 1981
- 1969

General Features

- Municipal Boundary
- Railway
- Other Road
- Contour (10 m Interval)

Highway 400 - Highway 404 Link (The Bradford Bypass) Assignment No. 2019-E-0048

Final Meander Belt for: HR-01

0 125 250 500 750 1000 1250 M

NAD 1983 UTM Zone 17N

Jan, 2023	1:17,000	**Data Sources:** MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
P:60636190	Rev:00	

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Figure 5-1

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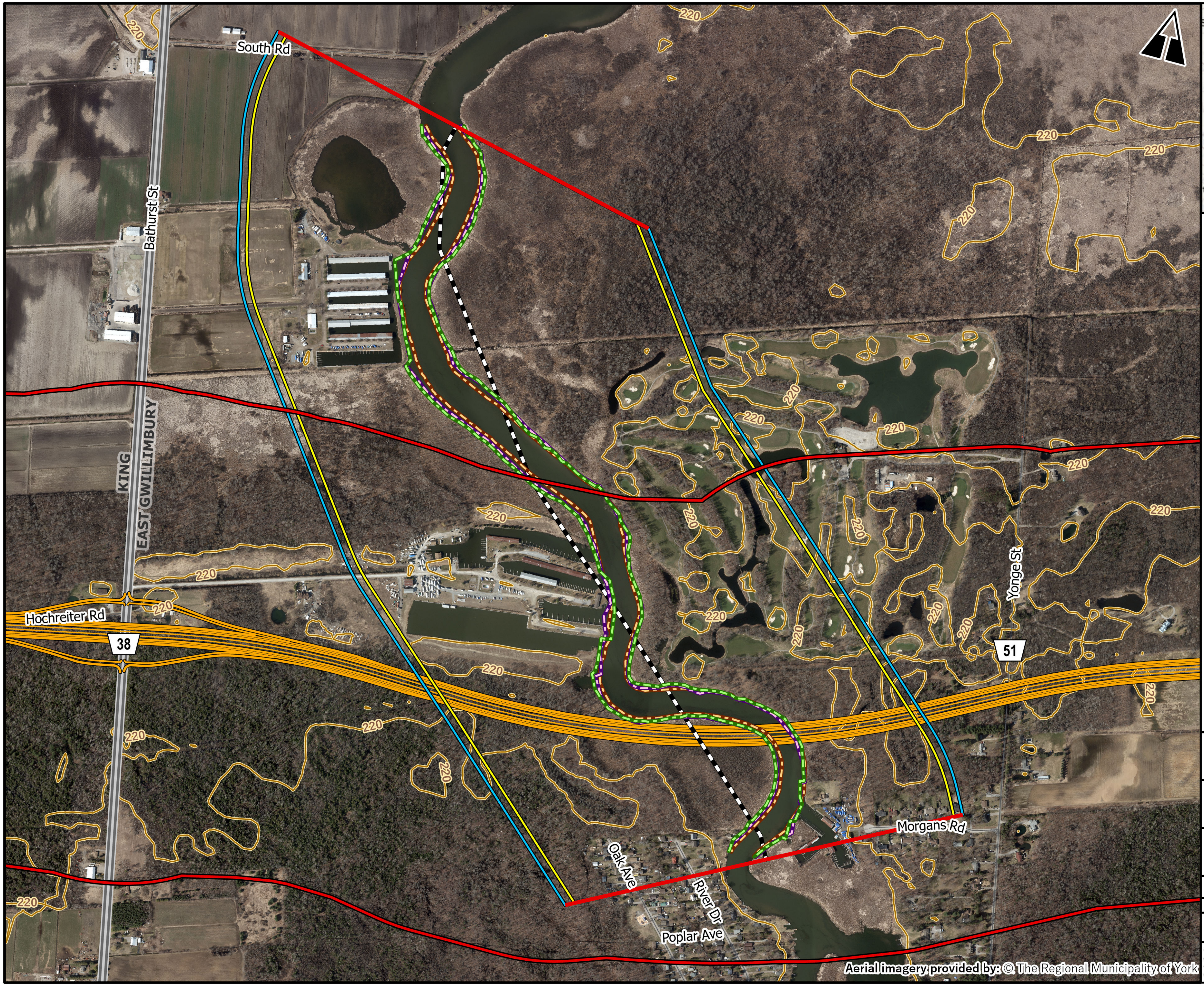

LEGEND

- Study Area (500 m)
- Bradford Bypass Works (Highway 400-404)

Meander Belt Type

- Empirical Preliminary Meander Belt
- Final Meander Belt
- Meander Belt Index
- Reach Break

Historical Watercourses

- 2018
- 1981
- 1969

General Features

- Municipal Boundary
- Other Road
- Contour (5 m Interval)

Highway 400 - Highway 404 Link (The Bradford Bypass) Assignment No. 2019-E-0048

Final Meander Belt for: HREB-01

0 65 130 260 390 520 650 M

NAD 1983 UTM Zone 17N

Jan, 2023	1:9,000	**Data Sources:** MTO, Town of Bradford West Gwillimbury, Town of East Gwillimbury, Region of York, Region of Simcoe
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Figure 5-2

6. Review of Hydraulic Modelling Outputs

As part of the assessment of the East and West Holland River crossings, a high-level review of the two-dimensional hydraulic model was completed to identify areas of sediment entrainment and transport in order to aid in the design of adequate protection and mitigation measures at the crossing site.

The 2-year return period flow analysis aims at determining the size of particles entrained based on the shear stress output for proposed conditions, to inform on channel stability. The objective of the 50-year, 100-year, and Regional Storm flow event analysis is to predict maximal grain size transported from the modelized velocity, to guide for protection design and erosion mitigation solutions.

The grain size entrained is based on a modified Shield's equation (Knighton, 1998) (**Equation 1**) and grain size transported was estimated based on an empirical equation presented by Komar (1998) (**Equation 2**).

Equation 1 – Shield's Equation

$$\tau c = \tau * c\ (\rho s - \rho w) g D50$$

Where τc is the critical shear stress (N/m^2), $\tau * c$ is the dimensionless channel shear stress (0.045), $\rho s - \rho w$ is the grain density – the water density (Kg/m^3), g is the gravitational acceleration (m/s), and D50 is the median grain size

Equation 2 – Velocity (Komar, 1988)

$$v = 57 D50^{0.46}$$

Where v is velocity (cm/s), and D50 is the median bed material grain size (cm). Values are then converted to m/s.

6.1 Results and Analysis

The output maps created from the HEC-RAS 2D modelling are available in **Appendix B**, where the existing conditions are compared to the proposed conditions for the 2-year, 50-year, 100-year, and regional storm flow events In general, the new conditions result in an increase in the grain size entrained for the 50-, 100-, and regional storm flow events at the proposed Bradford Bypass crossing over the Holland River and a slight decrease in the predicted sediment size entrained ~ 900 m downstream of the proposed crossing location. Additionally, it results in a greater grain size transported for the 50-, 100-, and regional storm flow events at the proposed Bradford Bypass crossing over the Holland River, and a decrease in grain size transported ~900 m downstream of the proposed crossing location. There are no major changes to grain size transported or entrained on the Holland River East Branch.

Bed substrate could not be safely measured with a Wolman Pebble Count (1954) due to depth of water, but bank material was identified as silt, clay, and sand which provides the sediment source for the channel bed. Based on the assumption that channel bed contains a similar gradation, it is assumed that the slight decrease in sediment size entrained will still result in a mobile bed during the 2-year return period flow events.

The higher flow events, specifically the 50-year, 100-year and regional flow events, represents extreme conditions, and therefore one can expect the entrained and transported sediment to be much larger. This can also occur in localized sections of the active channel, where the bridge crossing creates confinement and acceleration of flow velocity. Due to this, a bank protection solution should be considered during detailed design stages of the project.

Results are summarized in more detail below in **Table 6-1** and **Table 6-2.**

Table 6-1: Grain Size Entrained Results from HEC-RAS 2D

Grain Size Entrained		
	HR-01 Holland River	HREB-01 Holland River East Branch
Two-Year Return Period	Slight decrease in grain size entrained from very coarse sand to coarse sand at the proposed Bradford Bypass crossing over Holland River Decrease in predicted sediment size entrained from coarse sand to silt and clay ~900 m downstream of proposed Bradford Bypass crossing location with Holland River	No impact to sediment entrained in Holland River East Branch
Fifty-Year Return Period	Slight increase in grain size entrained from very fine gravel to fine gravel at the proposed Bradford Bypass crossing over Holland River Slight decrease in predicted sediment size entrained from coarse sand to medium sand ~900 m downstream of proposed Bradford Bypass crossing location with Holland River	No impact to sediment entrained in Holland River East Branch
100-Year Return Period	Increase in grain size entrained from very fine gravel to fine gravel at the proposed Bradford Bypass crossing over Holland River Slight decrease in predicted sediment size entrained from coarse sand to medium sand ~900 m downstream of proposed Bradford Bypass crossing location with Holland River	No impact to sediment entrained in Holland River East Branch
Regional Event	Increase in grain size entrained from very fine gravel to medium gravel at the proposed Bradford Bypass crossing over Holland River Slight decrease in predicted sediment size entrained from very coarse sand to coarse sand ~900 m downstream of proposed Bradford Bypass crossing location with Holland River	No impact to sediment entrained in Holland River East Branch

Table 6-2: Grain Size Transported Results from HEC-RAS 2D

Grain Size Transported		
	HR-01 Holland River	HREB-01 Holland River East Branch
Two-Year Return Period	Slight decrease in sediment size transported from very fine gravel to very coarse sand at the proposed Bradford Bypass crossing over Holland River Decrease in predicted sediment size transported ~900 m downstream of proposed Bradford Bypass crossing location with Holland River from coarse sand to silt and clay	No impact to sediment size transported in Holland River East Branch
Fifty-Year Return Period	Slight increase in grain size transported from medium gravel to fine gravel at the proposed Bradford Bypass crossing over Holland River Decrease in predicted sediment size transported ~900 m downstream of proposed Bradford Bypass	No impact to sediment size transported in Holland River East Branch

Grain Size Transported		
	HR-01 Holland River	HREB-01 Holland River East Branch
	crossing location with Holland River from very coarse sand to medium/coarse sand	
100-Year Return Period	Slight increase in grain size transported from medium gravel to fine gravel at the proposed Bradford Bypass crossing over Holland River Decrease in predicted sediment size transported ~900 m downstream of proposed Bradford Bypass crossing location with Holland River from very coarse sand to coarse sand	No impact to sediment size transported in Holland River East Branch
Regional Event	Slight increase in grain size transported from fine/medium gravel to coarse gravel at the proposed Bradford Bypass crossing over Holland River Decrease in predicted sediment size transported ~900 m downstream of proposed Bradford Bypass crossing location with Holland River from very fine gravel to very coarse sand	No impact to sediment size transported in Holland River East Branch

7. Crossing Design Considerations

The proposed channel design recommendations (in Preliminary Design) along the Bradford Bypass have been guided by the principles of fluvial geomorphology and flow hydraulics. Channel adjustments after the design has been constructed are expected and therefore various implementation recommendations have been provided to promote channel stability and the success of the design.

The recommendations provided by the LSRCA Watershed Development Guidelines were also reviewed, specifically section 9.1 General Guidelines – Alteration to Watercourses

9.1.1. In general, alterations to a watercourse shall not be permitted except in accordance with policies 9.1.2 through 9.2.6.

9.1.2. Notwithstanding Policy 9.1.1, the LSRCA may grant permission for the alteration of a watercourse provided that:

- *a) no reasonable alternative for the proposed alteration to the watercourse/shoreline exists and the alteration has been assessed through an Environmental Assessment or through site specific studies (e.g., geomorphological, flood plain), which are applicable based upon the scale and scope of the proposed works; and*
- *b) the alteration is designed in accordance with **natural channel design** principles where possible; and*
- *c) the alteration will not increase either upstream or downstream flood elevations, flood frequencies or rates of erosion; and*
- *d) the alteration will not adversely affect the **ecological function** of the **watercourse** and surrounding riparian area and will result in a net environmental improvement; and*
- *e) the alteration will not adversely affect neighbouring properties.*

9.1.3. Hardening techniques such as the use of concrete, steel sheet, railway ties, pressure treated lumber and gabion baskets will generally not be permitted.

