Columbia River Project Water Use Plan

Kinbasket and Arrow Lakes Reservoir Recreation Management Plan

Mid Columbia River Long Term Erosion Monitoring Program

Implementation Year 4

Reference: CLBWORKS #36

2014 Progress Report

Study Period: 2009 to 2014

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Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	March 6, 2015	Final	Revised based on client review.	EE
B	November 25, 2014	Draft	Revised draft for client review.	EE
A	November 13, 2014	Draft	Draft for internal review.	EE

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Status of Objectives, Management Questions and Hypotheses After Year 4

Objectives	Management Questions	Management Hypotheses
From CLBWORKS #36 ToR: "The primary objective of this program is to monitor shoreline erosion along the Columbia River in the region of influence of Revelstoke Dam, including operation of the fifth unit. This is to ensure that any incremental flows due to the five-unit operations do not impact the river banks in the area of influence. Specifically, the study will: • Identify shoreline areas susceptible to erosion (areas of concern) within the area, • Assess whether there are changes in the spatial extent of these areas of concern over the monitoring period, and • Assess whether any observed change in spatial extent is attributable to the operating regime of the fifth unit of Revelstoke Dam."	**From** CLBWORKS #36 ToR: "The key management question addressed by this Terms of Reference is: Will the addition and operation of a fifth unit at Revelstoke Dam increase, decrease or not affect erosion rates in the mid Columbia River from Revelstoke Dam downstream to Shelter Bay?"	**From** CLBWORKS #36 ToR: "Two management hypotheses will be considered: $H1_0$: Shoreline erosion does not differ significantly before and after start of operation of the fifth unit at Revelstoke Dam. $H2_0$: Shoreline erosion does not increase significantly through the duration of the Project."

Year 4 (2014) Status

- $H1_0$ cannot be addressed by this study as there were an insufficient number of years of baseline data collected prior to the start of operation of the fifth unit at Revelstoke Dam. This was identified at the beginning of the project.
- $H2_0$ will be tested in the final year of the project (Year 5 / 2016), so that the effects of any acceleration in the rate of erosion over the life of the project will be most evident.
- 2014 analysis includes a regression analysis to evaluate any trends (erosion or deposition), and test whether they are significantly different from zero.

Erosion pin data:

- Of the 14 actives sites:
  - 5 sites showed statistically significant deposition,
  - 6 sites showed statistically significant erosion, and
  - 3 sites showed no statistically significant change.
- Erosion rates (2010 to 2014) range from about 1 cm/year to about 7.5 cm/year (Table 3-2).
- Deposition rates (2010 to 2014) range from about 0.4 cm/year to about 1.7 cm/year (Table 3-2).
- Average rate of change over all sites (2010 to 2014) is 1.55 cm/year (erosion).

River cross-section data:

- Of the 14 actives sites:
  - Upper elevation band: 6 sites out of 14 showed statistically significant erosion (Table 3-4).
  - Middle elevation band: 4 sites out of 14 showed statistically significant erosion (
  - Table 3-5).
  - Lower elevation band: 6 sites out of 14 showed statistically significant change, evenly split between erosion and deposition (Table 3-6).
- Erosion rates (2010 to 2014) range from about 0.1 m/year to about 2 m/year (Table 3-4, Table 3-5, Table 3-6).
- Deposition rates (2010 to 2014) range from about 0.1 m/year to about 0.2 m/year.
- Average rate of change over all sites (2010 to 2014) is -0.19 m/year (erosion).

1. Introduction and Background

This report summarizes progress made by Kerr Wood Leidal Associates Ltd. (KWL) during 2014 on BC Hydro program CLBWORKS #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. The fifth generating unit was put in service in December, 2010.

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, 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.

Each program is conducted separately. No work was scheduled for CLBWORKS #35 in 2014 therefore the remainder of this report will focus on CLBWORKS #36.

1.1 Project Objectives, Management Question and Hypotheses

1.1.1 Project Objectives

As stated in the CLBWORKS #36 Terms of Reference (ToR):

> "*The primary objective of this program is to monitor shoreline erosion along the Columbia River in the region of influence of Revelstoke Dam, including operation of the fifth unit. This is to ensure that any incremental flows due to the five-unit operations do not impact the river banks in the area of influence.*
>
> *Specifically, the study will:*
>
> - *Identify shoreline areas susceptible to erosion (areas of concern) within the area,*
> - *Assess whether there are changes in the spatial extent of these areas of concern over the monitoring period, and*
> - *Assess whether any observed change in spatial extent is attributable to the operating regime of the fifth unit of Revelstoke Dam.*"

1.1.2 Management Question

As stated in the CLBWORKS #36 ToR:

> "*The key management question addressed by this Terms of Reference is:*
>
> *Will the addition and operation of a fifth unit at Revelstoke Dam increase, decrease or not affect erosion rates in the mid Columbia River from Revelstoke Dam downstream to Shelter Bay?*"

1.1.3 Management Hypotheses

As stated in the CLBWORKS #36 ToR:

"*Two management hypotheses will be considered:*

- *$H1_0$: Shoreline erosion does not differ significantly before and after start of operation of the fifth unit at Revelstoke Dam.*
- *$H2_0$: Shoreline erosion does not increase significantly through the duration of the Project.*"

1.2 Project Schedule

The ToR project schedule called for a 5-year program (2009, 2010, 2012, 2014 and 2016). Year 1 was to include an information review, sites selection, design of study, and the first ground site erosion assessment if conditions permitted. Subsequent erosion assessments were to be scheduled once per two years in Years 2, 3, 4 and 5.

As referenced above, the first management hypothesis ($H1_0$) specifically is focused on quantification and comparison of shoreline erosion before, and after the start of operation of the fifth unit at Revelstoke Dam. However, the project schedule did not support an evaluation of $H1_0$ for the following reasons:

- The ToR schedule did not include a period of baseline (pre- fifth unit) data collection equivalent or greater than the post-commissioning monitoring. This is problematic for some commonly-used statistical designs.
- Due to the timing of project award and water levels in early stages of the project, it was not possible to collect even one full year of baseline (pre- fifth unit) data to be compared to the post-commissioning monitoring.

As a result, it was not possible to detect changes in erosion prior to and following the installation of the fifth generating unit ($H1_0$). However, the project schedule does permit monitoring of erosion rates over time ($H2_0$).

2014 is Year 4 of the project, and the final year of the project will be 2016. The current schedule for CLBWORKS #36 is summarized in the following table.

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

Year	CLBWORKS#36	MONTH (FIELDWORK)
2009	Y1 – Site Selection	August-September
2010	Y1 – Installation / Monitoring	April-May
2010	Entry in operation, REV5	December
2011	Y2 – Monitoring	May-June
2012	Y3 – Monitoring	April
2013		
2014	Y4 – Monitoring	April
2015		
2016	Y5 – Monitoring	April (assumed)

1.3 Project Sites

As indicated in the ToR, the geographic area of influence of the dam includes the Mid Columbia River reach from immediately below the dam downstream to Shelter Bay (Figure 1-1). Fifteen long-term erosion monitoring sites have been established on the Columbia River between Revelstoke Dam and Shelter Bay (Figure 1-2). For a description of the monitoring sites, the reader is referred to preceding Annual Reports for CLBWORKS #36 (available through BC Hydro's Water Use Plan web-interface).

All sites were measured in Project Year 1 during baseline monitoring (2010). In 2011, the upland property owner at Site 14 expressed a preference for no erosion pins in the reservoir area adjacent to the upland property, and removed the majority of the erosion pins. Site 14 was not measured in 2012 or 2014, to avoid conflict with the property owner.

1.4 2014 Tasks

Major tasks undertaken in 2014 are summarized in Table 1-2.

Table 1-2: 2014 Work Program (CLBWORKS #36).

Task	Description
Erosion Assessment (CLBWORKS #36 Y4)	▪ Safety Plan ▪ Site Visit ▪ Measure Bank Change Using Pins ▪ Re-survey Monitoring Cross-Sections
2014 Data Entry and Analysis	▪ Populate Spreadsheet Databases ▪ Data Analysis (CLBWORKS #36 Y4)
2014 Progress Report	▪ Progress Report for CLBWORKS #36 Y4

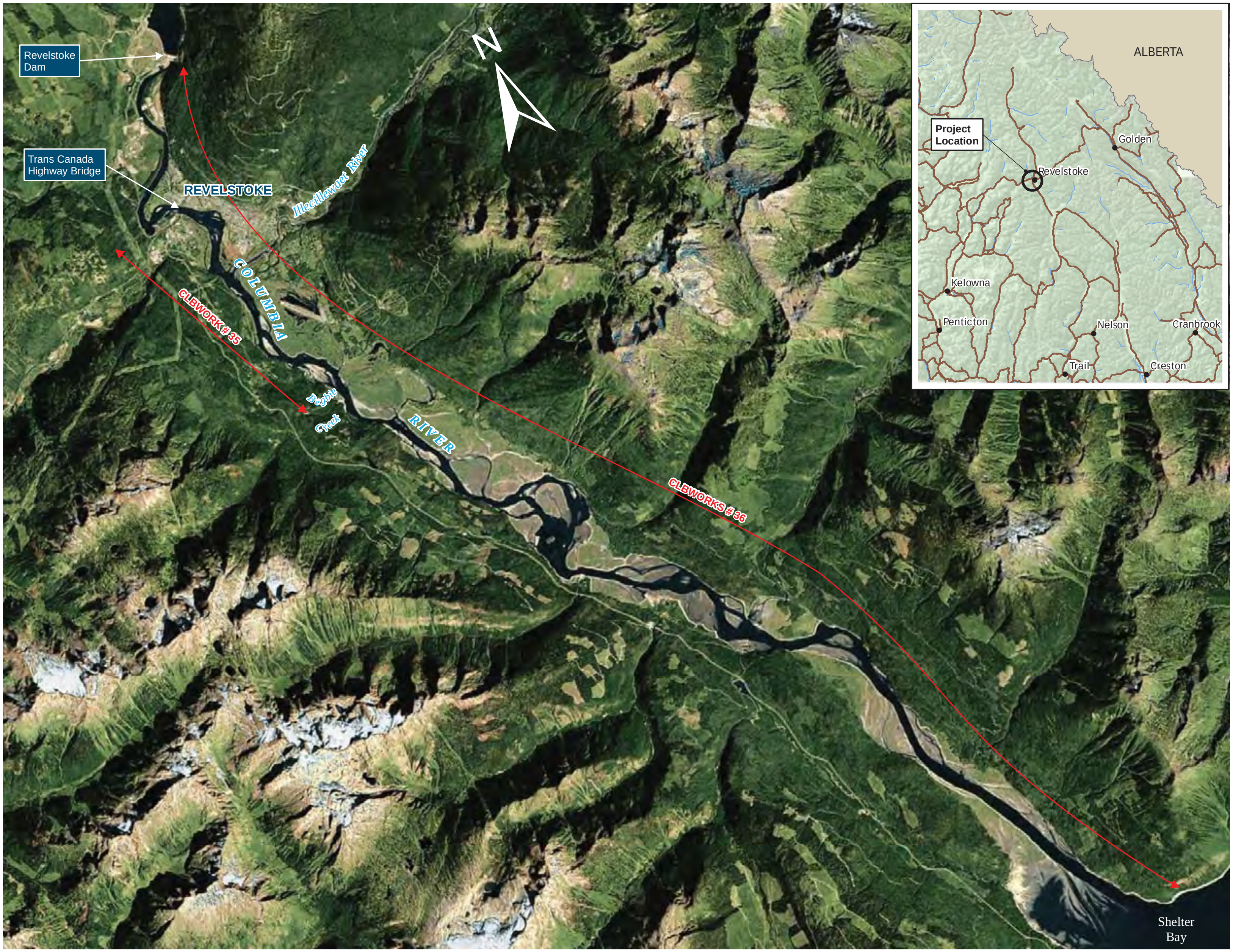
1.5 Project Team

Key project personnel for this project include KWL staff and sub-consultants listed in Table 1-3.

Table 1-3: Key Project Personnel

Name, Organization	Title	Project Role
Erica Ellis, M.Sc., P.Geo. – KWL	Fluvial Geomorphologist	Project Manager
Dave Murray, AScT, CPESC, P.Eng. – KWL	Senior Water Resources Engineer	Senior Technical Review
Sarah Lawrie, M.A.Sc., P.Eng. – KWL	Environmental Water Resources Engineer	Bioengineering Design Erosion Assessment
Jack Lau – KWL	GIS Specialist	GIS
Peter Tapp, Civil Technologist – KWL	Survey Coordinator	Survey Oversight and Coordination
Bruce VanCalsteren – KWL	Survey Technologist	Topographic Survey and Field Data Collection
Tony Minchenko – KWL	Technologist	Topographic Survey and Field Data Collection
Nick Page, B.L.A., M.Sc., R.P.Bio. Raincoast Applied Ecology	Professional Biologist	Bioengineering Design
Leska S. Fore, M.S., M.A. Leska, S. Fore, Statistical Design	Statistician	Statistical Design Statistical Analysis of Erosion Monitoring Data

Name, Organization	Title	Project Role
David Matsubara, M.Eng., P.Eng. Run of the River Boat Charters	Boat Operator	Boat Operator (Formerly KWL Project Manager)



BC Hydro
CLBWORKS #36 Mid-Columbia River Long-term Erosion Monitoring Program

Reference: Orthophoto from Bing aerial image map.

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2,500 0 2,500 (m)
1:125,000

Project No.	Date
478-081	November 2011

Location Plan

Figure 1-1

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2011\478081Fig1-1.mxd Date Saved: 11/29/2011 1:32:23 PM
Author: jlau

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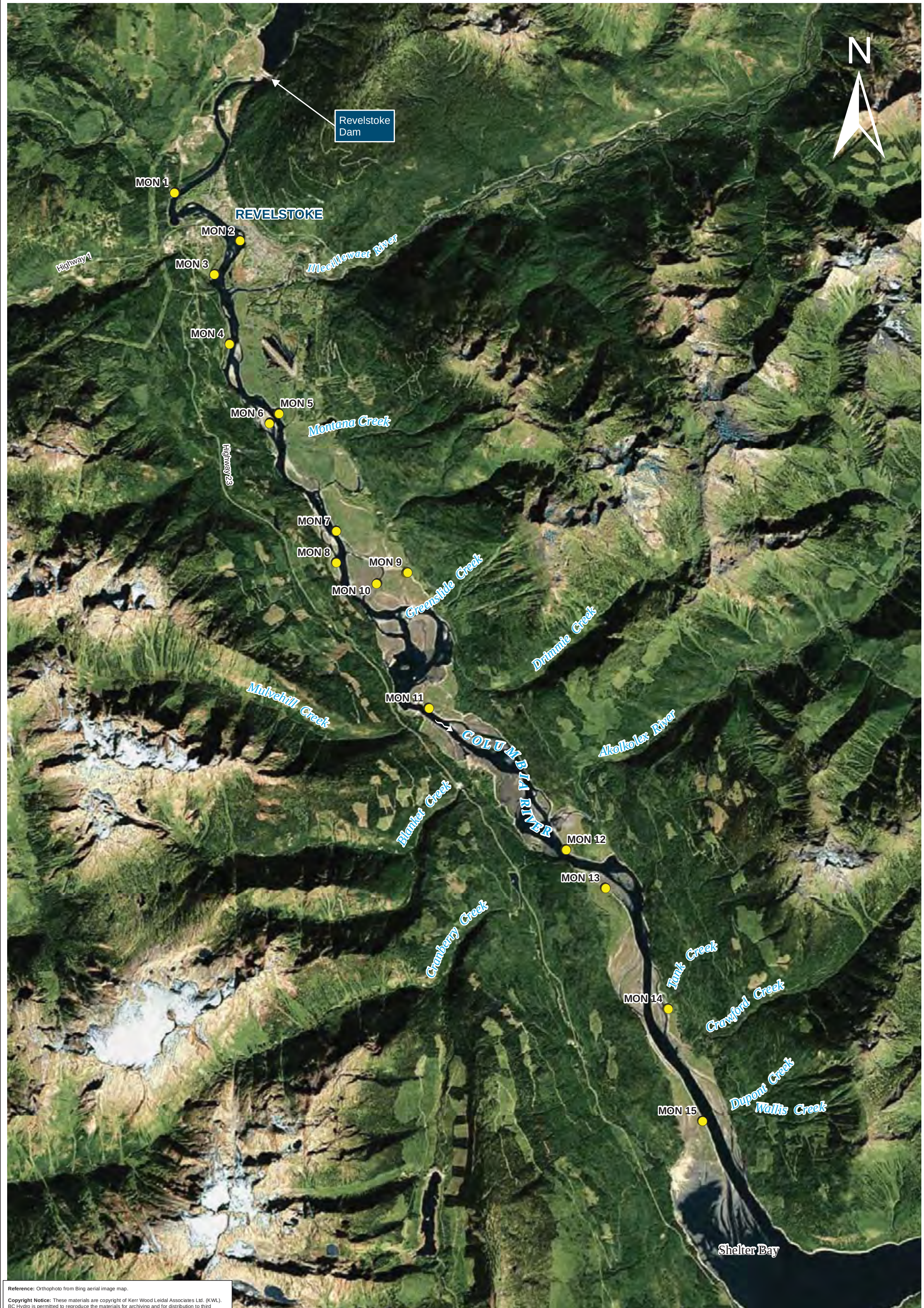
Author: jlau



Reference: Orthophoto from Bing aerial image map.

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BC Hydro
CLBWORKS #36 Mid-Columbia River Long-term Erosion Monitoring

Project No.	Date
478-081	November 2011

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Bank Erosion Monitoring Sites (CLBWORKS #36)

Figure 1-2

2. 2014 Monitoring

2014 monitoring work was conducted between April 23 and 27, 2014:

- Sites that could be accessed by vehicle were visited first, by a two-person field crew on April 23 and 24.
- Sites that require boat access (or for which vehicle access is less efficient) were visited by a three-person crew on April 26 and 27.

Water level and discharge conditions during the CLBWORKS #36 erosion monitoring work are summarized in Table 3-1.

Table 2-1: Water Level and Discharge Conditions During CLBWORKS #36 Fieldwork

Task	Dates	Arrow Lake Water Level (m)	Daily Average Revelstoke Dam Flow Release (3) (m^3/s)
Year 1 Site Installation	Apr. 28 to May 1, 2010	432.6 – 432.8 (1)	534 – 586
Year 2 Erosion Measurements	May 31 to Jun. 2, 2011 Jun. 13 to Jun. 14, 2011	433.3 – 433.5 (2) 435.4 – 435.6 (2)	292 – 815 841 – 1087
Year 3 Erosion Measurements	Apr. 11 to Apr. 25, 2012	427.7 – 428.1 (1)	178 – 949
Year 4 Erosion Measurements	Apr. 23-24, 26-27, 2014	429.1 – 429.3 (1)	267 – 615

Notes:
1. Water Survey of Canada: WSC 08NE104 (Arrow Reservoir at Nakusp).
2. BC Hydro (Arrow Reservoir at Fauquier).
3. Revelstoke Dam Flow Release data obtained from BC Hydro.

2.1 Field Methods and Measurements

Each site is evaluated for change (erosion or deposition) by two field methods:

- measuring the length of exposed pins placed in the bank (and comparing to previous measurements), and
- surveying cross-section transects perpendicular to the bankline (and comparing to previous surveys).

Field methods for both the erosion pins and the cross-sections are discussed in more detail, below.

2.1.1 Erosion Pins

At each site, 60 pins were placed in a random pattern and measured at installation in 2010. Each pin has a unique identifier so that it can be re-located and re-measured in subsequent years. Re-location is accomplished by maps, which show the locations of the pins relative to each other at the site, and a metal detector (to locate pins that have been buried through deposition of sediment).

Exposed (or buried) pin length has been measured again in 2011, 2012 and 2014. Erosion is measured as the length of exposed pin. Deposition is measured by locating the buried pin (using a metal detector and maps) and measuring the depth of deposited sediment to the top of the excavated pin (the hole is subsequently re-filled).

If erosion has exposed a substantial length of pin at the time of field visit, the pin is measured, re-set into the bank and re-measured. Occasionally rapid erosion will result in the pin 'toppling', in which case no measurement can be made and the pin is re-set (but noted to be toppled).

2.1.2 Cross-Sections

For each site, five cross-sections were also established and are surveyed at each monitoring interval. The surveyed cross-sections document distance and corresponding elevation (i.e., X,Y) from the top of the bank to the river's edge. The cross-sections are distributed over the same area of bank as is covered by the erosion pins.

Fieldwork involves locating the benchmarks that define the ends of the cross-section lines and then surveying each cross-section with a survey instrument. The orientation of the line is replicated year over year, so that cross-sections from different years can be compared (e.g. see Figure 2-1).

2.2 Data Reduction

2.2.1 Erosion Pins

Bank erosion exposes a greater length of a given pin compared to when it was last measured, whereas deposition covers the pin so that a shorter length is exposed (or completely buries it).

Steady erosion would result in a steadily-increasing pin length over time; however, since the pins are less than 1 m in length, they need to be re-set into the bank once a certain proportion of the pin is exposed, or they may topple out of the bank. In the field, the pin length data is recorded relative to the bank position at that time: data reduction is required to evaluate the overall change in the bank over a number of years.

To support the 2014 statistical analysis, the measured pin length data from all years was converted into cumulative pin length over time. This process takes into account any re-setting of the pins back into the bank for pins that were experiencing erosion.

Pins which were toppled part-way through the data collection are not included in the analysis. Issues related to toppled pins are discussed later in Section 3.3.

The resulting erosion pin dataset was provided to the project statistician for analysis.

2.2.2 Cross-Sections

To make comparisons of the cross-sections through time, survey data were reduced and plotted on drawings. Measurements were made between cross-sections surveyed in different years, at three points on each cross section. The points for measurement have been defined by dividing the total height of each cross-section into three equal ranges from the highest elevation (at the top of the bank) to the lowest elevation (at the river edge), to define a "lower", "middle" and "upper" portion of the bank. This is represented schematically in Figure 2-1.

As an example, if the surveyed elevation along a cross-section ranged from 400 m to 415 m, the total elevation range of 15 m would be divided into three equal elevation bands as follows:

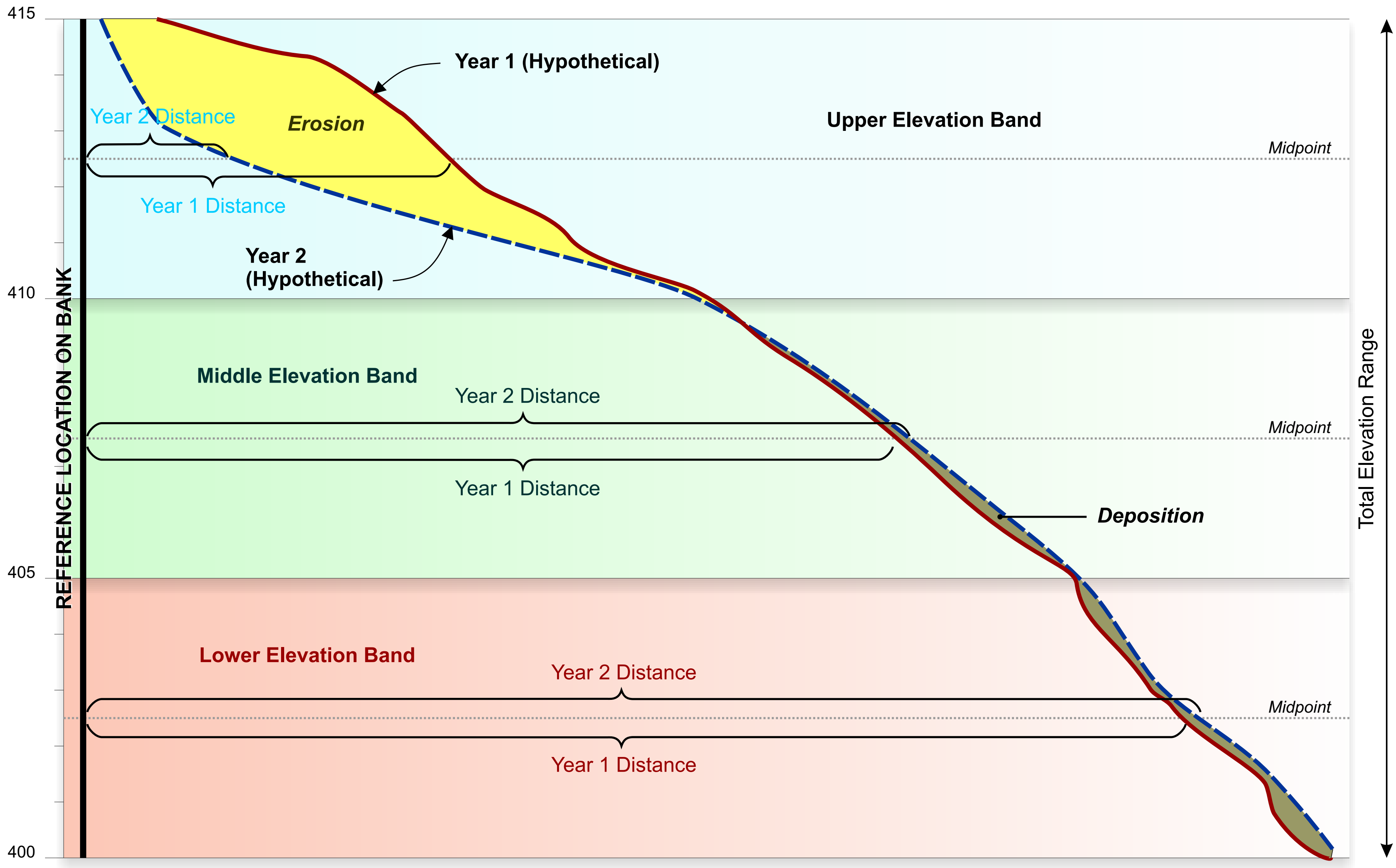
- lower elevation band: 400 m – 405 m;
- middle elevation band: 405 m – 410 m; and
- upper elevation band: 410 m – 415 m.

