Columbia River Project Water Use Plan

Kinbasket & Arrow Recreation Management Plan

Implementation Year 3

Reference:CLBWORKS-35 and CLBWORKS-36

Mid Columbia Erosion Protection and Long-Term Monitoring

Study Period: 2011

Kerr Wood Leidal Associates Limited
Consulting Engineers

December 01 2012

KERR WOOD LEIDAL

2012 Progress Report

CLBWORKS #35 and #36 Mid-Columbia Erosion Protection and Long-Term Monitoring

Final Report
December 2012
KWL Project No. 478.081-300

Prepared for:

BC hydro

Prepared by:

Kerr Wood Leidal Associates Ltd.

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Contents

Executive Summary i

1. Introduction 1-1
1.1 Project Overview 1-1
1.2 Updated Project Schedule 1-1
1.3 Project Team 1-3

2. CLBWORKS #35 2-1
2.1 Permits 2-1
2.2 Construction 2-1
2.3 Erosion Monitoring 2-3
2.4 Statistical Analysis 2-4

3. CLBWORKS #36 3-1
3.1 2012 Measurements 3-3
3.2 Wind Data 3-33
3.3 Statistical Analysis 3-35
3.4 Erosion pin evaluation 3-35
3.5 Cross-Section Evaluation 3-38
3.6 Interim Conclusions 3-42
3.7 Channel Mapping 3-43

4. Summary and Future Works 4-1
4.1 CLBWORKS #35 4-1
4.2 CLBWORKS #36 4-1
4.3 Report Submission 4-3

Figures

Figure 1-1: Location Plan 1-4
Figure 2-1: Bioengineering Site Splitting Site A 2-8
Figure 2-2: Bioengineering Site Splitting Site B to C 2-8
Figure 2-3: Bioengineering Site A1 2-8
Figure 2-4: Bioengineering Site A2 2-8
Figure 2-5: Bioengineering Site B 2-8
Figure 2-6: Bioengineering Site C 2-8
Figure 3-1: Revelstoke Dam Flow Releases and Arrow Lake Water Level (April 2010 to June 2011) 3-2
Figure 3-2: CLBWORKS #36 Bank Erosion Monitoring Sites 3-2
Figure 3-3: Monitoring Site #1 3-4
Figure 3-4: Monitoring Site #2 3-6
Figure 3-5: Monitoring Site #3 3-8
Figure 3-6: Monitoring Site #4 3-10
Figure 3-7: Monitoring Site #5 3-12
Figure 3-8: Monitoring Site #6 3-14
Figure 3-9: Monitoring Site #7 3-16
Figure 3-10: Monitoring Site #8 3-18
Figure 3-11: Monitoring Site #9 3-20
Figure 3-12: Monitoring Site #10 3-22
Figure 3-13: Monitoring Site #11 3-24
Figure 3-14: Monitoring Site #12 3-26
Figure 3-15: Monitoring Site #13 3-28
Figure 3-16: Monitoring Site #14 3-30
Figure 3-17: Monitoring Site #15 3-32
Figure 3-18: Nakusp Wind Rose (Station 1145297) 3-34
Figure 3-19: Revelstoke Airport Road Wind Rose (Station 1176751) 3-34
Figure 3-20: Revelstoke A Wind Rose (Station 1176749) 3-34
Figure 3-21: Average change in pin length (cm) at monitoring sites. 3-37
Figure 3-22: Sites closest to the dam were more eroded and sites further downstream from the dam had greater deposition (Spearman's correlation = 0.55, $p < 0.05$) 3-38
Figure 3-23: Average change at the 14 monitoring sites measured as change at the midpoint of the elevations (upper panel) and measured as the maximum observed difference (lower panel). Shown are changes in elevation for three time periods. 3-41

Tables

Table 1-1: Current Schedule for CLBWORKS #35 and #36. 1-2
Table 1-2: 2012 Work Program (CLBWORKS #35 and #36). 1-2
Table 1-3: Key Project Personnel 1-3
Table 2-1: Summary of Planting and Distribution 2-2
Table 2-2: Site name, average change in pin length (mean; cm) and number of pins measured (N) for control sites; mean and N for treatment (bioengineered) sites; and difference of means between control and treatment paired locations at each site 2-5
Table 2-3: Statistical results for testing the subtracted difference in change of mean pin length for 7 paired sites 2-5

Table 2-4: Site name (DS = downstream; US = upstream; C = control), site code, average change in pin heights (m) for upper, middle and lower elevation bands summarized as the midpoint of each elevation band and as the maximum change observed in each elevation band. 2-6
Table 2-5: Site name, average change in elevation (mean; m) for control sites (C) and treatment (bioengineered) sites (T), and the difference between control and treatment sites. 2-7
Table 2-6: Statistical results for testing the difference in Midpoint (m) and Maxima (m) for 7 paired sites.2-7
Table 3-1: Water Level and Discharge Conditions During CLBWORKS #36 Fieldwork 3-1
Table 3-2: Site name, mean change in pin length, and the number of pins (N), that were measured for three time periods. 3-36
Table 3-3: Statistical results for testing change in mean pin length during three time periods at 15 sites.3-36
Table 3-4: Mean horizontal bank change based on measurements at the midpoints of the cross-section profiles (m); and the number of measurements (N) for each monitoring location. Shown are changes for three time periods. 3-39
Table 3-5: Mean horizontal bank change based on maximum differences in the cross-section profiles (m); and the number of measurements (N) for each monitoring location. Shown are average maximum changes for three time periods. 3-40
Table 3-6: Statistical results for comparisons of cross-section changes at 14 locations during three time periods. Shown are results for the changes measured at the midpoint and measured as the maxima. 3-42
Table 3-7: Statistical results for comparison of change in cross-section elevations within lower, middle and upper bands along the bank. Shown are results for the changes measured at the midpoint and measured as the maxima. 3-42

Appendices

Appendix A: CLBWORKS #35 Drawings (Record Drawings)
Appendix B: CLBWORKS#35 Survey and Cross-section Drawings
Appendix C: CLBWORKS#36 Survey and Cross-section Drawing

Executive Summary

This report summarizes progress made by Kerr Wood Leidal Associates Ltd. (KWL) during 2012 on BC Hydro programs CLBWORKS #35 and #36. These two programs were initiated in 2009 after a multi-stakeholder review of the Columbia River Water Use Planning (WUP) process in response to the proposed installation of a fifth generating unit at Revelstoke Dam. CLBWORKS #35 and CLBWORKS #36 are part of a large suite of physical works and monitoring projects developed under the WUP for the Columbia River system.

CLBWORKS #35

The purpose of CLBWORKS#35 is to implement and test the performance of bioengineering treatments to reduce erosion in sections of the Columbia River downstream of Highway 1, with a total of 400 m of bioengineering works required under the Terms of Reference. Four bioengineering sites were selected, with three of the sites being further split to increase the total number of samples in the statistical analysis.

Construction of the bioengineering works is complete. The final lower elevation portion of Site A1 was installed in March 2012. Baseline erosion monitoring pins and cross-sections have been established at all CLBWORKS #35 sites, including the lower elevations of Site A1. Erosion monitoring pin measurement data and transect survey data was collected in April 2012. The initial data analysis is summarized in this report.

The first round of erosion monitoring measurements (Year 2) provides a partial year of data. This allows understanding of the change over a winter season of lower of the Arrow Lakes water levels and does not include a flood cycle.

Initial measurements of the erosion monitoring pins indicate that there is no statistically significant change in erosion or deposition from 2011 to 2012 for the bioengineered versus control sites. Control sites do show slightly more erosion based on average exposed pin length; however, it is not statistically significant. The transect profiles indicate that the control sites show slightly more deposition, again, these results are not statistically significant.

The length of time for this comparison is relatively short (four months) and changes likely will take longer to develop. Year 3 monitoring for this project is scheduled for spring 2013.

CLBWORKS #36

The purpose of CLBWORKS #36 is to monitor long term erosion rates along the Columbia River from Revelstoke Dam to Shelter Bay.

There are a total of 15 long term erosion monitoring sites that have been established for CLBWORKS #36. One site (MON 14) was excluded from data collection and analysis in 2012 because of conflicts with the upland landowner. Year 3 (2012) erosion monitoring measurements have been completed at the CLBWORKS #36 sites, and the data analysis is summarized in this report. Erosion pin measurements and transect surveys were conducted between May 31 and June 2, and between June 13 and 14, 2012.

Each of the 14 remaining monitoring sites was evaluated for change in erosion or deposition by comparing the average change in exposed erosion pin length for three time periods: 2010 to 2011, 2011 to 2012 and 2010 to 2012.

At each of the 14 monitoring sites, elevation was measured along five cross-sections (transects) from the top of the bank to the river's edge in 2010, 2011 and 2012. The average elevation of the transects at each site were compared for the same three time periods and the average elevation of the transects at each site separated into upper, middle and lower elevation bands were compared for the same three time periods.

In general, measurements made of the pins and transects agreed and most measurements indicated erosion. For the pins, a statistically significant change (erosion) was observed from 2010 to 2011; however, the trend was not statistically significant for 2011 to 2012 or from 2010 to 2012.

For the transects, approximately 75% of the measurements indicated erosion. A statistically significant amount of erosion was observed from 2010 to 2011 and over the overall period from 2010 to 2012. When erosion was evaluated within elevation bands, the upper and middle elevations showed some statistically significant erosion, while the lower elevations showed deposition that was not statistically significant.

It could also be seen this year that erosion patterns followed a gradient from upstream to downstream sites. The most eroded sites were located nearest to the Revelstoke Dam and sites with the greatest deposition were furthest downstream. While preliminary, this trend is physically consistent with what would be expected for a river mouth/lake environment.

Year 4 monitoring is scheduled for the spring of 2014 for this project.

Section 1

Introduction

1. Introduction

This report summarizes progress made by Kerr Wood Leidal Associates Ltd. (KWL) during 2012 on BC Hydro programs CLBWORKS #35 and #36. The proposed installation of a fifth generating unit at Revelstoke Dam resulted in a multi-stakeholder review of the Columbia River Water Use Planning (WUP) process. According to pubic BC Hydro reports, the fifth generating unit was expected to be complete by late, 2011.

As a result of the WUP review, it was recommended that two programs be undertaken:

- **CLBWORKS #35**: Develop and implement a bank erosion monitoring and mitigation program to identify and address current and future shoreline erosion concerns attributable to the Revelstoke Unit 5 project downstream of Revelstoke Dam (mid-Columbia River between the TransCanada Highway Bridge and Begbie Creek, see Figure 1-1).
- **CLBWORKS #36**: Monitor long-term erosion rates along the mid-Columbia River from Revelstoke Dam downstream to Shelter Bay (Figure 1-1).

Given the complementary nature of the work, these two physical works programs were combined into one project, which was awarded to KWL in summer 2009.

1.1 Project Overview

The purpose of CLBWORKS #35 and #36 is to provide information regarding bank erosion along the mid-Columbia River downstream of the Revelstoke Dam. Management questions of interest include:

- Does the installation of bioengineering bank protection works result in a significant decrease in bank erosion?
- Does the addition of Revelstoke Unit 5 result in a significant increase in bank erosion at unprotected sites?

The project schedule (Section 1.2) did not permit adequate baseline data (i.e. a period of time equivalent or greater than the post installation monitoring) to be collected before the fifth generating unit was installed at Revelstoke Dam; therefore, the second management question cannot be entirely addressed. Rather, the long-term erosion monitoring program will document rates of erosion at various sites over time, and will attempt to determine which mechanisms are responsible.

1.2 Updated Project Schedule

The original intent of the erosion monitoring work was to have repeat baseline measurements for the each of the sites prior to commissioning of Revelstoke Unit 5, and to assess erosion through several years of operation.

However, due to unusually high water levels in the system in 2010, no data could be collected in that year. In addition, the higher than average water levels made installation of the bioengineering works for CLBWORKS #35 impractical in the same year.

The schedule of both projects has been shifted to accommodate this change. The general schedule for CLBWORKS #35 and #36 is summarized in the following table.

Table 1-1: Current Schedule for CLBWORKS #35 and #36.

Year	CLBWORKS#35	CLBWORKS#35
2009	Y1 – Design	Y1 – Site Selection
2010	Y1 – Permitting	Y1 – Baseline Monitoring
2011	Y1 – Bioengineering Construction	Y2 – Monitoring
2012	Y2 – Monitoring	Y3 – Monitoring
2013	Y3 – Monitoring	
2014		Y4 – Monitoring
2015	Y4 – Monitoring	
2016		Y5 – Monitoring

The long-term erosion monitoring sites (CLBWORKS #36) were installed in late April 2010, and repeat measurements were conducted in late May / early June 2011 and in April 2012.

The bulk of the bioengineering works for CLBWORKS #35 were installed in October and November 2011, with large woody debris (LWD) installed in the lower elevation of Site A1 during April 2012. The erosion monitoring pins were installed for the bioengineering and control sites in November 2011 and measurements were taken in April 2012. Lower elevation erosion monitoring pins at Site A1 were installed after the completion of construction in April 2012.

2012 Project Work

Project work completed during 2012 is summarized in the following table. Task numbers reference the original work program proposed by KWL in 2009.

Table 1-2: 2012 Work Program (CLBWORKS #35 and #36).

Task No.	Task	Description
11.	**Erosion Assessment (CLBWORKS #36 Y3)**	▪ Safety Plan ▪ Site Visit ▪ Measure Erosion Pins ▪ Re-survey Monitoring Cross-Sections
6.&10.	**Bioengineering Works (CLBWORKS #35 Y2)**	▪ Low water construction for bioengineering design ▪ Installation of low water Baseline Monitoring Erosion Pins and Cross-section re-survey ▪ Monitoring of any repeat Erosion Monitoring Pins
11.	**2012 Data Entry and Analysis**	▪ Populate GIS Database ▪ Data Analysis (CLBWORKS #36 Y3)
11.	**2012 Progress Report**	▪ Progress Report for CLBWORKS #35 Y2 ▪ Progress Report for CLBWORKS #36 Y3

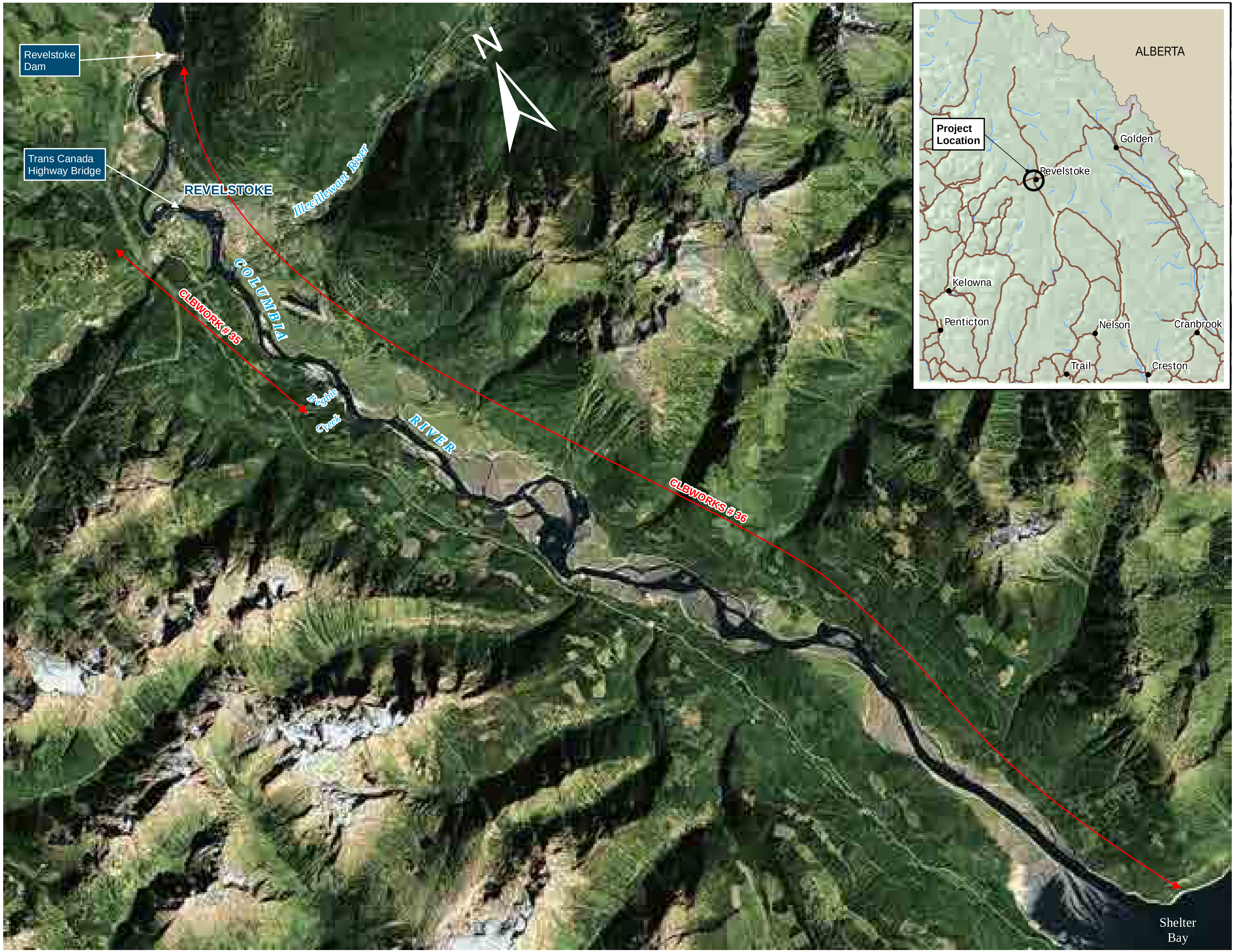
1.3 Project Team

Key Project Personnel for this project in the past year include the following KWL staff and subconsultants:

Table 1-3: Key Project Personnel

Name	Role, Organization
David Matsubara, M. Eng., P. Eng.	Project Manager Senior Water Resources Engineer Kerr Wood Leidal Associates Ltd.
Mike Currie, M.Eng., P.Eng.	Senior Technical Review Kerr Wood Leidal Associates Ltd.
Erica Ellis, M.Sc., P.Geo.	Fluvial Geomorphologist Kerr Wood Leidal Associates Ltd.
Sarah Lawrie, M.A.Sc., P.Eng.	Environmental Water Resource Engineer Kerr Wood Leidal Associates Ltd.
Jack Lau	GIS Specialist Kerr Wood Leidal Associates Ltd.
Peter Tapp, Civil Technologist	Survey Coordinator Kerr Wood Leidal Associates Ltd.
Bruce VanCalsteren	Survey Technologist Kerr Wood Leidal Associates Ltd.
Mike Moody	Technologist Kerr Wood Leidal Associates Ltd.
Nick Page, B.L.A., M.Sc., R.P.Bio.	Professional Biologist Raincoast Applied Ecology
Leska S. Fore, M.S., M.A.	Statistician Leska S. Fore, Statistical Design

As required, change orders were submitted to BC Hydro to add or substitute personnel to the team.



BC Hydro
CLBWorks No. 35 and 36
Mid-Columbia Erosion Protection
and Long Term Monitoring

Reference: Orthophoto from Bing aerial image map.

KERR WOOD LEIDAL
consulting engineers

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Project No.	Date
478-081	November 2011

Location Plan

Figure 1-1

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Author: jlau

Section 2

CLBWORKS #35

2. CLBWORKS #35

The purpose of CLBWORKS#35 is to implement and test the performance of bioengineering treatments to sections of the Columbia River at Revelstoke between Highway 1 and Bebgie Creek. Four bioengineering sites were selected to fulfil the regulatory goal of a total of 400 m of constructed bioengineering works. Three of the sites were further split to increase the total number of samples in the statistical analysis, as outlined in Figures 2-1 and 2-2.

Final bioengineering record drawings for CLBWORKS #35 are included in Appendix A.

2.1 Permits

For the project the following regulatory agencies were contacted for project referral:

- Fisheries and Oceans Canada;
- Transport Canada – Navigable Waters; and
- Ministry of Environment.

As follow-up for these referrals, permits were required by Transport Canada under the Navigable Waters Protection Act and by Ministry of Environment under Section 9 of the Water Act.

2.2 Construction

The construction of bioengineering works for CLBWORKS#35 was initiated in October 2011, following approval by BC Hydro. Due to water levels in the Fall of 2011, isolated low water work (comprising large wood, boulder installation, and aquatic bench creation) was delayed until April 2012, once snow had left the floodplain. This work was conducted by the selected contractor from 2011, Brinkman Reforestation. The April 2012 work also included planting of any potted plants on the floodplain to provide a higher chance of overall plant survival and growth. Some additional live cuttings were installed in April 2012.

A description of the bioengineering work from 2011 can be found in the CLBWORKS#35 and #36 2011 Progress Report. The following describes the installation of the low-water works at Site A1 and planting of potted plants.

Low-Water Works – Site A1

Site A1 is located on the west side (right bank) of the Columbia River a short distance from the Big Eddy Bridge. The site is readily accessible by public roads; however, access could be limited during very high water levels. This side of the Columbia River is frequented by the public for a variety of recreational activities.

The treatment for Site A1 differs from all of the other treatments in the level of complexity and bioengineering techniques. All of the bioengineering treatments have been selected to emulate features found near or at each site. In the case of Site A1, the treatment includes a higher reinforced soil slope, a bench for aquatic grasses, and large wood debris on the lower bank.

Photos of the large woody debris installation are shown in the following Photos 2-1 and 2-2.

Photo 2-1: Initial construction at Site A1

Photo 2-2: Installation of large woody debris at Site A1

Planting

Planting conducted in 2012 included a wide variety of potted and plug stock for the upland riparian areas and for the aquatic bench. Species and distribution of the species are summarized in the following table:

Table 2-1: Summary of Planting and Distribution

Common Name	Distribution	Sites Included
Bioengineering Slope Planting		
Pacific willow	30% by bank treatment length	All
Shrub willow (various)	70% by bank treatment length	All
Black cottonwood	2 plants per 10 m of bank	Sites A and C
Mountain alder	5 plants per 10 m of bank	Sites A and C
Red-osier dogwood	5 plants per 10 m of bank	Sites A and C
Upland Riparian Planting		
Shrub willow	30% by area	Sites A and C
Mountain alder	20% by area	Sites A and C
Paper birch	15% by area	Sites A and C

Common Name	Distribution	Sites Included
Englemann spruce	5% by area	Sites A and C
Western red cedar	5% by area	Sites A and C
Red-osier dogwood	10% by area	Sites A and C
Thimbleberry	5% by area	Sites A and C
Saskatoonberry	5% by area	Sites A and C
Black twinberry	5% by area	Sites A and C
Marsh Bench Plantings		
Sedges	85% by area	Sites A and C
Common spike rush	5% by area	Sites A and C
Redtop	10% by area	Sites A and C

The shrub willow used in the bioengineering work includes: *Salix barclayi, Salix bebbiana,* and *Salix drummondiana.*

2.3 Erosion Monitoring

Baseline Data

Following construction of the bioengineering treatments, an erosion monitoring program was implemented similar to the program established for CLBWORKS#36. The approach involves placing a series of 0.5 m long erosion monitoring pins throughout the bioengineering treatment and in the control areas outlined on Figures 2-1 and 2-2.

The erosions pins were installed at the upper elevations of Site A1 as well as Sites A2, B and C in November of 2011. In April, 2012, the lower elevation erosion pins were installed at Site A1, and the previously installed pins were re-measured.

Cross-section data was also collected for the bioengineering sites and the control sites. The locations of the cross-sections are shown on the site figures, and the baseline cross-section plots are provided in Appendix B.

2012 Measurements

A total of seven sites, based on site splitting, were modified with bioengineering methods designed to reduce erosion. Each site was paired with a control site that was not treated. The seven site pairs were evaluated for change in erosion (or deposition) by two methods:

- measuring the length of exposed pins in 2011 and 2012; and
- surveying transects along the site.

The number of pins measured at each site, including control sites, varied from 9 to 20. The difference in exposed pin length between 2011 and 2012 was calculated for each pin. The average change in exposed pin length was calculated for each site, and the *difference* between the change observed at the control and treatment sites was calculated for each pair of sites. The subtracted difference between each site pair was used to evaluate the amount of change in erosion (or deposition) associated with bioengineering methods at the treatment sites.

Measurements of all of the bioengineering sites were conducted between April 17 and 25, 2012. All pins installed in 2011 were re-measured, and 15 additional pins were installed at Site A1. Only one pin installed in 2011 at Site A1 was lost due to supplementary construction activity.

2.4 Statistical Analysis

Erosion pin evaluation

The statistical model used to evaluate change in site condition was a before/after control/impact design (BACI; Stewart-Oaten et al., 1992; Stewart-Oaten and Bence, 2001). A BACI model tests for change at an impacted site relative to a control site. The expectation is that influences outside the experiment, e.g., a high water year, will influence both the control and treatment sites in similar ways and in this way the change in the treatment site can be benchmarked with the change observed at its paired control site. In this case, the impacted sites are those treated with bioengineering designs to prevent erosion. Control sites are not treated.

Both control and treatment sites are measured through time and each site is compared with itself through time. This approach controls for the potential influence of site location because each site is paired with itself. The subtracted difference for exposed pin lengths is calculated and averaged for each site. Each site is next compared with its control site by subtracting to get the difference in average pin length for the control and treatment sites. This approach controls for influences outside of the paired sites, e.g., climate. Thus, the ‘difference of the differences’ is the test statistic. The statistical test determines whether the test statistics are significantly greater than or less than 0. A statistically significant result could be due to more deposition, less deposition, more erosion or less erosion at the treatment sites.

Changes at both the control and treatment sites were small from 2011 to 2012 (Table 1). Three control locations had 1-3 cm of erosion on average across all pins; other control sites had < 1 cm change. For treatment locations, one had ~5 cm of erosion and two had ~1 cm of deposition, others had < 1 cm of change. The largest changes were seen at A2_DS. Overall, five control sites had values indicating erosion and four treatment sites had values indicating erosion. Very few pins were missing; missing values were not estimated or included in any calculations. The overall difference between control and treatment sites was not statistically significant (–0.33 cm, $p = 0.4$; Table 2).

Table 2-2: Site name, average change in pin length (mean; cm) and number of pins measured (N) for control sites; mean and N for treatment (bioengineered) sites; and difference of means between control and treatment paired locations at each site

Site name	Control		Treatment		Control – Treatment
	Mean (cm)	N	Mean (cm)	N	Difference (cm)
A1_US	-0.90	15	0.15	10	-1.05
A1_DS	-0.06	18	0.83	9	-0.89
A2_US	-2.04	12	-0.58	12	-1.46
A2_DS	-3.32	14	-4.77	13	1.45
B	0.03	20	-0.06	24	0.09
C_US	0.03	20	-0.06	18	0.08
C_DS	-0.11	19	0.45	19	-0.55

In the above table negative values indicate erosion, positive values indicate deposition

Table 2-3: Statistical results for testing the subtracted difference in change of mean pin length for 7 paired sites

Change measured as	Period	Mean (cm)	SD	N	Std. Err.	t-value	df	p
Difference in mean pin length (cm)	2011 to 2012	-0.33	0.97	7	0.37	-0.91	6	0.40

The table above summarizes results for difference in change in mean pin length, time period of comparison, mean difference in change in pin length, the standard deviation of the difference, number of site pairs, standard error of the mean difference, test statistic, degrees of freedom and p-value for Student's t test.

Cross-section evaluation

Cross-sections were measured at 12 out of 14 of the sites. Two sites (A1_US and A1_DS) were only measured once because the installation was completed later than the other sites. Sites were paired for this analysis and a similar BACI statistical model was used to test for a difference in the amount of change in erosion (or deposition) for the paired sites.

Elevation was measured along cross-sections from the top of the bank to the river's edge in 2011 and 2012. Measurements taken along each cross-section were summarized at three points. The points were defined by dividing the total height of each cross-section into three equal heights from the highest elevation (at the top of the bank) to the lowest elevation (at the river edge). For example, if the elevation along a cross-section ranged from 400 to 415 m, the difference of 15 m was divided into three equal elevations (400–405, 406–410, and 411–415). The midpoint of each elevation band was intersected with the profile for each year. Thus, within each of the three "sub-sections" (lower, middle and upper), the elevation at the midpoint of the sub-section was calculated. A second statistic, the maximum change within each of the three sub-sections, was calculated in a similar manner.

Sites varied in the number of cross-sections measured (from two to four). Change in elevation was measured at three points along each cross-section. Changes in elevation were calculated by comparing measurements at each site to itself through time. Two types of measurements were made for each elevation: as the midpoint of each elevation band and as the maximum observed difference in the elevation band.

Years were compared by calculating the change in elevation at the midpoints of each subsection. The measurements of mean change at the midpoints of the three elevation bands were averaged for each site. Average change was compared for each control and treatment site by calculating the difference in change in elevation. For the BACI design, the difference of the differences is compared. Differences were tested for a statistical significance based on their difference from 0. In 2012, several measurements were missing, particularly from the lowest elevations of the site C_US and C_DS for both control and treatment sites (Table 2-4).

For midpoint measurements, two control sites had negative changes in elevation indicating erosion, and five sites had positive changes (Table 2-5). For the five treatment sites, two indicated erosion and three deposition. The treatment and control site pairs did not tend to agree on erosion or deposition. The difference between control and treatment sites from 2011 to 2012 was not statistically significant for measurements of elevation calculated at the midpoint of each elevation band (0.04 m, $p = 0.8$; Table 5).

For measurements based on the maximum difference in elevation within each elevation band, values were generally larger than for midpoints (see Table 4). All but one control site had values indicating deposition. Two out of five treatment sites indicated erosion. Statistical testing found no significant difference in deposition or erosion for control and treatment sites (0.1 m, $p = 0.6$; see Table 5).

Table 2-4: Site name (DS = downstream; US = upstream; C = control), site code, average change in pin heights (m) for upper, middle and lower elevation bands summarized as the midpoint of each elevation band and as the maximum change observed in each elevation band.

Site name	Site code	Midpoint (m)			Maximum (m)		
		Upper	Middle	Lower	Upper	Middle	Lower
A1_DS_C	104	-0.03	-0.02	0.20	1.83	0.38	0.01
A1_US_C	101	0.05	0.09	0.05	0.19	-0.13	0.02
A2_DS	107	0.69	-0.56	1.19	0.63	-0.64	0.63
A2_DS_C	108	0.75	-0.63	-0.28	0.48	-0.31	-0.40
A2_US	106	0.24	0.18	0.77	2.98	0.29	0.77
A2_US_C	105	0.12	0.11	0.97	1.84	0.48	1.07
B	110	0.04	0.17	-0.05	0.45	0.27	0.33
B_C	109	0.51	0.24	-0.09	1.78	0.41	-0.16
C_DS	113	-0.18			-0.05	-0.18	
C_DS_C	114	0.09	-0.28		0.16	-0.08	
C_US	112	-0.22	-0.13		-0.24	-0.20	-0.59
C_US_C	111	0.59	0.40	-1.51	0.77	0.67	-0.39

Table 2-5: Site name, average change in elevation (mean; m) for control sites (C) and treatment (bioengineered) sites (T), and the difference between control and treatment sites.

Site name	Midpoint (m)			Maximum (m)		
	Mean (C)	Mean (T)	Difference	Mean (C)	Mean (T)	Difference
A1_US	0.07			0.03		
A1_DS	0.05			0.74		
A2_US	0.29	0.32	-0.03	1.13	1.46	-0.33
A2_DS	-0.05	0.44	-0.49	-0.08	0.21	-0.29
B	0.31	0.07	0.24	0.68	0.35	0.33
C_US	0.21	-0.18	0.39	0.35	-0.26	0.61
C_DS	-0.1	-0.18	0.09	0.06	-0.11	0.18

Statistics were calculated for change measured at the midpoint of the elevation bands and for the maximum change observed in each elevation band. Mean values include all measurements from each elevation band.

Table 2-6: Statistical results for testing the difference in Midpoint (m) and Maxima (m) for 7 paired sites.

Change measured as	Period	Mean	SD	N	Std. Err.	t-value	df	p
Difference in Midpoints (m)	2011 to 2012	0.04	0.33	5	0.15	0.25	4	0.82
Difference in Maxima (m)	2011 to 2012	0.10	0.40	5	0.18	0.55	4	0.61

Shown are results for difference in change in the midpoint measures of elevation bands and for difference in change measured as the maximum change in elevation bands, time period of comparison, mean difference of change in elevation, the standard deviation of the difference, number of site pairs, standard error of the mean difference, test statistic, degrees of freedom and p-value for Student's t test.

Conclusions

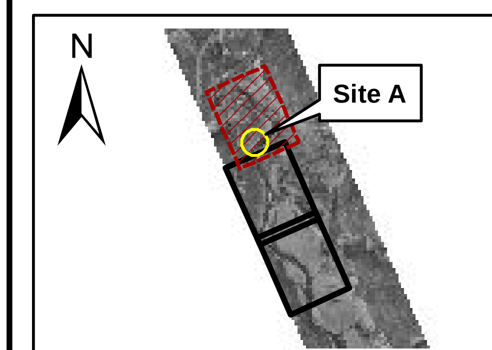
None of the statistical tests indicated a significant change in erosion (or deposition) from 2011 to 2012 for bioengineered vs. control sites. For pin length, control sites showed slightly more erosion on average (0.33 cm) than the site with bioengineering construction. This is the predicted change such that treatment reduces erosion. The length of time for this comparison was relatively short (four months) and changes likely take longer to develop.

For profile measurements, control sites showed slightly more deposition, the opposite of expectation. Differences between treatment and control sites were small, 0.04 m for profile measurements made at the midpoint of each elevation band and were not statistically significant.

CLBWorks No. 35 and 36
Mid-Columbia Erosion Protection and Long Term Monitoring

Legend

- Current Bio-engineering Location
- Current Control
- Proposed Control
- Proposed Bioengineering Site Split Location



KERR WOOD LEIDAL

100 0 100
Scale in Metres 1:5,000

Project No.	Date
478-081	December 2011

Bioengineering Site Splitting: Site A

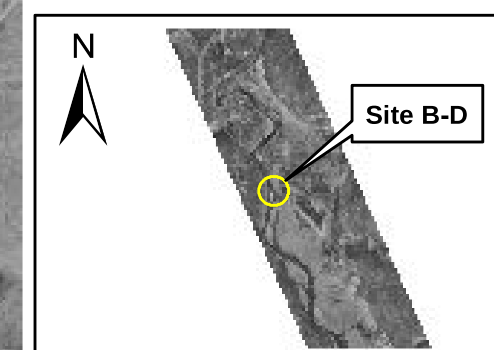
Figure 2-1

Path: O:\0400-0499\478-081\430-GIS\MXD-Rpt\2011\478081_SiteSplittingSiteAFig2-1.mxd Date Saved: 22/12/2011 3:16:14 PM
User: EEllis

CLBWorks No. 35 and 36
Mid-Columbia Erosion Protection
and Long Term Monitoring

Legend

- Current Bioengineering Location
- Current Control
- Proposed Control
- Proposed Bioengineering Site Split Location



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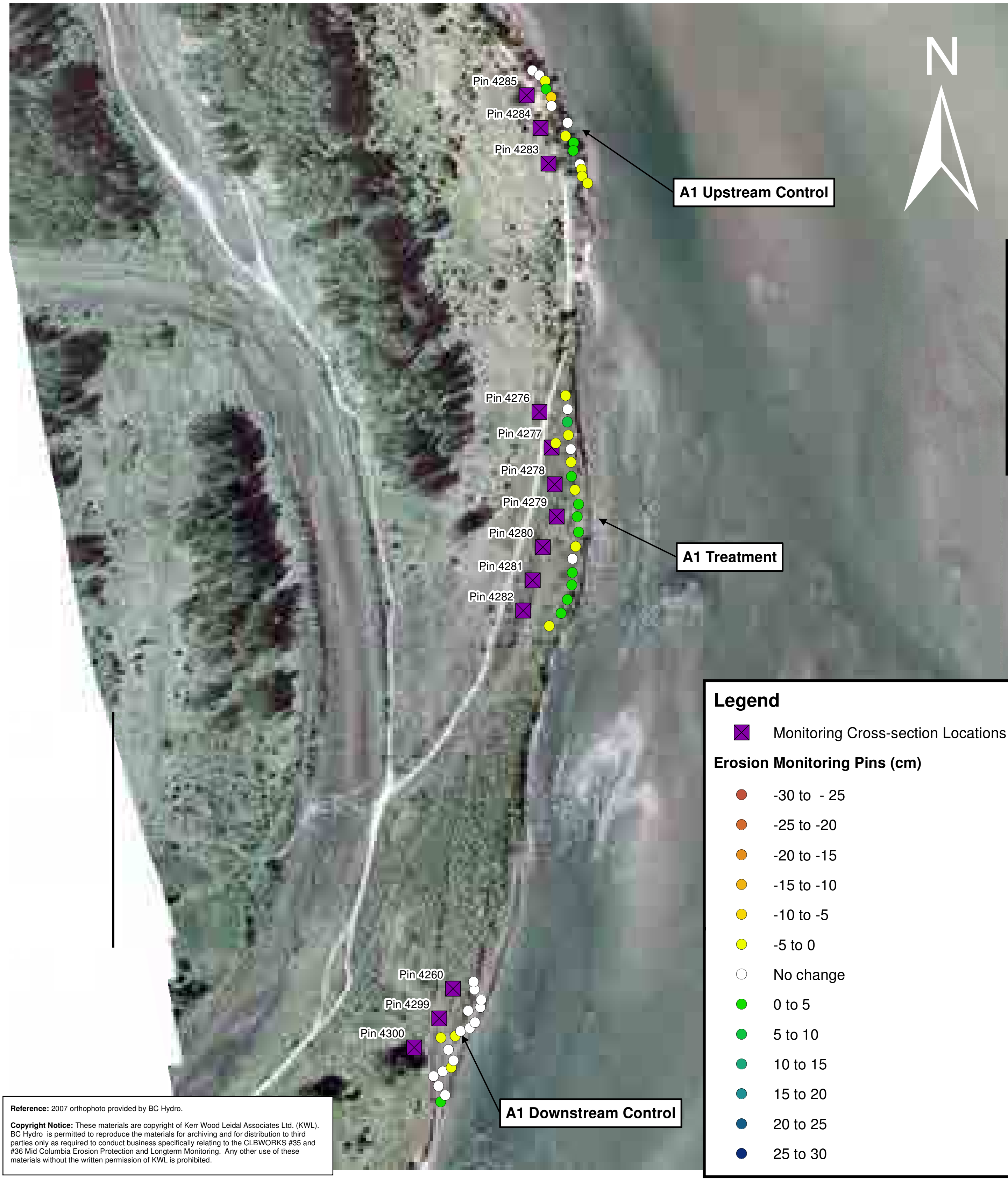
100 0 100
Scale in Metres 1:5,000

Project No.	Date
478-081	December 2011

Bioengineering Site Splitting: Site B to D

Figure 2-2

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2011\478081_SiteSplittingSiteBCFig2-2.mxd Date Saved: 22/12/2011 3:19:23 PM
User: EEllis



Reference: 2007 orthophoto provided by BC Hydro.

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CLBWORKS #35 and #36

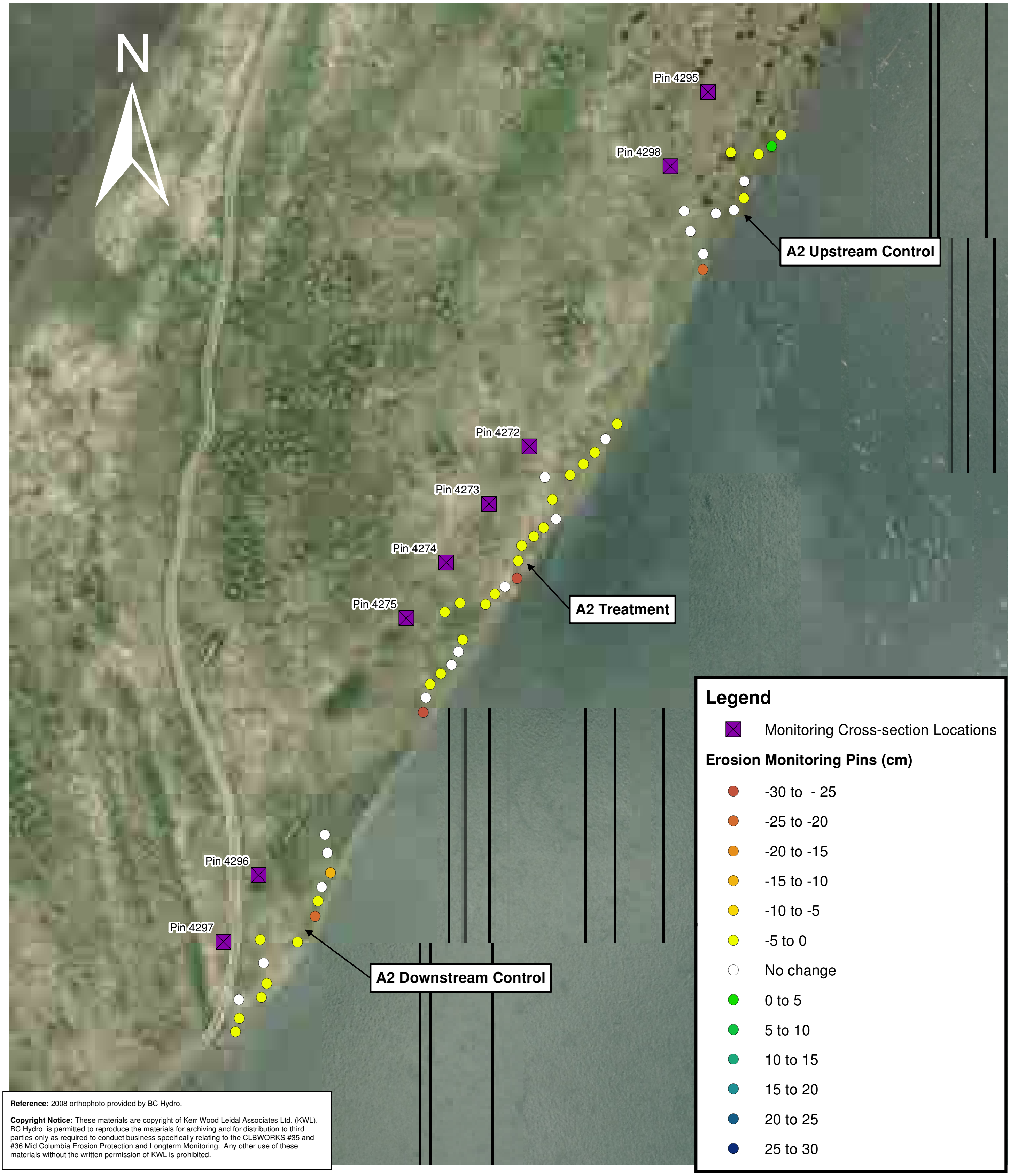
Project No.	Date
478-081	December 2012

50 0 50 (m)
1:3,000

Site A1

Figure 2-3

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081BioEngA1_2012.mxd Date Saved: 10/3/2012 5:22:05 PM
Author: DMatsubara



Reference: 2008 orthophoto provided by BC Hydro.

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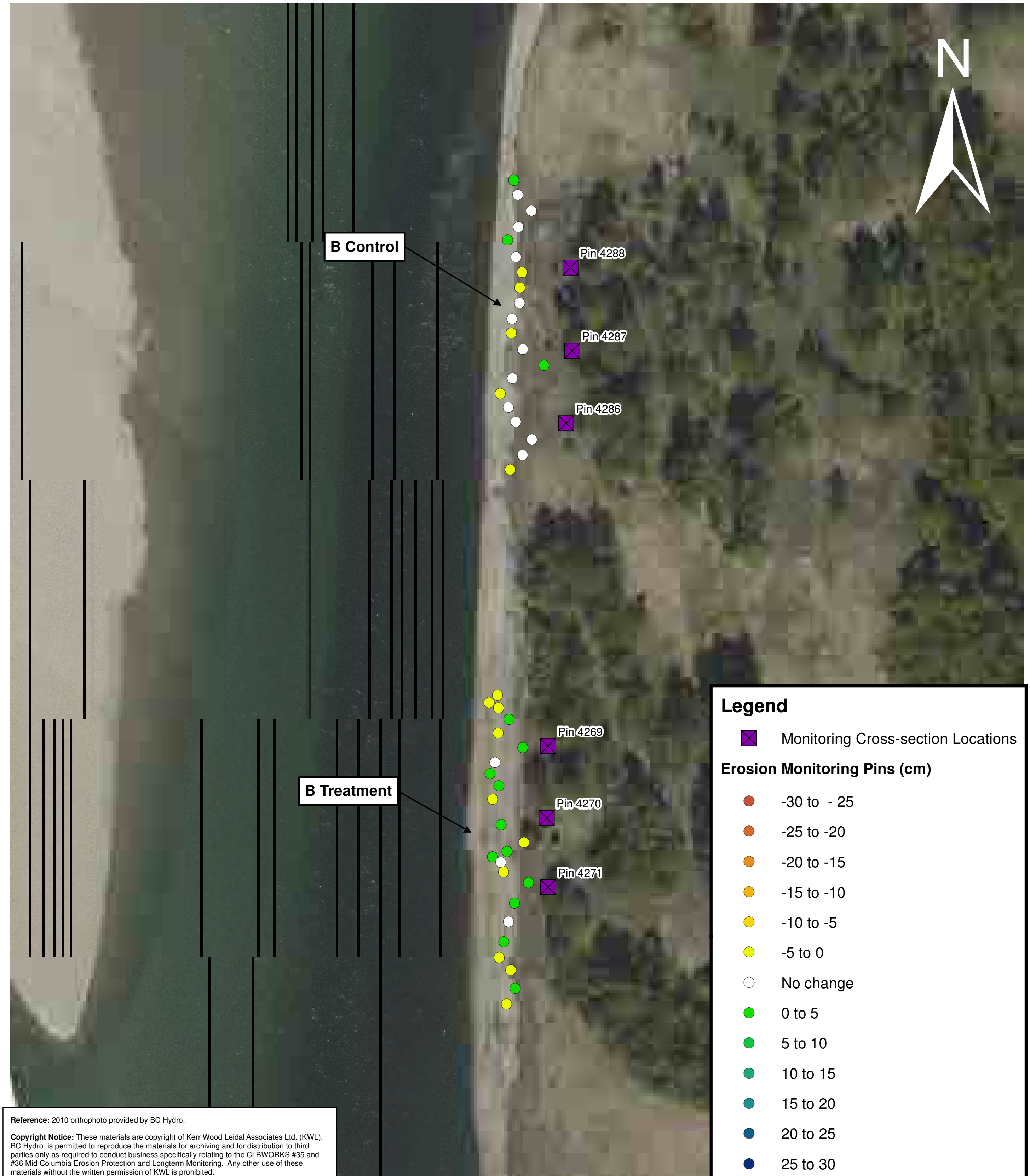
Project No.	Date
478-081	December 2012

20 0 20 (m)
1:1,500

Site A2

Figure 2-4

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081BioEngA2_2012.mxd Date Saved: 10/3/2012 5:23:00 PM
Author: DMatsubara



Reference: 2010 orthophoto provided by BC Hydro.

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CLBWORKS #35 and #36

Project No. 478-081

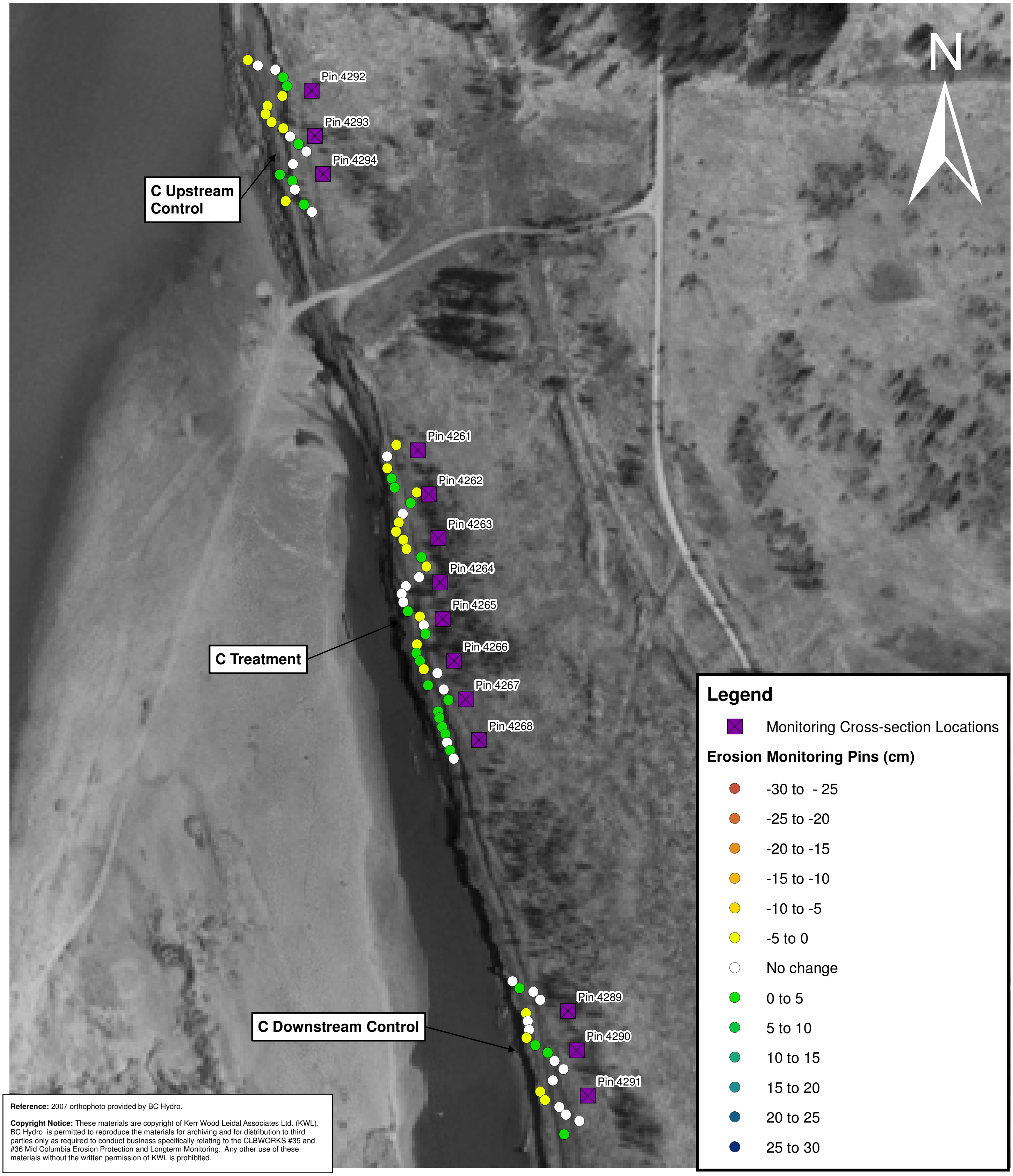
Date December 2012

20 0 20 (m)
1:1,500

Site B

Figure 2-5

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081BioEngB_2012.mxd Date Saved: 10/3/2012 5:23:41 PM
Author: DMatsubara



Reference: 2007 orthophoto provided by BC Hydro.

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CLBWORKS #35 and #36

Project No.	Date
478-081	December 2012

50 0 50 (m)
1:2,500

Site C

Figure 2-6

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081BioEngC1_2012.mxd Date Saved: 10/3/2012 5:27:13 PM
Author: DMatsubara

Section 3

CLBWORKS #36

3. CLBWORKS #36

Fifteen long-term erosion monitoring sites have been established on the Columbia River between Revelstoke Dam and Shelter Bay (Figure 3-1). Sites were installed in 2010 and measured in 2011 and again in 2012. One site (Site 14), was omitted in 2011 and 2012 due to discussions with a neighbouring upland owner, and preference for no erosion pins in the reservoir area adjacent to the upland property. Monitoring Site 12 was subject to a complete topographic survey in and transect survey in 2010, so erosion trends could be tracked in the future based on survey data for the final two years of monitoring.

2012 field measurements were conducted between May 31 and June 2, and between June 13 and June 14. Figure 3-1 shows the Revelstoke Dam discharge and Arrow Lakes reservoir level for the period between monitoring site installation and the 2011 field measurements. Table 3-1 below summarizes the water level and average daily flow for the site installation compared with the first round of erosion measurements.

Table 3-1: Water Level and Discharge Conditions During CLBWORKS #36 Fieldwork

Task	Dates	Arrow Lake Water Level (m)	Daily Average Revelstoke Dam Flow Release (m^3/s)
Year 1 **Site Installation**	Apr. 28 to May 1, 2010	432.6 – 432.8	534 – 586
Year 2 **Erosion Measurements**	May 31 to Jun. 2, 2011 Jun. 13 to Jun. 14, 2011	433.3 – 433.5 435.4 – 435.6	292 – 815 841 – 1087
Year 3 **Erosion Measurements**	Apr. 11 to Apr. 25, 2012	Not available at time of reporting	

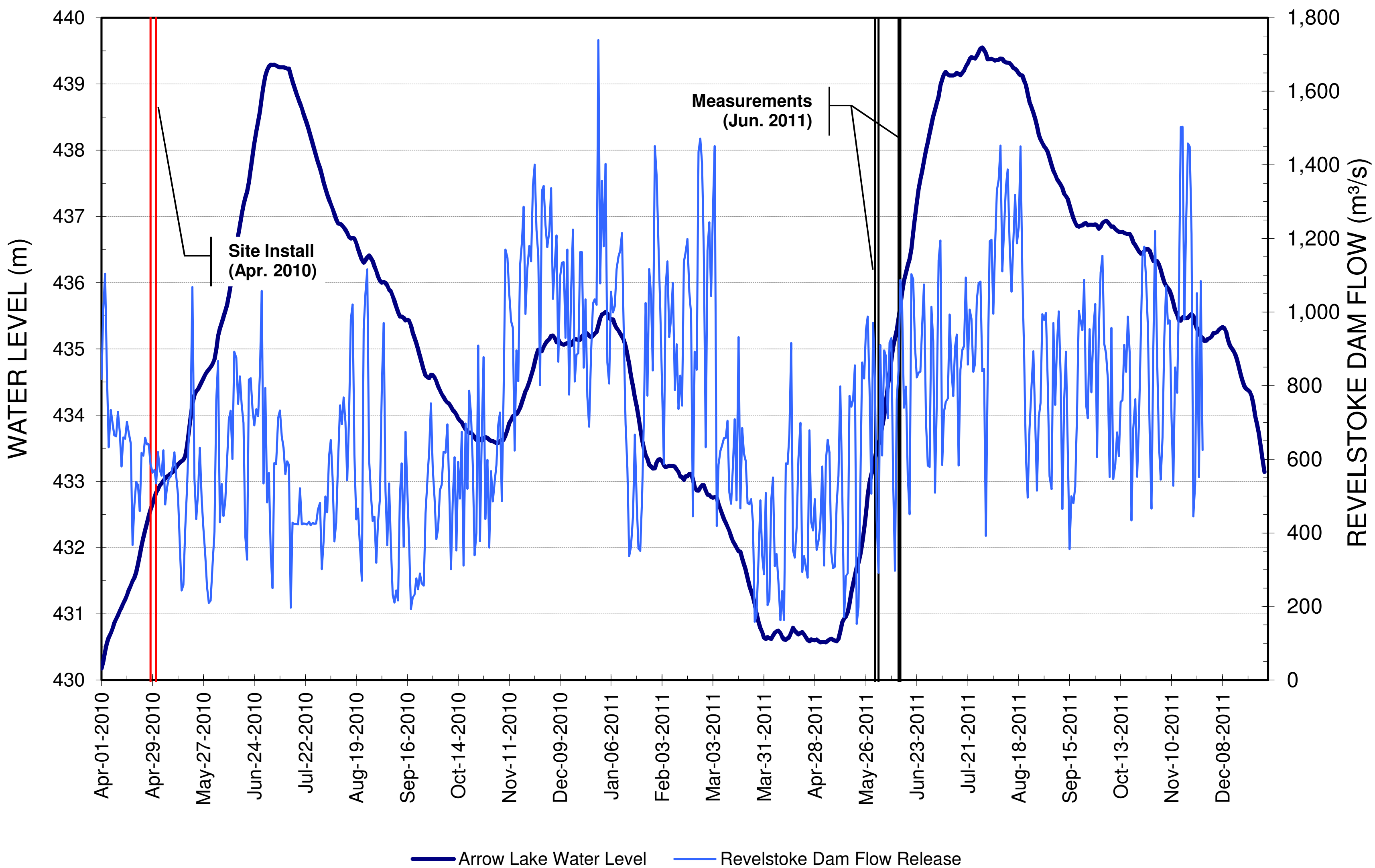
Notes:
1. Arrow Lake Water Level: 2010 data obtained from Water Survey of Canada (Arrow Lake at Nakusp), 2011 data obtained from BC Hydro (Arrow Lake at Fauquier).
2. Revelstoke Dam Flow Release data obtained from BC Hydro.

