Preliminary Fluvial Geomorphological Assessment and Erosion Hazard Delineation

12892 Dixie Road, Caledon, ON

Prepared for:

Tribal Partners Canada Inc.
201-2700 Steeles Ave West
Vaughan, ON L4K 1C8

February 24, 2021
PN20109

GEO MORPHIX
Geomorphology
Earth Science
Observations

Report Prepared by: GEO Morphix Ltd.
36 Main Street North
PO Box 205
Campbellville, ON L0P 1B0

Report Title: Preliminary Fluvial Geomorphological Assessment and Erosion Hazard Delineation
12892 Dixie Road, Caledon, ON

Project Number: PN20109
Status: Final
Version: 1.1
First Submission Date: February 24, 2021

Prepared by: Josie Mielhausen, M.Sc., Kat Woodrow, M.Sc.
Approved by: Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Approval Date: February 24, 2021

Table of Contents

List of Tables

Appendices

1 Introduction

GEO Morphix Ltd. was retained to complete a preliminary fluvial geomorphological assessment and erosion hazard delineation at 12892 Dixie Road, in the Town of Caledon, Ontario. The subject site is bounded by Dixie Road to the north/east, Old School Road to the north/west, and privately owned lands to the south. There are five (5) watercourse features within the subject property, including the main branch of the West Humber River which traverses the southwest extent of the property, two tributaries of the West Humber River which traverse through a woodlot at the center of the property, a tributary of the West Humber River which traverses through a wetland at the northeastern extent of the property, and a tributary of the West Humber River which also traverses through a wetland at the northern extent of the property. The preliminary geomorphological assessment was completed to support a proposed 78.9-hectare industrial development, including associated buildings and road networks.

For the preliminary fluvial geomorphological assessment and erosion hazard delineation, the following activities were completed:

- Review available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Complete watercourse reach delineation through a desktop assessment
- Review of recent and historical aerial photographs of the site to understand historical changes in channel form and function
- Complete rapid geomorphological assessments on a reach basis to document channel conditions and verify the desktop assessment where possible
- Document any areas of significant erosion, collect instream measurements of bankfull channel dimensions, and characterize bed and bank material composition and structure
- Delineate limits of the erosion hazard on a reach basis using field observations

2 Background Review and Desktop Assessment

2.1 Background Information

The subject section of West Humber River is situated within the Toronto and Region Conservation Authority (TRCA) jurisdiction and further, the Humber River watershed. The Humber River watershed originates in the Oak Ridges Moraine, outlets to Lake Ontario, and encompasses approximately 911 square kilometers (TRCA, 2021). The West Humber River specifically originates in Caledon (South Slope) and flows over 45 km (crossing Peel Plain) in Brampton prior to its confluence with the Main Humber River in Toronto (TRCA, 2021).

Several stream layer datasets were reviewed to understand existing drainage features on site. The review included data from MNRF's Ontario Hydro Network (OHN) stream layer, Peel Region's stream layer, and the TRCA Regulation Area stream layer. It should be noted that the three layers were generally in agreement, but that several additional features were noted in the TRCA mapping that were not captured in the MNRF or Peel Region layer.

Within the subject property, the main branch of the West Humber River flows generally west to east along the southern extent of the property boundary. This watercourse has a meandering planform with irregular meanders and flows through a confined valley system. Near the center of the subject property, two tributaries of the West Humber River generally flow west to east through a woodlot. These watercourses are straight with few meanders and flow through an unconfined

valley system. It should be noted that the MNRF and Peel Region stream layer only showed the southern tributary within the woodlot, but it is assumed that there is a secondary feature slightly to the north within the woodlot based on TRCA's stream mapping. The tributary through the northern extent of the woodlot is a first order stream and is likely characteristic of headwater drainage feature. At the northern extent of the subject property, two tributaries of the West Humber River generally flow northwest to southeast through existing wetland features. These channels are straight with limited sinuosity. The smaller tributary that flows adjacent to Dixie Road in the more central portion of the property was not documented in the MNRF and Peel Region stream layer, but it is assumed that this feature is present based on TRCA's mapping. Given that it is a first order feature with a small drainage area, it is characteristic of a headwater drainage feature.

Additional drainage features on site were observed through a desktop assessment of recent aerial imagery from Google Earth Pro. Recent aerial photographs indicate that there are small headwater drainage features on site that extend through existing agricultural fields. It should be noted that these features are only visible through aerial photograph interpretation and are not included in any available stream layer datasets reviewed through the desktop assessment.

2.2 Geology and Physiography

Geology and physiography act as constraints to channel development and tendency. These factors determine the nature and quantity of the availability and type of sediment. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

Within the subject property, the West Humber River and associated tributaries are dominated by the Till Plains (drumlinized) physiographic region of Ontario (Chapman and Putnam, 2007). In terms of surficial geology, the subject lands are characterized by till (OGS, 2010). Soils within these areas include clay to silt-textured clay derived from glaciolacustrine deposits or shale (OGS, 2010). Evidence of till exposure and shale were observed on site during field investigations. Additionally, along the southern extent of the subject property and the downstream extent of the northern tributary, soils were characterized by modern alluvial deposits, including clay, silt, sand, gravel, and organic remains (OGS, 2010). A geotechnical assessment was completed by MTE Consultants (2021) that included borehole analysis across the site. Results of the geotechnical study confirm the presence of modern alluvium materials and various glacial deposits.

2.3 Reach Delineation

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

Reaches are typically delineated based on changes in the following:

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

- Historical channel modifications

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others.

Several watercourse layers were reviewed to identify watercourses on site, which included those available through TRCA, Peel Region, and MNRF. Based on the existing channel conditions and the linear extent of the watercourses within the subject property, five (5) reaches were delineated. Further sub-reaches were delineated to identify minor differences in watercourse and/or landscape characteristics within reaches. It is important to note that two (2) reaches were identified as first order features and were only present in the TRCA stream layer data (**Reach/HDF 9** and associated sub-reaches and **Reach/HDF 8** and associated sub-reaches). Given that the two features were observable in aerial photographs, they have been included as part of the desktop assessment. All reaches are graphically defined in **Appendix A**. It should be noted that the watercourse layer included in **Appendix A** is a combination of TRCA and Peel Region linework, which was verified through field observations or confirmed to be the most accurate based on our desktop assessment.

Additional drainage features on site were observed through a desktop assessment of recent aerial imagery from Google Earth Pro. Recent aerial photographs indicate that there are small headwater drainage features on site that extend through existing agricultural fields. It should be noted that these features are only visible through aerial photograph interpretation and are not included in any available stream layer datasets reviewed through our desktop assessment. As such, they have not been included as part of the reach delineation exercise outlined here. We note that a preliminary review of headwater features was completed by WSP Canada in 2020. The results of that assessment are documented in their report (WSP, 2021).

2.4 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics.

Various aerial photographs and satellite images from 1960 to 2018 were retrieved to complete the historical assessment and inform the erosion hazard delineation. Specifically, aerial photographs from 1960, 1974 (National Air Photo Library), and satellite images from 2005 and 2018 (Google Earth Pro) were reviewed. All historical aerial photographs are provided in **Appendix B** for reference. The watercourse reaches outlined as part of the historical assessment are graphically presented on the map in **Appendix A**.

