Stoddart Creek Ecosystem Restoration Monitoring Site Establishment and Summary Report

January 2007

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Summary

In August 2006, the Fish and Wildlife Compensation Program – Columbia Basin (FWCP) initiated year one of a multi-year field study designed to monitor the effects of dry forest ecosystem restoration treatments on overstory and understory vegetation characteristics. Restoration treatments were prescribed in order to meet wildlife objectives on-site (badger and bighorn sheep). One site was installed in the South Stoddart Creek Restoration Area. This report summarizes activities associated with year one (2006), sample plot establishment and pre-treatment monitoring.

The restoration area is located approximately 11 km north of Invermere. Plots were permanently located and systematically sampled at each site. Understory and overstory monitoring was conducted according to general methods outlined in Machmer et al. (2002). Understory sampling (species composition, cover, diversity) was conducted from Aug 15 – 30th, 2006. Forage production (kg/ha)) was conducted from October 1 - 15, 2006. Overstory and surface fuel assessments were completed, using the Fire Effects Monitoring and Inventory System (FIREMON) methodology from October 15-30, 2006. The data were entered into EXCEL spreadsheets for easy import into an ACCESS relational database and the Fuels Management Analysis Plus (FMA Plus) software package.

Based on overstory closure, South Stoddart Creek was divided into three forest types (managed forest, open forest and open range). The managed forest site was characterized by a dense overstory and lack of an understory. Open forest plots were characterized by a healthy understory and high stem densities. Open range plots were characterized by an open overstory and by abundant bunchgrasses and forbs in the understory.

Overall the South Stoddart site is in good condition. In the open forest and open range type, forage production and species composition are characteristic of historic fire-maintained stands. Fuel loadings are also in line with historical conditions. The lack of non-native species at this site was notable; prescriptions for this site should strive to maintain the presence of non-native species at a minimum.

Further monitoring should focus on targets outlined in the stand prescriptions for species and plant communities of interest (e.g. Douglas fir / snowberry / balsamroot plant community). Based on pre-treatment conditions, restoration objectives should be achievable as outlined in the stand prescription.

Acknowledgements

The author would like to thank John Krebs, Larry Ingham and Doug Adama of the Columbia Basin Fish and Wildlife Compensation Program for initiating and administering this contract. Barb Houston and Andrea Davdison conducted the overstory and fuel field sampling. Beth Woodbridge provided valuable administrative support. Doug Adama (CBFWCP) prepared the maps included in this report.

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1. Introduction

Ecosystems can be characterized by their natural disturbance regime. For the purposes of setting biodiversity objectives in British Columbia (BC), five Natural Disturbance Types (NDTs) are recognized in the Province. Disturbance types range from NDT1, systems with rare stand-initiating events to NDT5 systems (alpine tundra and subalpine parkland) (Province of BC 1995). NDT4 systems of the southern interior of BC are comprised of the interior Douglas-fir, ponderosa pine and bunchgrass zones of the Cariboo, Kamloops, and Nelson forest regions (Gayton 2001a). There are approximately 4.5 million ha of NDT4 in the Province, of which, approximately 60% occurs crown land (Gayton 2001a).

NDT4 systems are characterized as shrublands mixed with open stands of ponderosa pine (*Pinus ponderosa* Douglas ex Lawson & Lawson var. *ponderosa*) and interior Douglas-fir [*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco]. The conventional assumption is that NDT4 systems historically experienced frequent (every 7 – 50 years), low intensity fires which limited encroachment by most conifer species and shrubs (Province of BC 1995), although there is little empirical data to back this assumption. Although NDT4 systems have been characterized as having a low-frequency fire regime, there is general agreement that BC's NDT4 was subjected to a 'mixed fire regime', meaning frequent low-intensity fires with occasional, randomly occurring stand-replacement fires (Gayton 2001a). Regardless of the fire regime, it is clear that dry, interior plant communities have undergone dramatic changes in structure and losses in diversity hypothesized to be due to forest ingrowth and encroachment brought about with fire suppression policies introduced by land management agencies in the 1940's (Daigle 1996).

Fire suppression, overgrazing, and selective logging in these forests are believed to have caused forest encroachment on grasslands and ingrowth within open forests. Encroachment is tree establishment in previously treeless openings. Ingrowth is excessive tree recruitment, primarily by shade-tolerant species, such as interior Douglas-fir, within low-density, open forests. The result of both these processes within NDT4 ecosystems of the southern interior of BC is believed to have resulted in a loss of wildlife habitat as well as in decreased timber and forage production (Powell et al. 1998). Forest structure conversions generally result in a loss of forage production for domestic livestock and native ungulates. Increased grazing pressure on a declining land base can result in further retrogression of the plant community. In a social context, densely stocked stands are prone to severe insect outbreaks and to catastrophic crown fires (Powell et al. 1998; Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000).

Conservation of grassland and open forest habitats is of primary concern to the Fish and Wildlife Compensation Program (FWCP) and other land management agencies (Ministry of Forests, Ministry of

Environment). Agencies with similar concerns have come together to form the Rocky Mountain Trench Ecosystem Restoration Steering Committee (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2006).

The Trench Restoration Program is the most extensive restoration terrestrial initiative in B.C. The primary objective of the Trench ecosystem restoration program is to restore 47% of Crown NDT4 to open forest or open range condition and maintain open conditions in perpetuity (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2006). This is in addition to restoration activities conducted on private conservation (e.g. The Nature Trust) and Federal land (Kootenay National Park). Restoration activities are primarily intended to restore key wildlife winter range, red- and blue- listed species habitat and increase forage for livestock, thus diminishing the wildlife/livestock conflict (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2006). The Trench Restoration Program is the largest, longest running terrestrial initiative underway in the Province of BC (Machmer et al. 2002).

Monitoring is an integral component of the FWCP restoration plan. Long-term monitoring of vegetation, of a particular species of interest, or of a key physical parameter is the only way to determine the success of a restoration effort or specific restoration prescription (Gayton 2001b). Monitoring involves the measurement of environmental characteristics, over an extended period of time, to determine status or trends in some aspect of environmental quality (Suter 1993). Environmental monitoring should address one or more specific objectives (Goldsmith 1991) that are associated with specific targets (e.g., a 5% increase in bunchgrass cover over five years). In dry forest ecosystem restoration, Ruiz-Jean and Aide (2005) suggest monitoring must focus on the recovery of stand structure, species diversity and ecosystem processes to ensure the ecosystem will persist in a stable state in the future. Given the significant investment in ecosystem restoration (ER), it is the responsibility of agencies to collect information that can inform practitioners and the public about whether ER is having the intended effect and whether forest and rangeland resources are being sustained (Noon 2003). The effectiveness monitoring (EM) strategy developed by Machmer et al. (2002) was intended to provide data that allows the Trench ER community to evaluate progress towards goals developed at different spatial scales (e.g., site, range unit and landscape level scales).

