Aberfeldie Redevelopment Project Water Use Plan

Riparian Vegetation Monitoring

Reference: ABFMON-5 Task 2C
Q9-9576 Aberfeldie Dam Station Fisheries Habitat Compensation Monitoring Project

Study Period: August 2011

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Executive Summary

The Aberfeldie Generating Station, a run-of-river hydroelectric facility, was upgraded in 2006. The potential loss of productive capacity associated with the increased diversion of flows, particularly during summer months, was identified as a concern (BC Hydro, 2006). Compensatory habitat was designed and constructed in 2008 and a five-year monitoring program - ABFMON #5 - was instituted. This newly created habitat required vegetation to restore disturbed areas and to provide shade for the channel to keep water temperatures cool and provide cover for fish. In addition to creating an ecologically stable native plant community, the re-vegetation work was to enhance slope stability thereby minimising sediment sources to the Bull River. The study area was stratified into two treatment units (TU) based on ecological differences: the berm (TU A) and the side channel area (TU B).

The grass and legume plant community seeded on the berm side exceeded 60% mean cover after the third growing season. Cover on the northern portion of the berm top will require supplemental seeding and fertilization for it to meet the target cover level of 60%. The vegetation on the berm has become competitive with planted seedlings for moisture and through mechanical damage (snow press).

Seeded grass and legume plant communities did not perform as well on the side channel. This is due to the large proportion of the TU that consists of steep, coarse textured materials that are dry ravelling. The side channel will not meet target revegetation objectives without additional intervention.

Third growing season seedling survival ranged from fair to excellent for all species except ponderosa pine which suffered 100% mortality in 2009. Cottonwood, paper birch, western larch and Saskatoon survival do not meet the target of 75%. Native chokecherry, cottonwood, birch, and aspen disturbed during construction activities continue to sprout from rhizomes, roots, and stems which will contribute to the diversity of the riparian plant community in the study area. Mortality is expected to continue for most species as indicated by the increase in seedlings in the poor condition class. The continued development of the seeded grass and legume plant community at TU A (berm) is having a negative impact on seedling condition and seedling survival.

Brush layers were constructed to improve side channel bank stability and to provide streamside vegetation to enhance the fisheries habitat. Only one of the modified brush layers that were investigated meets the recommended 70% effective length criteria. It is clear that some of the brush layers have failed while others were partially successful. The most significant issues include: poor selection of species for sill logs, inadequate staking of sill logs, use of stakes and cuttings that were too small in diameter, and stakes/cuttings planted too shallow.

Sedges are establishing along the side channel. Approximately 31% of the side channel had at least one plant per meter and three of the 20 sedge assessment sections met the suggested success criteria. Sedges are rhizomatous (Hauser 2006) and the numbers of plants are expected to increase over time making the planting successful.

The berm treatment unit (TU A) currently satisfies some of the structural integrity criteria. The berm is geologically stable. In addition, it is physically separated from the side channel and the Bull River and therefore should not contribute sediments to either water course. The seeded vegetation is developing well on the sides of the berm; the top of the berm will require additional treatments to promote target conditions. Survival of most of the planted species will not meet target conditions. Volunteers (i.e., plants

that were not planted) that are developing in response to project disturbances continue to grow and they will provide some of the long term habitat functions (nesting, perching, foraging) that may be considered components of structural integrity. A small “island” of native shrubs and trees could be planted to reduce the line of sight along the berm, increase species diversity, and provide a small patch of valuable wildlife habitat.

The side channel treatment unit (TU B) does not satisfy any of the structural integrity criteria and is unlikely to do so unless resloping treatments are applied. The sand and gravel substrate should be reasonably stable at approximately 30 degrees. Resloping would allow for the establishment of seeded grasses and legumes, planting of appropriate shrub species and use of live staking to establish willow, cottonwood and red-osier dogwood.

The Canada thistle and bull thistle populations have expanded such that repetitive mowing and/or herbicide treatment would be the best control method at this time. Aggressive treatments are required to have an impact on these species. As spotted knapweed, blueweed and sulphur cinquefoil are able to form monocultures over a few years, it is imperative that these species be eradicated immediately. Hand-pulling or digging during the spring and throughout the year when the soils are moist is recommended while species populations are low. Implementing these mechanical treatments multiple times throughout the year and from year to year will be required to control the spread and prevent seed dispersal. To prevent dispersal of common burdock burrs it is recommended that the plants be cut, bagged and disposed of properly. Due to its aggressive nature and without treatment, the cover of yellow hawkweed is expected to continue increasing and over time out-compete the preferred plant species. If controlling yellow hawkweed is desirable early spring treatment with Milestone (aminopyralid) will provide the best results. Treatment of invasive plant infestations located on BC Hydro land adjacent to the project area is also recommended to reduce the seed source and protecting the reclamation investment.

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Introduction

The Aberfeldie Generating Station is a run-of-river hydroelectric facility located on the Bull River in southeast British Columbia, Canada. In 2006, the facility was upgraded (equipment replacement) and the Aberfeldie Consultative and Fisheries Technical committees identified issues with the additional diversion flows and changes in operations associated with the redevelopment. In particular, the potential loss of productive capacity associated with the increased diversion of flows, particularly during summer months, was identified as a concern (BC Hydro, 2006).

Following consultation and review, a compensatory stream channel was designed and constructed in 2008 and located downstream of the Aberfeldie Generating Station on the north bank of the Bull River. In order to ensure the overall effectiveness of this habitat compensation project, a five-year monitoring program - ABFMON #5 - was instituted. The habitat compensation project constructed a protection berm, a series of four ponds linked by a small channel complemented with rock riffles, fish weirs, and coarse woody debris located throughout. This newly created habitat required vegetation not only to restore disturbed areas (e.g., berm) but also to provide shade for the channel to keep water temperatures cool and provide cover for fish. Following the physical construction, the area was re-vegetated with grasses, sedges, shrubs & trees, and various live staking and modified brush layers were added to complement the in-stream fish habitat work. In addition to creating an ecologically stable native plant community, the re-vegetation work was to enhance slope stability, thereby minimising sediment sources to the Bull River.

The main goal of the monitoring program is to assess whether the compensatory habitat fulfills the goal of no net loss of productive capacity after the Aberfeldie Dam redevelopment. The monitoring program described here - ABFMON #5 - will contribute to two larger management objectives, outlined in the Aberfeldie Effectiveness Monitoring Fish Habitat Works Terms of Reference (BC Hydro, 2008), which include:

1. Does the ecological productive capacity (e.g. plant survival, plant cover) realized in the constructed habitat, in combination with the productive capacity of the diversion reach at the 2 m^3/s summer minimum flow, achieve the Aberfeldie Redevelopment Project compensation goal of no-net-loss of productive capacity?

2. Is there a lower summer minimum instream flow discharge that, in combination with the productive capacity of the compensation habitat, could achieve the Aberfeldie Redevelopment project compensation goal of no-net-loss of productive capacity (BC Hydro 2008, p. 6)?

An additional goal for this monitoring program, although not one of the main objectives, is to provide information on fish usage and habitat quality in the constructed fish and aquatic habitat. The ABFMON #5 monitoring program includes the following tasks: primary and secondary productivity monitoring (TASK 2A), fish and fish habitat monitoring (TASK 2B), and riparian vegetation monitoring (TASK 2C). This report addresses TASK 2C, riparian vegetation monitoring, associated with the habitat compensation project. The results of the TASK 2C monitoring program will achieve the following specific objectives:

1. To monitor the development of seeded grass and legume plant communities (i.e. plant cover) and the survival of riparian vegetation planted at the compensation habitat site; and

2. To monitor the structural integrity of the compensation habitat.

The approach for the riparian vegetation monitoring component of ABFMON#5, TASK 2C consists of field surveys to evaluate survival and performance of riparian vegetation planted or seeded as part of the habitat compensation works. The vegetation surveys began in year 1 (2009) and will continue in years 2 (2010), 3 (2011) and 4 (2012). This report summarizes the vegetation monitoring work that has taken place over the first three years of this project.

Methods:

Study Area

The Aberfeldie Side Channel is located 500 m downstream of the Aberfeldie Generating Station, on the north side of the Bull River, approximately 35 kilometers east of Cranbrook in southeast British Columbia (Figure **1**). The study area includes a low gradient channel and a berm constructed of soil and parent materials that were removed during channel construction. The study area also includes a small area that was cleared to provide access to the site and that was reclaimed after construction activities were complete (see ABF Fish and Benthic Habitat Physical Works Design TOR, ABFMON #1).

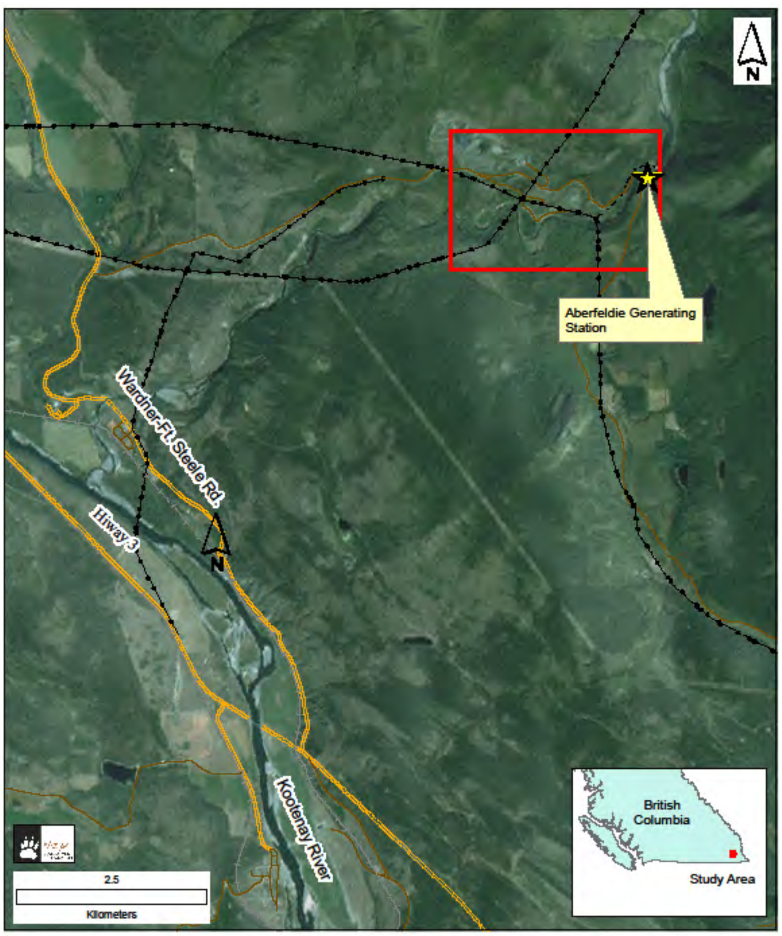


Figure 1. Overview of the study area location in south-eastern British Columbia.

Methodology

Study Site

The study area was stratified into two treatment units (TU; Figure 2): the berm (TU A) and the sides of the side channel (TU B). These treatment units were stratified to reflect ecological differences that included variation in slope, aspect, and proximity to a stream channel. These two TUs also received different restoration combinations (Table 1). TU A was further stratified for the purpose of monitoring the development of seeded agronomic grasses and legumes into Berm Side (BS; west-facing slope of the constructed berm) and Berm Top (BT; flat top of the constructed berm) and all other disturbances were combined. TU B was further stratified for the purpose of monitoring the development of seeded agronomic grasses and legumes into River Side (RS; westerly side of the channel) and Plant Side (PS; easterly side of the channel) to capture potential differences in seeding success.

Table 1. Revegetation treatments applied to the berm and side channel treatment units, Aberfeldie side channel study area.

