Columbia River Project Water Use Plan
Kinbasket and Arrow Lakes Revegetation Management Plan

Addendum for REV5
Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Implementation Year 1

Reference: CLBMON-12

Study Period: 2012

Delphinium Holdings Inc.
Castlegar, BC

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Original Report Cover

CLBMON-12
ARROW LAKES RESERVOIR MONITORING OF REVEGETATION EFFORTS AND VEGETATION COMPOSITION ANALYSIS: ADDENDUM: REV5 2012 FINAL REPORT

Low Elevation Cottonwood and Willows west of Illecillewaet River

Submitted to:

BC Hydro
Water Licence Requirements
Castlegar, B.C.

by:

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Cover photo: 2011 Cottonwood and willow west growing in the alluvial clays of Illecillewaet River, low elevation near Revelstoke BC

EXECUTIVE SUMMARY

This addendum presents preliminary results of a project that was added to CLBMON-12 and CLBMON-33 in 2009. CLBMON-12 and CLBMON-33 are vegetation monitoring projects included in the Columbia River Project Water Use Plan. The purpose of this project is to assess potential effects of the REV5 turbine on vegetation in the drawdown zone of Revelstoke Reach and distinguish them from other influences, including the current soft constraints operating regime. The REV5 turbine was made operational in December, 2010. Therefore, this addendum represents the REV5 effects measurement and evaluation after two years of operation.

The REV5 project was designed to assess changes in vegetation cover and diversity in response to the new turbine, and to assess the concern that REV5 might increase the duration of inundation of the Revelstoke Reach drawdown zone, which could potentially have an adverse effect on vegetation. Effects were expected to be most noticeable in the lower elevation zone (433 to 436 m) and the highest elevation zone (438 – 440 m). It was thought that REV5 could potentially result in the removal of, or reductions in, vegetation cover (Korman and Buszowski, 2007).

Potential effects of REV5 operations on drawdown zone vegetation and associated null hypotheses:

- decreased total cover, especially at low elevations, due to prolonged inundation periods (Ho: average total vegetation cover is the same in each elevation band as measured in 2010)
- decreased vegetation heights, especially at low elevations, due to prolonged inundation periods (Ho: average maximum vegetation height is the same in each elevation band as measured in 2010)
- decreased species diversity, due to the loss of species less tolerant of prolonged inundation or increased water energy, throughout the drawdown zone (Ho: average species diversity is the same in each elevation band as measured in 2010).

We examined vegetation plots located from the mouth of Illecillewaet River to Cranberry Creek, in Revelstoke Reach. These plots predated the operational status of REV5 for changes in vegetation cover and diversity. These plots were selected from an existing database to examine time-related comparisons of changes in the vegetation, using boxplots and repeated measures analysis. A redundancy analysis with forward selection of environmental variables was used to distinguish the influence of the independent variables, including the presence of sands, silts, clays, gravels and boulders, as well as duration and depth of inundation.

There was no obvious trend in the effects of REV5 on the vegetation of the Revelstoke Reach. Heights and covers of the vegetation are highest at the northern end of the Revelstoke Reach, due to the accumulation of clay in soils and invasion by shrubs, even at low elevation. There was no clear trend in response to the start of the REV5 turbine at Illecillewaet River, versus the downstream locations. REV5 has only been operational for two winter seasons, and the effects of REV5 related inundation may not yet be distinguishable from baseline inundation. Although there are no clear, detectable influences of REV5, the data show clear alignment of species groups with elevation and

inundation in the reservoir, and this is thought to be a response to the overall long-term growing conditions in the Arrow Lakes Reservoir.

A summary of the Management Questions for CLBMON-12 as they relate to the REV-5 addendum is provided in Table 1.

Table 1. Status of management questions (MQ) for the REV5 portion of CLBMON-12, supporting data and Results Summary. Note that there were no specific management questions developed for REV5; therefore the relevant CLBMON-33 MQ's have been adapted to reflect the objectives outlined in BC Hydro (2008)

Management Question	Field data	Results
1. What is the species diversity of existing vegetation communities in relation to elevation in the drawdown zone, with respect to REV5 operations?	Existing vegetation species compositions of plots sampled within the study area.	There was no significant difference detected in species diversity among any of the three elevation bands sampled between 2010 and 2012, with 2010 representing pre-REV5 conditions.
2. How does the current operating regime, including REV5 operations, affect the within-community quality and quantity of existing vegetation?	Species cover, diversity, and height measurements taken in the field. Daily Records of Water elevation in the Reach were used to determine the number of days that each plot was inundated. An increase in inundation heights compared to pre-REV5 years was observed. The increase spanned from August to October.	Vegetation height was found to be greater at higher elevations, where duration and depth of inundation are lowest. Neither cover nor diversity showed any clear pattern with respect to inundation that could be directly attributable to REV5 in the site specific field data. Aerial photographic comparisons over the long term may show changes that could be attributed to REV5.

KEYWORDS

REV5, Arrow Lakes Reservoir, Revelstoke Reach, Illecillewaet River, vegetation.

ACKNOWLEDGEMENTS

Evan McKenzie and Jane Enns provided fieldwork on this project. This project was overseen by Margo Dennis and Guy Martel of BC Hydro. Dr. Carl Schwarz provided the RDA and RMA statistics presented in this paper. Dr. Guy Martel provided review comments. Our thanks to them all.

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1.0 INTRODUCTION

BC Hydro implemented two 10-year monitoring programs in the Arrow Lakes Reservoir to assess the impacts of the soft constraints operating regime on existing and treated vegetation. The CLBMON-33 project, initiated in 2007, is a repeated aerial photographic survey of the vegetation, with subsequent field measures designed to assess changes in vegetation at the landscape scale. The CLBMON-12 project, initiated in 2008, is a detailed field study designed to assess changes in existing and treated vegetation.

In 2009, the REV5 project was initiated to examine the effects of a fifth generating unit (REV5) at Revelstoke Dam on vegetation in the drawdown zone of the Revelstoke Reach portion of the Arrow Lakes Reservoir. Changes in vegetation in response to REV5 are monitored within both the CLBMON-33 and CLBMON-12 projects.

The reason for the REV5 addendum to both projects was the concern that the addition of a fifth turbine to Revelstoke Dam might cause loss of vegetation at low, and possibly higher elevations in the northern portion of the Revelstoke Reach (closest to Revelstoke Dam). The most susceptible areas were thought to be at the mouth of the Illecillewaet River, south of Revelstoke (Enns and Enns 2011). This addendum to the CLBMON-12 report for 2012 includes an examination of the effects of REV5 on cover and diversity of vegetation at Illecillewaet River and southern locations in Revelstoke Reach during the first winter and spring after REV5 became operational.

The goals of the REV5 portion of the CLBMON-12 monitoring program (BC Hydro 2008) are to:

1) determine if the cover and diversity of vegetation in the drawdown zone occurring between 433 and 440 m as been influenced by the addition of the REV5 generating unit;
2) determine if cover and diversity of vegetation in the Revelstoke Reach portion of the Arrow Lakes Reservoir drawdown zone have been influenced by the addition of the REV5 generating unit at locations both near to and distant from the REV5 generating unit;
3) monitor the response of existing vegetation communities at the local site level to the continued operation of the REV5 generating unit and to other environmental variables.

REV5 was made operational in December of 2010. Annual re-measurements have been conducted in selected plots since 2009. The plots were established for two overarching BC Hydro monitoring projects; a landscape level study of vegetation change using aerial photography interpretation and field work (CLBMON 33) and a field study of revegetation efforts and vegetation composition (CLBMON-12). The first post-operational series of vegetation monitoring plots were completed in 2011.

This report summarizes the results of the second post-operational vegetation evaluation of potential effects of REV5 on vegetation.

2.0 CHARACTERISTICS OF INUNDATION IN THE RESERVOIR

Vegetation in the reservoir has been influenced by dam operations since the mid-1960s, and has adapted to and been shaped by those conditions. Figure 1 illustrates the timing, frequency, duration, and depth of inundation from January, 2006 to June, 2012.

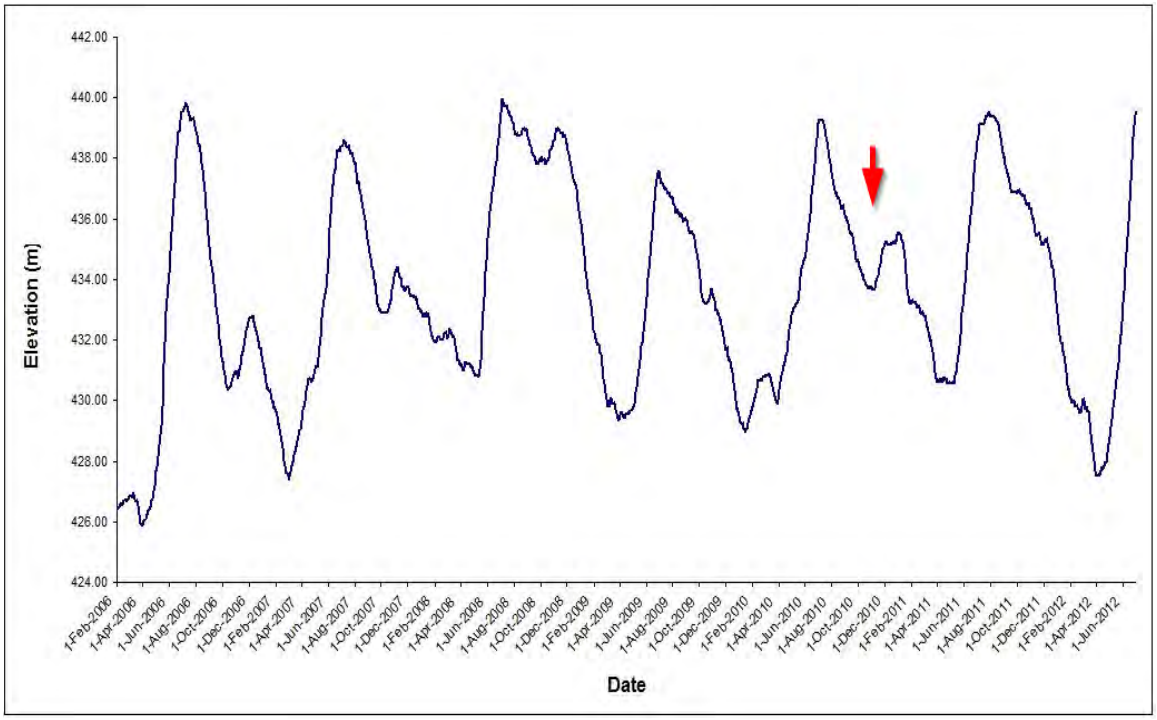

Figure 1. Water levels in the Arrow Lakes Reservoir from 2006 to 2012. The arrow indicates the commencement date for flows influenced by REV5 operations.