Water levels in 2012 on the lower reaches of the Columbia River were substantially lower than in both 2010 and 2011, which allowed much longer transect surveys for many sections. In the upper reaches, water levels are much more dictated by discharge from Revelstoke Dam and therefore, monitoring is often conducted earlier in the morning to get best conditions for monitoring.

The following section provides a description of each monitoring site, and an overview of the 2012 measurements. The monitoring sites can be categorized by a number of characteristic parameters. A consistent approach to describing the sites will be used throughout this section to allow some interpretation of the erosion and qualitative observations.

For each of the monitoring sites, a negative number indicates erosion and a positive indicated deposition. All bank references (left bank or right bank) are looking downstream.

Revelstoke Dam Flow Releases and Arrow Lake Water Level (April 2010 to June 2011)



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O:\0400-0499\478-081\442-Hydrology\RevFlow_ArrowLakeWL.xls \ FIG 2010-2011 WL & Q

Figure 3-1

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2011\478081Fig3-2.mxd Date Saved: 11/29/2011 1:26:31 PM
Author: jlau

Reference: Orthophoto from Bing aerial image map.

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CLBWORKS #35 and #36

Project No.	Date
478-081	November 2011

2,000 0 2,000 (m)
1:125,000

Bank Erosion Monitoring Sites (CLBWORKS #36)

Figure 3-2

3.1 2012 Measurements

Monitoring Site 1

Monitoring Site 1 is located near Revelstoke, on the right bank of the river opposite the Golf Course (Figure 3-2). This is the only site located upstream of Highway 1, and characterizes the only reach of the river that is not influenced by backwater from the Arrow Lakes. Based on observations, during some periods of the year the daily fluctuations in water level may be in the range of 1 m to 2 m, when flows vary quickly. The bed and banks are very well armoured and have likely adjusted, for the most part, to these operational flows. Directly across from Site 1 is the Revelstoke Golf Course, which has had issues with bank erosion.

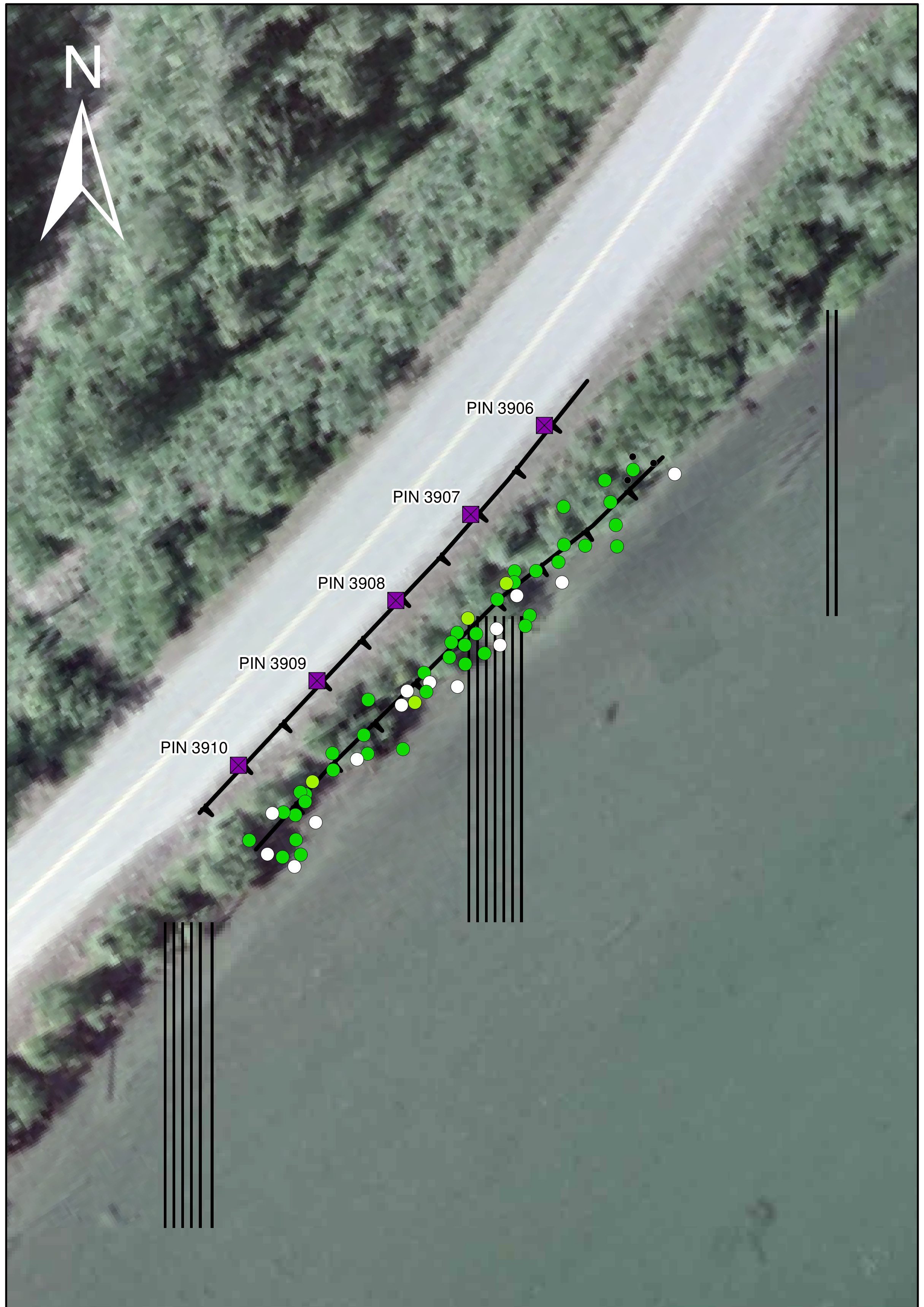
- bank sediment: **gravel**
- range of water levels: **1-2 m daily**
- influence of from Arrow Lakes: **very low**
- erosion mechanism: **fluvial erosion at toe of bank**
- riparian vegetation: **trees**
- exposure to river current: **high**
- exposure to waves: **low**

Both the erosion pins (

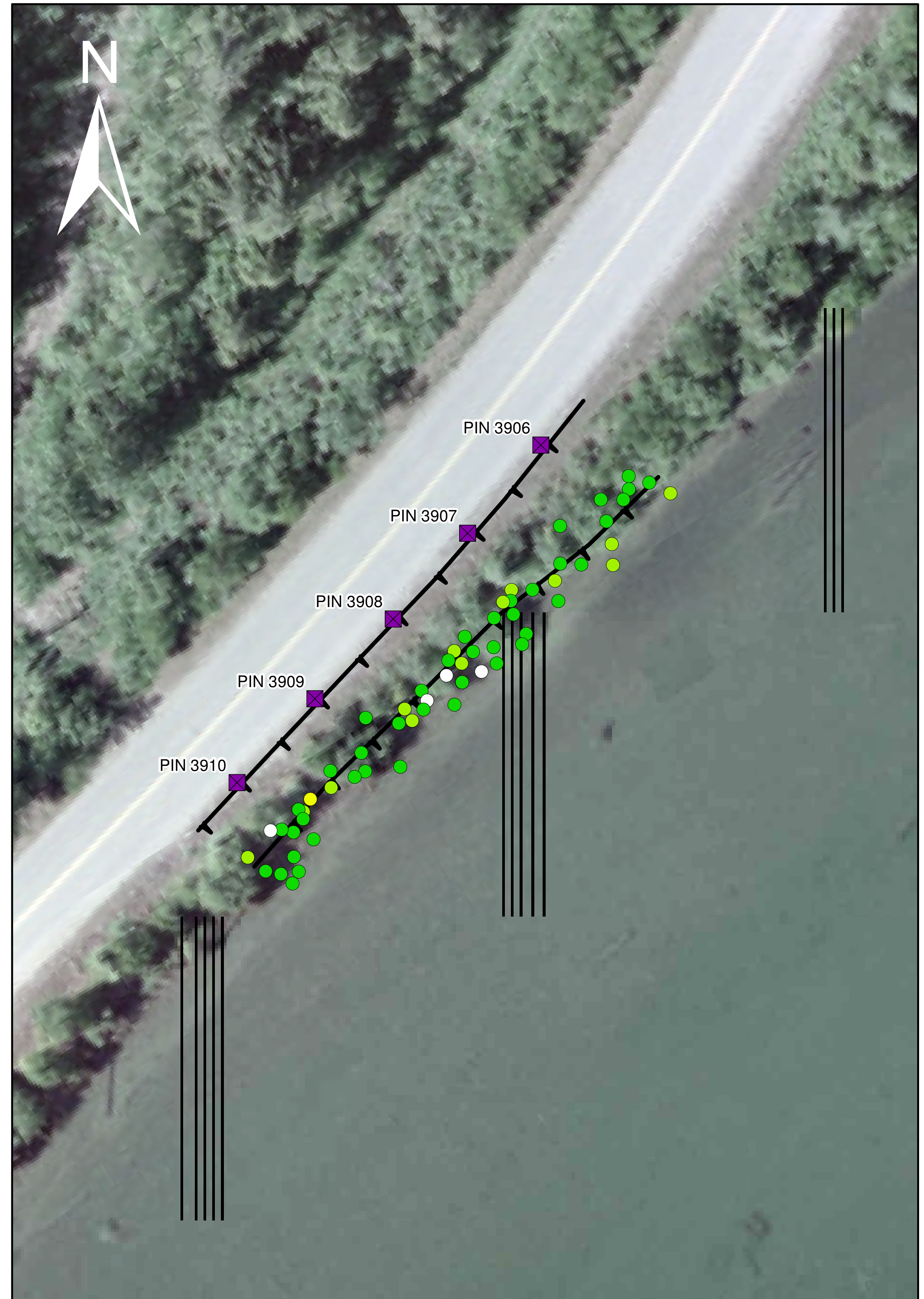
Figure 3-3) and the cross-section data Appendix C indicate that very little change occurred at this site between 2010 and 2012. The average change in pin exposure of +0.10 cm in 2011, increased to +0.6 cm in 2012, or a total two change of +0.7 cm. Currently this site is a net depositional environment. The total cross-sectional change in this location is 0.02 m or about 2 cm deposition.

Photo 3-1: Looking upstream along bank (MON 1, Apr 13, 2012).

Photo 3-2: Looking downstream along bank (MON 1, May 1, 2010).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
CLBWORKS #36

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 1

Figure 3-3

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Author: DMatsubara

Monitoring Site 2 (MON 2)

Monitoring Site 2 is located about 1.5 km downstream of the Highway 1 bridge, at Revelstoke, on the left bank of a mid-channel island (Figure 3-2). This site is located on a small island adjacent to a City of Revelstoke park area near downtown. The island cannot be easily accessed, and is actively eroding. As can be seen in the photos below, the type of bank retreat at this site is generally due to toppling or erosion of loose sand and gravel sediment and toppling of the organic and vegetated surface mat.

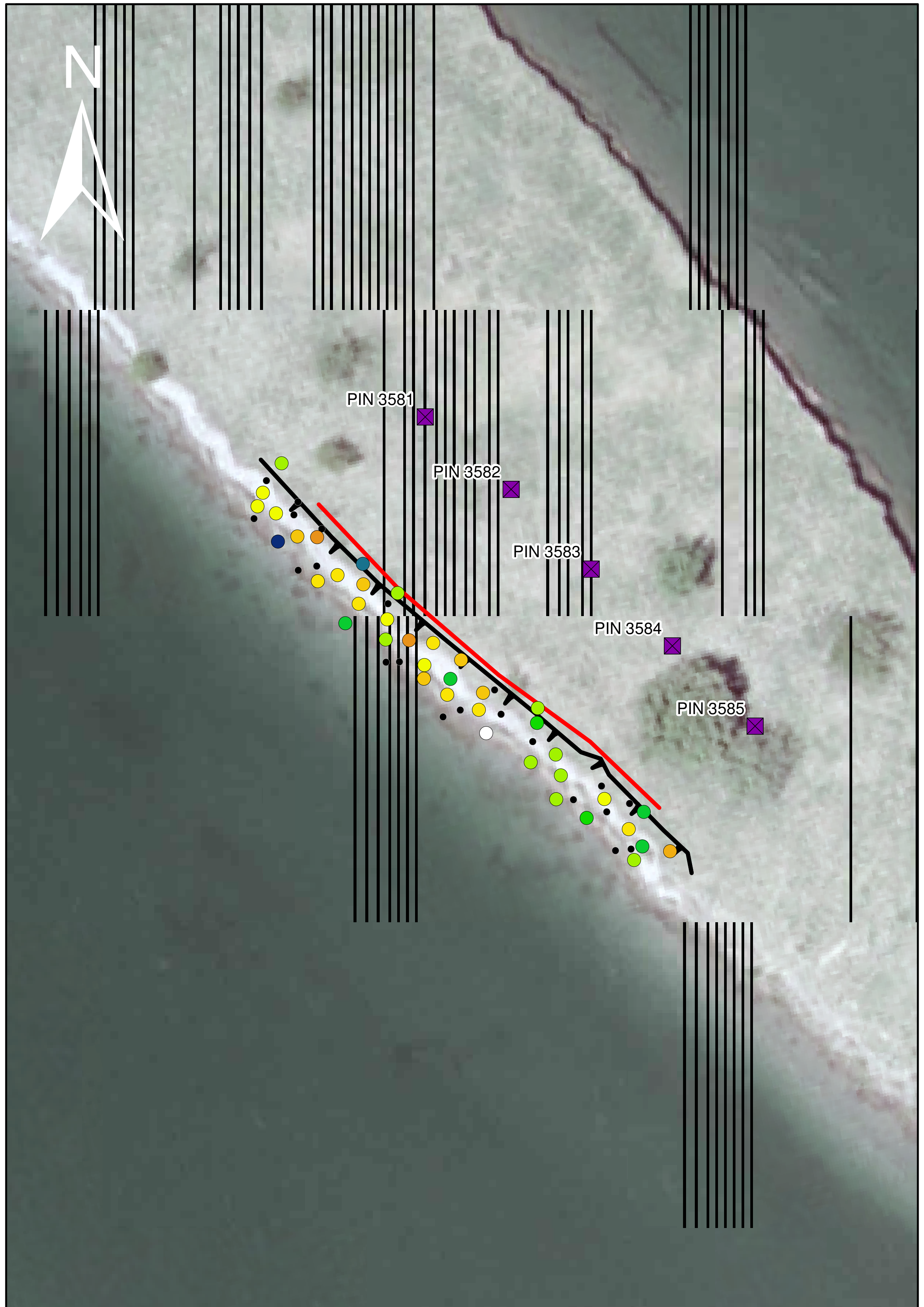
- bank sediment: **sand**
- range of water levels: **1-3 m annually**
- influence of from Arrow Lakes: **moderate**
- erosion mechanism: **fluvial and moderate wave erosion of the lower to mid bank leading to toppling**
- riparian vegetation: **grass**
- exposure to river current: **high**
- exposure to waves: **moderate**

Both the erosion pins (

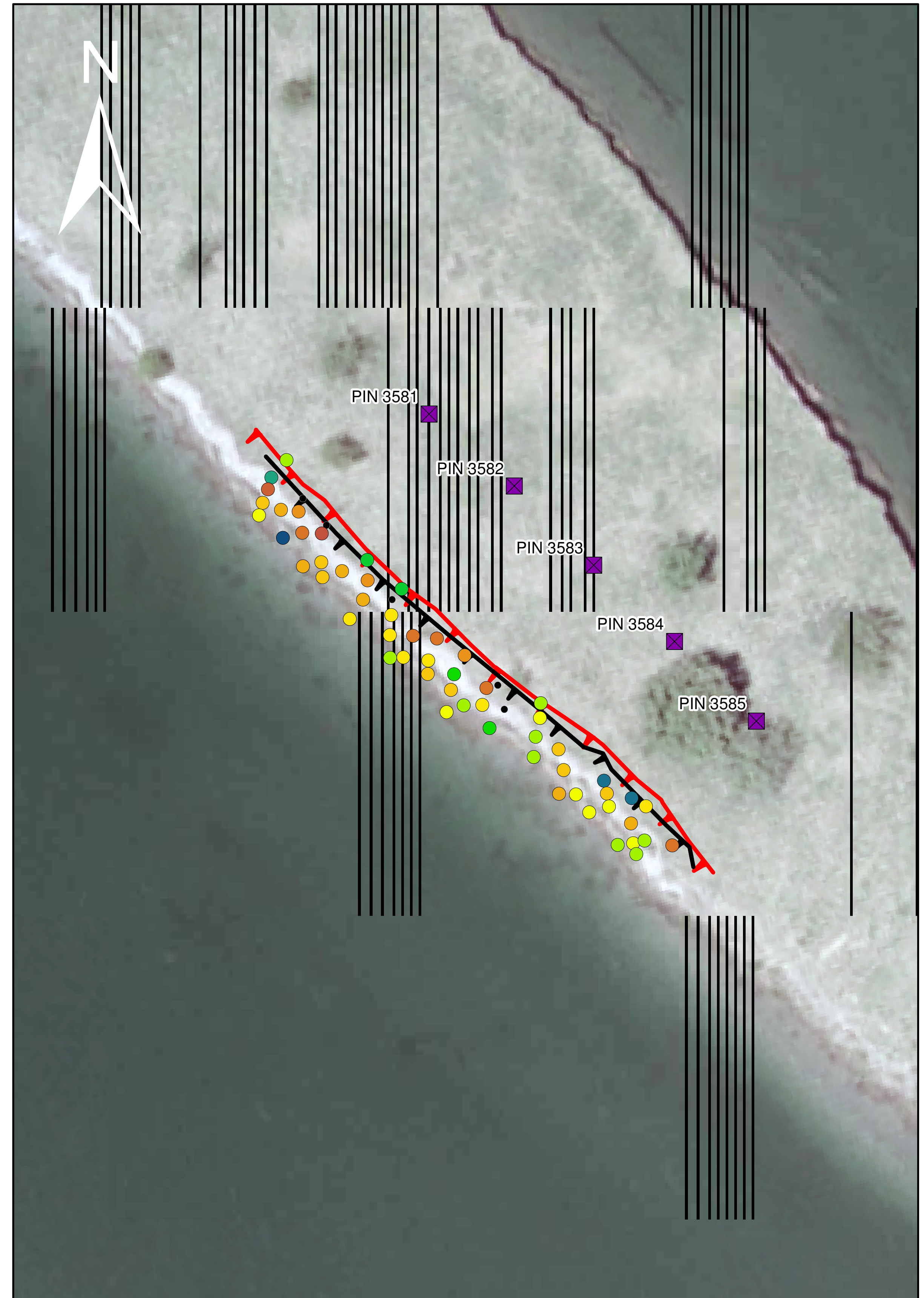
Figure 3-4) and the cross-section data indicate that bank erosion occurred at this site between 2010 and 2012. The average interannual change in pin exposure increased from -10.2 cm to -6.1 cm for 2012, which can be seen in the two comparison photos below. The average pin changes are very similar to the average cross-sectional changes of -0.13 m for 2012.

Photo 3-3: Looking upstream along bank (MON 2, May 12, 2010).

Photo 3-4: Looking upstream along bank (MON 2, Apr 20, 2012).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
CLBWORKS #36

Legend

Monitoring Cross-Section Locations

Erosion Monitoring Pin, No Data

Top of Bank (April 2010)

Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 2

Figure 3-4

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON2_2012.mxd Date Saved: 12/21/2012 10:38:44 AM
Author: DMatsubara

Monitoring Site 3 (MON 3)

Monitoring Site 3 is located about 0.5 km upstream of the Illecillewaet River confluence, at Revelstoke, on the right bank of the main channel (Figure 3-2). This site is located in the vicinity of bioengineering sites A1 and A2, and is easily accessible from roads from the west side of the Columbia River. Site 2 is a well-developed floodplain deposit, with primarily uniform sand over most of the bank height and gravel at the base of the bank. The type of bank retreat at this site is generally due to toppling or erosion of the fine sediment and toppling of the organic and vegetated surface mat.

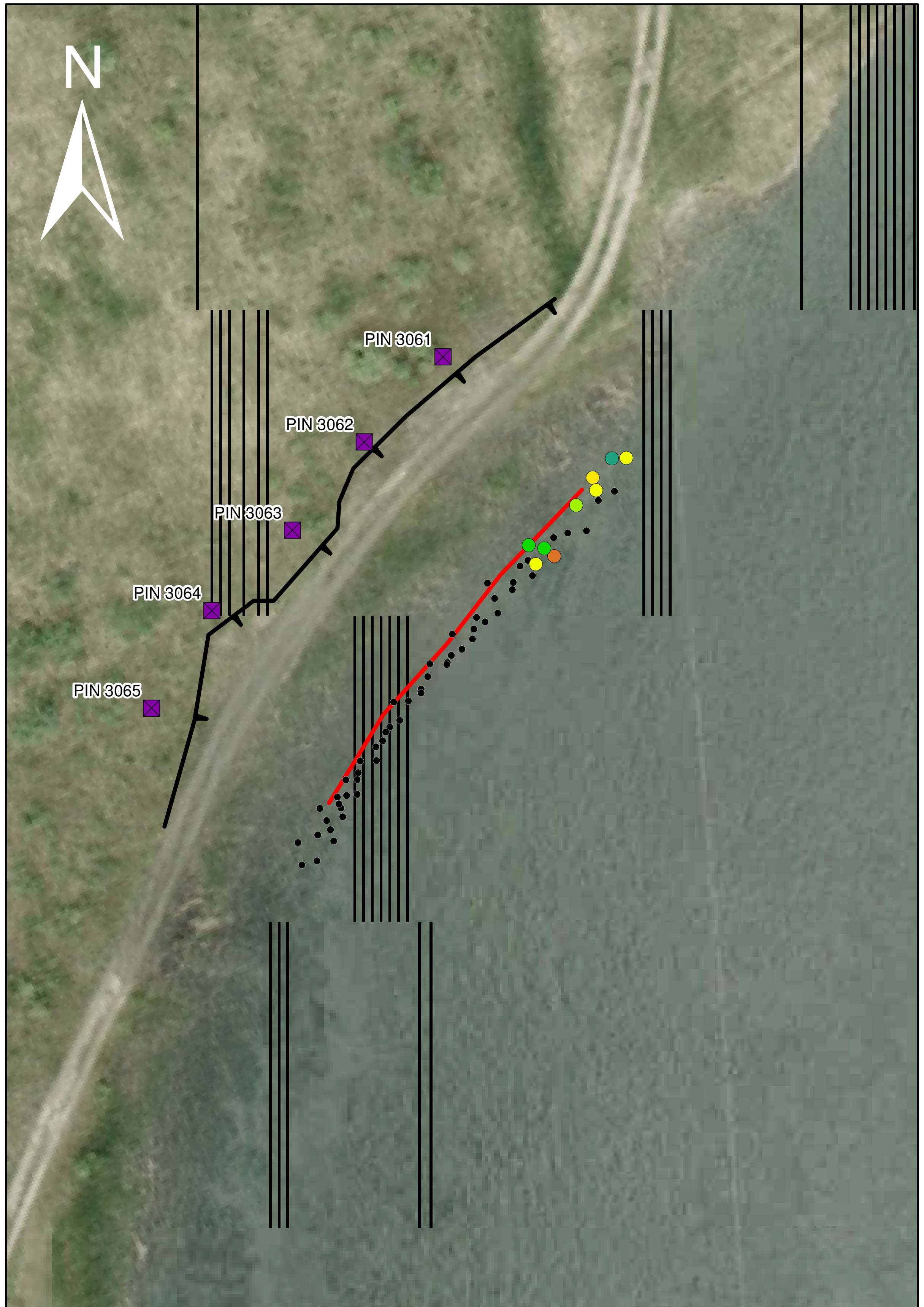
- bank sediment: **sand**
- range of water levels: **1-4 m annually**
- influence of from Arrow Lakes: **moderate**
- erosion mechanism: **fluvial and possible wave erosion of the sandy mid bank**
- riparian vegetation: **grass**
- exposure to river current: **high**
- exposure to waves: **moderate**

At the time of the 2011 field visit, much of the bank was underwater (see Photo 3-6), and about 16% of the erosion pins could be located (Figure 3-5). In 2012, a total of 42 pins were found and the total change from 2010 to 2012 was -14.4 cm. The cross-section data supports the pin measurement with a 2010 to 2012 bank change of -0.24 m, about twice the pin exposure.

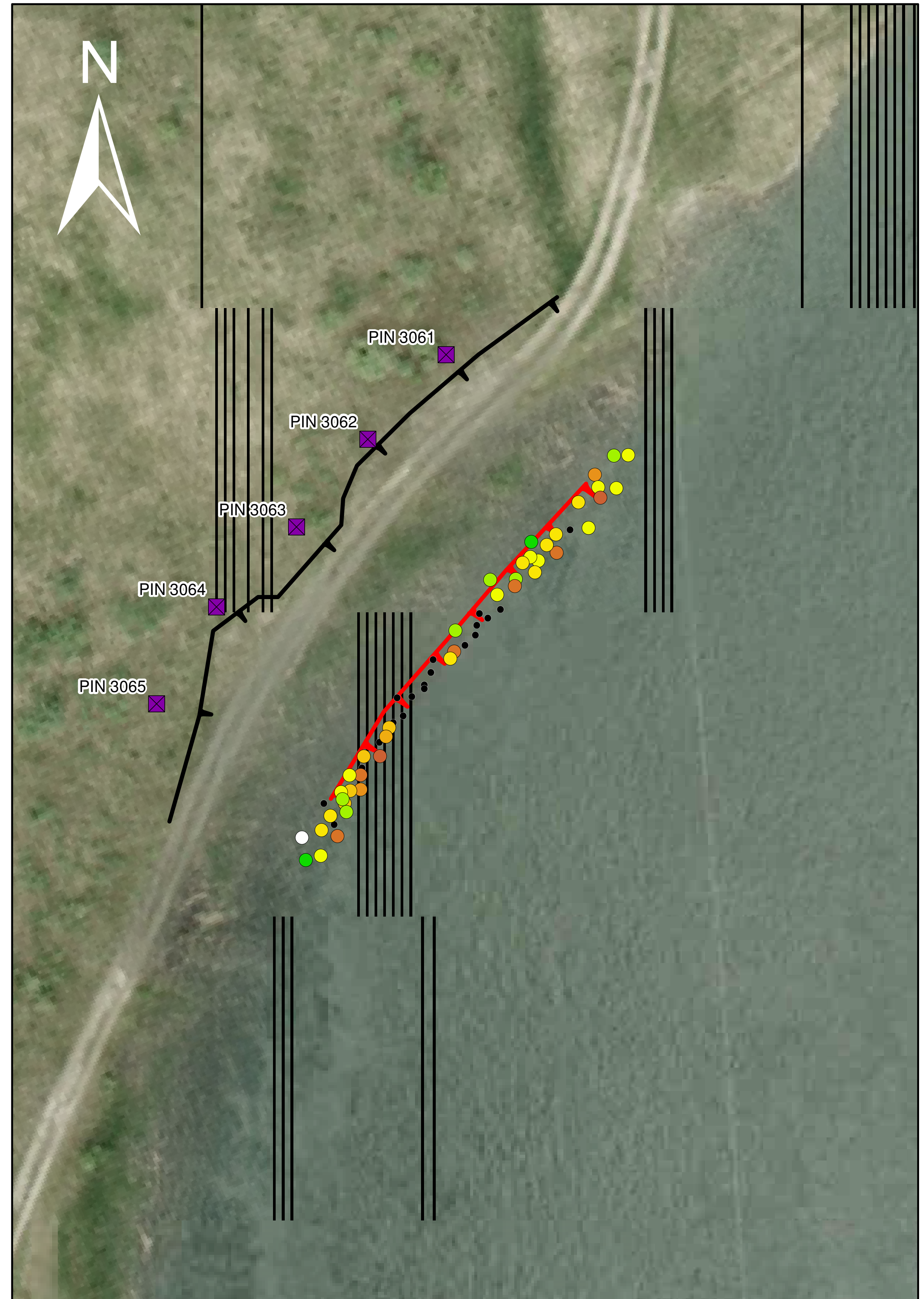
Photo 3-5: Looking downstream along bank (MON 3, April 25, 2012).

Photo 3-6: Looking downstream along bank (MON 3, June 13, 2011).

BC Hydro
CLBWORKS #36



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 3

Figure 3-5

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Author: DMatsubara

Monitoring Site 4 (MON 4)

Monitoring Site 4 is located opposite the upstream end of the airport runway, near Revelstoke, on the right bank of the main channel (Figure 3-2). This site is not easily accessed. The site has a well developed low gradient grassy bank followed by a cut bank near the gravel bed. The grassy upper slope transitions to a higher floodplain. The contemporary erosion is occurring on the lower bank.

- bank sediment: **gravel and sand**
- range of water levels: **1-5 m annually**
- influence of from Arrow Lakes: **moderately high**
- erosion mechanism: **fluvial and wave erosion of the lower bank**
- riparian vegetation: **grass**
- exposure to river current: **moderate**
- exposure to waves: **moderate**

At the time of the 2011 field visit, much of the bank was underwater (see Photo 3-7), and about half the erosion pins could be located (Figure 3-6). The interannual trend based on between 2010, 2011 and 2012 indicated minor deposition based on pin exposure (+0.2 cm) for each year. Based on all 60 pins, the average change on the site is -2.6 cm (between 2010 and 2012). The difference between the interannual and the biannual observations indicate the potential bias associated with a partial dataset. In this case, erosion in the edge of floodplain was not detected in 2011. Conversely, the cross-section data indicated an erosion trend -0.15 m in 2011, followed by deposition 0.04 m in 2012, and a total change of -0.07 m (-7 cm) for a two year period. For Site 4, there is a net trend of erosion.

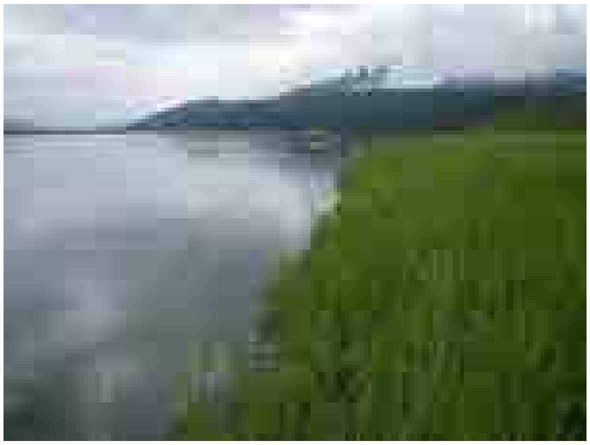

Photo 3-7: Looking downstream along bank (MON 4, June 13, 2011).

Photo 3-8: Looking downstream along bank (MON 4, April 20, 2012).

BC Hydro
CLBWORKS #36

Erosion Monitoring Pins - Change 2011 to 2012

Erosion Monitoring Pins - Change 2010 to 2012

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 4

Figure 3-6

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON4_2012.mxd Date Saved: 12/21/2012 11:20:22 AM
Author: DMatsubara

Monitoring Site 5 (MON 5)

Monitoring Site 5 is located about 1 km downstream of the airport, near Revelstoke, on the left bank of the main channel (Figure 3-2). This site is can be accessed by roads but the roads are quickly eroding, as is evident near the site. The banks are generally low compared to the right bank of the river and are uniformly sandy. Erosion at the downstream half of the site is most evident in the cross-sections.

- bank sediment: **sand**
- range of water levels: **1-5 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderate**
- exposure to waves: **high**

At the time of the 2011 field visit, most of the bank was underwater, but lower lake levels in 2012 provided much better site conditions for monitoring (see Photos 3-9 and 3-10). The erosion in 2011 based on erosion pins was relatively low, and likely did not capture all of the erosion due to site conditions. Based on a much higher number of pines, the interannual erosion increased for the 2012 measurement to -11.3 cm, or a total average change based on a larger sample of -8.5 cm over two years (Figure 3-7). It should also be noted that several pins were lost to toppling or larger scale erosion at this site.

The cross-section data indicates a higher level of general erosion with total average two year change of -0.85 m, and a -0.48 m change in 2012. The maximum loss of bank at the floodplain level was about 2 m in 2011 and 2012 at one cross-section. Site 4 at the floodplain level is eroding at scales that are beyond the measurement of the erosion pins.

Photo 3-9: Looking upstream along bank (MON 5, April 17, 2012).

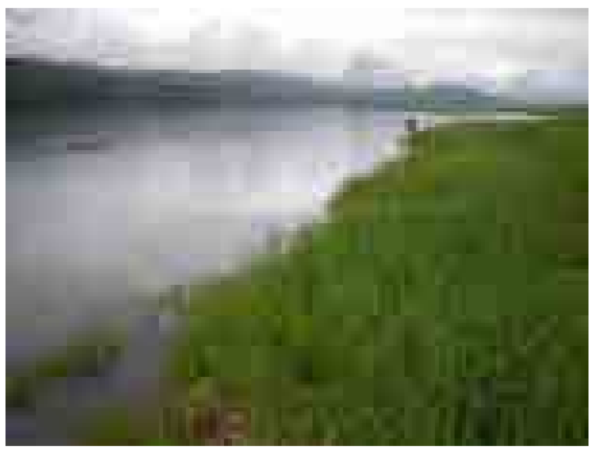
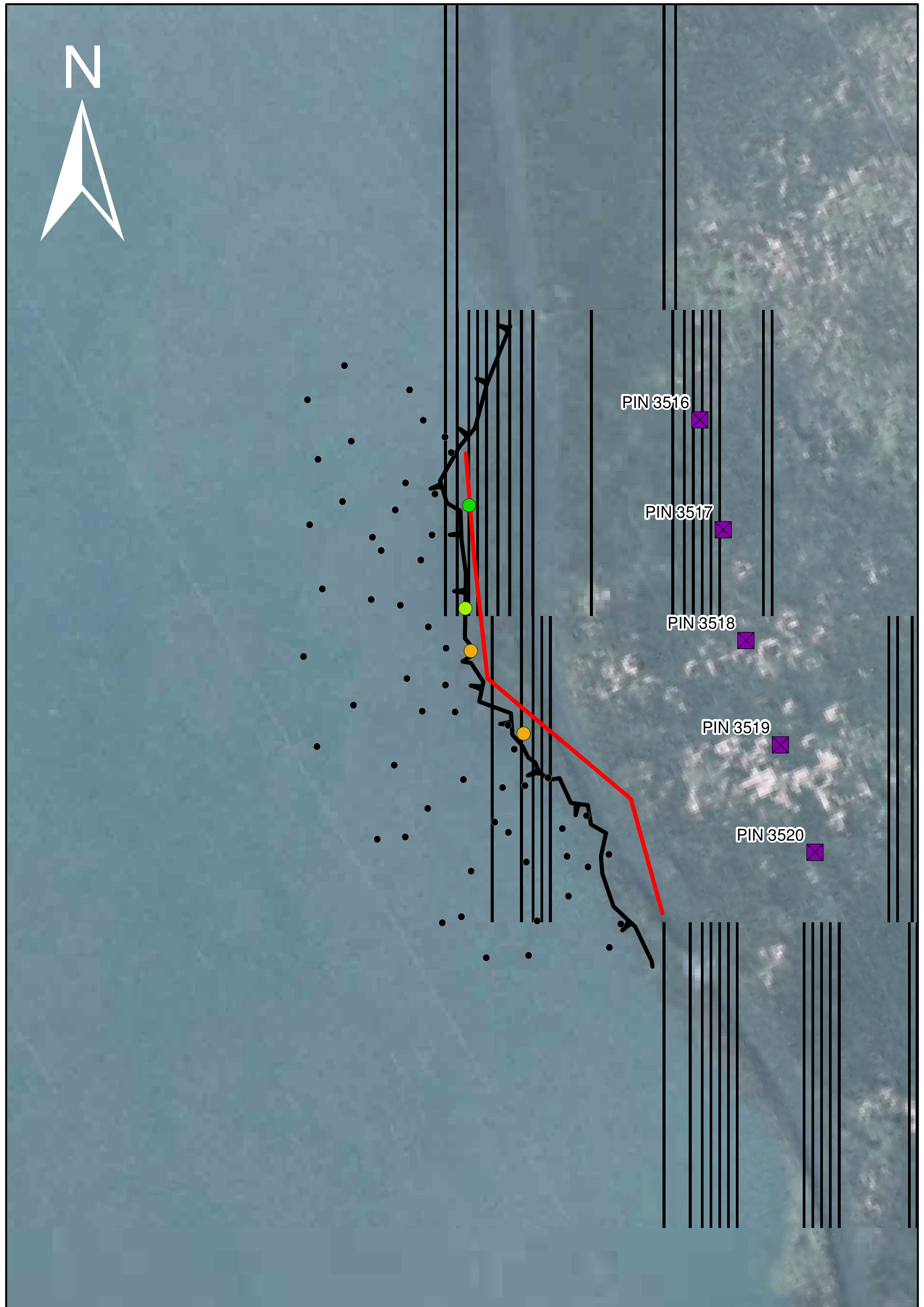
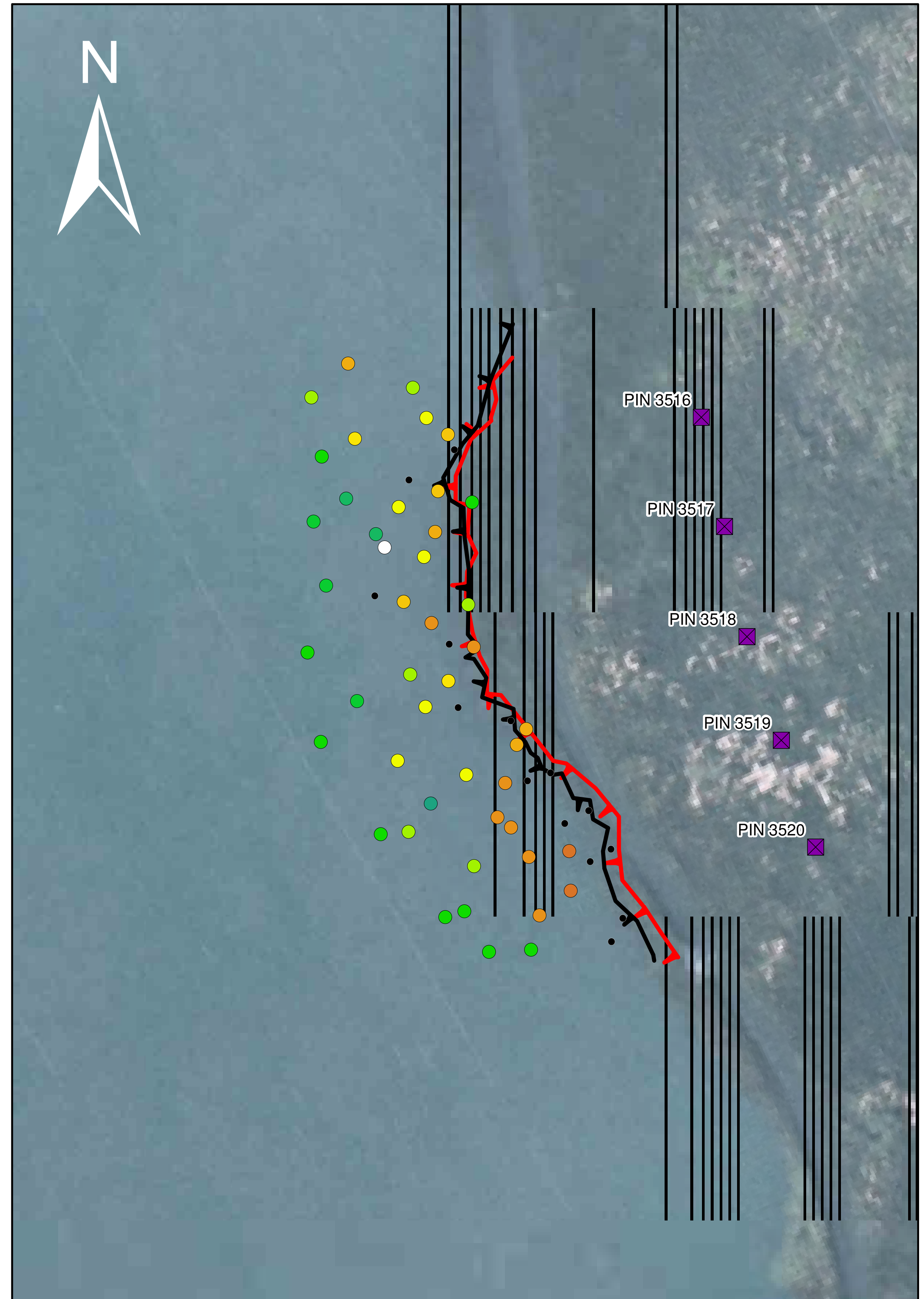


Photo 3-10: Looking upstream along bank (MON 5, June 13, 2011).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
CLBWORKS #36

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 5

Figure 3-7

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON5_2012.mxd Date Saved: 12/21/2012 11:26:02 AM
Author: DMatsubara

Monitoring Site 6 (MON 6)

Monitoring Site 6 is located about 1 km upstream of Begbie Creek, on the right bank of the river, on a vegetated island that is partially attached to the right bank floodplain (Figure 3-2). The floodplain is much lower than upstream sites, generally below 435 m elevation. The bank is not directly exposed to the main channel of the river, which is some 200 m to the east, but is fronted by a large side-channel that is partially wetted even at relatively low water levels. The water level at the time of the 2011 field visit was about 1.5 to 2 m higher than lower water conditions at the site. It is expected that this site is completely underwater for 3 months of the year.

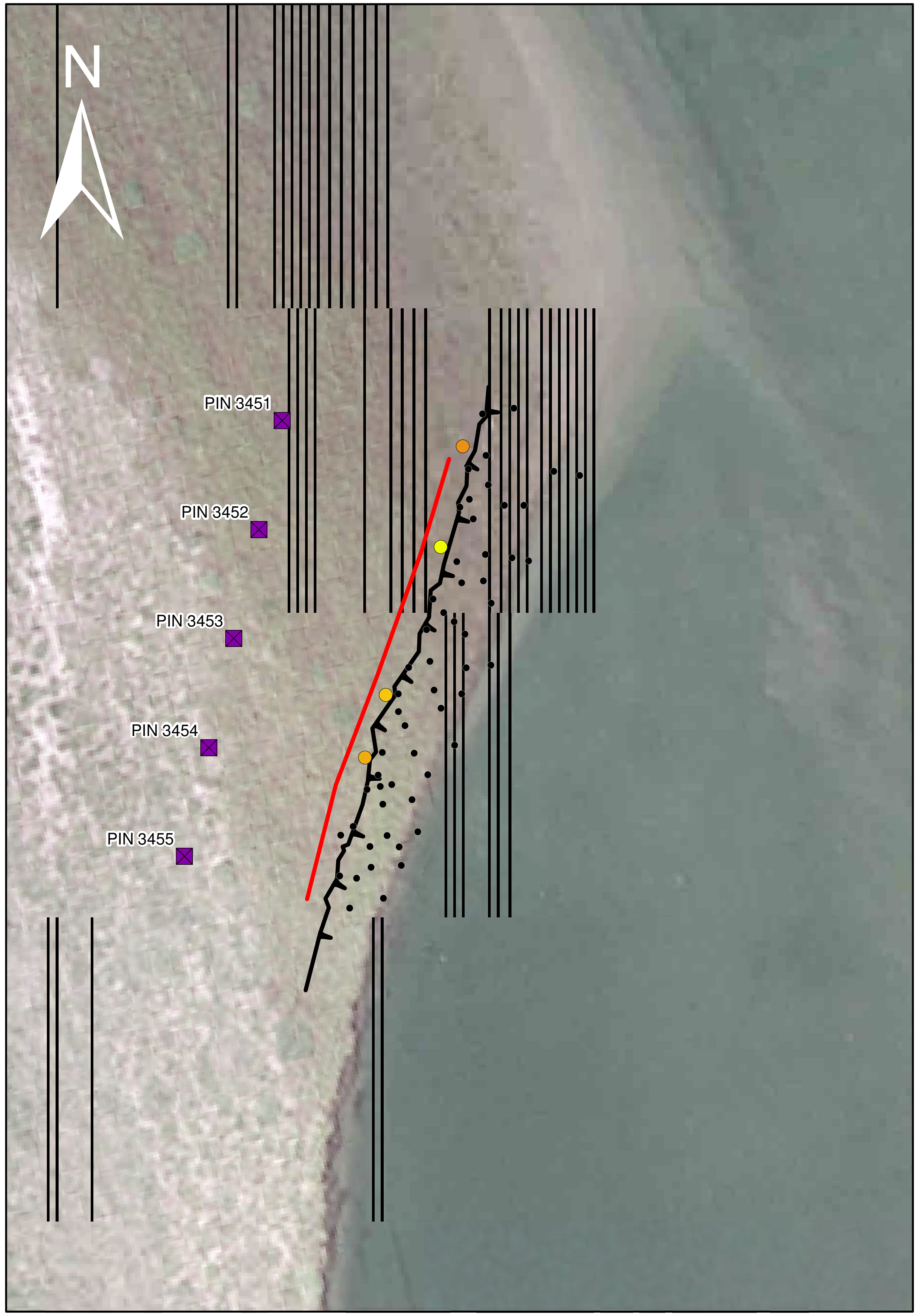
- bank sediment: **sand**
- range of water levels: **1-5 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately low**
- exposure to waves: **high**

The high water level at the time of the 2011 field visit precluded locating most of the erosion monitoring pins (Figure 3-8); however, the total two year erosion based on erosion pins indicates -10.3 cm of erosion. However, the monitoring cross-sections indicate that the bank is retreating much more, with a total two year change of -1.15 m. The maximum retreat at the top of bank is more than 1 m at four cross-sections.

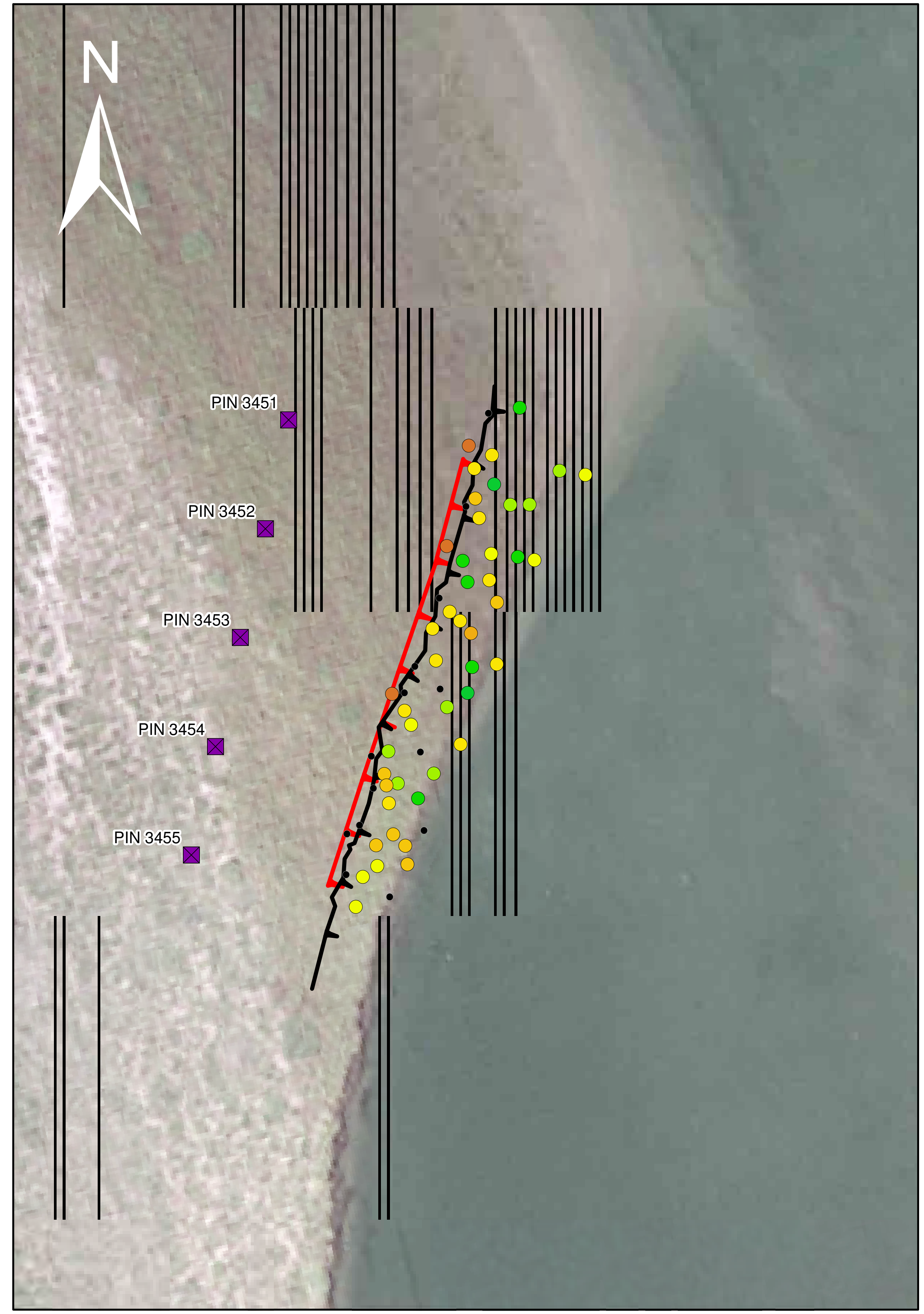
Photo 3-11: Looking upstream along bank (MON 6, April 18, 2012).

Photo 3-12: Looking upstream along bank (MON 6, June 1, 2011).

BC Hydro
CLBWORKS #36



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 6

Figure 3-8

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON6_2012.mxd Date Saved: 12/21/2012 11:28:09 AM
Author: DMatsubara

Monitoring Site 7 (MON 7)

Monitoring Site 7 is located about 3.2 km downstream of the confluence of Begbie Creek and Columbia River, on the left bank of the main channel (Figure 3-2). Similarly to Monitoring Site 6, the floodplain at Monitoring Site 7 is lower than upstream sites, generally below 435 m elevation. Monitoring Site 7 is located in a reach of the river with a small complex of islands on the right bank, and is exposed to the main channel discharge. The water level at the time of the 2011 field visit was about 2 m higher than lower water conditions at the site. It is expected that this site is completely underwater for 3 months of the year.

- bank sediment: **sand**
- range of water levels: **1-5 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately high**
- exposure to waves: **high**

At the time of the 2011 field visit, the entire site was underwater (see Photo 3-14), and therefore no erosion pins could be located (Figure 3-9). A two year pin measurement based on 25 pins indicates a total change of -0.2 cm. The cross-section data collected in 2011 indicates a very high average erosion of -1.88 m, and that erosion is occurring uniformly at the 434 m elevation, creating a cut bank several metres from the 2010 surveyed location (**Error! Reference source not found.**).

Photo 3-13: Looking upstream along bank (MON 7, April 13, 2012).

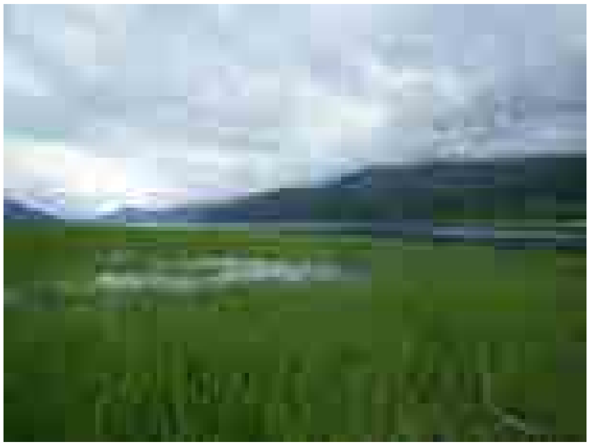

Photo 3-14: Looking downstream along upper bank (MON 7, June 13, 2011).

