Quantifying Emissions Reductions by Using Mastication Treatments for Ecosystem Restoration Projects in the Rocky Mountain Trench:

A Market and Non-market Cost-Benefit Approach

Rocky Mountain Trench Natural Resources Society

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Acknowledgements

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2.1 Project Partners

BC Ministry of Forests, Lands and Natural Resource Operations

Abstract

In recent years, the Rocky Mountain Trench region has been testing mastication (a mechanical means of tree removal whereby the wood is chopped/ground into a woody mulch cover) as tool to implement fuels treatments and ecosystem restoration (ER) projects. Questions as to what the benefits and limits are for using mastication as a tool in the ER tool box has led the formation of the current research. The project has assisted with the development of a new comprehensive ER database for the Trench region, which will provide the baseline data from ER work done over the past 20 years. These data will be linked with this research project, which evaluates mastication treatments done over the 2011-2012 period. The research includes a cost benefit analysis and discusses the ecological effectiveness of mastication treatments in the Trench. The primary focus of this study evaluates whether mastication as a management tool leads to lower emissions of CO2 e, PM 2.5, PM 10 equivalents than traditional ER methods. Results from the study indicate that although mastication creates CH_4 emissions which cause $CO2^e$ to be higher than open burning, PM 2.5, PM 10 from open burning are eliminated and the C sequestration from releasing these stands may offset and overshadow the offgas effects of down and decaying woody biomass. Mastication will be a cost savings in many instances and may reduce invasive plants. Overall, the cumulative non-market values for ecosystem benefits are clearly a strong driver for continuing the ER program. As open burning has become increasingly challenging within the Rocky Mountain Trench, using mastication as a future treatment method may allow the expansion of ER projects which, if implemented, could support the attainment of a higher total hectares of treatments to better meet ER program objectives

1.0 Background

Airsheds are under increasing pressures to meet air quality standards across B.C. and the Rocky Mountain Trench region is an airshed that has been challenged in meeting air quality targets. This study tested the hypothesis that mastication (a mechanical means of small-diameter tree removal whereby the wood is chopped/ground into a woody mulch ground cover) can improve emissions reductions (greenhouses gas and particulates) at a lower cost than the predominant ecosystem restoration (ER) methods. Currently, mechanical and hand slashing removal of small diameter trees along with follow up piling (either by hand or mechanical means) with follow up open burning have been the standard ER methods used across B.C. Using this standard ER approach has been a major cause of emissions within the Rocky Mountain Trench airshed and this applied research will quantify the emissions produced by mastication treatments vs. traditional ER methods.

The report will is organized and presented as follows: First, we give a background about ecosystem restoration that has been planned and followed from the guidance of the Ecosystem Restoration Steering Committee and the "Blueprint for Action" (Blueprint for Action 2006). Second, We review mastication treatments currently being tested in the region and compared with other North American examples as a tool to remove woody biomass; third we discuss the methods used for this research by which to estimate emissions, develop costs and estimate market and non-market values; fourth, we discuss the data collection process and issues related to collecting useful data; fifth, we provide results of the ecosystem restoration blocks that were under forest ER treatment prescriptions with associated calculated emissions; sixth, we present results of the cost-benefits of using mastication for market and non-market values; lastly, we draw conclusions and discuss the limitations of this research and seventh, we make recommendations for future forest management and the ongoing research.

The research team collected data, reviewed the literature and estimated the net emissions reductions between traditional ER treatment methods against mastication treatments. We have developed some initial parameters for determining the market and non-market net benefits of using mastication using a cost-benefit analysis approach and present our conclusions and management recommendations.

The results from this project will have great benefits for the development of forest management best practices within the Rocky Mountain Trench region of B.C. and in particular, the proposed 109,000 hectares of ER Open Forest and Open Range treatments planned within the Trench region. As provincial ER treatments have increased in many forest districts and regions of B.C., the lessons learned from this project offers new approaches for reducing emissions across the province as mastication has become an ER tool that has been of increasing interest by ER planners within B.C.

2.0 Ecosystem Restoration

Ecosystem restoration (ER) has been strategically planned and implemented for nearly 20 years in the Rocky Mountain Trench and has been guided by thoughtful proponents who are part of the Ecosystem Restoration Steering committee that includes several branches of government, First Nations, NGOs and others. This group developed a comprehensive "Blueprint for Action" (2006), which provides the mandate, goals and objectives for the ER program.

The ER Program focuses on restoring the forest to its historic ecological condition and mimicked fire regime for the Rocky Mountain Trench. The fire regimes typical for the region have departed from their historical norms. The program is structured to restore these ecosystems to reflect their historic variation. The ER Program has been very active over the past 20 years in their mission and vision to restore these landscapes; many of these principles have been used for many years throughout North America. Through the collective vision and efforts of these groups and individuals, forest ecosystems are being restored to provide healthy ecological functions that benefit wildlife, recreation and livestock.

The basic goals of the ER program are to remove forest ingrowth (overstocked stands where trees would have been fewer and grasslands more prevalent) that primarily consists of Douglas fir and ponderosa pine stands. The ingrowth poses a threat to the ecological functions desired and represents very significant fuel hazard putting these forests at risk of catastrophic wildfires.

The committee's strategic 30-year plan (2000 –2030) is based on the Kootenay/Boundary Land use Plan implementation strategy which identified 250,000 hectares (ha) of Crown land within the Rocky Mountain Forest District as fire-maintained, or Natural Disturbance Type 4 (NDT4). These 250,000 ha are further classified into four ecosystem components: shrublands, open range, open forest and managed forest. The restoration strategy targets the open range and open forest components. By 2030 the strategy aims to restore 118,500 ha, about 47% of the Crown NDT4, to open range or open forest conditions. Once restored, the committee intends to maintain these restored areas in perpetuity.

The strategic plan published in 2000 identified an estimated 135,000 ha to be restored. The current figure of 118,500 ha more accurately reflects conditions on the ground as determined by maps and restoration plans available since 2000.

Figure 1 provides a map and overview of the ER Program in the Rocky Mountain Trench and maps the program goals that are found in the Blueprint for Action (2006) which identifies Open Forest (OF), Open Range (OR) and Managed Forest (MF).

Figure 1: Ecosystem Restoration Area of the Rocky Mountain Trench

Ecosystem Restoration Program Overview Map

TOTAL HECTARES:
MF = 141,996.0 ha
OR = 35,017.0 ha
OR to be Treated = 10,527 ha
OF = 75,092.0 ha
OF to be Treated = 19,494 ha

1:1,100,000
18 April 2013

Kootney Lake

Legend
FMER_OR
FMER_OF
FMER

Cartography by: Sarah Sinclair
GSI Canada Ltd.
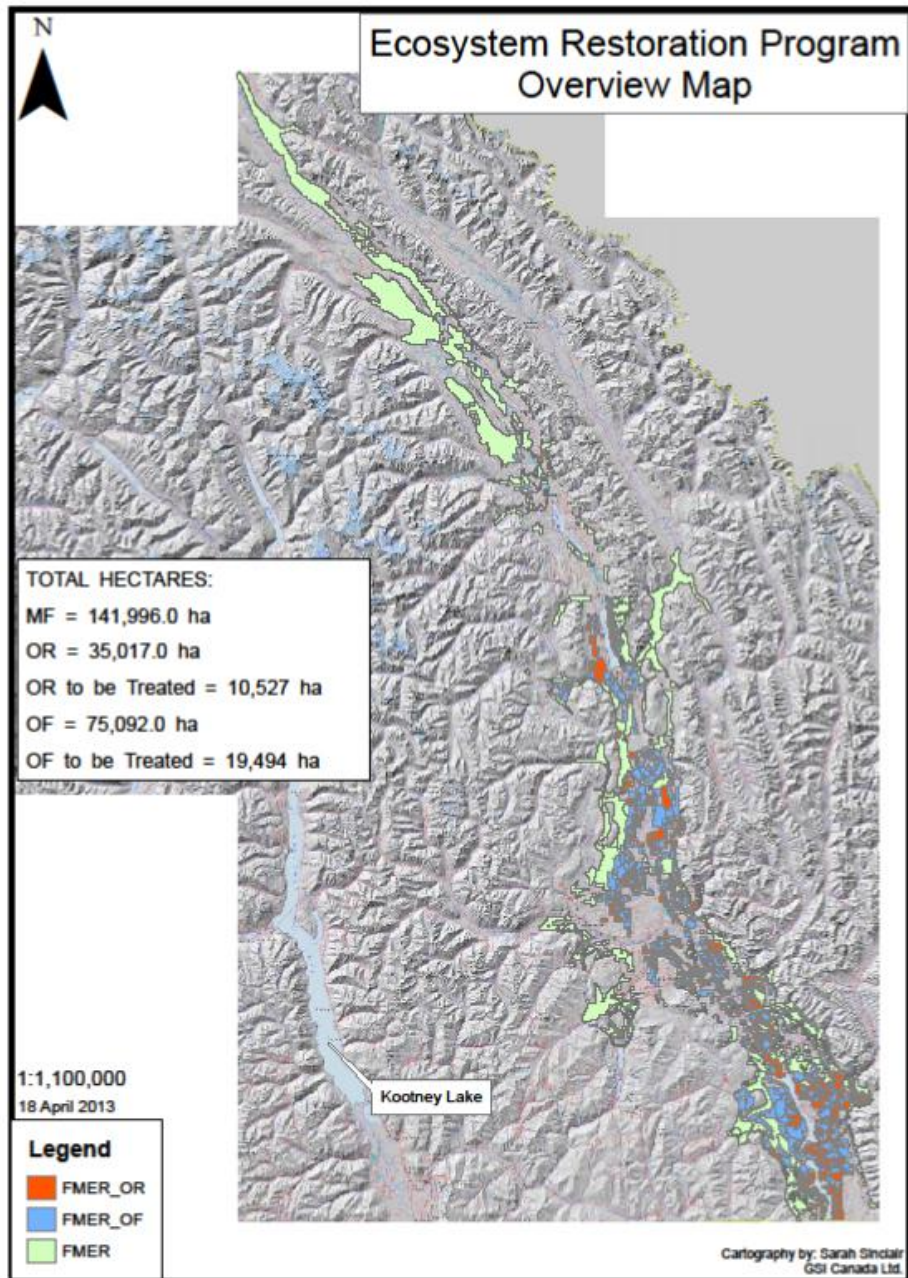
The area originally identified to be treated as outlined in the Blueprint for Action can also be classified as shrublands. The breakdown of these forest components (Hectares) and the previous forest state and the preferred state by 2030 are given in Table 1.

Table 1 Ecosystem Restoration Forest Targets within the Rocky Mountain Trench[1]

Ecosystem Component	Tree Stocking Range/Stems/ha	1997 Distribution	2004 Distribution	2030 Target ha *(%)*
Shrubland	• 0 sph • no target	5%	1%	5,000 *(5%)*
Open Range	• <75 sph • target 20 sph	10%	12%	43,500 *(17%)*
Open Forest	• <400 sph • target 150 sph	85%*	26%	75,000 *(30%)*
Managed Forest	• varied • Target 500-4000 sph	85%*	61%	119,000 *(48%)*
** Open and Managed forests were not disaggregated **into each of their individual components in 1997.***				

The current land in the NDT 4 is slightly above 250,000 hectares and the land classified primarily as Managed Forest, Open Forest, and Open Range.   Since 2000 when the first Blueprint for Action was written, there have been many thousands of hectares treated. The current distribution of these forest types are classified lands are shown in **Error! Reference source not found.**, which nets out the lands that have had ER treatments, have been logged, or have had disturbance.

Table 2 Current State of the Blueprint for Action since 1997

Ecosystem Component	Total Hectares	2013 Distribution	Treated/logged or disturbed	Remaining hectares to treat
Open Range	35,017	14%	24,490	10,527
Open Forest	75,092	30%	55,598	19,494
Managed forest	141,996	56%	N/A	

The overview map of the project areas have been broken down into smaller map subsets of the Rocky Mountain Trench and are provided in the following figures 2, 3, 4, & 5, which show the treatments done to date (including logging and disturbances such as wildfires). The legend indicates Open Range as OR,

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[1] **Blueprint for Action 2006**

Open Forest as OF, and Managed Forests FMER. The slashed/treated, logged or disturbed areas are shown in purple.