“Round” numbers have been used to illustrate this example: the actual elevations that define the upper, middle and lower elevation band at a given cross-section varied between cross-sections and sites.

To support the statistical analysis, the distance from a set point on the bank to the surveyed cross-section line from each year was measured. The distance was measured for each elevation band (lower, middle and upper) at the midpoint elevation of each band (Figure 2-1).

Steady erosion would result in decreasing distance over time, while steady deposition would result in increasing distance over time.

The resulting cross-section dataset was provided to the project statistician for analysis.



Demonstration of Cross-Section Comparison to Evaluate Erosion/Deposition

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Figure 2-1

3. Statistical Analysis

The statistical analysis tests whether erosion (or deposition) is occurring over time, using a regression analysis.

Based on the interim results presented herein, three conclusions are possible:

1. the bank change that is measured over time is not statistically significant,
2. statistically significant bank erosion has occurred over the 2010 to 2014 period, or
3. statistically significant bank deposition has occurred over the 2010 to 2014 period.

The Management Hypothesis asks a slightly different and more specific question, which is whether the rate of erosion is *increasing* over time. No mention is made of deposition in the Management Hypothesis although it is evident that sites that show statistically significant deposition are ones in which the null hypothesis would be rejected.

It should be noted that the question of whether erosion, if statistically significant, is actually increasing over time will be addressed in the final year of the project (2016), so that any acceleration in the rate of erosion over the life of the project will be most evident.

Results of the 2014 statistical analysis for the erosion pins and cross-sections are presented below.

3.1 Erosion Pins

Table 3-1 summarizes the number of pins measured at each site, in each measurement year. Records from pins that experienced toppling were not included in the statistical analysis. However, records from pins that were not located in a given year but found in later years were included in the analysis (with missing years).

In particular, re-locating the pins in 2011 was challenging due to the higher water levels during the measurement period: during the June portion of the fieldwork the Arrow Lake water level was about 3 m higher than it had been during the 2010 pin installation (see Table 2-1). In subsequent years, additional effort has been expended to carefully time fieldwork for the relatively short window following snowmelt (so that the ground is not obscured) but prior to a large increase in reservoir levels.

Table 3-1: Number of Pins Measured Each Year

Site	2010	2011[1]	2012	2014	2014 Pin Re-location Rate (Relative to 2010) (%)
MON1	60	57	60	60	100
MON2	60	40	41	39	65
MON3	61	9	35	17	28
MON4	60	33	56	52	87
MON5	60	4	46	43	72
MON6	60	5	46	43	72
MON7	60		25	25	42
MON8	60	22	48	47	78
MON9	60	58	57	57	95
MON10	60	53	59	59	98
MON11	59		14	15	25
MON12	60	45	58	59	98
MON13	60	56	59	57	95
MON14	60	7	N/A[2]	N/A[2]	N/A[2]
MON15	60	28	51	48	80

Notes:
1. Many pins could not be relocated in 2011 due to the higher water levels during part of the fieldwork (see Table 2-1).
2. MON14 data collection discontinued at request of upland property owner.

To evaluate change over time at each site, the change in pin length was evaluated for each pin by calculating a slope over years for pins that had two or more recorded measurements. The slope of the regression line for pin length by year was calculated and plotted for each pin at each site (Figure 3-1 and Figure 3-2). Appendix A includes site maps that display the location of the pins on the bank, as well as the regression slope for each pin.

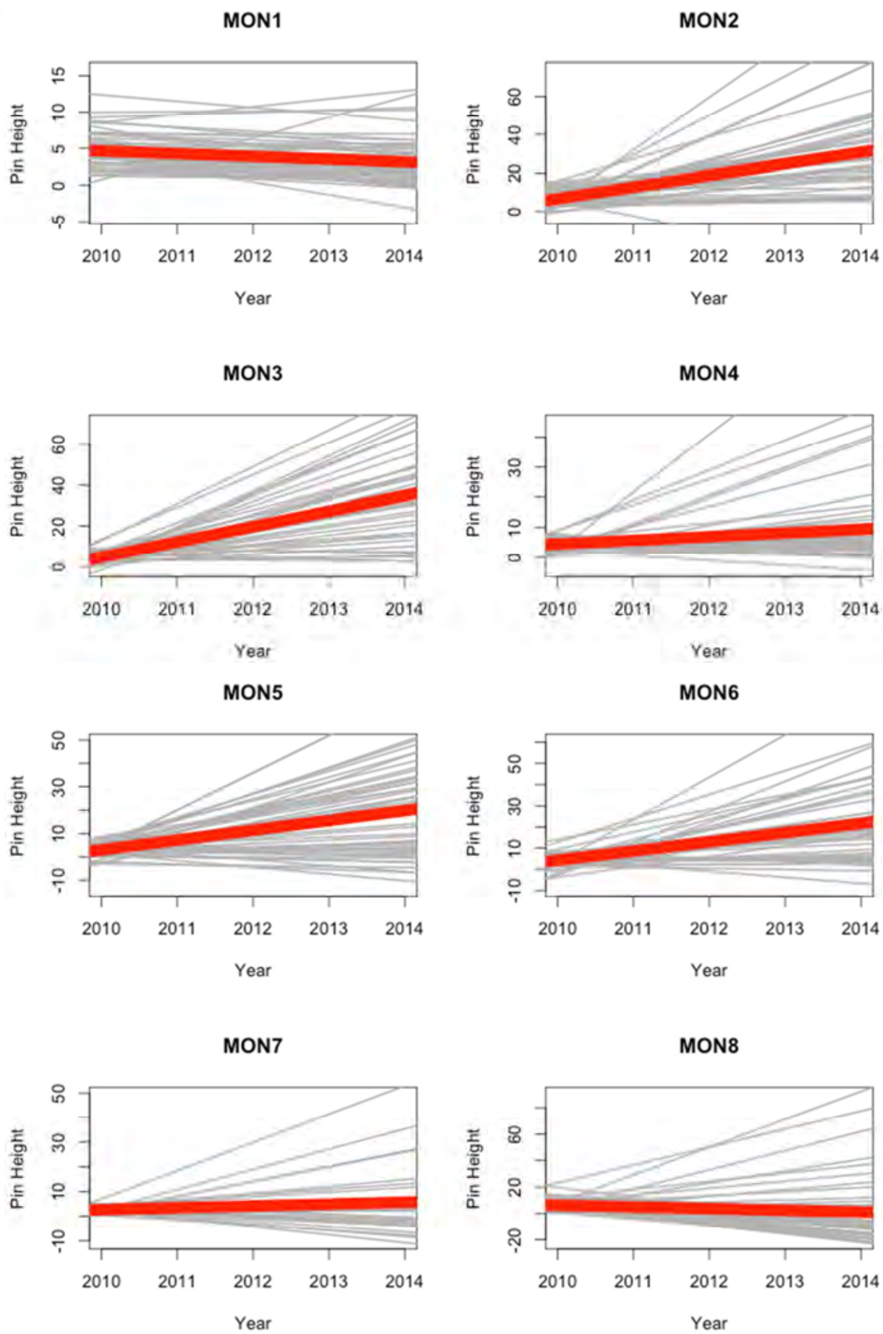

Figure 3-1: Erosion Pin Lengths (cm) Over Time Sites MON 1 Through MON 8 For Individual Pins (Grey Lines) And Site Average (Red Line). Erosion Indicated By Increasing Pin Length, Deposition Indicated By Decreasing Pin Length.

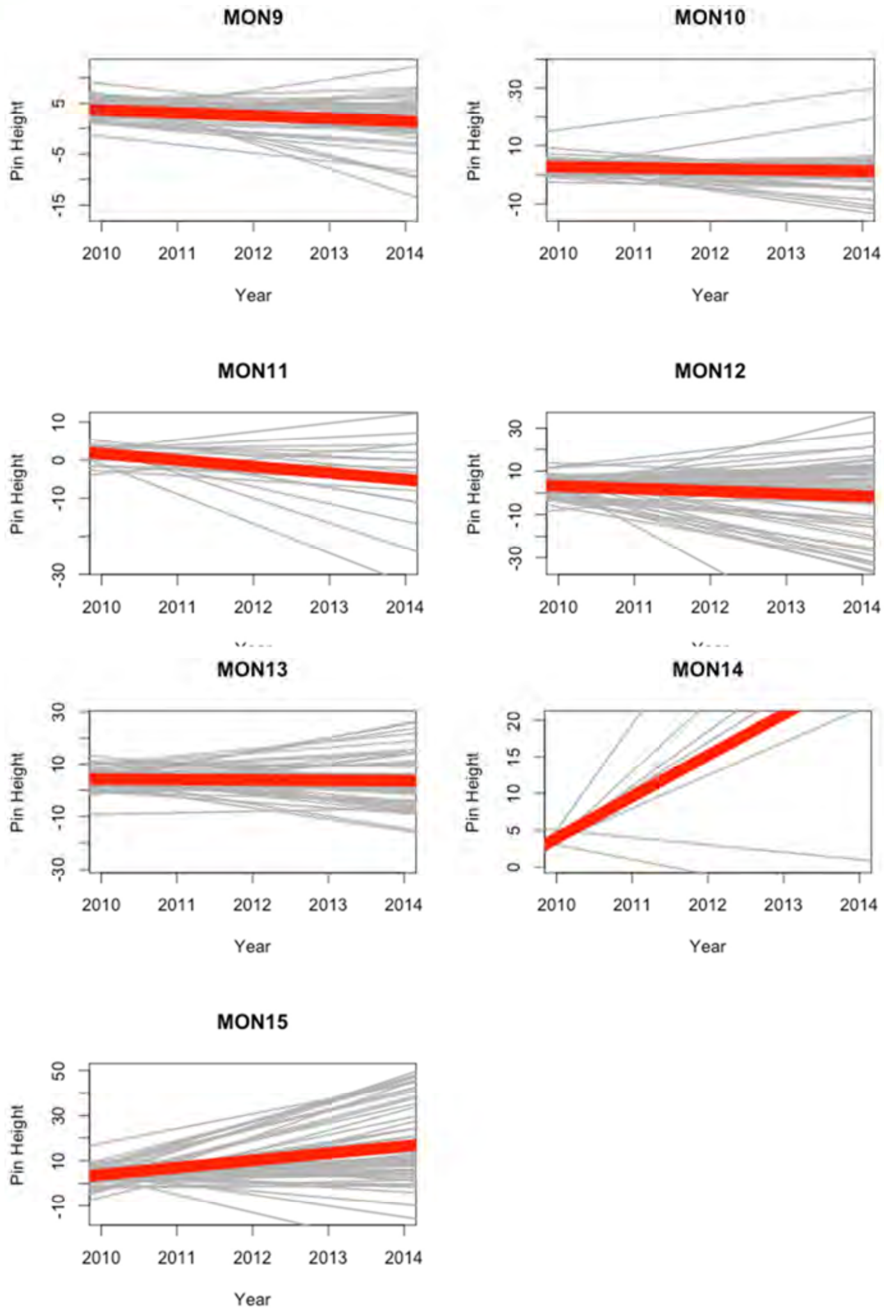

Figure 3-2: Erosion Pin Lengths (cm) Over Time Sites MON 9 through MON15 for Individual Pins (Grey lines) And Site Average (Red line). Erosion Indicated By Increasing Pin Length, Deposition Indicated By Decreasing Pin Length.

The average slope was calculated for each site and evaluated to determine if it was significantly different from 0 (one-sample t-test, two-sided test). The following results were obtained for the 14 active sites:

- five sites showed significant deposition,
- six sites showed significant erosion, and
- three sites showed no significant change.

Table 3-2 summarizes the results of the erosion pin regression analysis.

Table 3-2: Summary of Erosion Pin Regression Analysis By Site

Site	Average Slope (cm/yr)	SD (cm/yr)	Number of pins	P-value	Significance	Type of Change
MON1	-0.38	0.64	60	0.00	**	Deposition
MON2	6.02	6.08	48	0.00	**	Erosion
MON3	7.51	5.46	37	0.00	**	Erosion
MON4	1.23	3.69	56	0.02	*	Erosion
MON5	4.21	4.70	46	0.00	**	Erosion
MON6	4.34	4.42	47	0.00	**	Erosion
MON7	0.75	3.43	28	0.26	NS	
MON8	-1.27	5.77	50	0.13	NS	
MON9	-0.57	1.13	59	0.00	**	Deposition
MON10	-0.37	1.29	60	0.03	*	Deposition
MON11	-1.69	2.33	23	0.00	**	Deposition
MON12	-1.16	4.39	60	0.04	*	Deposition
MON13	-0.17	2.14	60	0.55	NS	
MON15	3.17	4.38	54	0.00	**	Erosion

Notes:
1. Positive slopes indicate erosion, negative slopes indicate deposition.
2. Individual pin slopes calculated for pins with two or more recorded measurements over the period of record. Average slope is the average of all calculated pin slopes for a given site.
3. Significance of change indicated as follows: * $p < 0.05$, ** $p < 0.01$, NS = Not significant, one-sample t-test, two-sided test.

Overall, the average change across all sites was 1.55 cm/year (erosion).

3.2 Cross-Section Data

At each of the 14 active sites, measurements were made from the 5 cross-sections at each of the three elevation bands (upper, middle and lower). Measurements were made from cross-sections surveyed in 2010, 2011, 2012, and 2014 (Table 3-3). In 2011, high water prevented measurements at several sites. These sites were included in the analysis with these data points treated as missing.

Table 3-3: Number of Cross-Section Measurements In Each Elevation Band By Year

Site	Upper				Middle				Lower			
	2010	2011	2012	2014	2010	2011	2012	2014	2010	2011	2012	2014
MON1	5	5	5	5	5	5	5	5	5	5	5	5
MON2	5	5	5	5	5	5	5	5	5	3[1]	5	5
MON3	5	5	5	5	5	5	5	5	5	3[1]	5	5
MON4	5	5	5	5	5	5	5	5	5	[1]	5	5
MON5	5	5	5	5	5	5	5	5	5	[1]	5	5
MON6	5	5	5	5	5	5	5	5	5	2[1]	5	5
MON7	5	5	5	5	5	[1]	5	5	5	[1]	5	5
MON8	5	5	5	5	5	5	5	5	5	[1]	5	5
MON9	5	5	5	5	5	5	5	5	5	4[1]	5	5
MON10	5	5	5	5	5	5	5	5	5	5	5	5
MON11	5	5	5	5	5	5	5	5	5	5	5	5
MON12	5	5	5	5	5	5	5	5	5	1[1]	5	5
MON13	5	5	5	5	5	5	5	5	5	5	5	5
MON14	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]	N/A[2]
MON15	5	5	5	5	5	5	5	5	5	0	5	5

Notes:
1. Missing cross-section measurements are due to high water levels at the time of survey, which limited the extent of the bank that could be surveyed. A blank indicates no data.
2. MON14 data collection discontinued at request of upland property owner.

For each site, change over time was measured as the change in the distance measured on each cross-section for each of the three elevation bands. A regression line was calculated for the resulting dataset (five cross-sections per site, and three elevation bands: 15 slope values).

The resulting regression lines are plotted for each site in Figure 3-3 and Figure 3-4. Note that in Figure 3-3 and Figure 3-4, a consistently decreasing distance (negative slope) would imply consistent erosion over time, while a consistently increasing distance (positive slope) would imply consistent deposition over time (i.e. opposite to how the erosion pin data are interpreted).

Appendix B includes drawings that display the surveyed cross-sections in each year.

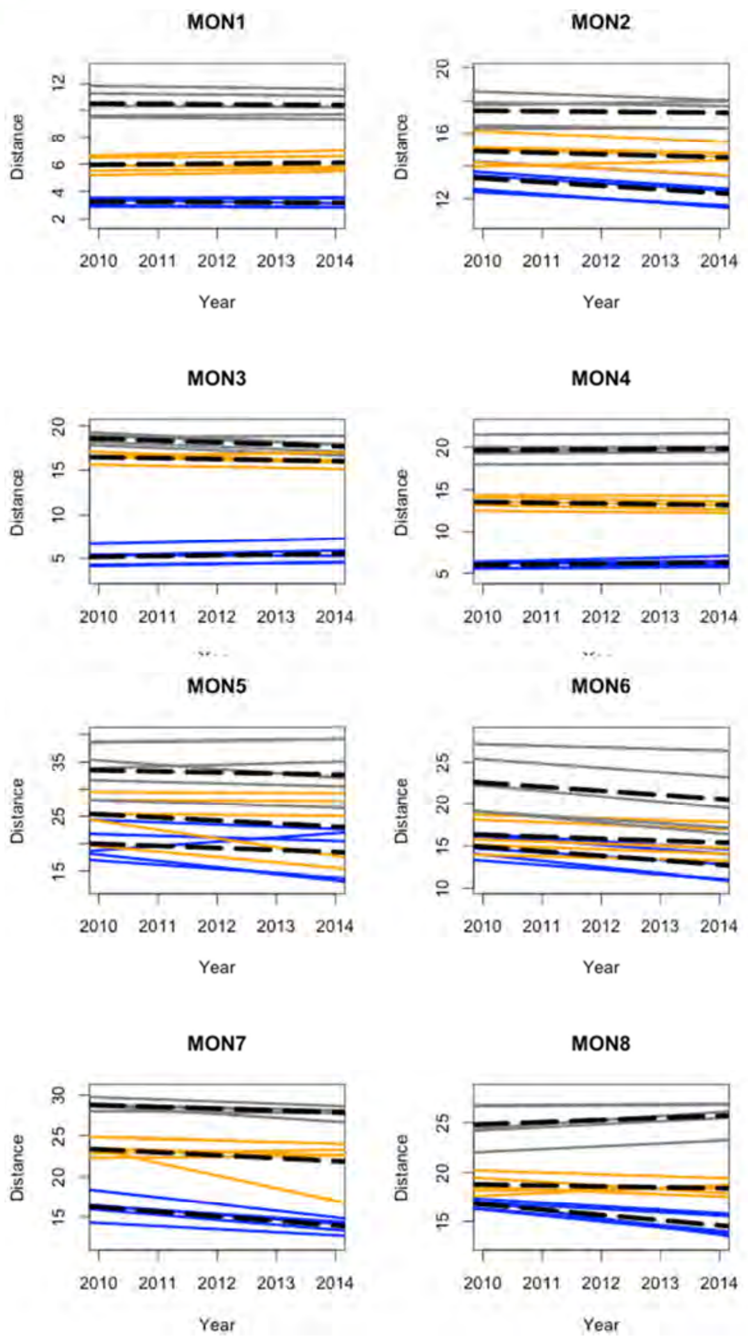

Figure 3-3: Distance To Cross-section (XS) Line (m) For Individual XS in Elevation Band (Upper: Blue, Middle: Orange and Lower: Grey), and Average (Black Dash), Sites MON 1 Through MON 8. Erosion Indicated By Decreasing Distance, Deposition Indicated By Increasing Distance.

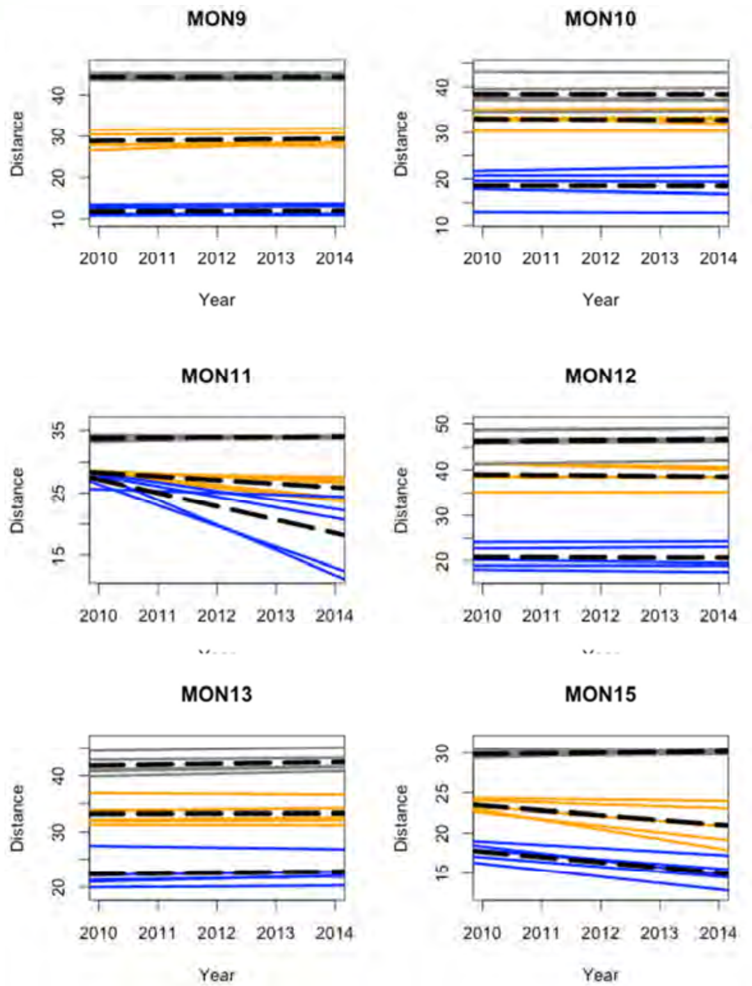

Figure 3-4: Distance To Cross-section (XS) Line For Individual XS In Elevation Band (Upper: Blue, Middle: Orange, Lower: Grey), And Average (Black Dash), Sites MON 9 Through MON 15. Erosion Indicated By Decreasing Distance, Deposition Indicated By Increasing Distance.

Within each site and elevation band, slopes were tested to determine if they were significantly different from 0 (i.e. no change over time) (one-sample t-test, two-sided test). Results for each site are summarized by elevation band and presented in Table 3-4 (Upper), Table 3-5 (Middle) and Table 3-6 (Lower).

In general, the following trends are noted:

- Changes in the upper elevation band, if statistically significant, are erosion: six sites out of 14 showed statistically significant erosion (Table 3-4).
- Similarly, changes in the middle elevation band, if statistically significant, are erosion: four sites out of 14 showed statistically significant erosion (Table 3-5).
- Statistically significant lower elevation band changes are evenly split between erosion and deposition (six sites out of 14 showed statistically significant change, Table 3-6).

The overall change for all sites and all elevation bands was -0.19 m/year (erosion).

Table 3-4: Summary of Cross-Section Regression Analysis By Site For Upper Elevation Band

Site	Elev. Band	Average Slope (m/yr)	SD (m/yr)	Number of XS	P-value	Significance	Type of Change
MON1	Upper	-0.02	0.03	5	0.23		
MON2	Upper	-0.23	0.03	5	0.00	**	Erosion
MON3	Upper	0.08	0.07	5	0.06		
MON4	Upper	0.07	0.08	5	0.12		
MON5	Upper	-0.37	0.73	5	0.32		
MON6	Upper	-0.53	0.12	5	0.00	**	Erosion
MON7	Upper	-0.57	0.17	5	0.00	**	Erosion
MON8	Upper	-0.54	0.20	5	0.00	**	Erosion
MON9	Upper	0.04	0.03	5	0.03	*	
MON10	Upper	-0.02	0.17	5	0.80		
MON11	Upper	-2.14	1.50	5	0.03	*	Erosion
MON12	Upper	-0.03	0.11	5	0.54		
MON13	Upper	0.09	0.15	5	0.23		
MON15	Upper	-0.66	0.19	5	0.00	**	Erosion

Notes:
1. Negative slopes indicate erosion, positive slopes indicate deposition.
2. Average slope is the average of all calculated cross-section slopes for a given elevation band and site.
3. Significance of change indicated as follows: * $p < 0.05$, ** $p < 0.01$, NS = Not significant, one-sample t-test, two-sided test.

Table 3-5: Summary of Cross-Section Regression Analysis By Site For Middle Elevation Band

Site	Elev. Band	Average Slope (m/yr)	SD (m/yr)	Number of XS	P-value	Significance	Type of Change
MON1	Middle	0.03	0.05	5	0.16		
MON2	Middle	-0.09	0.11	5	0.13		
MON3	Middle	-0.11	0.13	5	0.14		
MON4	Middle	-0.09	0.05	5	0.02	*	Erosion
MON5	Middle	-0.56	0.70	5	0.15		

MON6	Middle	-0.23	0.04	5	0.00	**	Erosion
MON7	Middle	-0.36	0.69	5	0.31		
MON8	Middle	-0.09	0.25	5	0.47		
MON9	Middle	0.13	0.19	5	0.22		
MON10	Middle	-0.05	0.18	5	0.55		
MON11	Middle	-0.59	0.41	5	0.03	*	Erosion
MON12	Middle	-0.11	0.13	5	0.13		
MON13	Middle	0.03	0.07	5	0.44		
MON15	Middle	-0.59	0.45	5	0.04	*	Erosion

Notes:
1. Negative slopes indicate erosion, positive slopes indicate deposition.
2. Average slope is the average of all calculated cross-section slopes for a given elevation band and site.
3. Significance of change indicated as follows: * $p < 0.05$, ** $p < 0.01$, NS = Not significant, one-sample t-test, two-sided test.