*9.1.4. Erosion and sediment control measures shall be put in place prior to any work along a watercourse or shoreline and maintained during construction and until the site is permanently stabilized. This will include, where applicable, the use of check dams, silt screens, sediment ponds and/or **vegetation protection zones.***

9.1.5. All surplus excavated fill material must be immediately removed from the work site and placed outside of the regulated area.

9.1.6. Baseflows must not be adversely affected by any work.

7.1 General Design Considerations

7.1.1 Potential Impacts on Crossing Infrastructure

When crossings are placed over a watercourse without due consideration of the geomorphic processes that are occurring within the watercourse, risks to the crossing structure and/or channel form and function may occur. Such risks could lead to the need for continual or emergency maintenance of the crossing and/or could adversely affect channel stability, fish passage potential and aquatic habitat conditions.

Channel processes that may contribute to impacts at a bridge or culvert crossing include:

- Channel bed degradation/lowering – this can lead to undercutting of bridge/culvert abutments/footings
- Channel migration – movement of meanders could cause erosion of culvert/bridge embankments
- Channel expansion – enlargement of cross-section areas (e.g., in response to urban hydro modification may lead to increased stress around culvert entrance leading to outflanking of a culvert and flow constriction
- Knickpoint regression along the channel bed profile, and
- Loss of riparian vegetation can also greatly diminish bank shear resistance which increases the potential for bank erosion and channel translation.

7.1.2 Potential Impacts on Channel Processes and Aquatic Habitat

Bridge crossings situated along a watercourse interact with, and exert an influence on, channel processes. The scientific literature has identified common impacts of watercourse crossings both on channel functions and on aquatic species. In some situations, impacts of a crossing on the channel result in a risk to the crossing. Typical adverse effects attributed to crossings include:

- Bridges with piers situated in the watercourse can pose a barrier to migrating fish if their placement interferes with flows within the channel
- Piers must be adequately spaced to prevent the formation of eddies, which could delay fish migration by causing disorientation, and may prevent fish from continuing to migrate (Cotterell, 1998), and
- Different pier shapes have different eddying effects, so a pier base that minimizes eddies should be incorporated into the design. Scour will also be minimized by preventing eddies.

Reduction in the potential impacts to crossing structures can be achieved through proper design (e.g., sufficiently wide span) and appropriate placement of the crossing structure piers relative to the watercourse.

7.1.3 General Crossing Design Recommendations

In keeping with the potential impacts to infrastructure, natural channels processes, aquatic habitat and adhering to the conservation authority's guidelines, the following general recommendations should be included as part of appropriate crossing design:

- Avoid, where possible, the need for substantial channel realignment
- Place watercourse crossings perpendicular to flow over relatively straight sections of channel planform
- Ensure that crossing structures are properly sized not only from a hydraulic perspective, but also to ensure minimal impacts to channel form and function
- Maintain continuity of channel form and function through the crossing wherever possible, and
- Ideally, wherever possible, bridge piers should be placed away from the channel and no alteration to the stream bed or banks should occur. Additionally, no infilling of the channel should occur.

7.2 Crossing-Specific Design Considerations

Considering the above statements, this fluvial geomorphology assessment has been used to develop recommendations for the two new river crossings to convey the Bradford Bypass over the Holland River and Holland River East Branch. A summary of observed issues and future considerations at the proposed new crossings are presented in **Table 7-1**.

Initial considerations for the proposed new crossing at HR-01 are:

- Bridge abutments and piers constrain channel function by preventing planform adjustment; watercourse is a sinuous channel. Significance of these controls is accentuated where the channel is

adjusting through widening. Siting of bridge crossing should be perpendicular to valley and stream corridors
- Large watercourse - erosive forces of larger watercourses tend to exceed stabilizing properties of vegetation, therefore there is an increased potential for migration
- Lateral migration likely in unconfined valleys (wide, flat floodplains)
- Dense vegetation existing adjacent to channel - removal of vegetation could increase erosion potential
- Based on the Rapid Geomorphic Assessment, the watercourse reach is stable, with dominant process occurring being aggradation. Over time sediment deposition may initiate meander development
- If piers are necessary within the meander belt of the watercourse, pier foundation should be designed with the assumption that it will be in contact with the watercourse in future and an allowance for channel downcutting over time should be considered
- Erosion protection may be required to protect the piers however, erosion protection disturbs natural geomorphological processes and typically has a negative impact on river integrity in the long-term, and
- It is recommended that a fluvial geomorphologist be consulted during the Detail Design stage of the project for the new proposed crossings in order to specifically address the observed geomorphological issues with the watercourses along the proposed Bradford Bypass route.

Initial considerations for the proposed new crossing at HREB-01 are:

- Bridge abutments and piers constrain channel function by preventing planform adjustment; watercourse is a sinuous channel. Significance of these controls is accentuated where the channel is adjusting through widening. Siting of bridge crossing should be perpendicular to valley and stream corridors
- Large watercourse - erosive forces of larger watercourses tend to exceed stabilizing properties of vegetation, therefore there is an increased potential for migration
- Upstream portion of the watershed is urbanized
- Lateral migration likely in unconfined valleys (wide, flat floodplains)
- Dense vegetation existing adjacent to channel - removal of vegetation could increase erosion potential
- Based on the Rapid Geomorphic Assessment watercourse reach is stable, with dominant process occurring being aggradation. Over time sediment deposition may initiate meander development
- If piers are necessary within the meander belt of the watercourse, their foundations should be designed assuming they will be in contact with the watercourse channel in future, taking into consideration the base elevation of the channel and an allowance for channel downcutting over time
- Erosion protection may be required to protect the piers however, erosion protection disturbs natural geomorphological processes and typically has a negative impact on river integrity in the long-term, and
- It is recommended that a fluvial geomorphologist be consulted during the Detail Design stage of the project for the new proposed crossings in order to specifically address the observed geomorphological issues with the watercourses along the proposed Bradford Bypass route.

Considering the above statements, this fluvial geomorphic assessment has been used to develop recommendations for the proposed pier placements for the crossings located at crossing #'s C17-A-1 (HR-01) and C20-A-1/C22-B-1 (HREB-01). Due to the length of the proposed bridge, it is likely not feasible to keep the piers outside of the meander belt i.e., the area across which the watercourse is could shift over time. Considering the site-specific fluvial geomorphic indicators, the following risks were considered in this assessment: feature type, valley setting/confinement, meander belt width, bankfull width, meander amplitude, 100-year erosion rate, observed issues, and RGA score. A summary of observed issues is presented in **Table 7-1**.

Table 7-1: Summary of Observations and Recommendations for Crossing Size

Reach	Crossing ID	Drainage Culvert ID	Conservation Authority	Feature Type	Drainage Area (Ha)	Bankfull Width (m)	Approx. Meander Amplitude (m)	Final Meander Belt Width (MBW)	Valley Setting/ Confinement	Erosion Risk	Recommendations for Pier Placement
HR-01	C17-A-1	N/A	LSRCA	Permanent defined meandering feature	32,927.4	120	~300	874.2	Unconfined	**Very Low** **RGA**: In Regime **Dominant processes:** Aggradation, degradation, and planimetric form adjustment **Erosion Rate from mapping:** 25 +/- 3 m **Erosion**: Minor (leaning trees) **Woody Debris**: Present **Entrenchment**: None **Historical Assessment:** No significant change in planform since 1969	Preferred (100 year erosion rate + Bankfull i.e., 24.5 m x 2 + 83 m): 132 m
HREB-01	C20-A-1 C20-B-1	N/A	LSRCA	Permanent defined meandering feature	20,389.7	130	~ 330	943.4	Unconfined	**Very Low** **RGA**: In Regime **Dominant processes:** Aggradation and planimetric form adjustment **Erosion Rate from mapping**: 22 +/- 3 m **Erosion**: No Active Erosion **Woody Debris**: Present **Entrenchment**: None **Historical Assessment:** No significant change in planform since 1969	Preferred (100 year erosion rate + Bankfull i.e., 21.9 m x 2 +100 m): 143.8 m

8. Summary of Environmental Commitments

8.1 2002 Approved Environmental Assessment Commitments

The 2002 Approved Environmental Assessment identified a number of proposed mitigation and commitments to future work for the project. **Table 8-1** below identifies the fluvial geomorphology commitments carried forward through to Preliminary Design, and describes any applicable changes to the 2002 Approved Environmental Assessment commitment. Commitments identified in the 2002 Approved Environmental Assessment are to be carried forward to Detail Design phase unless otherwise stated in **Table 8-1** below.

Table 8-1: 2002 Approved Environmental Assessment Commitments

Factor / Criterion	Issue	Concerned Group / Agency	Potential Net Environmental Effect (as taken from 2002 Approved Environmental Report)	Proposed Mitigation / Commitments to Future Work (as taken from 2002 Approved Environmental Report)	Changes to Mitigation/ Protection/ Monitoring (Yes/No/NA)	Description of Commitment Carried Forward through Preliminary Design for Mitigation, Protection and Monitoring
Surface Water Systems	■ Minimize potential adverse impacts to surface water systems (physical characteristics, water quality and quantity).	■ Ministry of Transportation, Ministry of Natural Resources and Forestry, Ministry of the Environment, Conservation and Parks, Fisheries and Oceans Canada, Lake Simcoe Region Conservation Authority, interest groups, general public.	■ Long-span bridges will carry the proposed 400-404 Link across both branches of the Holland River. Other stream crossings will use appropriately designed culverts, and ■ The continuity of the surface water system will be maintained.	■ Where appropriate: – design bridges and culverts that: ▪ maintain the existing channel form or include a low flow channel where appropriate ▪ do not impede fish movement ▪ do not place piers within the channel as defined by bankfull flow conditions, or are oriented in the direction of water flow to maximize hydraulic efficiency during high flow conditions ▪ minimize erosion and flood risk upstream and downstream of structure, and ▪ utilize open bottomed culverts in upwelling areas. – develop plans that minimize the disruption to natural systems and maintain slope stability when developing access roads for construction, including re-establishment or stabilization after construction.	■ No	■ Bridge and culvert designs are taking into consideration current information related to fish and fish habitat, fluvial geomorphology, hydrogeology, and surface water drainage studies ■ Project-specific assessment of environmental impacts will provide recommendations to the design to avoid, minimize or mitigate potential impacts resulting from new or modified watercourse crossings and structures ■ Where appropriate, environmental approvals will be sought under the Fisheries Act, Endangered Species Act, Ontario regulation 387/04, etc., and ■ In addition, the Ministry will complete a Stormwater Management Plan, and Groundwater Protection and Well Monitoring Plan per the Ontario Regulation this project is following.

8.2 Preliminary Design Commitments

Impacts to fluvial geomorphology and proposed mitigation measures, monitoring activities and commitments identified during this fluvial geomorphology assessment are summarized in **Table 8-2** below.

