Appendix I – Fluvial Geomorphic Assessment

Schedule “C” Class Environmental Assessment for Airport Road from Braydon Boulevard / Stonecrest Drive to Countryside Drive

AIRPORT ROAD FROM BRAYDEN BLVD/STONECREST DRIVE TO COUNTRYSIDE DRIVE, CITY OF BRAMPTON, SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

FLUVIAL GEOMORPHOLOGY ASSESSMENT

Report Prepared for:
HDR INC.

Prepared by:
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November 2020
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AIRPORT ROAD FROM BRAYDEN BLVD/STONECREST DRIVE TO COUNTRYSIDE DRIVE, CITY OF BRAMPTON, SHEDULE C CLASS ENVIRONMENTAL ASSESSMENT FLUVIAL GEOMORPHOLOGY ASSESSMENT

Report prepared for HDR Inc, November 2020

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VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	21-Nov-2017	Draft	25692-522 Airport Road EA 2017-11-21 draft	Issued to client for review
V1.0	19-Nov-2020	Final	24692-522 Airport Road EA 2020-11-19 final V1.0	Issued to client

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APPENDICES

1 INTRODUCTION

Matrix Solutions Inc. has been retained by HDR Inc. to provide fluvial geomorphic guidance to the Municipal Class Environmental Assessment (EA) Study Schedule C for the proposed widening of Airport Road (Regional Road 7) from Braydon Boulevard/Stonecrest Drive to Countryside Drive in the City of Brampton. The proposed widening spans approximately 1.6 km of road length and contains two watercourse crossings. The crossings contain two tributaries to the West Humber River, and cross Airport Road approximately 1,067 m and 815 m south of Countryside Road (Figure 1.1). Within this report, these watercourses are identified as Tributary B and Tributary C respectively.

The proposed road widening has resulted from the Long Range Transportation Planning Update for 2012, which identified the need for the following:

- widening Airport Road from Braydon Boulevard/Stonecrest Drive to Countryside Drive to meet existing and future needs
- improving other infrastructure such as transit and active transportation facilities to provide efficient movement of people and goods

The following fluvial geomorphic assessment identifies and evaluates impacts of proposed road improvements to the two watercourses within the study area and provides appropriate mitigation recommendations in support of the design and reconstruction of Airport Road.

Legend

- Geomorphic Reach Break
- Watercourse
- Contours 5m
- Railway
- Study Area
- Water Body
- Brampton Parcel Fabric

Streets

- Arterial
- Local

1:8,000

80 0 80 160 metres

NAD 1983 UTM Zone 17N

Reference: please refer to reference spreadsheet

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Airport Road Environmental Assessment

Study Area

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November 2017	24692	J. Henshaw	--

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Figure
1.1

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2 METHODS

This section describes methodologies used to characterize the fluvial form and function of watercourses within the Airport Road study corridor.

2.1 Broad Scale Historical Assessment

A broad historical assessment of the study area is completed on available historical imagery. A review of past conditions is typically carried out in order to document changes in land use and channel form over time, therefore historical aerial imagery was obtained for the study area for the years 1954, 1978, and 2005, and compared to more recent imagery from 2016.

2.2 Reach Delineation

Reaches are lengths of channel, typically 200 m to 2 km, which display similarity with respect to the degree of valley confinement, sinuosity, riparian vegetation, and land use. Reach length will vary with channel scale since the morphology of low-order watercourses will vary over a smaller distance than those of higher-order watercourses lower in a watershed. At the reach scale, characteristics of the river corridor exert a direct influence on channel form, function, and process (Parish, 2004).

Reaches were identified for watercourses within the study area based on the desktop assessment of characteristics including sinuosity, valley setting, gradient, and tributary confluences using aerial imagery, drainage network, and topographic mapping. Field reconnaissance is conducted within each reach for a distance of 200 m upstream and downstream of the road crossing or within the right-of-way if access is restricted.

2.3 Meander Belt Assessment

Streams and rivers are dynamic features that change their configuration and position within a floodplain by means of meander evolution, development, and migration processes. When meanders change in shape and position, the associated erosion and deposition that enable these changes to occur can cause loss or damage to private property and infrastructure. For this reason, accurate delineation of a meander belt is important for many planning purposes when developing in proximity to a watercourse, realignment of a channel, or determining the appropriate span of crossing structures. The meander belt assessment is performed to designate a corridor that is intended to contain all of the natural meander and channel migration tendencies. Outside of this corridor, it is assumed that private property and structures will be safe from the erosion potential of the watercourse. The space that a sinuous or meandering watercourse occupies on its floodplain, within which all associated natural channel processes occur, is commonly referred to as the meander belt.

The Belt Width Delineation Procedure is applicable to confined and unconfined systems and follows a process-based methodology for determining the meander belt width based on background information, historic data (including aerial photography), degree of valley confinement, and channel planform (Parish, 2004).

2.3.1 100-Year Erosion Rate

From a geomorphic perspective, the 100-year erosion migration rate quantifies the lateral and down valley (i.e., downstream) movement of meander bend features. This value typically represents the erosion setback to be applied to either side of the meander belt in order to account for future bank erosion and channel migration over time.

2.4 Rapid Assessments

Following the desk-based assessment, field reconnaissance is undertaken at each of the stream crossing locations, as well as along watercourse reaches where property access allowed. At each location, the following assessments were undertaken as required:

2.4.1 Rapid Geomorphic Assessment

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planimetric adjustment. Examples of these include the presence of bar forms, exposed infrastructure, head cutting due to knick point migration, fallen or leaning trees and exposed tree roots, channel scour along the bank toe, transition of the channel from single thread to multiple thread, and cut-off channels. Overall, the index produces values that indicate whether the channel is stable/in regime (score ≤0.20), stressed/transitional (score 0.21 to 0.40), or adjusting (score ≥0.40) (Table 2.1).

TABLE 2.1 Rapid Geomorphic Assessment Classification

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

2.5 Detailed Survey

Additional field reconnaissance was completed by Matrix fluvial geomorphology specialists in order to complete a detailed geomorphic assessment survey of watercourses within the study area. The survey was conducted to support preliminary design recommendations and included bankfull cross-sections and a longitudinal profile surveyed with a Total Station along with substrate characterization, following a modified Wolman pebble count, and characterization of bank properties. The surveys were used to determine channel bankfull dimensions and provide indications of bed morphology and local energy gradient.

2.6 Crossing Assessment

The stream crossing assessment was undertaken in order to collect data relating specific to the watercourse crossing in question. Information recorded includes crossing type, material, shape, and dimensions, structural condition as well as an assessment of potential issues relating to the crossing (e.g. bank erosion, bed scour, debris trapping, and fish passage).

3 BACKGROUND REVIEW

3.1 Watershed Characteristics

The study area is situated within the West Humber River subwatershed; the two tributaries within the study area are identified as first order watercourses (Strahler stream order) (Clayton et al., 2004). First order watercourses are single, unbranched, tributaries that are typically the first point where water flows through a defined channel. Depending on overall drainage area and function, first order watercourses may be considered headwater features. First order streams have moderate to high slopes and have higher proportions of coarse substrates such as gravels and cobbles overlying the stream bed compared to second and third order stream within the subwatershed. Additionally, pool to riffle ratios and the number of observed meanders would be low. Within the West Humber River subwatershed, these watercourses comprise 44% of the overall stream length but have the lowest percentage of woody riparian vegetation, 17%, due to the clearing of land for agricultural purposes (Clayton et al., 2004).

First order watercourse morphology for the West Humber River subwatershed was generally characterized by Clayton et al., 2004. The two subject watercourses have moderate slopes (i.e., 0.31 to 1.0%), are less sinuous and contain fewer pools than low gradient systems. Substrates tend to be comprised of larger materials like gravels and cobbles.

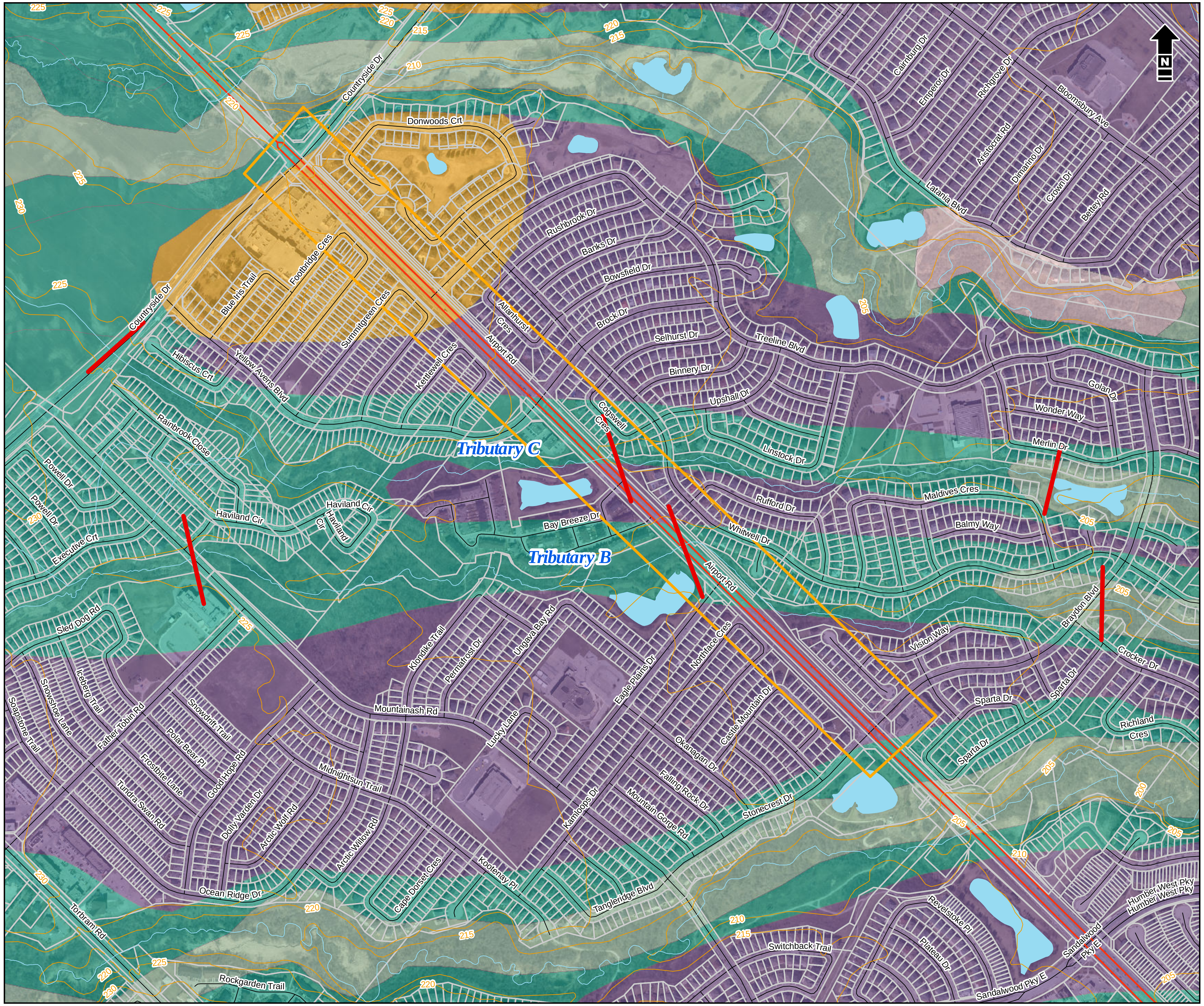
Characteristics for Tributary B and Tributary C have been derived from the Ontario Flow Assessment Tool (MNRF, 2017) and displayed in Table 3.1 below.