Figure 2 North Trench – Ivermere, Columbia Lake, Fairmont Hot Springs ER Treatment Area
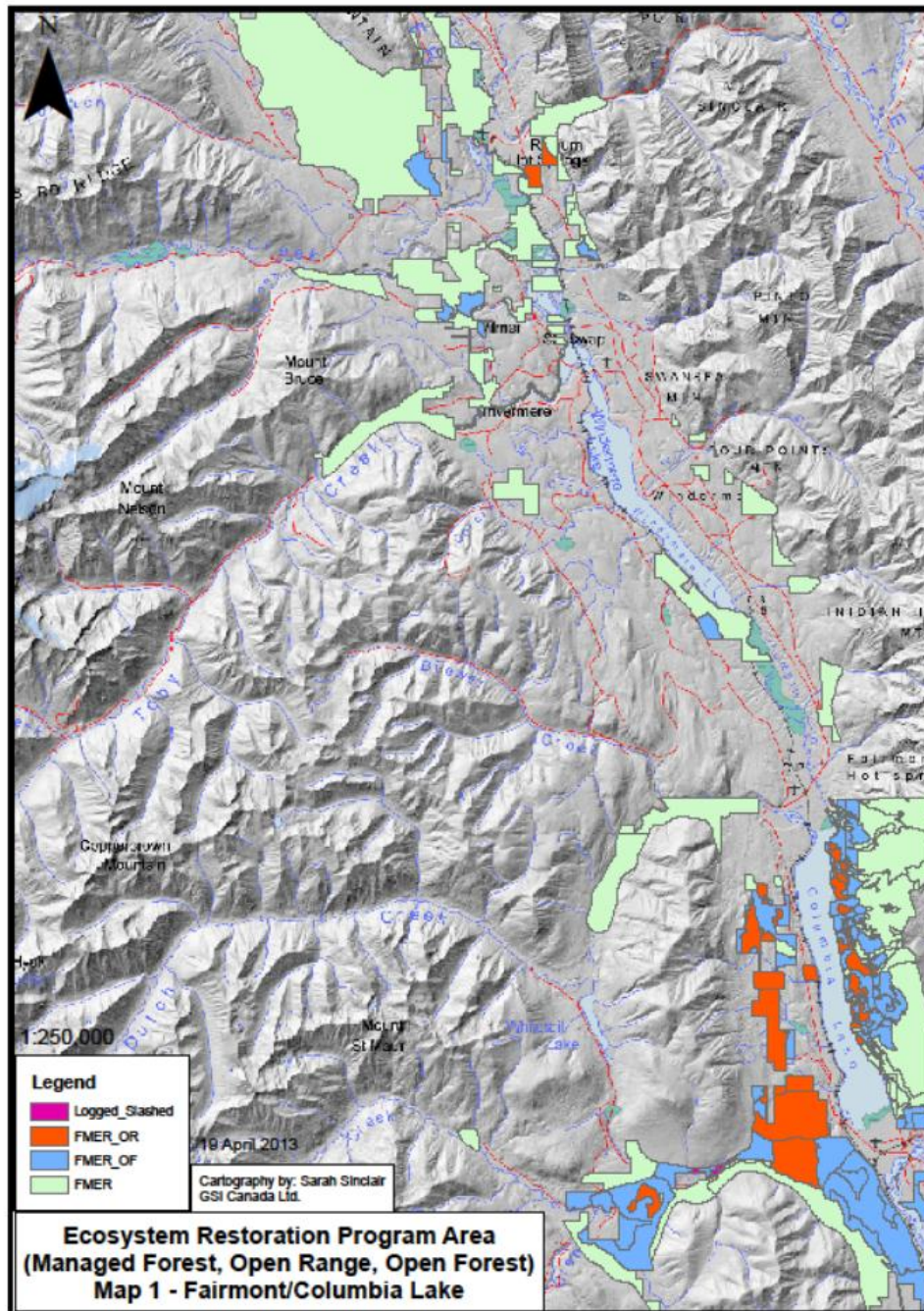
Figure 3 Tata Creek/ Wasa/Skookumchuck ER Area

Legend

- Logged_Slashed
- FMER_OR
- FMER_OF
- FMER

19 April 2013

Cartography by: Sarah Sinclair
GSI Canada Ltd.

**Ecosystem Restoration Program Area
(Managed Forest, Open Range, Open Forest)
Map 2 - Tata/Wasa/Skookumchuck**

1:250,000
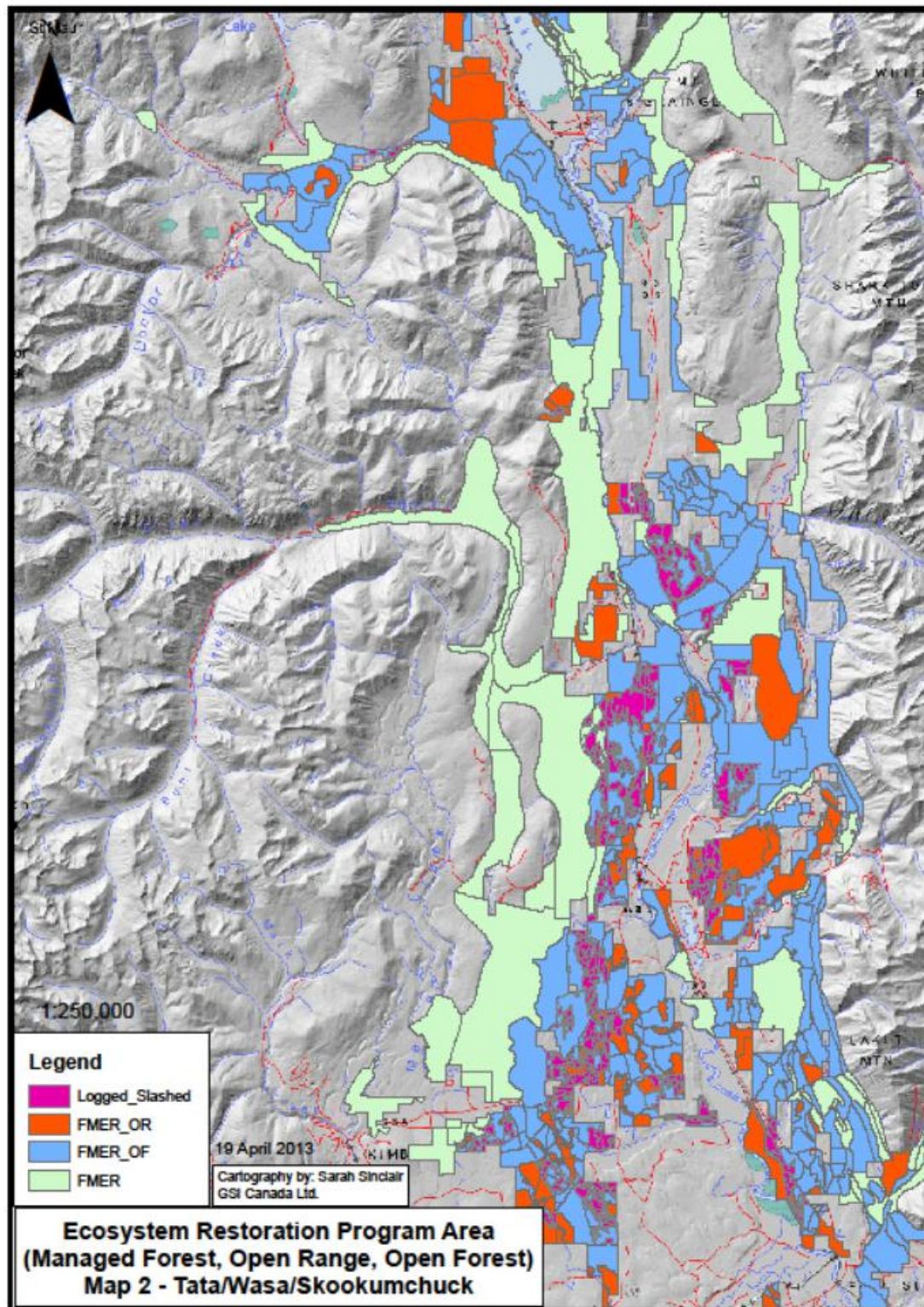
Figure 4 Cranbrook/Fort Steele ER Area

Ecosystem Restoration Program Area
(Managed Forest, Open Range, Open Forest)
Map 3 - Cranbook/Fort Steele

Legend

- Logged_Slashed
- FMER_OR
- FMER_OF
- FMER

1:250,000

19 April 2013

Cartography by: Sarah Sinclair
GSI Canada Ltd.

Figure 5 Galloway/Grasmere ER Treatment Area

Legend

Logged_Slashed
FMER_OR
FMER_OF
FMER

1:250,000

19 April 2013

Cartography by: Sarah Sinclair
GSI Canada Ltd.

**Ecosystem Restoration Program Area
(Managed Forest, Open Range, Open Forest)
Map 4 - Galloway/Grasmere**

2.1 Mastication Treatments

The benefits of mastication as part of fuel treatment regime and ecosystem restoration program are supported by United States literature and studies (see Appendix 1). Thousands of hectares treated using this method as it has been tested and proven as a cost effective method that may be used under certain forest conditions (Halbrook et. al 2005). Mastication can replace hand crews that pile forest slash which then is burned. The inclusion of mastication can reduce emissions, labour costs, and many issues associated with post slash burn environmental restoration. As mastication has not been extensively studied under B.C. conditions, there has been no evaluation to date of the potential for net emissions reductions, which could have a positive effect upon the Rocky Mountain Trench airshed.
A recently published Resource Guide for Fuels Management by Royal Roads University gives the following details about mastication (Hobby, 2010) and an abridged version is provided here in context of mastication.

Mastication involves reducing the size of forest vegetation and downed material by grinding, shredding, chunking or chopping material. Mastication in a context of ecosystem restoration in the Trench is intended to remove overstocked stands that are planned to have regeneration removed to meet prescription objectives for grassland restoration. The use of mastication is intended to remove the overstocked stands and change the fuelbed structure from a vertical orientation to a horizontal orientation, to increase fuel particle surface area to volume ratio, to decrease fuelbed bulk density and increase fuel particle adsorption and desorption rate (gain/loss of moisture). Research has shown that m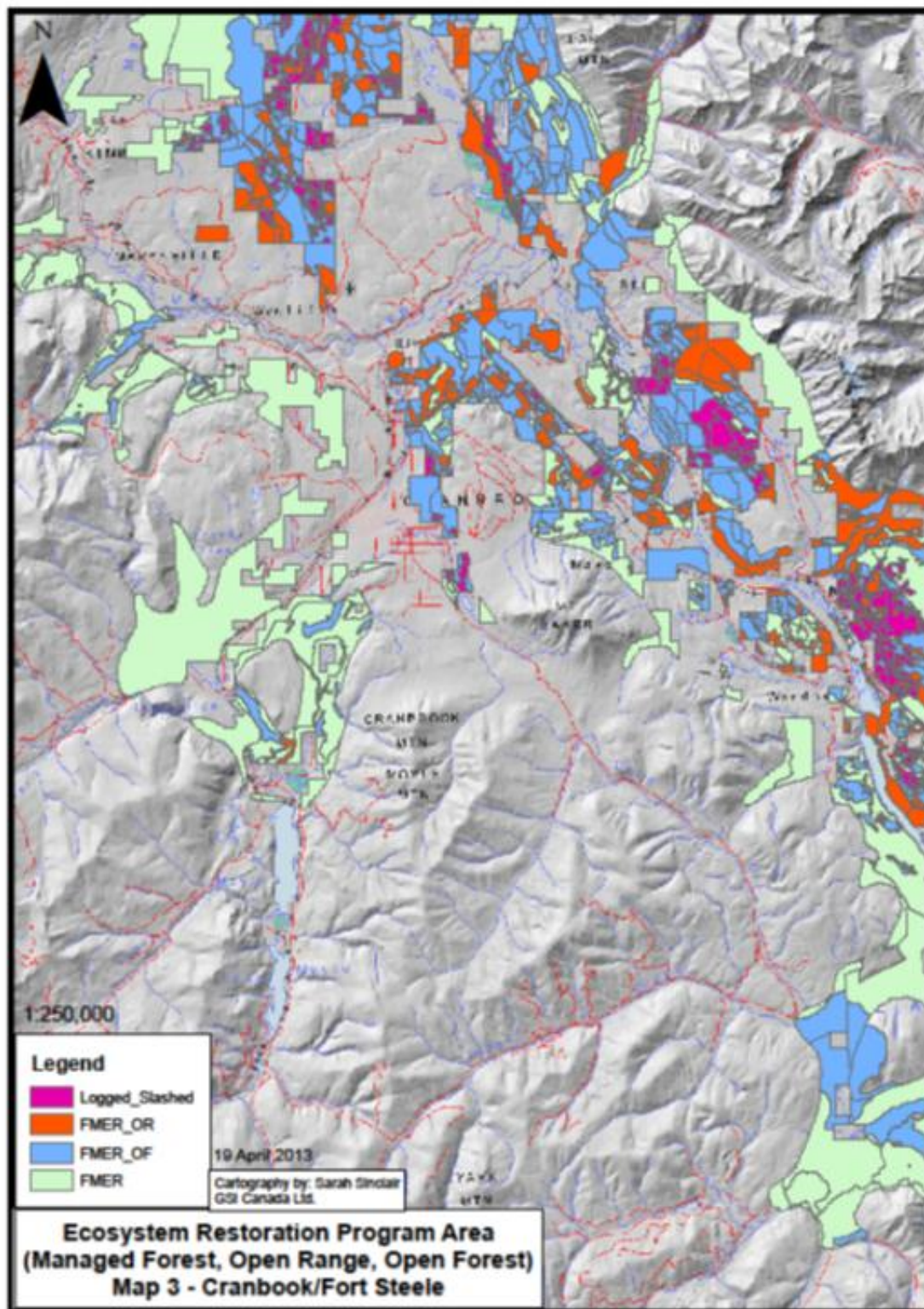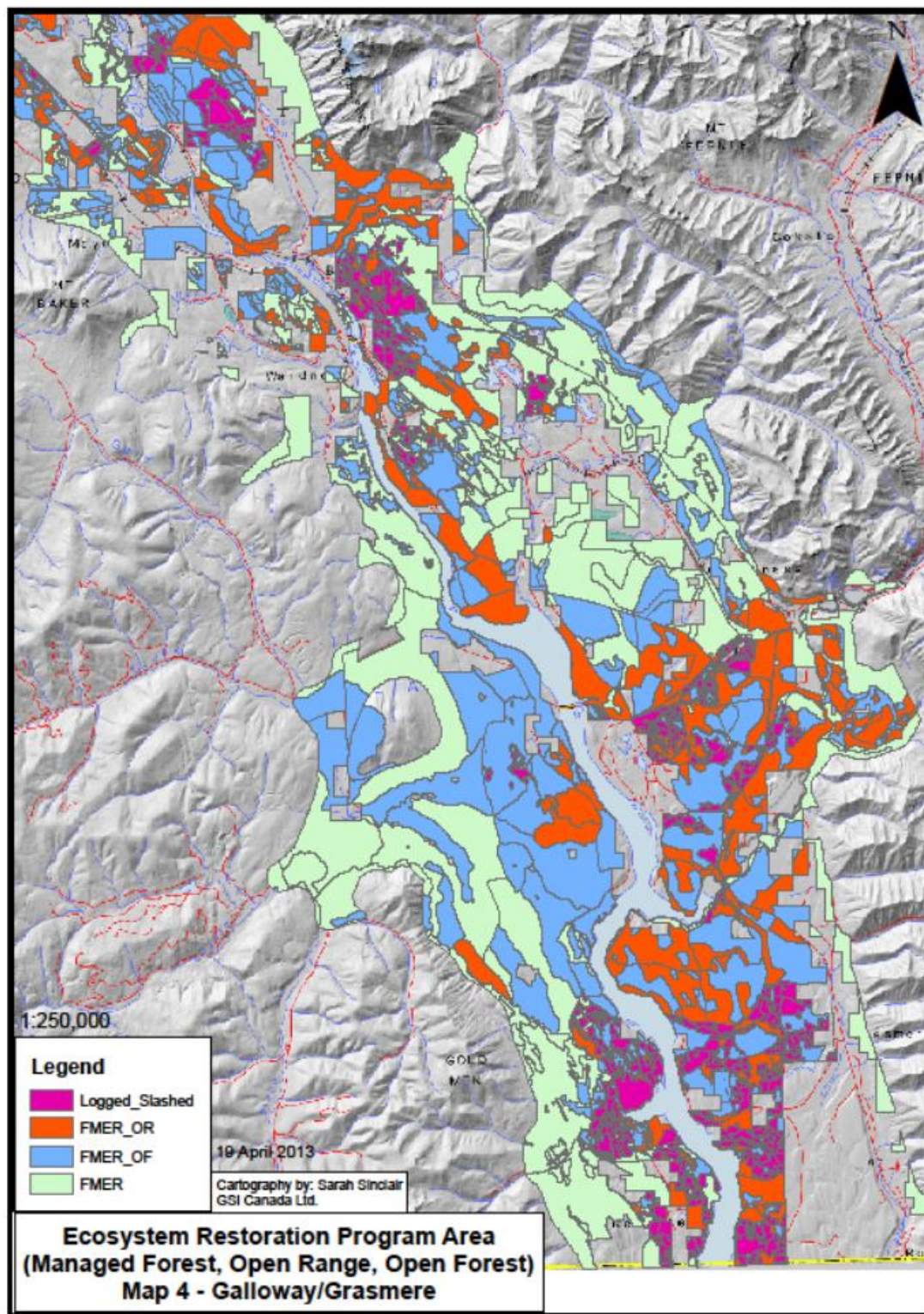astication can effectively chip/grind/mulch masticate surface fuels created from harvests, or can be used to remove standing live or dead trees (Graham et.al 2004). Mastication can also be used to increase the distance between the base of tree canopies and the soil surface (increasing Canopy Base Height), as well as increase wood decomposition rates by insuring wood is in contact with the soil surface (Edmonds and Mara 1998). Mastication equipment has been used to thin stands of trees of a variety of ages and densities (Harrod et al. 2008, Kobziar et. al 2007), mulched shrublands (Bradley et al. 2006), and activity fuels (Graham et.al 2004).