Table 3-6: Summary of Cross-Section Regression Analysis By Site For Lower Elevation Band

Site	Elev. Band	Average Slope (m/yr)	SD (m/yr)	Number of XS	P-value	Significance	Type of Change
MON1	Lower	-0.03	0.03	5	0.12		
MON2	Lower	-0.03	0.07	5	0.39		
MON3	Lower	-0.22	0.15	5	0.03	*	Erosion
MON4	Lower	0.04	0.04	5	0.05		
MON5	Lower	-0.19	0.42	5	0.36		
MON6	Lower	-0.49	0.19	5	0.00	**	Erosion
MON7	Lower	-0.22	0.16	5	0.04	*	Erosion
MON8	Lower	0.21	0.17	5	0.05	*	Deposition
MON9	Lower	0.00	0.04	5	0.97		
MON10	Lower	0.00	0.05	5	0.87		
MON11	Lower	0.05	0.12	5	0.39		
MON12	Lower	0.10	0.05	5	0.01	*	Deposition
MON13	Lower	0.15	0.05	5	0.00	**	Deposition
MON15	Lower	0.08	0.10	5	0.16		

Notes:
1. Negative slopes indicate erosion, positive slopes indicate deposition.
2. Average slope is the average of all calculated cross-section slopes for a given elevation band and site.
3. Significance of change indicated as follows: * $p < 0.05$, ** $p < 0.01$, NS = Not significant, one-sample t-test, two-sided test.

3.3 Discussion

3.3.1 Comparison of Observed Trends Between Methods

Direction of Trends

Table 3-7 (below) presents the statistically significant trends for each site based on the results for the erosion pins, and the cross-sections at each elevation band. Coloured shading has been used to indicate all sites where there was no disagreement in trend.

The following summary points may be made regarding trend direction:

- Statistically significant trends were detected in all 14 sites by one or more measures: in ten sites the trend was significant in more than one measurement method.
- Of those ten sites, most indicated agreement in the direction of the trend (i.e., either erosion or deposition).
- However, at two sites (MON 8 and MON11), the results indicate that statistically significant erosion and deposition both are occurring.
- There is a *tendency* for eroding sites to be located in the upstream portion of the study reach, and deposition sites to be located in the downstream portion of the reach.

Table 3-7: Summary of Statistically Significant Trends by Site and Measurement Method

Site	Erosion Pins	XS Upper	XS Middle	XS Lower
MON1	Deposition			
MON2	Erosion	Erosion		
MON3	Erosion			Erosion
MON4	Erosion		Erosion	
MON5	Erosion			
MON6	Erosion	Erosion	Erosion	Erosion
MON7		Erosion		Erosion
MON8		Erosion		Deposition
MON9	Deposition			
MON10	Deposition			
MON11	Deposition	Erosion	Erosion	
MON12	Deposition			Deposition
MON13				Deposition
MON15	Erosion	Erosion	Erosion	

Notes:
1. Shading indicates that there was no disagreement in trend (either agreement, or only one significant trend). Deposition = blue, Erosion = brown.

Magnitude of Trend

In general, more sites showed erosion than deposition for both erosion pin measurements and cross-section measurements (Table 3-7).

The change measured by erosion pins was 1.55 cm/year, or 0.0155 m/year, (erosion) when calculated as an average across all active sites. The change measured by cross-sections was -19 cm/year or -0.19 m/year (erosion) when calculated as an average across all active sites and elevation bands[1]. The average rates differ by an order of magnitude, with the cross-sections yielding the higher rate of erosion.

Some differences can be expected given the orientation of the measurements:

- the erosion pins are measuring erosion and deposition (quasi-) perpendicular to the bank surface,
- the cross-sections are measuring erosion and deposition along a horizontal line intersecting the bank profile.

As the bank angle approaches 90° (a vertical cut bank), the difference in the resulting measurement (by pin or by cross-section) approaches zero. However, for shallowly-sloping banks the difference would be magnified and the dimension measured by the cross-sections would be larger than what is being measured by the erosion pins.

[1]Note that both measures indicate erosion although one measure is negative and the other is positive.

Both measures are 'correct', but with a different frame of reference. Therefore, it is important simply to note the different orientation of the measurement when considering the overall rates of change.

Another factor is the degree to which rapid erosion may be contributing to bias in the erosion pin results: erosion that is sufficiently rapid that it causes pins toppling between site visits results in those toppled pins not being included in the analysis. The reason for not including toppled pins is that the amount of erosion that actually occurred is unknown: the erosion that occurred prior to toppling, as well as the erosion (or deposition) that may have occurred while the pin was toppled. As well, it is possible for toppling to occur as a result of human or animal intervention, although this is only likely to occur at certain sites (i.e., where vehicle access is possible and where there is evidence of human or vehicle impact at the site).

For sites at which rapid (natural) erosion is likely to have resulted in pin toppling, rates of erosion based on pins will have a bias which will yield lower rates of erosion than the "true" rate, while the cross-section results should provide an unbiased result.

The possibility of assuming a nominal 'maximum' erosion for toppled pins and then including those pins in the statistical analysis will be investigated in the final year of the project, to see if closer agreement may be achieved between erosion rates based on pins and those based on cross-sections.

4. Summary and Future Work

4.1 Summary

The following summary points may be made based on the interim results presented in this report:

- 2014 erosion monitoring fieldwork was conducted in late April, at a range of Columbia River discharges and Arrow Lakes water levels that is comparable, or lower than, previous years on the project.
- Fieldwork involved locating, identifying and measuring the length of exposed (or buried) erosion pins, and of re-locating and re-surveying cross-sections at each active monitoring site (14 sites total).
- Data reduction involved the following tasks:
  - converting erosion pin lengths from each year into a cumulative total pin length over time (2010 through 2014); and
  - measuring the distance from a fixed point on the bank to the intersection with each year's cross-section line, at set elevations (representing 'Upper', 'Middle' and 'Lower' elevation bands).
- Statistical data analysis of the resulting data set took the form of a regression analysis to test whether the erosion pin length and cross-section distances showed evidence for consistent trends over time (either increases or decreases, which would indicate erosion or deposition).
- Statistically significant erosion and deposition trends were detected, in both the erosion pins and cross-sections.
- A greater number of sites showed erosion than deposition.
- On average, erosion pins indicate an overall erosion rate of 1.55 cm/year (0.0155 m/year), while cross-sections indicate an overall erosion rate of 19 cm/year (0.19 m/year). The difference in erosion rate is likely partly due to the orientation of the measurements, and partly due to the potential for rapid erosion to result in missing data (thereby affecting the calculated average).

4.2 Future Work

The final year of CLBWORKS #36 erosion monitoring is scheduled for 2016. The final dataset will provide a record of bank change over seven years of monitoring (2010 to 2016).

The 2016 analyses will include the following elements:

- investigation of how best to include toppled pins in the data analysis;
- an explicit test of the Management Hypothesis ("*Shoreline erosion does not increase significantly through the duration of the Project.*");
- assess whether there have been changes in the spatial extent of areas susceptible to erosion over the monitoring period based on the project dataset;
- high-level identification of shoreline areas susceptible to erosion within the project reach based on generalization of the project results;
- commentary on erosion mechanisms, based on field observations and data analyses; and
- recommendations for future monitoring, if appropriate.

4.3 Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

PROFESSIONAL PROVINCE OF E. R. ELLIS #32982 BRITISH COLUMBIA GEOSCIENTIST

March 17, 2015

Erica Ellis, M.Sc., P.Geo.
Fluvial Geomorphologist

Reviewed by:

David Murray, P.Eng., AScT, CPESC
Senior Water Resources Engineer

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consulting engineers

Appendix A

Monitoring Site Erosion Pin Maps

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2014\478081_2014_MonSites.mxd Date Saved: 14/11/2014 3:21:31 PM
Author: SCowan

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No. 478-081

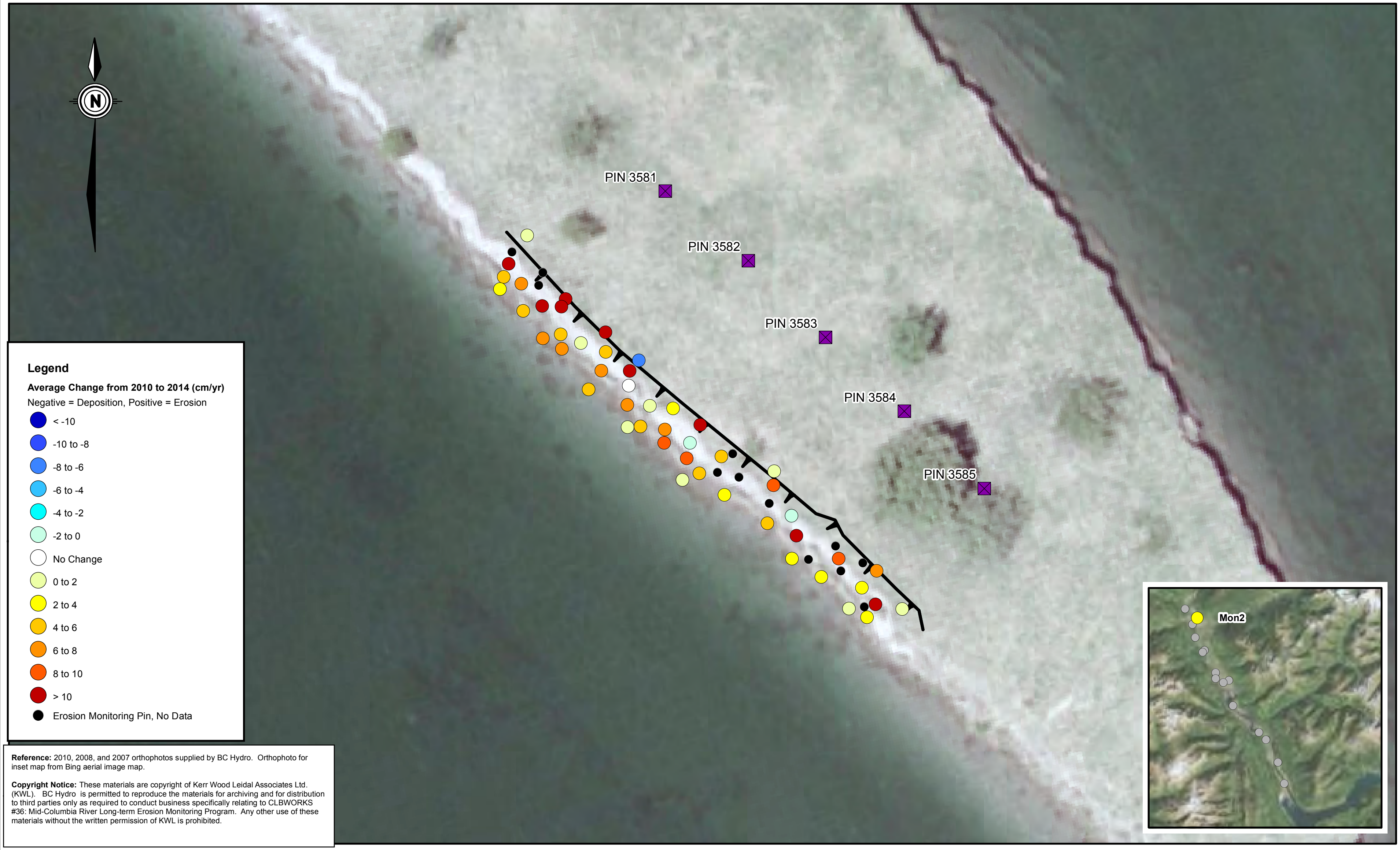
Date November 2014

10 0 10 (m)
1:500

MON 1 Erosion Pin Average Change (2010 to 2014)

Figure A1

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2014\478081_2014_MonSites.mxd Date Saved: 14/11/2014 3:21:31 PM
Author: SCowan



Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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MON 2 Erosion Pin Average Change (2010 to 2014)

Figure A2

Path: O:\0400-0499\478-081\430-GIS\MXD-Rp\2014\478081_2014_MonSites.mxd Date Saved: 14/11/2014 3:21:31 PM
Author: SCowan

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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MON 3 Erosion Pin Average Change (2010 to 2014)

Figure A3

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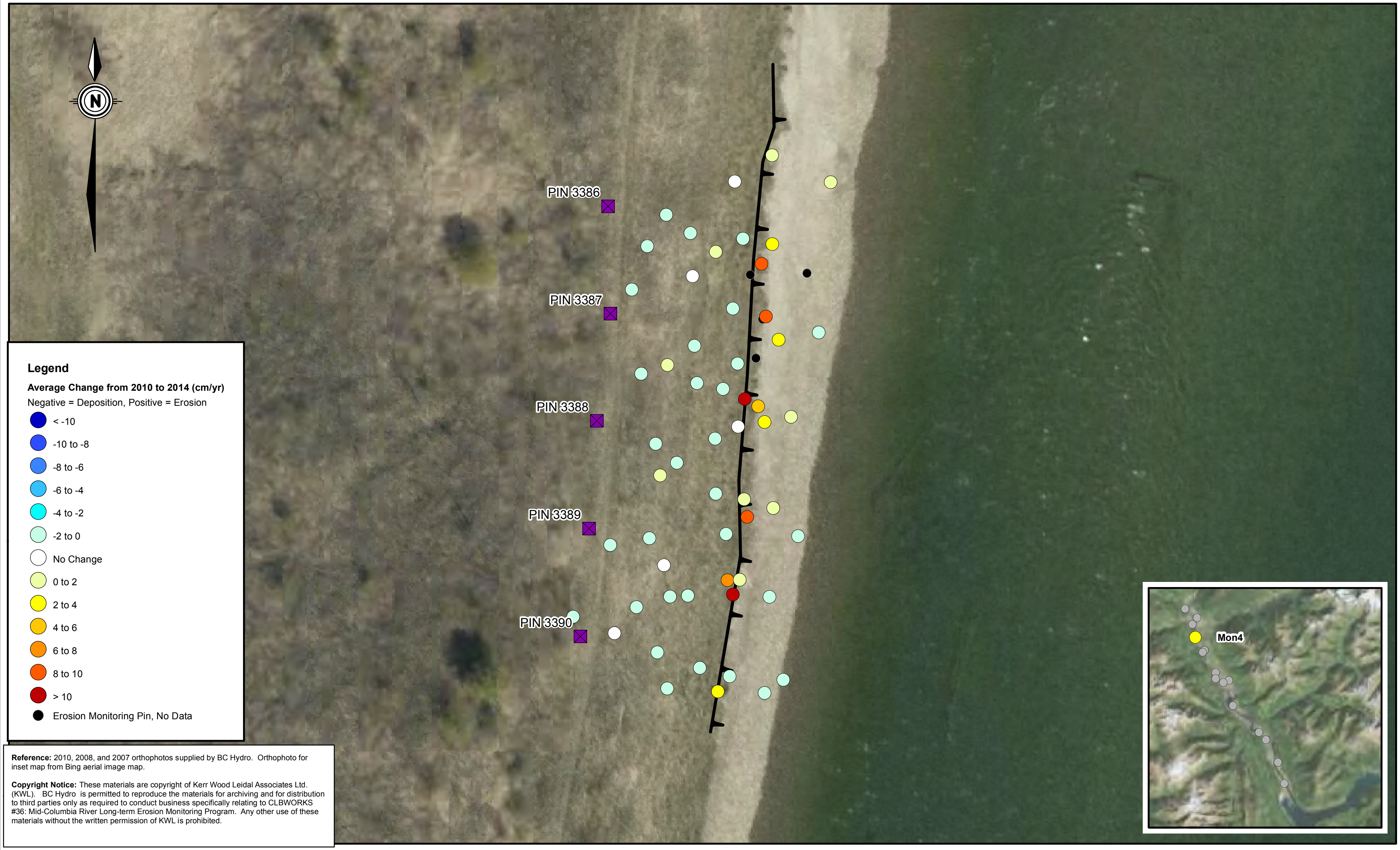

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No.	Date
478-081	November 2014

Scale: 10 0 10 (m)
1:500

MON 4 Erosion Pin Average Change (2010 to 2014)

Figure A4

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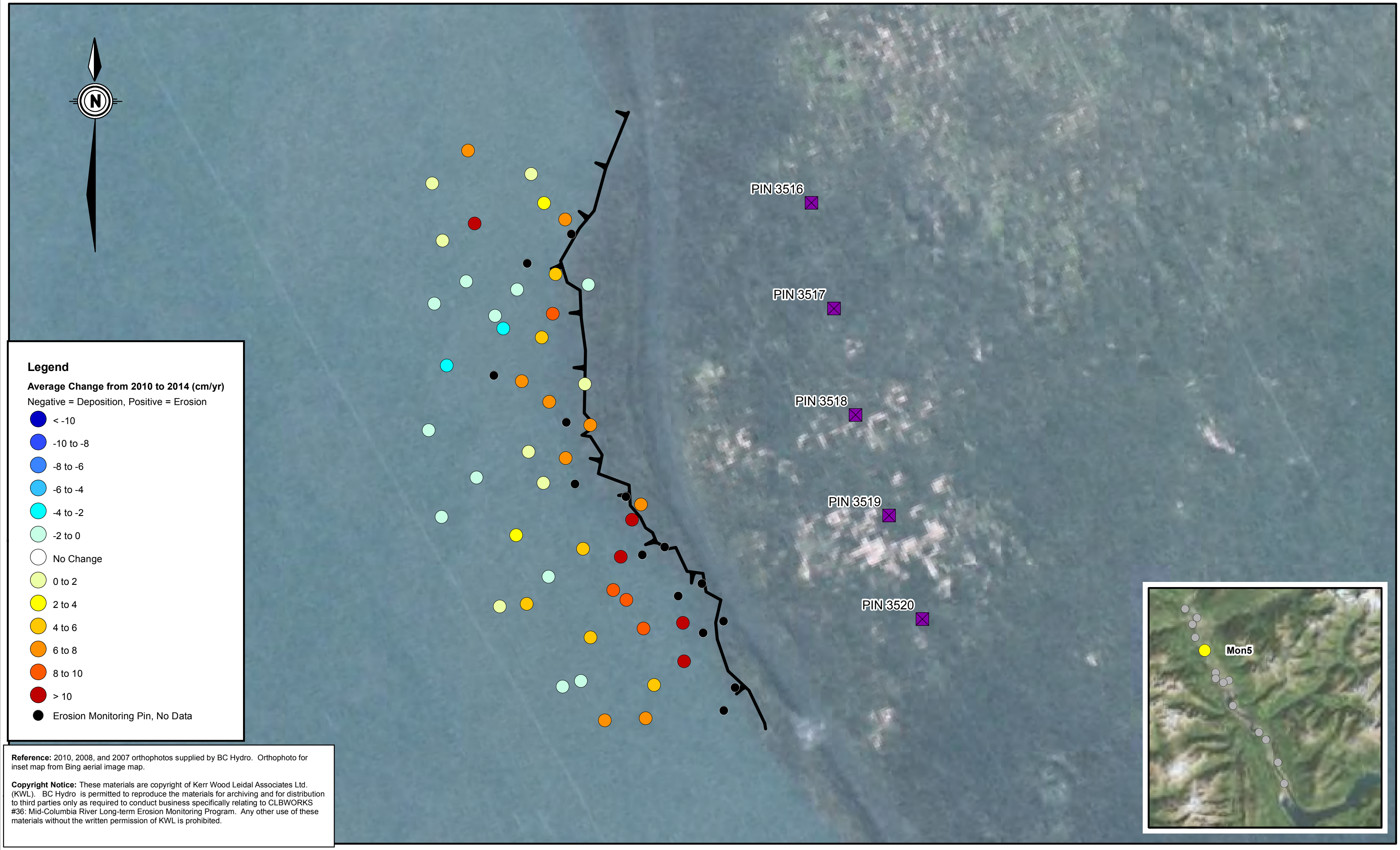
Author: SCowan



Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Date November 2014

10 0 10 (m)

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MON 5 Erosion Pin Average Change (2010 to 2014)

Figure A5

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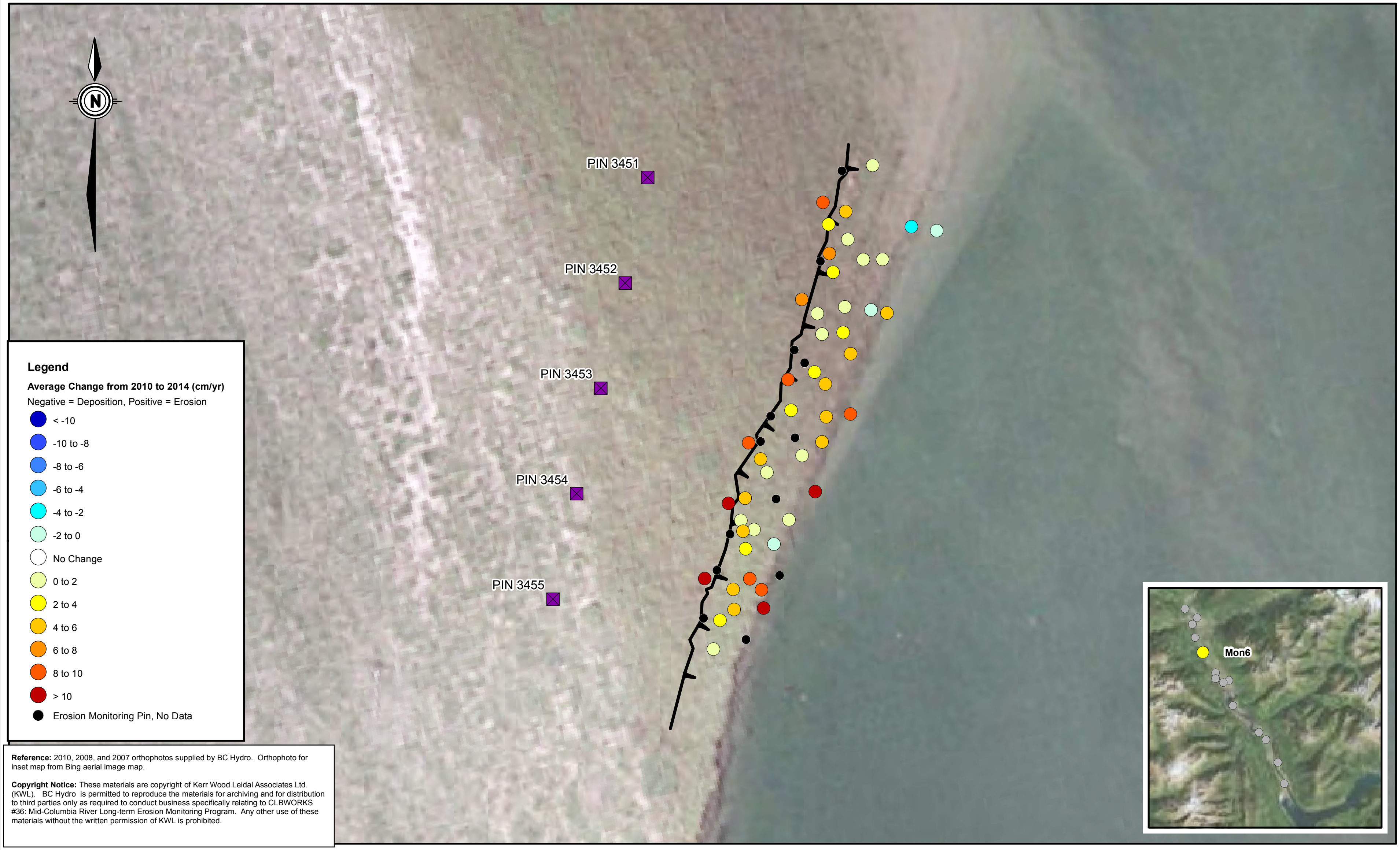
Author: SCowan



Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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478-081	November 2014

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MON 6 Erosion Pin Average Change (2010 to 2014)

