Teston Road Extension IEA
Fluvial Erosion Hazard Study

DRAFT REPORT

Prepared for

Morrison Hershfield

125 Commerce Valley Drive, Suite 300
Markham, Ontario
L3T 7W4

June 16, 2023
Project No. P2021-597

Prepared by

GeoProcess Research Associates Inc.
133 King Street West
PO Box 65506 DUNDAS
Dundas, ON L9H 6Y6

Version History

Version	Date	Issue	Description	Author	Approved
1	2023/06/16	Draft	Issued for Client review.	COJ	JPH

Table of Contents

List of Figures

List of Tables

1. Introduction

GeoProcess Research Associates Inc. (GeoProcess) was retained by Morrison Hershfield to complete a study of the fluvial erosion hazard for a tributary to the East Don River, located approximately 350 m west of the intersection of Dufferin Street and Teston Road within the City of Vaughan. The meander belt width is a governing component of the fluvial erosion hazard and was the focus of this study, which assessed the geomorphic conditions within the study reach to inform the design span of the future bridge associated with the extension of Teston Road. The determination of the geotechnical hazard (long-term stable slope) was not part of this work and is assumed to have been completed by others. Bridge pier and abutment scour assessment/protection also did not form part of this work.

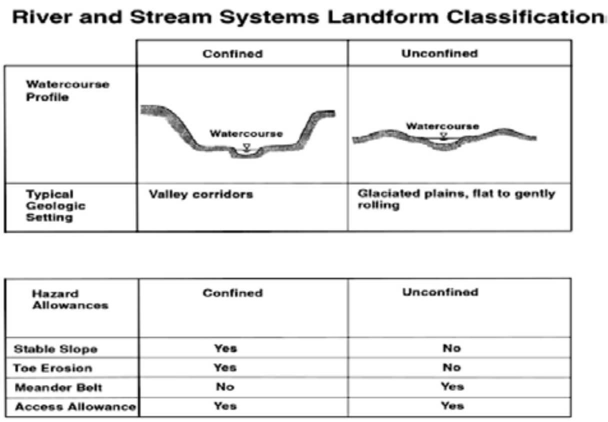
2. Background and Regulatory Context

A meander belt is a conceptual swath of river corridor that represents the potential limits of lateral channel migration for a watercourse (TRCA, 2001). Meander belts are commonly used to define erosion hazard setbacks and, in some cases, habitat protection zones for aquatic species at risk.

In the context of erosion hazards, the meander belt is a regulatory limit that establishes the setback for new developments, as defined by the MNRF's technical guidelines for land-use planning for erosion hazards, forming part of Section 3.1 of the Provincial Policy Statement (PPS) of the Provincial *Planning Act*. As a planning tool, the meander belt setback works with three other erosion-related hazard allowances specific to watercourses, including the access, toe erosion, and stable slope allowances. The landform setting defines the applicability of these allowances to different valley corridors, as illustrated in Figure 1, below.

In cases where the watercourse is not confined by a clear valley wall, such that the erosion processes are dominated by "flat to gently rolling, glaciated plains", the governing erosion hazard limit is defined by the flooding hazard limit or meander belt allowance plus an erosion access allowance. For cases where the watercourse is confined (or partially confined) within a valley corridor, the valley walls act to constrain the meander belt width and the setback is adjusted according to the remaining hazard allowances. The hazard allowances for unconfined valley corridors are illustrated in Figure 2.

The concept of the meander belt width is based on a fundamental aspect of river dynamics, where the belt width is the area of the floodplain that could be expected to be occupied by the river (due to erosional processes) in each planning time frame. In Ontario, this time frame is typically 100 years. Functionally, the meander belt width is illustrated in Figure 3 as the area between the red lines (the swath of land between the outside banks of the river). The condition illustrated in Figure 3 represents a static condition, depicting the river at one point in time. When the meander belt is less than 50 m, the rate of erosion is added to the outer limit of each meander belt, as a function of the 100-year predicted erosion distance to account for changes over time (annual rate of migration X 100 years). If the meander belt width is greater than 50 m and a change in flow regime is anticipated over the planning horizon, a 20% factor of safety is applied instead of the 100-year predicted erosion distance (TRCA, 2001). In the case where the meander belt width (the red line, below) intersects the valley wall, the belt width is modified to follow the path of the valley wall at an average distance between the top and bottom of the slope (Figure 4, below).



