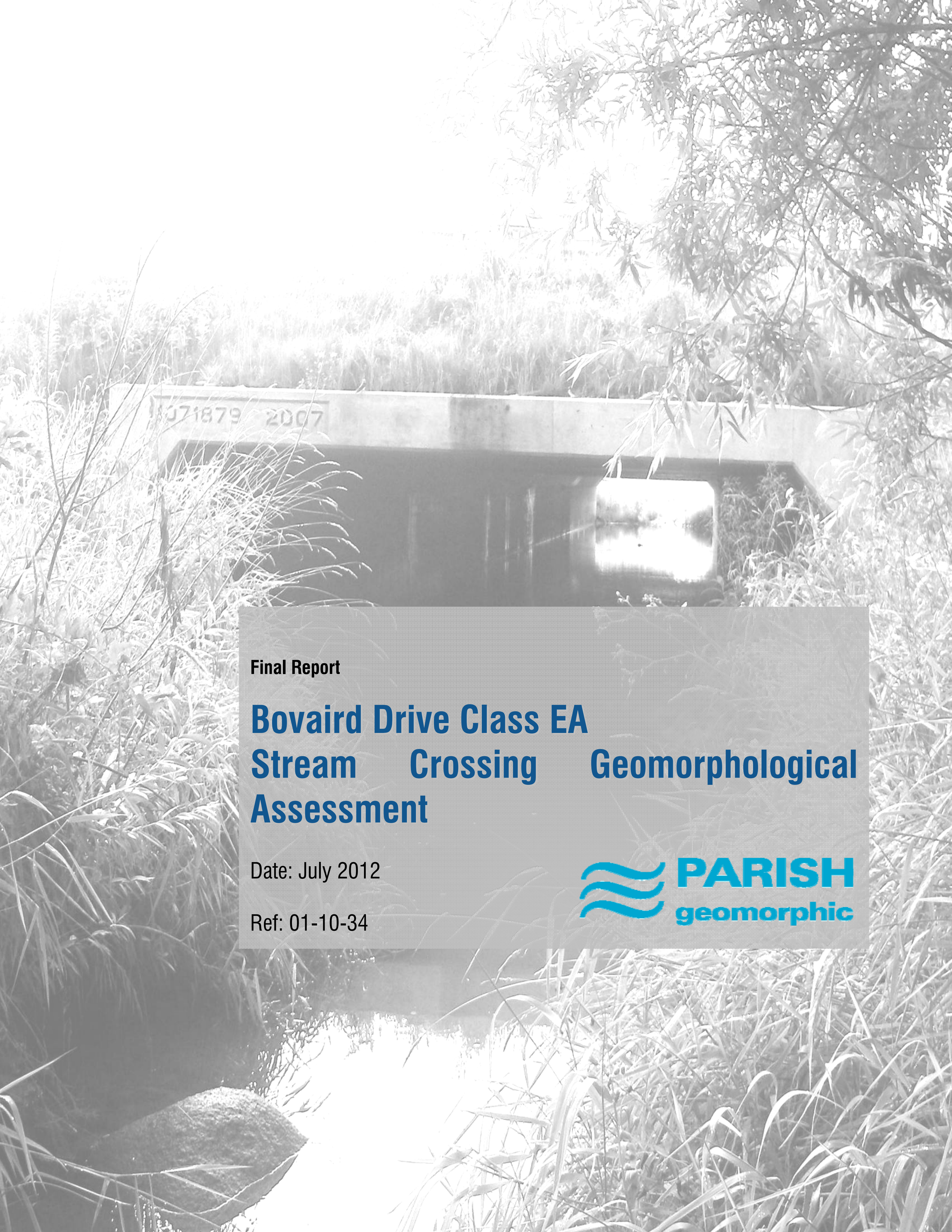

Final Report

Bovaird Drive Class EA Stream Crossing Geomorphological Assessment

Date: July 2012

Ref: 01-10-34

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Contents

1. Introduction

A Schedule “C” Class Environmental Assessment (EA) Study is being completed for Bovaird Drive from Lake Louise Drive / Worthington Avenue to the Peel / Halton boundary at Caseley Drive on behalf of the Regional Municipality of Peel. This report includes detailed assessments for all watercourse crossings within the study area, following the standard method for crossing assessments, as well as the Credit Valley Conservation Authority (CVC) Fluvial Geomorphic Guidleines (Fact Sheet III) checklist regarding crossing design (CVC, 2010).

A summary of the standard procedure for geomorphologically assessing watercourse crossings is provided in **Section 4**. The CVC checklist for ‘Geomorphological Consideration with Regards to Crossing Design’ (CVC, 2012) is as follows:

- ☑ Geomorphological assessment that provides information on stability
- ☑ Quantify channel migration, widening and potential downcutting or scour, based on historical observations
- ☑ Assessment and justification of crossing size based on stability and dynamics. The assessment must indicate how each hazard is addressed
- ☑ Additional width should be provided to account for channel dynamics
- ☑ Appropriate rationale of how other geomorphological processes are addressed

The scope of work for the Class EA includes consideration of fluvial geomorphology within the study area, with a particular focus on stream crossings. Parish Geomorphic Ltd has been retained by AMEC Earth and Environmental in order to provide fluvial geomorphological input to the Class EA. This report documents the findings of the fluvial geomorphological assessment, the objectives of which were to:

- Use digital ortho imagery and available GIS data for the study area to identify channel reaches within the vicinity of all existing road crossings;
- On a reach basis, establish a preliminary meander belt width following the orientation of the valley;
- Based on historic aerial photographs, complete a 100-year erosion analysis to identify the necessary setbacks or belt width allowance;
- Complete rapid field assessments for all existing road crossings to confirm physical setting of reach and appropriateness of results; and
- Provide comments on crossing structures/configuration based on channel processes.

Prior to undertaking the fluvial geomorphological assessment, a background review was undertaken in order to highlight other studies and previous work of relevance to fluvial geomorphology within the study area.

Field reconnaissance, collected in 2010, was completed for each crossing and included the following: **R**apid **G**eomorphic **A**ssessments (**RGA**s), documenting channel stability; **R**apid **S**tream **A**ssessment **T**echnique (**RSAT**) forms, documenting channel dimensions and degree of stream health; and Stream Crossing Assessment Forms, which record information regarding the condition of crossing structures and the watercourse upstream and downstream of the crossing. A detailed historic assessment was completed, using available mapping, aerial photos from 1974 and 1989, and digital ortho imagery from 2009, to quantify changes in channel location and migration tendencies.

The detailed assessment of watercourse conditions and crossing structure recommendations provided in the current report take into account the degree of stability (see **Table 2.1** for RGA results) and channel dynamics (see **Section 3** for historic and meander belt width assessments) upstream and downstream of Bovaird Drive. Additional factors of safety are provided, where appropriate to ensure the long term protection of crossing structures from channel migration and geomorphic processes.

2. Background Review

2.1 Study Area

The study area is located along Bovaird Drive (Highway 7) to the south west of Mount Pleasant (City of Brampton) and north of the Credit River, between Caseley Street and Lake Louise Drive (**Figure 2.1**). The area consists primarily of low-lying agricultural land and includes land within four subwatersheds as defined by Credit Valley Conservation (CVC) (www[1]). These subwatersheds are:

- 9 - Norval to Port Credit
- 7 – Huttonville Creek
- 8a – Springbrook Creek
- 8b – Churchville Creek

2.2 Previous / Ongoing Studies

A brief data review has been undertaken to provide background information to inform the fluvial geomorphological assessment of each crossing location. Due to the large number of previous studies within the area, this review has focused on the most recent work undertaken (which in itself draws on previous work), to extract specific details that are pertinent to this study. The data review was conducted using materials provided by AMEC and Parish Geomorphic Ltd.

Two key studies are currently ongoing within the study area:

- North West Brampton Subwatershed Study
- Widening of Mississauga Road Class Environmental Assessment

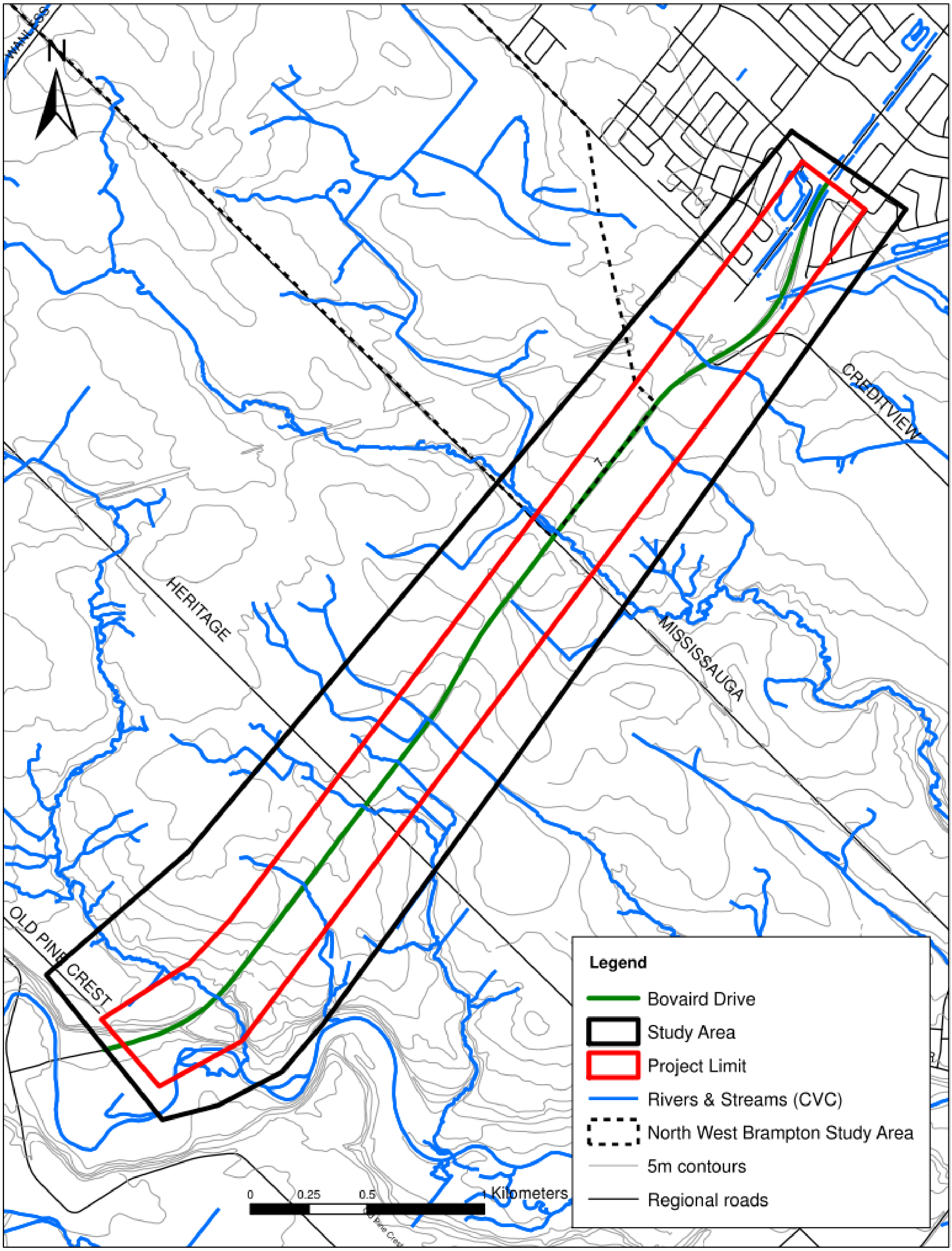

Figure 2.1: Study Area

2.3 Northwest Brampton Subwatershed Study

A Subwatershed Study is currently being prepared for proposed development to the North West of the City of Brampton. The relationship of the North West Brampton study area to the present area of interest is illustrated in **Figure 2.1**. As part of the subwatershed study, reaches within the North West Brampton study area have been delineated and characterized, including a high-level meander belt width quantification (AMEC Earth and Environmental, Blackport and Associates, C.Portt and Associates, Dougan and Associates and Parish Geomorphic Ltd, 2010). The reaches of relevance to the current study are HV02, HV03 and HV18, located upstream of Bovaird Drive, together with a swale entering Huttonville Creek immediately upstream of Bovaird Drive (**Figure 2.2**).

Key outputs of the geomorphological assessment relevant to this study are contained in **Table 2.1**. It should be noted that the meander belt widths for HV02, HV03 and HV18 were determined based on a surrogate reach downstream of Bovaird Drive in order to take into account prior modification of the stream within these reaches.

Table 2.1: Geomorphological assessment of reaches HV02, HV03 and HV18.

Reach	Watercourse	RGA Condition	RSAT Condition	Meander Belt and Erosion Setback	Geomorphological Constraint Rating	Overall Constraint Rating	Broad Management Strategy
HV02	Huttonville Creek	In Transition (0.357)	Moderate (24)	36 m* (30 + 6)	High	High	Maintain/enhance in situ
HV03	Huttonville Creek (West)	In Transition (0.328)	Moderate (25.5)	36 m* (30 + 6)	High	High	Maintain/enhance insitu
HV18	Huttonville Creek (East)	In Adjustment (0.470)	Low (19.5)	36 m* (30 + 6)	Medium	High	Maintain/enhance insitu
Swale	Unnamed	n/a	n/a	n/a	Low	Low	Potential to eliminate provided that function is maintained

* A description of Rapid Geomorphological Assessment and the Rapid Stream Assessment Technique is contained in **Section 3**.

Detailed management strategies for these reaches are currently being determined as part of the “Phase 3 – Implementation Plan”.

2.4 Widening of Mississauga Road

In addition to the North West Brampton Subwatershed Study, work has been undertaken at a more detailed scale on Huttonville Creek in relation to the proposed widening of Mississauga Road:

- In 2006 - between Bovaird Drive and Queen Street (downstream of Bovaird Drive)
- In 2010 – between Bovaird Drive and Mayfield Road (upstream of Bovaird Drive)

The findings of these studies relate to reaches HV02, HV03 and the surrogate reach of Huttonville Creek as identified in the North West Brampton Subwatershed Study (**Figure 2.2**).

Downstream of Bovaird Drive

A meander belt width assessment was undertaken in support of the Class Environmental Assessment for widening of Mississauga Road between Bovaird Drive and Queen Street (Trow, 2006 – see **Figure 2.2**). The assessment was undertaken according to protocols developed for the Toronto and Region Conservation Authority (Parish Geomorphic, 2004). The findings of the meander belt width assessment were subject to peer review on behalf of Credit Valley Conservation (CVC) (Geomorphic Solutions, 2006). Based on CVC recommendations, an additional factor of safety was added to the meander belt width to take into account potential geomorphologic response to change in hydrologic regime. The final meander belt width determined for the reach was 32.8m based on the parameters detailed in **Table 2.2**.

Table 2.2: Calculation of meander belt width downstream of Bovaird Drive (from Trow, 2006).