The aerial photograph from 1960 includes **Reach 6, Reach 9, Reach/HDFs 9a-b,** and **Reach 10.** The subject property and surrounding lands were dominated by agricultural activities with few residential dwellings along Dixie Road and Heart Lake Road. At the subject property and slightly downstream, **Reach 6** was characterized by a meandering planform with tortuous meanders. A valley wall is visible in the aerial photograph, which is indicative of a confined system. The riparian buffer was limited, dominated by grasses with established trees clustered along the southern bank of the channel. **Reach 10** was generally straight with few small meanders. **Reach 10** and **Reach/HDFs 9a-b** flow through a woodlot with headwater channels visible upstream through agricultural fields. Despite being surrounded by woody vegetation, riparian habitat appeared fragmented through the reach. Downstream from the woodlot, **Reach 9** had a generally straight planform with a limited riparian buffer dominated by grasses.

All reaches on the subject property were discernable in the aerial photograph from 1974. There were no changes in land use, land cover, or watercourse characteristics associated with **Reach 6, Reach 9, Reach/HDFs 9a-b,** or **Reach 10.** Within the subject property and slightly downstream, **Reach 8** was generally straight with limited sinuosity. The riparian buffer was limited to grasses with no large shrub/tree species in close proximity. Immediately upstream from Old School Road, the channel was meandering with irregular meanders, but appeared straightened/ditched further upstream to accommodate agricultural practices. **Reach/HDF 8a-1, 2,** and **3** were not clearly discernable from the aerial photograph; however, a vegetated change was observed.

Between 1974 and 2018, there were no changes in land use or land cover within and immediately surrounding the subject property. The channel planforms associated with all reaches were unchanged with more established riparian vegetation surrounding the watercourse features. The limited channel adjustments over time, as well as the increase in riparian vegetation surrounding the reaches, indicate that the watercourse features are generally stable. With the natural hazards delineated appropriately, it is expected that the channels will experience limited adjustments in morphodynamics over time.

3 Watercourse Characteristics

3.1 General Reach Observations

Field investigations were completed on November 26, 2020 for **Reaches 6** and **10**, and included the following:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including those completed for rapid assessments, are provided in **Appendix D**.

Due to field conditions on the day of assessment, **Reaches 8** and **9** were excluded from the investigation. To evaluate existing conditions at **Reaches 8** and **9**, a site visit is recommended when weather permits (i.e., spring 2021). Given the nature of **Reach/HDF 9a**, **b**, and **Reach/HDF 8a-1**, **2**, **3** as first order streams with small drainage areas, it is likely that these particular features are headwater channels. As such, they may require a specific assessment following the TRCA/CVC (2014) guidelines for headwater drainage feature evaluation. Although, it should be noted that these features are likely to require protection or conservation status through the TRCA/CVC HDF guidelines given their location within existing woodlot (**Reach/HDF 9a**, **b**) and wetland features (**Reach/HDF 8a-1**, **2**, **3**). The current development plan shows these features as being retained on the landscape in their current location. As such, additional study of these features is likely not required and will not affect current mitigation plans or development constraints.

Reach 6 flows west to east along the southern limit of the subject property. Upstream reaches traverse through agricultural lands and are straightened in several locations. Downstream from the subject property, **Reach 6** flows through an offline pond system and crosses Dixie Road.

Reach 6 was situated within a confined valley setting. The channel exhibited a meandering planform and had a confined sinuosity that ranged from 1.31 – 3.0. The surrounding land use consisted of agricultural land and the channel was in a transitional zone. The riparian buffer zone was approximately 1 to 4 channel widths beyond the watercourse and had continuous coverage. The dominant type of riparian vegetation was established (5 to 30 years) grasses. There was minimal encroachment of vegetation into the channel. The reach had perennial flow with a moderate gradient and moderate entrenchment. Bed material was composed of sand, gravel, and cobble. Riffle features consisted of sand, gravel, and cobbles, while pool features consisted of sand and gravel. Approximately 10% of the reach was occupied by rooted emergent aquatic vegetation, and there was a low density of woody debris present in the cutbank and channel.

Average bankfull width and depth were approximately 1.83 m and 0.78 m, respectively. Average wetted width and depth on the day of assessment were approximately 1.63 m and 0.68 m, respectively. Given the field conditions on the day of assessment, all measurements were estimated. Bank angles ranged from 60° to 90° and consisted of clay/silt, sand, and gravel. Evidence of erosion was observed through 30 to 60% of the channel, with bank undercuts measuring up to 1.5 m in depth. Meander amplitudes were approximately 15 m to 25 m.

Reach 10 flows west to east along the southern portion of the woodlot located in the south-central portion of the subject property. This reach is characteristic of a low-order stream, and based on our desktop assessment, likely receives hydrological inputs from an intermittent headwater drainage feature slightly upstream. Moving downstream, **Reach 10** exists the woodlot, traverses through the residential property on site, and crosses Dixie Road.

Reach 10 was situated within a partially confined valley setting. The channel exhibited a straight planform and had a low sinuosity that ranged from 1.06 – 1.30. The surrounding land use consisted of agricultural land beyond the woodlot and the channel was in a deposition zone. The riparian buffer zone was approximately 4 to 10 channel widths beyond the watercourse and had continuous coverage. The dominant type of riparian vegetation was established and mature (5 to > 30 years) tree species. There was minimal encroachment of vegetation into the channel. The reach had perennial flow with a moderate gradient and moderate entrenchment. Bed material was composed of clay/silt with no geomorphic units (i.e., riffles or pools) established. Less than 5% of the reach was occupied by rooted emergent aquatic vegetation. However, there was a high density of woody debris present in the cutbank and channel.

Average bankfull width and depth were approximately 2.84 m and 0.44 m, respectively. Average wetted width and depth on the day of assessment were approximately 1.22 m and 0.08 m, respectively. Bank angles ranged from 30° to 90° and consisted of clay/silt. Evidence of erosion was observed through 30 to 60% of the channel, with bank undercuts measuring up to 0.08 m in depth.

3.2 Rapid Assessment

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

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian

habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

These observations and measurements are summarized below. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including those completed for RGA and RSAT assessments, are provided in **Appendix D**. All RGA and RSAT results for **Reaches 6** and **10** are summarized in **Table 1**.

Reach 6 was assigned an RGA score of 0.15, indicating the reach was in regime. The dominant geomorphological indicator was evidence of widening by the observation of fallen/leaning trees, exposed tree roots, and basal scour on both inside meander bends and riffles through the reach. The secondary geomorphological indicator was evidence of degradation, based on observations of the channel being worn into undisturbed overburden/bedrock. These characteristics influence the delineation of erosion risk in terms of overall channel stability. **Reach 6** had an RSAT score of 27, or *good*. There were two limiting factors, including physical instream habitat and riparian habitat conditions. This was due to the limited geomorphological units, limited diversity in habitat types, and a narrow riparian area of mostly non-woody vegetation. It is important to note that the time of the field investigation (late fall) likely impacted the overall RSAT score in terms of habitat conditions.