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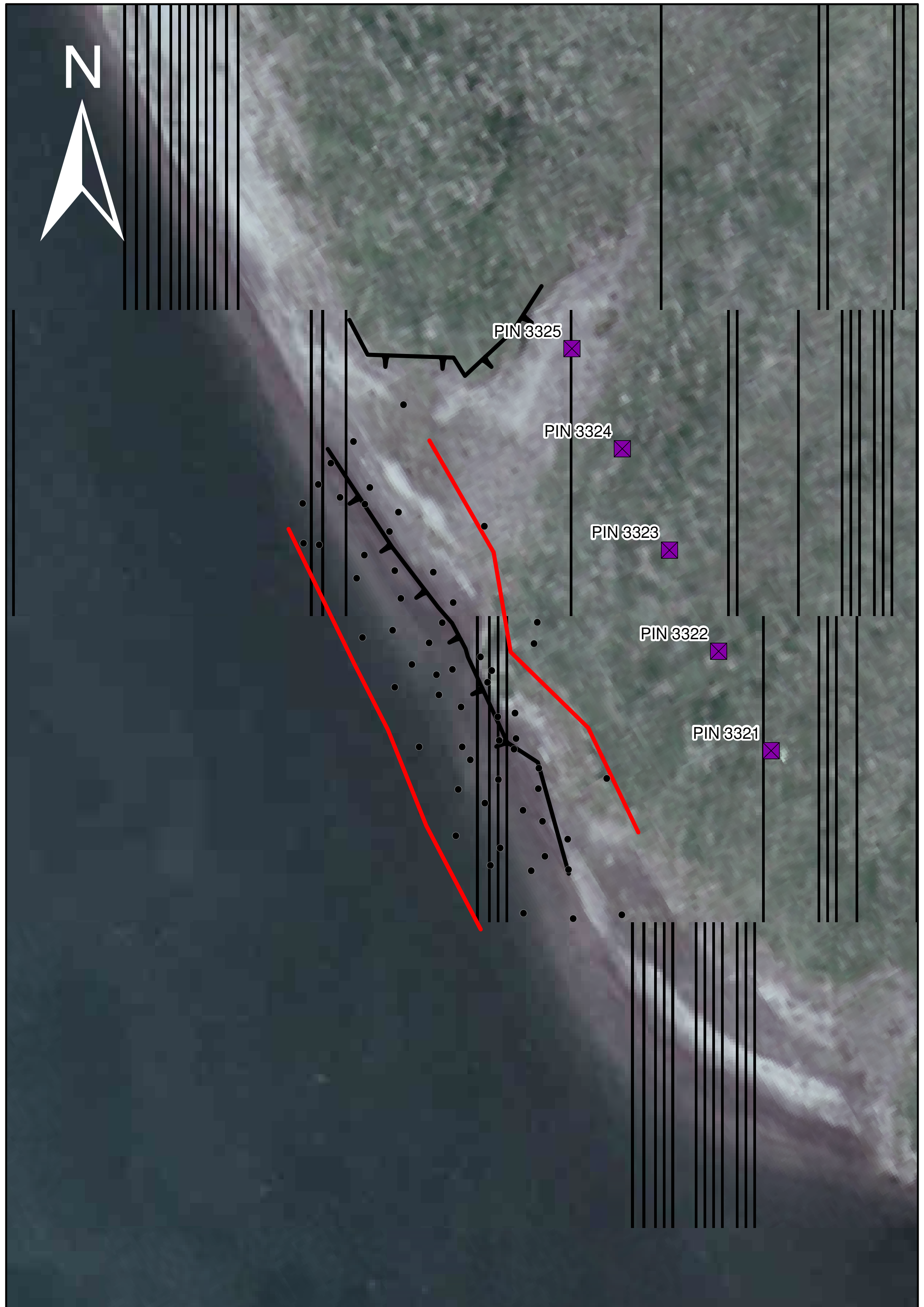
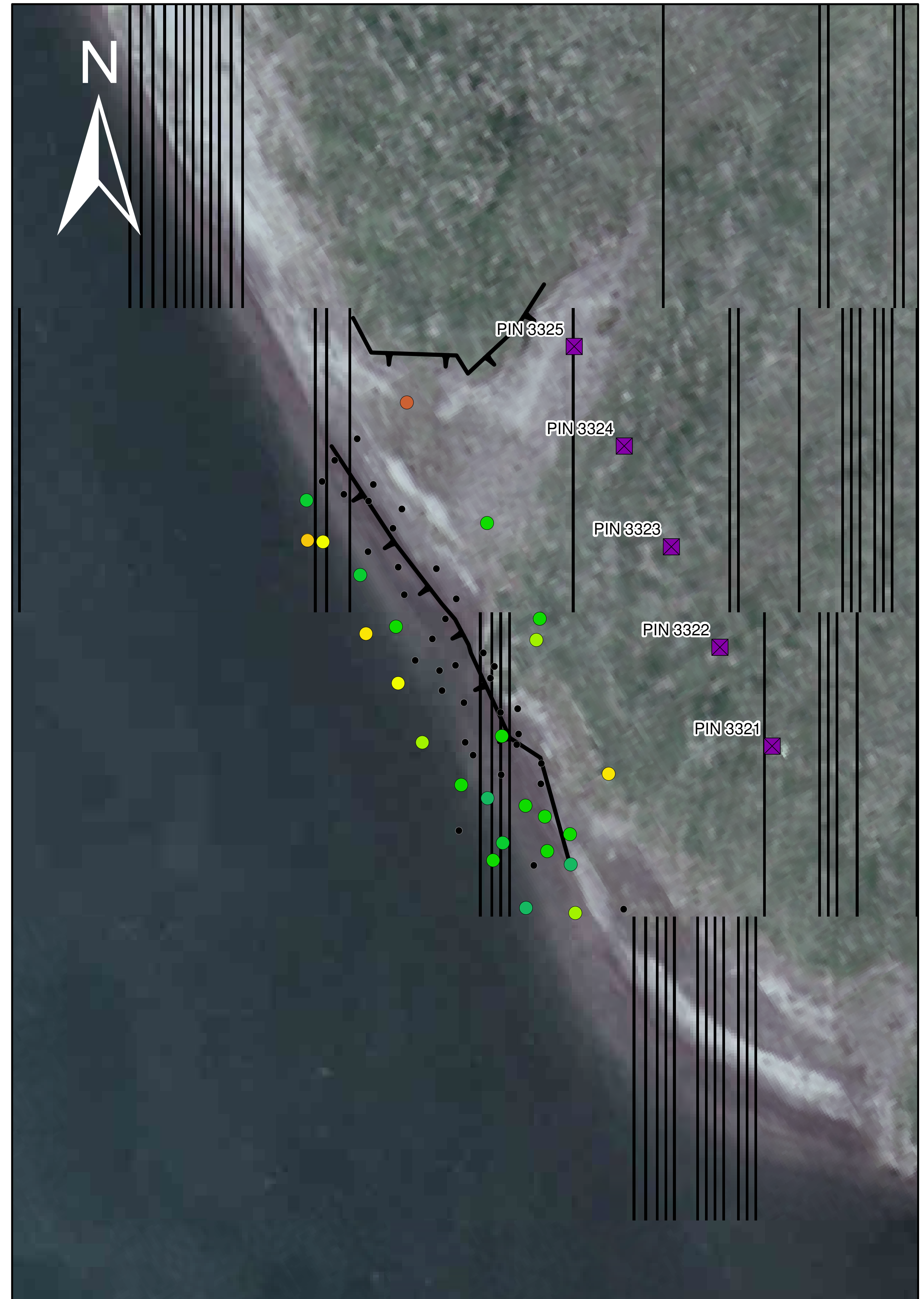


Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 7

Figure 3-9

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON7_2012.mxd Date Saved: 10/3/2012 11:27:38 AM
Author: DMatsubara

Monitoring Site 8 (MON 8)

Monitoring Site 8 is located, on the right bank of the river, opposite and slightly upstream of MON 9 (Figure 3-2). The site is located directly on the main channel of the river. Tree stumps on the terrace surface and historic air photos indicate that the terrace was previously forested prior to the creation of the Arrow Lakes reservoir. Observations during both field visits found that this site is very exposed to wind and wind generated waves. This site is slightly higher than the previous three floodplain sites.

The bank is relatively steep, as shown in Photos 3-15 and 3-16. The water level at the time of the 2011 field visit was 2 m higher than the low water level at the site.

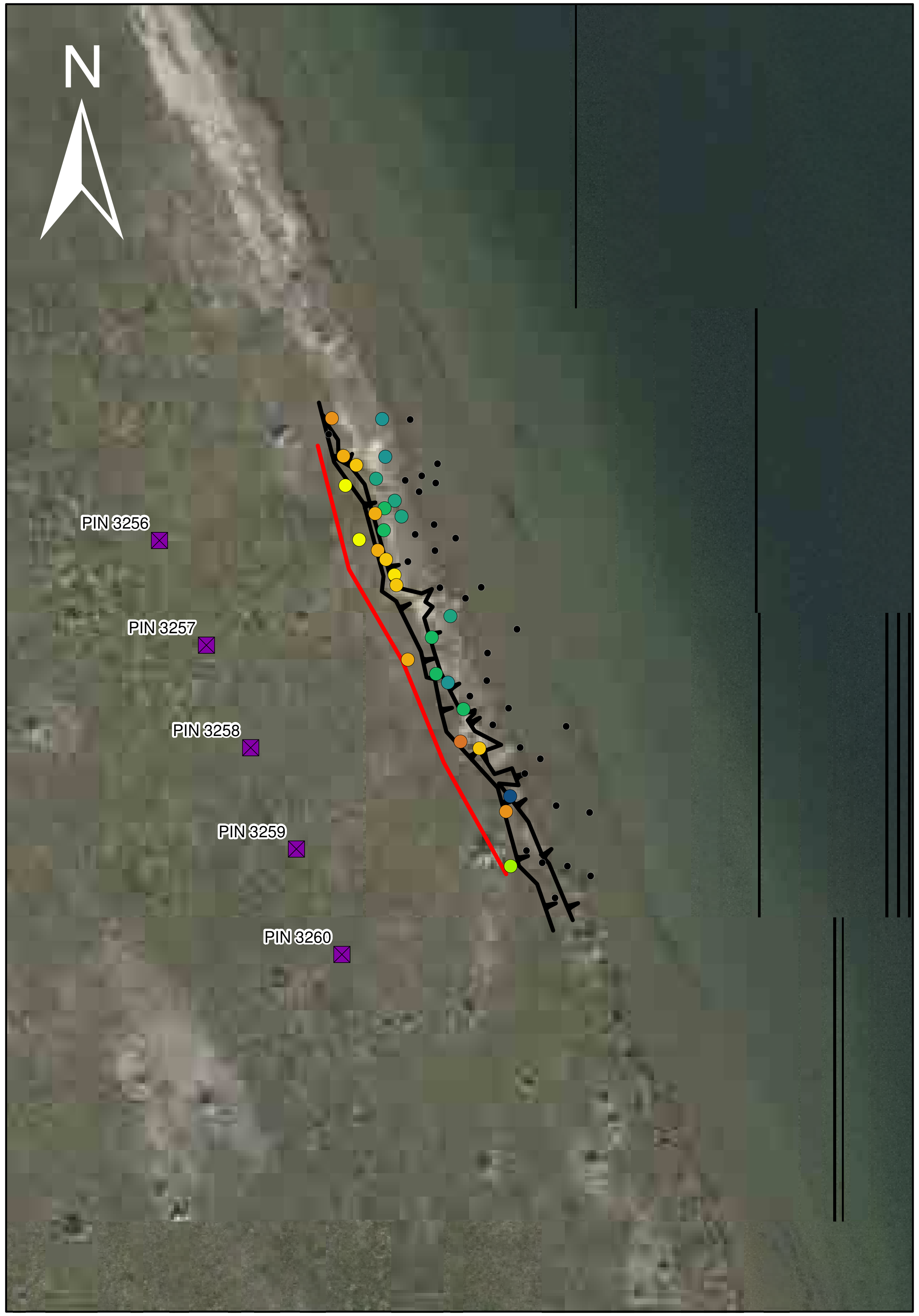
- bank sediment: **sand**
- range of water levels: **1-5 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately high**
- exposure to waves: **high**

As indicated in Figure 3-10 almost all of the pins placed in 2010 were found, with measurements indicating a total erosion of -2.2 cm for the two year period and a maximum erosion pin exposure of -10.8 cm. The 2012 exposed pin lengths are influenced by the process where the erosion at the top of bank is causing deposition lower down on the bank (Figure 3-10).

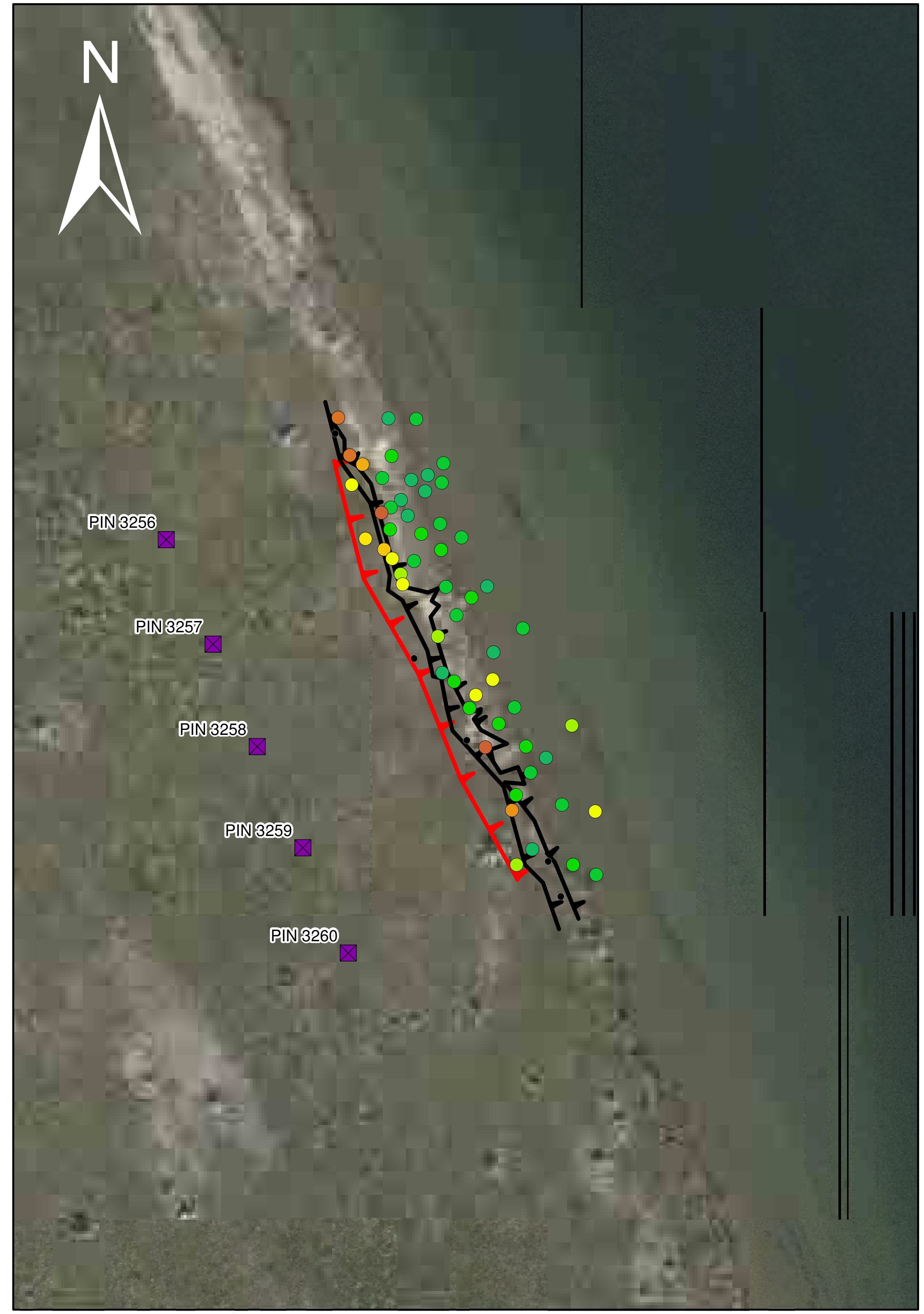
Based on the cross-sections, substantial erosion is occurring on the upper slope between about 433 and 435 m, which can be seen on the photos shown below. Based on the survey analysis, average cross-sectional erosion is -0.81 m and -0.54 for 2011 and 2012 monitoring respectively, with a total erosion of -0.52 m for the total period.

Photo 3-15: Looking upstream at steep, eroding bank (MON 8, June 1, 2011).

Photo 3-16: Looking upstream at steep, eroding bank (MON 8, April 18, 2011).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

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Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 8

Figure 3-10

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Author: DMatsubara

Monitoring Site 9 (MON 9)

Monitoring Site 9 is located about 1.7 km upstream of Greenslide Creek, on the left bank of the river (Figure 3-2). The site is located at the break between a lower and higher floodplain surface. Erosion pins and monitoring cross-sections extend from the higher floodplain surface (the treeline) down onto the lower floodplain surface (Figure 3-11). This site was selected to provide a site that represents the very highest pool elevations.

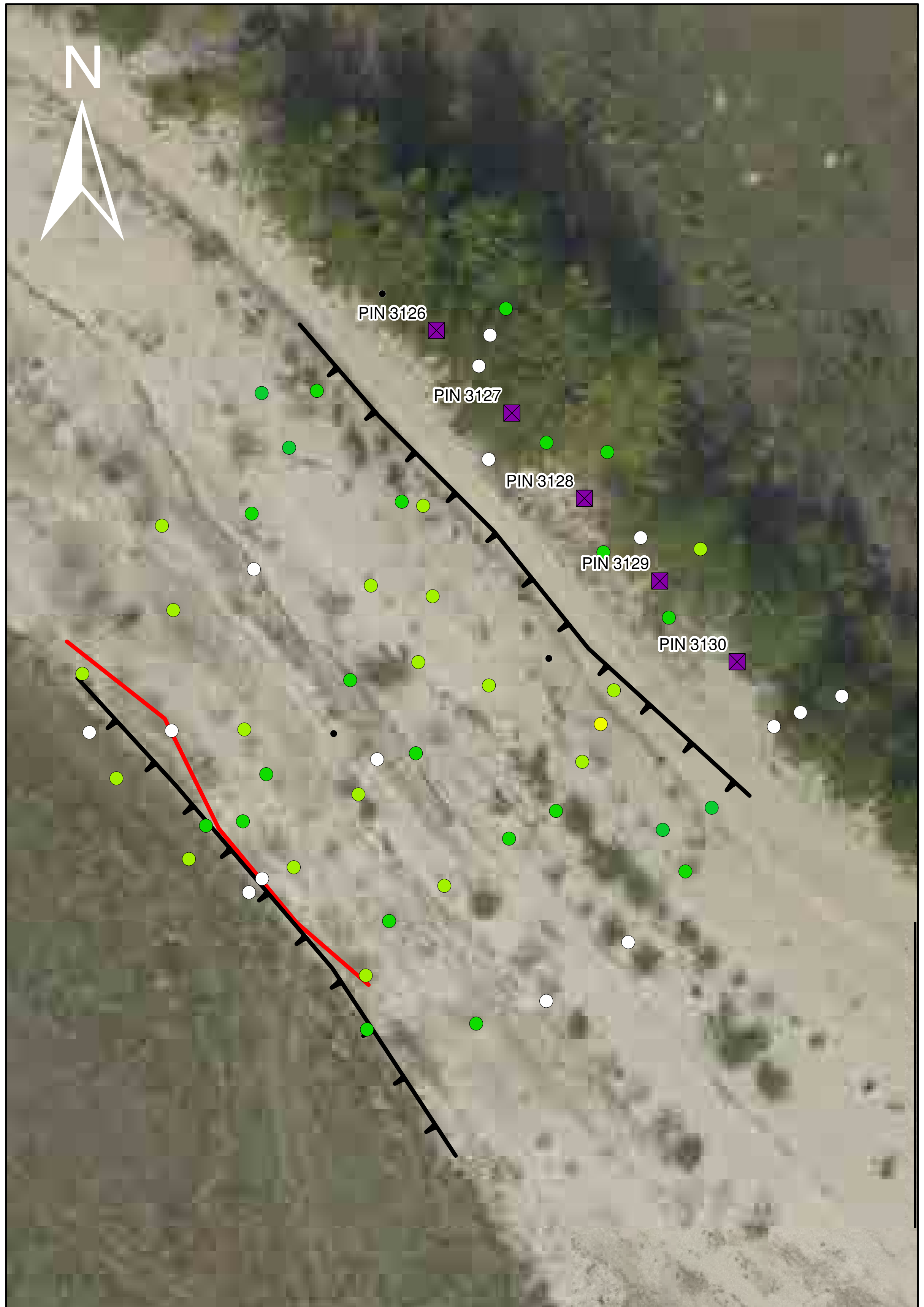
Photos 3-17 and 3-18 show the characteristic summer vegetation, which is grass and scattered shrubs. The lower floodplain surface is heavily grass-covered, while the gently-sloping bank between the upper surface and lower surface is sparsely covered.

- bank sediment: **gravel**
- range of water levels: **0-3 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **some grass**
- exposure to river current: **low**
- exposure to waves: **moderate**

As indicated in Figure 3-11, the site experienced very little change between installation (2010) and the 2012 re-survey. The site is located on the margin of the reservoir and would be expected to be a depositional environment. The average change in pin exposure decreased from +0.8 cm to +0.5 cm in 2012, with a total exposure of +1.4 cm. In terms of cross-sectional changes, the interannual changes have been from net deposition to erosion in 2012, and a total deposition since 2010 of +0.45 m. Monitoring Site 9 is a relatively stable site that is frequented for recreation.

Photo 3-17: Looking downstream at upper floodplain surface and treeline (MON 9, May 31, 2011).

Photo 3-18: Looking upstream near the top of pool (MON 9, April 12, 2012).



Erosion Monitoring Pins - Change 2011 to 2012

Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
CLBWORKS #36

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 9

Figure 3-11

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Author: DMatsubara

Monitoring Site 10 (MON 10)

Monitoring Site 10 is located about 1.2 km upstream of Greenslide Creek, on the left bank side of the river, fronted by a major side channel (Figure 3-2). The bank is relatively high and composed of gravel, cobble and sandy sediment. This site is located on a side channel that is not expected to be exposed to high currents. This site is used for recreation and a well-travelled road crosses the site.

- bank sediment: **gravel**
- range of water levels: **1-6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave erosion of the bank**
- riparian vegetation: **some grass**
- exposure to river current: **low**
- exposure to waves: **moderate**

As indicated in Figure 3-12, the site experienced very little change between installation (2010) and the 2012 re-survey, with a general trend of deposition. The average change in pin exposure for 2012 was negative at 0.1 cm; however, the total trend since 2010 has been depositional (positive) at 0.4 cm. Very little change can be detected from the cross-sectional surveys; however, the trends match the pin observations with deposition in 2011, erosion in 2012, and almost no net change since 2010 (-0.03 m). Observations, such as Photo 3-20 below, suggest that wave action is the primary erosion mechanism.

Photo 3-19: Looking downstream along bank (MON 10, April 11, 2012).

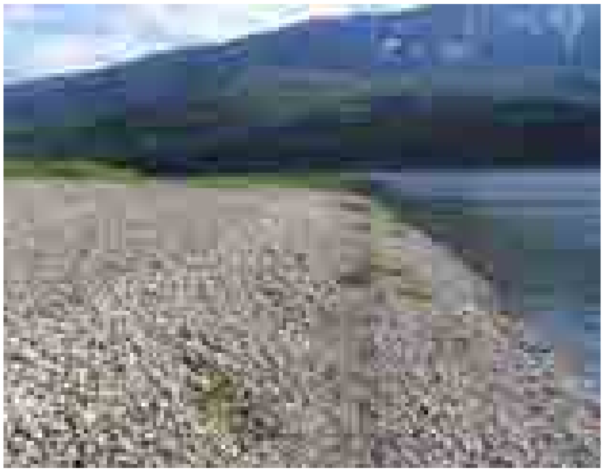

Photo 3-20: Looking downstream along bank (MON 10, June 1, 2011).

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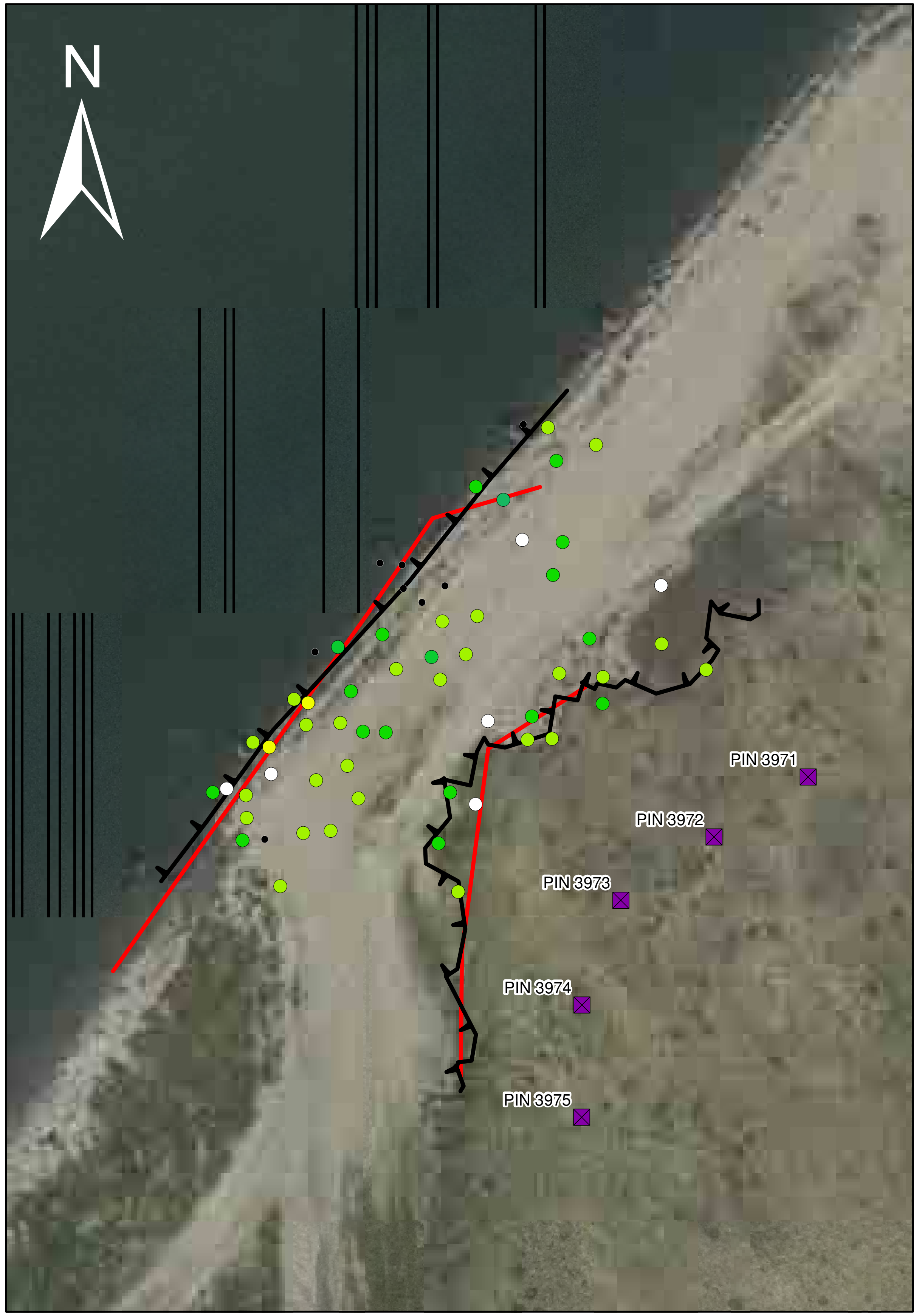
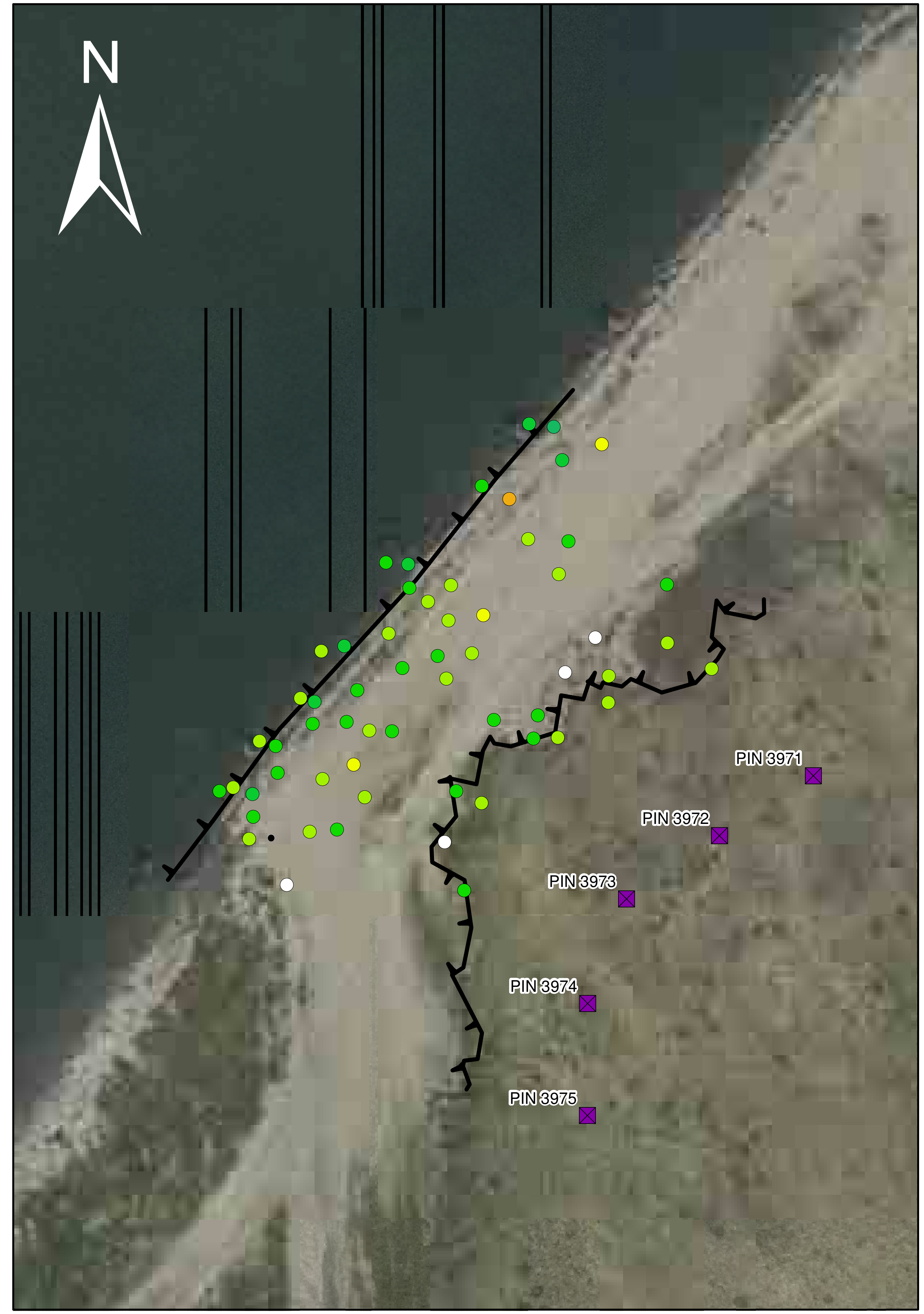


Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 10

Figure 3-12

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Author: DMatsubara

Monitoring Site 11 (MON 11)

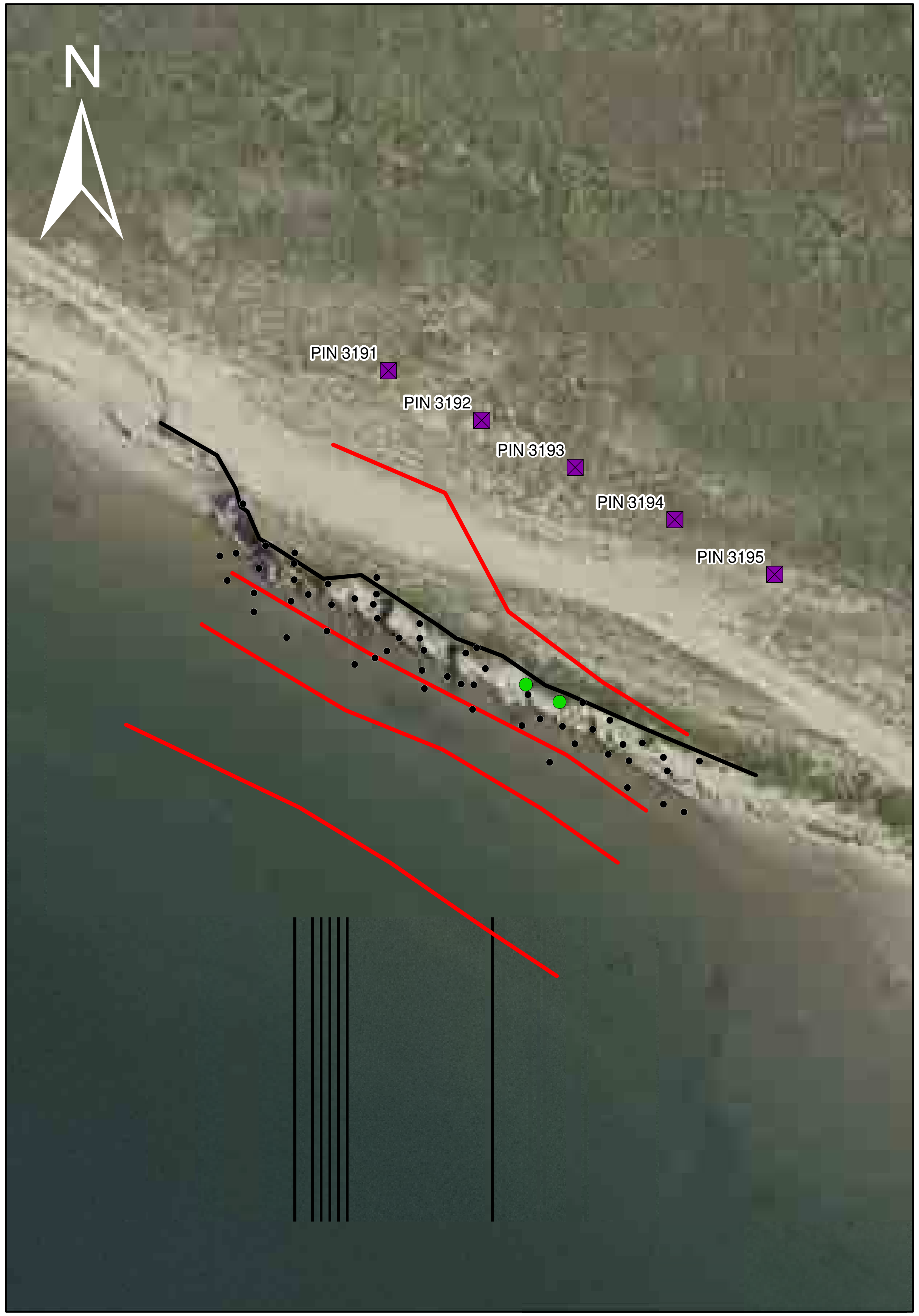
Monitoring Site 11 is located on the left bank of the main channel, opposite Mulvehill Creek (Figure 3-2). This site is typified by very fine sediment and zones of cohesive sediment in the floodplain stratigraphy. Erosion at this site is very rapid: maximum bank retreat at the toe of the cut bank between 2010 and 2011 was 5 m or more at the upstream end of the site. This site is exposed to river current and wave attack, compounded with very erodible soils. This floodplain is quite low and would be flooded for more than 3 months of the year.

- bank sediment: **sand and silt**
- range of water levels: **1-6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave and river erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately high**
- exposure to waves: **high**

In 2011, very few pins could be measured due to high water conditions, and five were found to be toppled, but were reset. In 2012, 24 of the original pins could be recovered, predominately at lower elevations. The 2010 to 2012 pin exposure comparisons report an average of +11.2 cm (deposition); however, this does not account for large erosion at the top of the bank indicated by the red line on Figure 3-13. The cross-sectional data reflects the larger changes, where an average change of -1.25 m was observed between 2010 and 2011 and -1.21 between 2011 and 2012. The total change is -2.38 m for both years, or as much as 10 m at the top of bank at one cross-section, which is the largest observed erosion from all 15 sites.

Photo 3-21: Looking upstream along eroding bank (MON 11, June 2, 2011).

Photo 3-22: Looking upstream, eroding bank at right side (MON 11, April 12, 2012).



Erosion Monitoring Pins - Change 2011 to 2012

Erosion Monitoring Pins - Change 2010 to 2012

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Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 11

Figure 3-13

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Author: DMatsubara

Monitoring Site 12 (MON 12)

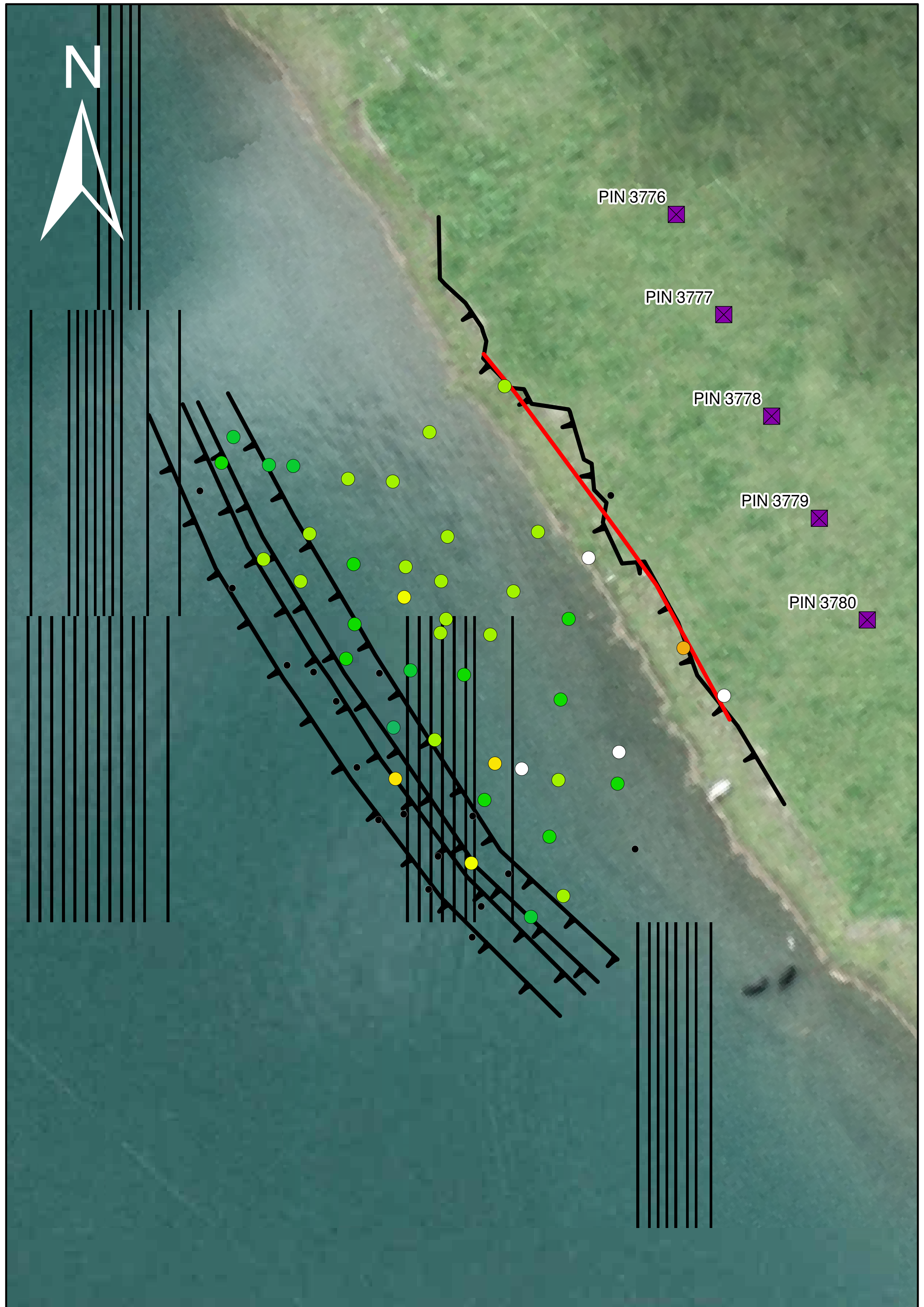
Monitoring Site 12 is on the left bank of the main channel, about 600 m downstream of the confluence of the Akolkolex River, and across from Cranberry Creek (north branch) (Figure 3-2). Monitoring Site 12 differs from the previous upstream sites in terms of the total height of the slope and bank composition. The floodplain surface at Site 12 is at about 438 m, and only would see inundation at the highest levels. However, the bank is exposed to a wide range of water levels on the rising and falling limb of the Arrow Lakes annual cycle. Observations during field work found this site to have a strong current and wave action.

- bank sediment: **gravel and sand**
- range of water levels: **up to 6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave and river erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately high**
- exposure to waves: **high**

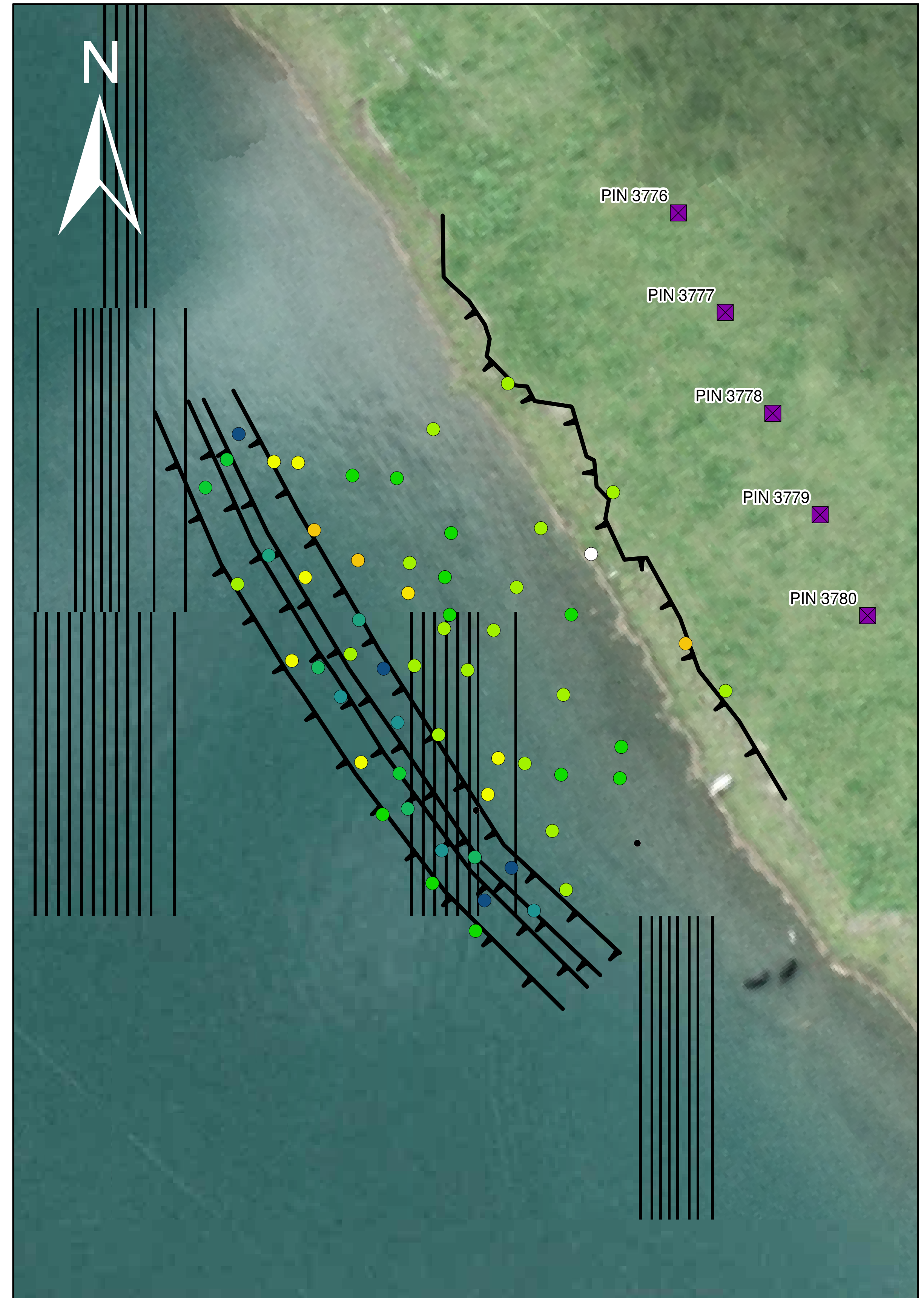
In 2012, the very low water levels allowed topographic survey that extended below the first 2010 topographic survey. Based on pin exposure there is moderate erosion in the mid-bank resulting in deposition on the lower pins (Figure 3-14). As a site, the average pin exposure varied slightly from year to year with +1.5 cm in 2011 and -0.6 cm in 2012, or a net change of +3.4 cm. The cross-sectional data is consistent through all time periods and is -0.06 m for 2011 to 2012 or a total change of -0.06 m (-6 cm). This site is strongly influenced by the reservoir level and wave effects. There is a very distinct stepped face to the gravel bank that is formed and observed each year.

Photo 3-23: Looking downstream along bank (MON 12, June 2, 2011).

Photo 3-24: Looking downstream along bank (MON 12, April 19, 2012).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

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Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 12

Figure 3-14

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Author: DMatsubara

Monitoring Site 13 (MON 13)

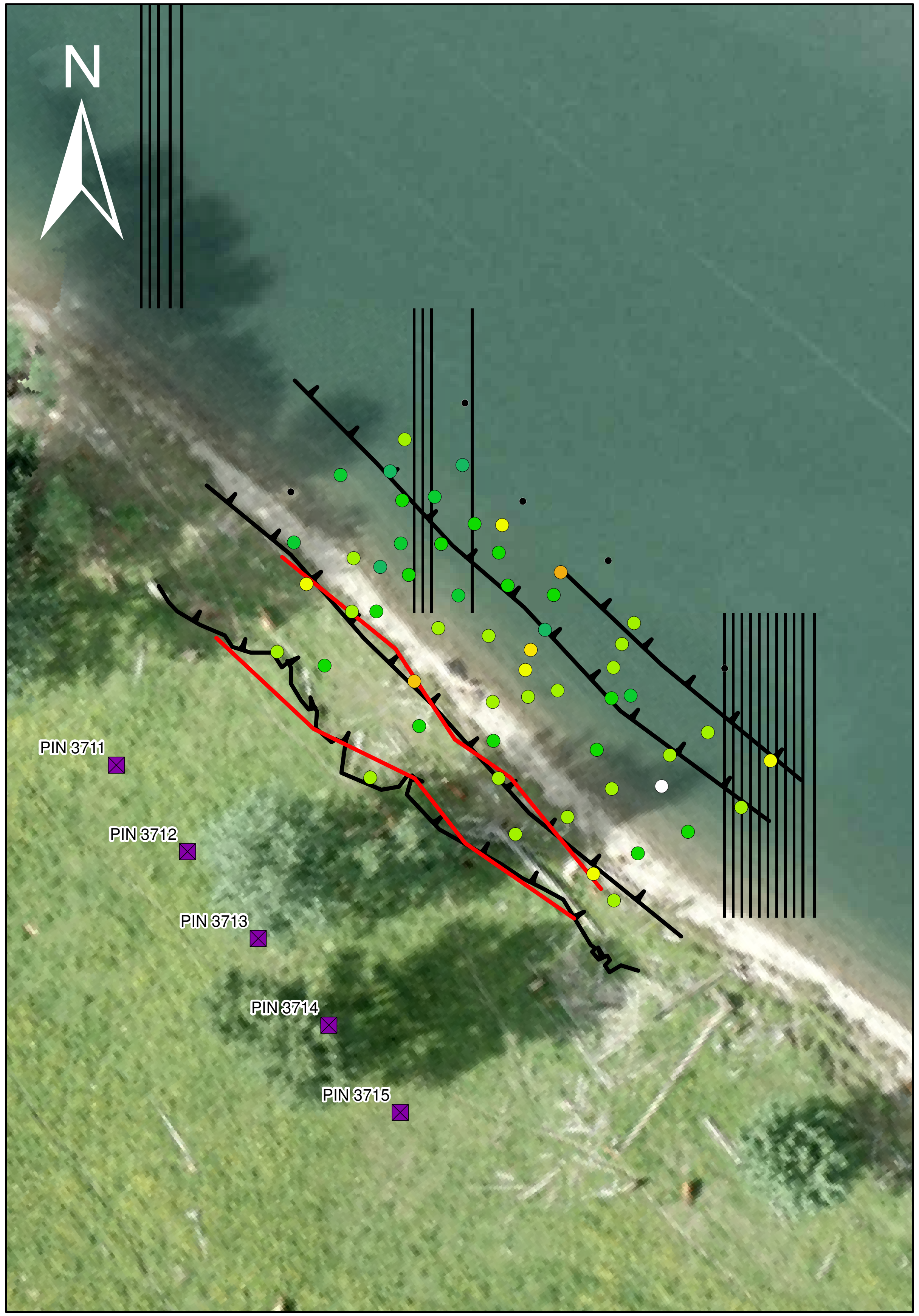
Monitoring Site 13 is located about 2.8 km downstream of the confluence of Cranberry Creek (north) and Columbia River, on the right bank of the main channel (Figure 3-2). Site 13 is a similar site to Site 12 in terms of slope height and composition. Site 13 is much more sheltered than the previous site from both river current and waves.

- bank sediment: **gravel and sand**
- range of water levels: **up to 6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave and river erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately high**
- exposure to waves: **high**

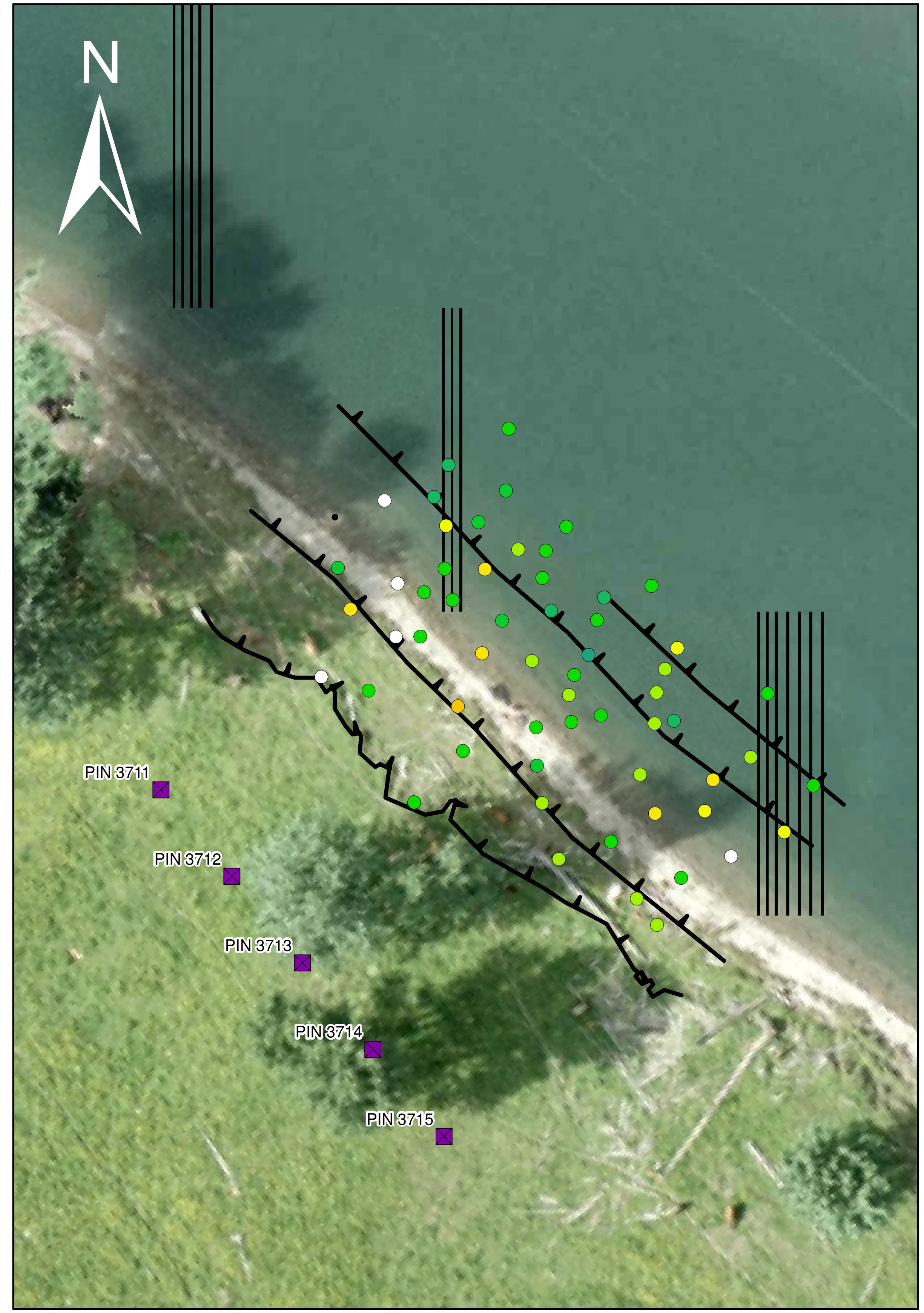
A high percentage of pins was recovered at Site 13 in both monitoring years, pin exposure alternated from minor deposition (0.8 cm) to minor erosion (-0.2 cm) from 2011 to 2012. The net average pin exposure for two years is deposition with average exposure of +0.8 cm. The erosion and deposition is well distributed as is seen in Figure 3-15. Based on cross-sectional data, Site 13 had an average of no change in 2011, and an average 0.18 m of deposition between 2011 and 2012. This is likely due to some shifting material on the bank; however Site 13 is very stable comparatively. Site 13 does have a similar stepped bank profile, similar to Site 12, but far less pronounced. The photos below indicate that the strong stepped profile in 2011 is much more subtle in 2012.

Photo 3-25: Looking downstream along bank (MON 13, June 2, 2011).

Photo 3-26: Looking downstream along bank (MON 13, April 19, 2012).



Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
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Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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Project No.	Date
478-081	December 2012

Monitoring Site # 13

Figure 3-15

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON13_2012.mxd Date Saved: 12/21/2012 1:20:34 PM
Author: DMatsubara

Monitoring Site 14

Monitoring Site 14 is located immediately downstream of the confluence of Tank Creek and Columbia River, on the left bank of the main channel (Figure 3-2). Monitoring Site 14 is composed of much sandier deposits and has a lower general slope angle. During the 2011 field work, the land owner approached the KWL staff to note that this site, while in the flooding reserve, is considered private property. Prior to the site visit, the land owner noted pins that had become exposed and that he had removed as many pins as could be found. The land owner also noted that he had tried to establish trees at the upper floodplain limit. There appears to be a trend of retreat of the top of the bank (about elevation 439 m) as well as general steepening of the beach slope.

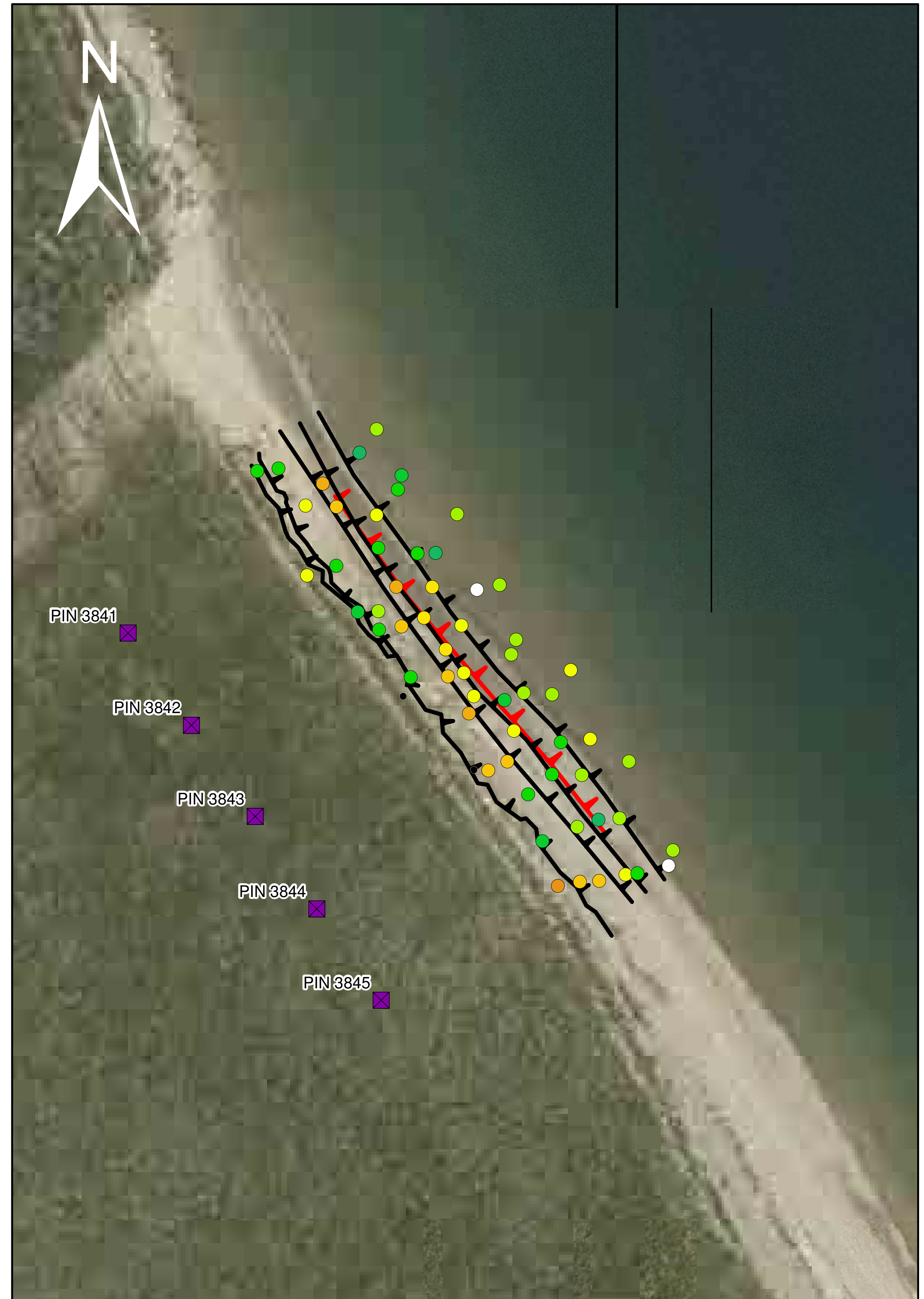
- bank sediment: **sand and gravel**
- range of water levels: **up to 6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave and river erosion of the bank**
- riparian vegetation: **grass and trees**
- exposure to river current: **moderately low**
- exposure to waves: **high**

Pin recovery at MON 14 was very low (Figure 3-16) because the nearby landowner removed the majority of the pins. The cross-sections show both modest erosion (cross-section 2 and 3) and modest deposition (cross-section 5). The average change in pin exposure is -5.6 cm, and based on observations this site is eroding. Site 14 was not visited in 2012 to avoid potential conflict. While the pin data cannot be replicated, the cross-section survey could be repeated in 2014 to determine larger cross-sectional changes.

Photo 3-27: Looking upstream along bank (MON 14, June 2, 2011).

Photo 3-28: Looking downstream along bank (MON 14, June 2, 2011).