Parameter	Width
Preliminary Belt Width (width between meander belt boundaries	**19.2 m**
Average bankfull width of channel	+3.5 m
Existing Meander Belt Width	**22.7 m**
Average 100-year migration distance	+8.9 m
Average 100-year meander axis migration distance	0m
Factor of safety to accommodate change in flow regime (5% of existing meander belt width recommended by CVC)	+1.2 m
Final Meander Belt Width	**32.8 m**

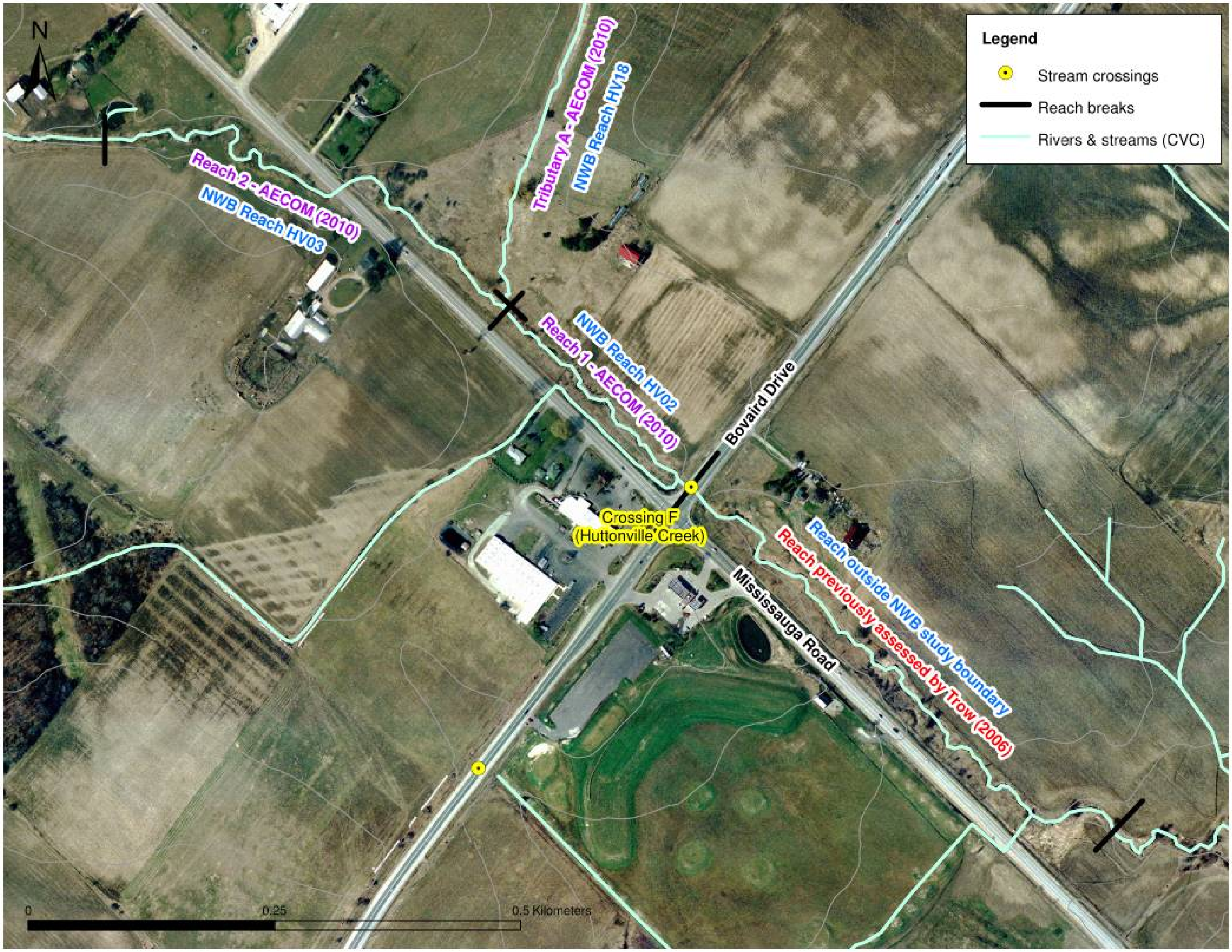

Figure 2.2: Reaches identified within previous studies in the relation to the Huttonville Creek crossing.

Upstream of Bovaird Drive

A second meander belt width assessment was undertaken upstream of Bovaird Drive as part of the proposed widening of Mississauga Road upstream of Bovaird Drive (AECOM, 2010). This assessment identified two reaches; Reach 1 corresponding to reach HV02 of the North West Brampton Subwatershed Study and Reach 2 corresponding to reach HV03 (**Figure 2.2**). Reach HV18 is referred to as Tributary A. The meander belt widths identified and the parameters on which they are based are detailed in **Table 2.3.**

Table 2.3: Calculation of meander belt widths upstream of Bovaird Drive (from AECOM, 2010).

Parameter		
Preliminary Belt Width (width between meander belt boundaries	**12 m**	**31 m**
Average bankfull width of channel	+3.5 m	+3.5 m
Existing Meander Belt Width	**15.5 m**	**34.5 m**
Average 100-year migration distance	+6 m	+3 m
Average 100-year meander axis migration distance	0 m	0 m
Factor of safety to accommodate change in flow regime (5% of existing meander belt width recommended by CVC)	0.8 m	+1.7 m
Final Meander Belt Width	**22 m**	**39 m**

The apparent down-valley narrowing of the meander belt width between the reaches despite Reach 1 having a larger drainage area and discharge was explained by the fact that continuous and mature vegetation along Reach 2 has limited the amount of lateral channel movement over the long term. This seems contradictory to the values determined as Reach 2 is the upstream reach with the larger belt width. These belt widths are discussed further in Section 4.

3. Methodology

Building on the works completed through previous studies, the following tasks were undertaken:

- Broadscale historical assessment
- Reach delineation
- Identification of stream crossing location
- Meander belt width assessment
- Field reconnaissance

3.1 Broadscale Historical Assessment

The 2010 assessment included a broad historical assessment of the study area was undertaken based on available historic 1:50 000 mapping of Brampton:

- Second Edition, Original Survey 1907, Revised 1942 and scaled 1951.
- Third Edition, amended in 1960 to add Highway 401
- Edition 4, information current as of 1960, printed 1964.
- Edition 5, information current as of 1976, printed 1979.
- Edition 6, information current as of 1980, published 1985.

This was coupled with study of aerial photographs from 2002 and current online aerial photography.

In 2012 a detailed historic assessment was completed using aerial photographs from 1974 and 1989 that were geo-referenced using GIS software, and 2009 orthophotography.

3.2 Reach Delineation

Reaches can be defined as lengths of channel that display similar physical characteristics and have a setting that remains nearly constant along their length. Thus, in a reach, the controlling and modifying influences on the channel are similar, and are reflected in similar geomorphological form, function and processes within the reach.
Reaches were defined for all streams crossing Bovaird Drive (Highway 7) using CVC's rivers and streams GIS layer. Reaches were defined within the study area based on desktop assessment of characteristics including sinuosity, valley setting, gradient and tributary using aerial photography, drainage network and topographic mapping.

3.3 Identification of Crossing Locations

Existing stream crossings were initially identified using aerial photography from both 2002 and current online sources. Crossing locations were subsequently refined based on field reconnaissance.

3.4 Meander Belt Width 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 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, when development or other activities are contemplated near a watercourse, it is desirable to designate a corridor that is intended to contain all of the natural meander and migration tendencies of the channel. 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 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 manual provides detailed documentation outlining the methods to be applied when identifying meander corridors in a range of systems (PARISH Geomorphic Ltd.) This document provides a processes-based methodology based on background information, degree of valley confinement and channel planform.

Meander belt width assessment was undertaken according to Procedure 1 for planning studies outlined in the publication “Belt Width Delineation Procedures” (Parish Geomorphic Ltd, 2004). This approach is appropriate to broadly define meander belt widths. An analysis of historic channel planform was completed in 2012 and was applied to the belt width assessment. A detailed meander belt width assessment, which includes historic planform and determination of 100-year erosion rates, was previously conducted for Huttonville Creek (Trow, 2006; AECOM, 2010).

3.5 Field Reconnaissance

Following the desk-based assessment, field reconnaissance was undertaken at each of the stream crossing locations. At each location, the following assessments were undertaken:

- Stream Crossing Assessment
- Rapid Geomorphic Assessment (RGA)
- Rapid Stream Assessment Technique (RSAT)

The Stream Crossing Assessment was undertaken in order to collect data relating specifically to the crossing in question. Information recorded included crossing type, material, shape and dimensions, structural condition and assessment of potential issues relating to the crossing (e.g. bank erosion, bed scour, debris trapping and fish passage).

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (1999) to assess reaches in urban channels. This qualitative technique is purely a presence/absence methodology designed to document evidence of channel instability. The various indicators are grouped into four categories indicating a specific geomorphic process: Aggradation, Degradation, Channel Widening and Planimetric Form Adjustment. Over the course of the survey, the existing geomorphic conditions of each

reach are noted and individual geomorphic indicators are documented. Upon completion of the field inspection, these indicators are tallied by category and used to calculate an overall reach stability index, which corresponds to one of three stability classes which correspond to their relative sensitivity to altered sediment and flow regimes (**Table 3.1**).

Table 3.1: RGA Classification (Source: Ontario Ministry of Environment, 2003 – App. C3).

Factor Value	Classification	Interpretation
$\leq$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
0.21-0.40	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
$\geq$0.41	In Adjustment (Most Sensitive)	Channel morphology is not within the range of variance and evidence of instability is wide spread

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli, 1996). The RSAT provides a more qualitative assessment of the overall health and functions of a reach in order to provide a quick assessment of stream conditions and the identification of restoration needs on a watershed scale. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- Channel Stability
- Erosion and Deposition
- Instream Habitat
- Water Quality
- Riparian Conditions
- Biological Indicators

Once a condition has been assigned a score, these scores are totaled to produce an overall rating that is based on a 50 point scoring system, divided into three classes:

- <20 Low
- 20-35 Moderate
- >35 High

While the RSAT does score streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions – pools provide resting areas while

riffles provide feeding areas and contribute oxygen to the water – good riparian conditions provide shade and food – woody debris and overhanging banks provide shade).

Photographs of each crossing taken during the course of the field reconnaissance are contained in **Appendix A**.

4. Historical Assessment

The available mapping was geo-referenced with a GIS and overlain by layers representing the study area, project limit and existing rivers and streams (from CVC). The resultant maps are illustrated in **Figures 4.1 to 4.6**.

Analysis of the time series reveals the following:

- Landuse within the study area has remained predominantly rural with scattered dwellings since 1942. Residential dwellings were present in Norval to the south west of the study area in 1942 and were greater in number in 1960. However, since 1980 residential development has also begun to encroach from the north east of the study area as illustratead in **Figures 4.5** and **4.6**. The stream crossing furthest to the north east of the study area has already been developed.

- The most significant changes shown in channel planform are between 1942 and 1960, in particular Huttonville Creek which was channelised upstream of Bovaird Drive. Huttonville Creek downstream of Bovaird Drive and the Unnamed Tributary to the Credit River to the south west of the study area are also shown on very different alignments. However, this may well be due to the accuracy of the mapping survey since it appears that these reaches were not straightened.

- Between 1976 and 1980 a pond was constructed downstream of Bovaird Drive along the second most south western tributary.

- Infrastructure and associated crossings have remained predominantly the same since 1942. The key change has been the construction of a viaduct for Bovaird Drive over the railway, which may have impacted the most north eastern stream (which is now within developed lands).

An updated historic assessment was completed in 2012 using aerial photographs from 1974 and 1989, as well as orthophotography from 2009. An evaluation of was completed to identify any changes in land use that may have affected channel conditions, as well as any changes in channel planform. As a whole, land use within the study area has changed very little over the 35 year period examined, with agriculture dominating land use. In the 1974 air photo a small area of construction was noted along the north side of Bovaird Drive between crossings B and C. A small commercial development is located at the north-west corner of Bovaird Drive and Mississauga Road, and several farm houses scatter the area. A railway runs from the north-west to the south-east and a racetrack was noted at the rail line and Creditview Road. Between 1974 and 1989, a slight increase in commercial and industrial development occurred in vicinity of the study area, however the majority of land use remains agricultural. By 2009, residential and commercial development increased significantly, especially to the east, where a large residential development extends to Creditview Road.

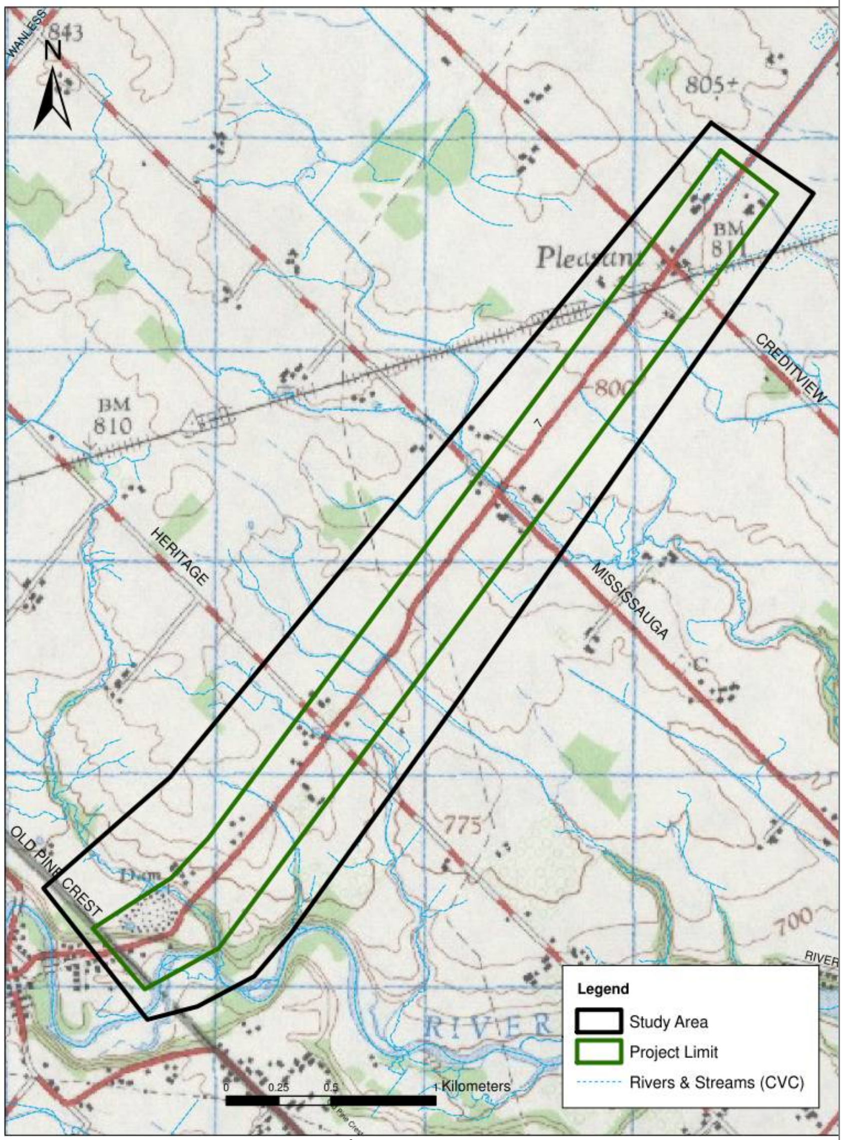

Figure 4.1: 3rd Edition Mapping, 1942.

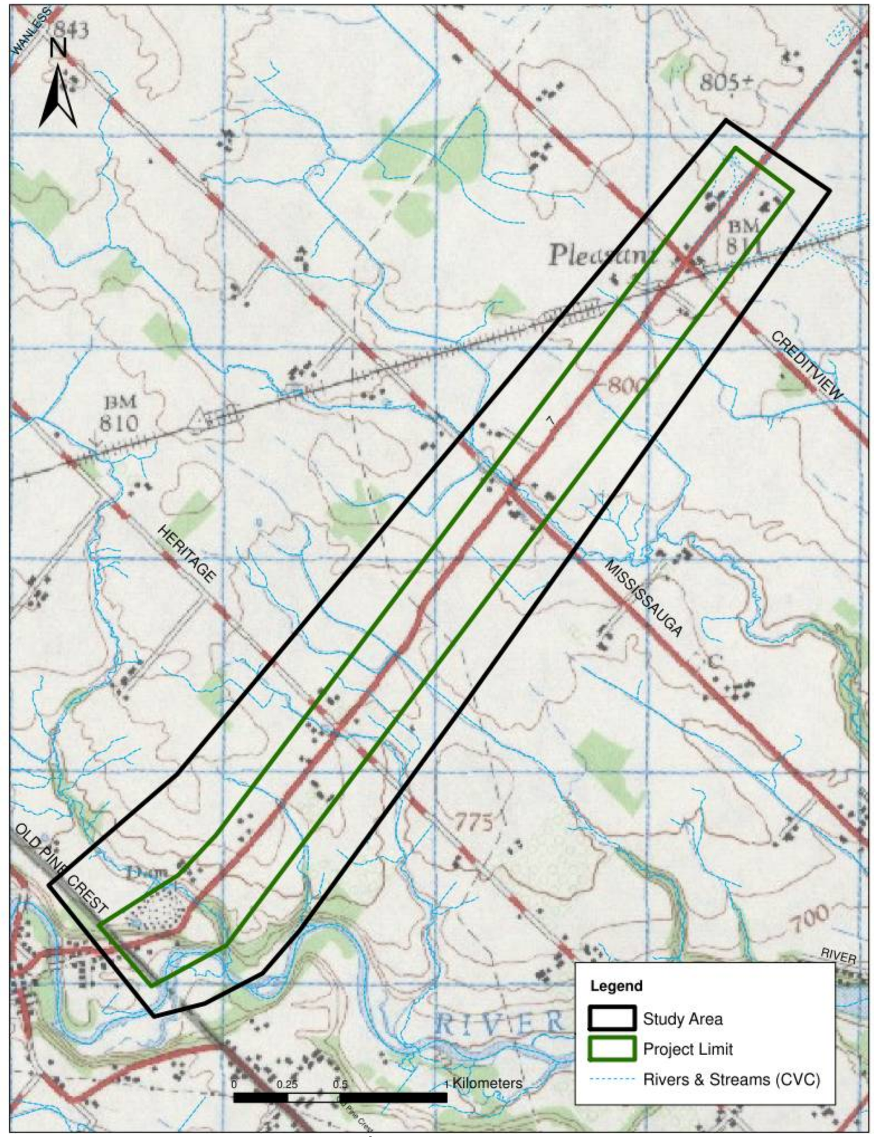

Figure 4.2: 4th Edition Mapping, 1960.