Figure A6

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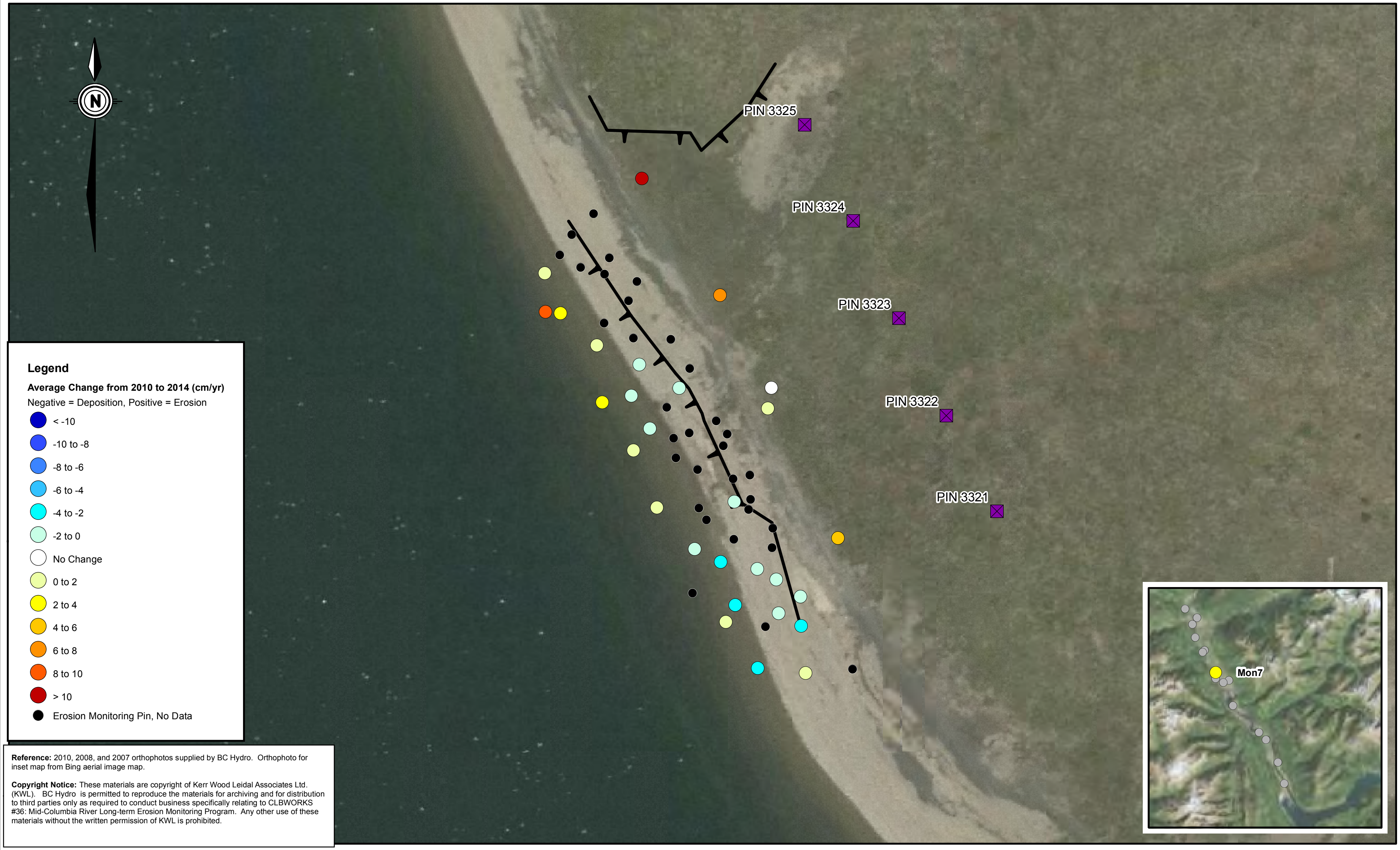

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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MON 7 Erosion Pin Average Change (2010 to 2014)

Figure A7

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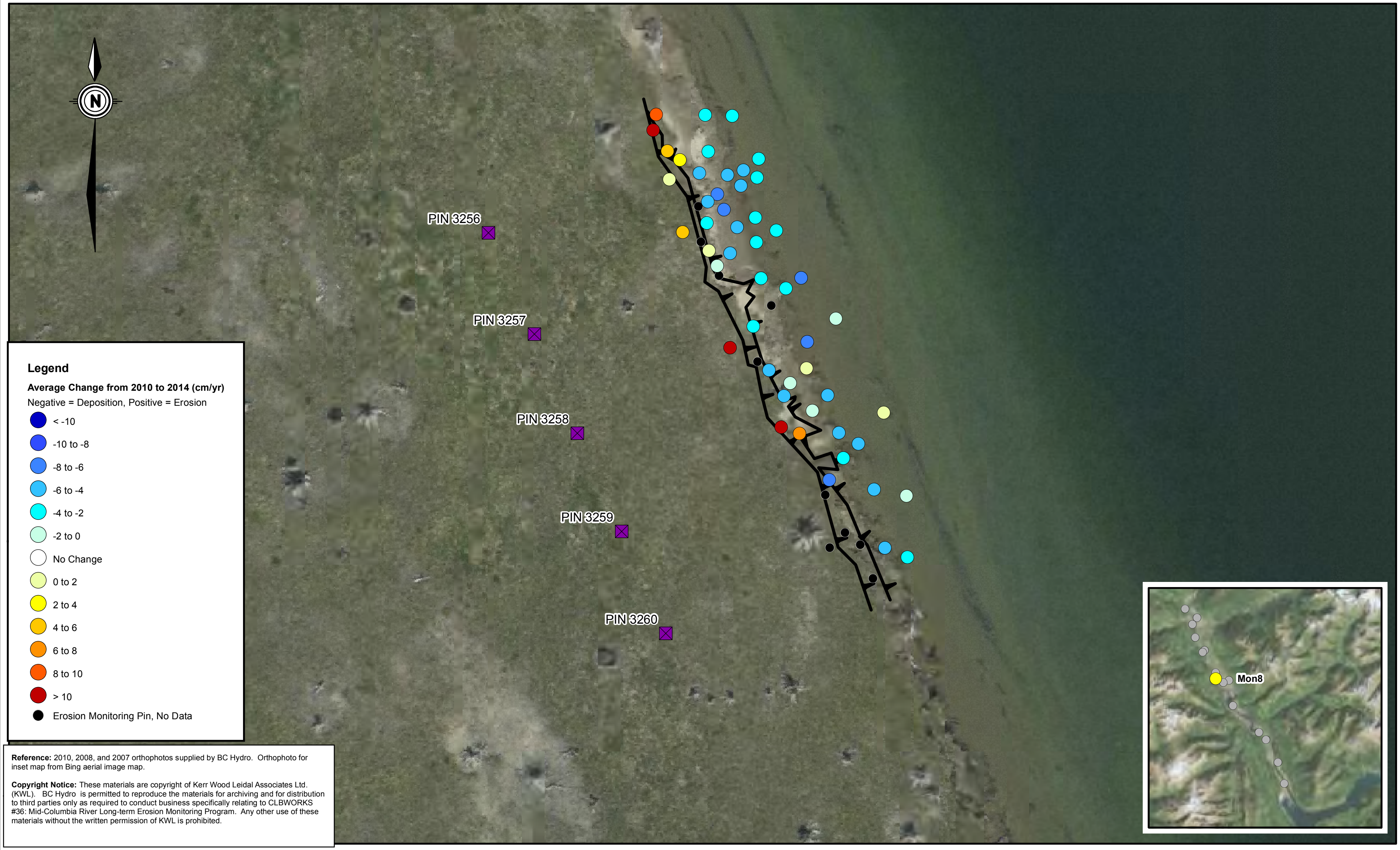

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MON 8 Erosion Pin Average Change (2010 to 2014)

Figure A8

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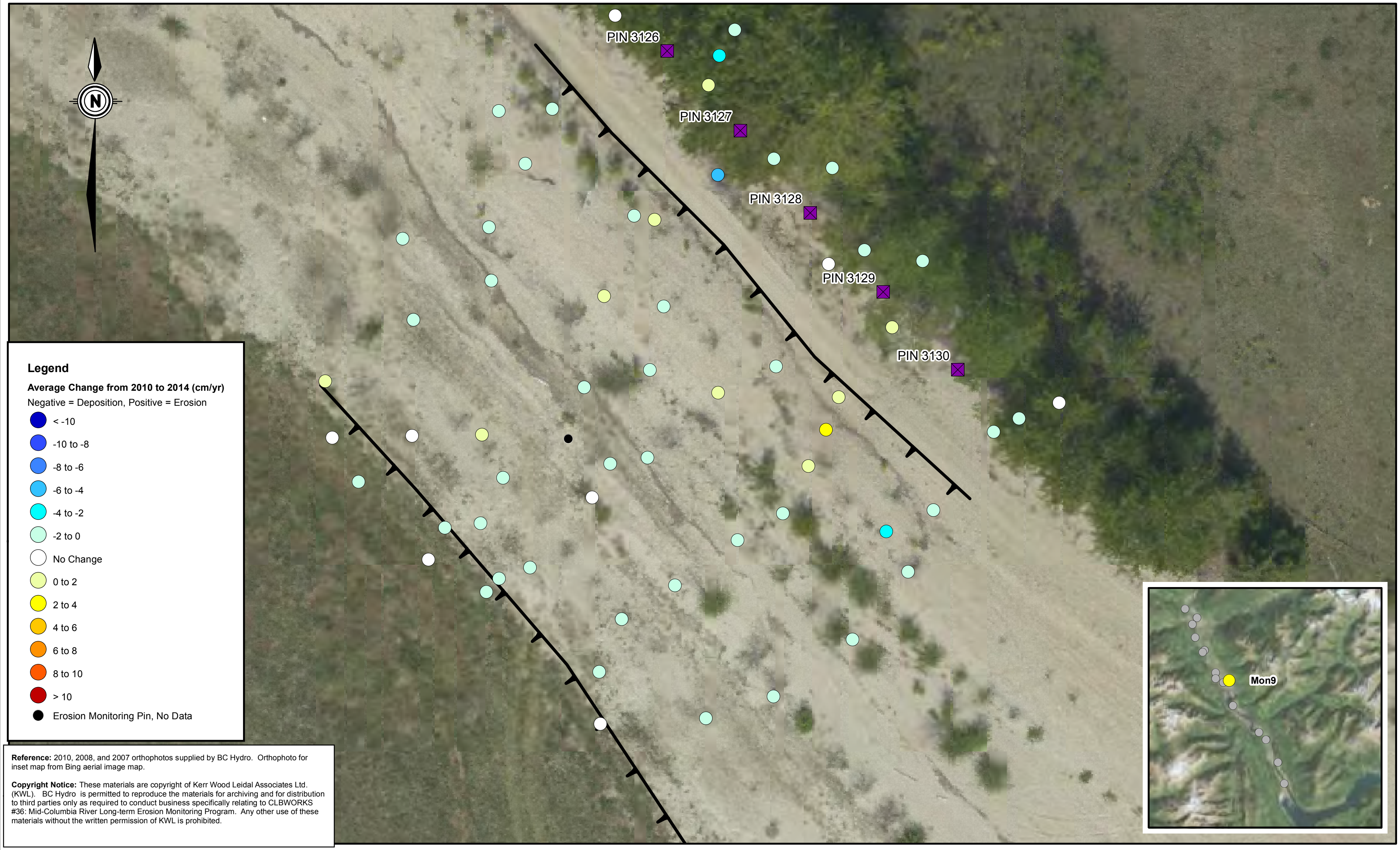

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No.	Date
478-081	November 2014

10 0 10 (m)
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MON 9 Erosion Pin Average Change (2010 to 2014)

Figure A9

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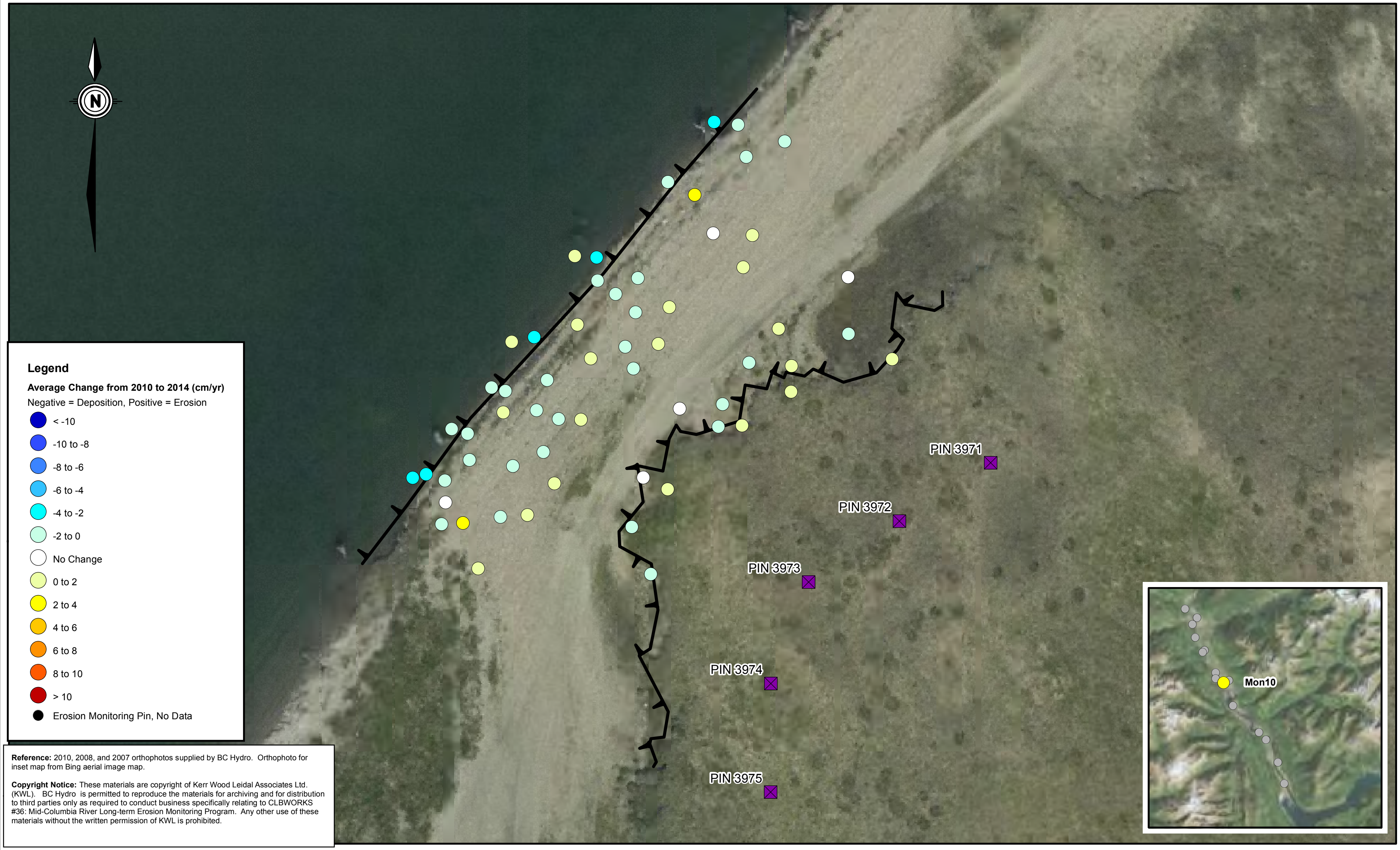
Author: SCowan



Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No.	Date
478-081	November 2014

Scale: 10 0 10 (m)
1:500

MON 10 Erosion Pin Average Change (2010 to 2014)

Figure A10

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Author: SCowan

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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10 0 10 (m)
1:500

MON 11 Erosion Pin Average Change (2010 to 2014)

Figure A11

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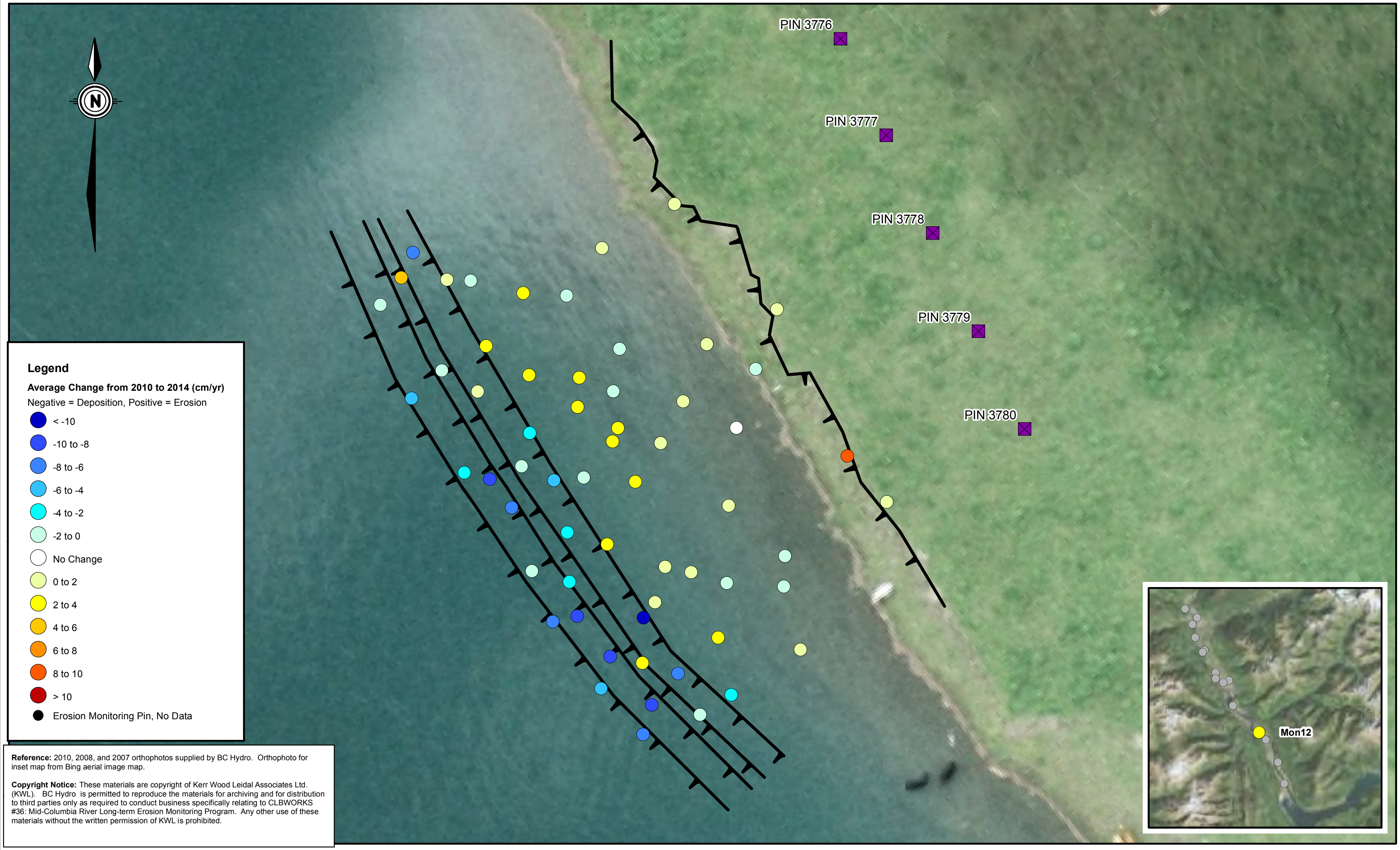

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No.	Date
478-081	November 2014

10 0 10 (m)
1:500

MON 12 Erosion Pin Average Change (2010 to 2014)

Figure A12

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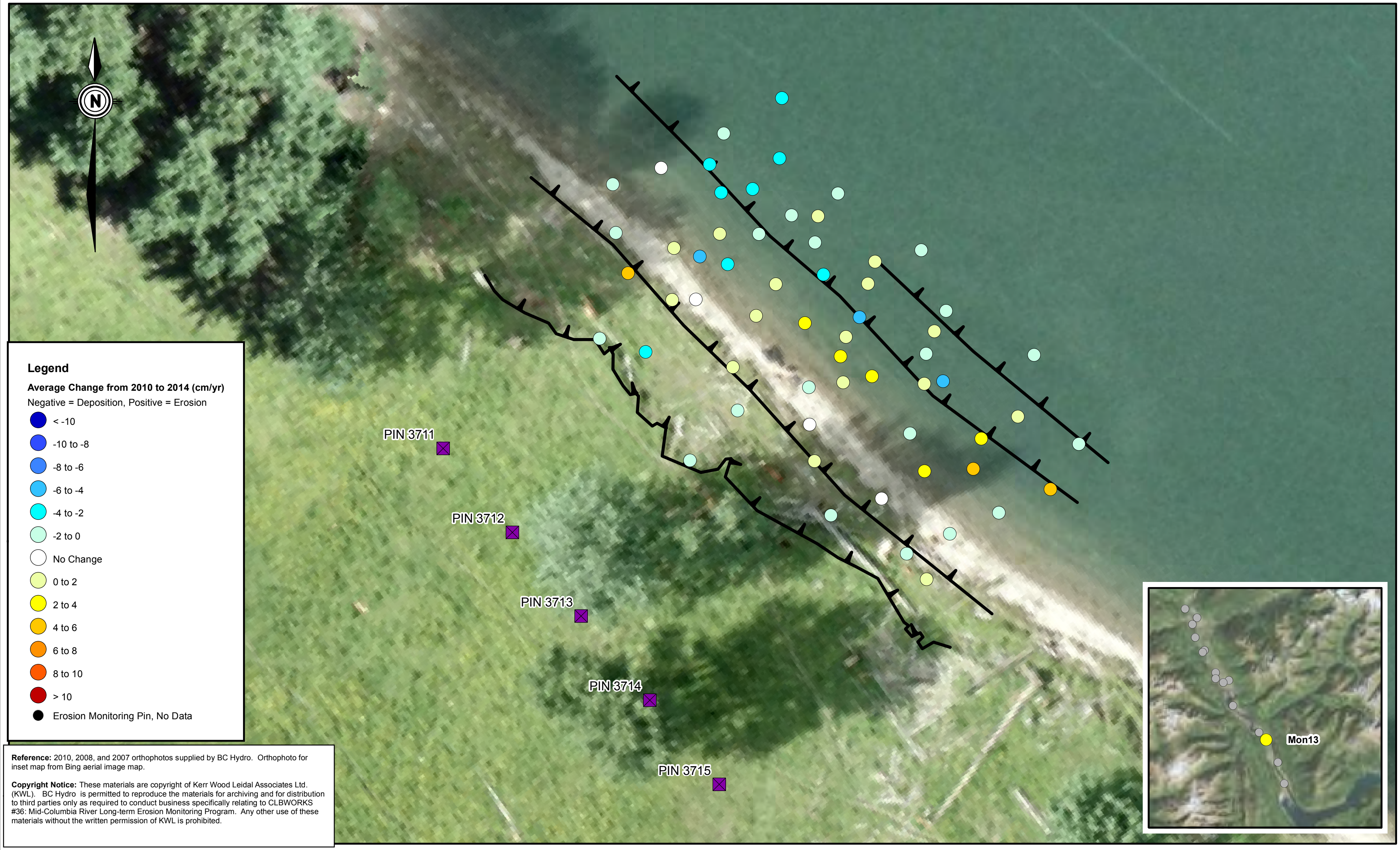

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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Project No.	Date
478-081	November 2014

10 0 10
(m)
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MON 13 Erosion Pin Average Change (2010 to 2014)

Figure A13

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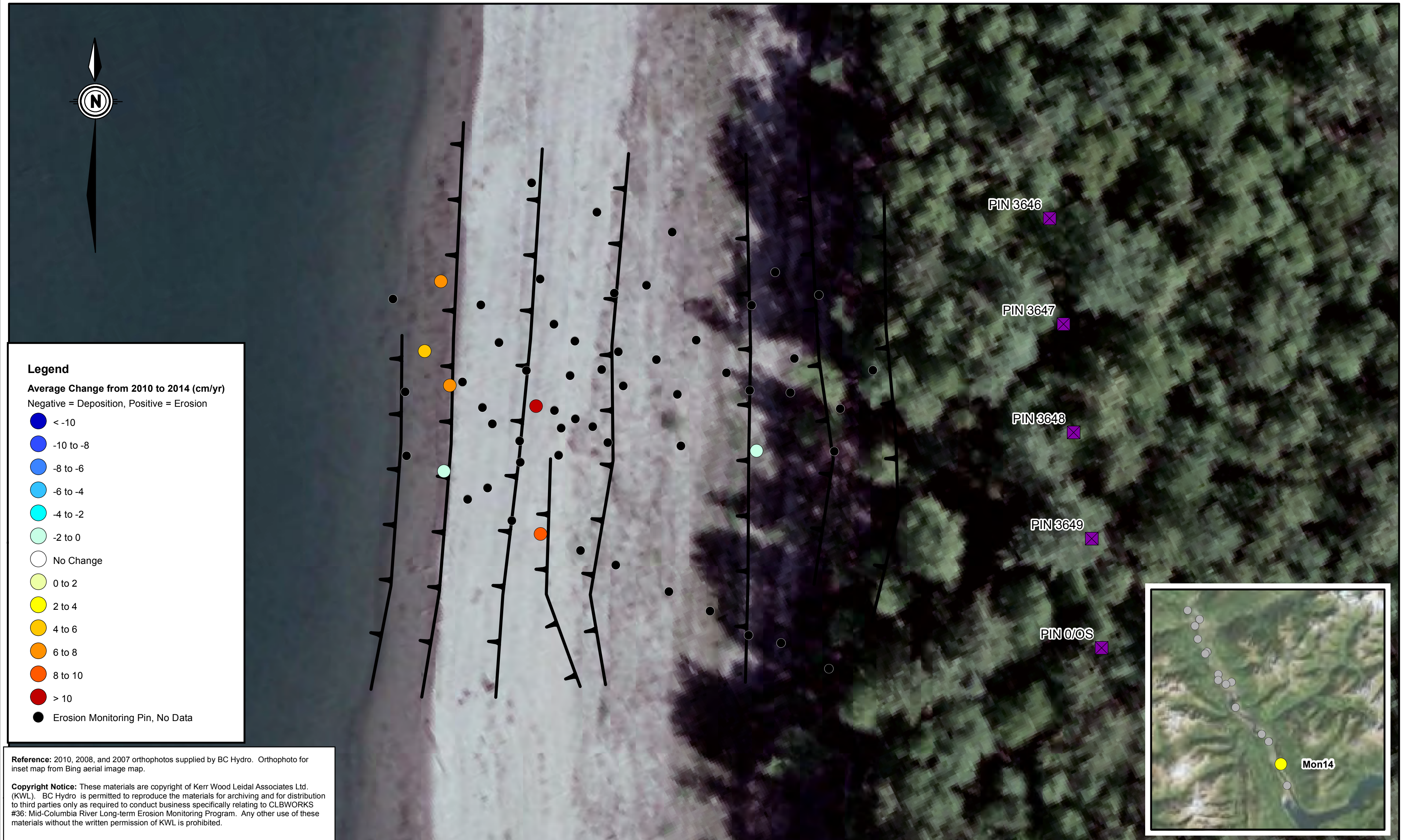

Legend

Average Change from 2010 to 2014 (cm/yr)

Negative = Deposition, Positive = Erosion

- < -10
- -10 to -8
- -8 to -6
- -6 to -4
- -4 to -2
- -2 to 0
- No Change
- 0 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10
- > 10
- Erosion Monitoring Pin, No Data

Reference: 2010, 2008, and 2007 orthophotos supplied by BC Hydro. Orthophoto for inset map from Bing aerial image map.