Treatment Unit	Revegetation treatment type					
	Seeding and Fertilization	Tree and Shrub Planting		Bioengineering		Sedge Planting
		Scattered Individuals	Groups	Modified Brush Layers	Live Staking	
A- Berm	✓	✓	✓			
B - Side Channel	✓	✓		✓	✓	✓

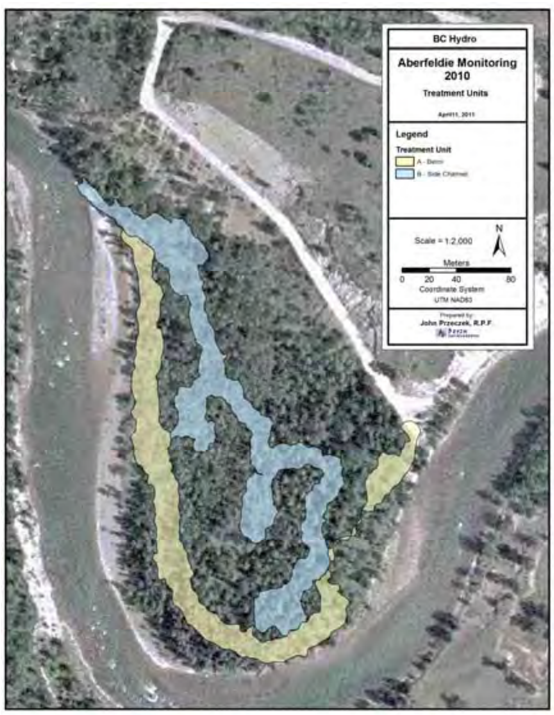


Figure 2. Treatment units identified at the Aberfeldie side channel study area (yellow=berm, TU A; blue=side channel, TU B).

Sampling Methodology

Permanent plots and transects were established both in TU A and TU B and marked during the first field season (2009). Please refer to the 2009 riparian vegetation monitoring report for details (Isaac & Przeczek 2010). Assessment of vegetation assessment transects, survival plots and lines, sedge planting, and bioengineering treatments occurred on August 23 and August 24, 2011. This was consistent with the timing of sampling in previous years to ensure that plant condition is similar among years.

Sampling methodologies were designed to determine if four specific treatments were successful:

1. Seeding agronomic grasses and legumes (Table 1, seeding and fertilization);
2. Planting native trees and shrubs (Table 1, tree and shrub planting);
3. Planting sedges (Table 1, sedge planting); and,
4. Bioengineering (Table 1, bioengineering).

The study also includes monitoring of invasive plants that may have been introduced to the habitat compensation site during the construction activity period. Invasive plant assessments were completed concurrent with other sampling activities.

Grass and Legume Seeding Success

Vegetative cover was assessed in TU A and TU B by placing 6 transects in each TU spaced every 3 metres. Five plots were located along each transect. In these plots, herbaceous plants were assessed using a 20 x 50 cm Daubenmire frame and woody species were assessed using a 1 x 2 m frame (Daubenmire 1959, Habitat Monitoring Committee, 1996). Data collected included species percent cover and distribution, percent cover of litter, bryophytes, and surface substrate (rocks, soil, wood and organic matter). Percent cover and distribution of shrubs and tree species were collected within the larger plots. Species identification was confirmed using reference materials by Douglas et al. (1998a, 1998b, 1998c, 1999, 2000, 2001a, 2001b, 2002) and Hitchcock and Cronquist (1973). Plants found in the general area of a transect, but not within plots, were recorded as additional species to provide a more complete picture of the plant community that is developing over time.

Three photos were taken of each transect: one vertical at 0 m, one overview from Start of Transect (SOT) and one overview from End of Transect (EOT); a meter pole was placed at 3 m. An additional photo was taken directly across the side channel from the EOT of each random side channel transect.

The target for plant cover is 60% of desirable species (Keefer, 2006).

Analyses

The purpose of this analysis was to assess differences in mean percent vegetative cover by area and between years. The four main areas – berm (Berm Top, Berm Side) and side channel (Plant Side, River Side) - were analysed separately due to ecological differences identified at the beginning of the study. Data analyses were conducted for the following groups: grass cover, forb cover, and total cover (grass + forb + shrub). Mean percent vegetative cover was calculated for each transect in all areas by year. That is, mean percent cover of grasses, forbs, and total cover (grass + forb + shrub) was calculated for each of the 12 transects from 2009-2011. We tested for differences in mean percent cover using a Two-Factor AVOVA (factors: year and location). Data transformations were not required.

Descriptive statistics were calculated for grass, forb, and total cover values for all TUs and years. Two-factor ANOVAs were constructed to test for differences in mean percent cover between years and location (Berm Top, etc.).

Tree and Shrub Seedling Survival

Eight shrub species were selected to be monitored over the length of the monitoring project (Isaac & Przeczek 2010). These species were chosen because they represented the largest proportion of the seedlings planted in the area and a minimum of five individuals for each species were located.

Plant survival was evaluated based on the ratio of live versus dead plants in the various plots relative to the original number of seedlings planted. The target seedling survival rate is 75% (Keefer 2006) and the target for seedling condition for successful planting was 60% (Keefer 2006) of the individual seedlings in each plot or line in condition class 2 or 3 (Table 2). Seedling condition class criteria were developed in the field prior to the 2009 assessment.

Table 2. Seedling survival success classes, Aberfeldie side channel study area.

Seedling Condition Class criteria			
Good (3)	**Fair (2)**	**Poor (1)**	**Dead (0)**
• good colour • good needle length • good leader extension • many, large buds • browsing light-none	• not good or poor	• chlorotic • etiolated • little or no leader growth • few or small buds • heavy browsing	• dead

Seedling Plots

Spruce (*Picea engelmannii* Parry ex Engelm.) and rose (*Rosa acicularis* Lindl.) were planted in clumps or groups on the top of the berm in sufficient numbers to allow for staked plots to be located to monitor survival. Circular 3.99 m radius plots (50 m^2) were established systematically until a minimum of 20 seedlings from each species was included within the plots. In 2010 each seedling location was mapped from the plot center (bearing and distance in meters) and seedlings were re-tagged and re-flagged. Four spruce plots and three rose plots were established on the top of the berm in 2009 (Isaac & Przeczek 2010).

Seedling Lines

Trees and shrubs were also planted on the berm in a random pattern, similar to seedlings along the side channel. Seedling survival was monitored using groups of 10 seedlings (where available) called survival lines due to the linear nature of the groups. Survival lines were established by tagging, numbering and flagging each seedling and georeferencing each seedling location in 2009 (Isaac & Przeczek 2010). Seedlings were reflagged and retagged in 2011 as required.

Analyses

We analysed tree and shrub survivorship using Wilcoxon's matched pairs test. We used this nonparametric test to assess survivorship from when plants were originally planted (2009 and 2011) and to assess how survivorship changed from last year (2010 and 2011).

Sedge Planting Success

In 2009, sedge (*Carex spp*.) planting success was assessed by stratifying the banks of the side channel into sections with similar numbers of living sedge plants per linear meter of bank length. Each section was reassessed in 2011 to maintain consistency over the monitoring project. Sedge survival success percent for the side channel was calculated for each sedge survival success class (Isaac & Przeczek 2010). There was no attempt to differentiate sedge condition classes because all living sedge plants had good colour and were growing vigorously. Sedge planting was considered successful if at least 60% of the bank length had at least one sedge plant and at least 40% of the bank had 2 sedge plants per linear meter.

Bioengineering Success

Live Staking

Live staking assessments in 2009 concluded that the treatment was not successful and that the lack of success would not compromise project objectives. Live staking was not assessed in 2010 or 2011.

Modified Brush Layers

Six modified brush layers were examined in detail to determine their potential to become established and contribute to side channel bank stability. Specific criteria evaluated included:

- sill log species
- sill log staking (includes presence/absence, size, and whether the stakes were still in place)
- brush layer length (start of sill log to end of sill log or first stake to last stake where sill logs were absent)
- number of cuttings in brush layer
- number of cuttings with leaves
- effective length (length in meters of a brush layer with live cuttings)

Modified brush layers were considered successful if the effective length[1] represents a minimum of 70% of the total length (Przeczek and Isaac, 2010).

Structural Integrity

One of the objectives of the project is to monitor the structural integrity of the compensation habitat. Structural integrity is a measure of the reliability of the structure to function as required (Pearson *et al.*, 2005). Furthermore, structural integrity refers to the ability of a structure to perform as it was intended to

[1] Effective length is defined as the total length that is occupied by living stakes with gaps that do not exceed 1.0 meter.

perform and function for as long as it is supposed to function. Structural elements are linked to the other objectives of this study, which include the development of an acceptable cover of seeded grasses and legumes, adequate survival of planted native trees and shrubs, successful establishment of planted sedge seedlings, successful establishment of bioengineering treatments, and the overall geological stability of constructed channel banks. Assessing structural integrity requires professional judgement based on the integration of the preceding components.

Invasive Plant Assessments

The Weed Control Act states: "Every occupier shall control, in accordance with the regulations, noxious weeds growing or located on land and premises, and on any other property located on land and premises, occupied by him." This means that private landowners, private companies, utility companies, regional districts and municipalities, and provincial government agencies or anyone in physical possession of land all have a responsibility to manage weeds in the Province[2]. An inventory of invasive plants was conducted by walking through the entire study area on August 23, 2011. Species, distribution, density and number of plants were recorded. The inventory was conducted by counting the number of plants or patches (for yellow hawkweed (*Hieracium spp.*) only) occurring in each of the two reclaimed areas (berm and side channel) and recording distribution (Table 3) and density codes (Table 4) according to protocols set out in the Invasive Alien Plant Program[3]. Options for the removal/eradication of the invasive species are discussed in Invasive Plant Assessments section of the Discussion.

Table 3. Distribution codes

Code	**Description**
1	Rare individual, a single occurrence
2	Few sporadically occurring individuals
3	Single patch or clump of a species
4	Several sporadically occurring individuals
5	A few patches or clumps of a species
6	Several well-spaced patches or clumps of a species
7	Continuous uniform occurrence of well-spaced individuals
8	Continuous occurrence of a species with a few gaps in the distribution
9	Continuous dense occurrence of a species

[2] The complete text of the Weed Control Act and Regulations can be accessed at: http://www.qp.gov.bc.ca/statreg/stat/W/96487_01.htm

[3] http://www.for.gov.bc.ca/hra/Plants/index.htm

Table 4. Density codes

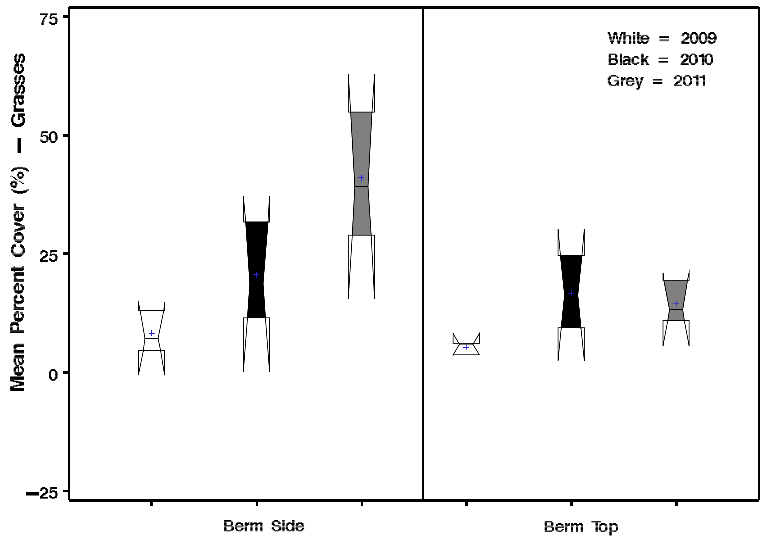
Code	Description	Reference
1	≤ 1 plant/m2	Low
2	2-5 plants/m2	Medium
3	6-10 plants/m2	High
4	> 10 plants/m2	Dense

