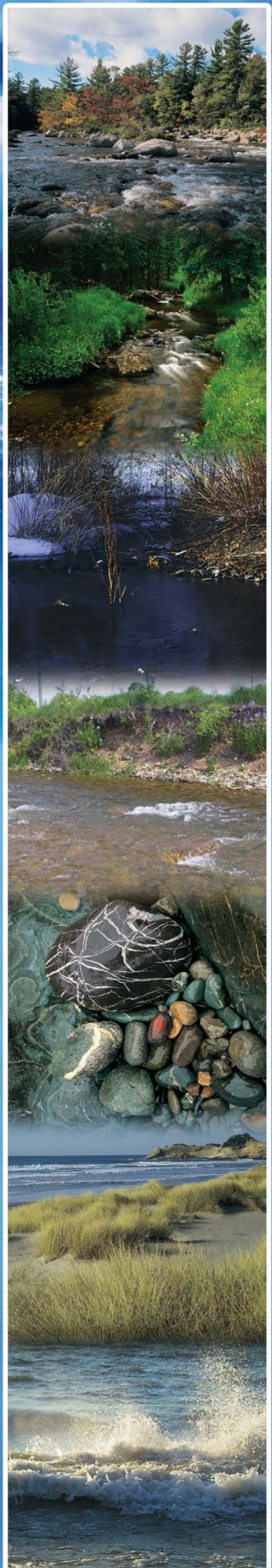
Appendix F
Fluvial Geomorphology Report



water's edge
ENVIRONMENTAL SOLUTIONS TEAM LTD.

Winston Churchill Boulevard
Mississauga, ON

Fluvial Geomorphological Assessment and Meander Beltwidth Assessment

May 10, 2016

May 10, 2016
WE 14036

Ms. Melissa Alexander, B.Sc., MCIP, RPP
Environmental Planner
Hatch Infrastructure
5035 South Service Road, Sixth Floor
Burlington, Ontario
L7L 6M9

Dear Ms. Alexander:

RE: Winston Churchill Blvd, Region of Peel, ON
Fluvial Geomorphological Assessment and Meander Beltwidth Assessment

Water's Edge was authorized by Hatch to complete a fluvial assessment and natural channel designs for three stream crossings – two tributaries of Levi's Creek and one tributary of Mullet Creek on Winston Churchill Blvd, in the Region of Peel.

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 1954, 1994, 2000, 2002 and 2013 (TRCA);
- 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 Hatch 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 Winston Churchill Blvd, just north of 5 Side Rd. /Embleton Rd. and continuing down to just south of Highway 401 (see Figure 1). 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 (Note: To Be Completed).

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 tributaries of Levi Creek and Mullet Creek and are located in the Credit River watershed in Mississauga, which drains into Lake Ontario. The study area includes ten culverts (Cu-1 to Cu-10), all passing under Winston Churchill Blvd. Only Cu-3, Cu-8 and Cu-10 will be focused on in this report.

Levi Creek North which flows through Cu-3 is likely a 2^{nd} order stream. Its contributing drainage area is 212.6 ha. Levi Creek is considered contributing habitat for Red Side Dace. The drainage area for Cu-8, which conveys Levi Creek South, is 98.53 ha and it is likely a 3^{rd} order stream. Mullet Creek which is conveyed by Cu-10 has a contribution drainage area of 267.78 ha and is likely a 3^{rd} order stream to the point of the study area. The land use of the contributing drainage areas at the study area is primarily agricultural as well as wetland.

Below is a description of the terrestrial conditions of the site from the 1996 Environmental Study Report completed by Paul Theil Associates Limited;

> “The first watercourse north of Steeles Avenue is identified as an intermittent watercourse with low fish habitat potential by the City of Brampton Official Plan Natural Environment database. East (downstream) of the roadway, the watercourse is only 0.25 to 0.50 metres in width with only 5.0 to 10.0 centimetres of water at the time of the field survey in November 1994. The primarily muck streambed and thick cattails reduce the fish habitat potential, although bait fish may utilize this watercourse during the spring and autumn. West of Winston Churchill Boulevard the watercourse consists only of a manicured grass swale with no stream cover or fish habitat potential.

> The remaining two tributaries located within the study area are part of the Levi's Creek subwatershed. Although Levi's Creek is classified as a warm water fishery with a cold migratory run, this habitat was not observed by E.S.P. staff during their field investigation. At the more southern tributary of Levi's Creek, east of the roadway, a 0.5 to 1.0 metre wide, grassed channel was observed among the vegetation with only about 5.0 centimetres of water in it. The upstream swale west of the roadway was grassed, with no stream cover. Horses have free access to the swale. As observed in the field, the Official plan review identified no fish habitat for this watercourse.
>
> The remaining watercourse crossing farthest to the north did not display a well-defined stream channel. The swale was completely grassed. The pools associated with the grassed swales may provide some amphibian habitat. Cattails were found east of Winston Churchill Boulevard, but no flow was observed toward the cattails."

The 2009 Addendum, completed by McCormick Rankin Corporation, reports no change from the original study report.

Figure 2: Locations of Levi Creek North and South and Mullet Creek

Culvert 3

This crossing is the closest crossing to Embleton Rd. and is the northern most crossing of the three. This culvert conveys Levi Creek North through Winston Churchill Blvd. The reach has little instream cover as the riparian buffer is comprised of tall grasses and no trees or shrubs. Some undercut banks were observed in this reach although flow appears to typically be low or intermittent. The majority of the banks and channel are stabilized only by the roots from the riparian grasses.

Approximately 200 metres were surveyed for this study. Four cross sections were surveyed in this reach, two on the east side and two on the west side. The channel showed low width-to-depth ratio (<12) and is slightly entrenched. The average bankfull slope is 0.015 m/m, and the bankfull width and average depth were noted to be 0.89 m and 0.09 m. The substrate in this reach is focused on sands and small gravels. A sieve sample was completed for the reach and the results show 96% sands and 3.5% gravels. No Rosgen classification will be given to this channel as 'field drainage' should suffice in conveying its general characteristics. Survey results can be seen in Table 1.

Figure 3: Aerial View of Cu-3 on Levi Creek North

Culvert 8

This crossing and reach are between Cu-3 and Cu-10 with approximately 1km separating each crossing. This culvert conveys Levi Creek South through Winston Churchill Blvd. The upstream and downstream sides of this reach are very different from one another. The upstream end (west side) is straightened grass channel with a small riparian buffer. The downstream end (east side) is a sinuous channel that has proper channel features and a wide riparian with large trees and shrubs.

Approximately 200 metres of channel were surveyed along with five cross sections to determine the typical channel geometry. The overall channel has a moderate width-to-depth ratio and is not entrenched. The average bankfull slope through the whole study area is 0.007 m/m, and the average bankfull width and depth were noted to be 1.37 m and 0.13 m.

The substrate in this reach ranges from silt to cobbles with small gravels and sand the dominant substrates. The sieve sample for this reach reveals that 85% of the substrate is gravel while 15% is sand. The banks are typically made up of highly erodible soils. Rosgen classification for this reach is determined to be an E4 channel type. Survey results can be seen in Table 1.

Figure 4: Aerial View of Cu-8 on Levi Creek South

Culvert 10

This crossing is the closest crossing to Steeles Ave. and is the southernmost crossing of the three. This culvert conveys Mullet Creek through Winston Churchill Blvd. The reach is similar to crossing Cu-8 in how it has a grassed upstream end (west side) and a forested downstream end (east side). The downstream end has some erosion occurring and also contains a fair amount of large woody debris. The majority of the banks and channel are stabilized only by the roots from the riparian grasses.

Approximately 215 metres of the channel at this crossing was surveyed for this study. Four cross sections were also surveyed in this reach, two on the east side and two on the west side. The channel has a high width-to-depth ratio (>12) and is slightly entrenched. The average bankfull slope is 0.006 m/m, and the bankfull width and average depth were noted to be 1.37 m and 0.12 m. The substrate in this reach contains sands and small gravels but also contains a larger percentage of cobbles. A sieve sample was completed for the reach and the results show 8% sands and 19% gravels and 72% cobbles. A Rosgen classification of B4 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-3	Cu-8	Cu-10
Bankfull Width (m)	0.89	1.37	1.94
Bankfull Mean Depth (m)	0.09	0.13	0.12
Bankfull Max Depth (m)	0.14	0.20	0.21
Bankfull Area (m^2)	0.09	0.17	0.24
Wetted Perimeter (m)	0.97	1.47	9.09
Hydraulic Radius (m)	0.08	0.11	0.11
Width-Depth Ratio	10.74	13.30	21.24
Entrenchment Ratio	8.71	2.58	2.87
Bankfull Slope (m/m)	0.015	0.007	0.006
Channel Substrate D_{50} (mm)	0.17	23.22	137.97
Channel Substrate D_{84} (mm)	0.38	48.87	180.15
Rosgen Classification	N/A	E4	B4

Figure 5: Aerial View of Cu-10 on Mullet 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 the tributaries of Levi's Creek and Mullet Creek, we used Rapid Geomorphic Assessment and Rapid Stream Assessment Technique. The raw worksheets for these assessments can be found in Appendix C.

3.1 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 score for the Levi's Creek crossings and Mullet Creek crossing were all determined to be low, from 0.01 to 0.05. All creeks in general can be considered to be "In Regime" and therefore relatively stable. The detailed RGA evaluation is presented in Appendix C. Score results are seen in Table 2.

Table 2: RGA and RSAT Scores

CULVERT	RGA	RSAT
Cu-3	0.03	19.5
Cu-8	0.01	16
Cu-10	0.05	13

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.

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 Cu-3 at 19.5 which is a "Poor" verbal ranking, and Cu-8 and Cu-10 have scores of 16 and 13 respectively, also giving them a "Poor" evaluation. The results of the RSAT evaluation are included in Appendix C.

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 the channel, natural channel design concepts include the creation of a bankfull flow channel to accommodate the dominant discharge.

Using data from the geomorphic field work, and using an assumed 'n' methodology, bankfull flows in this system were determined. The results of the assumed 'n' approach were very similar to that of Limerinos' method and the Strickler method.

Bankfull flows were obtained for each channel where the bankfull indicators were obvious and reliable. The flows for Levi Creek North in the crossing area, when using a Manning's 'n' of 0.045 were averaged to be approximately 0.04 m^3/s. The flows for Levi Creek South in the crossing area were averaged to be approximately 0.06 m^3/s when using a Mannings 'n' of 0.050. The flows for Mullet Creek in the crossing area were averaged to be approximately 0.06 m^3/s when using a Mannings 'n' of 0.060. The flows for each reach seem relatively low when looking at the bankfull width but this is attributed to the low slope for each creek.

We also regressed the existing return period flows as obtained from the 2009 Addendum to the 1996 Environmental Study Report. The resultant 1:1.5 year return period flow is expected to be 6.84 m^3/s for Levi Creek North (Culvert-3), 3.27 m^3/s for Levi Creek South and 8.52 m^3/s for Mullet Creek (see Figure 6, 7, 8). Typically, bankfull return periods have been associated with 1:1.5 year return period. Seeing that there is little correlation between the Mannings 'n' methodology and return periods it is unlikely that the 1.5 year return period applies in this case.