This project is in response to a Request for Proposals from the Fish and Wildlife Compensation Program (FWCP). Specific objectives of the project were to (1) establish a permanent monitoring site at South Stoddart Creek, and (2) collect data on pre-treatment vegetation overstory, understory conditions, crown fuels and surface fuels at each site and summarize. Post-treatment re-assessments are planned under separate contracts.

2. Methods

Methods are based on those described in trench EMP (Machmer et al. 2002), with modifications based on discussions with Doug Adama (FWCP). Modifications were made to accommodate the collection of overstory and surface fuel data using the Fire Effects Monitoring and Inventory (FIREMON) System methodology and to analyze collected data using the Fuels Management Analayst Plus (FMA Plus) software package. The following five restoration objectives outlined in the EMP were chosen for monitoring purposes:

Restoration Objective 1:
Reduce tree density, manage crown fuels, increase tree size, and achieve a tree species composition that falls within the historical range of variability for treated areas (based on aspect, slope, topography, moisture).

Restoration Objective 2:
Maintain or increase fire-adapted native understory vegetation in treated areas.

Restoration Objective 3:
Minimize the establishment and spread of non-native plant species, particularly noxious species, in treated areas.

Restoration Objective 4:
Maintain or increase forage production in treated areas.

Restoration Objective 5:
Manage surface fuels (coarse woody debris and fine fuels) in treated areas that falls within the historic range of variability.

2.1 Study area

Stoddart Creek South is located northeast of Invermere, north of the Juniper Heights residential area. The site is classified as Kootenay Dry Mild Interior Douglas fir Variant (IDFdm2; Braumandl and Curran 1992) with elevations ranging from 900m-1175m on southwest aspects (Fig. 1). Twenty-two plots were systematically established, avoiding areas that were heavily disturbed or unrepresentative of the rest of the block. Plots were established by FWCP staff prior to the initiation of monitoring. Plot locations were recorded using a GPS. Plot locations (UTMs) are provided in Appendix 1.

Plot centers were permanently marked using a 12" galvanized spike (with washer) in the centre of the conduit. Three 11.28 m transects were established radiating out from each plot center to form a spoke separated by 120°. The first bearing was randomly selected, with subsequent bearings determined by adding 120° and 240°, respectively. The second and third transects followed in a clockwise position (from plot center, facing north) to complete the spoke. All bearings were recorded and entered into a database (Appendix 1). Four Daubenmire frame locations were permanently marked on each transect (4 frames/transect = 12 total/plot) using an 8" galvanized spike and washer. Daubenmire frames were located on the left hand side of the transect at meters 3, 5, 7 and 9. The left hand corner located on the transect was marked with an 8" galvanized spike. Each spike was flagged and numbered.

2.2 Restoration objective monitoring

2.2.1 Restoration objective 1

Objective: To reduce tree density, increase tree size, and achieve a tree species composition that falls within the historical range of variability for treated areas (based on aspect, slope, topography, moisture, etc.) (Machmer et al. 2001).

Response Variables: Crown closure, density, crown fuel base height, height, diameter and species composition.

Overstory plot layout conformed to methods developed by the Fire Effects Monitoring and Inventory System (FIREMON). FIREMON is an agency independent plot level sampling system designed to characterize changes in ecosystem attributes over time. The system consists of a sampling strategy manual, standardized sampling methods, field forms, ACCESS database, and a data analysis program. The system was developed by the U.S. Forest Service, Missoula Fire Sciences Laboratory in cooperation with the U.S. Geological Survey, National Park Service and Systems for Environmental Management. Because data were analyzed in Fuels Management Analyst Plus (FMA Plus), all data necessary for FMA Plus input were also collected, although they are largely the same data collected using the FIREMON methodology.

Overstory plots were 11.28m radius (400m^2). All trees taller than 1.37m within the plot were tallied and described using a number of characteristics.

- *Tree species*
- *Tree Status*: Tree status was described using descriptors established by FIREMON (Table 1).

Table 1. Tree Status descriptors used to describe the health of a tree.

H	Healthy	tree with very little biotic or abiotic damage.
U	Unhealthy	tree with some biotic or abiotic damage; damage that will reduce growth. However, it appears the tree will not immediately die from the damage.
S	Sick	tree with extensive biotic or abiotic damage and this damage will ultimately cause death within the next 5 to 10 years.
D	Dead	tree or snag with no living tissue visible.

- *Diameter at breast height* (dbh)
- *Tree height*: Height was assessed using a laser on a reference tree. All other heights were estimated using the reference tree.
- *Crown Fuel Base Height* (CFBH): CFBH is important for assessing the risk of crown fire. The height of the dead material that is sufficient to carry a fire from the lower to the upper part of the tree crown was estimated. If the dead fuel was insufficient to estimate, the height of the lowest live foliage was estimated.
- *Crown Class*: Crown class represents the position in the canopy of the tree crown and describes how much light is available to the crown of that tree (Table 2).

Table 2. Crown Class descriptors used to describe the position of the tree crown in the overstory canopy.

O	Open Grown	the tree is not taller than other trees in the stand but still receives light from all directions.
E	Emergent	the crown is totally above the canopy of the stand
D	Dominant	the crown receives light from at least three to four directions
C	Codominant	the crown receives light from at least one to two directions
I	Intermediate	the crown only receives light from the top
S	Suppressed	the crown is entirely shaded and underneath the stand canopy

- *Live crown ratio*: the proportion of the total vertical tree height that is occupied by the vertical length of the tree crown (Crown Ratio = Live Crown Length/Tree Height)
- *Percent live crown*: Percent of the canopy that is live.
- *Wildlife tree class*: Wildlife tree class was assigned based on descriptions in the Field Guide for Describing Terrestrial Ecosystems (Fig. 2).