Table 8-2: Summary of Environmental Concerns and Commitments Table

ID	Issues / Concerns / Potential Effects	Concerned Agencies	ID	Mitigation, Protection, Monitoring, and Commitments
Fluvial Geomorphology				
FLU-1.00	Near and In-Water Work	DFO, MNRF, MECP, LSRCA, NVCA	FLU-1.01	■ Prohibit or limit access to banks or areas adjacent to waterbodies, to the extent required to protect the structural integrity of banks or shorelines.
			FLU-1.02	■ Design and implement erosion and sediment controls to contain/isolate the construction zone, manage site drainage/runoff and prevent erosion of exposed soils and migration of sediment to adjacent waterbody during all phases of the project.
			FLU-1.03	■ Erosion and sediment control measures should be maintained until all disturbed ground has been permanently stabilized, suspended sediment has resettled to the bed of the waterbody or settling basin and runoff water is clear. The plan should, where applicable, include: ■ Installation of effective erosion and sediment control measures before starting work to prevent sediment from entering the waterbody ■ Regular inspection and maintenance of erosion and sediment control measures and structures during construction, and ■ Repairs to erosion and sediment control measures and structures if damage occurs. ■ Removal of non-biodegradable erosion and sediment control materials once site is stabilized.
			FLU-1.04	■ Environmental Protection during Work in Watercourses and on watercourse banks in accordance with OPSS 182.
			FLU-1.05	■ Timing of in-water work in accordance with SSP101F23.
			FLU-1.06	■ An in-water work isolation plan should be designed and implemented to maintain clean flow around the work area(s) ■ Considerations: ■ Use of appropriately designed and sited temporary settling basin, filter bag, etc. such as sediment is filtered out prior to the water entering a waterbody, and ■ Use of energy dissipation measures to prevent bank or bed erosion.
			FLU-1.07	■ Whenever possible, operate machinery on land above the high-water level, on ice, or from floating barge in a manner that minimizes disturbance to the banks and bed of the waterbody.
			FLU-1.08	■ Operate, store and maintain (e.g. refuel, lubricate) all equipment, vehicles and associated materials in a manner that prevents the entry of any deleterious substance from entering the water (refueling and other such tasks should be completed at least 30m away from a watercourse).
			FLU-1.09	■ Any part of equipment entering the water or operating on the bank shall be free of fluid leaks, invasive species and noxious weeds and externally cleaned/degreased to prevent any deleterious substance from entering the water.
			FLU-1.10	■ Ensure work zones are stabilized against high flows at the end of each workday.
FLU-2.00	Temporary Alteration, Disruption, or Destruction of Watercourse	Fisheries and Oceans Canada, MECP, MNRF, LSRCA	FLU-2.01	■ Stream bed protection will consist of native material where possible and any rock protection below the highwater mark will consist of round riverstone in accordance with OPSS.PROV 1005 and NSSP008.
			FLU-2.02	■ Re-stabilize any portion of the bed of a waterbody disturbed during construction to pre-construction (or better) conditions. This shall include substrates as per OPSS 182 and OPSS.PROV 1005.
			FLU-2.03	■ Re-stabilize the banks of a waterbody that have been disturbed during construction to pre-construction (or better) conditions (as per OPSS 182 and OPSS 804). This shall include riparian vegetation or stone material, temporary measures and the avoidance of hard engineering (where applicable).
FLU-3.00	Erosion Risks	LSRCA, NVCA	FLU-3.01	■ Inspection of all materials brought on-site for construction of the channels and features therein should be undertaken to ensure that the material is suitable given specifications/gradations outlined on the design drawings, and ■ Stone sizing gradation and thickness along any designed watercourse will be determined through hydraulic analysis of 2-year return period event through regional scale flow events to minimize risks of erosion and bed degradation (LSRCA Guideline 9.1 & 9.2 and NVCA Guideline 4.6.3).
FLU-4.00	Ecological Function	LSRCA, NVCA	FLU-4.01	■ The alteration will not adversely affect the ecological function of the watercourse and surrounding riparian area and will result in a net environmental improvement (LSRCA Policy 9.1 & 9.2 and NVCA Policy 4.6.3).
			FLU-4.02	■ Fish movement should not be impeded. It is recommended that open bottom culverts should be used (LSRCA Guideline 9.3 (a) & NVCA Guideline 4.6.3.7(a)) and sized accordingly as per the fluvial specialist recommendations or/and in conjunction with available hydraulic models.
FLU-5.00	Channel Realignment	LSRCA, NVCA	FLU-5.01	■ Perform all channel realignment according to design drawings provided.
			FLU-5.02	■ The following realignment considerations and recommendations should be implemented into the channel realignment plans: ■ Channel realignment should be designed in accordance with Natural Channel Design principles and should be in compliance with LSRCA Guidelines 9.1 & 9.2, including Guideline 9.2.1 and NVCA Guideline 4.6.3.1 ■ Maintain bankfull channel dimensions, hydraulics, and floodplain connectivity. Assume existing bankfull width and depth to be maintained with further assessment completed at detailed design stage ■ Maintain meandering channel planform where required ■ Reduce impacts to infrastructure in close-proximity. Watercourse should be located away from highway embankment to avoid erosion at the embankment ■ Improve physical habitat conditions for fish. This includes a low flow channel to improve connectivity during low flows and incorporating habitat features ■ Maintain continuity of channel form and process. This includes an appropriate tie-in to the longitudinal profile and channel planform ■ Minimize the loss of channel length. There should be no net loss of channel length unless an increase in channel slope is beneficial to the overall design, and ■ Channel should flow perpendicularly through the crossing structure with a straighter path to the culvert which will eliminate erosion risk to the culvert inlet

ID	Issues / Concerns / Potential Effects	Concerned Agencies	ID	Mitigation, Protection, Monitoring, and Commitments
				Channel realignment will be designed in accordance with Natural Channel Design principles and should be in compliance with LSRCA Guidelines 9.1 & 9.2, including Guideline 9.2.1 and NVCA Guideline 4.6.3.1.
			FLU-5.03	■ All surplus excavated fill material must be immediately removed from the work site and placed outside of the regulated area (LSRCA, Guideline 9.1.5).
FLU-6.00	Considerations for Crossing Structures	LSRCA, NVCA	FLU-6.01	■ Crossing structures will be designed in accordance with Conservation Authority Guidelines including LSRCA Guidelines 9.1 & 9.2 and NVCA Guideline 4.6.3.1. ■ The following general crossing design recommendations are provided: ■ Minimize the length of channel enclosure ■ Avoid, where possible, the need for substantial channel realignment ■ Place watercourse crossings perpendicular to flow over relatively straight sections of channel planform ■ Ensure that crossing structures are properly sized not only from a hydraulic perspective, but also to ensure minimal impacts to channel form and function, and ■ Maintain continuity of channel form and function through the crossing wherever possible (e.g., bed morphology under open-bottomed crossings and embedded in closed-bottom crossings). ■ The following crossing-specific design considerations are provided: ■ New crossings should span the Meander Belt Width (MBW), where feasible. This approach would allow natural processes to occur over the next 100 years ■ At a minimum, the new crossings will need to span the bankfull width of the channel, with an additional allowance for localized channel adjustment over the lifespan of the structure ■ If the crossing does not span the MBW, additional erosion protection will be required to protect the crossing. Erosion protection disturbs natural geomorphological processes and typically has a negative impact on creek integrity in the long-term ■ At a minimum, the placement of bridge piers and open bottom culverts should be beyond the “Preferred” limit (spanning the bankfull of the feature plus the erosion allowance), as per the 100-year erosion rate (**Section 5.2)** ■ The design of bridges and culverts should maintain the existing channel form and flow as to minimize or eliminate erosion and flood risks upstream and downstream of structures ■ Fish movement should not be impeded. It is recommended that open bottom culverts should be used and sized accordingly as per the fluvial specialist recommendations, aquatic specialist recommendations (refer to AECOM, 2022b, available under a separate cover), and in conjunction with available hydraulic models. ■ It is recommended that a fluvial geomorphologist be directly involved in the Detail Design of the new proposed crossings in order to specifically address the observed geomorphological issues with the watercourses along the proposed Bradford Bypass route ■ Removal of vegetation surrounding the feature could impact erosional processes. Small upstream drainage area typically lowers the potential for lateral channel movement and erosion due to stabilization provided by vegetation ■ Culverts constrain channel function by preventing planform adjustment and disrupting longitudinal connectivity. Open bottom crossings are preferred to maintain geomorphological processes as closed bottom culverts reduce bed roughness and act as grade controls. Significance of these controls is accentuated where the channel is adjusting through downcutting and widening. Siting of crossings should be perpendicular to valley and stream corridor, and ■ Confinement of the watercourse should be considered as lateral migration is likely in unconfined valleys (wide, flat floodplains), whereas in confined valley watercourses, the valley slope in will impact erosion rate by limiting lateral erosion (can be more susceptible to down-cutting and/or channel widening). ■ Design of the pier placement, scour protection requirements, and additional design details for the Holland River watercourses will be more closely investigated during the Detail Design stage.

9. Conclusions and Recommendations

The following should be considered during the future Detail Design phase on the project with respect to the two proposed Holland River Bridge crossings:

- Given the low relief/flat topography in the vicinity of the Holland River and the Holland River East Branch, low rates of erosion are expected for the two watercourses. The watercourse is expected to remain stable given the result of the RGA (In Regime), the field observations, and providing that the current conditions (land cover) of the watershed remain unaltered
- The 100-year erosion rates for the Holland River and the Holland River East Branch were calculate using the mapping approach (**Table 5-4**). The approach used historical imagery from 1969, 1981, and 2018 to calculate the lateral migration of the watercourse. The erosional rates for the Holland River branch (HR-01) were calculated at **24.5 m** (+/- 3 m) and at **21.9 m** (+/- 3 m) for the Holland River East branch (HREB-01)
- The meander belt width assessment for the Holland River and the Holland River East Branch were completed using an empirical approach as it was deemed more reliable and accurate (**Table 5-5**). The final meander belt with, including the 100-year erosion rates (calculated using the mapping approach), is **923.2 m** for the Holland River (HR-01) and **987.2 m** for the Holland River East branch (HREB-01)
- It is unrealistic to keep the piers outside of the meander belt; therefore, it is recommended that the placement of the bridge piers be located outside of the 100-year erosion rate which is 24.5 +/- 3 m for HR-01 and 21.9 +/- 3 m for HREB-01 on either side of the bankfull channel (**Table 7-1)**. If this is not possible and piers are to span the bank-to-bank width of the channel without spanning the additional 100-year erosion rate, then scour protection measures will be required
- It is recommended that alterations to the current planform of the watercourses be minimized or avoided as it can alter to the current quasi-equilibrium of the watercourses and affect the erosion rates.
- The 2D HEC-RAS analysis identified that bank protection should be considered during the detailed design stage of the project at the proposed Bradford Bypass crossing over the Holland River (i.e., HR-01) (**Table 6-1, Table 6-2**)
- There are no major changes to grain size transported or entrained on the Holland River East Branch (HREB-01), and
- Based on the HEC-RAS results and the assumption that channel bed contains a similar gradation, it is assumed that the slight decrease in sediment size entrained will still result in a mobile bed during the 2-year return period flow events.

Along the proposed Holland River bridge crossings, the channel banks and bed will be impacted by the pier placement during construction and permanently after construction is complete due to the proximity of the piers to the watercourses. It is proposed that all piers will remain out of the active channel, however, it is anticipated that they will be located within the 100-year erosion rate.

It is proposed that the banks may be hardened along portions of both the Holland River East Branch and the Holland River watercourses to provide erosion protection around the piers. At this stage of design, it is also proposed that the bridges will span over provincially significant wetlands and floodplain, and any piers (shafts/ columns) are proposed to be placed outside of the current Holland River East Branch (i.e., no piers within the river), although temporary excavations and construction access within or near the river is anticipated (this includes the construction of footings for the Holland River East Branch bridge that will be located under the riverbed). Design of the pier placement, scour protection requirements, and additional design details for the Holland River watercourses will be more closely investigated during the Detail Design stage.

10. References

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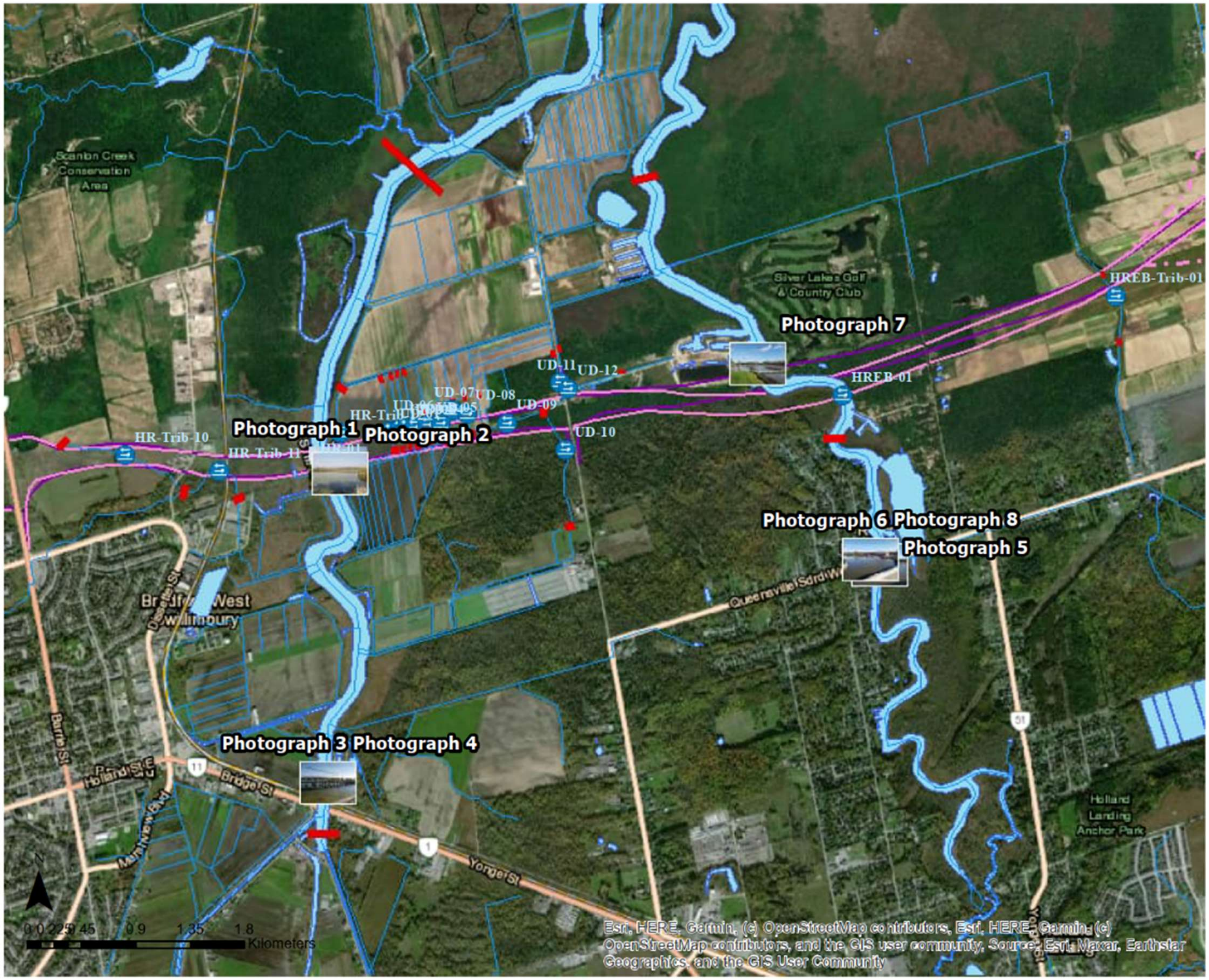
Appendix A. Photographic Record