TABLE 3.1 Watercourse Characteristics

Characteristic	Tributary B		Tributary C	
	At Airport Road	Total	At Airport Road	Total
Drainage Area (km^2)	1.579 km^2	2.251 km^2	0.691 km^2	1.199 km^2
Stream Length (km)	4.461 km	6.621 km	2.721 km	5.069 km
Channel Slope (%)	0.856 %	0.883 %	0.874 %	0.9 %
Major Land Use	Community Infrastructure (37.5% / 52.3%) Agricultural and Rural (53.5% / 37.685%) Deciduous Treed (6.6% / 7.6%) Other: Hedgerow, treed upland, swamp		Community Infrastructure (41.2% / 60.2%) Agricultural and Rural (53.5% / 30.9%) Deciduous Treed (3.3% / 4.7%) Other: Hedgerow, treed upland, swamp	
Approx. Bankfull Flow (Q_2) (Moin & Shaw, 1985)	0.55 m^3/s	0.8 m^3/s	0.23 m^3/s	0.43 m^3/s

3.2 Physiography and Geology

A review of surficial geology and physiography mapping reveals that the study area falls along the border of the South Slope and Peel Plain physiographic regions as defined by Chapman and Putnam (1984). Broad characterization of the South Slope describes smooth, faintly drumlinized, clay till plain containing the deeply incised stream valley of the Humber River. The Peel Plain topography is faintly undulating to flat till plain with a lacustrine clay veneer. Specific surficial geology units within the study area are mapped in Figure 3.1 below. Tributary B and Tributary C flow over glacial till deposits (Halton Till formation), dominated by clayey silt to sandy silt parent material. The downstream extent of the determined geomorphic study reaches (ref. section 5.1) indicated modern alluvium deposits as a result of fluvial processes. This material is comprised of silts, sands, and gravel. Also present are glaciolacustrine deposits from both foreshore and deltaic processes. A small section of Paleozoic bedrock (Dundas-Meaford Formation) is also indicated to be present along a neighbouring tributary but was not field verified.



Legend

- Geomorphic Reach Break
- Watercourse
- Contours 5m
- Railway
- Study Area
- Water Body
- Parcel Fabric

Streets

- Arterial
- Local

Surficial Geology

- Glacial - Halton Till, clayey silt to sandy silt
- Glaciolacustrine - Foreshore-basinal deposits, clay and silt
- Glaciolacustrine - Deltaic, sand
- Modern Alluvium - Silt, Sand, Gravel
- Bedrock - Dundas-Meaford Formation

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NAD 1983 UTM Zone 17N

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Surficial Geology

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Figure 3.1

4 HISTORICAL ASSESSMENT

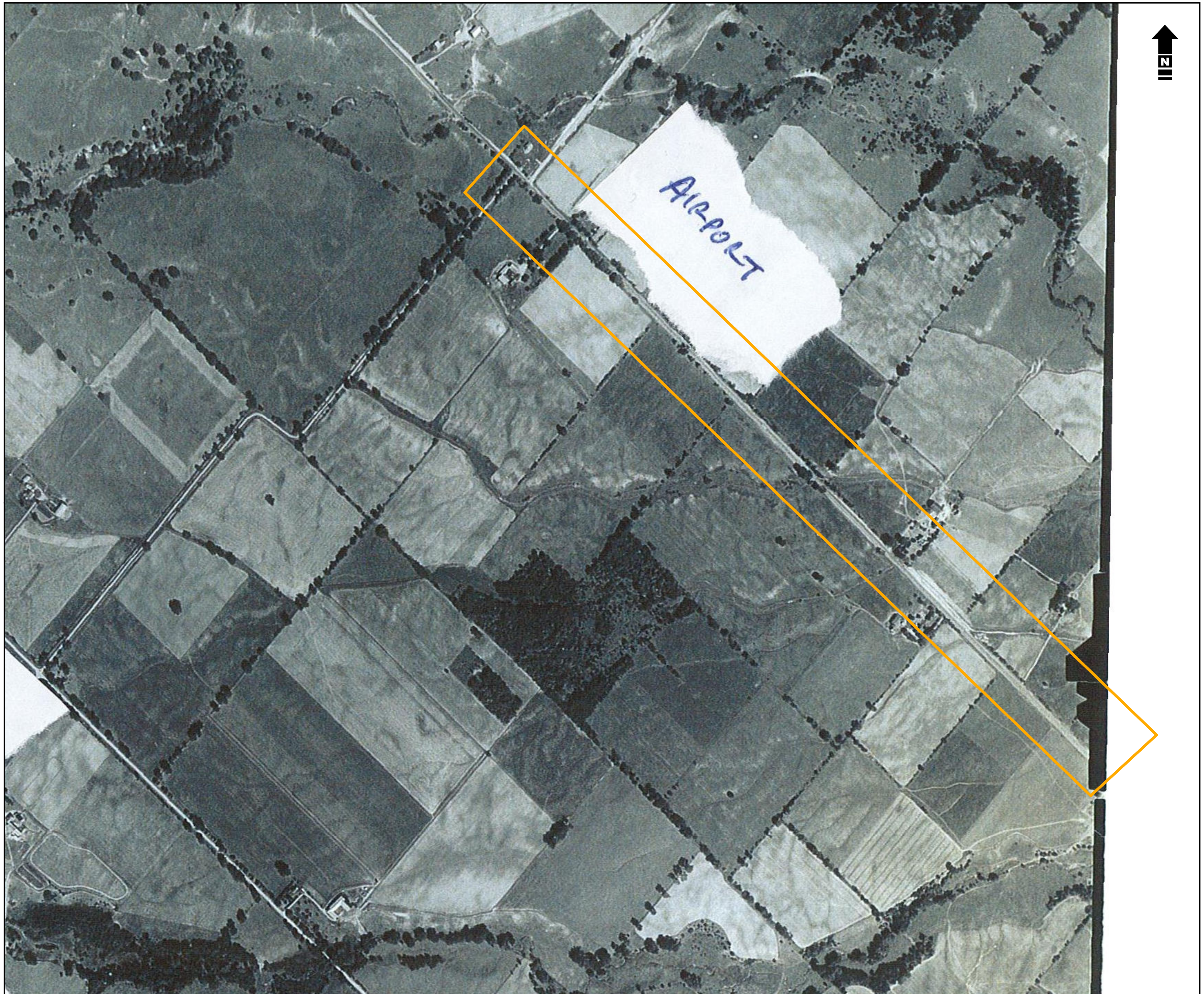
A review of historic conditions is typically carried out in order to document changes in land use and channel form over time. A collection of four aerial images, culminating a time period of 57 years, were georeferenced and reviewed for changes in land use and planform. Specifically, aerial photos from 1954 (Figure 4.1), 1978 (Figure 4.2), 2005 (Figure 4.3), and 2016 were utilized and conditions for the Airport Road Study Area is presented.

In 1954, study area was primarily agricultural land use. Both tributaries are visible on the aerial imagery and have maintained corridors through agricultural fields. Tributary C has a defined corridor extending downstream from Countryside Drive; the corridor is approximately 20 m wide and was sparsely vegetated with trees and shrubs. Downstream from Airport Road, the Tributary C continues to flow through agricultural fields. Two private farm crossings are located approximately 160 m and 230 m downstream from Airport Road. The watercourse had a sinuous planform, however due to historical alterations for farming practices there is a lack of tortuous meanders which are typically seen with natural watercourses and allowed to migrate laterally through the floodplain. The planform alignment of Tributary C remains generally consistent throughout the timeframe of observation. Tributary B was also identifiable and flows in straightened sections through hedge rows and agricultural fields. A section of the channel also flows through a wood lot located approximately 1 km upstream from Airport Road. Multiple headwater drainage features are observed draining into the Tributary B upstream of Airport Road. Downstream from the road the tributary was realigned to flow parallel to the road for 180 m before continuing south-east in a straight alignment. Approximately 350 m downstream from Airport Road, a private laneway crosses the channel.

In 1978, surrounding land use remains dominated by agricultural activities, with few changes observed from the 1954 condition. A few horse racing tracks have been constructed to the west or Airport Road and several residential and farm properties have expanded with larger buildings. No alterations to the Tributary B or Tributary C are observed.

By 2005, much of the land to the east of Airport Road has been developed with suburban residential housing. To the west of Airport Road, the riparian corridor of Tributary C has widened to over 60m in some locations, and tree growth has been extensive. Downstream, the corridor is confined to approximately 25 m between residential developments and is crossed numerous times by community roads and pedestrian bridges. Additionally, downstream from Airport Road the Tributary C has undergone a channel realignment following a sinuous planform is implemented along with an online retention pond. Suburban residential development also surrounds Tributary B to the east and west of Airport Road. At this time, Airport Road is a two-lane road however it is apparent that road widening activities are taking place. Where the Tributary B flows parallel along the east road embankment, the planform has been moved approximately 30m further east to accommodate construction activities.

Existing conditions observed in 2016 imagery indicates that further suburban residential development west of Airport Road took place, however no additional changes to the watercourses through realignment or alteration has occurred: observed watercourse corridor staking from 2005 has been maintained.



