September 28, 2023

Mayor & Council
City of Prince George
1100 Patricia Blvd,
Prince George, BC V2L 3V9

RE: Wildfire Hazard Assessment – Updating 2009 Report – For Council Meeting Agenda

Dear Mayor and Council:

In 2009 the City of Prince George retained B. Blackwell and Associates to undertake fire behaviour analysis to assess the wildfire hazard, particularly in regards to the forests surrounding the city boundary. At that time, the principle concern was the high wildfire hazard posed by the pine stands which were killed by the mountain pine beetle. The 2009 report, using fire behaviour models, determined that there were several areas with high and very high wildfire hazards identified to the west and northwest of the city.

Since 2009, there have been several wildfires in BC and Alberta with devastating impacts to communities and their properties. It has been observed that, despite rapid responses to wildfires close to a community, wildfire fronts can move extremely quickly when wildfires become “crown” fires. Embers, propelled by strong winds, can fly kilometers ahead of a fire front, landing into communities and starting several structural fires and quickly overwhelming fire protection services.

While the City and the Province have addressed much of the fire risk in and around the city related to the dead pine, the emerging concern is related to climate change. In particular we have experienced more severe drought conditions and higher summer temperatures. This year is the worst wildfire season on record with numerous wildfires of record-breaking size, and numerous community evacuations. Climate scientists are predicting a continuation of episodes of drought conditions leading to higher wildfire hazards.

As such, it would be prudent for Council to direct administration to review the 2009 report and to have a updated fire behaviour analysis prepared with the identification of high and very high wildfire hazard areas around Prince George, and recommendations on options with estimated costs for reducing the wildfire hazards. Since landscape level approaches to reducing wildfire hazards will involve different levels of government, it would be important to involve the Lheidli T'enneh First Nation, the Regional District of Fraser Fort George, and the BC Ministry of Forests in the development of an updated analysis and report.

I have attached the 2009 report and a copy of the presentation that was provided to Mayor and Council in June 2009.

Submitted:
Dan Adamson
246 Peardon Road
Prince George, BC

CITY OF PRINCE GEORGE LANDSCAPE SCALE FIRE BEHAVIOUR MODELLING

Submitted by: Amelia Needoba and Bruce Blackwell
B.A. Blackwell & Associates Ltd.
June, 2009

City Of Prince George Landscape Scale Fire Behaviour Modelling and Proposed Fuel Treatments

Where are the risks and what are the potential solutions?

DRAFT

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RPF PRINTED NAME		Registered Professional Foresters Signature and Seal
Bruce A. Blackwell	RPF 2073	
DATE SIGNED		
I certify that I have reviewed this document and I have determined that this work has been done to standards acceptable of a Registered Professional Forester.		

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Acknowledgements

The authors would like to thank Rob Scagel of Pacific Phytometric Consultants for his work on fire weather and cost-benefit analysis and Dan Adamson, Kim Menounos and Lauren Phillips for their editorial input.

Introduction

History of Fuel Treatments in Prince George

The social, economic and environmental losses associated with the 2003 fire season emphasized the need for greater consideration and due diligence in regard to fire risk in the wildland urban interface (WUI). In considering wildfire risk in the WUI, it is important to understand the specific risk profile of a given community, which can be defined by the probability and the associated consequence of wildfire within that community. The risk of a wildfire on the landscape is determined by the fire environment (defined as weather, topography, and fuels). Weather and topography being beyond our control, fire managers are limited to using fuel manipulation to substantially alter the fire environment.

In 2005 the City of Prince George was one of the first municipalities in BC to develop a Community Wildfire Protection Plan (CWPP) to address wildfire risk. The plan contained a number of recommendations and identified key areas within the municipal boundary where fuel treatments should be undertaken.

Treatments have been prescribed for City parks and greenspaces, undeveloped forested properties owned by the City and some Crown land within the City. For the most part, fuel treatments have been completed on municipal lands and several treatments are currently underway on Crown lands. Crown lands are treated under the Community Forest license held and managed by the City.

Fuel treatment methods include: 1) conversion (e.g., coniferous to deciduous); 2) modification (altering the fuel bed structure); and, 3) removal. The type and location of treatments is critically important to manipulating the spread and intensity of fire on the landscape. Since 2006 the City has planned more than 700 ha for treatment and has completed treatments over a substantial portion of that area. Treatments have included:

- Removal of dead pine attacked by the Mountain Pine Beetle;
- Understory thinning of dense conifer stands;
- Partial removal of overstory and understory trees;
- Conversion of mixed conifer/deciduous stands to deciduous stands.

The current fuel treatment program is effectively reducing the fuel hazards identified in the CWPP and is mitigating the risk of fire travelling out of, or into, the treated areas as well as reducing the risk of hazardous fire behaviour within these areas. In other words, the current fuel treatments are fulfilling their objective of providing a local benefit within the area treated.

However, the CWPP derived fuel treatment program does not address the arguably greater risk to the City posed by a landscape level fire event causing an ember shower from a distant fire to rain down on the City. An ember shower results when burning particles are lofted well ahead (kilometres) of the fire front by the convection column and wind. This fire behaviour phenomenon is commonly referred to by fire managers as ‘spotting’. The burning embers land and collect on combustible surfaces, and are the most common cause of structure ignition during wildfires. This type of ignition event led to the extensive loss of homes during the Kelowna wildfire.

In 2007, following the completion of the City’s CWPP and during the implementation of fuel treatments, City staff and the consultant conducted a helicopter reconnaissance of forested portions within and adjacent to the City. Based on observations made during the flight it was apparent that several large, contiguous forest areas outside of the City boundary were impacted by the mountain pine beetle and were composed of potentially hazardous fuels that could spot into the City. B.A. Blackwell and Associates Ltd. were retained to undertake a fire behaviour analysis of the broader landscape (10 km around the City boundary) using fire behaviour modelling to investigate the impacts of fire growth under extreme weather conditions. A number of assumptions and professional judgements made during the completion of this analysis will be discussed.

Purpose of this Analysis

In BC, fuel treatments are gaining acceptance as a key tool available to fire managers for community fire protection. It is, however, important to understand that fuel treatments do not stop fires, but lessen the impact of a fire on an identified area of concern by changing the behaviour of a fire entering a treated area. The purpose of assessing fuels and fuel treatments at a landscape level is identify a configuration of treatment areas that will slow the growth of large fires by reducing fire intensity, crown fire, and mid-long range spotting.

However, there are several key questions that need to be answered when considering the type and extent of treatments that would be effective in a given community, including:

1. What are the likely weather conditions and ignition scenarios that would enable a wildfire burning in hazardous fuels to pose a threat to property and public safety within the community?

2. What and where are the hazardous fuels on the landscape?

3. What are the key constraints to treating fuels on the landscape?

4. Of those fuels that do pose a potential threat, how much area should be treated in order to effectively mitigate the risk?

5. What is an 'acceptable' level of wildfire risk to property and public safety within the community?

Some of these questions can be answered with the help of decision tools such as fire behaviour modelling and spatial risk assessments. Others are determined by factors such as government policy, ownership and available funds. The purpose of this project was to use fire behaviour modelling, historic fire weather, previous fire locations and cost-benefit analysis theory to investigate these questions and to provide recommendations on how fuel treatments could be used to provide cost-effective wildfire protection.

What are the Likely Weather Conditions and Ignition Scenarios?

Background on City of Prince George Climate, Vegetation and Fire History

The following climate and vegetation description is an excerpt from the City's Community Wildfire Protection Plan[1] (Diamondhead Consulting et al. 2005):

The City of Prince George is located in the center of the Sub-Boreal Spruce zone (SBS) that covers much of BC's northern interior plateau. This area has a continental climate with characteristic extremes in temperature. Summers are generally short but warm and moist. The winters can be severe, with extended periods below -10◦C and extremes that can reach -40◦C or colder. Most of the zone is under snow from November to March.

There are three biogeoclimatic subzones that are found within the City. The majority of the main town site (south of the confluence of the Nechako and Fraser rivers) is classified as SBSdw3 (Stuart Dry Warm Sub Boreal Spruce). This subzone is relatively warm compared to other subzones in the area. It experiences relatively low winter precipitation and subsequent snowpacks. Summers are generally dry in this subzone.

The areas to the north of the Nechako River and to the east of the Fraser river are classified as SBSmk1 (Mossfale Moist Cool Sub-Boreal Spruce). This subzone experiences moderate temperatures and precipitation compared to other subzones with relatively long snowy winters and moist cool summers.

There is also a band of SBSmh (Moist Hot Sub-Boreal Spruce) either side of the Fraser River. This area is

[1] http://www.city.pg.bc.ca/rec_culture/parks/urbanforestry/wildfire/management_plan.pdf

characterized by one of the driest and warmest climates in the region with a relatively low winter snowfall.

Each of the three biogeoclimatic subzones found in this area is representative of a particular climate, topography and associated vegetation type. These characteristics directly influence the assemblage of vegetation, wildlife species and habitat requirements. In general, the climax tree species include hybrid white spruce and subalpine fir. Following disturbances such as wildfire, lodgepole pine and trembling aspen are typical pioneer species. Paper birch is another pioneer species that commonly establishes on wet and rich sites. Douglas-fir is also common and usually more abundant on dry, warm, rich sites. Forests of black cottonwood with small numbers of spruce occur occasionally on the active floodplains of the Fraser and Nechako Rivers.

The subzones in the Northern Interior Plateau of BC are classified as NDT 3 – Ecosystems with frequent stand-initiating events. These forests generally experienced frequent wildfires (the mean fire return interval is 125 years) that ranged in size from small spot fires to large scale wildfires covering thousands of hectares. Historically, this has created a mosaic of forest seral stages across the landscape characterized by fire-dependent or fire-resistant species with a relatively young age class distribution. Scattered patches of mature stands that escaped these fires are typically found across the landscape. Harvesting has traditionally created a more diverse pattern of varying seral stages. However, recent salvage operations for beetle kill are tending to create more large scale disturbance that more closely mimic historical disturbance patterns.

Table 1 shows climate normals for the Prince George area. Climate normals are based on the last 30 years of data and are intended to represent typical climatic values for an area. This data indicates that summer temperatures are generally quite mild. However, extreme temperature maximums have occurred in a number of years. Winds are predominantly from the south but strong winds can also come from the west and north.

Table 1. Climate normals during the fire season for Prince George A weather station from Environment Canada.

Temperature:	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Daily Average (°C)	5.2	9.2	13.3	15.5	14.8	10.1	4.6
Extreme Max (°C)	29.8	36	33.9	34.4	33.4	31.4	25.2
Precipitation (mm):	32.2	50.9	72.7	63.5	51.1	52.5	57.9
Wind:							
Speed (km/h)	10.2	9.3	8.6	7.7	6.9	7.7	10.3
Most frequent direction	S	S	S	S	S	S	S
Max hourly speed (km/h)	61	61	55	56	65	58	72
Dir. of max hourly speed	SW	S	S	S	S	N	S
Max gust speed (km/h)	119	101	97	113	95	91	129
Dir. of max gust	W	W	S	SW	W	S	W

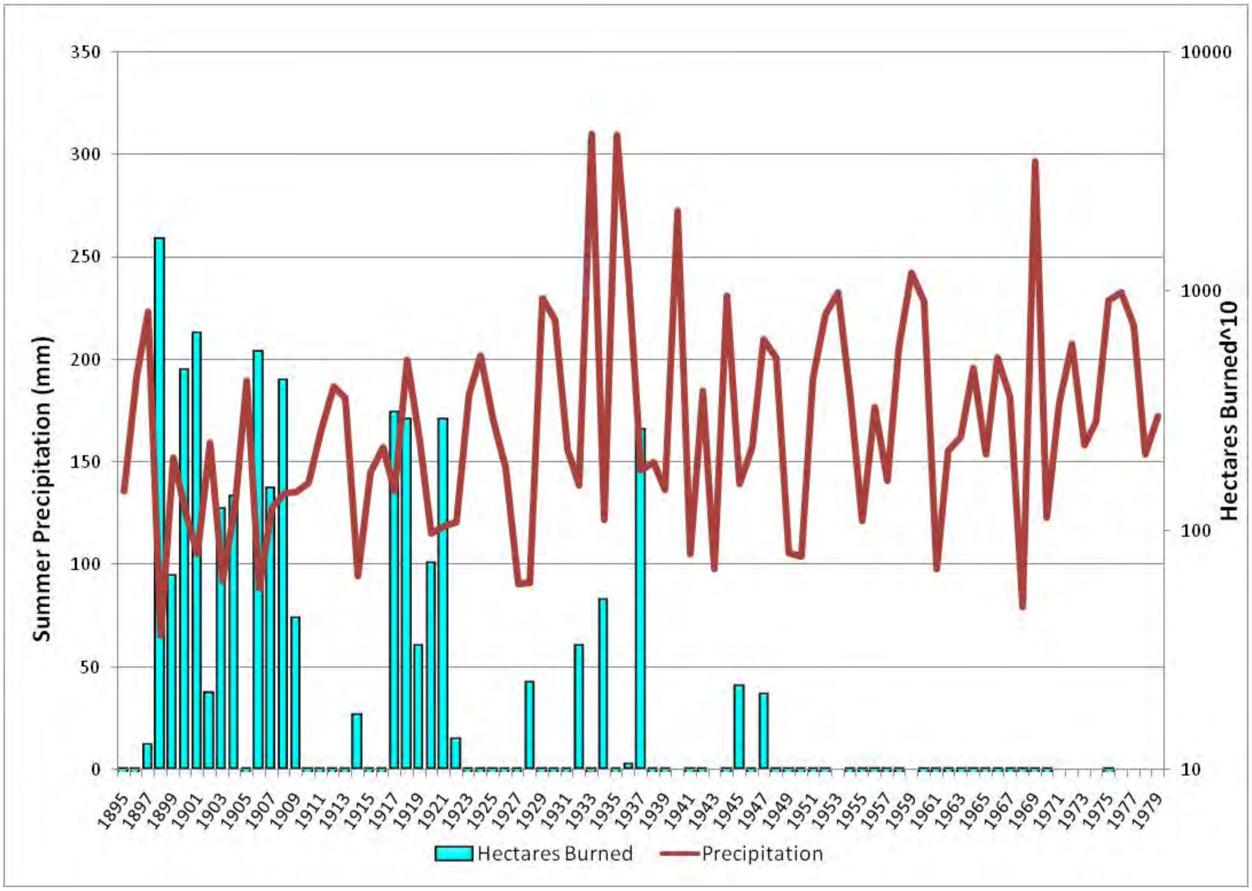


Figure 1. Image showing hectares burned plotted with summer precipitation.

Figure 1 shows that larger fire years tended to occur during years when summer precipitation was less than 200 mm. The number and size of fires appears to decrease substantially from 1933 onwards (Figure 2). Based on historic photo records and our understanding of fire suppression in BC, it is likely that the decline in fires from this point forward is due both to landscape level deforestation around the City that reduced the flammability of the landscape and then ongoing, effective fire suppression.

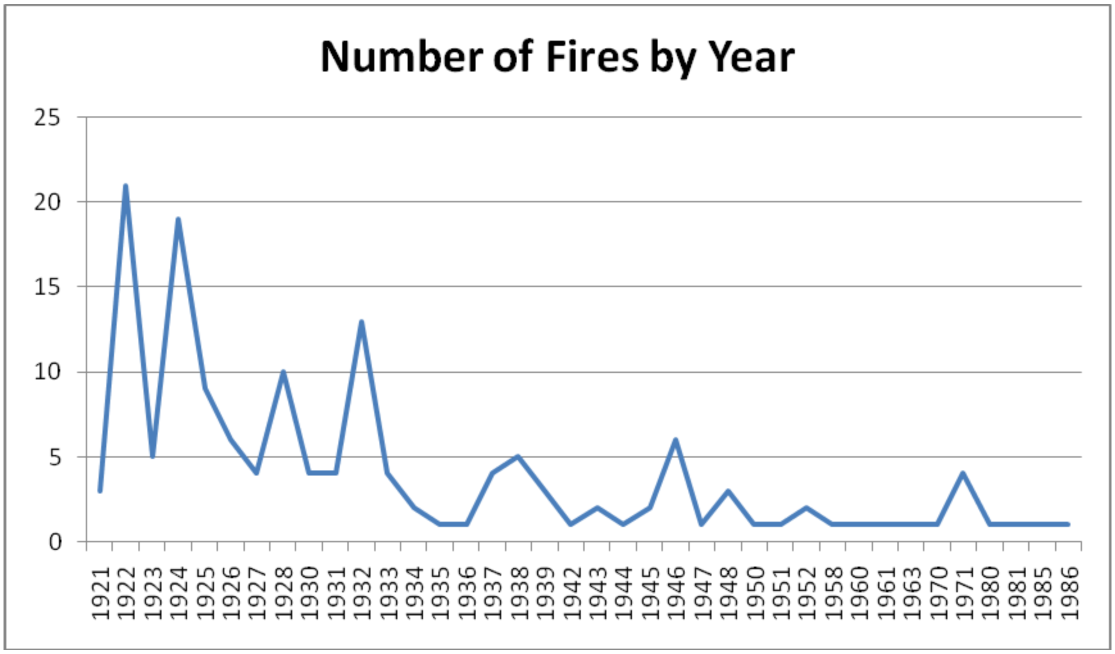


Figure 2. Number of fires > 1 ha per year.

Hectares burned per year also decrease on average from 1933 onwards except for a spike in 1961 when 25,000 hectares burned within the study area (Appendix 1 – The Citizen Special Edition: 'Great Fire of '61''[2]). These trends are most likely the result of effective fire suppression policies.

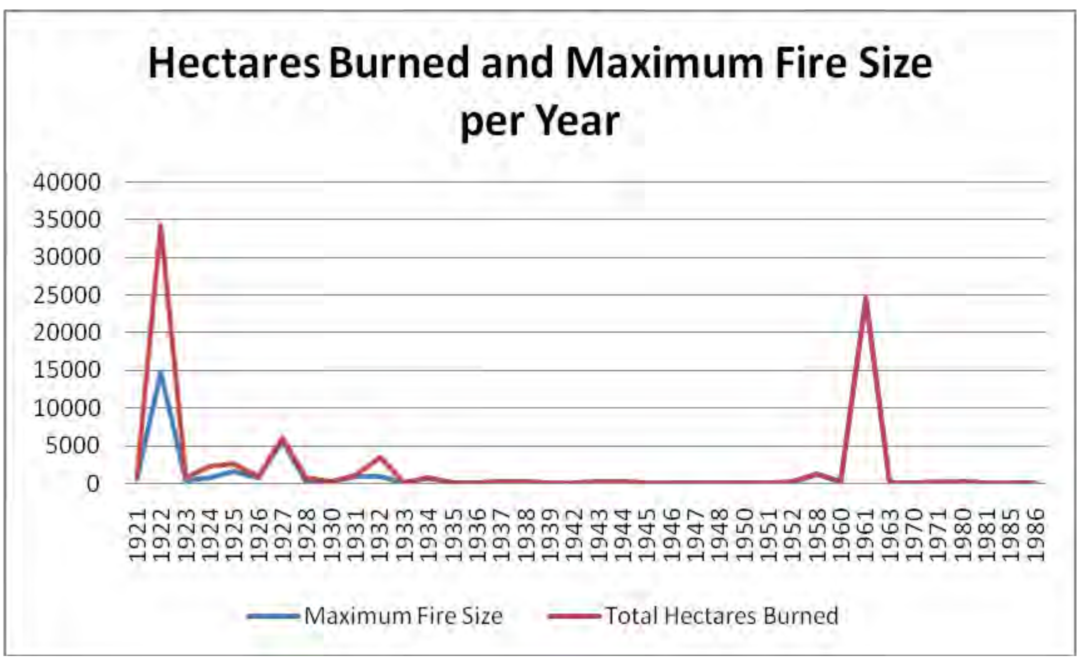


Figure 3. Hectares burned and maximum fire size per year.

[2] http://www.for.gov.bc.ca/rni/Research/Extension_notes/citizen_tabloid.pdf

The map shown in Figure 4 was created from fire history data provided in the Canadian National Fire Database[3], which was compiled by the Canadian Forest Service from data provided by the BC Ministry of Forests. The record shows fire perimeters within 10 km of the City from 1921 to 2007. However, this record is not complete as it only includes the available fire perimeters from each provincial or territorial agency. It is known from anecdotal and Ministry of Forest point data sources that additional fires have occurred in the area. However, complete records of fire perimeters are not available in the database or from other sources.

These records indicate 151 large fire starts from many locations around the City. Spread directions suggest that winds at the time of the fires were generally from the south, west or north. The majority of fires in the record were lightning caused. Prince George has been noted as a lightning hot spot in the Province.