Reach 10 was assigned an RGA score of 0.17, indicating the reach was in regime. The dominant geomorphological indicator was evidence of widening by the observation of fallen/leaning trees, occurrence of large organic debris, exposed tree roots, and basal scour through the reach. The secondary geomorphological indicator was evidence of planimetric form adjustment, based on observations of poorly formed and reworked bar formations. These characteristics influence the delineation of erosion risk in terms of overall channel stability. **Reach 10** had an RSAT score of 19, or *fair*. There were two limiting factors, including physical instream habitat and riparian habitat conditions. This was due to the limited geomorphological units, limited diversity in habitat types, and a riparian area predominantly wooded but with major localized gaps. It is important to note that the time of the field investigation (late fall) likely impacted the overall RSAT score in terms of habitat conditions.

Table 1. Summary of Rapid Assessment Results

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)		
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)
Reach 6	0.15	In Regime	Widening	27	Good	Physical instream habitat and riparian habitat
Reach 10	0.17	In Regime	Widening	19	Fair	Physical instream habitat and riparian habitat
Reach 9	Confirmation in spring 2021					
Reach/HDF 9a	Confirmation in spring 2021					
Reach/HDF 9b	Confirmation in spring 2021					
Reach/HDF 8a-2	Confirmation in spring 2021					
Reach/HDF 8a-3	Confirmation in spring 2021					
Reach 8b	Confirmation in spring 2021					

4 Erosion Hazard Assessment

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width or erosion hazard assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a watercourse.

When defining the erosion hazard for a watercourse, Ministry of Natural Resources and Forestry (MNRF, 2002) guidelines treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contact is possible.

When a meandering channel is confined, erosion of the valley wall needs to be considered. The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for establishing the erosion hazard for confined valley systems. This approach defines an appropriate erosion setback or toe erosion allowance from the channel bank where the creek is within 15 m from the toe of slope (MNRF, 2002). A toe erosion allowance can be determined in several ways: use of an average annual recession rate; use of a delineated toe erosion allowance in areas where the channel is within 15 m of the toe of slope; or use of soil information and field observations of geomorphic processes (MNRF, 2002).

At the subject property, an erosion hazard assessment was completed for **Reach 6** to identify the extent of possible erosion and delineate a natural hazard limit in support of development at the subject property. **Reach 6** was identified as a confined system with several observations of valley wall contact. As such, the MNRF (2002) approach was implemented for delineating the natural erosion hazard.

Given the scale of the channel and limited migration, erosion rates could not be measured from historical aerial photographs. Since **Reach 6** was within 15 m of the toe of slope (based on the topographic break in slope) through the subject property, a toe erosion allowance was determined to address the erosion hazard. Based on the type of bed and bank material (i.e., clay/silt, tills) and evidence of active erosion, a 5 m toe erosion was deemed appropriate using MNRF (2002) guidelines.

It is important to note that the total erosion hazard for confined valley systems is based on a combined influence of the toe erosion allowance and the stable slope. For confined systems, a stable slope is identified as 3:1 (H:V) or as determined by a study using accepted geotechnical principles (MNRF, 2002). A geotechnical investigation and slope stability analysis was completed for **Reach 6** by MTE Consultants (2021) to identify the stable top of slope. The geotechnical study confirmed that the slope is relatively stable under current conditions. The stable top of slope documented by MTE (2021) includes the 5 m toe erosion allowance, and as such, adequately characterizes the erosion hazard associated with **Reach 6**. The erosion setback delineation is provided in **Appendix E.**

It was determined that **Reach 6** of the West Humber River contains regulated (occupied) Redside Dace habitat, a species classified as endangered both provincially and nationally. As such, to satisfy the requirements of the Provincial Policy for development activities in Redside Dace protected habitat, a 30 m buffer from the toe of slope is also required (MNRF, 2016).

It is understood that a site walk was completed with members of TRCA, Town of Caledon, WSP, and Armstrong Planning on October 27, 2020 to stake the existing limits of natural features on site. This involved staking of the top of bank along the west side of **Reach 8b**. It is our understanding that the agreed upon limit of development in this location is associated with the setback from the staked top of bank. We note that there is outstanding field reconnaissance associated with **Reach 8b**. Given that this reach flows through a highly vegetated wetland feature and has been historically straightened, there is likely limited potential for channel migration. Field reconnaissance will be completed in spring 2021 (or when conditions permit) to confirm existing conditions for the feature.

5 Summary and Recommendations

Five (5) watercourse features, including the main branch of West Humber River and 4 tributaries, traverse the subject property at 12892 Dixie Road in the Town of Caledon, Ontario. The subject property is occupied by agricultural lands, several small wetland features, and a woodlot. The main branch of the West Humber River flows within a confined valley system, whereas the smaller tributaries occupy partially confined and unconfined valley systems.

A preliminary fluvial geomorphological assessment was completed for the property and included a review of previously completed studies, topographic and geology mapping/data, historical aerial photographs, reach delineation, and field reconnaissance to document existing channel conditions.

Field reconnaissance was completed along **Reaches 6** and **10** (**Appendix A**) to document existing channel characteristics. Due to conditions on the day of assessment, **Reaches 8** and **9** were not included in the field investigation. Instead, these features were reviewed through a desktop assessment based on detailed topographic information, recent aerial imagery, and previously collected data from others. The sub reaches of both **Reach 8** and **Reach 9** flow through existing wetland or woodlot features on the property.

Reach/HDF 9a, **b**, and **Reach/HDF 8a-1**, **2**, **3** are first order streams with small drainage areas, and as such, it is likely that these are headwater channels. As such, they may require a specific assessment following the TRCA/CVC (2014) guidelines for headwater drainage feature evaluation. Although, it should be noted that these features are likely to require protection or conservation status through the TRCA/CVC HDF guidelines given their location within existing woodlot (**Reach/HDF 9a**, **b**) and wetland features (**Reach/HDF 8a-1**, **2**, **3**). The current development plan shows these features as being retained on the landscape in their current location. As such, additional study of these features is likely not required and will not affect current mitigation plans or development constraints.

Additional drainage features on site were observed through a desktop assessment of recent aerial imagery from Google Earth Pro. It is understood that a review of headwater channels was completed separately by WSP in 2020 to address features within the areas of active agriculture on site.

Reach 6 was identified as a confined system with several observations of valley wall contact. As such, the MNRF (2002) approach for confined systems was implemented for delineating the erosion hazard. Given that **Reach 6** was within 15 m from the toe of slope within the subject property, a toe erosion allowance was determined. Based on the type of bed and bank material (i.e., clay/silt, tills) and evidence of active erosion, a 5 m toe erosion was deemed appropriate. The 5 m toe erosion allowance was also applied to the stable top of slope (MTE, 2021) to delineate the total erosion hazard.

Reach 6 was also identified as occupied Redside Dace habitat. As such, to satisfy the requirements of the Provincial Policy for development activities in Redside Dace protected habitat, a 30 m buffer is required from the toe of slope (MNRF, 2016).

We note that there is outstanding field reconnaissance associated with **Reach 8b**. It is our understanding that the agreed upon limit of development in this location is associated with the setback from the staked top of bank. Given that this reach flows through a highly vegetated wetland feature and has been historically straightened, there is likely limited potential for channel migration. Field reconnaissance will be completed in spring 2021 (or when conditions permit) to confirm existing conditions for the feature.