Legend

Study Area

1:8,000 metres
80 0 80 160
NAD 1983 UTM Zone 17N

Reference: please refer to reference spreadsheet

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1954 Historical Image

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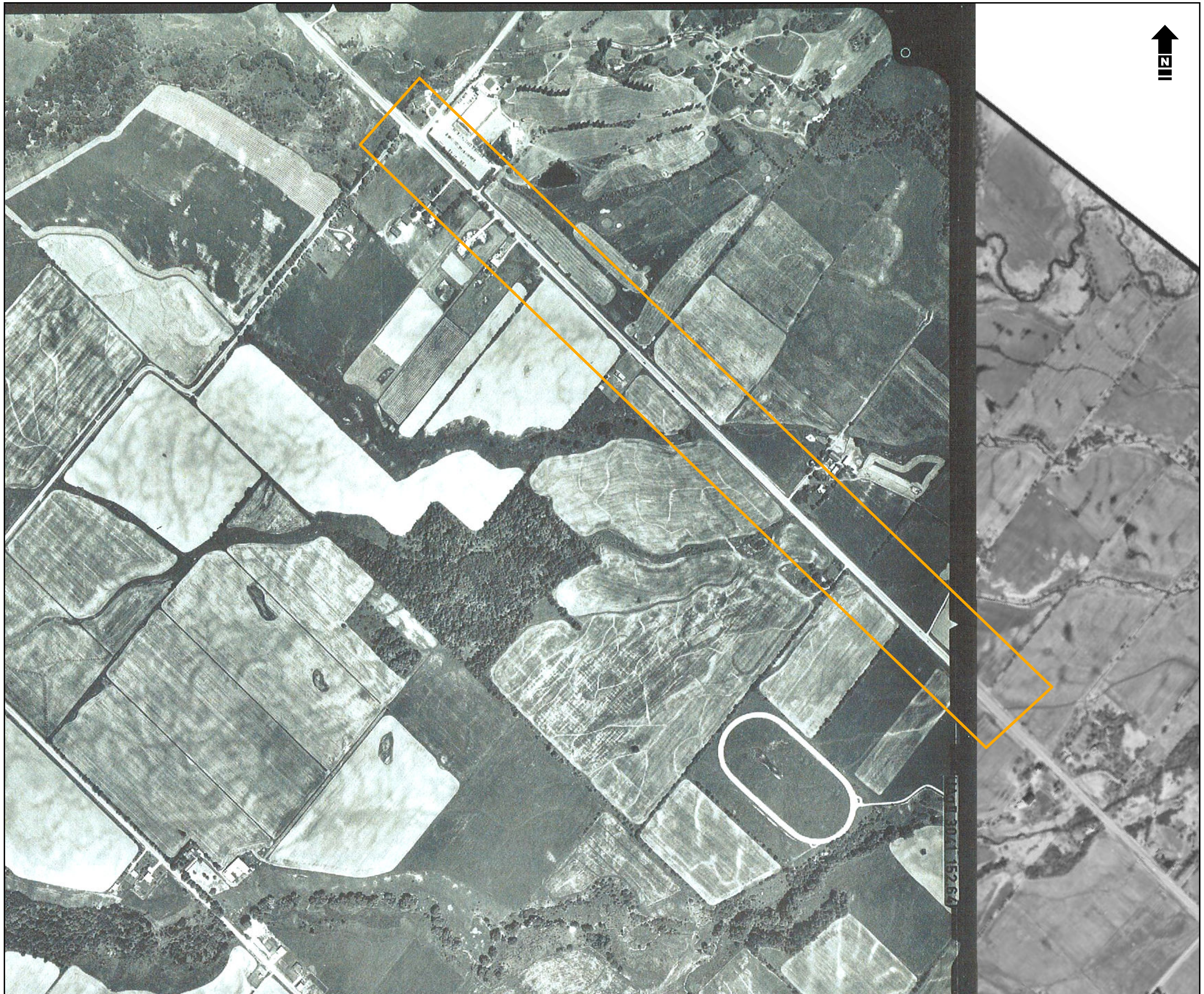
Figure 4.1



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Study Area

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1978 Historical Images

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Figure
4.2

Legend

Study Area

Reference: please refer to reference spreadsheet

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2005 Historical Images

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Figure 4.3

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5 REACH DELINEATION

Based on the watercourses' sinuosity, gradient, hydrology, local geology, degree of valley confinement, vegetative controls, and other parameters, the tributary reaches within the Airport Road Study Area were delineated. As these tributaries are unnamed, a simple naming convention identifying each watercourse relative to its upstream position along the West Humber River was adopted.

The geomorphic study reach delineated for Tributary B extends downstream from Mountainash Road to Brayden Boulevard and encompasses approximately 2 km of watercourse length. The geomorphic study reach for Tributary C extends downstream from Countryside Road to approximately 80m upstream from Braydon Boulevard, also encompassing approximately 2 km of watercourse length. Following field reconnaissance, and based on observed conditions, the geomorphic study reaches for each tributary were further divided into an upstream and downstream segment with Airport Road being the divide.

Figure 1.1 above displays the geomorphic reach breaks identified and the results of the field investigations are detailed below.

6 MEANDER BELT WIDTH ANALYSIS

Following field verification of existing conditions, a meander belt width assessment was undertaken to assess potential watercourse impacts due to road widening as well as inform recommendations for crossing size.

6.1 Preliminary Belt Width Delineation

Preliminary meander belt delineations for Tributary B and Tributary C were initially undertaken as recommended by Leopold and Wolman (1960) and as outlined in the Belt Width Delineation Procedures (Parish, 2004). Historical aerial imagery from 1954, 1978, and 2005 were reviewed and compared to existing conditions from 2016 to determine planform adjustments. The historical imagery was digitally scanned, enlarged, and layered to compare channel meander planform the vicinity to Airport Road. Since the majority of alterations to Tributary B and Tributary C occurred prior to air photo record, historic overlays with recent aerial imagery provide an adequate comparison of channel location (Figure 6.1). For the planform overlay exercise, tree cover within the watercourse corridor in the 2016 imagery obscured the channel hindering the ability to accurately digitize channel, therefore only channel planforms from 1954, 1978, and 2005 where digitally traced and compared. The Ontario Hydrologic Network Watercourse vector layer was used in the interpretation of 2016 planform conditions.

The resultant meander belt limits for Tributary B and Tributary C reflect the positions of laterally extreme meanders along each geomorphic reach according to existing and historical conditions. From an existing conditions perspective the mapping-based assessment, that uses historical channel conditions over estimates the potential hazard corridor as the reaches are laterally confined by development. Adjacent to Airport Road within the study area, Tributary B and Tributary C have been realigned and confined to an imposed corridor. For Tributary C, using existing and historic planforms to delineate a corridor would result in a belt of approximately 40 m wide and crosses through existing residential development.

6.2 Empirical Analysis

Since development adjacent to the watercourses has already occurred, and the tributaries are already confined to an assumed valley (particularly downstream from Airport Road), additional meander belt analysis was done using empirical relations for comparison purposes to ensure proper identification and characterization of potential erosion hazards.

Predicted planform metrics can be approximated using standard empirical relations developed by Williams (1986) and Ward (2002), that relate natural average channel cross-section metrics (width, depth, and area) to watercourse wavelength, amplitude, and radius of curvature. Empirical relations are based on measurements of real watercourses, however; their transferability to all watercourses is potentially limited due to possible differences in hydrologic regime, drainage area, and general controlling factors (e.g. land use, physiography, geology). These considerations should be kept in mind when applying the empirical relations.

TABLE 6.1 Empirical formulas for estimating meander belt width

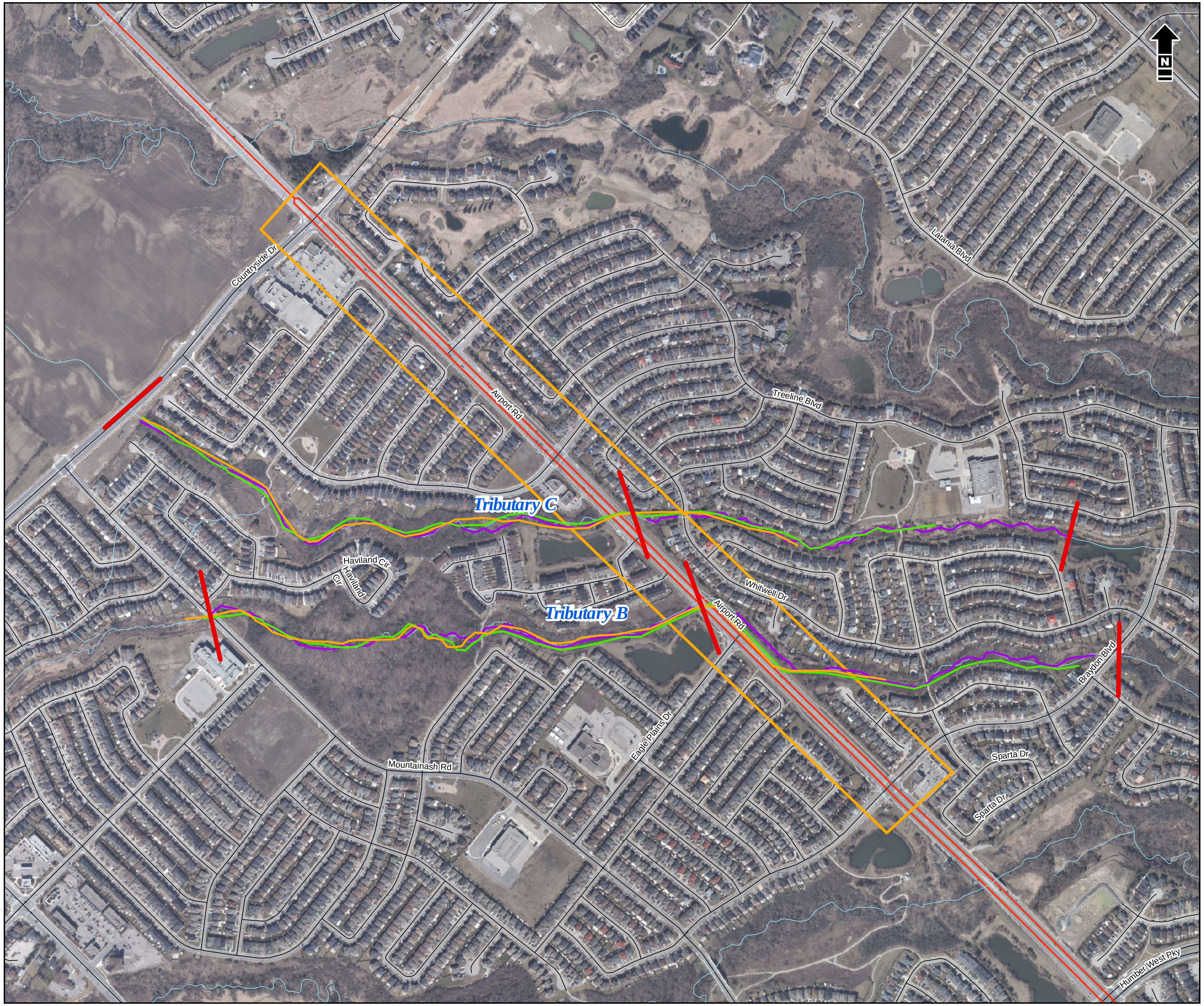
Source	Equation
Williams (1986) - bankfull width (m)	$4.3W^{1.12}$
Williams (1986) - channel area (m)	$18Ac^{0.65}$
Ward (2002) - bankfull width (ft)	$4.8W^{1.08}$

Bankfull channel dimensions measured during the field assessment were used as input parameters for the empirical analyses and the results are presented in Table 6.2. Two analyses were completed for Tributary C as the upstream and downstream channel measurements were different.

The average of all three equations was calculated and used for comparison purposes as the standard deviation was within 2 m. By using the average, a broader data set is applied to the empirical analysis, as opposed to defaulting to the largest value in order to be conservative.