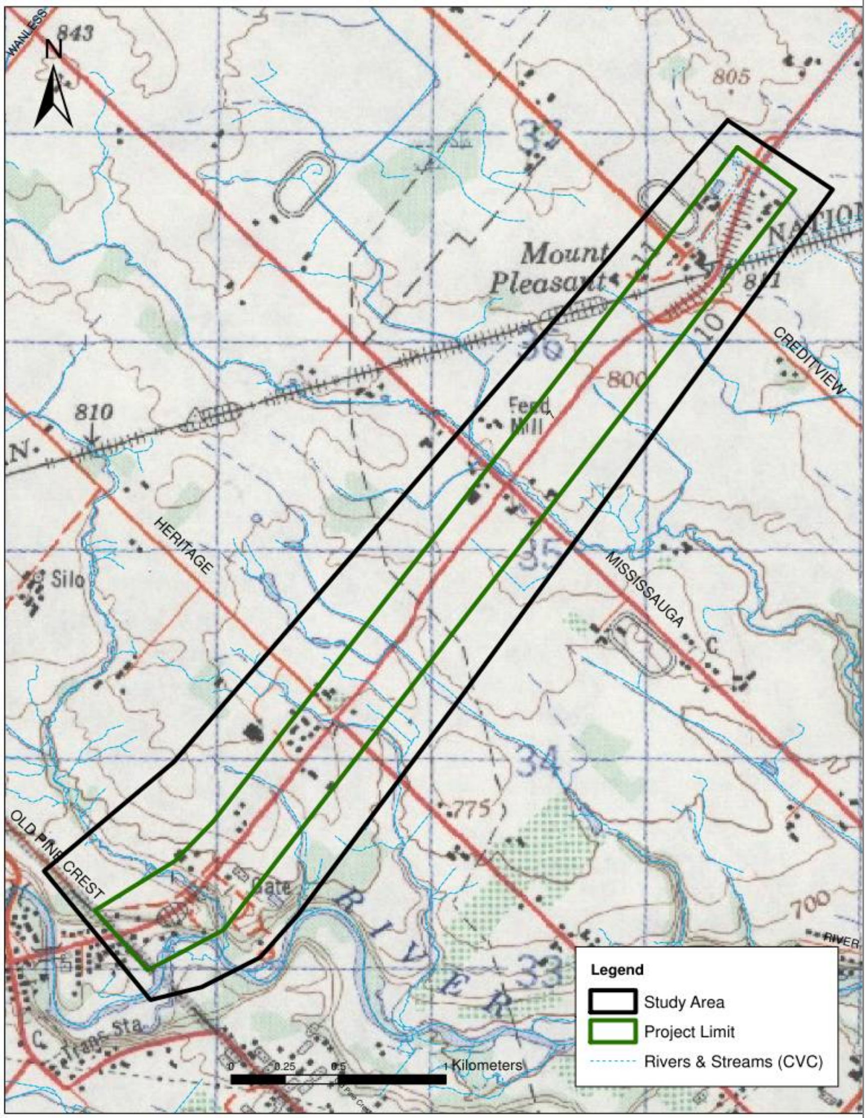

Figure 4.3: 5th Edition Mapping, 1976.

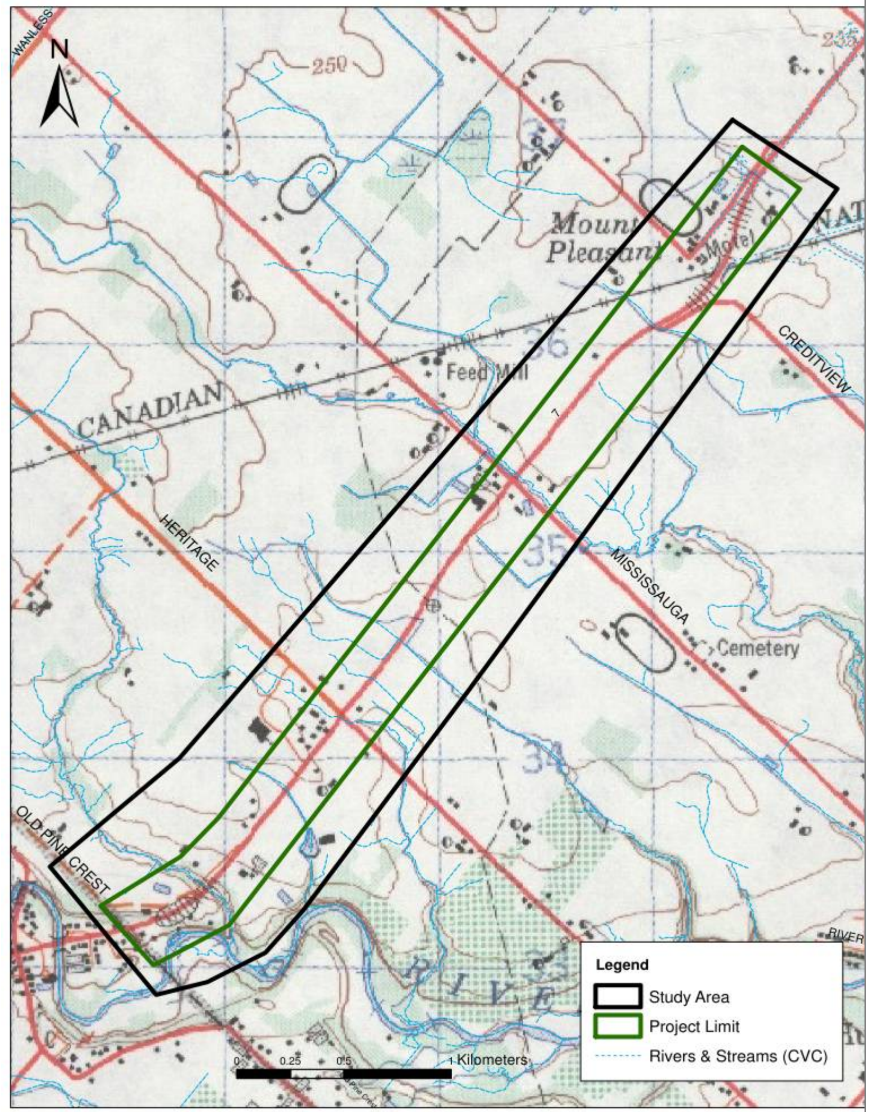

Figure 4.4: 6th Edition Mapping, 1980.

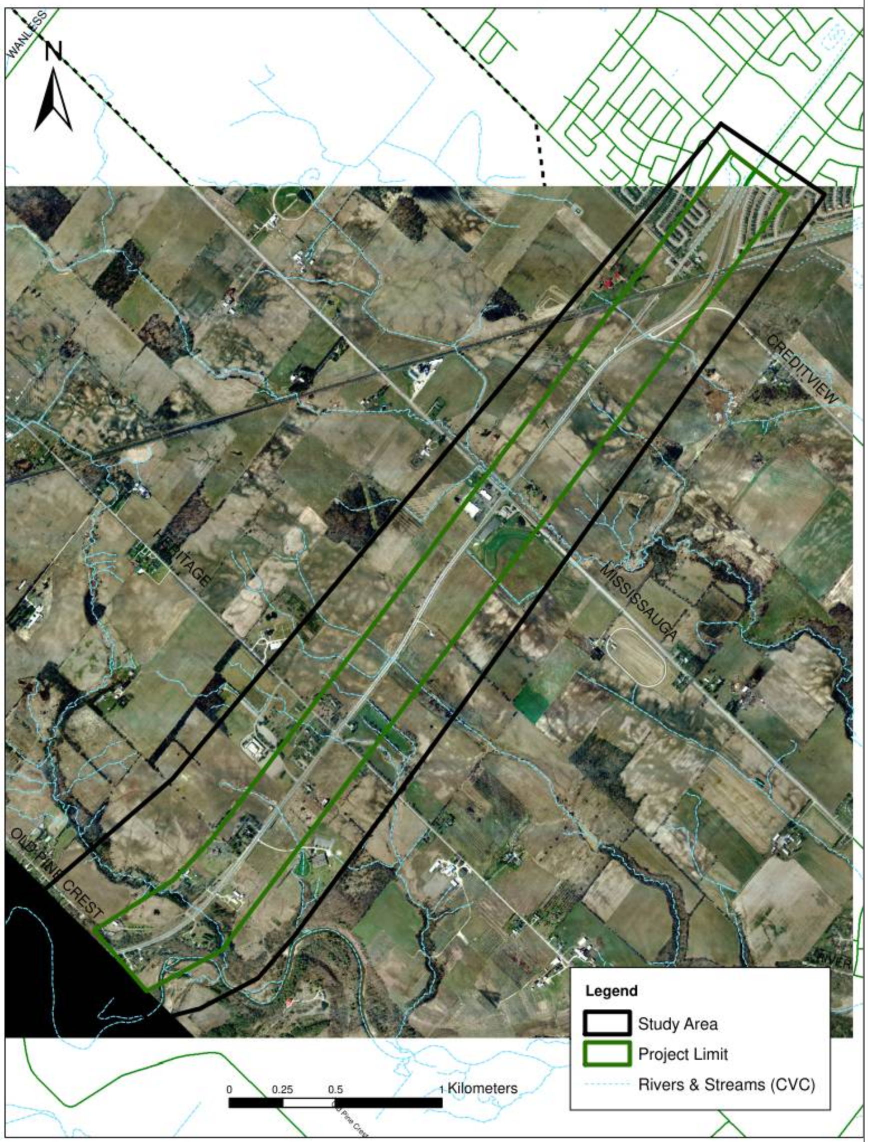

Figure 4.5: Aerial Photography, 2002.

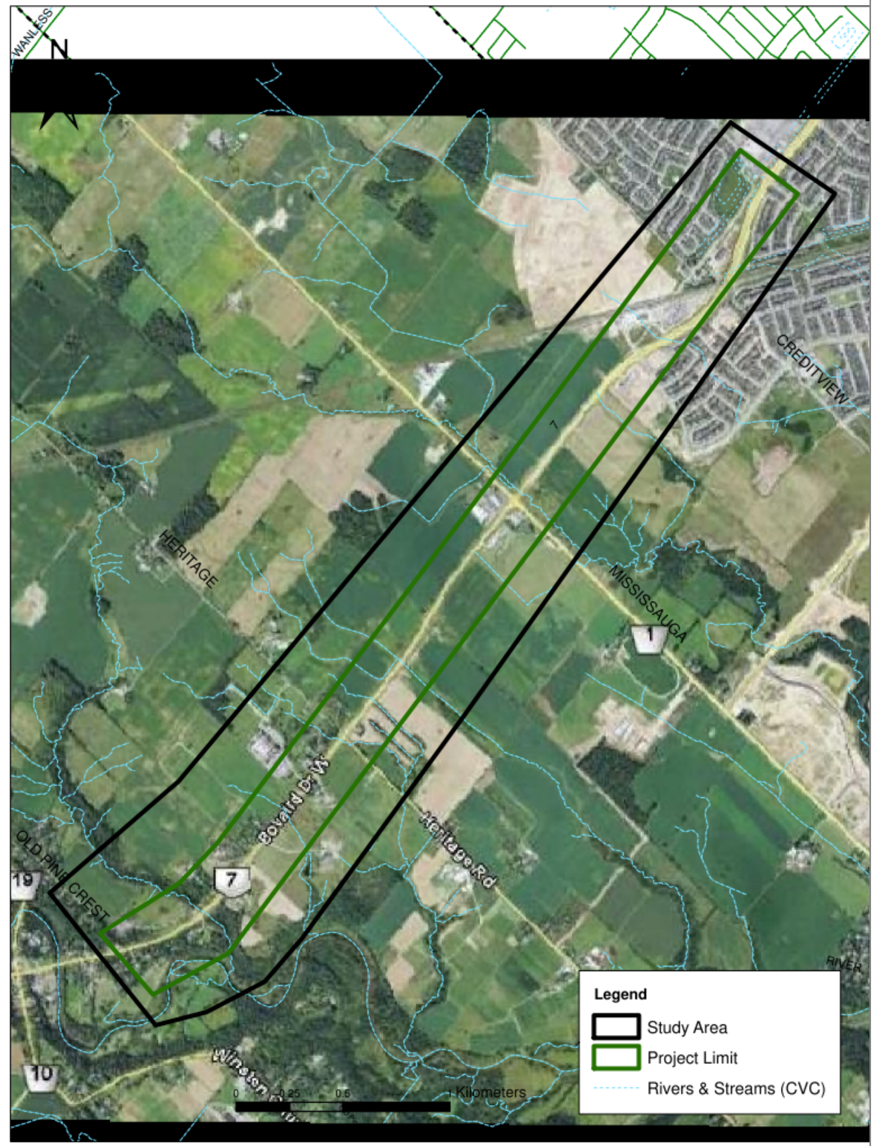

Figure 4.6: Aerial Photography, 2010.

5. Baseline Conditions

5.1 Identification of Crossing Locations

Crossing locations were initially identified from aerial photography together with GIS layers representing rivers and streams (CVC) and regional roads (showing Bovaird Drive). A total of 8 crossings were identified (**Table 5.1**). Please note that, according to the Credit Valley Secondary Plan Environmental Implementation Report (EIR) and Environmental Study Report (ESR) (2005), development will occur at crossing G and the watercourse will not be maintained. Information for crossing G is included in this report to provide as much information as possible for the study area.

Table 5.1: Stream crossings identified along Bovaird Drive.

Crossing No.	Easting	Northing	Associated Reached
A	592923	4833594	BV-A1 & BV-A2
B	593297	4834066	BV-B
C	593554	4834406	BV-C1 & BV-C2
D	593701	4834601	BV-C3 & BV-C4
E	593834	4834776	BV-D2
F	594161	4835298	BV-E
G	594372	4835572	BV-F1 (HV02) & BV-F2
H	594743	4836047	BV-G

5.2 Reach Delineation

Reaches were delineated for all streams crossing Bovaird Drive within the study area. The location of the reaches and stream crossings identified is illustrated in **Figure 5.1**. Additional reach references used in the North West Brampton Subwatershed Study are also shown in **Figure 5.1** to provide context. **Table 5.1** indicates which reaches are associated with which of the stream crossings. It should be noted that whilst some of the reaches are divided at Bovaird Drive, others are not depending on whether there is a change in the geomorphological characteristics or setting of the stream.

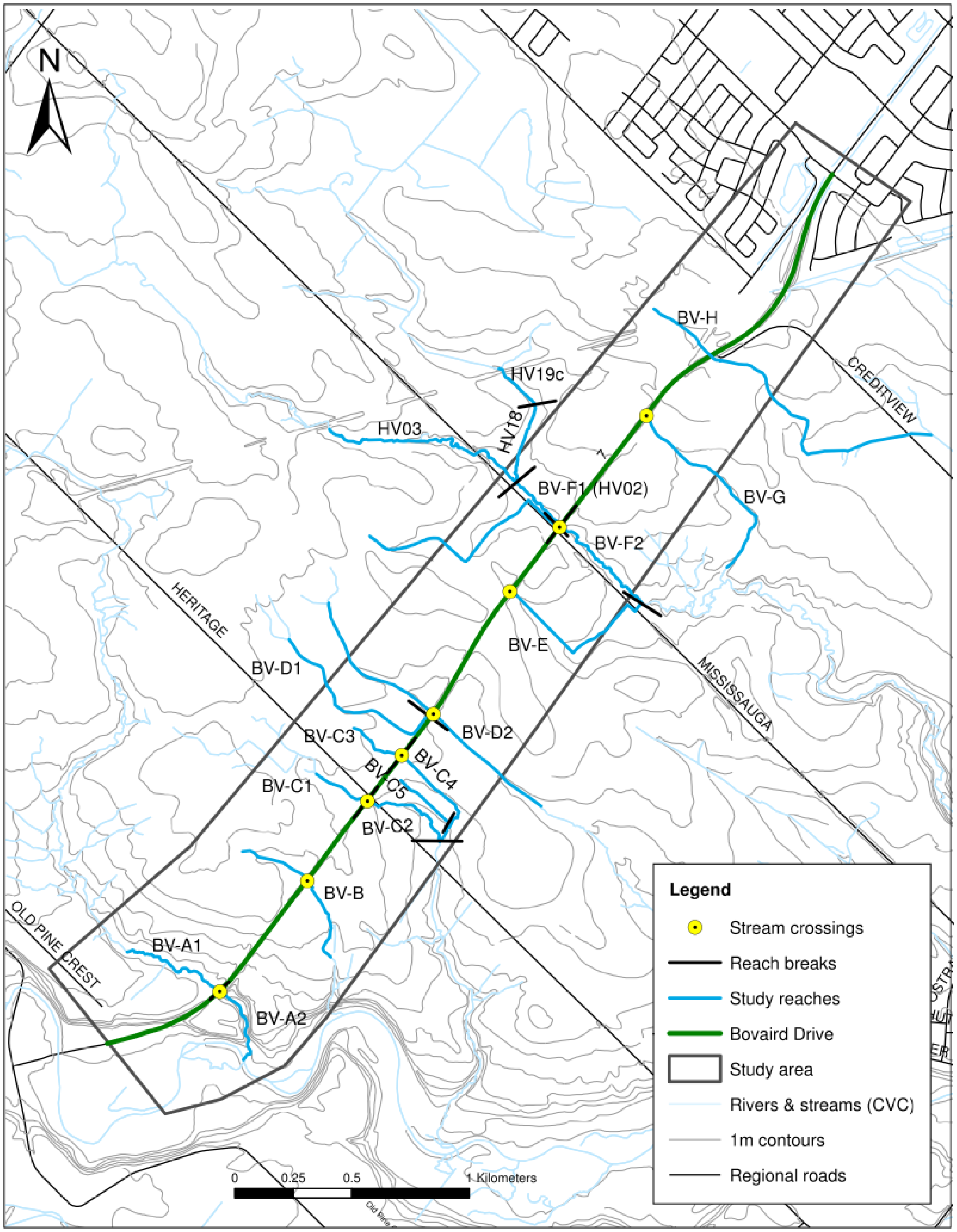

Figure 5.1: Location of Study Reaches and Stream Crossings.