Mastication is being employed as a stand-alone strategy for fuels management, or as a pre-burn treatment followed by prescribed fire. Used as an alternative to prescribed fire, the masticated

fuel bed presents a potential burn severity issue in ecosystems with slow decomposition rates. There have not been any studies to date looking specifically at masticated fuel decomposition rates. An appropriate surrogate is litter and duff. Keane (2008) investigated litter/duff decomposition rates in the northern Rocky Mountains in the U.S., and found the following:

- *decomposition rates were higher for foliage litterfall than for woody litterfall;*

- *foliage loss rate was variable and was tied to site conditions;*

- *slowest decomposition rates were in low elevation, south-facing forests with a highleaf area index;*

- *highest decomposition rates were found on the most productive sites, i.e., low elevation north aspects, or high elevation warm aspects; and*

- *decomposition pattern follows a temperature and moisture gradient.*

Other researchers have found the following as it relates to decomposition rates: nitrogen availability does not control rates of litter decomposition (Prescott 1995); decomposition rate decreases as recalcitrant chemical components become enriched in the litter material (Berg 2000); the degradation rate of lignin determines the overall decomposition rate (Berg 2000); and, the higher the nitrogen concentration (the lower the C/N ratio) the slower the decomposition rate (Berg 2000). Two recent studies have investigated the impact of masticated fuels on burn severity. Bradley et al. (2006) found that masticated fuelbeds in mixed shrub woodland ecosystems resulted in a short to medium term increase in fire intensity and severity potential. They recommend that where utilized, mastication prescriptions should consider greater canopy retention in order to hold soil moisture and increase decomposition rates. Busse et al. (2005) investigated lethal soil temperatures during the prescribed burning of masticated fuels. The authors found that soil moisture, soil depth, and masticated fuelbed depth were key variables. Soil moisture >20%, and soil depth >2.5 cm combined had a significant impact on soil temperature profile.

In summary, mastication holds promise as a tactic for re-organizing fuelbed characteristics and affecting potential fire behaviour and effects. Managers employing mastication need to be aware of the limitations of the practice and the ecological consequences associated with it.

The literature outlines that mastication has been successfully used in lieu of hand treatments, piling and burning woody biomass. Many other documented studies have also outlined the positive effects of mastication treatments on forest ecology and reducing fire risk. Several of these articles listed in Appendix 1 are related to mastication, ecosystem restoration and fuels management; these articles document the benefits of mastication, ecosystem restoration and fuels management treatments .

2.0 Methods

This study researched many aspects of mastication as a tool for conducting ER treatments in the Rocky Mountain Trench Region and there were many project goals and objectives that are referenced in the Appendix 1. This section of the report will outline the methods for each of these goals/objectives

2.1 Ecosystem Restoration Database

After the research team had an initial planning meeting and we determined the work plan for conducting the research project, the team became aware of a larger ER database project that was slated to be developed by the Ministry of Forests, Lands, and Natural Resource Operations in conjunction with the Ministry of Environment. The team met with MFLNRO and MOE and determined that the plan for the ERPro database would be an excellent fit with the mastication and ER project and the smaller database that we had planned to develop. However, as the ERPro database was slated to be developed in a manner that would allow it to be uploaded into the BC Data Warehouse, this caused the mastication research team to evaluate the benefits of this integration and determine what the best plan would be for developing a mastication database that would be able to meet the Data Warehouse requirements. After considering the trade-offs, it was decided to integrate the ERPro database with the ER treatments and Mastication research data. This was done allow future ER planners to make use of the ER inventory and cost data related to mastication in a manner that could assist them with ER planning on a province-wide scale. As this integration was not an originally planned part of the research proposal, and this would require more time and effort to integrate, the research team felt that the integration of the two databases would make the mastication research available to a wider audience and would be of greater benefit to ER planners across BC.

The main function of the ERPro database would be to develop a database similar to VPro, which is another large database for collecting ecological data. Ideally ERPro would be streamlined to have

similar variables and use the appropriate protocol and allow the data to be structured in a manner that would allow the database to meet BC Data Warehouse requirements. One requirement for developing the database is to have a management plan for maintaining the database once developed, and setting up clear procedures for managing and monitor the data. This strategic planning exercise led to the realization that a specific database contractor would need to take on this part of the project and this would take additional funding and support by the Ministries to be able to meet Data Warehouse requirements and be able to reach the goals and objectives of ERPro.

ERPro would be structured to house the data for range monitoring and would have several layers of data that would available through a GIS approach. The layout of the database would mirror how MFLNRO sets up ER treatments. The Ministry sets up their ER Plans and classification system as follows: first, they begin with large scale restoration units, which then narrows down to a smaller logical burn units (LBUs). LBUs are based on common sense and uses roads, ridges or other geographical landmarks or barriers that make planning for prescribed burns effective. The outline of how the flow of data and systems is provided for in **Figure 6**.

Figure 6 ER(Pro) – Ecosystem Restoration Database Structure Overview

Rocky Mountain Trench ER Management Units (Polygons)

Larger / Smaller

| Restoration Unit (RU) | ← - - - | Range Unit (RaU) |

| Logical Burn Unit (LBU) | ← - - - | Pasture (Pa) |

External Data
Forest Cover

| Treatment Unit (TU) | FMER (FMER) | Range Vegetation Inventory (RVI) |

???

MoE

Projects in the Trench

| Ecosystem Restoration | ER Monitoring | Range Inventory | Range Assessment |

???

ER Monitoring (Points)

Monitoring Categories

| Treatment Type(s) | Monitoring Levels | Effectiveness Categories | Effectiveness Indicators |

| Broadcast Burn Harvesting Maintenance Mastication etc. | Baseline Intensive Routine Research | Overstory Veg & Structure Understory Veg & Structure Wildlife Habitat & Biodiversity Ecosystem Health/Status Soils | Overstory Cover Stand Structure Forage Production Shrub Cover Understory Density etc. |

Intensive Monitoring "Data Sheets"

| Plot Characteristics | Stand Structure | Overstory Cover | Understory Cover |
| Culm and Weed Cover | Shrub Cover | Forage Production | Badger Use |

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Once a LBU is identified, it is divided into a Treatment Unit based upon a polygon approach. After the landscape has been classified into treatment units, the next stage is to plan treatments so that real project prescriptions can be developed for restoring the forestlands to an open forest or open range condition – the fundamental goal of the program. When a treatment unit is developed by prescription, the project can be implemented using different ER treatment tools including: mastication or traditional approaches such as slash, pile, and burn. Simultaneously with the development of an ER treatment, each LBU and Treatment Unit makes use of VRI forest cover data, which is merged with the Range Vegetation Inventory model (RVI) by which a range inventory is developed for each treatment unit (pre-treatment) ; once a project completes,   a treatment is then transitioned into a range inventory and range assessment monitoring phase conducted by MFLNRO and MOE.

Once the treatment is complete, this leads to the follow up monitoring points, which are supported by the latter intensive monitoring data sheets that are outlined in figure 6. The current mastication and traditional ER treatment type data would be integrated into ERPro, which would include data for each treatment unit using the following tables at a minimum: forest inventory, treatment cost, types of treatment methods used; additional modules could include an ER treatment method calculator, carbon tracking and emissions monitoring, and a biomass harvesting volume calculator that could be based on prescriptions. In addition, the prescriptions for each treatment unit could also be integrated into the ERPro database for decision makers to have access to prescription details which would be helpful to compare across projects within the province.

2.2 Literature Review

The research team began to review the literature at the beginning of the project and used the team leader's 6,000+ article database to search for articles related to ER and fuels treatments where mastication has been used as a treatment method. In addition, articles related to the ecology of ecosystem restoration treatments and fuels management were also searched including: a library from the Rocky Mountain Trench Natural Resources Society, Google and Melvyl (the UC California system) library database were also searched. The pertinent articles relating to research questions about mastication were reviewed along with other articles on emissions and the BC Forest Offset Protocol (BC Gov. 2013). These sources were used to base the research team's approach to estimating emissions and the impacts from mastication treatments.

2.3 Data Collection

Several datasets were collected in the field for conducting this study including: forest inventory data, mulch depth data, slash pile size data, along with time and fuel usage data from machinery used to conduct two mastication projects that were implemented during the 2012 season.

2.3.1 Forest Inventory Data

Forest Inventory data was primarily received from the Ministry of Forests that had developed prescriptions on 113 treatment areas. The method employed by Ministry staff was to put in a set of cruise plots in each treatment unit that would capture the large trees (mid-point diameter) from 15cm up to >60cm. Staff also counted small diameters trees and classified them into three categories: "regen" (1.5-3cm), "advanced regen" 3-6cm and "pole" (6-12.5 cm). These data were summarized and then used to make emissions estimates , which are calculated as part of the results section of the report.

The research team also wanted to verify trees & volumes per hectare using a more robust fixed plot methodology.   A modified FIREMON method (USDA Forest Service 2006a) was used at Brewery Ridge for Treatment Unit B by which to compare the cruise plots estimated volumes against those determined by the fixed plot method. The FIREMON method counts each tree and measures DBH of all trees greater than 5 cm and collects measurements for tree height and canopy base height. All less than 5cm dbh trees are counted via dot tally method into .5 metre classification units. These data were used to compare volume estimations between cruise plots and FIREMON fixed radius plots for emissions modelling.

2.3.2 Mulch Depth Model

Mulch depth data was also collected using a mulch fuelbed load methodology developed by the US Forest Service Rocky Mountain Research Station (USDA 2006b). Two orthogonal transects 50 meters in length and using a five point measuring method in 1 meters square increments were collected and each square meter average mulch depth were calculated. Data were collected at Brewery Ridge Treatment Unit F and Treatment Unit B. These data were used to better understand the fuel bed dynamics for the planning of follow up burns.