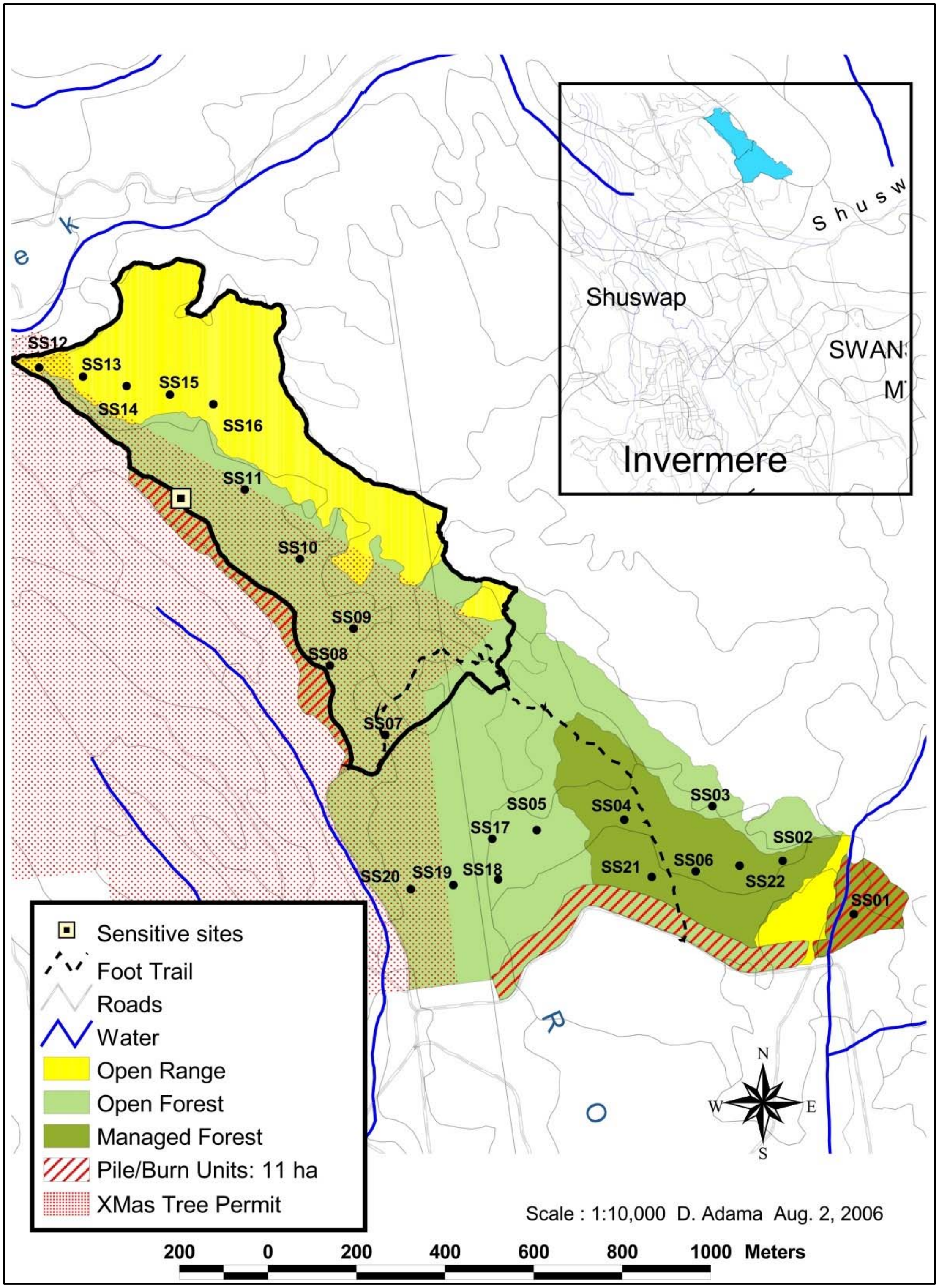

Figure 1. Restoration monitoring plot layout at South Stoddart Creek

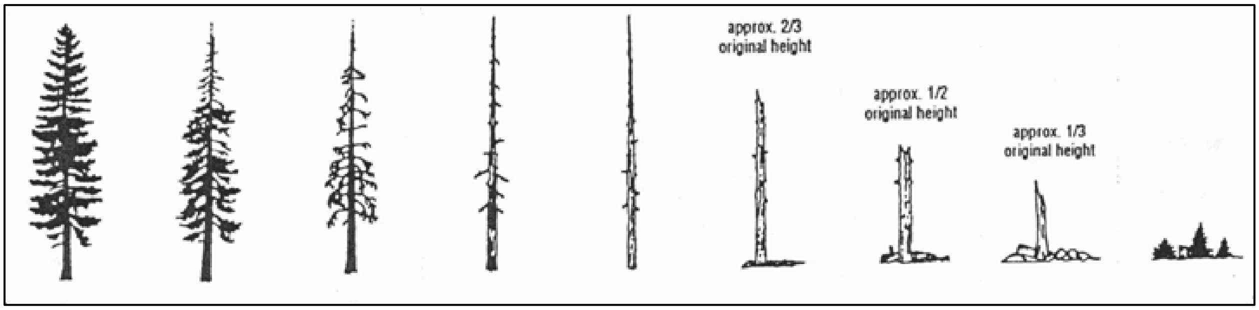

Figure 2. Visual appearance codes for wildlife trees. Numbers 1 – 9 are assigned from left to right (BC Ministry of Environment, Lands, and Parks and BC Ministry of Forests 1998).

- *Crown condition*: Crown condition is the condition of the crown in relation to a normal live crown (Table 3). Lower crown loss due to self-pruning was not counted as foliage or branch loss.

Table 3. Crown condition codes used to describe the appearance of a tree crown.

1	All foliage, twigs, and branches present
2	Some or all foliage lost; possibly some twigs lost; all branches usually present; possible broken top
3	No foliage present; up to 50% of twigs lost; most branches present; possible broken top
4	No foliage or twigs present; up to 50% of branches lost; top usually broken
5	Most branches gone; some sound branch stubs remain; top broken
6	No branches present; some sound and rotting branch stubs, top broken

- *Mortality codes:* mortality codes are used to identify the primary (first) agent that killed the tree (Table 4).

Table 4. Mortality code descriptors used to describe the agent presumed to be the primary agent that killed a tree.

F	Fire-caued
I	Insect-caused
D	Disease-caused
A	Abiotic (flooding, erosion)
H	Harvest-caused
U	Unable to determine

All data collected were entered into the FIREMON tree data form (with modifications) and then analyzed in FMA Plus.

2.2.2 Restoration objective 2

Objective: To maintain or increase fire-adapted native vegetation (grass, herb, shrub) in treated areas.

Response variables: Grass, herb and shrub cover by species, species richness and composition.

Understory plot layout conformed to methods developed by DeLong et al. (2001) and Powell et al. (1998). Three 11.28m transects were established radiating out from each plot centre to form a spoke separated by 120°. Understory vegetation cover and composition data were collected in Daubenmire frames (Daubenmire 1959). In each frame, percentage of herb and grass cover by species was recorded. Species richness was recorded by plot, and species diversity (by plot and overall) was determined using the Shannon-Weiner diversity index ($H=-P_i\log[P_i]$) (Bonham 1983).