5.3 Meander Belt Width Assessment

A meander belt width assessment was undertaken for the reaches associated with stream crossings along Bovaird Drive, using surrogates as appropriate where reaches have been artificially straightened. A factor of safety of 20% of the preliminary belt width (10% each side) was applied to obtain the final meander belt widths (**Table 5.2**). Where more detailed meander belt width assessment work has already been undertaken (i.e. for Huttonville Creek, see **Section 2.2.2**) this is referenced. However, it is recommended that the meander belt width determined for BV-F2 (Trow, 2006) should be used as a surrogate for BV-F1 (as previously applied within the North West Brampton Subwatershed Study; AMEC et. al, 2007). Although Huttonville Creek has been subject to historical straightening upstream of Bovaird Drive there is no remaining evidence of the original channel (AECOM, 2010). Downstream, however, there are traces of old meanders that were taken into account as part of the BV-F2 meander belt width assessment (Trow, 2006), which therefore provides a better indication of the natural meander belt width for Huttonville Creek.

Figures 5.2 to **5.9 i**llustrate the delineated meander belts for each reach with historic channel planform displayed where possible. Crossings D, E and G do not show historic planform as the channel could not be identified in aerial photographs.

Table 5.2: Meander belt width assessment for reaches crossing Bovaird Drive.

Reach	Stream Crossing	Surrogate (if applicable)	Meander Belt Width (m)	Factor of Safety (10%each side) (m)	Final Belt Width (m)
BV-A1	A	-	40	8	48.0
BV-A2	A	-	14	2.8	16.8
BV-B	B	-	18	3.6	21.6
BV-C1	C	-	18	3.6	21.6
BV-C2	C	-	20	4	24
BV-C3	C’	BV-C1	18	3.6	21.6
BV-C4	C’	BV-C2	20	4	24
BV-D	D	BV-C2	20	4	24
BV-E	E	BV-B	18	3.6	21.6
BV-F1 (HV02)	F	BV-F2	-*	-*	32.8*
BV-F2	F	-	-*	-*	32.8*
BV-G	G	BV-B	18	3.6	21.6
BV-H (developed)	H	-	20†	n/a	20
Outside					
HV03	None	-	-**	-**	39**
HV18	None	BV-F2	-*	-*	32.8*
HV19c	None	BV-F2	-*	-*	32.8*

*See Trow (2006).
** See AECOM (2010) Reach 2.
† Belt Width established in 2012 using historic planform and applied to existing (2009) planform

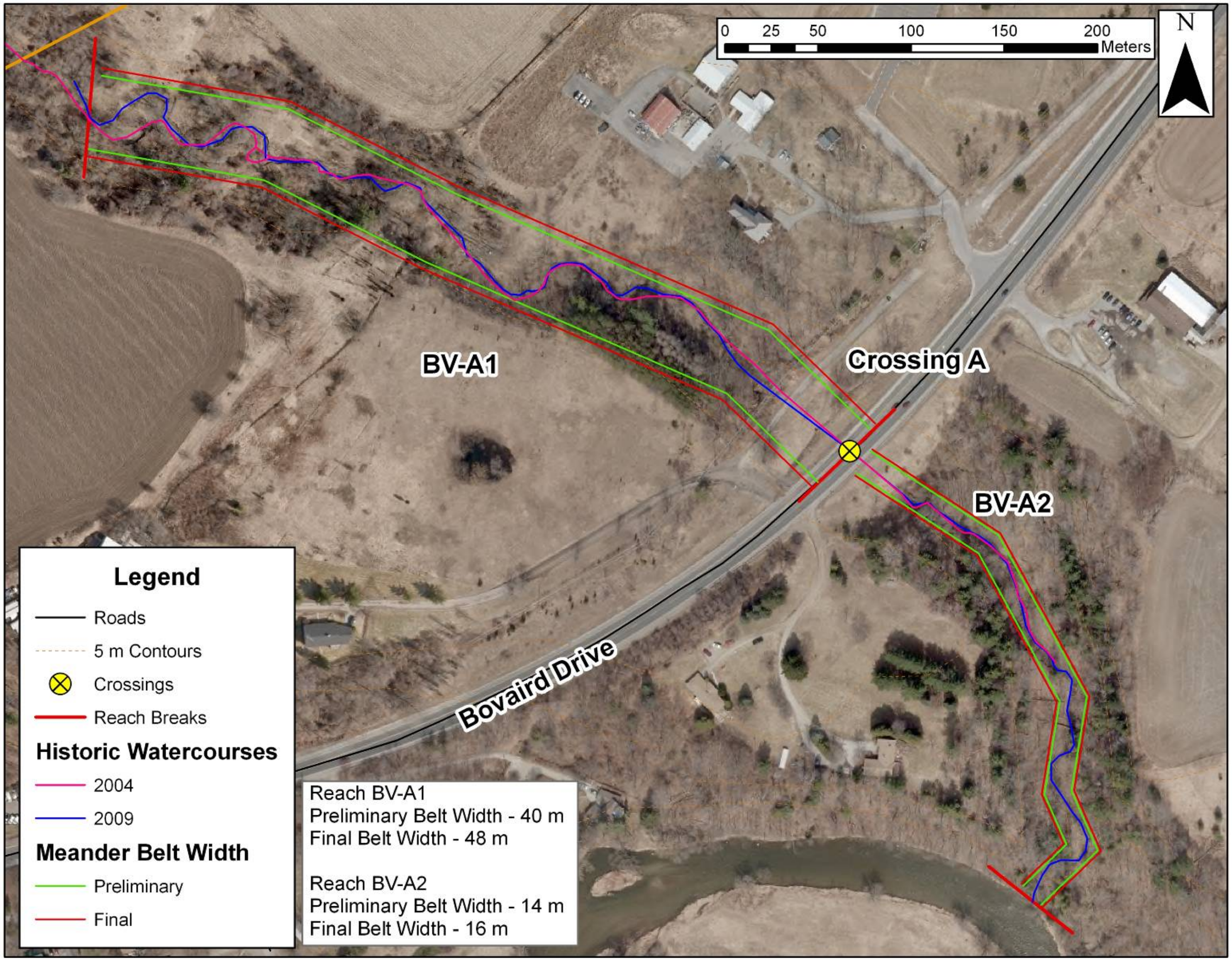

Figure 5.2: Crossing A - Delineated belt widths for reaches BV-A1 and BV-A2.

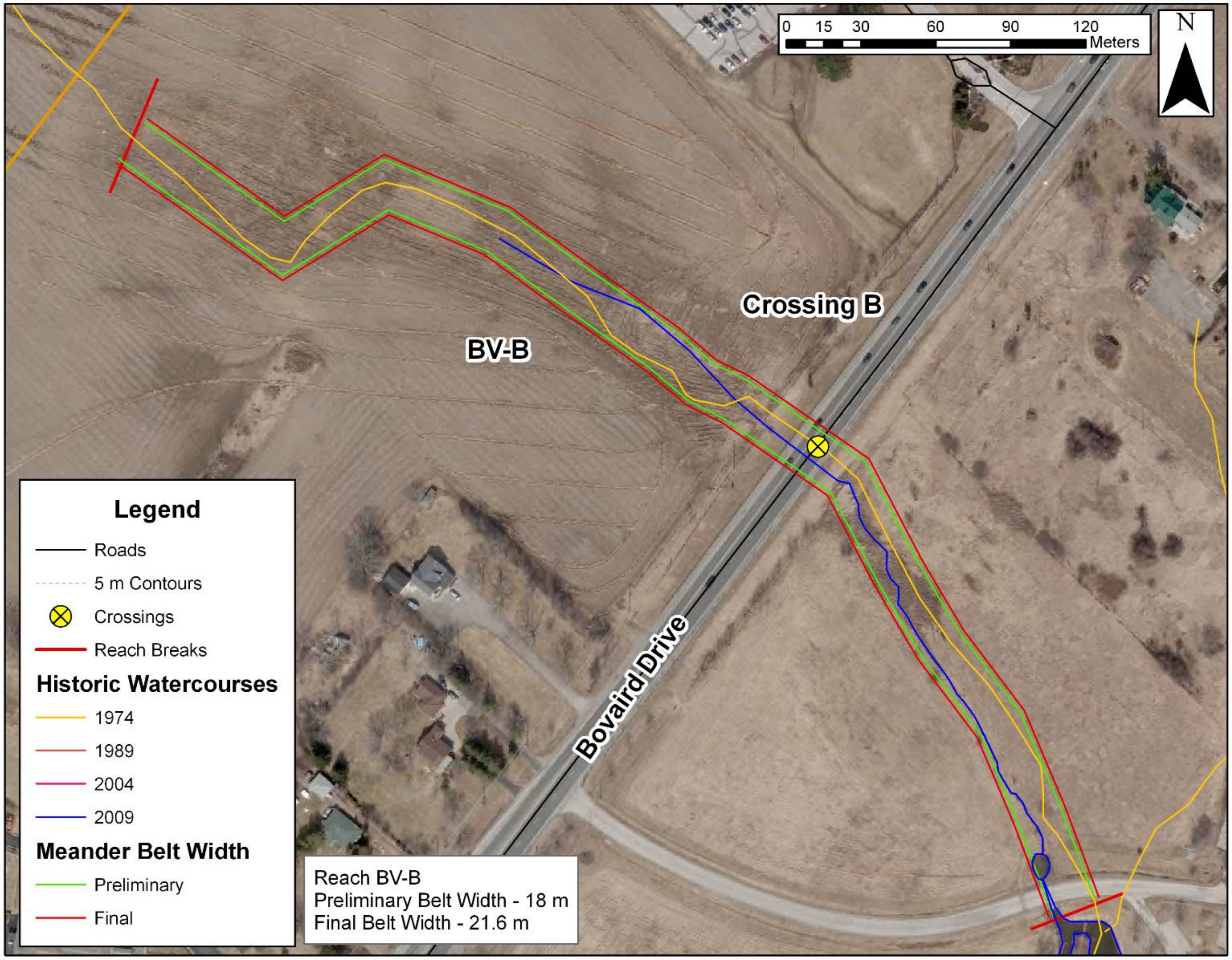

Figure 5.3: Crossing B - Delineated belt width for reach BV-B.

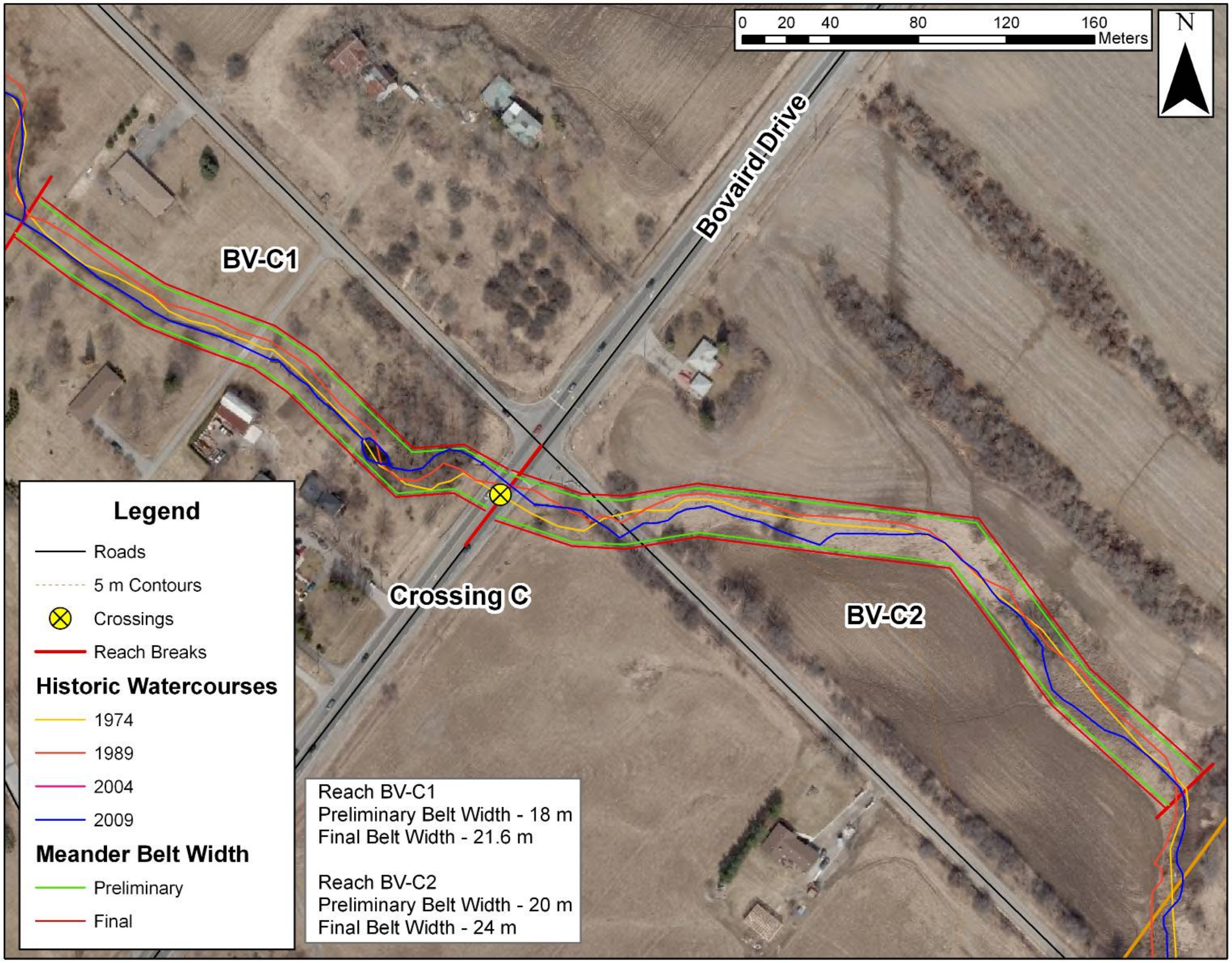

Figure 5.4: Crossing C - Delineated belt widths for reaches BV-C1 and BV-C2.