Erosion Monitoring Pins - Change 2011 to 2012



Erosion Monitoring Pins - Change 2010 to 2012

BC Hydro
CLBWORKS #36

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40

Reference: 2007 orthophoto provided by BC Hydro.

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10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 15

Figure 3-17

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON15_2012.mxd Date Saved: 12/21/2012 1:25:10 PM
Author: DMatsubara

Monitoring Site 15

Monitoring Site 15 is located about 1.5 km upstream of Shelter Bay, on the right bank of the main channel (Figure 3-2). This is a very low lying area, with floodplain levels around 435 m. There are two distinct erosional cut slopes, one at the floodplain top, the second at the waters edge at the time of the field work. The lower bank erosional feature may be a transitory feature that advances with the rising water levels and can move rapidly due to the very erodible soils.

- bank sediment: **sand and some gravel**
- range of water levels: **up to 6 m annually**
- influence of from Arrow Lakes: **high**
- erosion mechanism: **wave and river erosion of the bank**
- riparian vegetation: **grass**
- exposure to river current: **moderately low**
- exposure to waves: **high**

During the 2012 monitoring period, the very low water levels allowed survey of more bank than what was exposed in 2010. A very large percentage of pins were relocated, and the average interannual pin exposure decreased from -7.0 cm to -1.9 cm likely due to measurement of the lower elevation pins (Figure 3-17). The total average pin exposure for two years is -4.7 cm. Based on cross-sectional data, the very high erosion in -1.64 m between 2010 and 2011 changed trends to be +0.01 m in 2012. The net cross-sectional change for the site from 2010 to 2012 is -1.01 m. Maximum loss of floodplain was largest between 2010 and 2011 and was as high as 5 m in some locations.

Photo 3-29: Looking downstream along bank (MON 15, June 2, 2011).

Photo 3-30: Looking downstream along bank (MON 15, April 19, 2012).

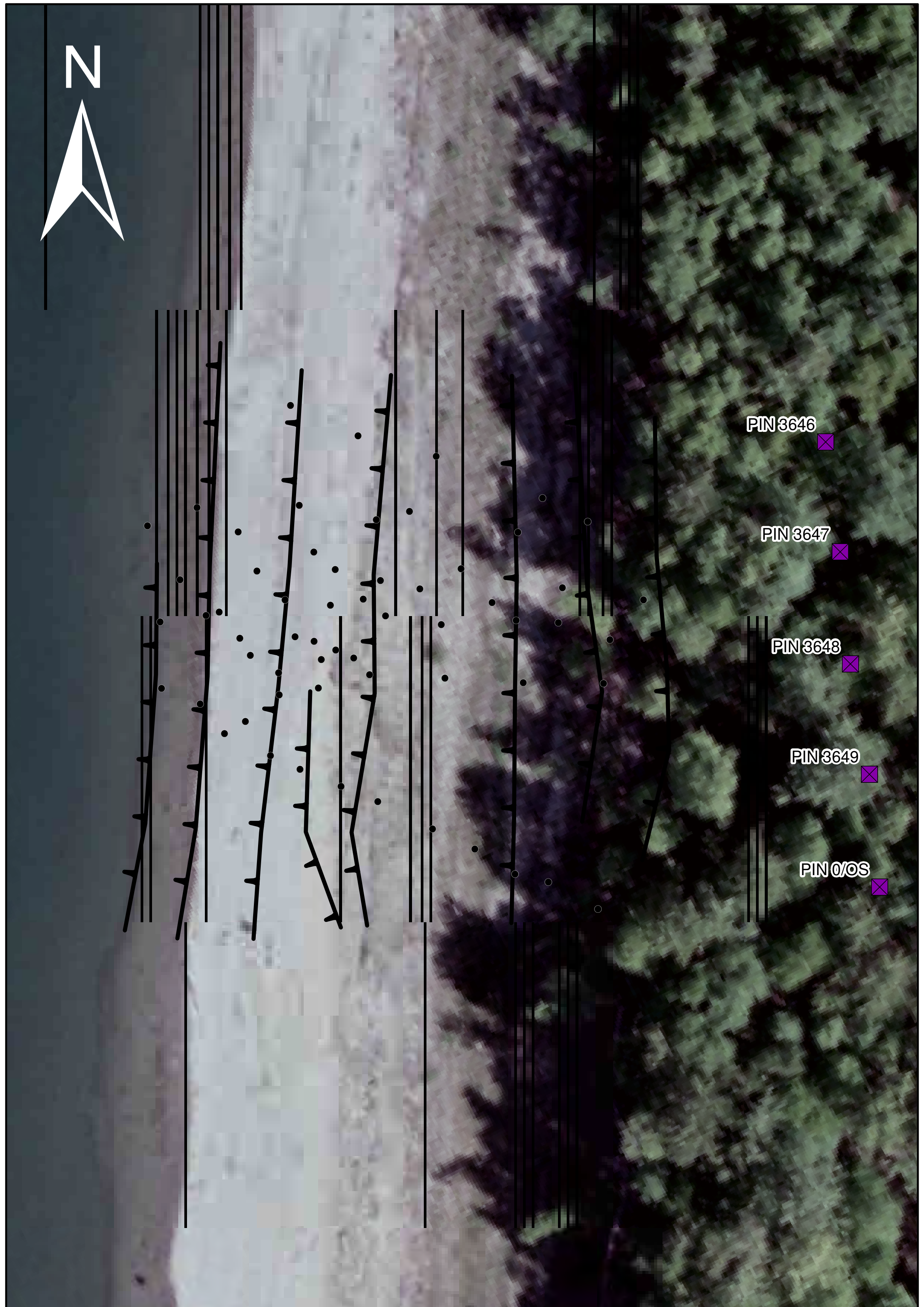
BC Hydro
CLBWORKS #36

Legend

- Monitoring Cross-Section Locations
- Erosion Monitoring Pin, No Data
- Top of Bank (April 2010)
- Significant Erosion

Erosion Monitoring Pins (cm)

< -40	No Change
-40 to -35	0 to 5
-35 to -30	5 to 10
-30 to -25	10 to 15
-25 to -20	15 to 20
-20 to -15	20 to 25
-15 to -10	25 to 30
-10 to -5	30 to 35
-5 to 0	35 to 40



Erosion Monitoring Pins - Change 2011 to 2012

Erosion Monitoring Pins - Change 2010 to 2012

Reference: 2007 orthophoto provided by BC Hydro.

KERR WOOD LEIDAL
consulting engineers

10 0 10 (m)
1:500

Project No.	Date
478-081	December 2012

Monitoring Site # 14

Figure 3-16

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2012\478081_MON14_2012.mxd Date Saved: 12/21/2012 1:23:07 PM
Author: DMatsubara

3.2 Wind Data

Based on field observations regarding the influence of wind generated waves on the erosion at the monitoring sites, hourly wind data were obtained from Environment Canada to characterize the wind climate in the CLBWORKS #36 study reach. Stations near or in the study reach include:

- Nakusp CS (station 1145297);
- Revelstoke A (station 1176749); and
- Revelstoke Airport Road (station 1176751).

Wind roses showing the dominant wind directions and speeds for the three stations are shown in Figure 3-18, Figure 3-19 and Figure 3-20. Note that the wind direction is the direction from which the wind blows.

The dominant wind direction at Nakusp is from the south-east, which is aligned with the large Slocan Lake valley.

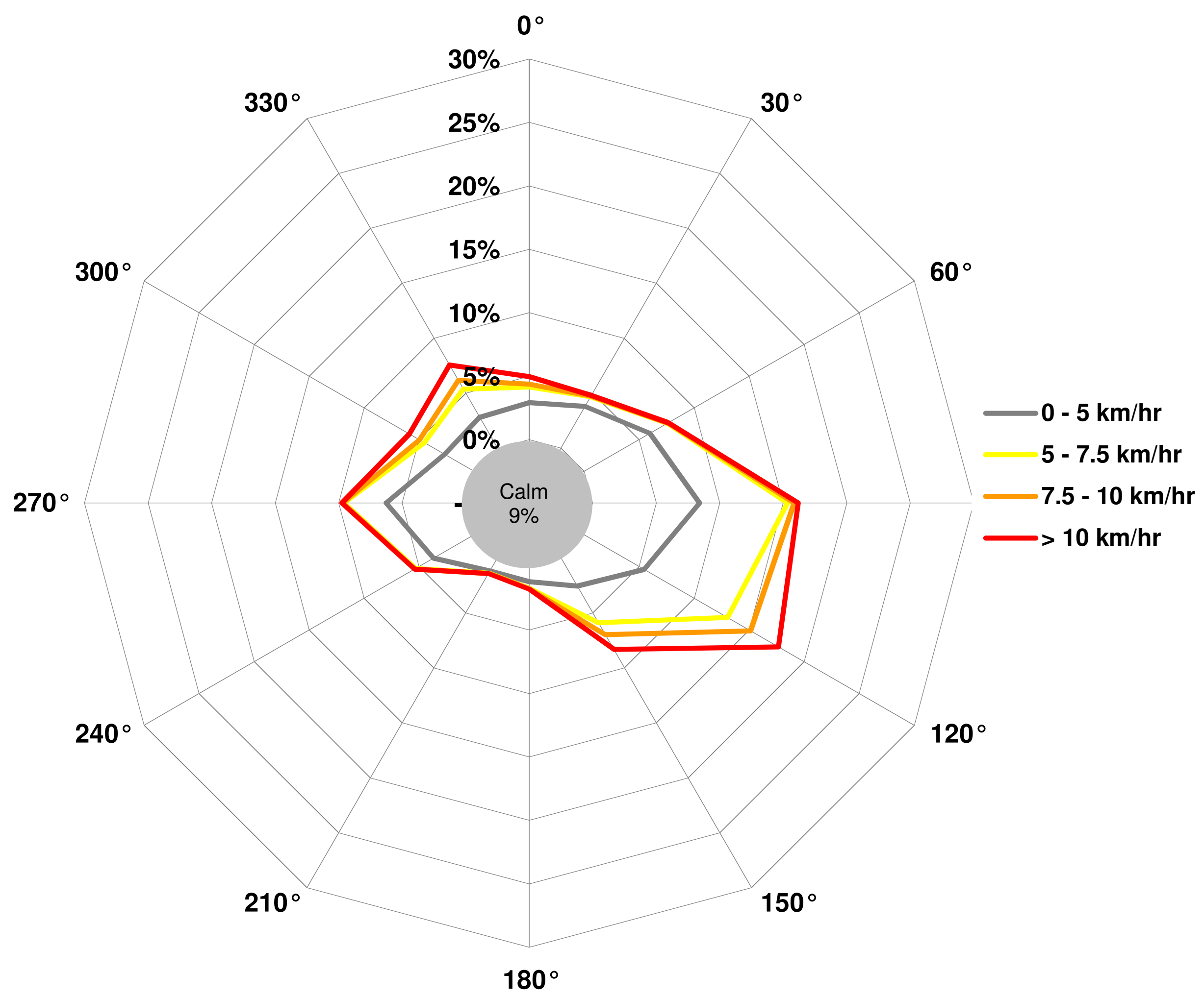
At Revelstoke, the wind direction is aligned with the Columbia River valley (NNW-SSE). Winds from the north are somewhat more common than from the south.

In general, “calm” conditions (i.e. no wind) are recorded much more frequently at Revelstoke (about 40% of the record) compared with Nakusp (about 9% of the record).

Based on these general observations, the monitoring sites have been reviewed as to probable wind exposure from a qualitative perspective. Some sites were found during the fieldwork to be quite windy, while others were sheltered.

There are currently seven of 14 sites that exhibit average cross-sectional bank erosion between 2010 and 2012 higher than -0.44 m. Six of the sites are located in the reservoir dominated reach of Columbia River and include Mon Sites: 5, 6, 7, 8, 11, and 15. These sites are located on either NNW or SSE facing aspects and erosion at these sites is likely to be exacerbated by wind generated waves.

Nakusp Wind Rose (Station 1145297)
Percent Duration, Hourly Data, 1994 to 2011



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O:\0400-0499\478-081\400-Work\WindAnalysis\1145297-Nakusp.xls / Figure WindRose

Figure 3-18

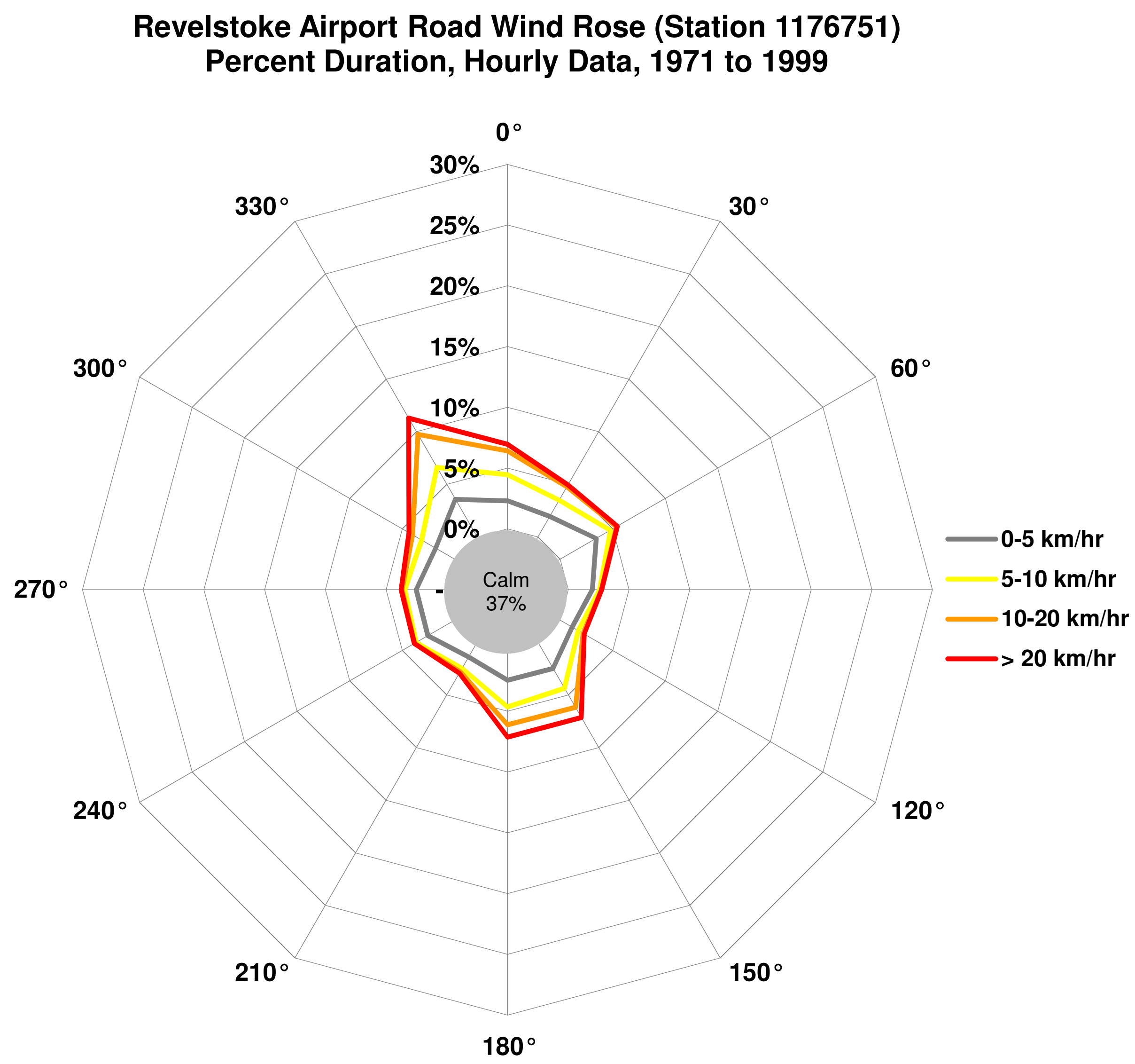

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Figure 3-19

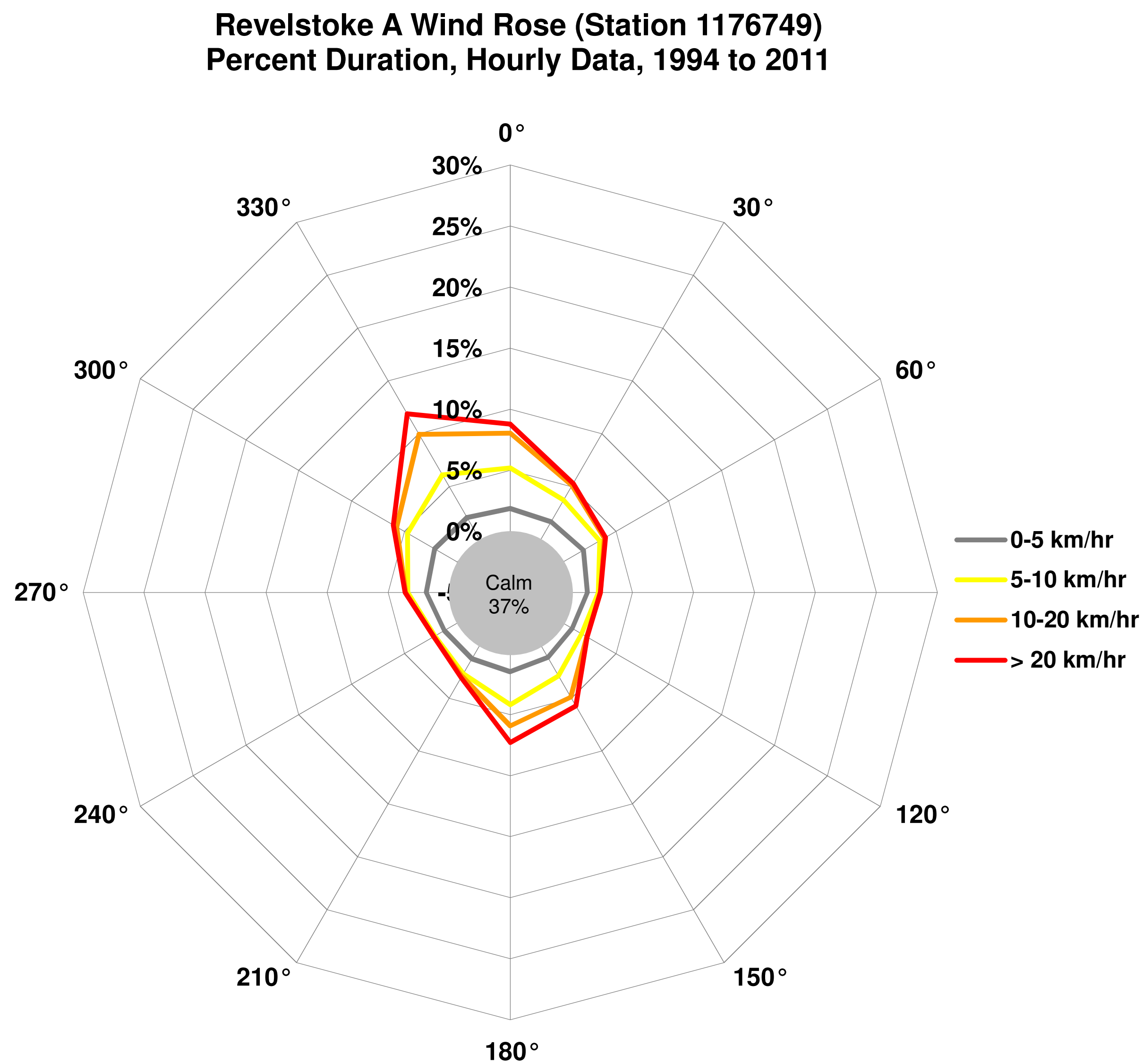

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Figure 3-20

3.3 Statistical Analysis

A statistical analysis was performed by Leska S. Fore (Statistical Design) to evaluate bank erosion from 2010 to 2012 at the 15 monitoring sites by:

1. Comparing the exposed length of pins placed in the river bank, and
2. Comparing the lateral distance between cross-section surveys at given elevations.

3.4 Erosion pin evaluation

Each of the 15 monitoring sites was evaluated for change in erosion (or deposition) by measuring the length of exposed pins in 2010, 2011, and 2012. At each site, 60 pins were placed in a random pattern and measured at installation in 2010. Sites were revisited in 2011 and 2012 and measured again. The difference in length between years was calculated for each pin, negative values indicating erosion and positive values indicating deposition.

To evaluate change in erosion (or deposition) through time at the sites, changes in pin lengths were averaged for all pins at each of the 15 monitoring sites. Overall change at a site was summarized by taking the average of changes for all pins.

Mean change in pin length for all sites was evaluated using a paired t test, such that each site was paired with itself through time. The change in mean pin length for all sites was averaged and evaluated for a statistical difference from 0 (indicating no change). The test statistic was calculated for three time periods, from 2010 to 2011, 2011 to 2012, and 2010 to 2012. The statistical test determines whether the mean change in pin length was significantly less than 0 (indicating erosion) or significantly greater than 0 (indicating deposition).

Several sites had missing pins. During the first revisit in 2011, 476 out of 900 pins could not be measured because they were submerged (>250 pins), toppled, lost or the bank was eroded. During the second revisit in 2012, a total of 195 out of 900 pins could not be measured because they were lost or toppled. Unmeasured pins were not included in any calculations and simply treated as missing. In 2011, toppled pins were reset and the number of pins available for comparisons from 2012 to 2010 increased.

Results varied across the 15 monitoring sites with some sites showing erosion and others showing deposition. From 2010 to 2012, three sites had an average increase in pin exposure (length), indicating deposition over 1 cm; seven sites showed a negative change in pin length (indicating erosion) of more than 2 cm; and four sites showed smaller changes. One site (MON14) was discontinued after discussions with the upland landowner. For comparisons from 2010 to 2012, most sites had more than 45 of the 60 pins that could be measured (N = 11 sites); three remaining sites had 24, 25, and 42 pins that could be measured. This was a large increase from 2011 when five sites had less than 10 pins that could be measured.

The average change in pin length at the 14 monitoring sites was negative for all three time periods, indicating erosion. From 2010 to 2011 the average change was statistically significant (–3.94 cm, Student's t test, $p < 0.05$; Table 2). From 2011 to 2012 the change in average pin length was not significant (–3.04, $p = 0.08$); nor was average change significant from 2010 to 2012 (–2.65, $p = 0.17$).

For each time period, a similar number of sites increased and decreased in mean pin length, but for sites with erosion, the change was generally a greater change (Table 3-2; Figure 3-22).

Monitoring sites were numbered from 1 to 15 beginning at the site closest to Revelstoke Dam. Sites were not placed equidistant downstream; therefore, locations represent a ranking from nearest the dam to furthest downstream toward Shelter Bay. Sites closer to the dam were significantly more eroded compared to sites downstream that had more deposition (Figure 3-22; Spearman's correlation coefficient = 0.55, $p < 0.05$).

Table 3-2: Site name, mean change in pin length, and the number of pins (N), that were measured for three time periods.

Site	2010 to 2011		2011 to 2012		2010 to 2012	
	Change (cm)	N	Change (cm)	N	Change (cm)	N
MON1	0.1	57	0.6	57	0.7	60
MON2	-10.2	41	-6.1	37	-12.0	53
MON3	-7.7	10	-4.5	9	-14.4	42
MON4	0.2	33	0.2	33	-2.6	60
MON5	-2.8	4	-11.3	4	-8.5	46
MON6	-18.0	5	-17.6	4	-10.3	47
MON7		0		0	-0.2	25
MON8	-10.1	26	-1.2	28	-2.2	57
MON9	0.8	58	0.5	57	1.4	57
MON10	0.2	53	-0.1	52	0.4	59
MON11	2.5	1	2.8	2	11.2	24
MON12	1.5	45	-0.6	43	3.4	58
MON13	0.8	56	-0.2	55	0.8	59
MON14	-5.6	7		0		0
MON15	-7.0	28	-1.9	32	-4.7	58

Negative values indicate erosion, positive values indicate deposition. MON1 is closest to the dam and MON15 is closest to Shelter Bay

Table 3-3: Statistical results for testing change in mean pin length during three time periods at 15 sites.

Change measured as	Period	Mean	SD	N	Std. Err.	t-value	df	p
Mean pin length (cm)	2010 to 2011	-3.94	6.02	14	1.60	-2.45	13	0.029
Mean pin length (cm)	2011 to 2012	-3.04	5.69	13	1.58	-1.93	12	0.078
Mean pin length (cm)	2010 to 2012	-2.65	6.82	14	1.82	-1.45	13	0.170

Shown are results for change in mean pin length, time period of comparison, mean change in pin length, the standard deviation of the site means, number of sites, standard error of the mean, test statistic, degrees of freedom and p-value for Student's t test. Only the change in pin length from 2010 to 2011 was statistically significant.

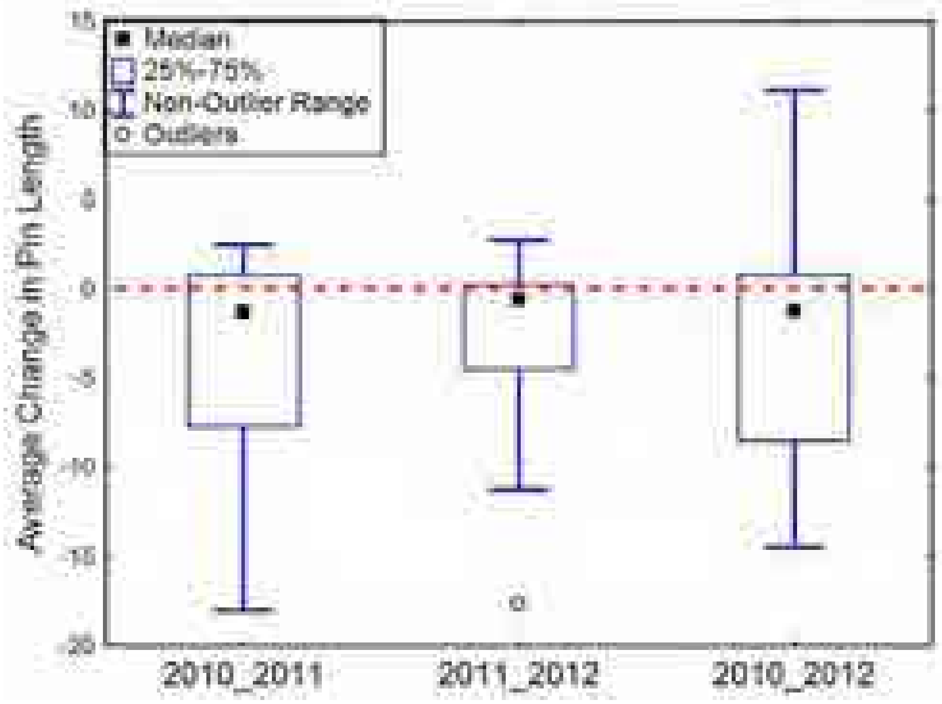


Figure 3-21: Average change in pin length (cm) at monitoring sites.

Shown are changes in the height of erosion pins from 2010 to 2011, 2011 to 2012 and 2010 to 2012. Negative values indicate erosion, positive values indicate deposition. See Table 3-2 for average values and number of sites.

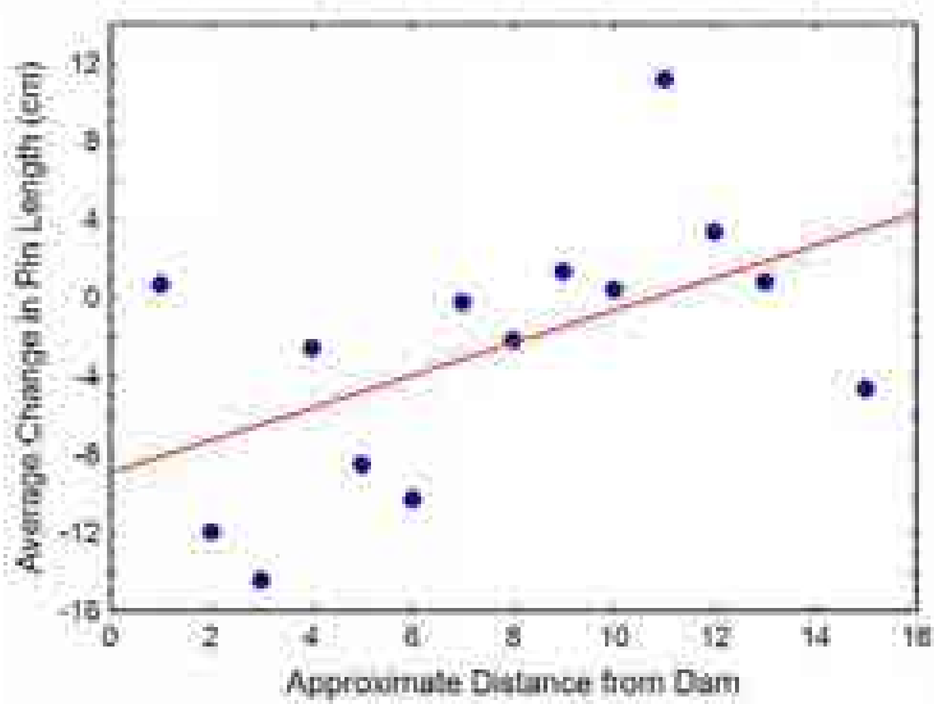


Figure 3-22: Sites closest to the dam had higher pin erosion, and sites further downstream had greater deposition (Spearman's correlation = 0.55, $p < 0.05$)

Sites are rank ordered according to distance from the dam. Shown are changes in the exposed length of erosion pins from 2010 to 2012; negative values indicate erosion, positive values indicate deposition.

3.5 Cross-Section Evaluation

At each of the 14 monitoring sites, elevation was measured along five cross-sections from the top of the bank to the river's edge in 2010, 2011 and 2012. Each monitoring site was compared to itself through time in two ways:

1. by comparing all measurements made at each site during each of the three time periods, and
2. by comparing measurements made at the upper, middle, and lower elevation bands for the time period from 2010 to 2012.

Mean change in horizontal bank change was calculated two ways for both comparisons: as the midpoint of each elevation band and as the maximum observed difference in the elevation band.

Measurements taken along each cross-section were summarized at three points. The points were defined by dividing the total height of each cross-section into three equal heights from the highest elevation (at the top of the bank) to the lowest elevation (at the river edge). For example, if the elevation along a cross-section ranged from 400 to 415 m, the difference of 15 m was divided into three equal elevations (400–405, 406–410, and 411–415). The midpoint of each elevation band was intersected with the profile for each year. Thus, within each of the three "sub-sections" (lower, middle and upper), the horizontal change at the midpoint of the sub-section was calculated. A second statistic, the maximum change within each of the three sub-sections, was calculated in a similar manner.

For five cross-sections summarized at three points, a total of 15 measurements were possible for each site-visit. Years were compared by calculating the horizontal change at the midpoint between years. Change over time was tested for statistical significant using a paired t-test. Changes were reported as the average for all 14 sites. These values were tested for a significant difference from 0 with a negative value indicating erosion and a positive value indicating deposition.

In 2011, many measurements were missing, particularly from the lowest elevations because many of the locations were underwater. High water was not a problem in 2012 and a complete data set was obtained with all 5 cross-sections measured at each elevation band for all 14 monitoring sites (Table 3-4). Data were complete in 2012 for both midpoint measurements and maximum measurements.

For comparisons made for the midpoints of the elevation bands from 2010 to 2012, more sites had negative values, indicating erosion (11 out of 14). For the shorter time periods from 2010 to 2011 and from 2011 to 2012 there were fewer measurements because many sites were underwater in 2011. Nonetheless, most sites showed a negative change indicating erosion (Figure 3-23). For comparisons made for the maximum differences in each elevation band, changes tended to be larger and also tended to indicate erosion (Table 3-4). For 2010 to 2012, 9 out of 14 sites had negative average values indicating erosion (Figure 3-23).

Statistical comparisons showed a significant difference for measures made at the midpoint from 2010 to 2011 and for 2010 to 2012 (–0.5 and –0.47 m, Student's paired t-test, $p < 0.05$; Table 5). Comparisons based on the maximum changes within each elevation band were not statistically significant for any of the three time periods. High variability in the maximum values contributed to the lack of significance when the sites were compared (Figure 3-5). Nonetheless, whether calculated at the midpoint or as the maximum, both provided very similar measures of site condition because the average values based on midpoint and maximum measurements were highly correlated (Pearson's correlation = 0.93, N = 42 [14 sites x 3 elevations]).

To evaluate the source of change, a similar statistical comparison was made for the upper, middle and lower elevations for the time period from 2010 to 2012 (Table 3-7). The three comparisons were made for measurements made at the midpoint and for the maximum differences.

For change measured at the midpoint of the elevation bands, change in the upper elevation band was significant (–0.97 m, $p < 0.05$) and nearly significant for the middle band (–0.56 m, $p = 0.06$). Both values were negative indicating erosion. Values for the lower elevation bands were positive for both the midpoint and maximum measurements, indicating deposition, but were not statistically significant. For change in elevation measured as the maximum for the elevation bands, change in the middle band was statistically significant (–1.0 m, $p = 0.05$).

Table 3-4: Mean horizontal bank change based on measurements at the midpoints of the cross-section profiles (m); and the number of measurements (N) for each monitoring location. Shown are changes for three time periods.

Site	Change 2010 to 2011	N	Change 2011 to 2012	N	Change 2010 to 2012	N
MON1	-0.07	15	0.10	15	0.02	15
MON2	-0.33	13	-0.13	13	-0.44	15
MON3	-0.28	12	-0.02	13	-0.24	15
MON4	-0.15	10	0.04	10	-0.07	15

Site	Change 2010 to 2011	N	Change 2011 to 2012	N	Change 2010 to 2012	N
MON5	-0.91	10	-0.48	10	-0.85	15
MON6	-0.54	12	-0.62	12	-1.15	15
MON7	-1.88	5	0.31	5	-0.55	15
MON8	-0.81	10	-0.54	10	-0.52	15
MON9	0.64	14	-0.22	14	0.45	15
MON10	0.25	15	-0.29	15	-0.03	15
MON11	-1.25	15	-1.21	15	-2.38	15
MON12	-0.05	11	-0.07	11	-0.06	15
MON13	0.00	15	0.18	15	0.21	15
MON15	-1.64	10	0.01	10	-1.01	15

Table 3-5: Mean horizontal bank change based on maximum differences in the cross-section profiles (m); and the number of measurements (N) for each monitoring location. Shown are average maximum changes for three time periods.

Site	Max Change 2010 to 2011	N	Max Change 2011 to 2012	N	Max Change 2010 to 2012	N
MON1	-0.15	15	0.22	15	0.09	15
MON2	-0.47	14	-0.14	14	-0.70	15
MON3	-0.34	15	0.04	15	-0.55	15
MON4	-0.33	15	0.17	15	-0.02	15
MON5	-1.35	10	-1.55	10	-1.79	15
MON6	-0.84	14	-0.43	14	-1.73	15
MON7	-3.07	6	0.41	6	-1.79	15
MON8	-1.13	10	-0.59	11	-0.62	15
MON9	2.07	15	-0.61	15	2.11	15
MON10	0.78	15	-1.13	15	0.03	15
MON11	-1.79	15	-1.90	15	-2.77	15
MON12	0.17	15	0.05	15	0.65	15
MON13	-0.06	15	0.49	15	0.79	15
MON15	-2.68	10	0.40	10	-1.82	15

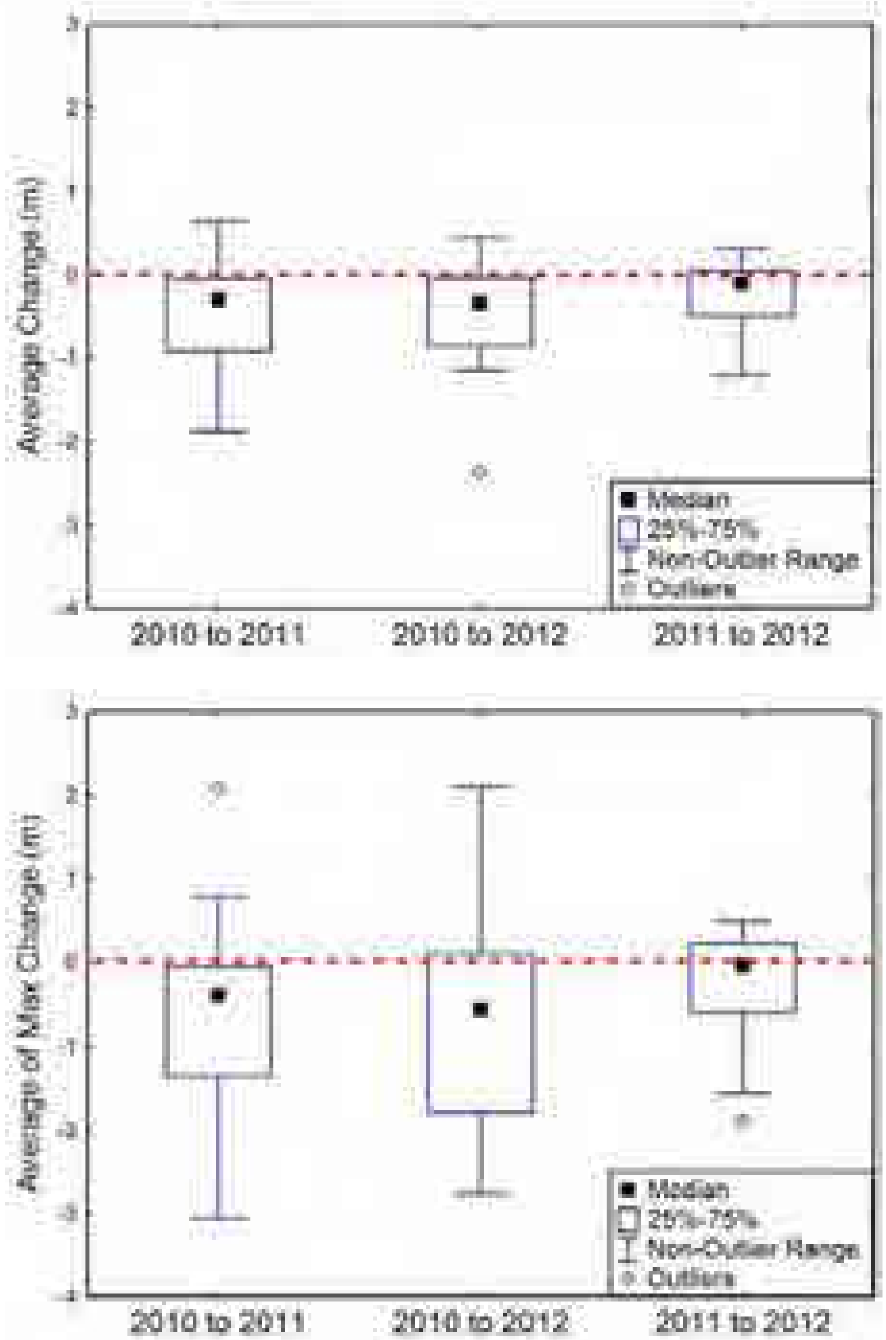


Figure 3-23: Average change at the 14 monitoring sites measured as change at the midpoint of the elevations (upper panel) and measured as the maximum observed difference (lower panel). Shown are changes in elevation for three time periods.

Table 3-6: Statistical results for comparisons of cross-section changes at 14 locations during three time periods. Shown are results for the changes measured at the midpoint and measured as the maxima.

Change measured as	Period	Mean	SD	N	Std. Err.	t-value	df	p
Average of Change at Midpoint	2010 to 2011	-0.50	0.72	14	0.19	-2.61	13	0.022
Average of Change at Midpoint	2011 to 2012	-0.21	0.40	14	0.11	-1.98	13	0.070
Average of Change at Midpoint	2010 to 2012	-0.47	0.72	14	0.19	-2.46	13	0.029
Average of Max Change	2010 to 2011	-0.66	1.33	14	0.36	-1.85	13	0.09
Average of Max Change	2011 to 2012	-0.33	0.75	14	0.35	-0.93	13	0.37
Average of Max Change	2010 to 2012	-0.58	1.31	14	0.35	-1.65	13	0.12

Each row represents a single statistical test; for each test are shown the mean, the standard deviation of the sample, the sample size, standard error of the mean, test statistic, degrees of freedom and p-value for Student's t test. Comparisons with $p < 0.05$ are highlighted in red.

Table 3-7: Statistical results for comparison of change in cross-section elevations within lower, middle and upper bands along the bank. Shown are results for the changes measured at the midpoint and measured as the maxima.

Measure	Elevation	Mean (m)	N	SD	Var	Std. Err.	t-value	p-value
Average change at Midpoint	Lower	0.11	14	0.57	0.32	0.15	0.74	0.47
Average Maximum change	Lower	0.33	14	1.17	1.37	0.31	1.04	0.32
Average change at Midpoint	Middle	-0.56	14	1.00	1.01	0.27	-2.09	0.06
Average Maximum change	Middle	-1.00	14	1.72	2.95	0.46	-2.17	0.05
Average change at Midpoint	Upper	-0.97	14	1.48	2.19	0.40	-2.44	0.03
Average Maximum change	Upper	-1.07	14	2.24	5.01	0.60	-1.79	0.10

For each test are shown the mean (m), the number of locations (N), the standard deviation, variance, standard error of the mean, test statistic, and p-value for Student's t test. Red highlighting indicates $p < 0.05$.

3.6 Interim Conclusions

Measurements made for pins and for profiles in general agreed, and most measurements indicated erosion. For the pins, a statistically significant change was observed from the 2010 to 2011 (-3.94 cm average of all sites), but the trend was not significant for 2011 to 2012 or 2010 to 2012.

For cross-sectional profiles, about 75% of measurements were negative, indicating erosion. A statistically significant amount of erosion (~ 0.5 m) was observed from 2010 to 2011 and a similar amount of erosion was significant for the overall period of measurement from 2010 to 2012. When erosion was evaluated within elevation bands, upper and middle elevations showed some statistically significant erosion (~ 1 m), while the lower elevation band had positive values indicating deposition, but were not statistically significant. Erosion of upper bands and deposition at lower bands may indicate sloughing of steep banks.

The erosion monitoring experimental design provided the means to assess erosion at two scales:

- erosion pins (change up to about 0.4 m and accurate to about 0.5 cm); and
- cross-sectional survey (change greater than about 0.2 m and accurate to about 0.05 to 0.1 m).

The erosion pins provide a very random sample of change occurring over the monitoring plot. The cross-sectional change provides a "spatially averaged" measure, where horizontal bank change is assessed at equally spaced cross-section locations, and three characteristic measurements are taken at equally representative elevation bands.

When reviewing that data, the erosion pins do not identify large change, i.e. where erosion is greater than 0.4 m, other than through loss of pins. This data is not included in the statistical analysis. There are always parts of the monitoring area where change is more subdued, and the erosion pins will tend to reflect those areas, rather than the larger change. In cross-sections where cross-sectional change is small or negligible, erosion pins data quantifies the erosional patterns and average change in an unbiased way. There are also potential problems with the erosion pins, when pins are lost, or un-measurable due to deep deposition, the average can be biased to the observable measures as was the case for some of the 2011 data. Erosion is also episodic, so measurement at short time scales can lead to erroneous or results not representative of a longer term average.

The cross-sectional data does not include extreme measures of erosion (i.e. top of floodplain horiztonal change) as this is an extreme measure and could negatively influence the statistics. Therefore, spatially representative measurements are provided for top, mid and lower bank ranges.

The amount of erosion on both the pins and the cross-sections is statistically significant for most periods. However, statistical significance does not describe the processes dictating the erosion, nor whether the erosion is significant within the larger Columbia River context.

It could also be seen this year that erosion patterns followed a gradient from upstream to downstream sites. The most eroded sites were located nearest the Revelstoke Dam and sites with greatest deposition were furthest downstream. While this is a preliminary result, this trend is physically consistent with what would be expected in a river mouth / lake environment.

3.7 Channel Mapping

The *2010 Progress Report* (KWL, 2010[1]) documented 2007 channel mapping and a comparison of 2000 to 2007 channel changes. Subsequent to that report, the 2010 orthophotos were obtained from BC Hydro. Upon review of the 2010 orthophotos, it was determined that they are not suitable for channel mapping. The main issue is that the 2010 orthophotos only cover a small fraction of the reach of interest, and therefore leave large sections of the river banks that could not be mapped. Since the goal of the channel mapping is to evaluate reach-scale changes, the 2010 orthophotos are not suitable.

[1] KWL, 2010. CLBWORKS #35 and #36 2010 Progress Report. Report prepared for BC Hydro. (KWL Project 478.081).

Section 4

Summary and Future Works

4. Summary and Future Works

4.1 CLBWORKS #35

Construction of the bioengineering works is complete. The final lower elevation portion of Site A1 was installed in April 2012. Baseline erosion monitoring pins and cross-sections have been established at all CLBWORKS #35 sites, including the lower elevations of Site A1. Erosion monitoring pin measurement data and transect survey data was collected in April 2012. The initial data analysis is summarized in this report.

The first round of erosion monitoring measurements (Year 2) provides a partial year of data. This allows understanding of the change over a winter season of lower of the Arrow Lakes water levels and does not include a flood cycle.

Initial measurements of the erosion monitoring pins indicate that there is no statistically significant change in erosion or deposition from 2011 to 2012 for the bioengineered versus control sites. Control sites do show slightly more erosion based on average exposed pin length; however, it is not significantly significant. The transect profiles indicate that the control sites show slightly more deposition, again, these results are not statistically significant.

The length of time for this comparison is relatively short (four months) and changes likely will take longer to develop. Year 3 monitoring for this project is scheduled for spring 2013.

4.2 CLBWORKS #36

Year 3 erosion monitoring measurements have been completed at the CLBWORKS #36 sites, and the data analysis is summarized in this report.

There are a total of 15 long term erosion monitoring sites for CLBWORKS #36. One site (MON 14) was excluded from data collection and analysis because of conflicts with the upland landowner. Erosion pin measurements and transect surveys were conducted between May 31 and June 2, and between June 13 and 14, 2012.

Each of the 14 remaining monitoring sites was evaluated for change in erosion or deposition by comparing the average change in exposed erosion pin length for three time periods: 2010 to 2011, 2011 to 2012 and 2010 to 2012.

At each of the 14 monitoring sites, elevation was measured along five cross-sections (transects) from the top of the bank to the river's edge in 2010, 2011 and 2012. The average elevation of the transects at each site were compared for the same three time periods and the average elevation of the transects at each site separated into upper, middle and lower elevation bands were compared for the same three time periods.

In general, measurements made of the pins and transects agreed and most measurements indicated erosion. For the pins, a statistically significant change (erosion) was observed from 2010 to 2011; however, the trend was not statistically significant for 2011 to 2012 or from 2010 to 2012.

For the transects, approximately 75% of the measurements indicated erosion. A statistically significant amount of erosion was observed from 2010 to 2011 and over the overall period from 2010 to 2012. When erosion was evaluated within elevation bands, the upper and middle elevations showed some statistically significant erosion, while the lower elevations showed deposition that was not statistically significant.

It could also be seen this year that erosion patterns followed a gradient from upstream to downstream sites. The most eroded sites were located nearest to the Revelstoke Dam and sites with the greatest deposition were furthest downstream. While preliminary, this trend is physically consistent with what would be expected for a river mouth/lake environment.

Year 4 monitoring is scheduled for the spring of 2014 for this project.

4.3 Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

Dec. 28/2012

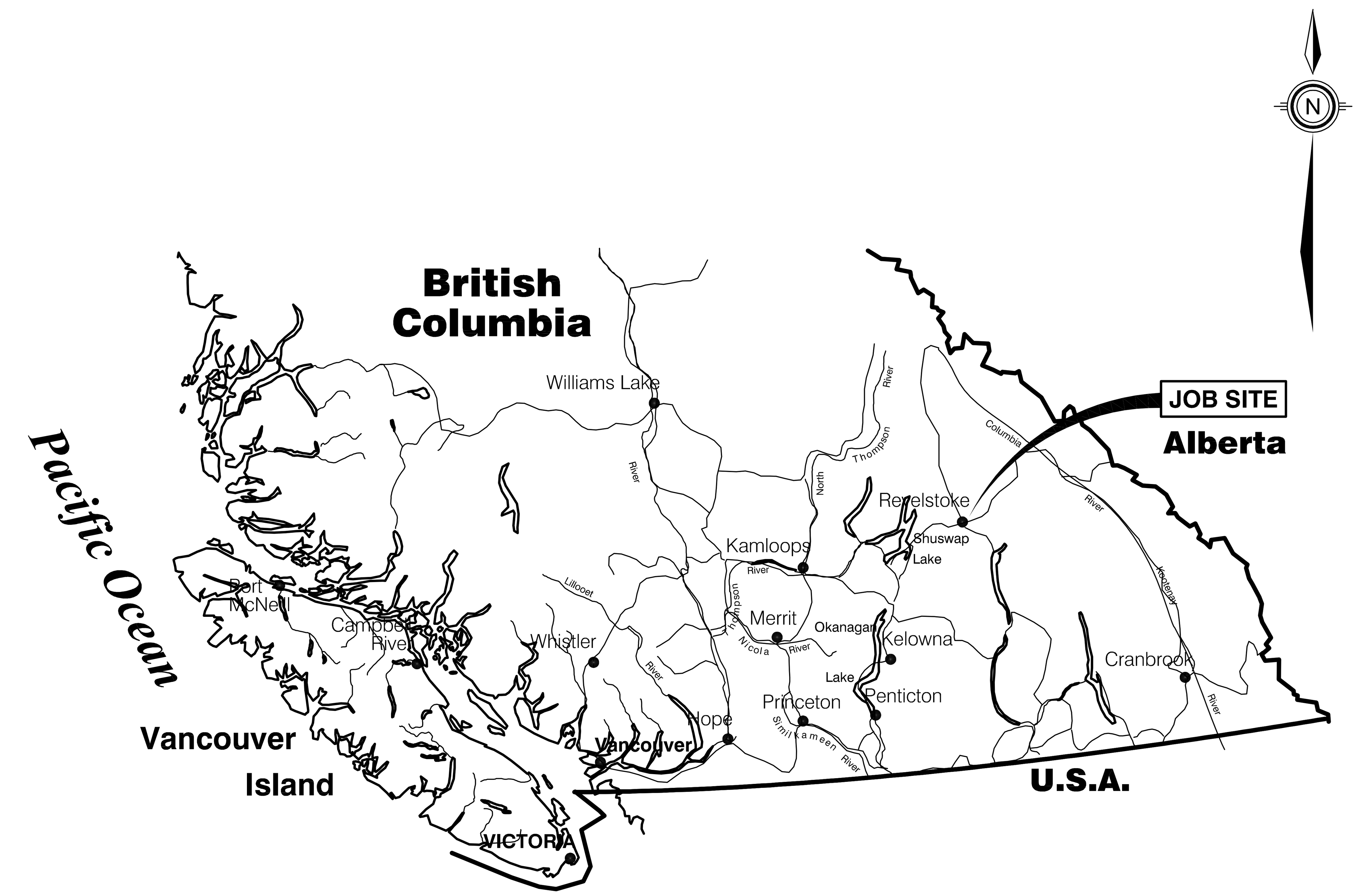
Sarah Loewen, M.A.Sc., P.Eng.
Water Resources Engineer

Reviewed by:

David Matsubara, M.Eng., P.Eng.
Project Manager

Appendix A
CLBWORKS #35 Drawings (Record Drawings)

KEY PLAN
N.T.S.



LOCATION PLAN
N.T.S.

		DRAWING LIST
SHT. NO.	DRAWING NO.	TITLE
1	G1	LOCATION PLAN, KEY PLAN AND DRAWING LIST
2	G2	OVERVIEW OF SITE ACCESS ROADS
3	SW1	SITE WORKS - SITES 'A1' & 'A2'
4	SW2	SITE WORKS - SITES 'B' & 'C'
5	SW3	SECTIONS - SITE 'A1'
6	SW4	SECTIONS - SITE 'A2'
7	SW5	SECTIONS - SITE 'B'
8	SW6	SECTIONS - SITE 'C'
9	SD1	STANDARD DETAILS

BC HYDRO
CLB#35 - MID COLUMBIA RIVER BANK PROTECTION WORKS
PROJECT # 478.119

SAVED 17-Jul-2012 10:09 AM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

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ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	JAN.19/10	SJL	BVC	DTM							
1	JUN.10/10	SJL	MP	DTM	REVISED NOTES						
2	APR.15/11	SJL	SC	DTM	ISSUED FOR PERMIT						
3	DEC.23/10	SJL	BVC	DTM	ISSUED FOR 2011 PROGRESS REPORTING						
4	JUL.27/12	SJL	BVC	DTM	ISSUED FOR 2012 PROGRESS REPORTING						

Seal

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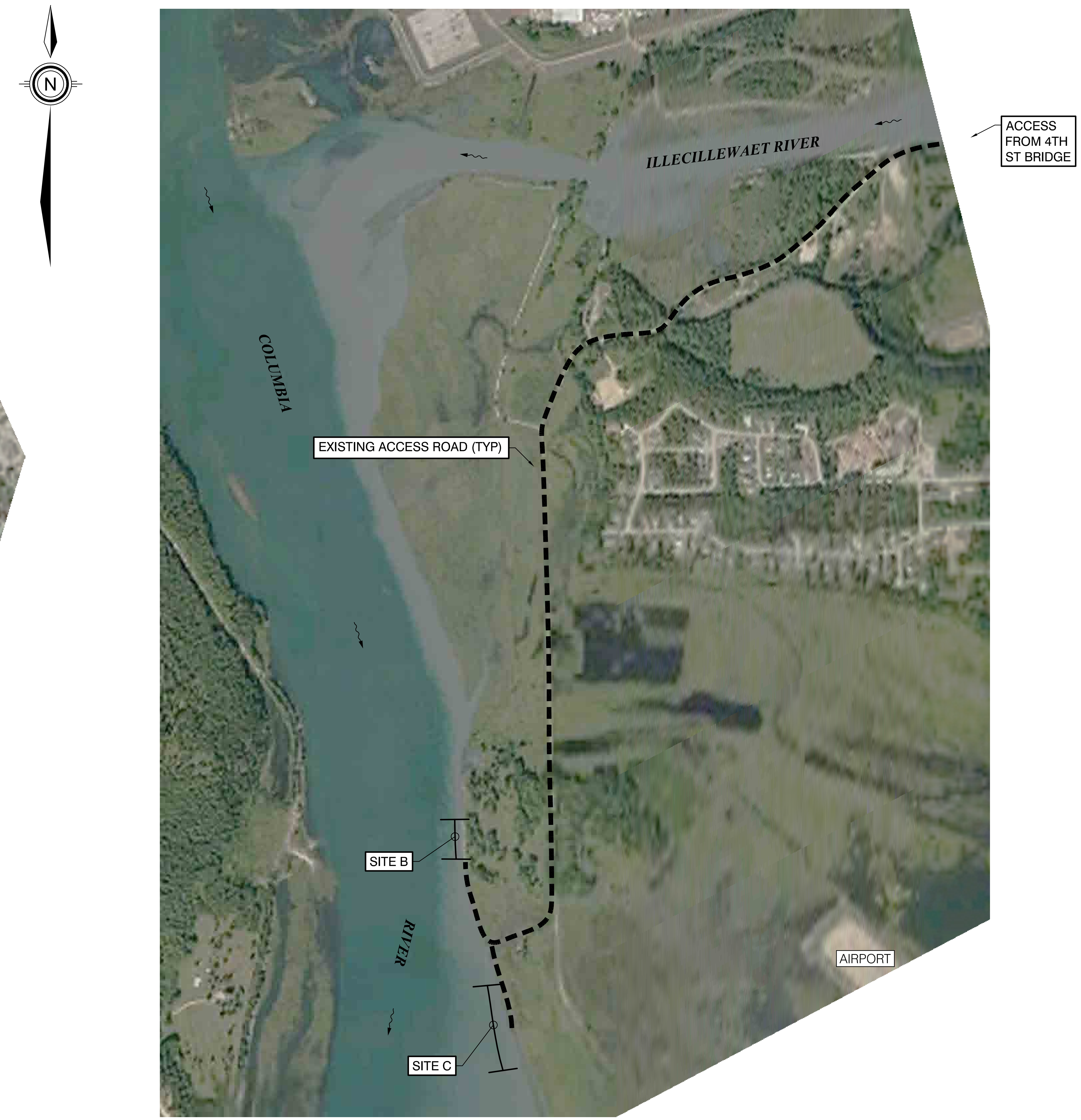
BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
LOCATION PLAN, KEY PLAN & DRAWING LIST

KWL Project No.	478-119	Scale	AS SHOWN
Sheet	01 of 9	Rev. No.	4
Client: BC HYDRO			

G1
Drawing Number

SITE ACCESS SITES 'A1' & 'A2'
N.T.S.