TABLE 6.2 Empirical formula results

Reach	Average Bankfull Width (m)	Williams (W) (m)	Williams (Ac) (m)	Ward (m)	Average	Standard Deviation (m)
Tributary B	4.5	23.2	24.2	26.8	**24.7**	1.9
Tributary C (upstream)	2.5	12.0	13.3	14.2	**13.2**	1.1
Tributary C (downstream)	4.0	20.3	22.4	23.6	**22.1**	1.7



Legend

- Geomorphic Reach Break
- 1954 Planform
- 1978 Planform
- 2005 Planform
- Watercourse
- Railway
- Study Area
- Brampton Parcel Fabric

Streets

- Arterial
- Local

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Planform Overlay

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Figure 6.1

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6.3 Factor of Safety

From a geomorphic perspective, the 100-year migration rate typically represents the erosion setback to be applied to either side of the meander belt width in order to account for bank erosion and channel migration over time. Due to historical alterations along the watercourses that affect natural erosion rates, erosion rate analysis was not feasible within the geomorphic study reaches of Tributary B and Tributary C. In this case, a factor of safety equivalent to 10% of the preliminary meander belt width is applied to either side of the channel. The 10% factor of safety was applied to all reaches in the study area, as the watercourses are small and in stable condition. This additional factor of safety is deemed necessary to accommodate future changes that may occur as a result of changing hydrologic regimes due to altered land use.

6.4 Final Belt Width with Setbacks

The process of developing a final meander belt width for each of the reaches involves: (1) an evaluation and selection of which method is most appropriate to obtain a preliminary belt width; (2) consideration of the inferred stability of the channel; and (3) the addition of a safety setback.

Attempts at following traditional belt width mapping procedures overestimated corridor constraints that have already been imposed on the watercourses by surrounding residential development; therefore, an empirical relations were used.

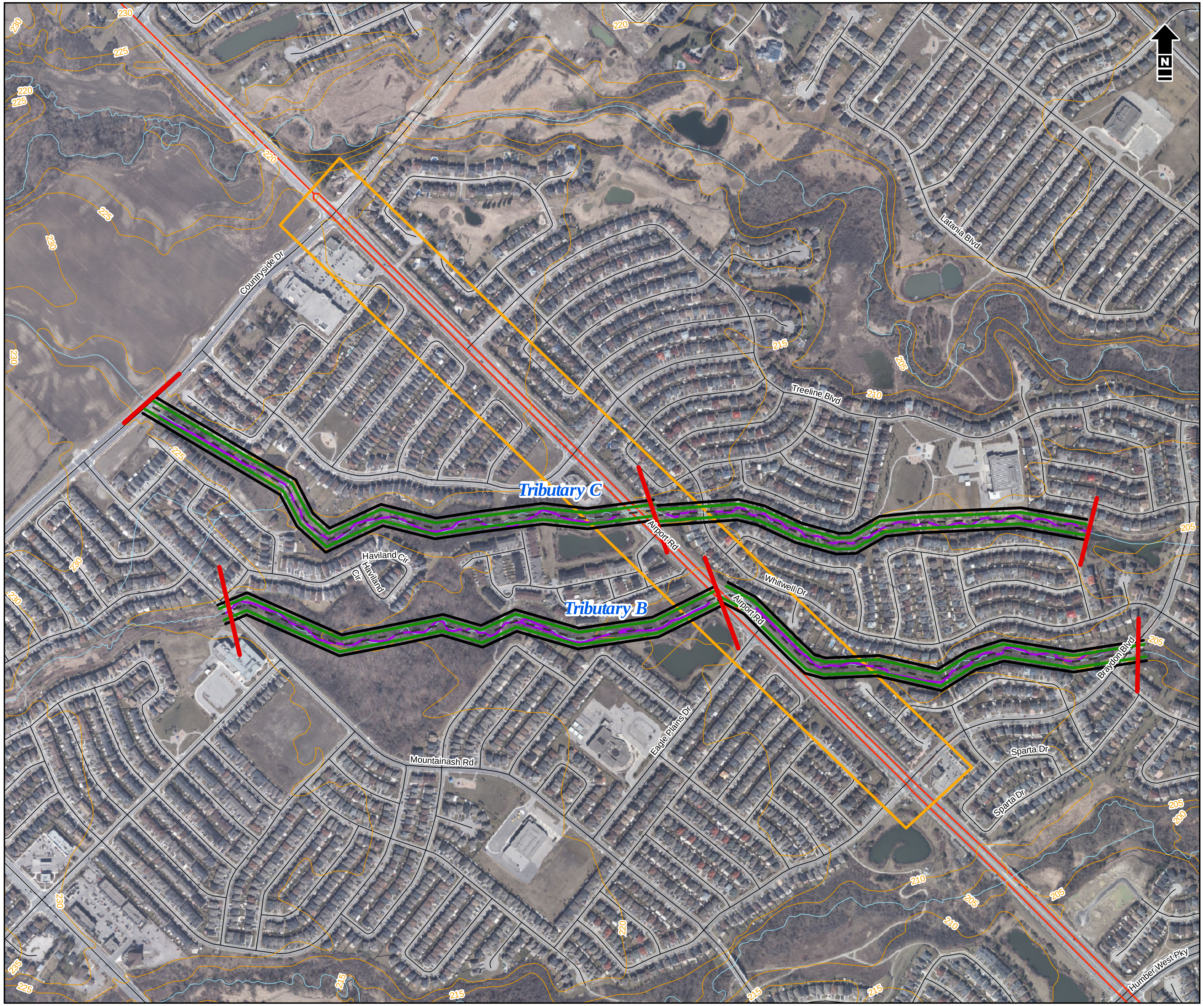
Empirically derived belt widths for Tributary B are similar for both upstream and downstream segments with a resulting belt width of 24.7. The channel segments were identified as being in a stable state, with minor evidence of widening and aggradation occurring. Applying a 10% factor of safety to either side of the empirically derived belt width to produce a final belt width of 30.0 m gives a conservative final belt width which is consistent with existing corridor limits.

Tributary C empirical belt widths of 13.2 m and 22.1 m where delineated for the upstream and downstream segments respectively. The belt with of 13.2 m for the upstream segment is not considered to adequately represent potential conditions particularly due to the observance of multiple flow pathways upstream from Airport Road, therefore this width was abandoned and 22.1 m preliminary belt width applied. Applying a 10% factor of safety to either side of the empirically derived belt width to produce a final belt width of 27.0 m gives a conservative final belt width which is consistent with existing corridor limits.

Table 6.3 presents the final values with the setbacks included which have also been presented visually in Figure 6.1. Empirically derived belt widths for the tributaries generally conform to results of the planform belt width but are in most cases less conservative.

TABLE 13 Final belt widths for Tributary B and Tributary C

Reach	Historical Planform Belt Width (m)	Empirical Belt Width (m)	10% Factor of Safety (m)	Recommended Final Belt Width (m)
Tributary B (upstream)	40.0	24.7	4.8	30.0
Tributary B (downstream)	40.0	24.7	4.8	30.0
Tributary C (upstream)	40.0	13.2	4.4	27.0
Tributary C (downstream)	40.0	22.1	4.4	27.0



Legend

- Geomorphic Reach Break
- Watercourse
- Belt Width (Empirical)
- Meander Axis
- Belt Width (Planform Mapping)
- 2005 Planform
- Contours 5m
- Railway
- Study Area
- Brampton Parcel Fabric

Streets

- Arterial
- Local

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Meander Belt Widths

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Figure 6.2

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7 EXISTING CONDITIONS

7.1 Field Reconnaissance

Geomorphic field assessments are required in order to characterize the form and function of the tributaries within the proposed development lands. General observations of channel dimensions, such as bankfull width and depth, substrate size, bank height, in-channel and riparian cover, channel hardening, and other disturbances (e.g., excessive erosion), were documented as part of the overall geomorphic assessment along both watercourses.

7.1.1 Tributary B

Tributary B is located 1,067 m south of Countryside Road. The tributary flows south-east through a wide riparian corridor and was assessed for 300 m upstream from Airport Road to 800 m downstream. Upstream from the road crossing, no flowing water was observed, however one location of standing water was noted, associated with a scour pool downstream from a woody debris jam. The watercourse is single thread and follows a generally straight planform as towards Airport Road. Upstream, the channel has near 100% canopy coverage from riparian (treed) vegetation. Course channel substrate is typically associated with pebbles or gravels, although artificial substrate in the form of engineering rip rap is introduced near the culvert inlet. Channel widening indicators such as leaning trees, exposed tree roots and organic debris are common upstream the crossing. Downstream, the channel flows parallel to Airport Road for approximately 230 m before changing direction to flow east. Immediately downstream from the culvert outlet, a large scour pool has formed in which substrate has become deposited and was filled with stagnant water during the site investigation. When disturbed, the fine grain substrate (silts and fine sands) easily becomes suspended and increases channel turbidity. In contrast to the upstream section, this segment has approximately 25% riparian cover. Overall, the watercourse has stable bank network with few observations of minor bank erosion or undercutting on meander bends. Of the pools observed, wetted depths ranged from 0.15 m to 0.2 m and have a hard clay material bed. Riffles are typically small, extending downstream for a length approximately 1x bankfull width, with substrates consisting of pebbles and gravels. Artificial rip rap formed some downstream riffles adjacent to Airport Road. Channel morphometrics taken in the vicinity of the culvert crossing, as well as other watercourse characteristics for Tributary B are presented in Table 7.1 below. Site photos for Tributary B are in Appendix A.

TABLE 7.1 Summary of channel characteristics for Tributary B

Reach	Average Bankfull Parameters*		Substrate Type	Channel Gradient (%)	Bed Morphology	Evidence of Hardening
	Width (m)	Depth (m)				
Tributary B (upstream)	4 to 5 m	0.2 to 0.4 m	Pebbles, gravels embedded in silts, and fine sand	Low	Straight with no distinct morphology	Boulder rip rap near culvert inlet
Tributary B (downstream)	4 to 5 m	0.4 to 0.5 m	Silts and fine sands	Low	Straight with some riffles and pools	Engineered riffles and toe protection

*Average bankfull parameters in the vicinity of culvert crossing

7.1.2 Tributary C

The watercourse flows through a densely vegetated riparian corridor. While no active flow was observed during field reconnaissance, evidence of multiple flow paths was apparent along the valley floor. Extensive woody debris along the valley floor is believed to be the cause for the multiple pathways as the debris would deflect flow leading to bank erosion and scour in multiple locations. Exposed tree roots are common along the multiple flow pathways. Throughout the upstream segment, no riffles were observed however areas of coarse grain deposition was noted along the bed and overbank areas approaching the culvert crossing. The material consisted of gravel sided to cobble sized particles and was often embedded. Riprap has been placed along the bed and banks approaching the Airport Road culvert. Immediately downstream from the crossing, a small scour pool with boulder rip rap and cat tail growth is present. Cat tails act to decrease flow conveyance making downstream flow nearly stagnant. Approximately 50 m downstream, the channel enters a wooded riparian area where vegetation growth on the bed stops and flows converge. Deposition along the bed includes silty fine material that is easily suspended when disturbed indicated an aggradation environment. Channel morphometrics recorded upstream and downstream from the culvert crossings, as well as other watercourse characteristics for Tributary C are presented in Table 7.2 below. Site photos for Tributary C are in Appendix B.

