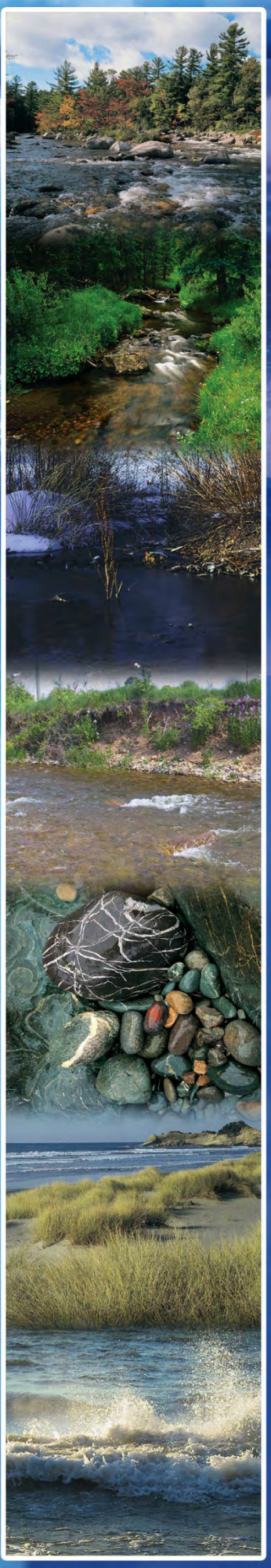

water's edge
ENVIRONMENTAL SOLUTIONS TEAM LTD.

Huntingdon Road
Vaughan, ON

Fluvial Geomorphological Assessment and Meander Beltwidth Assessment

August 21, 2017

August 21, 2017
WE 14017

Mr. Saad A. Syed, MBA, M.A.Sc., P.Eng., PMP
Parsons Corporation,
625 Cochrane Drive, Markham, ON
L3R 9R9

Dear Mr. Syed:

RE: Huntingdon Road, Region of York, ON
Fluvial Geomorphological Assessment and Meander Beltwidth Assessment

Water's Edge was authorized by Delcan Corporation (now a Parsons company) to complete a fluvial assessment and natural channel designs for eleven stream crossings of Rainbow Creek on Huntingdon Road, in the Region of York.

We have completed our assessment of the creek in accordance with the approved project Terms of Reference. Data sources for the analysis include:

- Aerial Photography for 1970, 1978, 1999, 2002, 2005, 2007, 2011, 2012, 2013, 2014 and 2015 (York Region);
- Maps of the study area (Google imagery);
- Physiography of Southern Ontario by Chapman & Putnam (digital data from MNDM);
- Site Surveys and Field Assessments; and,
- Discussions with Parsons staff.

Site inspections and a geomorphic survey of the study area were completed by Water's Edge staff in September 2015. The site inspection was undertaken after an initial review of the mapping and available literature was completed in order to confirm site and general system characteristics

The study area is located on Huntingdon Rd, between Langstaff Rd and Nashville Rd. In this report, we have outlined the results of our investigations and have provided recommendations related to any culvert replacements and to mitigate any impacts.

1.0 EXISTING CONDITIONS

1.1 Geology & Physiography

Reviewing the site area's surficial materials is important to evaluate active channel processes. Stream channel form and sediment supply are controlled by the region's physiography and surficial geology. This study area is located in the Peel Plain physiographic region and in the bevelled till plains landform. The geologic material underlying the plain is a till which is clay to silt textured and is generally derived from glaciolacustrine deposits

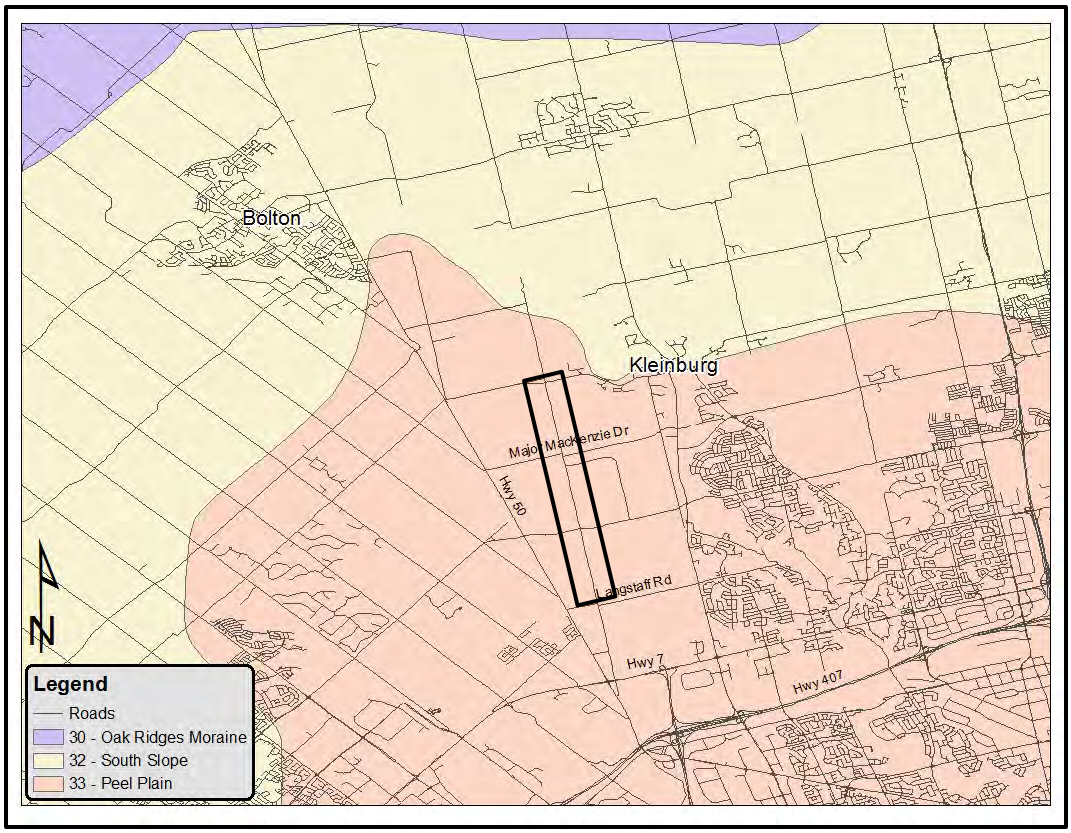

Figure 1: Local Physiography (data from MNDM)

1.2 General Watershed Characteristics and Site Conditions

The creeks in this study are all part of Rainbow Creek and Robinson Creek which are located in the Humber River watershed in Vaughan, which drains into Lake Ontario. The study area includes eleven culverts, all passing under Huntingdon Road. Cu-4, Cu-5, Cu-6, Cu-7 and Cu-9 will be focused on in this report.

East Robinson Creek at the location of Cu-4 is at most a 2nd order stream with a contributing area of 94 ha. Robinson Creek which flows through Cu-5 is likely a 3rd order stream. Its contributing drainage area is 1480 ha. The drainage area for Cu-6, which conveys East Rainbow Creek South, is 307 ha and it is likely a 3rd order stream. The watercourse that flows through Cu-7 is tributary of Rainbow Creek is a 2nd order stream with a drainage area of 71 ha. Cu-9 conveys West Rainbow Creek with a drainage area of 610 ha and is likely a 3rd order stream. The land use of the contributing drainage areas at the study area is primarily agricultural as well as wetland.

Cu-1 through Cu-3 are tributaries of East Robinson Creek. The watercourse through Cu-8 is a tributary of East Rainbow Creek and the one through Cu-10 is a tributary of Rainbow Creek. Cu-1 is a wetland area that crosses Huntingdon Rd with no defined channel. Cu-2 collects water from two culverts which then crosses the road and flows across a manicured lawn. Primarily field runoff flows through Cu-3 with a small wetland area on the downstream side. The culvert at Cu-8 comes from a maintenance hole which collects culverts from the roadside ditch and flows through a grassed channel on the downstream side. Cu-10 runs from the ditch upstream through farmed fields on the downstream side.

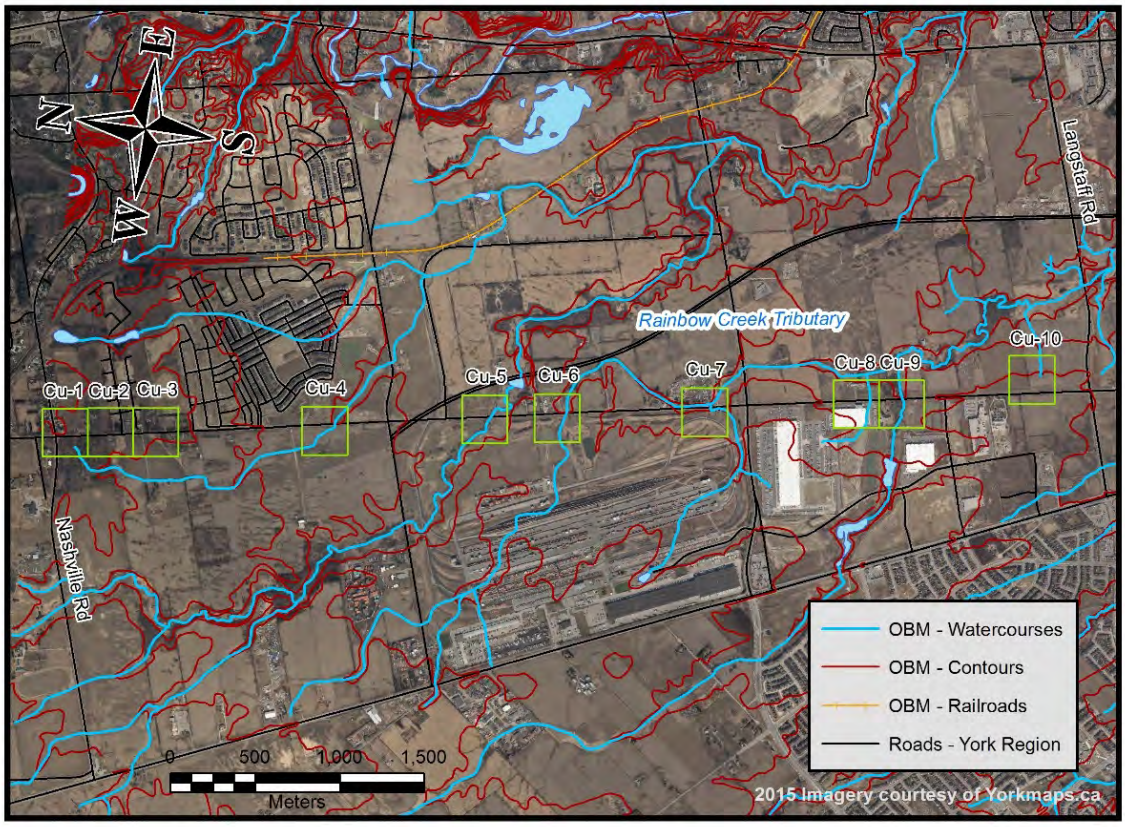

Figure 2: Locations of 10 culvert crossings

Culvert 4
A small depression collects field runoff and crosses Huntingdon Rd at Cu-4 (see Figure 3). The channel lining is vegetated with grasses. The bed slope is 0.003 m/m. The average bankfull width and mean bankfull depth of the channel was determined to be 1.66 m and 0.03 m, respectively.

Culvert 5
This crossing just south of Major Mackenzie Drive and McGillivray Rd (see Figure 4) is the largest of the crossings being observed. This culvert conveys Robinson Creek through Huntingdon Rd. The upstream reach shows proper channel features and has some riparian buffer but is close to agricultural lands in a few areas. In the areas where the stream comes close to the fields there are eroding and unstable banks. Some undercut banks were observed in this reach. The downstream reach runs through active grazing lands. Around 300m downstream of the culvert the stream flows into a pond which is also in active grazing lands. The downstream reach shows signs of cattle crossing creating a wide and slow-moving channel.

Approximately 200 metres were surveyed for this study. Three cross sections were surveyed in this reach, all three on the east side (upstream). The channel showed low width-to-depth ratio (<12) and is slightly entrenched. The average bankfull slope is 0.0028 m/m, and the bankfull width and average depth were noted to be 5.24 m and 0.48 m. The substrate in this reach is focused on gravels. A sieve sample was completed for the reach and the results show 4% silt, 20% sands, 56% gravels and 20% cobbles. Rosgen classification for this reach is determined to be a C4 channel type. Survey results can be seen in Table 1.

Culvert 6
This crossing is located halfway between Major Mackenzie Drive and Rutherford Rd (See Figure 5). This culvert conveys East Rainbow Creek through Huntingdon Rd. The upstream and

downstream sides of this reach are very similar to one another. This reach has a wide riparian buffer consisting mostly of wetland with areas of tree cover. Further upstream of this crossing, the creek runs alongside Huntington Road as a roadside ditch.

Approximately 175 metres of channel were surveyed along with three cross sections to determine the typical channel geometry. The overall channel has a low width-to-depth ratio and is slightly entrenched. The average bankfull slope through the whole study area is 0.0031 m/m, and the average bankfull width and depth were noted to be 1.47m and .22 m. The substrate in this reach ranges from silt to small gravel. The sieve sample for this reach reveals that 54% of the substrate is silt and 40% is sand while 6% is gravel. The banks are typically made up of highly erodible soils. Rosgen classification for this reach is determined to be an E6 channel type. Survey results can be seen in Table 1.

Culvert 7

The crossing at culvert 7 (See Figure 5) is fed by what appears to be two 1st/2nd order streams which are tributaries to East Robinson Creek Tributary. Based on OBM mapping, it appears that the main tributary is the watercourse that runs alongside the road south of the culvert. This tributary runs through grassed areas where the channel has multiple threads depending on the flow. Approximately 100 m of the channel was surveyed. The bankfull width of the channel upstream of the crossing is 1.1 m and the mean depth is 0.05 m. The channel has a bankfull slope of 0.0051 m/m.

Culvert 9

This crossing is south of Rutherford Rd (See Figure 6). This culvert conveys West Rainbow Creek through Huntingdon Rd. The upstream reach shows good C channel features which changes to an E channel just upstream of the culvert. The downstream reach starts as an E channel and moves into a C channel father downstream. The upstream and downstream reaches have a good riparian zone with areas of trees and grasses.

Approximately 210 metres of the channel at this crossing was surveyed for this study. Three cross sections were also surveyed in this reach. The channel has a high width-to-depth ratio (>12) and is slightly entrenched. The average bankfull slope is 0.0078 m/m, and the bankfull width and average depth were noted to be 2.81 m and 0.23 m. The substrate in this reach contains sands and gravels but also contains a larger percentage of cobbles. A sieve sample was completed for the reach and the results show 7% sands and 63% gravels and 30% cobbles. A Rosgen classification of C4 has been given to this channel. Survey results can be seen in Table 1.

Table 1: Summary of Survey Each Crossings Geomorphic Parameters

Parameter	Cu-4	Cu-5	Cu-6	Cu-7	Cu-9
Bankfull Width (m)	1.66	5.24	1.47	1.07	2.81
Bankfull Mean Depth (m)	0.03	0.48	0.22	0.05	0.23
Bankfull Max Depth (m)	0.03	0.78	0.35	0.1	0.43
Bankfull Area (m^2)	0.05	2.61	0.3	0.05	0.62
Wetted Perimeter (m)	1.67	5.73	1.76	1.11	3.96
Hydraulic Radius (m)	0.03	0.44	0.17	0.05	0.17
Width-Depth Ratio	55.33	10.82	7.1	21.4	13.53
Entrenchment Ratio	1.61	2.5	6.89	1.58	2.27
Bankfull Slope (m/m)	0.003	0.0028	0.0031	0.0051	0.0078
Channel Substrate D_{50} (mm)	grassed vegetation	37.3	0.06	grassed vegetation	39.3
Channel Substrate D_{84} (mm)		86.7	0.24		86.3
Rosgen Classification	B	C4	E4	B	C4