[3] http://cwfis.cfs.nrcan.gc.ca/en/historical/ha_lfdb_maps_e.php

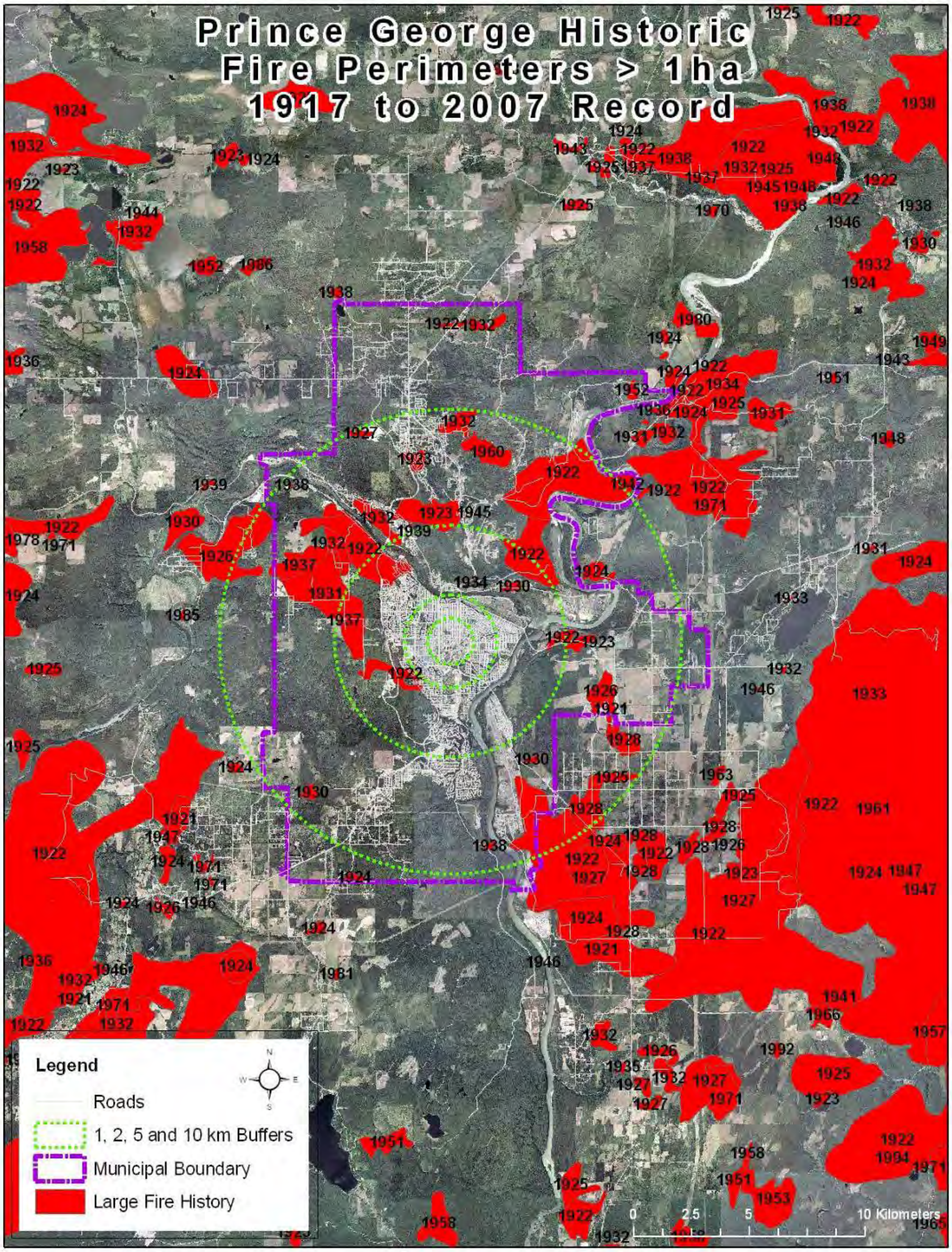


Figure 4. Fire history 1917 – 2007.

The weather in the lead-up and during the 1961 fire is shown in Table 2. The fires broke out around August 1st and were brought under control around August 29th. Eighty-six fires were burning in the Prince George Forest District at that time. Maximum daily temperatures in July averaged 25◦C and rainfall totalled 16.5 mm. Maximum daily temperatures in August averaged 25.4◦C and rainfall totalled 35.6 mm, 31 mm (87%) of which fell on the 30th and 31st of August. Precipitation in both months was well below the climate normal for Prince George (Table 1).

Table 2. Historic weather at 3pm each day leading up to and throughout the 1961 fires from Prince George A weather station.

Date 3pm	Temp (◦C)	Rel. Humidity (%)	Wind Dir. (◦)	Wind Spd. (km/hr)	Weather	Total Precip. (mm)	Comments
31-Jul	26	30	7	3	Cloudy	0	Fire started close to this date
1-Aug	29	24	18	10	Clear	Trace	Winds increased in the evening to a max of 42 km/hr with thunderstorms
2-Aug	27	29	27	13	Clear	0	
3-Aug	29	24	5	5	Clear	0	
4-Aug	32	14	20	29	Clear	0	The fire made a run this day
5-Aug	24	33	29	13	Showers	Trace	Brief rainfall
6-Aug	21	14	17	16	Clear	0	
7-Aug	21	36	25	23	Cloudy	0	
8-Aug	20	31	36	11	Cloudy	0	
9-Aug	23	27	36	14	Clear	0	
10-Aug	27	22	29	23	Cloudy	0	
11-Aug	28	21	16	6	Cloudy	0	Smoke in the morning
12-Aug	29	23	29	8	Clear	0	Smoke in the morning
13-Aug	28	23	34	18	Smoke	0	Smoke most of the day
14-Aug	29	18	14	19	Smoke	Trace	Smoke until late afternoon, lightning mentioned
15-Aug	26	28	32	10	Cloudy	0	No smoke
16-Aug	26	22	32	19	Clear	0	No smoke
17-Aug	23	31	5	16	Cloudy	0	Smoke in the morning
18-Aug	23	35	34	3	Smoke	0	Smoke most of the day
19-Aug	28	29	9	10	Smoke	0	Smoke all day
20-Aug	29	26	34	3	Smoke	0	Smoke most of the day
21-Aug	27	24	20	19	Clear	0	Smoke in the morning
22-Aug	24	27	25	19	Clear	0	Smoke in the morning
23-Aug	26	28	28	10	Clear	0	Smoke in the evening
24-Aug	26	24	26	16	Clear	Trace	Smoke in the morning
25-Aug	23	36	14	6	Cloudy	Trace	No smoke
26-Aug	19	50	23	6	Cloudy	1.5	Smoke in the morning
27-Aug	14	77	27	6	Showers	2.5	No smoke
28-Aug	15	78	16	3	Showers	3.6	No smoke

Summary of Prince George Fire Weather Conditions

The fire weather data compiled for this project suggests that , at a Provincial level, fire weather in Prince George is not particularly extreme. Temperatures of 29◦C only occur 2% of the time for the record. However, anecdotal[4] (Appendix 1 – The Citizen Special Edition: 'Great Fire of '61') and fire history data records indicate that, given temperatures in the late 20s, low relative humidity and strong winds, the landscape around Prince George is capable of supporting large wildfires.

Figure 5 indicates that the period of greatest concern during the fire season in Prince George is mid-July to the third week of August. This is the period of time when the probability of precipitation is lowest and the probability of temperatures > 23◦C is highest. In other words, this is the period of time over which the warmest and driest conditions are most likely to occur.

Figure 5. Graph of probability of rainfall versus probability of temperature > 23◦C

[4] Hawkes, Brad C. (1997) "Significant Fire Years in the Prince George Area – A Media Perspective Taken from the Prince George Citizen Newspaper (1912 – 1961)"
http://www.mcgregor.bc.ca/publications/SignificantFireYears.pdf

What and where are the Hazardous Fuels on the Landscape?

Introduction to Fire Behaviour Modelling

In order to investigate landscape level risks from extreme fire behaviour in hazardous fuels, several fire scenarios were modelled on a fuels landscape that included a 10 km buffer around the municipal boundary. Two spatial fire growth models and one fire behaviour mapping program were used to assess projected fire behaviour in fuels adjacent to the City under specified weather conditions within a twenty-four hour burning period. Both a Canadian and US fire behaviour model were used in order to investigate each model's utility in demonstrating relative changes in fire behaviour following mountain pine beetle attack and fuel treatments.

Prometheus and the CFFDRS

The Canadian fire growth model used was Prometheus[5], which is based on the Canadian Forest Fire Danger Rating System (CFFDRS)[6]. The CFFDRS consists of two main subsystems; the Fire Weather Index (FWI) system and the Fire Behaviour Prediction (FBP) system (Figure 6).

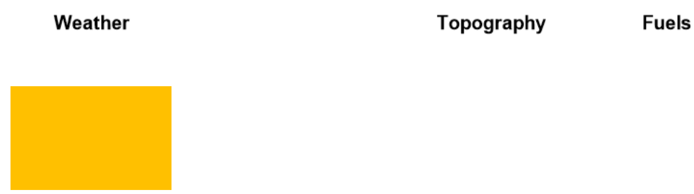


Figure 6. Diagrammatic representation of CFFDRS and Prometheus

[5] http://www.firegrowthmodel.com/index.cfm
[6] http://fire.cfs.nrcan.gc.ca/research/environment/cffdrs/cffdrs_e.htm

Fire Weather Index

The FWI system uses dry-bulb temperature, relative humidity, 10-meter open windspeed and 24-hour accumulated precipitation at noon local standard time as inputs to derive three fuel moisture codes:

1. Fine Fuel Moisture Code (FFMC): Moisture content of litter and fine fuels in a closed forest stand.
2. Duff Moisture Code (DMC): Moisture content of loosely compacted decomposing matter on the forest floor.
3. Drought Code (DC): Moisture content in deep, compact organic matter.

These in turn are used to derive:

4. Initial Spread Index (ISI): Wind speed with FFMC as an indicator of fire rate of spread.
5. Build-up Index (BUI): A combination of DMC and DC that has a longer response time to changes in humidity/precipitation. BUI is used to indicate the total fuel available for combustion.

The resulting FWI is:

6. A combination of generalized ISI and BUI indicators used to derive a relative estimate of the potential intensity of the fire.

The FWI indicates the potential intensity of a fire on level terrain in a stand of mature pine and assesses relative fire potential (Van Nest and Alexander 1999). Variation in fire behaviour by fuel type is addressed in the Fire Behaviour Prediction System. More comprehensive technical information on the FWI can be found in Van Wagner (1987).

Fire Behaviour Prediction System

The FBP system assesses fire behaviour and uses inputs including topography, fuels, weather, foliar moisture content and duration of prediction. The FBP system is primarily based on empirical data from 495 observations of experimental and wild fires. Data from observations made during these fires was analysed using statistical correlation techniques to derive fire behaviour predictions for 16 generalised boreal fuel types. Comprehensive technical information on the FBP can be found in Forestry Canada Fire Danger Group (1992). Primary outputs include:

1. Rate of Spread (ROS): speed of fire spread usually expressed in metres per second.

2. Head Fire Intensity (HFI): energy output of the flaming fire front usually expressed as kilowatts per metre.

3. Fuel Consumption (surface and crown): expressed in kilograms per square metre.

4. Fire Description (surface, intermittent and crown): Surface fire burns through surface fuels, intermittent fire refers to surface fire that periodically switches to crown fire via torching trees, and crown fire refers to fire burning continuously from the surface to the crown.

Secondary outputs from FBP include:

1. Flank and back fire rates of spread.

2. Flank and back fire intensity.

3. Head, flank and back fire spread distances.

4. Elliptical fire area.

5. Fire perimeter.

6. Rate of perimeter growth.

7. Length-to-breadth ratio.

Prometheus

Prometheus is an elliptical fire growth model that uses both the FWI values and the FBP calculations to estimate changes in the fire perimeter over time. In addition, text files created using a Geographic Information System (GIS) enable the inputs and outputs to be presented spatially.

FARSITE and FlamMap

FARSITE[7] (fire growth simulator) and FlamMap[8] (fire behaviour mapping) both utilize the existing fire behaviour models used in BehavePlus[9] (US fire behaviour prediction). The US approach to fire behaviour calculations is based on semi-empirical models developed using theoretical mathematical models refined through laboratory experimentation. Constants and coefficients are used to model the relationships between various fuels, weather, topography and risk conditions. Unlike the Canadian system, inputs for fuel moisture and weather parameters

[7] http://www.firemodels.org/content/view/112/143/
[8] http://www.firemodels.org/content/view/14/28/
[9] http://www.firemodels.org/content/view/12/26/

are direct, rather than through proxies such as the FFMC. In addition, the Rothermel (1972) fire spread model implemented in the US uses actual values on fuel bed structure such as load, bulk density and fuel particle size as inputs. For this system, a fuel model is defined as "a complete set of [fuel] inputs for the mathematical fire spread model" (Rothermel 1972). This again contrasts with the empirical approach of the Canadian system, which makes predictions of fire behaviour for generalized fuel types within which tests/wild fire observations have been made and subsequently used to statistically derive fire behaviour equations specific to those fuel types.

FARSITE and FlamMap inputs:

- Any of the 53 established US Fire Behaviour Fuel models or a customised fuel model.
- Minimum and maximum dry bulb temperature.
- Minimum and maximum relative humidity.
- Wind speed and wind direction (can be constant over the landscape or consist of gridded wind data varied based on topography and vegetative cover).
- Cloud cover.
- Precipitation amount and duration.
- Elevation.
- Canopy characteristics (foliar moisture, stem diameter, species of torching tree).
- 1-hr, 10-hr and 100-hr, live herbaceous and live woody fuel moistures.
- GIS derived landscape ASCII files for elevation, slope, aspect, canopy cover, stand height, crown base height and crown bulk density.

FARSITE and FlamMap outputs include GIS compatible results for fire perimeter, time of arrival, fireline intensity, flame length, rate of spread, head output/unit area, crown fire activity and direction of spread.

Benefits and Disadvantages of the Fire Behaviour Modelling Programs

FARSITE and Prometheus are similar in terms of how they are programmed to model deterministic spatial fire growth. Each program also has some variations in functionality; however, the primary difference between them is the fire behaviour modelling system that each uses (CFFDRS versus BehavePlus). All fire behaviour models are simplistic representations of complex systems. For this reason, the assumptions and limitations of the models being implemented must be considered both in their application and in the interpretation of results. Numerous sources (e.g., Andrews 1986; Forestry Fire Danger Group 1992; Pastor et al. 2003; Finney 1998) discuss the assumptions and limitations of the fire behaviour models underlying Prometheus, FARSITE and FlamMap, so a comprehensive discussion is not provided here.

The empirical CFFDRS system that underlies Prometheus has some advantages over semi-empirical systems (i.e, BehavePlus) including the fact that scale is less likely to be an issue (i.e., observations are from actual fires rather than attempting to apply small-scale laboratory tested equations to an actual fire) and that any small-scale heterogeneity within a fire is inherently incorporated into the fire behaviour models because equations are based on correlations with actual fire observations. FBP also incorporates a crown fire data set and spotting distance is included in the rate of spread, but Prometheus cannot grow the fire past a non-fuel type (i.e., it cannot model spotting over a fuel break). There are only 16 generalised fuel types in the system at this time, which reflects the empirical data set available from test/wildfires. This means that the model is only appropriate for use where these fuel types occur and cannot model variations in fuel bed structure that are not already represented in the 16 fuel types.

The semi-empirical system underlying FARSITE and FlamMap provides greater modelling flexibility than the CFFDRS because it can utilize any of the 53 defined US fire behaviour fuel types or a customised fuel type. This means that variations in fuel bed structure can easily be incorporated into the model. While this makes the model widely applicable, the model has not yet been validated in Canada. In addition, the semi-empirical approach is prone to errors of scale when equations based on laboratory test fire observations are applied to actual fires. FARSITE and FlamMap do not incorporate the burning of fuels greater than 3 inches (7.6 cm) in diameter as these fuels are not considered to contribute to rate of spread. Crown fire rate of spread is calculated within FARSITE and FlamMap (two different crown fire modelling options are provided). Maximum spotting distance is modelled and fire can 'jump' fuel breaks but spotting is not included in the rate of spread.

Rationale for utilizing both the Canadian and US fire behaviour modelling systems in the City of Prince George

FARSITE is the standard used by fire behaviour analysts from the US Department of Agriculture and the US Department of the Interior and has been widely applied within the US. Prometheus is a nationally applied inter-agency sponsored fire growth model in Canada. Prometheus and FARSITE are accepted as the dominant fire growth models used in Canada and the US respectively.

Given that the objectives of the analysis included an investigation of the potential impacts of fire growth in treated and non-treated fuel types, it was appropriate to use both the Prometheus and FARSITE fire growth models. While FBP (Prometheus) may provide appropriate fire behaviour outputs for fuel types surrounding the City of Prince George (pine and mixed conifer/deciduous types), the model cannot effectively show changes in fire behaviour as a result of fuel treatments or insect infestations that alter the fuel bed structure. This flexibility was provided by BehavePlus (FARSITE).

Given that the two models are not directly comparable and that neither model has been validated specifically in the Prince George area, the analysis did not focus on generating absolute fire growth predictions; rather, the intention was to investigate the relative changes in fire growth given changes in fuel type. Based on the strengths and weaknesses of each model, it was determined that both could assist in providing a more complete understanding of the potential fire behaviour and wildfire threat to Prince George. A number of assumptions were made in order to complete the analysis and these will be discussed in the following sections.

Model Inputs

Weather and Fuel Moisture Model Inputs

For weather inputs, we used existing data on the 98th percentile fire weather for the SBSdw3. In other words, these values occur 2% of the time during the April to October reporting period. This data was originally derived by first estimating the Fire Weather Index (FWI) and Fire Behaviour Prediction (FBP) at every fire weather station in BC and then developing percentile interpolations within each biogeoclimatic (BEC) subzone. For the SBSdw3, the interpolations are based on 15,546 individual daily operations from four stations with a total record from 1895 to 2002 (not all stations are represented over the entire time period). Only observations from the fire season were used to derive the percentiles. Days with precipitation were excluded. Head Fire Intensity (HFI) was used to derive the 98th percentile weather values used. The values input into Prometheus and FARSITE/FlamMap were as follows:

Max Temp. (◦C)	Min Temp. (◦C)	Max Rel. Humidity (%)	Min Rel. Humidity (%)	DMC*	DC*	FFMC*	Precip. (mm)	Cloud Cover (%)
29	5	100	21	120.3	477	95.3	0	0

* Prometheus inputs only.

The fuel moisture scenarios used in FARSITE and FlamMap were as follows:

Shaded					
Fuel moistures %	1hr	10hr	100hr	LH*	LW*

Extreme drought	3	4	6	60	90
Drought	4	5	7	90	120
Unshaded					
Fuel moistures %	1hr	10hr	100hr	LH	LW
Extreme drought	2	3	5	30	60
Drought	3	4	6	60	90

* LH = Live herbaceous, LW = Live woody

A 10 m open windspeed of 40 km/hr was selected for use in Prometheus. The windspeed used in FARSITE and FlamMap was 21 mph (34 km/hr) based on the adjustment procedure from VanNest and Alexander (1999):

- 10-m open wind x .85 = 20-ft wind (40 km/hr x 0.85 = 34 km/hr)

No wind adjustment factors were used in this analysis. The burn period modelled was 24 hours and weather inputs were maintained as constants for the entire burn period.

Landscape Inputs

Elevation, aspect and slope were derived from a digital elevation model for the Prince George area. Text files for input into each of the models were generated using GIS.

Fuel Type Inputs

Provincial fuel type data was available in GIS for the study area. This data was updated using fuel treatment polygons, cut block areas and an algorithm that incorporates attributes such as stand composition, age, height and BEC subzone to refine fuel typing. It is acknowledged that the fuel typing may contain some errors due to factors such as recent natural/human disturbance and heterogeneity within fuel type polygons, but the data accuracy was considered acceptable for the scale of this analysis. The Canadian and US fuel types used are listed in Table 3. Given that the most accurate fuel type data set available was for Canadian fuel types, and that time and funds were limited for the analysis, it was judged acceptable to select US fuel types with guidance from predicted fire rate of spread for the Canadian fuel types.

Mountain pine beetle affected stands were modelled based on assumed fuel conditions within a 15 year projected post beetle attack stand (i.e., a stand where most grey attack has fallen over and non-pine make up what remains of standing live trees). Red-attack stands were not modelled as existing fire behaviour models do not currently allow appropriate aerial fuel characteristics to represent these forests.

The following hypothesis was used when developing the custom fuel model for 15 year projected post-mountain pine beetle attacked stands in FARSITE/FlamMap: high loading of larger diameter surface fuels, low fuel moisture values, low crown base heights and low crown bulk density. In these 15-year post-beetle stands, it was expected that fire intensity would be high and passive crown fire (individual torching trees) would frequently occur, but that active crown fire (continuous fire from the surface to the canopy) would be unlikely because the canopy would be more open.

Table 3. Canadian and US fuel types used for the analysis.