SITE ACCESS SITES 'B' & 'C'
N.T.S.

ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

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4	JUL.27/12	SJL	BVC	DTM	ISSUED FOR 2012 PROGRESS REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
OVERVIEW OF SITE ACCESS ROADS

KWL Project No.	478-119	Scale	AS SHOWN
Sheet	02 of 9	Rev. No.	4
Client: BC HYDRO			

G2
Drawing Number

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PLAN - SITE A1

SCALE 1:250

PLAN - SITE A2

SCALE 1:250

ISSUED INFORMATION			
Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION					
Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SITE WORKS - SITES 'A1' & 'A2'

KWL Project No. 478-119 | Scale 1:250

Sheet 03 of 9 | Rev. No. 4

SW1 Drawing Number

Client: BC HYDRO

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AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

SAVED 5-Sep-2012 12:55 PM

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PLAN - SITE B

SCALE 1:250

PLAN - SITE C

SCALE 1:250

ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SITE WORKS - SITES 'B' & 'C'

KWL Project No.	478-119	Scale	1:250	**SW2**
Sheet	04 of 9	Rev. No.	4	Drawing Number
Client: BC HYDRO				

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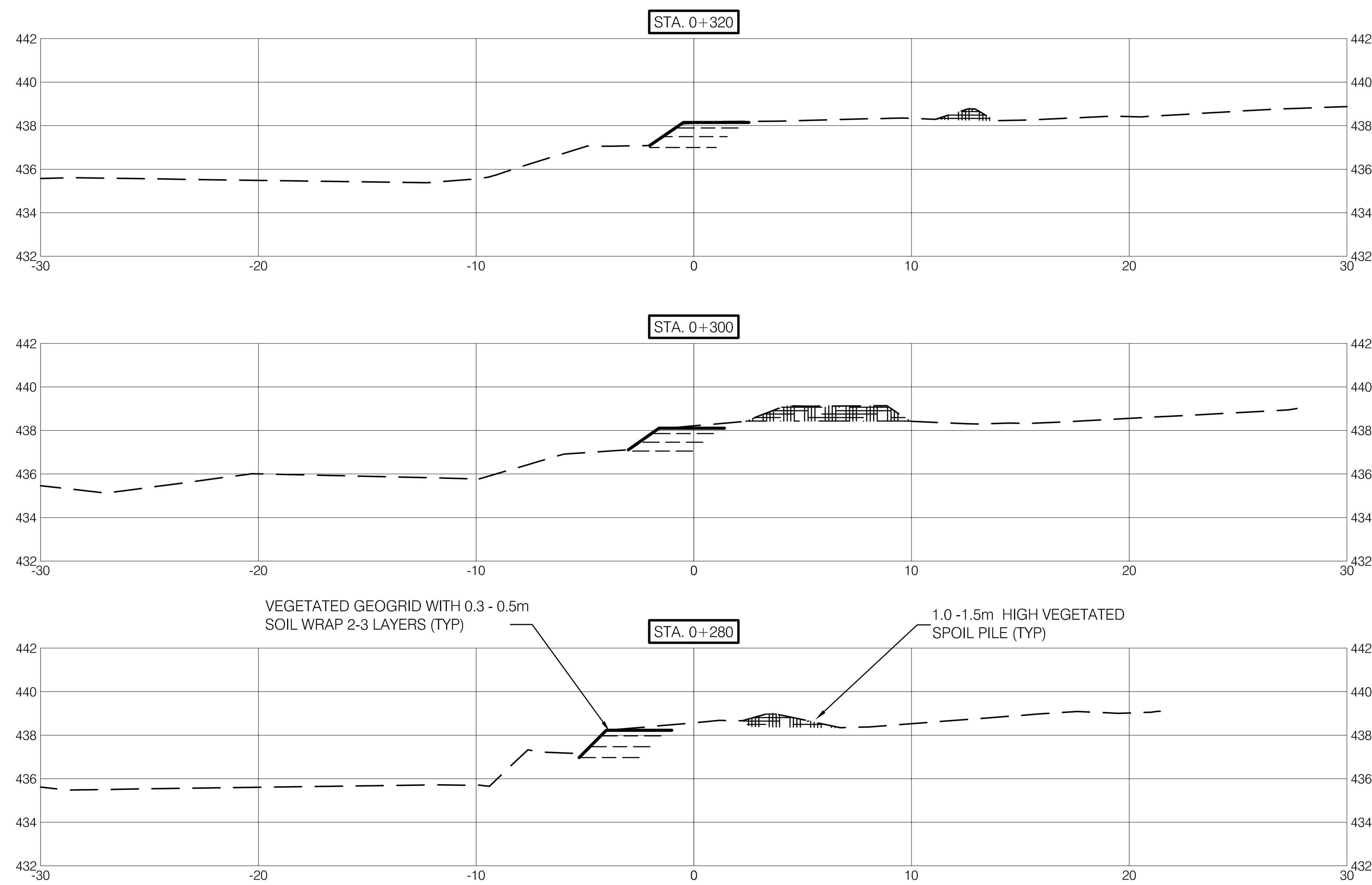

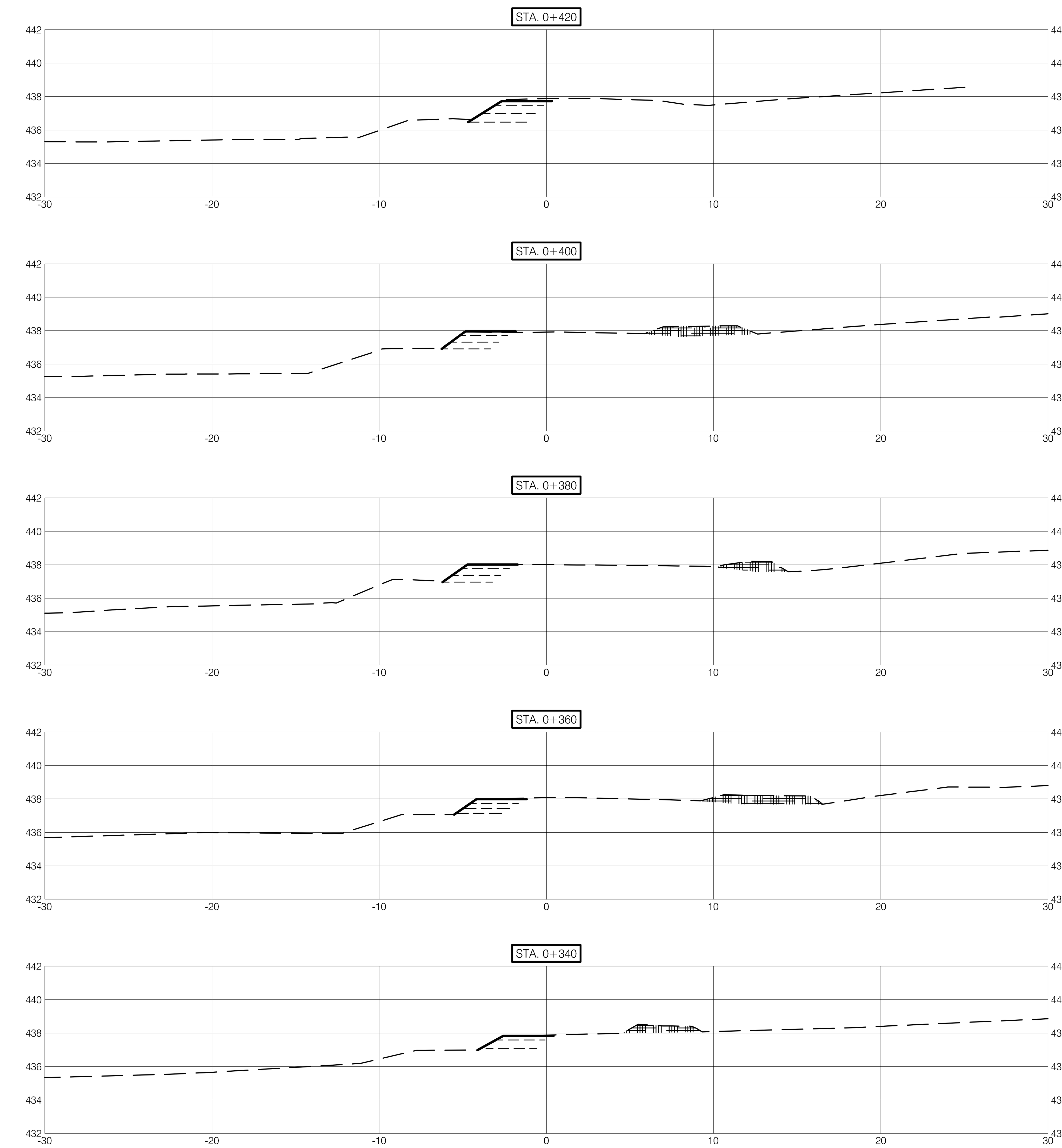

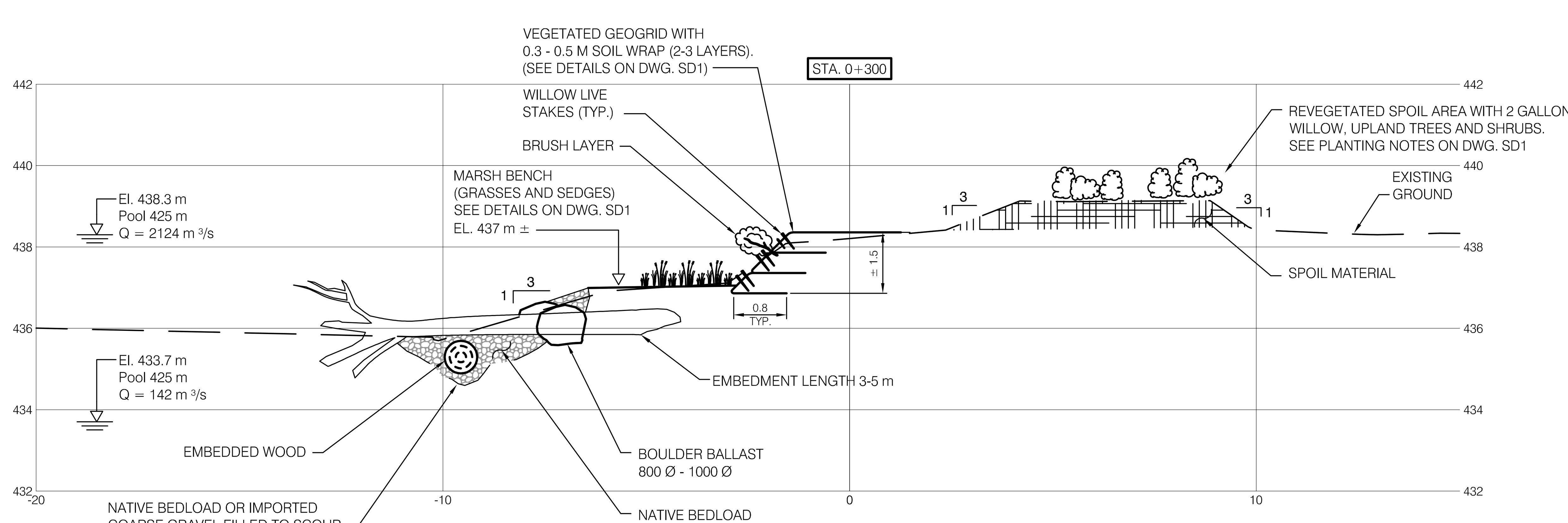

TYPICAL SECTION
SITE 'A1' STA 0+260 to STA 0+420
SCALE 1:100

0 2 (1:200) 10m

ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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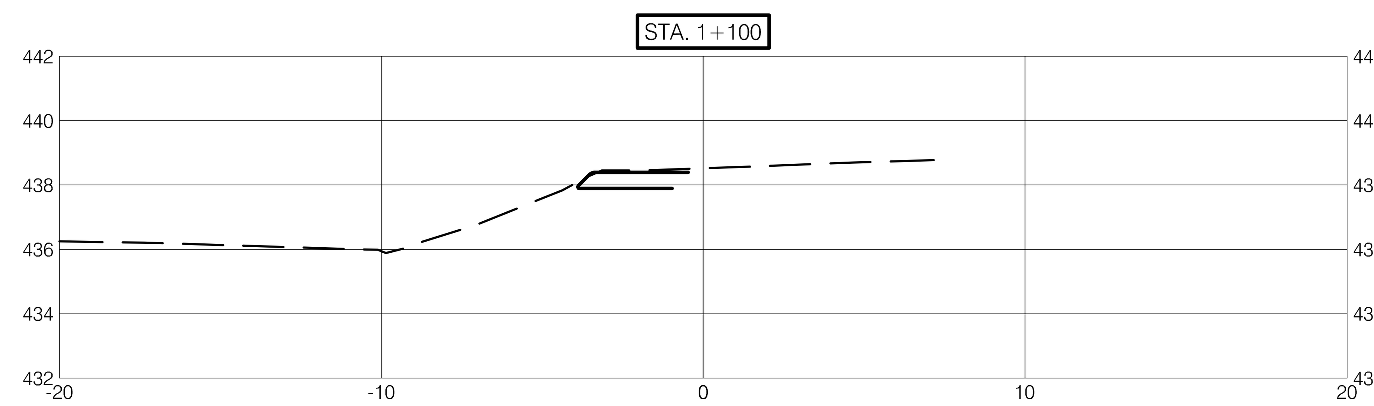
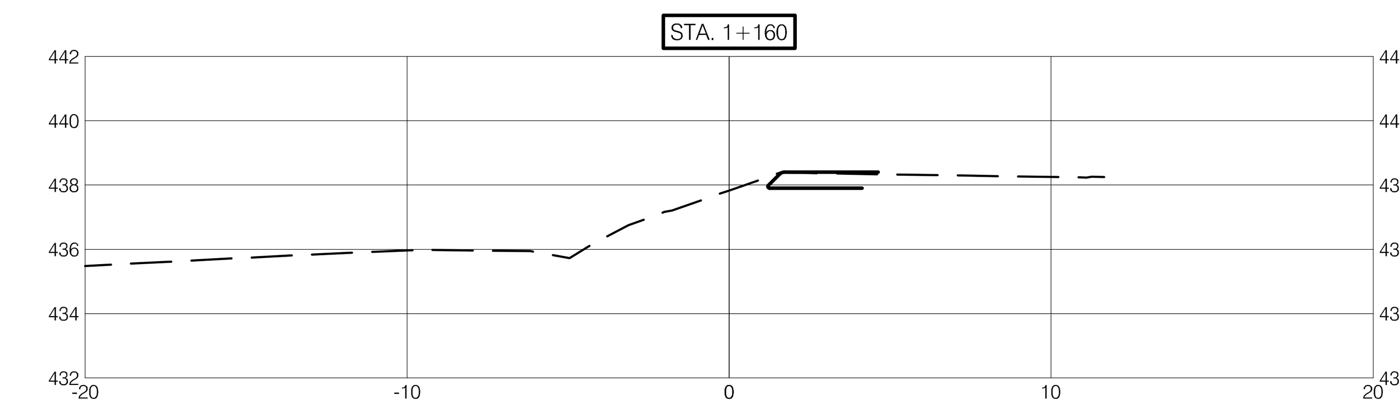
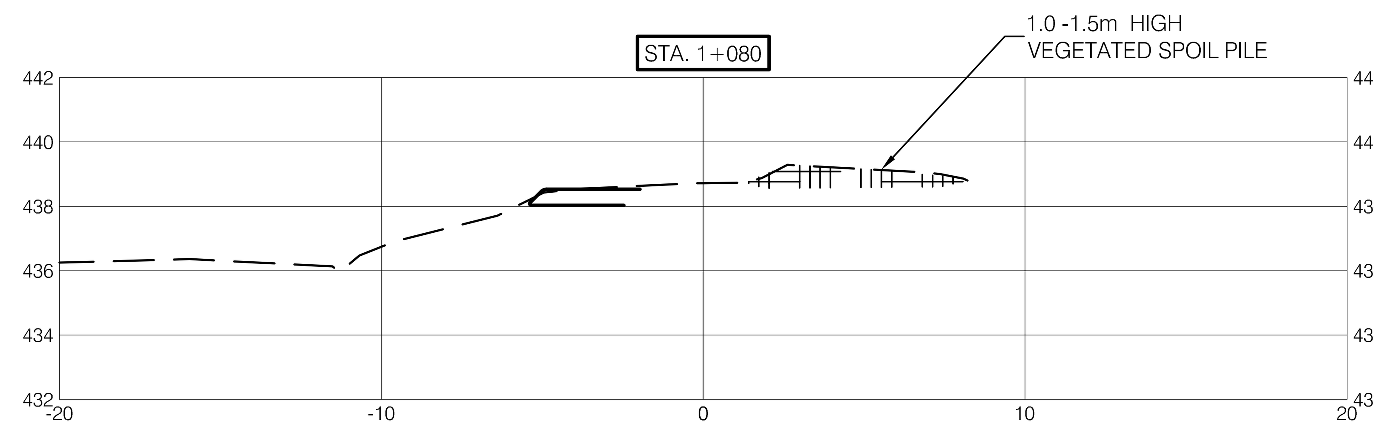
BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SECTIONS - SITE 'A1'

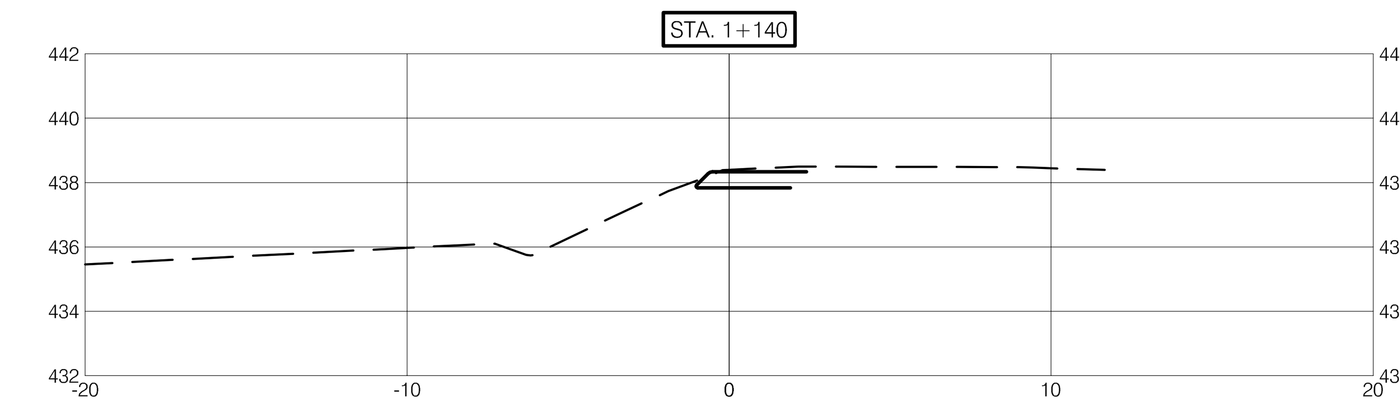
KWL Project No. 478-119 Scale 1:200
Sheet 05 of 9 Rev. No. 4
Client: BC HYDRO

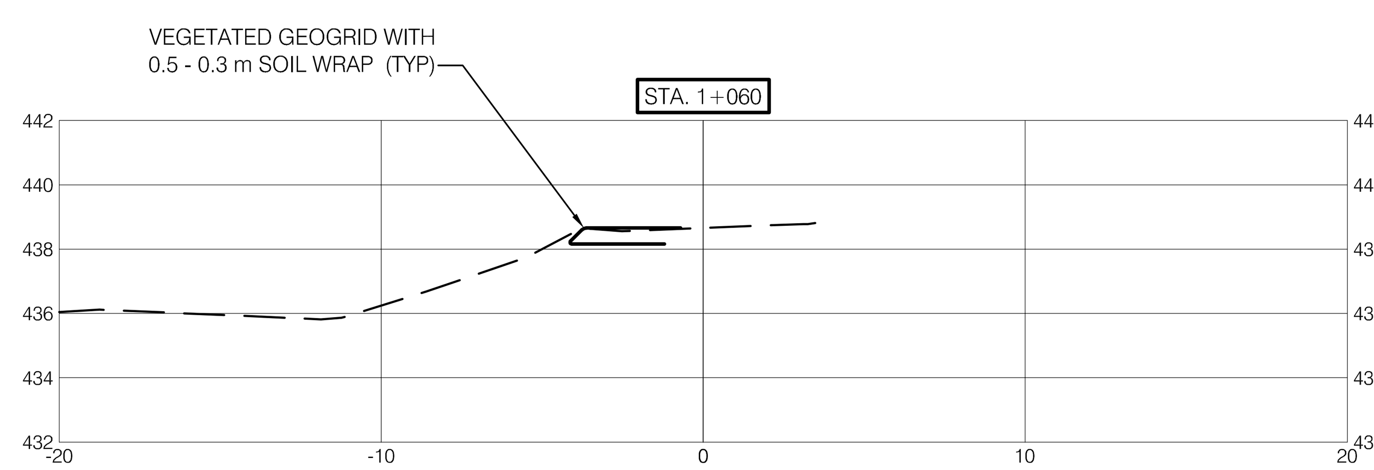
SW3
Drawing Number

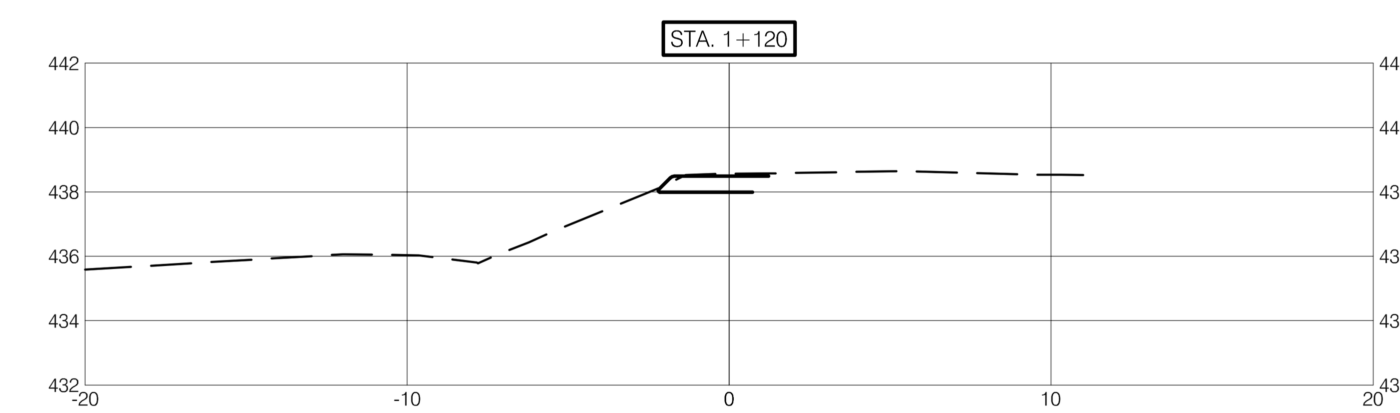












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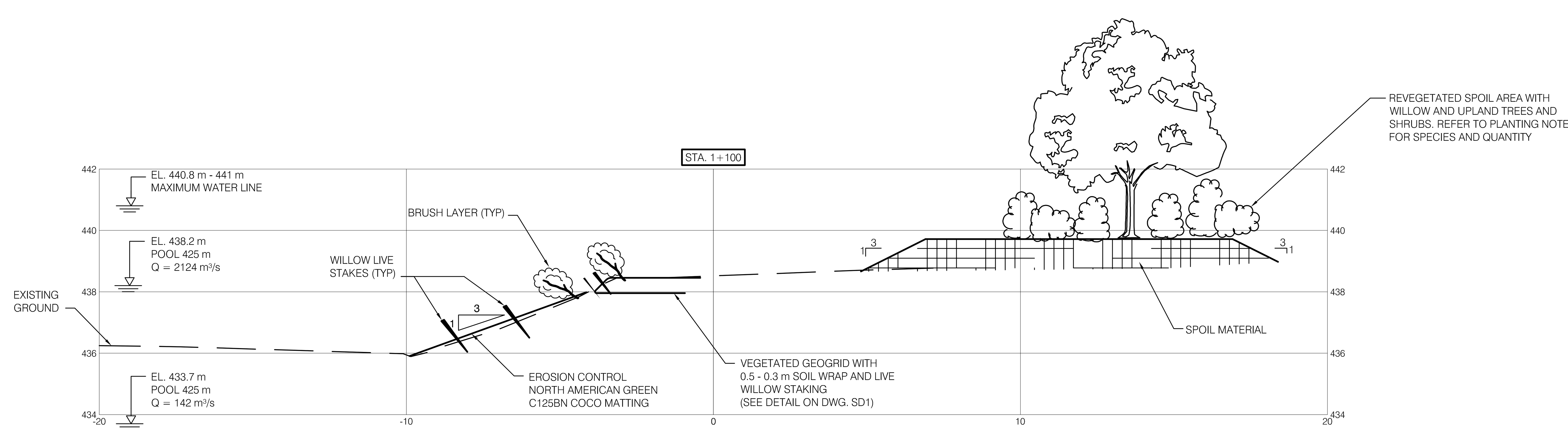

TYPICAL SECTION
SITE 'A2' STA 1+060 to STA 1+160

SCALE 1:100

ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SECTIONS - SITE 'A2'

KWL Project No.	478-119	Scale	1:200
Sheet	06 of 9	Rev. No.	4
Client: BC HYDRO			

SW4
Drawing Number

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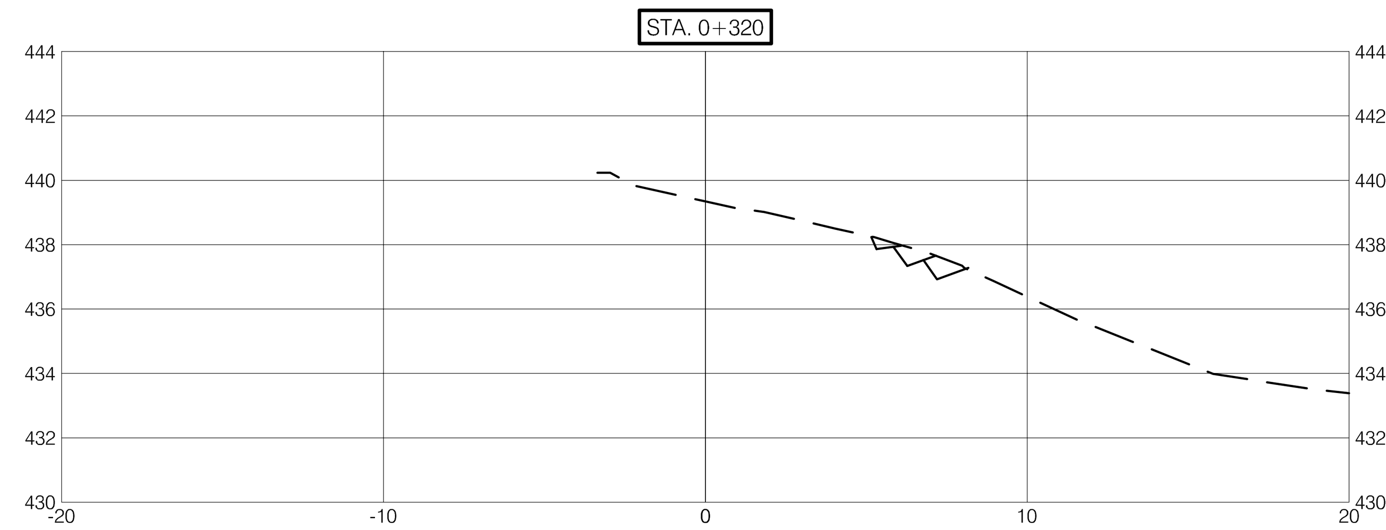
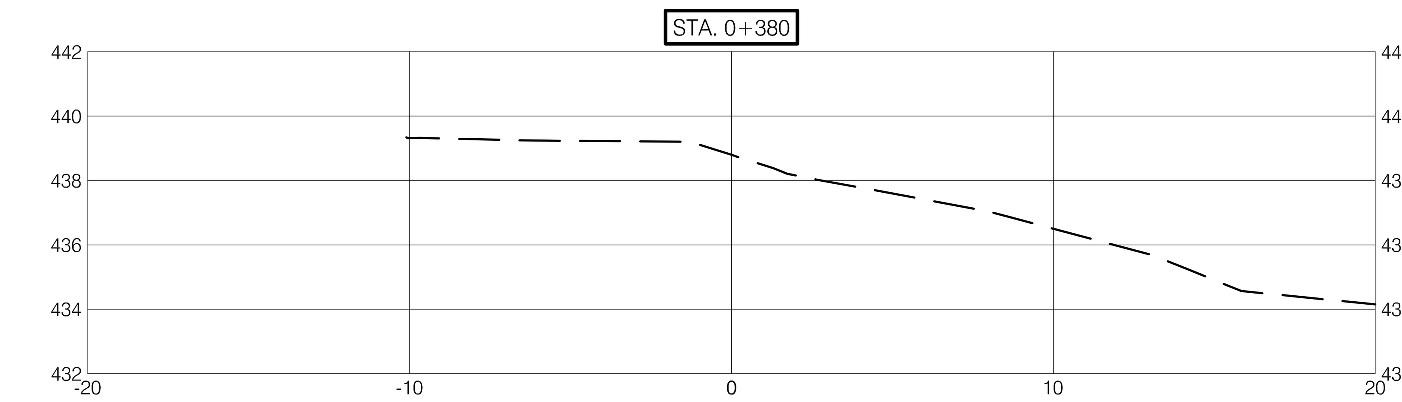
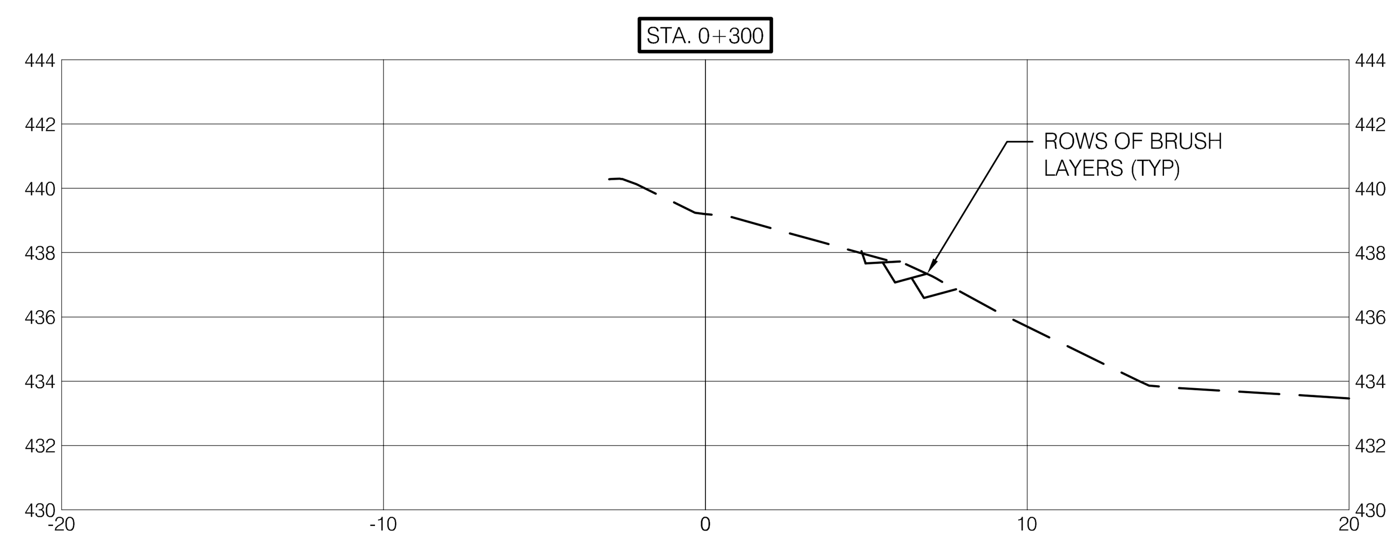
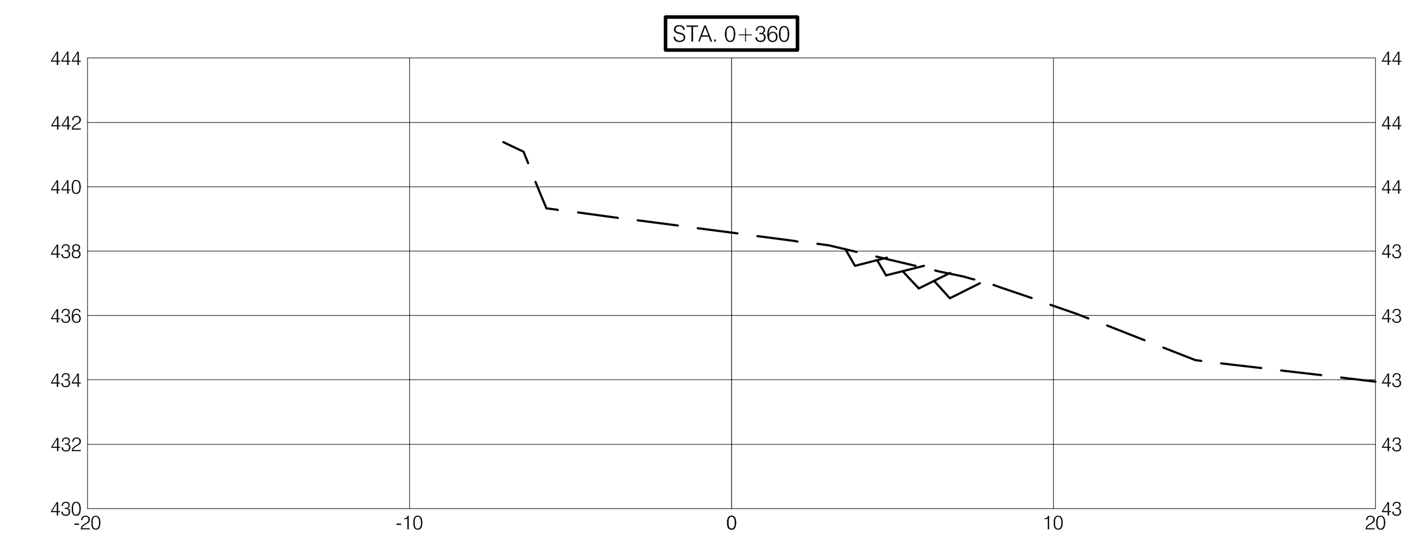
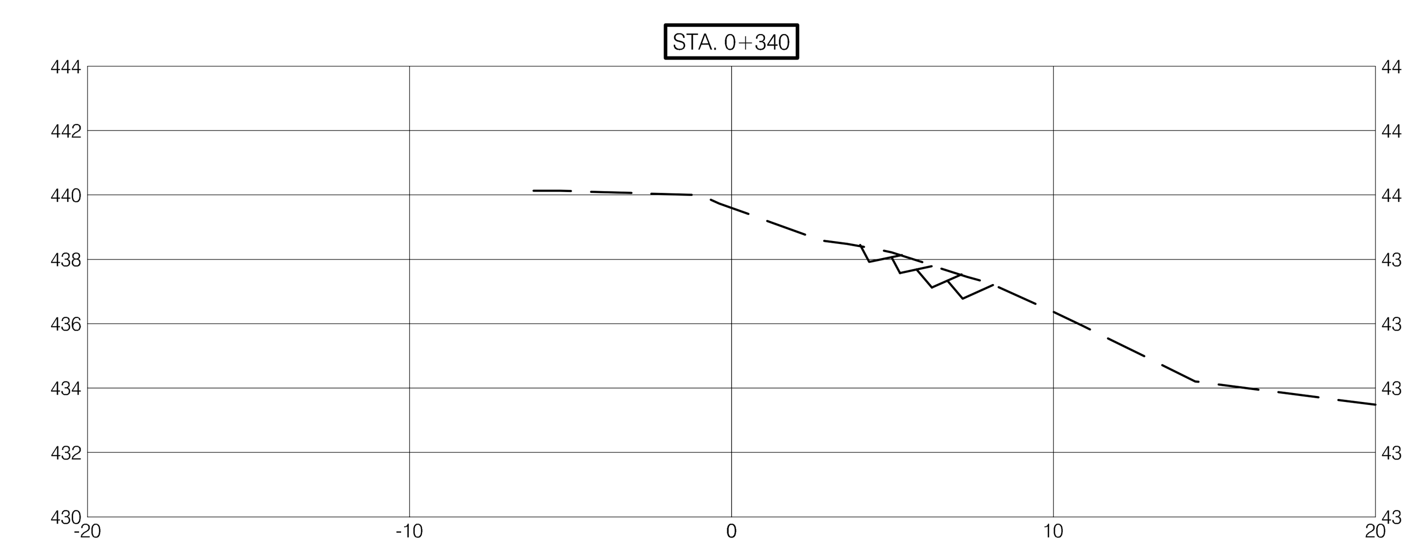


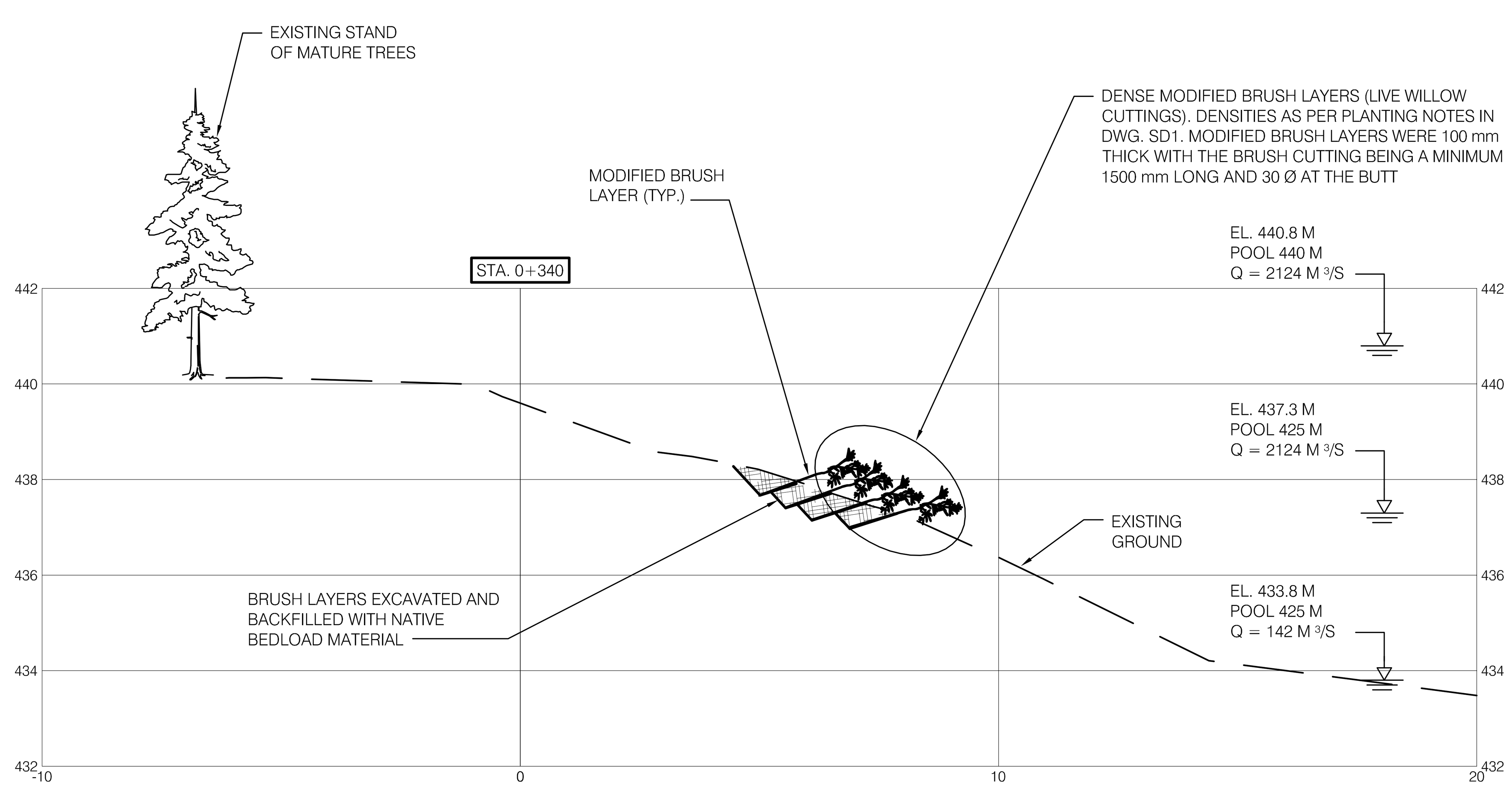




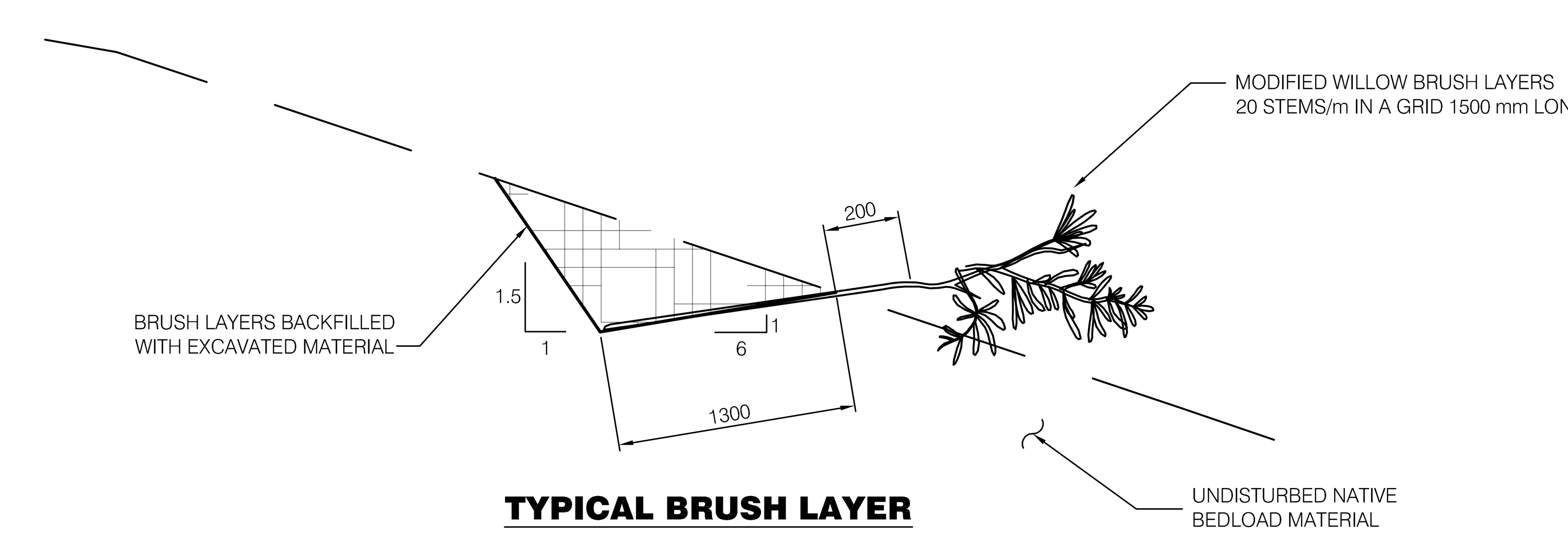




0 2 (1:200) 10m



TYPICAL SECTION
SITE 'B' STA 0+300 to STA 0+380
SCALE 1:100



TYPICAL BRUSH LAYER
SCALE 1:50

ISSUED INFORMATION Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
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REVISION INFORMATION Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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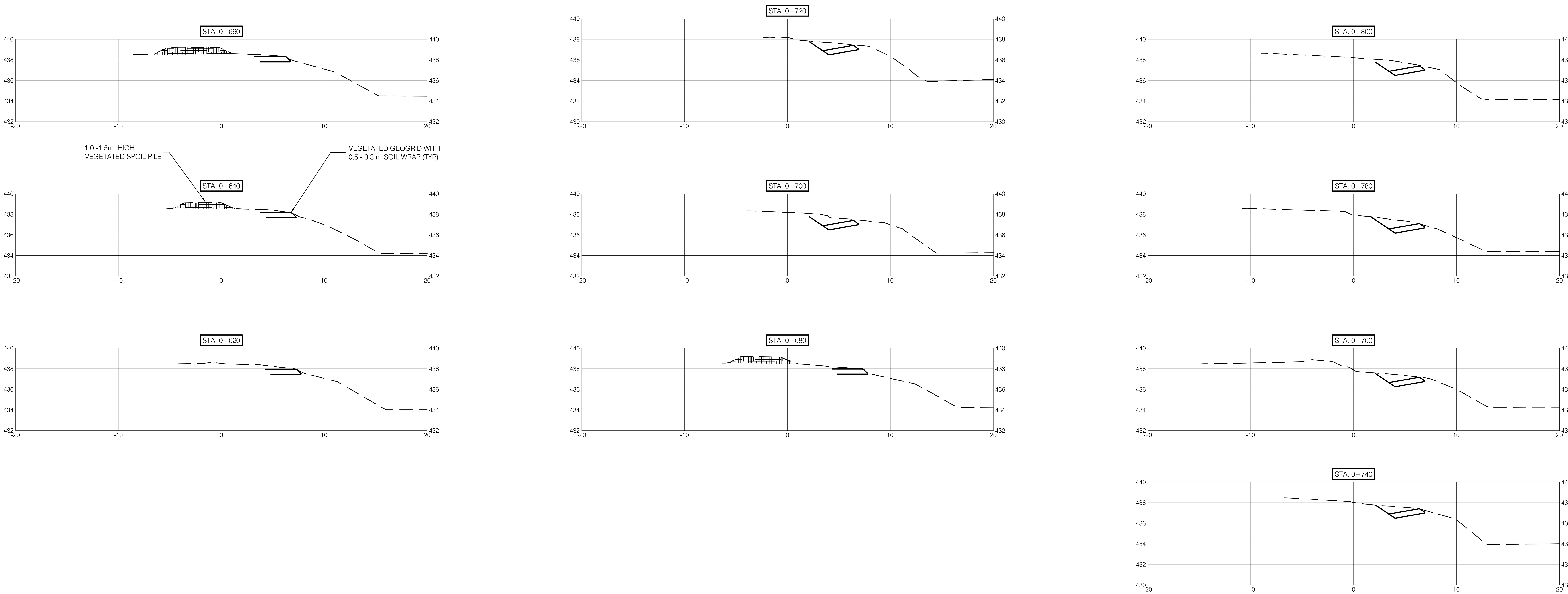
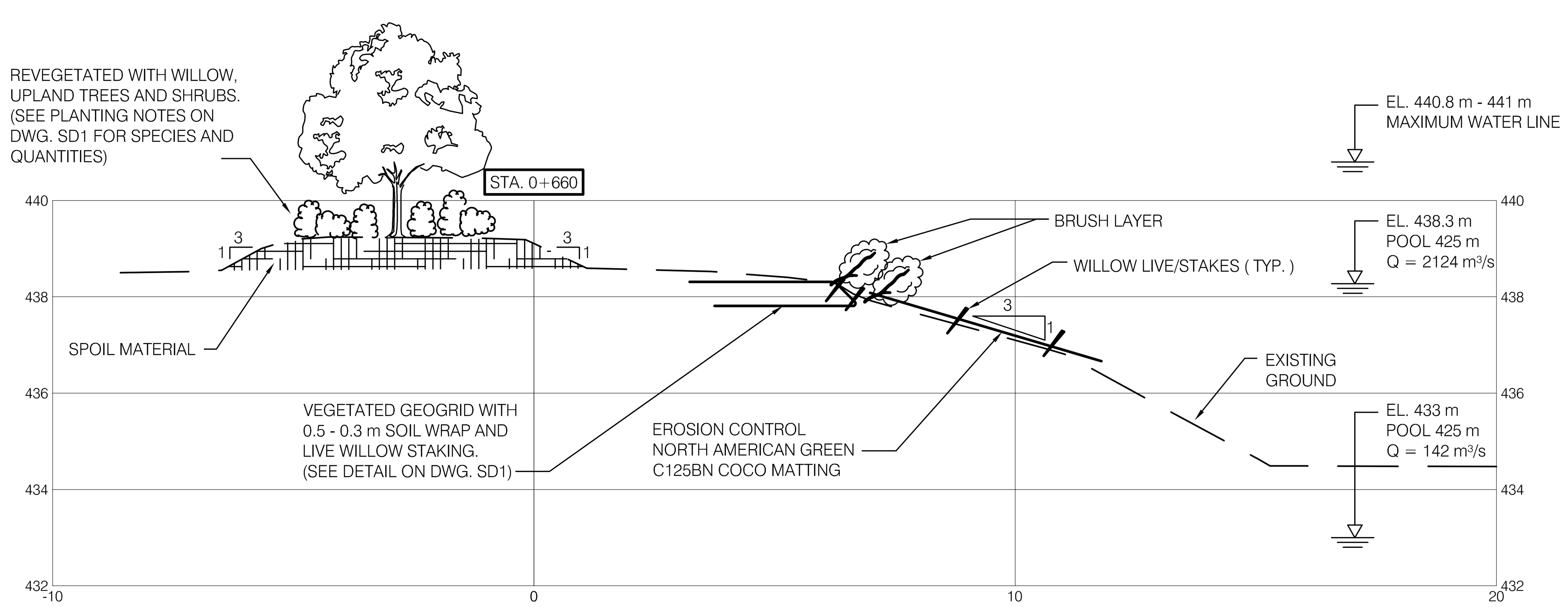
BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SECTIONS - SITE 'B'

KWL Project No. 478-119		Scale 1:200	SW5 Drawing Number
Sheet 07 of 9		Rev. No. 4	
Client: BC HYDRO			

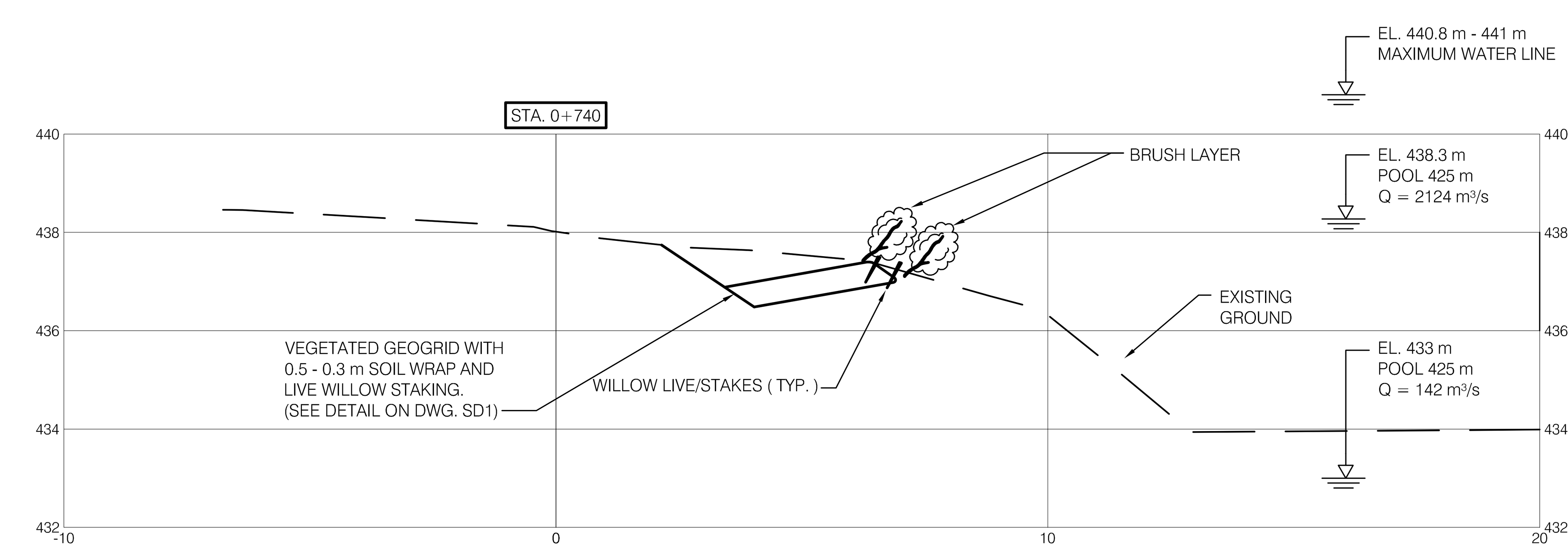




TYPICAL SECTION

SITE 'C' STA 0+620 to STA 0+695

SCALE 1:100



TYPICAL SECTION

SITE 'C' STA 0+695 to STA 0+810

SCALE 1:100

0 2 (1:200) 10m

ISSUED INFORMATION: Issued for	Issue	Date	Issued By
Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
SECTIONS - SITE 'C'

KWL Project No. 478-119		Scale 1:200	**SW6**
Sheet 08 of 9		Rev. No. 4	Drawing Number
Client: BC HYDRO			

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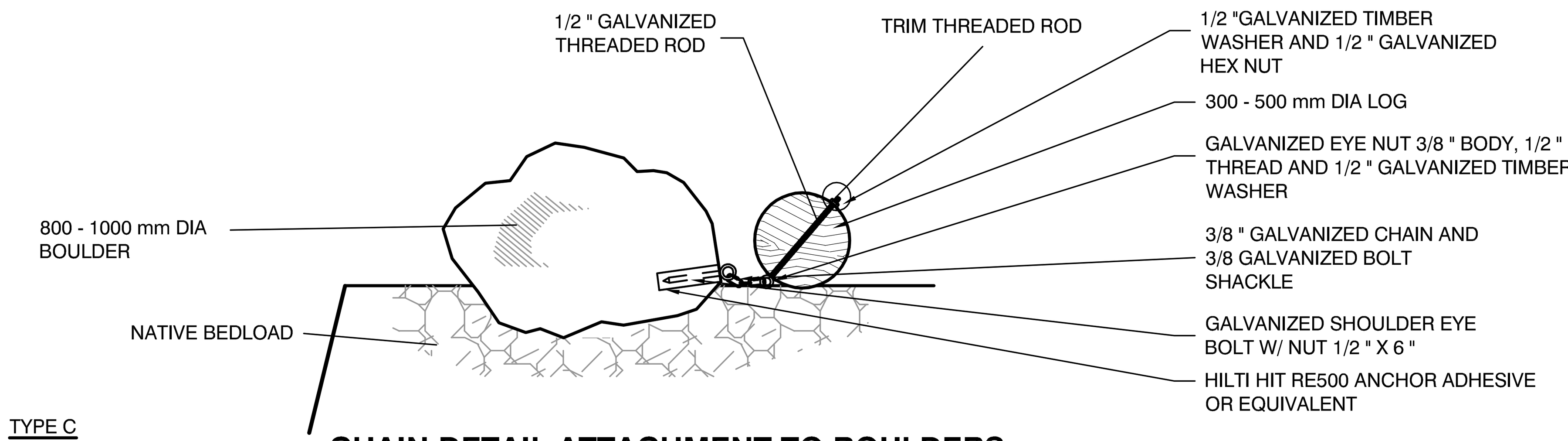
CHAIN DETAIL ATTACHMENT TO BOULDERS

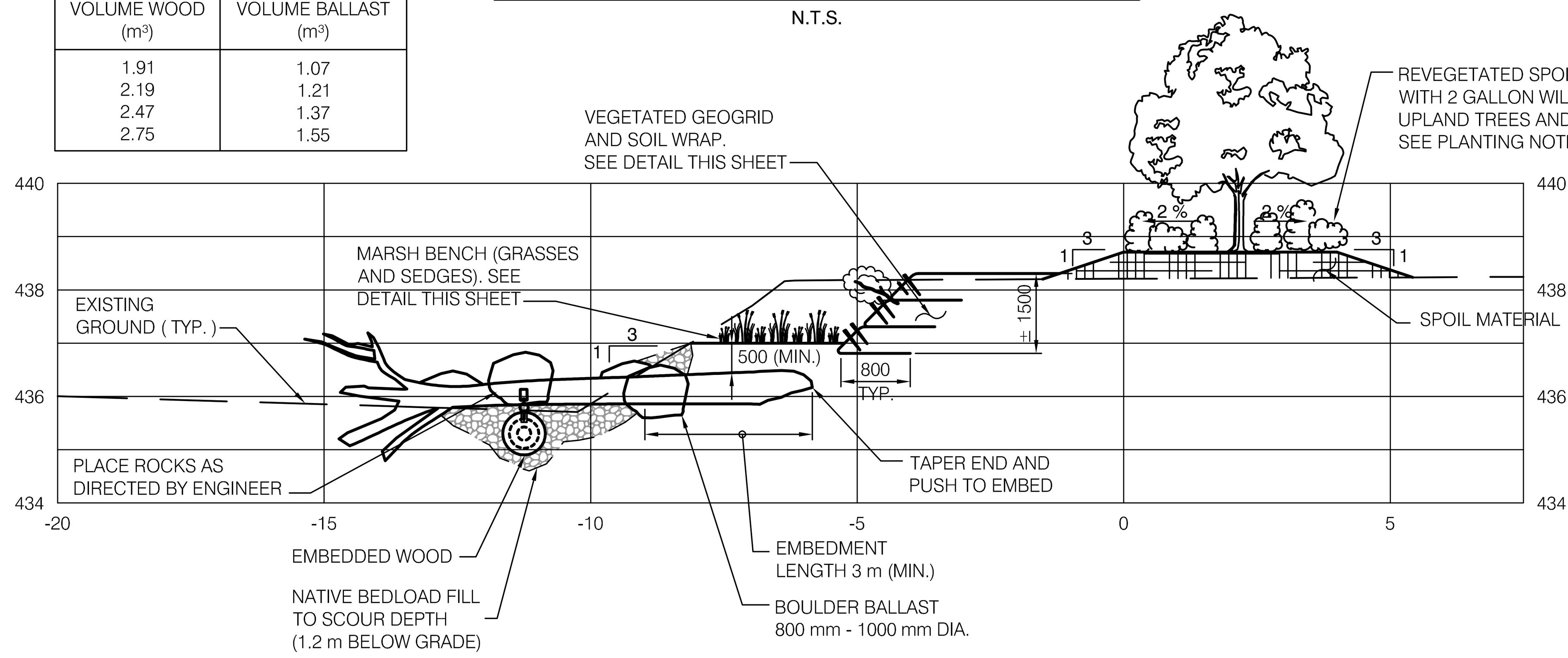


CHAIN DETAIL ATTACHMENT TO BOULDERS

N.T.S.