Shrub cover was estimated in 5.64m radius plots ($100m^2$). Shrubs greater than 2m height were classified as the B1 layer and shrubs less than 2m in height were classified as the B2 layer. Canopy cover rather than foliar cover was used to determine plant 'interception' (i.e., the outside perimeter of the plant).

2.2.3 Restoration objective 3

Objective: To minimize the establishment and spread of non-native plant species, particularly of noxious species, in treated areas.

Response variables: Number of species, cover, and noxious weed density (if cover <5%).

Non-native vegetation cover by species was estimated in Daubenmire frames in each of the 15 plots per site (Fig. 2b). If weed cover (noxious and nuisance weeds) was less than 5%, individual plants in the Daubenmire frames were counted to provide a density measure.

2.2.4 Restoration objective 4

Objective: To maintain or increase forage production in treated areas.

Response variables: Total production.

Fifteen clip plots (1 each per plot) were established to estimate production at each plot. Total annual forage production was measured in a 0.5 m^2 (70.7 cm x 70.7 cm) quadrat, located on the right hand side of meter one on the first transect, in each of the 15 permanently marked plots per site. Production quadrats will be rotated among transects in subsequent years to avoid the confounding effects of destructive sampling. Herbaceous vegetation and current annual growth of shrubs was clipped to ground level in mid-September, after peak growth was reached. Kinninick (bearberry) [*Arctostaphylos uva-ursi* (L.) Spreng.] was not clipped, as it is not of direct interest for ecosystem restoration. Samples were separated into bunchgrass, 'other grass', forb, weed, sedge (*Carex spp.*) and stored in paper bags. They were air-dried and then oven-dried at 70°C for 48 hours to a constant mass, and weighed to the nearest 0.1 mg.

2.2.5 Restoration objective 5

Objective: Manage surface fuels (coarse woody debris and fine woody debris) in treated areas that falls within the historic range of variability.

Response variables: Fuel load (tally of fine woody debris, tally of coarse woody debris, description of coarse woody debris on site, depth of duff/litter).

Fuel load measurements were conducted using FIREMON protocols. The fuel load is the amount of available and potentially combustible material, usually expressed as a weight/area. A description of the fuel load contributes directly to the development of the fuel model which is a standardized description of fuels available to a fire based on the amount, distribution and continuity of vegetation and wood.

The fuel load (FL) methods are used to sample dead and down woody debris, depth of the duff/litter profile and estimate the proportion of litter in the profile. The FL is measured using a line transect technique which estimates loadings of downed dead woody into four size classes (Brown 1979) (Table 5). Litter and duff depths are also estimated on the transect using methods outlined in Keane (1999).

Fuel load measurements allow for greater predictive abilities when writing future fire prescriptions. Fuel load measurements also serve as coarse woody debris monitoring for wildlife purposes.

Table 5. Fine and coarse woody debris fuel size classes and the segment of the line-intercept transect on which they are measured.

	Fuel Type	Fuel Size	Transect Segment
Fine Woody Debris	1 hour	0.0cm – 0.6cm	5m – 7m
	10 hour	0.6cm – 2.5cm	5m – 7m
	100 hour	2.5cm – 8cm	5m – 10m
Coarse Woody Debris	1000 hour	>8cm	5m – 25m

Three 25m transects were established based on the plot centers used for understory sampling. The first transect was run 25m from plot centre at 90°. The start of the second transect was established 1m from the first at 330° and run 25m at 330°. The third transect end was established 1m from transect two at 270°and run at 25m at 270°. All three transects had an 8" pin placed at meter 0. The slope of each sampling transect was recorded and entered into the data sheet.

Fine woody debris was tallied by the different size classes and sampled in different segments of the transect (Table 5). The sampling plane extended from the top of the litter layer vertically to a height of two meters. Pieces of FWD that were "woody", "dead" and "down" fell into three general categories: 1) pieces that were not attached to the plant stems or tree boles where they grew and had fallen to the ground, 2) pieces that were not attached to the plant stems or tree boles where they grew but were supported above the ground by live or dead material and 3) pieces attached to stems or boles of shrubs or trees that were themselves considered "dead" and "down". Needles, grass blades, pine cones, cone scales, bark pieces were not sampled, as they were not "woody" in nature (this material is considered litter and was measured as part of the duff/litter profile). If 100 pieces of a size class were tallied before sampling the segments of all three transects, sampling did not occur on further transects.

Coarse woody debris (CWD) (>8cm) was tallied and described by diameter (at the point of transect intersection), decay class (Table 6) and log length. CWD at an angle of greater than 45 degrees above horizontal where it passes through the sampling plane was only considered "down" if it was the broken bole of a dead tree where at least one end of the bole was touching the ground (not supported by its own branches, or other live or dead vegetation). If CWD is at an angle of 45 degrees or less above horizontal where it passes through the sampling plane then it is "down" regardless of whether or not it is broken, uprooted or supported in that position. CWD was not sampled if the central axis of the piece was lying in or below the duff layer where it passed through (actually, under) the sampling plane (these pieces burn more like duff).

Table 6. Descriptions used to characterize decay class of coarse woody debris.

Decay Class	Description
1	All bark is intact. All but the smallest twigs are present. Old needles probably still present. Hard when kicked
2	Some bark is missing, as are many of the smaller branches. No old needles still on branches. Hard when kicked
3	Most of the bark is missing and most of the branches less than 1 in. in diameter also missing. Still hard when kicked
4	Looks like a class 3 log but the sapwood is rotten. Sounds hollow when kicked and you can probably remove wood from the outside with your boot. Pronounced sagging if suspended for even moderate distances.
5	Entire log is in contact with the ground. Easy to kick apart but most of the piece is above the general level of the adjacent ground. If the central axis of the piece lies in or below the duff layer then it should not be included in the CWD sampling as these pieces act more like duff than wood when burned.

Duff/litter depth measurements were made at a point within 1 meter of the 15-meter and 25-meter marks along the line-intercept transect. The proportion of the profile that was litter (versus duff) was estimated. Three measurements of dead fuel depth were taken at meter-25. Depth was recorded as the vertical distance from the bottom of the litter layer to the highest intersected dead particle for each of three adjacent 30cm wide vertical partitions of the sampling plane.

The percentage of foliage retained on the dead down woody material was recorded for fine woody debris on each transect. This percentage is used in the calculation of the needle fuel loading. Fuel composition was also estimated (percentage of fuel made up of a certain species). Data were entered into FMA Plus.

2.3 Data entry

Raw data were entered into EXCEL spreadsheets (Appendix 1) in a format that permits easy import into ACCESS, JMP (Sall et al. 2005) and FMA Plus. Species codes and life-form identifications used were provided by the Ministry of Forests Research Branch. Raw data file names and descriptions are provided in Appendix 1 of this document.