5.1 Monitoring Plan

We have also assumed that a level of monitoring would be required for the site, specifically with regards to watercourses where hydrology changes are anticipated as a result of the proposed development. Geomorphological monitoring should include monumented cross section surveys and longitudinal profiles of the channel centre line at each site, channel substrate characterization, installation and documentation of erosion pins, and a collection of monumented photographs. Pre-construction monitoring should be completed prior to development to document baseline conditions. Monitoring should also continue through construction and the post-construction period, ending two-years following build-out of the site.

Results of the geomorphological monitoring should be summarized in annual reports for submission to regulatory agencies that include a comparison of pre- and post-development instream conditions and evaluate any changes in the context of anticipated natural variability in the system. These recommendations for monitoring are preliminary in nature. We have assumed that the monitoring program will be coordinated and finalized through consultation with TRCA and the Town as part of conditions of approval.

5.2 Report Considerations

This report was completed for the sole use of the Client. This report is not intended to be exhaustive in scope and may not address all aspects potentially applicable to the site. Further, this report may not address all aspects which may be of interest to the reader.

The results of analyses presented in this report are based on conditions as they existed during the period of work. The material in the report reflects our best judgement using the information available at the time of report preparation.

It is important to note that seasonality and/or year-to-year conditions can impact observations and interpretation of observations. Further, it should be recognized that the characterization of features, conclusions, and recommendations in this report may be affected over time, as site conditions and regulatory requirements change.

All design details were not known at the time of submission of this report. Refinements or changes to the design could impact our interpretation or recommendations related to the site.

Any use which another party makes of this report, or any reliance on, are the responsibility of such parties. GEO Morphix accepts no responsibility for liabilities incurred by, or damages by another party, as a result of decisions made or actions taken, based on this report.

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

Respectfully submitted,

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

Josie Mielhausen, M.Sc.
Junior Environmental Scientist

6 References

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228.

Ministry of Natural Resources and Forestry (MNRF). 2002. Technical Guide – River and Stream Systems: Erosion Hazard Limit.

Ministry of Natural Resources and Forestry (MNRF). 2016. Guidance for Development Activities in Redside Dace Protected Habitat. Version 1.2 Ontario Ministry of Natural Resources and Forestry, Peterborough, Ontario. iv+54 pp.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

MTE Consultants. 2021. 12892 Dixie Road Proposed Industrial Development: Geotechnical Investigation.

Ontario Geological Survey (OGS). 2010. Surficial geology of Southern Ontario. Ontario Geological Survey. Miscellaneous Release – Data 128-REV.

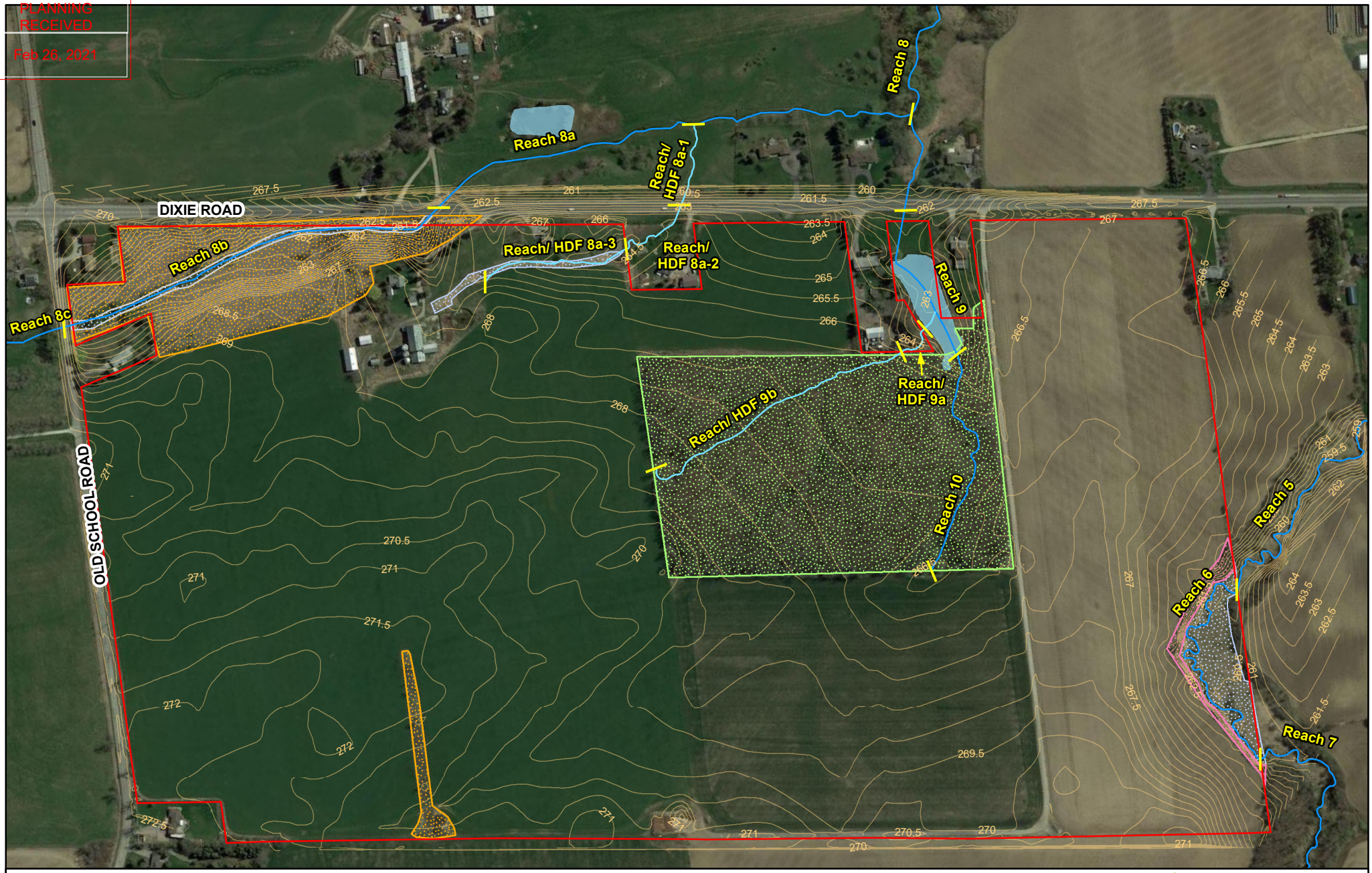
Richards, C., Haro, R.J., Johnson, L.B. and Host, G.E. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. Freshwater Biology, 37: 219-230.

Toronto and Region Conservation Authority. 2004. Belt Width Delineation Procedures.

Toronto and Region Conservation Authority and Credit Valley Conservation. January 2014. Evaluation, Classification, and Management of Headwater Drainage Features Guideline.