Results

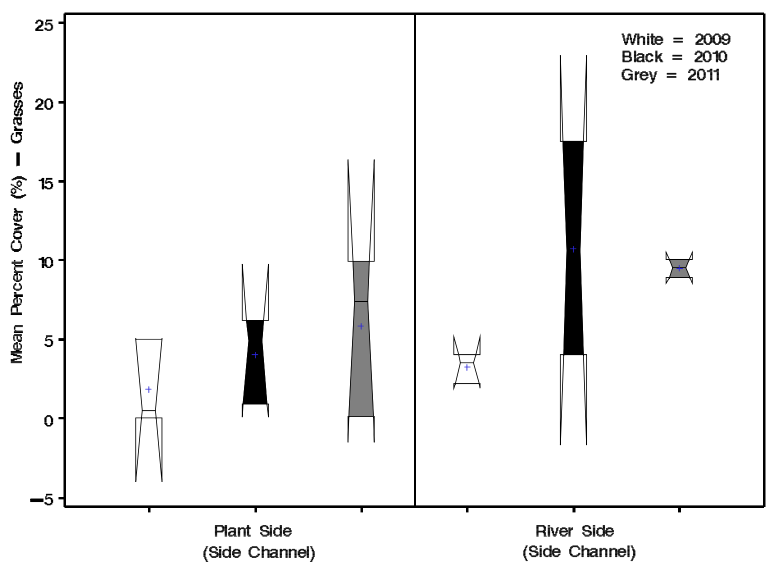
Percent Cover (Seeded Grasses and Forbs)

Grasses

Overall, the amount of grass cover varied with year and in different parts of the side channel (Figure 3, Table 5). The percent coverage of grass has steadily and significantly increased since the original planting in 2009 (mean % ± SE: 17.6% ± 2.2 in 2011 vs. 4.6% ± 0.6 in 2009). Grass coverage was greatest on the berm, particularly on the berm side (23.2% ± 2.9), whereas the coverage of grass in the side channel was considerably lower (plant side: 3.8% ± 0.9; river side: 7.8% ± 1.2).



a)



b)

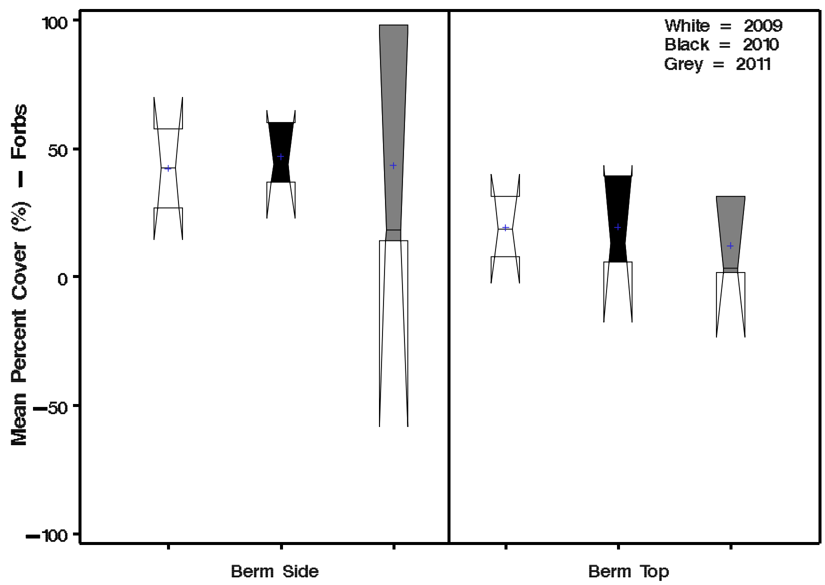
Figure 3. Box plot of mean percent cover (%) of grasses from 2009 to 2011in the two side channel sections a) side/top of berm and b) plant /river side of the side channel at the Aberfeldie side channel compensation project. Boxes represent 50% of the data. Medians are indicated by notches and the mean is indicated by '+'. Tails extend to minimum and maximum values. Note different vertical axis labels in b).

Table 5. Summary of changes in percent cover by year (2009-2011) and location (berm side, berm top, plant side, and river side of the side channel) for grasses, forbs, and total cover (grasses + forbs + shrubs) at the Aberfeldie side channel compensation project. Mean percent cover per transect for grasses, forbs, and grasses + forbs were used in this analysis. Interaction terms (i.e. YEAR*LOCATION) did not affect the analysis and were therefore removed for model simplification. Significant differences are indicated in bold.

Plant Type	**Location**	**F-value**	**p-value**
Grasses	Year	$F_{2,30}$ = 8.47	**0.0012**
	Location	$F_{3,30}$ = 10.13	**<0.0001**
Forbs	Year	$F_{2,30}$ = 0.09	0.9103
	Location	$F_{3,30}$ = 15.51	**<0.0001**
Total cover (grass + forb + shrub)	Year	$F_{2,30}$ = 2.32	0.1161
	Location	$F_{2,30}$ = 32.07	**<0.0001**

Forbs

Overall, the amount of forb cover across the two treatment areas has remained constant across all years of the vegetation monitoring project (mean % ± SE: 15.7% ± 2.7 in 2009 vs. 15.3% ± 3.9 in 2011; Figure 4,Table 5). However, there continues to be significant differences in forb coverage depending on the section of the habitat compensation project. Forb cover was significantly greatest on the berm side (44.4% ± 20.7) than the berm top (16.8% ± 3.0). Forb cover was significantly lower on both side channel locations (plant side: 1.2% ± 0.3; river side: 2.9% ± 0.6).



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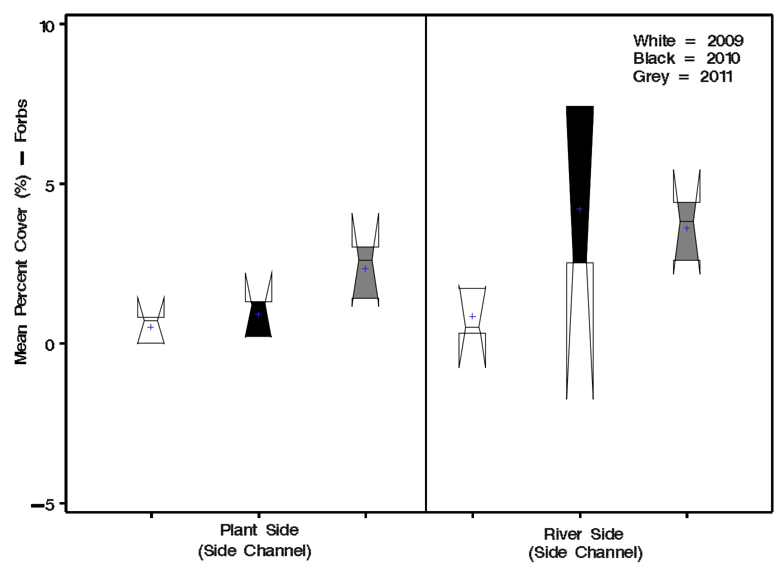


b)

Figure 4. Box plot of mean percent cover (%) of forbs from 2009 to 2011 in the two side channel sections a) side/top of berm and b) plant /river side of the side channel at the Aberfeldie side channel compensation project. Boxes represent 50% of the data. Medians are indicated by notches and the mean is indicated by '+'. Tails extend to minimum and maximum values. Note different vertical axis labels in b).

Total Cover

Overall, the amount of total vegetation cover has been holding constant between 20.9% ± 3.1 (since 2009 when the compensation project was initiated to 33.6% ± 5.0 in 2011 (Figure 5; Table 5).

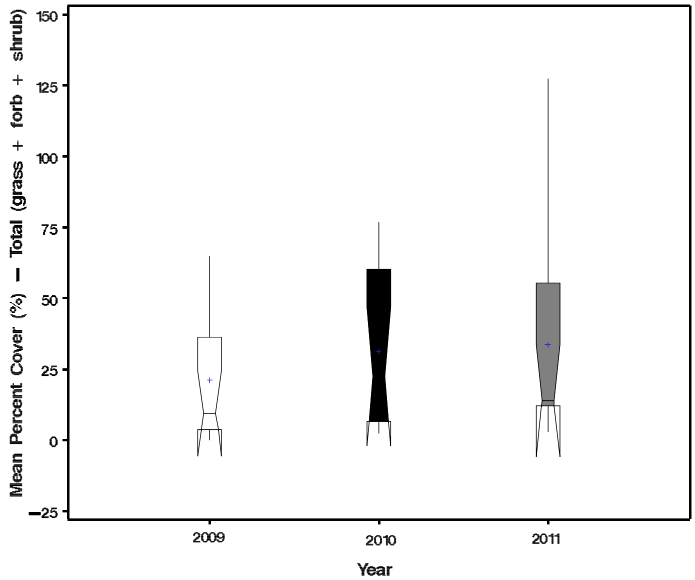


Figure 5. Box plot of mean total percent cover (%) for grass, forb & shrubs from 2009 to 2011 combined across all areas (berm and side channel) at the Aberfeldie side channel study area. Boxes represent 50% of the data. Medians are indicated by notches and the mean is indicated by '+'. Tails extend to minimum and maximum values.

Although total plant cover appears to have remained constant from 2009 to 2011, it depends on site location (Table 5). Total plant cover was significantly greater on the berm-side (mean ± SE: 85.5% ± 10.7) than on the berm top (27.2% ± 6.0; Figure 6). Total percent cover was significantly lower in the side channel, both on the plant (8.2% ± 1.6) and the river side (13.3% ± 1.83).

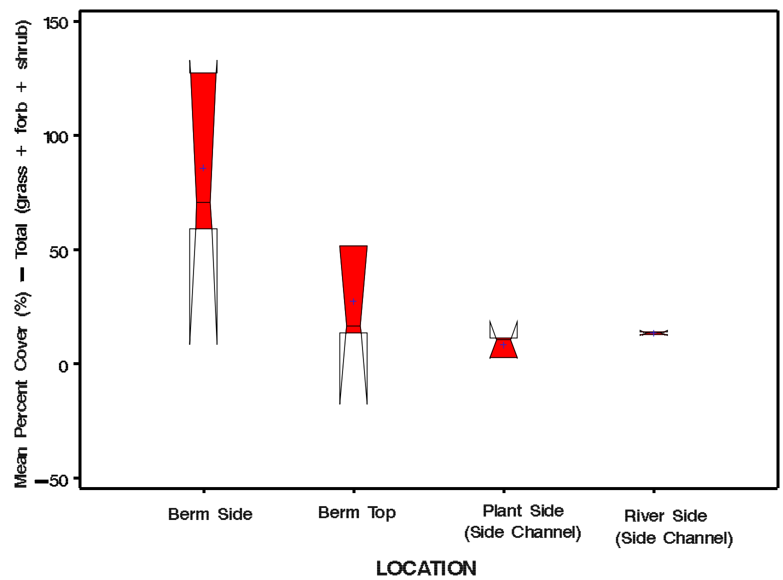


Figure 6. . Box plot of mean total percent cover (%) for grass, forb & shrubs at the berm (side/top) and side channel (plant/river side) areas in 2011 at the Aberfeldie side channel study area. Boxes represent 50% of the data. Medians are indicated by notches and the mean is indicated by '+'. Tails extend to minimum and maximum values.

Seeded vegetation at the two berm sites (berm top and berm side) germinated consistently. Vegetation on the berm side is growing well and has considerable coverage. On the other hand, it is unlikely that the berm top location will meet the standard of 60% cover (Plate 1 and Plate 2). Seeded vegetation at the two side channel sites (river side and power plant side) germinated inconsistently and mean total cover for each site will not meet the standard of 60% cover (Plate 3 and Plate 4). Vegetation cover at the two side channel sites continues to be very low and the likelihood of future plant establishment is low as long as slope instability continues to be an issue. Appendix 1 provides a summary of the vegetation data collected in 2009 - 2011.