2.4 Data summary and analysis

Data were summarized in EXCEL spreadsheets. Summary understory statistics were calculated using JMP software (2005). Data were summarized by species and by functional/descriptive group (e.g., shrubs, forbs, grasses, etc.). Due to inherent variability at sites sampled, understory cover data had very large variances. Some of these data will require transformation (arcsine or square root) prior to undertaking inter-year comparisons using ANOVA.

Overstory and surface fuel data were imported into FMA Plus. FMA Plus is a software package that includes a suite of tools designed to calculate down and dead woody inventories, using digital photo series, calculating crown mass for fire behavior predictions, and allows for the user to create their own fuel models to fit the local area. There was no macro available that allowed for easy import of FL data collected into FMA Plus. Extensive data manipulation was required prior to entering the data into FMA Plus.

3. Results and observations

3.1 General site description

3.1.1 Stoddart Creek South site description

The South Stoddart Creek treatment area consists of three forest types based on overstory closure; a managed forest unit, an open forest unit and an open range unit.

Managed forest (MF) areas (Fig. 3) are dominated by a closed understory of Douglas fir and a tall shrub layer consisting predominantly of Juniper species (*Juniperus* sp.). There was little to no understory vegetation in MF areas. There was a well-developed bryophyte layer in these plots relative to the other plots (Table 7). Depth of duff in these plots averaged 4cm (stdev=4).

The open forest (OF) site (Fig. 4) was dominated by an open overstory of Douglas fir with minor components of trembling aspen (*Populus tremuloides* Michx.) The understory was dominated by pinegrass and a high cover of shrubs, such as birch-leaved spirea, common juniper, soopolallie, and common snowberry. Litter cover was highest in these plots (Table 7). Depth of duff was 3cm (stdev=3). Five of eight open forest plots were slashed during the winter of 2005.

Figure 3. Plot photo from the managed forest site at South Stoddart Creek. Photograph taken in August 2007.

Figure 4. Plot photo from the open forest site at South Stoddart Creek. Photograph taken in August 2007.

Figure 5. Plot photo from the open range site at South Stoddart Creek. Photograph taken in August 2007.

Open Range (OR) areas were characterized by bunchgrasses (bluebunch wheatgrass, junegrass), dryland forbs and sparse juniper cover. The overstory was dominated by large diameter, open Douglas fir. There was a high cover of cryptogamic crust in these plots (Table 7). Cryptogamic crust is an element of healthy open grasslands at lower elevations. The crust is a layer of lichens, mosses, liverworts and cyanobacteria that covers the ground between widely spaced bunchgrasses (GCC 2005). The crust forms a protective cover for the soil, helps retain soil moisture, and prevents weedy species from becoming established. The crust is highly susceptible to disturbance, particularly mechanical. Open range plots had the lowest litter and the highest bare soil cover in the South Stoddart Creek restoration area (Table 7).

Soils at all three sites were classified as Orthic Eutric Brunisols (Lacelle 1990). Eutric Brunisols are strongly calcareous and low in organic matter (National Research Council of Canada 1998).

Table 7. Percent cover of litter, cryptogamic crust, bryophytes, dead wood, soil and rock in managed forest, open forest and closed forest plots at South Stoddart Creek.

	MF		OF		OR		Site	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
Litter	66	33	73	24	58	32	68	30
Crtyptogamic Crust	3	8	4	10	12	17	5	12
Bryophytes	26	34	13	22	1	6	13	25
Dead Wood	2	7	2	6	0	0	2	6
Soil	<1	1	2	7	16	20	5	12
Rock	3	10	2	7	8	12	3	4

3.2 Overstory characteristics

3.2.1 South Stoddart overstory structure

Stem density data were collected by an FWCP under a separate contractr in 2005, prior to any stand treatment. Stem density at the South Stoddart site in 2005 was 716 stems/ha (including all stems 5cm and greater). Stem density was highest in the managed forest plots (1158 stems/ha) and lowest in the open range plots (190 stems/ha). Stem density in the open forest plots was 800 stems/ha.

The predominant size class in all three forest types was 5 – 10cm (Fig. 6). The 0 – 5cm size class was excluded from this analysis for presentation purposes, although stem densities were high in this size class (492 stems/ha in the closed forest, 550 stems/ha in the open forest and 100 stems/ha in the open forest).

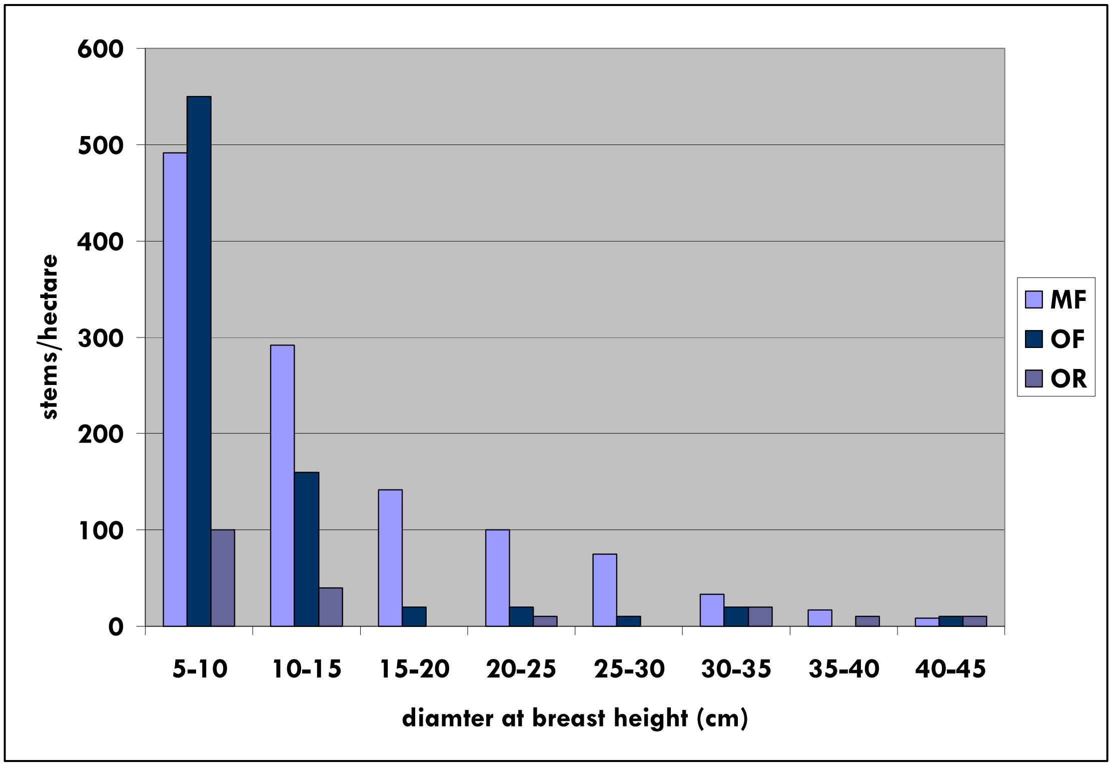

Figure 6. Stems per hectare within eight diameter at breast height (cm) classes (5-10, 10-25., 15-20, 20-25, 25-30, 30-35, 35-40, 40-45). Data collected prior to any slashing treatments on-site.