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10 0 10 (m)

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MON 14 Erosion Pin Average Change (2010 to 2014)

Figure A14

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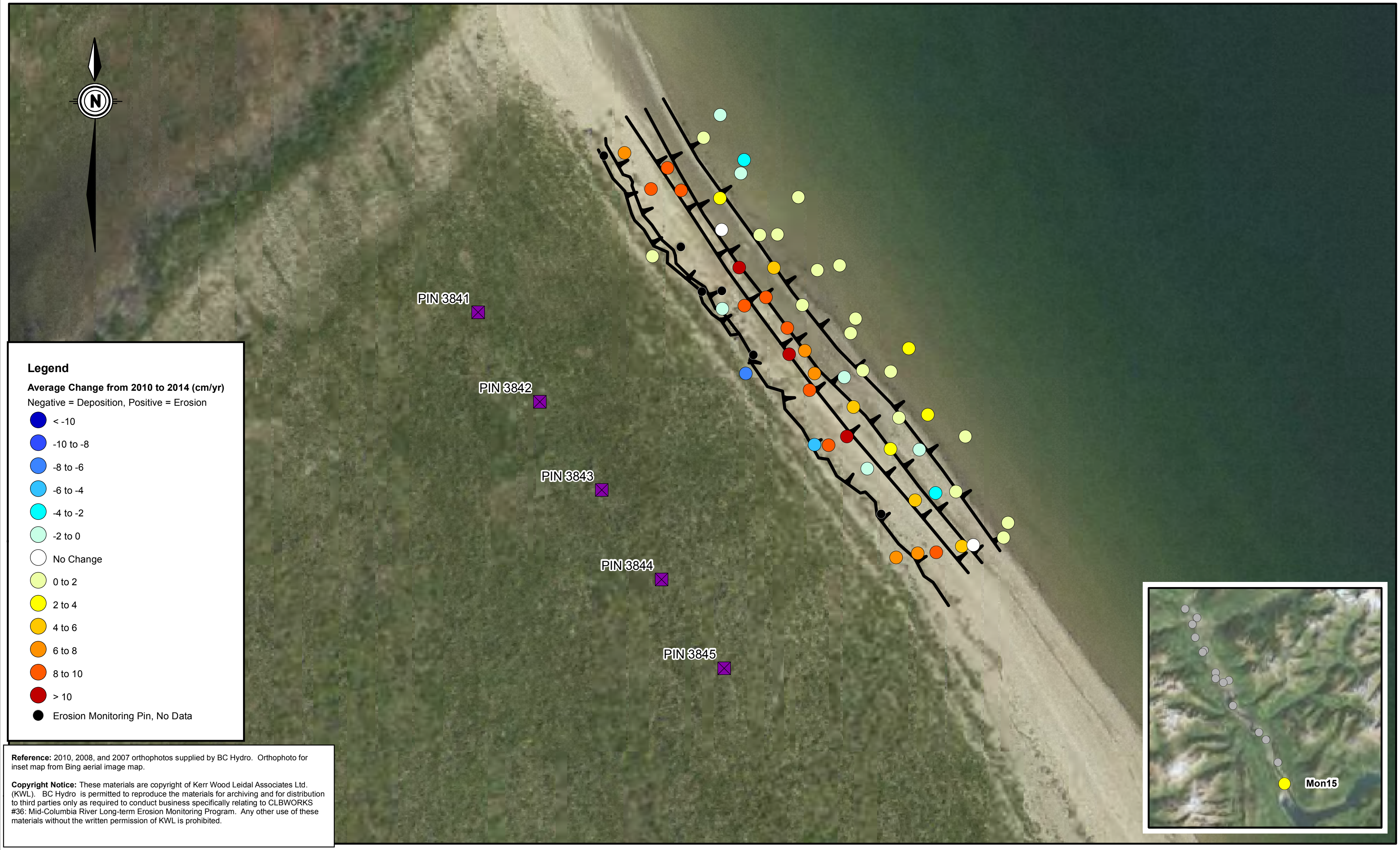

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478-081	November 2014

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MON 15 Erosion Pin Average Change (2010 to 2014)

Figure A15

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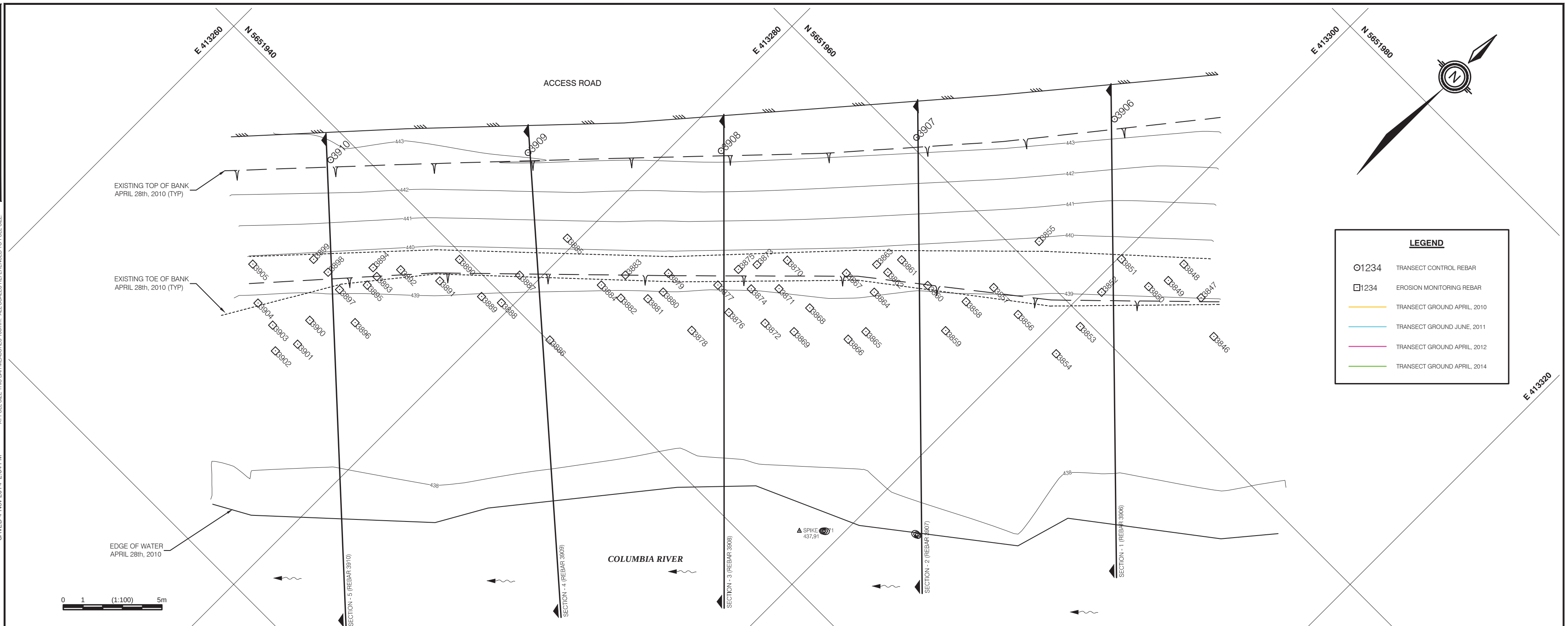
Appendix B

Monitoring Site Cross-section Plots



MONITORING SITE 1 - PLAN

1:100

MONITORING SITE 1 - 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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

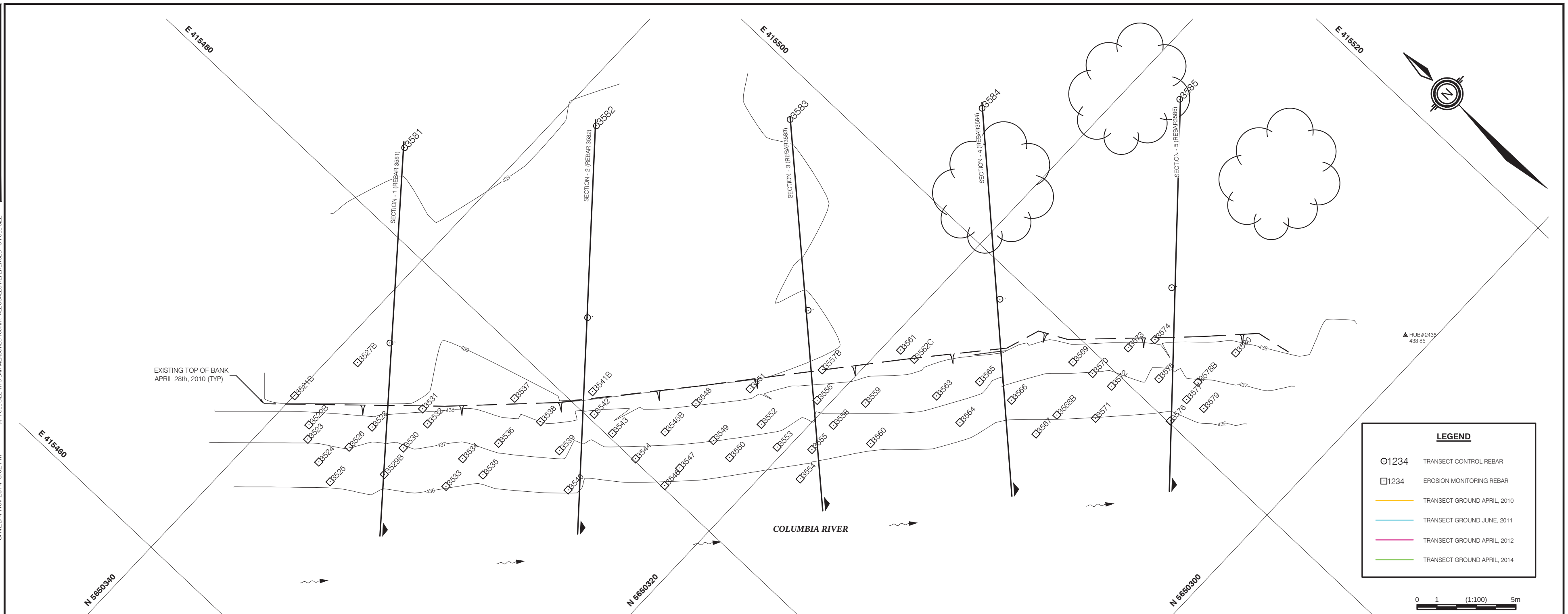
KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

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. 2
Client: BC HYDRO

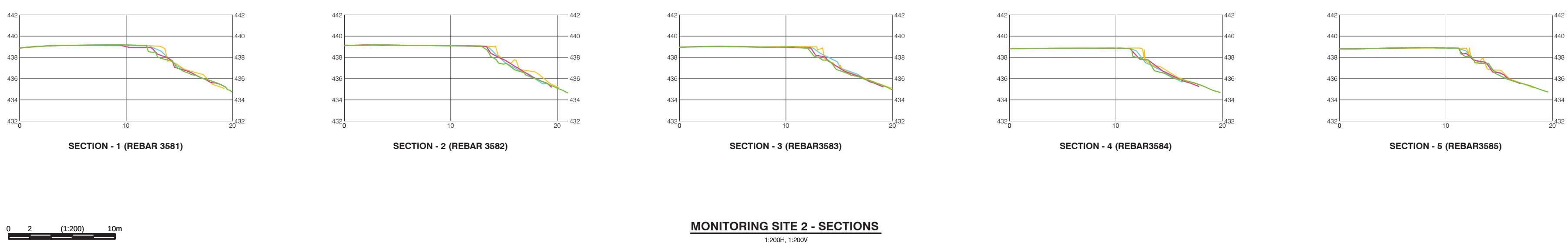
MON 1
Drawing Number

SAVED 4-Nov-2014 2:54 PM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.
O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #1.dwg



MONITORING SITE 2 - PLAN

1:100



MONITORING SITE 2 - SECTIONS

1:200H, 1:200V

SAVED 4-Nov-2014 3:02 PM AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.

O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #2.dwg

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

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						
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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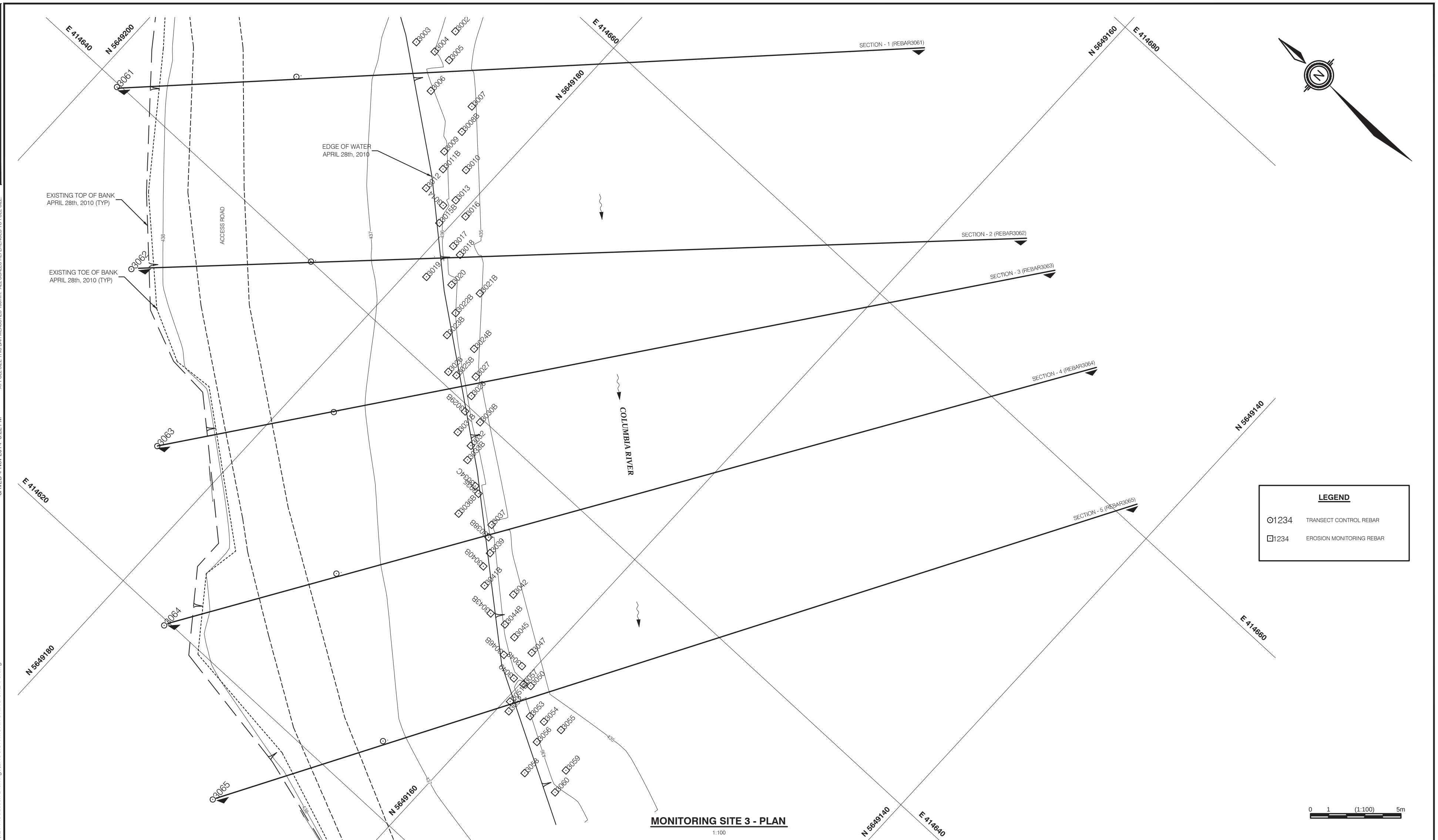
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #2

KWL Project No. 478.120	Scale AS SHOWN	MON 2	
Sheet 02 of 27	Rev. No. 2	Drawing Number	
Client: BC HYDRO			



MONITORING SITE 3 - PLAN

1:100

SAVED 4-Nov-2014 3:22 PM 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			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION

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0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING						
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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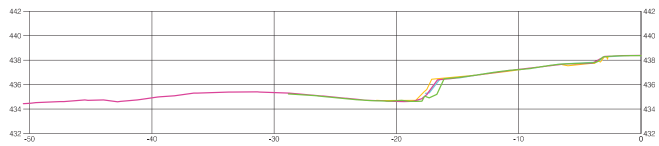
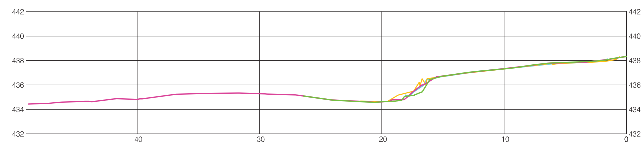
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #3

KWL Project No. 478.120	**Scale** 1:100	**MON 3**	
Sheet 03 **of** 27	**Rev. No.** 2	Drawing Number	

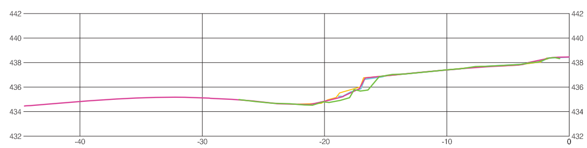
Client: BC HYDRO



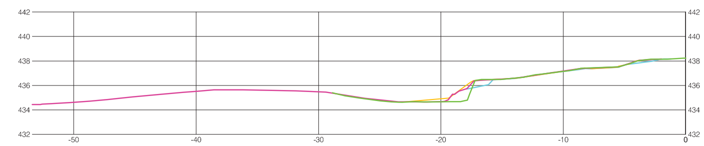
SECTION - 3 (REBAR3063)



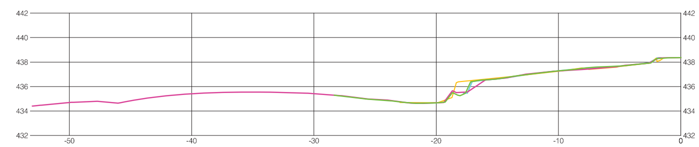
SECTION - 2 (REBAR3062)



SECTION - 1 (REBAR3061)



SECTION - 5 (REBAR3065)



SECTION - 4 (REBAR3064)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 3 - 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
0	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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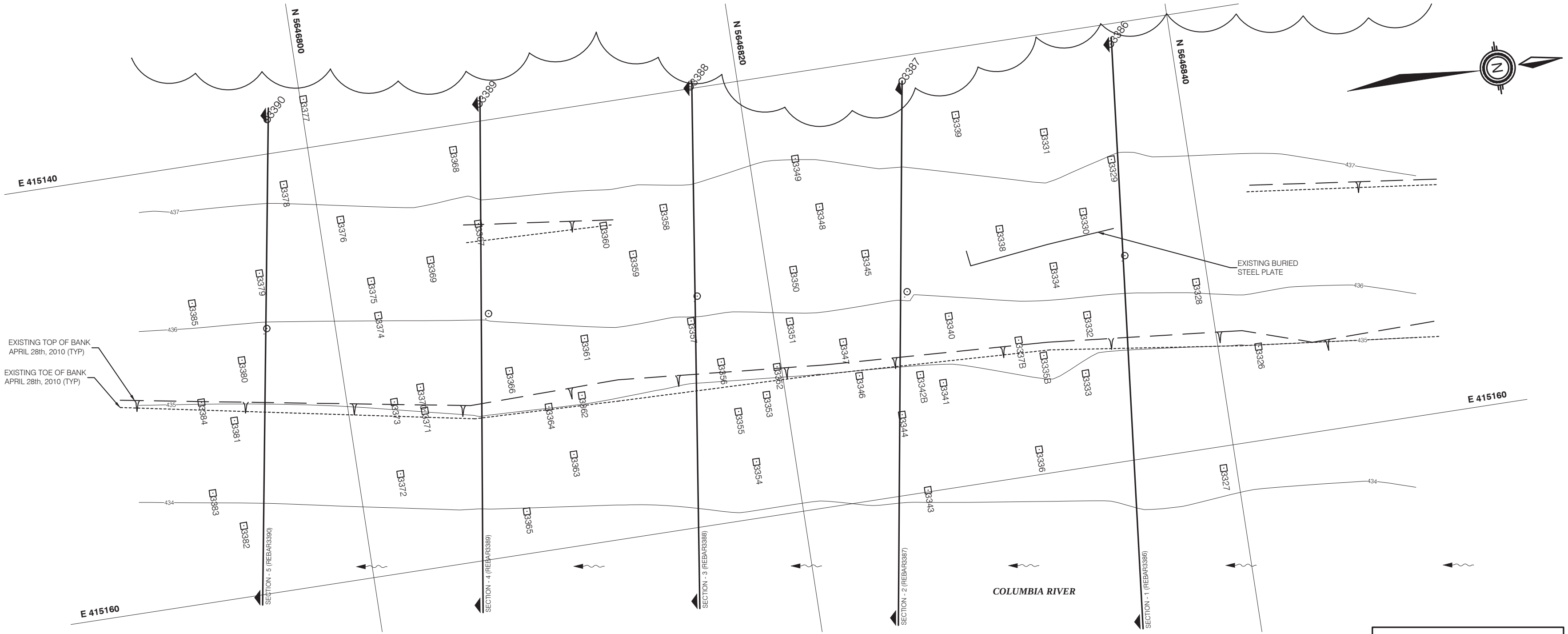
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #3 - SECTIONS

KWL Project No. 478.120
Scale 1:200 H 1:200 V
Sheet 04 of 27
Rev. No. 2
MON 3A
Drawing Number
Client: BC HYDRO



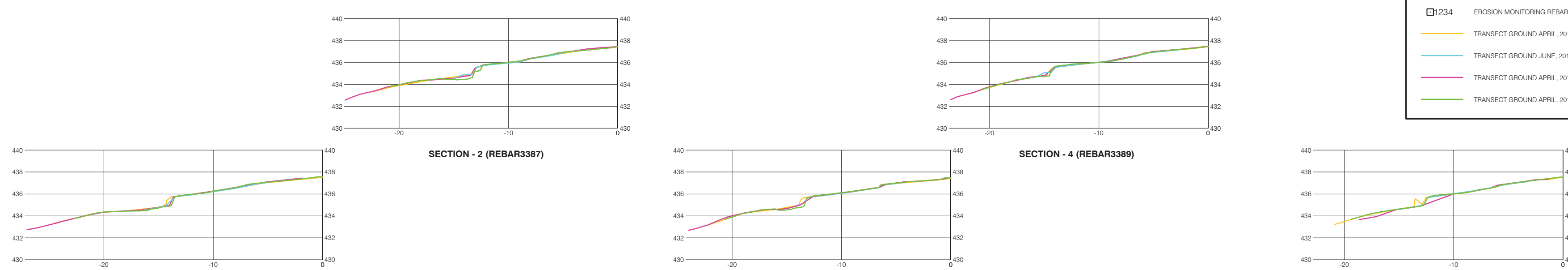
0 1 (1:100) 5m

MONITORING SITE 4 - PLAN

1:100

LEGEND

⊙1234	TRANSECT CONTROL REBAR
⊡1234	EROSION MONITORING REBAR
(yellow line)	TRANSECT GROUND APRIL, 2010
(cyan line)	TRANSECT GROUND JUNE, 2011
(magenta line)	TRANSECT GROUND APRIL, 2012
(green line)	TRANSECT GROUND APRIL, 2014



0 2 (1:200) 10m

MONITORING SITE 4 - SECTIONS

1:200H, 1:200V

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

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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Seal