2.3.3 Slash Pile Volumes

As there were still slash piles that had not been burned in the region that were made as part of the Job Opportunities Program in over the 2009-2011 seasons, these piles were measured to give an approximate volume calculation for piles using a method also developed by the US Forest Service (Hardy, 1996). The estimated volume of slash was used to calculate the emissions produced from pile burning and the pile burning emissions model used Blue Sky, which was developed by the US Forest service (USDA Forest Service 2013)

2.3.4 Ecosystem Restoration Treatment Costs

The costs for ER treatments were obtained from MFLNRO staff and the data compiled for the period 2009-2011. When reviewing the data available, it became evident that the measures used to track ER treatment costs had not been consistent over the past 20 years, therefore limiting the research teams' ability to use these data to make robust comparisons over time. As a result, the research team used data from the 2009-2011 period that was collected in a consistent manner where costs were known, which made it easy to compile compare.

For the mastication work done in 2012, this work was tracked on a total cost, cost per hectare and cost per volume measure. These costs will be used in comparison with US mastication work research and is used in this report for comparing with the cost benefit of mastication vs. traditional hand slash, pile and burn methods.

2.3.5 Rancher Invasive Plants Survey

The research team leader attended the Kootenay Livestock Association AGM and made a brief presentation to the group and asked for their support in filling out a questionnaire related to their range. Questions were asked related to their range operations. The questionnaire was developed to determine what impacts invasive plants have had on their operations related to ecosystem restoration treatments in the area (Appendix 6.4). As the survey was handed out to an approximate 25 ranchers at the meeting, the results were poor with only 2 responses which included follow up emails by the KLA and a survey set up on Survey Monkey . Many ranchers do not use computers and a paper follow up letter may have been more effective. In light of the poor return rate, the research team lead called individual ranchers and a local weed contractor to discuss the invasive plant and weeds issue, which is discussed in more detail in the results section of the report. The survey administered is provided in Appendix 5.

2.4 Estimating Emissions for Mastication Treatments

The approach used by the MFLNRO staff to calculate the total forest volumes for ER treatments differs from the standard cruising methods that traditional prism sweep calculations use to estimate basal area per hectare and make estimates for harvest volumes. Unlike the larger trees in a prism sweep, the small diameter trees were counted manually to allow for a basic inventory of regeneration trees that would allow the ER planner to develop an ER prescription. For this study, the volumes for each tree were needed in addition to a count of stems per hectare for trees than 15cm mid-diameter class. In order to derive these volumes, small diameter trees were calculated by using the standard calculation for a cone:

$$Volume = \frac{1}{3}(height)(radius)^2$$

This formula converts to the following formula when it is being used to calculate the volume of trees:

$$Volume = \frac{\pi}{3}(height)\left(\frac{dbh}{2}\right)^2$$

The small diameter trees were not individually measured during the cruise. Instead they were classified into three separate classes of less than 15cm in diameter: regeneration, advanced regeneration and pole sizes. To determine these small tree volumes, a count method following an amended FIREMON Model (USDA Forest Service 2006a) was used based on tree data collected by the research team and these data were correlated with the MFLNRO cruise data that was collected for all treatment units that

have had prescriptions developed.   FIREMON uses a standard height classification methodology for small tree class sizes less than 5cm dbh and this method was used at Brewery Ridge Treatment Unit B, where 10 fixed radius plots were put in and hand counting individual trees was done . These rules of thumb were used to establish an average volume per classification of trees.

Table **3** outlines this height classification methodology employed for this study:

Table 3 Standard Small Diameter Tree Volumes

FIREMON Count Classification Method	Assumed		Cruise Classification Method	Volume m^3	Average m^3
	Height (m)	dbh (cm)			
1	0.25	1	Regeneration	0.00001	0.0002
2	0.75	1.35		0.00004	
3	1.25	1.7		0.00009	
4	1.75	2.05		0.00019	
5	2.25	2.4		0.00034	
6	2.75	2.75		0.00054	
7	3.25	3.1	Advanced Regeneration	0.00082	0.0020
8	3.75	3.45		0.00117	
9	4.25	3.8		0.00161	
10	4.75	4.15		0.00214	
11	5.25	4.5		0.00278	
12	5.75	4.85		0.00354	
Pole	6	10	Pole	0.01570	0.0157

Under the MFLNRO cruise classification method, the amount of trees in each of the three cruise classification categories in table 3 was counted. Additionally, the radius of the cruise plot was also calculated to determine the multiplication factor required to net up from the plot tabulation to arrive at a stems per hectare calculation. For instance, if a plot radius was 5.64 meters then there would be 100 plots in a hectare. Thus to net up to the hectare level using the plot information the volume calculation would need to be multiplied by 100 to get the total volume per hectare.   The final calculation simply took average tree volume per category multiplied it by the number of stems from the cruise count and then multiplied this volume per plot value by the number of plots per hectare. Once calculated, this derives a volume per hectare calculation for small diameter trees, which is what a mastication treatment is primarily focused on.

In addition, in the dataset provided by the MFLNRO, some cruises had multiple plots in a cruise data table (see Table 12 in the Results section), so the multiplication factor had to be divided by the number of plots to arrive at a correct number. For instance if there were five 5.64 radius plots in a treatment

unit, then the multiplication factor would be 100 divided by the 5 to arrive at multiplication factor 20 times the number of stems recorded in the plot. Determining Mastication Treatment Units

Figure 7 describes how the treatment methods are derived from the forest inventory data for any given treatment unit. Essentially, a unit would either be logged or not logged. Whether any given unit was masticated or piled, slashed and burned, largely depended on the number stems per hectare. The larger the number of stems per hectare, the more likely the most appropriate treatment would be to masticate.

Figure 7 Hectare Treatment Rules
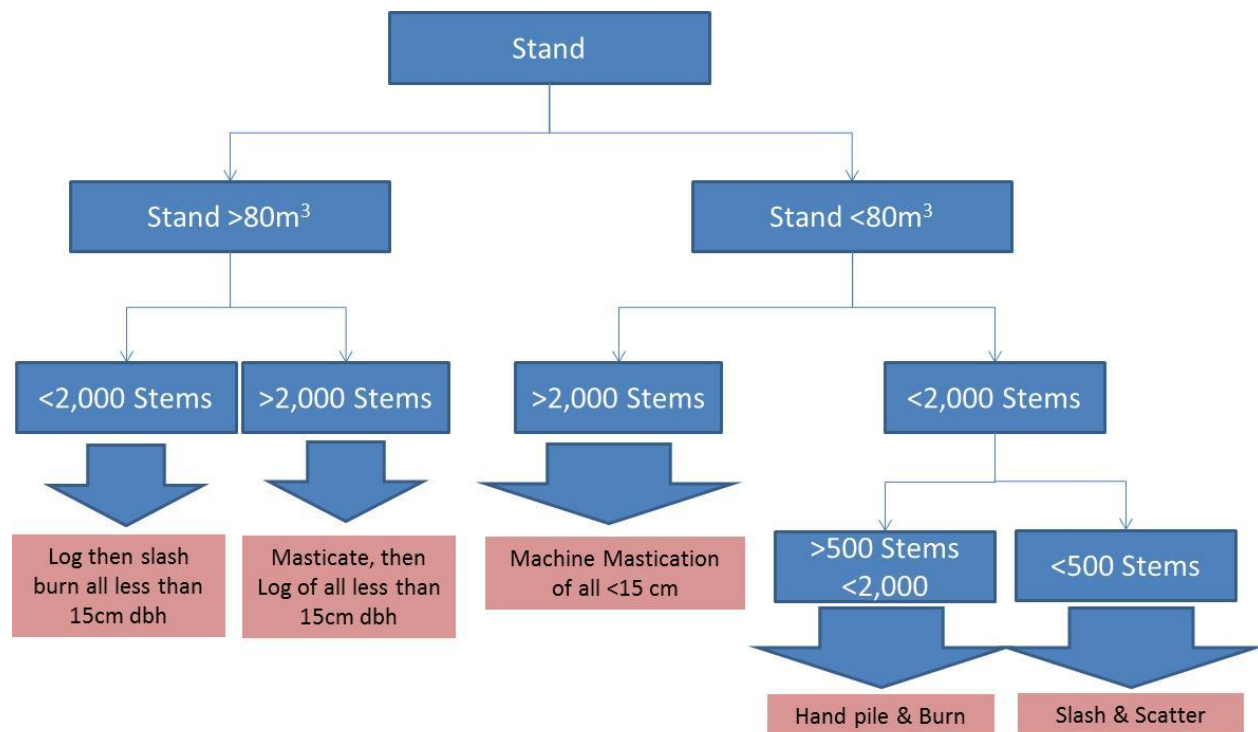
The treatment methodology determines whether any given treatment unit hectare's less than 15cm diameter trees will be masticated, slashed and burned, or slash and scattered in order to meet ER stand stocking objectives. Then emission factors are applied to the pre-calculated volume, calculated as described above, in order to determine the emissions from the various treatments on a per hectare basis. These per hectare calculations were then used to determine the difference in emissions between a slash, pile and burn treatment vs. a mastication treatment.

2.4.1 Calculating Emissions from Mastication Treatments

Once the volume and number of stems per hectare are established and the hectare treatment rules are applied to determine the appropriate tree removal for each treatment unit based on the prescription objectives of creating open forest (<400 stems per ha with a goal of 150 sph), or open range (<75 sph with a goal of 25sph). Once the mastication treatments units are estimated for the volume of biomass removed in cubic meters different emissions factors are applied based on whether the determined treatment was to slash, pile and burn or masticate. The emissions factors for mastication were drawn from a California study on the greenhouse gas emissions from down and decaying volumes of forest biomass (Sierra Nevada Conservancy, 2008). The mastication related machine emission factor was drawn from recorded fuel usage data collected during the mastication project that was done during 2012 in the Trench region. The diagram in Figure 8 outlines the emission and volume estimation process.

Figure 8 Emissions and Volume Estimation Process

Cruise:
Number of Regeneration, Advanced Regeneration and Pole tree stems are manually counted along with prism sweeps

Volume Calculation:
Basal area & cone formula, assuming volume per class and multiplied by number of stems per plot volume per plot is used

Net up Plot Volume to Hectare:
Using the volume calculations per plot these volumes are netted up to a volume per hectare.

Emissions Calculations:
A decision rules base on number of stems and volume per hectare determines treatment for the <15cm diameter class of either be slash &burned or mastication. An estimated emission factors per volume is applied to calculate the emissions per cruised hecatre.

Application to GIS Data:
The various cruised hectares are distributed to hectare type of either low, mid or high density stands. These classes of stands provide a representative profile that is then used across the entire study area to estimate emissions for a full treatment program.

2.4.2 Calculating Emissions from Traditional ER Treatments

The emission factors related to slash pile have been calculated using US Forest Service's BlueSky Playground tool http://www.getbluesky.org/ (USDA 2013). Data was collected on lands owned by the Nature Trust, near Kimberley, BC, where hand piled slash piles were waiting to be burned on the Cherry Creek treatment unit in 2012. Thirty four random slash piles were measured and slash volumes per pile were estimated, which were then averaged. These slash pile averages were used to calculate emissions on the various ER Treatment units that were completed over the 2009-2010 period under the Job Opportunities Program and the Community Adjustment Fund projects. The emission factors used to determine slash pile treatment emission are presented in the results section of the report.

2.4.3 Calculating Emissions from Mastication Treatments

To estimate mastication emissions, a Placer County, California study's findings (Sierra Nevada Conservancy, 2008) were used to establish an emission factor for methane released when forest residues were left down to decay, commonly referred "down and decayed volumes". These emission factors were applied to treatment hectare volumes of material removed from the stand after the decision tree model was used to determine which stands were to be logged, masticated, slashed, or a combination. The emission factors are presented in Table 4 below.

Table 4. Mastication Emissions in Tonne per Cubic Meter of Biomass Removed

Mastication	Machine	TOTAL
$CO2e/m^3$		
1.7745	0.0117	1.78622808

The net result is each of the cruised forest hectares has an emission and volume estimate. These are then grouped into three classes: high, mid and low density areas. Averages are established for each class are then used to establish the general emission from a treatment regime on a treatment unit area.

3 Results

3.1 Cost Analysis of ER Work in the Trench

The research team collected data relating to the ER work conducted over the past two decades and the team after close examination of the data, decided that due to the highly irregular reporting of these data, that only the more recent 2009-2012 data would be comparable with rigor and therefore the results and analyses of these data are felt to be more accurate and allows the research team to better report accurate ER treatment costs.

In addition to the traditional treatment methods and historical ER treatment cost data, over the 2011-2012 period, the Rocky Mountain Trench Society administered two Mastication pilot areas near Fort Steel and Premier Ridge, within the Rocky Mountain Resource District. Funding was obtained from the Land Based Investment Account and the BC Fish and Wildlife Compensation Fund. The prescriptions for these treatment units at Brewery Ridge and Premier Ridge outlined the use of mastication as a treatment method and these two projects were either direct awarded or tendered based on the requirements of the funding sources. These projects were tracked and are presented in the next section.

3.2 Ecosystem Restoration Cost Analysis

Over the past twenty years, there have been many ER treatments that have been done and there have been many reports for these ER projects. However, due to accounting procedures and methods employed, the true costs associated with ER treatments have been difficult to derive due to internal costs that were not valued as part of these treatments, which makes it difficult to track and make comparisons between projects and over time. Over the 2009-2011 period, there was a major opportunity for conducting ER treatments as part of the Job Opportunities Program and Community Adjustment Fund programs, which allowed the ER program to treat many thousands of hectares in the region over this period.