Category	Canadian Fuel Type	US Fuel Type
Grass	31 - O1a Matted Grass	1 – Short Grass
Grass	32 - O1b Standing Grass	106 – Moderate Load, Humid Climate Grass (Dynamic)
Timber/Litter	2 – C2 Boreal Spruce	163 – TU3 Moderate Load, Humid Climate Timber – Grass-Shrub (dynamic)
Timber/Litter	3 - C3 Mature Jack or Lodgepole Pine	163 – TU3 Moderate Load, Humid Climate Timber – Grass-Shrub (dynamic)
Timber/Litter	4 - C4 Immature Jack or Lodgepole Pine	164 – TU4 Dwarf Conifer with Understory
Timber/Litter	5 – C5 Red and White Pine	162 – TU2 Moderate Load, Humid Climate Timber-Shrub
Timber/Litter	7 - C7 Ponderosa Pine/ Douglas-fir	162 – TU2 Moderate Load, Humid Climate Timber-Shrub
Timber/Litter	575 - M2 Boreal Mixed wood – Green 75% conifer	7 – Southern Rough
Timber/Litter	13 - D1/D2 – Leafed Aspen	182 – TL2 Low load Broadleaf Litter
Timber/Litter	13 - D1/D2 – Post Fuel Treatment M2 conversion	182 – TL2 Low load Broadleaf Litter
Timber/Litter	5 - C5 Post- Fuel Treatment Conifer stand	162 – TU2 Moderate Load, Humid Climate Timber-Shrub
Slash	21 S1 15 Yr post-Beetle	50 – Custom Fuel Model (FM7 with increased 100 hr fuels)

The maps shown in Figure 7 and Figure 8 show the spatial distribution of the Canadian and US fuel types across the landscape. Those areas highlighted in red hatching indicate where pine-leading stands occur and have been assumed to be impacted by the mountain pine beetle. The areas of black hatching indicate fuel treatments that were identified in the Community Wildfire Protection Plan, many of which have now been completed. The area of green hatching identifies a gross 'ideal' treatment area that would be modified assuming no social, environmental or economic constraints on the landscape.

Table 4 outlines the fuel type specifications in more detail. Rate of spread for comparison between fuel types was selected with the following assumptions for Canadian types:

- ISI = 65, BUI = 145, 90% curing for grass types

Assumptions for US types were:

- 1-hr fuel moisture = 3%, 10-hr fuel moisture = 4%, 100-hr fuel moisture =5%

In both systems, slope was 0%. These were not necessarily the values assumed for modelling but were used to guide initial fuel type selection. Differences in crown base height and crown bulk density were used to manipulate the likelihood of crown fire in the US system. Crown bulk density and crown base height values were selected using professional judgement. However, Cruz et al. (2003) was used to guide the selection of crown bulk density values.

Table 4. Fuel type specifications

Canadian Fuel Type	Approximate ROS (m/min)	US Fuel Type	Approximate ROS (m/min)	Crown Base Height (m)	Crown Bulk Density (kg/m³)
01a	140	1	149	0	0
01b	187	106	183	0	0
C2	97	163	95	0.3	0.96
C3	104	163	95	1.3	0.32
C4	93	164	70	0.3	0.96
C5	32	162	44	12	0.18
C7	33	162	44	12	0.18
M2	73	7	80	6	0.18
D2 (1/5 ROS of D1)	4	182	1	6	0.01
C5 – Post Treatment	32	162	44	3	0.18
S1 – Post Beetle	80	50	70	0.3	0.18

Several additional inputs are required for FARSITE/FlamMap. These are:

- Canopy cover: derived from vegetation resource inventory data.
- Foliar moisture content: 100%.
- Stand height: set at a constant of 25 m.
- Diameter for torching trees: set at 25 cm.
- Species of torching tree: lodgepole pine.

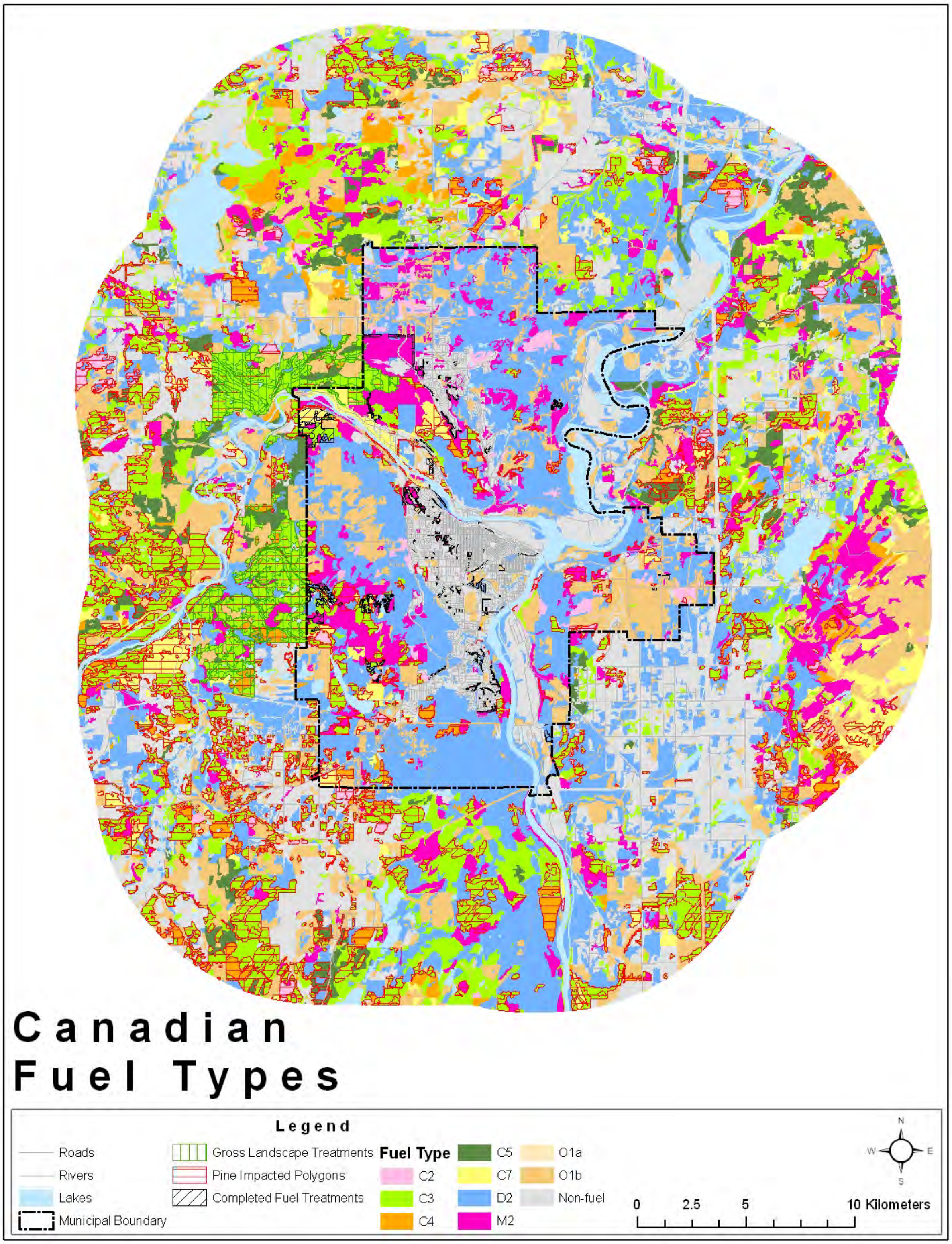


Figure 7. Canadian fuel type map.

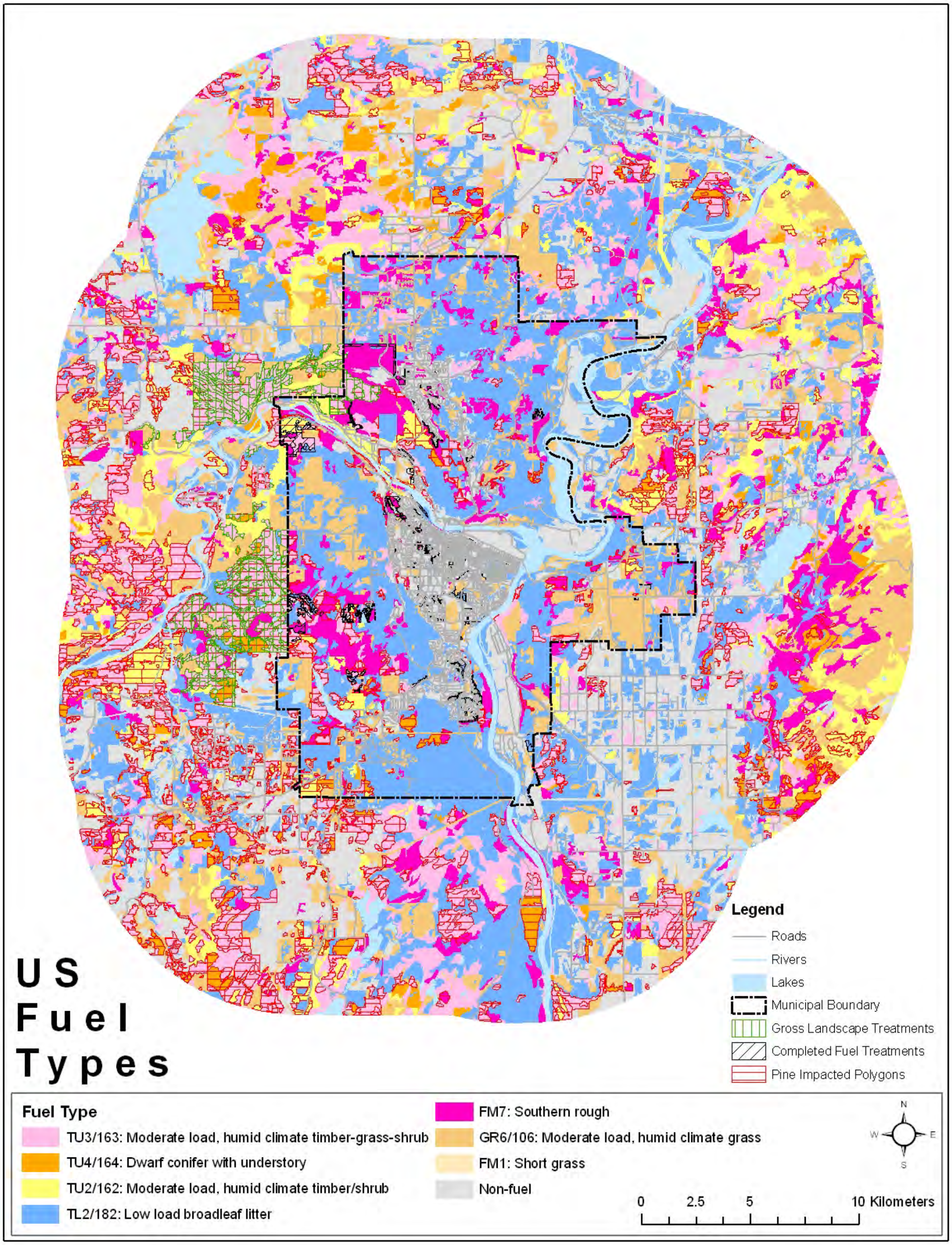


Figure 8. US fuel type map.

Ignition Inputs

Five initial ignition points were located on the landscape using GIS (Figure 9). Ignition points were selected at locations where the Ministry of Forests and Range historic ignition data indicated high densities of fire starts and were placed within fuel polygons that would burn (i.e., not within deciduous or non-fuel). The same ignition points were used in all but one scenario; two additional ignition points were selected to also show westerly fire spread in FARSITE under extreme drought condition.

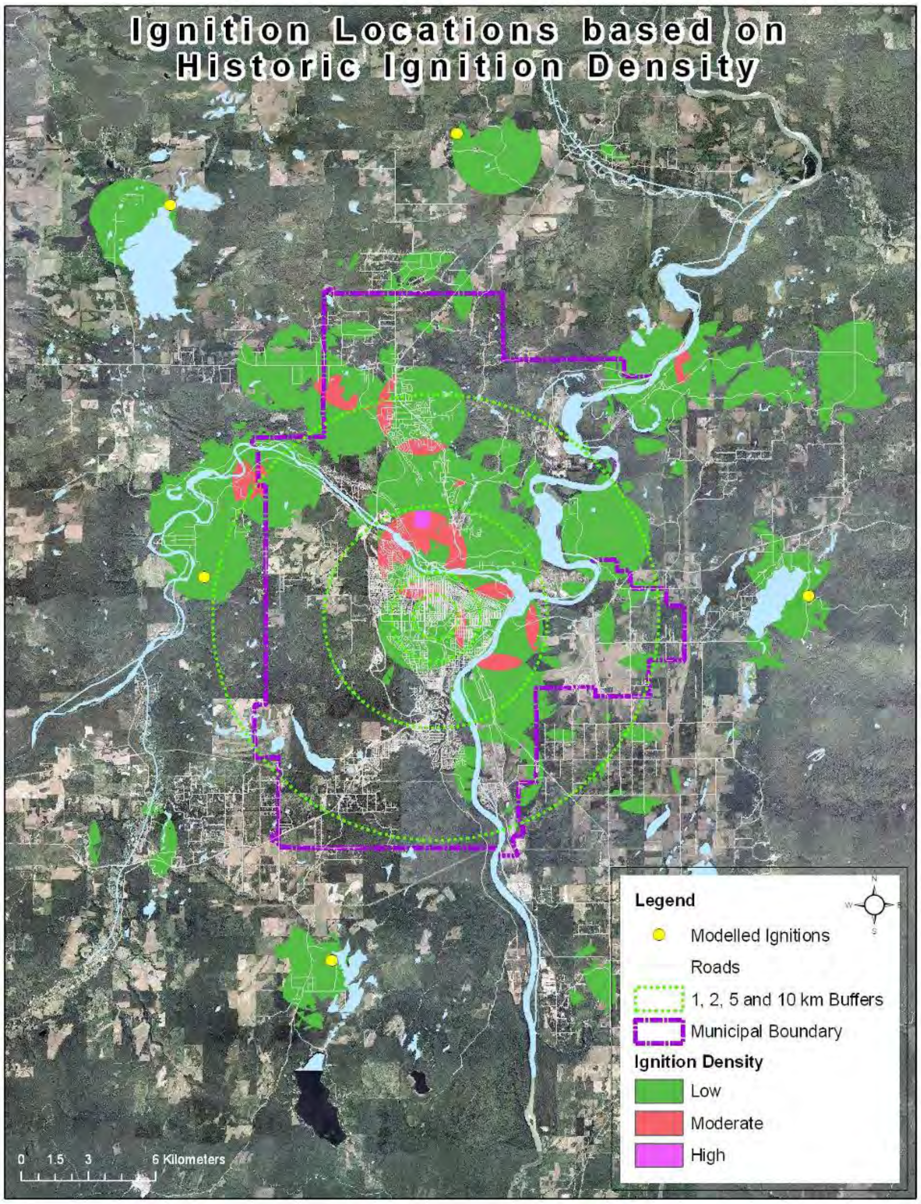


Figure 9. Modelled ignition locations and historic ignition density.

Scenarios

Prometheus

A total of 9 Prometheus scenarios were run. These consisted of 3 different wind directions (N, S and W) x 3 different fuel type landscapes (pre-beetle, projected post-beetle and projected post-beetle with fuel treatments).

Specific scenario parameter settings were 2 hour time steps and 90m distance and perimeter resolution. Otherwise, default model settings were retained (e.g., 32 starting vertices, acceleration on, BUI effect on, terrain effect on, green-up on, smoothing factor 0.4).

FlamMap

FlamMap was run on the projected post-beetle with fuel treatment landscape and used the Finney (1998) method of crown fire calculation. The same inputs were used as in FARSITE but only the westerly wind direction was modelled.

FARSITE

A total of 10 FARSITE scenarios were run. These consisted of:

- 3 different wind directions (N,S and W) x 3 different fuel type landscapes (pre-beetle, projected post-beetle and projected post-beetle with fuel treatments) without spot fire growth
- 1 westerly wind post-beetle with fuel treatment scenario run under extreme drought fuel moisture values with spot fire growth enabled

Specific scenario parameter settings were 2 hour time steps, 90m distance and perimeter resolution. Spot fire growth was enabled at 3% with the Finney (1998) method of crown fire calculation.

Model Outputs

Prometheus

Figure 10 shows the results of the Prometheus scenarios run under 40 km/hr northerly windspeed and constant weather conditions. The yellow perimeter represents fire growth pre-beetle. The orange perimeter represents fire growth post beetle with no fuel treatments on the landscape. The purple perimeter also models fire growth post beetle but includes current/proposed fuel treatments on the landscape. All fire perimeters overlap except where a different fuel type is encountered by the scenario, which is why the orange and purple perimeters are only visible in some areas. The yellow fire perimeter is on top of both the orange and purple perimeters. For example, the fire perimeter on the eastern side of the City (Figure

10) appears all yellow but an orange and a purple perimeter exist beneath that layer; the perimeters are almost exactly the same because there were very few beetle impacted fuels and no treatment areas on that part of the landscape to cause a difference in fire behaviour.

As can be seen on the map, use of the S1 fuel type to represent post-beetle fuels does not make a substantial difference to the forward rate of spread or the final fire perimeter. There is a higher backing fire rate of spread, which is responsible for the orange perimeter that can be seen to diverge from the yellow. S1 is not likely to be the appropriate fuel type to represent projected 15-year post-beetle stands as, in our hypothesis, passive crown fire would occur in these stands resulting in spotting and a faster forward rate of spread in the Canadian FBP model. The S1 fuel model does not include crown fire and therefore underestimates forward rate of spread expected under our hypothesis. No existing Canadian fuel models provide an appropriate representation of 15-year post-beetle stands.

The portion of the purple post-beetle (influenced by treatments) perimeter that can be seen in the middle left of the map is visible because the fuel treatments were modeled as a C5 fuel type. This is the only fire perimeter that encounters a fuel treatment on the landscape. This has caused a reduction in rate of spread resulting in a slightly smaller fire perimeter than either the pre-beetle or post-beetle (no treatment influence) scenarios. Selection of the C5 fuel type to represent treated stands is not ideal. However, we do expect decreased rates of spread in treated stands due to decreased likelihood of crown fire behaviour. The same factors explain the differences between fire perimeters in Figure 11.

In terms of hazardous fuels on the landscape, the Prometheus runs suggest that, under extreme fire weather conditions, fuels to the west of town and, to some extent, the south are contiguous and capable of supporting fire behaviour that results in rapid forward rate of spread into high density interface. These fuels are also supporting crown fire behaviour, which would result in spotting ahead of the fire front into the interface. However, the model does not support spot fire growth across non-fuel barriers that could be breached in reality (e.g., in Figure 11 the southern fire perimeter in the westerly wind scenario would, in reality, likely spot across the Fraser River).

The only modelled fire perimeter that encountered a fuel treatment on the landscape was the purple perimeter of the southwest fire (Figure 10 and Figure 11). In the model, the existing/proposed fuel treatments within the City are not substantially slowing the forward rate of spread or altering the final fire perimeter of this fire. While the current fuel treatment programs have effectively mitigated risk of fire in their immediate vicinity, the modelling suggests that additional, strategically placed fuel treatments would be needed to mitigate landscape level fire risks from a fire to the west of the City.