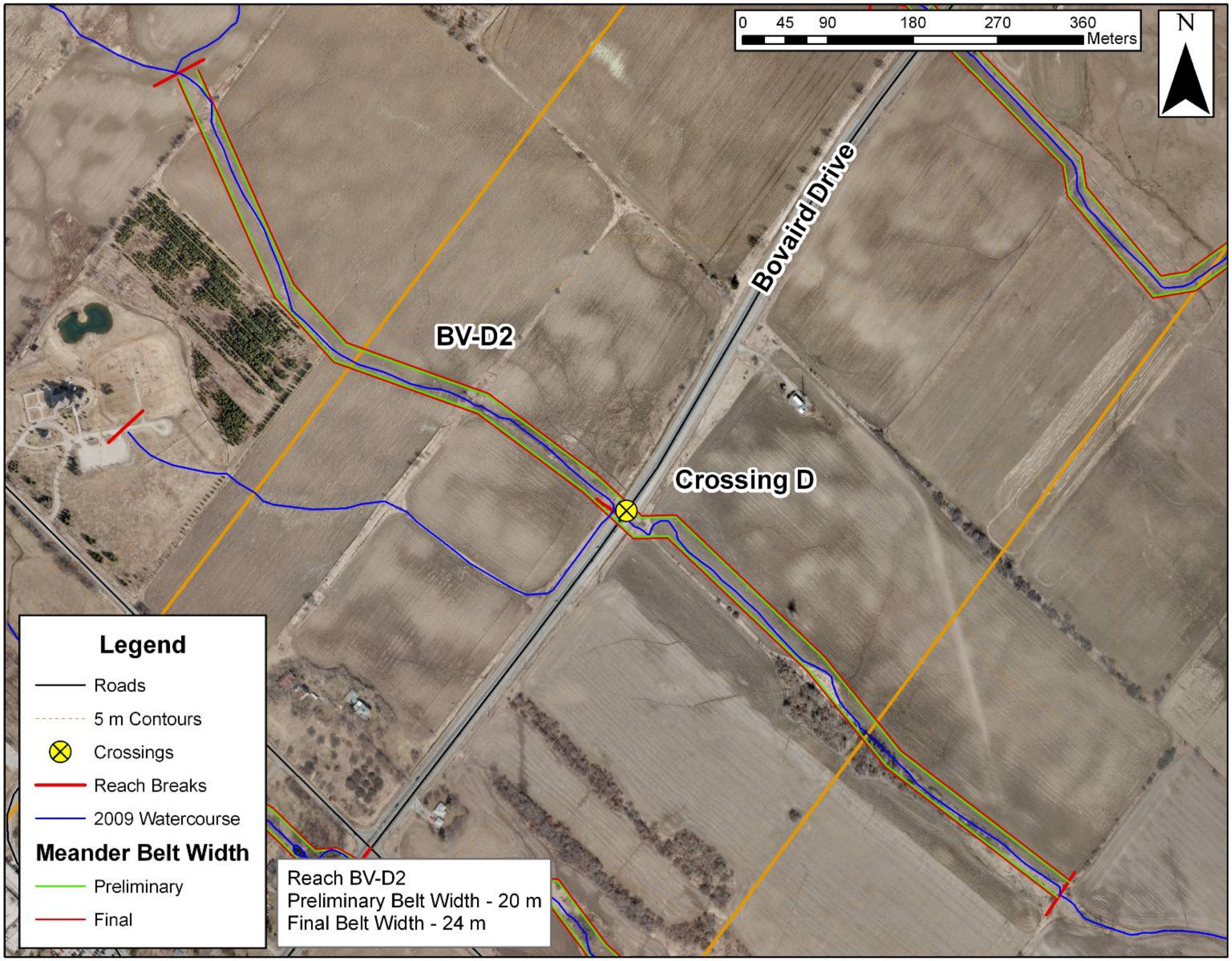

Figure 5.5: Crossing D - Delineated belt width for reach BV-D2.

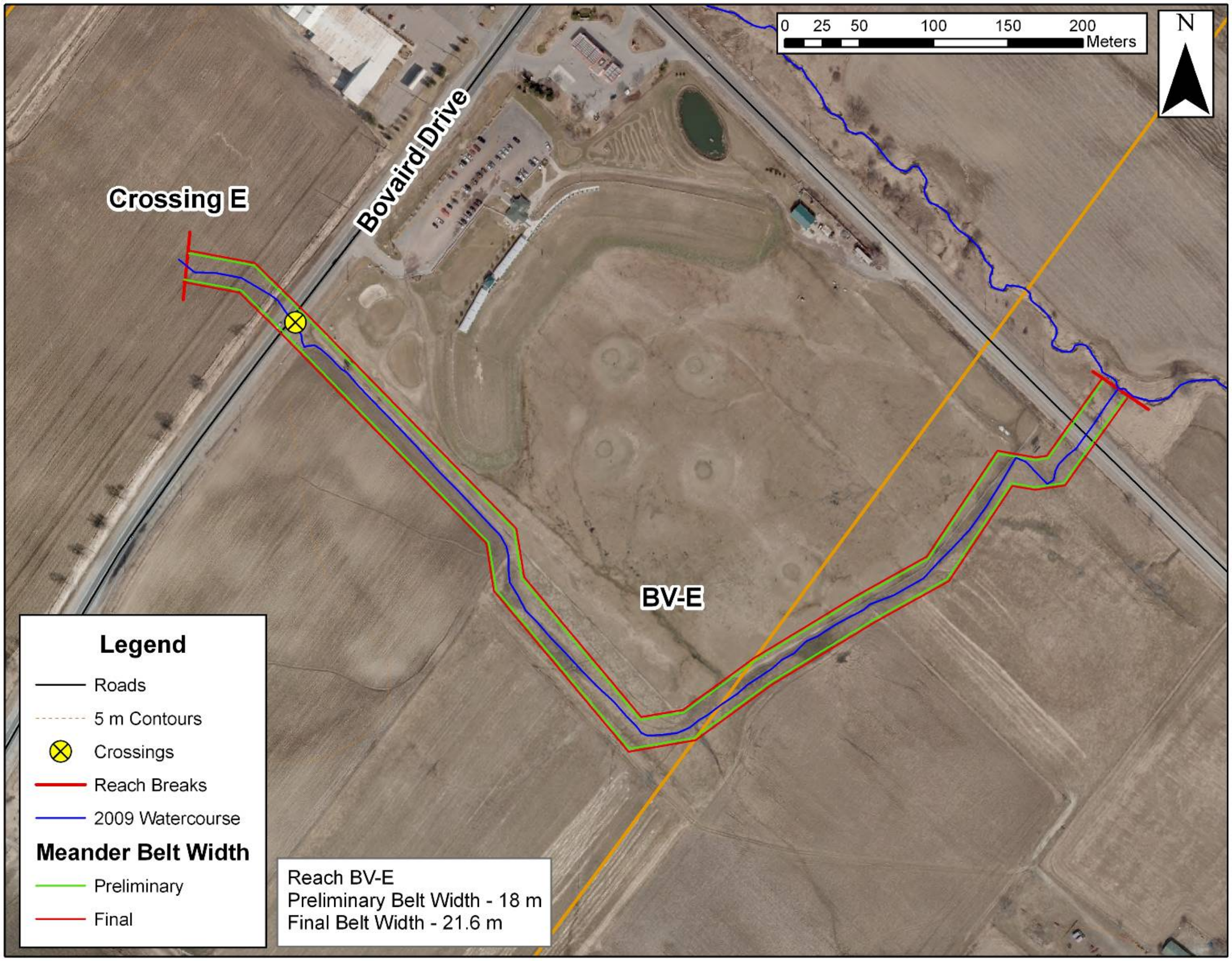

Figure 5.6: Crossing E - Delineated belt width for reach BV-E.

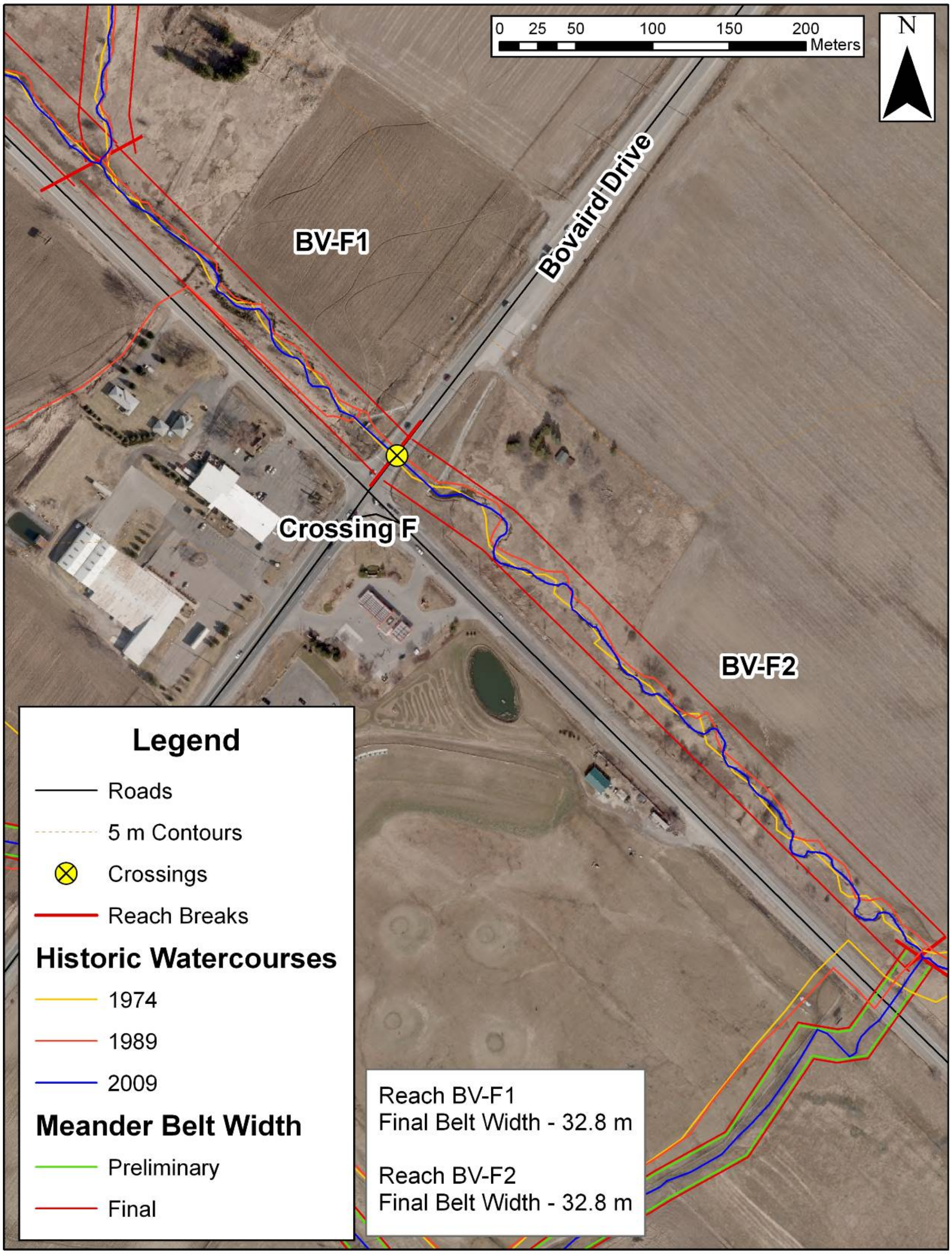

Figure 5.7: Crossing F - Delineated belt width for reaches BV-F1 and BV-F2.

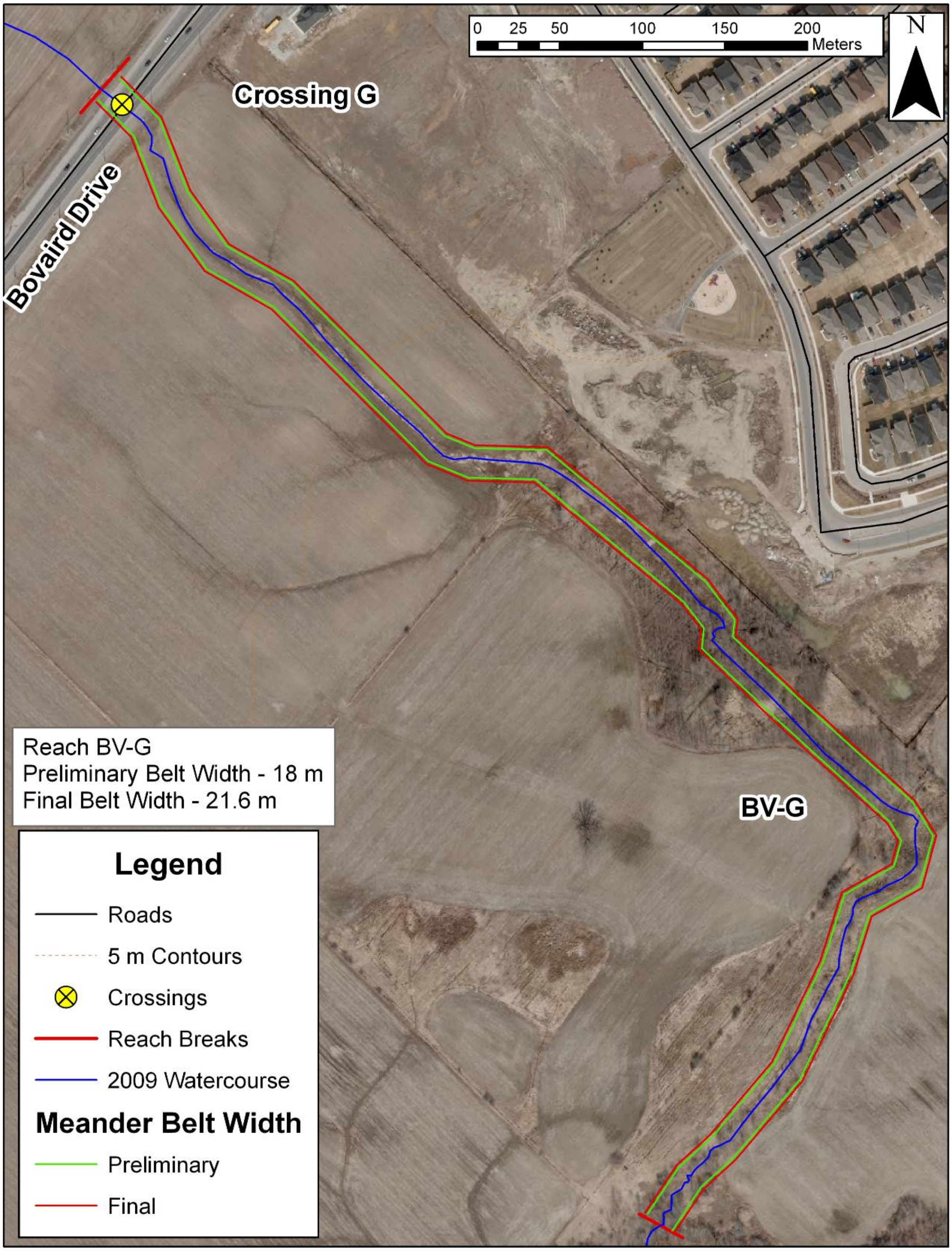

Figure 5.8: Crossing G - Delineated belt width for reach BV-G.

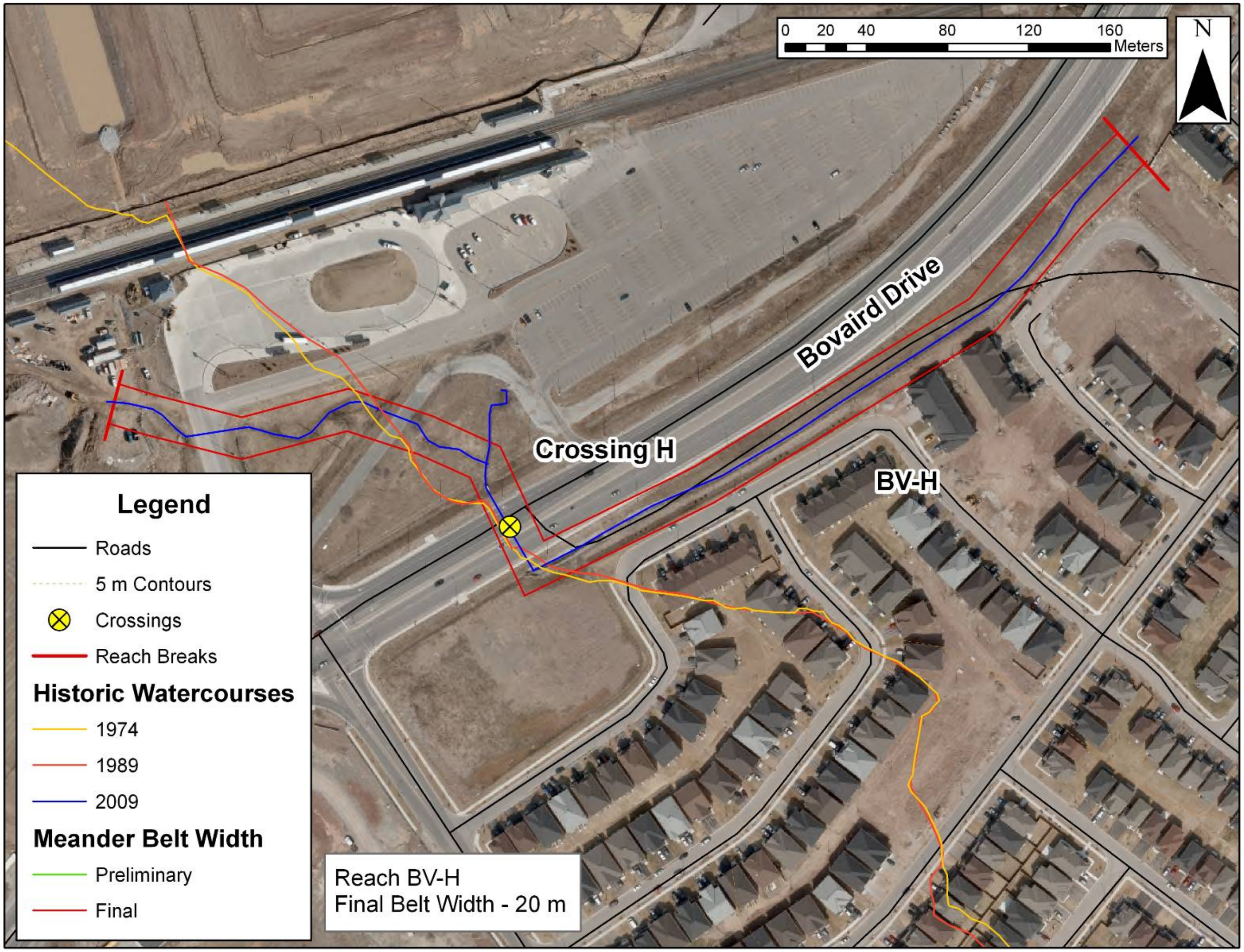

Figure 5.9: Crossing H - Delineated belt width for reach BV-H.