Many of these treatment costs were more accurately tracked. Nonetheless, these contracts were not competitively bid contracts so their costs were likely higher that may be expected within a competitive context.

For the ER treatments that were done through hand slashing, piling and burning, there were over 33 projects that were conducted in the Trench over the 2009-2011 period and the costs for these treatments are provided in Figure 7. The total treatment area was 2,978 hectares over the period.

Figure 7. ER Treatment Costs (JOP and CAF) projects over the 2009-2011 period

Hand Slashing Costs ($/ha)

Observations n=33
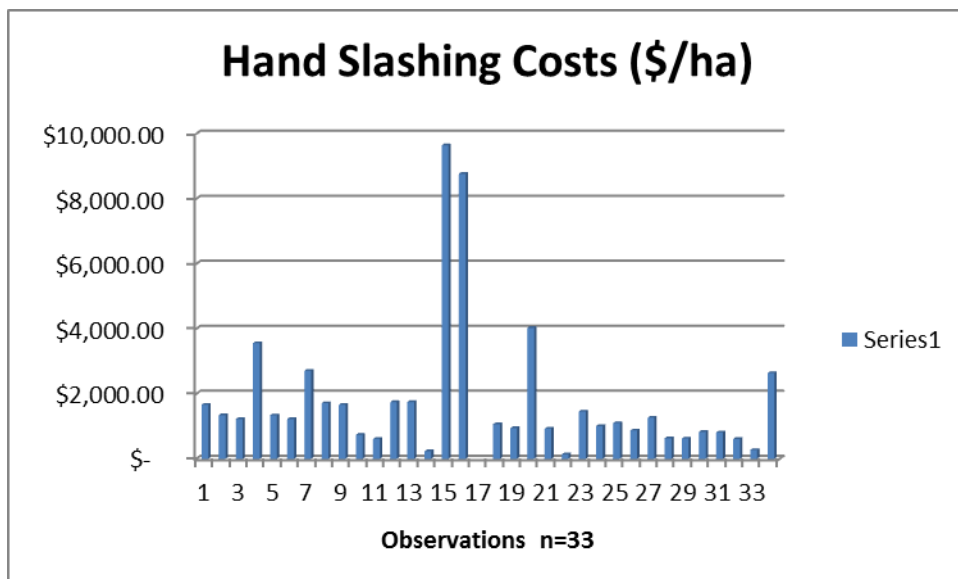
The resulting costs and were compiled as part of the annual reporting for the funders. The higher cost treatments were for treatment units with steep slopes and of denser stands which required more labour.

Pile burning costs were also derived and these costs were compiled over the 2009-2010 period. The costs for each unit were aggregated and are summarized for pile burning in Figure 8.

Figure 8. Pile Burning Costs for Ecosystem Restoration Treatments

Pile Burning Costs $/ha

n=7
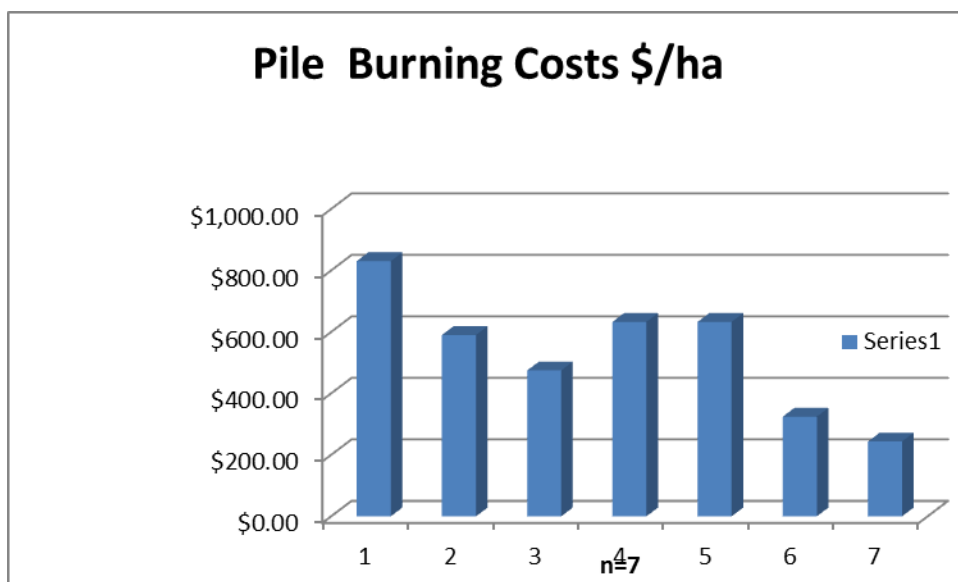
For these ER treatments, the pile burning costs were tracked and they were typically aggregated with multiple units. As such the pile burning costs were estimated to range in cost from $243-830 per hectare and averaged $532.

In addition to hand slashing, piling, and burning, these treatments required follow up monitoring and seeding the burn rings, which cost an additional $40-120 per hectare, which averaged $77 (pers. Comm. Dan Murphy, April 2013).

Therefore in aggregate, the total cost for hand treatments of these units was as follows:

Table 5 Treatment Costs

Treatment component	Cost/ha Low	Cost/ha High	Cost/ha Average
Hand slash/pile	$271	$9,643	$1,791
Pile burn	$243	$830	$532
Seeding*	$40	$120	$77

* this was to rake the burn rings and spread seed to prevent invasive plants and re-establish vegetation

From the project lead's previous work in the Rocky Mountain Trench, the following background was given in the WUI Resource Guide (Hobby 2010).

> There has been considerable research in the United States on wildland urban interface fuels reduction regimes and harvesting methods (Fried 2000, USDA 2005), with many similar issues that are faced in Rocky Mountain Trench and across British Columbia. The University of California Cooperative Extension has extensively studied various treatments of small diameter stands and has conducted economic analyses on fuels treatments using various specialized machinery adaptations (University of California Cooperative Extension 2001). Much of the research conducted by the University of California has focused on using innovative machinery and methods to treat this classic problem in the North American West. Extensive time and motion analyses have been conducted for estimating costs of treating fuels. However, these methods and studies have not been adequately replicated in British Columbia to be able to determine the least cost methods for maximizing fuels treatment benefits. In addition, studies by FERIC (Mac Donald 2006) estimated various costs of biomass recovery in lodgepole pine beetle-killed context and provided many details about harvesting thresholds between merchantable and non-merchantable harvesting methods.

In addition to traditional logging as a means of reducing fuel loads, there are many treatment options available for fuels reduction, which include:

Table 6 Treatment Types

Treatment Types
Mastication
mastication/burn,
Cut/Pile/Burn
Cut/Pile/Sloop Burn
Slash & Prescribe Burn

These methods all have trade-offs, which will be briefly discussed. Prescribed burning is generally the least expensive option for fuels reduction treatments. However, with the fuels hazard levels typically at a high level due to the departure from historical fire regimes, this tool is not a viable alternative until the fuel loads are reduced by other means.

In a WUI context, the costs (Table 8) associated with these methods vary and may range according to the USDA (2005) as follows.

Table 7 Selected fuels treatment methods and approximate range of costs

Treatment	Cost range ($USD)
Prescribed burn	$86-741/ha
Mastication in the woods	$247-2,470/ha
Cut/pile/burn	$247-1,852/ha
Cut/skid	$30-40/bdt
Cut/skid/chip	$34-48/bdt

3.3 Mastication Pilot Projects – Brewery Ridge and Premier Ridge

Over the 2011-2012 period there were two areas identified and funding secured to test mastication machinery for various prescriptions in the Rocky Mountain Trench.

3.3.1 Brewery Ridge Treatment Unit (TU) F

Brewery Ridge there were two treatment areas, TU F was done in 2011 and consisted of a very thick stand of approximately 20,000 stems per hectare (sph), ranging from 10,000, to 40,000 sph. This unit was a non-typical block that was tested for the mastication equipment and costs were $4,017 per hectare, which is higher than US averages and could have possibly been more efficient with the use of a larger machine. In addition, the depth of mulching on this site was a potential issue regarding nutrient cycling as the average mulch depth was greater than 5cm.   Treatment Unit B was a steeper and not as heavily stocked unit with approximately 1,200 sph regen, 2,300 sph advanced regen and 700 sph pole size of primarily Douglas Fir and Western Larch.

The Brewery Ridge project was an beginning ER trial for using mastication as a treatment type and there were some good lessons learned. TU F was a very dense stand as mentioned and the Cat 262C skidsteer with front mounted rotary head was used on this machine. The unit was flat and there were very dense pole size trees that were removed. While the unit was completed and it met program objectives, the machine was too small and costs per hectare were higher than anticipated as this unit was paid by the hour.

Figure 9 Caterpillar 262c Skidsteer

3.3.2 Brewery Ridge Treatment unit B

A detailed ER Prescription was developed for Brewery Ridge and the objective for the mastication equipment was to mulch or break up trees less than 20 cm in diameter at the butt or 15 cm diameter at breast height (mainly Douglas fir, ponderosa pine and lodgepole pine) and trees greater than 1.5 cm in diameter. Also, to distribute the mulch evenly with chip debris less than 15 cm in length and width, and a maximum soil disturbance allowance of 5 percent.

Treatment Unit B is a mature Douglas fir (Fd) stand with an estimated 338 stems per hectare of Douglas fir from 15 to 40 cm diameter breadth height (dbh). The understory consisted of 1200 stems/ha of Fd regen, 2300 stems/ha of Fd and Western Larch (Lw) advanced regen, and 700 stems/ha of Fd and Lw poles. TU B is a gross area of 50.1 ha and a net of 39.3 ha was treated, a map of the area is shown as **Figure 11**. In 2011, 4.4 ha were treated by mastication and 34.9 ha in 2012.

The treatment unit was a challenging not because of the density of the stand, but due to the slopes and rocks. For this unit, the Lam-Trac 8290 was used and the machine was excellent on steep slopes, which it could handle up to 60%. However, with the setup of the machine, and due to the amount of rock that was on this treatment unit, the operation was challenged by the constant rock issues and nearly one third of the contract was spent replacing the teeth on the unit's rotary head.

Figure 10 Lam-Trac 8290

Figure 11 Mastication Units for Brewery Ridge TU B and TU F

WTP ID	Area (ha)
WTP 1	28.12
WTP 2	0.05
WTP 3	0.14
WTP 4	0.08
WTP 5	0.08
WTP 6	0.12
WTP 7	0.07
WTP 8	0.04
WTP 9	0.05
WTP 10	0.46
WTP 11	0.05
WTP 12	0.12
WTP 13	0.08
WTP 14	0.19
WTP 15	0.18
WTP 16	0.12
WTP 17	0.18
WTP 18	0.42
WTP 19	0.06
WTP 20	0.09

ECOSYSTEM RESTORATION MAP
WildHorse - Lewis Creek Brewery
SLASHING CONTRACT
ER12-293-021
Rocky Mountain Forest District

ECOSYSTEM UNIT SUMMARY

ECOSYSTEM UNIT	TU A	TU B	TU C	TU D	TU E	TU F	TU G
STANDARD UNIT (OR: Open Range) (OF: Open Forest) (MF: Managed Forest)	OR	OR	OR	OR	OR	OR	OR
TREATMENT METHOD (TH: Thinning) (P: Piling) (SK: Skidding) (PB: Pile & Burn) (SL: Slashing)	No Treatment	SL	SL	SL	No Treatment	SL	SL
FALLING METHOD (MF: Mechanical Fall) (HF: Hand Fall) (PF: Push Fall)		HF	HF	HF		HF	HF
ALLOWABLE DISPERSED SOIL DISTURBANCE %							
NP & RESERVES AREA (ha) — Roads	6.0	3.4			5.5	0.3	1.8
WTP		1.4		0.7	28.1		0.8
Pipeline R/W							
SUB-TOTAL	6.0	4.8	0.0	0.7	33.6	0.3	1.8
NET	27.6	45.3	5.3	16.8	116.1	2.1	6.8
GROSS	33.6	50.1	5.3	17.5	149.7	2.4	8.4
TOTAL NET (ha)	220.0						
TOTAL GROSS (ha)	267.1						

CRITICAL SITE FACTORS

Potential Archaeological Areas - Harvest on dry/frozen ground or on sufficient snowpack.