Watershed Features: Humber River. 2021. https://trca.ca/conservation/watershed-management/humber-river/watershed-features/

Appendix A
Study Site Map and Reach Delineation



Legend

- Reach Break and Label (Reach 10)
- Watercourse (TRCA)
- Watercourse (Peel)
- Subject Land Boundary
- 0.5 m Contour
- Waterbody

Ecological Land Classification

- MAM2-2
- FOD5-1
- CUT1
- CUM1-1

12892 Dixie Road

Study Site and Reach Delineation

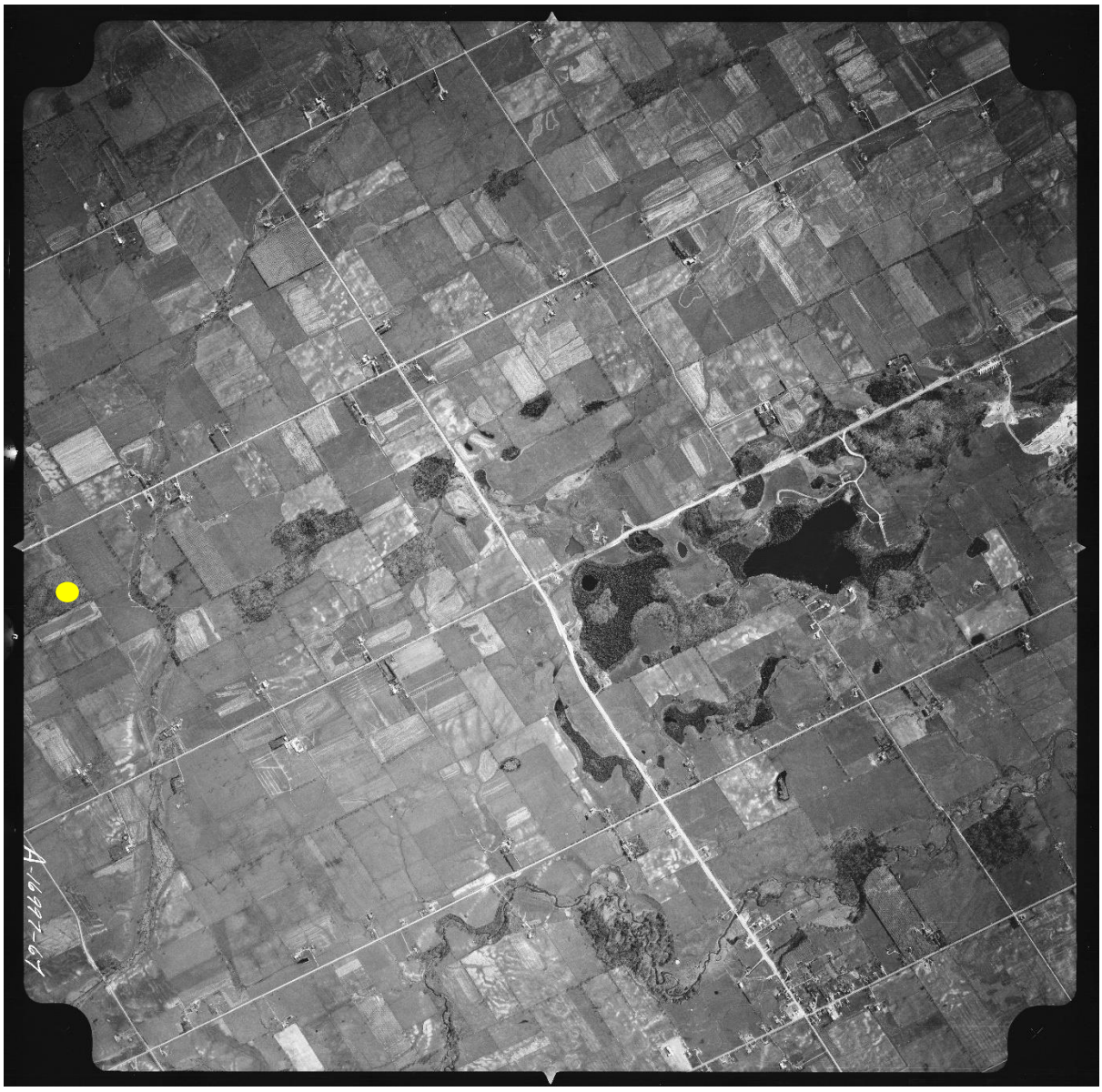
Caledon, Ontario

GEO MORPHIX™

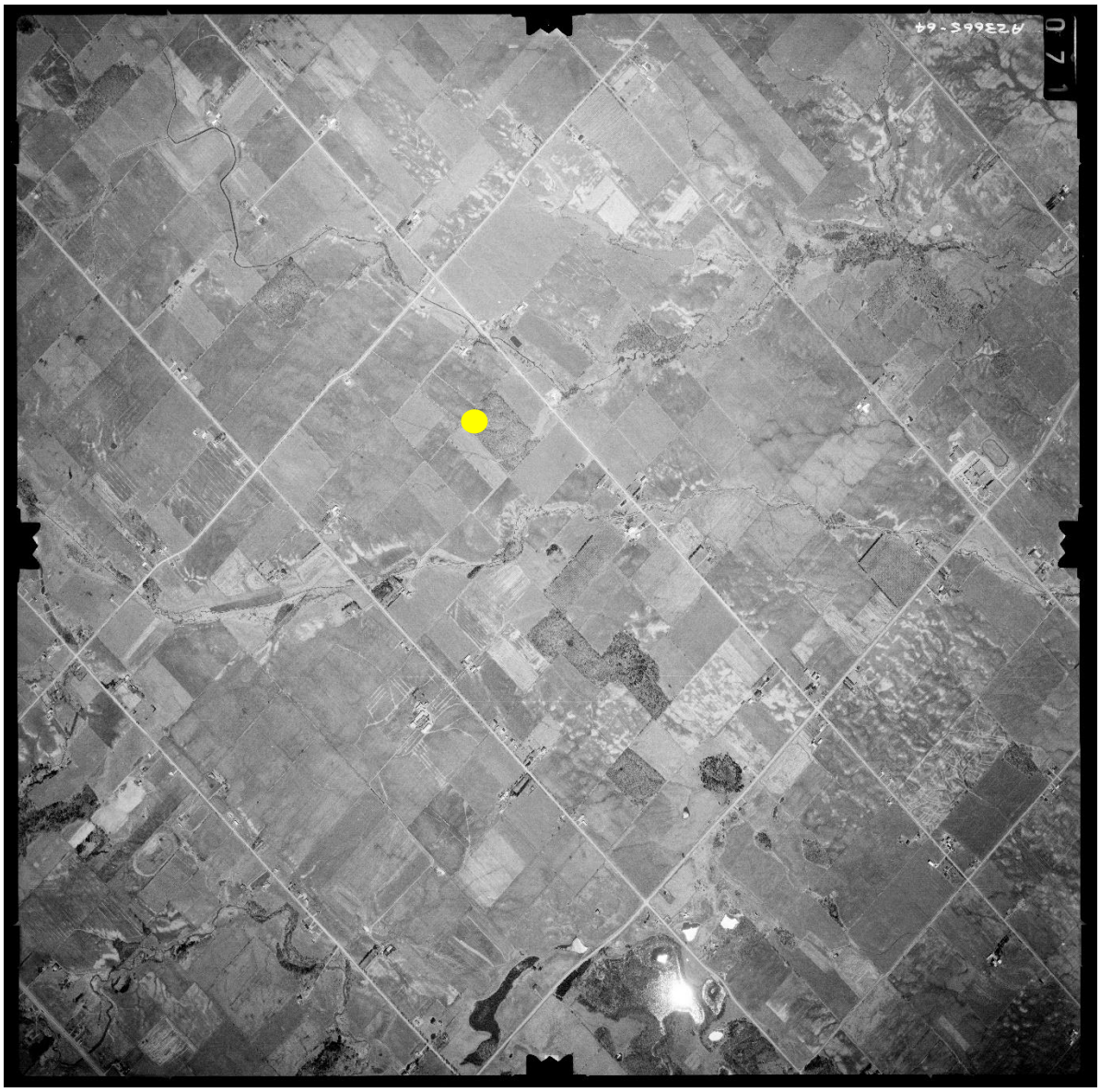
0 50 100
Metres

Imagery: Google Earth Pro, 2018.
Subject Land Boundary, and 0.5 m Contour: R. Avis Surveying Inc., 2020.
Reach Break and Label: GEO Morphix Ltd., 2021.
Ecological Land Classification: WSP, 2021.
Watercourse: Region of Peel, 2020 / TRCA 2021.
Waterbody: MNRF, 2021.
Printed: February 2021. PN20109. Drawn by M.H., J.M., P.V.

Appendix B
Historical Aerial Photographs



Location: 12892 Dixie Road, Caledon, ON (yellow dot)
Year: 1960
Scale: 25,000
Source: National Air Photo Library



Location: 12892 Dixie Road, Caledon, ON (yellow dot)
Year: 1974
Scale: 25,000
Source: National Air Photo Library

Location: 12892 Dixie Road, Caledon, ON (yellow dot)
Year: 2005
Source: Google Earth Pro

Location: 12892 Dixie Road, Caledon, ON (yellow dot)
Year: 2018
Source: Google Earth Pro

Appendix C
Photographic Record

Photo 1 Reach 6 – West Humber River	 Photograph at the furthest upstream extent of Reach 6 within the subject lands. The channel was single-thread, meandering, with tortuous meanders.
Photo 2 Reach 6 – West Humber River	 Photograph taken looking upstream. The estimated average bankfull width and depth was 1.83 m and 0.78 m, respectively. The riparian zone was 1 to 4 channel widths and dominated by grasses.

Photo 3 Reach 6 – West Humber River	
Photograph taken looking downstream. Reach 6 flowed through a confined valley system with the valley wall contact observed. Riparian habitat conditions were limited with < 50% canopy coverage.	
Photo 4 Reach 6 – West Humber River	
Photograph taken looking towards the left bank (facing downstream). Leaning and fallen trees were observed along the valley wall (arrows) and undercuts measured to 0.15 m in depth (circled). These observations indicated evidence of widening.	

Photo 5 Reach 6 – West Humber River	
Photograph taken looking downstream. There was limited development of geomorphic units, rather, the reach was dominated by riffles and runs with few pools present.	
Photo 6 Reach 6 – West Humber River	
Riffle substrate consisted of sand, gravel, and cobble, whereas bank material consisted of clay/silt, sand, and gravel. Basal scour was observed along inside meander bends and on both sides of the channel through riffles.	

Photo 7 Reach 6 – West Humber River	
	Photograph taken on the outside of a meander bend, facing downstream. Meander amplitude was measured as approximately 15 m to 25 m throughout the system.
Photo 8 Reach 6 – West Humber River	
	Photograph taken facing valley wall. Approximately 71 – 80% of the bank network was considered stable with infrequent signs of bank slumping or failure (circled).

Photo 9 Reach 6 – West Humber River	
	Photograph taken towards the left bank, facing generally downstream. Instream vegetation occupied 10% of the channel and consisted of submergent aquatic species.