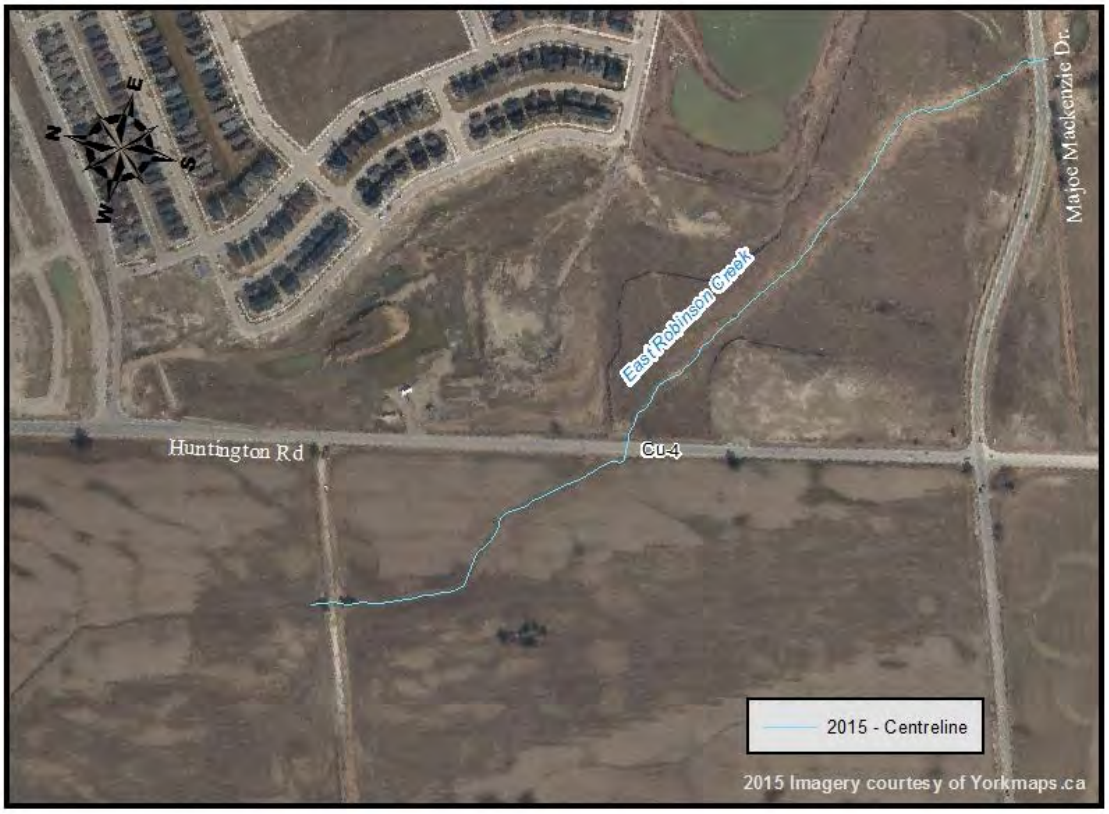

Figure 3: Aerial View of Cu-4 on East Robinson Creek

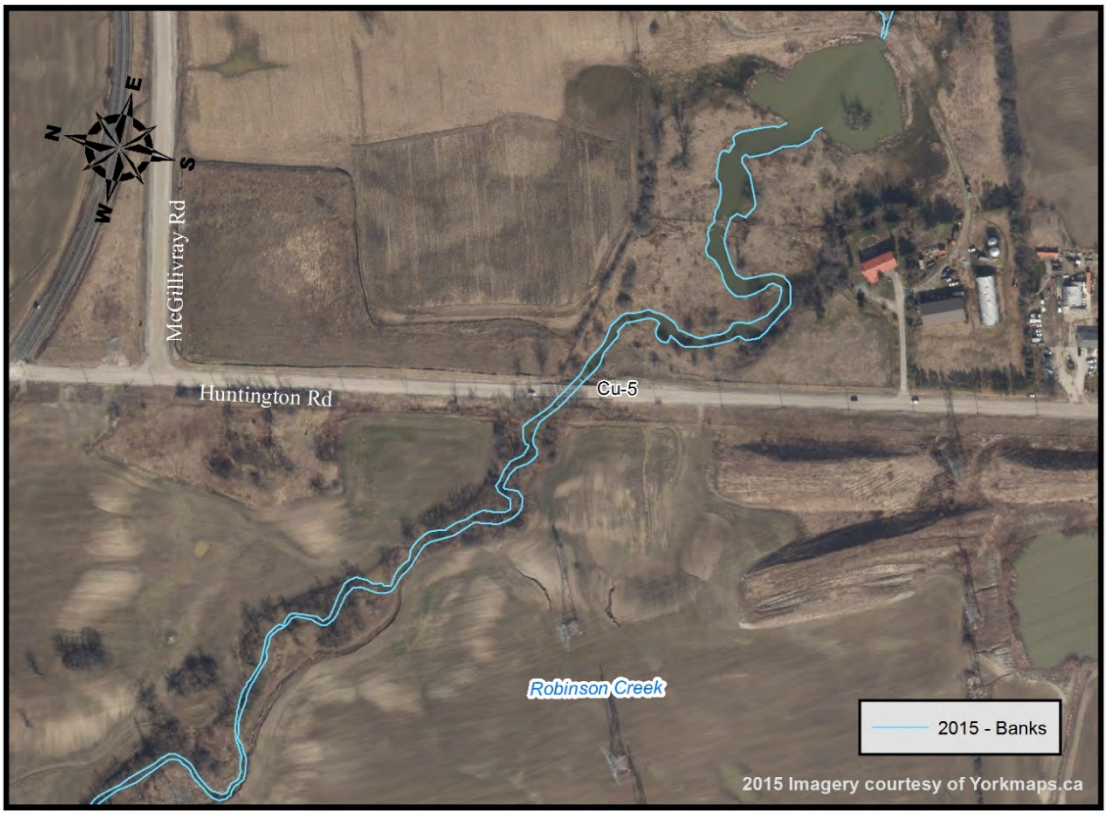

Figure 4: Aerial View of Cu-5 on Rainbow Creek

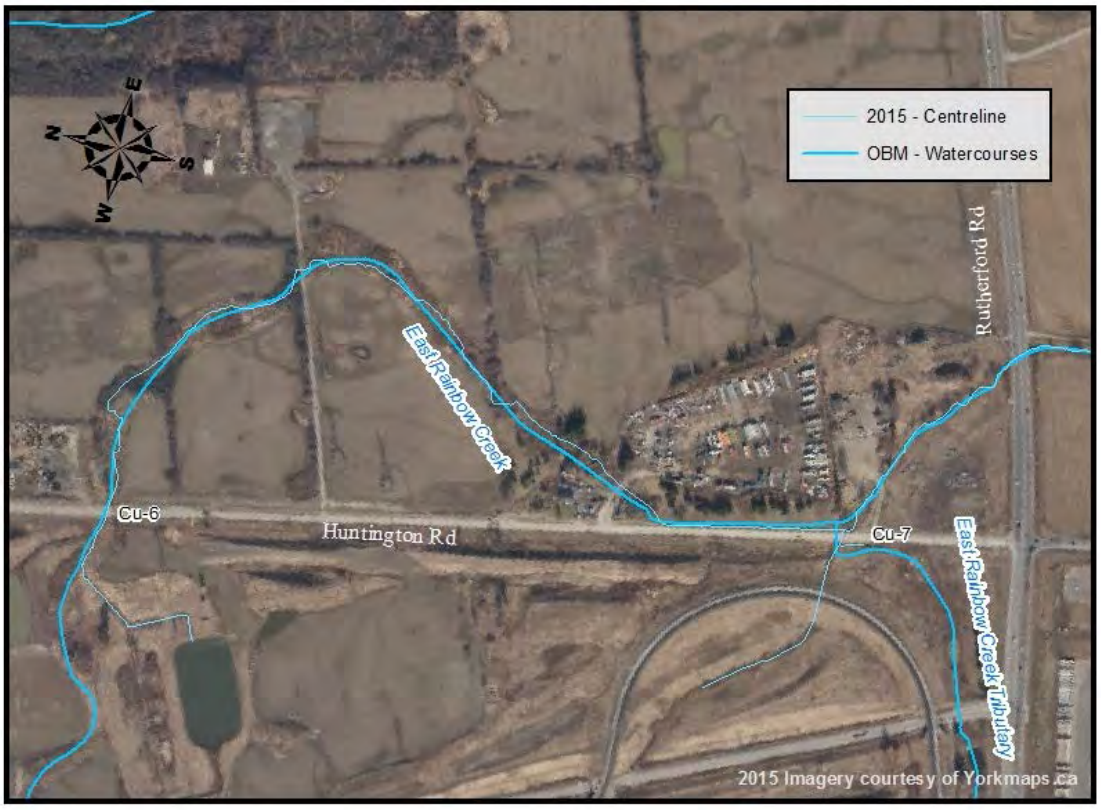

Figure 5: Aerial View of Cu-6 on East Rainbow Creek and Cu-7 (Rainbow Creek Trib)

Figure 6: Aerial View of Cu-9 on West Rainbow Creek

2.0 STREAM ASSESSMENT SCORES

In addition to classification of a stream system, various techniques for geomorphic assessments are used to better understand general stream conditions (stability, habitat, erosion/degradation, riparian, etc.). In our assessment of Rainbow Creek and its tributaries, we used Rapid Geomorphic Assessment and Rapid Stream Assessment Technique. The raw worksheets for these assessments can be found in Appendix C.

2.1 Rapid Geomorphic Assessment (RGA)

Creek stability was assessed using a Rapid Geomorphic Assessment (MOE, 2003). The RGA assessment focuses entirely on the geomorphic component of a river system. The RGA method consists of four factors that summarize various components of channel adjustment, specifically: aggradation, degradation, channel widening and plan form adjustment. Each factor is assessed separately and the total score indicates the overall stability of the system. This methodology has been applied to numerous streams and rivers and the following table details the ranking criteria (see Table 3).

The detailed RGA evaluation is presented in Appendix C. Score results are seen in Table 2.

2.2 Rapid Stream Assessment Technique (RSAT)

Rapid Stream Assessment Technique was developed by John Galli and other staff of the Metropolitan Washington (DC) Council of Governments (Galli et al, 1996). The RSAT systematically focuses on conditions reflecting aquatic-system response to watershed urbanization. It groups responses into six categories, presumed to adequately evaluate the conditions of the river system at the time of measurement on a reach-by-reach basis. The six categories are:

1. Channel stability;
2. Channel scouring and sediment deposition;
3. Physical in-stream habitat;
4. Water quality;
5. Riparian habitat conditions; and
6. Biological conditions.

River channel stability and cross-sectional characterization is a critical component of RSAT. The entire channel was inspected for signs of instability (such as bank sloughing, recently exposed non-woody tree roots, general absence of vegetation within bottom third of the bank, recent tree falls, etc.) and channel degradation or downcutting (such as high banks in small headwater streams and erosion around man-made structures). Observations were noted and cross-section measurements were made.

A rapid assessment of soil conditions along the river banks is also conducted to determine soil texture and potential erodibility of the watercourse bank. Qualitative water quality measurements were also made (temperature, turbidity, colour and odour) along with an indication of substrate fouling (i.e., the unwanted accumulation of sediment).

RSAT also typically involves a quantitative sampling and evaluation of benthic organisms. As no benthic sampling was undertaken, the score was based on site conditions and general observations of water quality.

Each category was assigned a value which was then summed to provide an overall score and ranking. Table 4 details the range of scores and rankings with a higher score suggesting a healthier system.

Within these broad categories, we evaluated the study area and determined an average RSAT score for the five watercourses. Watercourses Cu-4, Cu-5, Cu-6, and Cu-7 show RSAT scores

ranging from 21.0 to 23.5 which bears a qualitative ranking of "Fair". The watercourse at Cu-9 was evaluated as "Good" with a score of 31.3. The results of the RSAT evaluation are included in Appendix C.

Table 2: RGA and RSAT Scores

Crossing	RGA	RSAT
Cu-4	0.21	20.0
Cu-5	0.36	21.0
Cu-6	0.21	23.5
Cu-7	0.26	21.0
Cu-9	0.26	31.3

Table 3: Interpretation of RGA Score

Stability Index (SI) Value	Classification	Interpretation
SI ≤ 0.20	In Regime	The channel morphology is within a range of variance for rivers of similar hydrographic characteristics and evidence of instability is isolated or associated with normal river meander processes.
0.21 ≤ SI ≤0.40	Transitional/Stressed	Channel morphology is within a range of variance for rivers of similar hydrographic characteristics but the evidence of instability is frequent.
SI ≥ 0.40	In Adjustment	Channel morphology is not within the range of variance and evidence of instability is wide spread.

Table 4: Interpretation of RSAT Score

RSAT Score	Ranking
41-50	Excellent
31-40	Good
21-30	Fair
11-20	Poor
0-10	Degraded

3.0 CHANNEL FLOWS

An important concept in fluvial geomorphology is that of channel forming discharges or dominant discharges, also commonly referred to as bankfull flows. Dunne and Leopold (1978) define bankfull discharge as "*…the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meander, and generally doing work results in the average morphologic characteristics of channels.*" The bankfull discharges typically have an average recurrence interval of 1.5 years. Although in some urban settings, the recurrence can be more frequent. When re-naturalizing or altering the channel, natural channel design concepts include the creation of a bankfull flow channel to accommodate the dominant discharge. Therefore, the estimation of bankfull discharge is essential in the design of a new channel.

Using data from the geomorphic field work, Limerinos' method and the Strickler method. Bankfull flows were obtained for each channel where the bankfull indicators were obvious and reliable. The flows through Robinson Creek at the crossing Cu-5 average out to be 2.0 m^3/s. Similarly, the flows through East Robinson Creek at crossing Cu-6 average to be 0.44 m^3/s. The flows for West

Rainbow Creek at the crossing Cu-9 were averaged to be approximately 0.58 m^3/s. Independently, and based on our database of Rosgen E-type streams in quasi-equilibrium, we also examined a typical bankfull width and depth for this size of watershed. Based on the resultant area (width x depth, computed using information from our stream database) and a velocity determined with Manning's equation, the flows through the crossings Cu-5, Cu-6 and Cu-9 to be 1.55 m^3/s, 0.56 m^3/s and 0.76 m^3/s, respectively.

We also regressed the existing return period flows as obtained from Sanchez Engineering Inc. The resultant 1:1.5 year return period flow is expected to be 4.65 m^3/s, 2.42 m^3/s and 2.7 m^3/s for crossings Cu-5, Cu-6 and Cu-9, respectively. Typically, bankfull return periods have been associated with a 1:1.5 year return period. The bankfull discharges obtained from regression analysis suggest that they are higher than theoretical bankfull discharge values obtained through resistance equations, field data and our stream database. It is likely that the bankfull estimation using the 1:1.5 year return period is erroneous and that the bankfull discharge occurs at a more frequent interval.

Since the resistance equations methods and the stream database method provide a similar estimate of bankfull values, the bankfull discharge values for the three crossings can be taken to be the maximum values of discharges obtained from these approaches for a conservative yet realistic estimation of the bankfull discharge. The bankfull discharge for Cu-5, Cu-6 and Cu-9 are 2.0 m^3/s, 0.56 m^3/s and 0.76 m^3/s, respectively.

4.0 MEANDER BELTWIDTH & 100-YEAR EROSION ASSESSMENT

Assessment of the meander beltwidth is usually undertaken in accordance with commonly accepted standard meander beltwidth delineation procedures, particularly TRCA's Belt Width Delineation Protocol (2004) which are established for watercourses with well defined, meandering bankfull channels. In this study, we have used aerial photo measurements to determine the meander beltwidth. It has been assumed that there will be no change in the upstream hydrology as any future development upstream will require sufficient controls that post-development hydrology will match that of existing conditions.

4.1 Reach Delineation

Channel morphology and substrate characteristics can change along a watercourse. Hence, it becomes imperative to account for these changes by delineating lengths of a watercourse that exhibit similar planform, sediment substrate, land use, local geology, valley confinement, hydrology and slope. In this study, six different reaches were delineated for the Robinson Creek site, ten reaches for the East Rainbow Creek and three reaches for the West Rainbow Creek, to account for changes in valley trends and planform geometry. Other characteristics remained very comparable along the entire length of the watercourse. The delineated reaches are presented in Figure 7 and 8 at the end of this report.

4.2 Historic Assessment

As a watercourse works towards a state of quasi-equilibrium or responds to a change in its system (often at the watershed scale), it undergoes planform changes which can be identified through historic analyses. We have examined 1970, 1999, 2002, 2005, 2007, 2011, 2012, 2013, 2014 and 2015 aerial photography sourced from York Region's mapping services. The creek banks as visible from the aerial photography were delineated for the years: 1970, 1999, 2002, 2007, 2012, and 2015. It must be noted that the process of delineation is limited by the quality of the orthoimagery, presence of vegetation that makes the identification of creek banks difficult. For streams where both banks could not be identified, only the creek centrelines were delineated.

4.3 Meander Beltwidths from Aerial Photography

The meander belt width defines the lateral extend that a channel may occupy. It serves to provide an active channel zone beyond which development and infrastructure may be free from associated

erosion and depositional risk associated with the watercourse. Following the delineation of the creek banks and centrelines, the beltwidths were delineated along the valley trends by drawing lines to the outside meander bends of the planform. However, in the cases of confined (fully or partially) streams, the contours defining the valley walls were also taken into consideration.

For the purposes of this study, although meander beltwidths were delineated for all reaches, a complete meander beltwidth analysis was undertaken only for the reach through the crossing and those reaches adjacent to the crossing.

All six delineated reaches of Robinson Creek in the vicinity of Huntington Road are confined by valley walls as indicated by the 1 m contours obtained from York Region. Between 1970 and 2015, no change in meander axis was noted. Because of the confined nature of Robinson Creek, the application of the tangential meander belt width was not an accurate means to determine the extent of final beltwidth. The meander boundaries were adjusted to account for the irregularity in the valley walls and were placed at an average distance between the top and bottom of valley walls where applicable. The meander beltwidth for this creek is shown in Figure 9 (attached). Further, to account for the fact that the existing meander belt does not necessarily reflect a quasi-equilibrium form, a factor of safety of 10% is added to determine the final meander beltwidth. Along the Huntington crossing, the final meander beltwidth was determined to be 126.4m.

East Rainbow Creek is an unconfined system and much smaller system than Robinson Creek. Only the creek centrelines were delineated for this system as both banks were not visible in the aerial photos. Therefore, in the determination of meander beltwidths, the bankfull widths were added The reach through the Huntington Road crossing, ER-1 appears to be an anthropogenically altered stream. Therefore, a surrogate reach (ER-2) was chosen to determine the meander beltwidth. Similar to Robinson Creek, a 10% factor of safety was also added to determine the final beltwidth (23.9 m). The reach that runs parallel to Huntington Road, ER-5 was also determined to have the same beltwidth since ER-2 was also used as a surrogate reach. ER-5 also appears to be an artificial channel. The meander beltwidths for this creek is shown in Figure 10.

Similar to East Rainbow Creek, West Rainbow Creek's meander beltwidth was determined by adding the bankfull width and the 10% factor of safety to the preliminary beltwidth. The final beltwidth of Reach WR-3 (the reach through the crossing) was determined to be 29.5m and is shown in Figure 11.

4.4 100-Year Erosion Assessment & Culvert Size Recommendations

As per TRCA's guidance document on crossings in stream corridors, (TRCA, 2015), a 100-year erosion assessment is required to inform the crossing opening dimensions. Therefore, a 100-year erosion limit was determined using the historical air photos. Figures 13 to 17 (attached) show the locations at which the 100-year erosion measurements were made.

Measurements of channel deviation from one year to another were made based on delineated channel centrelines for the years 1970 or 1978, 1999, 2002, 2007, 2012 and 2015. The deviations between these years were measured and an average annual rate of erosion was obtained. The locations of measurement were situated on meander bends in the vicinity of the crossing. Typically, measurements were made at four locations except at the watercourses at Cu-6 and Cu-7 where there weren't many meander bends in the vicinity of the crossing. Based on the desktop assessments, it is clear that the channel is fairly stable in the immediate vicinity of the crossing. The deviations in channel centreline were generally noted to occur in grassed areas where there was tendency for the channel to flow in multiple threads.

The average annual rate of erosion was converted to a 100-year erosion distance. Detailed calculations for this assessment is presented in Appendix E. The size of the culvert opening must at the very least accommodate the average bankfull width. It is preferable for a culvert to accommodate about three times the average bankfull width (3*BkfW). The 100-year erosion distances were determined to be similar to the 3*BkfW value. Table 5 summarizes the erosion limits

and the recommended culvert opening sizes. The minimum recommended culvert opening width/span is the 100-year erosion limit.

Table 5: Culvert Size Recommendations

Crossing #	Watercourse	Bkf Width (m)	3* Bkf Width (m)	100-yr Erosion Limit (m)	Min. Culvert Width (m)
Cu-9	West Rainbow Creek	2.81	8.43	7.9	7.9
Cu-7	Rainbow Creek Trib	1.07	3.21	2.5	2.5
Cu-6	East Rainbow Creek	1.47	4.41	3.1	3.1
Cu-5	Robinson Creek	5.24	15.72	9.3	9.3
Cu-4	East Robinson Creek	1.66	4.98	3.7	3.7

5.0 PROPOSED CONDITIONS (CONCEPTUAL DESIGN)

In order to facilitate the road widening works, it is essential that reach ER-5 of East Rainbow Creek that at present runs alongside the Huntington Road be realigned. A conceptual plan (shown in Figure 13) is proposed. Following are its salient features:

- The creek realigned is approximately 260m long;
- The recommended alignment is at least 12m away from the existing road edge of pavement;
- The creek is to be a series of riffles and pools with a bankfull width of 3.4m;
- The planview alignment of the creek is designed such that as much as possible, the existing trees are to be left standing.

6.0 CONCLUSIONS

Based on our field and desktop assessments, we conclude the following:

1. The field assessments show that the channel is generally in a transitional state and is moving towards establishing quasi-equilibrium;
2. The geomorphic parameters for watercourses at the various crossing were determined and are listed in Table 1;
3. The meander beltwidths were delineated for the watercourses in the vicinity of the crossings and are shown in Figures 9 to 11 (attached);
4. A conceptual channel alignment is presented for East Rainbow Creek to accommodate road widening; and,
5. 100-year erosion distance calculations (Appendix E) were performed to determine the recommended minimum opening culvert size as presented in Table 5.

Respectfully submitted,

Ed Gazendam, Ph. D., P. Eng.,
President, Sr. Geomorphologist
Water's Edge Environmental Solutions Team Ltd.