Legend:
- Proposed TU
- Splitline Between Treatments
- GPS Station
- Existing Landing
- Roadside Decking Area
- Proposed Landing
- Wildlife Tree Reserve Area
- Reserve - Other (Biodiversity Reserve)
- Potential Archaeological Areas
- Private Land

Field References (Ribbon/Paint):
Pink - Ecosystem Restoration
Blue - Ecosystem Restoration
Triple Orange-glo
Pink-glo/black letters - WILDLIFE TREE RESERVE
Pink-glo/black letters - RESERVE ZONE

- Gravel Road
- Forest Service Road
- Paved Road/Highway
- Trail
- Fence
- Cattle Guard
- Gate
- Water Trough
- Badger Den

Streams and Wetlands:
- Riparian Streams
- Riparian Wetland (Class W1-W4)
- Lake (Class L1-L4)

Contours:
- Index - 100m interval
- Intermediate - 20m interval

Figure 12 Brewery Ridge Treatment Unit B

Area Summary (ha)	
Roads	3.4
WTP	1.4
Not Done	0.6
Too rocky	1.9
Too Steep	1.1
2011 masticate & trails	4.4
Removed by Ministry	2.4
SUB-TOTAL	15.2
NET	34.9
GROSS	50.1
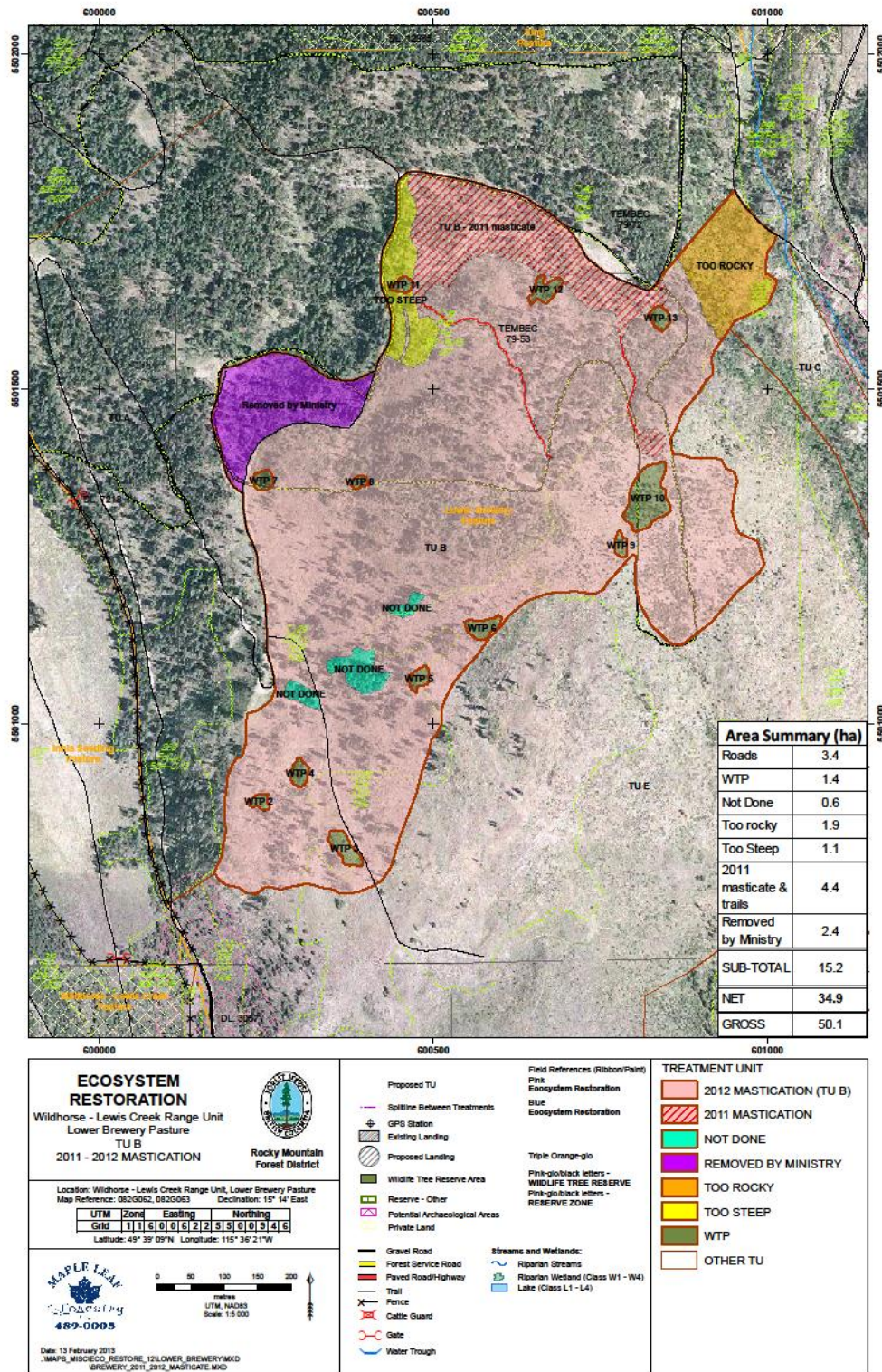
3.4 Premier Ridge Treatment Units

Premier Ridge was a second mastication treatment unit area where two different contractors work using excavators with a 52" rotary mulching heads were used. These machines were very different from the Lam-Trac and the Cat 320 Premier ridge was similar to Brewery Ridge Treatment Unit B, and the contractors had to maneuver around rocks and deal with similar stand conditions. At Premier, a total of 80+ hectares were treated.

Figure 13 *Cat 320 Excavator with 52" Rotary Head*

Figure 14 Premier Ridge Mastication Treatment Unit

ECOSYSTEM RESTORATION
Wolf - Sheep Range Unit
Quartz Pasture
MASTICATION CONTRACT MAP

Rocky Mountain
Forest District

Location: Wolf - Sheep Range Unit, Quartz Pasture
Map Reference: 082G082   Declination: 15° 14' East

UTM	Zone	Easting	Northing
Grid	11	6 3 6 9 8 0	5 4 6 0 7 7 0

Latitude: 49° 51' 32"N Longitude: 115° 39' 15"W

MAPLE LEAF
LOGGING
489-0005

Date: 27 September 2012
..\MAPS_MISC\ECO_RESTORE_12\WOLF-SHEEP\MXD\QUARTZ_MASTICATE.MXD

▭	Proposed TU
⁓	Splitline Between Treatments
⊕	GPS Station
▨	Existing Landing
◯	Proposed Landing
▨	Wildlife Tree Reserve Area
▨	Reserve - Other
▨	Potential Archaeological Areas
	Private Land
—	Gravel Road
—	Forest Service Road
—	Paved Road/Highway
—	Trail
✕	Fence
✕	Cattle Guard
◯	Gate
⁓	Water Trough

Field References (Ribbon/Paint)
Pink
Ecosystem Restoration
Blue
Ecosystem Restoration

Triple Orange-glo

Pink-glo/black letters -
WILDLIFE TREE RESERVE
Pink-glo/black letters -
RESERVE ZONE

Streams and Wetlands:
⁓ Riparian Streams
Riparian Wetland (Class W1 - W4)
Lake (Class L1 - L4)

Unit	Hectares
TU B - 1	0.6
TU B - 2	1.1
TU B - 3	0.8
TU B - 4	3.1
TU B - 5	11.0
TU B - 6	0.2
TU B - 7	2.1
TU B - 8	0.9
TU B - 9	1.2
TU B - 10	0.6
TU B - 11	0.4
TU B - 12	0.4
TU B - 13	1.5
M1	1.6
M2	2.6
M3	4.2
M4	30.3
M5	16.0
M6	35.8

Mastication Trial Results

The completed work done at Brewery Ridge and Premier Ridge was a good test of the various mastication machines to explore their ability to treat ER blocks in an effective and efficient manner. While these two treatment units are not enough data points to make statistical inferences, they do fall within the range of variability from the USA studies that were previously referenced in the fuels management guidebook (Hobby 2010). Both of the these treatment units had various challenges for the equipment and the end result was that these machines were mostly acceptable for meeting the ER objectives for these treatments. The main lesson learned is that there is a right machine for the right job and that it is the prescription developers' job to select the best machine that is efficient and effective to complete the treatment. The lessons and results from these treatments are given in table 9.

Table 8. 2010-2012 Mastication Trial Results

Machine/head	Handle Slope >30%	Rock issues	Productivity Rate/day	Cost effectiveness	Quality of end product
Cat 320 excavator with 52" disk mulcher	No problem up to 50%	Could see rocks from operator cab, just had to leave higher stumps in rocky areas	1.5-2 ha	$1500/ha	Fair to Good; stumps in rocky areas more of an aesthetic problem; keeps atv's off site
John Deere excavator with twin rotary 52" mulching blade	No problem up to 50%	Could see rocks from operator cab, just has to leave higher stumps in rocky areas	1.5-2 ha contractor	$1800/ha	Fair to Good; had little more trouble with larger trees near 6 inch DBH
Lam-Trac 8290 front mounted disk mulching head	No problem up to 60%	Couldn't see rock very well from operator cab, excessive tooth replacement at significant cost	1.75-2 ha	$1560/ha	Poor to fair; had to hire hand slashing crew to bring quality up to contract standards
Jobkat Cat 262 C Skid-Steer	Problems over 20%	Operator could see surface rock most of the time	N/A	$2173/ha	Good on slopes less than 20% and hand slash piles

3.5 Mastication vs. Hand Slash and Burn Cost Comparisons

From the literature and from the 2011-2012 mastication trials performed in the Rocky Mountain Trench, it appears that mastication can provide an effective and efficient means by which to treat ER blocks.

The cost of the Brewery Ridge and Premier Ridge mastication units ranged from $1,500 - $2,273 per hectare, which is comparable to the hand slashing and piling, burning, seeding costs which together averaged $2,400/ hectare and ranged from $271-9,643.   A key benefit for using mastication as a treatment tool is the fact that mastication eliminates the need to burn, which has become increasingly difficult to complete as there are few good burn days per year that allow for burning. Another key advantage for mastication is the fact that eliminating pile burning can reduce the potential invasive plants issues which can be caused by burning slash piles.

3.6 Emissions Comparisons between Mastication and Slash and Burn ER Treatments

The emissions comparisons between mastication and traditional slash, pile and burn treatments indicate that while mastication will eliminate most all of the particulate matter that is associated with ER treatments by not open burning, one issue in terms of emissions is that the material masticated will stay in situ and decay. When evaluating the long term decay functions for down woody debris, these materials offgas methane CH_4 which is 21 times more potent than CO_2 (BC Govt. 2013) Therefore, the main issue is the fact that CO_2^e emissions are higher for down and decaying biomass produced from mastication relative to the open burning of slash pile biomass. However, the total amounts of greenhouse gas emissions in terms of tonnes of CO_2^e as an ER program, are very small overall as the tonnes of masticated biomass are typically lower than 20 cubic metres per hectare, which would lead to minimal amounts of CH_4 being produced. The down and decaying biomass CO_2^e may be overshadowed by the overall net carbon balance that ER treatments would arguably produce. It is the researcher's hypothesis that net additional sequestered carbon (above and below ground) due to the silvicultural release factors affecting tree growth and other understory vegetation, would be greater within a few years than the NH_4/ CO_2^e short term effects. As these carbon values associated with ER treatments are uncertain and not well documented or understood, therefore these questions warrant further research.

For the mastication emissions, there were no particulate emissions modelled as there was no open burning. However when the calculation for CH_4 was converted into $CO2^e$, this increased the $CO2^e$ per cubic metre to an estimated 1.77 Tonne $CO2^e$/$M^{3.}$ for biomass masticated and left in the block. This figure per cubic metre is believed to be an overstated $CO2^e$ value as the mastication units will not be left for 10 years typically to decay, but will have follow up prescribed fire burns, therefore, if a follow up burn is done within 2-3 years of the mastication treatment, then $CO2^e$ would be significantly lower as some of these fuels would be eventually consumed. One factor that was not included in the total emissions calculations for burning piles was the impacts of using diesel to light these piles. As diesel would also create addition emissions, these calculations were not included in the model, but would make the differential lower that currently estimated between mastication and slash pile burning.

Aggregate Emissions were estimated for the slash piles that there was data collected over the 2009-2011 period. The estimates were derived from running the piles through Blue Sky and are given in . Total emissions for the slash piles are estimated on a per hectare basis to give an indication of emissions averages per hectare.

Table 9 Average Emissions from Biomass Slash Pile Burning per Cubic Metre of Biomass

CO	CO_2	CH4	TOTAL CO2e	PM	PM2.5	PM10	NMHC
			$tonnes/m^3$				
0.002091	0.091708	0.000153	**0.097666**	**0.000603**	**0.000374**	**0.000428**	**0.000123**

For the Mastication Units, the decision tree method that was explained in the previous section and discussed in **Figure 7** allowed the research team the ability to analyze which stands that the Ministry had under prescription and the mastication decision tree model was used to determine which treatment units would be candidates for mastication. **Table 10** shows the output from the analysis used to calculate which treatment type should be used for various stands. The analysis predicted that there were 22 masticate first, then log stands, 8 log stands and then slash and burn; 24 units that require mastication only; 31hand slash and scatter, and 28 hand slash and burn.

Table 10 Predicted ER Treatments by Type for Treatment Units Under Prescription and Inventoried

Treatment		
Log	Masticate First	22
	Slash Burn After	8
No Logging	Machine Masticate	24
	Slash & Scatter	31
	Hand Slash Burn	28
	TOTAL	113

3.6.1   Mastication Emissions Predictions

Emissions predictions were made for treatment units that were under prescription, or have had forest inventories collected for these units. The presentation of these results has been calculated by extrapolating the forest cruise inventories into volume estimates as previously discussed and the cruise plot data is shown in table 12, and the cruse calculation of cubic metres per hectare volumes are given in table 13. As full cruise data nor a full count fixed radius plot method were not available to make the emissions calculations, the accuracy of the emissions calculation can be viewed as a coarse scale estimate, which will be refined over the next year as the research team has requested access to fixed

radius count plot data, which was unavailable to the research team in 2012. Once these data are used in the model, the emissions estimates for these treatment units will be more accurate.