Overstory data collected in 2006 were summarized in the CrownMass program of Fuels Management Analyst Plus (FMA Plus). Data were summarized by open range, open forest slashed, open forest unslashed and managed forest unslashed plots (winter 2005 slashing treatments had been implemented in all open range plots and select open forest plots). Basal area, stand volume, canopy base height, canopy bulk density (canopy biomass divided by the volume occupied by crown fuels), stand height and canopy ceiling height (the height above the ground of the highest canopy layer where the density of the crown mass within the layer is high enough to support vertical movement of a fire) were calculated in the program (Table 8). Slashed open forest plots were thinned to volumes equivalent to open range plots (Table 8). Basal area was higher in the open range plots as there were a number of large diameter stems (>30cm dbh) in the open range plots. Volumes in the slashed open forest plots were significantly lower than the open forest plots that were not slashed (Table 8). Open forest plots that were not treated in 2005 had basal areas equivalent to managed forest plots.

Table 8. Basal area (m^2), canopy base height (m), canopy bulk density (kg/m^3), average stand height (m) and canopy ceiling height at South Stoddart Creek.

	open range slashed (n=5)	open forest slashed (n=5)	open forest unslashed (n=3)	managed forest unslashed (n=2)
Basal Area (m^2)	14.7	13.88	52.93	47.00
Canopy Base Height (m)	0.30	0.9	0.3	0.3
Canopy Bulk Density (kg/m3)	0.12	0.10	0.51	0.61
Average Stand Height (m)	7.62	10.4	8.8	6.4
Canopy Ceiling Height (m)	17.0	15.2	21.3	14.9

FMA Plus enabled determination of overstory fuel loading by fuel type (foliage, 1-hour, 10-hour, 100-hour and 1000-hour) (Table 9; Fig. 7). Fuel loading in the slashed, open forest plots was lower or roughly equivalent to fuel loadings in the open range plots (Fig. 7). Fuel loading was highest in the unslashed, open forest and managed forest plots.

Similar fuel loading and canopy characteristics between the unslashed, open forest type and managed forest type is also due to pre-treatment forest types. The open forest slashed area had been managed as a Christmas tree permit and had lower pre-treatment stem densities then the open forest type that was not slashed. The unslashed forest type has historically been managed at the upper stem density end of the open forest/managed forest stem density boundary.

Table 9. Overstory fuel loadings (foliage, 1-hour, 10-hour, 100-hour and 1000-hour) (kg/m^2) in open range, open forest slashed, open forest unslashed and managed forest unslashed plots at South Stoddart Creek.

	open range *slashed* (n=5)		open forest *slashed* (n=5)		open forest (n=3)		managed forest (n=2)	
	mean	**stdev**	**mean**	**stdev**	**mean**	**stdev**	**mean**	**stdev**
Foliage (kg/m^2)	1.11	0.47	0.84	0.58	3.33	1.72	4.31	0.43
1-Hour (kg/m^2)	0.53	0.20	0.46	0.32	2.37	0.64	2.09	0.19
10-Hour (kg/m^2)	0.94	0.36	0.72	0.50	3.56	1.07	3.04	0.53
100-Hour (kg/m^2)	0.59	0.29	0.57	0.49	1.44	0.90	0.59	0.46
1000-Hour (kg/m^2)	0	0	0.02	0.04	0.02	0.04	0	0

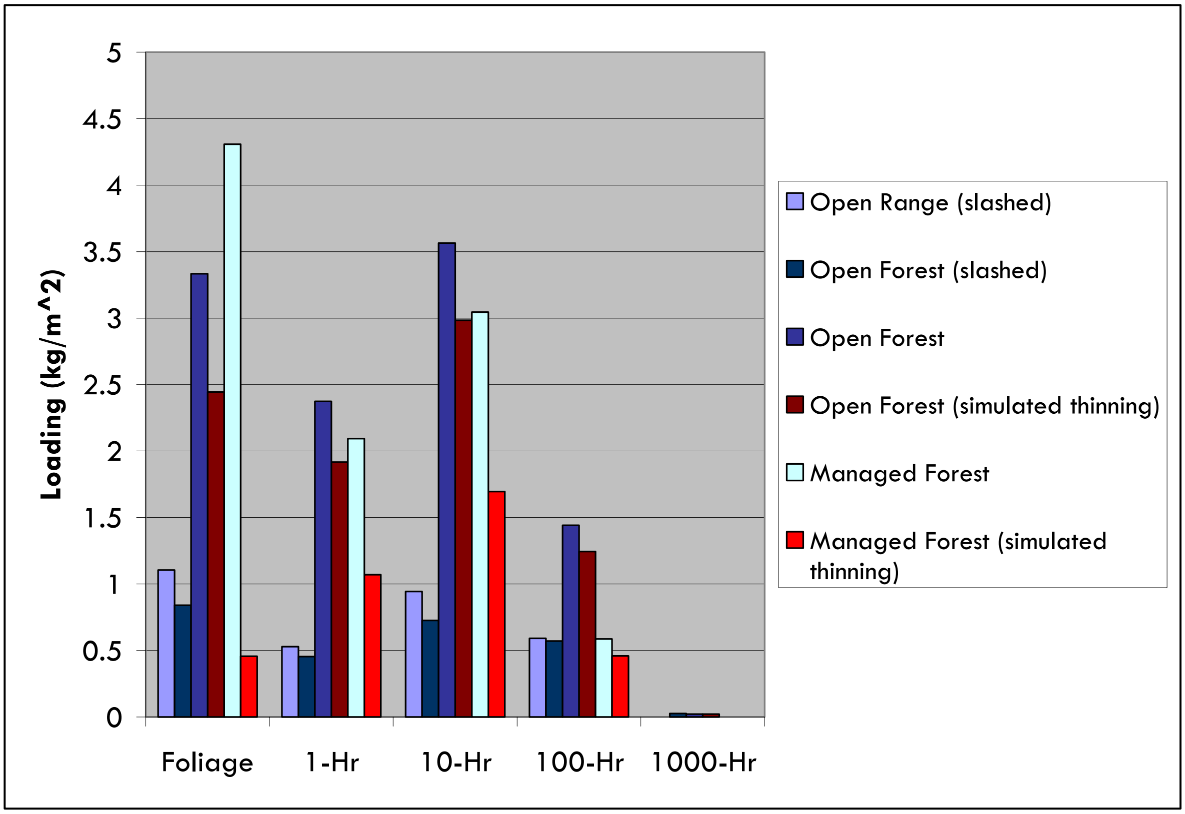

Figure 7. Overstory fuel loadings (foliage, 1-hour, 10-hour, 100-hour and 1000-hour) (kg/ha) in open range, open forest slashed, open forest unslashed and managed forest unslashed plots at South Stoddart Creek. Simulated fuel loadings are presented in thinned, open forest plots and thinned managed forest plots. Simulations were conducted in FMA Plus®.