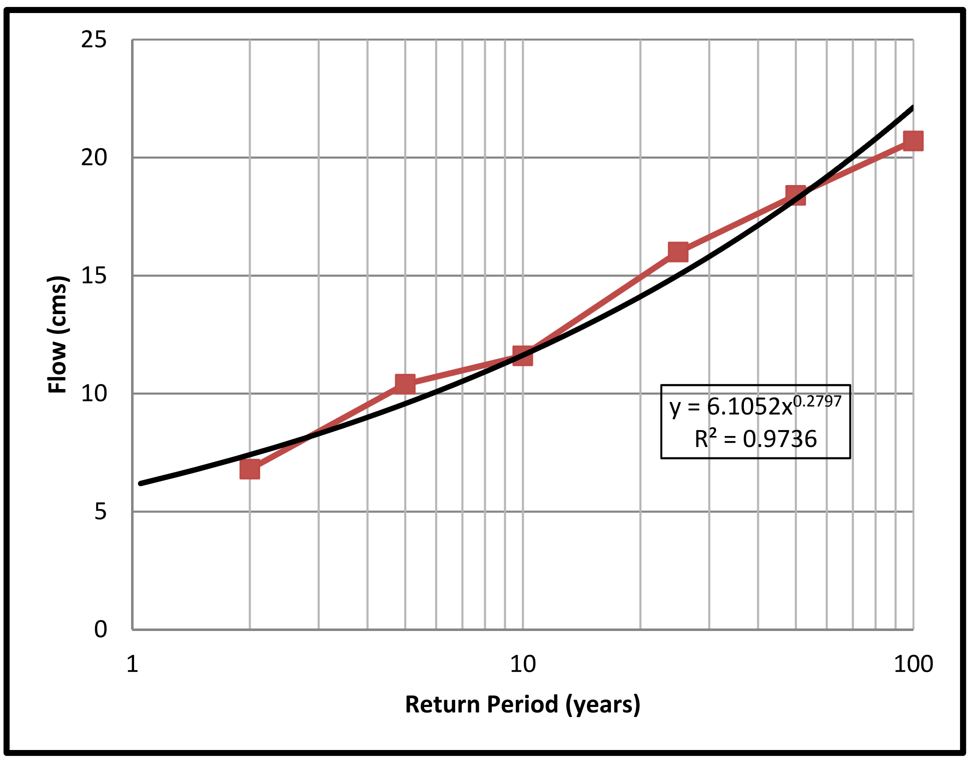


Figure 6: Flow Regression Analysis for Levi Creek North

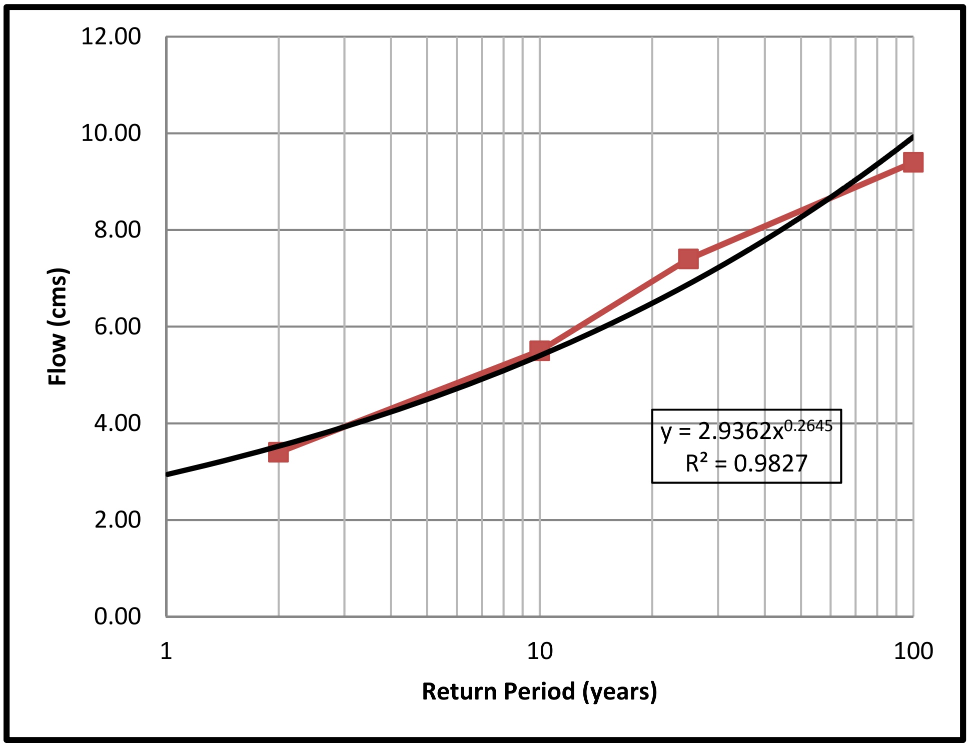


Figure 7: Flow Regression Analysis for Levi Creek South

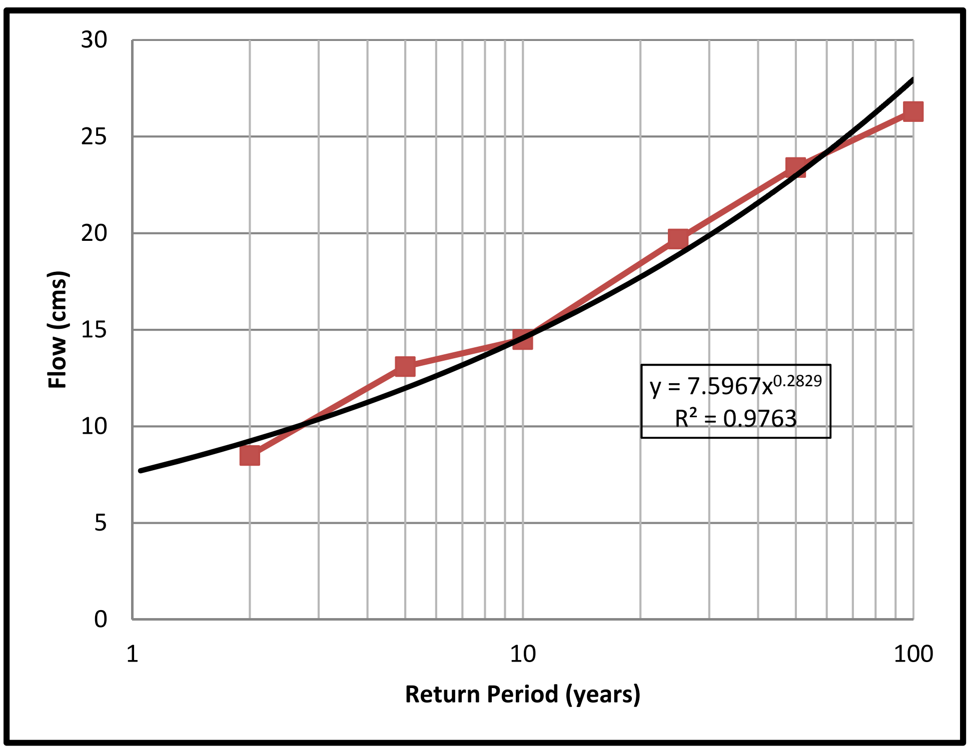


Figure 8: Flow Regression Analysis for Mullet Creek

In this case the bankfull flows for each creek in the vicinity of the crossings at Winston Churchill Blvd. are as follows; 0.04 m^3/s for Levi Creek North, 0.06 m^3/s for Levi Creek South and 0.06 m^3/s for Mullet Creek.

4.0 MEANDER BELTWIDTH AND 100 YEAR EROSION ASSESSMENTS

Assessment of the meander beltwidth is undertaken in accordance with commonly accepted standard meander beltwidth delineation procedures which are established for watercourses with well defined, meandering bankfull channels. In this study, parts of the watercourse are swales with intermittent flows. In such cases, we have used regime equations that are based on bankfull characteristics and aerial photo measurements.

Meander Beltwidths from Regime Equations
Inferences on meander beltwidths can also be made based on regime equations as per Williams (1986). These equations are based on bankfull dimensions of the channel such as cross sectional area, width and mean depth. In addition to the regime equations, measurements were also made from aerial photography. The measurements made resemble the regime equations based on cross sectional area. The meander beltwidths measured and calculated are listed in Table 5. At certain locations, and where measurements could not be made because of lack of clear channel delineation in aerial photography, we recommend that the empirical equations based on cross sectional width be used.

Aerial Photography Analysis
Air photos were collected from the years of 1994, 2000, 2002, 2013 and analyzed using GIS mapping. The photos are used to trace a centreline from each of the years to compare their change over the time period. Also used in the analysis is the alignment from the geomorphic survey completed by Water's Edge in 2015. When determining the preliminary beltwidths the belts are offset parallel to the channel's historical meander axis alignment. The preliminary beltwidths are at the widest extent of the channels meander pattern along each meander axis. These axes can be seen in the meander beltwidth figures; Figures 10, 11 and 12.

The characteristics of each of the channel crossings in the study area are different from the upstream side (west side) compared to the downstream side (east side). On the west side we see primarily straightened channels with little or no riparian buffer or cover. While on the east side we typically see a natural meandering channel with good riparian structure. The only exception to this is with Culvert 3 where both sides of the road have historically been straightened. It is because of this that in determining the preliminary beltwidth only the east side of each channel was taken into account. When determining the preliminary beltwidths the average width of each meander axis on the east side for approximately 125 - 200 metres was measured. The totals were then averaged to come up with the representative preliminary beltwidth for each crossing which can be seen in Table 5 and 6.

Table 5: Meander Beltwidth (m) based on Regime Equations and Aerial Photography

Culvert #	Regime Equations based on XS Area	Regime Equations based on Width	Regime Equations based on Mean Depth	Measured Preliminary Beltwidth
#3	4	4	4	4.42
#8	6	6	7	3.74
#10	7	9	6	5.92

Final Meander Beltwidths
Based on the calculated meander beltwidths using regime equation and those measured using aerial photographs, we have determined the final meander beltwidths. Table 6 presents a summary of the beltwidths from each of these methods and the final beltwidths. Locations where meander beltwidths were measurable, the final beltwidth was calculated to be the sum of the bankfull width and preliminary beltwidth and a 10% factor of safety added as no 100-year migration rates were

calculated. As mentioned in the previous sub-section, the regime equations based on cross sectional width provided the most reliable estimate of meander beltwidth as they corroborated with the measured beltwidths. To provide a conservative estimate, the largest of the available beltwidths (measured or calculated) for a reach was chosen as the final beltwidth. Figures 10, 11 and 12 show the preliminary and final beltwidths for the channels.

Table 6: Summary of Beltwidths (m) at the Culvert Locations (Chosen beltwidth highlighted in grey)

Culvert #	MBW based on XS width Regime Equations (m)	Measured Prelim MBW (m)	Bankfull Width(m)	Final MBW from sum of Bkf width and Prelim MBW (m)	Final MBW (m)
#3	4.0	4.42	0.89	5.84	5.84
#8	6.0	3.74	1.37	5.62	6.0
#10	9.0	5.92	1.94	8.65	9.0

5.0 PROPOSED CONDITIONS / RECOMMENDATIONS

Culvert extensions are proposed for both sides of culverts 3, 8 and 10. As such the following recommendations should be considered during channel modification and culvert installation.

- All proposed channel dimensions should closely resemble existing geomorphic parameters laid out in Table 1, specifically bankfull width, depth and slope;
- Proper pool/riffle sequences should be laid with pools generally on the outside bend of a meander and riffles through the transitions;
- Stone sizing should take into account the existing substrate of each reach while at the same time protecting the road embankments and culverts;
- The channel at the upstream end of culvert 3 will require realignment due to its proximity to the existing roadway. A conceptual design has been completed and is shown in Appendix E;
- Channel realignment (culvert 3) should observe the final meander beltwidths as shown in Table 6 and;
- Low flow channels should be created through culverts using stone to form the banks.