Highway 400 to Highway 404 Link - Bradford Bypass Holland River Crossings Photolog



Reach HR-01

Photograph 1. ↑
West branch of Holland River. Looking upstream from right bank, west of Hochreiter Rd. Taken approximately 2km downstream of the Queensville Sideroad West crossing

Photograph 2. ↑
West branch of Holland River. Looking downstream from right bank, west of Hochreiter Rd. Taken approximately 2km downstream of the Queensville Sideroad West crossing

Photograph 3. ↑
Bridge crossing along West branch of Holland River. Looking south towards bridge

Photograph 4. ↑
Bridge crossing along West branch of Holland River. Looking south towards bridge

Reach HREB-01

Photograph 51. 🡅
Holland River East Branch, looking downstream from Queensville Sideroad West. Boat marinas located on right and left banks.

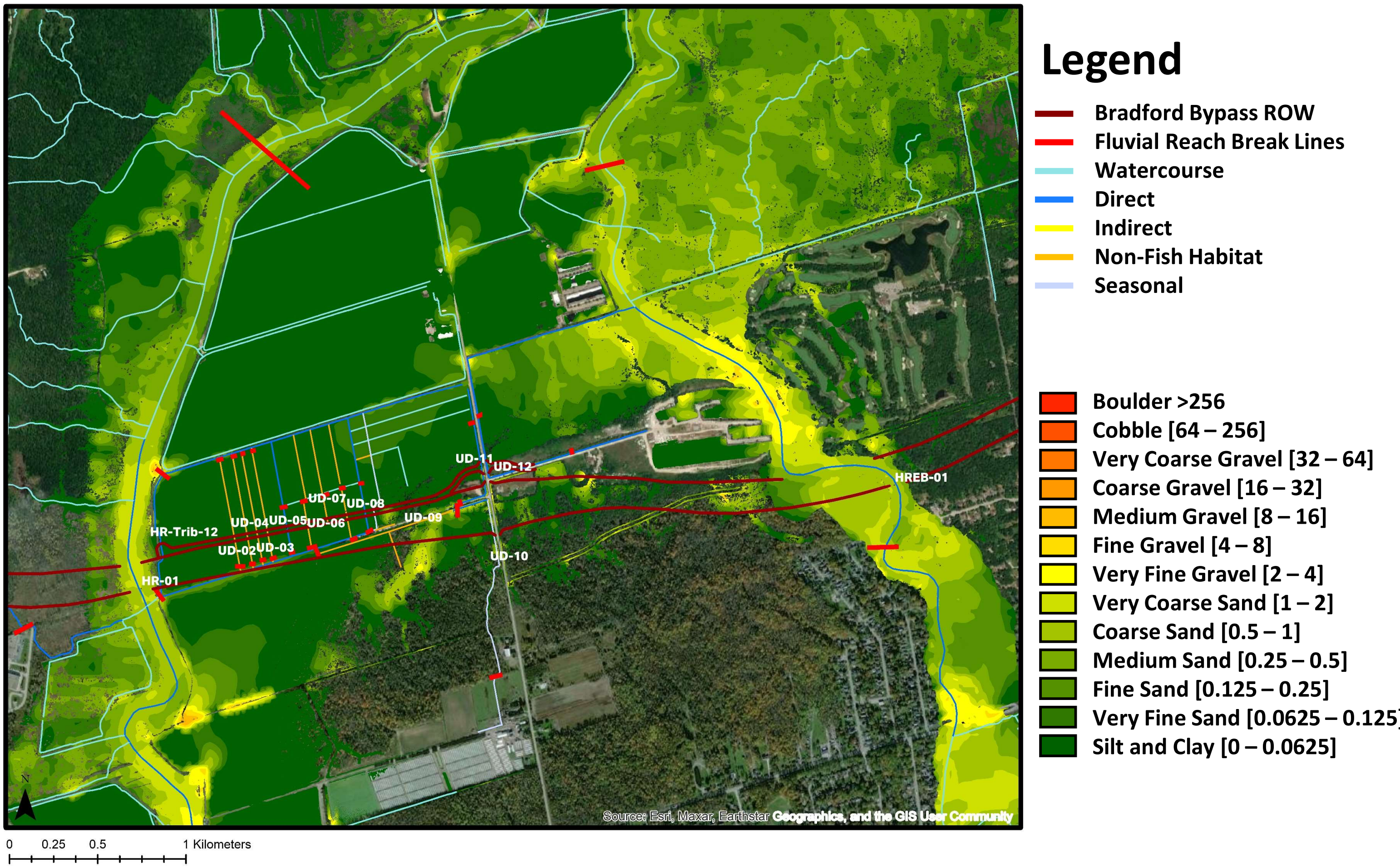
Photograph 6. 🡅
Holland River East Branch, looking upstream from Queensville Sideroad West. Boat marinas located on left bank.

Photograph 72. 🡅
Holland River East Branch, looking at the docks set up near Albert's marina approximately 1.4km downstream from the Queensville Sideroad West crossing

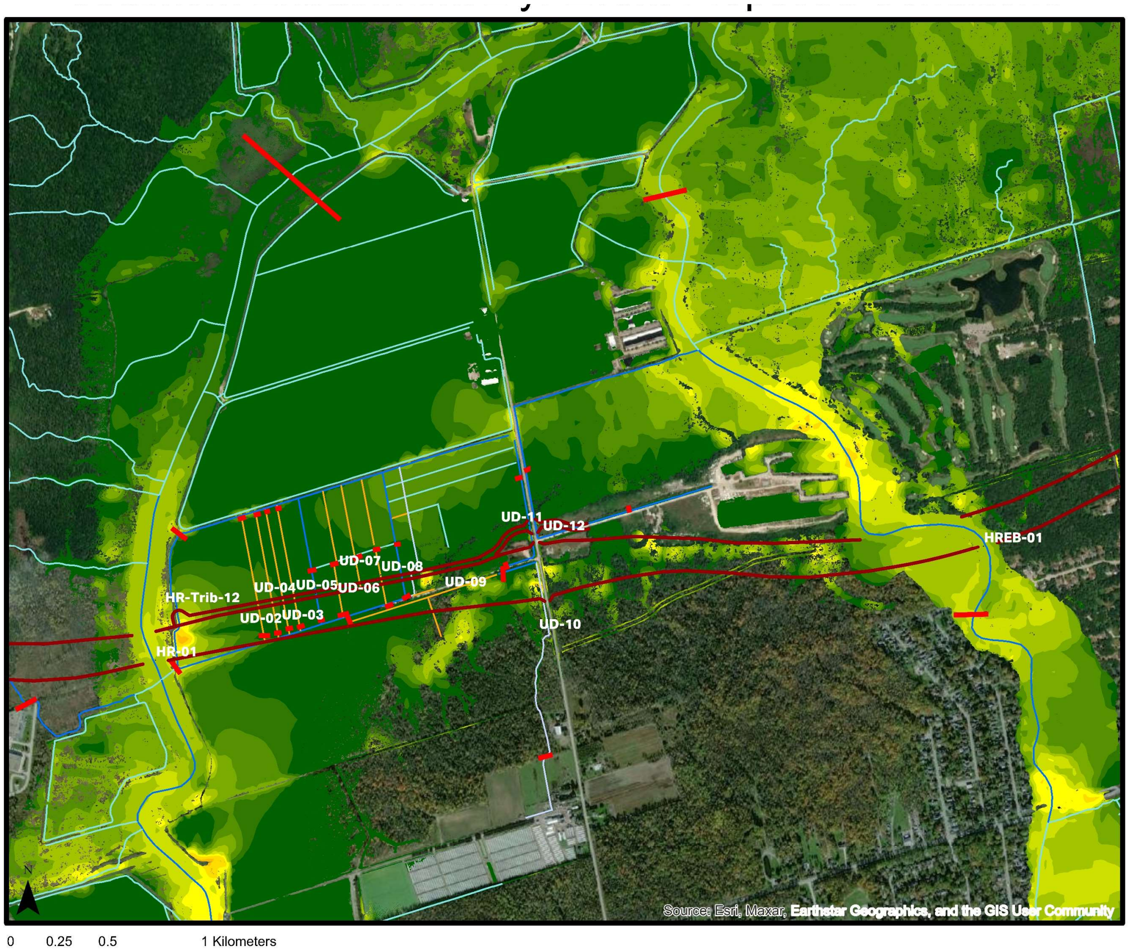
Photograph 83. 🡅
Holland River East Branch, looking across the bridge that spans Queensville Sideroad West

Appendix B. Grain Size Entrained and Transported

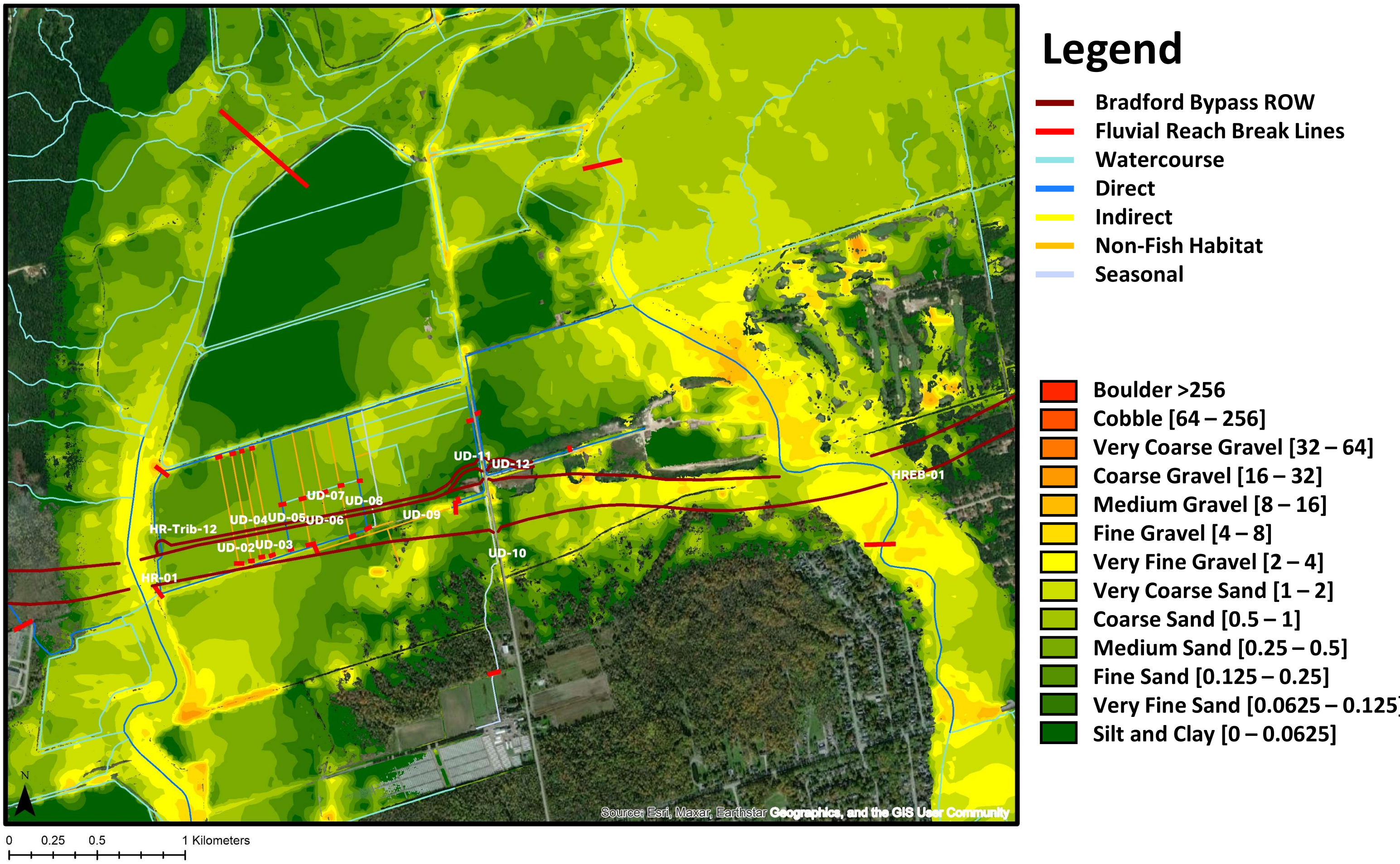
Predicted Sediment Entrainment for the 2-year Flow Return Period Event (Existing Conditions)