River and Stream Systems Landform Classification

	Confined	Unconfined
Watercourse Profile	Watercourse	Watercourse
Typical Geologic Setting	Valley corridors	Glaciated plains, flat to gently rolling

Hazard Allowances	Confined	Unconfined
Stable Slope	Yes	No
Toe Erosion	Yes	No
Meander Belt	No	Yes
Access Allowance	Yes	Yes

Figure 1: River and stream systems landform classification and applicability of landform components to the hazard allowance designation (MNRF Erosion Hazard - Technical Guidelines, 2002).

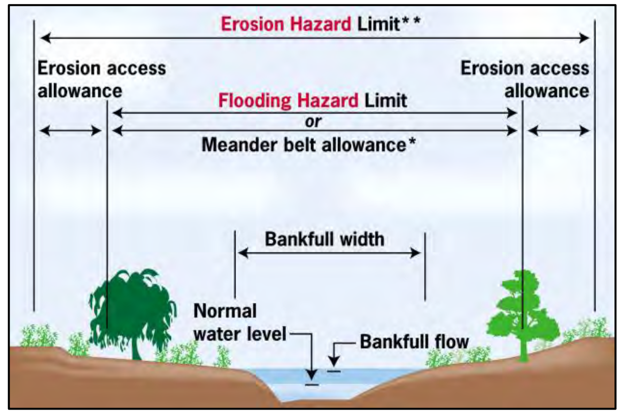


Figure 2: Erosion hazard limit in an unconfined system (MNRF, 2002).

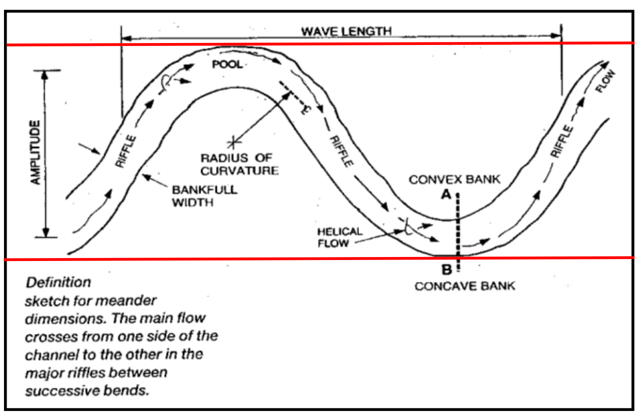


Figure 3: River planform dimensions and terminology (reproduced from the MNRF Erosion Hazard Technical Guidelines, 2002). The meander belt limit for this schematic has been added as red lines.

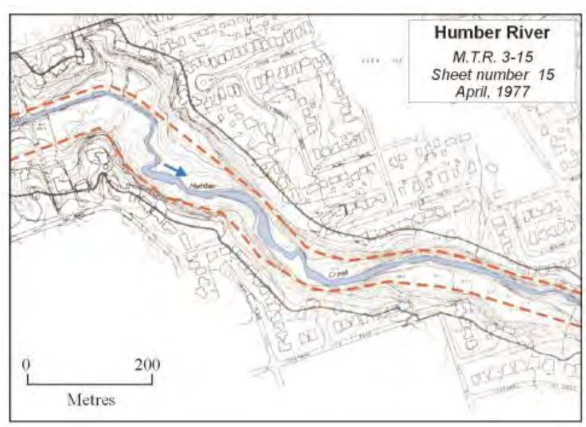


Figure 4: Excerpt from the TRCA Belt Width Delineation Procedure document (2001), illustrating the meander belt in a confined setting "placed at an average distance between the top and bottom of the valley walls".