6.0 CONCLUSIONS

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

1. The surveyed reaches of Levi's Creek and Mullet Creek tributaries have different geomorphic characteristics as described in Tables 1 and 2;
2. RSAT scores show that all three creeks are currently in 'Poor' condition although the RGA scores determined that the channels are all relatively stable;
3. Bankfull flows for Levi Creek North, Levi Creek South and Mullet Creek are 0.04 m^3/s, 0.06 m^3/s and 0.06 m^3/s, respectively;
4. The final meander beltwidths at the Winston Churchill culvert crossings, as outlined in Table 6, are 5.8m for Cu-3, 6.0m for Cu-8 and 9.0m for Cu-10.

Respectfully submitted,

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

ATTACHMENTS

Appendix A: Figures 10-13 Meander Beltwidths
Appendix B: Surveyed Profiles and Cross Sections
Appendix C: Photographs
Appendix D: Rapid Field Assessment Worksheets

REFERENCES

Galli, J. 1996, *Rapid Stream Assessment Technique (RSAT) field methods*. 36 pp. Metropolitan Washington Council of Governments, Department of Environmental Programs, Washington, DC.

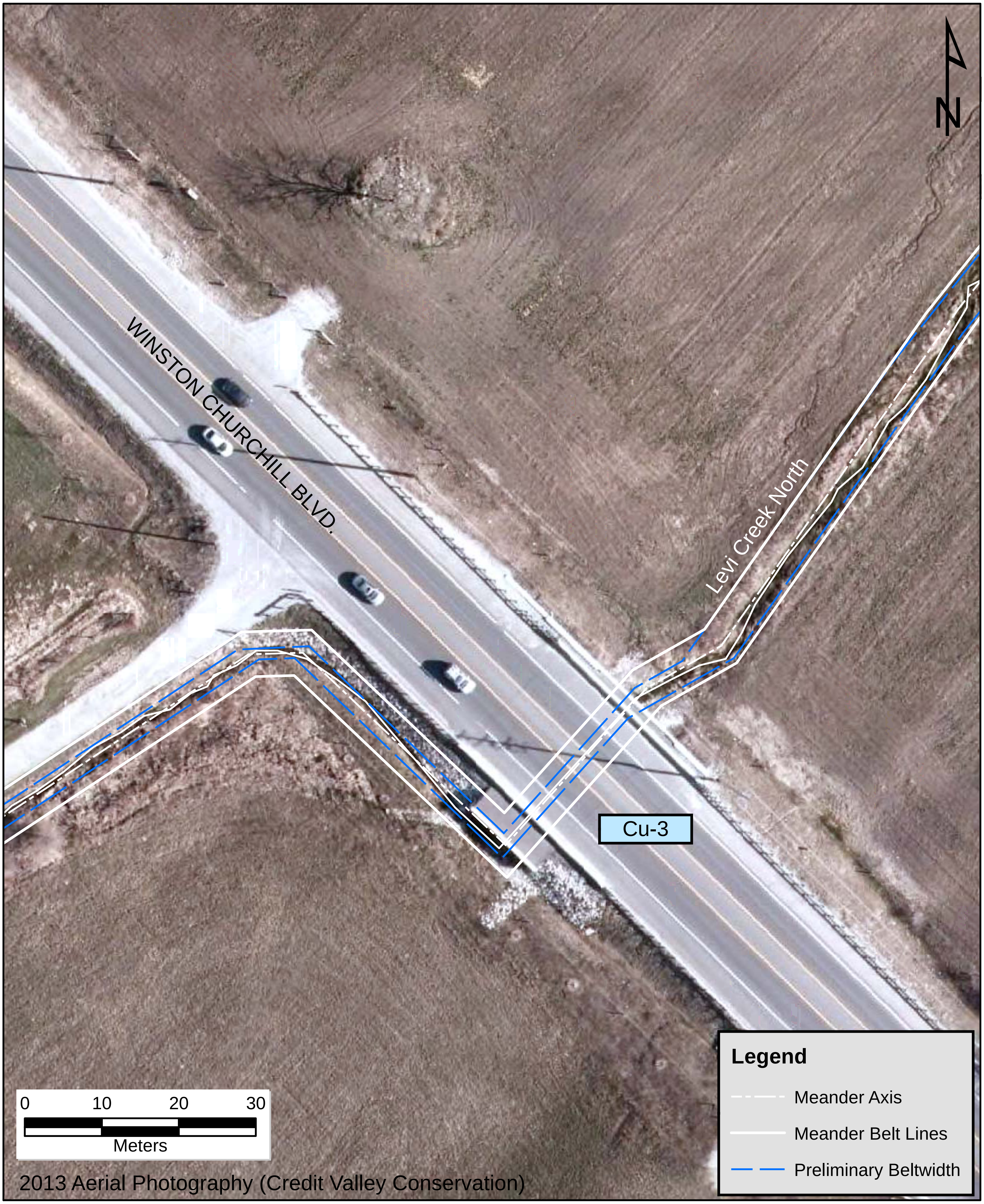
Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, New York

Winston Churchill Boulevard from Steeles Ave. to Embleton Rd. Class Environmental Assessment Study. March 1996. Regional Municipality of Peel. Paul Theil Associates Limited.

Reconstruction and Widening of Winston Churchill Boulevard from Steeles Avenue to Embleton Road Class Environmental Assessment Study, Addendum to the Environmental Study Report. February 2009. Regional Municipality of Peel. McCormick Rankin Corporation

APPENDIX A:

Meander Beltwidth Figures



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Winston Churchill Meander Beltwidth Assessemnt	Figure No.: 10	Date: Dec. 23, 2015
Culvert 3 Levi Creek North	Checked By: EG	Drawn By: NG

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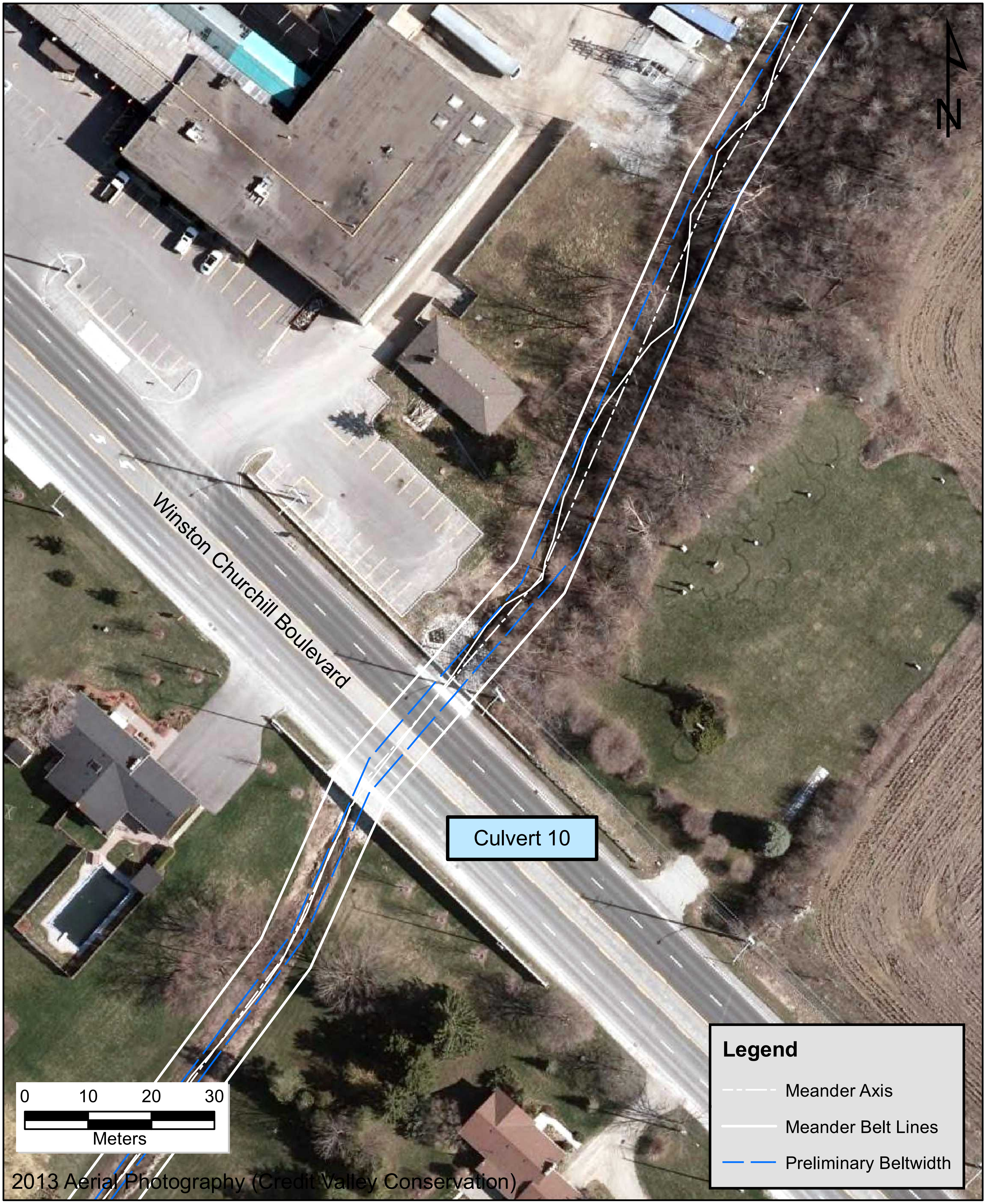
Winston Churchill Meander Beltwidth Assessemnt	Figure No.: 11	Date: Dec. 23, 2015
Culvert 8 Levi Creek South	Checked By: EG	Drawn By: NG