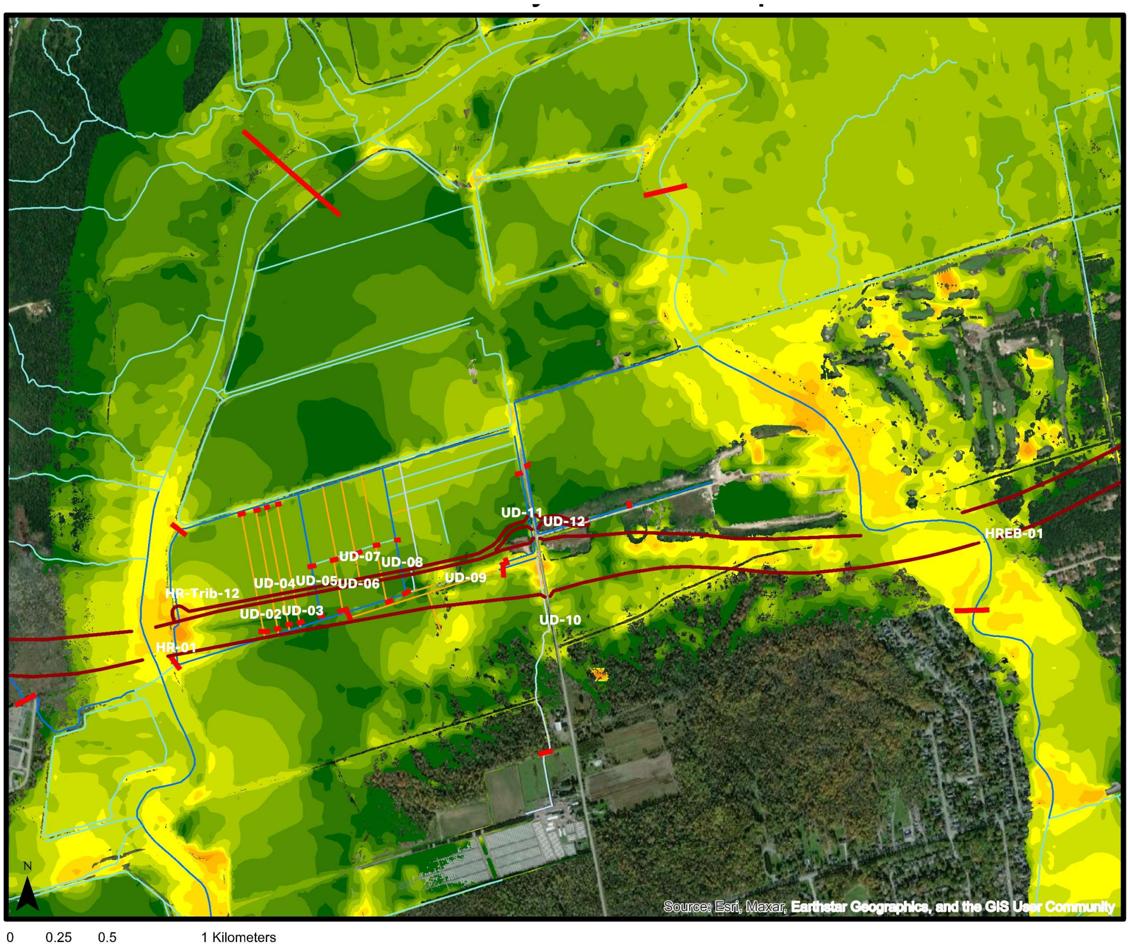
Predicted Sediment Entrainment for the 2-year Flow Return Period Event (Proposed Conditions)



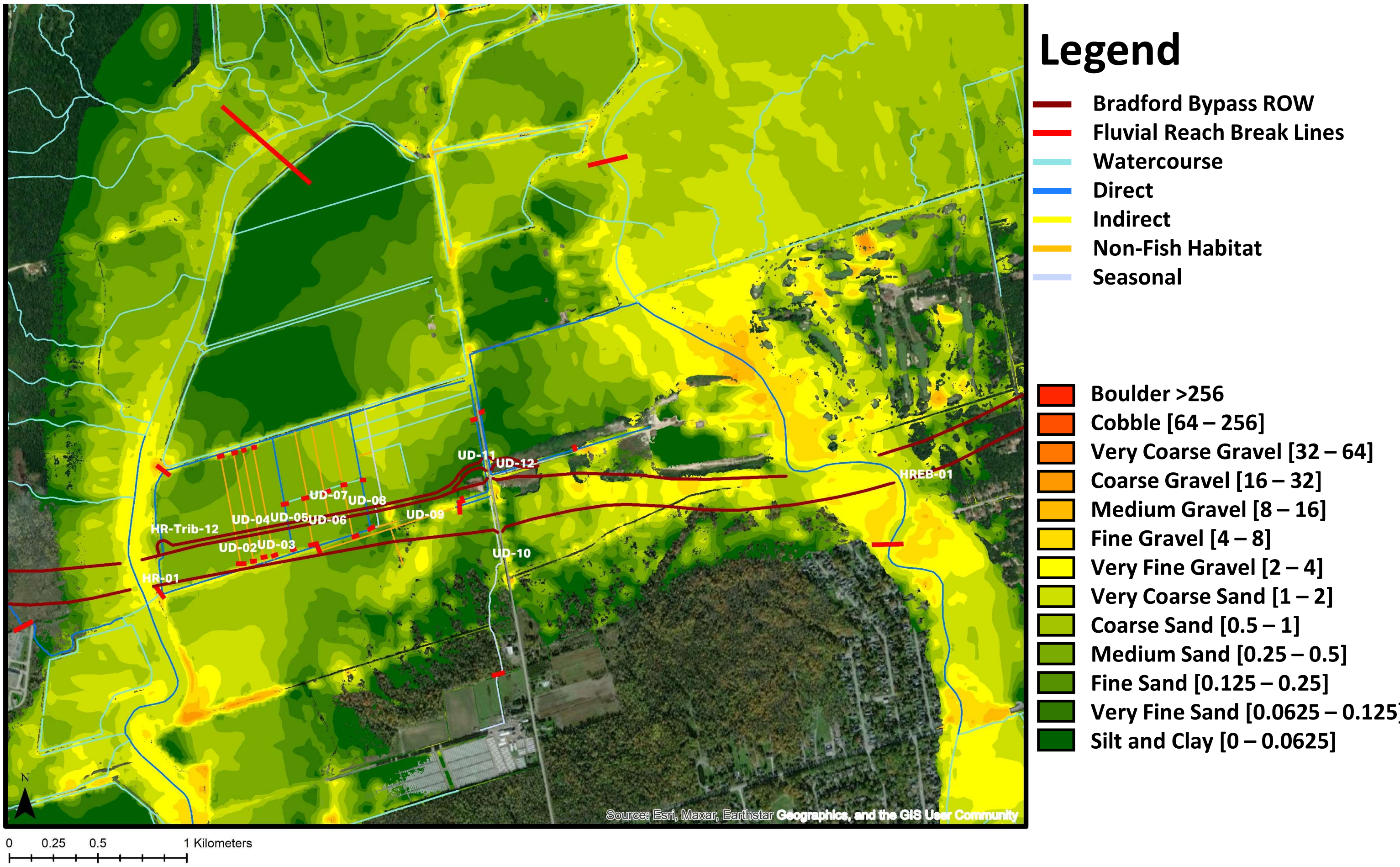
Predicted Sediment Entrainment for the 50-year Flow Return Period Event (Existing Conditions)



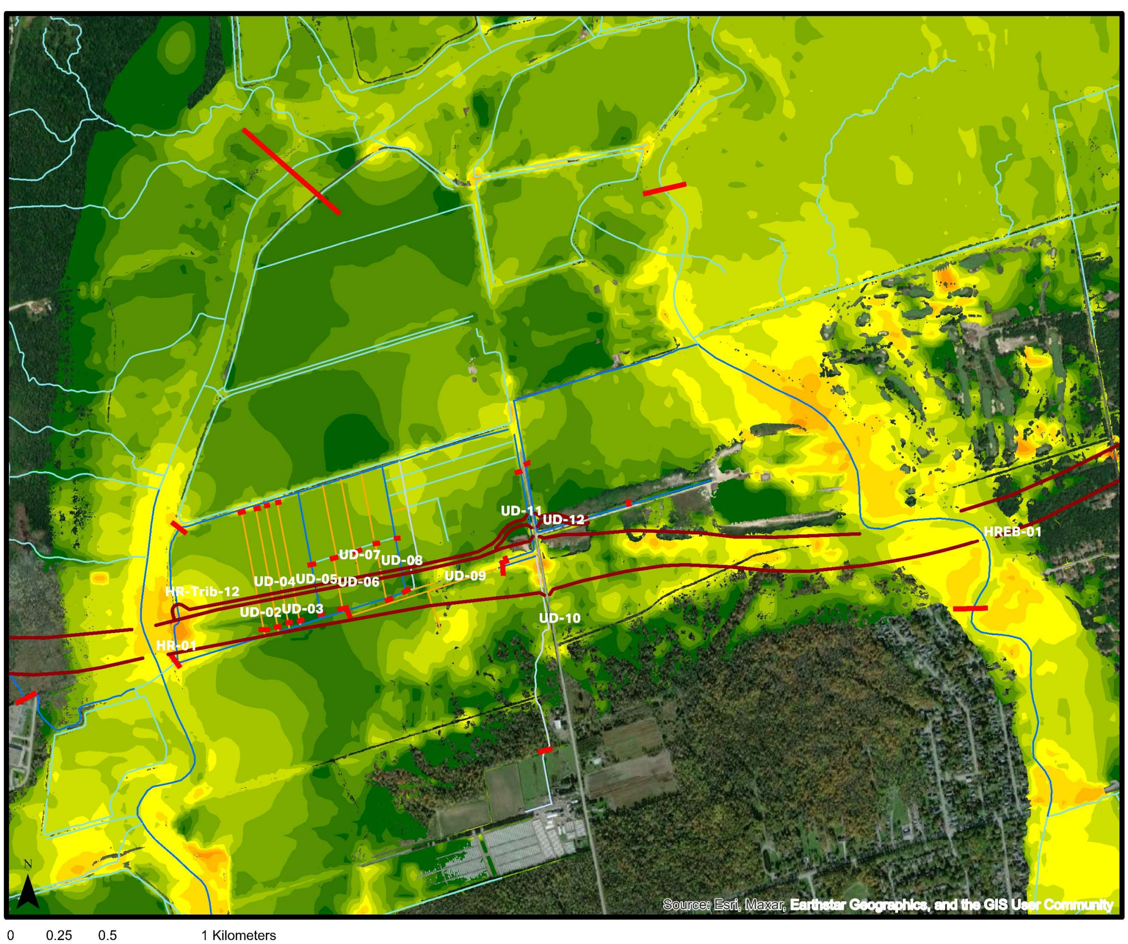
Predicted Sediment Entrainment for the 50-year Flow Return Period Event (Proposed Conditions)