3. Existing Conditions

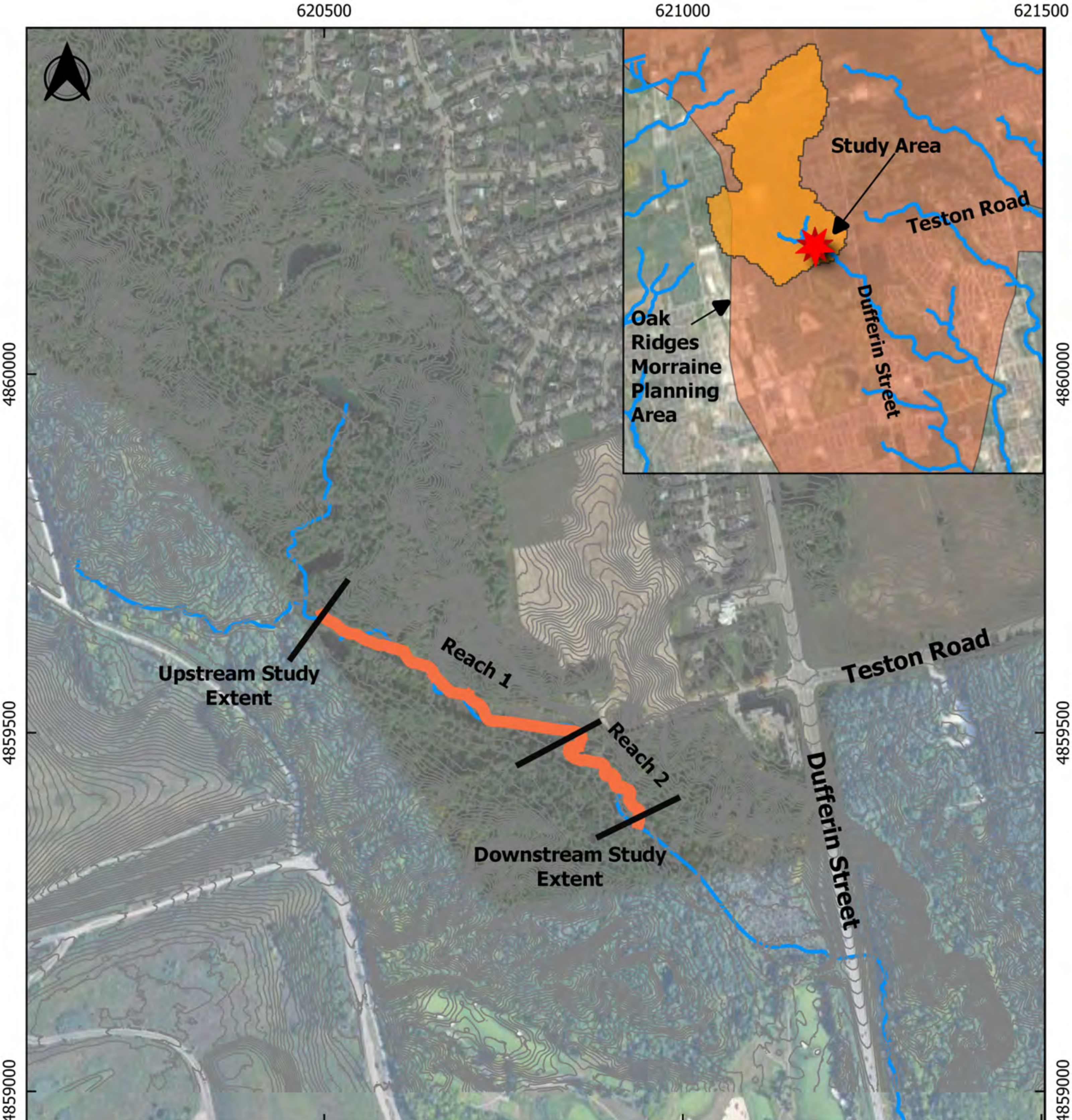
The study area is near the headwaters of the East Don River. At the study reach, the channel has a drainage area of approximately 3.3 km^2 as estimated using the Ontario Watershed Information Tool (OWIT). The drainage area is almost entirely within the Oak Ridges Moraine Planning Area. Contributing cover within this area predominantly consists of agriculture and rural land use (44%), forests and swamps (34%), and community and infrastructure (21%). The channel is within a natural core area land use designation of the Oak Ridges Moraine. The Oak Ridges Moraine is also the main physiographic feature within the drainage area with the resultant geology of the area consisting of ice-contact deposits of sand, gravel and silt (Sharpe, 1980).