The patterns of inundation have generally been similar over the past seven years, although there have been some year-to-year differences in water levels. The influence of REV5 was thought to be mainly observable at low elevations in the Revelstoke Reach portion of the Arrow Lakes Reservoir (Korman and Buszowski 2007).

3.0 METHODS

The methods describing field data collection, data entry, analysis and interpretation are provided in the main CLBMON-12 report for 2012 (Enns 2012). Only the methods relevant to the analysis of data for the REV5 addendum are provided here. A series of field plots in Revelstoke Reach were assessed annually in 2009 through 2012. The locations of these plots are illustrated in Figure 2. The vegetation cover, diversity and heights in this subset of plots were examined for trends in response to depth and duration of inundation (i.e., elevation and days of inundation).

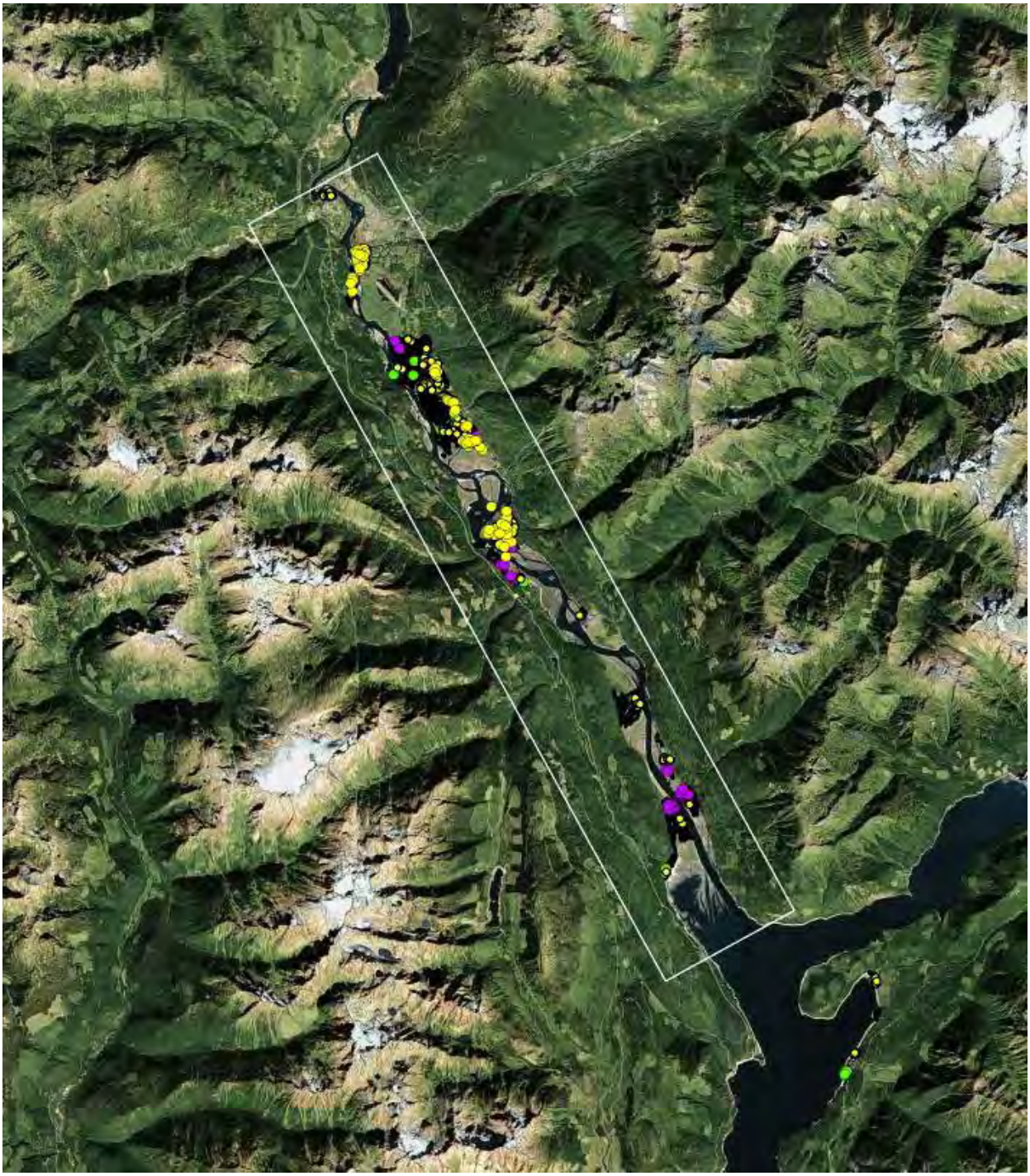

Figure 2. **Locations of field plots assessed annually from 2009 through 2012 for impacts of REV5 on vegetation within the Revelstoke Reach portion of the Arrow Lakes Reservoir for the CLBMON-12 and CLBMON-33 projects. The yellow dots indicate plots (which tend to overlap at this scale) surveyed for the REV5 assessment. Purple and green dots are plots for the remainder of the CLBMON-33 project.**

The detailed methods used to measure vegetation changes in plots are provided in the main CLBMON33 report (Enns, 2012). A total of 33 plots in Revelstoke Reach were measured from 2009 through 2012 and were used in the analysis of the influence of REV5 operations on vegetation. We attempted to sample the same plots, and replicates within Vegetation Community Types (VCTs) and elevation bands, at variable distances from the dam. Descriptions of each VCT and a table showing the number of plots sampled in each VCT and elevation band are provided in Appendix 1.

Boxplots were used to compare the distributions of vegetation cover, height and diversity in plots from 2009 through 2012 (Figures 3 and 4).

The response of vegetation in the repeated plots was evaluated using ANOVAs. We tested for significant differences in vegetation height, cover, and distribution between sampling years, elevation classes, and vegetation community types. Vegetation data was tested for agreement with the underlying assumptions of ANOVA analysis such as normality of distribution and equal variances in the groups compared.

For the purposes of testing the null hypothesis of no relationship between the environmental variables (predictor matrix) and the species (response matrix), a redundancy analysis (RDA) was run 998 times with randomized data. This procedure consisted of randomly shuffling the rows in one matrix relative to the other, performing the RDA on the randomized data, recording test statistics, and comparing those to the eigenvalues from the non-randomized RDA to determine the probability of a Type I error. A list of the environmental variables included in the RDA analysis is provided in the Results section, below.

Repeated Measures Analysis of Variance was used to identify significant year-wise differences in cover and height in repeated plots over time and in relation to distance from the dam. We tested for differences among VCTs, elevation bands, and sampling years, as well as for a Elevation Band x Year interaction effect. Because the dataset was small, changes in species compositions over time within individual plots were also examined and described.

4.0 RESULTS

4.1 Differences in vegetation cover, height and diversity among years and elevation classes

The distributions of vegetation cover, height and diversity in repeated vegetation monitoring plots are shown in Figures 3 and 4.

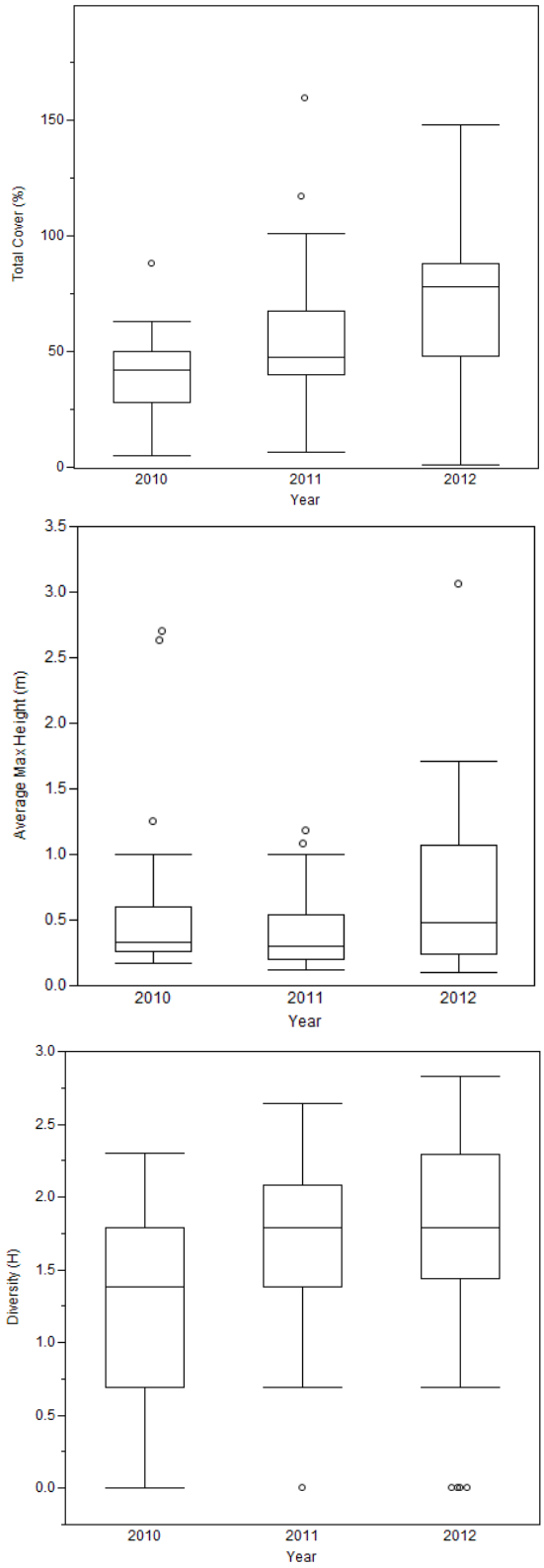

Figure 3. Total Vegetation Cover (top), Average Maximum Vegetation Height (middle) and Species Diversity (bottom) for repeated plots sampled in 2010 through 2012 in Revelstoke Reach, all elevations combined. N = 33 for each year. The 2010 distributions represent a pre-REV5 vegetation baseline.