Photo 10 Reach 6 – West Humber River	
	Photograph taken looking upstream. Given the watercourse was confined within the subject property, a toe erosion allowance was determined to delineate the erosion hazard limit. Additionally, a 30 m setback was recommended to account for Redside Dace habitat.

Photo 11 Reach 10 – Tributary of West Humber River	
	Photograph taken looking towards the furthest downstream extent of the reach. The watercourse was within a partially confined valley and traversed through a woodlot.
Photo 12 Reach 10 – Tributary of West Humber River	
	Photograph taken looking upstream. Leaning and fallen trees, exposed tree roots, and occurrences of large organic debris were observed through the reach. This indicated evidence of widening.

Photo 13 Reach 10 – Tributary of West Humber River	
	A high density of woody debris was observed within the channel and cutbank, with approximately 1 woody debris jam every 50 m.
Photo 14 Reach 10 – Tributary of West Humber River	
	Photograph taken facing upstream. The channel exhibited a generally straight planform with a low sinuosity which ranged from 1.06 to 1.30. The dominant riparian vegetation was characterized as established and mature tree species.

Photo 15 Reach 10 – Tributary of West Humber River	
	Photograph taken looking upstream. Average bankfull width and depth were approximately 2.84 m and 0.44 m, respectively. Bank angles ranged from 30° to 90° and consisted of clay/silt.
Photo 16 Reach 10 – Tributary of West Humber River	
	Photograph taken looking upstream. Bank erosion was observed through 30 to 60% of the channel, with undercuts measuring approximately 0.08 m in depth. Basal scour was also observed through over 50% of the reach.

Photo 17 Reach 10 – Tributary of West Humber River	 Photograph taken facing downstream. Approximately 50 to 70% of the bank network was considered stable, with recent signs of bank sloughing, slumping, and failure quite common. Further, stream bend areas were considered unstable.
Photo 18 Reach 10 – Tributary of West Humber River	 Photograph taken facing upstream. The reach was dominated by one habitat type (runs) with no riffles and few large pools. There was also limited diversity in channel depth and velocity.

Photo 19 Reach 10 – Tributary of West Humber River	 Bed and bank materials were characterized by clay/silt. Large cobbles were also observed in some locations immediately downstream from woody debris jams.
Photo 20 Reach 10 – Tributary of West Humber River	 Moving upstream, the system became more confined with bank heights approaching 2 m. Leaning and fallen trees contributing to woody debris jams, as well as exposed tree roots, were indicative of channel widening.

Photo 21 Reach 10 – Tributary of West Humber River	
	Photograph looking towards left bank (facing downstream). Valley wall contact was observed in this location, in addition to erosion scarring and exposed tree roots.
Photo 22 Reach 10 – Tributary of West Humber River	
	At the furthest upstream extent of the reach, tile drains were observed conveying flows beneath the agricultural field and into the watercourse. An enlarged scour pool was present immediately downstream from the tile drain outlets.