6. Reach Characteristics

In order to provide context for the detailed crossing assessment of crossings A to G, a review of previously collected data is provided below. Additional data collected May 2012 for crossings I and J have been included in the summary tables and the discussion.

6.1 Field Reconnaissance

Three field reconnaissance assessments were undertaken (where possible) to characterize the watercourses within the study are: the Rapid Geomorphic Assessment (RGA), the Rapid Stream Assessment Technique (RSAT), and the Stream Crossing Assessment. The RGA was developed by the Ontario Ministry of the Environment in 1999 and documents evidence of channel instability. The result is an overall score that places the watercourse in one of three categories: "In Regime" (≤ 0.20), "Transitional or Stressed" (0.21-0.40), and "In Adjustment" (≥ 0.41). The RSAT was developed by John Galli at the Metropolitan Washington Council of Governments in 1996 and provides a more qualitative assessment of overall channel health and function. The result of the assessment is a score that is identifies the reach as either of low (<20), moderate (20-35), or high (<35) stream health. In combination with the stream crossing assessment and the meander belt width assessment, the RGA and RSAT provide information that is used to identify an appropriate structure size for the road crossing. The findings of the field reconnaissance surveys have enabled more detailed characterization of the streams and stream crossings associated with Bovaird Drive. In order to provide context for the consideration of their crossings, the characteristics of the streams themselves are considered first.

The Stream Crossing Assessment is utilized to characterize the watercourse in vicinity of the road crossing. Information is gathered on the type, condition, and dimensions of the crossing structure as well as any erosion protection along the embankments. Channel dimensions (i.e. bankfull width and depth, and wetted width and depth) are collected as well as channel gradient and sinuosity upstream and downstream of the crossing. Information regarding evidence of flow restriction, erosion, and scour pools is collected as well as the condition of the road above the crossing structure.

6.1.1 Rapid Geomorphological Assessment

Findings of the Rapid Geomorphological Assessment are summarized in **Table 5.3**. Crossing C' could not be located on the day of field survey.

Table 6.1: Summary of RGA results.

Reac	Crossing	Factor Value				Stability Index	Condition
		Aggradation	Degradation	Widening	Planimetric Adjustment		
BV-A1	A	0.22	0	**0.25**	0.29	0.19	In Regime
BV-A2		0.11	0.57	**0.63**	0.14	0.36	Transitional/Stressed
BV-B	B	**0.33**	0.14	0	0	0.12	In Regime
BV-C1 BV-C2	C	**0.22**	0.14	0	0	0.09	In Regime
BV-C3 BV-C4	C'	Not Assessed					N/A
BV-D	D	0.22	0.14	**0.25**	0	0.15	In Regime
BV-E	E	**0.22**	0.14	0.13	0	0.12	In Regime
BV-F1 BV-F2	F	0.22	0	**0.38**	0.14	0.19	In Regime
BV-G	G	**0.22**	0.14	0	0	0.09	In Regime
BV-H (Developed)	H	**0.5**	0.25	0.11	0.17	0.26	Transitional/Stressed

The reaches associated with Crossing C' were not assessed due to lack of channel definition. Results of the RGA survey indicate that the majority of channels within the study area are in a state of dynamic equilibrium (i.e. are transient as all watercourses are but exhibit a good balance of all processes examined). Downstream of Bovaird Drive, Reach BV-A2 is in a state of transition with widening as the most prominent form of adjustment. Evidence of widening and degradation were observed immediately downstream of the crossing where the channel is over widened and has formed a deep scour pool. Reach BV-H is also in a state of transition as the area has recently undergone development and the channel now drains the GO station parking lot and provides drainage for Bovaird Road. The channel is attempting to re-form and stabilize itself. Reaches associated with crossings B, C, E, and G are experiencing aggradation as the most prominent mode of adjustment; while reaches associated with crossings D and F show evidence of widening as the dominant mode of adjustment. All reaches associated with these six crossings are in regime (i.e. in a state of dynamic equilibrium).

6.1.2 Rapid Stream Assessment Technique

Findings of the Rapid Stream Assessment Technique (RSAT) survey are summarized in **Table 5.4**.

Table 6.2: Summary of RSAT results.

Reach	Crossing	Factor Value						Overall Score	Condition
		Channel stability	Scour / deposition	Instream Habitat	Water Quality	Riparian Condition	Biological Indicators		
Max. Score		**11**	**8**	**8**	**8**	**7**	**8**	**50**	
BV-A1	7	6	5	3.5	4	4	4	26.5	Moderate
BV-A2		5	3.5	4	3.5	4	4	24	Moderate
BV-B	6	Channel definition too limited						N/A	N/A
BV-C1 BV-C2	5a	6.5	4.5	2	2.5	3	3	21.5	Moderate
BV-C3 BV-C4	5b	Not Assessed						N/A	N/A
BV-D	4	7	4	2	2	2	2	19	Low
BV-E	3	8	5	1	2	2.5	2	20.5	Moderate
BV-F1 BV-F2	2	6	4.5	4	2.5	3	4	24	Moderate
BV-G	1	8	5	1	1.5	2	2	19.5	Low
BV-H (developed)	0	7	4	3	2	2	1	19	Low

Findings of the RSAT survey indicate that, although the channels are relatively stable, habitat conditions associated with the streams within the study area are low to moderate. Several of the channels are agricultural swales and lack channel definition, well-developed morphology and in-stream habitat features. Riparian zone conditions and biological indicators are also predominantly poor along these channels. The best habitat conditions are associated with the more permanent watercourses - Huttonville Creek (Crossing F) and the Un-named Tributary to Credit River (Crossing A). However, these channels have also been impacted by channel modification and would also benefit from enhancement.

6.2 Stream Crossing Assessment

Based on the findings of the rapid assessments and stream crossings assessment a summary has been compiled for each crossing, highlighting:

- Key characteristics of the structure,
- Overall stream character
- Issues and disturbances noted during the field reconnaissance survey.

This is considered alongside the meander belt width assessment and rapid assessment data to highlight management considerations.

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
Crossing A 	**Structure** • Pre-cast concrete box culvert, closed bottom, • Dimensions: 1.20m (w) x 2.80m (h) x 65m (l) • Condition : Culvert intact but heavily eroded around the structure downstream, where a scour pool has developed (0.6m deep). **Overall stream character** : • u/s – defined channel in ravine setting with valley wall contact and good pool-riffle sequencing. • d/s – geomorphologically active channel degrading into bedrock. Valley wall contact in ravine setting • Riparian zone 100m, deciduous forest. **Issues / Disturbance:** • Channel width > Opening • Major pooling and erosion downstream • Culvert perched • Concerns regarding fish passage	**BV-A1** **RGA:** In regime **RSAT:** Moderate habitat quality **BV-A2** **RGA:** Transitional **RSAT:** Moderate habitat quality	• Culvert currently does not take into account channel width or the meander belt width and is causing major pooling and erosion downstream. • Key opportunity for improvement through culvert widening and regrading. Some rehabilitation work likely to be required. • Improvement of fish passage.

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
Crossing B  **Upstream looking downstream**	**Structure** • Pre-cast concrete box culvert, closed bottom, • Dimensions: 0.95m (w) x 0.68m (h) x 36m (l) • Condition : Good **Overall stream character** : • u/s – channel undefined, drains road ditch • d/s – undefined within area colonized by cattails. • Riparian zone 30-40m, cattails, dense herbs. **Issues / Disturbance:** • Channel width > Opening • Agricultural practices upstream. • Minor pooling downstream	**BV-B** **RGA:** In regime **RSAT:** Channel definition too limited	• Reduction of the impact of agricultural practices upstream. • Culvert currently does not take into account channel width or the meander belt width and is causing minor pooling.
Crossing C  **Downstream looking upstream**	**Structure** • Pre-cast concrete box culvert with corrugated steel pipe downstream, • Dimensions: u/s 1.30m (w) x 0.90m (h) x 30m (l) d/s 0.5m diameter pipe • Condition : Good **Overall stream character** : • u/s – heavily vegetated with minimal channel definition. • d/s – channel widens with riffle substrate but becomes less defined d/s of Heritage Road crossing. • Riparian zone 15m, herbaceous plants & willow. **Issues / Disturbance:** • Channel width > Opening • Fencing along RHB berm downstream	**BVC1 & C2** **RGA:** In regime **RSAT:** Moderate habitat quality	• Culvert currently does not take into account channel width or the meander belt width.

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
Crossing D  **Upstream looking downstream**	**Structure** • Pre-cast concrete box culvert, open bottom, • Dimensions: 1.25m (w) x 0.80m (h) x 23m (l) • Condition : Good **Overall stream character** : • u/s – agricultural swale • d/s – agricultural swale, • Evidence of some erosion, patches of vegetation in channel. • Riparian zone 10-15m, herbaceous plants. **Issues / Disturbance:** • Channel width > Opening • Minor pooling upstream and downstream	**BV-D** **RGA:** In regime **RSAT:** Low habitat quality	• Reduction of the impact of agricultural practices**.** • Culvert currently does not take into account channel width or the meander belt width and is causing pooling upstream and downstream.
Crossing E  **Downstream looking upstream**	**Structure** • Pre-cast concrete box culvert, open bottom, • Dimensions: 0.90m (w) x 1.10m (h) x 33m (l) • Condition : Good **Overall stream character** : • u/s – agricultural swale • d/s – agricultural swale, bounded by driving range. • Riparian zone 6m, cattails, tall herbs. **Issues / Disturbance:** • Channel width > Opening • Driving range berm and fence	**BV-E** **RGA:** In regime **RSAT:** Moderate habitat quality	• Reduction of the impact of agricultural practices. • Reduction of riparian pressures along the driving range would improve riparian conditions. • Culvert currently does not take into account channel width or the meander belt width.

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
Crossing F  **Upstream looking downstream**	**Structure** • Pre-cast concrete box culvert, open bottom • Dimensions: 5.0m (w) x 1.5m (h) x 60.00m (l) • Condition : Good **Overall stream character** : • Identified as Redside Dace habitat. • u/s defined channel has pool-riffle sequence, bank scouring and channel rehabilitation evident. • d/s large pool (width of culvert) prior to narrowing. • Riparian zone 20-25m, herbaceous plants with trees. **Issues / Disturbance:** • Channel width > Opening • Pooling occurring upstream and downstream, with erosion noted upstream. • Riprap and siltation upstream and through culvert	**BV-F1 & F2** **RGA:** In regime **RSAT:** Moderate habitat quality	• Redside Dace habitat protected under Endangered Species Act. • Culvert currently does not take into account channel width or the meander belt width and is causing erosion and pooling. • Key opportunity for improvement through culvert widening.
Crossing G*  **Upstream looking downstream**	**Structure** • Pre-cast concrete box culvert, closed bottom, • Dimensions: 0.94m (w) x 0.92m (h) x 33m (l) • Condition : Good **Overall stream character** : • u/s – no channel, culvert drains from ditch • d/s – agricultural swale, sections of wetland vegetation where channel becomes undefined. • Riparian zone 5m, herbaceous plants & crops. **Issues / Disturbance:** • Channel width > Opening • Agricultural practices.	**BV-G** **RGA:** In regime **RSAT:** Low habitat quality	• Reduction of the impact of agricultural practices. • Culvert currently does not take into account channel width or the meander belt width.

Crossing and Photograph	Description	RGA / RSAT	Management Considerations
Crossing H  **Upstream looking downstream**	**Structure** • Pre-cast concrete box culvert with corrugated steel pipe downstream, • Dimensions: u/s 0.94 (w) x 0.92m (h) x 30m (l) d/s 0.9 m diameter pipe • Condition: Good, **Overall stream character** : • u/s – defined channel for 100 m u/s that becomes undefined • d/s – channel is road side ditch with cattails growing in stream. • Riparian zone 250 m at u/s end, herbaceous plants and cattails; d/s 5 m, herbaceous plants, grasses and cattails. **Issues / Disturbance:** • Channel width > Opening • Channel drains GO station parking lot and Bovaird Drive.	**BV-H** **RGA:** Transitional **RSAT:** Low habitat quality	• Mitigation for surface runoff from GO station parking lot would improve channel conditions • Culvert currently does not take into account channel width or the meander belt width .

*** Note that crossing G will not be retained following development of the area – Credit Valley Secondary Plan – EIR and ESR**

7. Detailed Risk-based Crossing Assessment

This section provides a detailed analysis of reach characteristics (excluding Huttonville Creek, which was assessed previously in the February 2011 final report) in vicinity of Bovaird Drive within the study area. In order to provide recommendations regarding structure sizes from a geomorphic perspective, a risk-based methodology is typically applied. A detailed description of the risk-based approach is provided in the February 2011 Final Report (PARISH Geomorphic Ltd., 2011) and is briefly summarized in this section.

The risk assessment process involves analysis of six parameters:

- Channel Size
- Valley Setting
- Meander Belt Width
- Meander Amplitude
- Rapid Geomorphic Assessment (RGA)
- 100-year Migration Rates

Analysis of channel condition, migration tendencies and trends, existing planform, and valley configuration leads to the selection of an appropriate structure size from a geomorphic perspective. The risk-based procedure is outlined visually in **Figure 4.1**. Two primary factors must be considered from a geomorphic perspective when evaluating and recommending crossing structures: potential for channel migration/erosion; and incision. These two risk factors are affected by the following structure design parameters:

1. Channel migration/erosion (lateral instability)
   a) Length
   b) Span
   c) Skew
2. Channel incision (vertical instability)
   a) Invert (footing or bed)
   b) Length

Each crossing (i.e. A to E, G and H) is assessed in detail using the risk-based procedure in **Section 4.1**. Crossing recommendations and justification for the suggested span are also provided in this section.