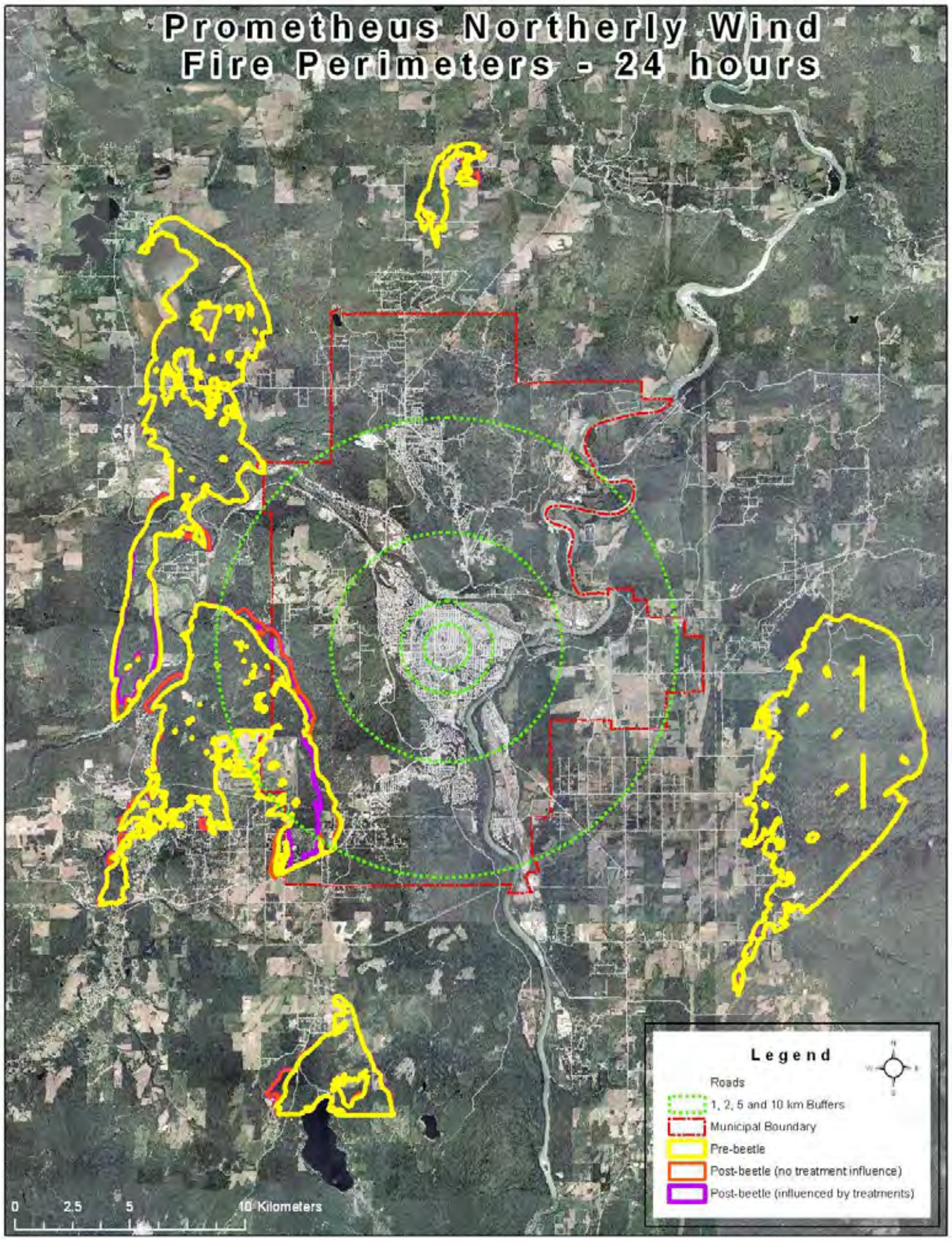


Figure 10. Prometheus runs with 40 km/hour northerly winds.

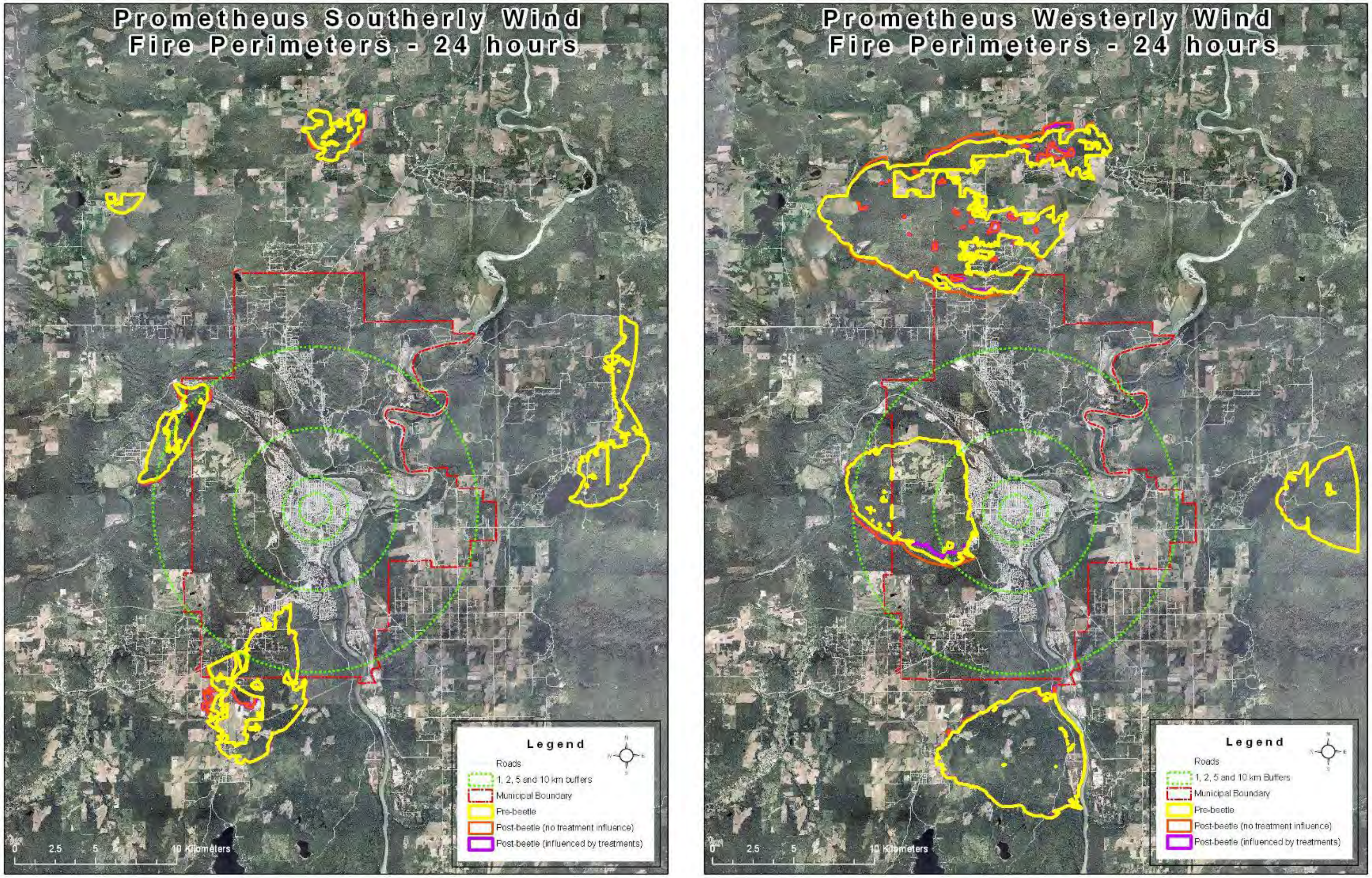


Figure 11. Prometheus runs with 40 km/hr southerly and westerly winds.

It is important to remember that, while the predicted fire behaviour values (e.g., rate of spread, crown fire etc.) are reasonable in these fuel types, the actual fire perimeters are not predictive in terms of where a fire would most likely end up on the landscape in a 24 hour burn period. In reality, weather conditions and winds would most probably vary both for the better and the worse during the burn period and fire suppression would change the final shape of the fire perimeter. These same caveats apply when interpreting the FARSITE and FlamMap results.

FARSITE

Figure 12 shows the results of the FARSITE scenarios run under 34 km/hr northerly windspeed and constant weather conditions. The yellow perimeter represents fire growth pre-beetle. The orange perimeter represents fire growth post beetle with no fuel treatments on the landscape. The purple perimeter also models fire growth post beetle but includes current/proposed fuel treatments on the landscape. All fire perimeters overlap except where a different fuel type is encountered by the scenario, which is why the orange and purple perimeters are only visible in some areas. The yellow fire perimeter is on top of both the purple and orange perimeters. For example, the fire perimeter on the eastern side of the City (Figure 12) appears almost all yellow but an orange and a purple perimeter exist beneath that layer; the perimeters are exactly the same where there are no beetle impacted fuels or treatment areas to cause any difference in fire behaviour.

As can be seen on the map, use of the custom fuel type to represent post-beetle fuels increases the forward rate of spread and advances the final fire perimeter where beetle impacted stands occur. The custom fuel model meets the expectations of the projected 15-year post-beetle hypothesis in terms of forward rate of spread and passive crown fire.

The only modelled fire perimeter that encountered a fuel treatment on the landscape was the purple perimeter in southwest fire of Figure 12. The purple perimeter is smaller than the orange perimeter on this fire because the fuel treatment has slowed the rate of spread through this fuel type.

Because the selection of US fuel types was based on comparative fire behaviour of the Canadian system, these types may not be the most realistic models of projected 15-year post-beetle stands or post-treatment fuel types. However, they provide a better approximation of these fuel types in terms of our hypothesized fire behaviour scenario than is possible in the Canadian system because of FARSITE’s sensitivity to changes in fuel bed structure within a fuel model.

The results of the FARSITE runs also indicate that, under extreme fire weather conditions, fuels to the west of town are capable of supporting fire behaviour that results in rapid forward rate of spread into high density interface. These fuels are also capable of supporting crown fire behaviour, which would result in spotting ahead of the fire front into the interface. However, unlike the Prometheus runs, the model indicates that the existing/proposed fuel treatments within the City will slow the forward rate of spread to some degree. This is due to both FARSITE's sensitivity to the fuel models used and inherent differences between the Canadian/US models, particularly the fact that FARSITE is not incorporating spotting into the forward rate of spread.

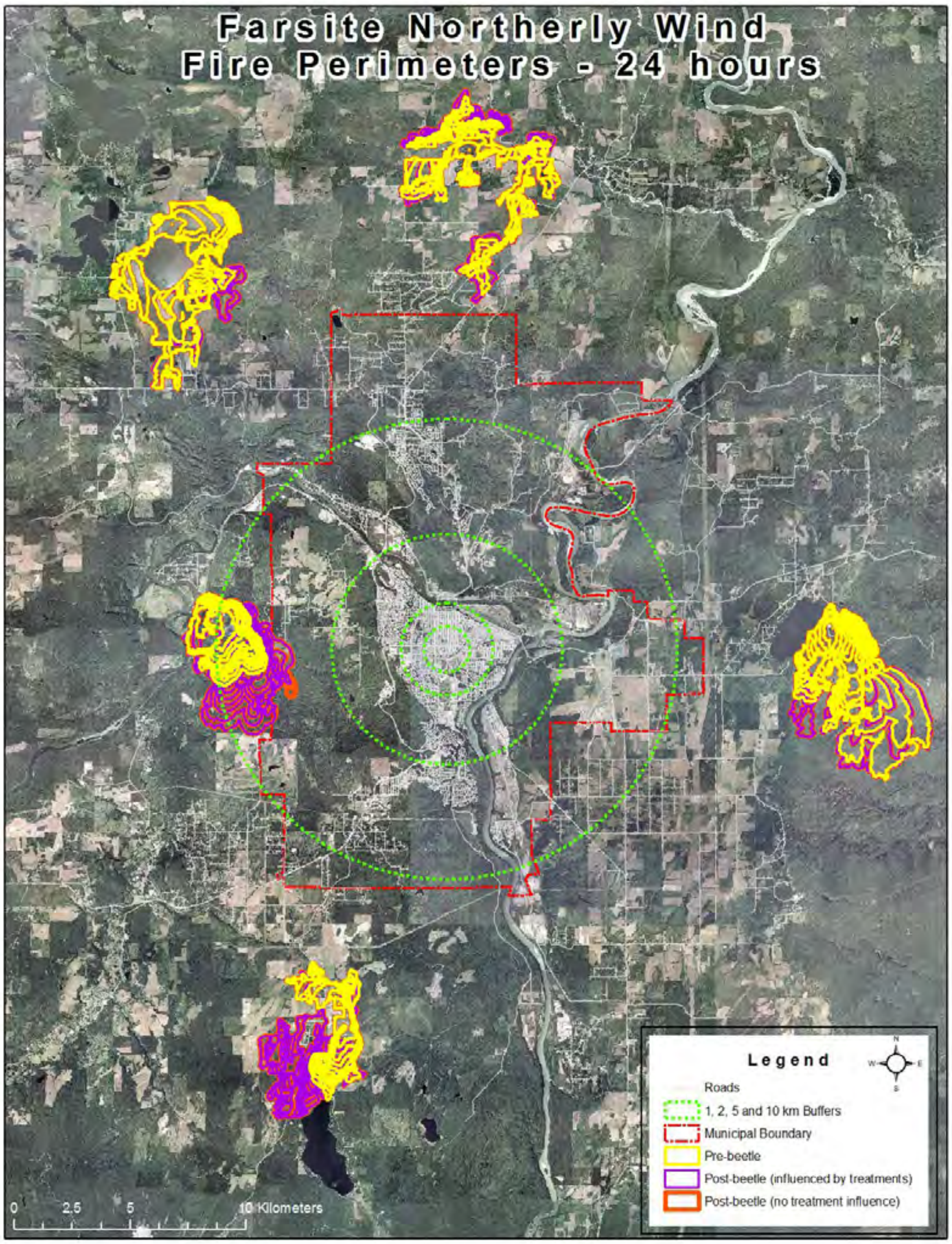


Figure 12. FARSITE runs with 34 km/hr northerly winds without spot fire growth enabled.

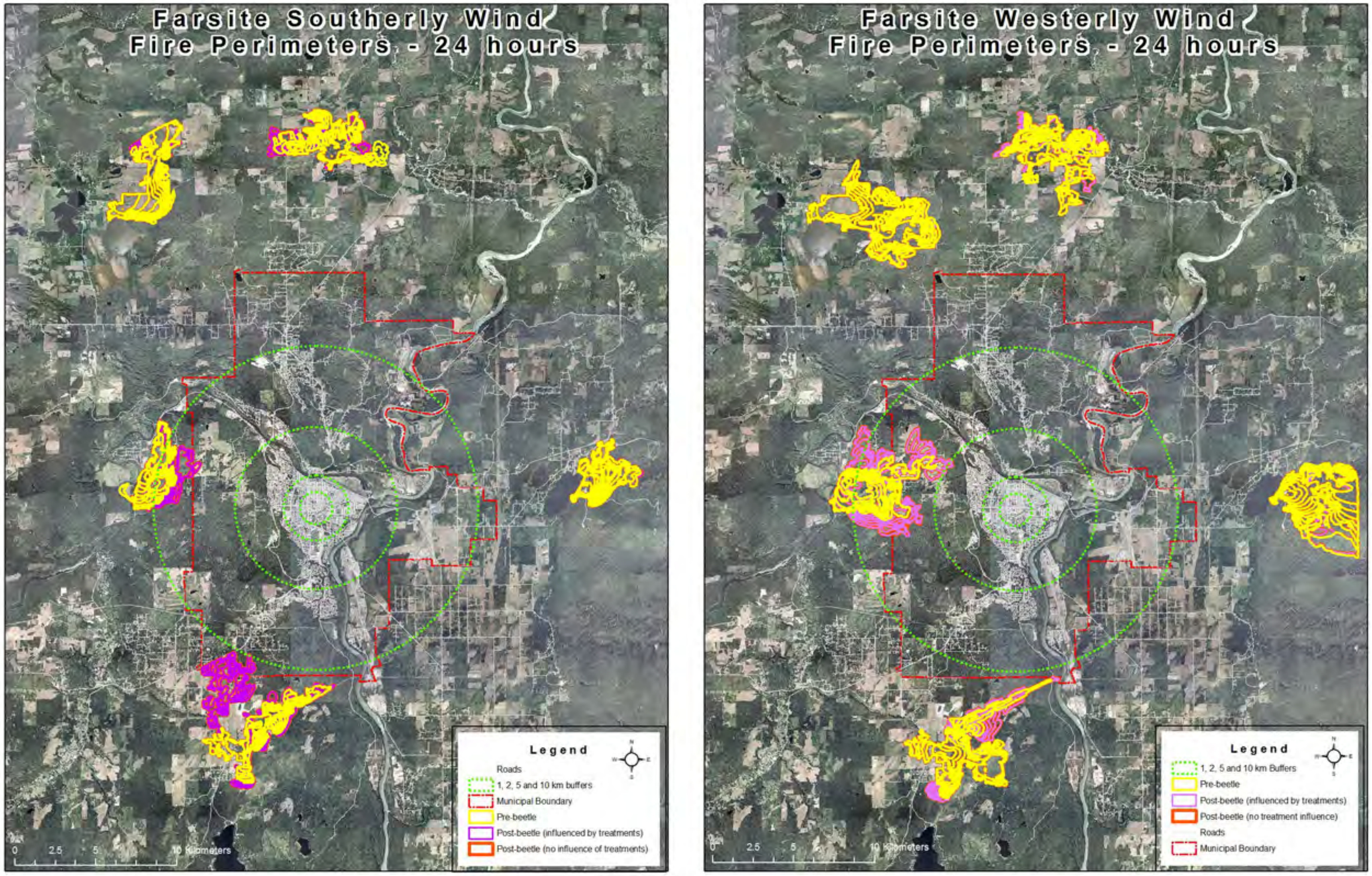


Figure 13. FARSITE runs with 34 km/hr southerly and westerly winds without spot fire growth enabled.

An additional run was completed in FARSITE to investigate ignition scenarios (two new and one existing ignition) to the west of town burning under extreme drought fuel moisture conditions and with spot fire growth enabled. The post-beetle landscape scenario was modelled.

These runs suggest that fuel breaks such as the Nechako River are jumped by the fire when spot fire growth is enabled. While the southern fire perimeter is stopping at the deciduous fuel type, burning embers lofted ahead of the fire front would be landing in the high density interface. The red perimeter represents the post beetle landscape and shows that two of the three ignition points result in fires reaching the edge of the City within the 24 hour burn period.

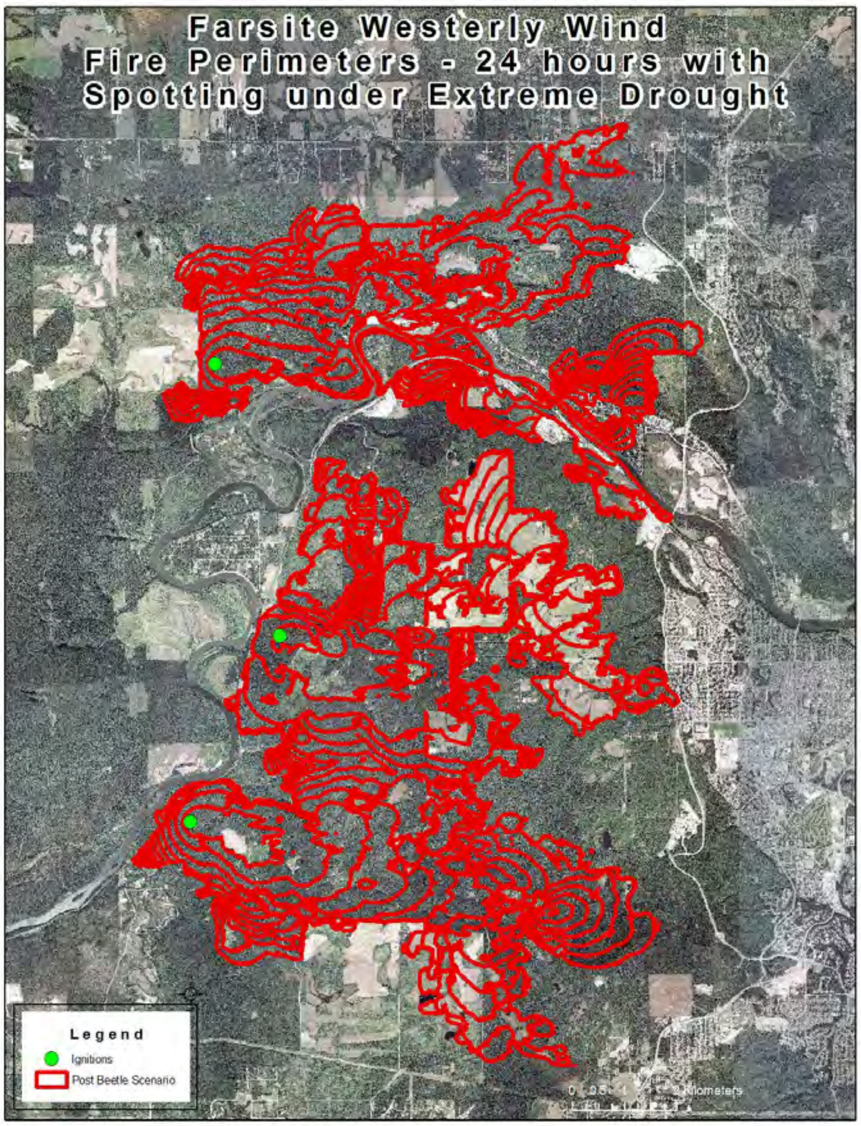


Figure 14. FARSITE run with extreme drought fuel moistures and spotting enabled.

FlamMap

The FlamMap run was used to show the location of fuels exhibiting crown fire behaviour. The projected post-mountain pine beetle and treatment scenario was used as this approximates the future fuel condition surrounding Prince George. Crown fire polygons shown in **Error! Reference source not found.** indicate the highest hazard fuels surrounding Prince George. Due to high fire intensity, spotting and rapid rates of spread, crown fire is typically the most difficult type of fire behaviour for suppression crews to control.