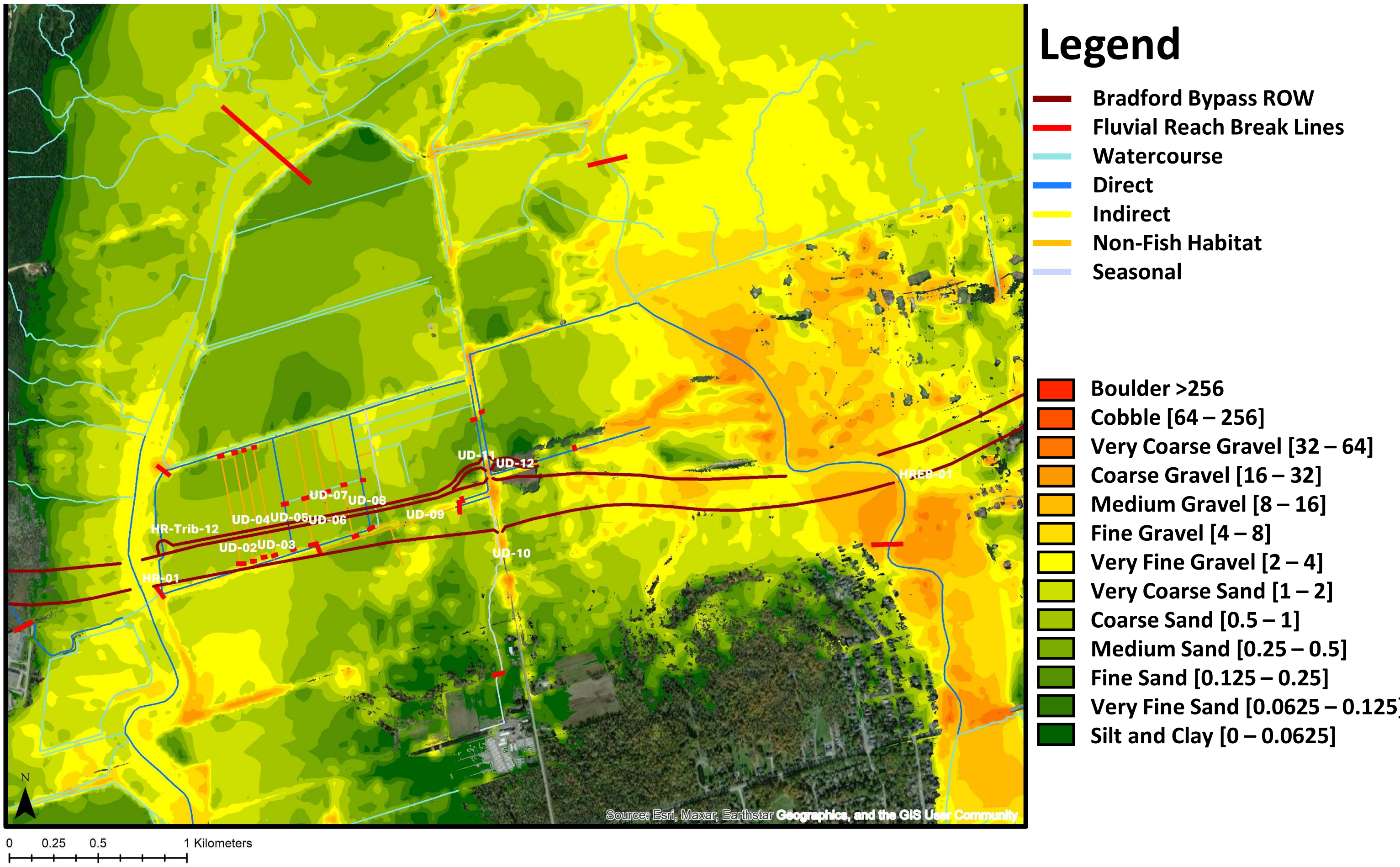
Predicted Sediment Entrainment for the 100-year Flow Return Period Event (Existing Conditions)



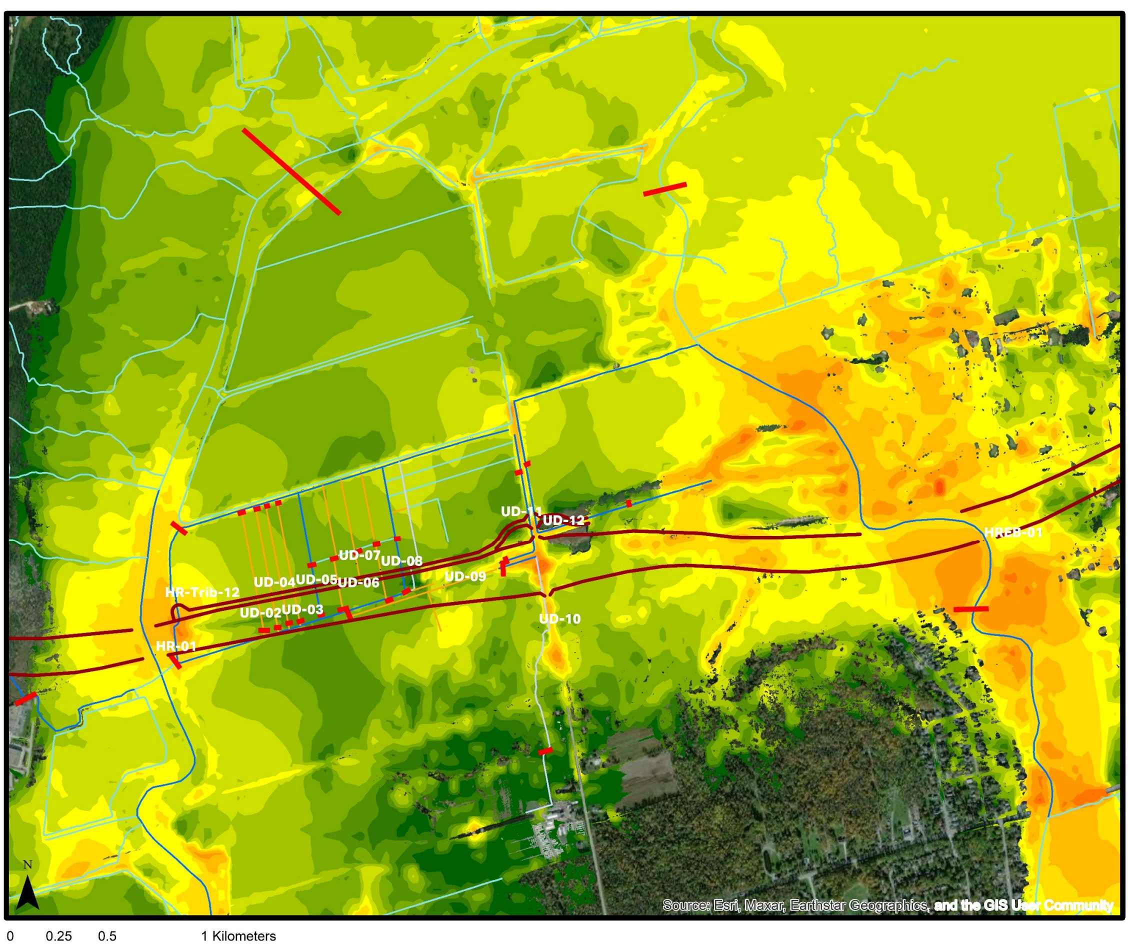
Predicted Sediment Entrainment for the 100-year Flow Return Period Event (Proposed Conditions)



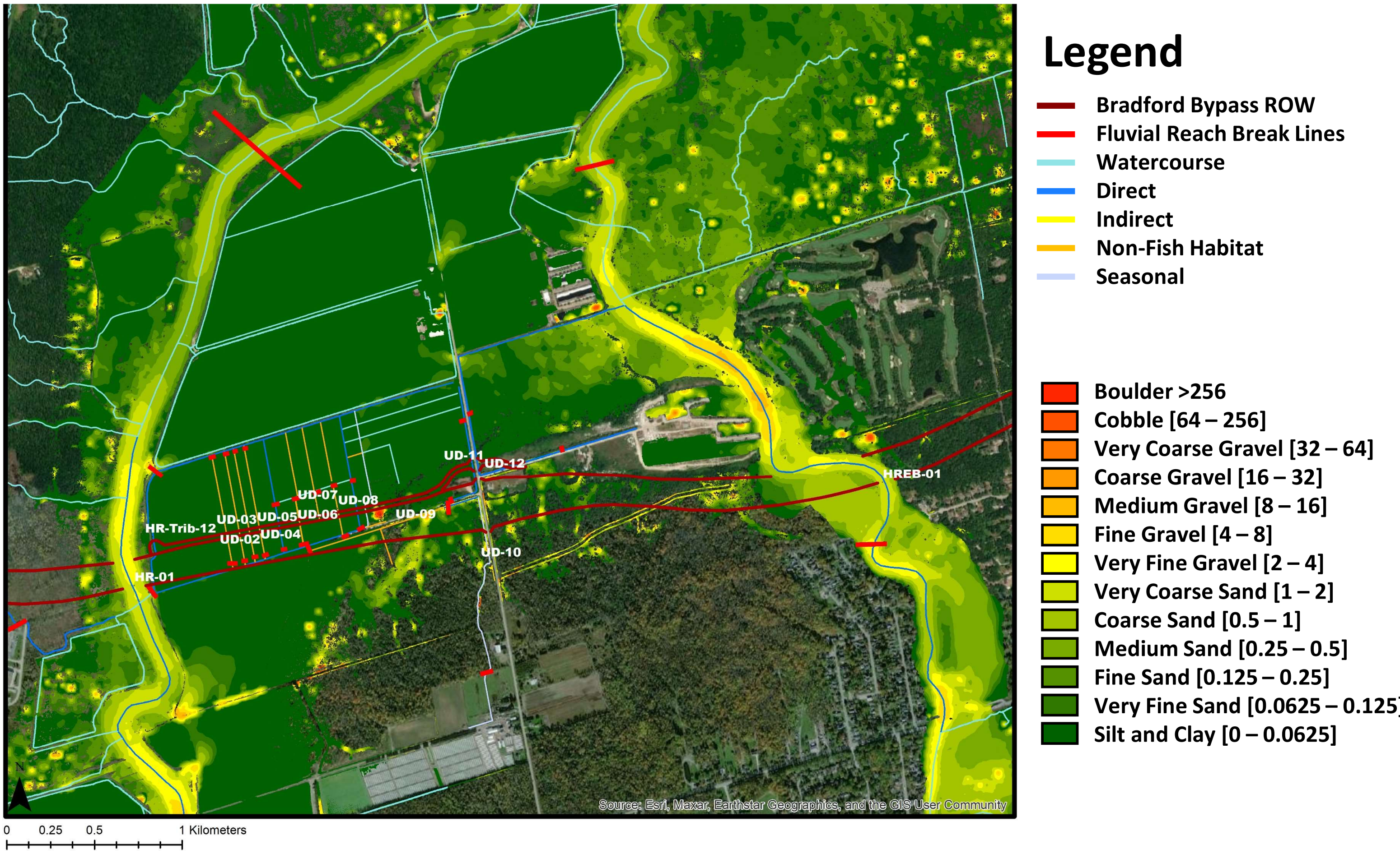
Predicted Sediment Entrainment for the Regional Flow Return Period Event (Existing Conditions)