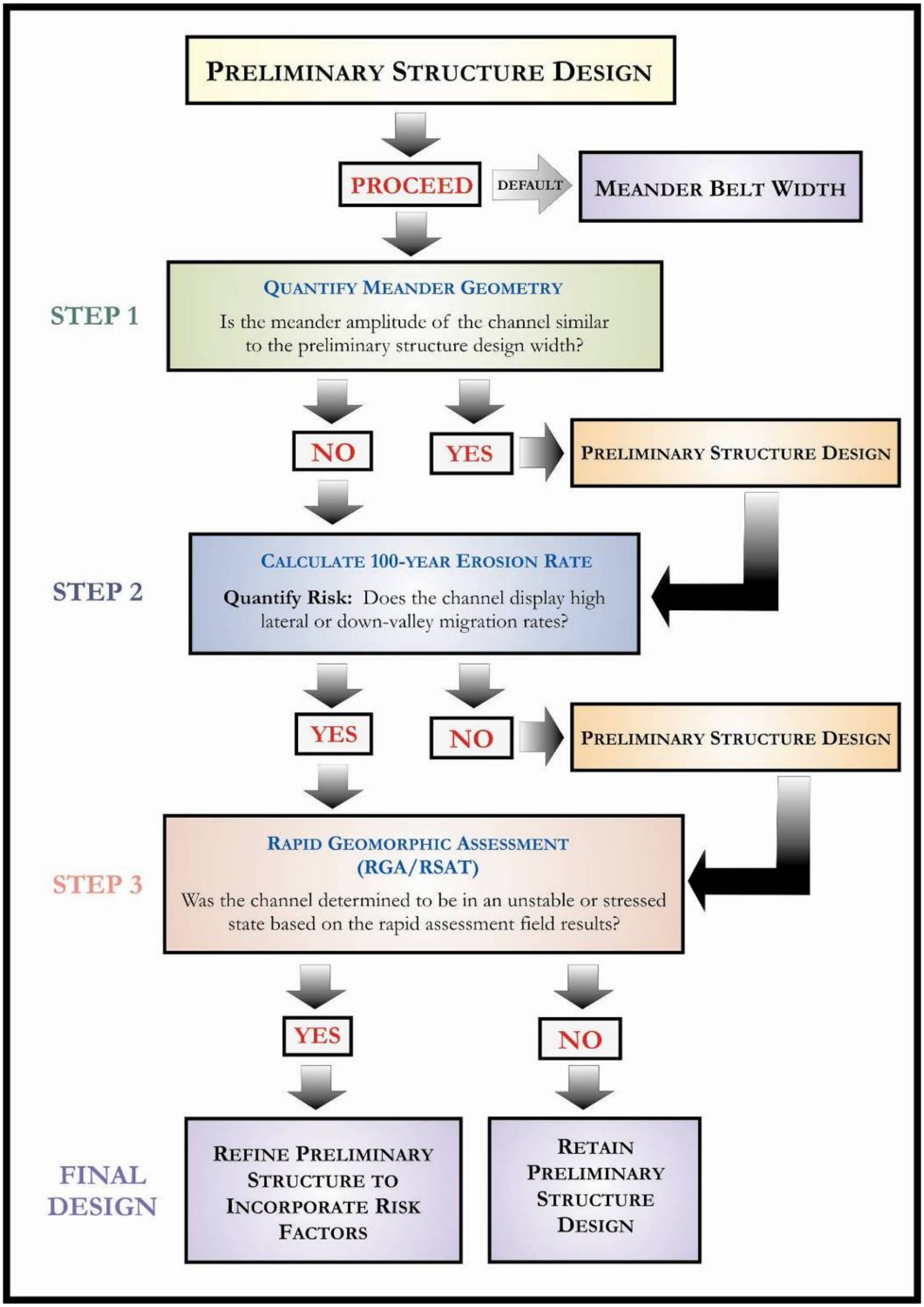

Figure 7.1: Geomorphic risk-based assessment protocol for crossing recommendations.

7.1 Crossing A

7.1.1 Characteristics of Reaches BV-A1 and BV-A2

Channel Size: Upstream of Bovarid Drive, bankfull width ranges from 2.5 to 6.0 m. Immediately downstream of the crossing, the bankfull width measures 8.5 m, becoming narrower further downstream. The channel is overwidened downstream of the crossing due to major erosion and pooling and is therefore wider than the culvert opening.

Valley Setting: Reach BV-A1 (upstream of Bovaird) flows through an unconfined setting. The downstream reach, BV-A2 flows within a partially confined setting with valley wall contacts along the 300 m length.

Meander Belt Width: Belt widths were previously established through the February 2011 Final report and are discussed in **Section 5**. Reach BV-A1 has a preliminary meander belt width of 40 m, 48.0 m with a 10% factor of safety, due to the large meander amplitudes and planform visible in the 2009 ortho photography. The downstream reach, BV-A2 has a smaller meander belt width of 16.8 m as the channel is much straighter and is more confined.

Meander Amplitude: Meander amplitude was measured upstream of the crossing on two meander bends; 16 m, at 208 m upstream of the culvert; and 10 m, at 100 m upstream of the culvert.

RGA Score: The upstream reach, BV-A1, has an RGA score of 0.19, indicating the reach is in a state of dynamic equilibrium and is "In Regime". Planform adjustment was identified as being the most prominent form of adjustment, with the formation of chutes and islands observed in the field. Reach BV-A2, downstream, has an RGA score of 0.36, which indicates that the reach is "Transitional/Stressed". Widening was identified as the most prominent form of adjustment with degradation as the secondary mode of adjustment. Fallen and leaning trees, large organic debris, and basal scour through more than 50% of the reach were observed as evidence of widening. Degradation was observed through channel incision into the undisturbed bedrock, headcutting due to knick point migration, elevated tree roots and a suspended armour layer visible in the bank.

100-year Migration Rates: Aerial photographs for the historic assessment were limited for Crossing A, and therefore 100-year migration rates could not be accurately assessed.

7.1.2 Recommendations for Crossing A

The existing culvert at crossing A is 1.2 m wide by 2.8 m high. Upstream of Bovarid Drive, a catchbasin drains a road side ditch and empties into the culvert, adding additional flow and exacerbating erosion downstream. Upstream and downstream of Bovaird Drive the bankfull widths are larger than the existing culvert. During high flow events, water is forced through the narrow opening, increasing velocities and causing a large scour pool to form at the downstream end. It is recommended that the existing crossing structure be replaced and widened in order to, at minimum, convey the bankfull flow and to minimize potential impacts on stream morphology. The recommended preliminary structure size of 10 m is based

on meander amplitudes measured in vicinity of the crossing at the upstream end. A 2 m factor of safety was deemed appropriate, as discussed below, resulting in a final recommended structure size of 12 m.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-A1 and BV-A2, the crossing would need to be 40 m wide. However, from a geomorphic perspective, it is more critical that the structure accommodate the meander geometry in vicinity of the crossing.

- Conservative estimates of meander amplitude were measured from 2009 orthophotography provided by the Credit River Conservation Authority. The meander bend closest to the crossing was measured at 10 m, 100 m upstream of Bovaird Drive. This represents the minimum required structure size from a geomorphic perspective in order to ensure that the crossing can accommodate the existing meander geometry of the channel

- Available historic aerial photography was not extensive enough to provide an accurate measure of the 100-year migration rates. Therefore, field observations of existing conditions and the rapid assessments were analyzed to determine a recommended structure size. Evidence of planform adjustment was noted upstream of Bovaird Drive and widening and degradation were noted downstream. As it is clear the channel is attempting to adjust and modify its current planform and dimensions, the application of a factor of safety was deemed appropriate to minimize future risk to the crossing structure.

Using a risk-based approach, the recommended structure size for Crossing A was evaluated from a geomorphic perspective. Based on the meander amplitude measured upstream of the crossing, a preliminary structure size of 10 m was identified. An examination of the channel size and rapid assessment results, in particular the RGA scores which identified widening and planform adjustment as the dominant modes of adjustment, a 2 m factor of safety was applied. The result is a recommended span of 12 m, which is sufficient to support the long-term form and function of the channel and minimize risk to the crossing structure from fluvial processes. Specifically this refers to a culvert that is set at an optimal skew of 90 degrees to the meander axis, applied to the existing channel alignment.

Table 7.1: Geomorphic parameters and recommended structure size for Crossing A.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-A1 Upstream	40	N/A	10*	6.0 At crossing	Unconfined	0.19 In Regime (low)	12.0 m
BV-A2 Downstream	14	N/A	--	8.5 At crossing	Partially Confined	0.36 Transitional/Stresses (moderate)	

*** Governing meander amplitude in vicinity of the crossing**

7.2 Crossing B

7.2.1 Characteristics of Reach BV-B

Channel Size: Bankfull widths in vicinity of the crossing are undefined as the channel drains an agricultural field and Bovaird Drive.. However wetted widths upstream and downstream of Bovaird Drive are 1.0 m.

Valley Setting: The channel flows within an unconfined valley setting.

Meander Belt Width: The preliminary meander belt width established in the February 2011 Final Report for reach BV-B is 18 m. With a 10% factor of safety added to each side of the belt width, the final meander belt is 21.6 m.

Meander Amplitude: Due to the undefined nature of the channel, meander amplitudes upstream of the crossing could not be obtained. However, an amplitude of 3.6 m was measured 17 m downstream of the crossing.

RGA Score: The RGA score determined for reach BV-B is 0.12, indicating the channel is in a state of dynamic equilibrium. Aggradation was found to be the most prominent mode of adjustment with evidence observed through the poor sorting of bed material, a soft, unconsolidated bed, and deposition occurring in and around structures.

100-year Migration Rates: An examination of the 1974, 2004, and 2009 aerial photography revealed that the channel continues to be ploughed over, through the agricultural field upstream. The 1974 air photo shows that the downstream reach was once ploughed through as well. The 2004 and 2009 aerial images reveal that the channel now flows through scrub vegetation. However, migration rates could not be calculated between 2004 and 2009 due to the lack of channel definition.

7.2.2 Recommendations for Crossing B

The existing culvert at Crossing B is 0.95 m wide by 0.68 m high. Currently, wetted widths upstream and downstream of the crossing are wider than the structure causing minor pooling to occur. The existing structure is performing well, however minor pooling and wetted widths larger than the culvert are of concern. It is recommended that that existing structure be replaced with a 2.5 m structure.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-B, the crossing would need to be 18 m wide. It is more critical, from a geomorphic perspective, that the structure accommodates the meander geometry in vicinity of the crossing.

- Meander amplitudes could not be calculated as the channel is undefined and flows through agricultural fields, as well as drains a road side ditch. Wetted widths in vicinity of the crossing are 0.95 m to 1.0 m.

- An examination of historic aerial photographs revealed that the channel is ploughed through on a regular basis. Due to this modification, 100-year migration rates could not be calculated. Therefore field observations, rapid assessment results, and channel size were analyzed to determined a recommended structure.

A risk-based approach was followed for crossing B in order to recommend an appropriate crossing structure form a fluvial geomorphic perspective. Based on evidence of minor pooling, and wetted widths that are wider than the existing crossing, a 2.5 m structure is recommended for crossing B. This structure size will allow for channel flow to be conveyed effectively while providing a factor of safety should the channel become more defined and contain higher flows in the future. Specifically, this refers to a structure that is set at an optimal skew of 90 degrees to the meander axis and is applied to the existing channel alignment.

Table 7.2: Geomorphic parameters and recommended structure size for Crossing B.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-B	18	N/A	3.6 m Downstream	1.0 Wetted width	Unconfined	0.11 In Regime (low)	2.5 m

7.3 Crossing C

7.3.1 Characteristics of Reaches BV-C1 and BV-C2

Channel Size: Upstream and downstream of Bovaird Drive bankfull widths are 1.5 m. Approximately 40.0 m downstream of Bovaird Drive the channel widens out to 2.6 m immediately upstream of Heritage Road.

Valley Setting: Reach BV-C1, upstream of Bovaird Drive, flows through an unconfined valley setting. Downstream, through reach BV-C2, the channel is partially confined by Bovaird Drive and Heritage Road embankments.

Meander Belt Width: The preliminary belt width for reach BV-C1 is 18 m, 21.6 m with a factor of safety added to either side. Downstream of Bovaird Drive the preliminary belt width is slightly wider at 20.0 m due to the wider, more defined channel. The 10% factor of safety results in a final meander belt of 24.0 m.

Meander Amplitude: A meander amplitude of 2.3 m was measured 29.0 m upstream of the crossing. Downstream of the crossing a meander amplitude of 4.2 m was measured 93 m from the culvert. Amplitudes are less than the meander belt width due to historic alterations to the channel.

RGA Score: The RGA score for crossing C is 0.09 and is in a state of dynamic equilibrium. Aggradation was noted as the most dominant form of adjustment with observations of mid-channel bars, and poor longitudinal sorting of bed materials.

100-year Migration Rates: Due to alterations on channel planform and changes to culvert locations along Bovaird Drive and Heritage Road, 100-year migration rates could not be calculated.

7.3.2 Recommendations for Crossing C

The existing crossing structure at crossing C consists of a 1.3 m wide and 0.9 m high box culvert at the upstream end and a 0.5 m diameter CSP in the downstream end. Upstream, the bankfull channel is slightly wider than the crossing structure. Currently the crossing appears to convey flows well with little evidence of pooling or erosion occurring upstream or downstream. However, in order to provide a geomorphologically functional structure, it is recommended that the current crossing be replaced. Based on meander amplitudes measured upstream of the crossing a minimum of 2.3 m is required from a geomorphic perspective.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-C1 and BV-C2, the crossing would need to be 20 m wide. However, from a geomorphic perspective, it is more critical that the structure accommodate the meander geometry in vicinity of the crossing.

- Meander amplitudes were conservatively estimated from 2009 orthophotography (provided by CVC). A 2.3 m amplitude was measured approximately 30 m upstream of the existing culvert. This represents the minimum required structure size from a geomorphic perspective in order to ensure that the crossing can accommodate the existing meander geometry of the channel

- Historic aerial photography from 1974, 1989, and 2009 was reviewed for crossing C. The channel was straightened prior to 1974 and altered as Bovaird Drive and Heritage Road were constructed. The location of the crossing structure appears to have changed between 1989 and 2009. Due to these alterations 100-year migrations rates could not be accurately measured. Therefore, field observations of existing conditions and rapid assessment results were analyzed to determine a recommended structure size. RGA scores indicated that BV-C1 and BV-C2 are in a state of dynamic equilibrium with aggradation noted as the dominant form of adjustment. The bankfull channel widens out further downstream before flowing beneath Heritage Road. For this reason, a factor of safety was deemed appropriate in order to maintain the integrity of the crossing structure into the future.

A risk-based approach was applied in order to recommend a geomorphologically appropriate crossing structure for crossing C. Based on the meander amplitudes measured approximately 30 m upstream of the existing culvert, a preliminary structure size of 2.3 m was identified. An examination of the channel size, RGA results and existing channel conditions, a 0.7 m factor of safety was applied. The result is a recommended span of 3.0 m, which is sufficient to support the long-term form and function of the channel, as well as minimize future risk to the structure. Specifically this refers to a culvert that is set at an optimal skew of 90 degrees to the meander axis, applied to the existing channel alignment.

Table 7.3: Geomorphic parameters and recommended structure size for Crossing C.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-C1 Upstream	21.6	N/A	2.3 m*	1.5 m at crossing	Unconfined	0.09 In Regime (low)	3.0 m
BV-C2 Downstream	24	N/A	--	1.5 m at crossing	Partially Confined	0.09 In Regime (low)	

*** Governing meander amplitude in vicinity of the crossing**

7.4 Crossing D

7.4.1 Characteristics of Reaches BV-D1 and BV-D2

Channel Size: The bankfull width for reaches BV-D1 and BV-D2 is 0.9 to 1.0 m. At crossing D, wetted widths at the upstream end are 1.3 to 1.5 m, while the downstream end is 1.5 m. The channel drains agricultural fields upstream and downstream of Bovaird Drive.

Valley Setting: Reaches BV-D1 and BV-D2 are situated within an unconfined valley setting.

Meander Belt Width: A surrogate was applied in order to determine the belt width for crossing D as the channel has been artificially straightened through agricultural fields. The belt width for reach BV-C2 was applied for reaches BV-D1 and BV-D2. The preliminary belt width is 20 m and with a 10% factor of safety applied to either side, the final belt width is 24 m.

Meander Amplitude: Due to the straightened and altered nature of the channel, the closest meander bend to the crossing is 150 m upstream. The meander amplitude at this bend is 4.0 m.

RGA Score: The RGA score for reaches BV-D1 and BV-D2 is 0.15 and "In Regime". Widening was found to be the most prominent mode of adjustment. Evidence of widening was observed through steep bank angles and basal scour through more than 50% of the reach length.

100-year Migration Rates: 100-year migration rates could not be calculated for reaches BV-D1 and BV-D2 due to the historically straightened planform.

7.4.2 Recommendations for Crossing D

Currently, the crossing structure at crossing D is 1.25 m wide and 0.80 m high, which is larger than the measured bankfull width for reaches BV-D1 and BV-D2. Minor pooling and erosion are occurring immediately upstream and downstream of the crossing structure resulting in wetted widths 1.3 to 1.5 m. It is therefore recommended that the crossing structure be replaced and widened in order to prevent further exacerbation of erosion and pooling at the upstream and downstream end, and to ensure conveyance of the watercourse. The recommended structure size of 6 m , six times the average bankfull width, was deemed appropriate to convey the watercourse.

Applying the Risk-based Approach

- The preliminary meander belt width for BV-D1 and BV-D2 is 20 m, which would result in a 20 m wide crossing structure. It is more important, from a geomorphic perspective, that the structure accommodates the meander geometry in vicinity of the crossing. .

- The watercourse is fairly straight and provides drainage for the agricultural fields upstream and downstream of Bovaird Drive. The meander amplitude of a bend located 150 m upstream of the

crossing was measured at 4.0 m. Due to the nature of the channel and the distance of this bend from the crossing, the risk of migration of the bend into the crossing is low.

- Available historic aerial photographs reveal that the watercourse has been ploughed through since 1974. A planform is clearly visible in all aerial images; however, due to the modified nature of the channel 100-year migration rates could not be accurately calculated.

Crossing D was evaluated from a geomorphic perspective using a risk-based approach. An examination of RGA results indicated that widening was the most dominate form of adjustment with basal scour occurring through more than 50% of the reach. Consideration of the channel size, along with the RGA scores, has resulted in a recommended span of 6.0 m, which is sufficient to support the long-term form and function of the channel and minimize risk to the crossing structure from fluvial processes. Specifically this refers to a culvert that is set at an optimal skew of 90 degrees to the meander axis, applied to the existing channel alignment.