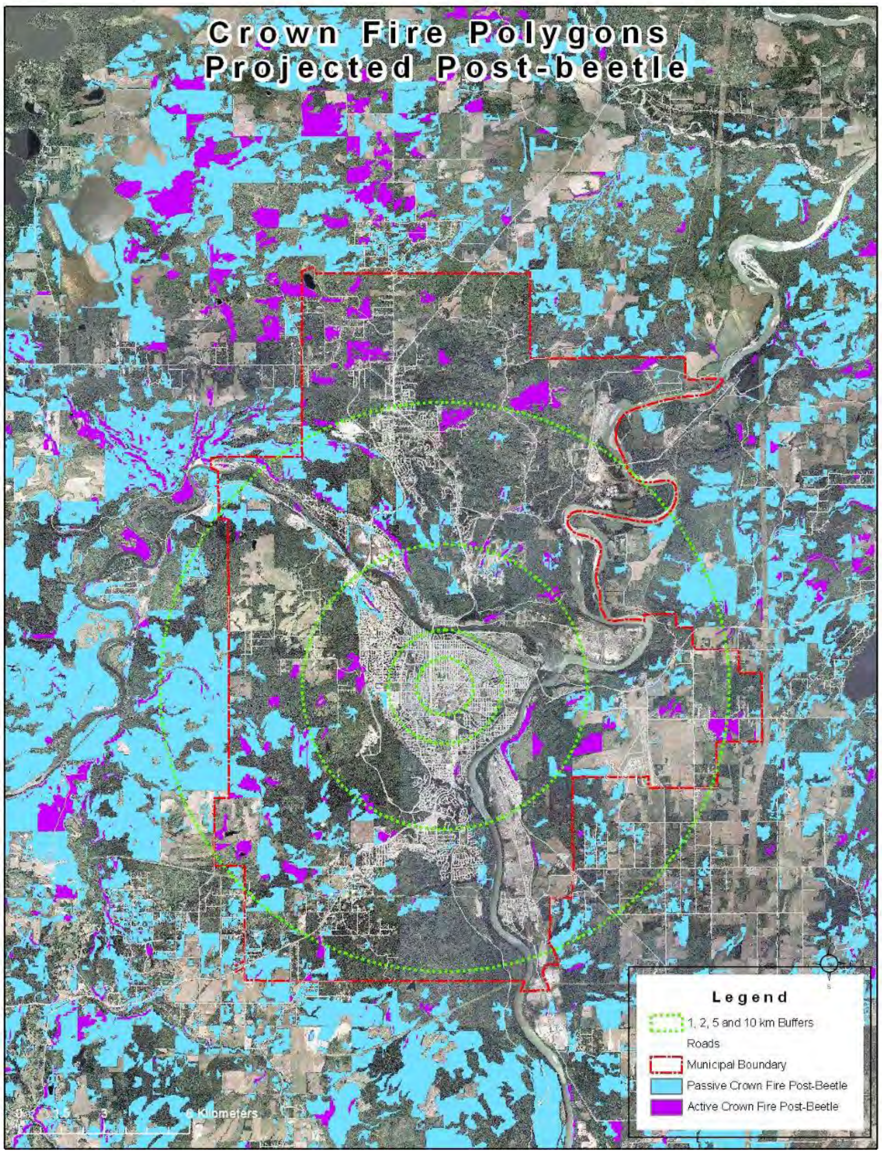


Figure 15. FlamMap run showing crown fire behaviour projected post-mountain pine beetle.

Assumptions and Limitations of the Analysis

Some key assumptions were made in the design of the analysis. The use of constant weather parameters, while not realistic, was desired given that the analysis was intended to investigate the relative differences in modelled fire behaviour following changes in fuel type rather than absolute fire behaviour values. It is important to note that the weather values used are entirely realistic and have occurred in Prince George in the past, although it is unlikely that they would remain exactly the same over 24 hours.

Selection of US fuel types on the basis of predicted fire behaviour in Canadian fuel types is not generally desirable and various tools are available (e.g., Fuel Characteristic Classification System) that could enable better mapping of US fuel types in Canada. Selection of how to parameterise each fire behaviour model was based largely on professional judgement. Given different circumstances of time and budget, it would be desirable to invest further study in both calibration and validation of each model. However, the authors believe that the underlying data and current parameter settings within each model are acceptable for the purposes of identifying hazardous fuels on the landscape and demonstrating the type of extreme weather conditions and ignition scenarios that could enable fire to endanger the community.

It is not recommended that these results alone be used to design and budget a detailed fuel treatment program, or for specific applications such as the location of suppression resources on the landscape.

Summary of Hazardous Fuels on the Landscape

While modelling indicates that large fires are possible in the north and the east of the City, it is fires advancing from the west and, potentially, the south that pose the greatest threat to the high density interface of Prince George. This is due to prevailing wind directions and the location of the high density interface. Areas of particular concern for extreme fire behaviour include Cranbrook Hill and the Nechako Ridge.

The large area of deciduous fuels (D1 in Figure 7) that flanks the interface to the west and south of the City provides a natural fuel break and the fuel treatment currently planned at the western boundary of the City would further fortify that natural break (Figure 7). Grasslands (O1a/O1b in Figure 7) of the rural landscape exhibit fast fire rates of spread but relatively low fire intensity and can therefore provide areas where suppression resources can safely make a stand against an advancing wildfire. There are, however, substantial areas of contiguous fuels to the west and south that are likely to exhibit passive and active crown fire behaviour, and could cause an ember shower over the high density interface. Figure 16 indicates the approximate area within which high hazard fuels are considered a landscape-level concern.

Based on the analysis, the 'Problem Fire' for Prince George is defined as a large fire advancing from the west through the Cranbrook Hill and/or Nechako Ridge areas under drought or extreme drought fuel moistures coupled with high windspeeds.

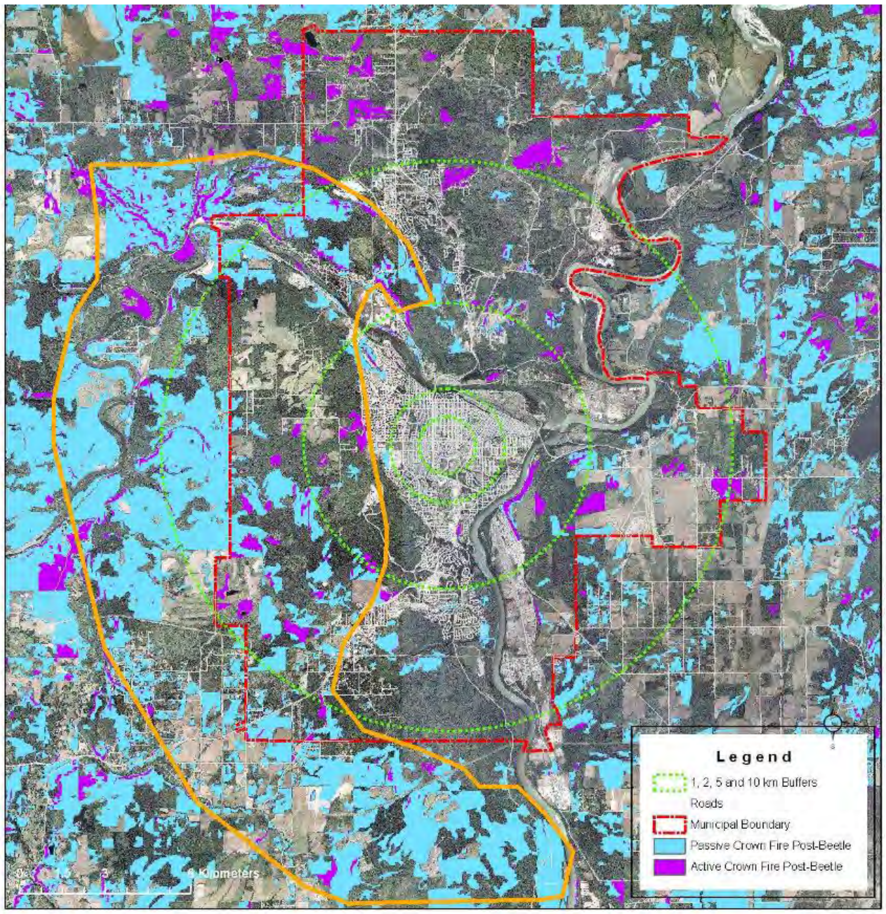


Figure 16. Approximate area of hazardous fuels that pose the greatest threat to the City indicated by the orange boundary.

What are the key constraints to treating and how much area should be treated in order to effectively mitigate the risk?

Definition of Constraints and Refinement of Treatment Area

In this case, constraints include any factor that must be explicitly addressed before a fuel treatment can occur and may exist for reasons including, but not limited to: political, social, environmental, operational, economic, archaeological, cultural and ownership issues. Given the limited time frame of this work, a detailed assessment of the constraints across the landscape was not undertaken and only ownership was considered. However, constraints would be assessed in detail prior to any expansion of the Community Forest Area or detailed fuel treatment planning.

In order to narrow down the area of focus for fuel treatments, the coarse delineation of hazardous fuels and the 'Problem Fire' defined in the previous section was further studied. It was determined that fuels in the vicinity of Cranbrook Hill and the Nechako Ridge were the key areas of concern given their continuity and the extreme fire behaviour modelled (Figure 14 and Figure 16). In addition, treatments would be focused within 10 km of the interface as beyond that spotting risk would be very low. Initially, any fuels exhibiting crown fire behaviour in those two areas were selected. They were then overlaid with ownership data to net out any private lands, which would definitely not be treated under the Community Forest Agreement. The gross 'ideal' treatment areas are shown in Figure 17.

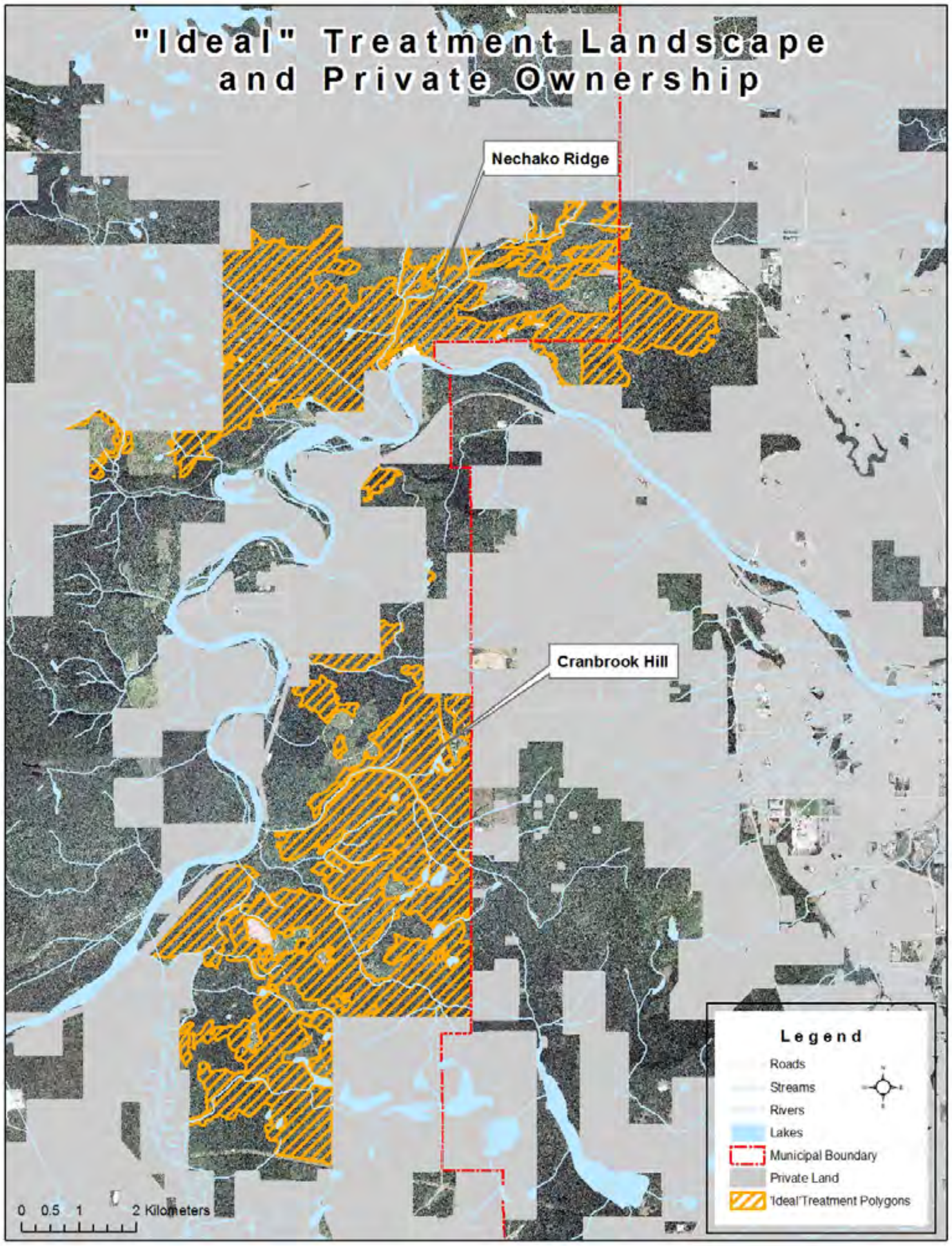


Figure 17. "Ideal" fuel treatment areas identified outside private lands.

The gross 'ideal' fuel treatment areas were then converted in to a fuel type landscape and input in to FARSITE and FlamMap. In FARSITE, the areas were run under the same ignitions and extreme drought fuel moisture conditions as were shown in Figure 14. As is demonstrated by the fire perimeters, the modified fuel areas result in a dramatic reduction in fire growth over the 24 hour period (Figure 18). The orange perimeter is influenced by the 'ideal' treatment areas and the red perimeter reflects the post-beetle landscape without these treatments. The fire is slowed by the 'ideal' treatments but, in the Nechako Ridge area, still spots over the river.

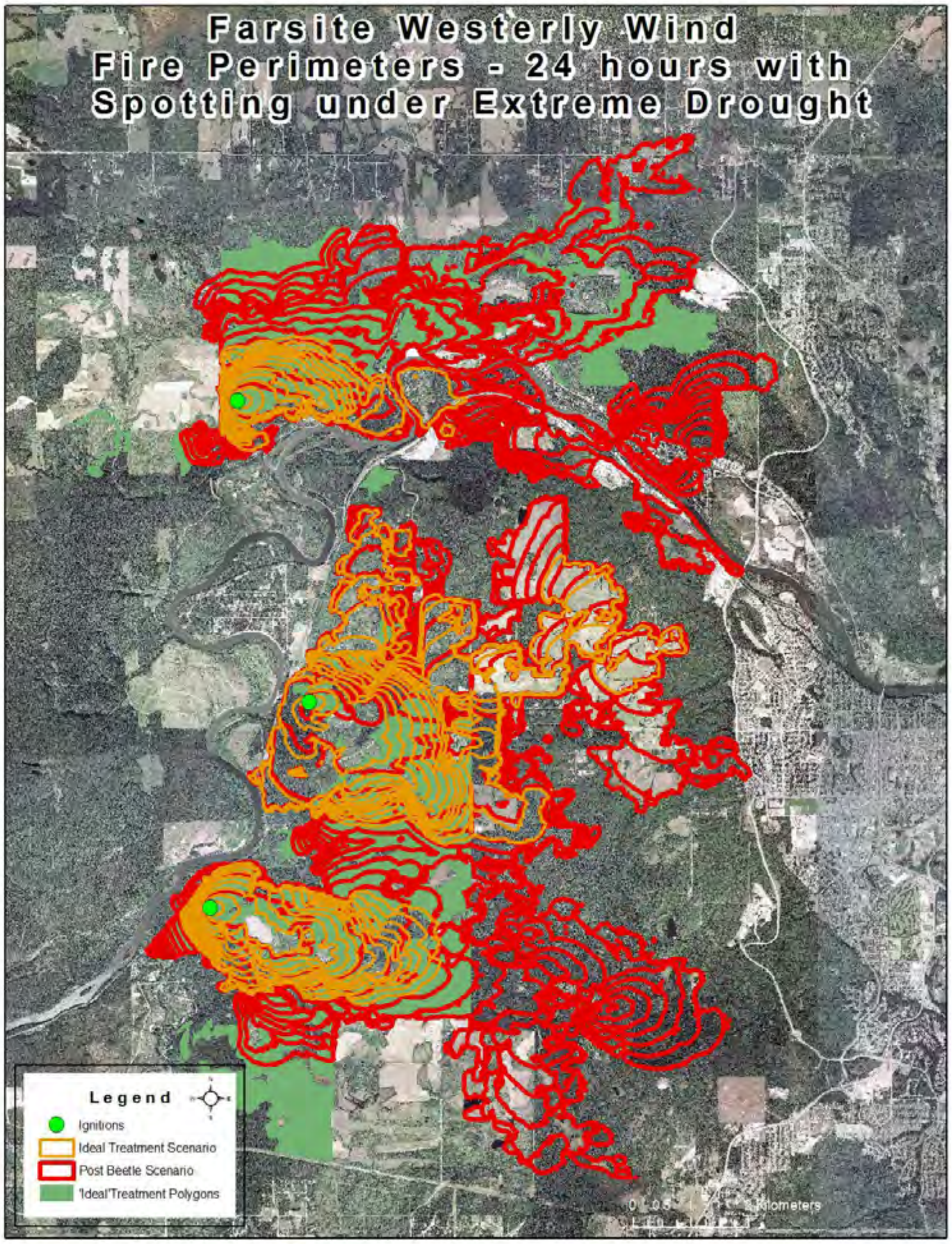


Figure 18. FARSITE run under extreme drought fuel moistures with spotting for the "Ideal" and post-beetle treatment landscapes.

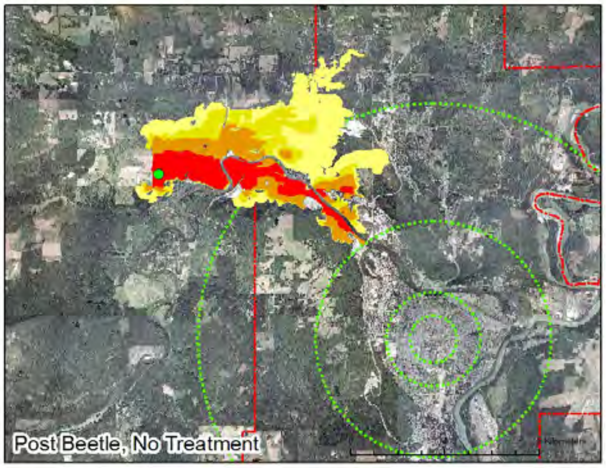
The Nechako Ridge area fire was modelled alone and the following changes were calculated for the "ideal" landscape versus the post-beetle landscape:

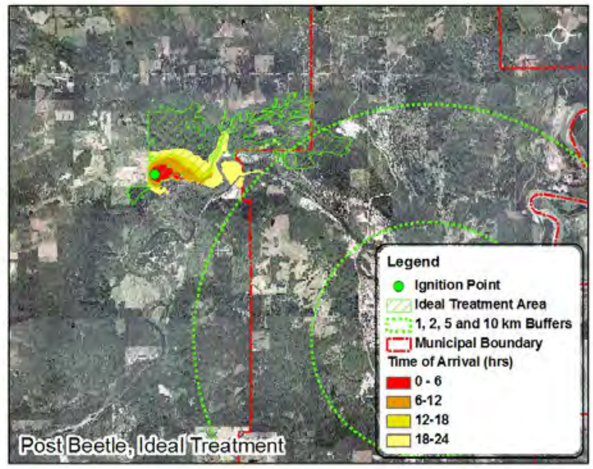
- Fire size was reduced by 89%
- Fire perimeter was reduced by 87%
- Spot fires were reduced by 90%

- Crown fire was reduced by 93%

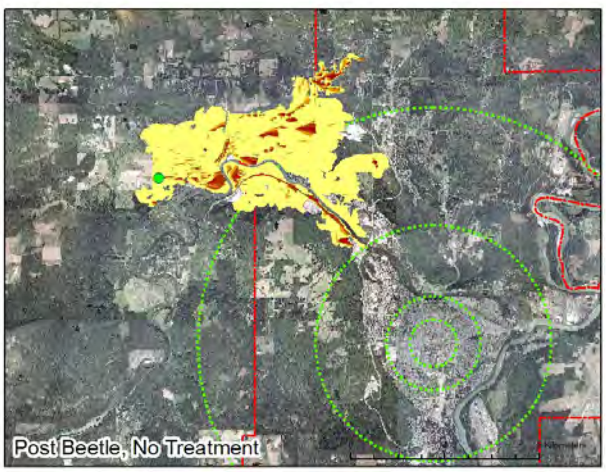
Table 5. Nechako Ridge Fire Behaviour for the "ideal" and post-beetle landscapes.