TABLE 7.2 Summary of channel characteristics for Tributary C

Reach	Average Bankfull Parameters		Substrate Type	Channel Gradient (%)	Bed Morphology	Evidence of Hardening
	Width (m)	Depth (m)				
Tributary C (upstream)	1 to 3 m	0.2 to 0.3 m	Pebbles, gravels embedded in silts, and fine sand	Low	Meandering with no distinct morphology	Boulder rip rap near culvert inlet
Tributary C (downstream)	3 to 5 m	0.3 to 0.4 m	Gravels, cobbles, silts, and fine sands	Low	Meandering with some riffles and pools	Boulder rip rap at culvert outlet

*Average bankfull parameters in the vicinity of culvert crossing

7.1.3 Rapid Results

The following section provides results of the rapid assessments for Tributary B and Tributary C within the study area. The RGA scores are summarized in Table 7.3.

Both watercourses are First Order tributaries to the West Humber River. They are intermittent streams that run seasonally dry. Existing conditions were observed in August 2017, along both watercourses no active flow was observed upstream from Airport Road, however flowing water occurred downstream.

Both the upstream and downstream channel segments of Tributary B were evaluated using the RGA (MOE, 2003). Upstream from the culvert crossing, the primary geomorphic processes observed are channel widening and aggradation. Downstream from the crossing aggradation becomes the primary process. However, the limited geomorphic indicators along the watercourse results in overall low Stability Index Values for the channel, 0.18 for the upstream reach and 0.15 for downstream, indicating that watercourse is *stable* or *in regime* and are not considered to be sensitive to altered sediment or flow regimes. Indicators of channel instability along Tributary B are within and expectable range of variance for stream of similar hydrographic characteristics and that evidence of instability is isolated or associated with normal river meander propagation processes.

Similarly, both the upstream and downstream channel segments of Tributary C were evaluated using the RGA. Upstream from the culvert crossing, the primary geomorphic process observed is channel widening, while downstream from the crossing, aggradation becomes the primary process. Similar to Tributary B, limited observation of geomorphic indicators along the watercourse results in overall low Stability Index Values for the channel, 0.18 for the upstream reach and 0.2 for downstream, indicating that watercourse is stable or in regime. The threshold Stability Index Value indicating a stressed or transitional environment is 0.21, as such the downstream segment of Tributary C is approaching a moderate sensitivity to altered sediment or flow regime.

TABLE 7.3 Summary of RGA scores for Tributary B and Tributary C

Reach	Factor Value				Stability Index	Condition
	Aggradation	**Degradation**	**Widening**	**Planimetric Adjustment**		
Tributary B (upstream)	0.29	0.0	0.3	0.14	0.18	In Regime
Tributary B (downstream)	0.29	0.2	0.1	0.0	0.15	In Regime
Tributary C (upstream)	0.14	0.0	0.3	0.29	0.18	In Regime
Tributary C (downstream)	0.57	0.0	0.1	0.14	0.20	In Regime

7.2 Detailed Channel Characterization

A geomorphic survey was conducted on August 23 and 24, 2017 along Tributary B and Tributary C within the Airport Road Study Area in order to gain an understanding of the existing channel function and stability.

The collection of more complete field data to also aids in defining current channel geometry and hydraulics. Detailed field data collection included the following tasks:

- measurement of bankfull channel geometries via cross-section surveys at five to seven locations
- characterization of bank parameters, such as height, angle, sediment composition, degree of vegetative cover, and other metrics
- substrate characterization using a modified Wolman pebble count
- determination of local energy gradients through a survey of channel bottom and bankfull elevations, including top-of-riffle and bottom-of-riffle (where applicable), maximum depth, and any obstructions to flow

7.2.1 Bankfull Geometry

Bankfull geometry was recorded at six representative cross-sections along Tributary B and seven cross-sections along Tributary C. In most cases, the cross-section survey extended beyond the bankfull indicator (i.e., inflection in slope or start of vegetation growth) and onto the adjacent overbank in order to gain a conservative estimate of channel dimensions. Table 7.4 contains a summary of the bankfull parameters, including mean values for all cross-section sites in the study reaches. Figure 7.1 and Figure 7.2 provide a typical channel cross-section for each tributary and Figure 7.3 and Figure 7.4 depict the overall longitudinal profile surveyed for each watercourse.

The typical cross-section for Tributary B (Figure 7.1), has been monumented for future monitoring purposes. The cross-section depicts generally consistent bank heights and a U-shape channel bed. Due to the U-shape cross-section, the thalweg through the reach is primarily located in the center of the channel. Surveyed bankfull channel width ranged from 4 to 8 m, with an average of 6.27 m. Bankfull hydraulic depths (i.e., average depth across the cross-section) varied between 0.14 and 0.38 m, averaging 0.24 m. The average maximum depth was 0.46 m. These recorded channel widths and depths form cross-sections with areas between 1.01 and 1.92 m^2 and an average width to depth ratio of 30.22. The long profile (Figure 7.3) shows that the surveyed gradient is low with local increases, with an upstream average bed slope of 0.66% and a downstream bed slope of 0.9%.

The typical cross-section for Tributary C (Figure 7.2) has also been monumented for future monitoring purposes. Bankfull widths along the tributary raged from 2.21 to 4.46 m with an average of 3.67 m. Bankfull hydraulic depths varied between 0.12 and 0.3 m, averaging 0.2 m. The average maximum depth was 0.38 m. The recorded channel widths and depths form cross-sections with areas averaging 0.68 m^2

and an average width to depth ratio of 21.04. The long profile shows that the gradient through this reach is low, with an average upstream bed slope of 0.35% and a downstream bed slope of 0.84%.

TABLE 7.4 Channel geometry data for Tributary B and Tributary C

Cross-section Parameter	Minimum	Maximum	Tributary B Average	Minimum	Maximum	Tributary C Average
Bankfull Width (m)	4.82	8.35	**6.27**	2.21	4.46	**3.67**
Average Bankfull Depth (m)	0.14	0.38	**0.24**	0.12	0.3	**0.2**
Maximum Bankfull Depth (m)	0.31	0.68	**0.46**	0.21	0.5	**0.38**
Bankfull Width:Depth	12.7	59.7	**30.22**	7.47	33.49	**21.04**
Cross-sectional Area (m^2)	1.01	1.92	**1.43**	0.42	1.02	**0.68**
Wetted Perimeter (m)	5.34	8.48	**6.46**	2.48	4.53	**3.82**
Hydraulic Radius (m)	0.13	0.37	**0.23**	0.11	0.23	**0.19**