FMA Plus allows for simulations of thinning treatments using plot data collected. In the first simulation, all stems below 10cm in the managed forest plots were selected for removal. In this simulation basal area decreased from 47m^2 to 24 m^2. Canopy base height increased from 0.3m to 2.4m, although average stand and canopy ceiling height remained the same (at 6.4m and 14.9m respectively). A second simulation was run where all stems below 15cm dbh were removed from the untreated open forest plots. Basal area, in this simulation, declined from 53m^2 to 43m^2. Canopy base height increased from 0.9m to 4.3m. Average stand height and canopy ceiling height remained the same (Table 8). In the second simulation (removing all stems less than 15cm in the open forest plots) the volume remained relatively high (43m^2). This simulation suggests that maybe all trees less than 10cm dbh should be removed from the open forest plots (rather than 15cm dbh).

Both simulations demonstrated significant effects on the canopy fuel loading in the foliage, 1-hr, 10-hr, 100-hr and 1000-hr fuel class categories (Fig. 7). The simulated thinning treatment was highly effective at reducing fuel loads in the open range plots. Caution should be taken with interpretation of these data as the simulation was run only using two plots. The thinning simulation was not as effective at reducing fuel loads in the open forest plots (Fig. 7). Fuel loads, in all categories, were much higher than fuel loads in the simulated thinning of open range plots. Collection of overstory fuel data allows for in-depth overstory analysis and also enables the user to simulate treatments. Simulated treatments are highly beneficial to managers as it allows for the development of more appropriate prescriptions for individual sites.

3.3 Understory characteristics

3.3.1 South Stoddart Creek understory structure

Forb (6%; stdev=8) and bunchgrass (5%; stdev=8) descriptive groups had the highest levels of cover at South Stoddart Creek. Pinegrass had 1% cover (stdev=5) across the entire site. The three most abundant species at this site were bluebunch wheatgrass (2%), kinnikinnick (2%) and pinegrass (1%). This is the only restoration site monitored by FWCP where a bunchgrass species was the most abundant species pre-treatment. Descriptive group cover was highly dependent on the location of the plots (i.e. open forest, closed forest, open range) (Fig. 8)

Cover of bunchgrass and forb was highest in the open range plots while pinegrass and sedge cover were the lowest (Fig. 8).

There were no significant occurrences of non-native species at the South Stoddart site. The lack of non-native species is notable as, in the past, the site had been managed by FWCP for extensive leafy spurge infestations.

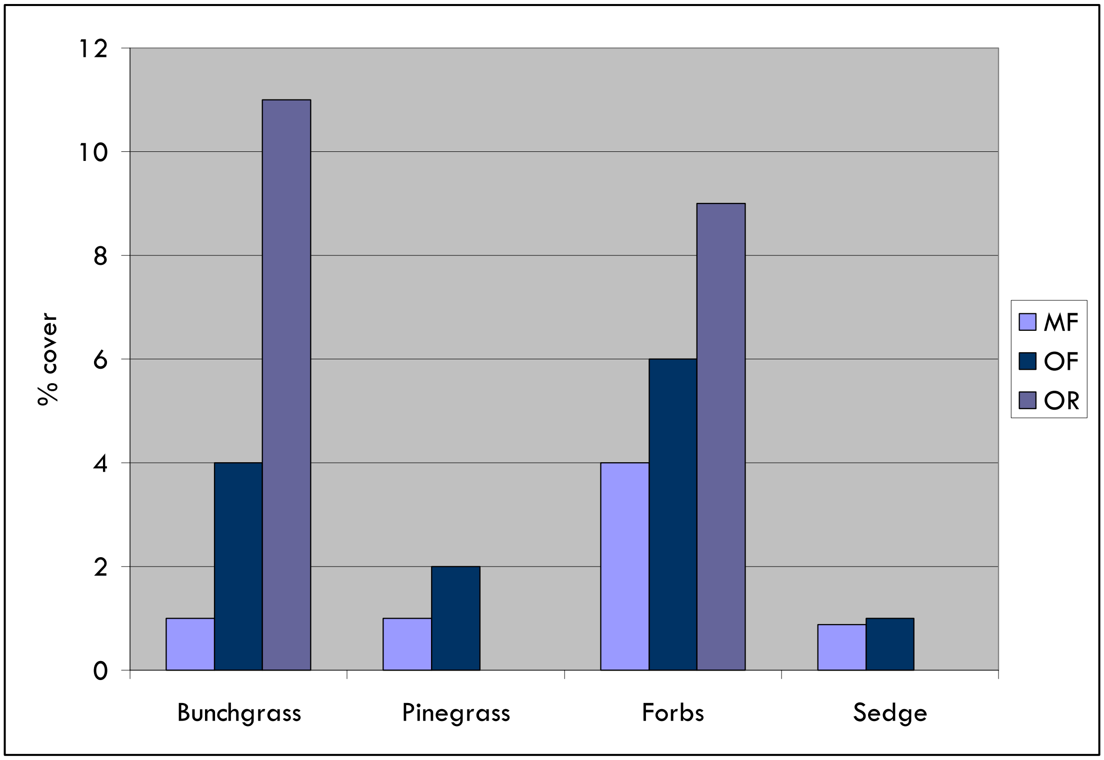

Figure 8. Summary of pre-treatment understory cover characteristics by functional/descriptive group at Stoddart Creek South as sampled in 2006.

Shrub cover was high across the entire site (Table 10). The site was characterized by two well-developed tall and low shrub layers. Douglas fir (9%; stdev=13), Rocky Mountain juniper (4%; stdev=6), and common juniper (1%; stdev=5) had the highest levels of tall shrub cover across the site. Common juniper (9%; stdev=12), Rocky Mountain juniper (5%; stdev=5) and common snowberry (3%; stdev=5) had the highest levels of low shrub cover across the entire site.