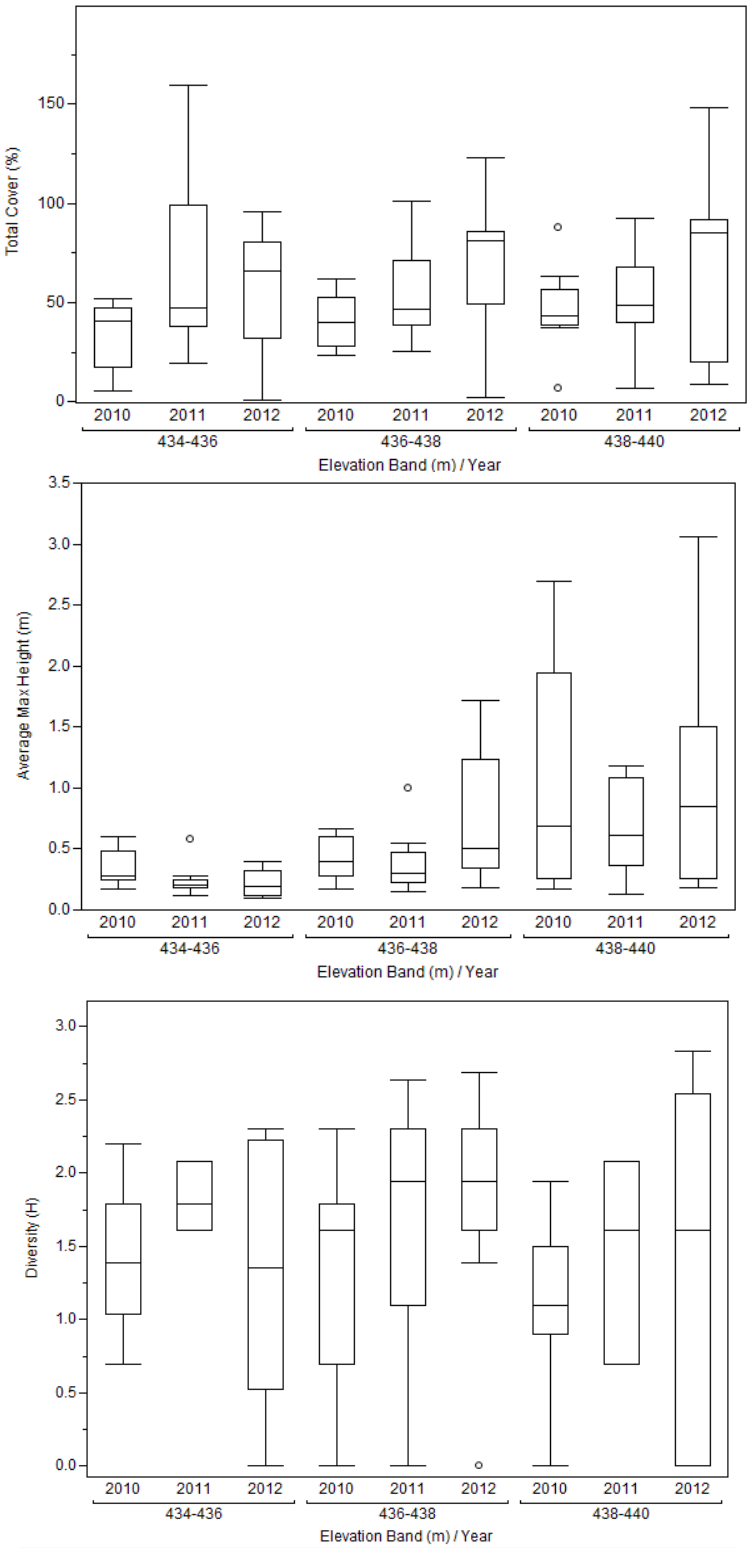

Figure 4. Total Vegetation Cover (top), Average Maximum Vegetation Height (middle) and Species Diversity (bottom) in plots repeated in 2010 through 2012 in Revelstoke Reach, by elevation band. N = 33 for each year. The 2010 distributions represent a pre-REV5 vegetation baseline.

As described in the methods, two-way ANOVAs were used to test for relationships between vegetation height, cover and diversity over elevation bands and over the three years of repeated measures (Table 2). The plot data used in the following statistical tests was taken from the sampling years (2010 through 2012) in which a sufficient number of the exact same plots had been repeated in each elevation band to make a reliable comparison between both years and elevation bands.

Table 2. Results of Two-way ANOVA for vegetation height, cover and diversity in repeated plots (2010 through 2012) in the Revelstoke Reach portion of the Arrow Lakes Reservoir. Statistically significant results are indicated with an asterisk *

Dependent variable	Independent variable	P value
Total vegetation cover in the Repeated 2010 through 2012 plots	Elevation band	0.786
	Year	0.002*
	Elevation Year Interaction	0.52
Average maximum vegetation height in the Repeated 2010 through 2012 plots	Elevation band	0.000*
	Year	0.198
	Elevation Year Interaction	0.457
Shannon-Weiner Diversity Index in repeated 2010 through 2012 plots	Elevation band	0.217
	Year	0.111
	Elevation Year Interaction	0.462

The 438 – 440 m elevation band had significantly taller vegetation, on average, than the other two bands. There was no significant difference, however, in vegetation height between the 436 – 438 m elevation band and the 434 – 436 m band. There was no significant change in vegetation height due to the effect of sampling year, and there was no significant interaction between the year and elevation band levels.

Cover was significantly higher in 2012 than in 2010. There was no significant difference in cover between 2010 and 2011, or between 2011 and 2012. There was no difference in total cover based on the effect of elevation band alone, and there was no significant interaction between sampling year and elevation band levels.

There was no significant difference detected in species diversity across either sampling years or elevation bands, and no significant interaction between these levels.

We also tested for changes in vegetation height and cover within each of the elevation bands designated for the project (Table 3). Plot data from 2010 through 2012 was used in the analysis.

Table 3. P-values from ANOVA for changes in vegetation height and cover in the three designated elevation bands for selected VCTs (IN, PA, PC and PE), sampled in 2010 through 2012. Statistically significant results are indicated with an asterisk.

Elevation Band (m)	Avg. Max Height	Total Cover
434-436	0.061	0.094
436-438	0.858	0.040*
438-440	0.014*	0.001*

Average maximum vegetation height was found to have increased significantly between 2010 and 2012 in the high elevation band (438 - 440 m) only. Total vegetation cover increased in both the high and mid elevation bands, but no change was detected at the low elevation band. These results indicate that there has been no detectable change in vegetation covers or heights at low elevations, where the effects of REV5 operations would likely be most noticeable, and that vegetation covers and heights have actually increased at higher elevations.

We looked for differences in total vegetation cover and height among sampling years within selected VCTs, for each elevation band. The results are illustrated in Figures 5 through 10, and contain data from 2008 and 2009 where available. Note that operation of REV5 commenced in 2010.

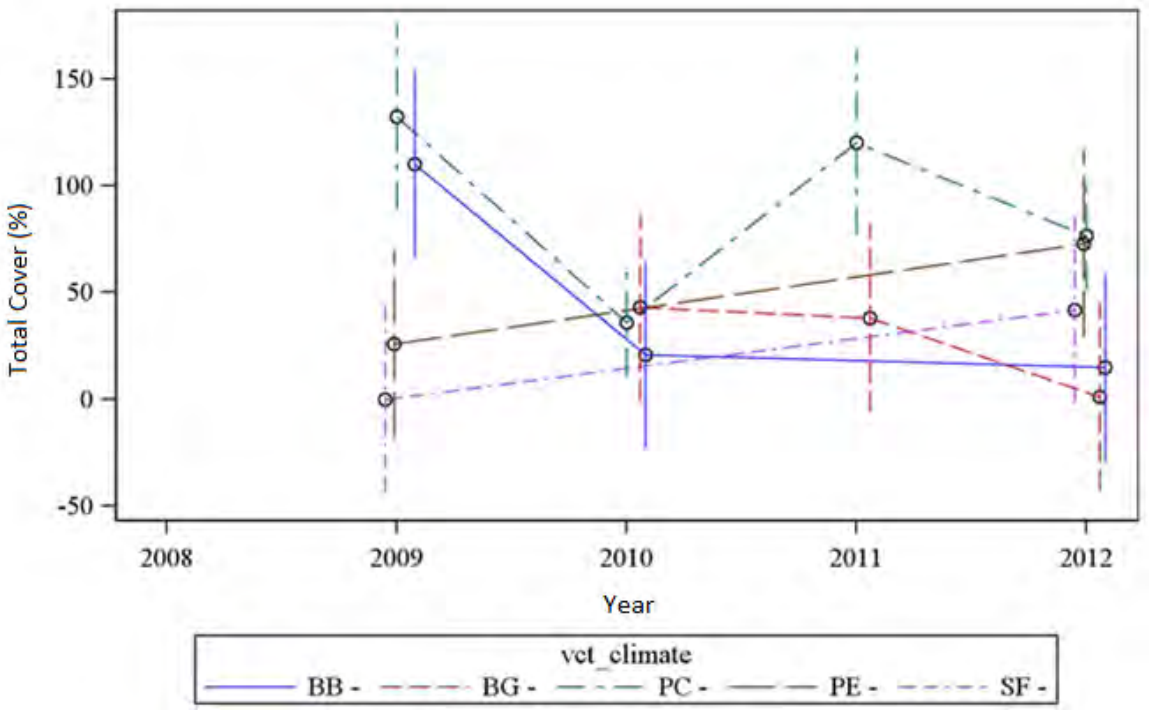

Figure 5. Total vegetation cover for selected VCTs from plots sampled in 2009 through 2012 in the 434 to 436 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.