TYPE C

VOLUME WOOD (m^3)	VOLUME BALLAST (m^3)
1.91	1.07
2.19	1.21
2.47	1.37
2.75	1.55

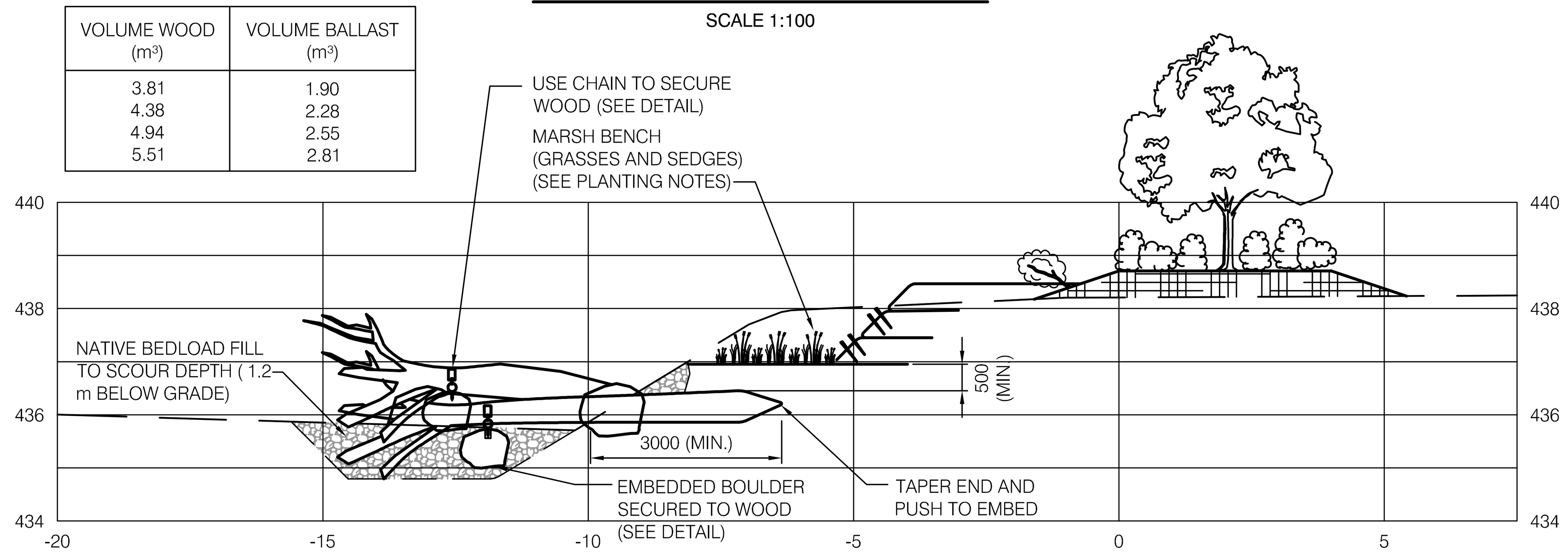


TYPE C - 2 LOG "T" STRUCTURE

SCALE 1:100

TYPE B

VOLUME WOOD (m^3)	VOLUME BALLAST (m^3)
3.81	1.90
4.38	2.28
4.94	2.55
5.51	2.81

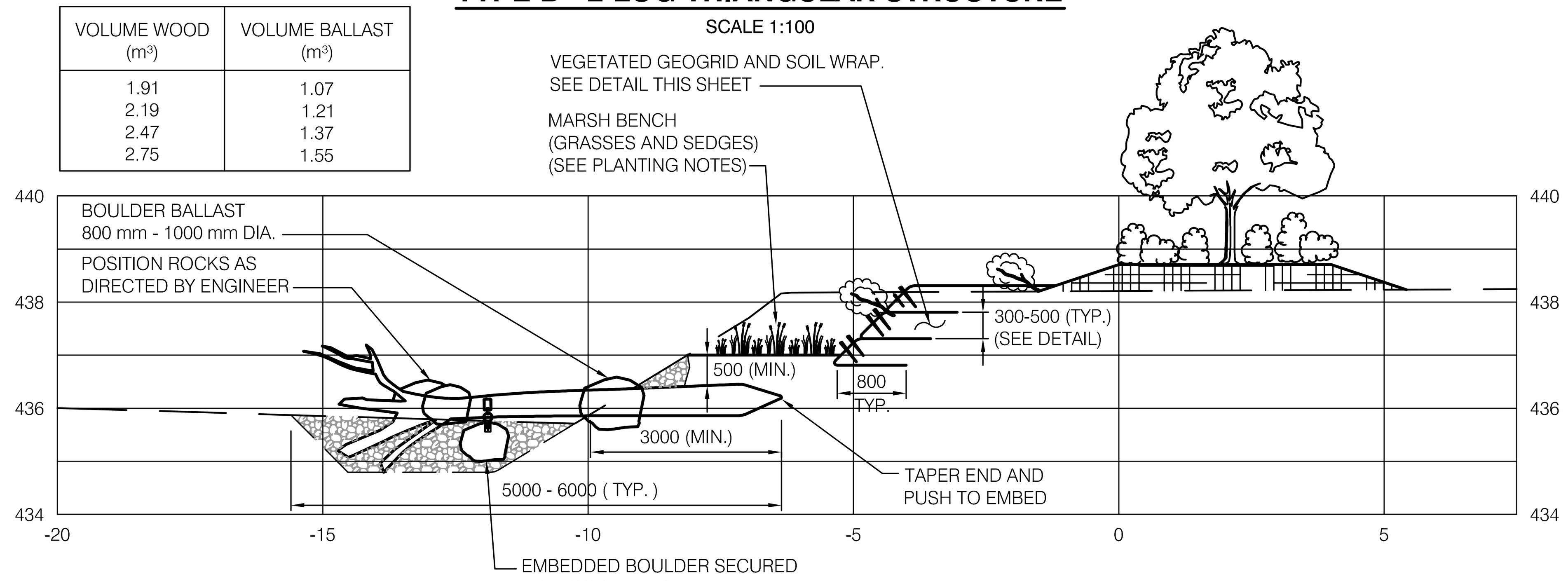


TYPE B - 2 LOG TRIANGULAR STRUCTURE

SCALE 1:100

TYPE A

VOLUME WOOD (m^3)	VOLUME BALLAST (m^3)
1.91	1.07
2.19	1.21
2.47	1.37
2.75	1.55



TYPE A - SINGLE LOG STRUCTURE

SCALE 1:100

0 1 (1:100) 5m

SUMMARY PLANT LIST

COMMON NAME	SPECIES NAME	BY AREA/LENGTH	STOCK SIZE	CALCULATE QUANTITY BASED ON
BIOENGINEERING PLANTINGS				
PACIFIC WILLOW	SALIX LUCIDA	30% BY BANK TREATMENT LENGTH	1.5 m CUTTING; 40 mm DIAMETER AT BUTT 0.65 m CUTTING; 40 mm DIAMETER AT BUTT	CALCULATE BASED ON 20 LIVESTAKES PER LINEAR METER OF BRUSH LAYER CALCULATE LIVESTAKES BY EITHER 30 cm OR 50 cm ON CENTRE SPACING BY AREA
SHRUB WILLOWS	SALIX BARCLAYI, SALIX BEBBIANA, SALIX DRUMMONDIANA	70% BY BANK TREATMENT LENGTH	1.5 m CUTTING; 40 mm DIAMETER AT BUTT 0.65 m CUTTING; 40 mm DIAMETER AT BUTT	CALCULATE BASED ON 20 LIVESTAKES PER LINEAR METER OF BRUSH LAYER CALCULATE LIVESTAKES BY EITHER 30 cm OR 50 cm ON CENTRE SPACING BY AREA
BLACK COTTONWOOD	POPULUS TRICHOCARPA	2 PLANTS PER 10 m OF BANK	1 GAL	THESE ARE ADDED TO THE FOUNDATION PLANTINGS OF WILLOW (NEED LINEAR METERS
MOUNTAIN ALDER	ALNUS INCANA	5 PLANTS PER 10 m OF BANK	1 GAL	THESE ARE ADDED TO THE FOUNDATION PLANTINGS OF WILLOW (NEED LINEAR METERS
RED-OSIER DOGWOOD	CORNUS SERICEA	5 PLANTS PER 10 m OF BANK	1 GAL	THESE ARE ADDED TO THE FOUNDATION PLANTINGS OF WILLOW (NEED LINEAR METERS
RIPARIAN (UPSLOPE) PLANTINGS				
SHRUB WILLOWS	SALIX BARCLAYI, SALIX BEBBIANA, SALIX DRUMMONDIANA	30% BY AREA	1 GAL	CALCULATE LIVESTAKES BY EITHER 30 cm OR 50 cm ON CENTRE SPACING BY AREA
MOUNTAIN ALDER	ALNUS INCANA	20% BY AREA	2 GAL	TREE SPACING IS 2.5 m ON CENTRE
PAPER BIRCH	BETULA PAPYRIFERA	15% BY AREA	2 GAL	TREE SPACING IS 2.5 m ON CENTRE
ENGLEMANN SPRUCE	PICEA ENGELMANNII	5% BY AREA	2 GAL	TREE SPACING IS 2.5 m ON CENTRE
WESTERN REDCEDAR	THUJA PLICATA	5% BY AREA	2 GAL	TREE SPACING IS 2.5 m ON CENTRE
RED-OSIER DOGWOOD	CORNUS SERICEA	10% BY AREA	1 GAL	TREE SPACING IS 1.5 m ON CENTRE
THIMBLEBERRY	RUBUS PARVIFLORUS	5% BY AREA	1 GAL	TREE SPACING IS 1.5 m ON CENTRE
SASKATOONBERRY	AMELANCHIER ALNIFOLIA	5% BY AREA	1 GAL	TREE SPACING IS 1.5 m ON CENTRE
BLACK TWINBERRY	LONICERA INVOLUCRATA	5% BY AREA	1 GAL	TREE SPACING IS 1.5 m ON CENTRE
MARSH BENCH PLANTINGS				
SEDGES	CAREX LENTICULARIS, CAREX UTICULATA, CAREX AQUATALIS	85% BY AREA	25 mm DIAMETER PLUG	SEDGE AND GRASS SPACING IS 30 CM ON CENTRE
COMMON SPIKE RUSH	ELEOCHARIS PALUSTRIS	5% BY AREA	25 mm DIAMETER PLUG	SEDGE AND GRASS SPACING IS 30 CM ON CENTRE
REDTOP	AGROSTIS GIGANTEA	10% BY AREA	25 mm DIAMETER PLUG	SEDGE AND GRASS SPACING IS 30 CM ON CENTRE

NOTES ON PLANTING:

GENERAL PLANTING
1. ALL PLANT MATERIALS CONFORMED TO BCSLA / BCNTA LANDSCAPE STANDARD.
2. SUPPLIES OF WILLOW LIVE STAKES AND BRUSH LAYERS APPROVED BY PROJECT BIOLOGIST PRIOR TO ON-SITE DELIVERY INCLUDING LOCATION AND TIMING OF HARVEST.
3. WILLOW BRUSH LAYERS AND LIVESTAKES PROTECTED FROM DESSICATION DURING STORAGE AND INSTALLATION.
4. NO SUBSTITUTIONS WITHOUT APPROVAL FROM PROJECT BIOLOGIST.

VEGETATED GEOGRID - WILLOW BRUSH LAYERS
1. WILLOW FOR BRUSH LAYERS WAS 1.5 m LONG AND 40 mm MINIMUM DIAMETER AT BUTT AND 20 mm MINIMUM DIAMETER AT TOP.
2. ALL WILLOW WAS SALIX LUCIDA, SALIX BARCLAYI, SALIX BEBBIANA, SALIX DRUMMONDIANA OR SUBSTITUTE APPROVED BY PROJECT BIOLOGIST.
3. AVERAGE OF 20 STEMS PER METER.
4. BRUSH LAYERS STAGGERED BETWEEN WRAP LAYERS TO CREATE A CHECKERBOARD PATTERN.
5. INSTALLED BRUSH LAYERS AT VARIABLE ANGLES (HORIZONTALLY WITHIN WRAP STRUCTURE) TO PROMOTE ROOT DEVELOPMENT.

VEGETATED GEOGRID - WILLOW LIVE STAKES
1. WILLOW FOR BRUSH LAYERS WAS 0.65 m LONG AND 40 mm MINIMUM DIAMETER AT BUTT AND 20 mm MINIMUM DIAMETER AT TOP.
2. ALL WILLOW WAS SALIX LUCIDA, SALIX BARCLAYI, SALIX BEBBIANA, SALIX DRUMMONDIANA OR SUBSTITUTE APPROVED BY PROJECT BIOLOGIST.
3. WILLOW LIVESTAKES DRIVEN AT ANGLES; DEPTH INTERSECTED AT LEAST BRUSH LATER INTERFACE.
4. WILLOW LIVESTAKES DRIVEN AT 500 mm SPACINGS IN EACH WRAP AND STAGGERED BETWEEN SUCCESIVE LAYERS.

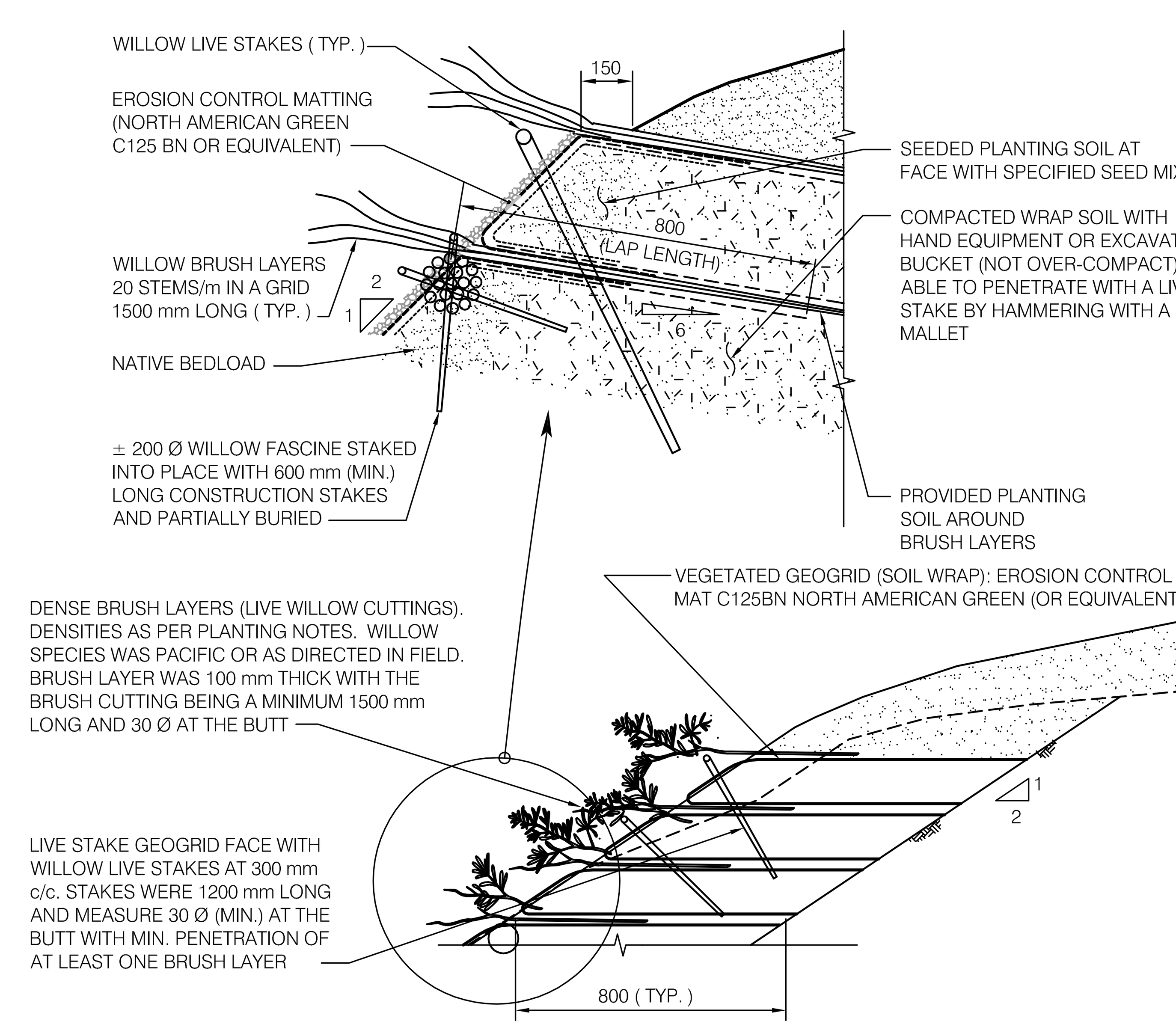
VEGETATED GEOGRID - WILLOW FASCINE
1. WILLOW FOR FASCINES WAS A MINIMUM OF 1.0 m LONG AND 40 mm MINIMUM DIAMETER AT BUTT AND 15 mm MINIMUM DIAMETER AT TOP.
2. ALL WILLOW WAS HOOKER'S WILLOW (SALIX HOOKERIANA) OR SUBSTITUTE APPROVED BY PROJECT BIOLOGIST.
3. FASCINES COMPOSED OF A OVERLAPPING WILLOW STEMS WITH A MINIMUM OF 10 STEMS AT ANY POINT.
4. FASCINES TIED WITH JUTE CORD OR SIMILAR BIODEGRADABLE SUBSTITUTE EVERY 300 mm.

VEGETATED GEOGRID - SEEDING
1. SEEDED THE OUTER FACE OF EACH GEOGRID WRAP PRIOR TO CLOSURE WITH RICHARDSON'S COASTAL RECLAMATION MIX OR AN APPROVED SUBSTITUTE AT THE MANUFACTURES RECOMMENDED RATE OF APPLICATION.

MARSH BENCH
1. INSTALLED 25 mm DIAMETER PLUGS OF SEDGES, RUSHES AND GRASSES.

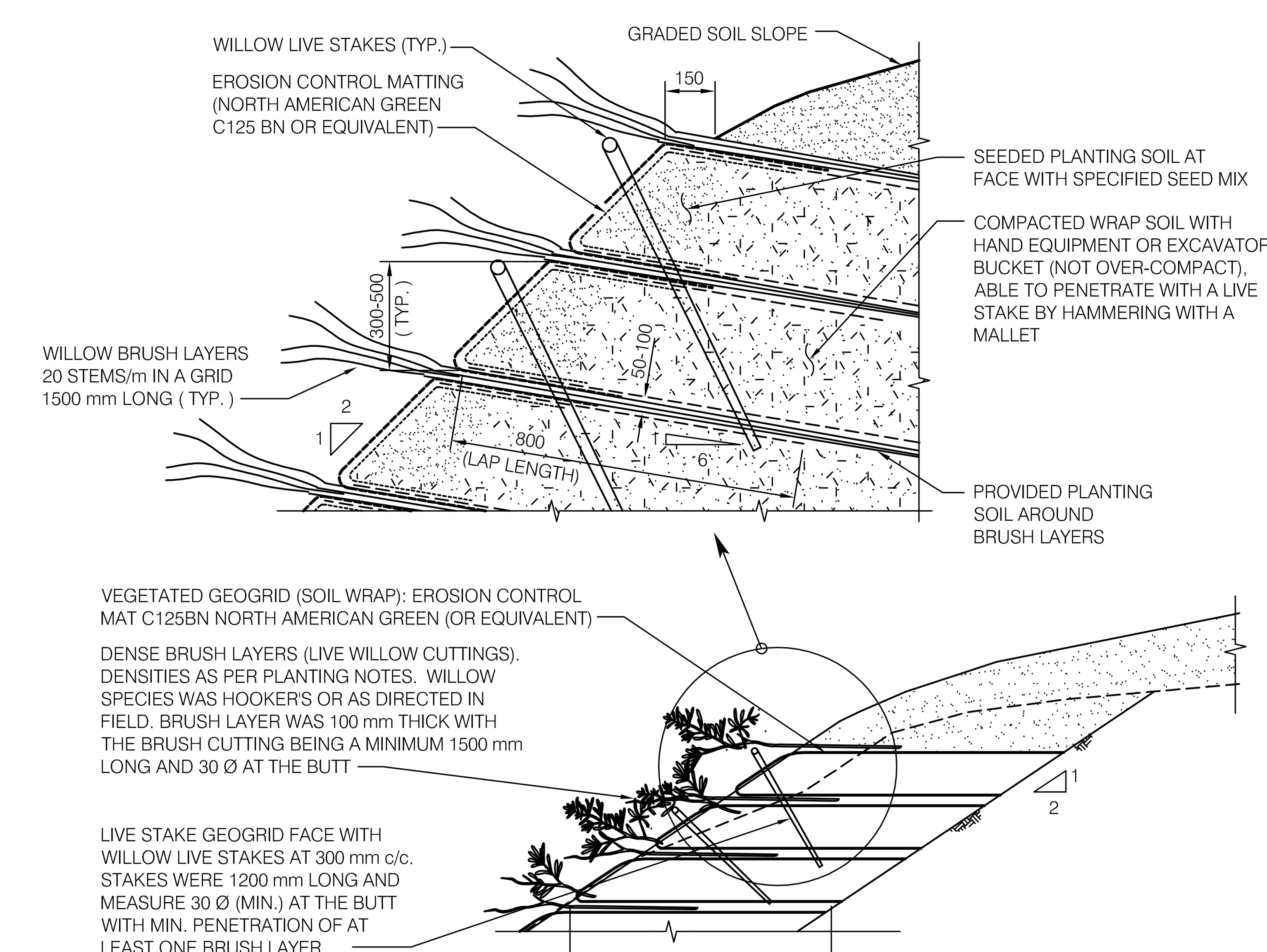
RIPRARIAN - SEEDING, SHRUBS AND TREE PLANTINGS
1. 1 AND 2 GALLON SHRUBS (SEE PLANTING LIST FOR LISTS OF SPECIES) PLANTED AT SPACING GIVEN IN PLANT LIST.
2. BROADCAST SEEDED ALL EXPOSED SOIL IN THE RIPARIAN PLANTING ZONE WITH RICHARDSON'S INTERIOR REVEGETATION MIX, AT THE MANUFACTURER'S SPECIFIED RATES (OR APPROVED EQUAL).
3. CLUMP CONSISTED OF 10 TO 15 PLANT IN IRREGULAR PATCHES OF SAME SPECIES.

MODIFIED BRUSH LAYERS
1. WILLOW FOR MODIFIED BRUSH LAYERS WAS 1.5 m LONG AND 40 mm MINIMUM DIAMETER AT BUTT AND 20 mm MINIMUM DIAMETER AT TOP.
2. ALL WILLOW WAS SALIX LUCIDA, SALIX BARCLAYI, SALIX BEBBIANA, SALIX DRUMMONDIANA OR SUBSTITUTE APPROVED BY PROJECT BIOLOGIST.
3. AVERAGE OF 20 STEMS PER METER.
4. MODIFIED BRUSH LAYERS STAGGERED TO CREATE A CHECKERBOARD PATTERN.
5. INSTALLED MODIFIED BRUSH LAYERS AT VARIABLE ANGLES (HORIZONTALLY) TO PROMOTE ROOT DEVELOPMENT.



VEGETATED GEOGRID - SOIL WRAP WITH WILLOW FASCINE (SECTION) DETAIL

N.T.S.



VEGETATED GEOGRID - SOIL WRAP (SECTION) DETAIL

N.T.S.

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

SAVED 21-Aug-2012 4:19 PM

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Reference			
Approvals	A1	JUN.10/10	-
Tender			
Permits	P0	APR.15/11	-
Construction			
Record Drawings			

REVISION INFORMATION

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	JAN.19/10	SJL	BVC	DTM	
1	JUN.10/10	SJL	MP	DTM	REVISED NOTES
2	APR.15/11	SJL	SC	DTM	ISSUED FOR PERMIT
3	DEC.23/10	SJL	BVC	DTM	ISSUED FOR 2011 PROGRESS REPORTING
4	JUL.27/12	SJL	BVC	DTM	ISSUED FOR 2012 PROGRESS REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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BC HYDRO
MID COLUMBIA RIVER BANK PROTECTION WORKS
STANDARD DETAILS

KWL Project No. 478-119		Scale AS SHOWN	SD1
Sheet 09 of 9		Rev. No. 4	Drawing Number
Client: BC HYDRO			

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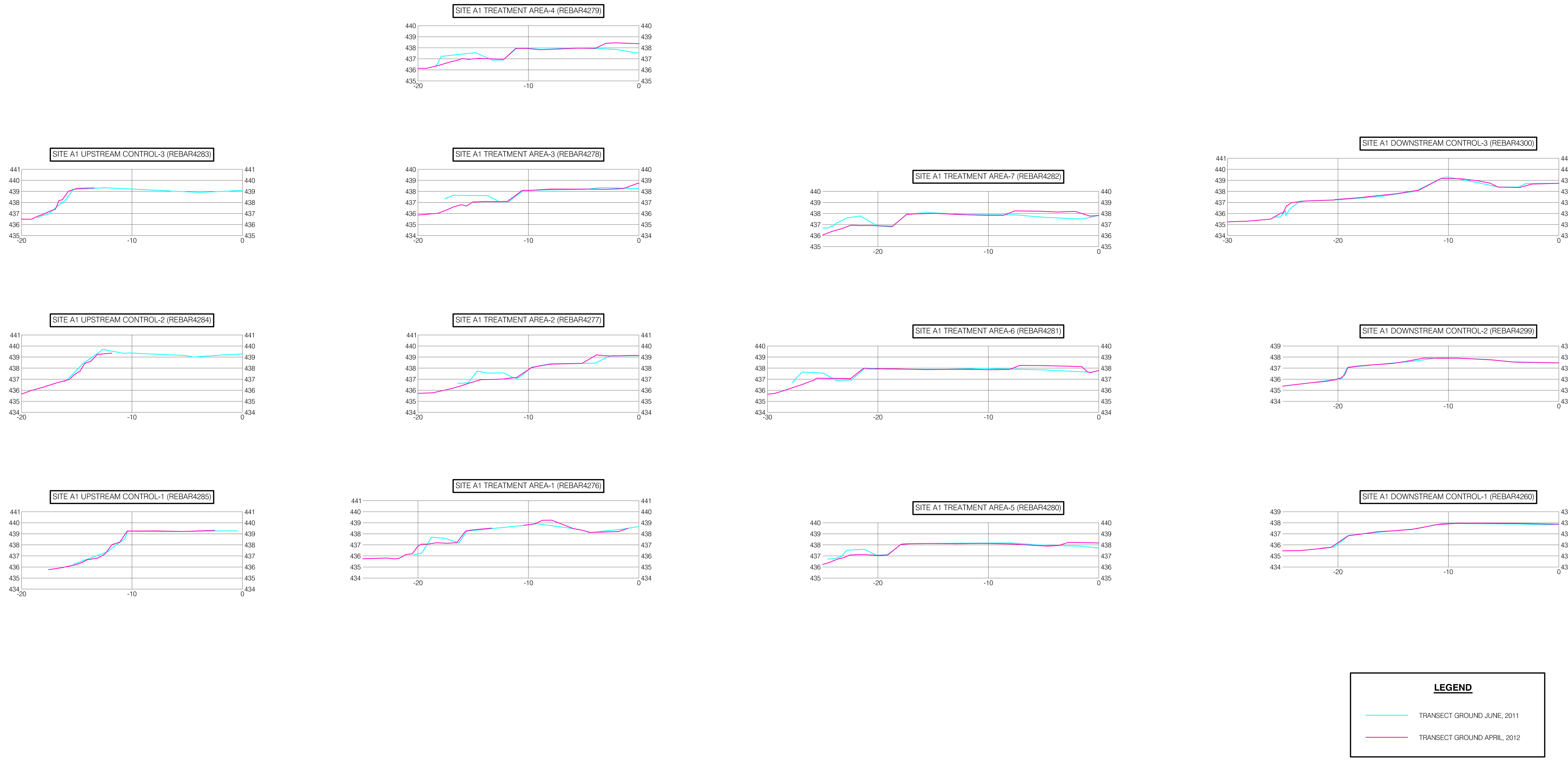
Appendix B
CLBWORKS#35 Survey and Cross-section Drawings



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Reference			
Approvals			
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Permits			
Construction			
Record Drawings			

REVISION INFORMATION Rev. No.	Date	Designed	Drawn	Checked	Description of Revision	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						

Seal

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REVELSTOKE BIOENGINEERING SITE WORKS SITE A1 SECTIONS

KWL Project No. 478.119
Scale 1:200
Sheet 1 of 4
Rev. No. 0
SW1 Drawing Number
Client: BC HYDRO

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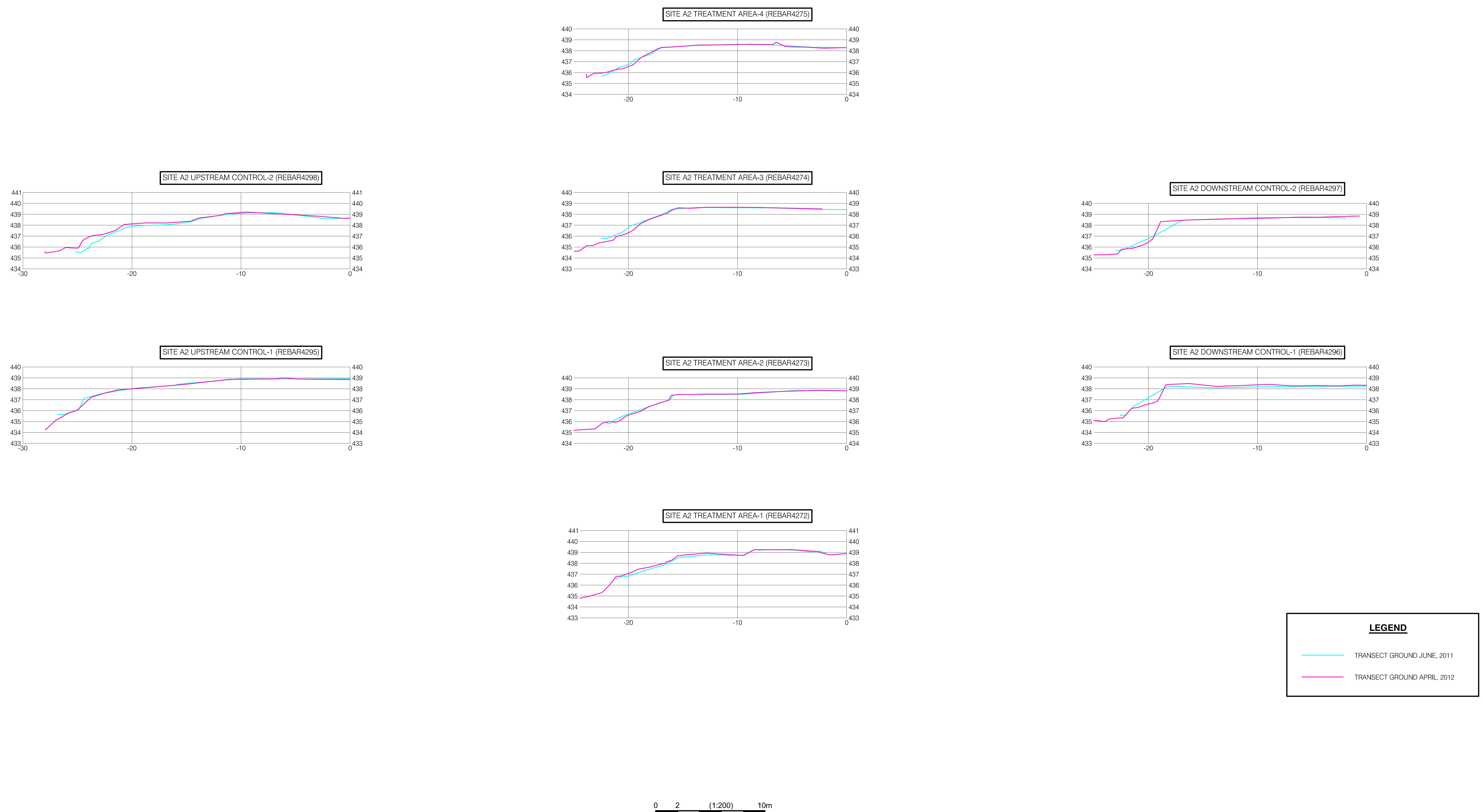

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Permits			
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Record Drawings			

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0	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						

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REVELSTOKE BIOENGINEERING SITE WORKS SITE A2 SECTIONS

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Sheet	2 of 4	Rev. No.	0

SW2
Drawing Number

Client: BC HYDRO

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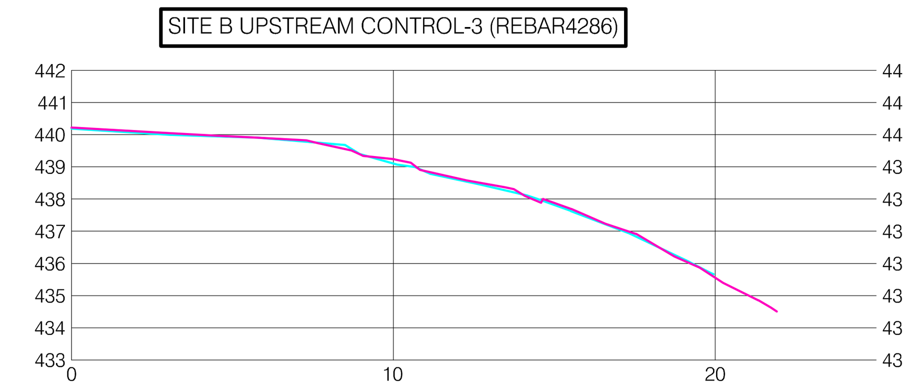

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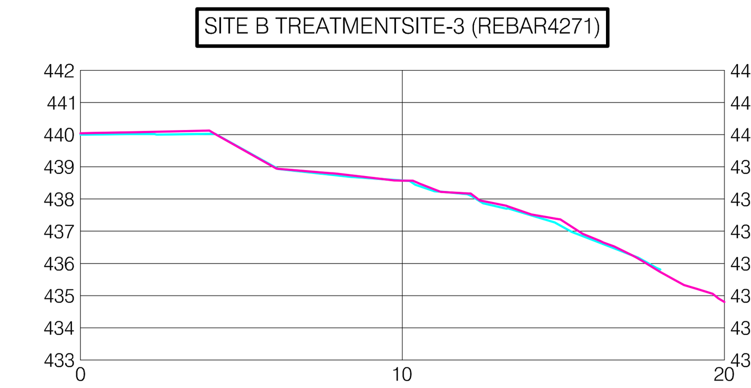

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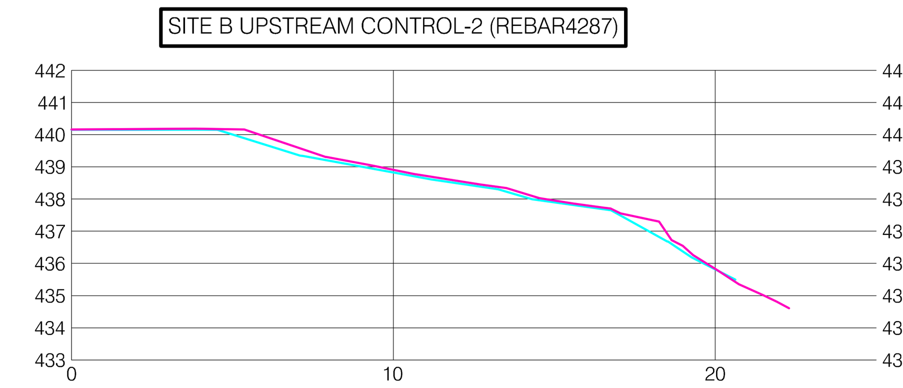

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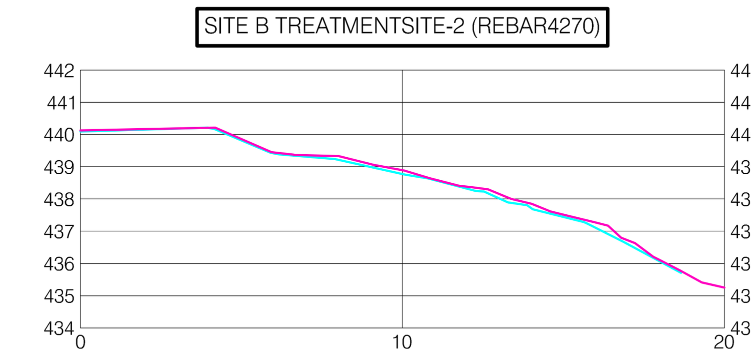

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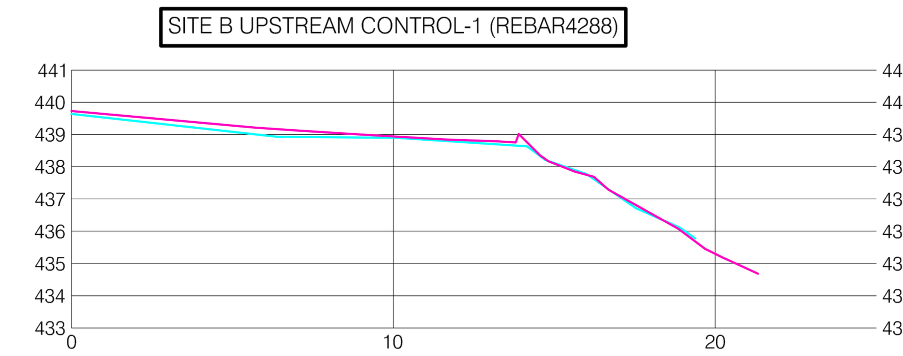

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LEGEND

TRANSECT GROUND JUNE, 2011

TRANSECT GROUND APRIL, 2012

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Approvals			
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0	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						

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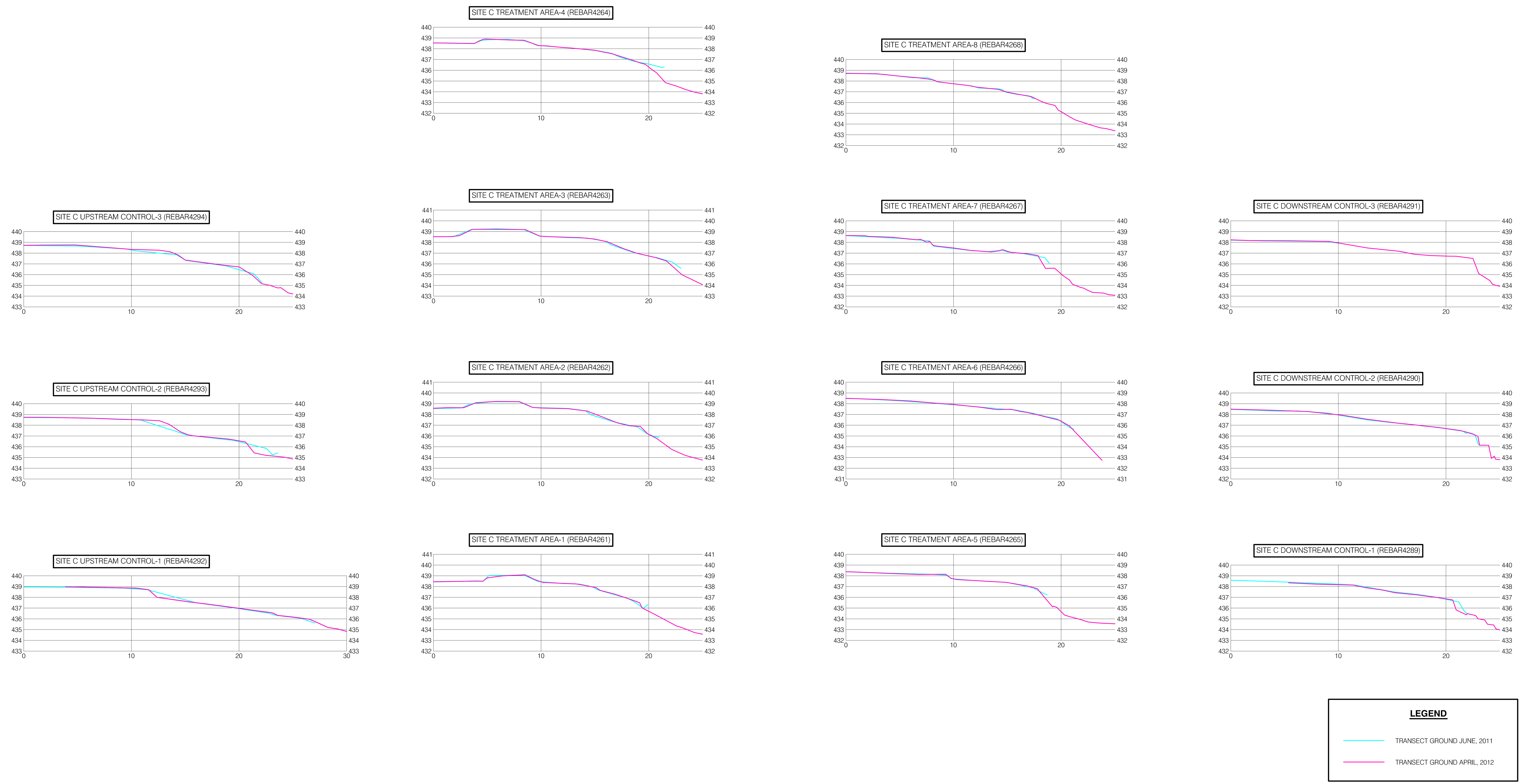
REVELSTOKE BIOENGINEERING
SITE WORKS
SITE B SECTIONS

KWL Project No.	478.119	Scale	1:200
Sheet	3 of 4	Rev. No.	0

SW3
Drawing Number

Client: BC HYDRO



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Tender			
Permits			
Construction			
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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REVELSTOKE BIOENGINEERING SITE WORKS SITE C SECTIONS

KWL Project No.	478.119	Scale	1:200
Sheet	4 of 4	Rev. No.	0
Client: BC HYDRO		Drawing Number	SW4

Appendix C
CLBWORKS#36 Survey and Cross-section Drawings

MONITORING SITE 1 - PLAN

1:100

MONITORING SITE 1 - SECTIONS

1:200H, 1:200V

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Issued for	Issue	Date	Issued By
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Permits			
Construction			
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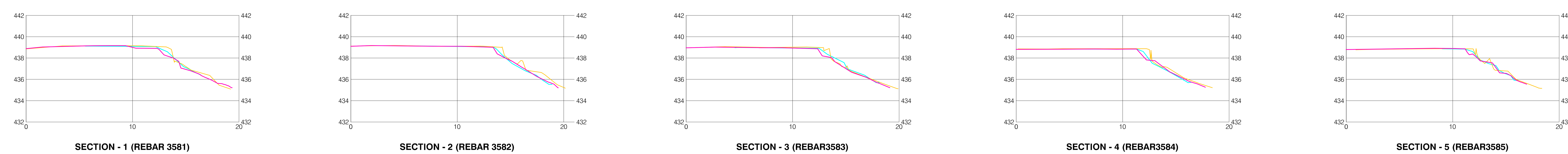
BC HYDRO
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #1

KWL Project No.	478.120	Scale	AS SHOWN
Sheet	01 of 27	Rev. No.	1
Client: BC HYDRO			

MON 1
Drawing Number

MONITORING SITE 2 - PLAN

1:100



MONITORING SITE 2 - SECTIONS

1:200H, 1:200V

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Issued for	Issue	Date	Issued By
Reference			
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #2

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Client: BC HYDRO		Drawing Number	MON 2

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MONITORING SITE 3 - PLAN

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #3

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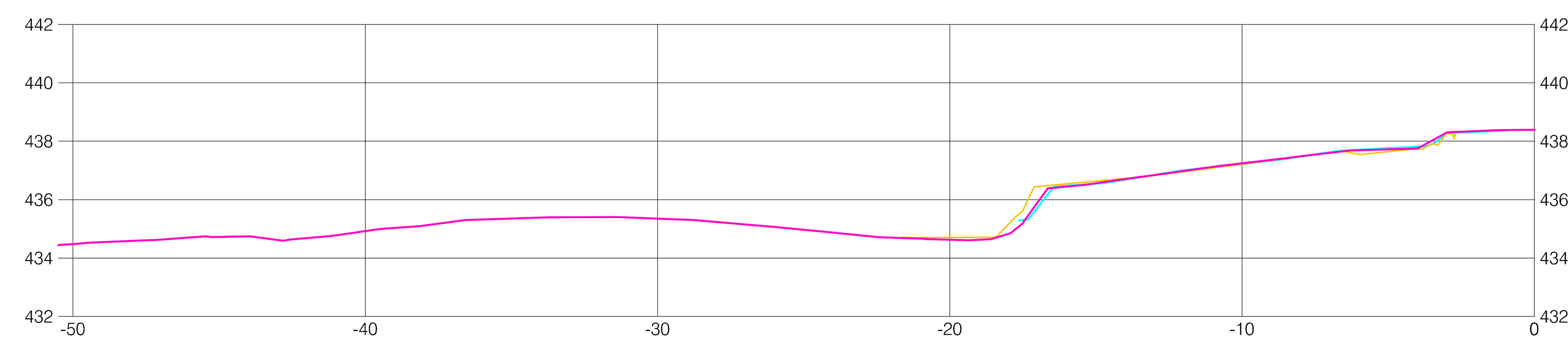
Sheet 03 of 27		Rev. No. 1	Drawing Number
Client: BC HYDRO			



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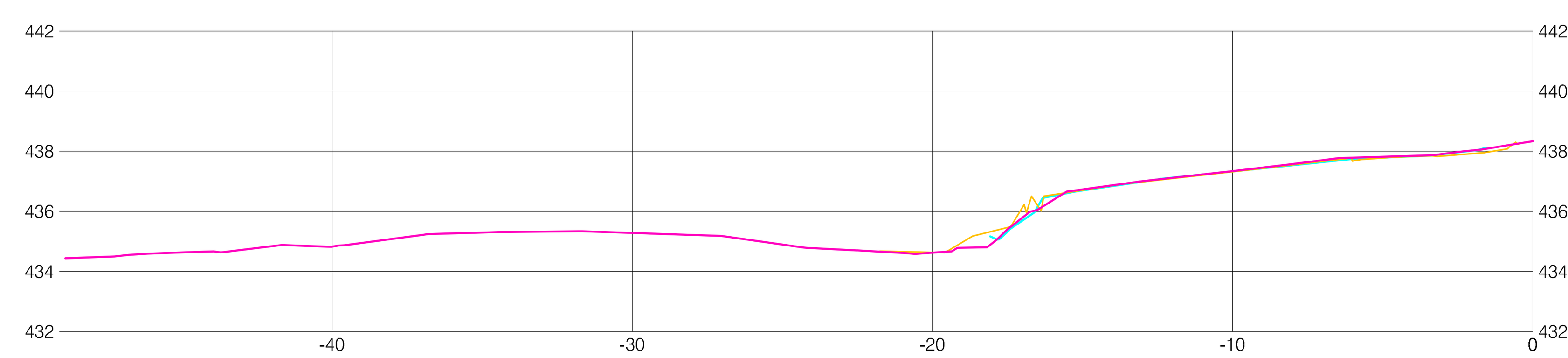

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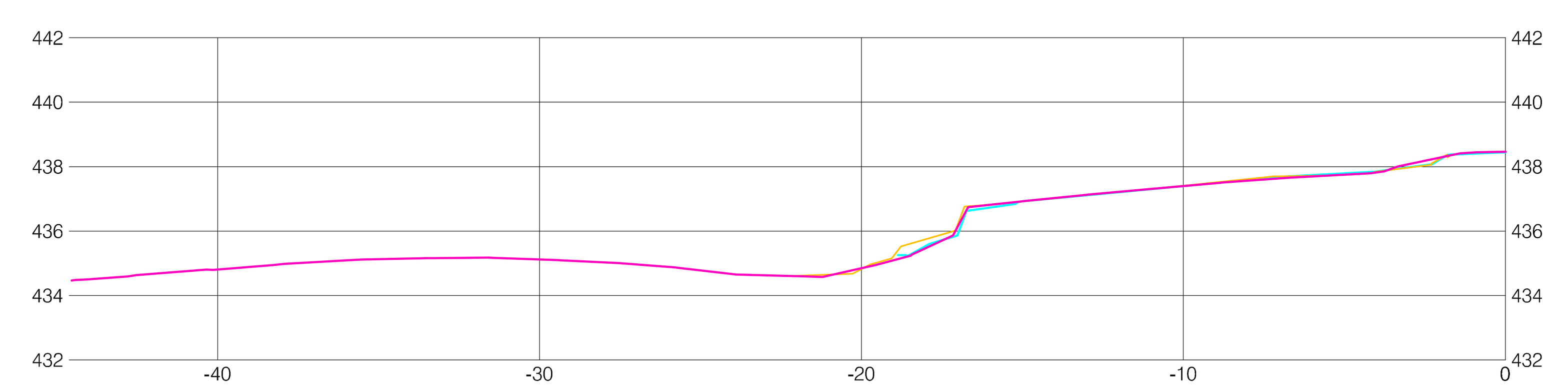

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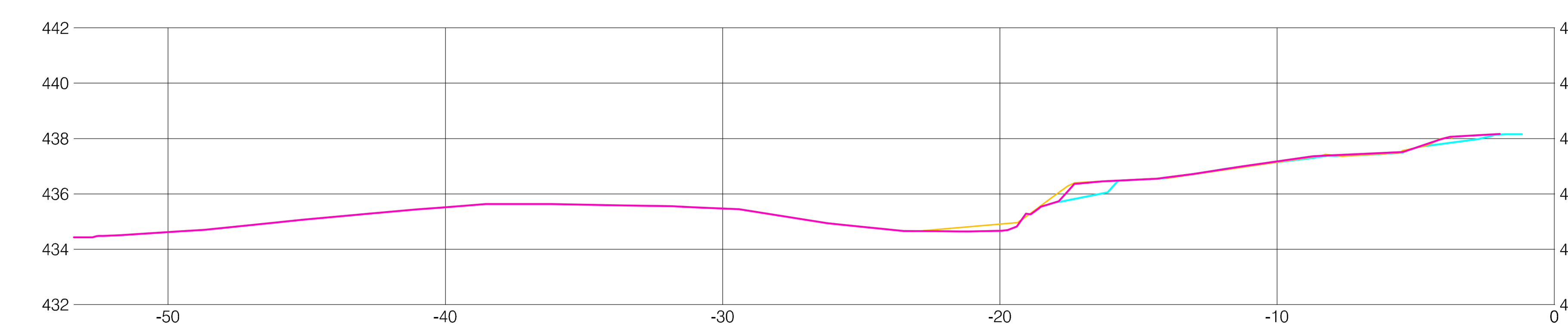

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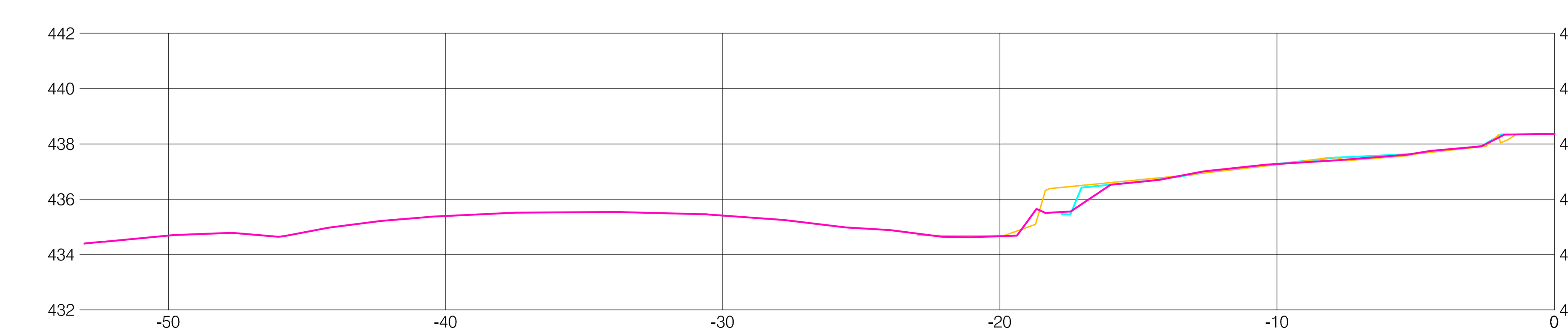

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- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

MONITORING SITE 3 - SECTIONS

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AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

SAVED 19-Jul-2012 3:18 PM

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Approvals			
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1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #3 - SECTIONS

KWL Project No.	478.120	Scale	1:200 H 1:200 V
Sheet	04 of 27	Rev. No.	1
Client: BC HYDRO			

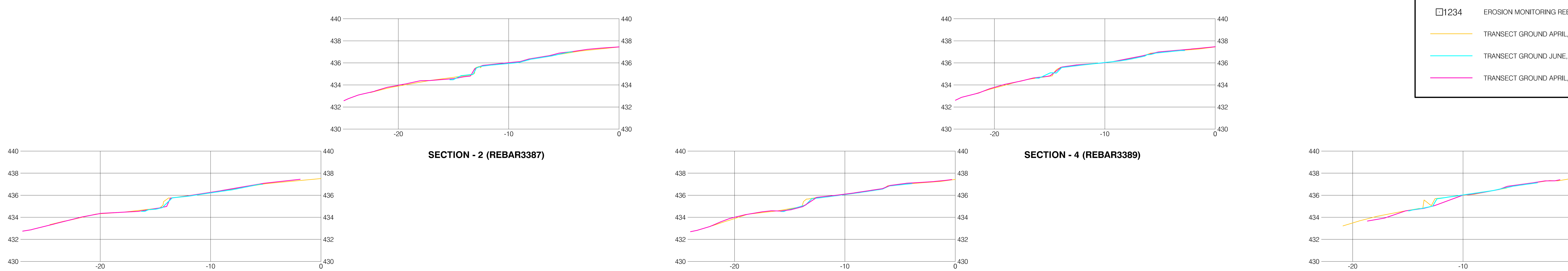
MON 3A
Drawing Number

MONITORING SITE 4 - PLAN

1:100

LEGEND

- ○1234 TRANSECT CONTROL REBAR
- □1234 EROSION MONITORING REBAR
- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012