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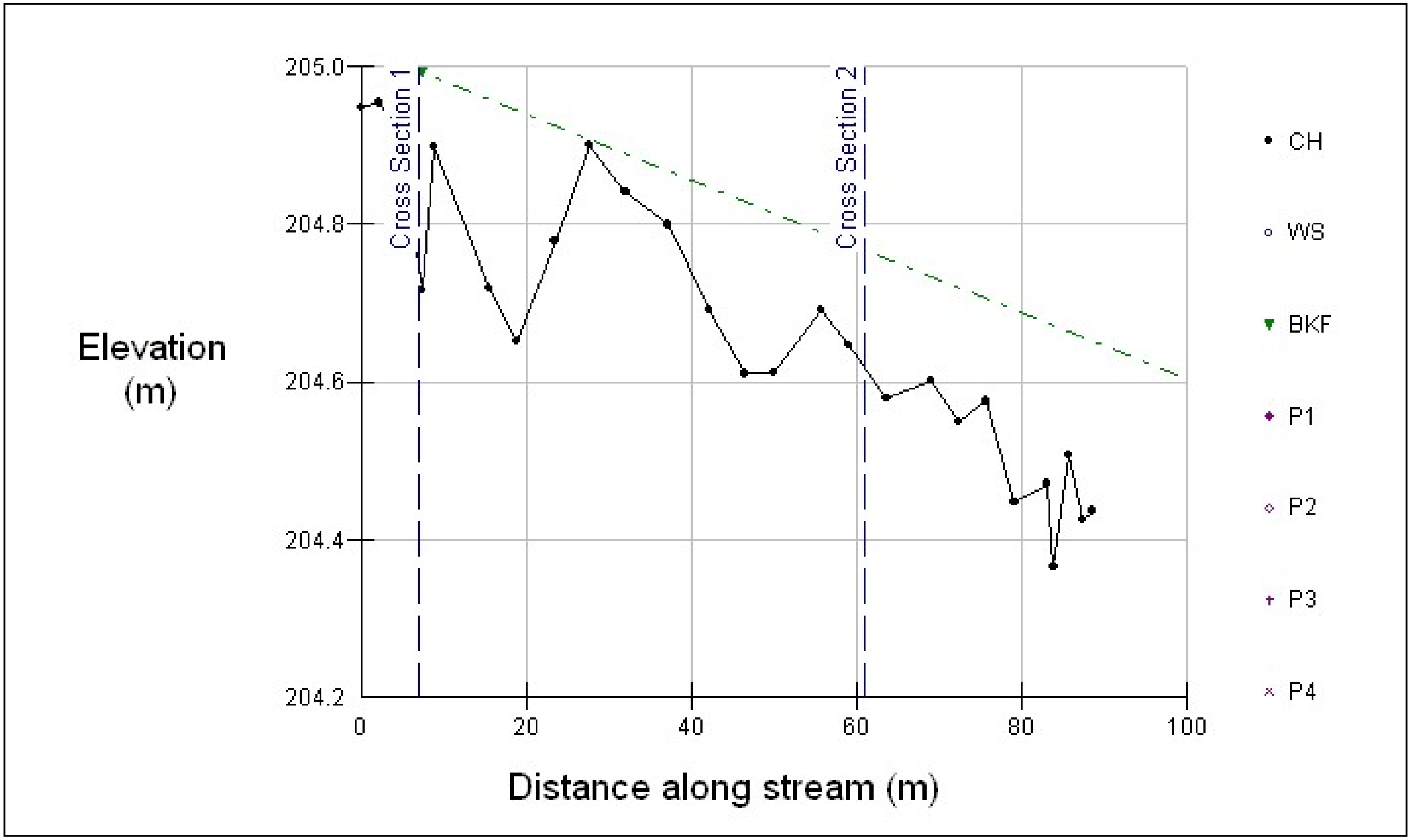
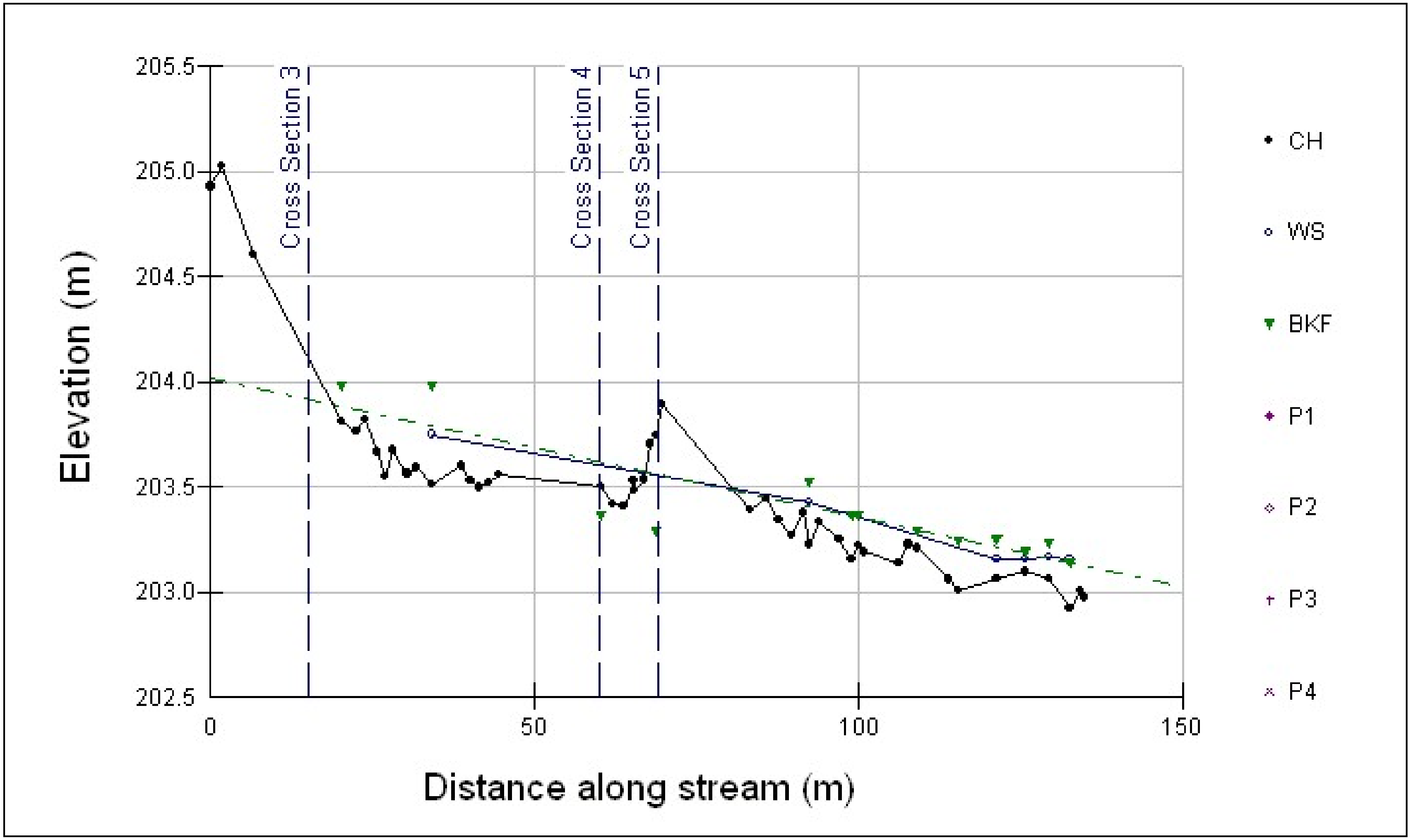
Winston Churchill Meander Beltwidth Assessemnt	Figure No.: 12	Date: May 10, 2016
Culvert 10 Mullet Creek	Checked By: EG	Drawn By: NG

APPENDIX B:

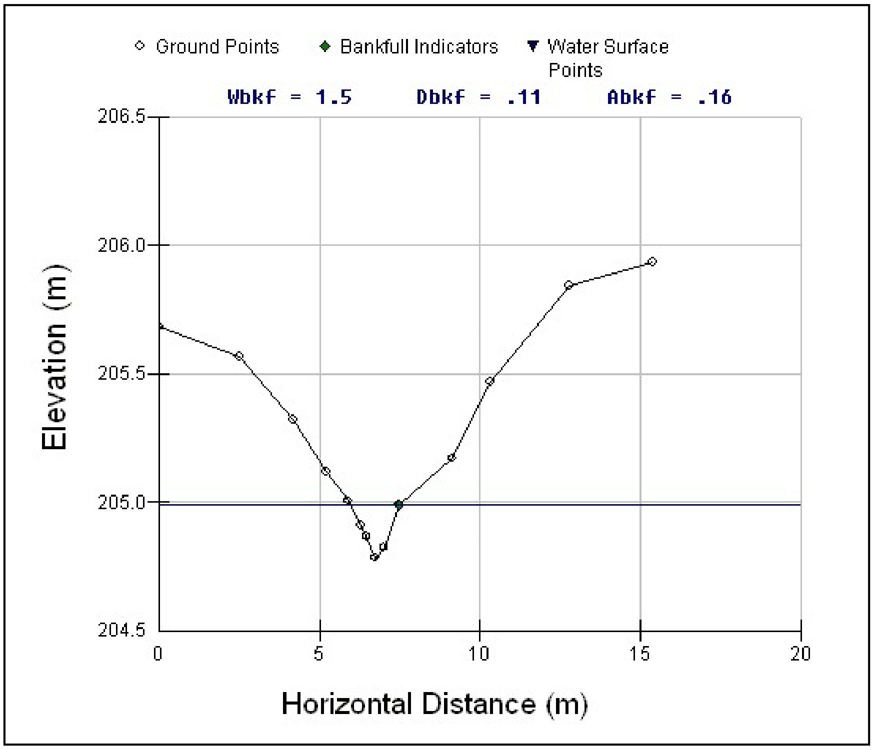
Surveyed Profiles and Cross Sections



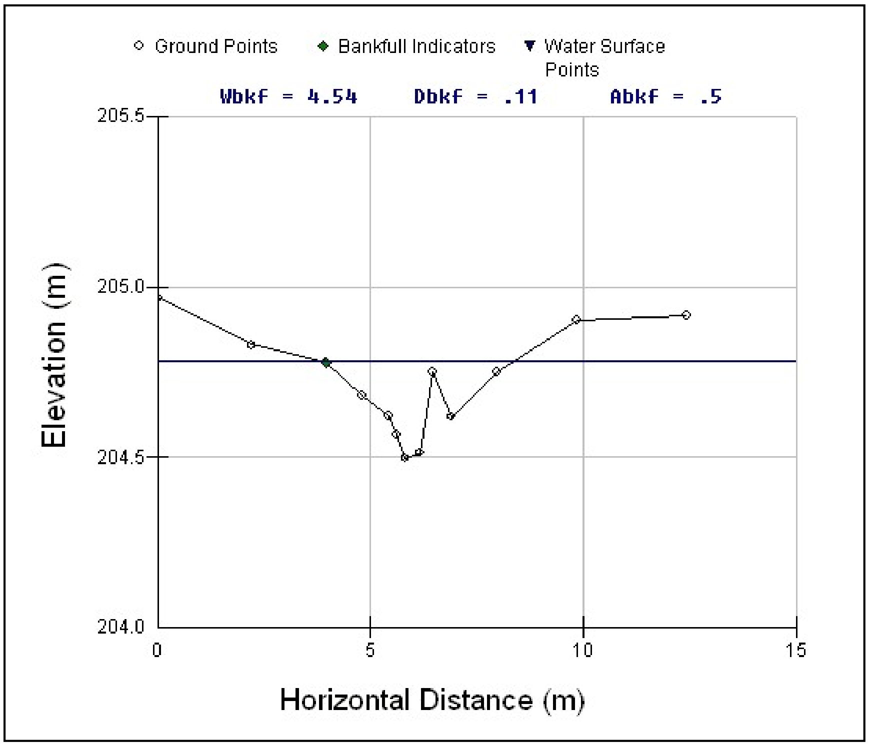
Levi Creek North Upstream Profile



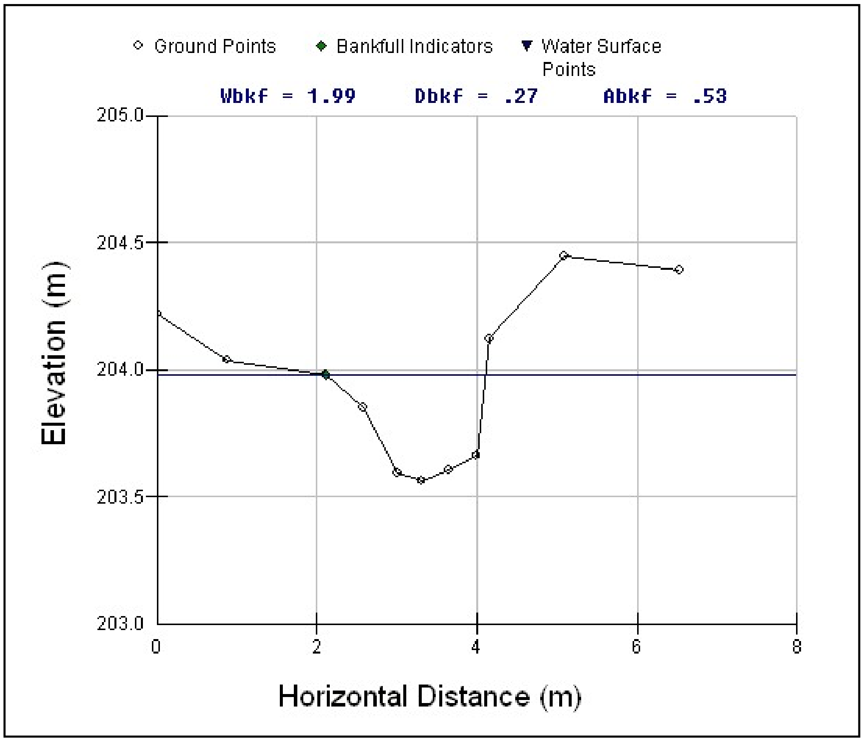
Levi Creek North Downstream Profile



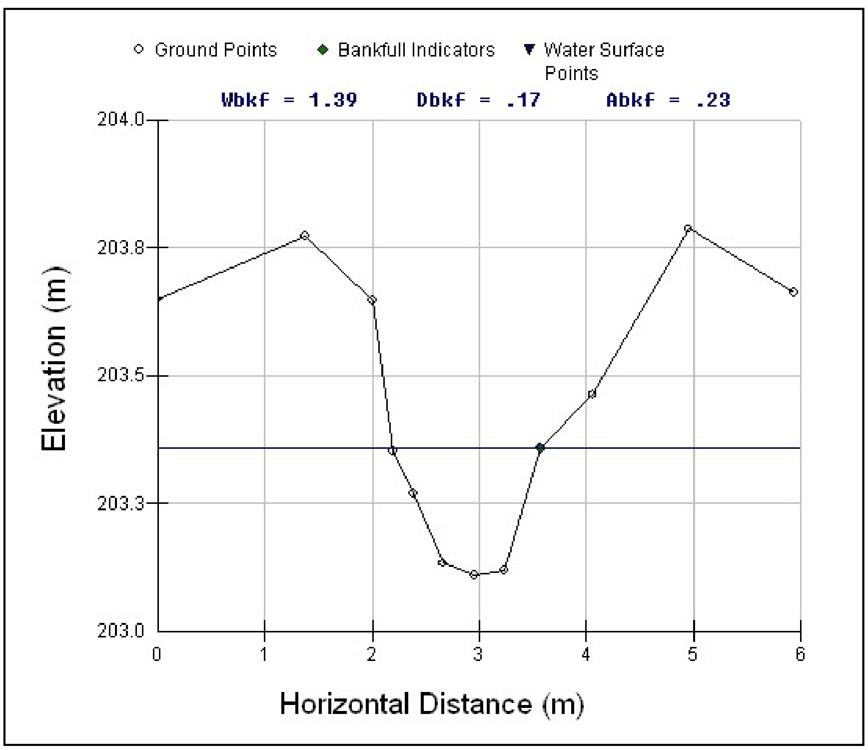
Levi Creek North Cross Section 1



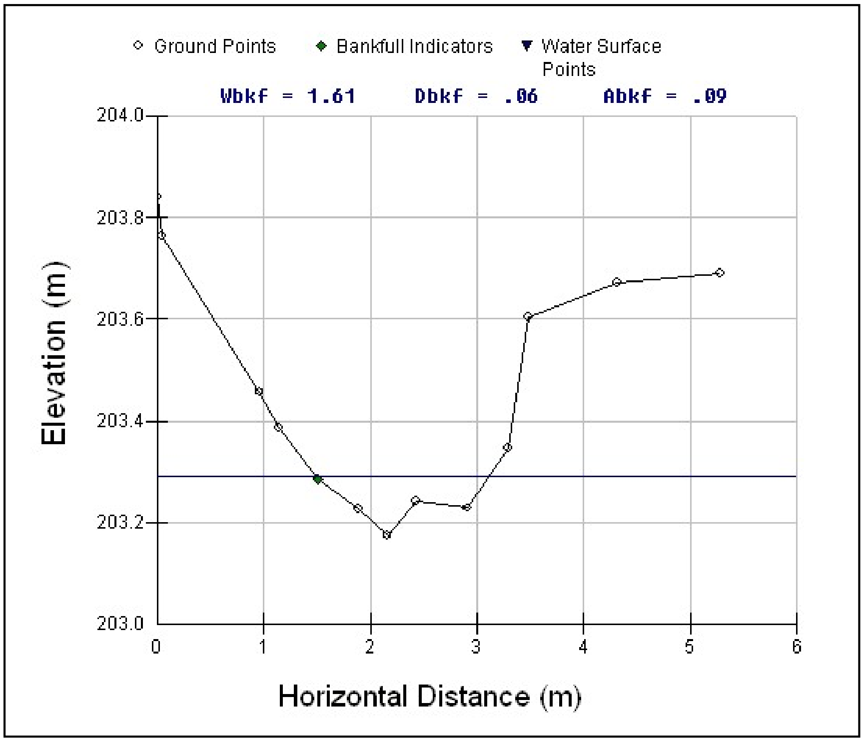
Levi Creek North Cross Section 2



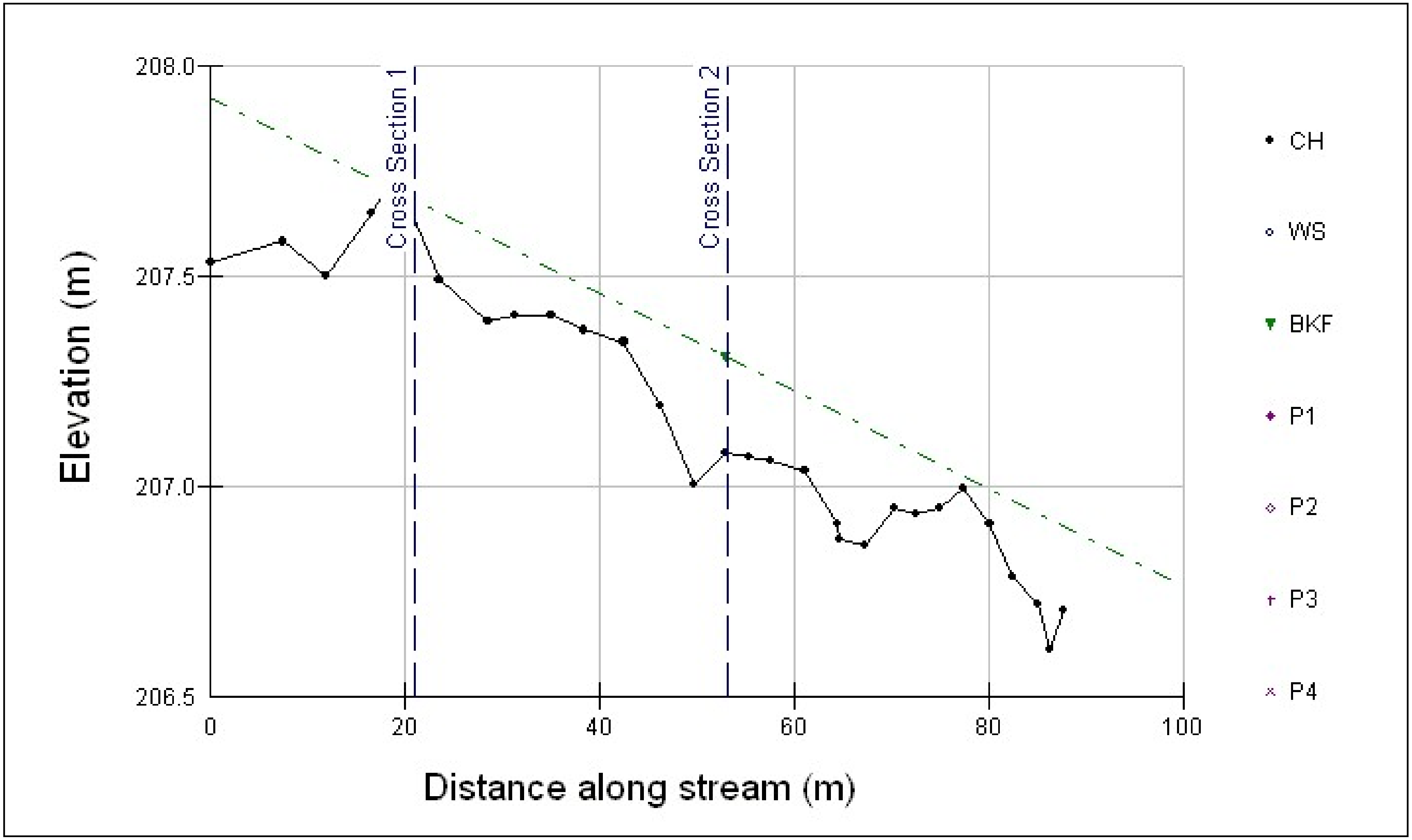
Levi Creek North Cross Section 3



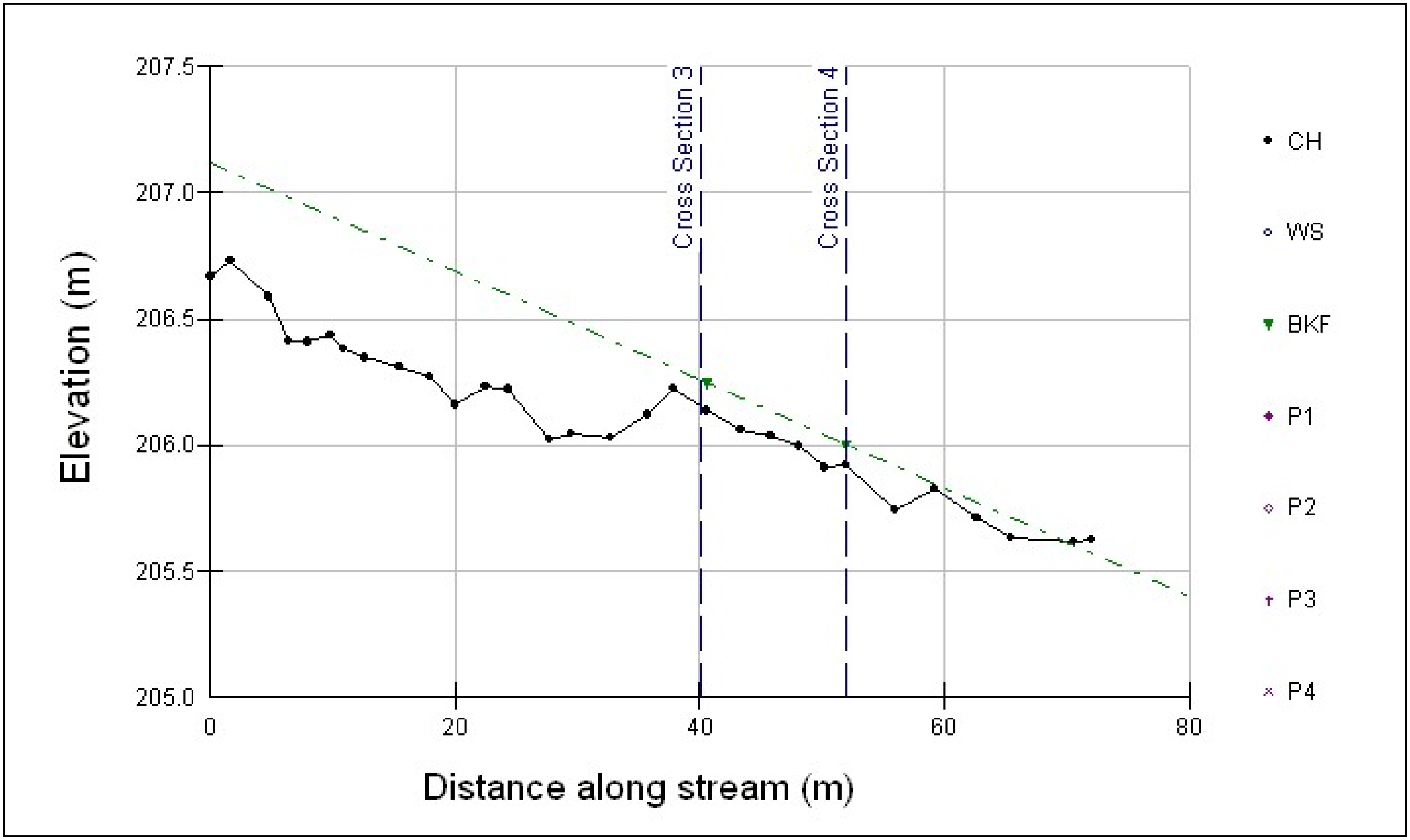
Levi Creek North Cross Section 4



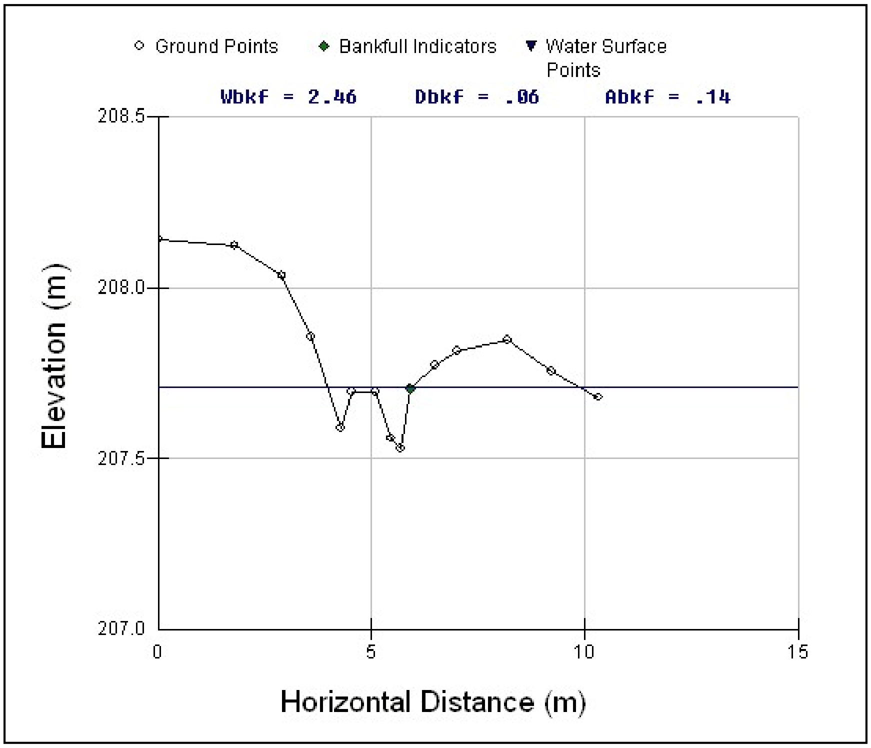
Levi Creek North Cross Section 5



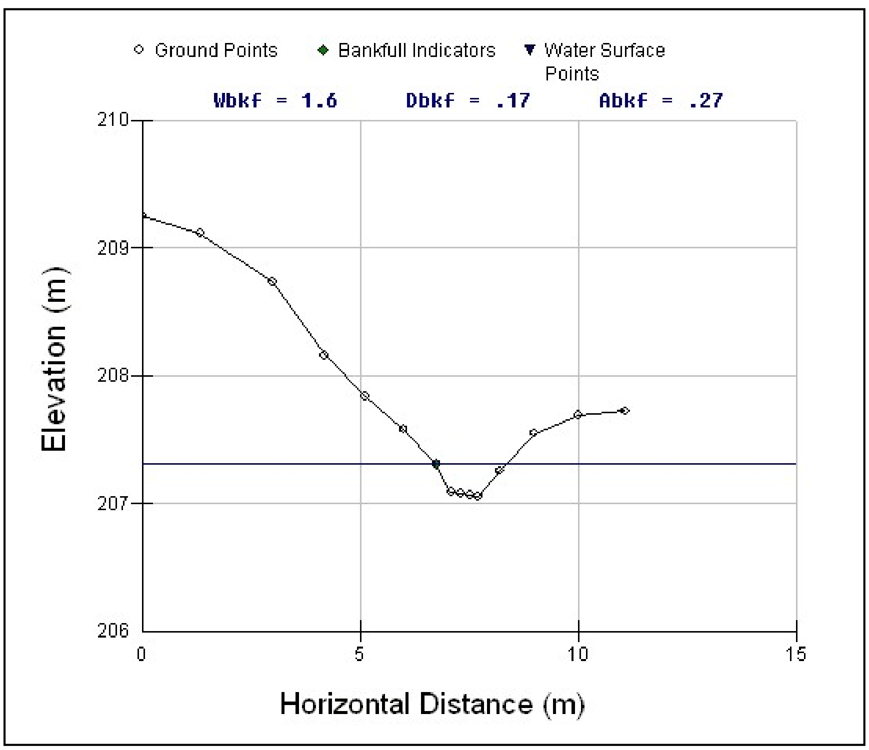
Levi Creek South Upstream Profile



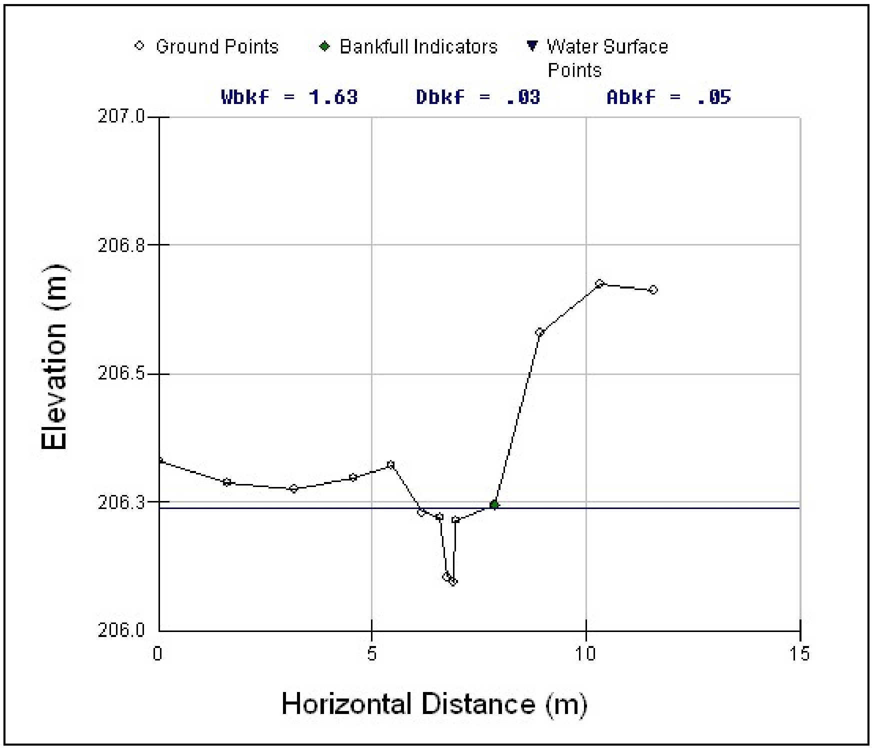
Levi Creek South Downstream Profile



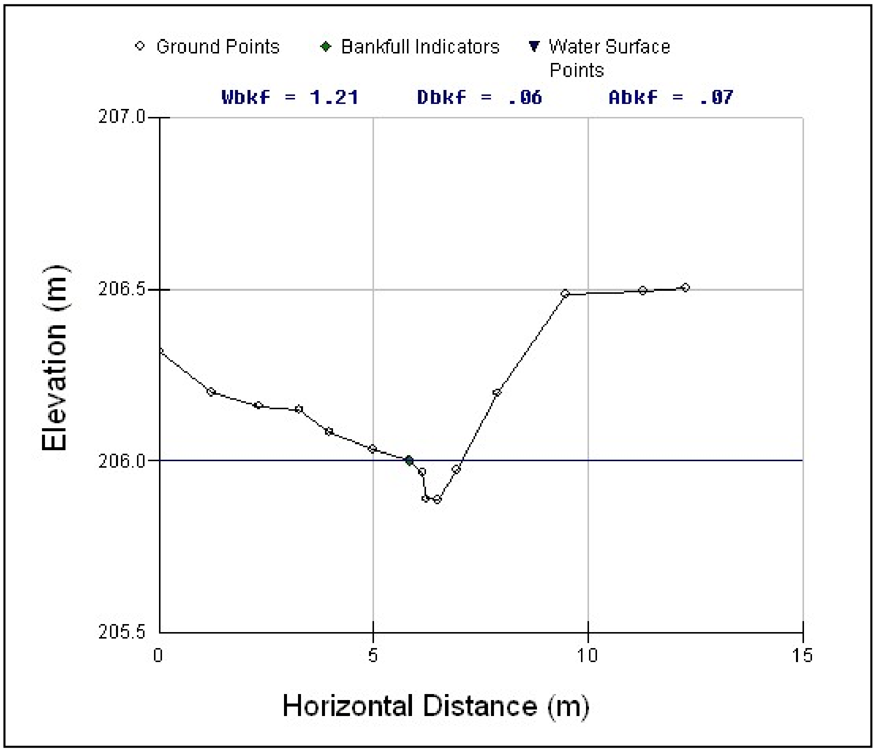
Levi Creek South Cross Section 1



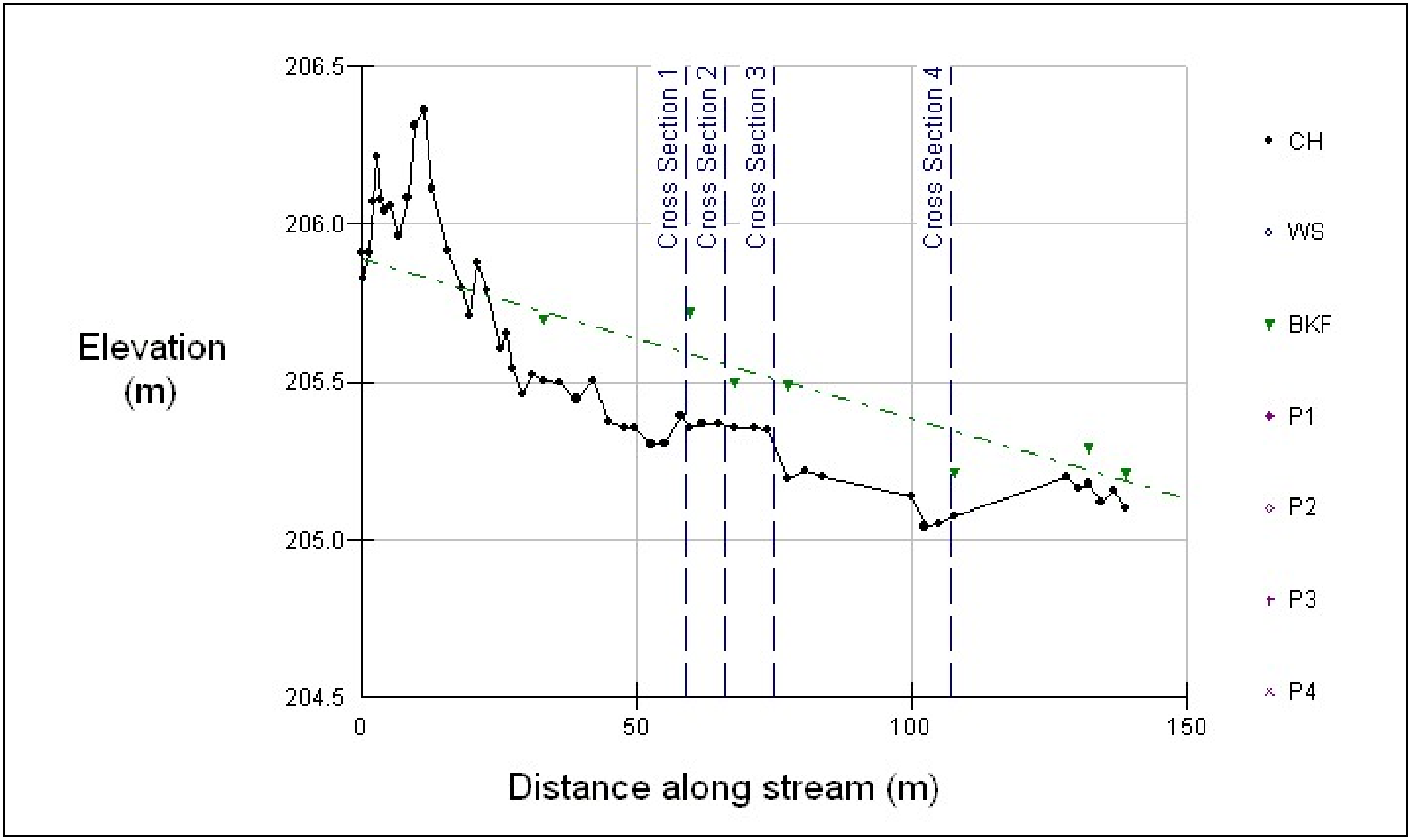
Levi Creek South Cross Section 2