Planted Tree and Shrub Seedling Survival

Seedling Survival

Although the most significant mortality occurred during the 2010 growing season, tree and shrub survivorship continued to decline in 2011, three growing seasons after planting (Table **6**). The target survivorship (75%) was not met for black cottonwood, paper birch, western larch, ponderosa pine and Saskatoon. Some species (e.g. black cottonwood, western larch) suffered immediate declines in survivorship (i.e. between 2009 and 2010) whereas other species (e.g. Engelmann spruce, Saskatoon, prickly rose) began declining in survivorship later (i.e. in 2011).

It was difficult to detect statistically significant shifts in survivorship between years due to small and unequal sample sizes. Prickly rose shrubs planted in lines were the only species where shrub survivorship significantly decreased in 2010 (Appendix 2).

Table 6. Summary of survivorship (live or dead) by shrub species and planting type (line vs. plot). Overall, survivorship declined in 2011 vs. 2010. Values represent percentage of the total number of individuals falling into each category.

Species	Code	Transect Type	Year	Live	Dead
Black Cottonwood	Ac AC	LINE	2009	90	10
			2010	50	50
			2011	50	50
Paper Birch	Ep EP	LINE	2009	100	0
			2010	100	0
			2011	60	40
Hawthorn (*Craetaegus chrysocarpa* Ashe)	HW	LINE	2009	100	0
			2010	85	15
			2011	85	15
Western Larch (*Larix occidentalis* Nutt.)	Lw LW	LINE	2009	70	30
			2010	50	50
			2011	50	50
Ponderosa Pine (*Pinus ponderosa* C. Lawson)	PP	LINE	2009	0	100
Prickly Rose	RA	LINE	2009	100	0
			2010	90	10
			2011	88	12
Prickly Rose	RA	PLOT	2009	100	0
			2010	100	0
			2011	96	4
Saskatoon (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem.)	SASK	LINE	2009	90	10
			2010	80	20
			2011	70	30
Engelmann Spruce	Sx SX	LINE	2009	100	0
			2010	94	6
			2011	90	10
Engelmann Spruce	Sx SX	PLOT	2009	100	0
			2010	91	9
			2011	82	18

Seedling Condition

There was a general decline in seedling condition in all species in 2011 (Table 7) from previous years. The condition target (60% of plants must fall in good and/or fair category) was only met for prickly rose in lines and plots and hawthorn and Engelmann spruce in lines.

Table 7. Summary of condition by shrub species and planting type. Overall, condition declined in 2011 vs. 2010. Values represent percentage of the total number of individuals falling into each condition class relative to original numbers planted..

Species	Code	Transect Type	Year	Dead	Poor	Fair	Good	G+F
Black Cottonwood	Ac AC	LINE	2009	10	10	40	40	80
			2010	50	10	20	20	40
			2011	50	20	20	10	30
Paper Birch	Ep EP	LINE	2009	0	0	40	60	100
			2010	0	40	40	20	60
			2011	40	40	20	0	20
Hawthorn	HW	LINE	2009	0	0	30	70	100
			2010	15	5	60	20	80
			2011	15	10	35	40	75
Western Larch	Lw LW	LINE	2009	30	0	0	70	70
			2010	50	0	50	0	50
			2011	50	10	40	0	40
Ponderosa Pine	PP	LINE	2009	100	0	0	0	0
Prickly Rose	RA	LINE	2009	0	0	4	96	100
			2010	10	2	52	36	88
			2011	12	20	30	38	68
Prickly Rose	RA	PLOT	2009	0	0	0	100	100
			2010	0	4	60	36	96
			2011	4	36	32	28	60
Saskatoon	SASK	LINE	2009	10	10	60	20	80
			2010	20	30	35	15	50
			2011	30	25	40	5	45
Engelmann Spruce	Sx SX	LINE	2009	0	0	22	78	100
			2010	6	10	70	14	84
			2011	10	20	56	14	70
Engelmann Spruce	Sx SX	PLOT	2009	0	0	9	91	100
			2010	9	4.5	82	4.5	86.5
			2011	18	64	13.5	4.5	18

Sedge Planting Success

There was a general decline in the proportion of sedge plants along the side channel (Table 8). Surviving plants were well established, had good colour and vigour, and many were producing seed heads. Three survival class sections meet the suggested 40% good + fair and 60% good + fair + poor success criteria (Table 9).

Table 8. Comparison of mean sedge success class percent between 2009 and 2011 at the Aberfeldie side channel study area.

	Mean Sedge Success Class %			
Year	Good (3)	Fair (2)	Poor (1)	None (0)
2009	46.9	17.3	15.0	21.0
2010	13.4	14.5	15.9	56.3
2011	13.3	7.7	10.2	68.9

Table 9. Percent of sedge section length in each sedge success class, Aberfeldie side channel study area.

Sedge Survival Section		Success Class %				
Start	End	Good (3)	Fair (2)	Poor (1)	None (0)	G+F
000	**001**	**39**	**26**	**21**	**14**	**65**
001	002	23	0	8	69	23
002	003	5	0	5	91	5
003	004	4	1	5	90	5
004	005	16	0	3	81	16
005	006	0	0	15	85	0
006	007	0	2	15	83	2
007	008	10	10	17	63	20
008	009	14	0	2	84	14
009	**010**	**30**	**39**	**11**	**19**	**69**
010	011	2	10	16	73	12
011	012	0	2	5	93	2
012	013	0	0	5	95	0
013	**014**	**78**	**0**	**3**	**19**	**78**
014	015	0	5	20	75	5
015	016	25	0	0	75	25
016	017	11	0	5	83	11
017	018	1	3	4	92	4
018	019	4	17	25	54	21
019	020	4	38	18	40	42
Average %		*13.3*	*7.7*	*10.2*	*68.9*	*21.0*

Notes: bolded Sedge Survival Sections meet the suggested minimum success criteria.
Sedge Survival Sections 020-021 and 021-000 were not assessed in 2011.

Bioengineering Success

Modified Brush Layers

Six modified brush layers, ranging from 4.4 to 17.9 meters in length (Table 10), were re-assessed to determine if they had established sufficiently to provide effective erosion control and become important components of the streamside riparian plant community. Modified brush layer 6 was the only one to meet the recommended minimum 70% effective length criterion. Brush layers 1, 6, 9, and 12 had fewer live cuttings in 2011 than in 2010.

Table 10. Selected brush layer assessment data, Aberfeldie side channel study area.

Assessment Year	Attribute	Brush Layer Number					
		1	4	6	9	12	16
2009	Length (m):	10.2	4.8	17.4	7.9	4.4	17.9
	Total Cuttings:	38	19	100	35	19	71
	Live cuttings (with leaves):	9	8	41	14	4	29
	% Live Cuttings:	23.7	42.1	41.0	40.0	21.1	40.8
2010	Live cuttings (with leaves):	4	1	22	6	4	6
	% Live Cuttings:	10.5	5.3	22	17.1	21.1	8.5
	Effective Length (m)	3.32	1.00	14.93	5.22	2.42	5.55
	% Effective Length	32.5	20.8	**85.8**	66.1	55.0	31.0
2011	Live cuttings (with leaves):	2	1	18	4	3	6
	% Live Cuttings:	5.3	5.3	18.0	11.4	15.8	8.5
	Effective Length (m)	2.00	1.00	13.74	3.80	2.42	5.49
	% Effective Length	19.6	20.8	**79**	48.1	55	30.7

Plate 5 includes views of some unsuccessful brush layers and Appendix 4 presents a summary of the modified brush layer assessments.

Invasive Plant Assessments

Invasive plants were concentrated along the river side of both the side channel and the berm; there has been a 90% increase in populations from 2010.

The bull thistle (BT, *Cirsium vulgare* (Savi) Ten.) population more than doubled, becoming the most common invasive plant observed with most plants scattered along the edge of the side channel and the river side of the berm. A number of patches have formed along the berm with densities ranging from 5-10 plants/m2. Canada thistle (*Cirsium arvense* (L.) Scop.) also increased substantially from 2 plants observed in 2010 to approximately 54 plants in 2011. Distribution was the same as bull thistle with the majority of plants found along the berm. A 67% increase in yellow hawkweed was observed with most plants invading the side-channel banks.

Occurrence of hound's-tongue (HT, *Cynoglossum officinale* L), common burdock (CB, *Arctium minus* L) and blueweed (BW, *Echium vulgare* L.) have remained constant (HT=75, CB=2, BW=2). Hound's-tongue was observed scattered throughout the reclaimed areas whereas common burdock and blueweed occur only along the berm.

Two new species were found in 2011. A single spotted knapweed plant (SK, *Centaurea biebersteinii* DC) was found on the river side of the berm. Seven sulphur cinquefoil plants (SC, *Potentilla recta* L) were also found with 5 plants found on the edge of the side-channel and 2 on the berm. These were sporadically distributed.

These species all pose a threat to the success of the reclamation project due to the lack of competitive vegetation, presence of exposed mineral soil, and presence of wind and wildlife that transport seed and disturb the soil. Potential control measures are reviewed in the Discussion section.

Discussion

The results of the TASK 2C monitoring program address the following objectives:

1. Monitor the development of seeded areas (grass & legumes) and the survival of riparian vegetation (trees & shrubs) planted at the compensation habitat site; and,
2. Monitor the structural integrity (bioengineering structures) of the compensation habitat.

In addition, the occurrence, density and distribution of invasive plants were also assessed.

Grass and Legume Seeding Success

The cover levels of the two berm sites were higher than those of the two side channel sites (Figure 6).

Berm TU (TU A)

Seeded vegetation on the side of the berm was distributed relatively evenly and after the second growing season the target objective of 60% cover is being met or exceeded. Vegetation on the top of the berm is growing adequately and the south end supports a larger forb component than the central and northern sections (Appendix 1). The top of the berm may meet the target cover objective by the end of the third growing season and supplemental seeding and fertilization treatments could be considered to improve the potential for success. The relatively aggressive plant community that is developing may create moisture competition and mechanical damage (snow press) issues for planted seedlings over the next two growing seasons.

Side Channel TU (TU B)

Side channel vegetation development is characterized by poor and patchy establishment and mean vegetative cover below 15%. The side channel has large areas with steep dry ravelling banks that will not support vegetation that meets target cover levels until the banks stabilize. The current unsatisfactory performance of the seeded grasses and legumes is expected to continue until slopes are modified to a profile that will support plant growth (Plate **5**)[4].

Planted Tree and Shrub Seedling Survival

The third growing season seedling survival ranged from fair to excellent for all species except ponderosa pine which suffered 100% mortality in 2009. Cottonwood, paper birch, western larch and Saskatoon do not meet the target of 75% survival. Native chokecherry, cottonwood, birch, and aspen disturbed during construction activities continue to sprout from rhizomes, roots, and stems which will contribute to the diversity of the riparian plant community in the study area.

Mortality is expected to continue for most species as indicated by the increase in seedlings in the poor condition class. The continued development of the seeded grass and legume plant community at TU A (berm) is having a negative impact on seedling condition and seedling survival. Reduced moisture availability for trees and shrubs, due to the well established grass/legume plant community, is probably the most important constraint on planting success.

[4] In coarse sandy materials a slope of approximately 30 degrees would be stable.

If the extended line of sight along the berm is a concern, a small planting project focussed on creating a mixed native shrub and tree species “island” could be considered. Site preparation would be required to reduce moisture competition from the established grasses and forbs. A section of the berm top where grass and legume establishment is not meeting target conditions would be the best location for this project. Planting a small island would reduce the line of sight along the berm and create a unique habitat that would be functional for shrub nesting bird species and it would provide hiding cover for ungulates.