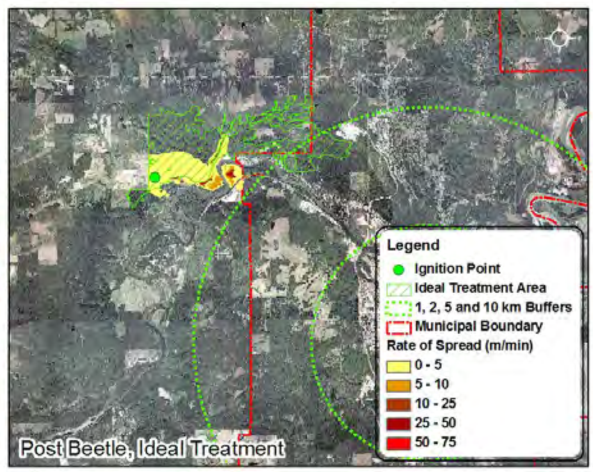
Time of Arrival



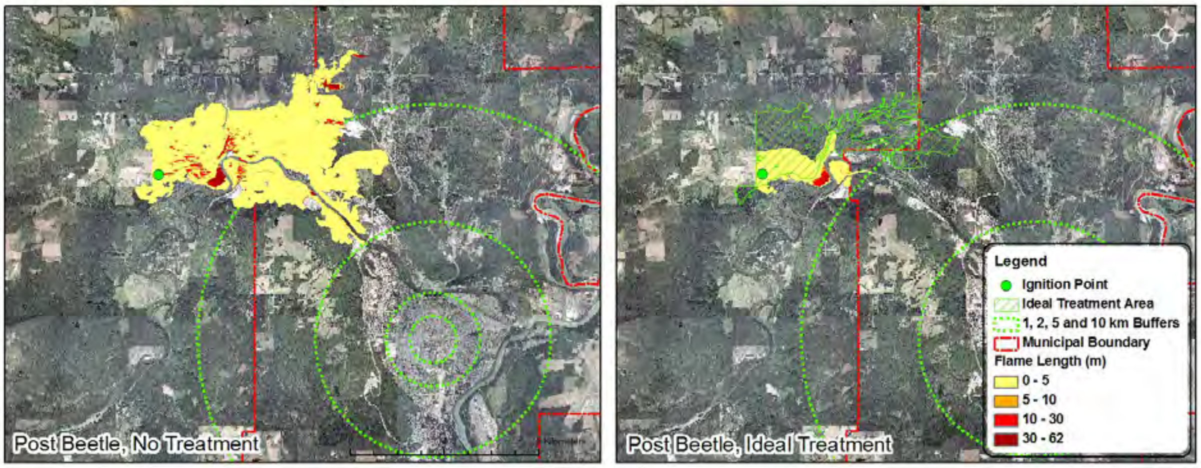


Rate of Spread

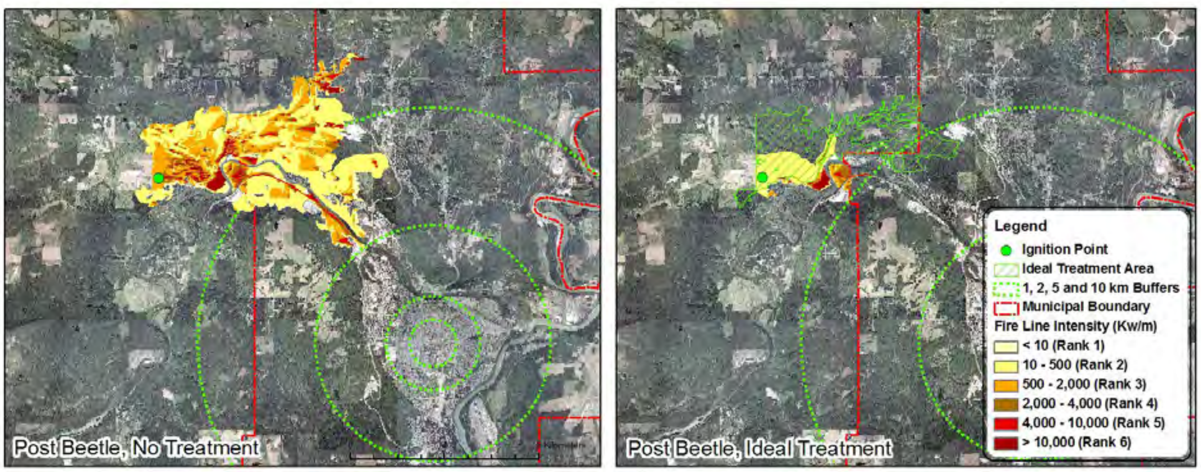




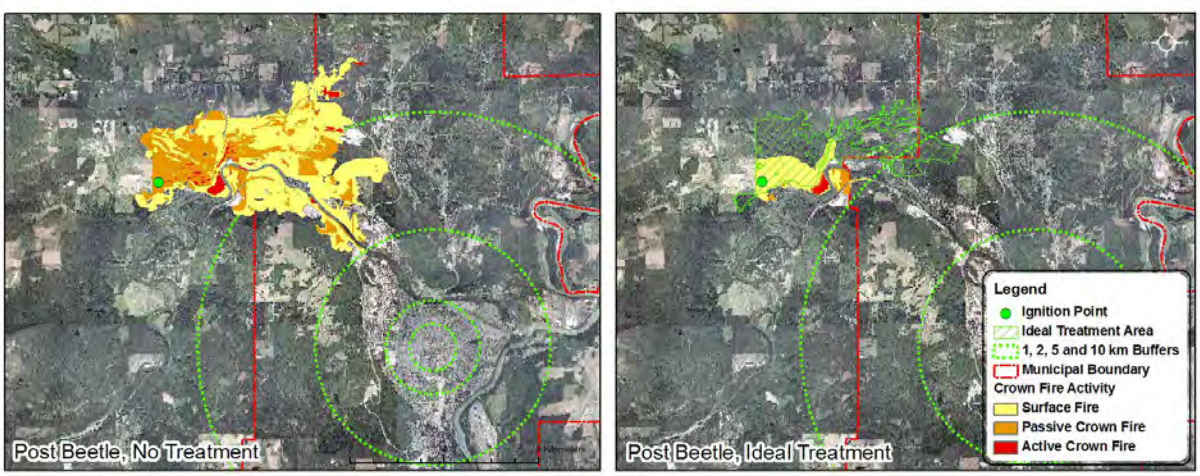
Flame Length



Fire Line Intensity



Crown Fire Activity



The results shown in Figure 18 and Table 5 both suggest dramatic and effective results from the treatment areas. However, the 'ideal' treatments encompass more than 3,400 ha and, even if unconstrained, the scale and cost of such a treatment area would be prohibitive in Prince George.

To further refine the treatment area while still retaining a benefit, the 'ideal' landscape was input into FlamMap's treatment optimization model. Several key assumptions of this modelling exercise as identified by Finney (2006) are that:

- A reduction in large fire growth is possible using multiple fuel treatment units on the landscape
- Wildfires are larger than the fuel treatment units therefore the directions fires move is more of a focus than their start locations
- Treatments are targeted to perform under a specific set of weather conditions

A line ignition (representing a large advancing fire front) was set to the west of the treatment areas and then the model was run for two iterations to derive the optimal treatment location. FlamMap does this by calculating major fire flow pathways across the landscape (Figure 19) and attempting to block them with fuel treatments (Figure 20).

When comparing where FlamMap located the treatments with the largest fires in the post-beetle landscape run under extreme drought fuel moisture conditions (Figure 21), treatments generally appear to be located at points where fires would become largest and advance towards the interface. This would be anticipated based on the major fire flow paths output by FlamMap (Figure 19). The reason the FARSITE fire perimeter and the FlamMap optimized treatment outputs do not match exactly is that FlamMap has assessed major fire flow paths and burned every cell on the landscape, whereas the FARSITE fire growth perimeters have grown from one cell to the next and do not follow every fire flow path.

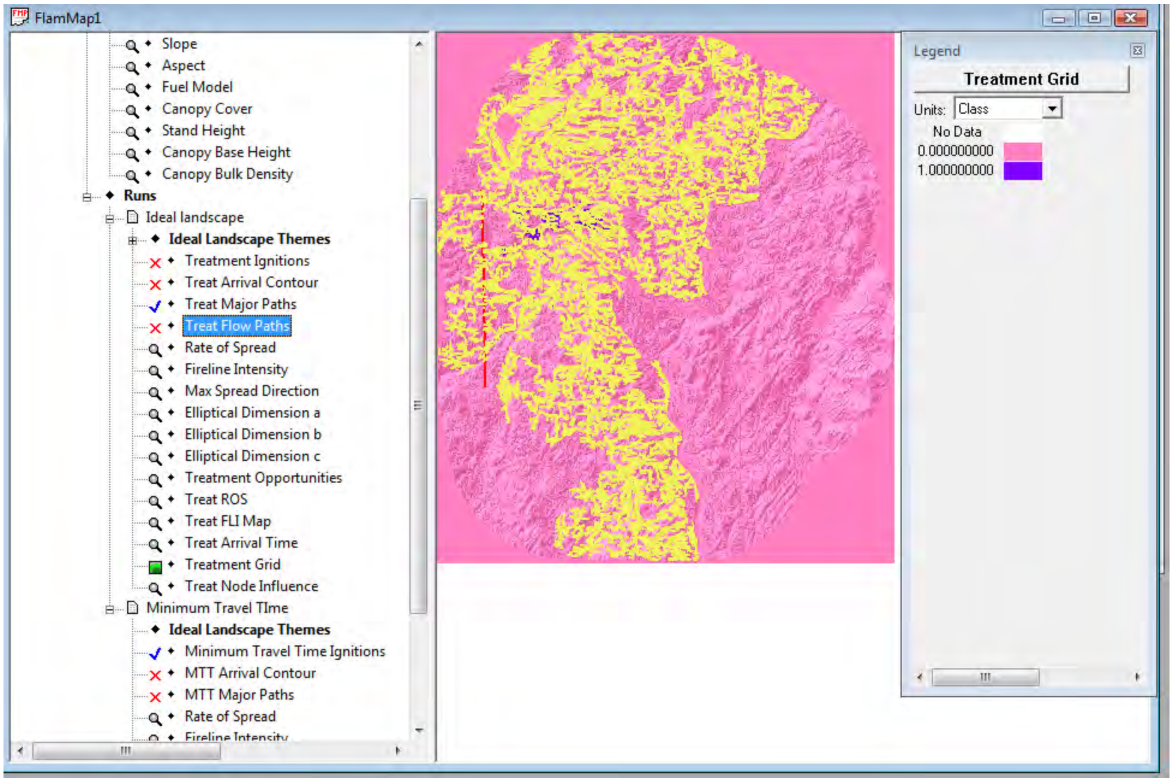


Figure 19. FlamMap screen capture of Treat Major Flow Paths

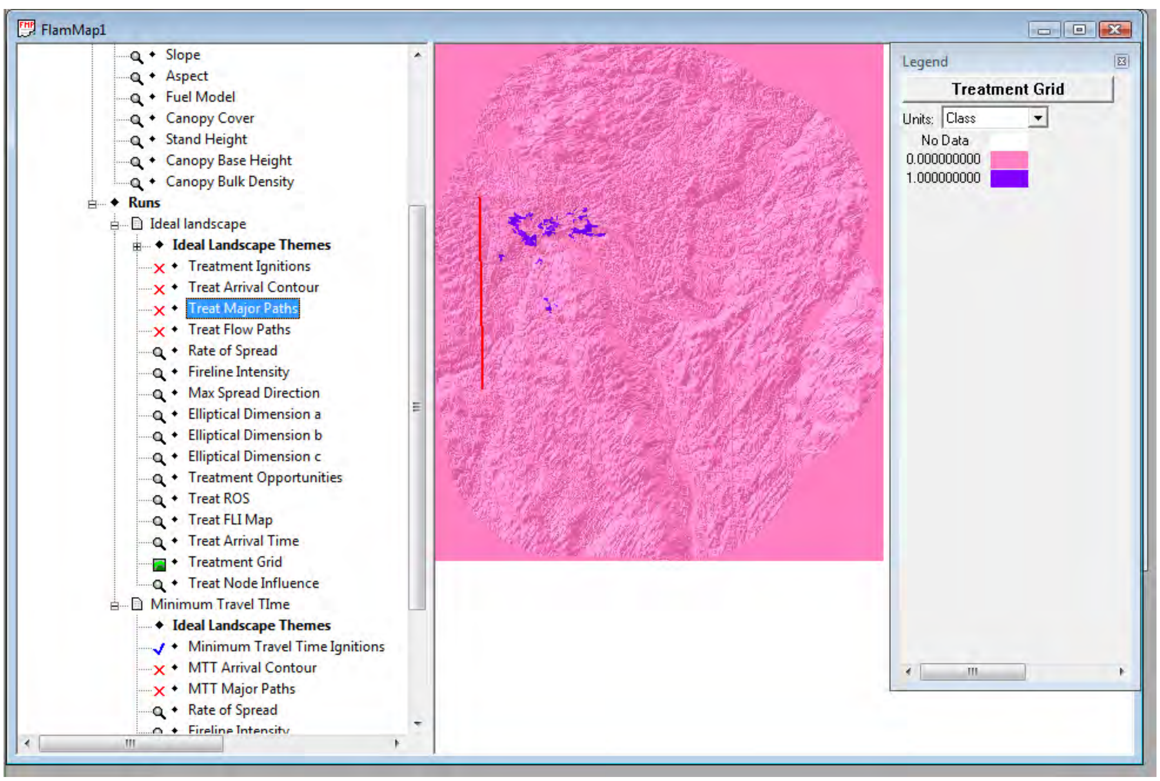


Figure 20. FlamMap screen capture of Treatment Grid

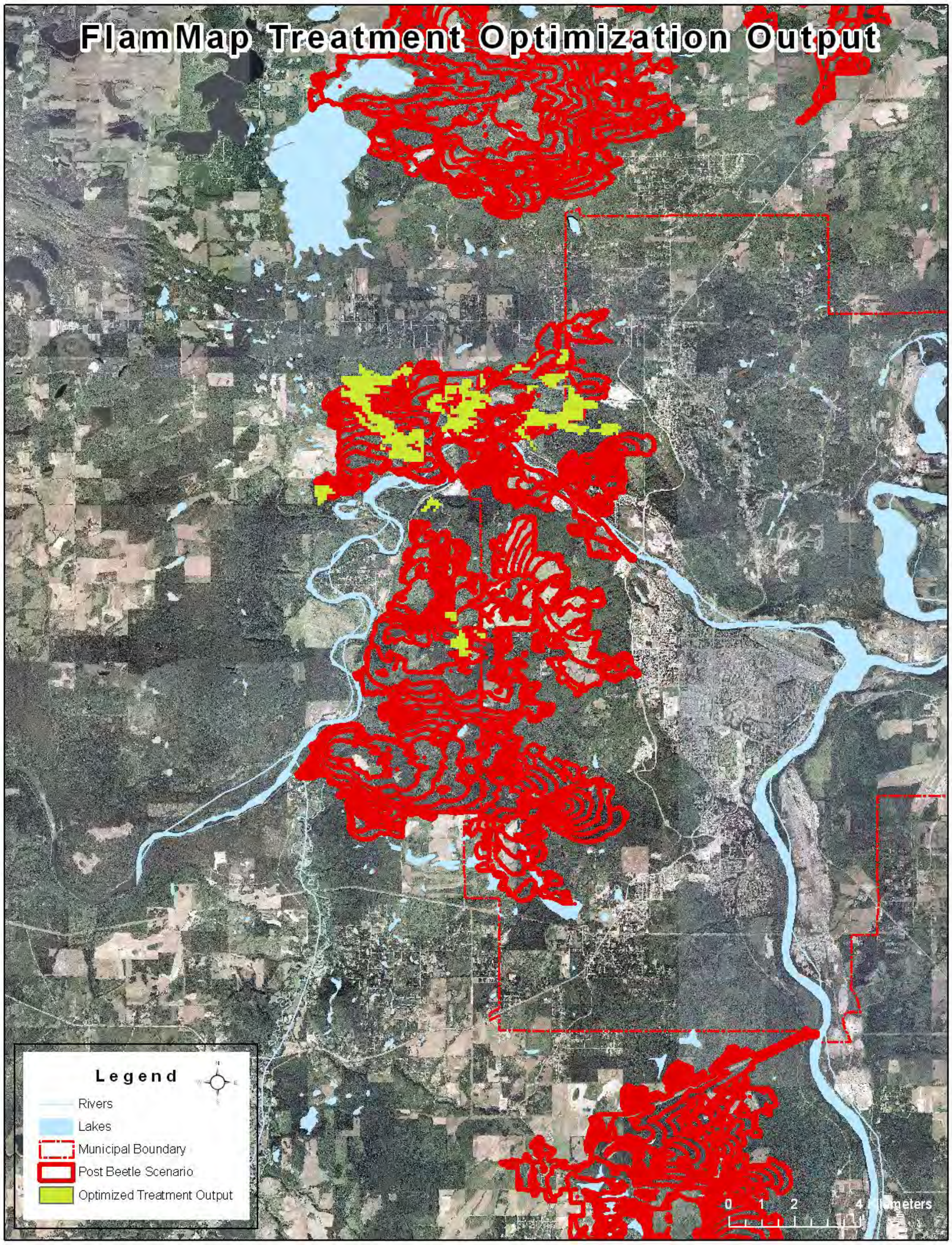


Figure 21. FlamMap Treatment Optimization Model output with FARSITE post-beetle landscape extreme drought output.

Summary of how much Area should be Treated

Based on the FlamMap outputs a polygon treatment area was defined (Figure 22). The total area that should be prioritized for treatment is 958 ha (represented by the green hatched polygons). Ground-truthing of these polygons is essential prior to any the expansion of the Community Forest or implementation of fuel treatments. Ground-truthing and professional judgement may yield additional or alternative treatment areas.

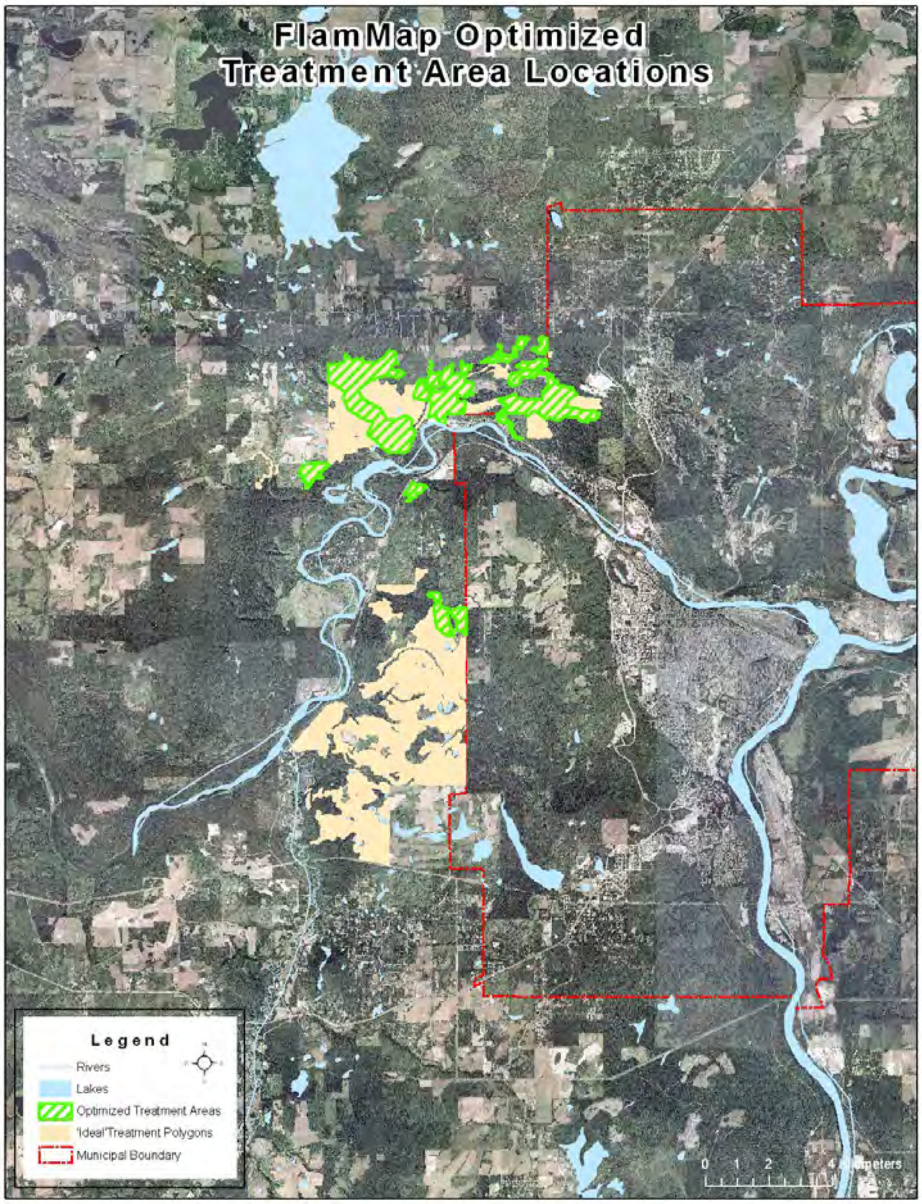


Figure 22. Map showing optimized treatment areas based on FlamMap Treatment Optimization Model.