Calculating all the ER treatment areas that were identified in the GIS layers for Open Forest and Open Range within the Blueprint for Action NDT4 stands were first netted out for logging and disturbance using our methodology to determine the areas possible for mastication treatments. Projecting the remaining treatment units' timber and non-merchantable volumes for Open Forest and Open Range treatment units based on Forest Cover data, were not deemed appropriate for our analysis and therefore for this report, the emissions modelling was limited to the treatment units that had appropriate forest inventories or prescriptions completed. Only a subset of the 17,000 hectares that cruise plot data has been collected by the MFLNRO was used in the analysis as over half of the cruise estimates have yet to be field checked. Therefore, within the 17,000 hectares of planned treatment units, a smaller subset of 8,526 hectares that has been laid out for ER treatments with accurate cruise plots that have been field checked and of the 8,526 hectares, 5,277 hectares have full treatment prescriptions written. These treatment units with good inventory data were used for estimating stand volumes, associated mastication vs. slash and burn treatments emissions trade off estimates. It should be noted that the total emissions volumes presented may have significant variations and while useful for a coarse scale comparisons, the research team plans to collect better forest inventory data as mentioned that will improve the model sensitivities and provide lower emissions variability.

3.6.2 Slash and Burn Emissions Predictions

When analyzing slash and burn operations that have been the typical treatment methods in the past, the projects under the Job Opportunities Program (JOP) and Community Adjustment Fund (CAF) were calculated using the average slash pile emissions factors from the previous emissions calculations that were converted to a bone dry tonne based on .   The estimated slash pile bone dry tonne volumes are estimated in Table 14 and the associated emissions using Blue Sky are given in table 15.

3.6.3 Comparing Mastication Emissions to Slash and Burn Emissions

The ability to compare mastication emissions against traditional slash and burn emissions is challenging to present as the real issues at hand are the fact that mastication reduces particulate emissions almost completely (excepting machine exhaust particulates) and while the NH4 offgas issue of down and decaying biomass releases a significantly higher amount of emissions over time. Therefore, one could argue that if these emissions could be compared with the annual increased carbon sequestration in above and below ground biomass that is additional to the base case for ER treatment stands, the net CO2e effects from the mastication treatments would theoretically have a net carbon sink effect over time. The resulting comparative emissions for all treatment units are provided in table 16.

Table 11 Cruise Plot Data Table Example (Brewery Ridge TU- B)

Treatment Unit B

Stem count — 5.64 radius plot — Midpoint of diameter class — Number plots 1.0

Species	Regen	Advanced Regen	Pole	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	
Douglas fir	12.0	20.0	5.0	1.0	2.0	2.0	0.0	0.0	1.0						
Ponderosa Pine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0						
Lodgepole Pine	0.0	0.0	0.0	0.0	0.0	0.0									
Larch		3.0	2.0												6.0
Aspen	0.0														
	12.0	23.0	7.0	1.0	2.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	
				15.0	40.0	50.0	0.0	0.0	40.0	0.0	0.0	0.0	0.0	0.0	2.0

Table 12 Projected Stand and Stock Table from Cruise Plots Example (Brewery Ridge TU- B)

Stems/ hectare multiplier 100.0 — Stems/ha BAF 2 PRF 0.3535 — Number plots 1.0

Species	Regen	Advanced Regen	Pole	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	
Douglas fir	1200.0	2000.0	500.0	113.2	127.4	81.5	0.0	0.0	15.9	0.0	0.0	0.0	0.0	0.0	338.0
Ponderosa Pine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lodgepole Pine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Larch	0.0	300.0	200.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aspen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total all Spp	1200.0	2300.0	700.0	113.2	127.4	81.5	0.0	0.0	15.9	0.0	0.0	0.0	0.0	0.0	338.0
			<25cm DSH		Cut will take			240.6stem/ha Leave		97.4						
Basal area by diameter class all spp				2.0	4.0	4.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	12.0
Log length				6.0	9.0	10.0	12.0	13.0	15.0	18.0	21.0	21.0	22.0	24.0	
Volume/ha by diameter class all spp				3.4	10.2	11.3	0.0	0.0	8.5	0.0	0.0	0.0	0.0	0.0	33.4

Table 13 Biomass Estimates from JOP/CAF Slash Pile Burning for Treatments over the 2009-2011 period

Range Unit	Project Location-Pasture	Total Hectares	hectares to pile burn	Piles ha	number of piles	Estimated BDTs
St. Mary's Prairie	North Cherry Pasture	232.3	76.4	50	3820	1222
St. Mary's Prairie	North Cherry Pasture 1B 1F	232.3	49.3	12.00	592	189
St. Mary's Prairie	South Cherry Pasture 1D	480.1	61.0	50	3050	976
St. Mary's Prairie	Artesian-Dry	387.9	9.0	30.0	270	86
St. Mary's Prairie	Artesian-Dry	387.9	51.4	30.0	1542	493
St. Mary's Prairie	Artesian-Dry	387.9	21.4	30.0	642	205
Waldo	Rabbit Mtn Tu 1 and 7	210	59.3	30.0	1779	569
Waldo	Elko Airport TU A only	215.9	93.6	50.0	4680	1498
Cranbrook -Fort Steele	Standard Hill	350.0	34.0	5.0	170	54
St. Mary's Prairie	Steer	238.6	62.8	25.0	1570	502
Cranbrook -Fort Steele	Overpass	238.0	48.4	10.0	500	160
Cranbrook -Fort Steele	Standard Hill	350.0	18.9	30.0	567	181
Waldo	North Waldo	492.1	123.0	12	1476	472
Dutch Findlay	4 Amigos	167	20.0	25	500	160
Dutch Findlay	4 Amigos	167	13.2	25	330	106
Dutch Findlay	Thunderbob Pasture TU B	350	39.3	12.00	472	151
Dutch Findlay	Thunderbob Pasture TU B	350	37.0	12.00	444	142
Windermere Sinclai	Juniper HeightsCTP 101	108.1	96.0	15.0	1440	461
Calculated Using BlueSky	Summary	5345.1	914.0	25.2	23843	7630

Table 14 Emissions Estimates from JOP/CAF Slash Pile Burning for Treatments over the 2009-2011 period (tonnes)

Range Unit	Project Location-Pasture	CO	CO_2	PM	$PM_{2.5}$	PM_{10}	NMHC
St. Mary's Prairie	North Cherry Pasture	38.03	1651.11	10.88	6.70	7.70	2.26
St. Mary's Prairie	North Cherry Pasture 1B 1F	5.89	255.71	1.68	1.04	1.19	0.35
St. Mary's Prairie	South Cherry Pasture 1D	30.36	1318.29	8.69	5.35	6.15	1.80
St. Mary's Prairie	Artesian-Dry	2.69	116.70	0.77	0.47	0.54	0.16
St. Mary's Prairie	Artesian-Dry	15.35	666.50	4.39	2.70	3.11	0.91
St. Mary's Prairie	Artesian-Dry	6.39	277.49	1.83	1.13	1.29	0.38
Waldo	Rabbit Mtn Tu 1 and 7	17.71	768.93	5.07	3.12	3.59	1.05
Waldo	Elko Airport TU A only	46.59	2022.83	13.33	8.21	9.43	2.77
Cranbrook -Fort Steele	Standard Hill	1.69	73.48	0.48	0.30	0.34	0.10
St. Mary's Prairie	Steer	15.63	678.60	4.47	2.75	3.16	0.93
Cranbrook -Fort Steele	Overpass	4.98	216.11	1.42	0.88	1.01	0.30
Cranbrook -Fort Steele	Standard Hill	5.64	245.07	1.61	0.99	1.14	0.34
Waldo	North Waldo	14.69	637.97	4.20	2.59	2.98	0.87
Dutch Findlay	4 Amigos	4.98	216.11	1.42	0.88	1.01	0.30
Dutch Findlay	4 Amigos	3.29	142.64	0.94	0.58	0.67	0.20
Dutch Findlay	Thunderbob Pasture TU B	4.70	203.84	1.34	0.83	0.95	0.28
Dutch Findlay	Thunderbob Pasture TU B	4.42	191.91	1.26	0.78	0.89	0.26
Windermere Sinclai	Juniper HeightsCTP 101	14.34	622.41	4.10	2.53	2.90	0.85
Calculated Using BlueSky	Summary	237.37	10305.69	67.91	41.82	48.06	14.11

Table 16. Comparing Emissions between Slash and Burn vs. Mastication

Mastication Emissions Comparisons			SLASH AND BURN								MASTICATION		
			CO	CO$_2$	CH$_4$	TOTAL tCO$_2$e	PM	PM$_{2.5}$	PM$_{10}$	NMHC	MASITCATION	Machine Emissions	Total Tonnes
Comparison of Emissions on these treatment units			Emission Factors tonnes			Emission Factor tCO2e	tonnes				Emission Factors tCO2e		
Mastication Units		Hectares	0.0058	0.2559	0.0004	0.2725	0.0017	0.0010	0.0012	0.0003	4.9509	0.0327	4.9836
Cherry - Ta Ta	China North South	169.0	1.0	43.2	0.1	46.1	0.3	0.2	0.2	0.1	836.7	5.5	842.2
Community Forest	Sylvan lakes	10.8	0.1	2.8	0.0	2.9	0.0	0.0	0.0	0.0	53.5	0.4	53.8
Community Forest	Sylvan lakes	5.3	0.0	1.4	0.0	1.4	0.0	0.0	0.0	0.0	26.2	0.2	26.4
Dutch-Findlay Creek	Sun Lakes	41.8	0.2	10.7	0.0	11.4	0.1	0.0	0.0	0.0	206.9	1.4	208.3
Findlay Basin	Stinky	45.0	0.3	11.5	0.0	12.3	0.1	0.0	0.1	0.0	222.8	1.5	224.3
Findlay Basin	Stinky	100.0	0.6	25.6	0.0	27.2	0.2	0.1	0.1	0.0	495.1	3.3	498.4
Findlay Basin	Stinky	15.0	0.1	3.8	0.0	4.1	0.0	0.0	0.0	0.0	74.3	0.5	74.8
Findlay Basin	Stinky	47.0	0.3	12.0	0.0	12.8	0.1	0.0	0.1	0.0	232.7	1.5	234.2
Findlay Basin	Stinky	9.0	0.1	2.3	0.0	2.5	0.0	0.0	0.0	0.0	44.6	0.3	44.9
Gold - Plumbob	Bare Mtn	14.7	0.1	3.8	0.0	4.0	0.0	0.0	0.0	0.0	72.8	0.5	73.3
Premier Ridge	Alkali South	140.8	0.8	36.0	0.1	38.4	0.2	0.1	0.2	0.0	697.1	4.6	701.7
Premier Ridge	Alkali South	60.2	0.4	15.4	0.0	16.4	0.1	0.1	0.1	0.0	298.0	2.0	300.0
Premier Ridge	Gina	31.2	0.2	8.0	0.0	8.5	0.1	0.0	0.0	0.0	154.5	1.0	155.5
Premier Ridge	Quartz	4.9	0.0	1.3	0.0	1.3	0.0	0.0	0.0	0.0	24.3	0.2	24.4
Sheep Creek North	Johnson Lake	53.8	0.3	13.8	0.0	14.7	0.1	0.1	0.1	0.0	266.4	1.8	268.1
Sheep Creek North	Johnson Lake	70.9	0.4	18.1	0.0	19.3	0.1	0.1	0.1	0.0	351.0	2.3	353.3
Sheep Creek North	Springbrook South	76.2	0.4	19.5	0.0	20.8	0.1	0.1	0.1	0.0	377.3	2.5	379.8
Sheep Creek North	Springbrook South	34.0	0.2	8.7	0.0	9.3	0.1	0.0	0.0	0.0	168.3	1.1	169.4
St. Mary's Prairie	Cherry North-South	28.1	0.2	7.2	0.0	7.7	0.0	0.0	0.0	0.0	139.1	0.9	140.0
St. Mary's Prairie	Cherry North-South	9.8	0.1	2.5	0.0	2.7	0.0	0.0	0.0	0.0	48.5	0.3	48.8
St. Mary's Prairie	Cherry North-South	4.8	0.0	1.2	0.0	1.3	0.0	0.0	0.0	0.0	23.8	0.2	23.9
St. Mary's Prairie	Cherry North-South	2.6	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	12.9	0.1	13.0
St. Mary's Prairie	Cherry North-South	1.7	0.0	0.4	0.0	0.5	0.0	0.0	0.0	0.0	8.4	0.1	8.5
St. Mary's Prairie	Cherry North-South	1.2	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	5.9	0.0	6.0
St. Mary's Prairie	Dry Lake-Artesian	57.3	0.3	14.7	0.0	15.6	0.1	0.1	0.1	0.0	283.7	1.9	285.6
Waldo	Elko-Airport East	76.4	0.4	19.5	0.0	20.8	0.1	0.1	0.1	0.0	378.2	2.5	380.7
Waldo	Elko-Airport East	51.5	0.3	13.2	0.0	14.0	0.1	0.1	0.1	0.0	255.0	1.7	256.7
Waldo	Fusee West Alpha	63.2	0.4	16.2	0.0	17.2	0.1	0.1	0.1	0.0	312.9	2.1	315.0
Waldo	Rabbit Mtn	24.4	0.1	6.2	0.0	6.6	0.0	0.0	0.0	0.0	120.8	0.8	121.6
Wildhorse Lewis	Brewery Ridge	50.0	0.3	12.8	0.0	13.6	0.1	0.1	0.1	0.0	247.5	1.6	249.2
Wildhorse Lewis	Brewery Ridge	40.0	0.2	10.2	0.0	10.9	0.1	0.0	0.0	0.0	198.0	1.3	199.3
Wildhorse Lewis	Brewery Ridge	4.0	0.0	1.0	0.0	1.1	0.0	0.0	0.0	0.0	19.8	0.1	19.9
Mastication Summary		1344.6	7.8	344.0	0.6	366.4	2.3	1.4	1.6	0.5	6657.0	44.0	6701.0

3.6.4 Invasive Plants Mitigation

The results of the rancher survey for invasive plants was unsuccessful but anecdotal evidence from the 2 respondents and discussions with local ranchers and a weed contractor indicate that invasive plants are a significant issues to be addressed when considering developing an ecosystem restoration treatment plan and invasive plan pre-assessments should be integrated into planning vs. responding only when there is an invasive outbreak ex-post. The two ranchers that responded noted that they spent from $1,000 - $5000 per year on spraying weeds, and over the past few years, government funding sources have diminished.