Sedge Planting Success

Sedges are establishing along the side channel. Approximately 31% of the side channel had at least one plant per meter and three of the 20 sedge assessment sections assessed in 2011 met the suggested success criteria. Sedges are rhizomatous (Hauser 2006) and the numbers of plants are expected to increase over time making the planting successful.

Bioengineering Success

Modified Brush Layers

Only one of the assessed brush layers met the recommended criteria of at least 70% effective length. The poor performance of the modified brush layers was probably due to improper installation in 2009. Installation problems included poor choice of sill log species, inadequate staking of sill logs and shallow planting of cuttings for brush layers.

Structural Integrity

Berm Treatment Unit (TU A)

This treatment unit currently satisfies some of the criteria associated with assessing its structural integrity. The berm is geologically stable. It is physically separate from the side channel and the Bull River and therefore should not contribute sediments to either water course. The seeded vegetation is developing well (particularly on the sides of the berm). Survival of most of the planted seedlings is below target levels and moisture competition from seeded grasses and legumes has had a negative effect on seedling quality. Volunteers are developing in response to project disturbances and as they continue to grow they will provide some of the long term habitat functions (nesting, perching, foraging) that may be considered components of structural integrity. It is unlikely that poor survival of planted species will impact the long term structural integrity of this treatment unit.

Side Channel Treatment Unit (TU B)

This treatment does not satisfy any of the criteria associated with assessing its structural integrity and it is unlikely to do so unless resloping treatments are applied. The sand and gravel substrate should be reasonably geologically stable at approximately 30 degrees[5]. Resloping would allow establishment of seeded grasses and legumes, planting of appropriate shrub species and use of live staking to establish

[5] Arthon Construction Ltd. “Aggregates : ANGLE of REPOSE”. April 11 2009. http://www.arthon.com/library/angleofrepose.html

willow, cottonwood and red-osier dogwood. However, resloping treatments may introduce unacceptable amounts of sediment into the side channel with negative effects on the establishing invertebrate and fish populations.

Invasive Plant Assessments[6]

Blueweed, Canada thistle and hound's-tongue are on the BC list of most unwanted invasive species. Locally, however, the East Kootenay Invasive Plant Council (EKIPC) has listed blueweed and spotted knapweed as category 2[7] species, and common burdock, Canada thistle and sulphur cinquefoil as a category 3 species (EKIPC 2011).

Invasive plant populations have increased throughout the project area over the past year. There are several strategies that can be implemented to control the spread of invasive plants. The control method or combination of methods selected is dependent upon the goals and objectives and the weed species targeted therefore it is helpful to be familiar with each plant's characteristics (Table 11). Table 12 provides a summary of the strategies that we believe are best suited to the Aberfeldie side channel study area and Table 13 summarizes the various treatment options for each of the invasive species present on the Aberfeldie reclaim site.

Table 11. Reproductive characteristics of invasive plant species present in the Aberfeldie side channel study area.

Invasive Plant	Reproduction	Seed bank	Management Techniques
Bull thistle	4,000 seeds	Viable up to 3 years	Mowing, digging, herbicide
Canada thistle	1,500 seeds	Viable up to 3 years	Repeated mowing, intensive cultivation and herbicide
Common burdock	6,000 – 16,000 seeds	Unknown	Herbicide; prevent dispersal of burs
Hound's-tongue	2,000 – 4,000 seeds	Viable for 2 – 3 years	Herbicide; prevent seed production
Sulphur Cinquefoil	1,650 seeds	< 2 years	Prevent infestation; herbicide and hand-pulling.
Spotted Knapweed	400 – 25,000 seeds	Viable + 7 years	Herbicide, hand-pulling and bio-control; prevent seed dispersal and establishment of new infestations.
Yellow hawkweed	60-1,500 seeds, stolons and rhizomes	n/a	Herbicide

Bull thistle is a biennial and tends to invade over-grazed or otherwise disturbed pastures, rangeland, roadsides, and waste areas. Biennial thistles reproduce only from seed, so the key to a successful management program is to control the plants before flowering. Small infestations can be effectively hand-pulled or dug up. Chemical control on exotic thistles is most effective when plants are in the rosette stage and least effective when thistles are flowering. On severely disturbed sites, 2,4-D ester is most effective when applied 10-14 days before bolting of the flowering stems. Dicamba can be used earlier in the spring

[6] Information for this section was taken from: http://www.for.gov.bc.ca/hra/Plants/index.htm.

[7] The invasive plant categories reflect the risk of spread and threat to RDEK resources. They range from 1 (extremely invasive) to 4 (aggressive or under bio-control) (EKIPC 2011)

than 2,4-D. Picloram, alone or in combination with the other herbicides mentioned, gives the best late-season control, but is more expensive, cannot be used near groundwater or during certain seasons of the year, and presents a greater risk of damaging non-target species. Digging up small infestations is effective though labour-intensive. Mowing or cutting top-growth before seed-set will eliminate annual seed production and nuisance burrs.

Table 12. Weed control strategies suitable to the Aberfeldie side channel project area.

Strategy	**Advantages**	**Limitations**	**Comments**
Biological	Cost-effective on large infestations. Self-perpetuating. Self-dispersing. Long-term.	Takes time to establish. Does not eradicate weeds. Not effective in all habitats.	Includes a variety of different target insect species. Optimal where infestations are too extensive to be reduced effectively and economically by other treatment strategies
Mechanical	All types: applicable near water. Prevents seed production.	All types: Must repeat. Labour-intensive. Can be costly. **H**: creates soil disturbance. Root fragments may remain. Moist or loose soils required. **M**: roots remain, resprouting. Timing important.	Includes: hand-pulling/digging (**H**), mowing/cutting (**M**). Suitable for small infestations.
Herbicide	No soil disturbance. Kills whole plant. Residual herbicides will affect seed bank and emerging plants.	Soil and water limitations. Long-term costs. Can affect non-target vegetation.	It is important to choose the appropriate herbicide that targets the invasive plant of interest. The location (e.g. proximity to water) and longevity (e.g. long lasting in soil) will also affect herbicide choice. Effective application should be completed at the appropriate growth stage. Use the right herbicide on the right location at the right stage of growth.

Table 13. Treatment options for invasive plant species on the Aberfeldie side channel study area.

Invasive Plant	Treatment Options*	Preferred Treatment Option and Rationale
Bull thistle	Herb Mech Bio	Rosette stage or after mowing To prevent seed production Use on large sites
Canada thistle	Herb Mech	Integrate a combination of management tools to deplete the aggressive creeping root system
Common burdock	Herb Mech	Cost-effective To prevent seed production
Hound's-tongue	Herb Mech Bio	Cost-effective To prevent seed production Use on large sites
Sulphur Cinquefoil	Herb HP	Ensure control To prevent seed production
Spotted Knapweed	Herb HP Mow	Cost-effective Small sites in remote areas To prevent seed production
Yellow hawkweed	Herb IPM	Cost-effective on large sites Reduce grazing pressure

* Herb – herbicide, Mech – mechanical, Bio – biological control, IPM – Integrated Pest Management

Canada thistle is a colony-forming perennial that develops from deep and extensive roots. Herbicides should be applied either when plants are in the bud stage or to re-growth in the fall. At the bud stage, leaf area for herbicide coverage and absorption is maximized, and root reserves are at their lowest. In the fall, translocation of the herbicide to the roots is the greatest. Aminopyralid (Milestone®), clopyralid (Transline®), and Picloram (Tordon 22K®) provide similar suppression of Canada thistle. For light infestations, pulling or hand-cutting can be effective if done several times each season to starve underground roots and stems. Mowing in late June when root reserves are lowest may result in the greatest reduction of the weed.

Hound's-tongue tends to be a nuisance weed rather than a noxious plant unless infestations grow to become large patches. The burrs often become imbedded in the hair, eye or eyelids of animals. They can be problematic for hikers, hunters and fishermen, and also to their pets. Hound's-tongue contains alkaloids that are especially toxic to cattle and horses. Within the study area hound's-tongue has not reached the noxious stage. In general, spring application of herbicide provides consistently better control of hound's-tongue than fall treatments. First-year hound's-tongue rosettes are controlled easily with 2,4-D. Picloram, dicamba, and metsulfuron. Herbicide treatment should be restricted to rosettes and bolting plants should be pulled and disposed of. Mowing before flowering will prevent seed production. Hand-pulling of small infestations is very effective but in harder soils the root will break off, resulting in re-sprouting. A better approach is to sever the root below ground level by tilling which should inhibit re-sprouting. Biocontrol using the root weevil, *Mogulones cruciger*, is very effective on large infestations (Table 14).

Table 14. Recommended biocontrol agents.

Biocontrol Agent	Invasive Plant Species	Mode of Action	Release Timing
Mogulones cruciger Herbst.	Hound's-tongue	Reduces plant vigour through damage to the root and stem.	May-June

Sulphur cinquefoil reproduces by seed and rootstocks forming colonies on both disturbed and un-disturbed sites with plants living up to 20 years. This species is unpalatable and is a very competitive pioneer species that can dominate sites displacing native vegetation. Small infestations can be managed by digging. Once a colony is established early spring or fall treatment (after green-up) with Picloram, clopyralid, or 2,4-D is effective in controlling or eradication this noxious weed.

Spotted knapweed is a short-lived perennial (3-9 years) that invades and rapidly colonizes disturbed areas in low- to mid-elevation grasslands and open forests. It may spread into adjacent undisturbed sites. Spotted knapweed reproduces by seed that germinate in spring or fall. Dormant seeds remain viable for over 8 years. Hand-pulling can be effective in controlling small infestation of spotted knapweed however follow-up treatments will be required to deplete the seed bank. Clopyralid and aminopyralid are the most effective herbicides for spotted knapweed control, having soil residual activity that provides extended control of germination.

Yellow hawkweed is a creeping perennial that spreads by stolons and rhizomes creating colonies. Yellow hawkweed is not on the BC weed list, however in the United States it is a classified weed and control is mandatory. The invasiveness of the introduced species of hawkweed (14 in BC) is evident along road sides and on pasture lands in BC. Spring treatment with Picloram, combinations of Picloram plus 2,4-D or aminopyralid can be effective in controlling the hawkweed; 2,4-D alone is inadequate. Cultural and mechanical methods are usually ineffective as the smallest segment of remaining root can develop into a new plant.

The Canada thistle and bull thistle populations have expanded such that repetitive mowing and/or herbicide treatment would be the best control methods at this time. Aggressive treatments are required to have an impact on these species. As spotted knapweed, blueweed and sulphur cinquefoil are able to form monocultures over a few years, it is imperative that these species be eradicated immediately. Hand-pulling or digging during the spring and throughout the year when the soils are moist is recommended while species populations are low. Implementing these mechanical treatments multiple times throughout the year and from year to year will be required to control the spread and prevent seed dispersal. To prevent dispersal of common burdock burrs it is recommended that the plants be cut, bagged and disposed of properly. Due to its aggressive nature and without treatment, the cover of yellow hawkweed is expected to continue increasing and over time out-compete the preferred plant species. If controlling yellow hawkweed is desirable early spring treatment with Milestone (aminopyralid) will provide the best results. Treatment of invasive plant infestations located on BC Hydro land adjacent to the project area is also recommended to reduce the seed source and protecting the reclamation investment.

The population of bull thistle, Canada thistle and sulphur cinquefoil have expanded such that the present inventory methodology is no longer efficient. Using the Provincial methodology the entire project area would be considered a single invasive plant site as there is less than 100m between any given invasive plant. It may be possible to GPS the larger infestations to create mapable polygons. Some research will be necessary in order to devise a methodology that would capture a clear picture of the invasive plant population within the study area.