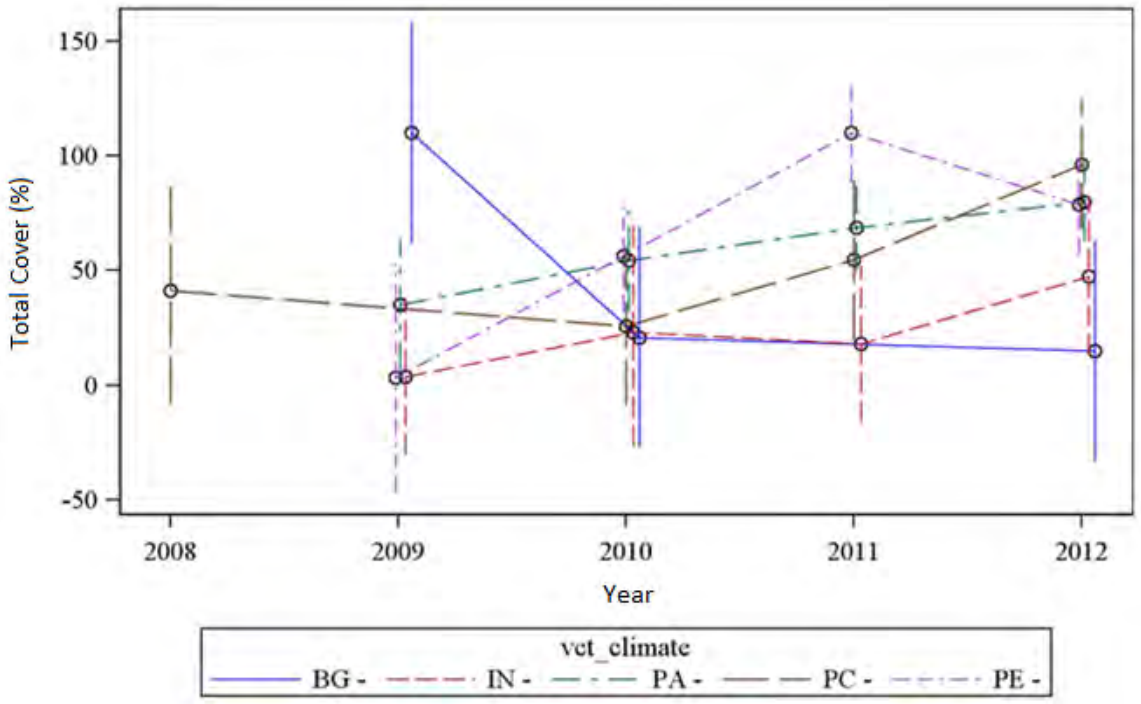

Figure 6. **Total v egetation co ver f or sel ected V CTs f rom p lots samp led i n 2009 through 2012 in the 436 to 438 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.**

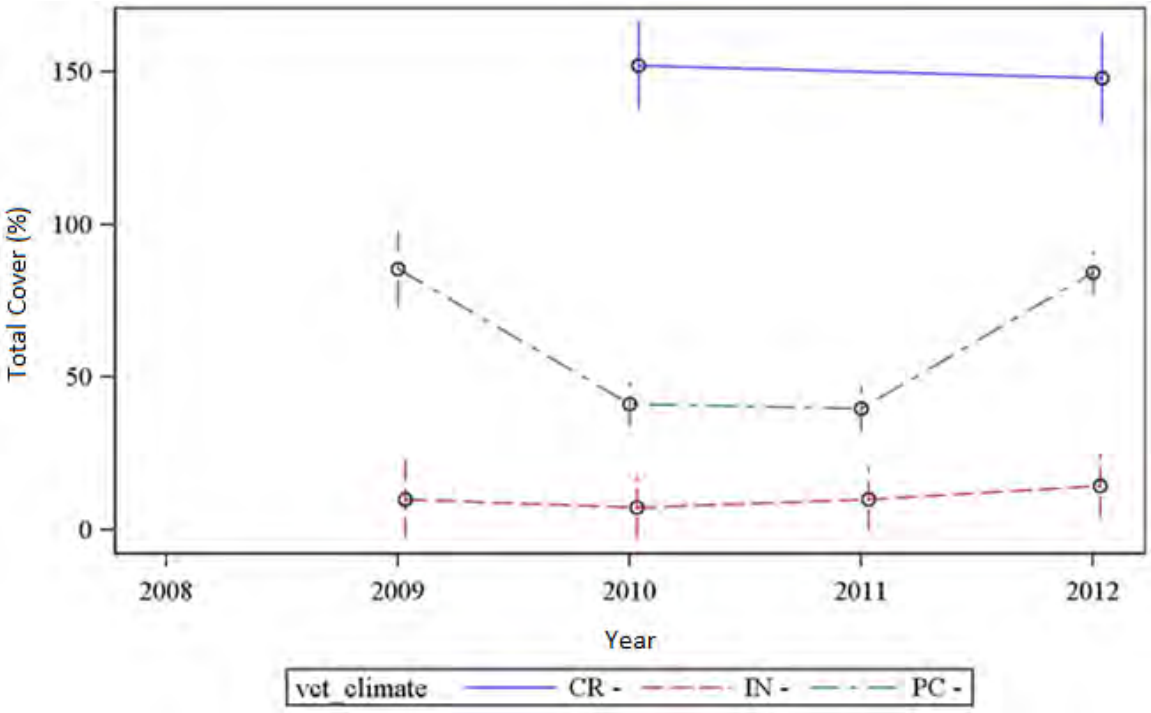

Figure 7. **Total veg etation co ver f or sel ected V CTs f rom p lots samp led i n 2009 through 2012 in the 438 to 440 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.**

There was a significant decrease in total vegetation cover in the BB type between 2009 and 2010 in the low elevation band (434 - 436 m). This was not apparent in the comparison between 2010 and 2012. Vegetation cover in the PE and PC types increased from 2010 to 2012. In the 436 - 438 m elevation band, cover in the BG type decreased between 2009 and 2012, but moderate increases in cover occurred in the PE, PA and PC types over the same time period. In the 438 - 440 m elevation band there was a significant decrease in cover in the CR type between 2009 and 2010, but a subsequent increase in cover between 2011 and 2012. No significant changes in cover were observed in the other VCTs assessed in the high elevation band. Taken together these results indicate that there has been little change in total vegetation covers since the onset of REV5 operations in 2010, and that the only significant changes have been increased covers in some VCTs.

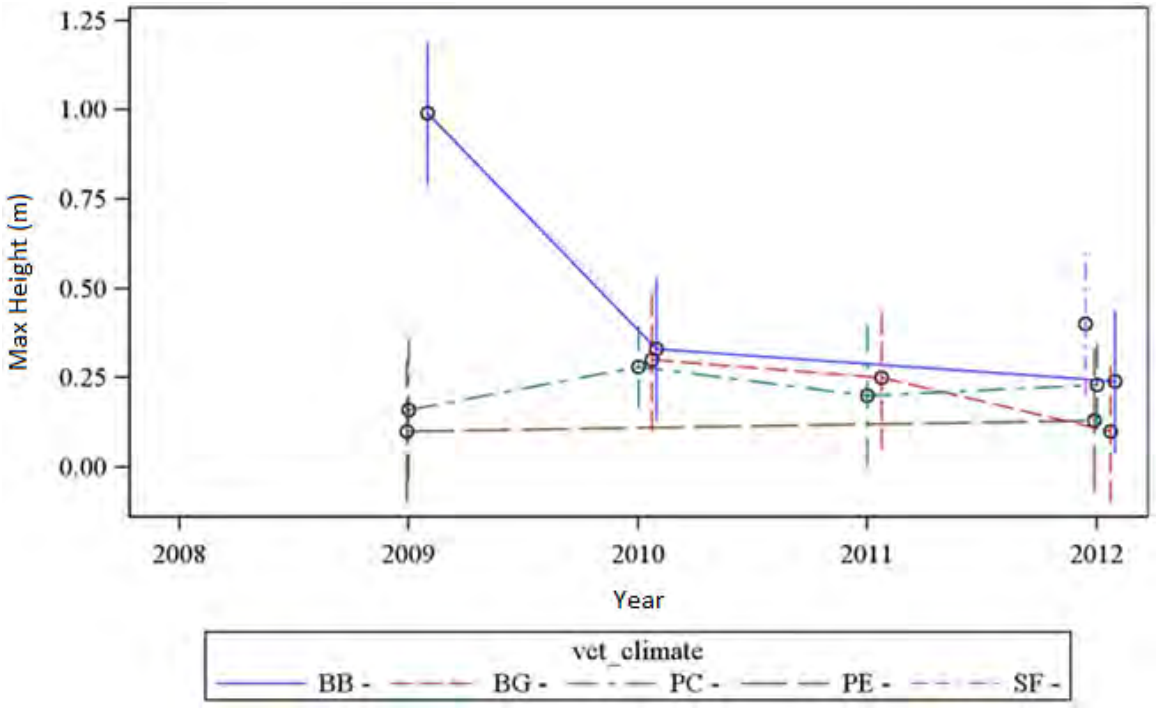

Figure 8. **Maximum vegetation heights for selected VCTs from plots sampled in 2009 through 2012 in the 434 to 436 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.**