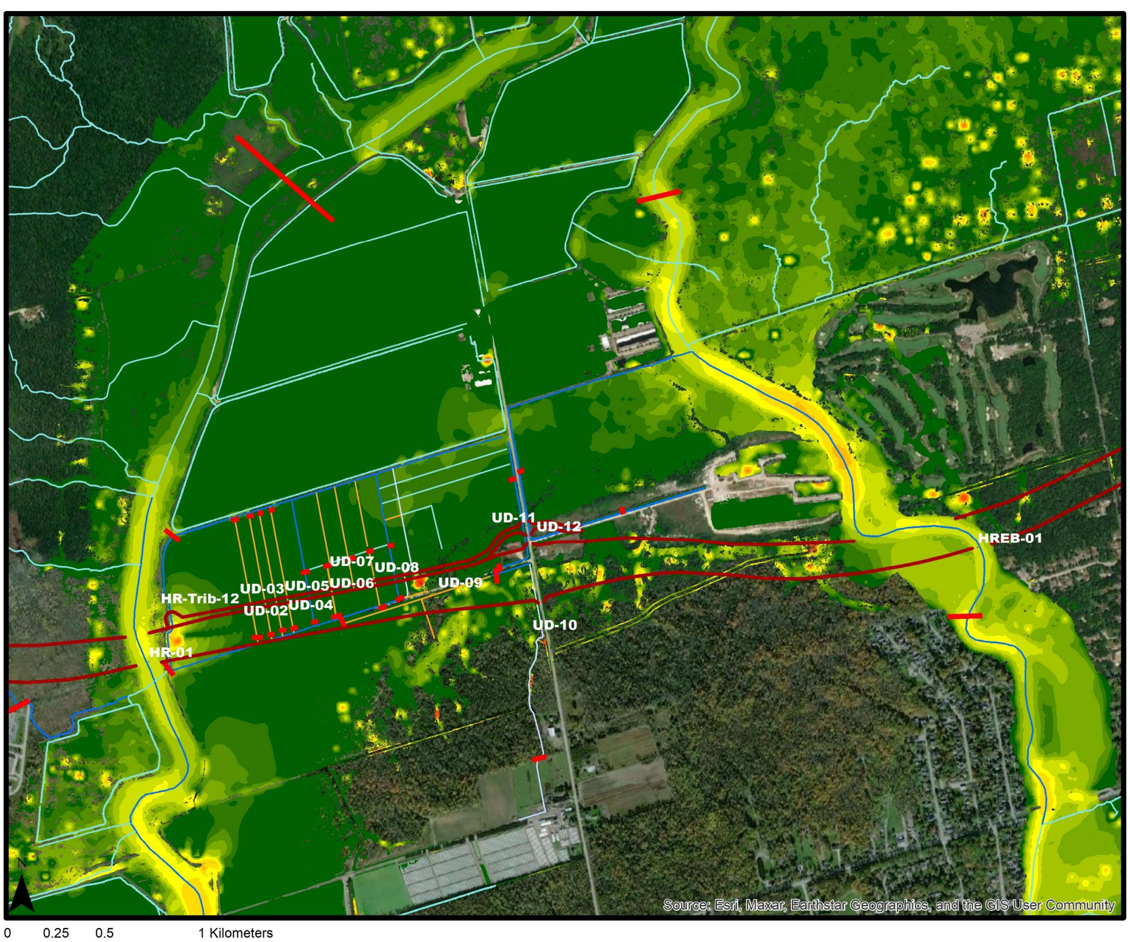
Predicted Sediment Entrainment for the Regional Flow Return Period Event (Proposed Conditions)



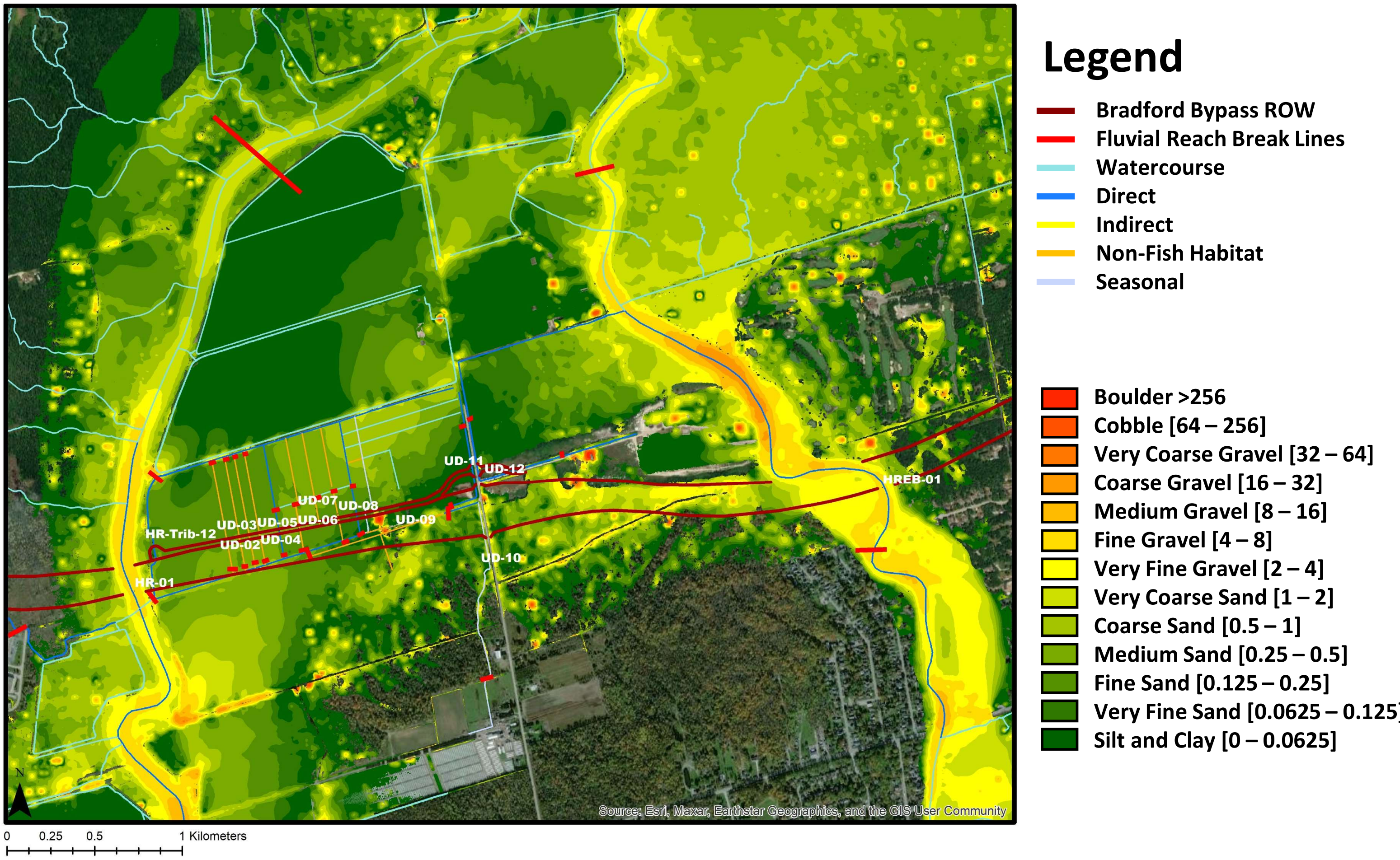
Predicted Sediment Transport for the 2-year Flow Return Period Event (Existing Conditions)



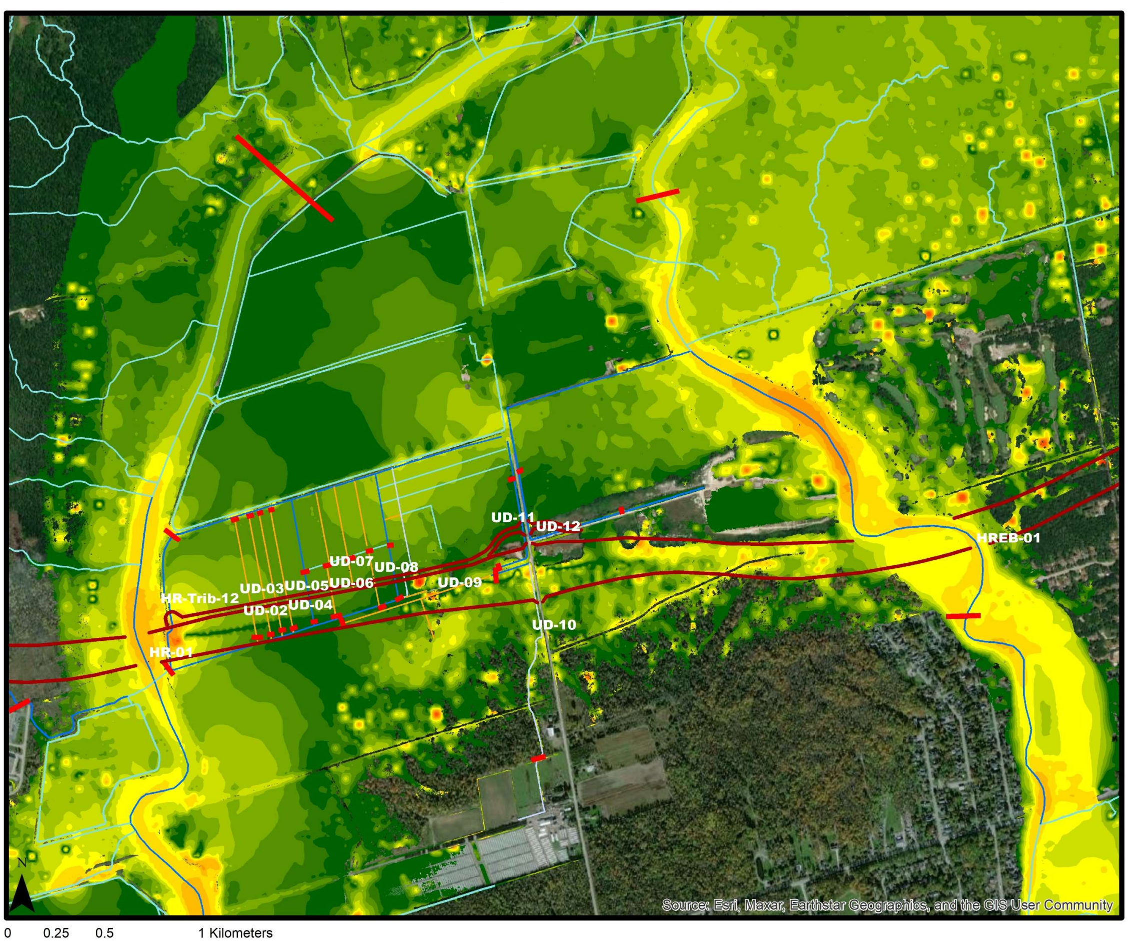
Predicted Sediment Transport for the 2-year Flow Return Period Event (Proposed Conditions)



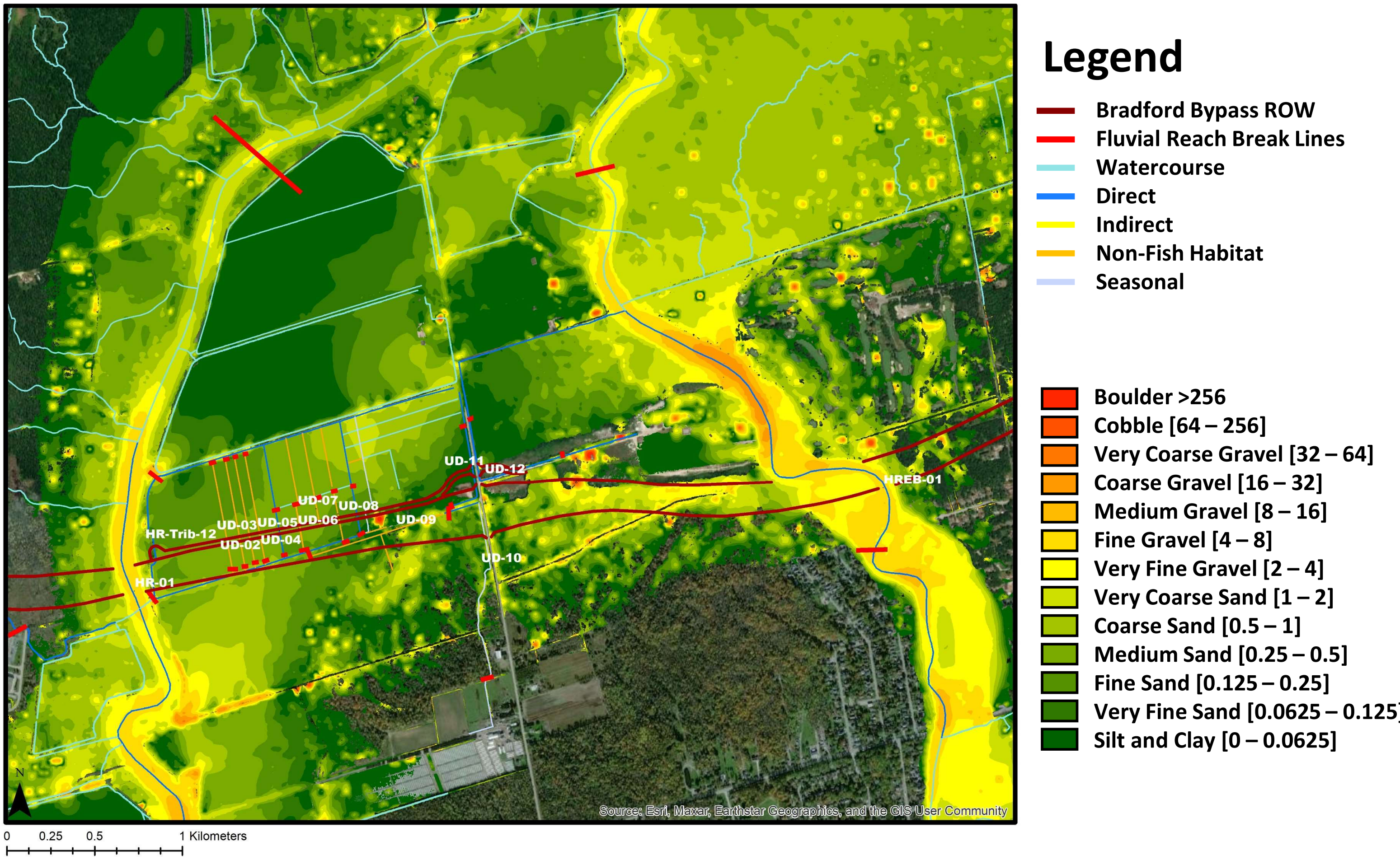
Predicted Sediment Transport for the 50-year Flow Return Period Event (Existing Conditions)