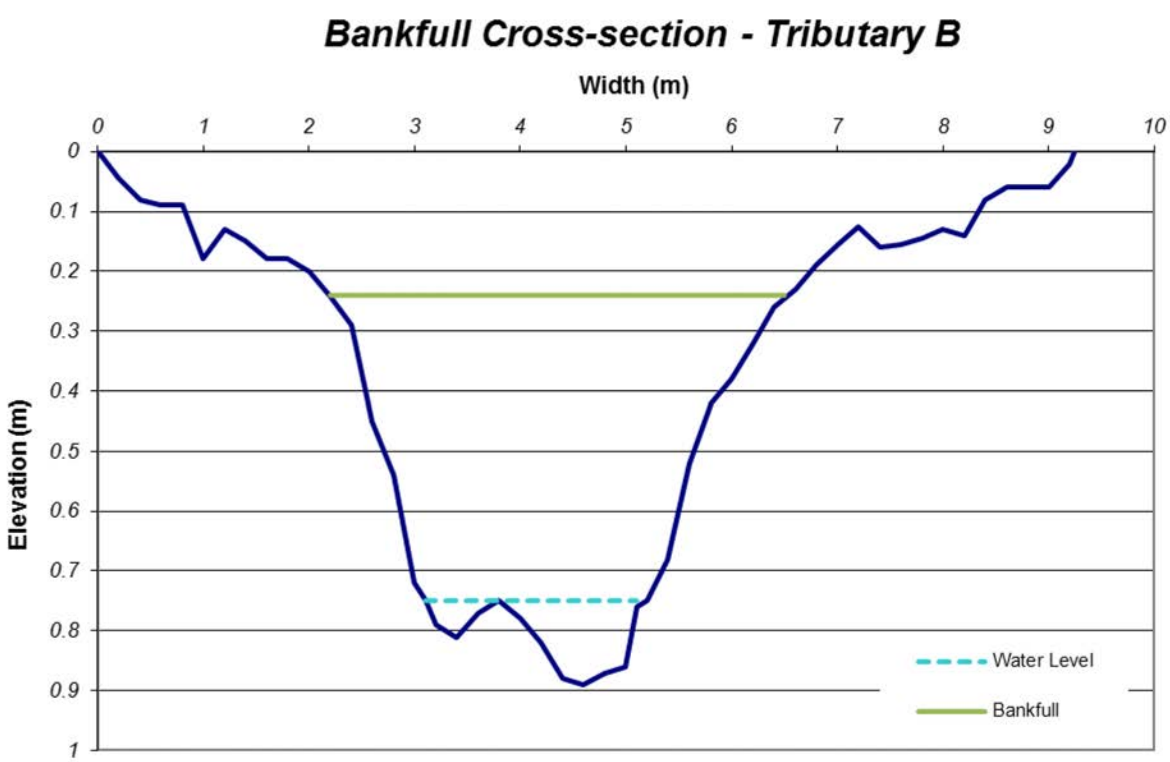


FIGURE 7.1 Monitoring cross-section, Tributary B

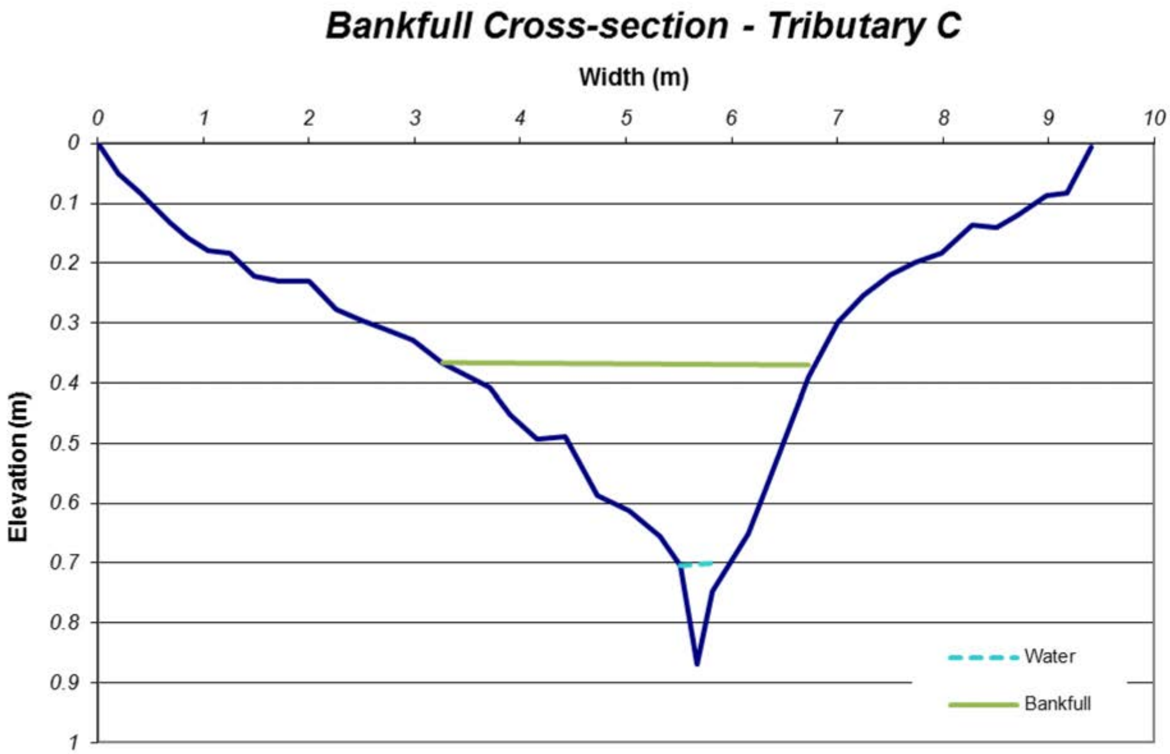


FIGURE 7.2 Monitoring cross-section, Tributary C

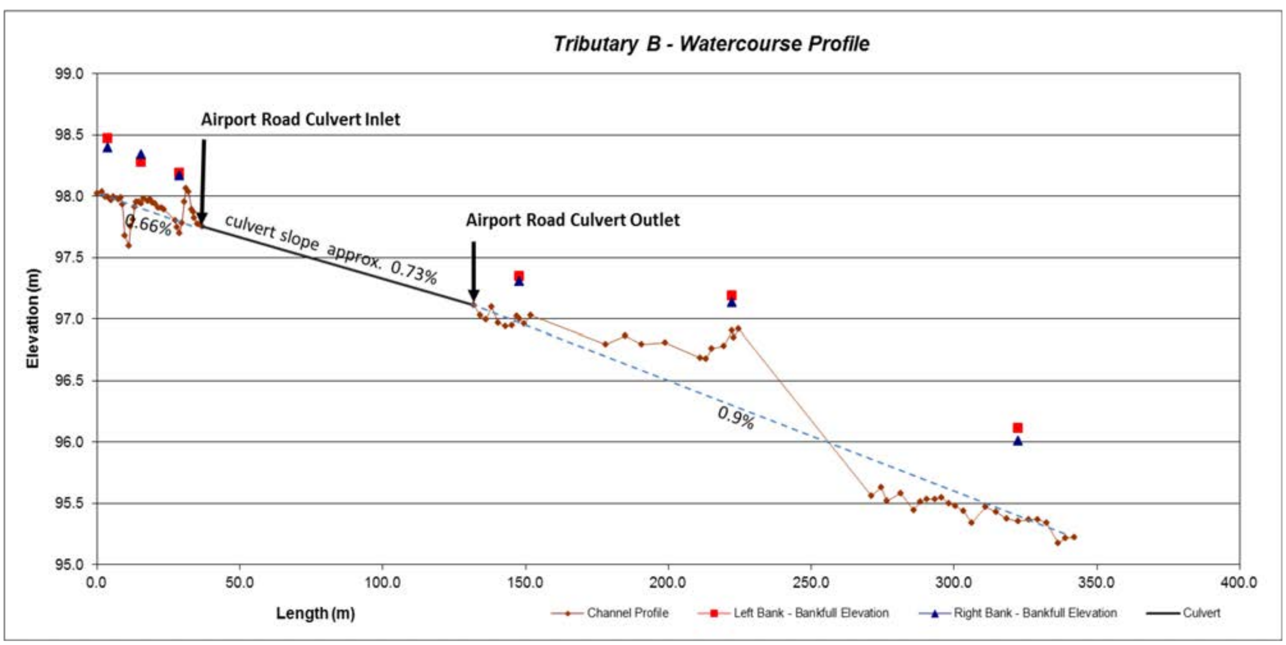


FIGURE 7.3 Surveyed watercourse profile, Tributary B

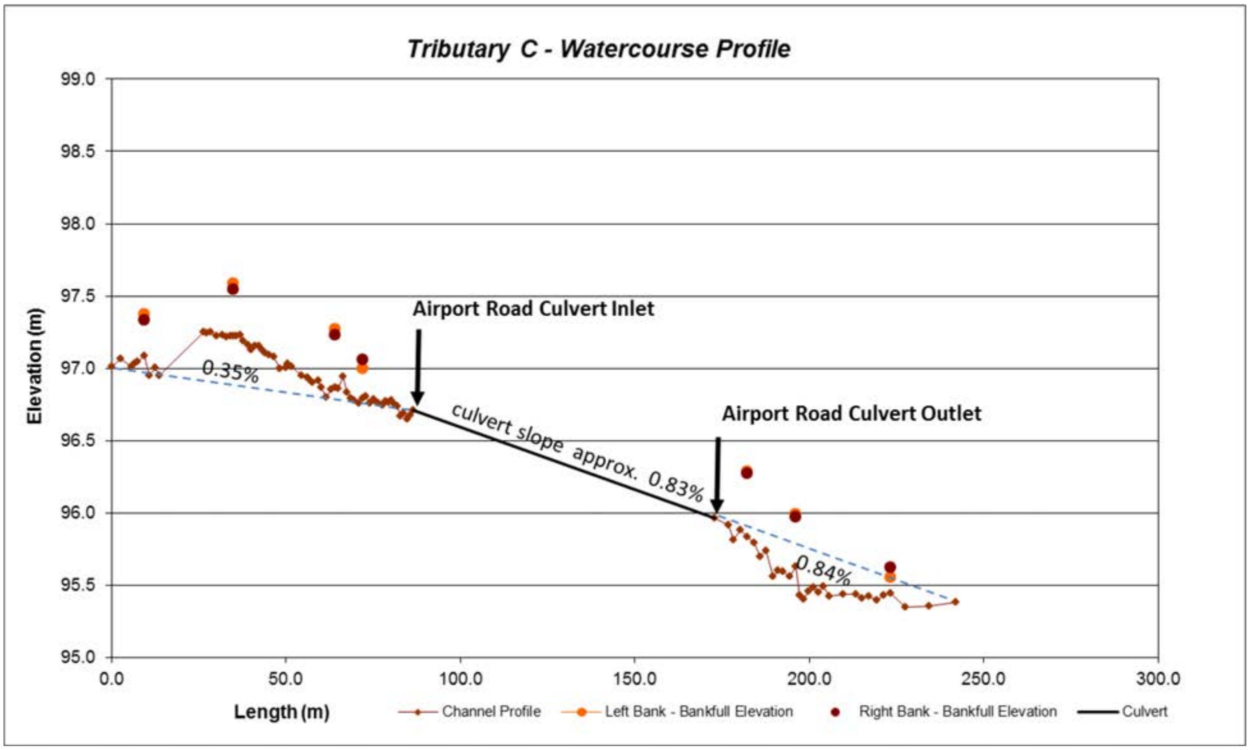


FIGURE 7.4 Surveyed watercourse profile, Tributary C

8 IMPACT ASSESSMENT

Existing conditions and results from the desktop assessments are used alongside proposed roadway grading to assess potential impacts to the tributaries within the study area from the proposed road widening efforts. The primary impact to the tributaries from road widening would be if they are to be further constricted within their corridor leading to erosion risk. Therefore, with regards to road crossings a primary target to achieve when assessing the potential impacts to ensure the risk to public and private property from channel erosion and evolution is maintained, minimized, or eliminated. Since it is proposed that existing culvert structures will be maintained without the need for extension, impacts to the watercourse are expected to be low.

8.1 Erosion Potential

Observations of channel erosion during the field assessments were limited. Tributary B had few observations of minor bank erosion and undercutting focused on outside meander bends, and Tributary C had evidence of erosion in the vicinity of debris jams. RGA Stability Index Values for both tributaries also indicate low erosion potential with values ranging from 0.15 to 0.20 indicating that the tributaries are stable or in regime.

In order to further assess erosion potential, stream power was calculated along the tributaries to identify potential areas where erosion may occur. Stream power is expressed as the potential for flowing water to perform geomorphic work (i.e., transport sediment), therefore peaks in stream power along the watercourse can infer areas where sediment transport and erosion are more likely to occur. The equation for *total* stream power (Ω):

$$\Omega = \gamma Q S$$

Where γ is the specific weight of water, Q is stream discharge and S is channel slope. *Total* stream power per unit length of stream is expressed in Wm^{-1}. Alternatively, *specific* stream power can also be expressed per unit bed width by dividing by channel width (w):

$$\omega = \frac{\gamma Q S}{w}$$

Where ω is specific stream power in units of Wm^{-2}. Both the *total* and *specific* stream power have advantages. However acknowledging that channel widths are a direct response to total stream power (i.e., Q and S) and boundary conditions (i.e., bank strength), *specific* stream power has a more direct link to sediment transport and has previously been selected as the parameter to gauge fluvial processes in southern Ontario (Phillips and Desloges, 2014).

To evaluate the special properties of specific stream power along Tributary B and Tributary C. Data inputs for the stream power assessment were a Digital Terrain Model (DTM) grid and the Ontario Hydrologic Network Watercourse vector layer. The DTM was a 5-metre resolution grid derived from the GTA 2002 orthophoto project. ArcHydro, an ArcGIS hydrology tool, was used to define a hydrologic stream along each tributary and to create a flow accumulation grid indicating the catchment area allocated to points at 10 metre intervals along the streams. This, along with the elevation values at each point were exported as a table to Excel where hydrologic functions were used to calculate slope, bankfull discharge, and width for the streams. Specific stream power was calculated at each point as the product of discharge (obtained from OFAT), slope and the weight of water, and this value is divided by the stream width to provide the final stream power energy value per square metre. A smoothing function was then applied and used for mapping purposes in order to dampen the inherent noise for DTM-derived channel slopes and to represent meaningful scales of fluvial processes (Phillips and Desloges, 2014). Figure 8.1 and Figure 8.2 below graphically illustrate specific stream power calculated for Tributary B and Tributary C. Figure 8.3 depicts the special distribution of specific stream power within the study area.

Results of the assessment indicated smoothed *specific* stream power results range from 0 - 25 Wm^{-2} for Tributary B and 0 - 20 Wm^{-2} for Tributary C. These results are comparable to results from Phillips, 2014 that indicate average specific stream power for all southern Ontario watercourses is 34 Wm^{-2}, and glaciolacustrine dominated landforms such as the current study consistently fall below this average (Figure 8.4). Based on the mapped results, there are no substantial increases in stream power in the vicinity to Airport Road. Tributary B indicates stream power in the range of 10 - 15 Wm^{-2} near the road crossing and Tributary C has stream power in the range of 5 - 10 Wm^{-2}. These are considered to be low values and, coupled with observations taken in the field, indicate that erosion potential near the road crossings to be low.