Table 10. B1 and B2 shrub layer cover at the South Stoddart Creek Restoration site.

	MF		OF		OR		Site	
	mean	stdev	mean	stdev	mean	stdev	mean	stdev
B1 (tall shrubs)	32	17	12	20	4	5	16	19
B2 (low shrubs)	29	16	27	21	11	9	24	19

3.3.2 South Stoddart production

Production values mirror trends in plant species composition across the site (Fig. 8).Bunchgrass and forb production levels are highest in the open range areas while sedge and pinegrass covers are the lowest (Fig. 9).

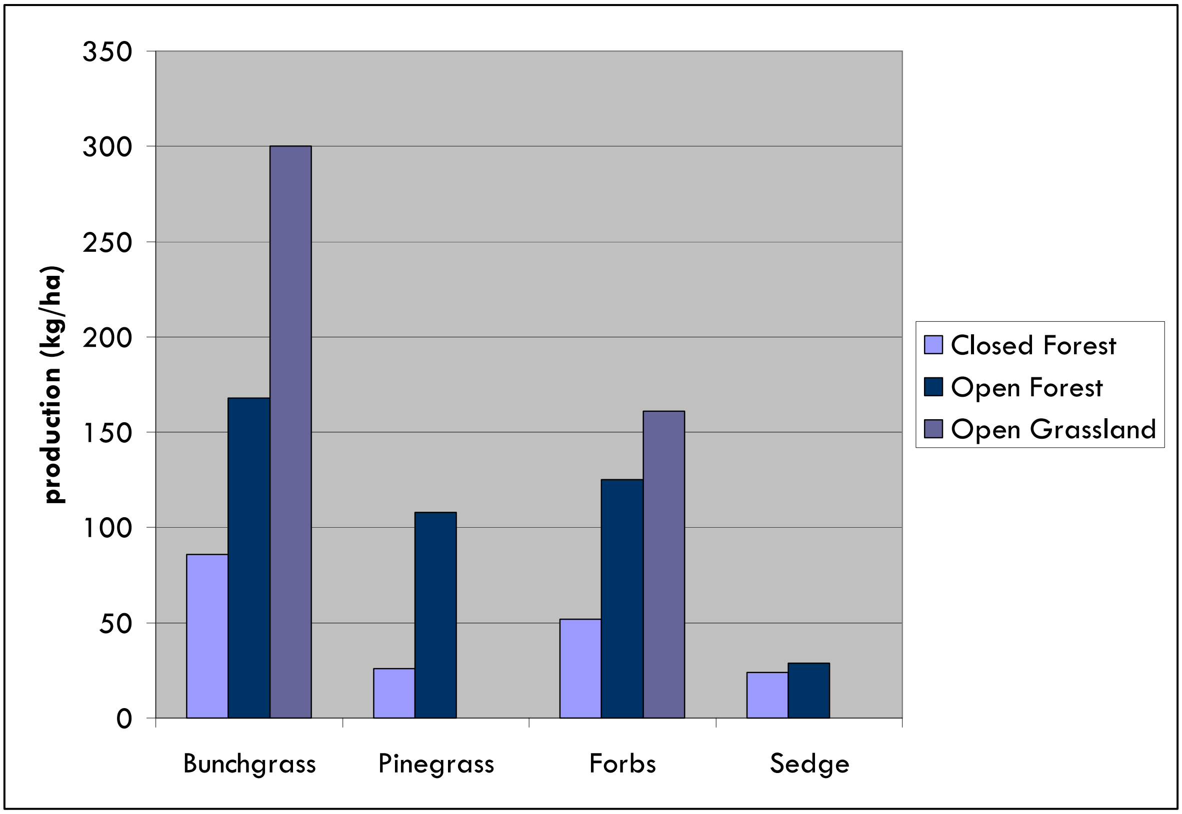

Figure 9. Summary of pre-treatment understory production (kg/ha) characteristics at South Stoddart Creek by functional/descriptive group and habitat type (closed forest, open forest and open grassland) as measured in 2006.

Production levels across the site are average for the Upper Trench (Page 2005), however production values in the open range areas are higher than have been recorded pre-treatment on other restoration sites in the Upper Trench (Hoodoo, Hawke Road, Westside Road). Bunchgrass production is relatively high in comparison to pinegrass, which is also not common in the Upper Trench. This is true across the entire site, not only in the open range areas.

4. Summary and Recommendations

Pre-treatment surveys of the South Stoddart restoration area indicate existing grasslands are in very good condition. Condition, in this context, is assessed by production, species composition and the lack of non-native species presence. Good condition pre-treatment implies achieving restoration objectives (red-listed plant communities, badger and flammulated owl habitat) should be straightforward. It is imperative that restoration treatments minimize disturbance. Even minimal soil disturbance can lead to the establishment of non-native species in the Stoddart treatment unit. Given the resources invested in treating leafy spurge at this site, preventing non-native species establishment should be paramount in future restoration prescriptions. Based on current plant community conditions and recovery in the treated areas, it is apparent that prescriptions to date have considered the importance of minimizing soil disturbance.

This project is the first to use FIREMON methodology and the FMA Plus software for a Trench ecosystem restoration monitoring project. Collection of these data is highly valuable for the prescription writing process. In addition to being able to describe current surface and overstory fuel loads, prescription simulations (e.g. cutting all stems less than 15cm dbh) allow managers to predict results of specific restoration treatments. Another benefit of collecting fuel data is managers can set specific objectives for fuel loading by size class (e.g. coarse woody debris) and write targeted prescriptions in order to meet these objectives. In the future, in order to meet specific treatment objectives, overstory and surface fuel loading data should be incorporated into the prescription. To make data collection and analysis easier, a macro should be developed that allows for the easy import of collected data into FMA Plus.

Further monitoring should focus specifically on restoration objective indicators such as species composition (restoring listed plant communities), stand structure, the presence of ground squirrel and badger burrows, forage production and line of sight monitoring for bighorn sheep. Modifications may be required to current effectiveness monitoring protocols in order to monitor restoration objectives selected for this project (e.g. badger habitat monitoring). There should also be an emphasis place on monitoring for the presence of non-native species.

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Appendix 1 List of EXCEL raw data files and their descriptions (RW-CD format).

File/Folder Name	Description
FMER_composite	Includes plot location and ID information, as well as understory species composition raw data (species richness, species canopy cover, flowering culm and weed density).
FMER_production	Includes all production data. Production values are classified by vegetation groups (e.g., shrubs and bunchgrass).

Appendix 2. Scanned photos (RW-CD format).