What is an 'acceptable' level of wildfire risk to property and public safety within the community?

A cost-benefit analysis provides the information needed to support the type and extent of treatments that would be effective for the City of Prince George. While the fire behaviour modelling indicates that there are significant risks associated with this landscape it does not provide any information on the potential costs of treatment and the associated benefit. The following discussion is focused on quantification of the relative costs of fuel treatments and the benefits of these treatments in protecting the values at risk within the City of Prince George. All costs are based on a per hectare estimate with an average volume of merchantable timber. In reality, costs and benefits vary greatly depending on timber type, access and merchantability. However, a large portion of the area currently under consideration for treatment would likely fall within this stand average.

Typically in BC and in other jurisdictions around the world there is limited analysis of the costs of wildfire suppression and the associated values that are lost to wildfires. The suppression of a large wildfire is often only a fraction of the overall cost to society and does not really account for other economic, social and environmental losses that can be related to a large wildfire. Residents exposed to a wildland urban interface fire are directly impacted, but a complete account of the wildfire associated costs includes broader societal impacts.

A full accounting of costs considers long-term and complex costs, including impacts to watersheds, ecosystems, infrastructure, businesses, individuals, and the local and regional economies (Western Forestry Leadership Coalition 2009). The specific costs of a wildfire event can include property losses, post fire impacts (flooding, erosion, and degradation of water quality), air quality and related health issues, injuries, fatalities and lost revenues associated with economic disruption. Other costs include those associated with evacuations, disruption of transportation networks, lost wildlife habitat and other related ecosystem services.

Wildfire suppression can be viewed as treatment of a symptom that masks many of the underlying issues that caused the fire problem and that are related to the post fire condition. As a society we feel good about fire suppression like we feel when taking medication to treat the pain and not the specific injury. Treatment of fuels is analogous to exercise and diet in humans, which promotes good health and limits disease.

Wildfire suppression costs are often seen as the only real cost of wildfire, yet the vast majority of fire related costs are ignored or not accounted for in any post fire review. Wildfire costs extend well beyond the active suppression and mop-up stages. Quantification of wildfire costs requires a thorough accounting of the direct costs (suppression), rehabilitation costs, indirect costs, and additional costs that may be influenced by the longer-term post fire (e.g. degradation of water quality).

For the purposes of this project we have applied the methods and techniques described by Mason et. al. (2003), Western Forestry Leadership Coalition (2009), and the USDA Forest Service (2003). The approach of this exercise has been to estimate the treatment values (those values not lost by a wildfire), avoided costs (e.g., suppression costs) and to quantify the fuel treatment costs associated with two representative Prince George fuel types.

Figure 24 and 25 quantify the cost benefit of two fuel treatment types, one with an average treatment cost of $5,000/ha and the other where treatment costs average $20,000/ha and where the planning costs for both treatments are $500/ha. As part of this approach the value of the woody biomass has been quantified and three different log utilization factors have been applied to assess the treatment related commercial benefits including biomass, merchantable lumber and chips, thermal energy value and cogeneration avoidance of petrochemicals. Additionally, the avoided costs associated with suppression activities, timber losses, stumpage losses, biomass energy losses, and regeneration/restoration costs have been quantified. Non-timber value losses have not been documented but associated losses are recognized in the accounting.

Other important avoided costs include direct smoke and post fire emissions and degradation of air quality and the losses of stored carbon and reduction of carbon sequestration. Within the new British Columbia carbon tax regime these costs can be monetised based on the volume of wood in a particular stand type and have, for the purpose of this analysis, been included.

Indirect losses that have been avoided, but not included in the analysis are property value, property insurance, rural job loss, recreation/aesthetic losses, and regional economic losses. Placeholders were inserted for losses in ecosystem services including erosion, flooding, habitat and water quality.

When the cost benefit of fuel treatments are compared with avoided losses the cost benefit of fuel treatments shows a large benefit where the treatment costs are $5,000/ha. The net benefit ranges from $40,722 to $47,162/ha. When the cost of treatment increases to $20,000/ha the range of the net benefit by merchantable utilization class ranges from $25,722/ha to $47,162/ha. The cost benefit remains positive when the avoided costs associated with air quality, postfire emissions, and carbon sequestration values are not included.

The results of this simple accounting exercise suggest that, when the commercial values and the potential avoided costs are considered in this framework, there is a very positive cost benefit.

			Low	Med	Hi		Commentary
Stand Conditions							**Commentary**
	Cruise Volume				300	m³/ ha	Average SBS degraded stand
	Biomass				219	BDT/ ha	15% moisture content; 1.3x stand biomass multiplier; 660Kg/ m³ wood density
	Net caloric value				2,133	GJ/ ha	15 MJ/ kg; 65% energy conversion
	Carbon dioxide equivalent				401	tonnes CO2e/ ha	
Treatment Benefits			**Low**	**Med**	**Hi**		
Commercial benefits							
	Merchantible log utilization		17%	30%	50%		
	Biomass recovery		83%	70%	50%		
	Merchantible lumber and chip recovery		41	73	122	m³/ ha	Includes mill LRF and CRF
	Biomass bycatch		204	192	174	BDT/ ha	Includes mill fibre bycatch
	Lumber and chip value		$ 4,180	$ 7,524	$ 12,540	$/ ha	Prices: $120/m³ lumber; $80/ m³ chip
	Thermal value of energy		$ 16,293	$ 15,334	$ 13,895		Natural gas of $8.20
	Cogeneration avoidance of petrochemical		$ 993	$ 935	$ 847		Carbon tax of $0.5/ GJ or $10/ tonne CO2e
			$ 21,466	**$ 23,793**	**$ 27,282**		
Avoided costs							
On site	Fire fighting/ suppression		$ 4,200	$ 4,200	$ 4,200	$/ ha	Provincial average: $3000/ ha
		Fatalities	$ -	$ -	$ -		US: $25/ ha
		Facility losses	$ -	$ -	$ -		US: $200 - $400/ ha
	Timber losses		$ 4,180	$ 7,524	$ 12,540		See above
	Stumpage revenue		$ 239	$ 431	$ 718		Logs: $10/ m³; Chips: $0.25/m³
	Wild-crafting (non-timber) losses		$ -	$ -	$ -		
	Biomass energy losses		$ 16,293	$ 15,334	$ 13,895		See above
	Regeneration/ restoration		$ 1,200	$ 1,200	$ 1,200		Planting, prep, planning
Off site	Community values		$ 156.00	$ 156.00	$ 156.00		US: $156/ ha
		Property value					
		Property insurance	$ -	$ -	$ -		
		Willingness to pay	$ -	$ -	$ -		
		Rural jobs	$ -	$ -	$ -		
		Recreation/ amenity activity	$ -	$ -	$ -		
	Regional economic values	Economic multiplier (2:1)	$ -	$ -	$ -		
Ecosystem goods and services			$ 159	$ 159	$ 159		Pembina Institute BWEAS
	Aesthetics		$ -	$ -	$ -		
	Hydrology	Erosion	$ -	$ -	$ -		
		Flooding	$ -	$ -	$ -		
		Quality	$ -	$ -	$ -		
	Habitat		$ -	$ -	$ -		
	Smoke and emissions		$ 11,510	$ 11,510	$ 11,510		Assume 20% combustion; GWP for: CO2, CO, NOx, CH4, PM 2.5
	Post fire emissions		$ 4,270	$ 4,270	$ 4,270		30-years decomposition and reduced sequestration
	Carbon sequestration		$ 4,015	$ 4,015	$ 4,015		
			$ 46,222	**$ 48,798**	**$ 52,662**		
Treatment Costs							
	Planning and prep		$ 500	$ 500	$ 500	$/ ha	$250 - $750
	Treatment		$ 5,000	$ 5,000	$ 5,000		$2,500 - $10,000
	Environmental Impacts		$ -	$ -	$ -		
Total			**$ 5,500**	**$ 5,500**	**$ 5,500**		
Cost: Benefit			**$ 40,722**	**$ 43,298**	**$ 47,162**	$/ ha	

Figure 23. Cost Benefit Calculation with Treatments at $5,000/ha.

Item	Sub-item	Low	Med	Hi	Units	Commentary
Stand Conditions						**Commentary**
Cruise Volume		300			m³/ ha	Average SBS degraded stand
Biomass		219			BDT/ ha	15% moisture content; 1.3x stand biomass multiplier; 660Kg/ m³ wood density
Net caloric value		2,133			GJ/ ha	15 MJ/ kg; 65% energy conversion
Carbon dioxide equivalent		401			tonnes CO2e/ ha	
Treatment Benefits		**Low**	**Med**	**Hi**		
Commercial benefits						
Merchantible log utilization		17%	30%	50%		
Biomass recovery		83%	70%	50%		
Merchantible lumber and chip recovery		41	73	122	m³/ ha	Includes mill LRF and CRF
Biomass bycatch		204	192	174	BDT/ ha	Includes mill fibre bycatch
Lumber and chip value		$ 4,180	$ 7,524	$ 12,540	$/ ha	Prices: $120/m³ lumber; $80/ m³ chip
Thermal value of energy		$ 16,293	$ 15,334	$ 13,895		Natural gas of $8.20
Cogeneration avoidance of petrochemical		$ 993	$ 935	$ 847		Carbon tax of $0.5/ GJ or $10/ tonne CO2e
		$ 21,466	**$ 23,793**	**$ 27,282**		
Avoided costs						
On site – Fire fighting/ suppression		$ 4,200	$ 4,200	$ 4,200	$/ ha	Provincial average: $3000/ ha
	Fatalities	$ -	$ -	$ -		US: $25/ ha
	Facility losses	$ -	$ -	$ -		US: $200 - $400/ ha
Timber losses		$ 4,180	$ 7,524	$ 12,540		See above
Stumpage revenue		$ 239	$ 431	$ 718		Logs: $10/ m³; Chips: $0.25/m³
Wild-crafting (non-timber) losses		$ -	$ -	$ -		
Biomass energy losses		$ 16,293	$ 15,334	$ 13,895		See above
Regeneration/ restoration		$ 1,200	$ 1,200	$ 1,200		Planting, prep, planning
Off site – Community values		$ 156.00	$ 156.00	$ 156.00		US: $156/ ha
	Property value					
	Property insurance	$ -	$ -	$ -		
	Willingness to pay	$ -	$ -	$ -		
	Rural jobs	$ -	$ -	$ -		
	Recreation/ amenity activity	$ -	$ -	$ -		
Regional economic values	Economic multiplier (2:1)	$ -	$ -	$ -		
Ecosystem goods and services		$ 159	$ 159	$ 159		Pembina Institute BWEAS
Aesthetics		$ -	$ -	$ -		
Hydrology	Erosion	$ -	$ -	$ -		
	Flooding	$ -	$ -	$ -		
	Quality	$ -	$ -	$ -		
Habitat		$ -	$ -	$ -		
Smoke and emissions		$ 11,510	$ 11,510	$ 11,510		Assume 20% combustion; GWP for: CO2, CO, NOx, CH4, PM 2.5
Post fire emissions		$ 4,270	$ 4,270	$ 4,270		30-years decomposition and reduced sequestration
Carbon sequestration		$ 4,015	$ 4,015	$ 4,015		
		$ 46,222	**$ 48,798**	**$ 52,662**		
Treatment Costs						
Planning and prep		$ 500	$ 500	$ 500	$/ ha	$250 - $750
Treatment		$ 20,000	$ 20,000	$ 20,000		$2,500 - $10,000
Environmental Impacts		$ -	$ -	$ -		
Total		**$ 20,500**	**$ 20,500**	**$ 20,500**		
Cost: Benefit		**$ 25,722**	**$ 28,298**	**$ 32,162**	$/ ha	

Figure 24. Cost Benefit Calculation with Treatments at $20,000/ha.

Conclusions and Recommendations

The historic fire record and the current configuration of fuels (including dead pine) on the landscape supports the notion that a large, landscape-level fire event could occur within the study area. In addition, the influence of climate change could result in longer periods of high fire danger than have occurred historically. Climate change modelling has suggested that extreme weather events such as droughts will occur with greater frequency in the future.

Fire behaviour modelling indicates that, while the last 4 years of the MPB removal work has reduced the fire hazard in many sites within the City, there remain areas of high and very high wildfire hazard; particularly in the western (Cranbrook Hill) and north western (Nechako Ridge) areas of the City. These areas, while outside the bowl of the City, constitute significant wildfire hazards because of the amounts of dead pine, potentially extreme fire behaviour, access challenges for fighting wildfires, and the proximity to residential development and UNBC. Strategically treating some of these areas through a wildfire-fuel reduction program would substantially reduce the wildfire hazards. Given that much of the high hazard fuels are on Crown owned land, the City's Community Forest Agreement could provide a mechanism for reducing fuel hazards in these areas outside the municipal boundary.

The City's existing fuel hazard treatment program has focussed on mitigating high hazard fuels (C2, C3 and C4 fuel types) immediately surrounding high density interface. In contrast, this analysis has focussed on identifying fuels that are further away from the interface but that could endanger the City during a landscape level fire event.

In considering fuel treatments on crown land adjacent to the City, costs per hectare would be expected to be considerably lower for landscape-level treatments than for those sites treated within the City to date because treatment areas would be larger and could utilize more conventional harvesting methods. Costs could be further reduced depending on factors such as the availability of MOFR Fire Crews to assist with treatments. These treatment areas would be less constrained by issues such as private property, public safety, geotechnical concerns and park management objectives and there would be a higher proportion of revenue from timber removed and sold. However, access could be an issue in some areas potentially increasing the cost of treatment.

Ground truthing and thorough prescription design implementation would be an essential part of any landscape level fuel treatment program. The effectiveness of any fuel treatments is substantially affected by treatment methods, completeness of treatment application and treatment design. When laying out treatment area boundaries on the ground, general principles of fuel treatments should be considered including orienting cut-blocks to the prevailing wind, following natural fuel type changes, topography, hydrology and, where possible, using prescribed fire to further reduce fuel hazards on site post-harvest and in surrounding unproductive forests.

While landscape level fuel treatments cannot guarantee that the City would be unscathed by an extreme fire event, if properly designed and implemented, the treatments will reduce the overall probability of a landscape-level fire, improve suppression capability and reduce the likelihood of extensive structural losses from an ember shower.

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Appendix 1 – The Citizen Special Edition: 'Great Fire of '61'

THE CITIZEN

The Only Daily Newspaper Serving North Central British Columbia

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Special Edition: The Great Fire of '61

Phone LOgan 4-2441 Vol. 5 Nos. 152-169 **Prince George, British Columbia, Thursday, AUGUST 3 to Tuesday, AUGUST 29, 1961** 7c a Copy BY CARRIER $1.50 per Month

Thursday August 3, 1961

1,000 ACRES

Crews Beefed-Up As Blaze Grows

B.C. Forest Service today beefed-up suppression crews on a huge fire burning out of control 20 miles from here as the blaze mushroomed to 1,000 acres.

Thirty five unemployed men were rushed to the Buckhorn Lake area to join a 55 man fire fighting crew taken to the fire shortly after it broke out late Wednesday.

Smoke from the fire believed caused by a spark from a power saw, was billowing 10,000 feet into the air and was visible from the city.

Blaze was being fanned by wind today as it relentlessly cut a huge swath through the bush. Seven firefighters were cutting and widening fire guards around the fire.

Forest Service officials hope the guard will hold the fire away from Schlitt Bros. Sawmill and timber stand. The mill is less than two miles from the fire.

Forest service officials have no immediate plans to evacuate the Schlitt Bros. camp where there is a handful of women and children.

August 15, 1961

SPORTS HIGHLIGHTS

Argos mislaid their Winnipeg jinx as Bombers win by 14-13 score.

★ ★ ★

Halfback Quillen stands out as Edmonton trounces Roughriders.

★ ★ ★

Maris, Mantle and Ford go after records against Chicago today.

The view from Third Avenue of the column of smoke rising from Tabor Mountain. - Photo: Fraser-Fort George Regional Museum

Friday August 4, 1961

EVACUATION PLANNED

Blaze Threatens Mill Near Here

The huge forest fire burning 20 miles south east of here today was threatening to force evacuation of about a dozen women and children at a sawmill in the path of the blaze.

Forest service reported the fire "went crazy" about 9 p.m. Thursday, jumped most free guards that had been constructed and today was less than a mile from Schlitt Bros. sawmill.

Plans to evacuate were made Thursday night. However, the women and children remained overnight. "Its up to them when they go," a forest service spokesman said. "We can only advise them when to evacuate." The men from the camp are all on the fire lines.

The fast- spreading forest fire has more than doubled in size since Thursday night and now covers well over 2,000 acres.

The fire is the worst in the immediate Prince George area since the disastrous fires in the Summit Lake area in 1958.

Tuesday August 8, 1961

Timber Dry

Blaze Advancing On Two Centres

Residents of Giscome and Willow River sawmill communities east of here, watched anxiously as a forest fire continued to move towards them.

The blaze was still 10 miles away today, but if it continues on its course and maintains its current size, the centres could be in danger, a B.C. Forest Service spokesman warned. "There's a lot of good, dry timber between them and the fire."

Size of the blaze, known as the Grove Fire was placed at about 25,000 acres.

It was one of two major fires in the area which are still burning out of control. The other is the Tsus Fire, 40 miles southeast of here, which covers 30,000 acres.

WEATHER HELPS

"The weather helped us a little on Monday," the forest service spokesman said, "but today's weather isn't going to. And, if we get wind, all hell will break loose." (Forecast for today was for warmer, drier weather for the next several days. Chances of rain were nil.)

The Grove Fire completely destroyed Tabor Lake Sawmill Monday. Mill owner Alf Strom said today a bulldozer coming to protect the mill "arrived 15 minutes too late. We had nothing else to fight the fire with." Loss has been estimated at $40,000. It was partially covered by insurance.

Vic Hunter who, with wife Bernice, escaped Sunday morning from the forest service lookout on Tabor Mountain said the woods were like "gunpowder."

"You just look at it and it explodes," he said.

Wednesday August 9, 1961

Blaze Pretty But...

To many people, a forest fire is beautiful. Or perhaps the word should be fascinating.

But to the men on the fire lines and the mill owners, a fire such as the Grove Fire, is an ugly monster, an enemy.

TIMBER GONE

For Mr. Kirschke, owner of Six Mile Lake Sawmill, the fire has been a disaster. It has destroyed his timber.

"Here I protect a stand of timber for almost 30 years and now its gone - taken out by a fire that started miles away. It just breaks my heart."

Mr. Kirschke is no longer a young man, but sitting on the sidelines isn't for him. "Bill Kirschke is working like a horse," a B.C. Forest Service official said. "He's one of the most valuable men we've got."

However, the pace caught up with Bill Kirschke early Monday morning and he literally collapsed after fighting the fire since early Saturday.

FINALLY SLEPT

His wife, Irene said, "We finally got him to sleep, but he had to collapse before he'd do it."

Later that morning, Bill Kirschke was back at his post, helping direct the battle against the part of the Grove Fire burning over Tabor Mountain.

"The wind holds the key to this fire," said ranger supervisor John Keefe. "It has us at its mercy. We don't know which way it is going to blow."

One of the men helping to slash a fire guard was Doug Pruden of Shelley Sawmills, a cat skinner. He and his huge D 8 arrived on the fire line about 11 a.m. Monday. They were put to work cutting a guard. Doug, is almost a magician with his big bulldozer, skillfully guiding it over big trees and swampy ground. The bulldozers are the big guns in the battle on the Grove Fire.

Unsung heroines of the fight against the huge blaze are the women at Six Mile Lake Sawmill. They are feeding 190 men three times a day. They were performing the task on a tiny wood-burning stove and with facilities designed for only a dozen men.

The only rewards the ladies get for their hard work is an occasional "This sure is good," or "Could I please have some more?" But that's enough.

The women at Six Mile Lake Sawmill, feeding 190 men three times per day! - Photo: Fraser-Fort George Regional Museum

Friday August 11, 1961

AN UGLY CALLING CARD

Blackened Waste Is Fire's Legacy

Once it was a pleasant hillside.

Tall spruce and fir thrust lofty spires into the heavens, red berries splashed colour among green grass and bushes and wild flowers opened to receive the sun.

Deer and moose browsed lazily among shady trees, birds sang, squirrels chattered sharply in the stillness and rabbits bounded along the trails.

Men and snorting monsters logged some of the trees but many were left standing.

Today it is all gone the trees, the flowers, the animals...