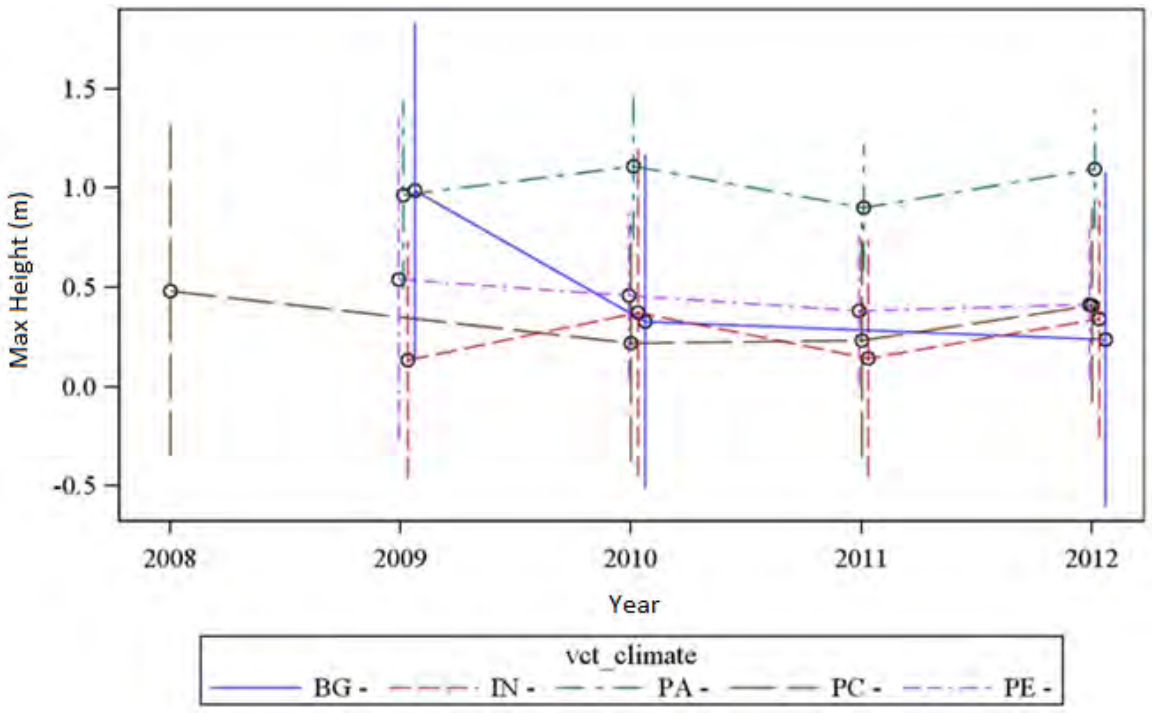

Figure 9. **Maximum vegetation heights for selected VCTs from plots sampled in 2009 through 2012 in the 436 to 438 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.**

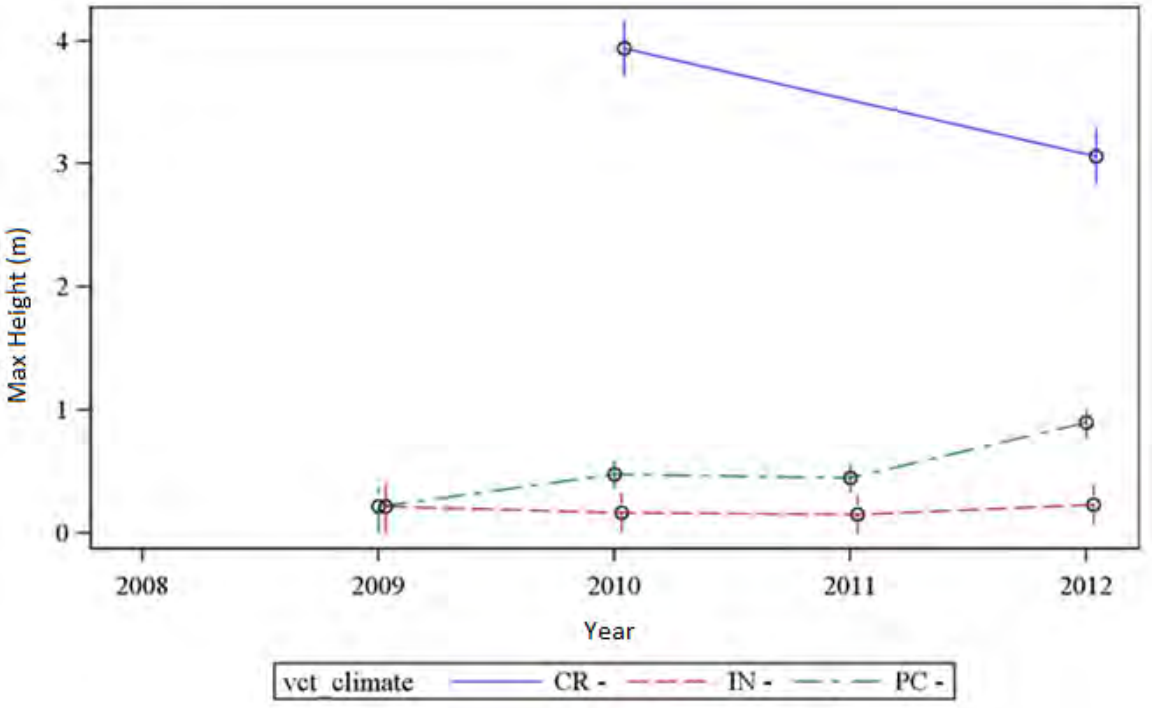

Figure 10. **Maximum vegetation heights for selected VCTs from plots sampled in 2009 through 2012 in the 438 to 440 m elevation band. 95% confidence intervals for the mean are shown. Definitions of VCTs are provided in appendix 1.**

There was a significant decrease in maximum vegetation height in the BB type between 2009 and 2010 at the lowest elevation band (434 - 436 m). No other significant differences in height in the other VCTs between 2009 and 2010 were observed in this elevation band. There were no significant changes in vegetation heights at the middle elevation (436 - 438 m), for any of the VCTs. There were fluctuations in height over time in the CR VCT at the highest elevation band (438 – 440 m). However, these fluctuations were attributed to overall high variation in tree heights and measurement error associated with high tree crowns.

These results indicate that there has been little change in vegetation height since the onset of REV5 operations in 2010.

Plant species diversity and cover were high at low elevation sites, even though the period of inundation at this elevation was longer than at high elevation. This was due to the presence of inundation-tolerant plants such as lenticular sedge (*Carex lenticularis*), scouring rushes and horsetails (*Equisetum* spp.) that are tolerant of inundation.

The mouth of the Illecillewaet River is influenced by both the Columbia and the Illecillewaet Rivers, and is the CLBMON-12 project study area closest to the Revelstoke Dam. If REV5 is having measurable effects on vegetation, it was assumed they would appear in the vegetation monitoring plots at Illecillewaet. Pacific willow appeared to be declining at this location. Figure 11 shows a declining low-elevation willow (*Salix* spp.) and reed canary grass plant community in a cut-off oxbow with sheltering topography and a relatively high clay and silt content in soils.

Figure 11. A sheltered cut-off oxbow at the mouth of the Illecillewaet River at 431 to 434 meter elevation in the Arrow Lakes Reservoir with high cover over reed canary grass (*Phalaris arundinacea*) and sparse, declining Pacific willow (*Salix lucida*)

4.2 Effect of Duration of Inundation on vegetation cover, height and diversity

The relationships between vegetation cover, height and diversity versus days of inundation in 2010, 2011 and 2012 are shown in Figures 12 and 13.