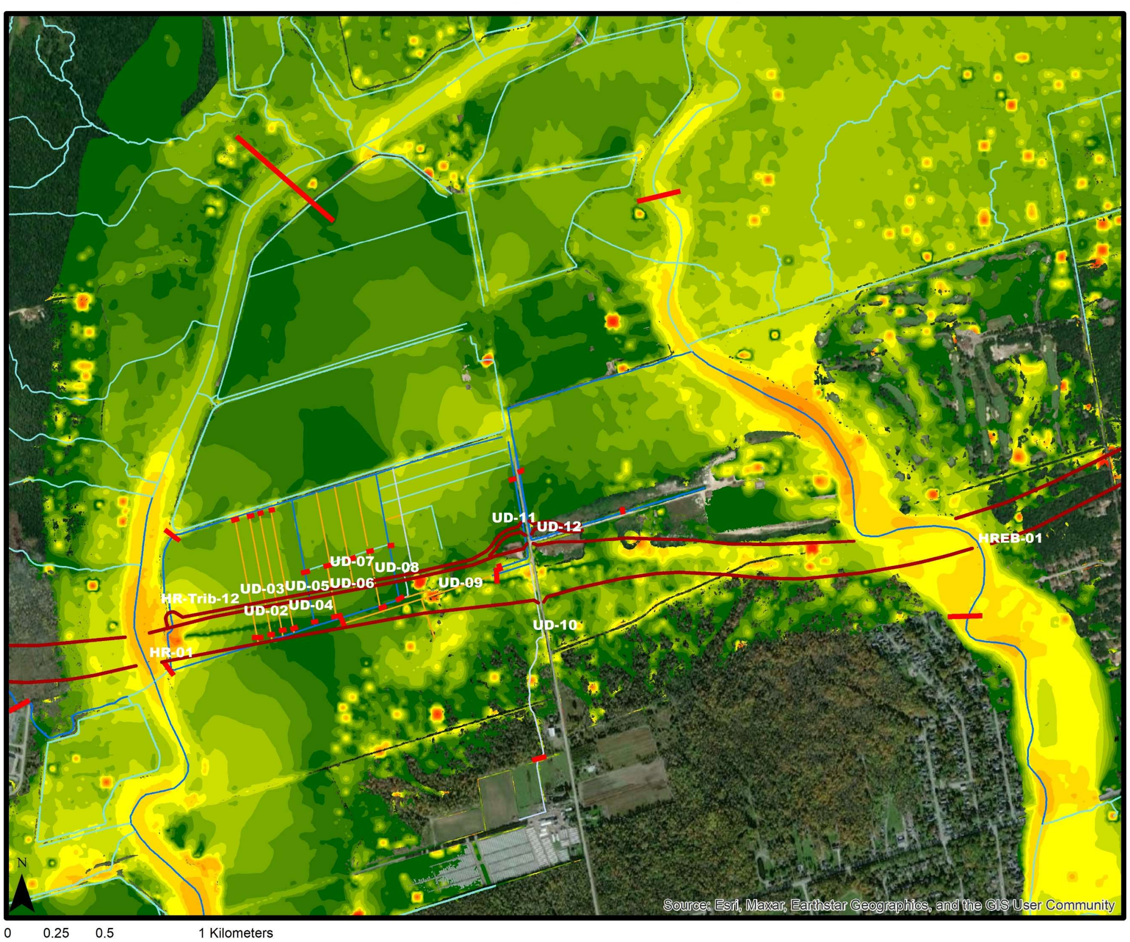
Predicted Sediment Transport for the 50-year Flow Return Period Event (Proposed Conditions)



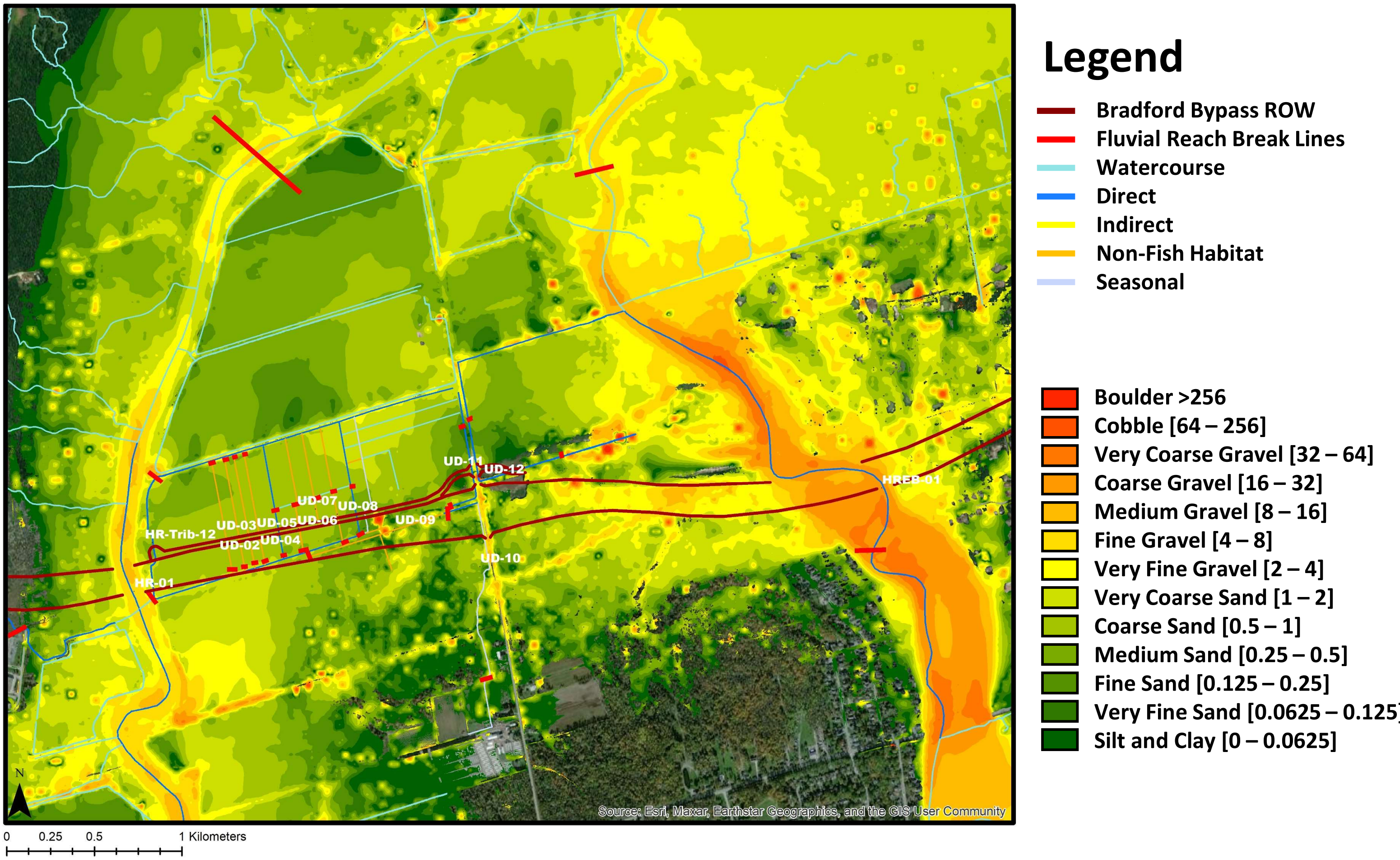
Predicted Sediment Transport for the 100-year Flow Return Period Event (Existing Conditions)



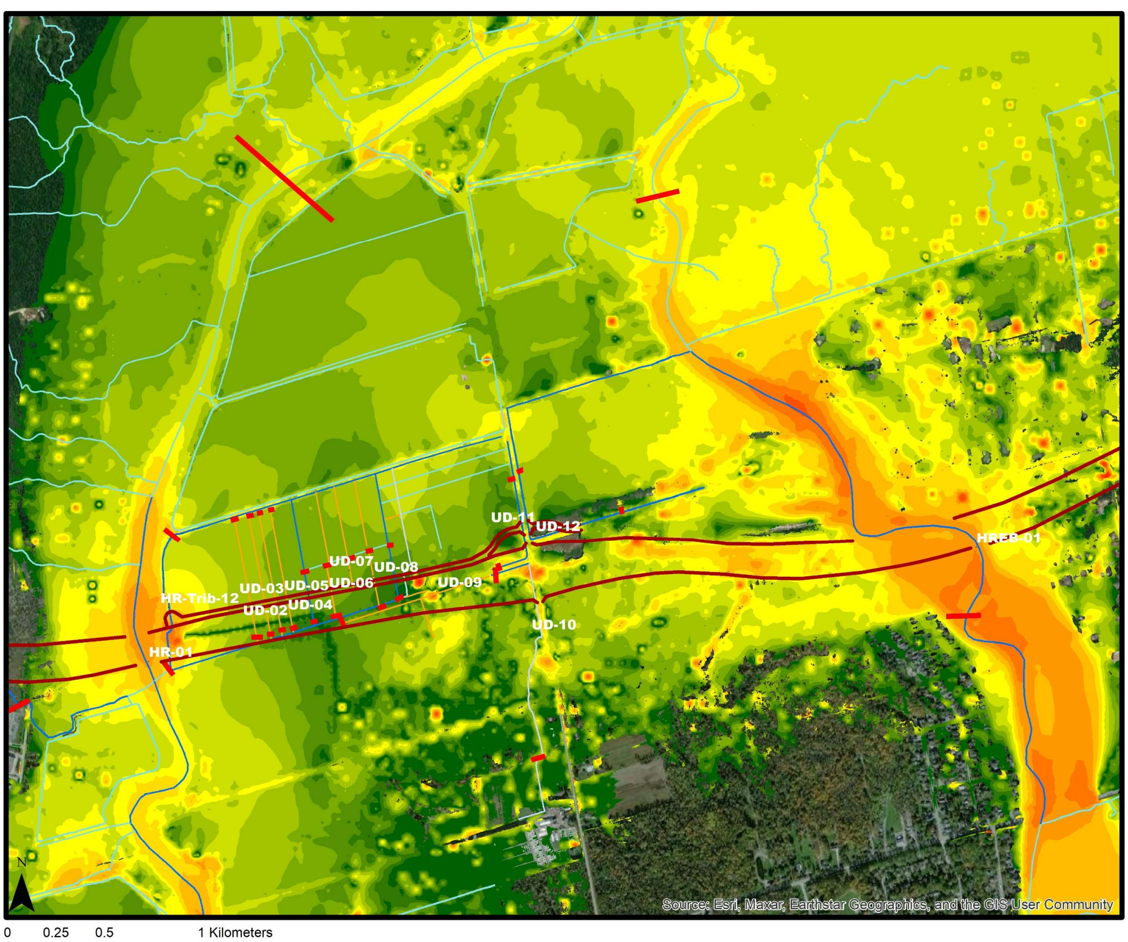
Predicted Sediment Transport for the 100-year Flow Return Period Event (Proposed Conditions)



Predicted Sediment Transport for the Regional Flow Return Period Event (Existing Conditions)



Predicted Sediment Transport for the Regional Flow Return Period Event (Proposed Conditions)



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