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SECTION - 4 (REBAR3389)

SECTION - 1 (REBAR3386)

SECTION - 3 (REBAR3388)

SECTION - 5 (REBAR3390)

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MONITORING SITE 4 - SECTIONS

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #4

KWL Project No.	478.120	Scale	AS SHOWN
Sheet	05 of 27	Rev. No.	1
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MON 4
Drawing Number

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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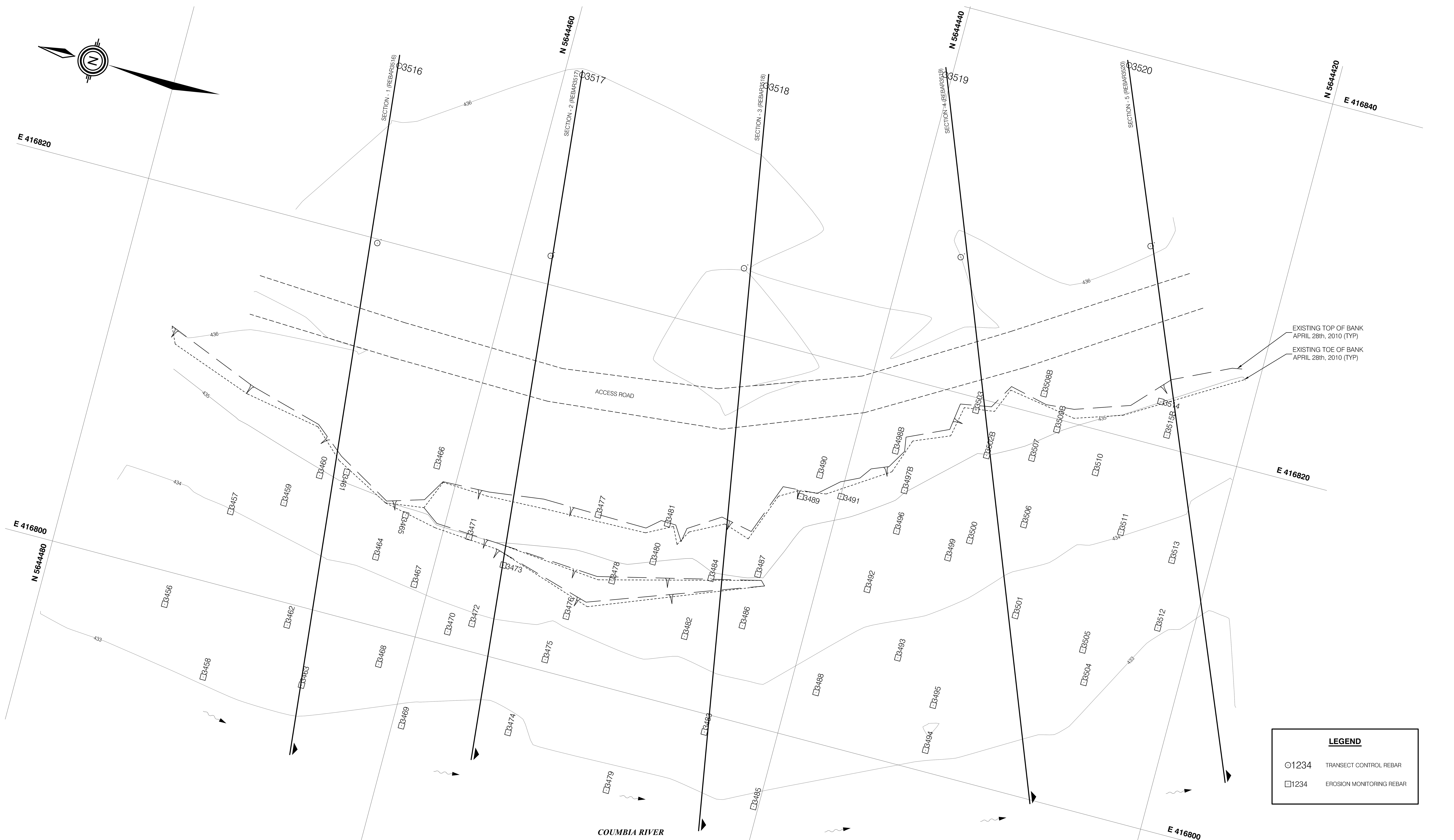

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Approvals			
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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BC HYDRO
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #5

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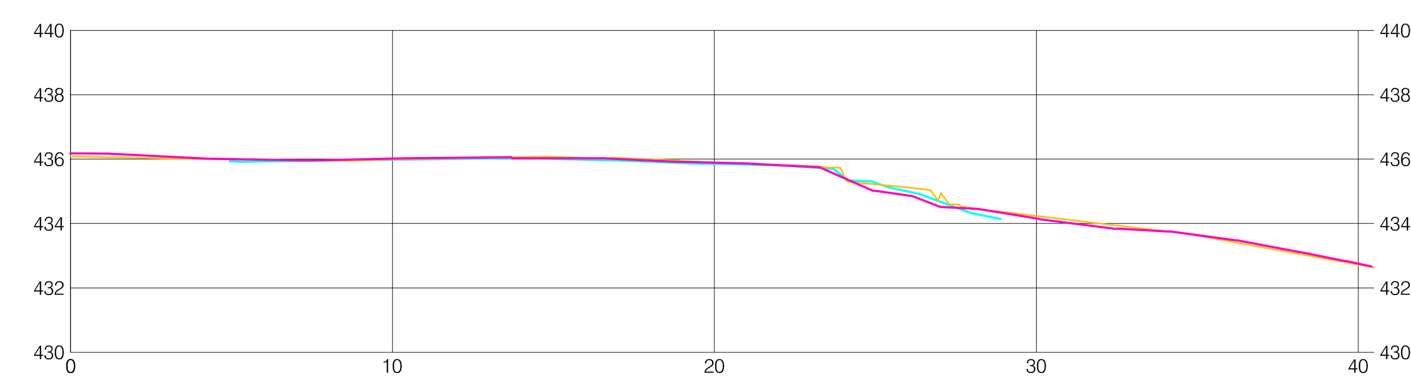
Sheet	06 of 27	Rev. No.	1
Client: BC HYDRO			

MON 5
Drawing Number



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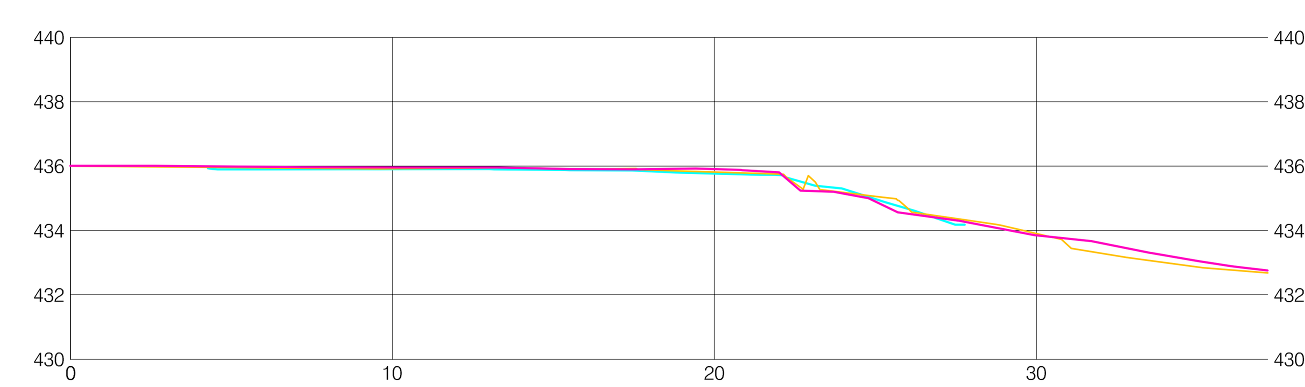

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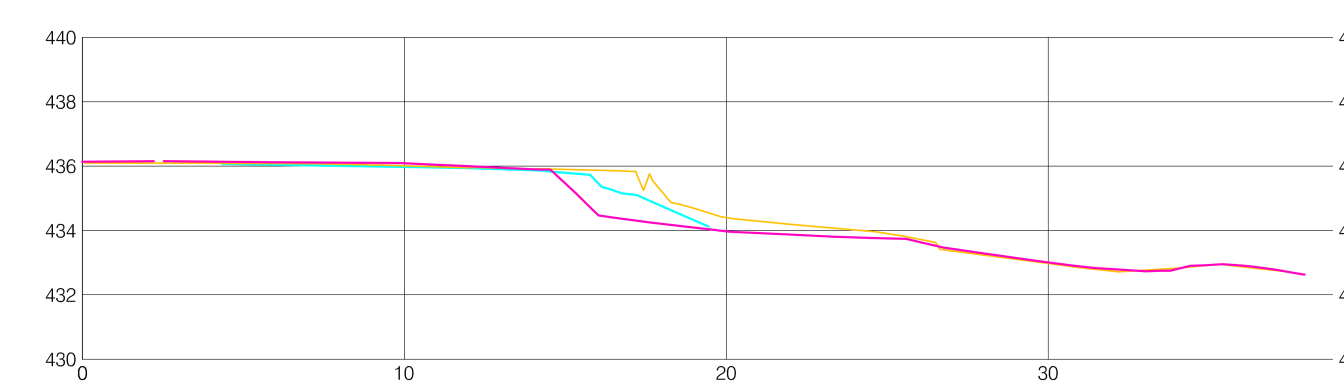

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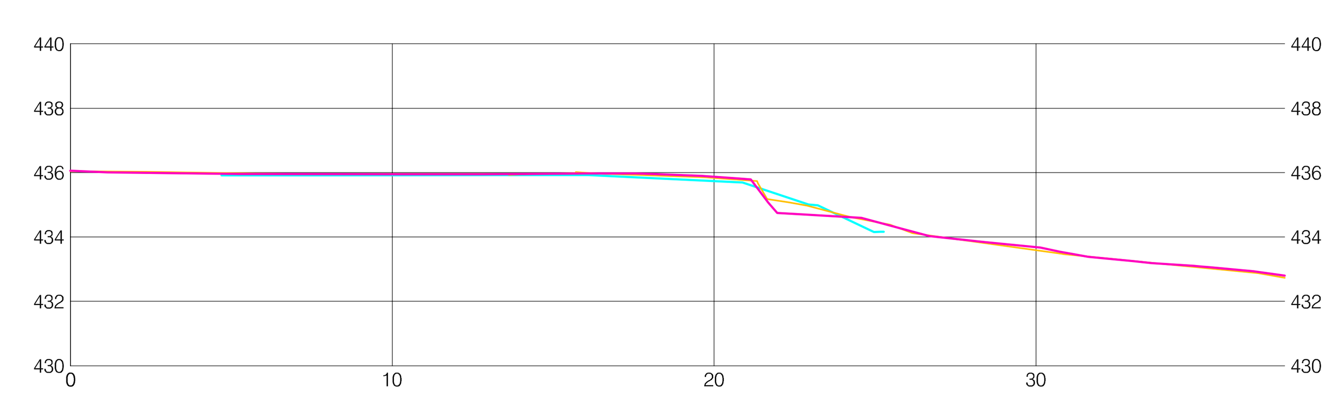

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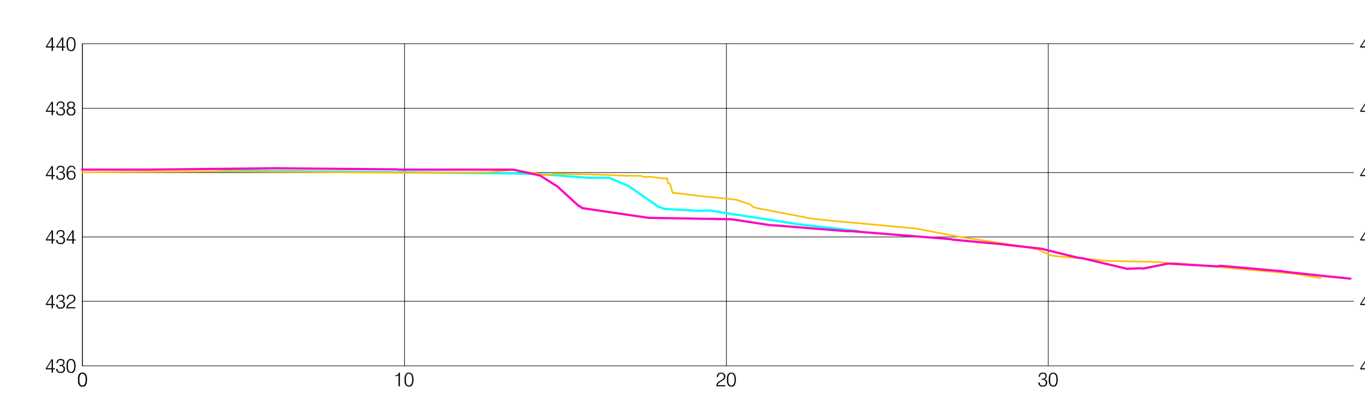

SECTION -4 (REBAR3519)

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- TRANSECT GROUND APRIL, 2012

MONITORING SITE 5 - SECTIONS

1:200H, 1:200V

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ISSUED INFORMATION Issued for	Issue	Date	Issued By
Reference			
Approvals			
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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #5 - SECTIONS

KWL Project No. 478.120 Scale 1:200 H 1:200 V

Sheet 07 of 27 Rev. No. 1

MON 5A Drawing Number

Client: BC HYDRO

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AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

MONITORING SITE 6 - PLAN

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SAVED 20-Jul-2012 8:45 AM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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BC HYDRO
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #6

KWL Project No.	478.120	Scale	1:100
Sheet	08 of 27	Rev. No.	1
Client: BC HYDRO			

MON 6
Drawing Number

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

SAVED 20-Jul-2012 8:38 AM

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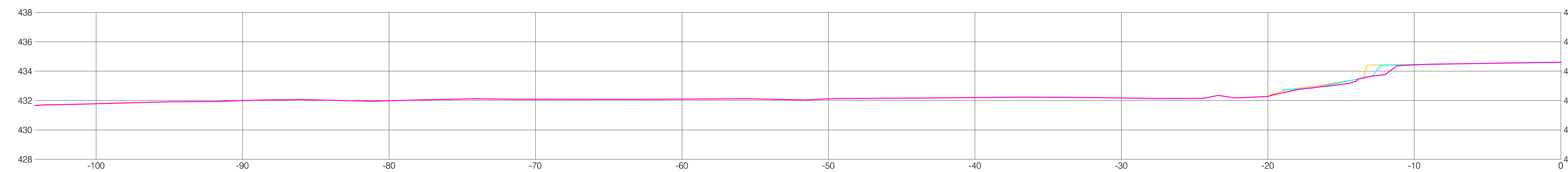

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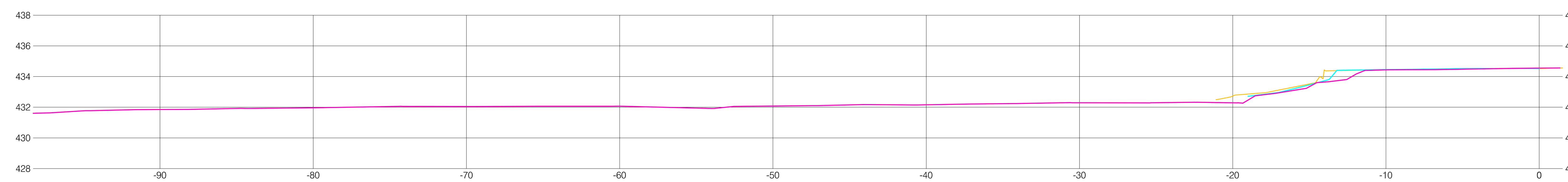

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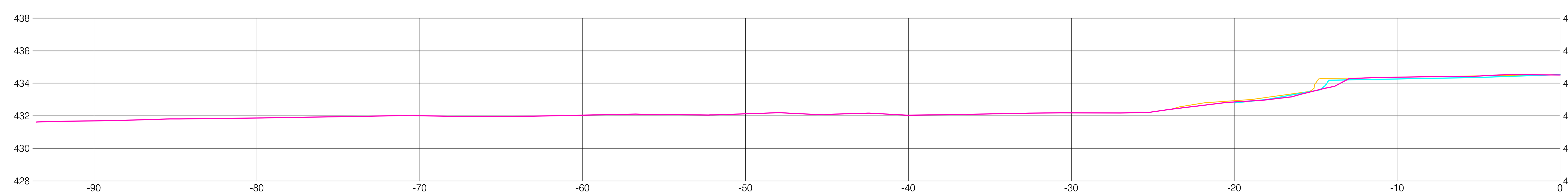

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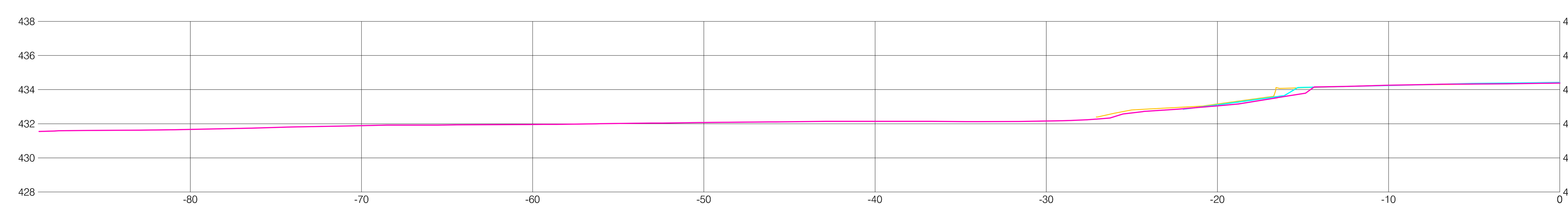

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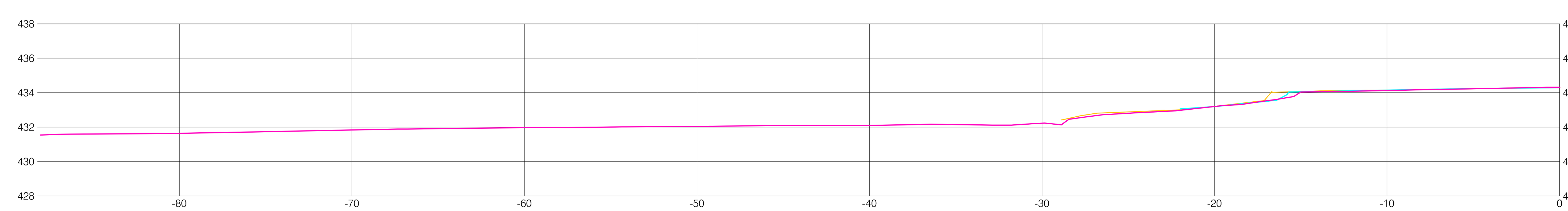

SECTION - 1 (REBAR3451)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

0 2 (1:200) 10m

MONITORING SITE 6 - SECTIONS

1:200H, 1:200V

ISSUED INFORMATION	Issued for	Issue	Date	Issued By
	Reference			
	Approvals			
	Tender			
	Permits			
	Construction			
	Record Drawings			

REVISION INFORMATION	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
	0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
	1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #6 - SECTIONS

KWL Project No. 478.120		Scale 1:200 H 1:200 V	**MON 6A**
Sheet 09 of 27		Rev. No. 1	Drawing Number
Client: BC HYDRO			

MONITORING SITE 7 - PLAN

1:100

0 1 (1:100) 5m

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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Permits			
Construction			
Record Drawings			

REVISION INFORMATION: Rev. No.	Date	Designed	Drawn	Checked	Description of Revision	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #7

KWL Project No.	478.120	Scale	1:100
Sheet	10 of 27	Rev. No.	1
Client: BC HYDRO			

MON 7
Drawing Number

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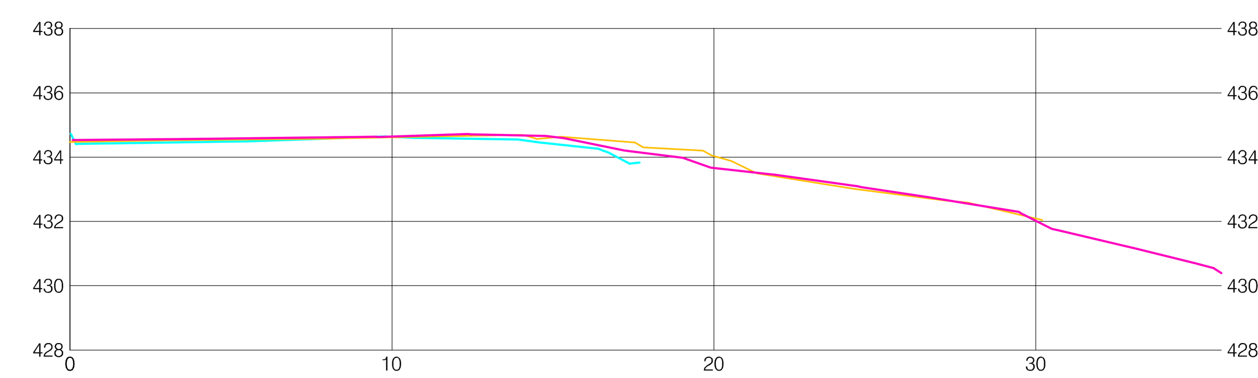
SAVED 20-Jul-2012 9:14 AM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.



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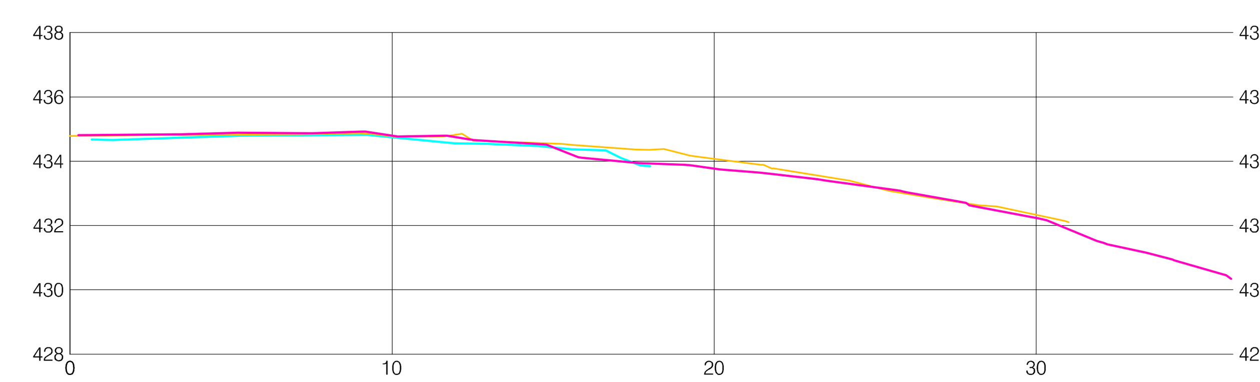


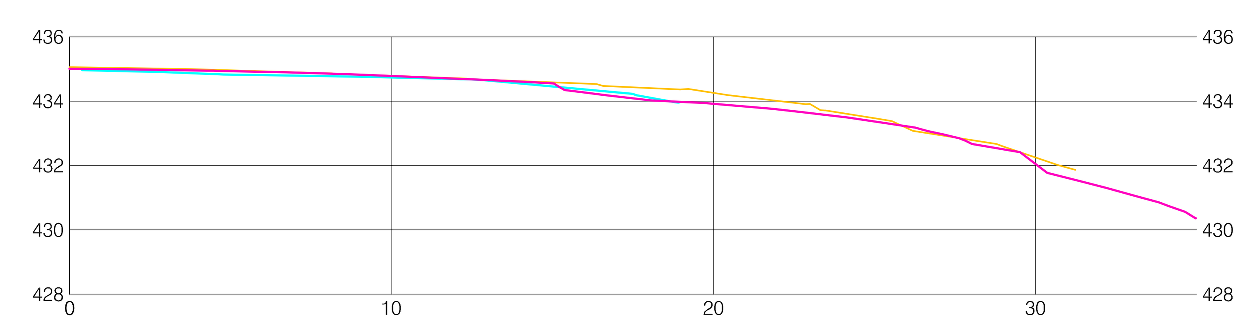
SECTION - 2 (REBAR3324)

LEGEND

TRANSECT GROUND APRIL, 2010

TRANSECT GROUND JUNE, 2011

TRANSECT GROUND APRIL, 2012



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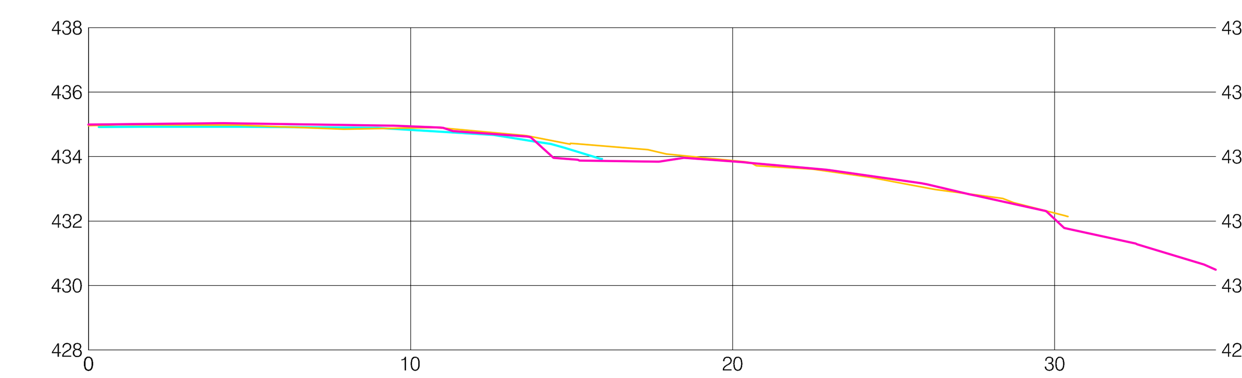

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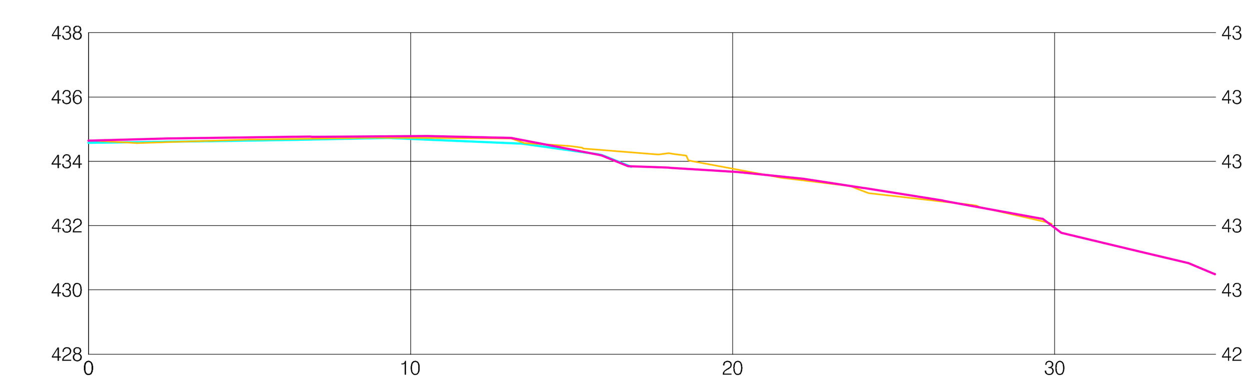

SECTION - 4 (REBAR3322)

MONITORING SITE 7 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

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Permits			
Construction			
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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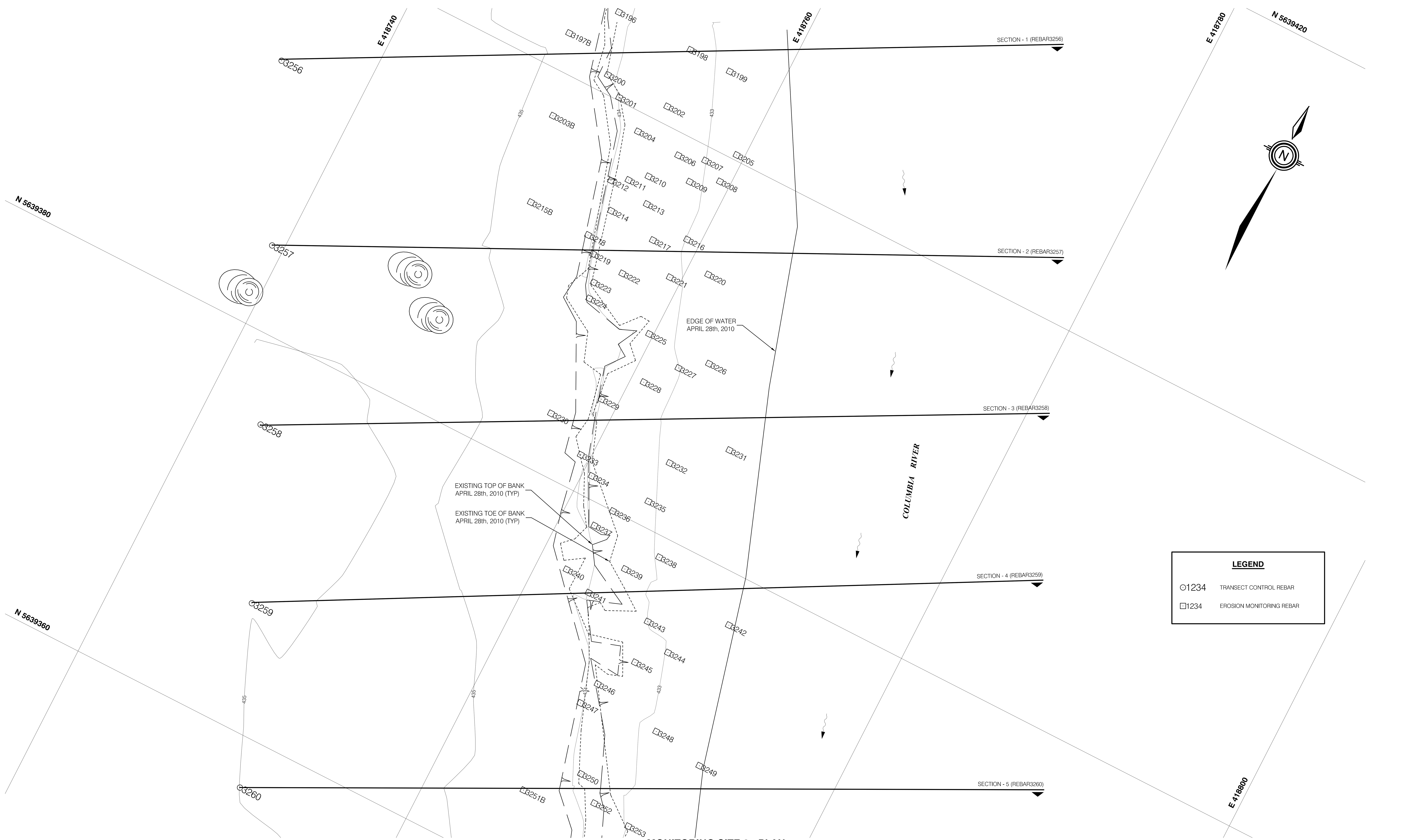
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #7 - SECTIONS

KWL Project No. 478.120 | Scale 1:200 H 1:200 V

Sheet 11 of 27 | Rev. No. 1

MON 7A
Drawing Number

Client: BC HYDRO



MONITORING SITE 8 - PLAN

1:100

SAVED 20-Jul-2012 10:09 AM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #8

KWL Project No. 478.120 | Scale 1:100
Sheet 12 of 27 | Rev. No. 1
Client: BC HYDRO

MON 8
Drawing Number

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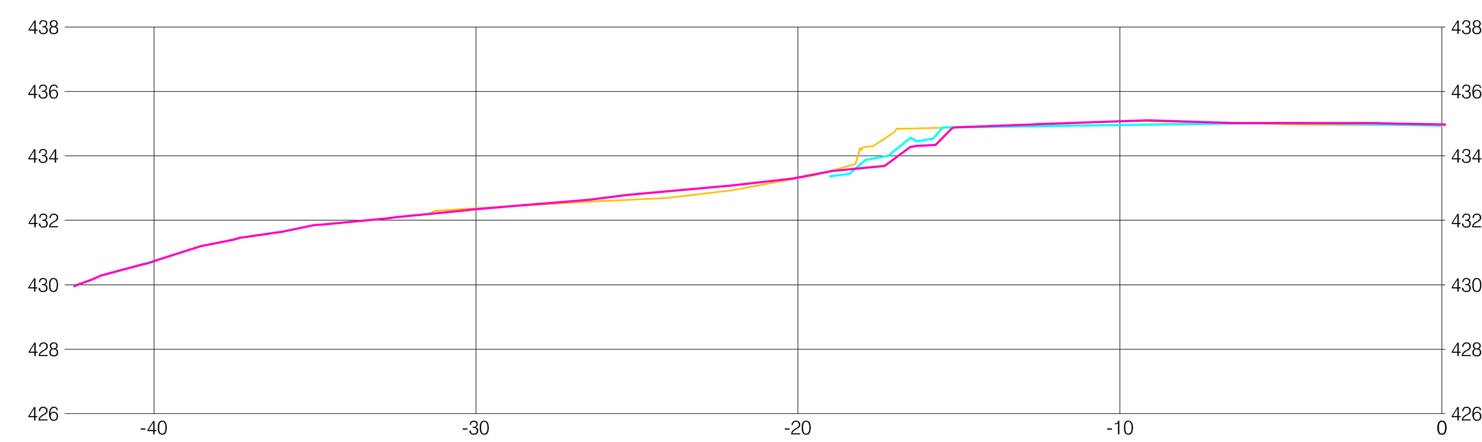
SAVED 20-Jul-2012 10:09 AM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.



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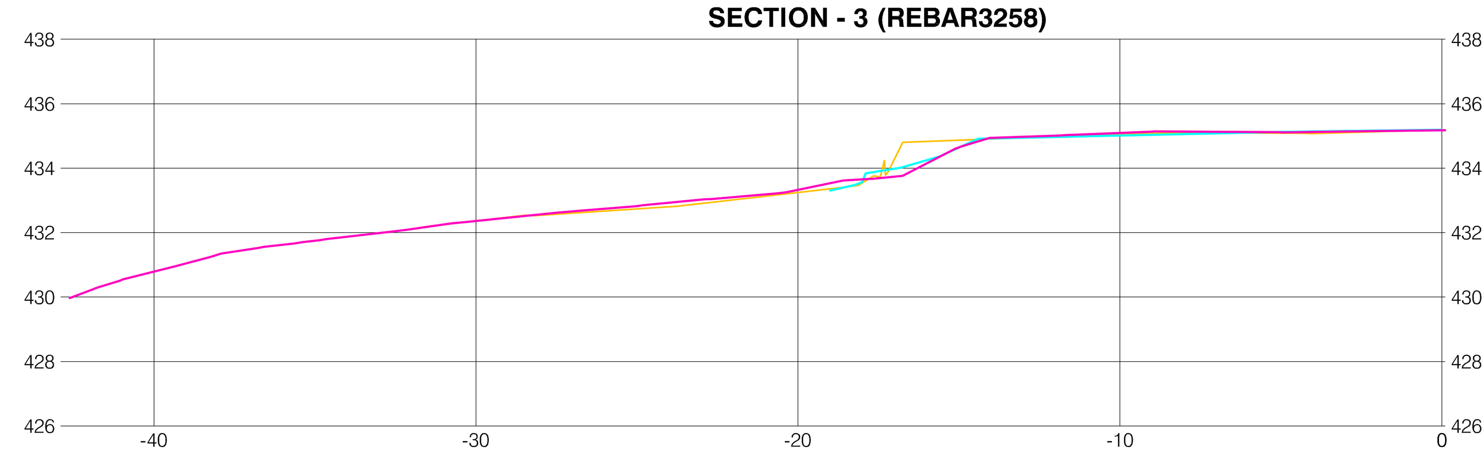

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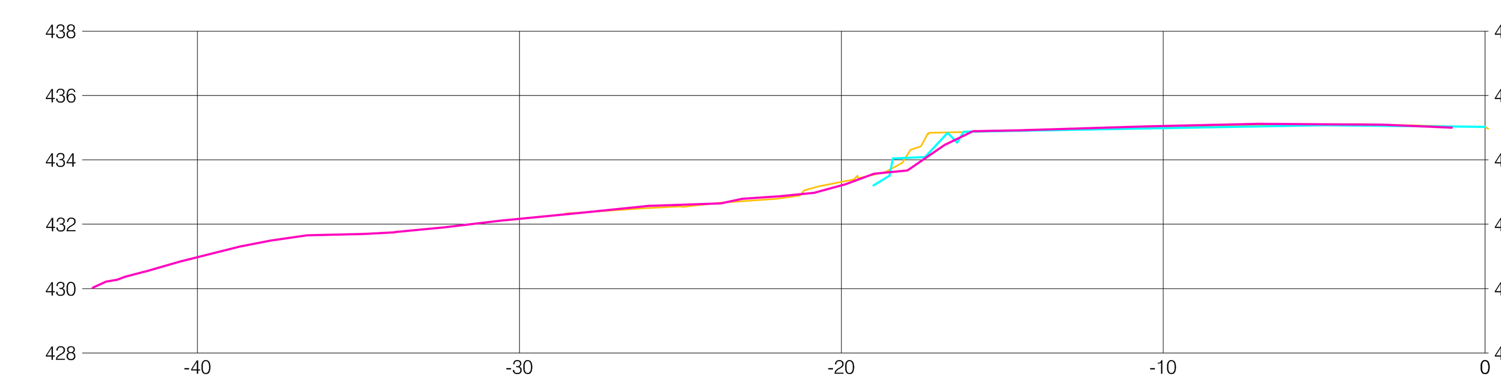

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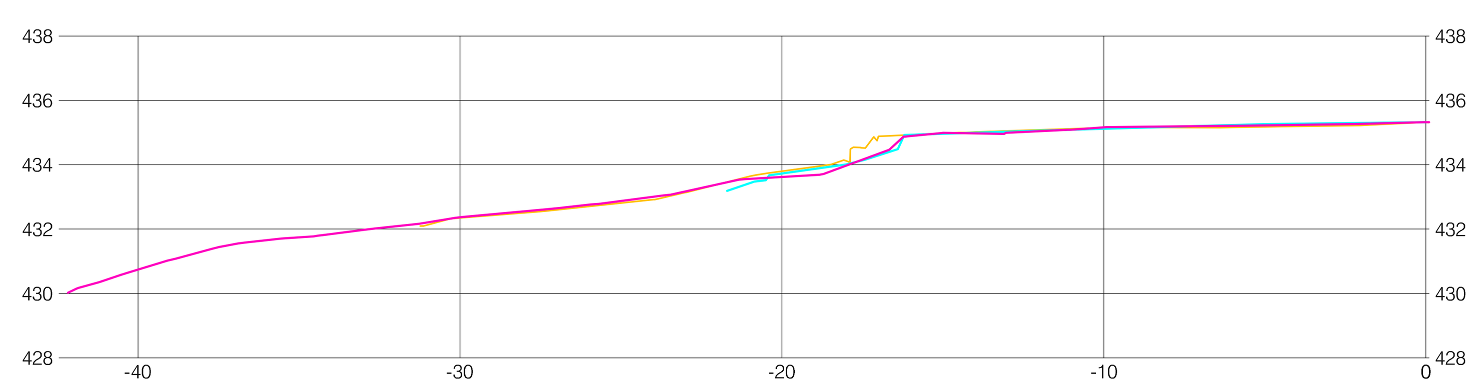

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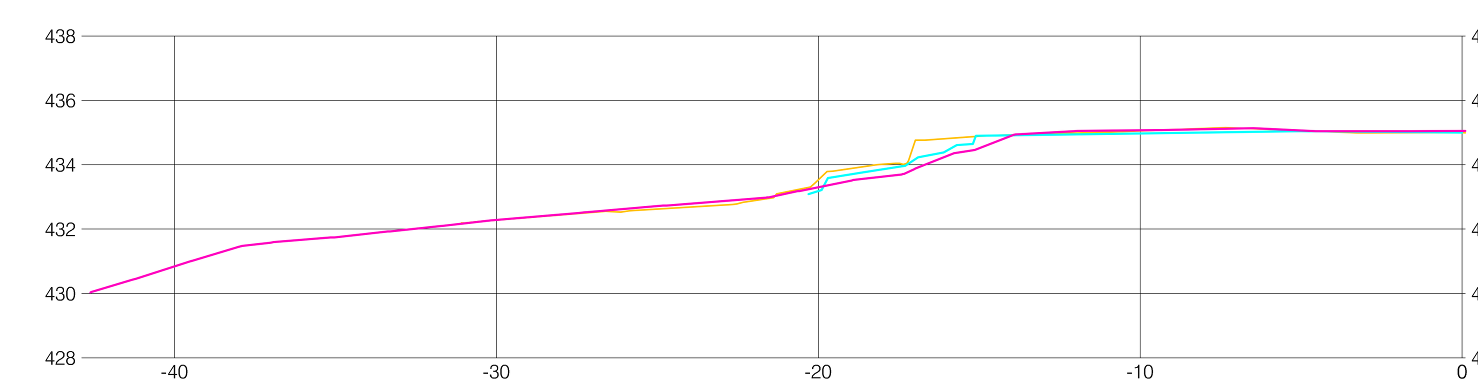

SECTION - 4 (REBAR3259)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

MONITORING SITE 8 - SECTIONS

1:100

0 2 (1:200) 10m

ISSUED INFORMATION	Issue	Date	Issued By
Issued for			
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #8 - SECTIONS

KWL Project No. 478.120		Scale 1:200 H 1:200 V	MON 8A
Sheet 13 of 27		Rev. No. 1	Drawing Number
Client: BC HYDRO			

MONITORING SITE 9 - PLAN

1:100

SAVED 20-Jul-2012 10:48 AM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION: Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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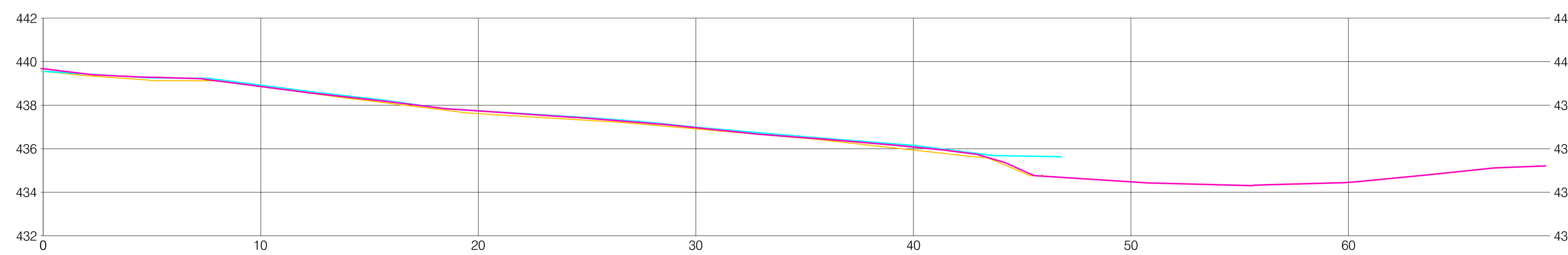
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #9

KWL Project No.	478.120	Scale	1:100
Sheet	14 of 27	Rev. No.	1
Client: BC HYDRO			

MON 9
Drawing Number



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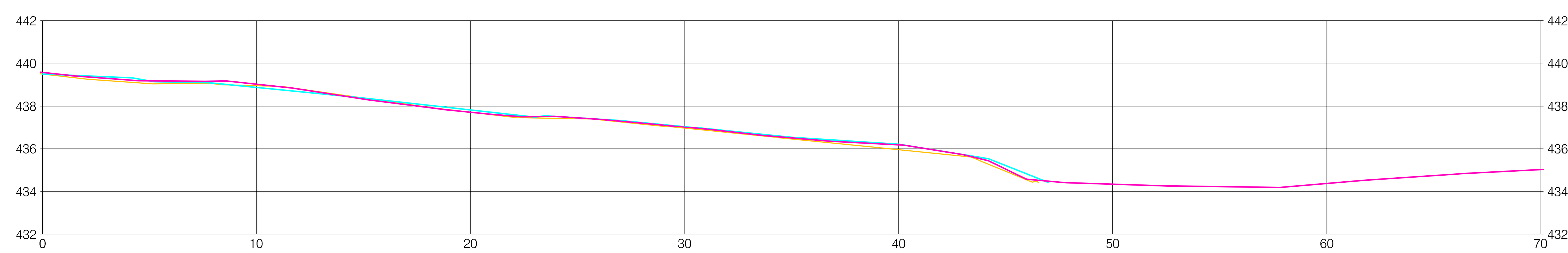

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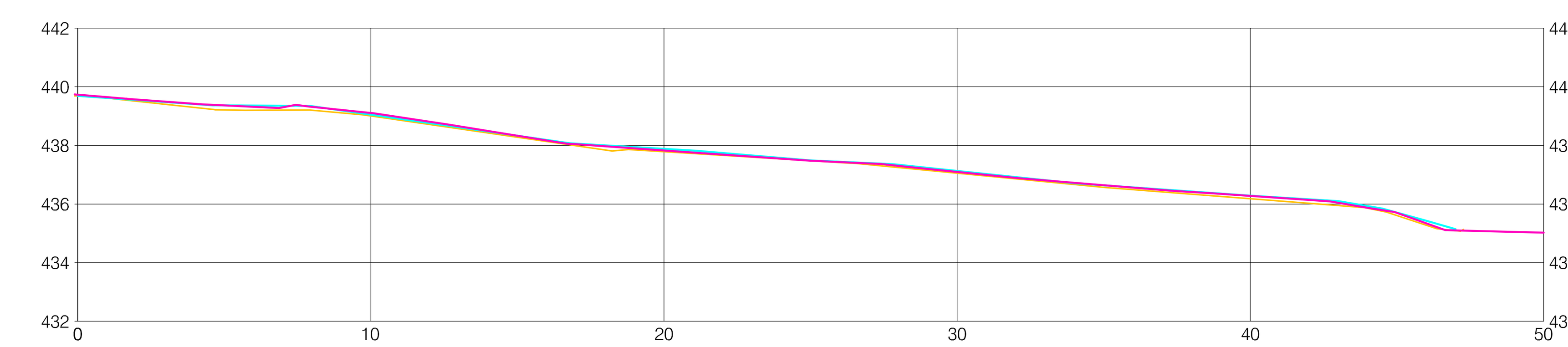

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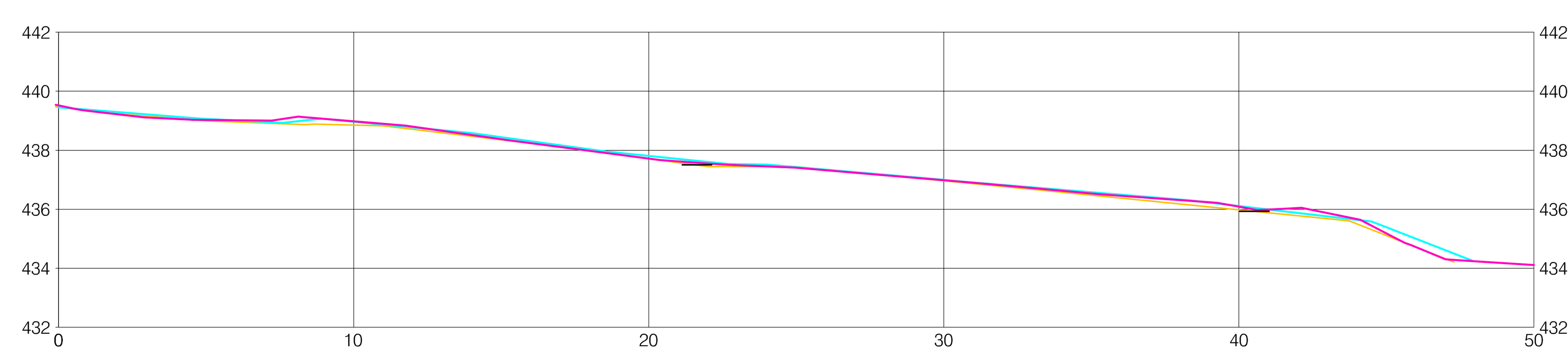

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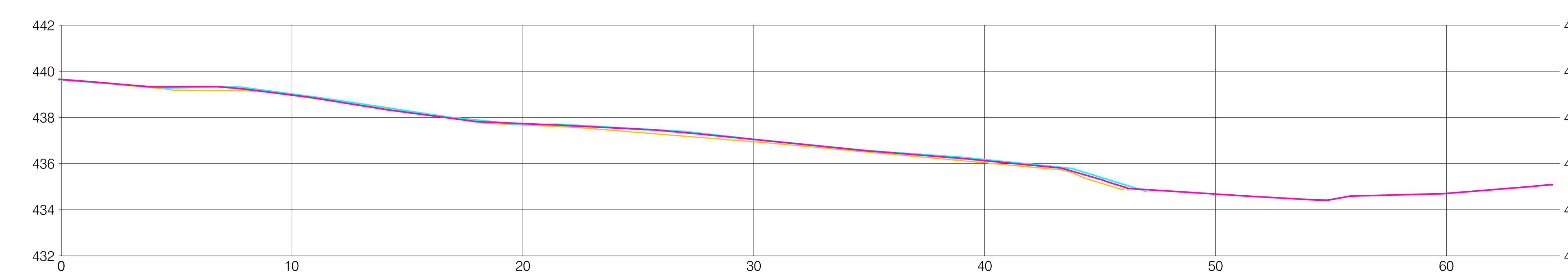

SECTION - 4 (REBAR3129)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

MONITORING SITE 9 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

ISSUED INFORMATION Issued for	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION Rev. No.	Date	Designed	Drawn	Checked	Description of Revision	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING						
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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #9 - SECTIONS

KWL Project No. 478.120 Scale 1:200 H 1:200 V
Sheet 15 of 27 Rev. No. 1
Client: BC HYDRO

MON 9A
Drawing Number

MONITORING SITE 10 - PLAN

1:100

SAVED 23-Jul-2012 10:10 AM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

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Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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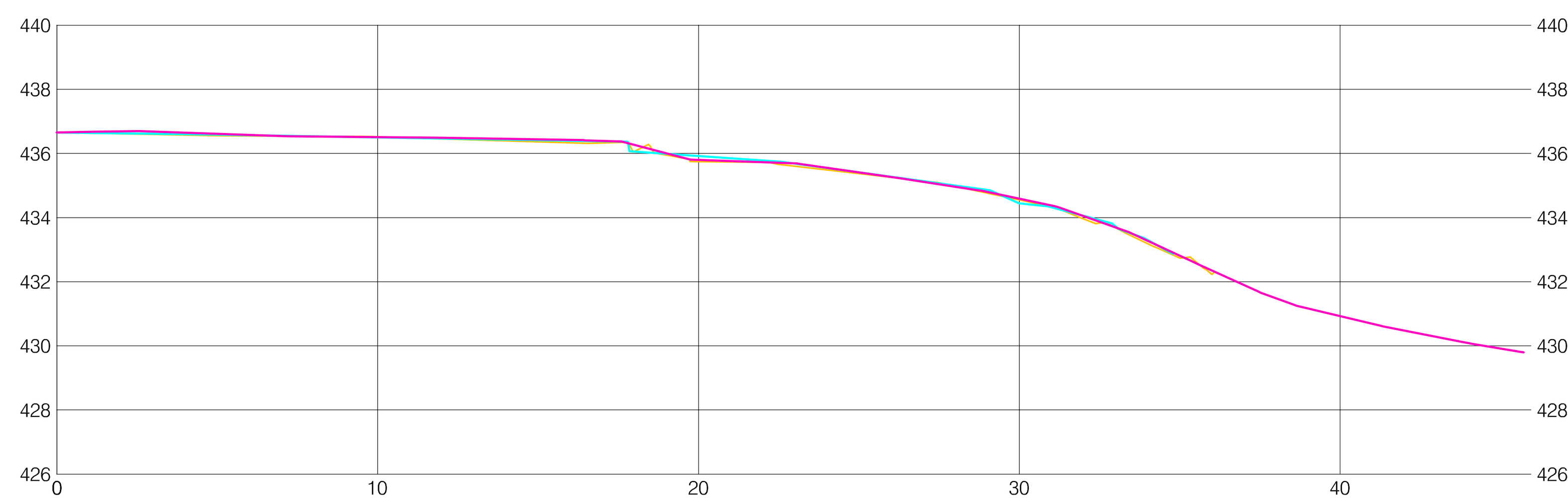
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #10

KWL Project No.	478.120	Scale	1:100
Sheet	16 of 27	Rev. No.	1
Client:	BC HYDRO		

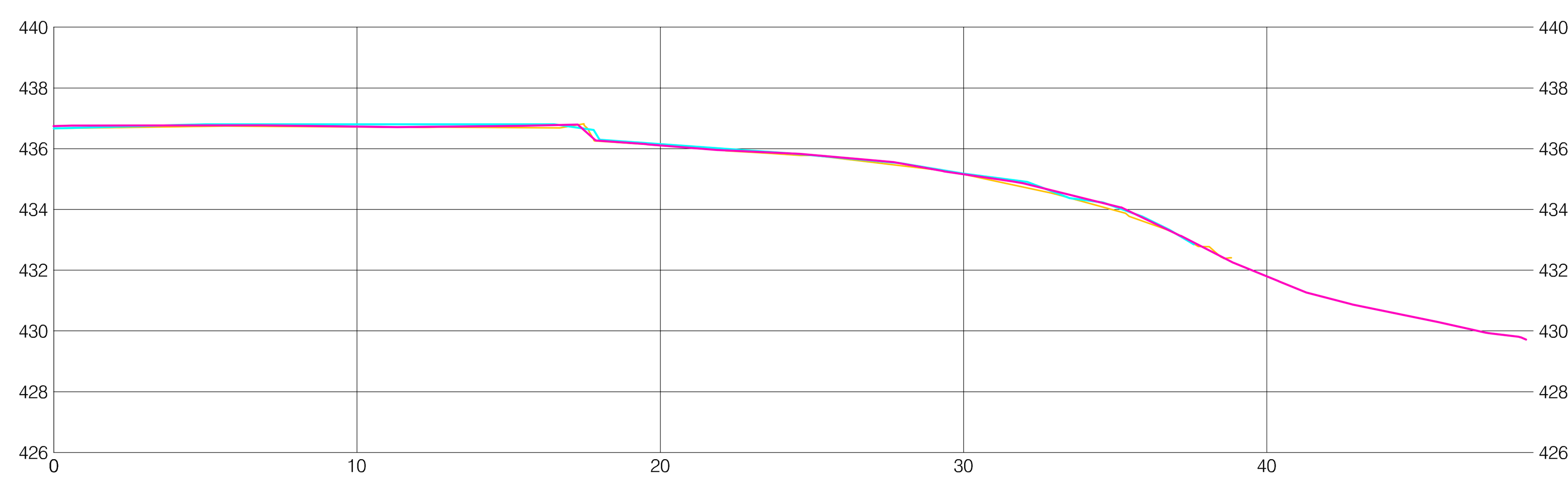
MON 10
Drawing Number



SECTION - 3 (REBAR3973)