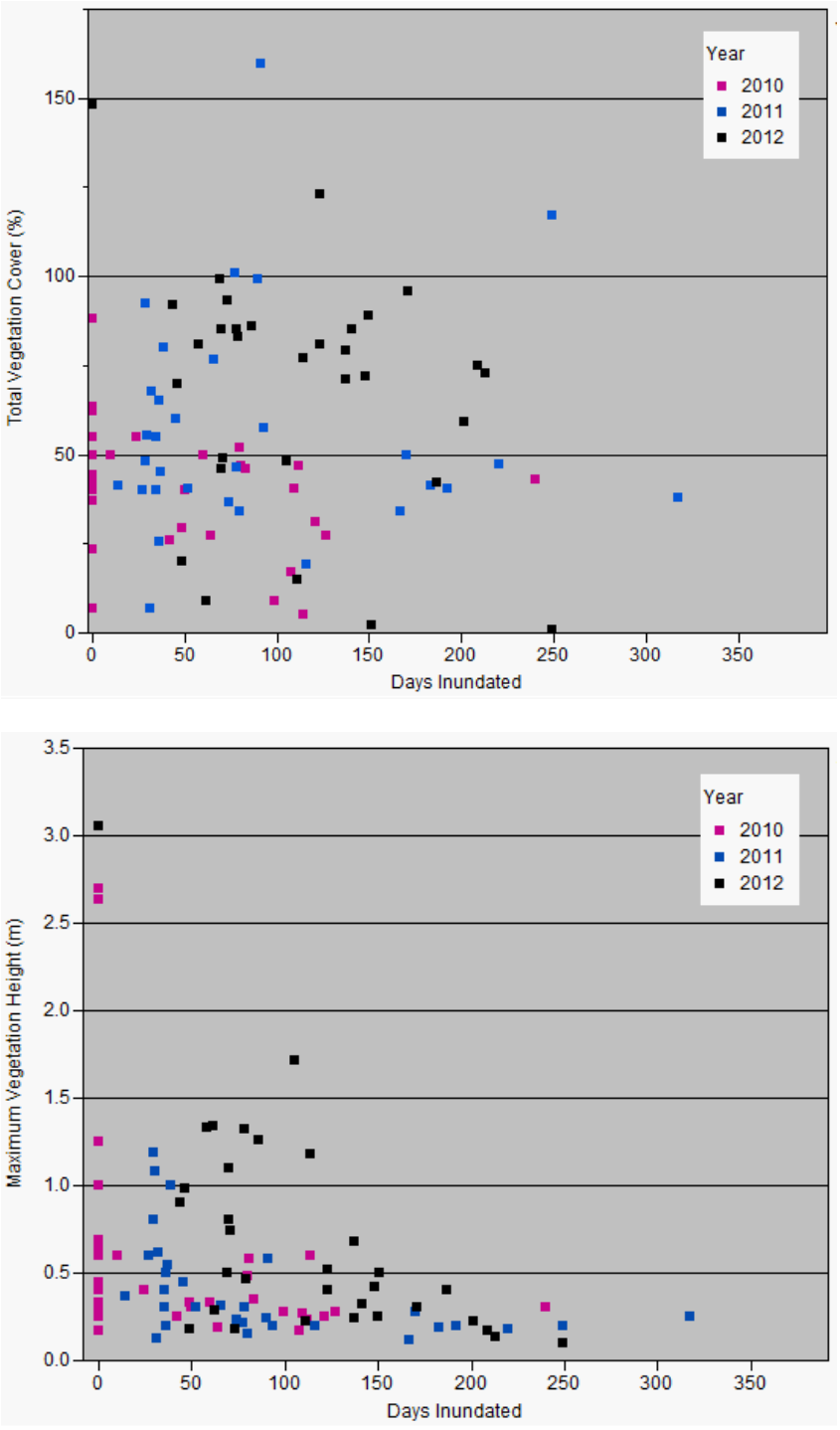

Figure 12. Total vegetation cover (top) and average maximum vegetation height (bottom) vs. days of inundation in 2010 through 2012

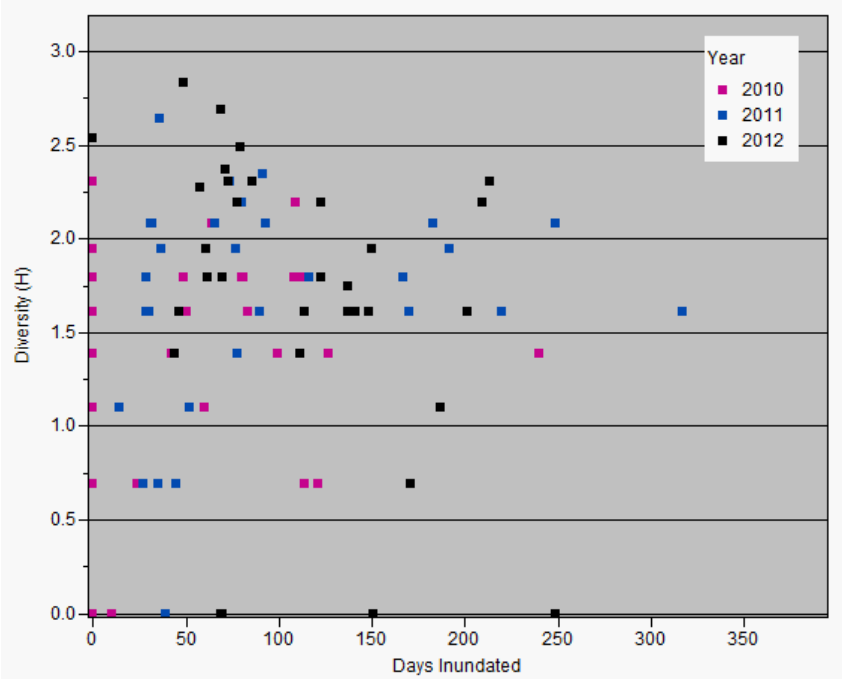

Figure 13. Shannon-Weiner Diversity Index (H) vs. days of inundation in 2010 through 2012

Only average maximum vegetation height appeared to have any relationship with duration of inundation. Plant heights tended to be lower in plots with longer periods of inundation. Several plots were not inundated, particularly in 2010. There was no clear relationship between either total plot cover or diversity and duration of inundation.

4.3 Observed changes in species composition between years

Repeated plots were examined for changes in species composition between 2010 and 2012 (Table 4).

Table 4. Plant species lost or gained in 2012 from repeated plots in the Revelstoke Reach portion of the Arrow Lakes Reservoir, arranged by elevation band

Elevation Band	Found in 2012 but not previously	
	Scientific Name	**Common Name**
434-436 m	Drepanocladus aduncus	common hook-moss
	Mimulus guttatus	yellow monkey-flower
	Persicaria maculate	lady's-thumb
	Poa annua	annual bluegrass
436-438 m	Brachythecium sp.	ragged-moss
	Hieracium sp.	hawkweed
	Hieracium caespitosum	yellow king devil
	Juncus ensifolius var. montanus	dagger-leaf rush
	Parmelia sulcata	waxpaper
	Persicaria amphibian	water smartweed

	Pohlia wahlenbergii	pale nodding-cap moss
	Polytrichum juniperinum	juniper haircap moss
	Prunella vulgaris	self-heal
	Salix bebbiana	Bebb's willow
	Senecio pauperculus	Canadian butterweed
	Ulota sp.	pincushion moss
	Xanthoria polycarpa	pincushion orange lichen
438-440 m	Betula papyrifera	paper birch (seedling)
	Cornus stolonifera	red-osier dogwood (seedling)
	Danthonia spicata	poverty oatgrass
	Epilobium angustifolium	fireweed
	Erigeron subtrinervis	triple-nerved fleabane
	Fragaria virginiana	wild strawberry
	Hieracium glomeratum	yellowdevil hawkweek
	Hordeum brachyantherum	meadow barley
	Leucanthemum vulgare	oxeye daisy
	Pinus monticola	western white pine
	Rhinanthus minor	yellow rattle
	Rubus idaeus	red raspberry
	Rubus parviflorus	Thimbleberry
	Thuja plicata	western red cedar
	Trifolium sp.	clover
	Trifolium pretense	red clover
	Vicia cracca	tufted vetch

Elevation Band	**Found previously but not present in 2012**	
	Scientific Name	**Common Name**
436-438 m	Brachythecium albicans	lawn moss
	Cardamine pensylvanica	Pennsylvanian bitter-cress
	Carex utriculata	beaked sedge
	Pleurozium schreberi	red-stemmed feathermoss
	Polytrichum juniperinum	haircap moss
	Rumex crispus	curled dock
434-436 m	Salix sitchensis	Sitka Willow
	Trifolium repens	white clover

Several species were found in 2012 that had not occurred in previous years, mostly in the 436 to 438 meter elevation band. They are almost all relatively weedy invasive species, or occurring as seedlings. Most of the species that were lost in 2012 were also somewhat ephemeral, with the exception of Sitka willow which is shown in Figure 11. Only two species found in the low elevation band (434 to 436 m) in previous years were not present in 2012.

The 2011 assessments showed recruitment of six species at low elevation, four at middle elevation and three at high elevation. The meadow-foxtails are aggressive annual grasses that have been increasing in frequency of occurrence in the reservoir over the past three years. Smooth scouring rush has increased in the number of times it occurred in the plots. This species is tolerant of inundation. Pineapple weed, lady's-thumb and Norwegian cinquefoil are all aggressive weedy annuals and well adapted to conditions in

the reservoir. The hawkweed, dandelion and white clover are a similar group of aggressive annual weeds but are more typical of drier sites above the drawdown zone. Their presence in the 438 to 440 m elevation band in 2011 and 2012 may represent a temporary invasion from the drier variants of the Cottonwood Riparian Forest Vegetation Community Type.

In 2012, several species were recruited, 17 in the 438-440 m elevation band, 13 in the 436-438 m band, and 4 in the 434-436 m band. Thus an overall increase in species diversity was observed in 2012 compared to baseline data from 2009 and 2010.

In summary, these results indicate that species diversity has not declined since the commencement of REV5. Rather, diversity appears to have increased slightly, particularly in the higher elevation bands.

4.4 Effects of environmental variables on vegetation

Redundancy analyses (RDA) was used to define the vegetation character of the repeated plots in Revelstoke Ridge and to examine the importance of environmental variables including duration of inundation, soil composition, and scouring. A list of the environmental variables included in the analysis is provided in Table 5.

Table 5. Environmental variables used in RDA analysis. Variable names are given as they appear in the RDA summary plot in Figure 8

Variable	Explanation of Variable
Sand	% sand in soil material
Silt	% silt in soil material
Clay	% clay in soil material
Gravels	% gravel in soil materials
Boulders	% boulders in soil materials
wave ridges	visible wave action effects at ground level (binary)
scouring	visible scouring effects at ground level (binary)
sheltered	plot physically sheltered from main channel (binary)
DistToDam	Straight line distance (m) from dam to plot centroid
AVGTMP	average daily temperature of plot while exposed
TOTPCP	total precipitation near plot while exposed
EXPTIME	number of days plot was exposed (not inundated) per year
ELEV_M	elevation of plot centroid (m above sea level)
exposed	plot is exposed to main channel when inundated (binary)

Figure 14 illustrates the results of the RDA analysis of total vegetation cover and average maximum height in response to environmental variables in 33 vegetation plots sampled in the Revelstoke Reach from 2010 through 2012.