GeoProcess completed a geomorphological reconnaissance of the study area on April 21st, 2022. The unconfined valley setting was verified (per Section 2) and an online pond, having an outlet structure in disrepair, was documented. The study area was subsequently divided into two reaches, illustrated in Figure 5, with the pond being the divide. The upstream extent of the study reach is the confluence of the main tributary channel with a smaller ephemeral channel. The downstream extent is a historical (remnant) flow structure that may have been a culvert or low-head dam. Two offline ponds contribute flow to the channel near the upstream extents of the study reach.

At the upstream extent of Reach 1, there is a steep valley wall present on the northeast side of the channel and a berm separating an offline pond is located along the southwest side of the channel. The valley subsequently transitions to a more expansive, unconfined setting. The Reach 1 channel is a low gradient, parabolic-shaped swale having poorly defined banks and stability controlled by vegetation. The channel bottom is primarily muck and detritus. The floodplain is readily connected to the channel due to the low profile banks. The backwater and low gradient impact of the existing pond (at the downstream limit of Reach 1) is likely contributing to the channel form here. This reach includes a section where the channel transitions into the pond/wetland, having substantial cattail growth. There are no indicators of systemic instability in Reach 1.

Reach 2 flows out of the existing pond, and is within the footprint of a remnant pond, terminating at the historically failed outlet structure. The nature of this outlet is not clear (dam or culvert crossing). The channel in Reach 2 is a very low gradient and its slope is maintained by the rock outlet, which provides grade control. The form of the channel is almost indistinguishable from the floodplain at some locations, except for localized instances of scour where the channel intersects the valley wall (near the discharge from the existing pond). There are also no indicators of systemic instability in Reach 2.

Downstream of Reach 2, outside of the proposed road corridor, the channel definition increases and there are indicators of geomorphic instability by way of undercut vegetation and downcutting. This condition may be related to the past failure of the historical pond's flow conveyance structure, but the detailed history of this feature could not be ascertained. The channel incision downstream of Reach 2 is not predicted to propagate upstream, owing to the generally low flows (minimal energy) and presence of the historical rock outlet structure at the downstream extent of Reach 2, which provides grade control.



Project No. P2021-594
Jun 08, 2023

0 100 200 metres

G:\Shared drives\Projects-2021\P2021-597 York Region Teston IEA Geomorphology\GIS\Teston Road- East Don River MBA.qgz
[Drawing by: COJ]

LEGEND

- Reach Break
- Study Reach (2022 Centreline)
- 1 m contours
- Watercourse (TRCA)
- Drainage Area
- Oak Ridges Moraine Planning Area

GeoProcess RESEARCH ASSOCIATES

Figure 3: Study Area Map

Teston Road IEA, Vaughan, Ontario

Table 1 provides a summary of key planform parameters for the two study reaches.

Table 1: Summary of valley setting and meander patterns.

Reach	Valley Setting	Meander Pattern	Reach Length (m)	Valley Length (m)	Sinuosity (-)
Reach 1	unconfined	Straight	410	390	1.05
Reach 2	unconfined	regular	180	130	1.38

Photos 1 through 4 depict some of the main features identified during the site visit, including the existing pond perimeter dam and representative depictions of the upstream and downstream reaches.

Photo 1: View of Reach 1, upstream of the pond

Photo 2: Dam creating the in-line pond and delineating the reach break

Photo 3: View of Reach 2, looking downstream from pond perimeter berm

Photo 4: Downstream extents of Reach 2

4. Historic Site Context

To understand the fluvial geomorphological context of the system, historical aerial imagery of the site was reviewed. While aerial imagery was available dating back to 1954 the small size of the channel, along with dense vegetation, obstructed reliable channel delineations. Nonetheless, the imagery was useful in identifying major changes to the channel and surrounding land use. Imagery from 1954, 1970, 1988, 2002 and 2021 were reviewed and their corresponding interpretations are summarized below in Table 2.