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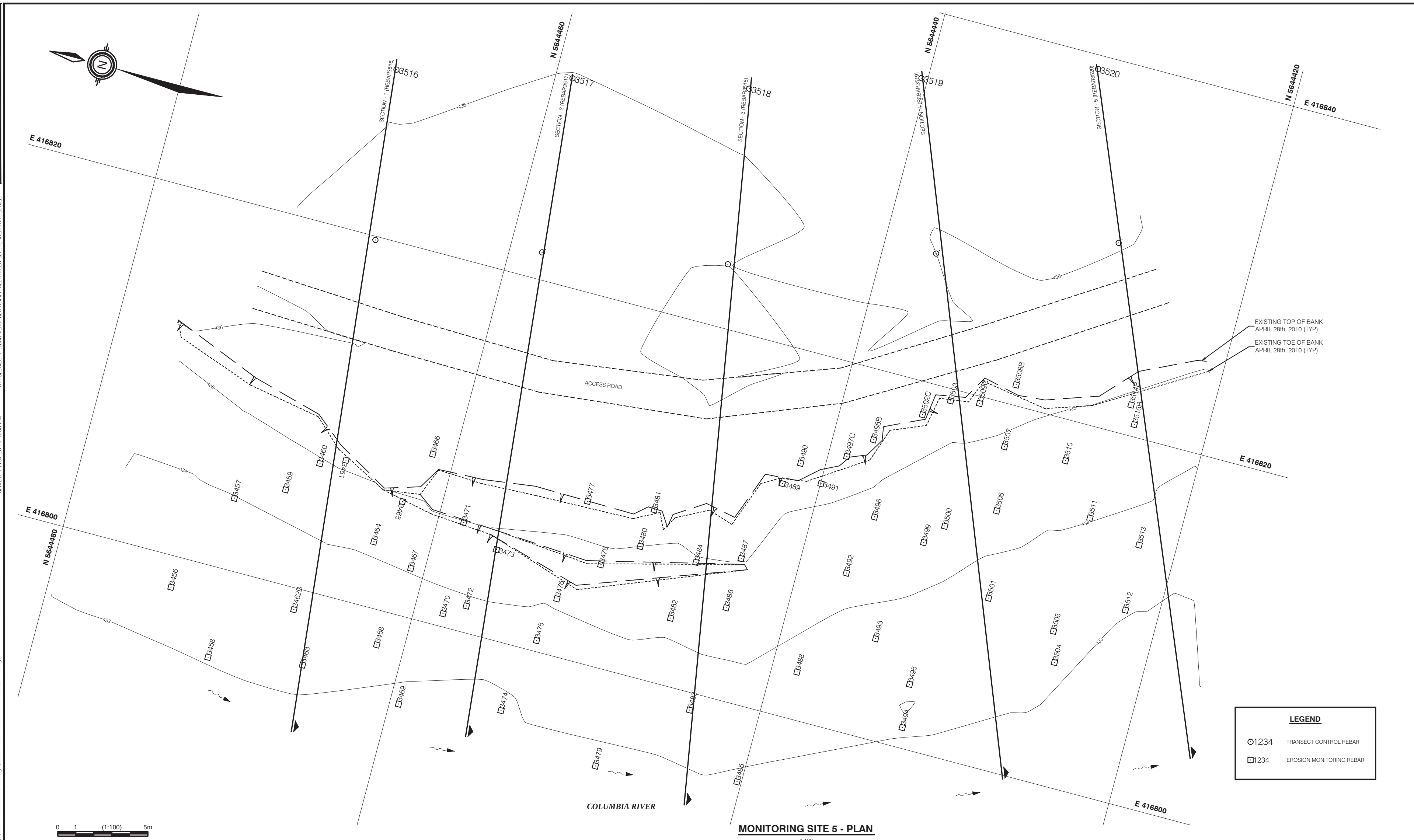
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #4

KWL Project No. 478.120 | Scale AS SHOWN
Sheet 05 of 27 | Rev. No. 2
MON 4 Drawing Number
Client: BC HYDRO



MONITORING SITE 5 - 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	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						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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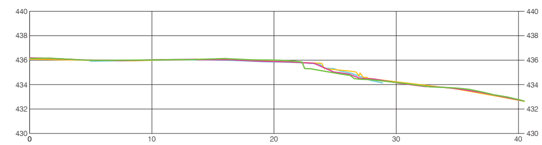
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #5

KWL Project No. 478.120 **Scale** 1:100
Sheet 06 **of** 27 **Rev. No.** 2

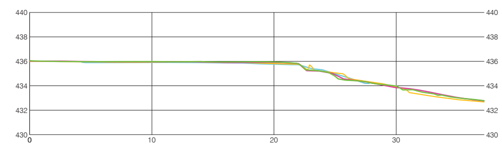
MON 5
Drawing Number

Client: BC HYDRO

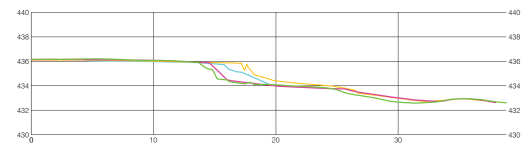
O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #5.dwg
SAVED 4-Nov-2014 3:30 PM
AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.



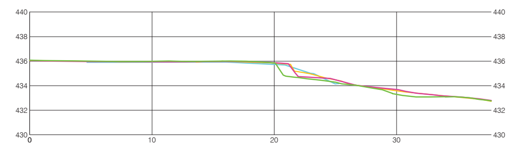
SECTION - 3 (REBAR3518)



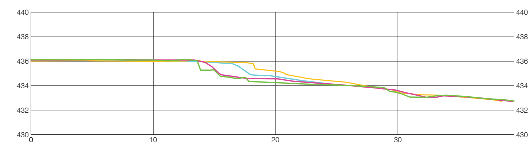
SECTION - 2 (REBAR3517)



SECTION - 5 (REBAR3520)



SECTION - 1 (REBAR3516)



SECTION -4 (REBAR3519)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 5 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

Issued for	Issue	Date	Issued By
Reference			
Approvals			
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Permits			
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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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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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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. 2
MON 5A
Drawing Number
Client: BC HYDRO

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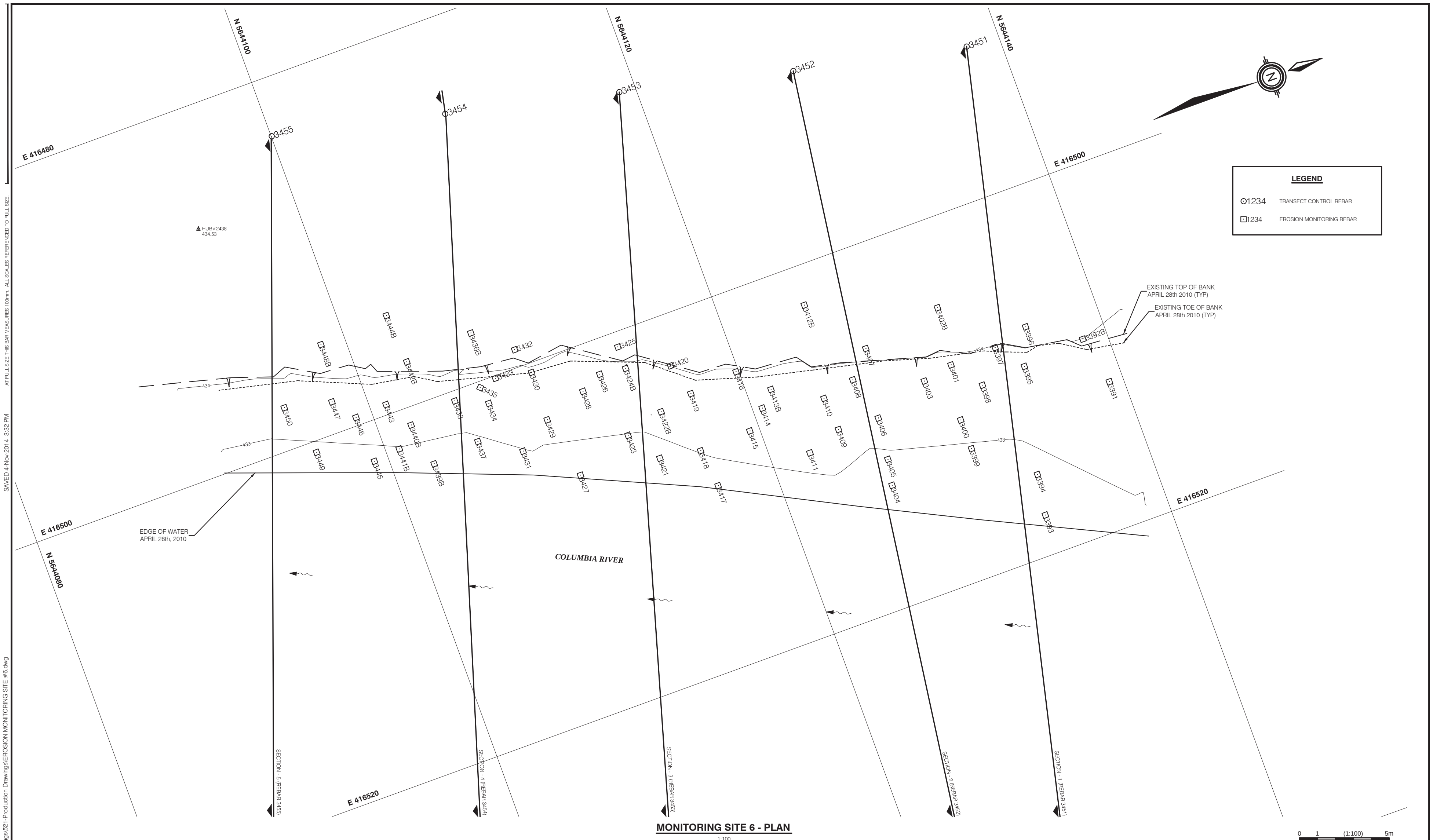
AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.



MONITORING SITE 6 - PLAN

1:100

O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #6.dwg

SAVED 4-Nov-2014 3:32 PM

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

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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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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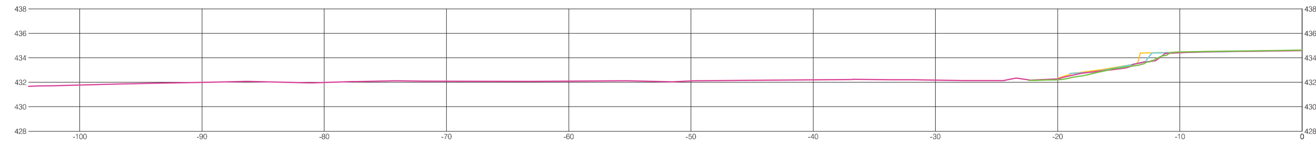
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #6

KWL Project No. 478.120 | Scale 1:100
Sheet 08 of 27 | Rev. No. 2
MON 6 Drawing Number
Client: BC HYDRO



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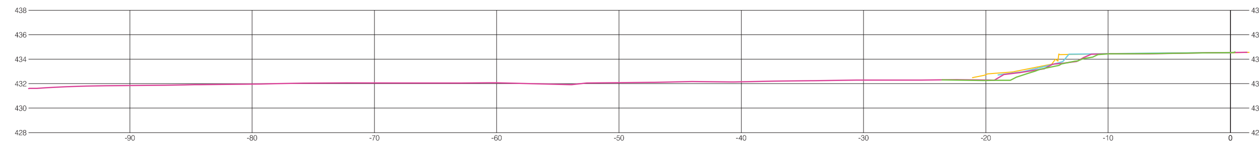
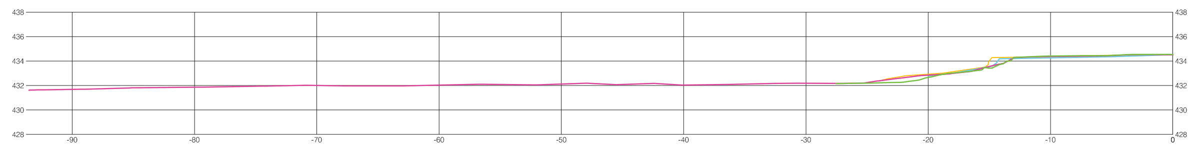
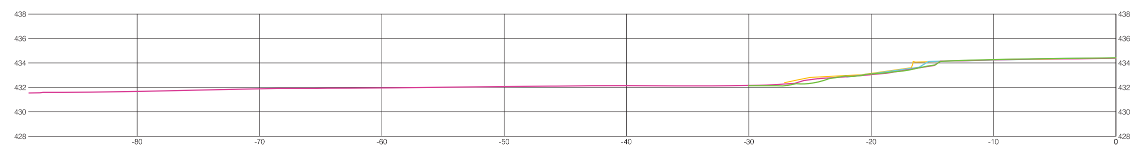


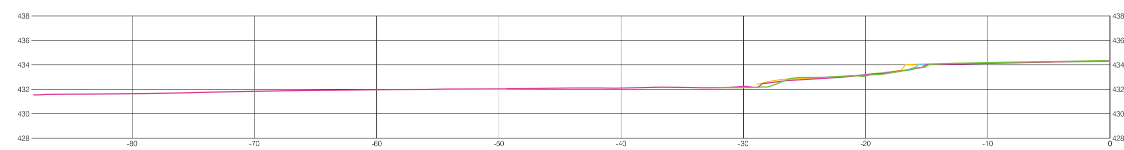
SECTION - 4 (REBAR3554)



SECTION - 3 (REBAR3453)



SECTION - 2 (REBAR3452)



SECTION - 1 (REBAR3451)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

0 2 (1:200) 10m

MONITORING SITE 6 - SECTIONS

1:200H, 1:200V

ISSUED INFORMATION: Issued for	Issue	Date	Issued By
Reference			
Approvals			
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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

Seal

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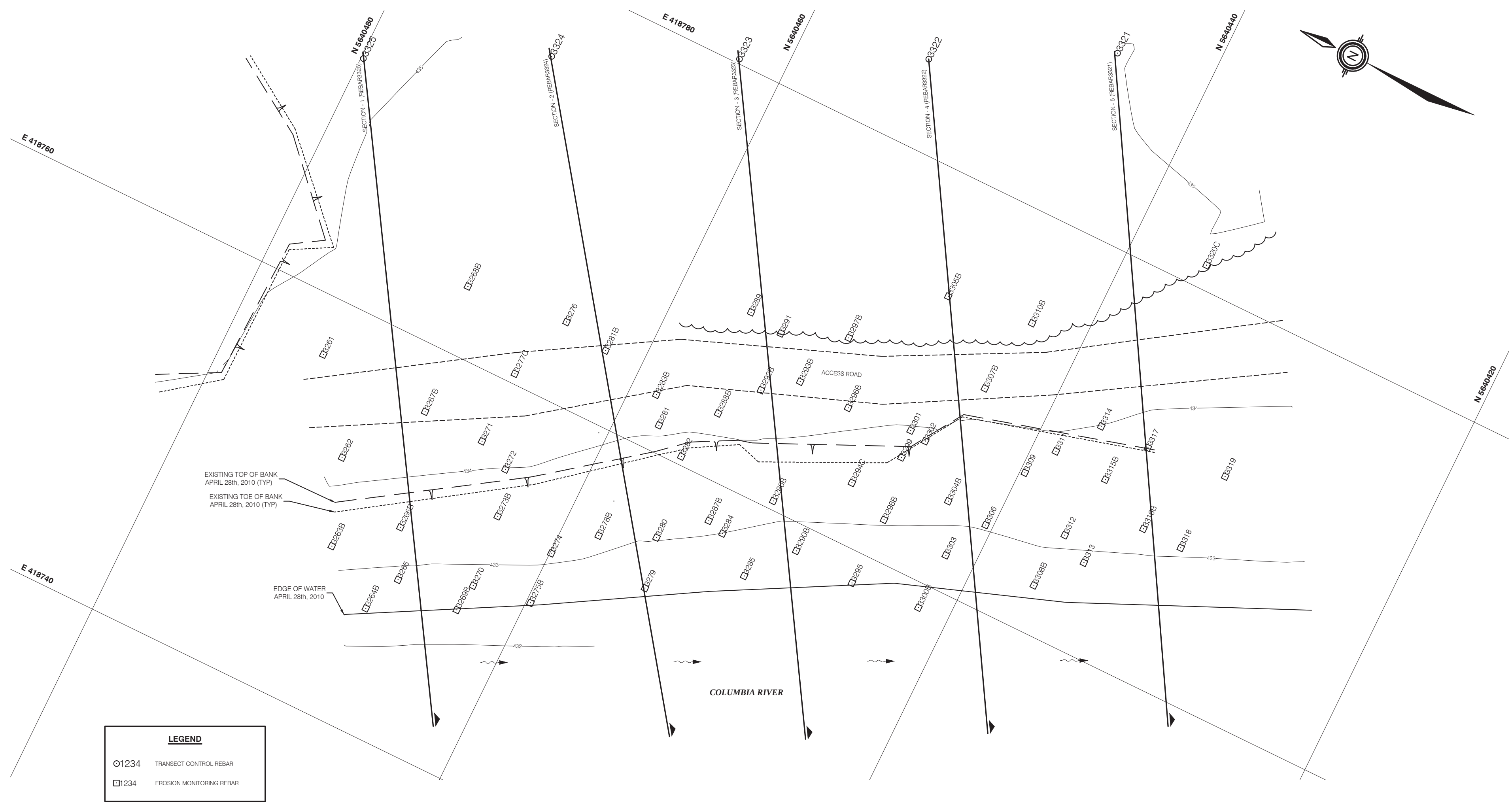
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #6 - SECTIONS

KWL Project No. 478.120 Scale 1:200 H 1:200 V
Sheet 09 of 27 Rev. No. 2
Client: BC HYDRO

MON 6A
Drawing Number



MONITORING SITE 7 - PLAN

1:100

0 1 (1:100) 5m

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

SAVED 4-Nov-2014 3:34 PM

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ISSUED INFORMATION

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

REVISION INFORMATION

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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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

KWL Project No. 478.120	Scale 1:100	MON 7	
Sheet 10 of 27	Rev. No. 2	Drawing Number	

Client: BC HYDRO

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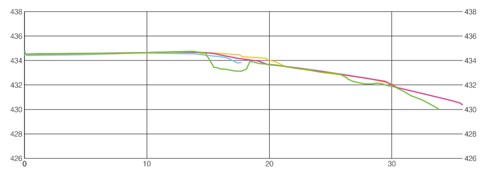
SAVED 4-Nov-2014 3:34 PM
AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE



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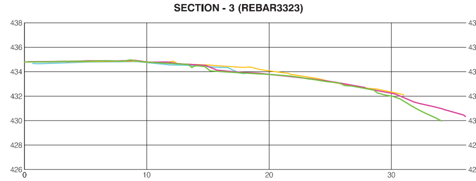
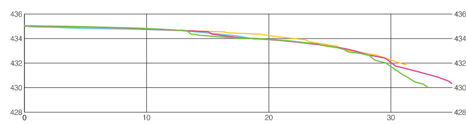
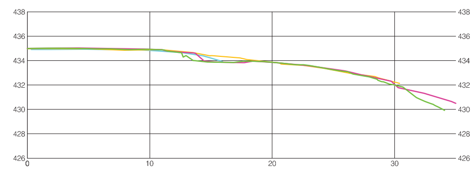


SECTION - 2 (REBAR3324)



SECTION - 1 (REBAR3325)



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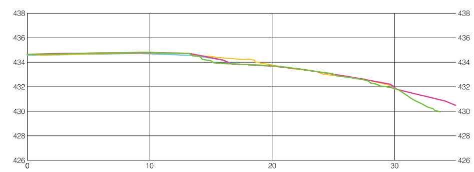

SECTION - 4 (REBAR3322)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 7 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

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

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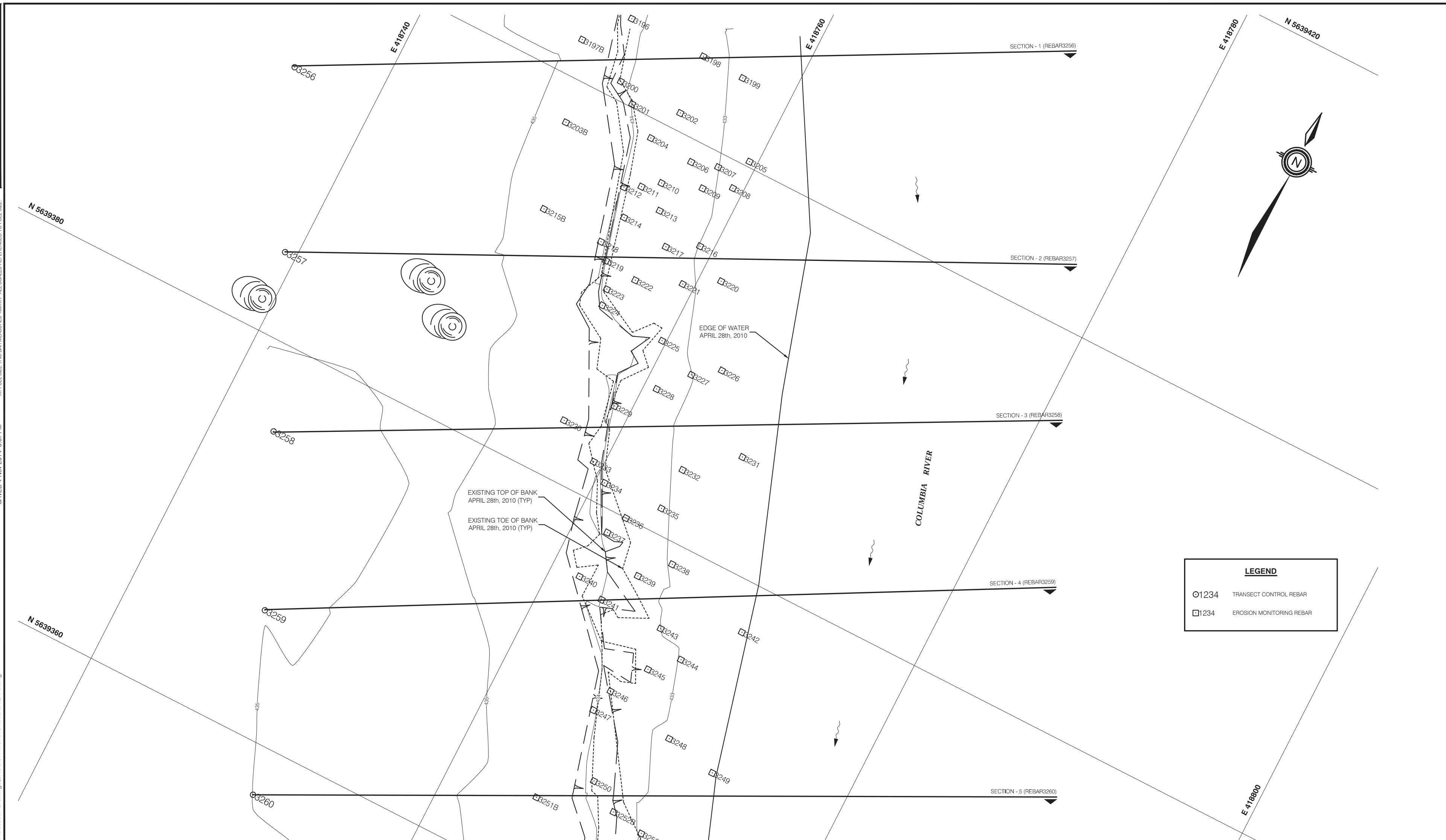
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #7 - SECTIONS

KWL Project No. 478.120	Scale 1:200 H 1:200 V		
Sheet 11 of 27	Rev. No. 2	MON 7A (Drawing Number)	
Client: BC HYDRO			



MONITORING SITE 8 - PLAN

1:100

SAVED 4-Nov-2014 3:37 PM

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			
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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

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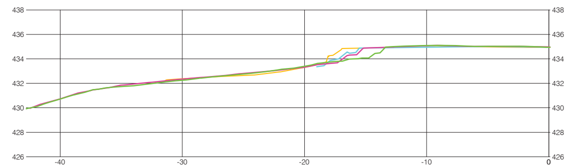
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #8

KWL Project No.	478.120	Scale	1:100
Sheet	12 of 27	Rev. No.	2
Client: BC HYDRO			

MON 8
Drawing Number



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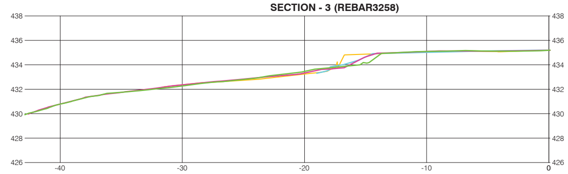
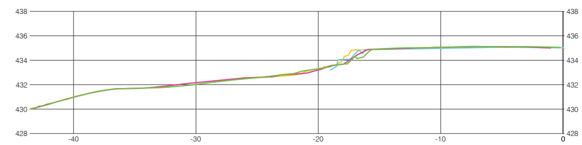
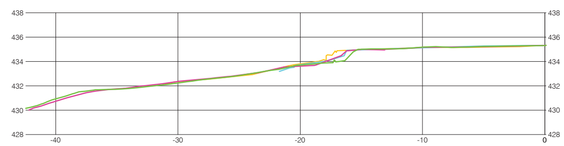


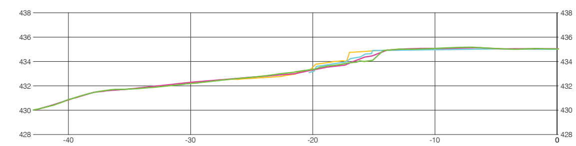
SECTION - 2 (REBAR3257)



SECTION - 5 (REBAR3260)



SECTION - 1 (REBAR3256)



SECTION - 4 (REBAR3259)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 8 - SECTIONS