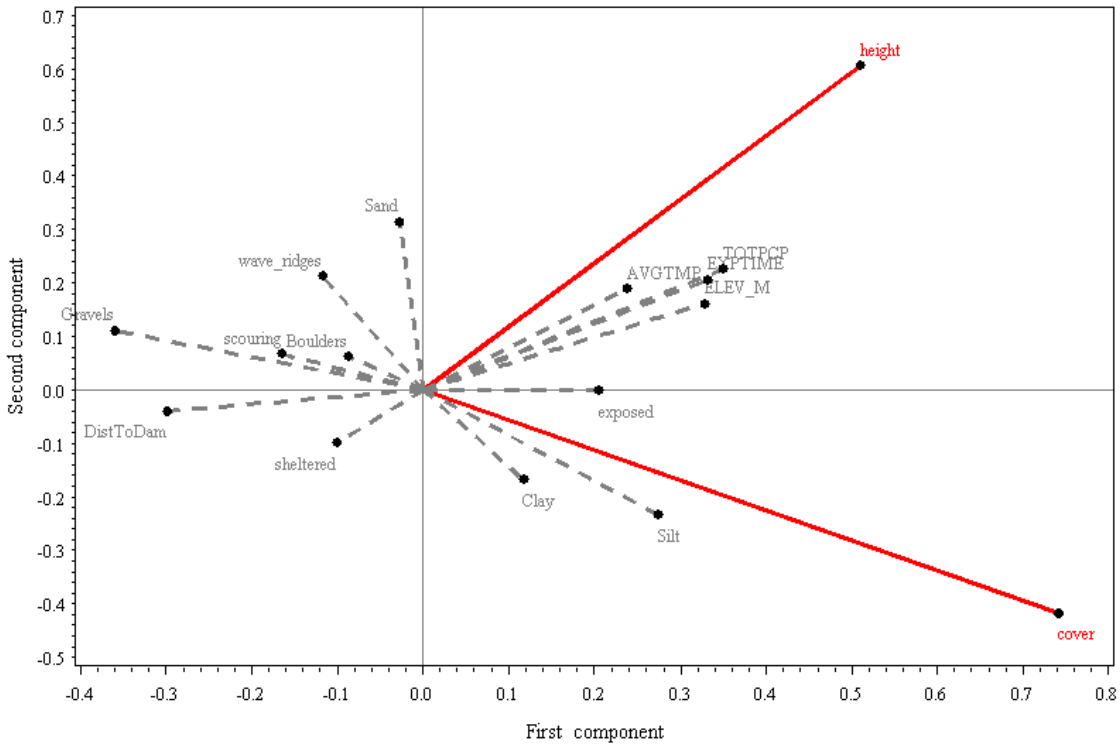

Figure 14. Principal components plot of total cover and height, and environmental variables from 33 plots in the Revelstoke Reach portion of the Arrow Lakes Reservoir. The dotted line vectors represent environmental variables, vectors that point in the same direction can be considered to have similar effects on the vegetation variables (cover and height). The lengths of the environmental variable vectors indicate the relative strengths of their effects. AVGTEMP = average temperature over the exposure period for the plot in Celsius, ELEV = meters above sea level as a centroid measure, EXPTIME = amount of time in days the plot was exposed and above water, TOTPCP = accumulated precipitation (mm) during exposure, exposed = water supplies from upslope, sheltered = topographic sheltering from scouring or waves.

These results are very similar to the RDA for the larger set of data presented in the main CLBMON33 report (Enns, 2012). Total vegetation cover was positively associated with soils containing a high percentage of sand and silt, and negatively associated with scouring, abundance of gravels and boulders, and locations with high wave action. Vegetation height was positively associated with high average daily temperatures, total annual precipitation, high elevation, and with fewer days of inundation. Vegetation height was negatively associated with sheltered locations. The first principal components accounted for 75 per cent of the predicted values of species cover and 65 per cent of the predicted values of species height. Both vegetation cover and height varied with respect to distance from the dam. These relationships are illustrated with scatter plots in Figures 15 and 16, which plot total vegetation covers and maximum vegetation heights (as measured in the 2012 field season) against sampling plot distance from the Revelstoke dam.

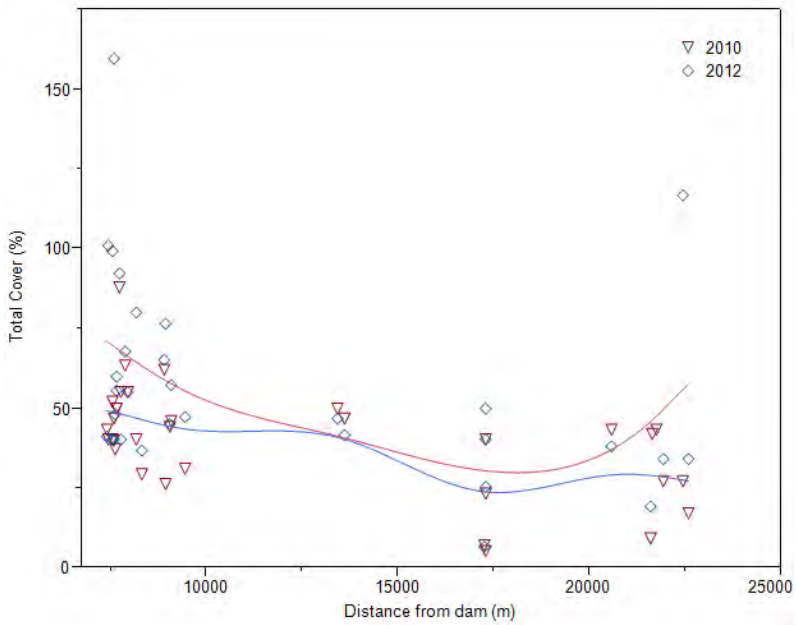

Figure 15. Vegetation height vs. distance from Revelstoke dam (m), individual plots; comparing 2010 to 2012[1].

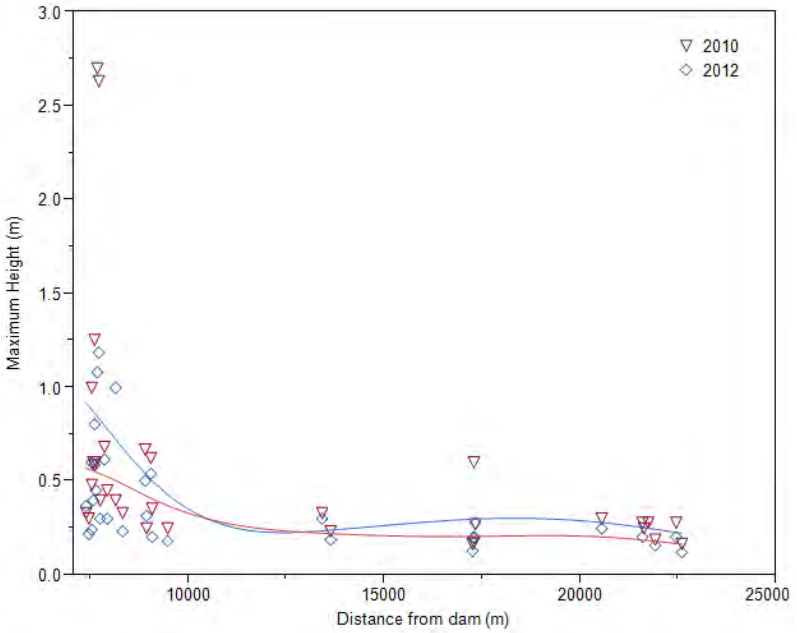

Figure 16. Total vegetation cover vs. distance from the dam (m), individual plots comparing 2010 to 2012.

[1] The fitted lines shown in Figures 15 and 16 are not statistically generated. They are kernel smoother lines that are generated to show the *overall* trends in a data set. Further, they emphasize *local* trends in the data; the signal from noisy observations is decreased and the signal from observations that fit the local trend is increased. The term "Local trends" means a directional trend for nearby data points, if most nearby points indicate a decrease, the smoother will decrease the line slope and direction until a change in the next set of points occurs.

The CR (Cottonwood riparian) and PA (Redtop upland) community types were consistently found to have the tallest vegetation of all VCTs in the study area and were almost exclusively confined to elevations above 438 meters throughout the reservoir (Enns et al. 2010, Enns and Enns 2011, Enns 2012). An exception to this is at Illecillewaet River, Old Mans Beach and an area outside the study area for CLBMON 33 northwest of the Revelstoke airstrip. These areas have relatively high clay contents in soils from alluvial deposition from the illiciliwaet River. The PA and CR shrub and tree dominated VCTs occur at low elevation where these relatively dense soils occur (Figure 17). As a consequence, taller vegetation communities are more common nearer to the dam than further away from it, but this is a parent materials related controlling factor, and so far has not been influenced by REV5. This suggests that the relationship between vegetation height and distance from the dam is due to the distribution of vegetation community types and their soils within Revelstoke Reach than to changes to the operating regime, at the present time.

Figure 17. Revelstoke Reach in 2012 alluvial clay deposition areas with brush and tree vegetation at low elevation.

As noted above, total vegetation cover was found to be negatively associated with distance from the dam. It should be noted that no relationship between total vegetation cover and the duration of inundation was detected in this assessment (Figure 12), indicating that the observed relationship may not be directly due to the effects of REV5. Furthermore, there was no significant change in total vegetation cover in the low elevation (434 – 436 m) plots between sampling years (Table 3). If changes to the operating regime from 2010 through 2012 were leading to a change in vegetation covers, we would expect the change to be most pronounced for plants in low elevation plots. We also tested for relationships between vegetation cover and height and distance from the dam within selected VCTs (Appendix 2). No significant differences in vegetation cover or height in relation to distance from the dam were detected for any of the four VCTs tested.