Table 2: Summary of historic observations of the watercourse within the study area.

Year	Summary
1954	The land immediately adjacent to the channel is a densely vegetated woodlot. Surrounding land use is agricultural. No inline ponds or offline ponds are present.
1970	The land adjacent to the channel on both sides is densely vegetated. To the southwest, the edge of an aggregate mining operation is visible, to the northeast the land use is agricultural and to the north, the land is a densely vegetated woodlot. One offline pond is present at the upstream extents of Reach 1. Two inline ponds are visible; the one observed during the site visit and a second pond where Reach 2 currently is.
1988	The land use surrounding the channel has not changed since 1970 and dense riparian vegetation remains. The second offline pond at the upstream extents of the study area is now present. Both inline ponds remain present
2002	The riparian corridor remains densely vegetated. The aggregate mining operation remains present on land to the south and west, and a residential development has started construction to the northeast. The downstream inline pond is no longer present and Reach 2 flows through a grassed valley.
2021	The riparian corridor remains densely vegetated. The aggregate mining to the south and west appears inactive, with a portion of the lands to the south now a golf course. Residential development is present to the northeast of the channel and East of Dufferin Street. A single inline pond remains.

5. Method for Meander Belt Width Delineation

The valley setting within the study site was determined from 1m topographic contours obtained from the Lidar-derived Ontario Digital Terrain Model. Despite the evidence of distinct valley walls throughout the study area, there is a sufficiently wide valley bottom for both reaches to be considered unconfined.

Within the context of planform analysis and land-use planning, the intent of the meander belt width as a planning tool and geomorphic parameter is to identify potential hazard lands; those areas of the floodplain that may expect to be occupied by the watercourse within a planning horizon. Typically, this horizon is assumed to be 100 years. The belt width concept aims to account for lateral migration of the watercourse over time and assumes the following about the current watercourse's planform alignment:

a) It is the result of hydraulic processes acting on an erodible boundary; and,
b) Factors affecting rates of erosion and the resulting change in the watercourse planform are consistent throughout the assumed planning horizon. These factors include those affecting the flow regime (rainfall-runoff intensity, duration, and frequency), sediment regime (supply and transport of bed material load), and stream and valley geometry (i.e., changes to the channel slope resulting from straightening).

The degree to which assumptions a) and b) affect the estimated belt width varies based on geology and physiography (i.e., the overall erosion potential of the system). Inherently, confined systems are less prone to channel migration beyond the limits of the valley wall, owing to the resistive nature of the valley wall material and how the channel form evolves relative to its floodplain. Erosion (over long periods) of less resistive bank material would not result in steep, high valley walls because of fluvial erosion and gravity acting on the slope. Thus, the landform itself is an indicator of erosion potential manifested over time.

Land-use change can affect the future hydrological conditions of a study site. The catchment of the study area encompasses the Oak Ridges Moraine Planning area and any development causing a change in hydrology would have to meet the regulations associated with the land use designation under the Oak Ridges Moraine Conservation Plan (Ministry of Municipal Affairs and Housing, 2017). Approximately half of the drainage area falls within a natural core area, which dictates that "only existing uses, agricultural uses and very restricted new resource management, low intensity recreational, home business and infrastructure uses are allowed in these areas" (Ministry of Municipal Affairs and Housing, 2017). The balance falls within the land use designation of settlement area which permits urban uses and development as set out in municipal office plans. To reflect the presence of designated settlement areas within the drainage area, it was assumed that there will be a future change in hydrology.

For unconfined systems, the meander belt limit is defined as the distance between lines tangential to the outside of extreme meander bends and in the direction of the meander axis (TRCA 2001). A final meander belt limit is then defined to account for lateral channel migration over the 100-year planning horizon. For meander belt widths greater than 50 m, the final belt width is calculated as the existing width multiplied by a factor of safety of 1.1 (when a significant change in hydrology is not anticipated over the planning horizon). However, this is not directly applicable in situations where the watercourse has been historically modified.