1:100

0 2 (1:200) 10m

ISSUED INFORMATION Issued for	Issue	Date	Issued By
Reference			
Approvals			
Tender			
Permits			
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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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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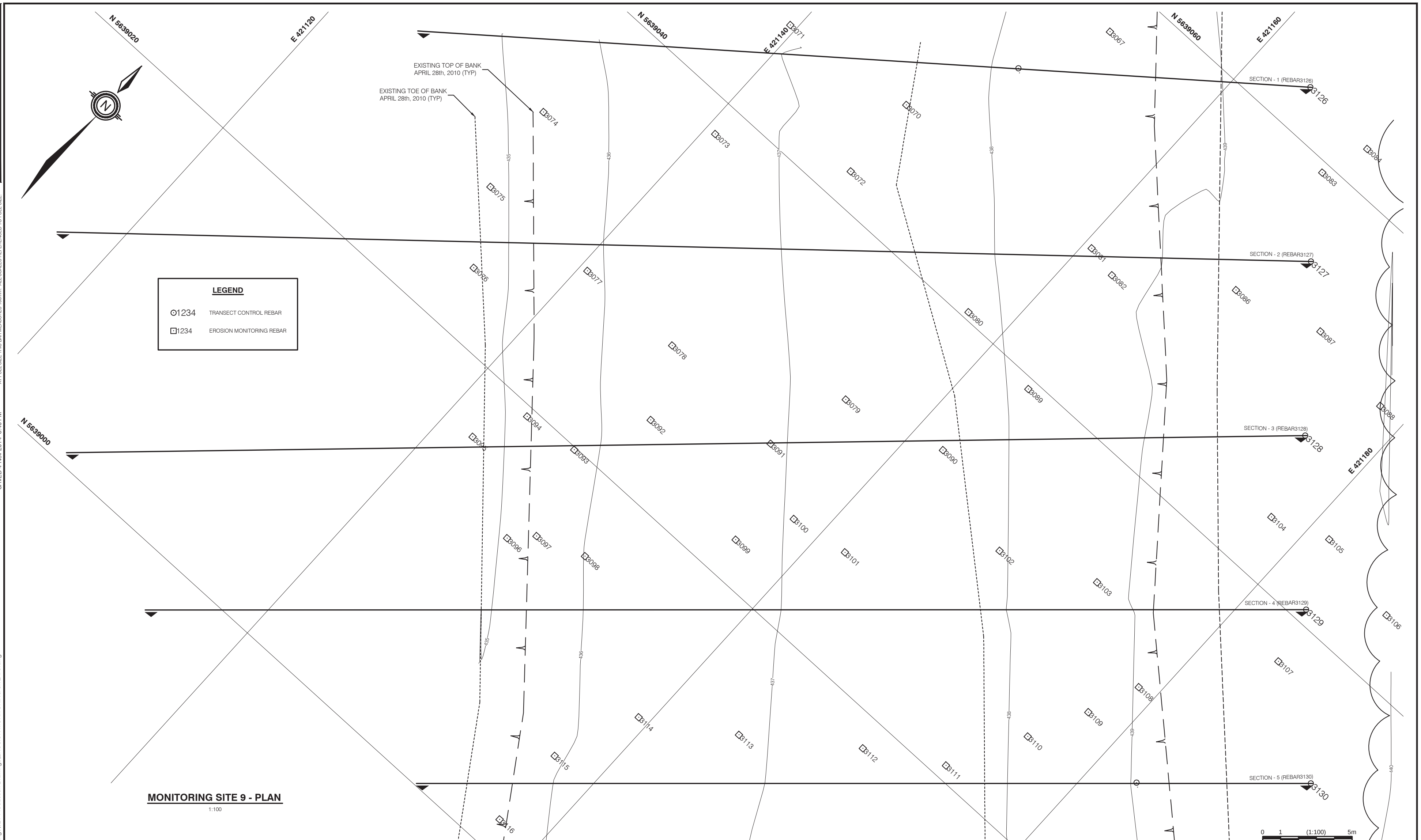
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #8 - SECTIONS

KWL Project No. 478.120   Scale 1:200 H 1:200 V
Sheet 13 of 27   Rev. No. 2
MON 8A Drawing Number
Client: BC HYDRO



MONITORING SITE 9 - PLAN

1:100

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

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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

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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. 2
Client: BC HYDRO

MON 9
Drawing Number

AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE.
SAVED 4-Nov-2014 3:40 PM
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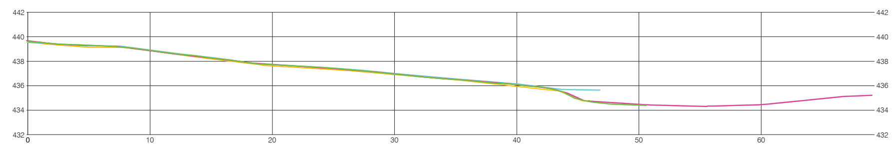

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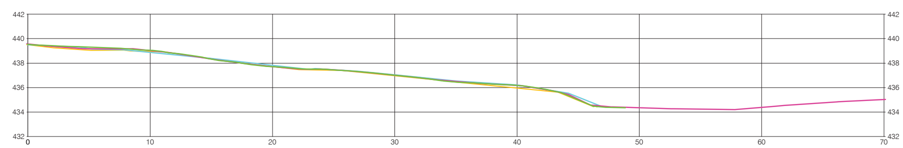

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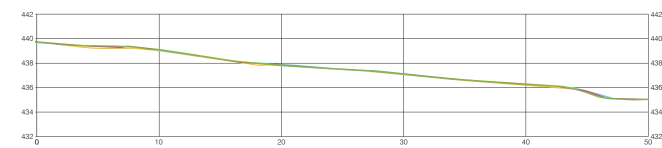

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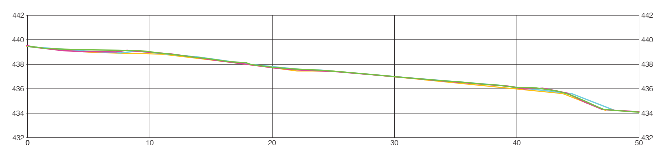

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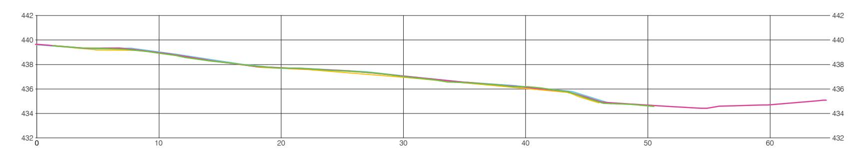

SECTION - 4 (REBAR3129)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

0 2 (1:200) 10m

MONITORING SITE 9 - SECTIONS

1:200H, 1:200V

SAVED 4-Nov-2014 3:40 PM

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
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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	DEC.16/11	DTM	BVC		ISSUED FOR 2011 REPORTING						
1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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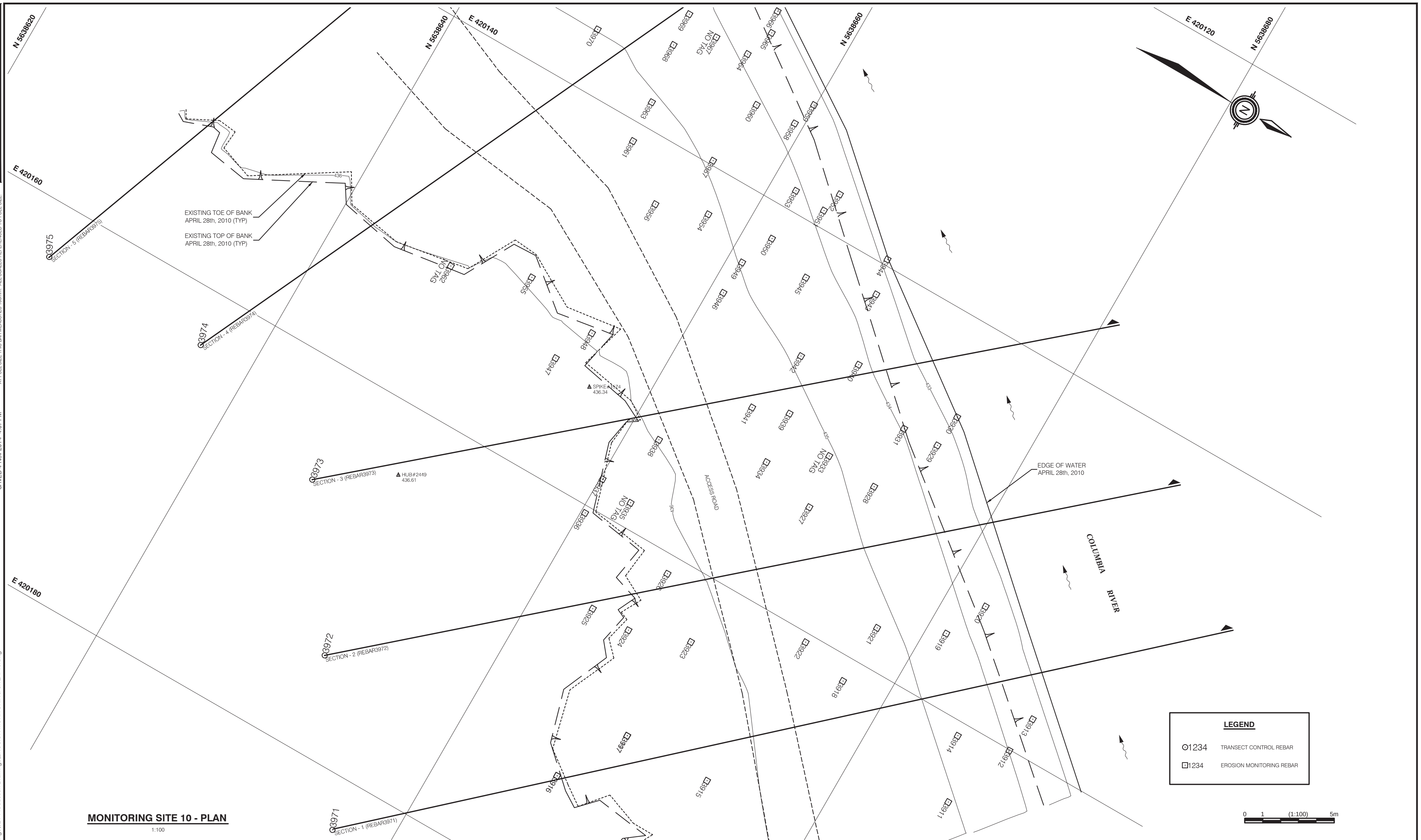
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #9 - SECTIONS

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

Sheet 15 **of** 27 **Rev. No.** 2

MON 9A
Drawing Number

Client: BC HYDRO



MONITORING SITE 10 - PLAN

1:100

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

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Issued for	Issue	Date	Issued By
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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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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

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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. 2
Client: BC HYDRO

MON 10
Drawing Number

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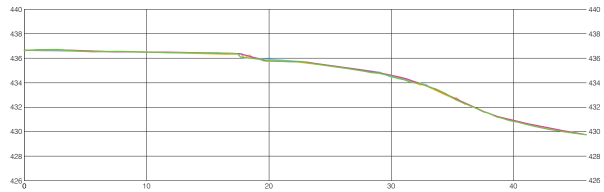
SAVED 4-Nov-2014 4:07 PM

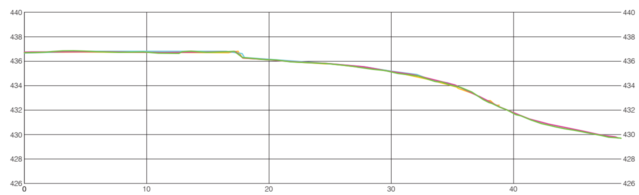
AT FULL SIZE THIS BAR MEASURES 100mm. ALL SCALES REFERENCED TO FULL SIZE



SECTION - 3 (REBAR3973)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014



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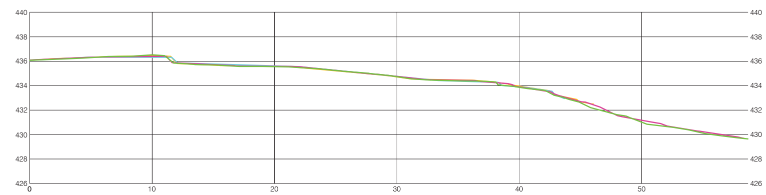
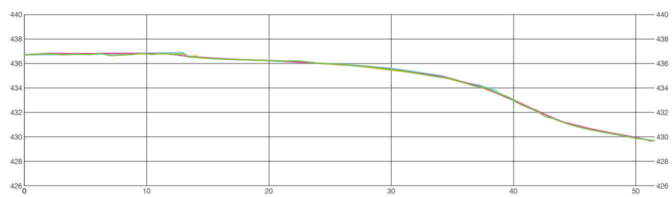


SECTION - 5 (REBAR3975)



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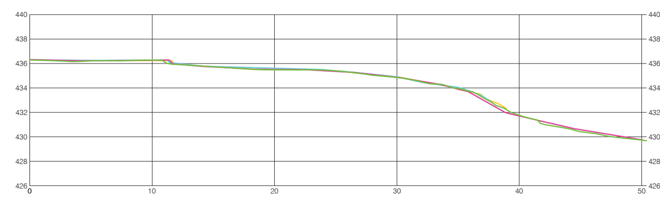

SECTION - 4 (REBAR3974)

MONITORING SITE 10 - 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
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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

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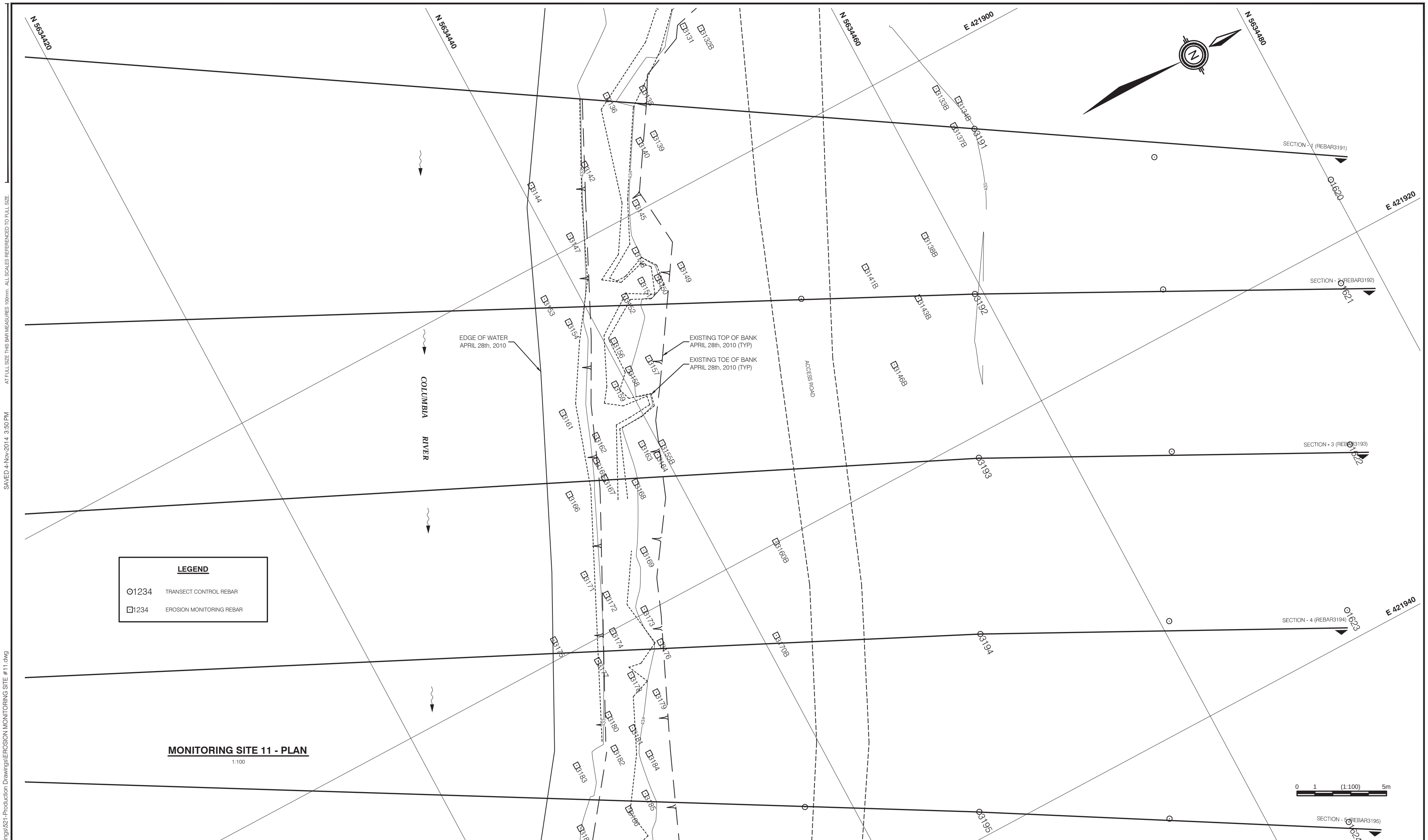
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #10 - SECTIONS

KWL Project No. 478.120 Scale 1:200 H 1:200 V
Sheet 17 of 27 Rev. No. 2

MON 10A
Drawing Number

Client: BC HYDRO



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Reference			
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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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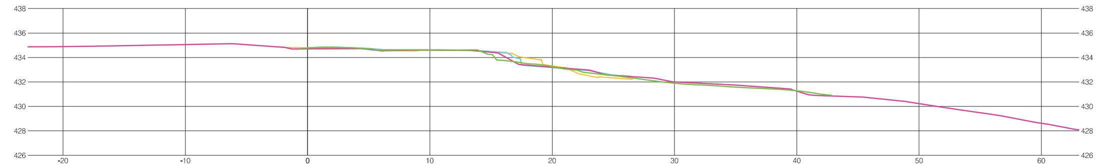
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #11

KWL Project No.	478.120	Scale	1:100
Sheet	18 of 27	Rev. No.	2
Client: BC HYDRO			

MON 11
Drawing Number



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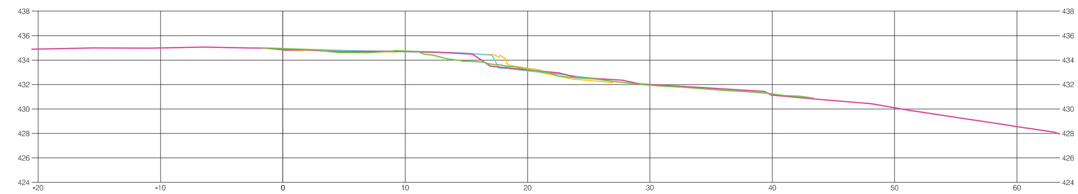

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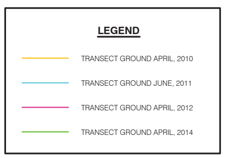

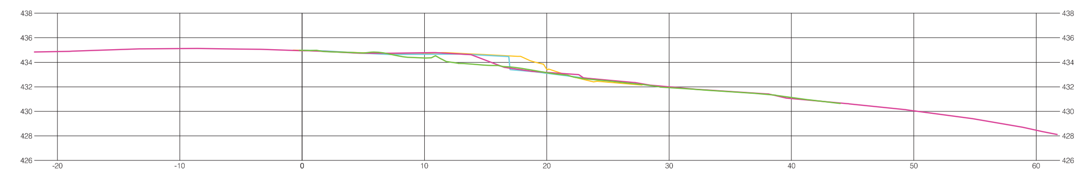

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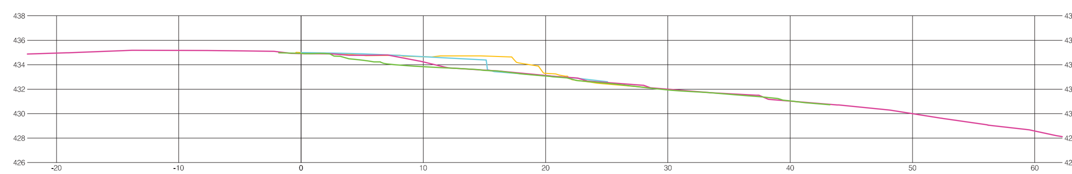

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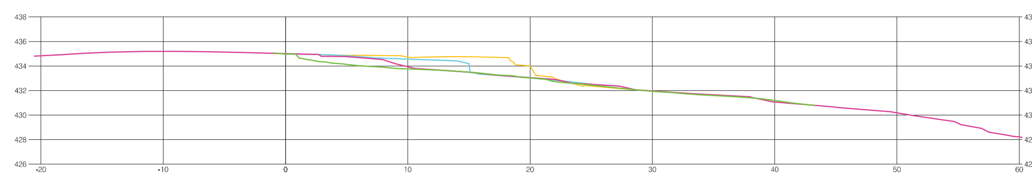

SECTION - 1 (REBAR3191)

MONITORING SITE 11 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

ISSUED INFORMATION			
Issued for	Issue	Date	Issued By
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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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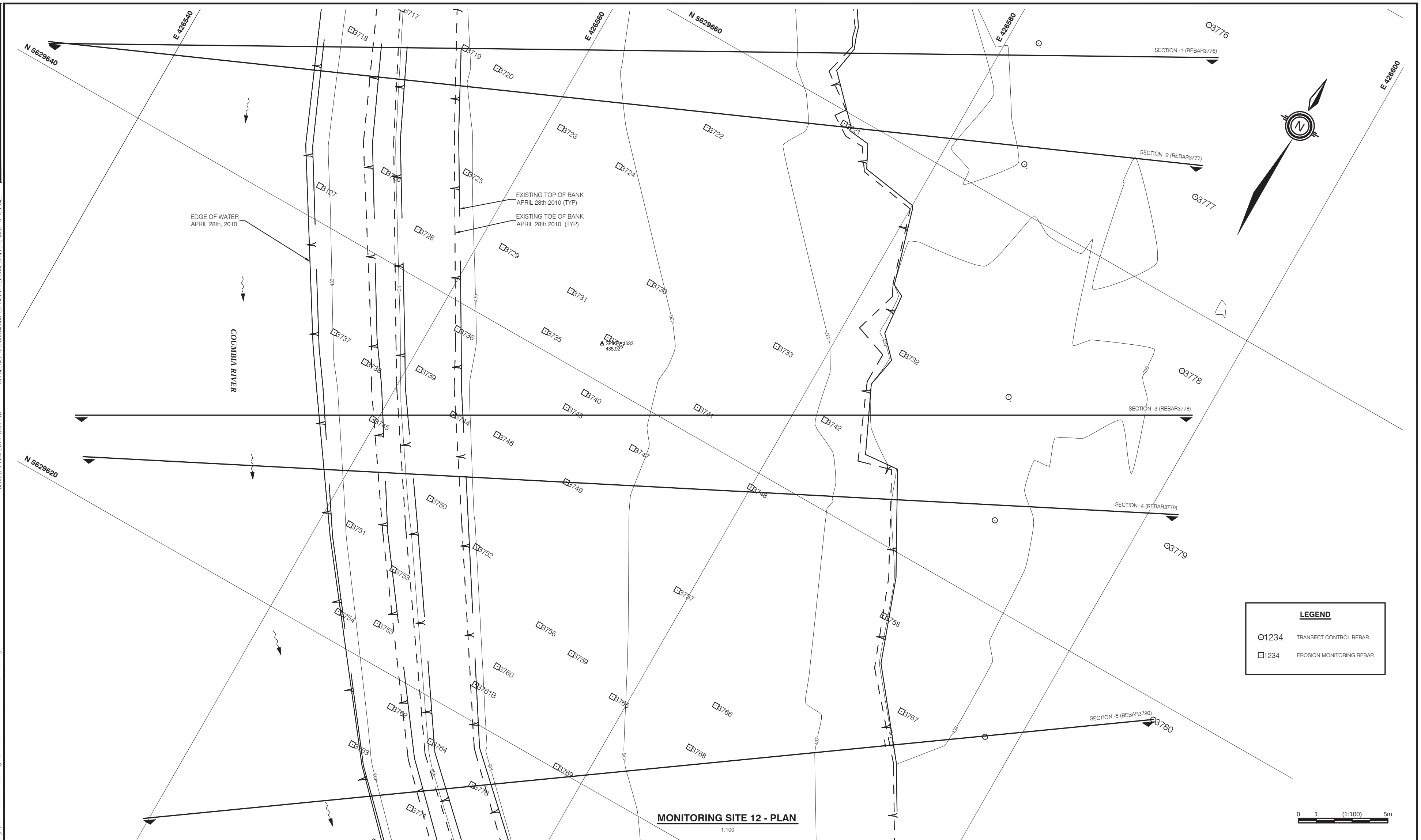
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #11 - SECTIONS

KWL Project No. 478.120	Scale 1:200 H 1:200 V		MON 11A
Sheet 19 of 27	Rev. No. 2		Drawing Number
Client: BC HYDRO			



MONITORING SITE 12 - PLAN

1:100

SAVED 4-Nov-2014 3:54 PM 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			
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

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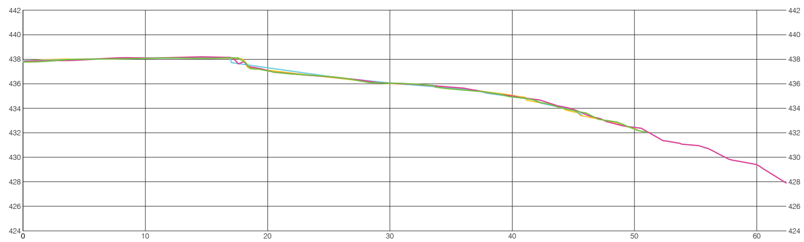
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #12