LEGEND

TRANSECT GROUND APRIL, 2010
TRANSECT GROUND JUNE, 2011
TRANSECT GROUND APRIL, 2012



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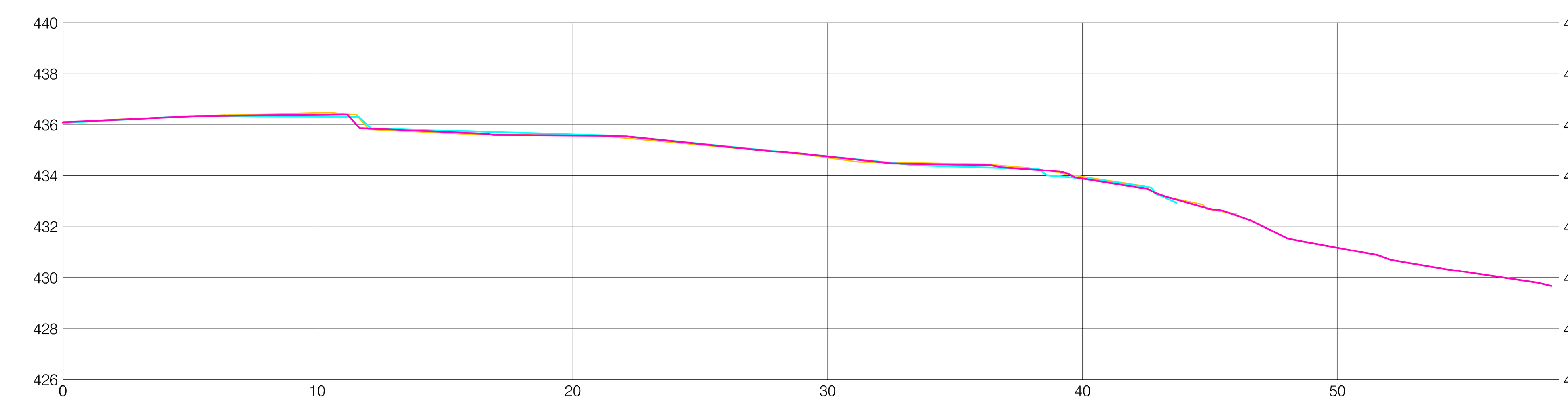

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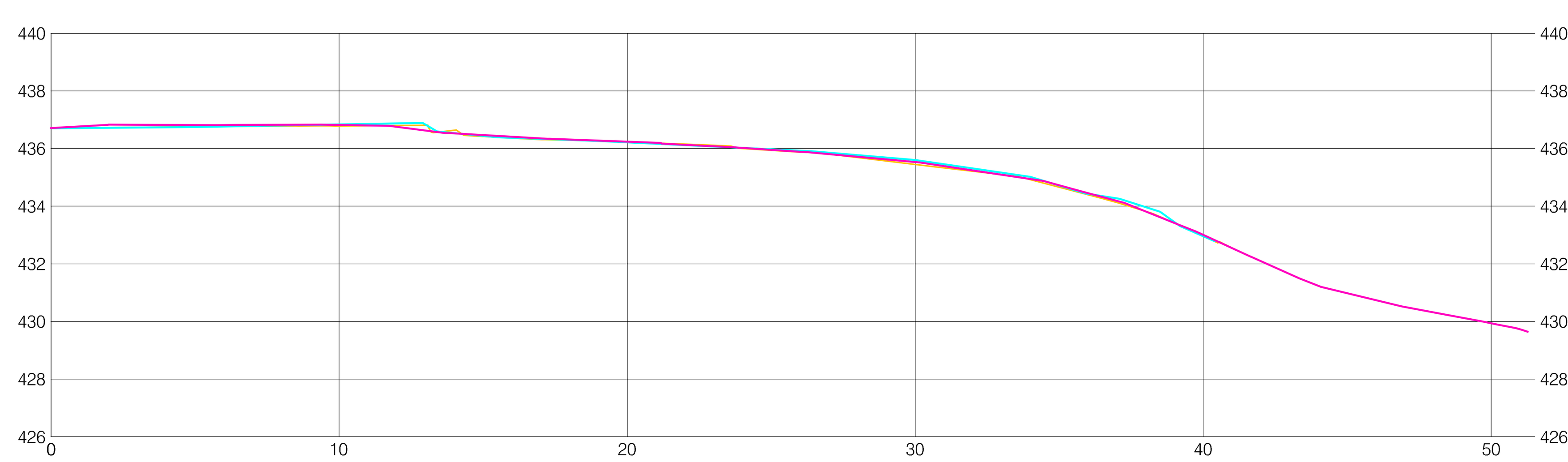

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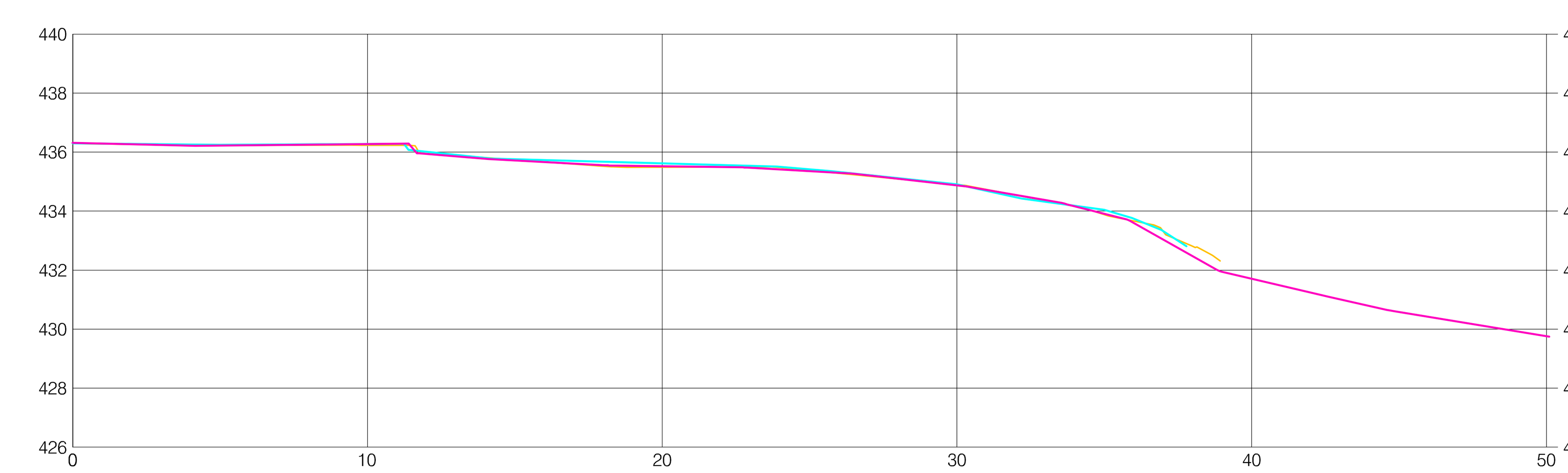

SECTION - 4 (REBAR3974)

MONITORING SITE 10 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

ISSUED INFORMATION: Issued for	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION: Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #10 - SECTIONS

KWL Project No. 478.120 Scale 1:200 H 1:200 V
Sheet 17 of 27 Rev. No. 1
MON 10A Drawing Number
Client: BC HYDRO

MONITORING SITE 11 - PLAN

1:100

ISSUED INFORMATION	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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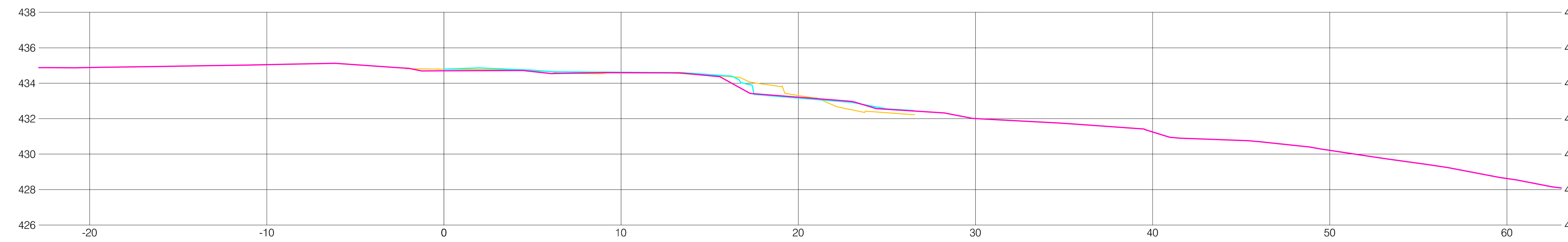
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #11

KWL Project No.	478.120	Scale	1:100
Sheet	18 of 27	Rev. No.	1
Client: BC HYDRO			

MON 11
Drawing Number



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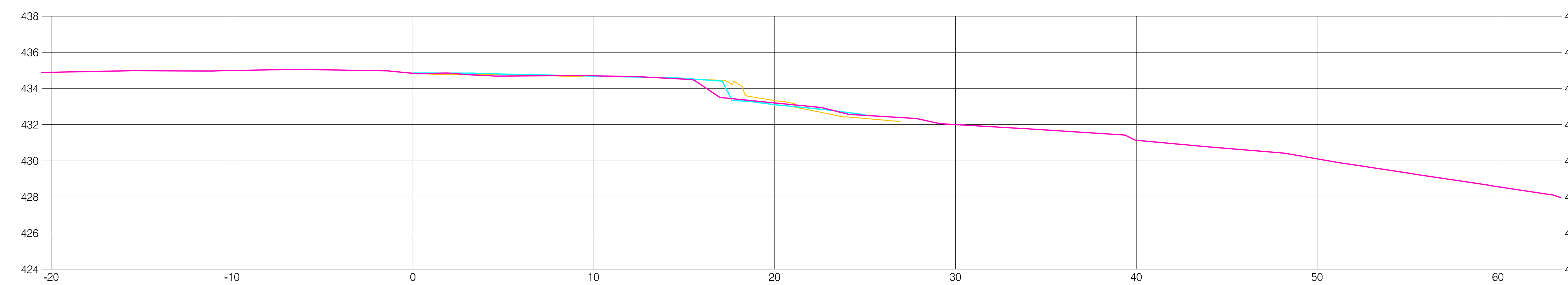
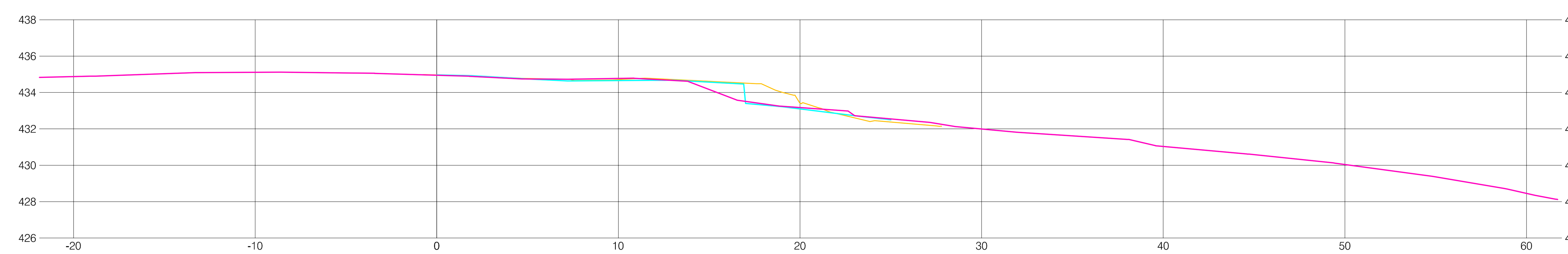


SECTION - 4 (REBAR3194)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012



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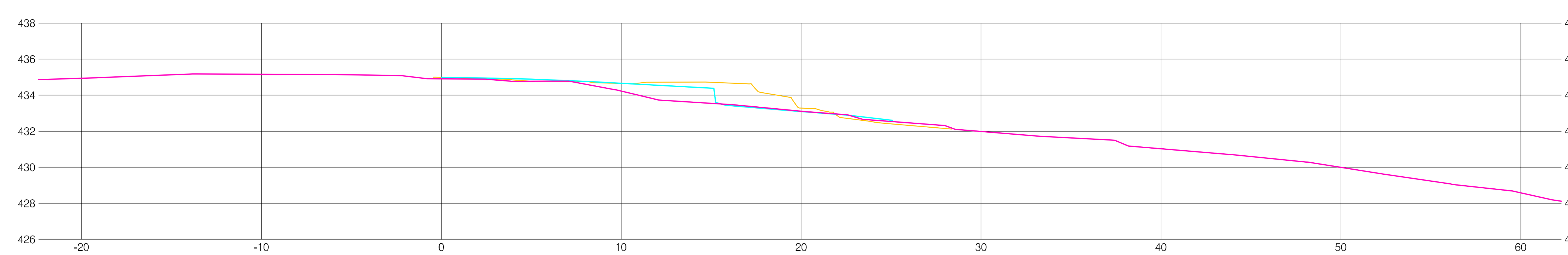

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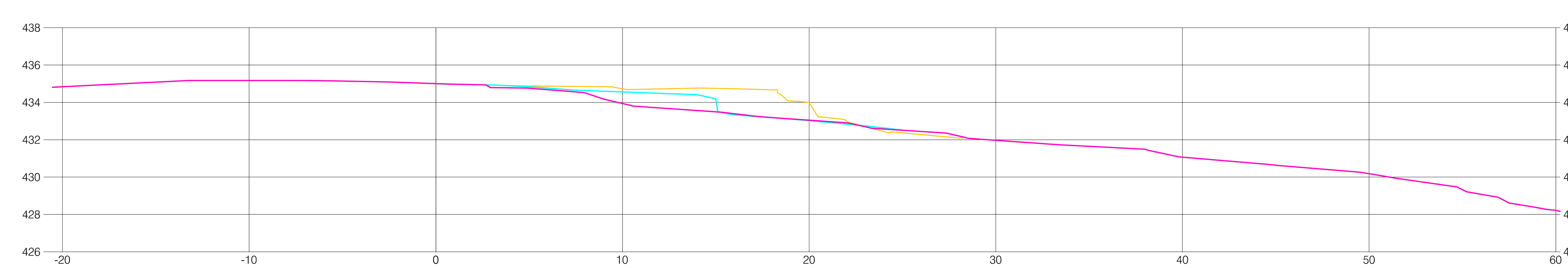

SECTION - 1 (REBAR3191)

MONITORING SITE 11 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

ISSUED INFORMATION	Issue	Date	Issued By
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #11 - SECTIONS

KWL Project No.	478.120	Scale	1:200 H 1:200 V
Sheet	19 of 27	Rev. No.	1

MON 11A
Drawing Number

Client: BC HYDRO

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AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

MONITORING SITE 12 - PLAN

1:100

SAVED 25-Jul-2012 2:42 PM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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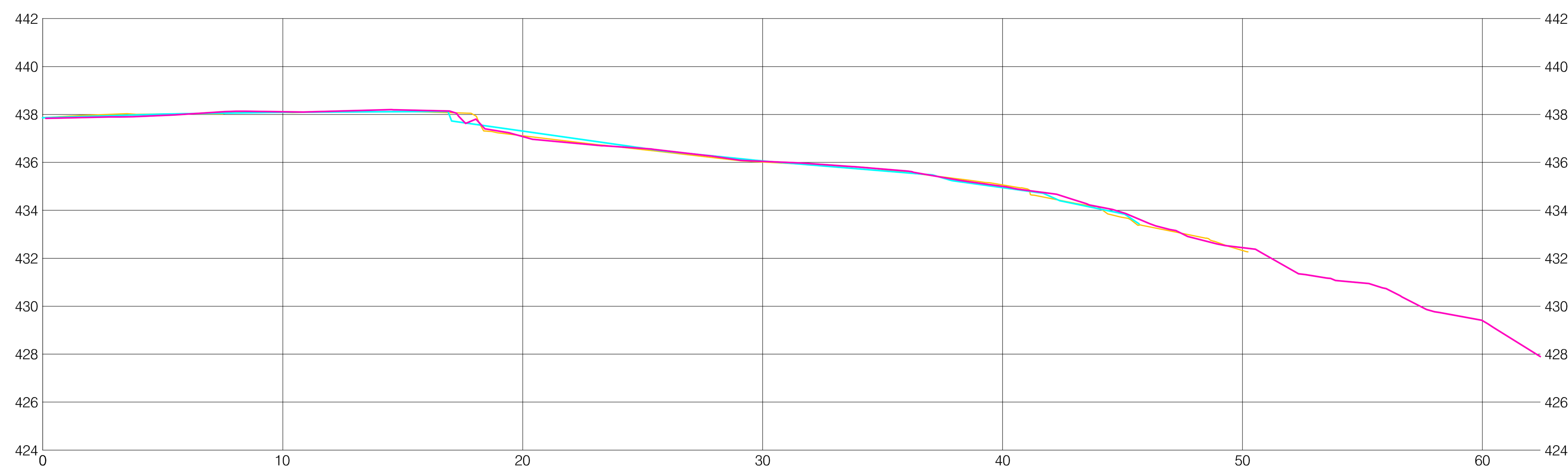
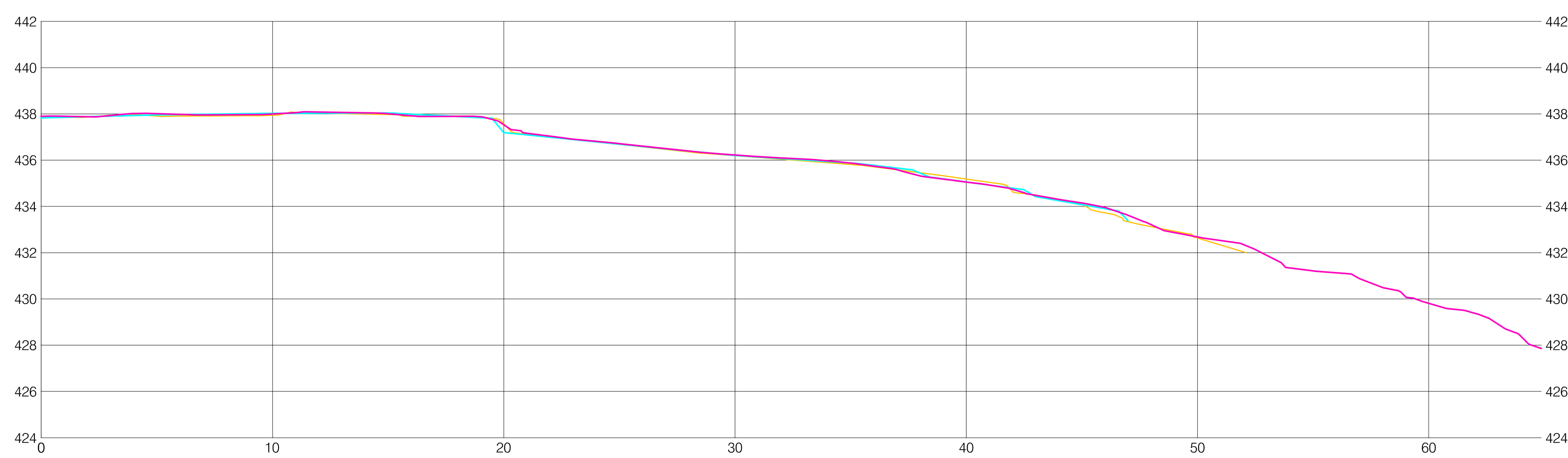
COLUMBIA RIVER EROSION MONITORING - CLB#36
ERSOSION MONITORING SITE #12

KWL Project No.	478.120	Scale	1:100
Sheet	20 of 27	Rev. No.	1
Client: BC HYDRO			

MON 12
Drawing Number



SECTION -3 (REBAR3778)



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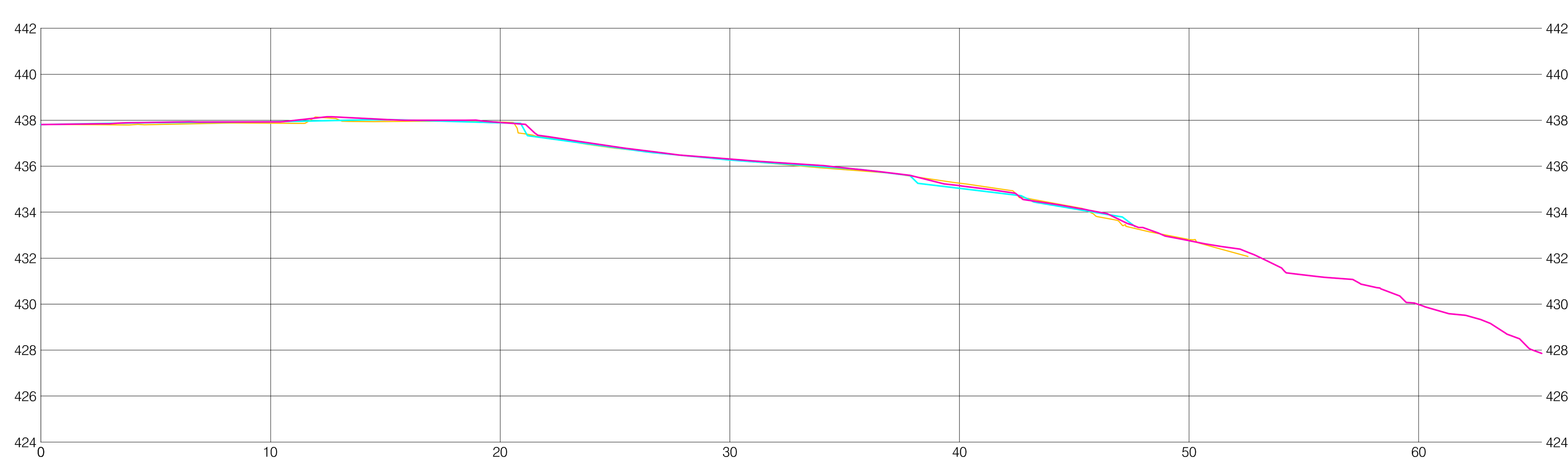
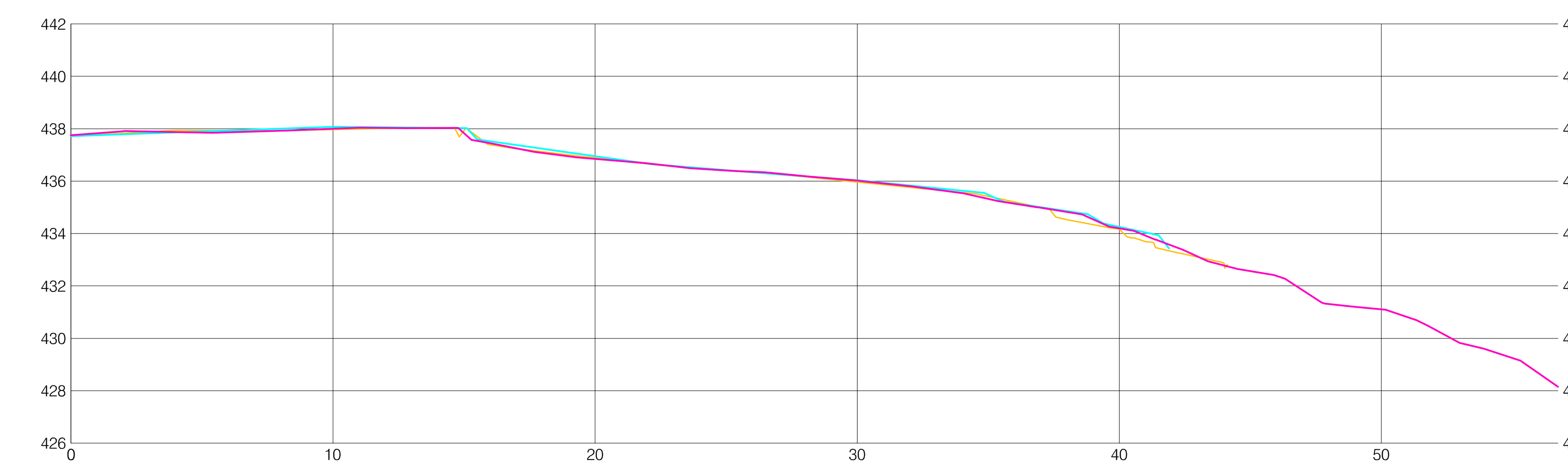


SECTION -1 (REBAR3776)



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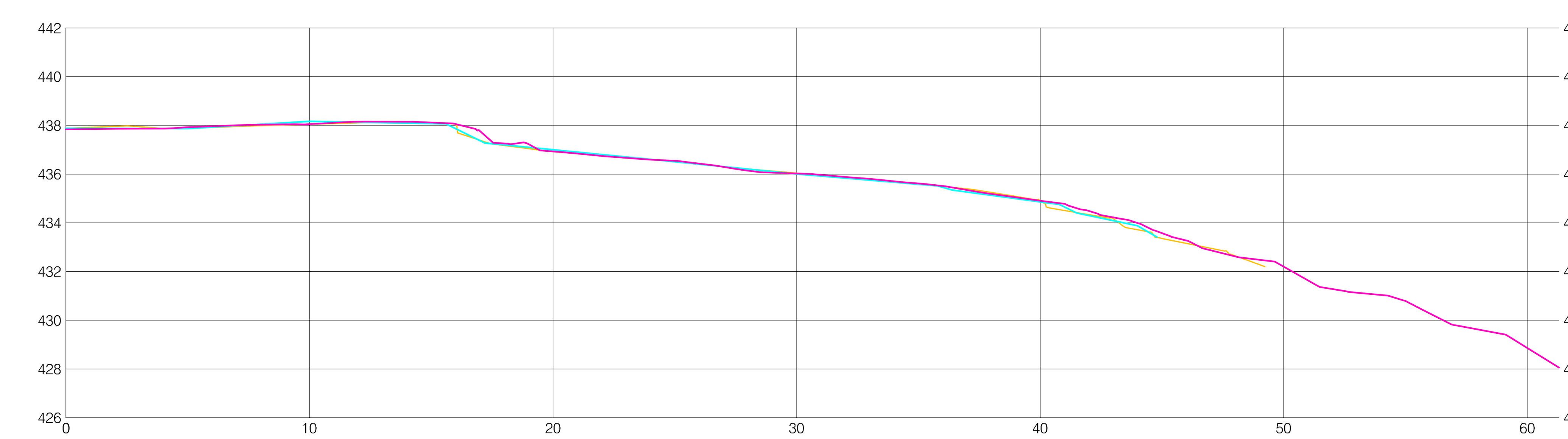

SECTION -4 (REBAR3779)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

0 2 (1:200) 10m

MONITORING SITE 12 - SECTIONS

1:200H, 1:200V

O:\0400-0499\478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #12.dwg

SAVED 25-Jul-2012 2:42 PM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #12 - SECTIONS

KWL Project No. 478.120	Scale 1:200 H 1:200 V	MON 12A
Sheet 21 of 27	Rev. No. 1	Drawing Number
Client: BC HYDRO		

MONITORING SITE 13 - PLAN

1:100

Issued for	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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EROSION MONITORING SITE #13

KWL Project No.	478.120	Scale	1:100
Sheet	22 of 27	Rev. No.	1
Client: BC HYDRO			

MON 13
Drawing Number

SAVED 25-Jul-2012 3:17 PM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

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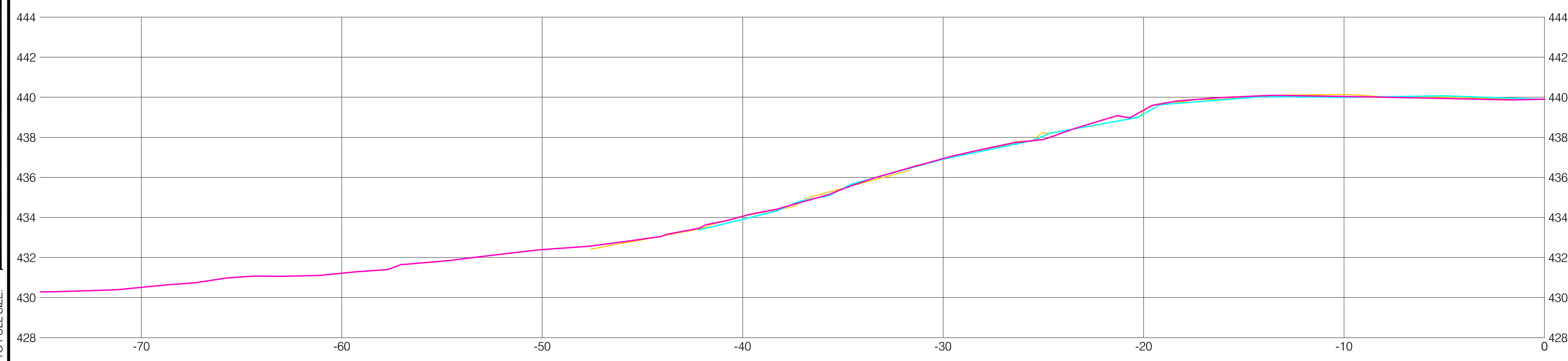
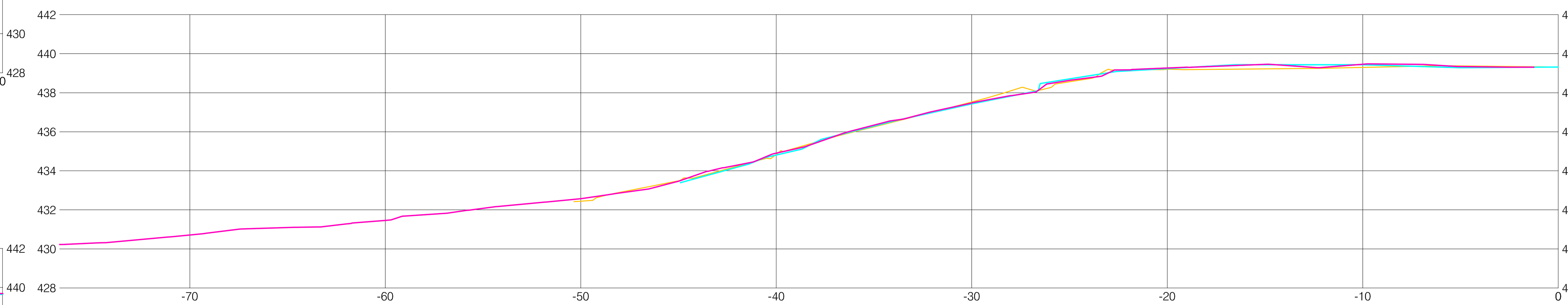
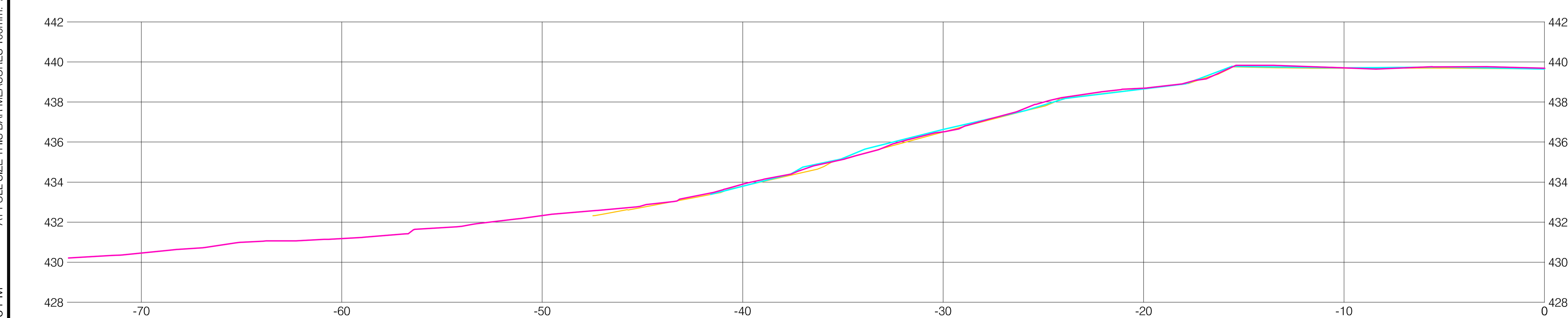


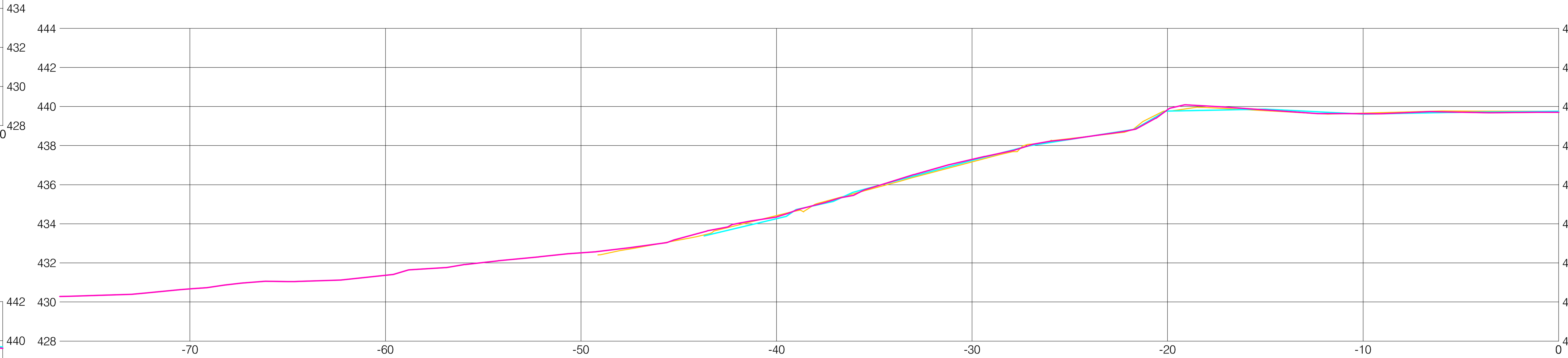
SECTION - 3 (REBAR3713)



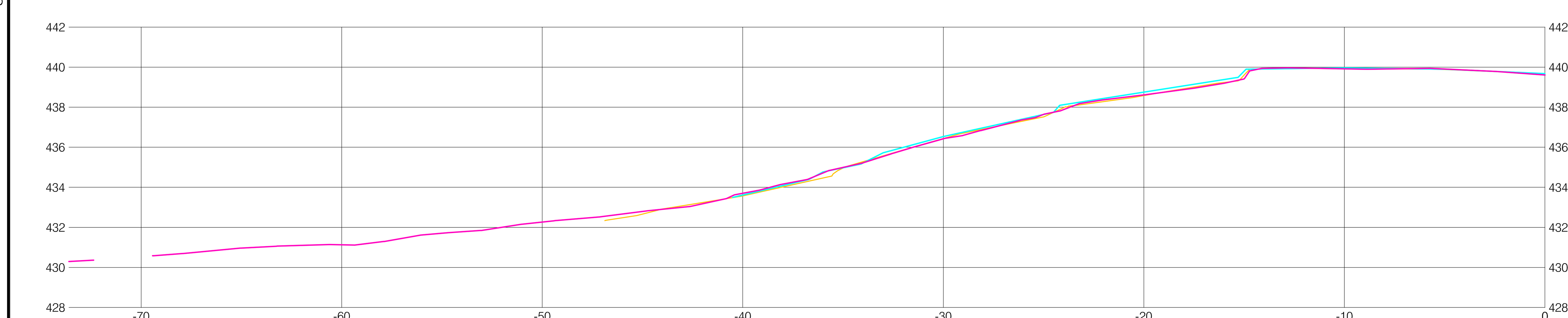
SECTION - 5 (REBAR3715)



SECTION - 2 (REBAR3712)



SECTION - 4 (REBAR3714)



SECTION - 1 (REBAR3711)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012

MONITORING SITE 13 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE

SAVED 25-Jul-2012 3:26 PM

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Permits			
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Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #13 - SECTIONS

KWL Project No.	478.120	Scale	1:200 H 1:200 V
Sheet	23 of 27	Rev. No.	1
Client: BC HYDRO			

MON 13A
Drawing Number

MONITORING SITE 14 - PLAN
1:100

ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #14

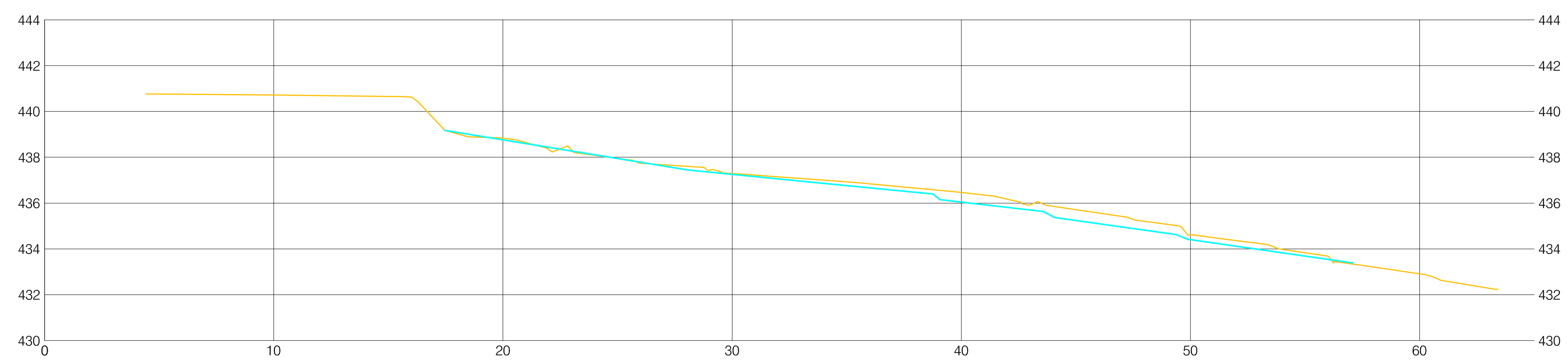
KWL Project No.	478.120	Scale	1:100
Sheet	24 of 27	Rev. No.	1
Client: BC HYDRO			

MON 14
Drawing Number

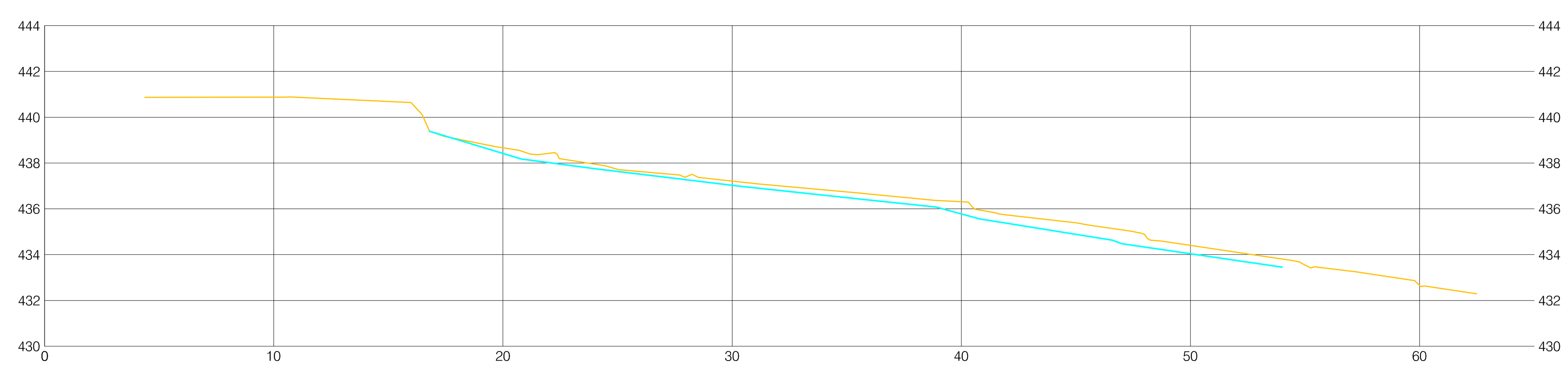
O:\0400-0499\478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #14.dwg

SAVED 25-Jul-2012 3:36 PM

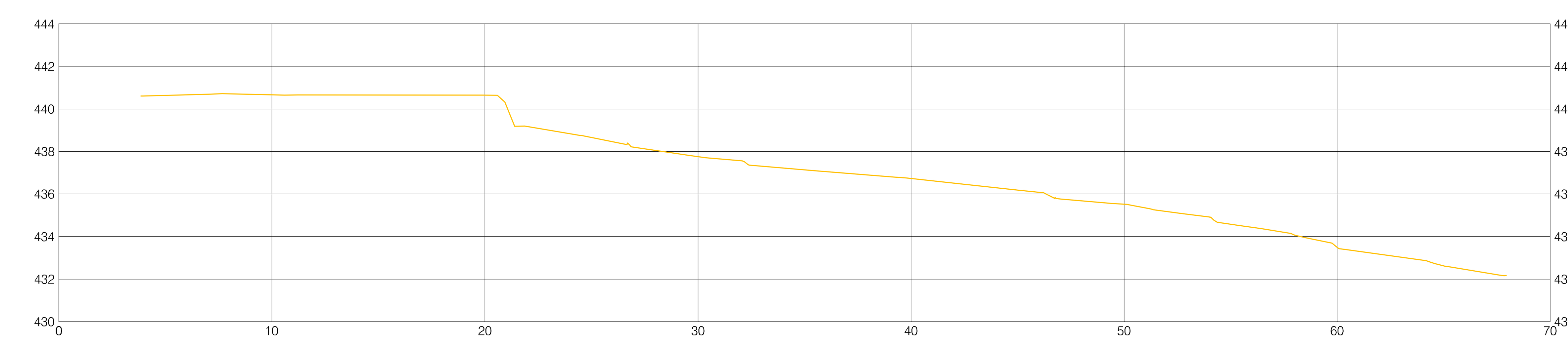
AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE



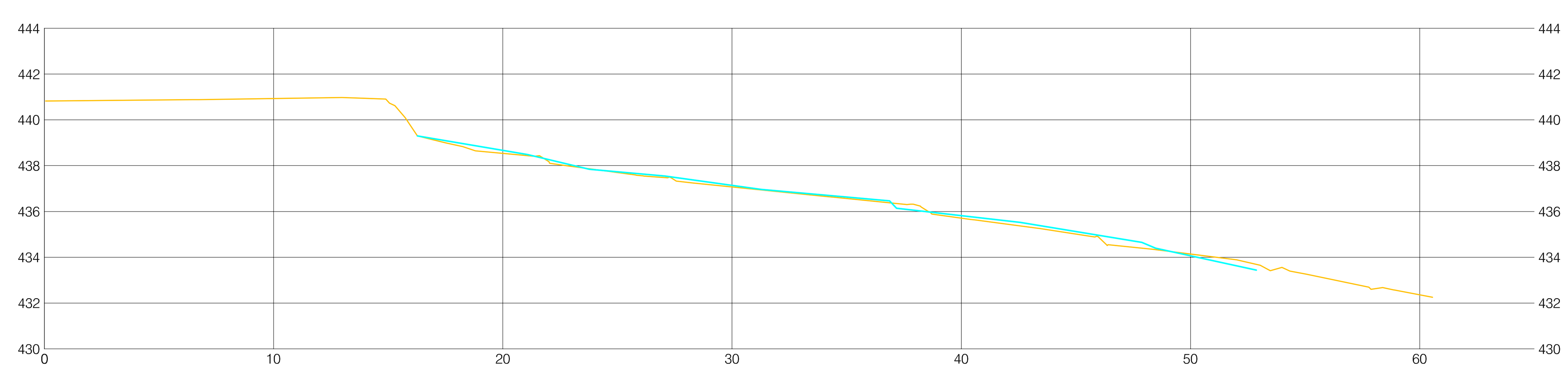
SECTION -3 (REBAR3648)



SECTION -2 (REBAR3647)



SECTION -5 (REBAR3650)



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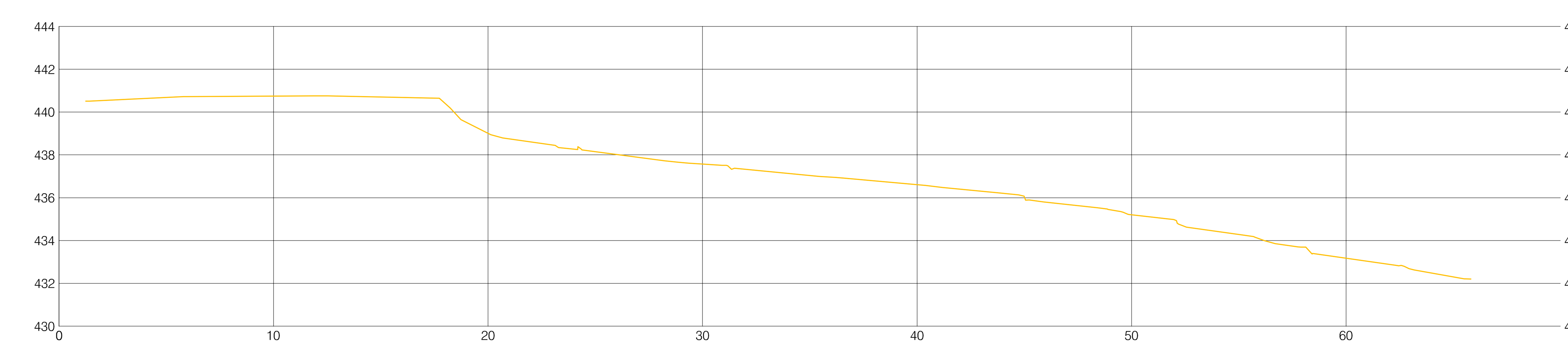

SECTION -4 (REBAR3649)

LEGEND

-------- TRANSECT GROUND APRIL, 2010

TRANSECT GROUND OCTOBER, 2010

NOTE:

MONITORING SITE #14 NOT SURVEYED IN 2012.

0 2 (1:200) 10m

MONITORING SITE 14 - SECTIONS

1:200H, 1:200V

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Reference			
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Construction			
Record Drawings			

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0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #14 - SECTIONS

KWL Project No.	478.120	Scale	1:200 H 1:200 V
Sheet	25 of 27	Rev. No.	1
Client: BC HYDRO			

MON 14A
Drawing Number

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SAVED 26-Jul-2012 10:27 AM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

MONITORING SITE 15 - PLAN

1:100

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Reference			
Approvals			
Tender			
Permits			
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #15

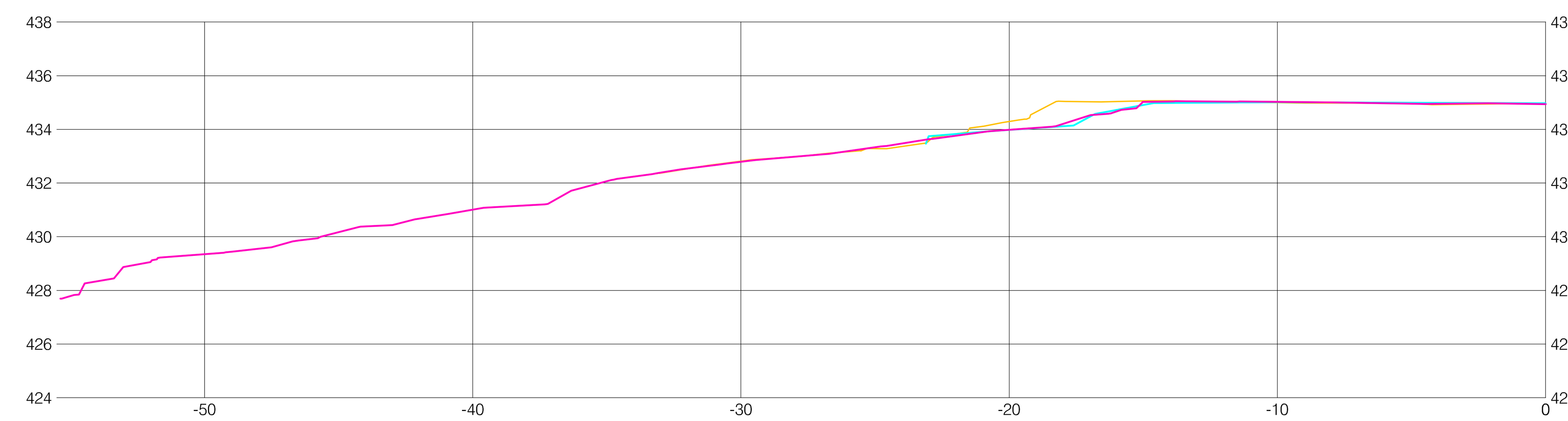
KWL Project No.	478.120	Scale	1:100
Sheet	26 of 27	Rev. No.	1
Client: BC HYDRO			

MON 15
Drawing Number

O:\0400-0499\478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #15.dwg

SAVED 26-Jul-2012 10:33 AM

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE



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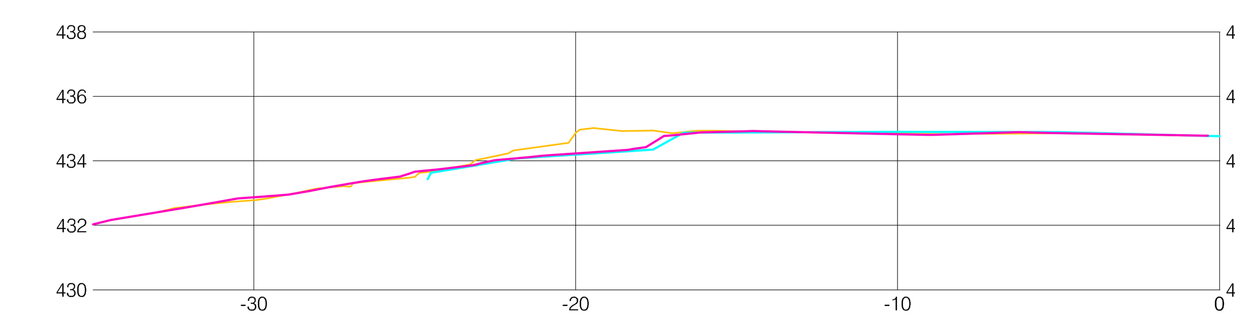

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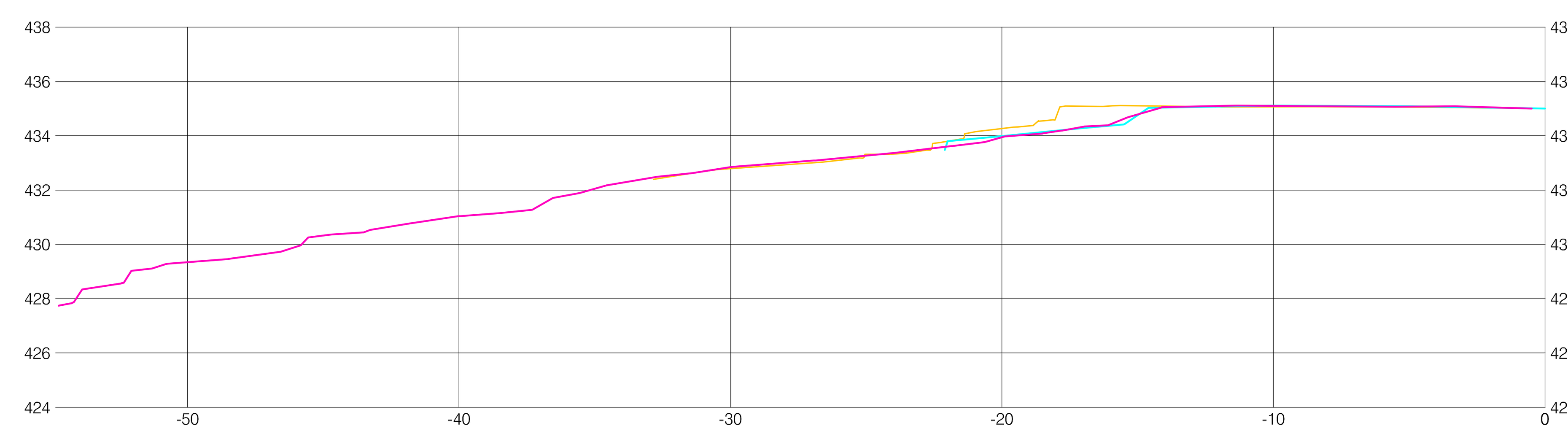

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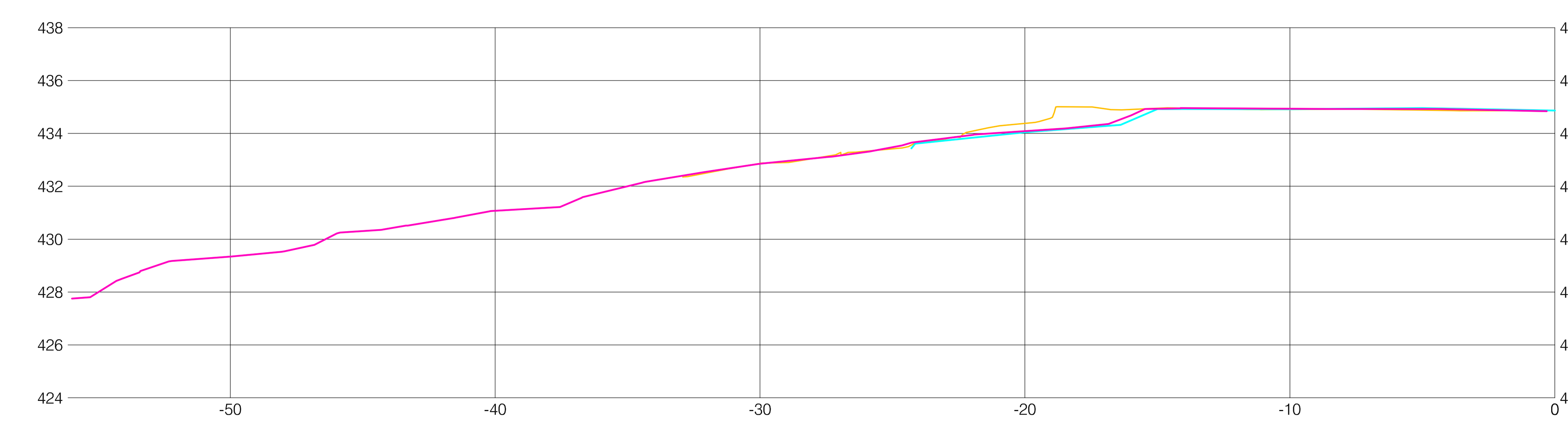

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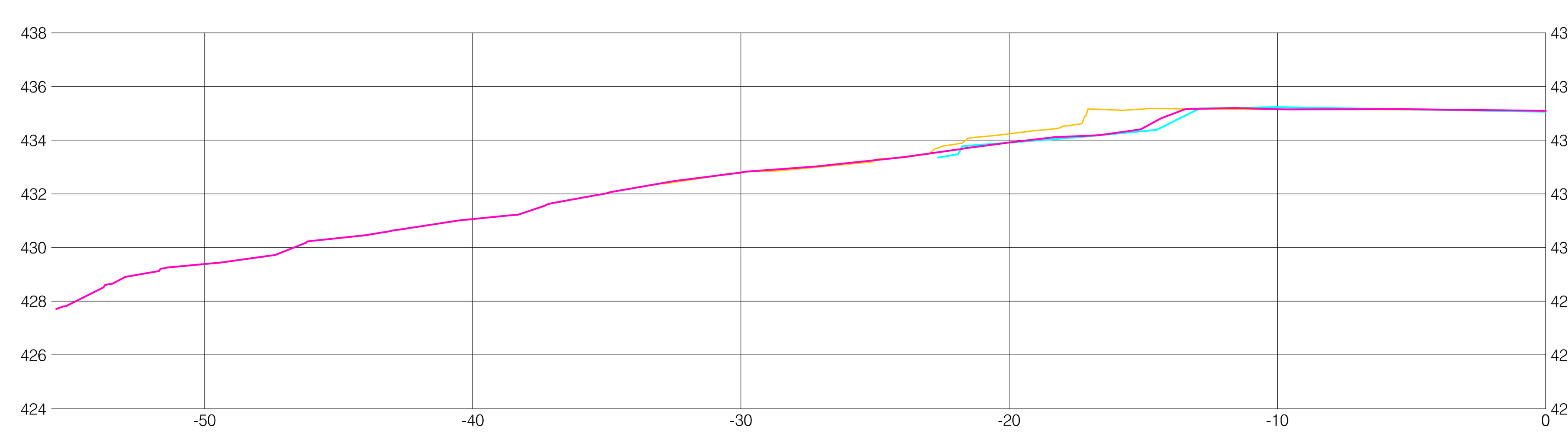

SECTION - 1 (REBAR3841)

LEGEND

TRANSECT GROUND APRIL, 2010

TRANSECT GROUND JUNE, 2011

TRANSECT GROUND APRIL, 2012

MONITORING SITE 15 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

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Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #15 - SECTIONS

KWL Project No. 478.120		Scale 1:200 H 1:200 V	**MON 15A**
Sheet 27 of 27		Rev. No. 1	Drawing Number
Client: BC HYDRO			