Recommendations

1. Seedlings were planted without regard for relocation, total numbers available for assessment, or potential for replication in an experimental design. Consider designing and laying out survival assessment plots that would allow for more effective statistical analysis of seedling survival for each species.
2. Consider planting a small native tree and shrub island on a section of the berm top (TU A) that is not currently meeting target revegetation conditions. This will improve species diversity, provide additional wildlife habitat, and reduce the line of sight along the berm.
3. Consider supplemental seeding and fertilizing of the portion of the berm top TU that is not achieving 60% cover in the spring of 2012 and 2013. This may provide the boost required to meet the target vegetation cover of 60%. The additional nutrients are not expected to affect either the side channel or the Bull River. Additional site preparation may be required to provide sufficient acceptable seedbed for improving the cover of seeded grasses and forbs.
4. The current physical configuration of the side channel treatment unit (TU B) will not promote achieving revegetation and structural integrity objectives for the project. Consider resloping and revegetating the side channel to promote revegetation success.
5. Hand-pulling and digging spotted knapweed, blueweed, sulphur cinquefoil and common burdock plants during the spring and throughout the year when the soil is moist is highly recommended to eradicate these species.
6. Repetitive mowing and/or herbicide treatment is recommended to control further spread of Canada thistle and bull thistle.
7. If controlling yellow hawkweed is desirable, early spring treatment with Milestone (aminopyralid) will provide the best results.
8. Treatment of invasive plant infestations located on BC Hydro land adjacent to the project area is also recommended to reduce the seed source and protect the reclamation investment. Treatments would be the adjacent land owner’s responsibility and dialogue between them and BC Hydro would be required
9. Consider developing an appropriate invasive plant inventory methodology for the study area.

Literature Cited

BC Hydro. 2006. *Aberfeldie Redevelopment Project Water Use Plan, Revised for Acceptance by the Comptroller of Water Rights.*

BC Hydro. 2008. *Aberfeldie Project Water Use Plan, Monitoring Program Terms of Reference. ABFMON 5 - Effectiveness Monitoring Fish Habitat Works.*

Daubenmire, R. 1959. *A canopy-coverage method of vegetational analysis*. Northwest Science, 33:43-64.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 1998a. *Illustrated Flora of British Columbia, Vol. 1 Gymnosperms and Dicotyledons (Aceraceae through Asteraceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 1998b. *Illustrated Flora of British Columbia, Vol. 2 Dicotyledons (Balsaminaceae* through *Custutaceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 1998c. *Illustrated Flora of British Columbia, Vol. 3 Dicotyledons (Diapensiaceae* through *Onagraceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 1999. *Illustrated Flora of British Columbia, Vol. 4 Dicotyledons (Orobanchaceae* through *Rubiaceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 2000. *Illustrated Flora of British Columbia, Vol. 5 Dicotyledons (Salicaceae* through *Zygophyllaceae) and Pteridophytes*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 2001a. *Illustrated Flora of British Columbia, Vol. 6 Monoctyledons (Acoraceae* through *Najadaceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 2001b. *Illustrated Flora of British Columbia, Vol. 7 Monocotyledons (Orchidaceae through Zosteraceae)*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

Douglas, George W., Gerald B. Straley, Del Medinger and Jim Pojar. 2002. *Illustrated Flora of British Columbia, Vol. 8 General Summary, Maps and Keys*. Ministry of Forests and Ministry of Environment, Lands and Parks, Province of British Columbia, Victoria, BC.

East Kootenay Invasive Plant Council. 2011. *2011- 2012 Regional strategic plan*. East Kootenay Invasive Plant Council, Cranbrook, BC. 52 p.

Habitat Monitoring Committee. 1996. *Procedures for environmental monitoring in range and wildlife habitat management*. Version 5. B.C. Ministry of Environment, Lands, and Parks and B.C. Ministry of Forests. Victoria, B.C. 225 pp.

Hauser, A. Scott. 2006. *Carex aquatilis*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2010, April 19].

Hitchcock, C.L. and A. Cronquist. 1973. *Flora of the Pacific Northwest.* University of Washington Press. Seattle. 730p.

Isaac, Leigh Anne and John Przeczek. 2010. *Riparian vegetation monitoring: Aberfeldie Dam Station fisheries habitat compensation monitoring project*. Consultants report. BC Hydro31 pp + append.

Keefer, M. 2006. *Aberfeldie Revegetation Design, Seed Collection Proposal*. Draft Report. BC Hydro.

Pearson, M.P., J.T. Quigley, D.J. Harper, and R.V. Galbraith. 2005. *Monitoring and assessment of fish habitat compensation and stewardship projects: study design, methodology and example case studies*. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2729, Oceans, Habitat and Enhancement Branch, Fisheries and Oceans Canada, Vancouver, BC.

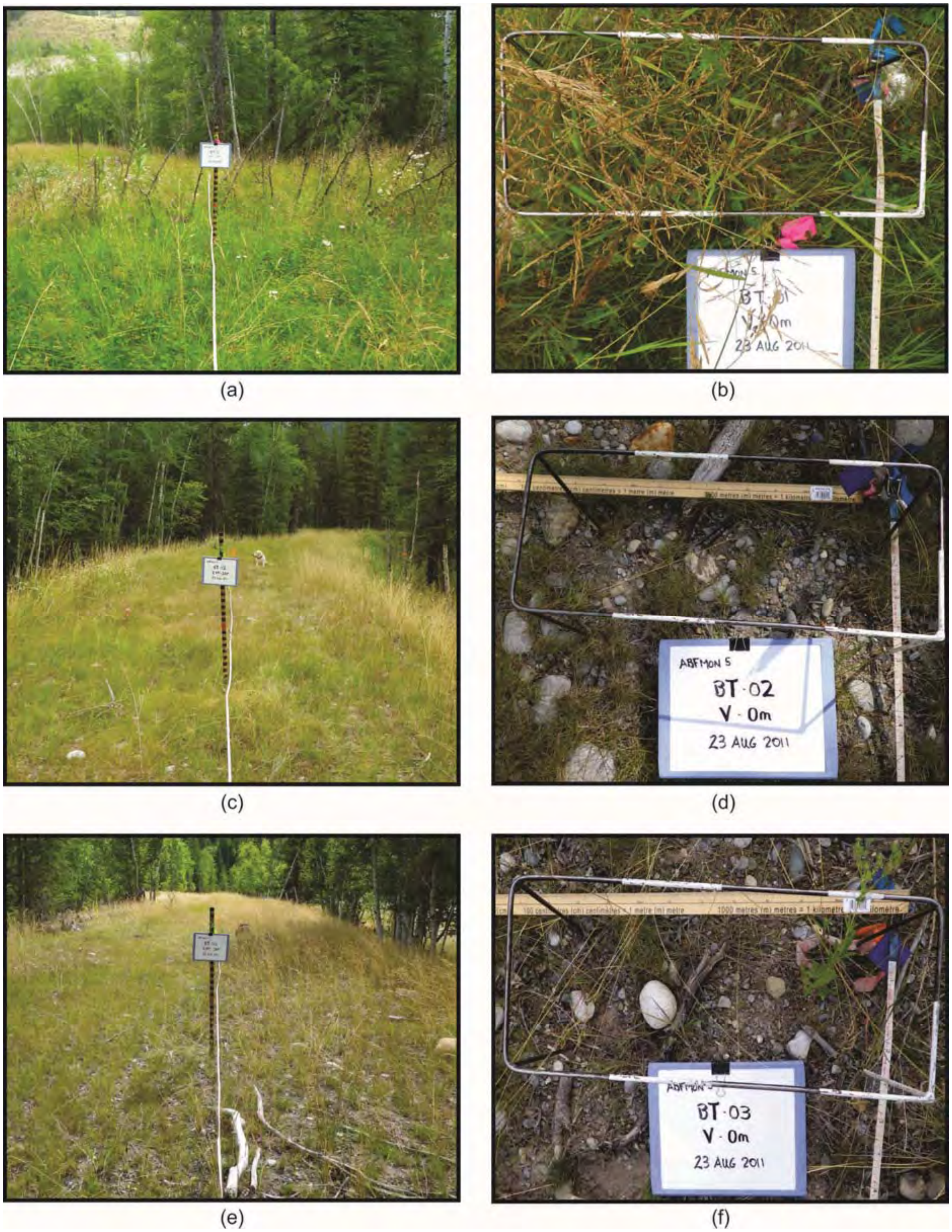


Plate 1. Various views of the three permanent vegetation monitoring transects on top of the berm: (a) BT01 from SOT to EOT, (b) BT01 at 0 meters, (c) BT02 from EOT to SOT, (d) BT02 at 0 meters, and (e) BT03 from EOT to SOT, (f) BT03 at 0 meters.

Plate 2. Various views of three permanent vegetation monitoring transects on the side of the berm: (a) BS01 from EOT to SOT, (b) BS01 at 0 meters, (c) BS02 from EOT to SOT, (d) BS02 at 0 meters, (e) BS03 from EOT to SOT, and (f) BS03 at 0 meters.

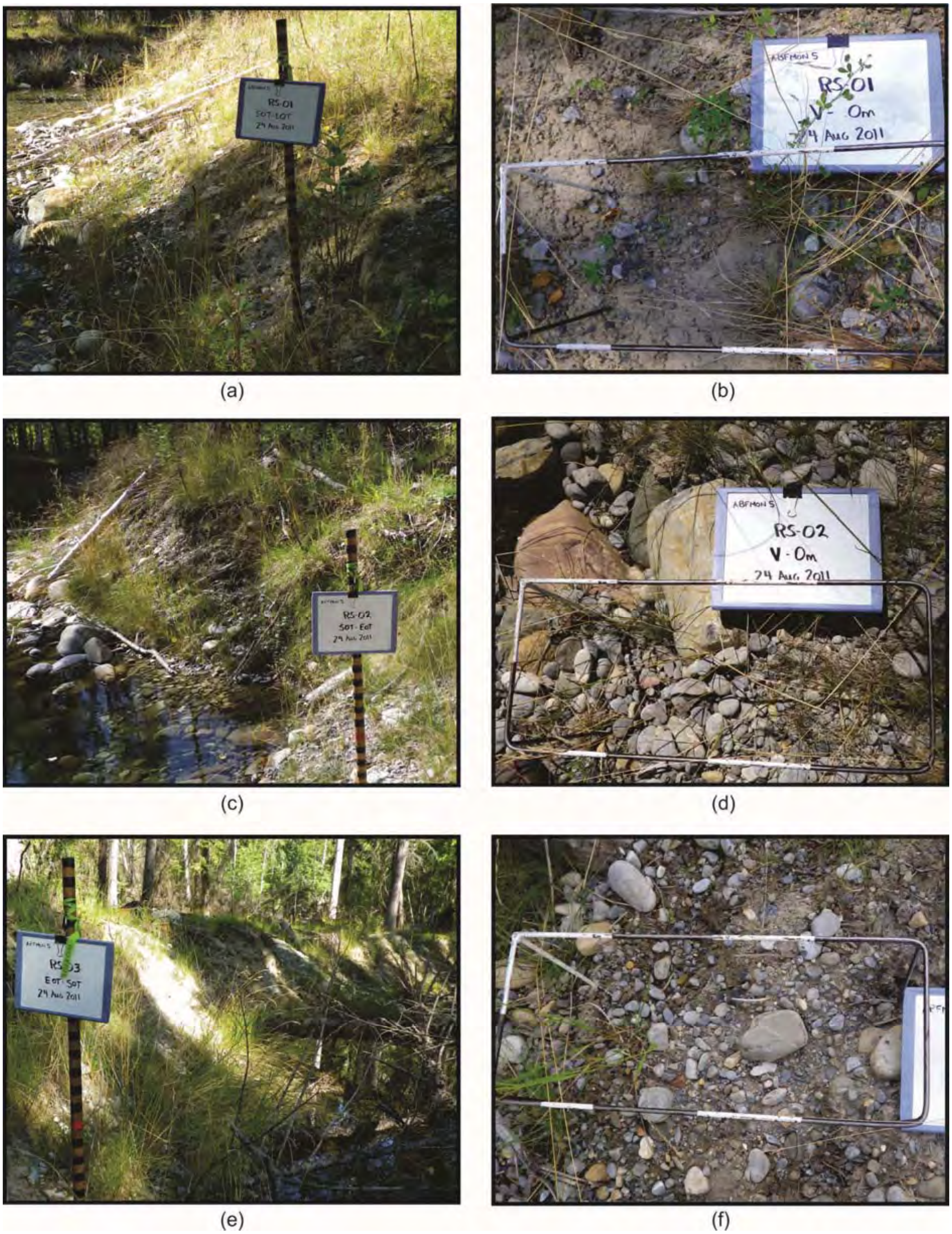


Plate 3. Various views of three temporary vegetation monitoring transects on the river side of the side channel: (a) RS01 from SOT to EOT, (b) RS01 at 0 meters, (c) RS02 from SOT to EOT, (d) RS02 at 0 meters, (e) RS03 from EOT to SOT, and (f) RS03 at 0 meters.