Good pre-planning for invasive plant range assessments can prevent catastrophic spread of invasive plants. Over the past few years, ER treatments that had slashed and burned piles have been followed up and treated aggressively by raking and grass seeding the burn rings. These steps have increased grass production and helped compete with invasive plants to reduce their impacts. The burn rings exhibited mostly Mullen weed after treatments, which with raking and seeding, the Mullen typically dies out within a few years and is not a long-term problem for most range units. It should be noted however, that a well trained eye when developing ER prescriptions is necessary for good invasive plant mitigation. It was reported that one 6 foot in diameter section of Blueweed (Echium vulgare L.) created a quarter mile infestation along one skid trail that required follow up treatments, as an example of how paying close attention to invasives pre-treatment can mitigate large scale invasive plant problems.

4 Non-Market Values

Mastication as a part of ecosystem restoration has many benefits for improving ecosystem services. Some of the clear benefits include: reduced particulates emissions from the airshed of the Rocky Mountain Trench as there are typically only a few days each year that burns can be prescribed and executed, so having another tool to conduct ER treatments without burning will be valuable to the successful operations of the ER Program. Non-market valuation has been well researched in the literature and in terms of emissions, and there are clear health benefits for humans by reducing particulates. (Mason, 2006,) (Douglas & Sasser 2008), (Venn & Calkin 2011).

 These avoided market and non-market values have been estimated to range between $4,895/ha for high hazard fuels, and $2,929/ha for moderate hazard fuels in the Pacific Northwest excluding health risk benefits (Mason et. al 2006). Some of the non-market values from the literature are given below.

- Emissions reduction – particulate emissions
- Community value of fire risk reduction
- Fatalities avoided
- Facility losses avoided
- Invasive plant vectors reduced
- Increased watershed protection (soils etc.)
- Regeneration and rehabilitation costs avoided
- Reduced Health Costs**

- Respiratory hospital admission
- Cardiac hospital admission
- Emergency room visit
- Childhood bronchitis
- Restricted activity day Asthma symptom day
- Minor restricted activity day
- Acute respiratory symptom day

Market Value Improvements Derived from Ecosystem Restoration via reducing wildfire hazards

- Firefighting costs avoided
- Timber losses avoided
- Increased water yield
- Potentially improved property values (reduced wildfires and burnt areas)
- Non-timber forest products
- Regional economic benefits – Hunting and recreation

While these non-market values are derived by complex statistical models and have been developed over the past several decades to determine punitive damages such as the Exxon Valdez case in 1989 that was upheld by the US Supreme Court, these non-market valuation methods have become increasingly used as legitimate methods for determining compensatory damages for environmental damage.

In the context of smoke emissions, Fann et. al (2009) did a nationwide US study that determined the health benefits by reducing a ton of air pollution. In the study, 12 metropolitan areas of the USA were surveyed for air quality using an Environmental Protection Agency matrix model for $PM_{2.5}$ and other pollutants.   Based upon the population dynamics, the model estimated the avoided cost value for reducing $PM_{2.5}$ emissions ranged from \$1.27-4.2 million/ton of $PM_{2.5}$ precursors annually. While the study cautions the use of these values outside of these specific urban areas studied, the evidence is clear that reducing particulate emissions has a significant health benefit for the surrounding population that is impacted by these emissions.

4.1 Carbon Offsets

This year's research results would be premature to develop a detailed carbon offset analysis and recommendations. However, next year's research analysis will include a biomass energy component and a full carbon offset analysis will be delivered. The research team is confident that removing biomass from ER treatment sites will avoid emissions from their associated slash pile and burn, or mastication treatments, which will have a significant carbon offset benefit. Notwithstanding that carbon sink additionality could be achieved by treating these stagnant forests, these stands, once treated, will most likely have increased carbon sequestration rates, which is greater than their current state. These results

should indicate that ER treatments yield a net carbon sink over time for these forest types and carbon offset opportunities are possible .

5 Conclusions and Recommendations

The project was an excellent applied research adventure for the research team and the resulting continued improvement for the ER Program will be significant. Over the past year, the research yielded the following results:

- The ER database was networked with a larger ER(Pro) database project that will have provincial influence and benefits for other regions of BC that are conducting ER treatments

- A literature review was searched and costs and non-market benefits of mastication were identified by which planners and others may use these studies to guide future research and ER operations.

- Data collection for ER mastication treatment units was collected and used for this study and can be used by future researchers that are working on mastication studies in the Trench or other areas of BC

- ER Costs were from recent projects were accounted for and presented, which may be used for delivering future projects and by which to evaluate program effectiveness

- An emissions model for slash piles and mastication was developed and can be used for future research and possible incorporation into the ER(Pro) database.

- Invasive plant mitigation and impacts were addressed and identified as part of ongoing mastication and ER treatments.

- Cost/Benefits for mastication were identified and will be used for future research and ER Planning

- Carbon offset potential has been explored and will continue with additional work in the next funding year. Next year's work will in particular explore a biomass utilization model which diverts waste and reduces potential emissions.

The mastication trials conducted over the 2011 -2012 period were a success and the lessons learned were beneficial to the planning and operations of ER treatments within the Rocky Mountain Trench. The mastication trials taught the ER planning team some valuable lessons with respect to the positive impacts of mastication treatments and some of the limitations of the equipment as a tool for implementing ER projects. Mastication costs were within a reasonable range of variability for a new

venture and it is possible that future project bids will decrease over time slightly due to the lessons learned by contractors who become more efficient and through competition keep their pencils sharp.

The research team recommends that the forest inventory for mastication and all ER treatments be improved by which more accurate forest volume estimates can be derived. This will have a positive impact for the mastication contractors bidding, but also will influence the biomass harvesting models, which will be important for biomass energy initiatives to have a deep understanding of these impacts upon the viability of these projects.

As the ER(Pro) database is developed, a full emissions accounting system should be established by which the ER planning team can have better metrics to determine the impacts of mastication and logging vs. open burning. The database would also allow for better annual planning and reporting of aggregate emissions and could be a positive public engagement factor by which the ER program can show the benefit of the program reducing emissions while increasing the program targeted hectares treated.

A separate non-market valuation study on the health benefits for reducing PM2.5 in the region would be helpful to determine this significant non-market benefit of the ER program in a similar manner as the Fann et.al (2009) study reported.

6 Appendices

6.1 Appendix 1 – Goals

1. Compile and organize data from Ecosystem Restoration treatments in terms of fossil fuels used in the process for traditional mechanical and hand treatments, including follow up pile burning, along with fossil fuels used for mastication treatments.

   a. Model the associated emissions CO2 e, NOx, CH4 and particulates, including: PM 2.5, PM 10 equivalents, that are produced under typical burning conditions associated with traditional ER operations and mastication methods.

   b. Report local costs of ecosystem restoration treatment methods (hand slashing and mastication).

   c. Calculate the potential (overall) emissions reductions achieved by mastication vs. pile burning in terms of CO2 e, NOx, CH_4 and particulates, including: PM 2.5, PM 10 equivalents.

   d. Calculate the potential greenhouse gas offset benefits from using mastication vs. traditional ER treatment methods.

   e. Calculate the overall Cost-Benefit of mastication vs. traditional ER treatments including carbon offset estimated values.

   f. Estimate the overall avoided greenhouse gas emissions and particulate matter that have been achieved to date within the Rocky Mountain Trench "Blueprint for Action" area that has been treated to date.

   g. Derive an approximate range of avoided greenhouse gas emissions and particulate matter on a per hectare basis for the Rocky Mountain Trench from implementing mastication as a prescribed ER treatment method.

   h. Evaluate other market and non-market values achieved through the use of mastication, including soils benefits from mastication vs. burning and the reduction of invasive species related to the reduction of pile burning.

6.2 Project Objectives

1. Develop a database of ecosystem restoration projects and develop an associated model with parameters for calculating the current estimated emissions.

2. Review the current literature on emissions modelling from pile burning and mastication and determine how to apply the lessons within the literature to this BC study.

3. Develop current cost estimates for both hand/mechanical slashing, piling and burning, along with mastication costs to date that have been done within the Rocky Mountain Trench for various Ecosystem Restoration treatments under various stand types and conditions.

4. Model the associated emissions CO2 e, NOx, CH_4 and particulates, including: PM 2.5, PM 10 equivalents that are produced from mastication vs. Traditional ER hand and machine pile and burning methods.

5. Develop a Non-Market Valuation model for current emissions values in the RMT.

6. Estimate the value for carbon offset opportunities that mastication treatments could offer.

7. Estimate the soils pre and post nutrient flux for mastication over the short and long term.

8. Estimate the reduced impacts of invasive species from mastication treatments.

9. Estimate the aggregate cost-benefit for market and non-market values for mastication treatments done to date compared with past traditional ER treatments in the region, and estimate the range of net benefits per hectare basis.

10. Attend and or host a regional event that will allow for the research team to present the findings of this study.

11. Produce a newsletter with a brief extension note to be distributed through the Trench Society and RMT ER Program members and to be submitted for publication by the B.C. Journal of Ecosystems and Management (Forrex).

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6.4 Appendix Rancher Survey

Mastication Research in the Rocky Mountain Trench

Funded by the Columbia Basin Trust and the Fraser Basin Council "BC Clean Air Research Fund"

Led by the Rocky Mountain Trench Natural Resources Society

Principal Investigator – Tom Hobby

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– Benefits to Mitigate Invasive Plants

This applied research project would quantify the emissions produced by mastication (a mechanical method that grinds/shreds biomass) vs. hand slashing, piling, and burning. The study compares the market and non-market benefits of using mastication methods for removing unmerchantable trees as part of ecosystem restoration treatments. The results from the project will benefit the development of forest management best practices within the region.

The evidence of mastication benefits (economic and ecological) as part of fuels treatment and ER projects is supported in the United States literature. Mastication has been tested and proven as a cost effective method that may be used under certain conditions, which if used, can replace hand crews and open burning, thereby reducing emissions, labour costs, and eliminating post burn environmental restoration issues. To date, mastication has been used as an ER treatment method for hundreds of hectares within the Trench.

One component of the study is to determine whether there are potential non-market benefits from using mastication vs. hand slashing, piling and burning. As invasive plants can be spread when vectors such as opening harvesting blocks and subsequent pile burning, these ecosystem restoration treatments have pre and post treatment monitoring for invasive plants. If there are problem pastures that exist, performing an ER treatment may be more costly due to invasives. This survey will attempt to elicit whether invasives are a significant impact on your operation and what value would mastication be perceived to a ranch manager who is keen on maintaining long-term forage sustainability

Questionnaire

1. What type of livestock do you raise?
   I.e. cow/calf, stocker steers, pure-breds, sheep, other

2. How many head do you manage of each species or type?

3. How many head of livestock do you annually sell of the ranch?

4. What type of range ownership do you have? Please check all that apply
   a. □ Crown tenure/license/lease total hectares within the range) _____
   b. □ Private land
      i. □ Lease (total hectares/acres) _____
      ii. □ Own (hectares/acres) _____

5. What are the main invasive plants that affect your range?

6. Have you treated your range lands over the past five years for invasives? □ Yes or □ No

7. How do you presently treat these invasive plants once identified? (select all that apply)
   a. □ Burn
   b. □ Chemical
   c. □ Mechanical
   d. □ Other- describe

8. How many AUMs to you manage?
   a. Private AUMs _____
   b. Crown AUMs_____

9. What would you estimate your annual hard cost to be related to weed/invasive plant treatments? I.e. equipment, spray materials, burning, hired labour etc.

10. How many hours/ or days per year would you personally contribute (unpaid) to combat invasives?

11. Has your crown tenure or private land had an ecosystem restoration treatment project conducted? If so when and how many hectares?

12. If yes to 12, following the pile burning, were there issues with invasive plants? Yes or No

13. If yes to 12, were there specific costs related to invasives that were incurred and if so an estimated cost?

14. Did you receive any payments (from Invasive Plant Council or other funder) to mitigate invasives post ER treatment, and if so how much were you paid? (please define how paid)

15. If mastication would eliminate burning slash piles and therefore reduce vectors for invasive plant infestations, what would you be willing to pay (on a dollars per hectare basis) for an ER treatment area to avoid risks of invasion and subsequent treatment costs?

16. What payments would you be willing to accept to be responsible for post ER treatment Invasive plant treatments on a dollars per hectare basis?

17. Other comments or suggestions for developing good ecosystem restoration practices

If you would like to email the survey, please email tomhobby@sustainingcreation.com

Or you may fax the survey to 888-496-3445

Thank you for your time and support