Christina Bright, M.A.Sc.
River Scientist

ATTACHMENTS

Figures Meander Beltwidths
Appendix B: Surveyed Profiles and Cross Sections
Appendix C: Photographs
Appendix D: Rapid Field Assessment Worksheets

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APPENDIX A:

Meander Beltwidth Figures

N E S W

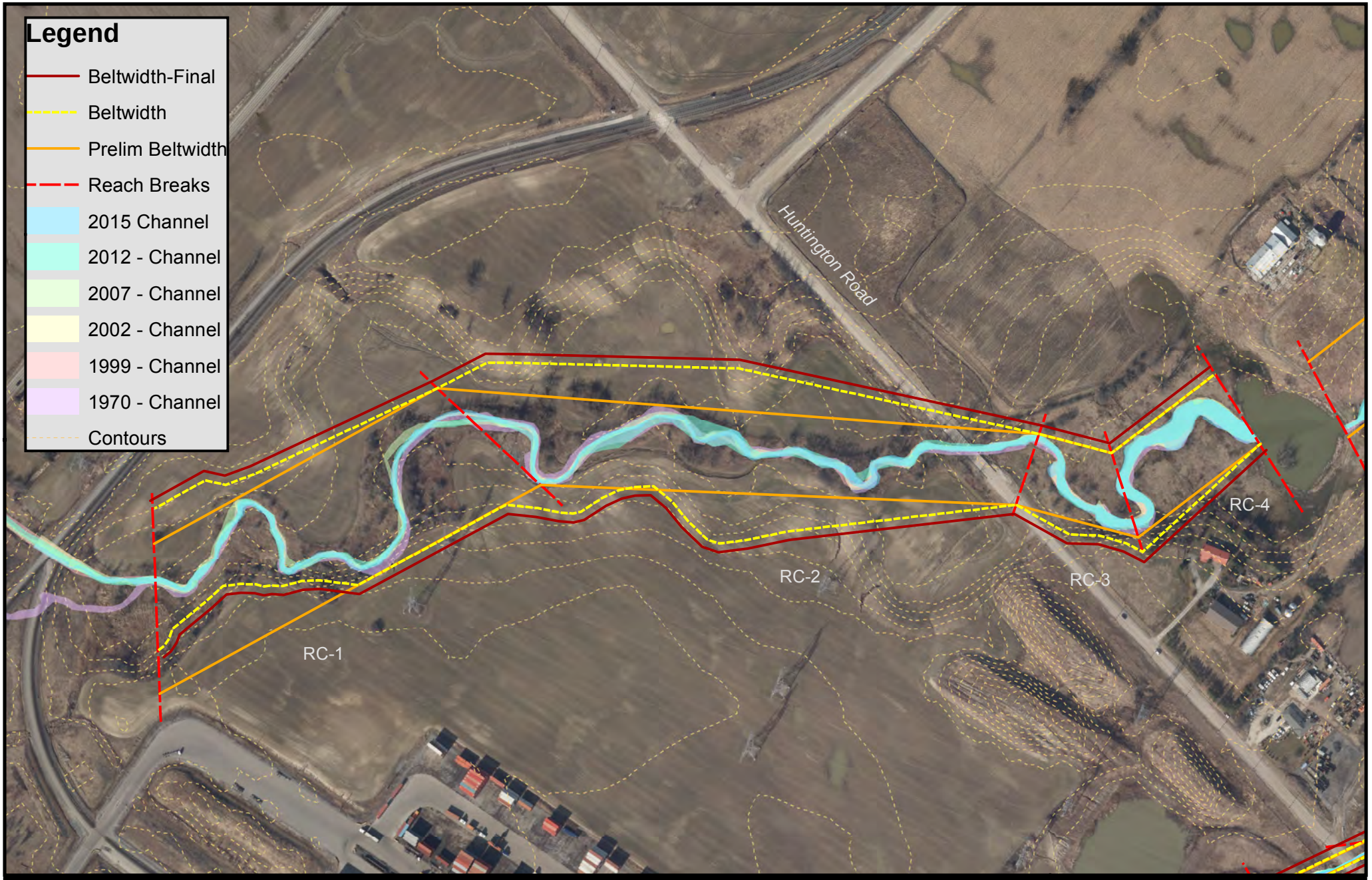
0 75 150 300 450 600 Meters

Huntington Road
Vaughan, Ontario

Reach Delineation - Robinson Creek

Figure No.:	Date:
7	May 31, 2016
Checked By:	Drawn By:
EG	CB

	Huntington Road Vaughan, Ontario	Figure No.: 8	Date: May 31, 2016
	Reach Delineation - East & West Rainbow Creek Tributaries	Checked By: EG	Drawn By: CB



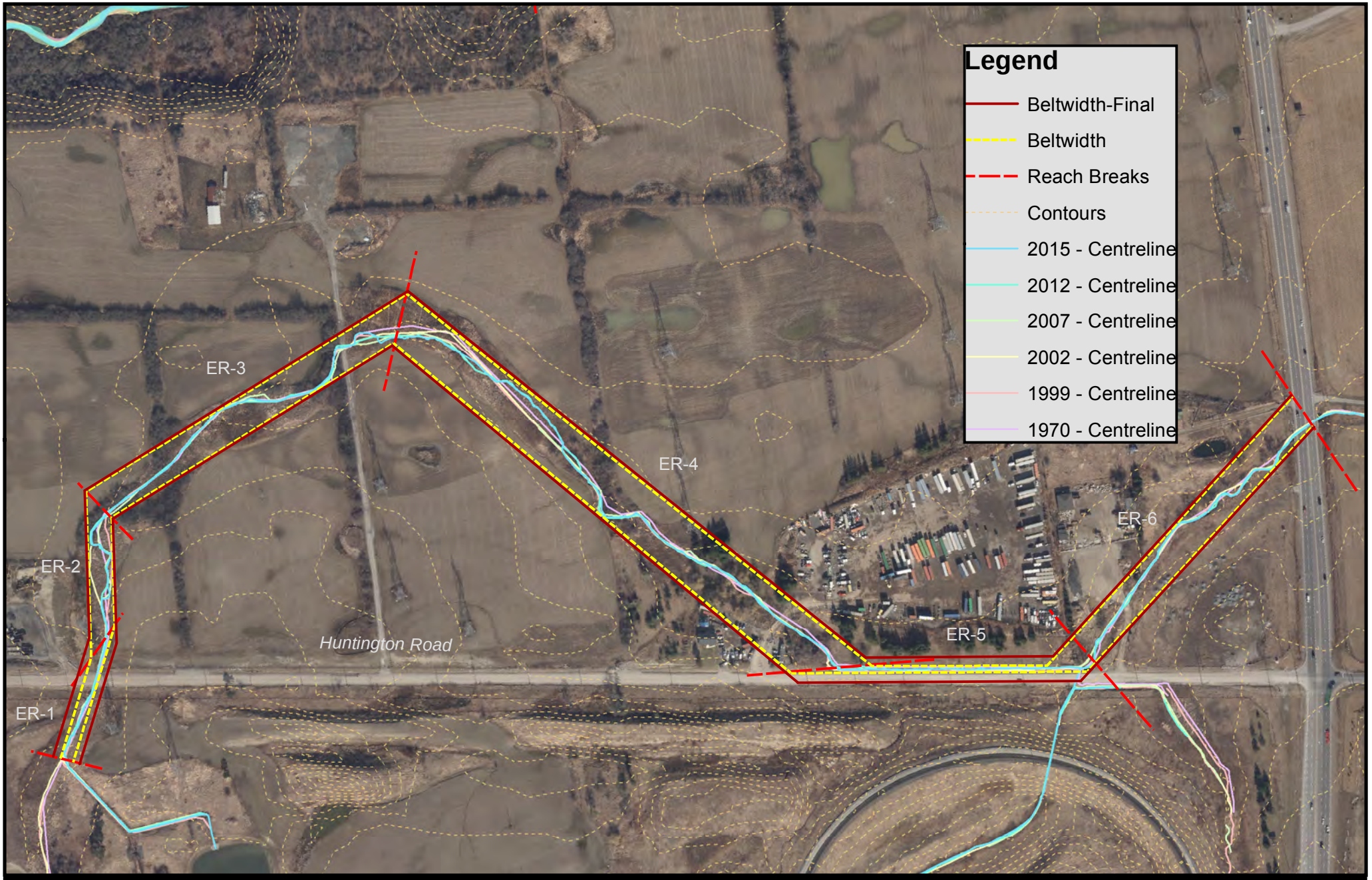
N E S W

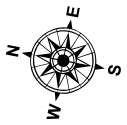
0 35 70 140 210 280 Meters

Huntington Road
Vaughan, Ontario

Meander Beltwidth Assessment - Robinson Creek

Figure No.:	Date:
9	May 31, 2016
Checked By:	Drawn By:
EG	CB



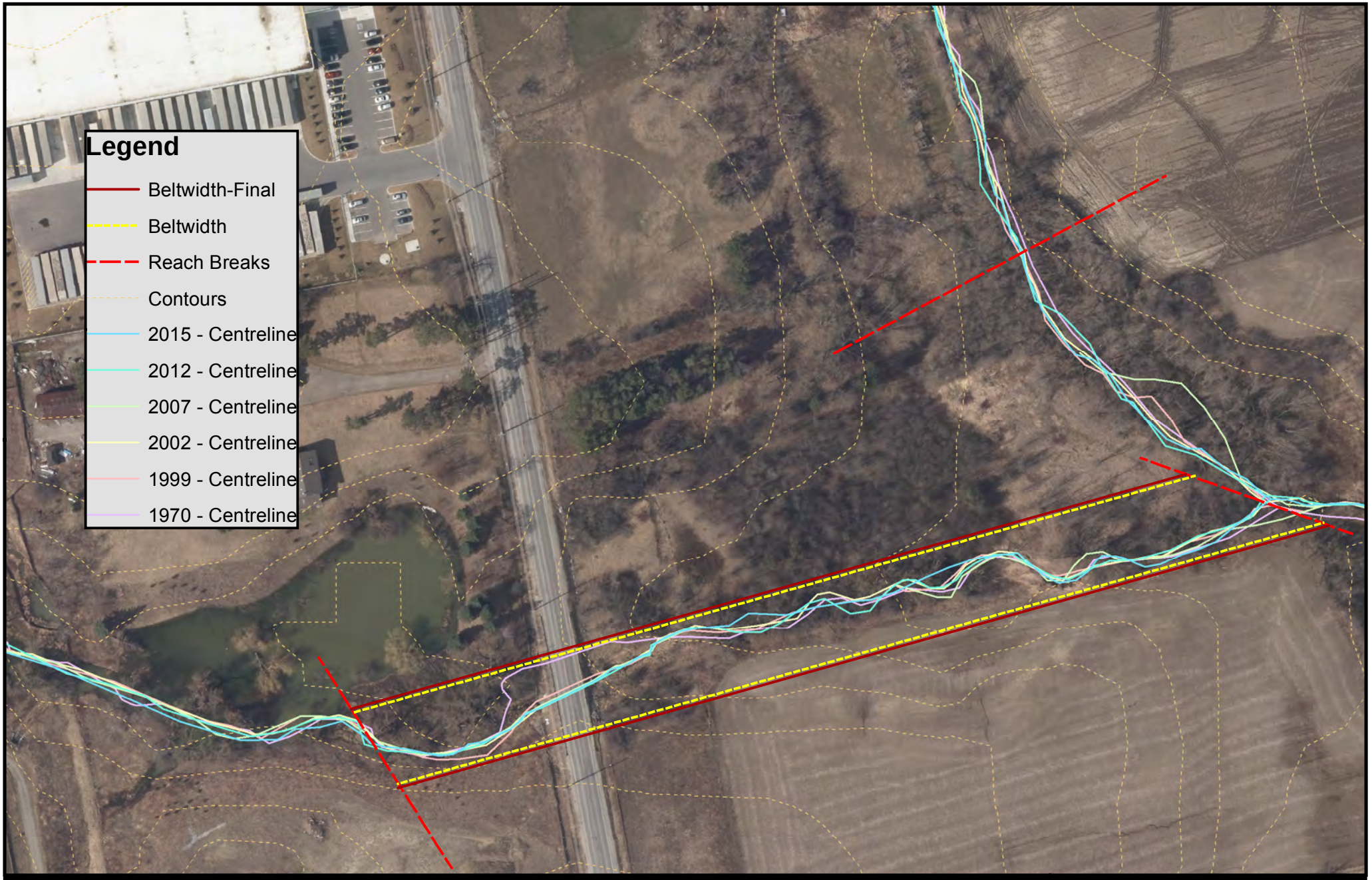


0 37.5 75 150 225 300 Meters

Huntington Road
Vaughan, Ontario

Meander Beltwidth Assessment - East Rainbow Creek

Figure No.:	Date:
10	May 31, 2016
Checked By:	Drawn By:
EG	CB



Huntington Road Vaughan, Ontario		Figure No.: 11	Date: May 31, 2016
Meander Beltwidth Assessment - West Rainbow Creek		Checked By: EG	Drawn By: CB

N E S W

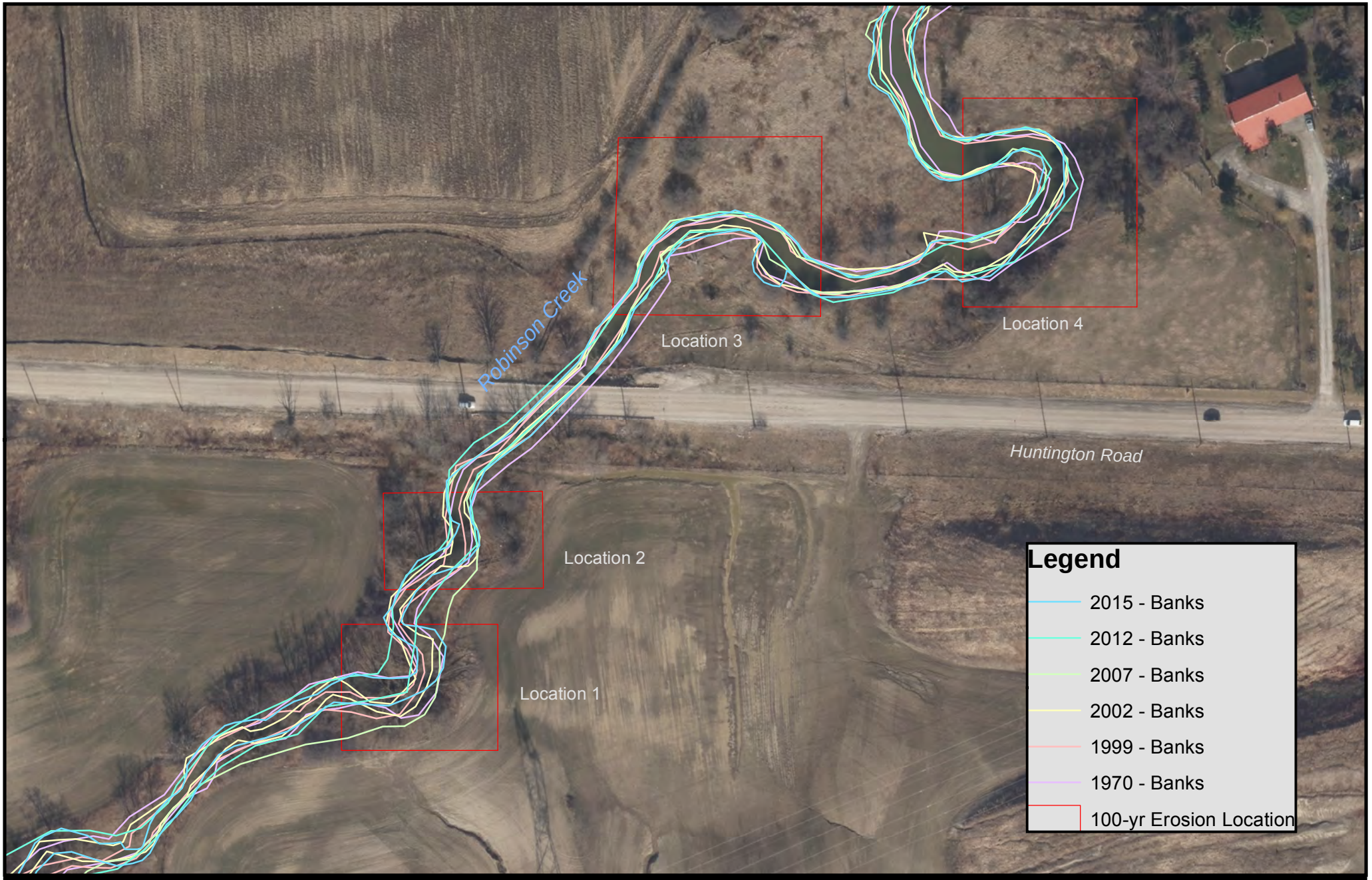
0 10 20 40 60 80 Meters

Huntington Road
Vaughan, Ontario

Proposed Realignment (Conceptual)

Figure No.:	Date:
12	May 31, 2016
Checked By:	Drawn By:
EG	CB

	Huntington Road Vaughan, Ontario	Figure No.: 13	Date: Aug 21, 2017
	100-Yr Erosion Assessment Locations East Robinson Creek (Cu-4)	Checked By: EG	Drawn By: CB



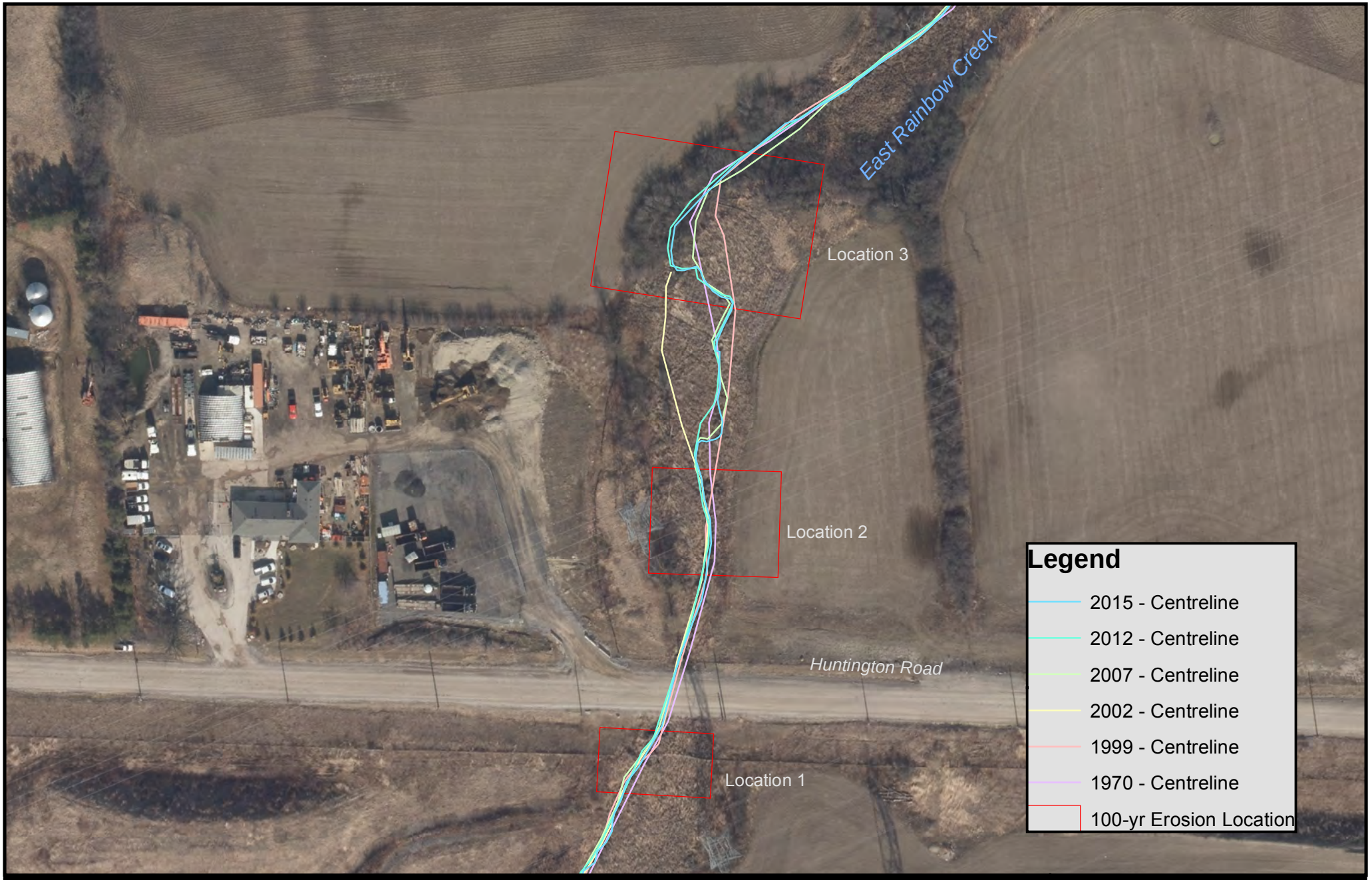
N E S W

0 12.5 25 50 75 100 Meters

Huntington Road
Vaughan, Ontario

100-Yr Erosion Assessment Locations
Robinson Creek (Cu-5)