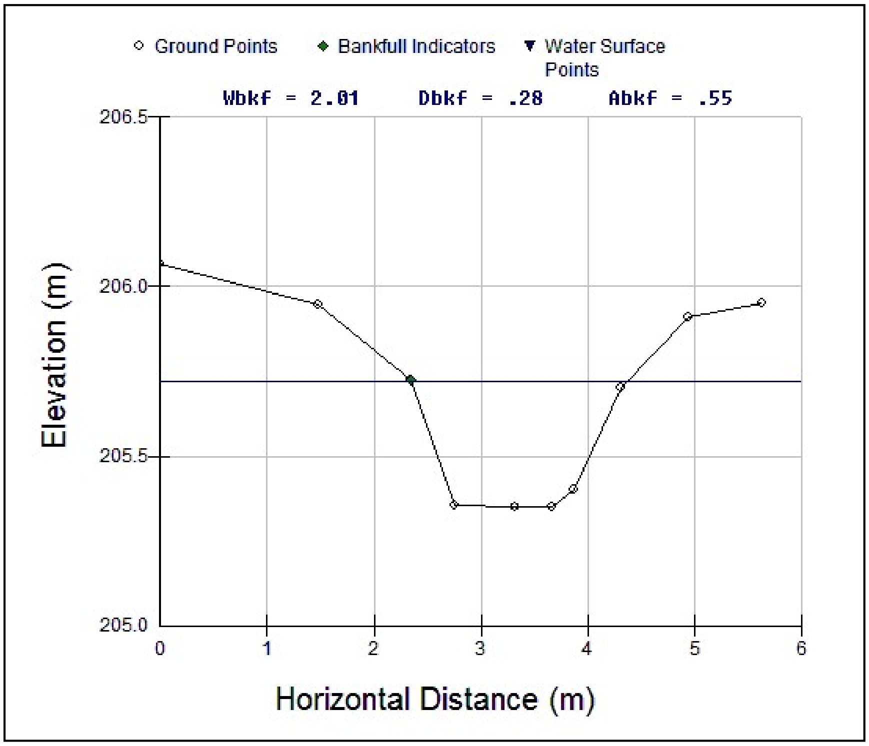
Levi Creek South Cross Section 3



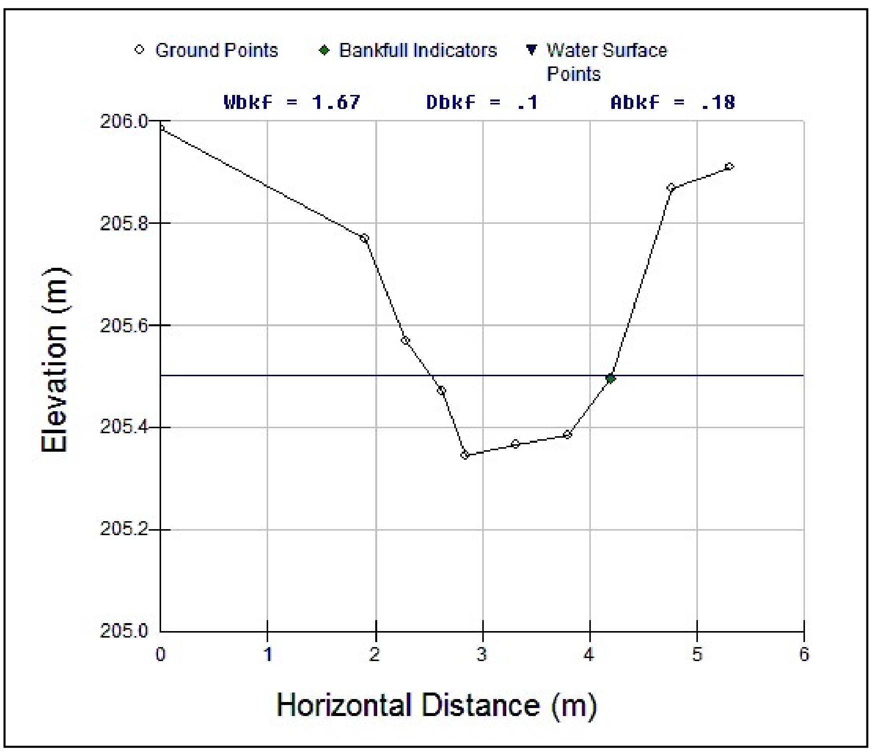
Levi Creek South Cross Section 4



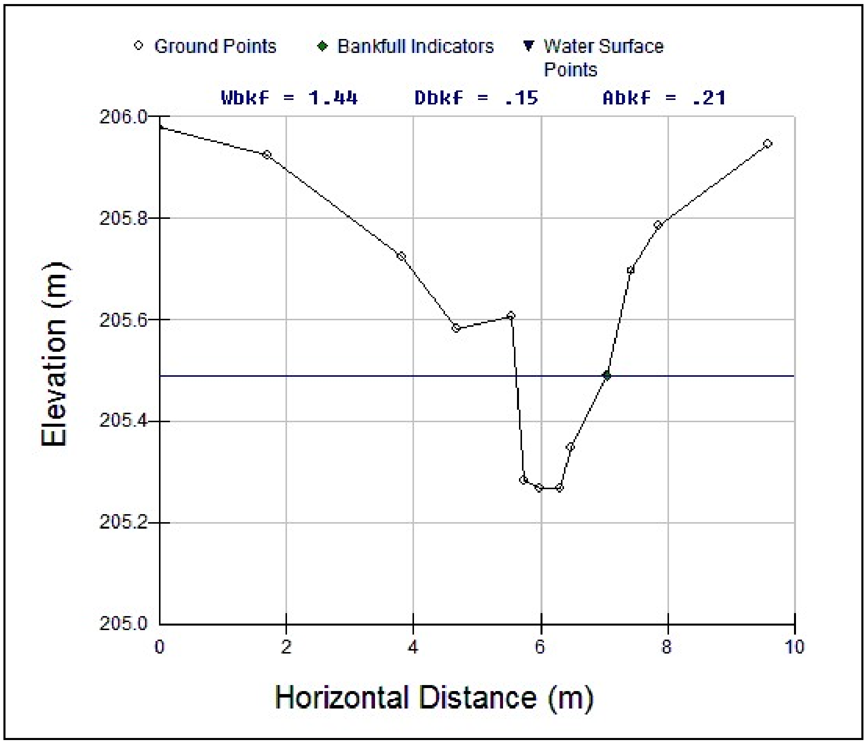
Mullet Creek Profile



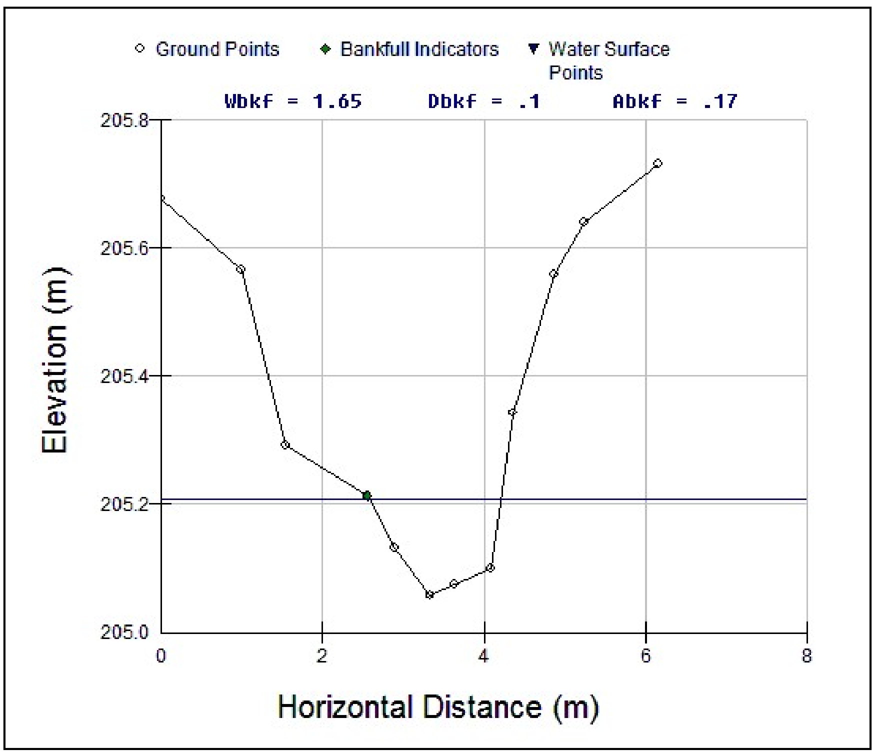
Mullet Creek Cross Section 1



Mullet Creek Cross Section 2



Mullet Creek Cross Section 3



Mullet Creek Cross Section 4

APPENDIX C:

Photographs

PHOTOGRAPH NO.: 1 - Culvert 3
FROM: From road culvert
LOOKING: Downstream at channel
COMMENT:

PHOTOGRAPH NO.: 2 - Culvert 3
FROM: In Channel
LOOKING: Downstream at channel
COMMENT:

PHOTOGRAPH NO.: 3 - Culvert 3
FROM: In channel
LOOKING: At channel bed
COMMENT: Note lack of flows

PHOTOGRAPH NO.: 4 - Culvert 3
FROM: From road culvert
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 5 - Culvert 3
FROM: From road
LOOKING: At culvert 3
COMMENT:

PHOTOGRAPH NO.: 6 - Culvert 3
FROM: Road
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 7 - Culvert 8
FROM: In channel on downstream side
LOOKING: Downstream
COMMENT:

PHOTOGRAPH NO.: 8 - Culvert 8
FROM: From culvert on road
LOOKING: Downstream at channel
COMMENT:

PHOTOGRAPH NO.: 9 - Culvert 8
FROM: Downstream side of culvert
LOOKING: Through culvert
COMMENT:

PHOTOGRAPH NO.: 10 - Culvert 8
FROM: Upstream of culvert at road
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 11 - Culvert 8
FROM: From road culvert
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 12 - Culvert 10
FROM: In channel on downstream side
LOOKING: Upstream
COMMENT:

PHOTOGRAPH NO.: 13 - Culvert 10
FROM: In channel on downstream side
LOOKING: Downstream
COMMENT:

PHOTOGRAPH NO.: 14 - Culvert 10
FROM: In channel on downstream side
LOOKING: Downstream
COMMENT:

PHOTOGRAPH NO.: 15 - Culvert 10
FROM: Upstream of bridge
LOOKING: Through culvert
COMMENT:

PHOTOGRAPH NO.: 16 - Culvert 10
FROM: In channel on downstream side
LOOKING: Upstream
COMMENT:

PHOTOGRAPH NO.: 17 - Culvert 10
FROM: In channel on upstream side
LOOKING: Upstream at channel
COMMENT:

PHOTOGRAPH NO.: 18 - Culvert 10
FROM: In channel on upstream side
LOOKING: Channel
COMMENT:

APPENDIX D:

Rapid Field Assessment Worksheets

Rapid Geomorphic Assessment

Date: 21-Aug-15
Evaluator: EEG/NG
Stream: 14036 - Winston Churchill
Conditions: ____

	Geomorphic Indicator		**Reach Number:**											
Form / Process	**No**	**Description**	**Cul-3**		**Cul-8**		**Cul-10**							
Evidence of Aggradation (AI)	1	Lobate bar					1							
	2	Coarse material in riffles embedded	1				1							
	3	Siltation in pools	1		1									
	4	Medial bars	1				1							
	5	Accretion on point bars												
	6	Poor longitudinal sorting of bed materials												
	7	Deposition in the overbank zone												
		Sum of Indices												
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												
	6	Cut face on bar forms												
	7	Head cutting due to knick point migration												
	8	Terrace cut through older bar material												
	9	Suspended armour layer visible in bank												
	10	Channel worn into undisturbed overburden/bedrock												
		Sum of Indices												
Evidence of Widening (WI)	1	Fallen/leaning trees/fence posts/etc.												
	2	Occurrence of large organic debris												
	3	Exposed tree roots												
	4	Basal scour on inside meander bends	1				1							
	5	Basal scour on both sides of channel through riffle	1				1							
	6	Gabion baskets/concrete walls/etc. out flanked												
	7	Length of basal scour >50% through subject reach												
	8	Exposed length of previously buried pipe/cable/etc.												
	9	Fracture lines along top of bank												
	10	Exposed building foundation												
		Sum of Indices												
Evidence of Planimetric Form Adjustment (PI)	1	Formation of cut (s)												
	2	Single thread channel to multiple channel												
	3	Evolution of pool-riffle form to low bed relief form												
	4	Cutoff channel(s)												
	5	Formation of island(s)												
	6	Thalweg alignment out of phase meander form												
	7	Bar forms poorly formed/reworked/removed												
		Sum of Indices												
Stability Index (SI) = (AI + DI+ WI+ PI) /m			0.03		0.01		0.05							

General Comments:

RAPID STREAM ASSESSMENT TECHNIQUE

RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range				
	Excellent	Good	Fair	Poor	Points
1. Channel Stability	9-11	6-8	3-5	0-2	7
2. Channel Scouring/Deposition	7-8	5-6	3-4	0-2	4
3. Physical Instream Habitat	7-8	5-6	3-4	0-2	6
4. Water Quality	7-8	5-6	3-4	0-2	6
5. Riparian Habitat Conditions	6-7	4-5	2-3	0-2	5
6. Biological Indicators	7-8	5-6	3-4	0-2	8

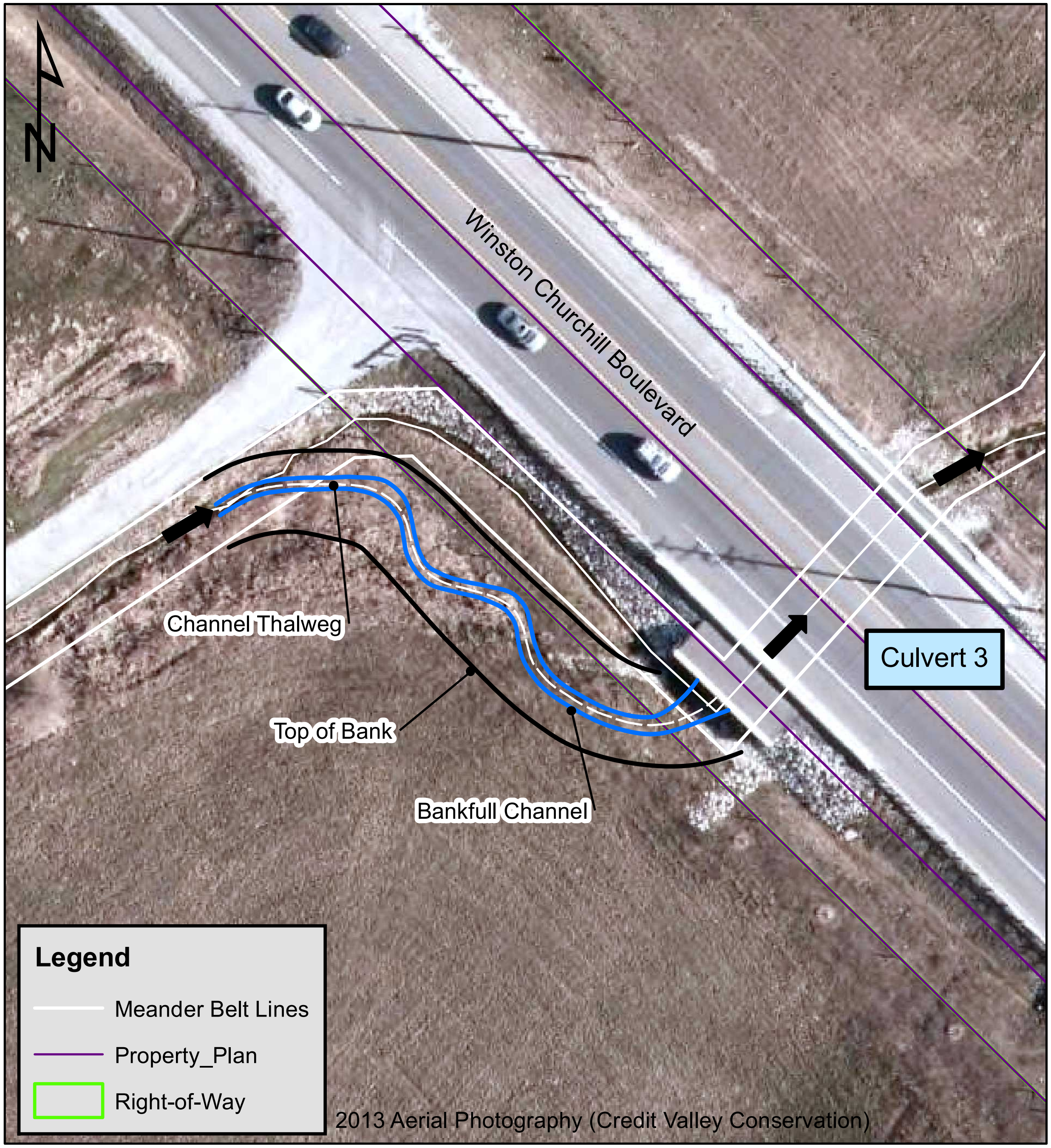
RSAT Score	Ranking
41-50	Excellent
31-40	Good
21-30	Fair
11-20	Poor
0-10	Degraded

Creek Name: 14036 - Winston Churchill
Date: Aug 21, 2015
Assessor: EEG

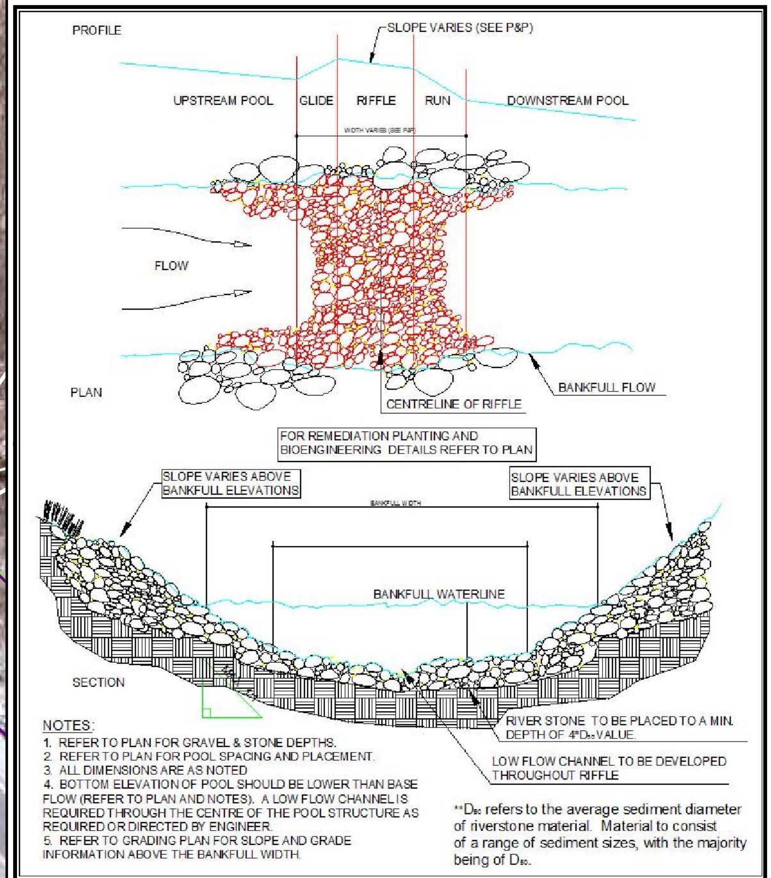
Evaluation Category	Site # Cul-3 US	Cul-3 DS		Cul-8		Cul-10					
1 Channel Stability	5	1		4		3					
2 Channel Scour and Sediment Deposition	4	0		4		4					
3 Physical In-stream Habitat	6	2		2		2					
4 Water Quality	6	1		1		1					
5 Riparian Habitat Conditions	6	1		3		2					
6 Biological Indicators	6	1		2		1					
Total Score:	**33**	**6**		**16**		**13**					
Verbal Ranking:	**good**	**degrad**		**poor**		**poor**					

APPENDIX E:

Conceptual Realignment



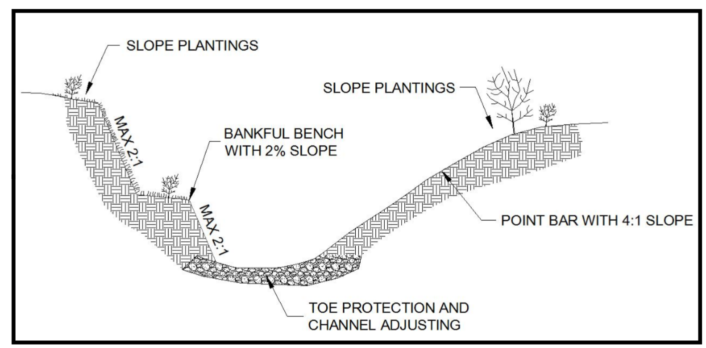
TYPICAL RIFFLE DETAIL



NOTES:

1. REFER TO PLAN FOR GRAVEL & STONE DEPTHS.
2. REFER TO PLAN FOR POOL SPACING AND PLACEMENT.
3. ALL DIMENSIONS ARE AS NOTED
4. BOTTOM ELEVATION OF POOL SHOULD BE LOWER THAN BASE FLOW (REFER TO PLAN AND NOTES). A LOW FLOW CHANNEL IS REQUIRED THROUGH THE CENTRE OF THE POOL STRUCTURE AS REQUIRED OR DIRECTED BY ENGINEER.
5. REFER TO GRADING PLAN FOR SLOPE AND GRADE INFORMATION ABOVE THE BANKFULL WIDTH.

**D_{50} refers to the average sediment diameter of riverstone material. Material to consist of a range of sediment sizes, with the majority being of D_{50}.



TYPICAL POOL DETAIL

water's edge ENVIRONMENTAL SOLUTIONS TEAM LTD.

0 10 20 30
Meters

Winston Churchill Meander Beltwidth Assessment	Figure No.: 13	Date: Oct. 20, 2016
Culvert 3 (Levi Creek North) Conceptual Realignment	Checked By: EG	Drawn By: NG