For the study reach, the channel has undergone multiple modifications, with each instance affecting the channel's balance between flow and sediment and its long-term stability. The offline ponds upstream of the study area, and online ponds within the study reach, will have changed the routing of water through the channel and the sediment supplied to the stream. The subsequent removal of an online pond (in the present-day Reach 2) would have also altered these characteristics. These changes confounded the historical channel comparison, resulting in a comparison of different geomorphic regimes across periods. Dense vegetation throughout the study reach, and the small channel size (~1 m in width), also inhibited accurate delineation of channel alignments, which limited a meaningful historical alignment comparison to small sections of the channel. This also limited the number of stream bends from which representative erosion rates could be estimated.

Consequently, the meander belt was estimated by empirical equations, as listed in Table 3. These relationships were informed by data collected during the desktop investigation, and channel dimensions observed during the site visit. Due to negligible differences in channel dimensions and drainage areas between the two reaches, a single belt width was calculated using the most conservative parameters available, and was applied to both reaches.

Table 3: Meander belt width empirical equations.

No.	Equation	Variables	Source
1	$W_b = -14.827 + 8.319\ln(SPxDA)$ $SP = \omega Q_2 s$	$W_b = meander\ belt\ width\ (m)$ $SP = stream\ power\ (W/m^2)$ $DA = drainage\ area\ (km^2)$ $\omega = specific\ weight\ of\ water\ (9806\ kg/m^2s^2)$ $Q_2 = 1{:}2\ year\ flow\ (m^3/s)$ $s = channel\ slope\ (m/m)$	TRCA, 2001
2	$W_b = 4.3W_{BF}{}^{1.12}$	$W_b = meander\ belt\ width\ (m)$ $W_{BF} = bankfull\ width\ (m)$	Williams, 1986
3	$W_b = 4.8W_{BF}{}^{1.08}$	$W_b = meander\ belt\ width\ (ft)$ $W_{BF} = bankfull\ width\ (ft)$	Ward, 2002

The TRCA empirical approach (Equation 1) utilizes a 1:2-Year return period discharge as an input parameter. A 1:2-year return period discharge of 0.27 m^3/s was obtained from the 2018 Don River Hydrology Update prepared by AECOM for the Toronto and Region Conservation Authority (TRCA, 2018). This is the modelled 2-year flow under expected future conditions at node 17, located where the study channel crosses Major Mackenzie Drive. Since this is approximately 2.5 km downstream of the study area, it represents a conservative estimate of the future flow conditions during the 2-year event.

Table 4: Empirical equation input parameter values.

Parameter	Value	Source
Drainage Area (DA)	3.34 km^2	OWIT
1:2-Year Discharge	0.27 m^3/s	TRCA, 2018
Channel Slope (s)	0.015 m/m	Ontario Digital Terrain Model – Lidar Derived (2014)
Bankfull Width (W_{BF})	1.2 m	2022 Site Visit (maximum stable value)

6. Results

The resulting meander belt width estimates derived from the suite of empirical equations are listed in Table 5. The empirical equations resulted in estimates ranging from 5.3 m to 25.8 m.

Table 5: Meander belt width empirical equation results.

Equation No.	Source	Meander Belt Width (m)
1	TRCA, 2001	25.8
2	Williams, 1986	5.3
3	Ward, 2002	6.4

Based on observations made during the site visit, the meander belts estimated using the Williams (1986), and Ward (2002) empirical equations are not representative of the site conditions and would not encompass the observed channel alignment. As such, they were not used to determine the final belt width.

The TRCA empirical belt width requires that a factor of safety be added to the preliminary belt width. Given that a change in hydrologic conditions is anticipated, the factor of safety is calculated by adding two times the site-specific standard error associated with empirical equation 1 to the preliminary meander belt width (TRCA, 2001). This factor of safety and the resulting final belt width are demonstrated below in Table 6.

Table 6: Application of Safety Factor and Final Belt Width.