Figure No.:	Date:
14	Aug 21, 2017
Checked By:	Drawn By:
EG	CB



0 12.5 25 50 75 100 Meters

Huntington Road
Vaughan, Ontario

100-Yr Erosion Assessment Locations
East Rainbow Creek (Cu-6)

Figure No.:	Date:
15	Aug 21, 2017
Checked By:	Drawn By:
EG	CB

	Huntington Road Vaughan, Ontario	Figure No.: 16	Date: Aug 21, 2017
	100-Yr Erosion Assessment Locations Rainbow Creek Trib. (Cu-7)	Checked By: EG	Drawn By: CB

Huntington Road
Vaughan, Ontario

100-Yr Erosion Assessment Locations
West Rainbow Creek (Cu-9)

Figure No.:	Date:
17	Aug 21, 2017
Checked By:	**Drawn By:**
EG	CB

APPENDIX B:

Surveyed Profiles and Cross Sections

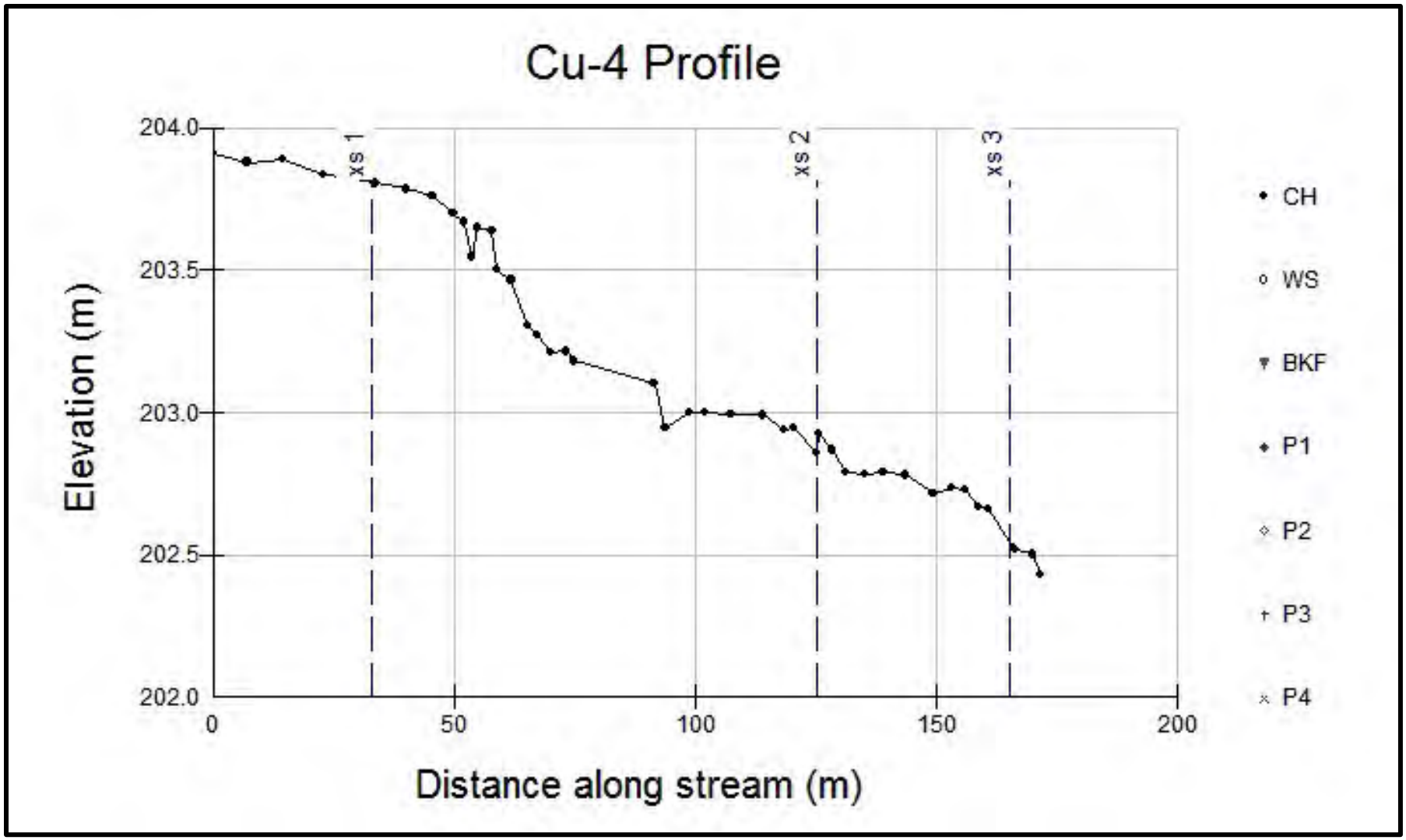


Figure 1: Cu-4 Profile

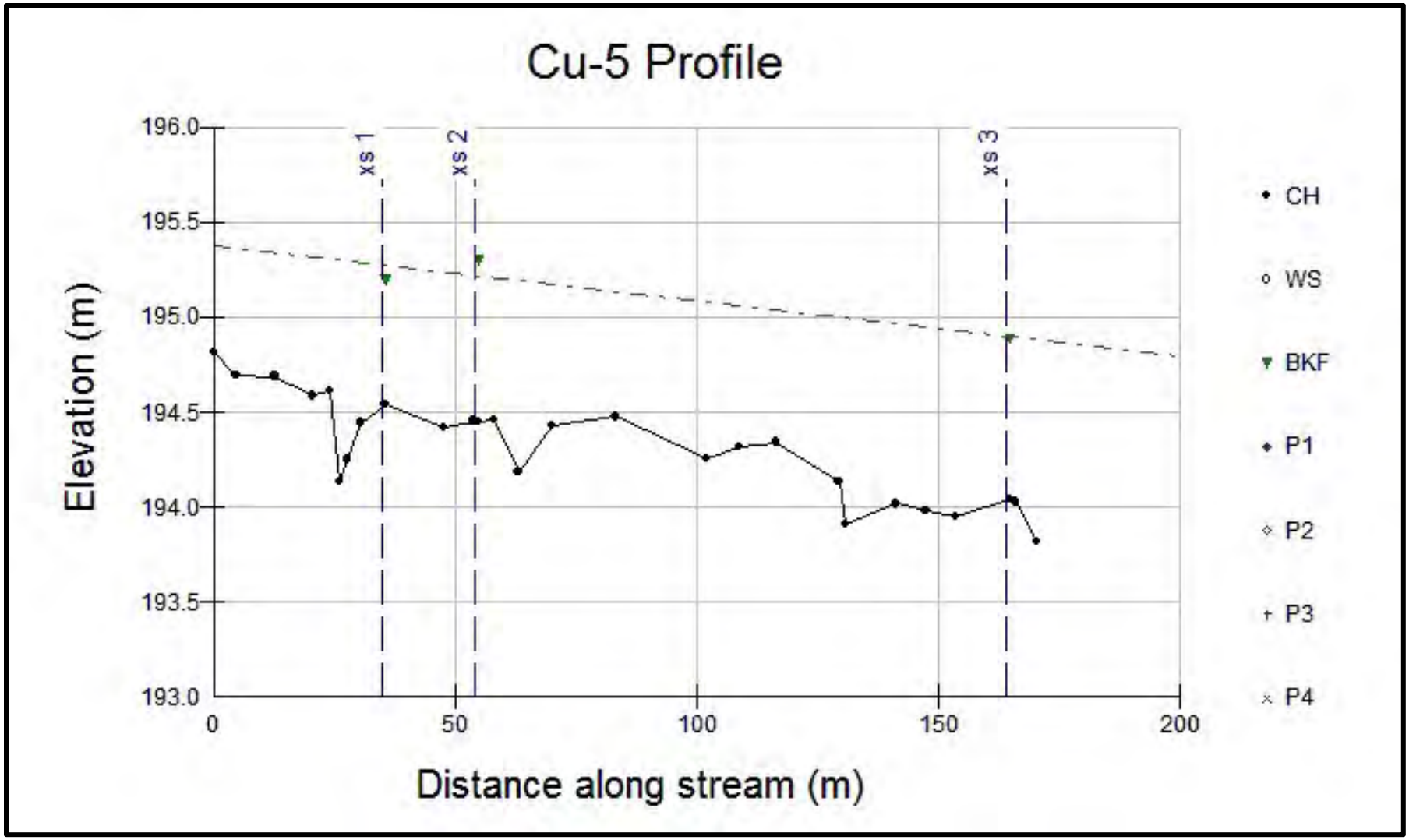


Figure 2: Cu-5 Profile

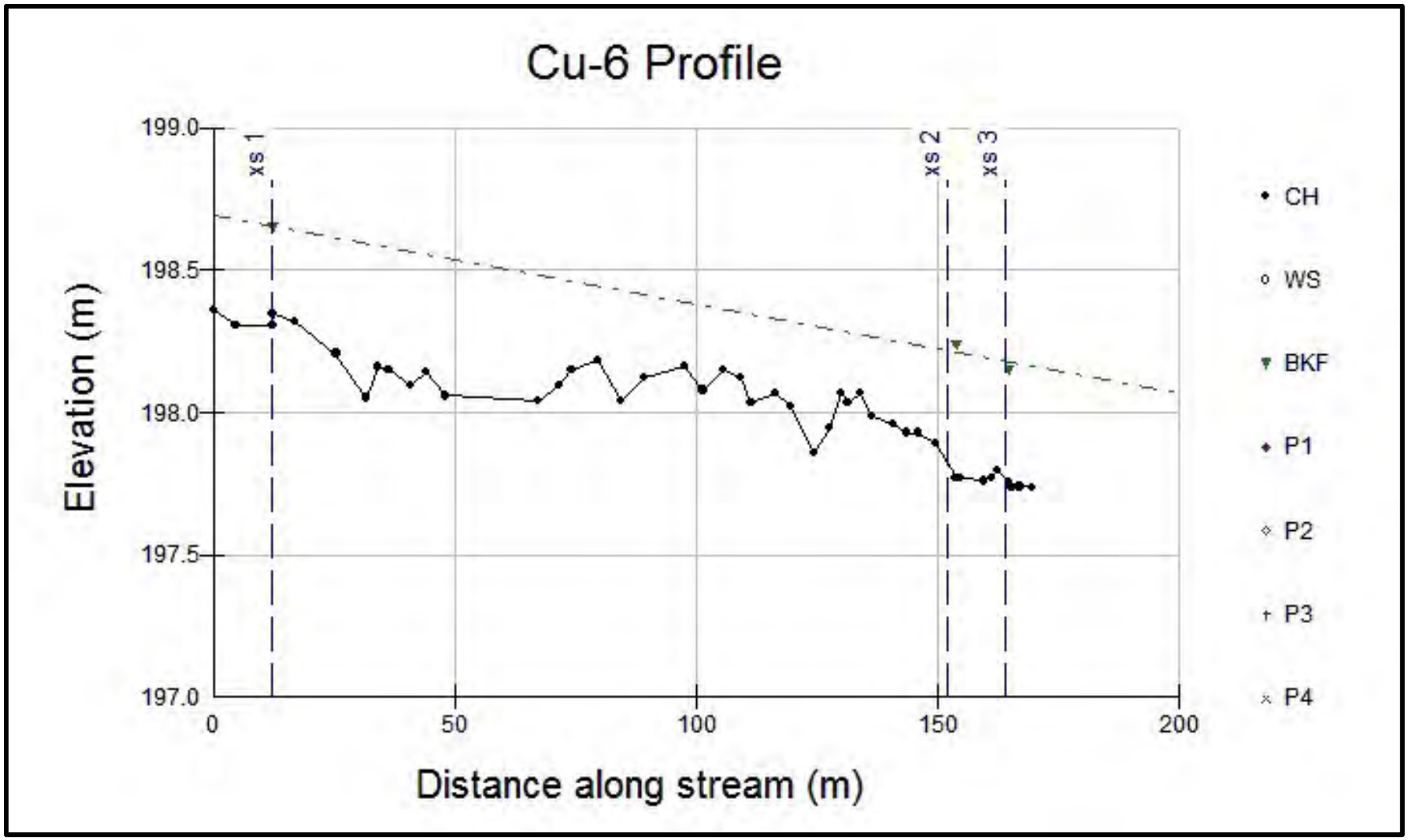


Figure 3: Cu-6 Profile

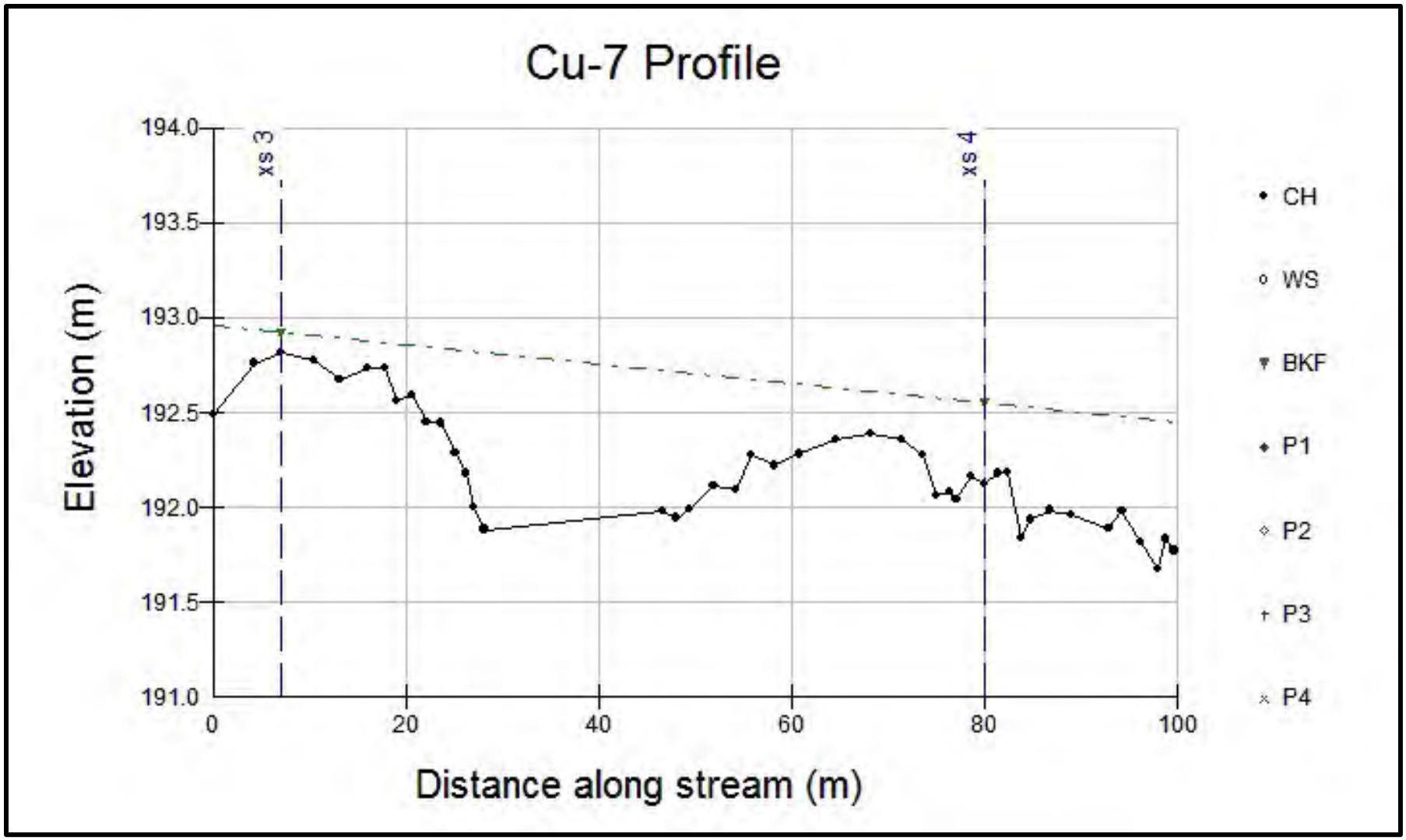


Figure 4: Cu-7 Profile

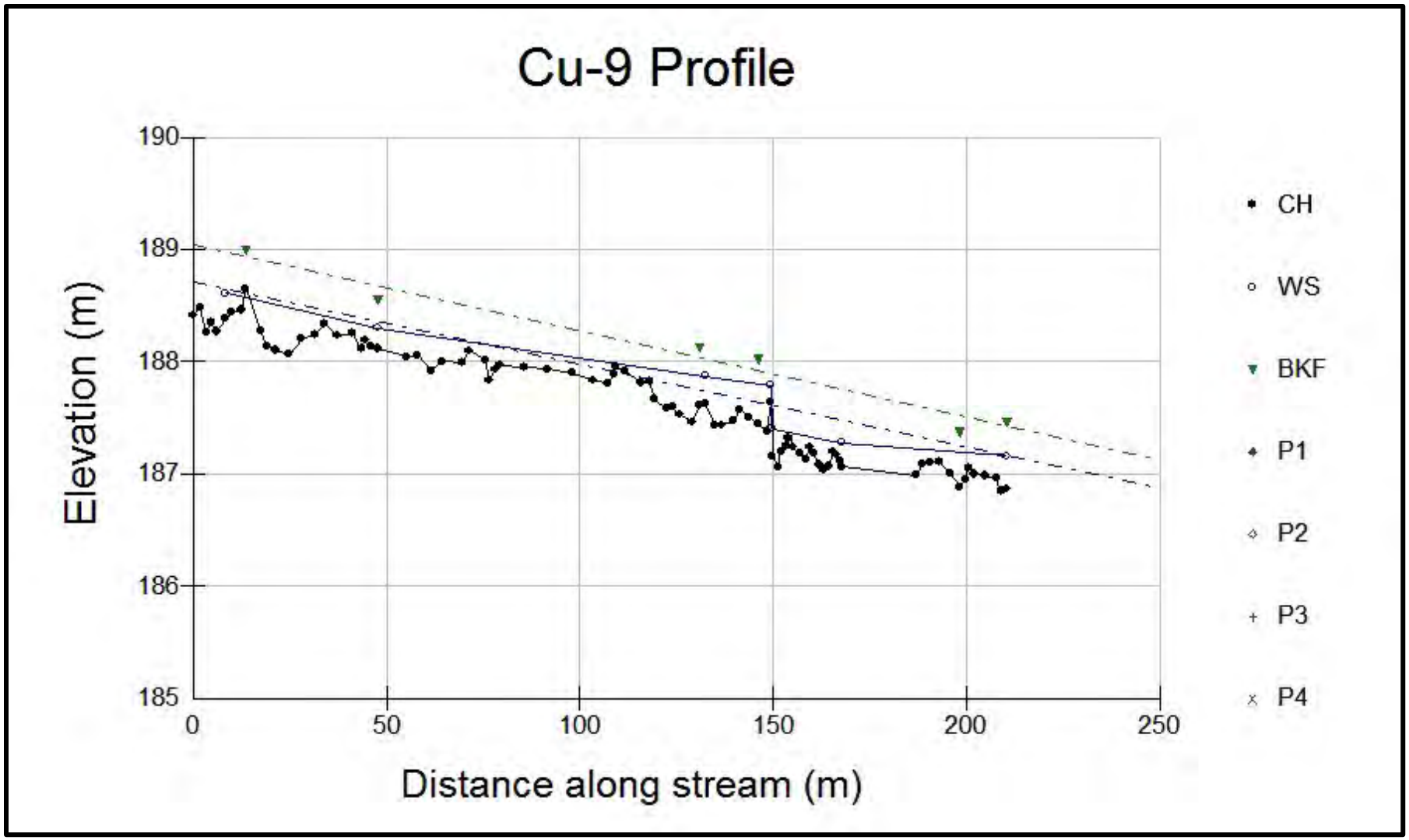


Figure 5: Cu-9 Profile

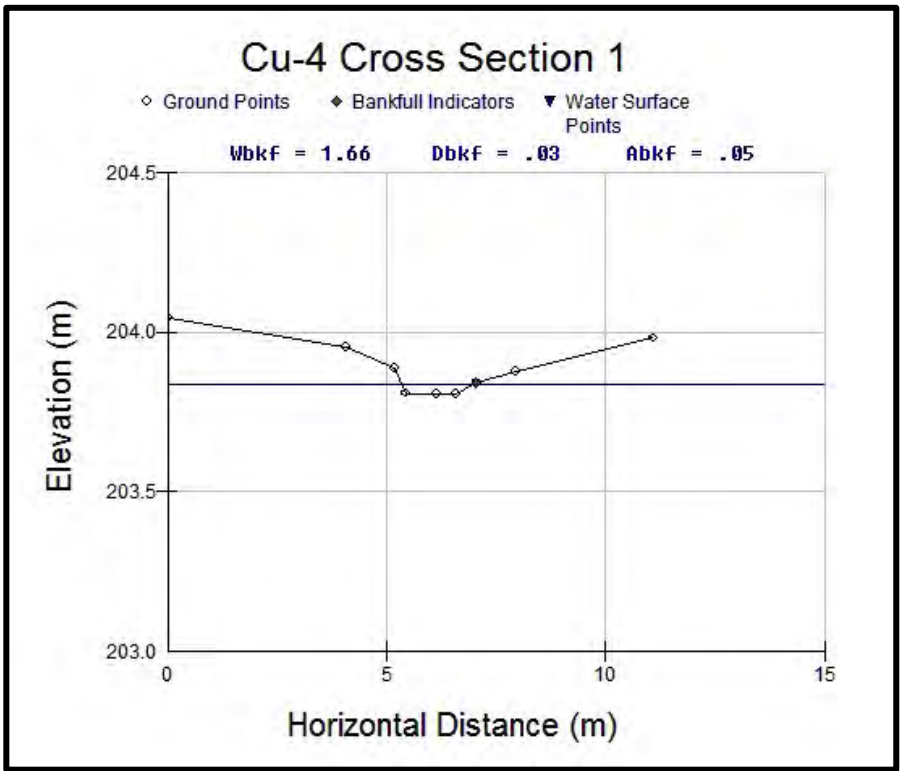


Figure 6: Cross Section 1 @ Cu-4

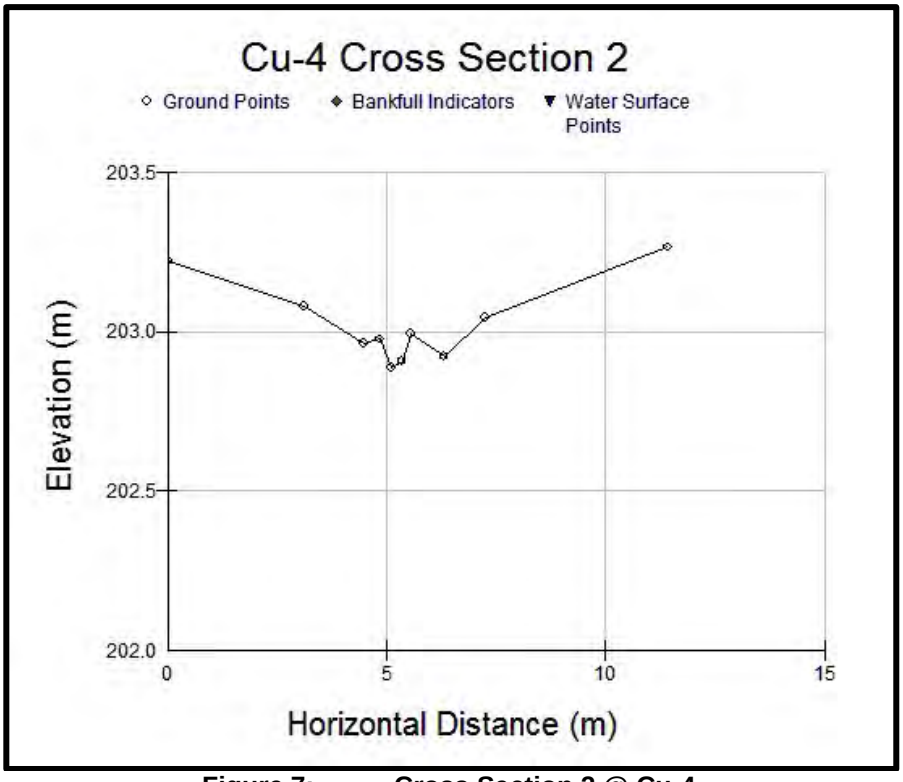


Figure 7: Cross Section 2 @ Cu-4

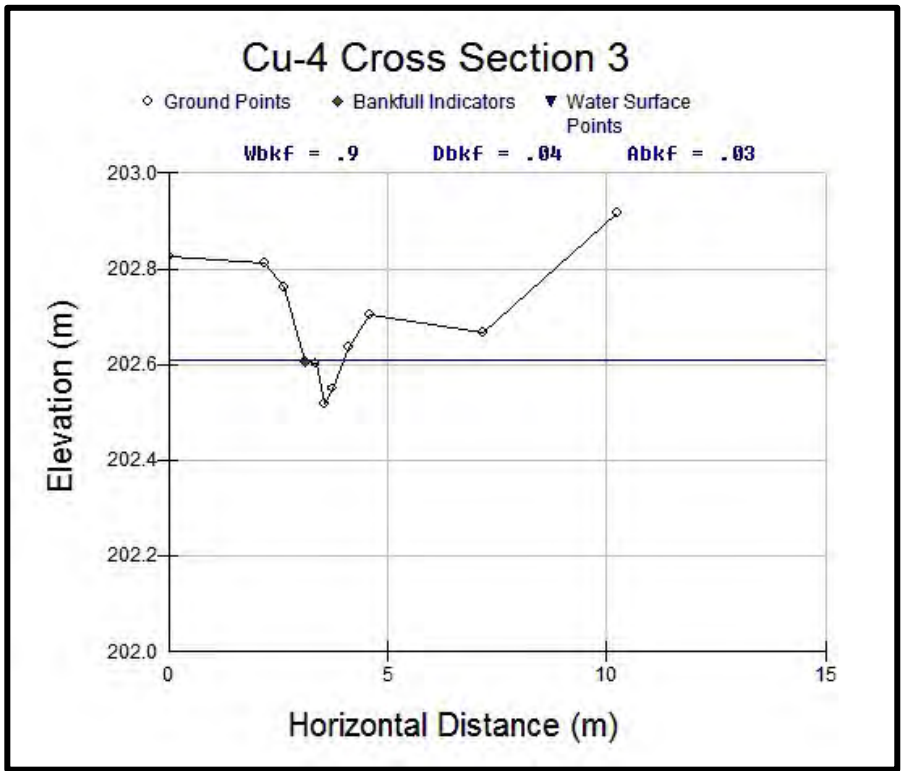


Figure 8: Cross Section 3 @ Cu-4

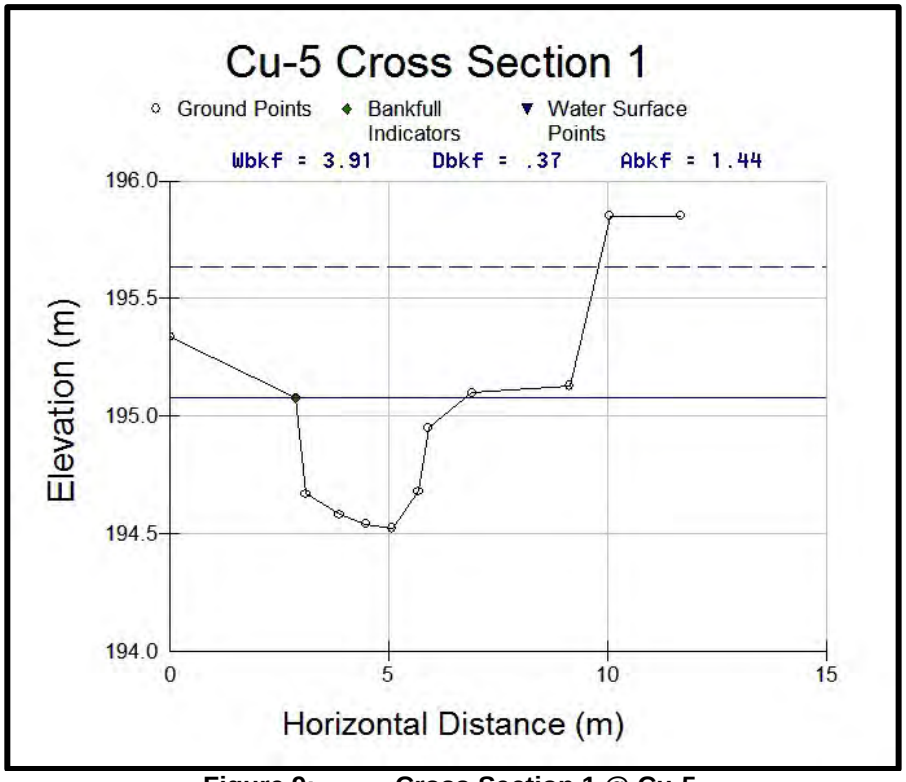


Figure 9: Cross Section 1 @ Cu-5

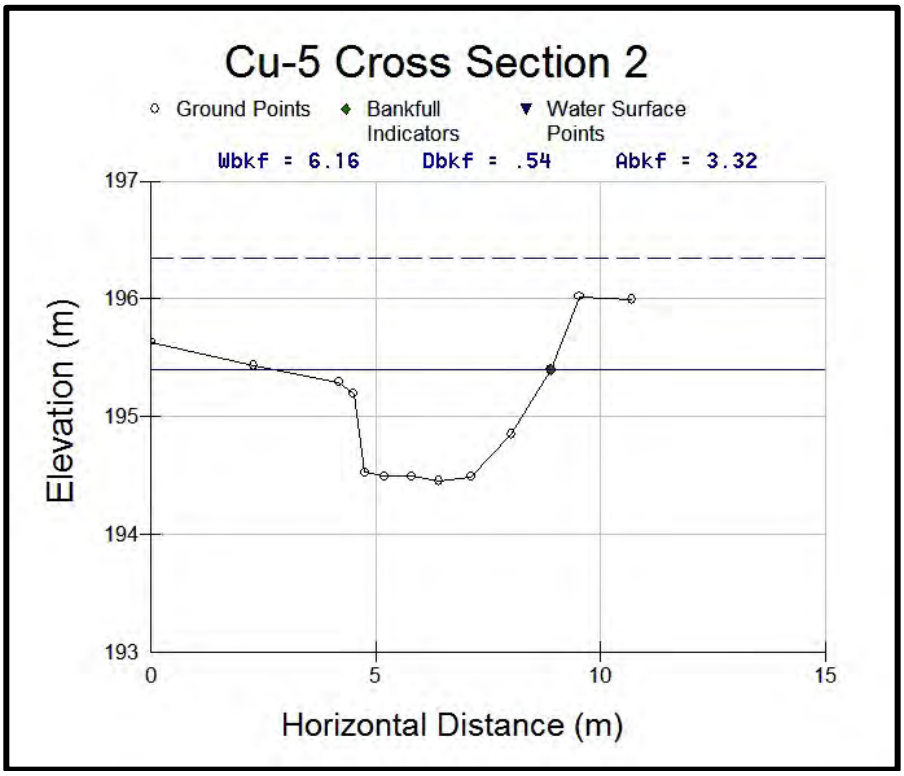


Figure 10: Cross Section 2 @ Cu-5

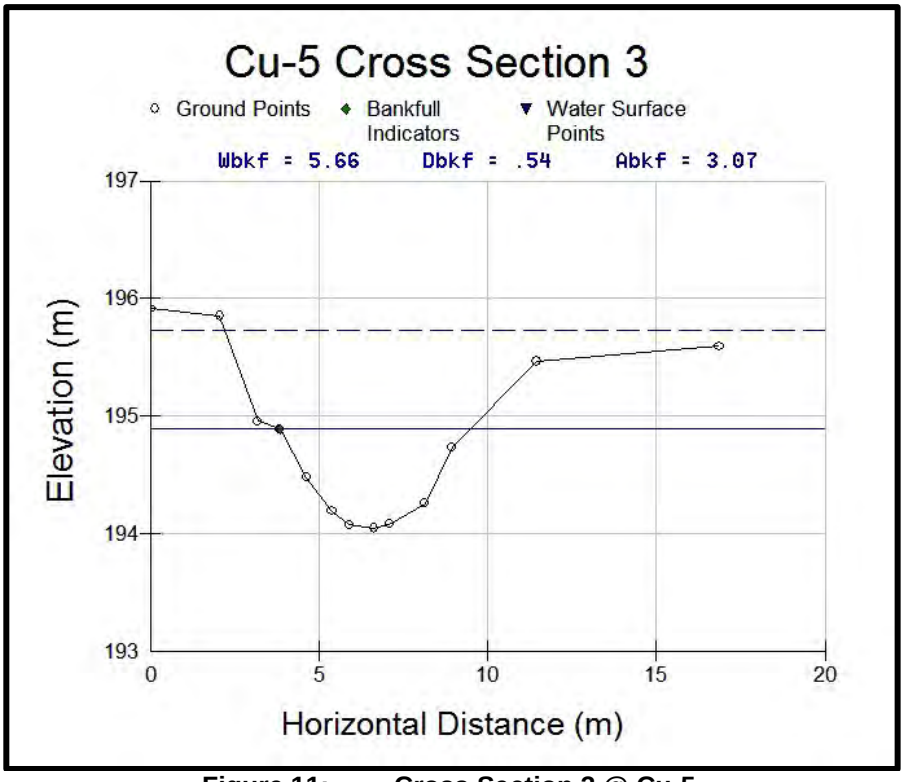