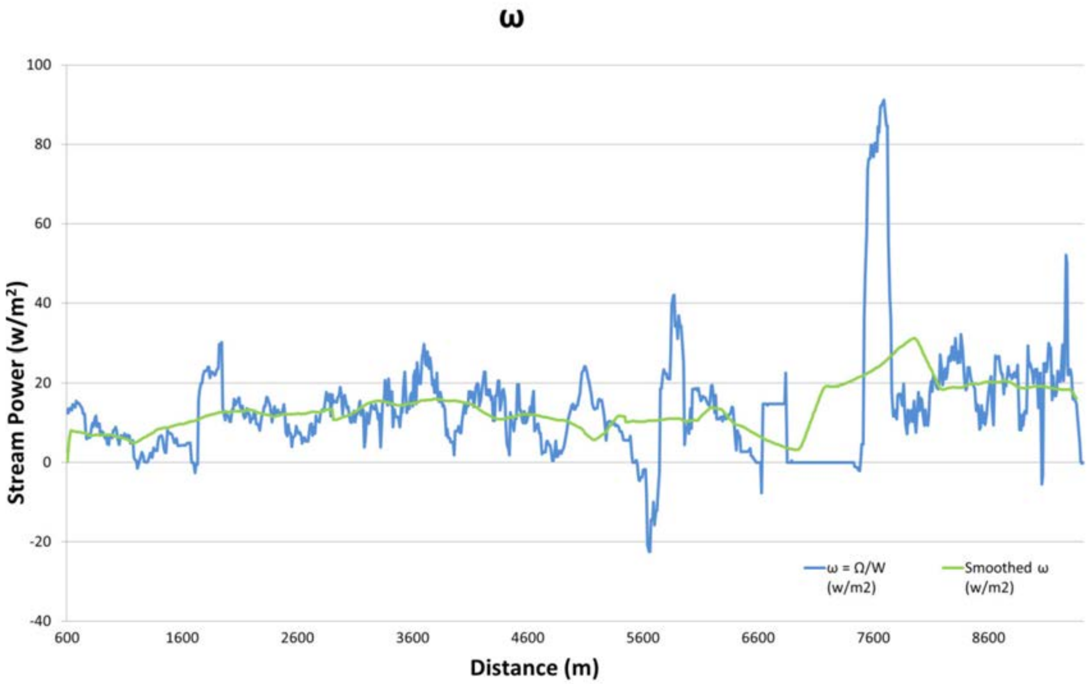


FIGURE 8.1 Specific stream power for Tributary B

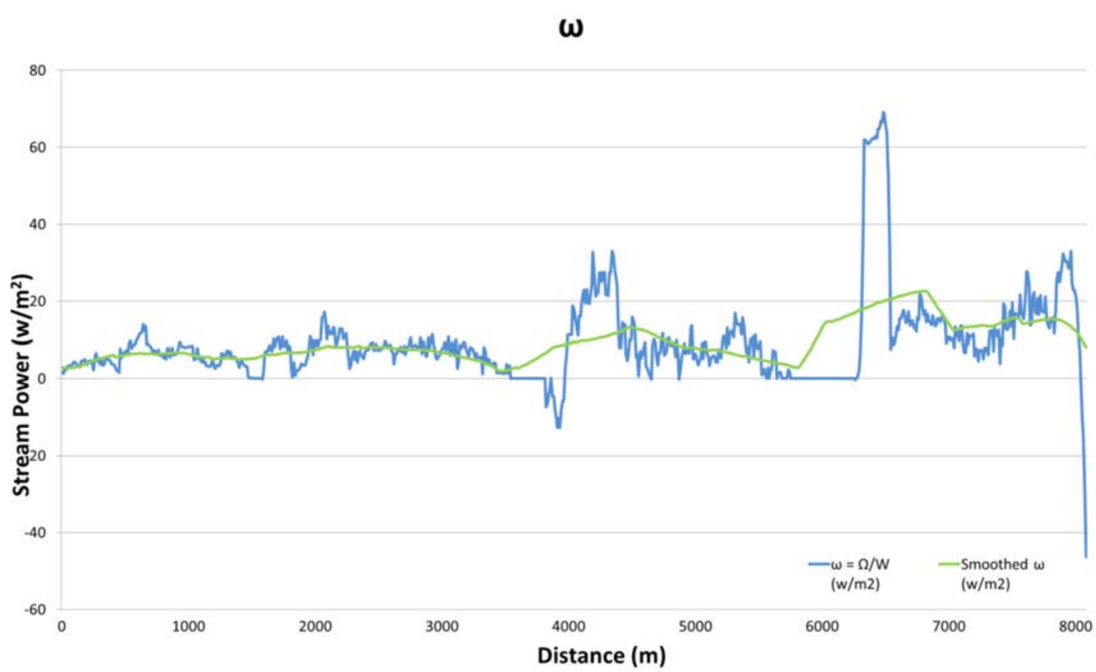
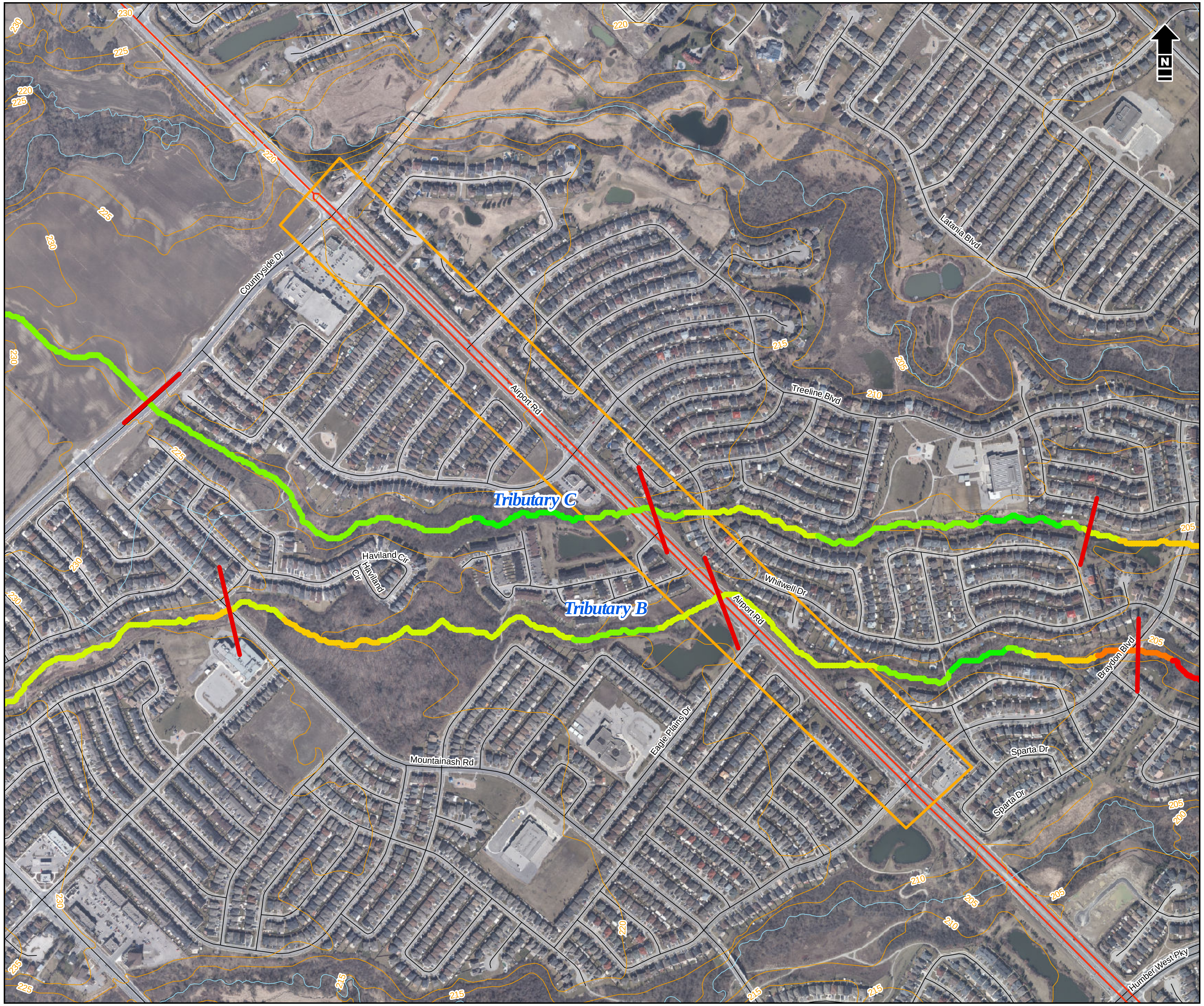


FIGURE 8.2 Specific stream power for Tributary C



Legend

- Geomorphic Reach Break
- Watercourse
- Contours 5m
- Railway
- Study Area
- Brampton Parcel Fabric

Streets

- Arterial
- Local

Stream Power (W/m2)

- 0 - 5
- 5 - 10
- 10 -15
- 15 - 20
- 20 - 25
- > 25

1:8,000 metres
80 0 80 160
NAD 1983 UTM Zone 17N

Reference: please refer to reference spreadsheet

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

HDR Corporation
Airport Road Environmental Assessment

Stream Power

Date:	Project:	Submitter:	Reviewer:
November 2017	24692	J. Henshaw	--

Figure 8.3

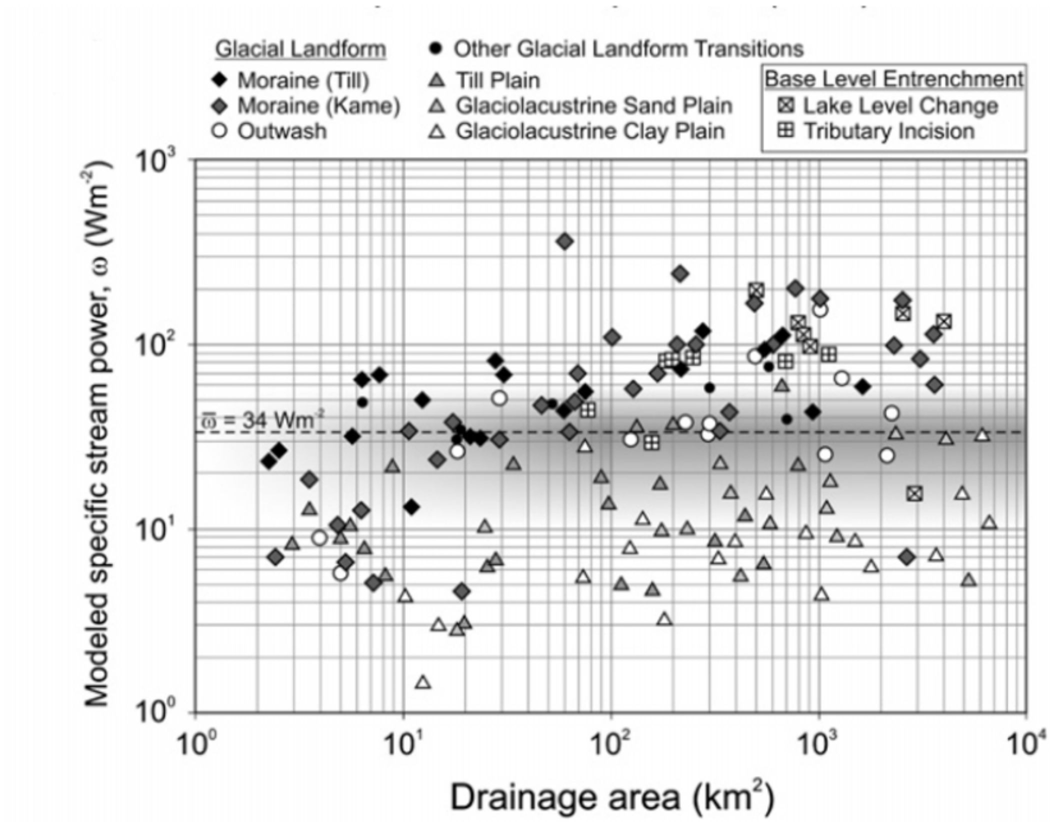


FIGURE 8.4 Plot of modelled specific stream power versus drainage area for 146 river reaches in southern Ontario. Reaches are classified by dominant glacial landforms. Figure taken directly from Phillips and Desloges, 2014.