Preliminary Belt Width (m)	Source	Equation Standard Error	Final Belt Width (m)
25.8	TRCA, 2001	8.63	43.1

It is noted that the final belt width represents the minimum valley bottom width related to erosion hazard limits. The preferred bridge alignment identified by Morrison Hershfield consists of a single span bridge with an 80 m bottom width between the abutments. By spanning a distance greater than the final meander belt width, the bridge span will mitigate against long-term erosion risk to the structure caused by lateral stream erosion. Additional setbacks and constraints beyond the meander belt width (e.g., stable side slopes, erosion access allowance, flood hazard) were not included in this assessment.

7. Conclusions

Following a desktop review and field analysis, a meander belt width limit of 43.1 m was delineated for the tributary to the East Don River at the proposed Teston Road extension (West of Dufferin Street). The belt width can be used in subsequent land-use planning and constraint mapping. If you have any questions regarding this study, please do not hesitate to contact Jeff Hirvonen at 416-452-5037 or by email at jhirvonen@geoprocess.com.

Project No. P2021-597
Jun 08, 2023

0 30 60 90 120 150 metres

G:\Shared drives\Projects-2021\P2021-597 York Region Teston IEA Geomorphology\GIS\Teston Road- East Don River MBA.qgz
[Drawing by: COJ]

LEGEND

- Final Belt Width
- Meander Axis
- 1 m contours
- 2021 centreline
- 2002 centreline
- 1988 centreline
- 1970 centreline

GeoProcess RESEARCH ASSOCIATES

Figure 6: Final Meander Belt

Teston Road, Vaughan, Ontario

References

Ministry of Natural Resources and Forestry (MNRF) (2001). *Understanding Natural Hazards: Great Lakes – St. Lawrence River System and large inland lakes, river and stream systems and hazardous sites*. report 51499. ISBN 0-7794-1008-4. Queen's Printer for Ontario.

MNRF (2002). *Technical Guide; River & Stream Systems: Erosion Hazard Limit*. prepared by Terraprobe Ltd. And Aqua Solutions.

MNRF (2020). *Ontario Digital Terrain Model (Lidar-Derived) User Guide*. LIO Dataset, Provincial Mapping Unit, Mapping and Information Resources Branch, Corporate Management and Information Division, Ontario Ministry of Natural Resources and Forestry.

Ministry of Municipal Affairs and Housing (2017). *Oak Ridges Moraine Conservation Plan*.

Sharpe, D. R. (1980). *Quaternary Geology of Toronto and Surrounding Area*. Ontario Geological Survey Preliminary Map P. 2204, Geological Series. Scale 1:100 000. Compiled 1980.

TRCA (2001). *Belt Width Delineation Procedures*. submitted by Parish Geomorphic. report no. 98-023.

Toronto Region Conservation Authority (TRCA) (2018). *Don River Hydrology Update.* Prepared by AECOM.

Ward, A. D., Mecklenburg, D., Mathews, J., Farver, D. (2002) "Sizing Stream Setbacks to Help Maintain Stream Stability", *Paper Number: 022239, 2002 ASAE Annual International Meeting,* Chicago, Illinois, USA, July 28-July 31, 2002.

Williams, G. P. (1986) "River Meanders and Channel Size", *Journal of Hydrology,* 88: 147-164.

York Region Teston Road IEA – Meander Belt Width Final Report

Prepared for Morrison Hershfield

June 16, 2023

Prepared by:

Caleb Jefferies, BASc, EIT
Water Resources Specialist

Reviewed by:

Jeff Hirvonen, MASc,
Principal

Disclaimer

We certify that the services performed by GeoProcess Research Associates were conducted in a manner consistent with the level of care, skill and diligence to be reasonably exercised by members of the engineering and science professions.

Information obtained during the site investigations or received from third parties does not exhaustively cover all possible environmental conditions or circumstances that may exist in the study area. If a service is not expressly indicated, it should not be assumed that it was provided. Any discussion of the environmental conditions is based upon information provided and available at the time the conclusions were formulated.

This report was prepared exclusively for Morrison-Hershfield by GeoProcess Research Associates. The report may not be relied upon by any other person or entity without our written consent and that of Morrison-Hershfield. Any uses of this report or its contents by a third party, or any reliance on decisions made based on it, are the sole responsibility of that party. GeoProcess Research Associates accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report.

Project Number P2021-597