Figure 11: Cross Section 3 @ Cu-5

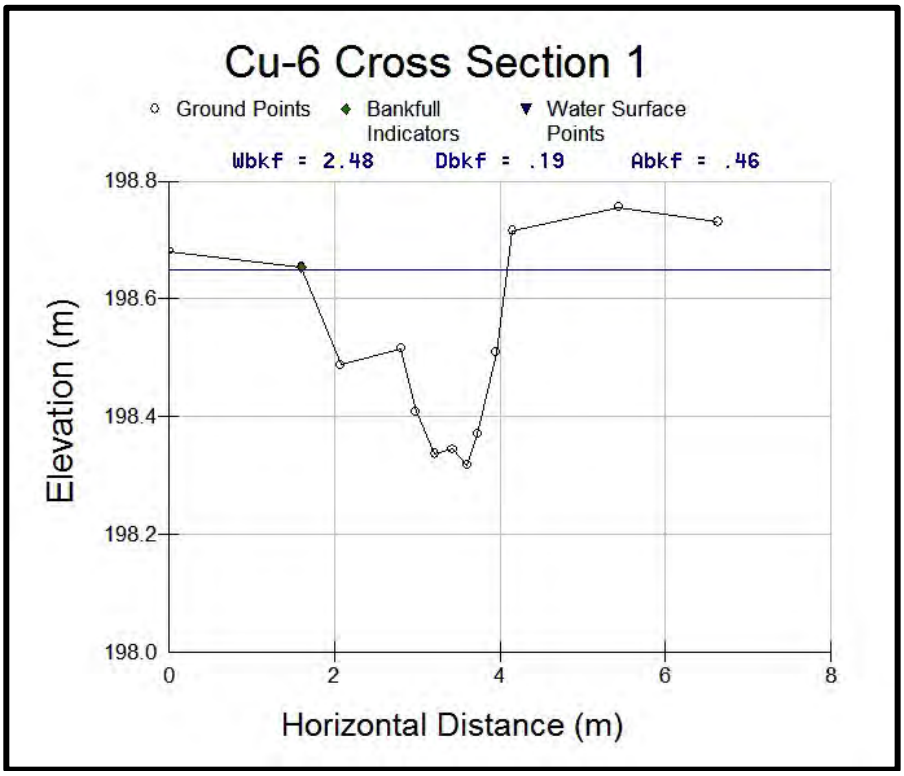


Figure 12: Cross Section 1 @ Cu-6

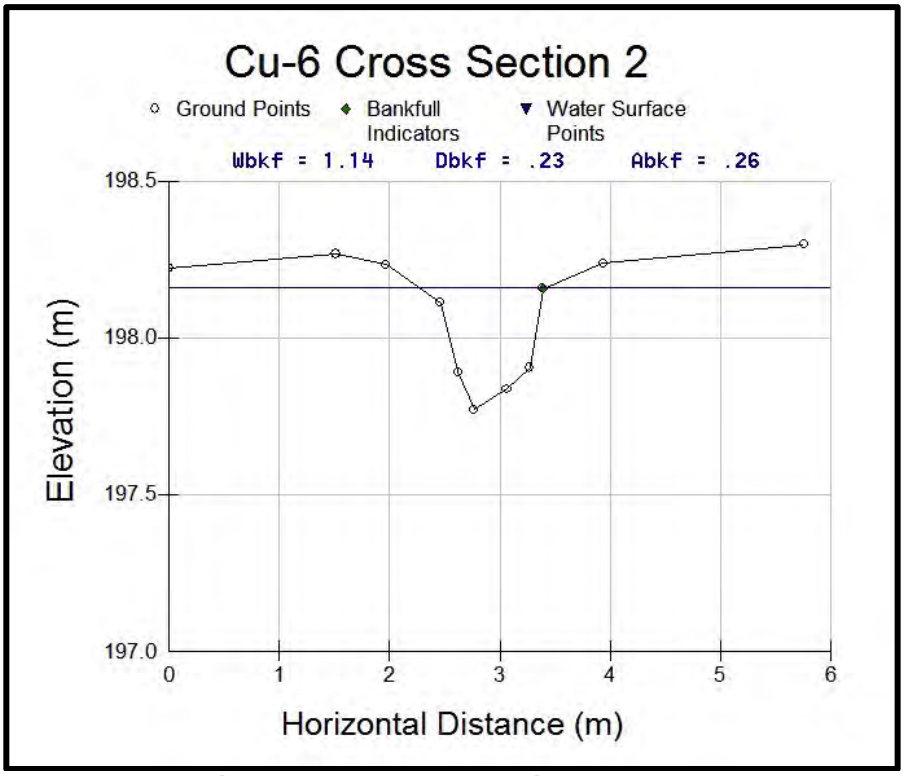


Figure 13: Cross Section 2 @ Cu-6

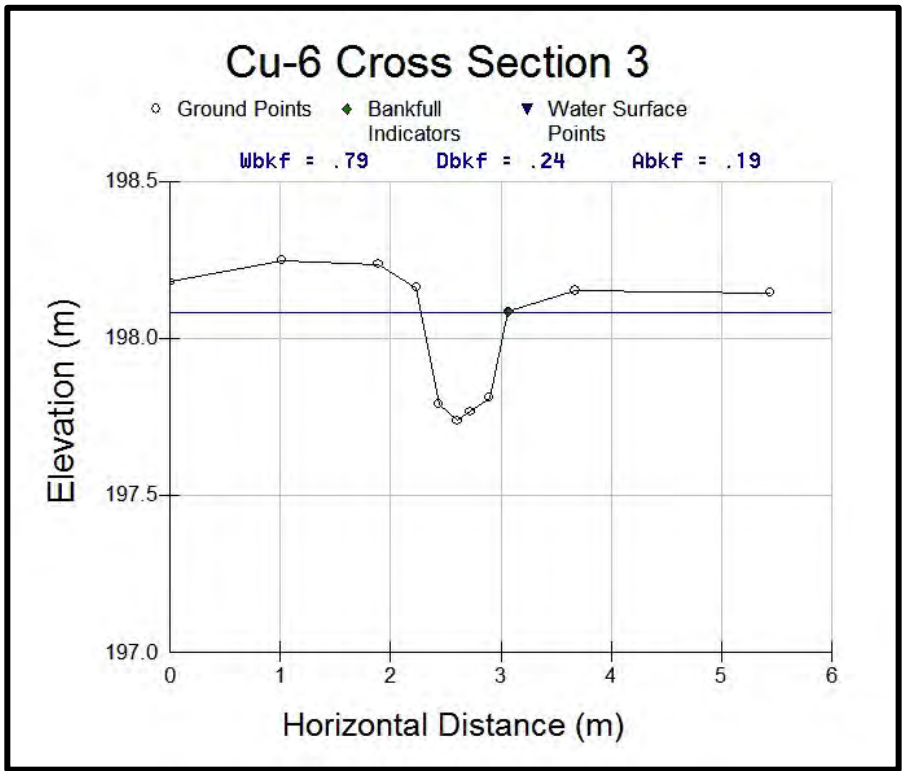


Figure 14: Cross Section 3 @ Cu-6

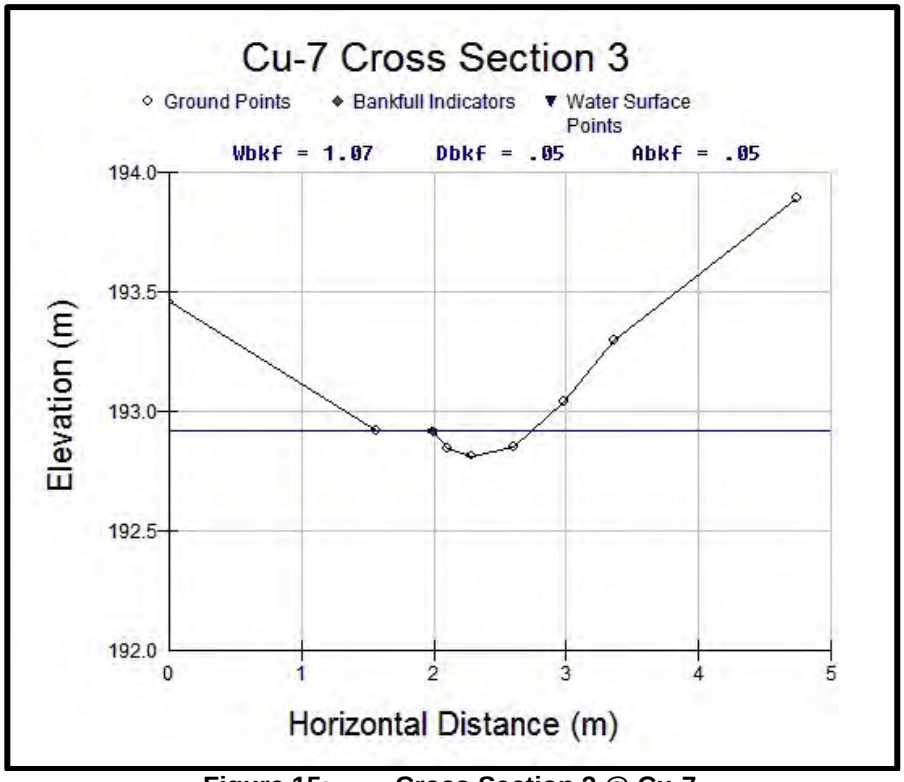


Figure 15: Cross Section 3 @ Cu-7

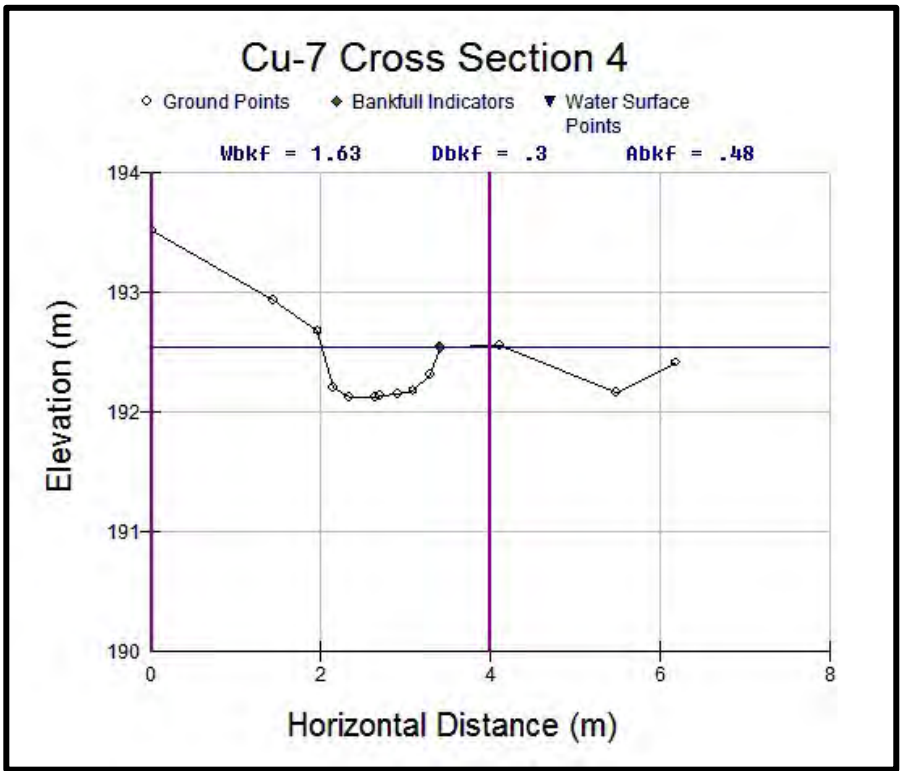


Figure 16: Cross Section 4 @ Cu-7

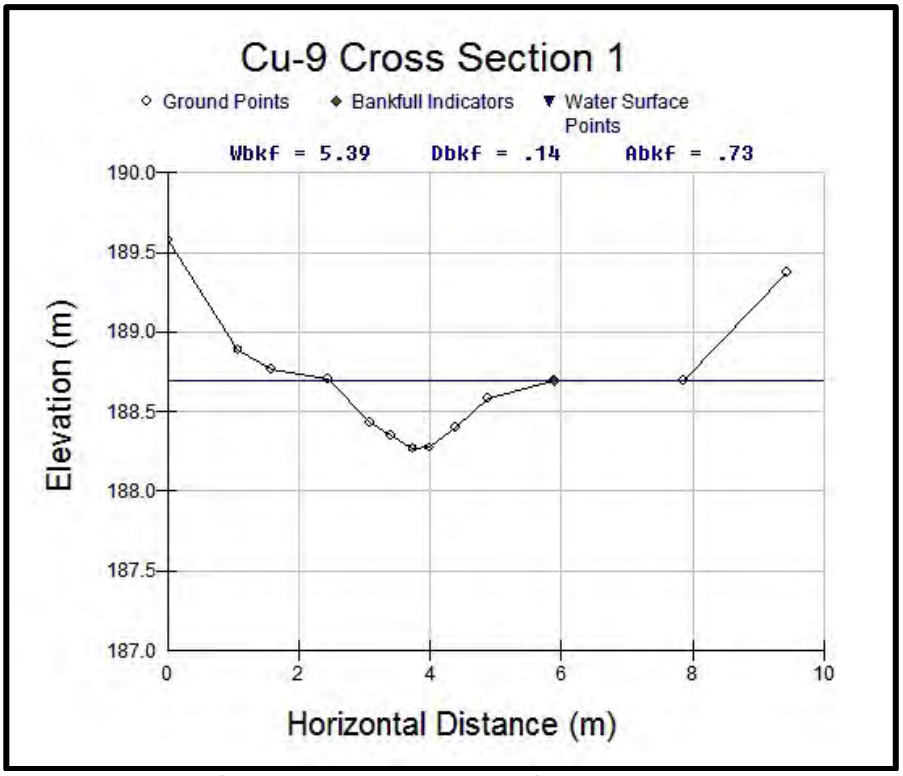


Figure 17: Cross Section 1 @ Cu-9

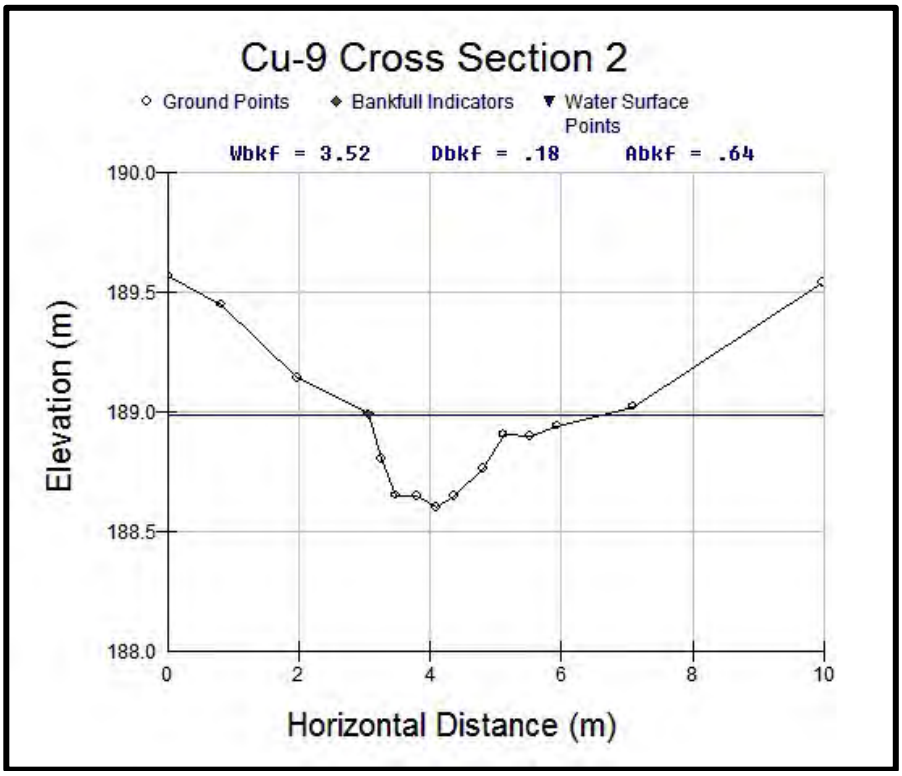


Figure 18: Cross Section 2 @ Cu-9

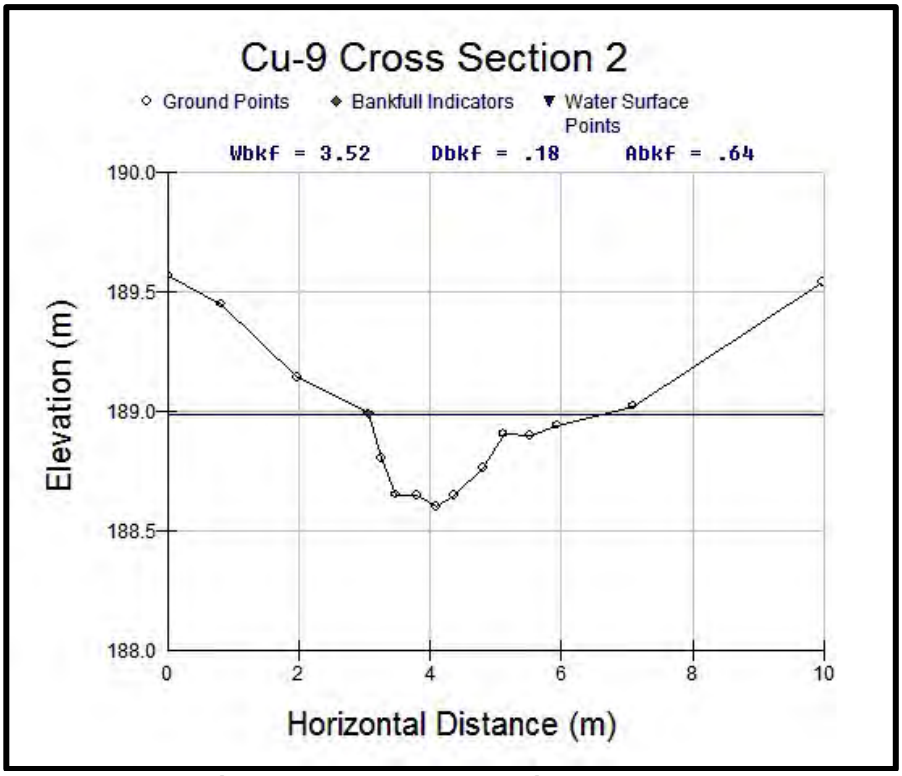


Figure 19: Cross Section 3 @ Cu-9

APPENDIX C:

Photographs

PHOTOGRAPH NO.: 1 – Culvert 4
FROM: Huntington Road
LOOKING: Downstream
COMMENT: East Robinson Creek

PHOTOGRAPH NO.: 2 - Culvert 4
FROM: Huntington Road
LOOKING: Upstream
COMMENT:

PHOTOGRAPH NO.: 3
FROM: Channel
LOOKING: At channel conditions, upstream of culvert 4
COMMENT:

PHOTOGRAPH NO.: 4
FROM: Channel
LOOKING: At channel conditions, downstream of culvert 4
COMMENT:

PHOTOGRAPH NO.: 5 – Culvert 5
FROM: Upstream of road
LOOKING: Downstream at culvert
COMMENT:

PHOTOGRAPH NO.: 6 - Culvert 5
FROM: Upstream of culvert
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 7 - Culvert 5
FROM: Downstream end of culvert
LOOKING: Downstream at channel bed
COMMENT: Active grazing lands

PHOTOGRAPH NO.: 8 - Culvert 5
FROM: From road