8.2 Watercourse Crossings

Based on the results of the field and desktop assessments the existing crossing structures for Tributary B and Tributary C were evaluated, highlighting key characteristics of the structure, overall stream character, and any issues or disturbances noted during the field reconnaissance. This information should be considered when developing mitigation recommendations for road widening at each location.

Existing crossing structure for Tributary B is approximately 5.5 m wide and 0.9 m tall. Average bankfull width of the watercourse in the vicinity of the crossing is approximately 4-5m wide based on inflections in the bank slope and vegetation indicators. Bankfull width along the entire survey extents is just over 6m wide. The existing crossing structure for Tributary C is approximately 3.5 m wide and 0.9 m tall. Upstream from the crossing, bankfull widths were measured at 1 to 3 m wide however reach average widths 3.65 m. These measurements indicate that the crossing structures do not take into consideration factors of safety regarding future erosion. However, given that the erosion potential along the tributaries is low, existing morphologies are not well developed upstream from the crossing, and previous geomorphic design aspects have been implemented (i.e., rip rap control and realignments) the existing crossing structures (i.e., span) within the study area are considered adequate from a geomorphic perspective.

Following best management practices and taking into consideration Toronto and Region Conservation Authority (TRCA) Crossing Guidelines (TRCA, 2015); should replacement of the crossing structure be required due to hydrologic or habitat related requirements, a risk based crossing assessment was completed to determine the appropriate span required from a geomorphic perspective. This assessment takes into consideration belt widths, meander amplitude, bankfull widths, and erosion factors of safety in order to recommend an appropriate crossing size (Table 8.1). Since the tributaries are small, stable features, the preferred crossing span will take into consideration the 100-year erosion limit or the factor of safety.

For Tributary B, the minimum recommended crossing span is 8.70 m. For Tributary C, the minimum recommended crossing span is 6.10 m. These recommended spans take into consideration the existing bankfull widths as well as a 10% factor of safety. The spans also consider existing meander amplitudes measured in the vicinity of the existing crossing along each tributary.

TABLE 8.1 Risk based crossing assessment

Reach	Recommended Belt Width	Factor of Safety (10%)	Avg Bankfull Width	Channel Modification	Valley Setting	Meander Amplitude	RGA Score	Existing Structure		Recommended Structure Size
								Width (m)	Condition (Pooling/Erosion)	
Tributary B	30.0 m	2.4	6.27 m	Rip rap near crossing, realignment downstream	Built valley (confined)	4 m	0.15 to 0.18	5.5 m	No erosion at crossing, ponded water downstream on scour pad	8.70 m
Tributary C	27.0 m	2.4	3.67 m	Rip rap near crossing, realignment downstream	Built valley (confined)	6 m	0.18 to 0.20	3.5 m	No erosion at crossing, ponded water downstream on scour pad	6.10 m

9 CONCLUSIONS

Based on RGA scores along both tributaries, the dominant geomorphic process observed to occur upstream from the Airport Road crossing is channel widening, while aggradation was the dominant process observed downstream from the crossing. Observations of channel instability and erosion were minor and both Tributary B and Tributary C within the study area are considered to be in regime or stable. Lack of flowing water upstream from the crossings during the field assessment was indicative of an intermittent flow regime, where flow is only likely during spring freshet of following substantial rainfall events. Lack of flow decreases the risk of erosion. The above observations coupled with specific stream power results, which relate channel slope, discharge, and width to erosion potential conclude that both Tributary B and Tributary C are low risk.

Spans for the existing crossing structures are approximately equal to the channel bankfull widths. While consideration for TRCA guidelines was given, the perceived threat to public or private property is considered to be low enough from a watercourse erosion perspective that replacement of the structures is not considered necessary.

10 RECOMMENDATIONS

10.1 Channel Works

It is not anticipated that channel works will be required to accommodate the proposed road widening. However, due to aggradation conditions observed downstream, special consideration should be made regarding Erosion and Sediment Control during construction to ensure additional sediment is not entering the channel.

10.2 Monitoring

Two monitoring sites have been installed within the study area, including one located on Tributary B and one on Tributary C. Both sites are located downstream from Airport Road. While effects on the watercourse due to road widening actives are not expected, monitoring is recommended to take place for 3 years post construction. Monitoring the tributaries following road widening activities can yield information regarding the response of the watercourse to any changes in upstream conditions. Monitoring is recommended to take place annually at the installed locations with the following steps taken:

- **Control Cross-sections:** Are to be monitored annually during periods of low flow. An additional site visit should be conducted at each site following a peak storm in excess of the 5-year storm event for the system. Changes in cross-sectional area in excess of 20% will trigger a review of the need for mitigation in the form of restoration (based on professional review).

- **Substrate Composition:** A modified Wolman pebble count should be conducted at each control cross-section on an annual basis, the results of which will be tabulated in a particle size distribution chart. An additional site visit will be conducted at each site following a peak storm in excess of the 5-year storm event for the system. Grain size adjustments in excess of an order of magnitude will act as a trigger for mitigation. Due to the dynamic nature of substrate composition, no action will be taken until Year 5 unless the adjustment is identified as a potential risk to the function of the channel by a qualified geomorphologist.

- **Lateral Migration:** A series of erosion pins (minimum of 5) installed in areas of active bank migration as well as areas of anticipated migration should be measured on an annual basis during low flow conditions to determine rates of bank adjustment. An additional site visit will be conducted at each site following a peak storm in excess of the 5-year storm event for the system. Annual migration rates in excess of 15 cm/year will trigger an assessment by a geomorphologist to determine whether the adjustment is localized or representative of broader site conditions. Mitigation measures would be recommended based on the extent and source of the issue.

- **Photographic Record:** Photographs from a known vantage point should be used to document general geomorphic site conditions on an annual basis. An additional site visit will be conducted at each site following a peak storm in excess of the 5-year storm event for the system. These photographs will be used as supplemental information to inform decisions regarding the need for mitigation.

This monitoring could be undertaken by a variety of parties, including the City of Brampton or the Toronto and Region Conservation Authority. However, a fluvial geomorphologist should be used to interpret the findings and assess whether substantial change has occurred. The geomorphologist should also be able to link any change with the causative factors and processes.

11 REFERENCES

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APPENDIX A
Site Photos Tributary B

Matrix Solutions Inc.
August 23, 2017

1. Looking upstream along channel. No flowing water is present however flow path is visible along vegetated floodplain.

Matrix Solutions Inc.
August 23, 2017

2. Flow pathway typically devoid of vegetation as it is frequently wetted. Pebble and gravel substrate is common throughout the reach.

Matrix Solutions Inc.
August 23, 2017

3. Extensive woody debris jam covering channel. Scour pool with standing water downstream from debris jam.

Matrix Solutions Inc.
August 23, 2017

4. Exposed tree roots along bank are indicator of channel widening processes.

Matrix Solutions Inc.
August 23, 2017

5. Typical channel substrate, pebble and gravel, upstream from Airport Road culvert crossing.

Matrix Solutions Inc.
August 23, 2017

6. Cat tail growth is extensive approaching the Airport Road culvert inlet. No discernable flow pathway was observed.

Matrix Solutions Inc.
August 23, 2017

7. Downstream Airport Road culvert outlet, multiple outlets observed discharging into stagnant pool with unconsolidated silty-fine deposition.

Matrix Solutions Inc.
August 23, 2017

8. Looking downstream from culvert outlet.

Matrix Solutions Inc.
August 23, 2017

9. Add photograph caption here

Matrix Solutions Inc.
August 23, 2017

10. Add photograph caption here

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August 23, 2017

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August 23, 2017

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August 23, 2017

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APPENDIX B
Site Photos Tributary C

Matrix Solutions Inc.
August 24, 2017

1. Looking upstream along flow path with wood debris along channel.

Matrix Solutions Inc.
August 24, 2017

2. Extensive wood debris along flow pathway, evidence of trees being outflanked.

Matrix Solutions Inc.
August 24, 2017

3. Wood debris jam deflects flow around meander bend.

Matrix Solutions Inc.
August 24, 2017

4. Coarse grain (gravel) deposition in front of wood debris jam.

Matrix Solutions Inc.
August 24, 2017

5. Example of channel substrate upstream from Airport Road. Substrate typically gravel to cobble sized embedded in clay-sand.

Matrix Solutions Inc.
August 24, 2017

6. Looking downstream, single flow path with gravel substrate approaching Airport Road culvert.

Matrix Solutions Inc.
August 24, 2017

7. Looking upstream, multiple flow pathways divert around woody debris causing a cut off bank and tree mid-channel.

Matrix Solutions Inc.
August 24, 2017

8. Approaching Airport Road, flow pathway becomes narrow and well vegetated with grasses.

Matrix Solutions Inc.
August 24, 2017

9. Long grasses and shrubs are over grown at the Airport Road culver inlet.

Matrix Solutions Inc.
August 24, 2017

10. Downstream culvert outlet with boulder rip rap and cat tail vegetation.

Matrix Solutions Inc.
August 24, 2017

11. Secondary outlet downstream from Airport Road. Standing water in channel.

Matrix Solutions Inc.
August 24, 2017

12. Looking upstream to the Airport Road culvert outlet. Cat tail grown increases bed roughness resistance and slows the velocity of downstream flow.

Matrix Solutions Inc.
August 24, 2017

13. Channel enters woody riparian area approximately 50m downstream from culvert outlet. Banks at this location are oversaturated and easily collapse when stepped on.

Matrix Solutions Inc.
August 24, 2017

14. Looking downstream along channel towards monitoring cross section. Banks are well vegetated with grasses. Wood debris on overbank indicates channel was recently overtopped by low.

Matrix Solutions Inc.
August 24, 2017

15. Looking downstream along channel, material deposited along the bed becomes easily entrained when disturbed increasing the turbidity of flow.

Matrix Solutions Inc.
August 24, 2017

16. Organic material and silty fine particle deposition is frequently observed along the channel bed indicating an aggradation environment.

Matrix Solutions Inc.
August 24, 2017

17. Looking upstream along channel as it approaches Whitwell Dive culvert. Cat tail vegetation grown in channel and dense vegetation grown on floodplain.

Matrix Solutions Inc.
August 24, 2017

18. Looking downstream at Whitwell Drive culvert.