Appendix D
Field Assessment Sheets

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 6
Weather:	OVERCAST 11°C	**Location:**	13893 DIXIE RD, CALEDON
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

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

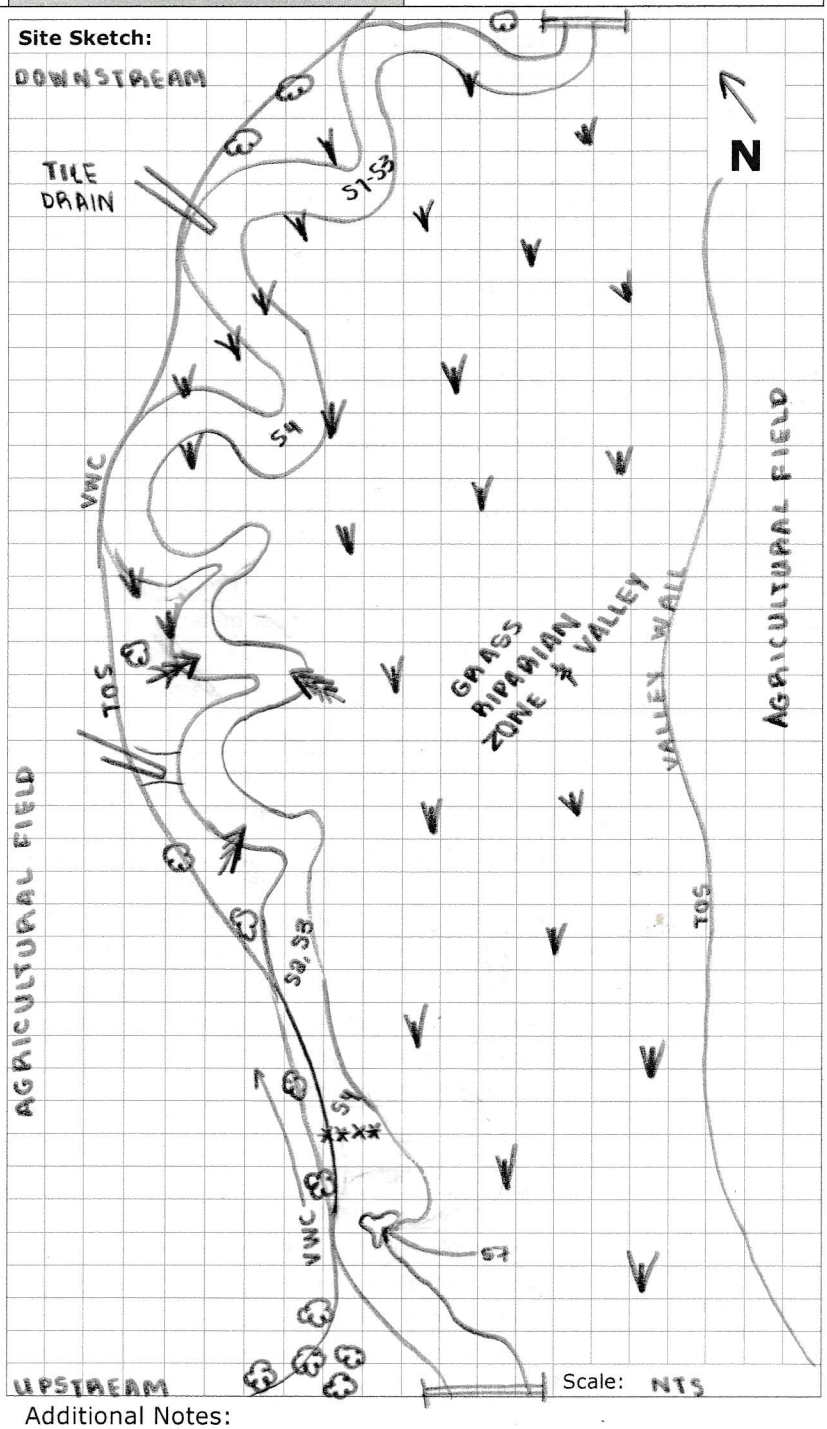
Substrate

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

Other

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

Site Sketch:



Additional Notes:

Completed by: BB Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 6
Weather:	OVERCAST 11°C	**Location:**	13893 DIXIE RD, CALEDON
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		X	0/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	0	7	0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		1/9
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s) *		X	
	4	Undermined gabion baskets / concrete aprons / etc.		X	
	5	Scour pools downstream of culverts / storm sewer outlets		X	
	6	Cut face on bar forms		X	
	7	Head cutting due to knick point migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock	X		
		Sum of indices =	1	8	0.11
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		4/8
	2	Occurrence of large organic debris		X	
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends	X		
	5	Basal scour on both sides of channel through riffle	X		
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation	N/A		
		Sum of indices =	4	4	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	7	0

Additional notes: * ELEVATED TILE DRAINS NOT DUE TO DEGRADATION

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.15

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: BB Checked by: _____

GEO | MORPHIX

Rapid Stream Assessment Technique

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 6
Weather:	OVERCAST 11°C	**Location:**	13892 DIXIE RD
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☒ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8

GEO | MORPHIX

Date:	2020-11-26	Reach:	REACH 6	Project Code:	PN20109

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☒ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) = 37	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: BB Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 6
Weather:	OVERCAST 11°C	**Location:**	12892 DIXIE RD, CALEDON
Field Staff:	CVM BB	**Watershed/Subwatershed:**	
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 13 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 3
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☒ 1-4
- ☐ 4-10
- ☐ > 10

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

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 2 | **Coverage of Reach (%):** 10

Woody Debris
- ☒ Present in Cutbank
- ☒ Present in Channel
- ☐ Not Present

Density of WD:
- ☒ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9)	Sinuosity (Degree) (Table 10)	Gradient (Table 11)	Number of Channels (Table 12)
5	3	2	1

Entrenchment (Table 13)	Type of Bank Failure (Table 14)	Downs's Classification (Table 15)
2	2/6	C

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☒	☒	☒	☐	☐	☐
Pool Substrate	☐	☒	☒	☐	☐	☐	☐
Bank Material	☒	☒	☒	☐	☐	☐	☐

Bankfull Width (m) EST.	1.50	1.75	2.25	**Wetted Width (m)** EST.	1.20	1.60	2.00
Bankfull Depth (m) EST.	0.65	0.70	1.00	**Wetted Depth (m)** EST.	0.55	0.60	0.90

Riffle/Pool Spacing (m): N/A | **% Riffles:** 5 | **% Pools:** 45 | **Meander Amplitude:** 15-25 LOCAL

Pool Depth (m): 0.50 | **Riffle Length (m):** ~5 | **Undercuts (m):** 0.15 | **Comments:**

Velocity (m/s): \ \ \ **Wiffle ball / ADV / Estimated**
NOT MEASURED

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

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

Notes:

- FEW/NO RIFFLES PRESENT
- BANKFULL/WETTED MEASUREMENTS ESTIMATED

Completed by: BB Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN30109

Date:	2020-11-26	**Stream/Reach:**	REACH 9
Weather:	OVERCAST 11°C	**Location:**	13893 DIXIE RD, CALEDON
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