LOOKING: Downstream at channel through grazing lands
COMMENT: Stream flows into online pond 50m outside of picture

PHOTOGRAPH NO.: 9 - Culvert 6
FROM: From upstream end of culvert
LOOKING: Upstream
COMMENT:

PHOTOGRAPH NO.: 10 - Culvert 6
FROM: Downstream end of culvert
LOOKING: Downstream at channel
COMMENT:

PHOTOGRAPH NO.: 11 - Culvert 6
FROM: Downstream end of culvert
LOOKING: Upstream
COMMENT:

PHOTOGRAPH NO.: 12 - Culvert 6
FROM: Downstream end of survey
LOOKING: Upstream at channel
COMMENT: Typical shape of channel through reach

File #:14017

PHOTOGRAPH NO.: 13 - Culvert 7
FROM: Huntington Road
LOOKING: Upstream of Culvert
COMMENT: Rainbow Creek

PHOTOGRAPH NO.: 14 - Culvert 7
FROM: Huntington Road
LOOKING: Downstream of Culvert
COMMENT: Rainbow Creek Tributary

PHOTOGRAPH NO.: 15
FROM: Top of Bank on Channel on the west of Huntington Road
LOOKING: Downstream of Culvert 7 at south channel
COMMENT: Rainbow Creek Tributary

PHOTOGRAPH NO.: 16 - Culvert 9
FROM: Upstream end of culvert
LOOKING: Upstream at channel
COMMENT:

File #:14017

PHOTOGRAPH NO.: 17 - Culvert 9
FROM: Upstream of culvert at road
LOOKING: Downstream at culvert
COMMENT:

PHOTOGRAPH NO.: 18 - Culvert 9
FROM: Downstream end of culvert
LOOKING: Downstream at channel
COMMENT:

APPENDIX D:

Rapid Field Assessment Worksheets

Rapid Geomorphic Assessment

Date:
Evaluator: EEG & CB
Stream: Rainbow Creek & Tribs
Conditions:

Form / Process (1)	Geomorphic Indicator No (2)	Description (3)	Culvert # 5	6	9	4	7
Evidence of Aggradation	1	Lobate bar	1	0	1	0	0
	2	Coarse material in riffles embedded	1	0	0	1	1
	3	Siltation in pools	1	0	0	1	1
	4	Medial bars	1	0	1	0	0
	5	Accretion on point bars	1	0	0	0	0
	6	Poor longitudinal sorting of bed materials	0	1	0	0	0
	7	Deposition in the overbank zone	0	0	0	0	0
		Sum of Indices	**5**	**1**	**2**	**2**	**2**
		Factor Value	**0.71**	**0.14**	**0.29**	**0.29**	**0.29**
Evidence of Degradation (DI)	1	Exposed bridge footing(s)					
	2	Exposed sanitary/storm sewer/pipeline/etc.					
	3	Elevated storm sewer outfall(s)					
	4	Undermined gabion baskets/concrete aprons/etc.					
	5	Scour pools d/s of culverts/storm sewer outlets	0	0	0	0	0
	6	Cut face on bar forms	0	0	0	0	0
	7	Head cutting due to knick point migration	0	0	1	0	0
	8	Terrace cut through older bar material	0	0	0	0	0
	9	Suspended armour layer visible in bank	0	0	0	0	0
	10	Channel worn into undisturbed overburden/bedrock	0	0	0	0	0
		Sum of Indices	**0**	**0**	**1**	**0**	**0**
		Factor Value	**0.00**	**0.00**	**0.17**	**0.00**	**0.00**
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.	1	0	1	0	
	2	Occurrence of large organic debris	1	0	1	0	1
	3	Exposed tree roots	1	1	1	1	1
	4	Basal scour on inside meander bends	0	0	0	0	0
	5	Basal scour on both sides of channel through riffle	1	0	1	0	0
	6	Gabion baskets/concrete walls/etc. out flanked					
	7	Length of basal scour >50% through subject reach	0	0	0	0	0
	8	Exposed length of previously buried pipe/cable/etc.					
	9	Fracture lines along top of bank	0	0	0	0	0
	10	Exposed building foundation					
		Sum of Indices	**4**	**1**	**4**	**1**	**2**
		Factor Value	**0.57**	**0.14**	**0.57**	**0.14**	**0.33**
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cut (s)	0	0	0	0	0
	2	Single thread channel to multiple channel	0	1	0	1	1
	3	Evolution of pool-riffle form to low bed relief form	0	0	0	0	0
	4	Cutoff channel(s)	1	1	0	0	0
	5	Formation of island(s)	0	1	1	0	0
	6	Thalweg alignment out of phase meander form	0	0	0	1	1
	7	Bar forms poorly formed/reworked/removed	0	1	0	1	1
		Sum of Indices	**1**	**4**	**0**	**3**	**3**
		Factor Value	**0.14**	**0.57**	**0.00**	**0.43**	**0.43**
Stability Index (SI) = (AI + DI+ WI+ PI) /m			0.36	0.21	0.26	0.21	0.26

RAPID STREAM ASSESSMENT TECHNIQUE (RSAT) Evaluation

Creek Name: Robinson Creek **RSAT Section #: 5**

Assessor: EEG **Date:**

Coordinates:

Evaluation Category	Relative Significance	Criteria	Rating Excellent	Good	Fair	Poor	Score
1 Channel Stability	Indicative of hydrologic/flow regime alteration and general condition of physical aquatic habitat. Provides insight into past, present and possible future changes in channel morphometry	Bank Stability	>80%	71-80 %	50-70 %	< 50 %	2
		Stream Bend Stability Outer bank height/bank overhang	<0.60 m / <0.60m	0.60 to 0.90 m / 0.60 to 0.75 m	0.90 to 1.20 m / 0.75 to 0.90 m	>1.20 m / >0.90 m	3
		Exposed roots and falls	old and large / 0-1	some young / 2-3	young common / 4-5	young abundant / >6	4
		Bottom 1/3 of Bank	resistant plant/soil	resistant plant/soil	highly erodable plant/soil	highly erodable plant/soil	3
		Cross-Section	V or U	V or U	Trapezoidal	Trapezoidal	4
		Typical Score:	**9 to 11**	**6 to 8**	**3 to 5**	**0 to 2**	**3.2**
	NOTES:						
2 Channel Scour and Sediment Deposition	Relates to level of uncontrolled stormwater runoff, sediment load and transport and degradation of instream habitat.	Riffle Embeddedness	<25% sand & silt	25-50%	50-75%	>75%	6
		# of deep pools / substrate	high # / <30% fines	mod # / 30-60% fines	low-mod # / 60-80% fines	few # / >80 % fines	5
		Streak marks/sediment deposits absent	marks / dep absent	uncommon	common	common	4
		large sand deposits/fresh	rare / no fresh dep.	uncommon and small localized dep	common and small localized dep.	common and heavy dep along major portion	3
		Point bar/vege/sand	few / well vege / none	small/well vege/little	mod-large& unstable/high am't of sand common	mod-large& unstable/high am't of sand at most bends	3
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4.2**
	NOTES:						
3 Physical In-stream Habitat	Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well-balanced aquatic community (eg: depth of flow, water velocity, water temperature, substrate type and quality, etc).	Wetted Perimeter	> 85% of bottom width	61-85%	40 - 60 %	< 40 %	3
		Diversity of structure, velocity and depth of flow	All forms present, diverse vel. and depth of flow	Good mix of form, rel. diverse velocity and depth	Few pools, riffles and runs dominant, vel & depth gen shallow/slow	dominated by 1 type (usually runs) and 1 vel/depth (usually slow & shallow	2.5
		Riffle substrate	cobble, gravel, rubble, boulder mix with little sand & >50 % cobble	Good mix of gravel, cobble and rubble & 25-49% cobble	predominantly small cobble, gravel and sand & 5 - 24 % cobble	Predominantly gravel with high % sand & <5% cobble	4
		Riffle depth	>0.20 m	0.15 - 0.19 m	0.10 - 0.14 m	< 0.10 m	4
		Large Pool Depth	> 0.60 m	0.45 - 0.59 m	0.30 - 0.44 m	< 0.30 m	6
		Channel Process	No channel alteration of significant point bar formation or enlargement	Slight increase in point bar formation or slight amount of channel mod.	Mod. increase in point bars and / or channel mod.	extensive channel alteration or point bar formation / enlargement	3
		Riffle-Pool Ratio	0.9 - 1.1 to 1	0.7 - 0.89 to 1 or 1.11 - 1.3 to 1	0.5 - 0.69 to 1 or 1.31 - 1.5 to 1	< 0.49 to 1 or > 1.51 to 1	4
		Stream Temp. on a Summer Afternoon	< 20 ○ C	20 to 24 ○ C	24 to 26 ○ C	>27 ○ C	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3.9166667**
	NOTES:						
4 Water Quality	Indicative of watershed perturbations / general level of human activity, point and non-point source loads, and aquatic habitat conditions.	Substrate Fouling (on rock underside)	None: 0 -10%	Light: 11-20%	Mod: 21 - 50 %	High >50%	3
		Total Dissolved Solids (TDS)	<50mg/L	50-100 mg/L	101-150 mg/L	>150 mg/L	
		Clearness of Water	>0.90 m visibility	0.45 - 0.89 m	0.15 - 0.44 m	<0.15 m visible	3
		Odour	None	Slight organic odour	Slight - Moderate odour	Moderate to strong odour	5
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3.6666667**
	NOTES:						
5 Riparian Habitat Conditions	Provides insight into change(s) in stream energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of Riparian Buffer	Wide > 200' with mature forests on both sides	Forested buffer >100' along major portion	Predom. Wooded but major localized gaps	Mostly non-wooded vegetation, narrow width.	3
		Canopy coverage (Shading)	>80% shading	60-79% shading	50-60 % shading	<50 % shading	3
		Typical Score:	**6 to 7**	**4 to 5**	**2 to 3**	**0 to 1**	**3**
	NOTES:						
6 Biological Indicators	Best overall indication of stream health and level of watershed perturbation	Diversity of macro-invert community	Diverse community present (mayflies, stoneflies, and cased caddisflies (few snails or leeches)	Mayflies and caddisflies (stoneflies absent)	Pollution-tolerant species; aquatic worms dominant	Poor diversity dominated by midgeflies, aquatic worms and snails.	3
		Number of Individuals	Mod to High #	Mod to High #	Low - Mod #	Low #	3
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3**
	NOTES:						

TOTAL SCORE:	**20.98333333**
CONDITION:	**Fair**

RAPID STREAM ASSESSMENT TECHNIQUE (RSAT) Evaluation

Creek Name: East Raibow Creek **RSAT Section #: 6**

Assessor: EEG **Date:**

Coordinates:

Evaluation Category	Relative Significance	Criteria	Rating Excellent	Good	Fair	Poor	Score
1 Channel Stability	Indicative of hydrologic/flow regime alteration and general condition of physical aquatic habitat. Provides insight into past, present and possible future changes in channel morphometry	Bank Stability	>80%	71-80 %	50-70 %	< 50 %	1
		Stream Bend Stability Outer bank height/bank overhang	<0.60 m / <0.60m	0.60 to 0.90 m / 0.60 to 0.75 m	0.90 to 1.20 m / 0.75 to 0.90 m	>1.20 m / >0.90 m	2
		Exposed roots and falls	old and large / 0-1	some young / 2-3	young common / 4-5	young abundant / >6	2
		Bottom 1/3 of Bank	resistant plant/soil	resistant plant/soil	highly erodable plant/soil	highly erodable plant/soil	1
		Cross-Section	V or U	V or U	Trapezoidal	Trapezoidal	4
		Typical Score:	**9 to 11**	**6 to 8**	**3 to 5**	**0 to 2**	**2**
	NOTES:						
2 Channel Scour and Sediment Deposition	Relates to level of uncontrolled stormwater runoff, sediment load and transport and degradation of instream habitat.	Riffle Embeddedness	<25% sand & silt	25-50%	50-75%	>75%	2
		# of deep pools / substrate	high # / <30% fines	mod # / 30-60% fines	low-mod # / 60-80% fines	few # / >80 % fines	2
		Streak marks/sediment deposits absent	marks / dep absent	uncommon	common	common	5
		large sand deposits/fresh	rare / no fresh dep.	uncommon and small localized dep	common and small localized dep.	common and heavy dep along major portion	5
		Point bar/vege/sand	few / well vege / none	small/well vege/little	mod-large& unstable/high am't of sand common	mod-large& unstable/high am't of sand at most bends	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3.5**
	NOTES:						
3 Physical In-stream Habitat	Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well-balanced aquatic community (eg: depth of flow, water velocity, water temperature, substrate type and quality, etc).	Wetted Perimeter	> 85% of bottom width	61-85%	40 - 60 %	< 40 %	5
		Diversity of structure, velocity and depth of flow	All forms present, diverse vel. and depth of flow	Good mix of form, rel. diverse velocity and depth	Few pools, riffles and runs dominant, vel & depth gen shallow/slow	dominated by 1 type (usually runs) and 1 vel/depth (usually slow & shallow	5
		Riffle substrate	cobble, gravel, rubble, boulder mix with little sand & >50 % cobble	Good mix of gravel, cobble and rubble & 25-49% cobble	predominantly small cobble, gravel and sand & 5 - 24 % cobble	Predominantly gravel with high % sand & <5% cobble	2
		Riffle depth	>0.20 m	0.15 - 0.19 m	0.10 - 0.14 m	< 0.10 m	7
		Large Pool Depth	> 0.60 m	0.45 - 0.59 m	0.30 - 0.44 m	< 0.30 m	6
		Channel Process	No channel alteration of significant point bar formation or enlargement	Slight increase in point bar formation or slight amount of channel mod.	Mod. increase in point bars and / or channel mod.	extensive channel alteration or point bar formation / enlargement	2
		Riffle-Pool Ratio	0.9 - 1.1 to 1	0.7 - 0.89 to 1 or 1.11 - 1.3 to 1	0.5 - 0.69 to 1 or 1.31 - 1.5 to 1	< 0.49 to 1 or > 1.51 to 1	2
		Stream Temp. on a Summer Afternoon	< 20 ○ C	20 to 24 ○ C	24 to 26 ○ C	>27 ○ C	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
4 Water Quality	Indicative of watershed perturbations / general level of human activity, point and non-point source loads, and aquatic habitat conditions.	Substrate Fouling (on rock underside)	None: 0 -10%	Light: 11-20%	Mod: 21 - 50 %	High >50%	
		Total Dissolved Solids (TDS)	<50mg/L	50-100 mg/L	101-150 mg/L	>150 mg/L	
		Clearness of Water	>0.90 m visibility	0.45 - 0.89 m	0.15 - 0.44 m	<0.15 m visible	3
		Odour	None	Slight organic odour	Slight - Moderate odour	Moderate to strong odour	3
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3**
	NOTES:						
5 Riparian Habitat Conditions	Provides insight into change(s) in stream energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of Riparian Buffer	Wide > 200' with mature forests on both sides	Forested buffer >100' along major portion	Predom. Wooded but major localized gaps	Mostly non-wooded vegetation, narrow width.	5
		Canopy coverage (Shading)	>80% shading	60-79% shading	50-60 % shading	<50 % shading	7
		Typical Score:	**6 to 7**	**4 to 5**	**2 to 3**	**0 to 1**	**6**
	NOTES:						
6 Biological Indicators	Best overall indication of stream health and level of watershed perturbation	Diversity of macro-invert community	Diverse community present (mayflies, stoneflies, and cased caddisflies (few snails or leeches)	Mayflies and caddisflies (stoneflies absent)	Pollution-tolerant species; aquatic worms dominant	Poor diversity dominated by midgeflies, aquatic worms and snails.	5
		Number of Individuals	Mod to High #	Mod to High #	Low - Mod #	Low #	5
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**5**
	NOTES:						

TOTAL SCORE:	**23.5**
CONDITION:	**Fair**

RAPID STREAM ASSESSMENT TECHNIQUE (RSAT) Evaluation

Creek Name: West Rainbow Creek **RSAT Section #: 9**

Assessor: EEG **Date:**

Coordinates:

Evaluation Category	Relative Significance	Criteria	Rating Excellent	Good	Fair	Poor	Score
1 Channel Stability	Indicative of hydrologic/flow regime alteration and general condition of physical aquatic habitat. Provides insight into past, present and possible future changes in channel morphometry	Bank Stability	>80%	71-80 %	50-70 %	< 50 %	6
		Stream Bend Stability Outer bank height/bank overhang	<0.60 m / <0.60m	0.60 to 0.90 m / 0.60 to 0.75 m	0.90 to 1.20 m / 0.75 to 0.90 m	>1.20 m / >0.90 m	6
		Exposed roots and falls	old and large / 0-1	some young / 2-3	young common / 4-5	young abundant / >6	6
		Bottom 1/3 of Bank	resistant plant/soil	resistant plant/soil	highly erodable plant/soil	highly erodable plant/soil	7
		Cross-Section	V or U	V or U	Trapezoidal	Trapezoidal	6
		Typical Score:	**9 to 11**	**6 to 8**	**3 to 5**	**0 to 2**	**6.2**
	NOTES:						
2 Channel Scour and Sediment Deposition	Relates to level of uncontrolled stormwater runoff, sediment load and transport and degradation of instream habitat.	Riffle Embeddedness	<25% sand & silt	25-50%	50-75%	>75%	6
		# of deep pools / substrate	high # / <30% fines	mod # / 30-60% fines	low-mod # / 60-80% fines	few # / >80 % fines	7
		Streak marks/sediment deposits absent	marks / dep absent	uncommon	common	common	
		large sand deposits/fresh	rare / no fresh dep.	uncommon and small localized dep	common and small localized dep.	common and heavy dep along major portion	5
		Point bar/vege/sand	few / well vege / none	small/well vege/little	mod-large& unstable/high am't of sand common	mod-large& unstable/high am't of sand at most bends	5
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**5.75**
	NOTES:						
3 Physical In-stream Habitat	Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well-balanced aquatic community (eg: depth of flow, water velocity, water temperature, substrate type and quality, etc).	Wetted Perimeter	> 85% of bottom width	61-85%	40 - 60 %	< 40 %	6
		Diversity of structure, velocity and depth of flow	All forms present, diverse vel. and depth of flow	Good mix of form, rel. diverse velocity and depth	Few pools, riffles and runs dominant, vel & depth gen shallow/slow	dominated by 1 type (usually runs) and 1 vel/depth (usually slow & shallow	7
		Riffle substrate	cobble, gravel, rubble, boulder mix with little sand & >50 % cobble	Good mix of gravel, cobble and rubble & 25-49% cobble	predominantly small cobble, gravel and sand & 5 - 24 % cobble	Predominantly gravel with high % sand & <5% cobble	6
		Riffle depth	>0.20 m	0.15 - 0.19 m	0.10 - 0.14 m	< 0.10 m	5
		Large Pool Depth	> 0.60 m	0.45 - 0.59 m	0.30 - 0.44 m	< 0.30 m	5
		Channel Process	No channel alteration of significant point bar formation or enlargement	Slight increase in point bar formation or slight amount of channel mod.	Mod. increase in point bars and / or channel mod.	extensive channel alteration or point bar formation / enlargement	4
		Riffle-Pool Ratio	0.9 - 1.1 to 1	0.7 - 0.89 to 1 or 1.11 - 1.3 to 1	0.5 - 0.69 to 1 or 1.31 - 1.5 to 1	< 0.49 to 1 or > 1.51 to 1	6.5
		Stream Temp. on a Summer Afternoon	< 20 ○ C	20 to 24 ○ C	24 to 26 ○ C	>27 ○ C	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**5.5833333**
	NOTES:						
4 Water Quality	Indicative of watershed perturbations / general level of human activity, point and non-point source loads, and aquatic habitat conditions.	Substrate Fouling (on rock underside)	None: 0 -10%	Light: 11-20%	Mod: 21 - 50 %	High >50%	
		Total Dissolved Solids (TDS)	<50mg/L	50-100 mg/L	101-150 mg/L	>150 mg/L	
		Clearness of Water	>0.90 m visibility	0.45 - 0.89 m	0.15 - 0.44 m	<0.15 m visible	6
		Odour	None	Slight organic odour	Slight - Moderate odour	Moderate to strong odour	5
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**5.5**
	NOTES:						
5 Riparian Habitat Conditions	Provides insight into change(s) in stream energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of Riparian Buffer	Wide > 200' with mature forests on both sides	Forested buffer >100' along major portion	Predom. Wooded but major localized gaps	Mostly non-wooded vegetation, narrow width.	3.5
		Canopy coverage (Shading)	>80% shading	60-79% shading	50-60 % shading	<50 % shading	3
		Typical Score:	**6 to 7**	**4 to 5**	**2 to 3**	**0 to 1**	**3.25**
	NOTES:						
6 Biological Indicators	Best overall indication of stream health and level of watershed perturbation	Diversity of macro-invert community	Diverse community present (mayflies, stoneflies, and cased caddisflies (few snails or leeches)	Mayflies and caddisflies (stoneflies absent)	Pollution-tolerant species; aquatic worms dominant	Poor diversity dominated by midgeflies, aquatic worms and snails.	5
		Number of Individuals	Mod to High #	Mod to High #	Low - Mod #	Low #	5
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**5**
	NOTES:						

TOTAL SCORE:	**31.28333333**
CONDITION:	**Good**

RAPID STREAM ASSESSMENT TECHNIQUE (RSAT) Evaluation

Creek Name: East Robinson Creek **RSAT Section #: 4**

Assessor: CB **Date:**

Coordinates:

Evaluation Category	Relative Significance	Criteria	Rating Excellent	Good	Fair	Poor	Score
1 Channel Stability	Indicative of hydrologic/flow regime alteration and general condition of physical aquatic habitat. Provides insight into past, present and possible future changes in channel morphometry	Bank Stability	>80%	71-80 %	50-70 %	< 50 %	
		Stream Bend Stability Outer bank height/bank overhang	<0.60 m / <0.60m	0.60 to 0.90 m / 0.60 to 0.75 m	0.90 to 1.20 m / 0.75 to 0.90 m	>1.20 m / >0.90 m	
		Exposed roots and falls	old and large / 0-1	some young / 2-3	young common / 4-5	young abundant / >6	
		Bottom 1/3 of Bank	resistant plant/soil	resistant plant/soil	highly erodable plant/soil	highly erodable plant/soil	
		Cross-Section	V or U	V or U	Trapezoidal	Trapezoidal	
		Typical Score:	**9 to 11**	**6 to 8**	**3 to 5**	**0 to 2**	**5**
	NOTES:						
2 Channel Scour and Sediment Deposition	Relates to level of uncontrolled stormwater runoff, sediment load and transport and degradation of instream habitat.	Riffle Embeddedness	<25% sand & silt	25-50%	50-75%	>75%	
		# of deep pools / substrate	high # / <30% fines	mod # / 30-60% fines	low-mod # / 60-80% fines	few # / >80 % fines	
		Streak marks/sediment deposits absent	marks / dep absent	uncommon	common	common	
		large sand deposits/fresh	rare / no fresh dep.	uncommon and small localized dep	common and small localized dep.	common and heavy dep along major portion	
		Point bar/vege/sand	few / well vege / none	small/well vege/little	mod-large& unstable/high am't of sand common	mod-large& unstable/high am't of sand at most bends	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
3 Physical In-stream Habitat	Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well-balanced aquatic community (eg: depth of flow, water velocity, water temperature, substrate type and quality, etc).	Wetted Perimeter	> 85% of bottom width	61-85%	40 - 60 %	< 40 %	
		Diversity of structure, velocity and depth of flow	All forms present, diverse vel. and depth of flow	Good mix of form, rel. diverse velocity and depth	Few pools, riffles and runs dominant, vel & depth gen shallow/slow	dominated by 1 type (usually runs) and 1 vel/depth (usually slow & shallow	
		Riffle substrate	cobble, gravel, rubble, boulder mix with little sand & >50 % cobble	Good mix of gravel, cobble and rubble & 25-49% cobble	predominantly small cobble, gravel and sand & 5 - 24 % cobble	Predominantly gravel with high % sand & <5% cobble	
		Riffle depth	>0.20 m	0.15 - 0.19 m	0.10 - 0.14 m	< 0.10 m	
		Large Pool Depth	> 0.60 m	0.45 - 0.59 m	0.30 - 0.44 m	< 0.30 m	
		Channel Process	No channel alteration of significant point bar formation or enlargement	Slight increase in point bar formation or slight amount of channel mod.	Mod. increase in point bars and / or channel mod.	extensive channel alteration or point bar formation / enlargement	
		Riffle-Pool Ratio	0.9 - 1.1 to 1	0.7 - 0.89 to 1 or 1.11 - 1.3 to 1	0.5 - 0.69 to 1 or 1.31 - 1.5 to 1	< 0.49 to 1 or > 1.51 to 1	
		Stream Temp. on a Summer Afternoon	< 20 ○ C	20 to 24 ○ C	24 to 26 ○ C	>27 ○ C	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3**
	NOTES:						
4 Water Quality	Indicative of watershed perturbations / general level of human activity, point and non-point source loads, and aquatic habitat conditions.	Substrate Fouling (on rock underside)	None: 0 -10%	Light: 11-20%	Mod: 21 - 50 %	High >50%	
		Total Dissolved Solids (TDS)	<50mg/L	50-100 mg/L	101-150 mg/L	>150 mg/L	
		Clearness of Water	>0.90 m visibility	0.45 - 0.89 m	0.15 - 0.44 m	<0.15 m visible	
		Odour	None	Slight organic odour	Slight - Moderate odour	Moderate to strong odour	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
5 Riparian Habitat Conditions	Provides insight into change(s) in stream energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of Riparian Buffer	Wide > 200' with mature forests on both sides	Forested buffer >100' along major portion	Predom. Wooded but major localized gaps	Mostly non-wooded vegetation, narrow width.	
		Canopy coverage (Shading)	>80% shading	60-79% shading	50-60 % shading	<50 % shading	
		Typical Score:	**6 to 7**	**4 to 5**	**2 to 3**	**0 to 1**	**1**
	NOTES:						
6 Biological Indicators	Best overall indication of stream health and level of watershed perturbation	Diversity of macro-invert community	Diverse community present (mayflies, stoneflies, and cased caddisflies (few snails or leeches)	Mayflies and caddisflies (stoneflies absent)	Pollution-tolerant species; aquatic worms dominant	Poor diversity dominated by midgeflies, aquatic worms and snails.	
		Number of Individuals	Mod to High #	Mod to High #	Low - Mod #	Low #	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3**
	NOTES:						

TOTAL SCORE:	**20**
CONDITION:	**Fair**

RAPID STREAM ASSESSMENT TECHNIQUE (RSAT) Evaluation

Creek Name: Rainbow Creek Trib **RSAT Section #:** 7

Assessor: CB **Date:**

Coordinates:

Evaluation Category	Relative Significance	Criteria	Rating: Excellent	Good	Fair	Poor	Score
1 Channel Stability	Indicative of hydrologic/flow regime alteration and general condition of physical aquatic habitat. Provides insight into past, present and possible future changes in channel morphometry	Bank Stability	>80%	71-80 %	50-70 %	< 50 %	
		Stream Bend Stability Outer bank height/bank overhang	<0.60 m / <0.60m	0.60 to 0.90 m / 0.60 to 0.75 m	0.90 to 1.20 m / 0.75 to 0.90 m	>1.20 m / >0.90 m	
		Exposed roots and falls	old and large / 0-1	some young / 2-3	young common / 4-5	young abundant / >6	
		Bottom 1/3 of Bank	resistant plant/soil	resistant plant/soil	highly erodable plant/soil	highly erodable plant/soil	
		Cross-Section	V or U	V or U	Trapezoidal	Trapezoidal	
		Typical Score:	**9 to 11**	**6 to 8**	**3 to 5**	**0 to 2**	**5**
	NOTES:						
2 Channel Scour and Sediment Deposition	Relates to level of uncontrolled stormwater runoff, sediment load and transport and degradation of instream habitat.	Riffle Embeddedness	<25% sand & silt	25-50%	50-75%	>75%	
		# of deep pools / substrate	high # / <30% fines	mod # / 30-60% fines	low-mod # / 60-80% fines	few # / >80 % fines	
		Streak marks/sediment deposits absent	marks / dep absent	uncommon	common	common	
		large sand deposits/fresh	rare / no fresh dep.	uncommon and small localized dep	common and small localized dep.	common and heavy dep along major portion	
		Point bar/vege/sand	few / well vege / none	small/well vege/little	mod-large& unstable/high am't of sand common	mod-large& unstable/high am't of sand at most bends	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
3 Physical In-stream Habitat	Relates to the ability of a stream to meet basic physical requirements necessary for the support of a well-balanced aquatic community (eg: depth of flow, water velocity, water temperature, substrate type and quality, etc).	Wetted Perimeter	> 85% of bottom width	61-85%	40 - 60 %	< 40 %	
		Diversity of structure, velocity and depth of flow	All forms present, diverse vel. and depth of flow	Good mix of form, rel. diverse velocity and depth	Few pools, riffles and runs dominant, vel & depth gen shallow/slow	dominated by 1 type (usually runs) and 1 vel/depth (usually slow & shallow	
		Riffle substrate	cobble, gravel, rubble, boulder mix with little sand & >50 % cobble	Good mix of gravel, cobble and rubble & 25-49% cobble	predominantly small cobble, gravel and sand & 5 - 24 % cobble	Predominantly gravel with high % sand & <5% cobble	
		Riffle depth	>0.20 m	0.15 - 0.19 m	0.10 - 0.14 m	< 0.10 m	
		Large Pool Depth	> 0.60 m	0.45 - 0.59 m	0.30 - 0.44 m	< 0.30 m	
		Channel Process	No channel alteration of significant point bar formation or enlargement	Slight increase in point bar formation or slight amount of channel mod.	Mod. increase in point bars and / or channel mod.	extensive channel alteration or point bar formation / enlargement	
		Riffle-Pool Ratio	0.9 - 1.1 to 1	0.7 - 0.89 to 1 or 1.11 - 1.3 to 1	0.5 - 0.69 to 1 or 1.31 - 1.5 to 1	< 0.49 to 1 or > 1.51 to 1	
		Stream Temp. on a Summer Afternoon	< 20 ○ C	20 to 24 ○ C	24 to 26 ○ C	>27 ○ C	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
4 Water Quality	Indicative of watershed perturbations / general level of human activity, point and non-point source loads, and aquatic habitat conditions.	Substrate Fouling (on rock underside)	None: 0 -10%	Light: 11-20%	Mod: 21 - 50 %	High >50%	
		Total Dissolved Solids (TDS)	<50mg/L	50-100 mg/L	101-150 mg/L	>150 mg/L	
		Clearness of Water	>0.90 m visibility	0.45 - 0.89 m	0.15 - 0.44 m	<0.15 m visible	
		Odour	None	Slight organic odour	Slight - Moderate odour	Moderate to strong odour	
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**4**
	NOTES:						
5 Riparian Habitat Conditions	Provides insight into change(s) in stream energetics, temperature regime, and both aquatic and terrestrial habitat conditions	Width of Riparian Buffer	Wide > 200' with mature forests on both sides	Forested buffer >100' along major portion	Predom. Wooded but major localized gaps	Mostly non-wooded vegetation, narrow width.	
		Canopy coverage (Shading)	>80% shading	60-79% shading	50-60 % shading	<50 % shading	
		Typical Score:	**6 to 7**	**4 to 5**	**2 to 3**	**0 to 1**	**1**
	NOTES:						
6 Biological Indicators	Best overall indication of stream health and level of watershed perturbation	Diversity of macro-invert community	Diverse community present (mayflies, stoneflies, and cased caddisflies (few snails or leeches)	Mayflies and caddisflies (stoneflies absent)	Pollution-tolerant species; aquatic worms dominant	Poor diversity dominated by midgeflies, aquatic worms and snails.	
		Number of Individuals	Mod to High #	Mod to High #	Low - Mod #	Low #	3
		Typical Score:	**7 to 8**	**5 to 6**	**3 to 4**	**0 to 2**	**3**
	NOTES:						

TOTAL SCORE:	**21**
CONDITION:	**Fair**

APPENDIX E:

100-Year Erosion Assessment Calculations

Locations listed upstream to downstream
Direction of migration accounted for

3.7 m

Cu-4 - East Robinson Creek

Location 1					Location 2					Location 3					Location 4				
Start	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**
1978	1999	0.92	R	-0.04	1978	1999	2.07	L	-0.10	1978	1999	0.94	R	-0.04	1978	1999	1.59	L	0.08
1999	2002	0.36	R	-0.12	1999	2002	0.5	L	-0.17	1999	2002	0.24	R	-0.08	1999	2002	0.29	L	0.10
2002	2007	2.54	L	0.51	2002	2007	0.74	L	-0.15	2002	2007	1.55	L	0.31	2002	2007	1.19	L	0.24
2007	2012	0.08	L	0.02	2007	2012	0.6	R	0.12	2007	2012	1.78	L	0.36	2007	2012	0.22	L	0.04
2012	2015	1.16	R	-0.39	2012	2015	0.67	R	0.22	2012	2015	0.12	L	0.04	2012	2015	0.6	R	-0.20

Annual	Min			-0.39	Annual	Min			-0.17	Annual	Min			-0.08	Annual	Min			-0.20
Erosion	Avg.			-0.01	Erosion	Avg.			-0.01	Erosion	Avg.			0.12	Erosion	Avg.			0.05
Rate	Max			0.51	Rate	Max			0.22	Rate	Max			0.36	Rate	Max			0.24
100-year	Min			-38.7	100-year	Min			-16.7	100-year	Min			-8.0	100-year	Min			-20.0
Erosion	Avg.			-0.5	Erosion	Avg.			-1.4	Erosion	Avg.			11.6	Erosion	Avg.			5.1
Rate	Max			50.8	Rate	Max			22.3	Rate	Max			35.6	Rate	Max			23.8

Notes: Based on channel centreline
1970 has been excluded because it looks like that the Huntington Rd culvert location was altered at some point between 1970 and 1999
Location1: L + ve R - ve
Location2: R +ve L - ve
Location3: L + ve R - ve
Location4: L + ve R - ve

9.3 m

Cu-5 - Robinson Creek

Location 1 Upstream					Location 2 Upstream					Location 3 Downstream					Location 4 Downstream				
Start	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**
1970	1999	4.9	L	-0.17	1970	1999	1.5	L	-0.05	1970	1999	1.39	R	-0.05	1970	1999	1.53	L	-0.05
1999	2002	1.78	R	0.59	1999	2002	1.88	R	0.63	1999	2002	2.64	L	0.88	1999	2002	1.49	R	0.50
2002	2007				2002	2012	2.5	L	-0.25	2002	2007	0.99	R	-0.20	2002	2007	1.4	L	-0.28
2007	2012				2007	2012				2007	2012	0.89	L	0.18	2007	2012	3	R	0.60
2002	2015	1.8	L	-0.14	2012	2015	0.76	R	0.25	2012	2015	0.79	R	-0.26	2012	2015	1.98	L	-0.66

Annual	Min			-0.17	Annual	Min			-0.25	Annual	Min			-0.26	Annual	Min			-0.66
Erosion	Avg.			0.10	Erosion	Avg.			0.14	Erosion	Avg.			0.11	Erosion	Avg.			0.02
Rate	Max			0.59	Rate	Max			0.63	Rate	Max			0.88	Rate	Max			0.60
100-year	Min			-16.9	100-year	Min			-25.0	100-year	Min			-26.3	100-year	Min			-66.0
Erosion	Avg.			9.5	Erosion	Avg.			14.5	Erosion	Avg.			11.0	Erosion	Avg.			2.1
Rate	Max			59.3	Rate	Max			62.7	Rate	Max			88.0	Rate	Max			60.0

Notes: Based on creek banks
2007, 2012 - channel vegetation is heavy; therefore should be excluded from Location 1
2007 cannot be applied in Location 2
Location1: R +ve L - ve
Location2: R +ve L - ve
Location3: L + ve R - ve
Location4: R +ve L - ve

3.1 m based on Locations 1 and 2

Cu-6 - East Rainbow Creek

Location 1 Upstream					Location 2 Downstream					Location 3 Downstream					Location 4				
Start	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**
1970	1999	2.84	L	0.10	1970	1999	2.59	L	-0.09	1970	1999	8.23	R	-0.28	1970	1999			0.00
1999	2002	0.81	R	-0.27	1999	2002	0.73	R	0.24	1999	2007	5.66	R	-0.71	1999	2002			0.00
2002	2007	1.4	L	0.28	2002	2007	0.57	R	0.11	2002	2007				2002	2007			0.00
2007	2012	1.51	R	-0.30	2007	2012	0.83	L	-0.17	2007	2012	4.6	L	0.92	2007	2012			0.00
2012	2015	0.45	L	0.15	2012	2015	0.76	R	0.25	2012	2015	0.65	R	-0.22	2012	2015			0.00

Annual	Min			-0.30	Annual	Min			-0.17	Annual	Min			-0.71	Annual	Min			0.00
Erosion	Avg.			-0.01	Erosion	Avg.			0.07	Erosion	Avg.			-0.07	Erosion	Avg.			0.00
Rate	Max			0.28	Rate	Max			0.25	Rate	Max			0.92	Rate	Max			0.00
100-year	Min			-30.2	100-year	Min			-16.6	100-year	Min			-70.8	100-year	Min			0.0
Erosion	Avg.			-0.9	Erosion	Avg.			7.1	Erosion	Avg.			-7.2	Erosion	Avg.			0.0
Rate	Max			28.0	Rate	Max			25.3	Rate	Max			92.0	Rate	Max			0.0

Notes: Based on channel centreline
Channel at Location 3 during 2002 unclear due to vegetation
Location1: L + ve R - ve
Location2: R +ve L - ve
Location3: L + ve R - ve

-2.5 m

Cu-7 - Rainbow Creek Trib

Location 1 Upstream					Location 2 Downstream					Location 3					Location 4				
Start	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**
1970	1999	1.98	R	0.07	1970	1999	3.76	L	-0.13	1970	1999				1970	1999			
1999	2002	1	L	-0.33	1999	2002	0.98	R	0.33	1999	2002				1999	2002			
2002	2007	1.16	L	-0.23	2002	2007	0.74	R	0.15	2002	2007				2002	2007			
2007	2012				2007	2012	5.63	R		2007	2012				2007	2012			
2012	2015				2012	2015	0.81	R		2012	2015				2012	2015			

Annual	Min			-0.33	Annual	Min			-0.13	Annual	Min				Annual	Min			
Erosion	Avg.			-0.17	Erosion	Avg.			0.12	Erosion	Avg.				Erosion	Avg.			
Rate	Max			0.07	Rate	Max			0.33	Rate	Max				Rate	Max			
100-year	Min			-33.3	100-year	Min			-13.0	100-year	Min				100-year	Min			
Erosion	Avg.			-16.6	Erosion	Avg.			11.5	Erosion	Avg.				Erosion	Avg.			
Rate	Max			6.8	Rate	Max			32.7	Rate	Max				Rate	Max			

Notes: Based on channel centreline
Multiple channels on the one branch at the upstream end; therefore, quite difficult to delineate the migration
2012, 2015 - the channel movement is unclear due to vegetation (grasses)
Mulitple channels downstream as well - therefore, the average for Location 2 excludes migration from 2007 to 2012
Location1: R +ve L - ve
Location2: R +ve L - ve

-7.9 m

Cu-9 - West Rainbow Creek

Location 1 Upstream					Location 2 Upstream					Location 3 - not a large meander bend Downstream					Location 4				
Start	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**	**Start**	**End**	**Dist. (m)**		**Rate (m/yr)**
1970	1999	0.87	L	0.03	1970	1999	2.62	R		1970	1999	2.27	L	0.08	1970	1999	0.53	L	0.02
1999	2002	1.1	L	0.37	1999	2002	2.74	L	-0.91	1999	2002	0.63	L	0.21	1999	2002	1.1	L	0.37
2002	2007	1.4	R	-0.28	2002	2007	0.33	R	0.07	2002	2007				2002	2007	1.2	R	-0.24
2007	2012	0.63	L	0.13	2007	2012	0.32	L	-0.06	2002	2012	2.34	R	0.23	2007	2012	0.89	L	0.18
2012	2015	2.52	R		2012	2015	1.26	L	-0.42	2012	2015	3.2	L	1.07	2012	2015	0.43	R	-0.14

Annual	Min			-0.28	Annual	Min			-0.91	Annual	Min			0.08	Annual	Min			-0.24
Erosion	Avg.			0.06	Erosion	Avg.			-0.33	Erosion	Avg.			0.40	Erosion	Avg.			0.04
Rate	Max			0.37	Rate	Max			0.07	Rate	Max			1.07	Rate	Max			0.37
100-year	Min			-28.0	100-year	Min			-91.3	100-year	Min			7.8	100-year	Min			-24.0
Erosion	Avg.			6.1	Erosion	Avg.			-33.3	Erosion	Avg.			39.7	Erosion	Avg.			3.6
Rate	Max			36.7	Rate	Max			6.6	Rate	Max			106.7	Rate	Max			36.7

Notes: Based on channel centreline at locations 1, 2 & 4
Channel at Location 3 during 2007 unclear due to vegetation
Channel at Location 1 during 2015 not included as the adjacent pond size increases and "eats into" the watercourse
Channel at Location 2 during 1970 not included as the culvert appears to be at a different location
Location1: L + ve R - ve
Location2: R +ve L - ve
Location4: L + ve R - ve