KWL Project No. 478.120 Scale 1:100
Sheet 20 of 27 Rev. No. 2
Client: BC HYDRO

MON 12
Drawing Number



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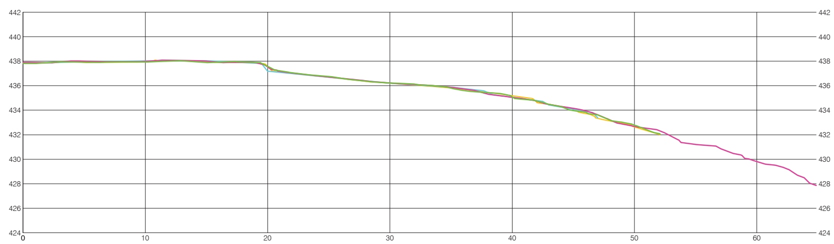

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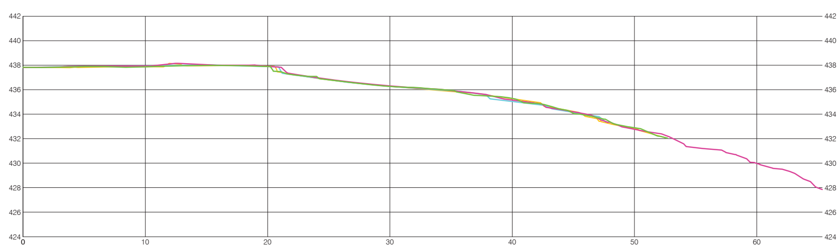

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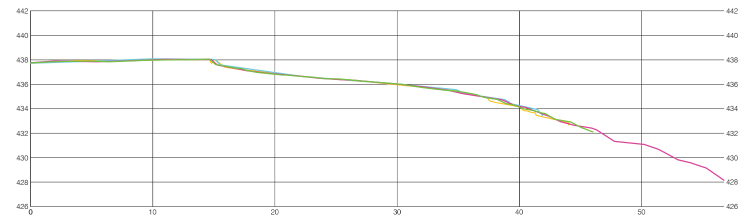

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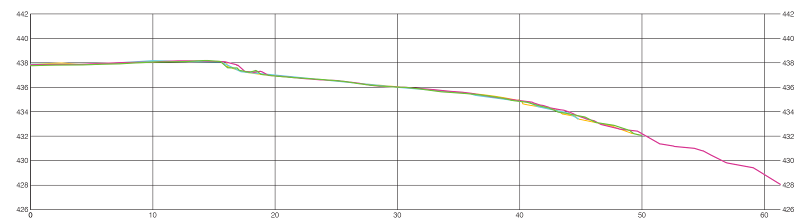

SECTION -4 (REBAR3779)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

0 2 (1:200) 10m

MONITORING SITE 12 - SECTIONS

1:200H, 1:200V

ISSUED INFORMATION: Issued for	Issue	Date	Issued By
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
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1	JUL.27/12	DTM	BVC		ISSUED FOR 2012 REPORTING						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

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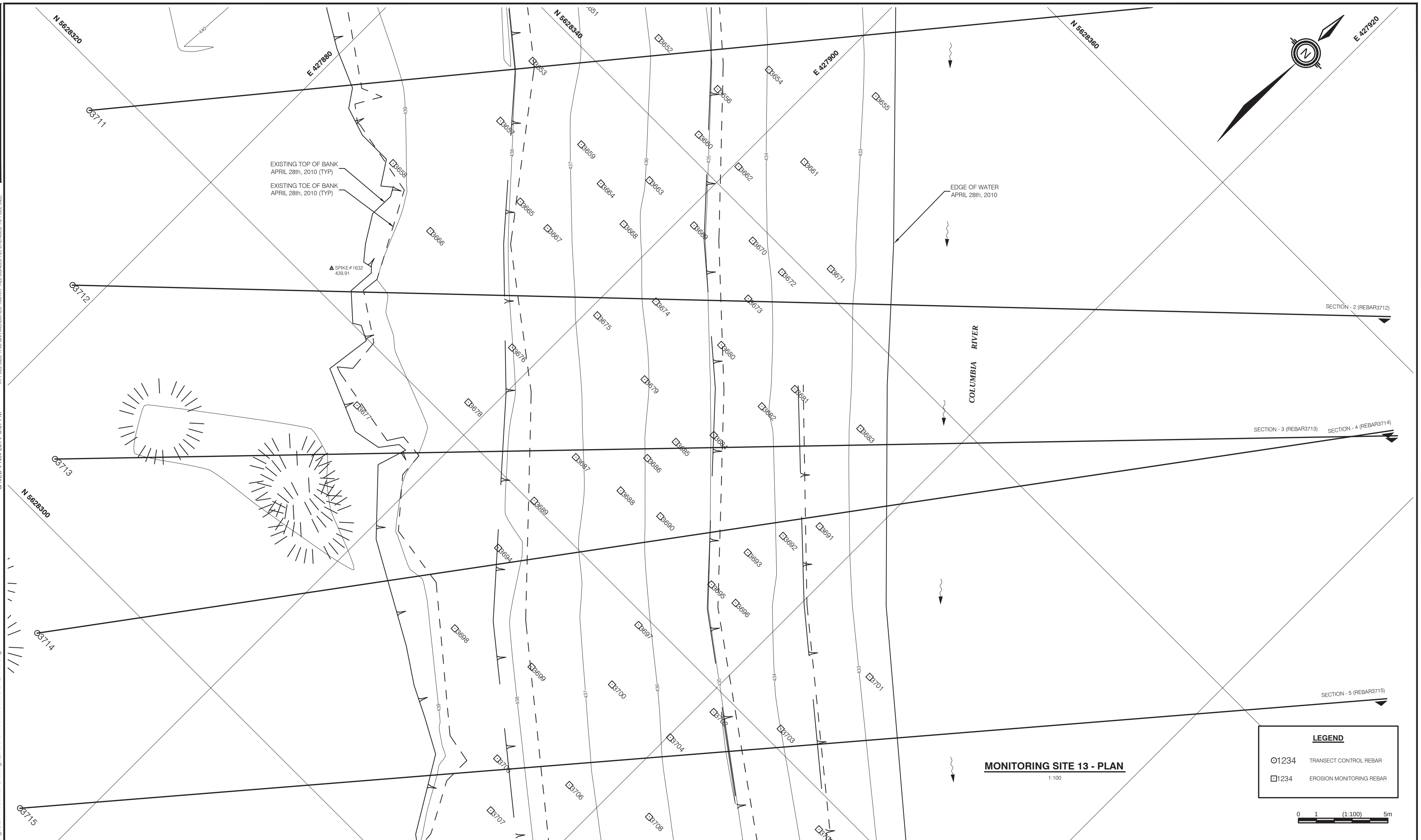
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #12 - SECTIONS

KWL Project No. 478.120	Scale 1:200 H 1:200 V		MON 12A
Sheet 21 of 27	Rev. No. 2		Drawing Number
Client: BC HYDRO			



MONITORING SITE 13 - 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	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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	2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

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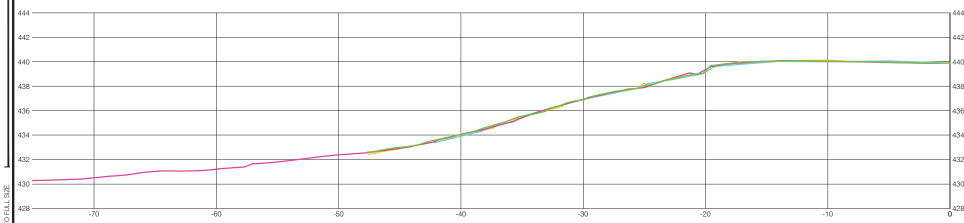
COLUMBIA RIVER EROSION MONITORING - CLB#36
EROSION MONITORING SITE #13

KWL Project No. 478.120	**Scale** 1:100	**MON 13** Drawing Number
Sheet 22 **of** 27	**Rev. No.** 2	

Client: BC HYDRO



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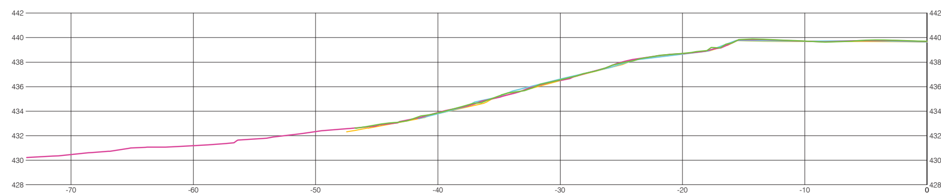

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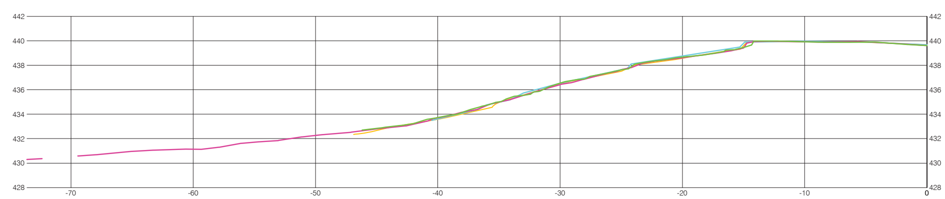

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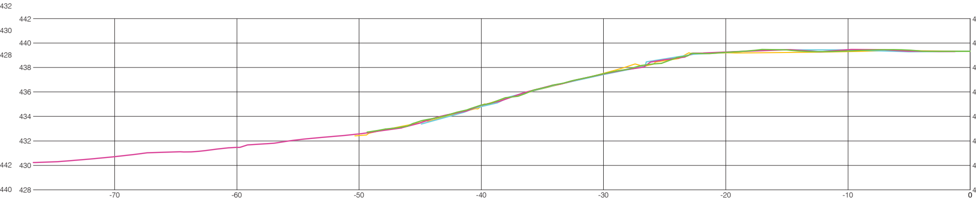

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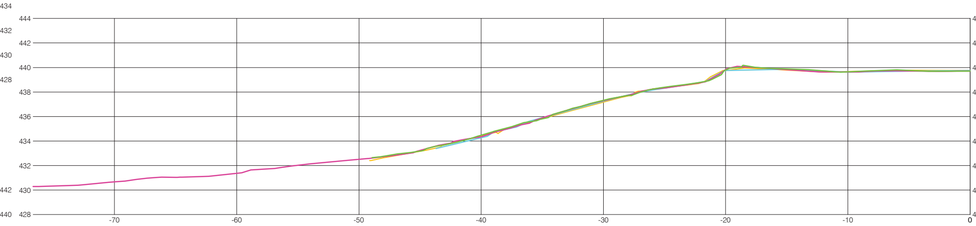

SECTION - 4 (REBAR3714)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 13 - SECTIONS

1:200H, 1:200V

0 2 (1:200) 10m

ISSUED INFORMATION	Issue	Date	Issued By
Issued for			
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Construction			
Record Drawings			

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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.** 2

MON 13A
Drawing Number

Client: BC HYDRO

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

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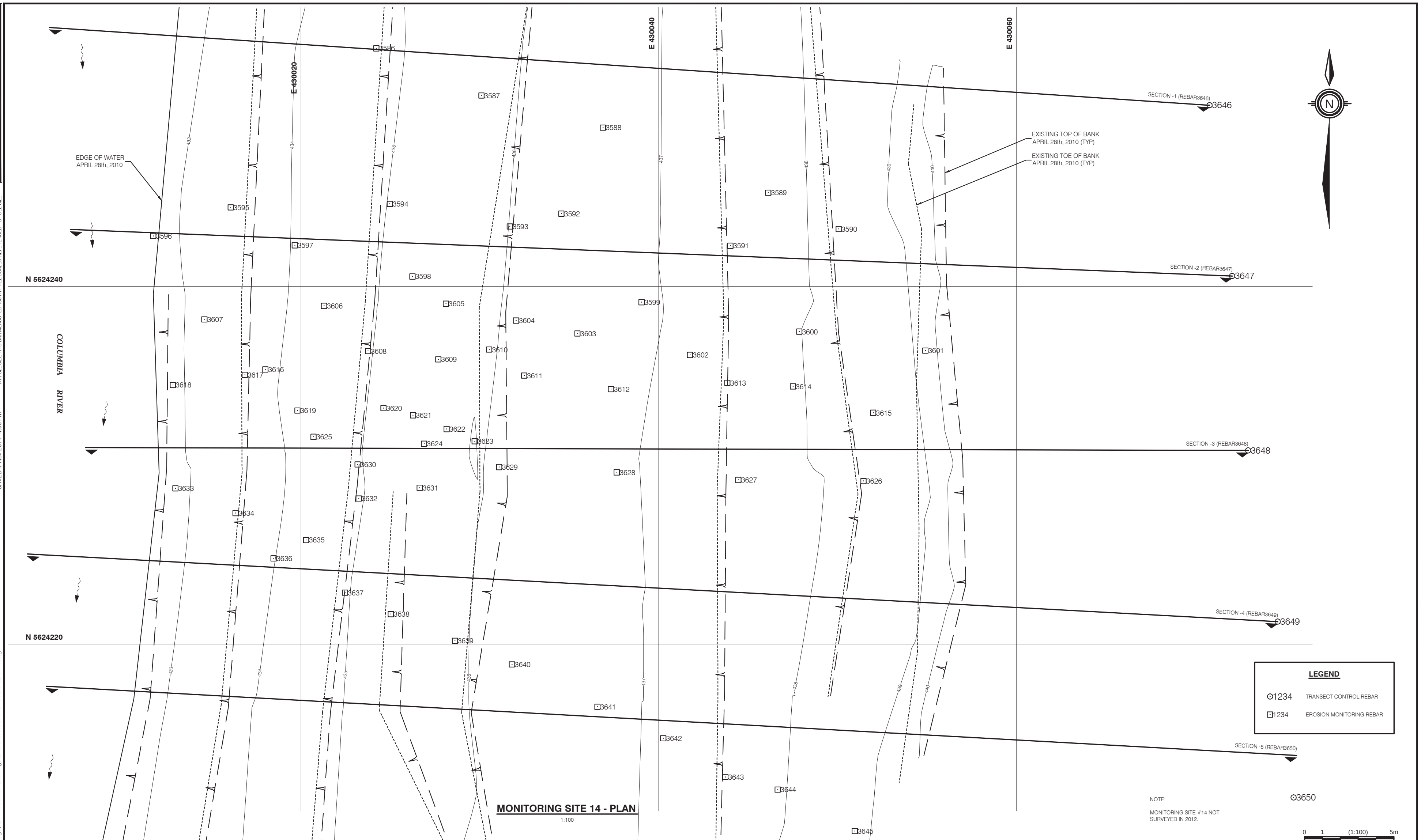

MONITORING SITE 14 - PLAN

1:100

ISSUED INFORMATION	Issued for	Issue	Date	Issued By
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	Approvals			
	Tender			
	Permits			
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	2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 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
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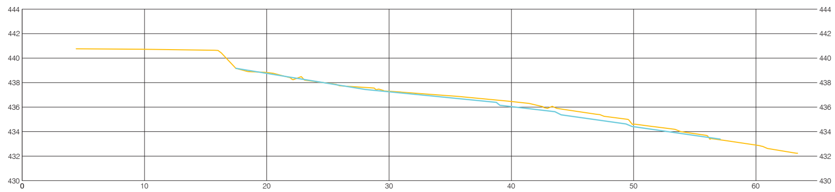
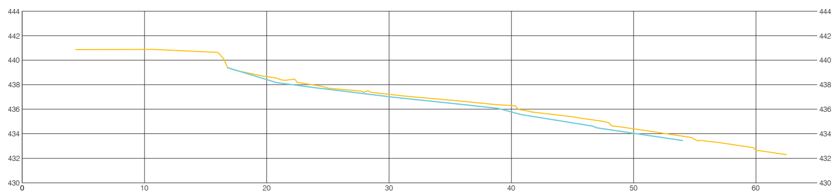
Client: BC HYDRO			

MON 14
Drawing Number



SECTION -3 (REBAR3648)



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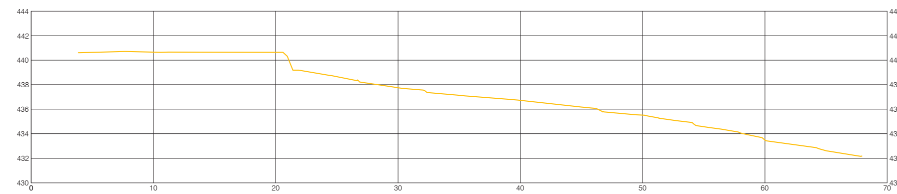

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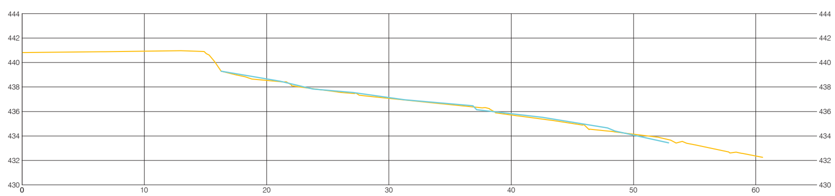

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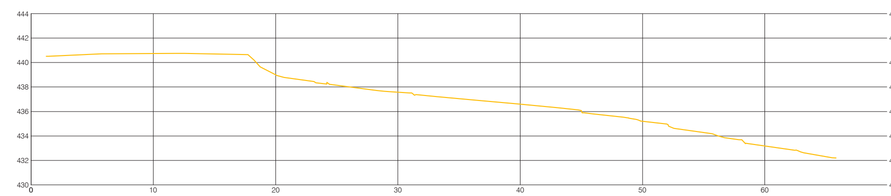


SECTION -4 (REBAR3649)

LEGEND

- - - - - TRANSECT GROUND APRIL, 2010

—— TRANSECT GROUND OCTOBER, 2010

NOTE:

MONITORING SITE #14 NOT SURVEYED IN 2012/2014.

0 2 (1:200) 10m

MONITORING SITE 14 - 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
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING

Rev. No.	Date	Designed	Drawn	Checked	Description of Revision

Seal

KERR WOOD LEIDAL associates limited CONSULTING ENGINEERS

BC HYDRO
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. 2

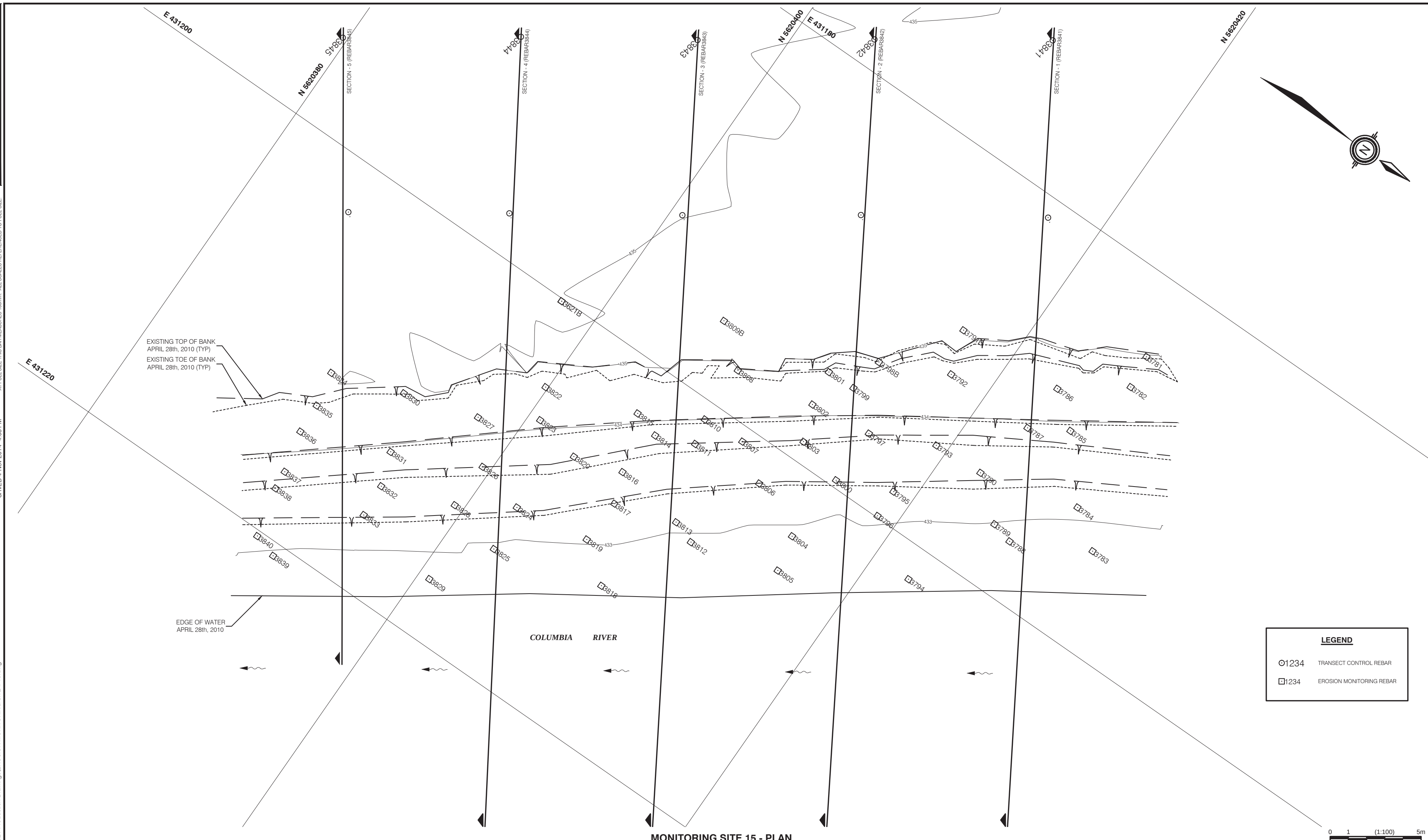
MON 14A
Drawing Number

Client: BC HYDRO

O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #14.dwg

SAVED 4-Nov-2014 4:00 PM

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



MONITORING SITE 15 - 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	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						
2	NOV.17/14	DTM	BVC		ISSUED FOR 2014 REPORTING						

Seal

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

KWL Project No. 478.120 | Scale 1:100
Sheet 26 of 27 | Rev. No. 2
MON 15
Drawing Number
Client: BC HYDRO

O:\0400-0499\0478-120\500-Drawings\521-Production Drawings\EROSION MONITORING SITE #15.dwg

SAVED 4-Nov-2014 4:03 PM

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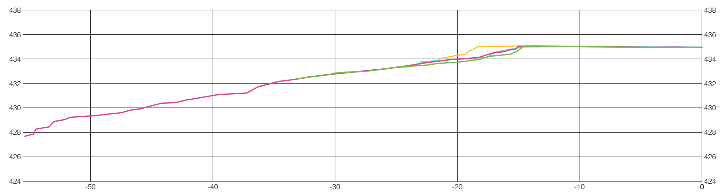
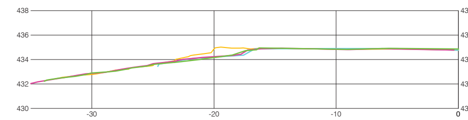


SECTION - 3 (REBAR3843)



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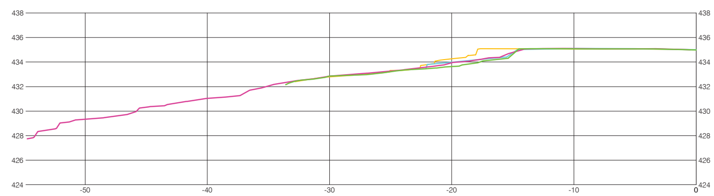
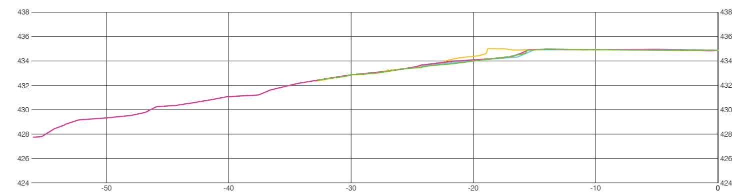
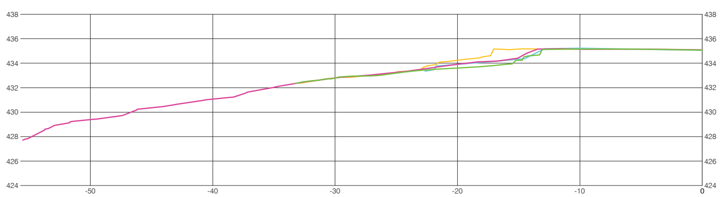


SECTION - 2 (REBAR3842)



SECTION - 4 (REBAR3844)



SECTION - 1 (REBAR3841)

LEGEND

- TRANSECT GROUND APRIL, 2010
- TRANSECT GROUND JUNE, 2011
- TRANSECT GROUND APRIL, 2012
- TRANSECT GROUND APRIL, 2014

MONITORING SITE 15 - 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

Seal

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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
Sheet 27 of 27 | Rev. No. 2

MON 15A
Drawing Number

Client: BC HYDRO