Plate 4. Various views of three temporary vegetation monitoring transects on the power plant side of the side channel: (a) PS01 from SOT to EOT, (b) PS01 at 0 meters, (c) PS02 from SOT to EOT, (d) PS02 at 0 meters, (e) PS03 from SOT to EOT, and (f) PS03 at 0 meters.

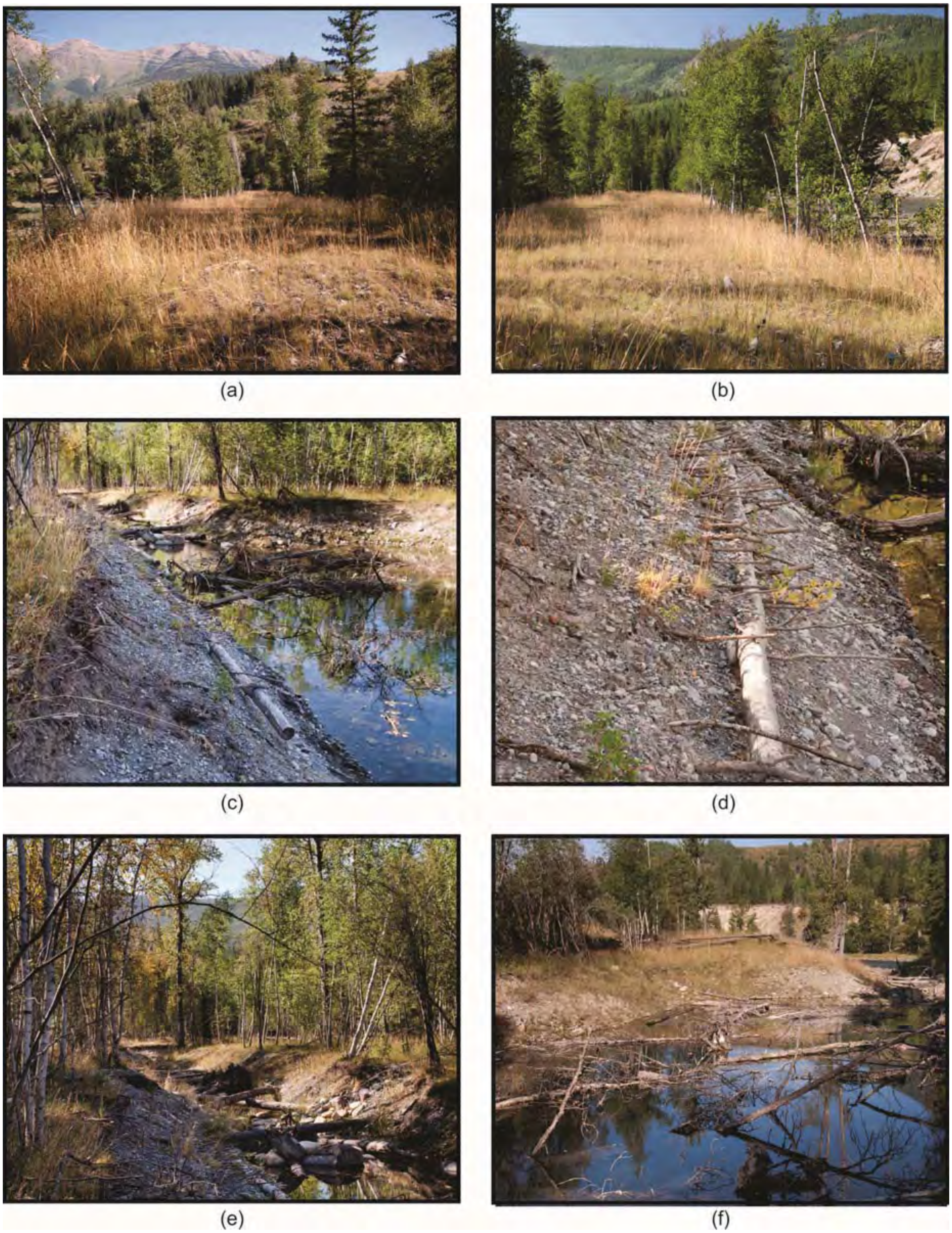


Plate 5. Selected photographs showing: (a) overview of the berm looking north, (b) overview of the berm looking south, (c) unsuccessful modified brush layer on a steep dry ravelling slope in TU B (side channel), (d) unsuccessful modified brush layer, (e) overview of the side channel, and (f) overview of the mouth of the side channel.

Appendix 1. Vegetation Data

Summary transect information by year and species group

	Berm Side			
2009	**BS-01**	**BS-02**	**BS-03**	**Mean**
Forb	57.4	42.2	26.8	42.1
Grass	4.5	13	7	8.2
Shrub	2.6	2.7	1.3	2.2
Total	**64.5**	**57.9**	**35.1**	**52.5**
2010				
Forb	60.0	43.6	36.9	46.8
Grass	11.4	31.7	18.6	20.6
Shrub	2.1	1.3	0.9	1.4
Total	**73.5**	**76.6**	**56.4**	**68.8**
2011				
Forb	98.1	14.0	18.0	43.4
Grass	28.8	54.8	39.1	40.9
Shrub	0.3	47.5	1.9	16.6
Total	**127.2**	**116.3**	**59.0**	**100.8**

	Berm Top			
2009	**BT-01**	**BT-02**	**BT-03**	**Mean**
Forb	31.2	7.9	18.6	19.2
Grass	6.1	3.7	5.9	5.2
Shrub	0.2	1.0	0.0	0.4
Total	**37.5**	**12.6**	**24.5**	**24.9**
2010				
Forb	39.3	5.7	12.8	19.3
Grass	24.5	16.2	9.3	16.7
Shrub	0.2	0.4	0.3	0.3
Total	**64.0**	**22.3**	**22.4**	**36.2**
2011				
Forb	31.2	1.0	3.7	12.0
Grass	27.6	18.3	13.2	19.7
Shrub	0.8	0.5	0.2	0.5
Total	**59.6**	**20.4**	**17.1**	**32.4**

	Side Channel Plant Side			
2009	**PS-01**	**PS-02**	**PS-03**	**Mean**
Forb	0.7	0.8	0	0.5
Grass	0.5	5	0	1.8
Shrub	0.0	0.0	0.0	0.0
Total	**1.2**	**5.8**	**0**	**2.3**
2010				
Forb	1.3	0.2	1.2	0.9
Grass	0.9	6.2	4.9	4
Shrub	0.1	0.0	0.0	0.0
Total	**2.3**	**6.4**	**6.1**	**4.9**
2011				
Forb	3.0	2.6	1.4	2.3
Grass	7.4	0.1	9.9	5.8
Shrub	0.0	0.2	0.0	0.1
Total	**10.4**	**2.9**	**11.3**	**8.2**

	Side Channel River Side			
2009	**RS-01**	**RS-02**	**RS-03**	**Mean**
Forb	0.5	0.3	1.7	0.8
Grass	2.2	4	3.5	3.2
Shrub	0.0	0.0	0.0	0.0
Total	**2.7**	**4.3**	**5.2**	**4.1**
2010				
Forb	2.7	7.4	2.5	4.2
Grass	10.6	17.5	4	10.7
Shrub	0.0	0.0	0.1	0.0
Total	**13.3**	**24.9**	**6.6**	**14.9**
2011				
Forb	4.4	2.6	3.8	3.6
Grass	8.9	18.5	9.5	12.3
Shrub	0.6	0.1	0.1	0.3
Total	**13.9**	**21.2**	**13.4**	**16.2**

Appendix 2. Seedling Survival Data

2011 seedling count by condition class

Code	Transect Type	Year	Live	Dead	Fair	Good	Poor	Grand Total
Ac	LINE	2011	5	5	2	1	2	10
Ep	LINE	2011	3	2	1		2	5
HW	LINE	2011	17	3	7	8	2	20
Lw	LINE	2011	5	5	4	0	1	10
Pp	LINE	2009	0	10	0	0	0	10
Ra	LINE	2011	44	6	15	19	10	50
Ra	PLOT	2011	27	1	9	8	10	28
SASK	LINE	2011	14	6	8	1	5	20
Sx	LINE	2011	45	5	28	7	10	50
Sx	PLOT	2011	18	4	3	1	14	22

Note: shaded rows show species that are below the target minimum of 75% survival.

2011 VS. 2009

Species	Planting Type	z-score	p-value	General trend
Black Cottonwood	Line	1.85	0.06	Survivorship in 2011<2009.
Paper Birch	Line	1.35	0.18	Survivorship in 2011<2009.
Hawthorn	Line	1.75	0.08	Survivorship in 2011<2009.
Western Larch	Line	0.85	0.4	Survivorship in 2011<2009.
Saskatoon	Line	1.54	0.12	Survivorship in 2011<2009.
Engelmann spruce	Line	2.02	**0.04**	Survivorship in 2011 is significantly less than survivorship in 2009.
Engelmann spruce	Plot	2.05	**0.04**	Survivorship in 2011 is significantly less than survivorship in 2009.
Prickly rose	Line	2.51	**0.01**	Survivorship in 2011 is significantly less than survivorship in 2009.
Prickly rose	Plot	0	1.0	Survivorship in 2011 is marginally less than survivorship in 2009.

2011 VS. 2010

Species	Planting Type	z-score	p-value	General trend
Black Cottonwood	Line	0	1	Survivorship was equal between years.
Paper Birch	Line	1.35	0.18	Survivorship in 2011<2010.
Hawthorn	Line	0	1	Survivorship was equal between years.
Western Larch	Line	0	1	Survivorship was equal between years.
Saskatoon	Line	0.70	0.48	Survivorship in 2011<2010.
Engelmann spruce	Line	0.38	0.70	Survivorship in 2011<2010.
Engelmann spruce	Plot	0.85	0.40	Survivorship in 2011beginning to decline and was <2010.
Prickly rose	Line	0.31	0.76	Survivorship in 2011 beginning to decline and was < 2010.
Prickly rose	Plot	0.96	0.34	Survivorship in 2011<2010.