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

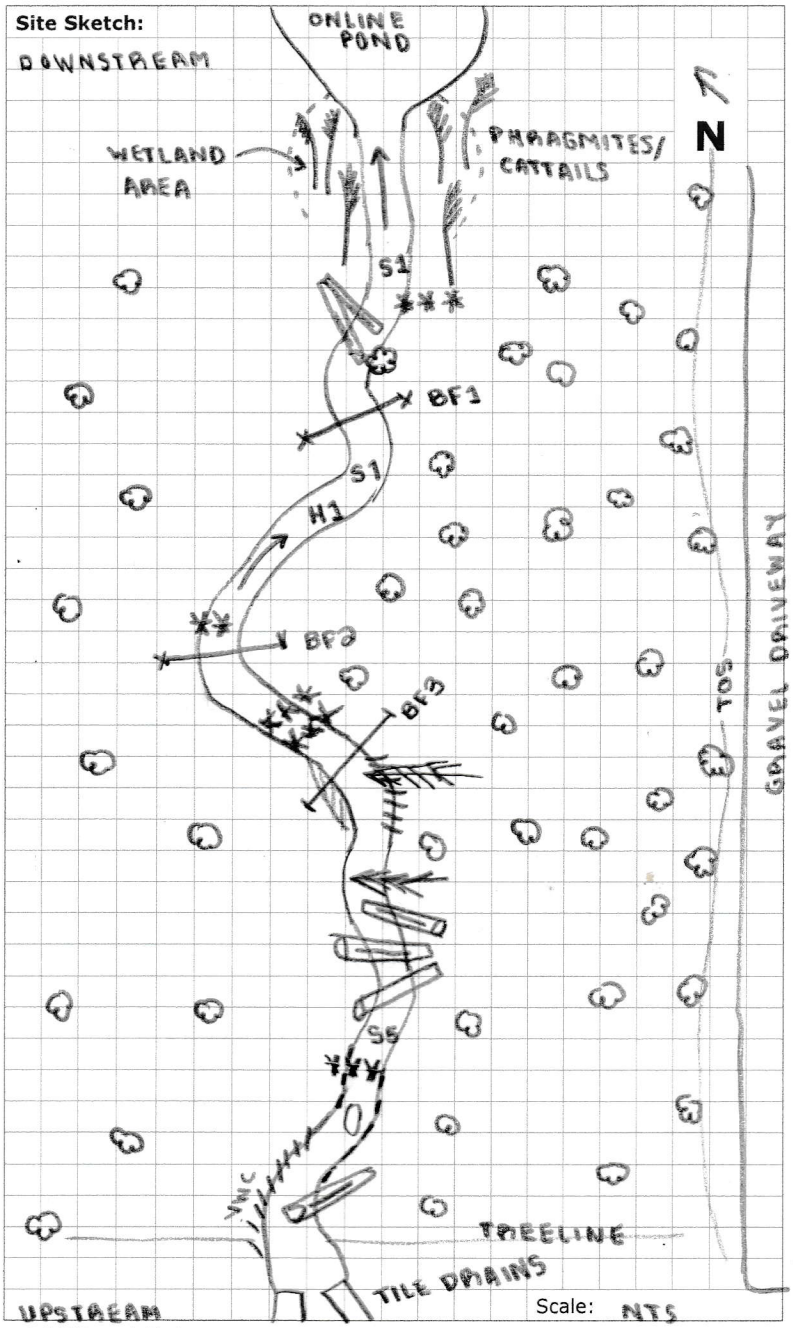
Substrate

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

Other

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

Site Sketch:



Additional Notes:

Completed by: BB Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 9
Weather:	OVERCAST 11°C	**Location:**	13893 DIXIE RD
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		X	0/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars		X	
	5	Accretion on point bars		X	
	6	Poor longitudinal sorting of bed materials		X	
	7	Deposition in the overbank zone		X	
		Sum of indices =	0	7	0
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		0/8
	2	Exposed sanitary / storm sewer / pipeline / etc.		X	
	3	Elevated storm sewer outfall(s)		X	
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets		X	
	6	Cut face on bar forms		X	
	7	Head cutting due to knick point migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	0	8	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		4/8
	2	Occurrence of large organic debris	X		
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc.	N/A		
	7	Length of basal scour >50% through subject reach	X		
	8	Exposed length of previously buried pipe / cable / etc.		X	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation	N/A		
		Sum of indices =	4	4	0.50
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	1/7
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed	X		
		Sum of indices =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.16

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☒ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: BB Checked by: _____

GEO | MORPHIX

Rapid Stream Assessment Technique

Project Code: PN30109

Date:	2020-11-26	**Stream/Reach:**	REACH 9
Weather:	OVERCAST 11°C	**Location:**	13892 DIXIE RD
Field Staff:	CVM BB	**Watershed/Subwatershed:**	

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☒ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas) NO RIFFLES	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8

GEO | MORPHIX

Date:	2020-11-26	Reach:	REACH 9	Project Code:	PN20109

Evaluation Category	Poor	Fair	Good	Excellent
	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
NO RIFFLES Physical Instream Habitat	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
N/A	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☒ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☒ 5 ☐ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☒ 3	☐ 4 ☐ 5	☐ 6 ☐ 7

Total overall score (0–42) = 19	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: BB Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN20109

Date:	2020-11-26	**Stream/Reach:**	REACH 9
Weather:	OVERCAST 11°C	**Location:**	13893 DIXIE RD
Field Staff:	CYM BB	**Watershed/Subwatershed:**	
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 | **Valley Type** (Table 2): 3 | **Channel Type** (Table 3): 6 | **Channel Zone** (Table 4): 3 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: NONE

Riparian Vegetation

Dominant Type: (Table 6): 1
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☒ Continuous

Channel widths
- ☐ 1-4
- ☒ 4-10
- ☐ > 10

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

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): 1 | Coverage of Reach (%): <5

Woody Debris
- ☒ Present in Cutbank
- ☒ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☐ Moderate
- ☒ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 1 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 2 | **Type of Bank Failure** (Table 14): 2 | **Downs's Classification** (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate (BED)	☒	☐	☐	☐	☐	☐	☐
Pool Substrate (NO RIFFLES)	☒	☐	☐	☐	☐	☐	☐
Bank Material (NO POOLS)	☒	☐	☐	☐	☐	☐	☐

	BF1	BF2	BF3	Wetted Width (m)			
Bankfull Width (m)	1.30	3.04	4.20		0.86	1.30	1.52
Bankfull Depth (m)	0.29	0.47	0.57	Wetted Depth (m)	0.08	0.09	0.08

Riffle/Pool Spacing (m): N/A | **% Riffles:** 0 | **% Pools:** 0 | **Meander Amplitude:** N/A

Pool Depth (m): N/A | **Riffle Length (m):** N/A | **Undercuts (m):** 0.08 | **Comments:** _____

Velocity (m/s): 0 | 0 | 0 | **Wiffle ball / ADV** (Estimated)
STANDING WATER

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

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

Notes:

- HIGH AMOUNT OF WOODY DEBRIS
- NO RIFFLES/POOLS, 100% RUNS
- UNDERCUT, FALLEN TREES

Completed by: BB | Checked by: _____

Appendix E
Erosion Setback Mapping

Legend

- Erosion Setback Point
- Stable Top of Slope
- 5 m Erosion Setback
- 10 m Erosion Setback Allowance
- Toe of Slope
- Top of Slope
- Watercourse
- Watercourse Central Tendency
- Subject Land Boundary
- 0.5 m Contour

12892 Dixie Road

Preliminary Erosion Setback

Caledon, Ontario

GEO MORPHIX™

0 25 50

Metres

Imagery: Google Earth Pro, 2018.
Top of Slope, Subject Land Boundary, and 0.5 m Contour: R. Avis Surveying Inc., 2020.
Erosion Setback Point/ Line / Allowance, Stable Top of Slope, Watercourse Central Tendency, and Toe of Slope: GEO Morphix Ltd., 2020.
Watercourse: Region of Peel, 2020.
Printed: February 2021. PN20109. Drawn by M.H., J.M., P.V.