The most dramatic response in vegetation in Revelstoke Reach has been due to site specific erosion. Figure 18 is a photograph taken south of the mouth of Illecillewaet River, illustrating sloughing of vegetation as influenced by increased water energy.

Figure 18. Sloughing of soils and vegetation near the Illecillewaet River

5.0 DISCUSSION

There was no observed effect in the vegetation that could be directly attributed to REV5 operations based on comparison of the 2012 field data to previous years (2009, 2010 and 2011). There was a significant increase in vegetation heights in the 438 to 440 m elevation band and in the covers of vegetation in the 436 to 438 m band and the 438 to 440 m band. Of the three dependent variables (total vegetation cover, average maximum vegetation height and Shannon-Weiner Diversity Index), only average

maximum vegetation height was found to be correlated with inundation time, which could be the result of REV5 operations if REV5 is increasing the length of inundation periods.

A modest negative association between distance from the dam and both vegetation height and cover was detected. However, this association could not be directly attributed to REV5 operations, and may be explained as a function of the pre-existing distribution of VCTs in Revelstoke Reach. Isolating the effects of REV5 from overall reservoir-wide inundation effects will likely require continued site-specific repeated monitoring over time.

Species invasions from upslope occurred annually in the reservoir, and repeated observations indicate that these invasions have been short-lived and usually due to annual seeding. Few plants species were lost from plots. An exception is that some semi-aquatic or amphibious species disappeared from the lowest-elevation plots over the winter high-water period. On the whole, however, species diversity in the drawdown zone was found to have increased since 2010, particularly in the mid and high elevation bands.

RDA analyses indicates that both the duration of inundation and elevation account for some of the observed variation in plant cover and height. The autecology of the plants (Enns and Enns 2011) and their tolerances or requirements for substrates, moisture regimes and water energy levels explain some of this variation. However, the data may not sufficiently represent the more dramatic and somewhat random effects of scouring or erosion losses of plants and soils in Revelstoke Reach (Figure 17), which may be due to increased water energy as a result of REV5 operations. Assessment of the magnitude of these effects may best be done through comparisons of the aerial photographs taken in 2007 and 2010 to the photos taken in 2012.

Comparisons of the aerial photographic series from 2007 to 2012 are currently being undertaken.

6.0 CONCLUSIONS

REV5 has been operational for two growing seasons. The effects of changes in inundation duration and depth may not yet be distinguishable from baseline conditions. There were no obvious trends in the effects of REV5 on the vegetation of the Arrow Lakes Reservoir following the first winter of operation (Enns and Enns, 2011). Aerial photographic comparisons using data from 2007 to 2010 showed isolated effects of scouring on the vegetation (Enns and Enns draft report 2011). The existence of a spatial pattern of frequency of occurrence of scouring over time in the imagery is currently being compiled from imagery data. From the analysis of the field data alone, however, and using comparisons of plot data collected in 2009, 2010, 2011 and 2012, no significant decreases in vegetation height, cover, or diversity were found following the onset of REV5 operations in December, 2010.

7.0 REFERENCES

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Appendix 1. Vegetation community types (VCTs) found in the Revelstoke Reach study area.

Table A1.1 VCTs found in the Revelstoke Reach portion

BE: Sandy beach: sandy, mostly non-vegetated to sparsely vegetated with herbaceous plants, seedlings and grasses, occasionally with sedges and mosses.	
BG: Gravelly beach: sparsely vegetated mid-slope gravels with grasses and herbaceous plants, especially drought-tolerant weeds and occasionally small cottonwood and willows.	
CR: Cottonwood riparian: upland forest edge on relatively deep, occasionally bouldery soils. Includes some managed lands.	
PA: Redtop upland: gravelly to sandy upper-elevation beaches, often with remnants of former forested or farmed soils, dominated by shrubs and several species of grasses, drought-tolerant herbs, mosses, lichens and several species of weeds.	
PC: Reed canary grass mesic: silty sandy, mostly flat beaches; comparatively species=poor, and dominated by reed canary grass but can include a minor component of mint, horsetail and agronomic species.	
PE: Horsetail lowland: lowest-elevation VCT with dense, silty soils often poorly drained and receiving moisture from the reservoir, dominated by wetland species including sedges, rushes and reeds.	
RR: Reed – rill: submerged seepage tracks extending from high elevation to the reservoir edge, occasionally upwelling, and dominated by herbs, liverworts, wetland grasses, mosses, sedges, rushes and reeds. Uncommon, but does occur in Revelstoke Reach.	

Table A1. 2 VCTs in the Arrow Lakes Reservoir that are included in the mapping, but are thought to be less influenced by the soft constraints operating regime than by other variables, or are uncommon

BB: Boulders, steep: mostly non-vegetated and steeply sloping boulders and cobble beaches.
CL: Cliffs and rock outcrops: often very steep, bedrock-dominated with cliff vegetation.
SF: Slope failure: slumps and minor slope failures dominated by silt sands. .
IN: Industrial/residential/recreational: all potential soils and parent materials; strongly influenced by recreational and industrial vehicle use.
PO: Ponds: mostly permanently flooded backwaters or collection sites.
RS: Willow stream entry: incoming stream channels, may be ephemeral.
SS: Steep sand: steep slopes dominated by sand. Usually non-vegetated.
WR: Silverberry river entry: occurs only in major river entries with year-round water flow.

Table A1.3 Numbers of plots in each type and elevation band used in RMA (N/A = type does not occur)

	Elevation Band (m)		
Type	**434-436**	**436-438**	**438-440**
PC	3	3	4
PA	NA	4	5
PE	3	3	0
IN	0	2	2
BG	1	1	0
CR	N/A	N/A	1

Appendix 2. Summary of ANOVAs for vegetation height, cover and diversity in repeated plots (2010 through 2012) in the Revelstoke Reach portion of the Arrow Lakes Reservoir.

Total Vegetation Cover:

Table A3.1. Summary of ANOVA results.

Source	DF	Sum of Sq	F Ratio	P value
Elevation Band	2	388.699	0.241	0.786
Year	2	10796.521	6.695	0.002*
Elevation Band * Year	4	2621.406	0.813	0.520

Changes in vegetation cover among sampling years: 2010 < 2011 < 2012

Table A3.2. Least squares means and standard errors for all levels.

Effect	Level	Least Sq Mean	Std Error
Elevation Band	434-436	51.610	5.588
	436-438	55.952	4.301
	438-440	56.540	5.963
Year	2010	40.295	4.999
	2011	56.175	5.276
	2012	67.632	5.696
Elevation Band * Year	434-436,2010	33.191	8.562
	434-436,2011	63.973	8.562
	434-436,2012	57.667	11.593
	436-438,2010	41.715	7.876
	436-438,2011	54.339	7.876
	436-438,2012	71.800	6.515
	438-440,2010	45.978	9.465
	438-440,2011	50.214	10.733
	438-440,2012	73.429	10.733

Maximum Vegetation Height:

Table A3.3. Summary of ANOVA results.

Source	DF	Sum of Sq	F Ratio	P value
Elevation Band	2	4.983	10.899	0.000*
Year	2	0.756	1.653	0.198
Elevation Band * Year	4	0.841	0.919	0.457

Difference in vegetation heights among elevation bands: 434-436 < 436-438 < 438-440

Table A3.4. Least squares means and standard errors for all levels.

Effect	Level	Least Sq Mean	Std Error
Elevation Band	434-436	0.268	0.094

	436-438	0.507	0.072
	438-440	0.916	0.103
Year	2010	0.595	0.084
	2011	0.433	0.089
	2012	0.662	0.099
Elevation Band * Year	434-436,2010	0.344	0.144
	434-436,2011	0.240	0.144
	434-436,2012	0.219	0.195
	436-438,2010	0.409	0.133
	436-438,2011	0.377	0.133
	436-438,2012	0.734	0.107
	438-440,2010	1.033	0.159
	438-440,2011	0.681	0.181
	438-440,2012	1.034	0.195

Shannon-Wiener Species Diversity Index (H):

Table A3.5. Summary of ANOVA results.

Source	DF	Sum of Sq	F Ratio	P value
Elevation Band	2	2.015	2.254	0.111
Year	2	1.391	1.556	0.217
Elevation Band * Year	4	1.627	0.910	0.462

Table A3.6. Least squares means and standard errors for all levels.

Effect	Level	Least Sq Mean	Std Error
Elevation Band	434-436	1.533	0.139
	436-438	1.634	0.096
	438-440	1.334	0.140
Year	2010	1.296	0.120
	2011	1.653	0.126
	2012	1.552	0.134
Elevation Band * Year	434-436,2010	1.437	0.223
	434-436,2011	1.844	0.223
	434-436,2012	1.317	0.273
	436-438,2010	1.335	0.173
	436-438,2011	1.679	0.173
	436-438,2012	1.887	0.153
	438-440,2010	1.114	0.223
	438-440,2011	1.435	0.253
	438-440,2012	1.452	0.253

Table A3.7. Summary of ANOVA results for total cover and total height of selected VCTs by year, elevation band, distance from the dam, elevation band year interaction, and distance year interaction.

	AvgMaxHeight					Total Cover				
	Dist To Dam	Dist To Dam* Year	Elev Band	ElevBand * Year	Year	Dist To Dam	Dist To Dam* Year	Elev Band	Elev Band * Year	Year
VCT	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value
IN	0.944	0.997	0.689	0.856	0.997	0.602	0.903	0.953	0.807	0.903
PA	0.051	0.690	.	.	0.701	0.154	0.858	.	.	0.743
PC	0.264	0.612	0.014*	0.048*	0.028*	0.218	0.329	0.076	0.022*	0.036*
PE	0.297	0.211	0.885	.	0.243	0.118	0.408	0.928	.	0.339