Table 7.4: Geomorphic parameters and recommended structure size for Crossing D.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-D Upstream	20	N/A	4.0	0.9-1.0	Unconfined	0.15 In Regime (low)	6.0 m

7.5 Crossing E

7.5.1 Characteristics of Reach BV-E

Channel Size: The bankfull width for reach BV-E is 0.6 m. Upstream of the crossing the channel is densely vegetated with grasses, cattails, and wild flowers. A bankfull width could not be determined upstream of Bovaird.

Valley Setting: The channel is set within an unconfined valley setting but is partially confined in the downstream end where it flows adjacent to a fence.

Meander Belt Width: A surrogate was applied in order to determine the belt width for crossing E as the channel has been artificially straightened through agricultural fields. The belt width for reach BV-B was applied for reach BV-E. The preliminary belt width is 18 m with a 10% factor of safety applied to either side, the final belt width is 21.6 m.

Meander Amplitude: Due to the lack of channel definition upstream of Bovaird Drive and the straightened channel at the downstream end, meander amplitudes could not be measured for crossing E.

RGA Score: Results of the RGA reveal that the reach is in a state of dynamic equilibrium with a score of 0.12. Aggradation is the most dominant mode of adjustment through reach BV-E with deposition occurring around structures and poor longitudinal sorting of bed materials.

100-year Migration Rates: Due to the undefined nature of the channel upstream of Bovaird Drive and the historically straightened channel, 100-year migration rates could not be calculated for reach BV-E.

7.5.2 Recommendations for Crossing E

The existing structure at crossing E is 0.9 m wide and 1.10 m high, which is larger than the measured bankfull width for reach BV-E. No evidence was found of pooling or erosion upstream or downstream of the crossing and the reach is “In Regime” with some evidence of aggradation noted. The existing structure seems to be conveying channel flow well.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-E, the crossing would need to be 18 m wide. However, from a geomorphic perspective, it is more imporatnat that the structure accommodate the meander geometry in vicinity of the crossing.

- Due to the lack of channel definition upstream and the straightened channel downstream, meander amplitudes could not be measured.

- Analysis of the historic aerial photographs revealed that reach BV-E was straightened prior to the earliest image taken in 1974. Little to no channel migration has occurred over the historic period. However, the channel appears to have been artificially moved further west between 1989 and 2009. Accurate 100-year migration rates could not be calculated due to the historic alteration of this reach.

Using a risk-based approach, crossing E was evaluated from a geomorphic perspective in order to recommend an appropriate crossing structure. Bankfull widths were measured in the field and found to be smaller than the existing crossing structure. No evidence of pooling or erosion was observed upstream and downstream of Bovaird Drive. The existing structure seems to convey channel flow well. However, it is recommended that the current structure be replaced with a 1.2 m culvert to ensure the long-term integrity of the structure. This refers to a structure that is set at an optimal skew of 90 degrees to the meander axis and is applied to the existing channel alignment.

Table 7.5: Geomorphic parameters and recommended structure size for Crossing E.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-E Upstream	18.0	N/A	N/A	0.6	Partially confined by a fence d/s of crossing	0.12 In Regime (low)	1.2 m

7.6 Crossing F

7.7 Characteristics of Reach BV-F1 and BV-F2: Huttonville Creek

Channel Size: The channel upstream and downstream of the crossing has a bankfull width of approximately 3.5m based on conservative field estimation (a width which concurs with the findings for Reach BV-F1. The channel is slightly wider upstream of the culvert due to erosion and pooling - the channel width was thus recorded as larger than the existing culvert width (5m) at the crossing site itself.

Valley Setting: Huttonville Creek flows within a broad poorly defined valley that is slightly incised into the till plain.

Meander Belt Width: The meander belt width previously established through detailed assessment of Reach BV-F2 (downstream of the crossing) is 32.8m (Trow, 2006). For reasons discussed in the draft report for this project this meander belt width is also a suitable surrogate for the reach upstream (Parish Geomorphic, October 2010).

Meander Amplitude: Meander amplitudes upstream of the existing culvert crossing are smaller than the meander belt width as a result of historical straightening of this section of Huttonville Creek. The amplitude of meanders upstream of the crossing is no more than 9m.

RGA Score: The RGA score recorded for the reach in 2010 was 0.19 indicating that the channel is on the upper side of the “In regime” category. Channel widening was the dominant geomorphological process occurring as indicated by exposed tree roots, steep bank angles and basal scour.

100-year Migration Rate: 100-year migration rates have previously reported as summarized in **Table 6.1**.

Table 7.6: 100-yr migration rates calculated at for Huttonville Creek

Reach	Average 100-yr lateral erosion rate (m)	Average 100-yr downstream erosion (m)	Source
BV-F1 (Upstream)	6	14	AECOM (2010)
BV-F2 (Downstream)	8.9	Not calculated	Trow (2006)

It is notable that active meander migration appears to have occurred immediately upstream of the crossing between 1982 and 2004, although this meander did not form part of the original assessment (Figure 1 in AECOM, 2010). The shift of this meander was 3.5m between 1982 and 2004, giving a lateral migration rate of 0.16m per year over this period, although there was negligible movement between 1961 and 1982. The rate of migration between 1961 and 2004 is therefore 0.08m or 8m over 100 years, which when taken into account brings the average migration rate to 8m. This meander has now reached an amplitude of 9m, similar to that of other meanders upstream.

7.7.1 Recommendations for Crossing F

The existing culvert under Bovaird Drive is approximately 5m wide. This width is wider than the reach-average bankfull channel width of 3.5m but is narrower than the bankfull channel width at the crossing itself, where backwater conditions during peak events have resulted in localized over-widening of the channel. This indicates a lack of crossing capacity and it is therefore recommended that the replacement structure be wider to minimize any potential impacts on stream morphology.

Applying the Risk-based Approach

- By default, in order to accommodate the full meander belt width of the reach, the crossing would need to be 32.8m wide. From a geomorphic perspective, however, it is more critical that the structure accommodate the localized meander geometry in vicinity of the crossing.

- Based on conservative measurements taken from digital aerial photography of the study area, the governing meander amplitude immediately upstream of the crossing measures 9m. As such, this represents the minimum required structure size from a geomorphic perspective in order to ensure that the crossing can accommodate the existing meander geometry of the channel.

- Based on the combined consideration of 100-year migration rates and field observations of existing conditions made through the rapid assessment phase, this site was deemed low risk from an erosion/channel migration perspective. However, evidence of channel widening was noted at the time of survey and the current planning context does anticipate urban development of lands to the north. With this in mind, an additional factor of safety would benefit the channel and minimize future risk to the structure.

Using a risk based approach, the recommended structure size for the Bovaird Drive crossing of Huttonville Creek was evaluated from a geomorphic perspective. Based on the governing meander amplitude in vicinity of the structure, a preliminary crossing size of 9 m was identified. While 100-year migration rates were in the range of 8m (moderate risk), rapid assessment results indicated the channel is currently stable, although it does show evidence of widening. With this in mind, an additional factor of safety was applied, resulting in a recommended span of 14.6 m. This span is sufficient to support the long-term form and function of the channel. Specifically, this span refers to an open-bottom culvert that is set at an optimal skew (90 degrees) to the meander axis and is applicable to the current channel alignment.

Table 7.7: Geomorphic parameters and recommended structure size for Huttonville Creek.

Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
32.8	8.0 (Moderate)	9*	3.5	Unconfined	0.19 (Stable - low)	14.6 m

* Governing meander amplitude in vicinity of the crossing

7.8 Crossing G

Please note that according to the Credit Valley Secondary Plan – Environmental Implementation Report and Environmental Study Report development is to occur at crossing G and the watercourse will not be retained. The information below is included so that a complete assessment is provided for the study area.

7.8.1 Characteristics of Reach BV-G

Channel Size: The bankfull width for reach BV-G is 0.4-1.0 m. Upstream of Bovaird Drive the channel is undefined agricultural and road side drainage and was dry at the time of the field survey. Downstream of the crossing the channel has a defined bed and banks for approximately 100 m before loosing definition as it flows through dense vegetation between fields.

Valley Setting: Reach BV-G is situated within an unconfined valley setting.

Meander Belt Width: A surrogate was applied in order to provide an effective meander belt width for reach BV-G. The preliminary belt width is 18 m, and with a 10% factor of safety applied to either side, the final belt width is 21.6 m.

Meander Amplitude: Upstream of Bovaird Drive, the watercourse is a roadside ditch with no sinuosity. As a result, meander amplitude was measured downstream of the crossing. A meander amplitude of 5.1 m was measured approximately 20 m downstream of the crossing.

RGA Score: Results of the RGA survey indicate that the reach is in a state of dynamic equilibrium, with a score of 0.09. Aggradation was determined to be the most prominent mode of adjustment with deposition occurring around structures and poor longitudinal sorting of bed materials through the reach.

100-year Migration Rates: The reach has been historically altered as it flows through an agricultural field downstream of the crossing. 100-year migration rates could not be measured and calculated due to these alterations.

7.8.2 Recommendations for Crossing G

Currently, the structure at crossing G is 0.94 m wide by 0.92 m high. The measured bankfull widths for reach BV-G range from 0.4 m to 1.0 m. No evidence of pooling or erosion was noted upstream or downstream of Bovaird Drive and the reach is “In Regime” with some evidence of aggradation noted. In general, the existing structure appears to convey flow well.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-G, the crossing would need to be 18 m wide. However, from a geomorphic perspective, it is more important that the structure accommodate the meander geometry in vicinity of the crossing.

- Due to channel form upstream of the crossing (i.e. a road side ditch), meander amplitude was measured downstream. A single bend was found approximately 20 m downstream with an amplitude of 5.1 m.

- Historic photographs revealed that reach BV-G was straightened prior to the earliest photograph in 1974. The channel appears to have been artificially shifted to the east between 1989 and 2009. Due to the lack of natural channel processes occurring within the reach 100-year migration rates could not be calculated.

A risk-based approach was applied to evaluate crossing G from a geomorphic perspective, in order to recommend an appropriate crossing structure. Bankfull widths in vicinity of the crossing were measured in the field and found to be less than the crossing width. Approximately 50 m downstream of the crossing the channel widens out to 1.0 m. No evidence of pooling or erosion was observed upstream or downstream of Bovaird Drive, and the existing structure appears to convey channel flow well. In order to ensure the long-term integrity of the structure and allow the channel to shift and migrate through the crossing, it is recommended that the current structure be replaced with a larger structure. A 3.0 m sulvert will allow natural fluvial processes to occur within the crossing. This refers to a structure that is set at an optimal skew of 90 degrees to the meander axis and is applied to the existing channel alignment.

Table 7.8: Geomorphic parameters and recommended structure size for Crossing G.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-G Upstream	18.0	N/A	5.1*	0.4-1.0	Unconfined	0.09 In Regime (low)	3.0 m

*** Governing meander amplitude in vicinity of the crossing**

7.9 Crossing H

7.9.1 Characteristics of Reach BV-H

Channel Size: Bankfull width upstream of Bovaird Road was between 0.8 m to 1.0 m, while bankfull widths downstream ranged from 2.5m to 3.0 m. The upstream end drains the GO station parking lot and bus terminal as well as Bovaird Road. Channel form is present and well defined for approximately 100 m. Downstream the channel drains Bovaird Road and is a roadside ditch with several outfalls along its length.

Valley Setting: Reach BV-H is set within an unconfined valley. However the upstream end is confined on all sides by road embankments, and the downstream end is confined on the north side by a road embankment and on the south side by development.

Meander Belt Width: A meander belt width was not previously established due to the highly developed nature of the channel. However, based on an evaluation of historic channel planform from 1974 and 1989, a preliminary meander belt width of 20 m is appropriate.

Meander Amplitude: Approximately 40 m upstream of the crossing, a meander amplitude of 5.5 m was measured on the 2009 orthophotography provided by the CVC.

RGA Score: Reach BV-H was surveyed in 2012 and was determined to be in a state of transition with a score of 0.26. Aggradation was noted as the dominant form of adjustment with siltation in pools, deposition in the overbank zone, and poor longitudinal sorting of bed materials observed.

100-year Migration Rates: An examination of historic aerial photos revealed that reach BV-H was straightened prior to the earliest available photograph (i.e. 1974). Between 1989 and 2009, the channel was significantly altered to provide drainage for Bovaird Road and the GO station parking lot and terminal. Due to these alterations 100-year migration rates could not be calculated.

7.9.2 Recommendations for Crossing H

The existing structure at crossing H is composed of a 0.94 m wide by 0.92 m high box culvert at the upstream end and a 0.9 m diameter CSP at the downstream end. Measured bankfull widths are larger than the current structure and minor pooling and erosion were noted both upstream and downstream of the crossing. It is recommended that the crossing structures be replaced with a single box culvert of 4.0 m in order to improve the geomorphic function of the watercourse and to convey flow appropriately through the crossing.

Applying the Risk-based Approach

- In order to accommodate the meander belt width for reach BV-H, the crossing would need to be 20 m wide. From a geomorphic perspective, however, it is more critical that the crossing accommodate local meander geometry in vicinity of the structure.

- Reach BV-H provides drainage for the GO station parking lot and bus terminal as well as Bovaird Drive resulting in a highly modified channel planform. A meander bend was measured approximately 40 m upstream and was 5.5 m wide.
- An evaluation of the historic record indicated that the channel was straightened and modified prior to the earliest available aerial photograph and as such 100-year migration rates could not be calculated.

In order to provide a recommended structure size, a risk-based procedure was applied and crossing H was evaluated from a geomorphic perspective. Bankfull widths in vicinity of the crossing are larger than the structure width and minor pooling and erosion were noted. A recommended structure size of 4.0 m was based on bankfull widths and the measured meander amplitude upstream of the crossing. A single structure is recommended rather than the current combination of a box culvert and CSP in order to enhance flow conditions within the culvert. A larger culvert will ensure the future integrity of the structure and allow for natural fluvial processes to occur in and around the structure. These recommendations refer to a structure that is set at an optimal skew of 90 degrees to the meander axis and is applied to the existing channel alignment.

Table 7.9: Geomorphic parameters and recommended structure size for Crossing H.

Reach	Preliminary Meander Belt Width (m)	100-Year Migration Rates (Risk)	Meander Amplitude (m)	Bankfull Width (m)	Valley Setting	RGA Score (Risk)	Recommended Structure Size (m)
BV-G Upstream	20.0	N/A	5.5*	0.8-1.0 Upstream 2.5-3.0 Downstream	Confined by Road embankments	0.26 Transitional/Stressed (moderate)	4.0 m

*** Governing meander amplitude in vicinity of the crossing**

8. Conclusions

A fluvial geomorphological assessment has been conducted involving the following:

- Historic assessment including historic mapping and aerial photos from 1974, 1989, and 2009
- Reach delineation
- Identification of stream crossing locations
- Meander belt width assessment
- Field reconnaissance
- A risk-based assessment of the watercourse crossings.

The streams and the crossings along Bovaird Drive have been characterized and key management considerations highlighted. Many of the streams are swale features which are impacted by agricultural activities. There are also two well defined streams at Crossing F (Huttonville Creek) and Crossing A (Un-named Tributary to Credit River). These streams warrant specific consideration as they have well-defined channel and morphology, are actively adjusting, and are of greater habitat value. Please note that according to the Credit Valley Secondary Plan – Environmental Implementation Report and Environmental Study Report development will occur at crossing G and the watercourse will not be retained.

The following summarizes the key findings:

- In all cases, the existing crossings at Bovaird Drive do not accommodate the bankfull channel width or the meander belt width and widening the culvert would be of benefit to stream connectivity.

- At Crossing A the dominant processes are widening and degradation. The existing culvert is perched, may limit fish passage, and is associated with significant downstream erosion. Widening and regrading the exit to the culvert would be of benefit.

- At Crossing B, D, E, G and H the dominant process is aggradation. The majority of channels are agricultural swales and drainage, with the exception of the channel at crossing H, which drains the GO station parking lot at the upstream end and Bovaird Drive at the downstream end. All watercourse crossings would benefit from a wider area of conveyance.

- At Crossing D the dominant process is widening, however the RGA score is low and the channel is “In Regime”. Evidence of some erosion is present in vicinity of the crossing. The channel would benefit from a wider corridor in which to convey flow.

- At Crossing F the dominant processes are widening and aggradation. There is existing pooling upstream and downstream of the culvert with erosion also noted upstream. The stream has also been identified as Redside Dace habitat which is protected under the Endangered Species Act

(2007). Widening of the culvert would benefit the reach. A width of at least 14.6 m is recommended.

9. References

City of Brampton (2005) Credit Valley Secondary Plan – Environmental Implementation Report and Environmental Study Report.

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Websites

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