Appendix 3. Sedge Data

Sedge Survival Section		**Success Class (est. meters)**			
Start	End	Good (3)	Fair (2)	Poor (1)	None (0)
000	001	22	15	12	8
001	002	3	0	1	9
002	003	2	0	2	40
003	004	3	1	4	71
004	005	5	0	1	25
005	006	0	0	3	17
006	007	0	1	7	38
007	008	5	5	8	30
008	009	7	0	1	42
009	010	30	39	11	19
010	011	2	12	19	89
011	012	0	1	3	52
012	013	0	0	1	20
013	014	29	0	1	7
014	015	0	1	4	15
015	016	4	0	0	12
016	017	15	0	7	110
017	018	1	2	3	72
018	019	1	4	6	13
019	020	2	21	10	22

Appendix 4. Bioengineering Data

2009

Brush Layer Number:	**1**	**4**	**6**
Sill Log Species:	Lw	Ac (old, decaying)	Ac (old, dead), Ep
Sill Log Staked:	no	yes (undersized stakes)	partially
Length (m):	10.2	4.8	17.4
Total Layer Cuttings:	38	19	100
Cuttings with Leaves:	9	8	41
% Live Cuttings:	23.7	42.1	41.0
Comments:	cuttings too shallow many small diameter cuttings poor sill log choice	sill logs stakes too small cuttings too small too far up the bank poor sill log choice	some stakes too shallow right on river, good location poor sill log choice

Brush Layer Number:	**9**	**12**	**16**
Sill Log Species:	Ac (old, dead), Sx	Ep	Ac (sprouting)
Sill Log Staked:	partially (inadequately)	yes (50%), no (50%)	no (failed or failing)
Length (m):	7.9	4.4	17.9
Total Layer Cuttings:	35	19	71
Cuttings with Leaves:	14	4	29
% Live Cuttings:	40.0	21.1	40.8
Comments:	sill logs stakes too small cuttings too small poor sill log choice	some stakes too shallow cuttings too small poor sill log choice	some stakes too shallow cuttings too small Ac sill log looks good if it holds

2010

Live Stem Quality					
Brush Layer	Good	Fair	Poor	2010 Total	2010 % Live Cuttings
1	2	1	1	4	10.5
4		1		1	5.3
6	17	5		22	22
9	5	1		6	17.1
12	4			4	21.1
16	5	1		6	8.5

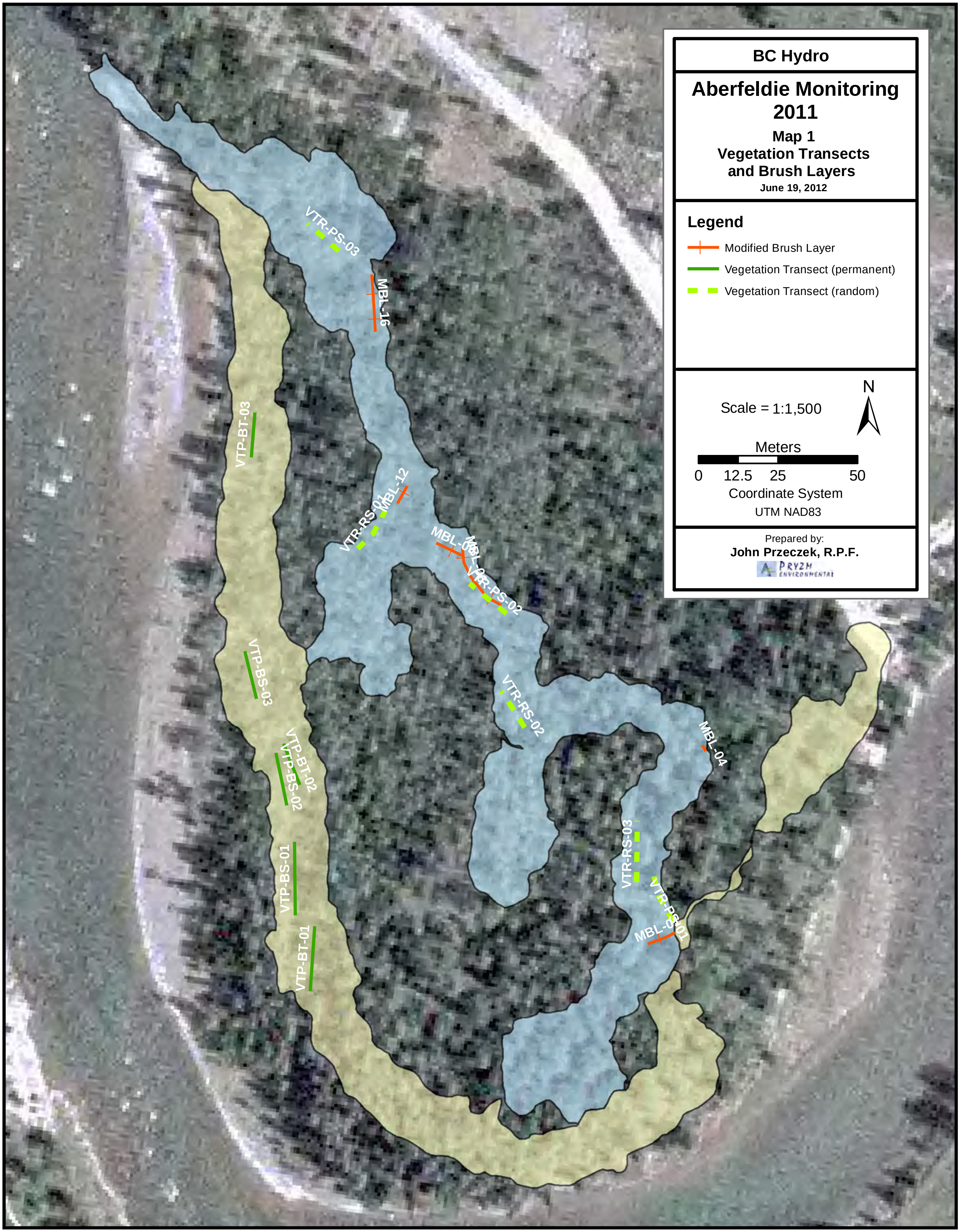
Effective Length								
Brush Layer	Isolated Cuttings (count)	1	2	3	4	Total Effective Length (m)	2009 Brush Layer Length (m)	% Effective
1	1	2.32				2.82	10.2	27.6
4	1					0.5	4.8	10.4
6		2.99	6.34	2.88	2.72	14.93	17.4	85.8
9	2	3.22				4.22	7.9	53.4
12		1	1.42			2.42	4.4	55
16	4	1.55				3.55	17.9	19.8

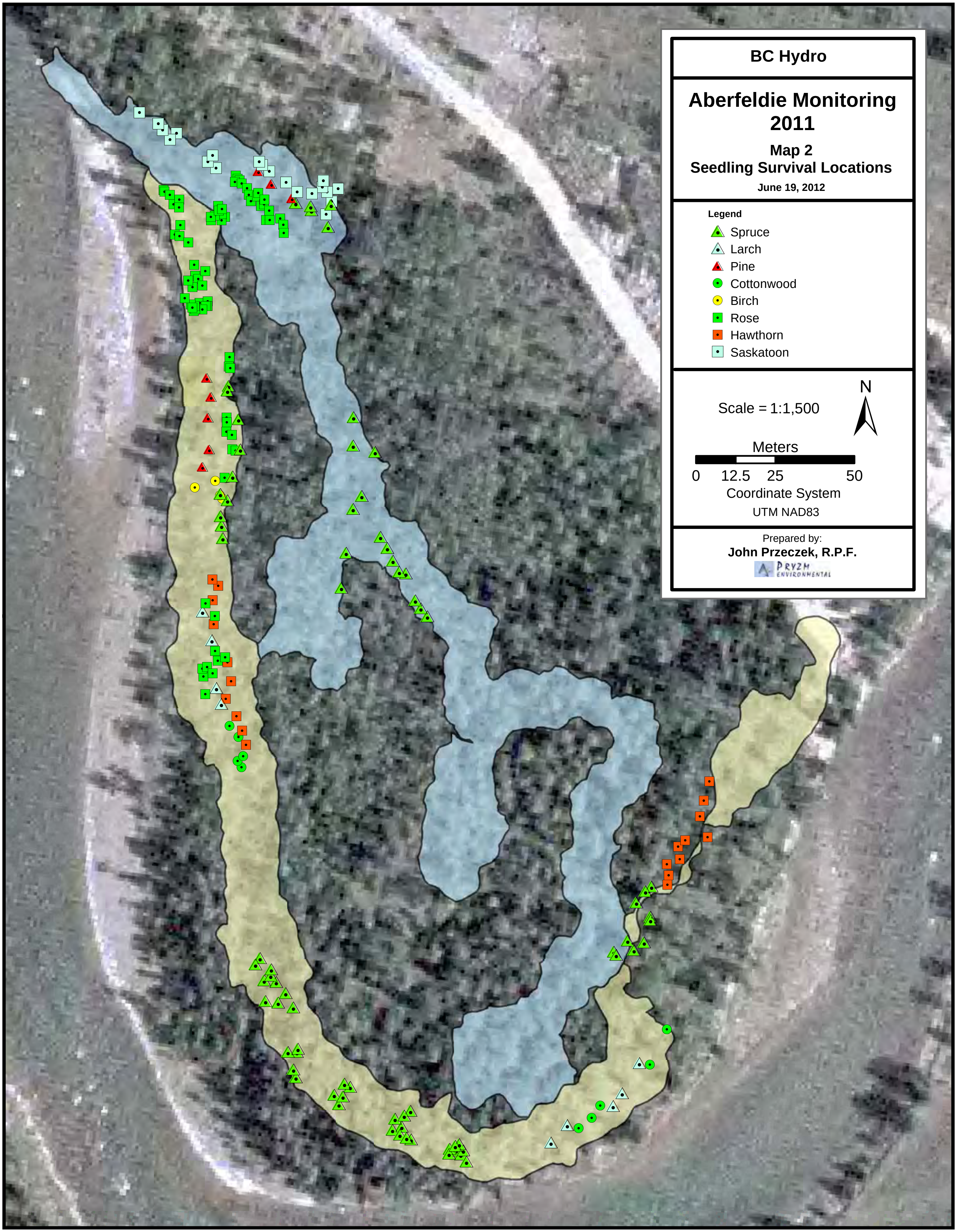
2011

Live Stem Quality - 2011					
Brush Layer	Good	Fair	Poor	2011 Total	2011 % Live Cuttings
1		2		2	5.3
4		1		1	5.3
6	11	5	2	18	18
9		4		4	11.4
12	1	2		3	15.8
16		6		6	8.5

Effective Length - 2011								
Brush Layer	Isolated Cuttings (count)	1	2	3	4	Total Effective Length (m)	2009 Brush Layer Length (m)	% Effective
1	2					2.00	10.2	19.6
4	1					1.00	4.8	20.8
6		1.8	6.34	2.88	2.72	13.74	17.4	79.0
9	2	1.8				3.80	7.9	48.1
12	1	1.42				2.42	4.4	55.0
16	4	1.49				5.49	17.9	30.7

Appendix 5. Maps


BC Hydro
Aberfeldie Monitoring 2011
Map 1
Vegetation Transects and Brush Layers
June 19, 2012
Legend
Modified Brush Layer
Vegetation Transect (permanent)
Vegetation Transect (random)
Scale = 1:1,500
N
Meters
0 12.5 25 50
Coordinate System
UTM NAD83
Prepared by:
John Przeczek, R.P.F.
PRYZM ENVIRONMENTAL
VTR-PS-03
MBL-16
VTP-BT-03
MBL-12
VTR-RS-01
VTR-PS-02
VTP-BS-03
VTR-RS-02
MBL-04
VTP-BT-02
VTP-BS-02
VTP-BS-01
VTR-RS-03
VTR-PS-01
VTP-BT-01


BC Hydro
Aberfeldie Monitoring 2011
Map 2
Seedling Survival Locations
June 19, 2012
Legend
Spruce
Larch
Pine
Cottonwood
Birch
Rose
Hawthorn
Saskatoon
Scale = 1:1,500
N
Meters
0
12.5
25
50
Coordinate System
UTM NAD83
Prepared by:
John Przeczek, R.P.F.
PRYZM ENVIRONMENTAL