Today, gaunt, shriveled reminders of what were once stately trees stick forlornly into the air, or lean exhausted against one another. The earth has been scorched down to the sub-soil. Its sooty colour is grim and lifeless.

This is what the Grove Fire has done to Tabor Mountain.

Fire leveled everything in its path, cutting a huge swath up the side of the mountain, laying its gullies and hillocks bare like the ribs on a skeleton.

Girdling the burned out areas, like a belt pulled tight on an empty stomach, are the fire guards, mute reminders of man's futile efforts against the raging inferno.

And still the fire burns and simmers and smoulders and burns.

No longer do the birds sing, rabbits play, squirrels chatter or deer or moose roam around the mountain.

No longer can man take his living from the soil. It is all gone now. Death has ravaged the land like a plague. It will be many years before it is green and alive again.

And the fire still simmers and smoulders and burns.

Tuesday, August 15, 1961

CONSCRIPTION 'OUT'

Fire-Fighting Credited with Decline in Jobless

Number of men employed in fighting forest fires in the district is credited with giving Prince George its lowest number of unemployed in two years.

Meanwhile, Forest Service officials today denied men are being conscripted to fight fires in the area.

"The Forest Service has not conscripted men, nor is it contemplating such action," the spokesman said. He added: "Under no circumstances is it intended that tourists be recruited to fight forest fires. This is emphasized most emphatically."

The statements were made apparently to counter reports allegedly rife in southern B.C. that tourists, including Americans, would be forced to fight fires if they ventured into any of the province's fire areas.

Tuesday August 15, 1961

MACHINES BREAK DOWN

Forests 'Explosive' After Lightening

A lightening storm that hit part of Prince George district Monday night combined with the continued drying trend to make the forest fire situation here "explosive" today.

B.C. Forest Service officials in Prince George said they are also faced with another major problem how to replace the heavy bulldozers that are starting to break down.

"We've got every big machine in the area on the fire lines now," a spokesman said. "There just aren't any around that we can use as replacements. Many of the big machines have been going hard for almost 2 weeks."

"It will be a disaster if too many break down."

On the fireline - Photo: Fraser Fort George Regional Museum

Thursday August 17, 1961

Grove Fire Hops Guard

Fire situation in the giant Prince George Forest Region is grimmer today following unexpected flare-us of the two largest blazes in the district Thursday.

The flare-ups were entirely unexpected a B.C. Forest Service spokesman said.

The Grove Fire flared up on two fronts, jumping guards and chasing one suppression crew to safety. One of the bulldozers used to build fire guards in the area, threw a tread in the dash for safety and had to be abandoned. Firefighters were holding the outbreak this morning, but trouble is expected with today's forecast hot, dry weather.

Tuesday August 22, 1961

GROVE FLARES UP

New Spot Fires Trouble Harassed Forest Crews

Successful snuffing of spot fires breaking out in the area is saving the day for firefighters hard-pressed in their efforts to contain the three major blazes in the Prince George Fire District.

BUILDING GUARDS

New guards were being built today around the southern end of the Grove Fire, after a flare-up late Monday drove the blaze three miles farther east.

The fire, the largest in the beleaguered Prince George Forest District, moved around a sawmill at Frost Lake. Local "devil" winds - those created by the fire itself - caused the flare-up.

CHECK BY AIR

One of the two new spot fires covers about 2,000 acres at Haggen Creek, 65 miles south east of here. The country is remote and believed to be heavily timbered.

The second was burning at the 4,000 foot level of a mountain north of Narrow Lake, 40 miles southeast of here. It was bombed with mud late Monday, although it was expected to burn itself out as it reaches rock and scrub at higher levels.

Considered out of danger for the moment were Schlitt Brothers Sawmill, the mill at Frost Lake and four farm homes as the Grove Fire moved eastward.

Tuesday August 29, 1961

BIG FIRES CONTROLLED

Number of Firefighters Reduced In Area by 400

The number of men employed in firefighting operations in the Prince George Forest District dropped by 400 to 1,240 today.

For the first time since they broke out last month, the major fires were described today as under control. But, a forestry spokesman said they will probably continue to smolder until the snow falls.

There are still 86 fires burning in the forest district, with no new ones reported since early Monday.

CITY OF PRINCE GEORGE LANDSCAPE SCALE FIRE BEHAVIOUR MODELLING AND PROPOSED FUEL TREATMENTS

By
Amelia Needoba and Bruce Blackwell
B.A. Blackwell and Associates Ltd.

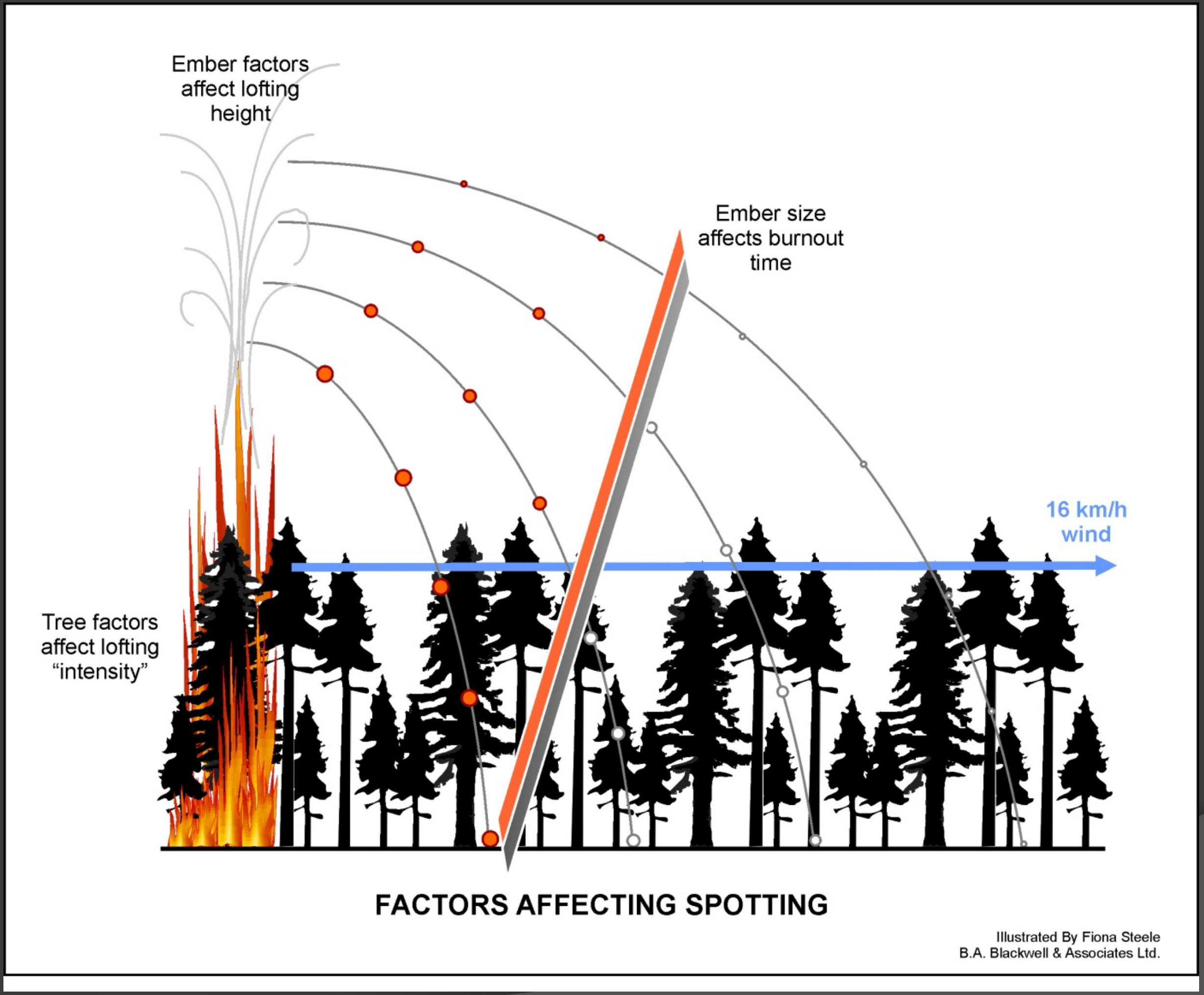
Progress to Date

- In 2005 the City of Prince George was one of the first municipalities in BC to develop a Community Wildfire Protection Plan (CWPP) to address wildfire risk. The plan contained a number of recommendations and identified key areas within the municipal boundary where fuel treatments should be undertaken.
- Treatments have been prescribed for City parks and greenspaces, undeveloped forested properties owned by the City and some Crown land within the City. For the most part, fuel treatments have been completed on municipal lands and several treatments are currently underway on Crown lands. Crown lands are treated under the Community Forest license held and managed by the City.

Landscape Level Risk

- However, the CWPP derived fuel treatment program does not address the arguably greater risk to the City posed by a landscape level fire event causing an ember shower from a distant fire to rain down on the City. An ember shower results when burning particles are lofted well ahead (kilometres) of the fire front by the convection column and wind.

Spotting Slide



The Effect of Fuel Treatments

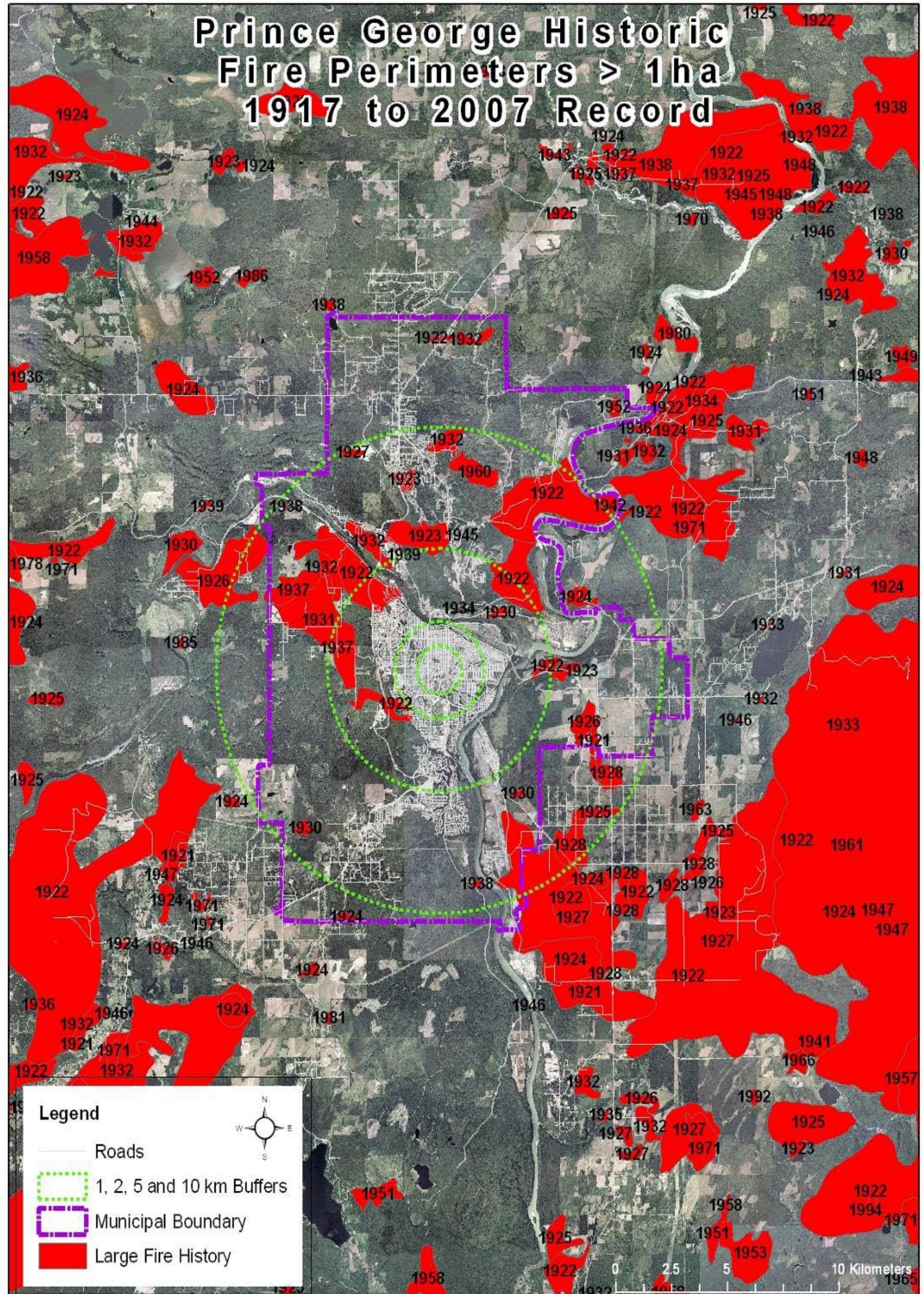
- In BC, fuel treatments are gaining acceptance as a key tool available to fire managers
- Important to understand that fuel treatments do not stop fires, but lessen the impact of a fire on an identified area of concern by changing the behaviour of a fire entering a treated area.
- The purpose of assessing fuels and fuel treatments at a landscape level is identify a configuration of treatment areas that will slow the growth of large fires by reducing fire intensity, crown fire, and mid-long range spotting.

Fuel Treatment Examples

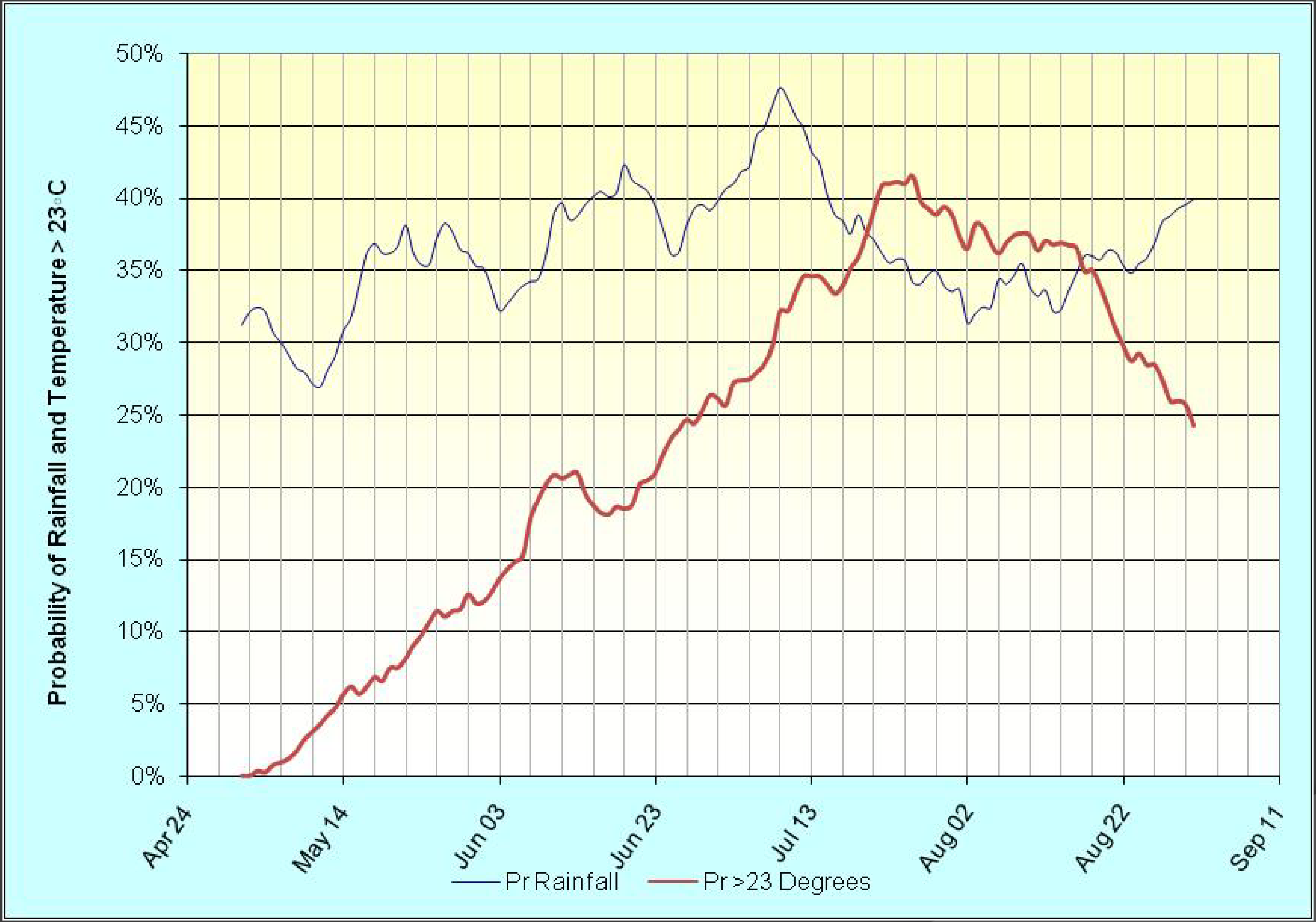
Fire History and Weather Trends

- During the period from 1921 to 2007 fire history records indicate 151 large fire starts from many locations from around the City.
- Spread directions suggest that winds at the time of the fires were generally from the south, west or north. The majority of fires in the record were lightning caused.
- Weather records also highlight that the period of greatest concern during the fire season is mid-July to the third week of August.
- This is the period of time when the probability of precipitation is lowest and the probability of temperatures >23^{0}C is highest.

Fire History



Weather Trends



Fire Growth and Behavior Modeling

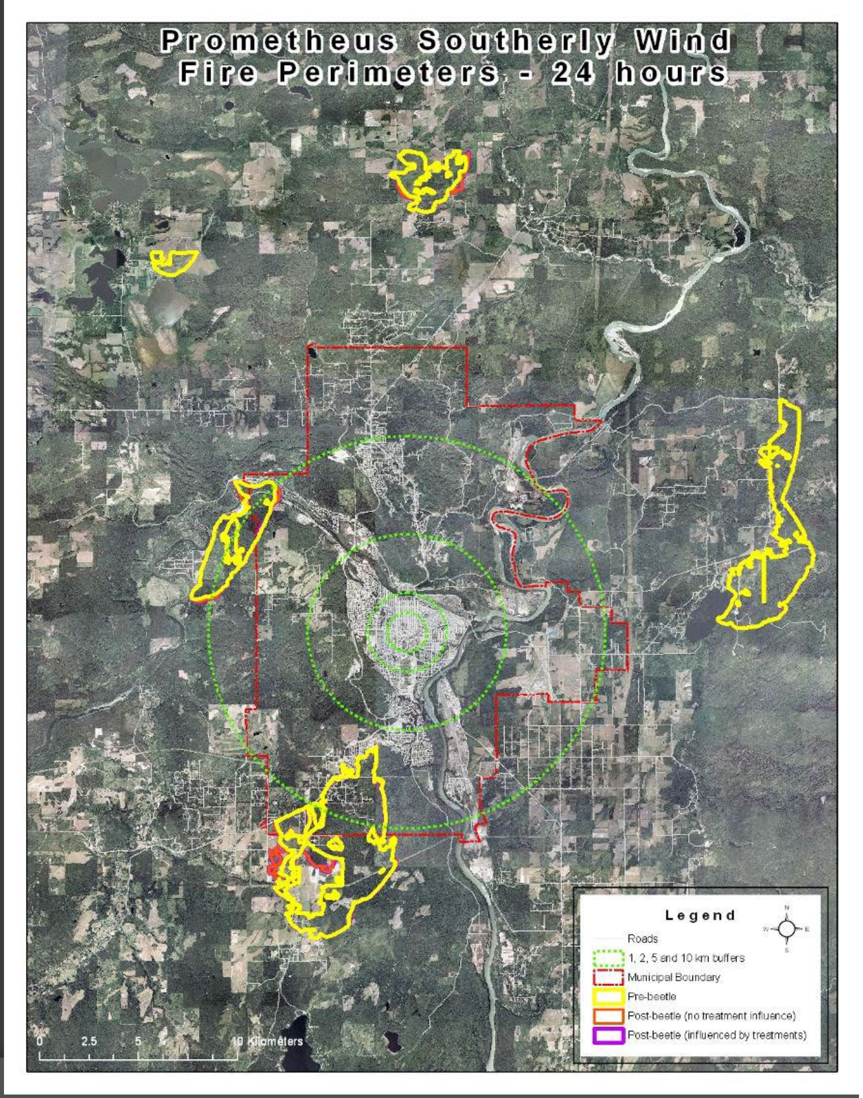
- In order to investigate landscape level risks from extreme fire behaviour in hazardous fuels, several fire scenarios were modelled on a fuels landscape that included a 10 km buffer around the municipal boundary.
- Two spatial fire growth models and fire behavior mapping were used to evaluate fire behaviour in fuels adjacent to the City under specified weather conditions within a twenty-four hour burning period.
  - Prometheus (Canadian)
  - Farsite (U.S.) and
  - fire behaviour mapping (Flammap) program were used to assess projected

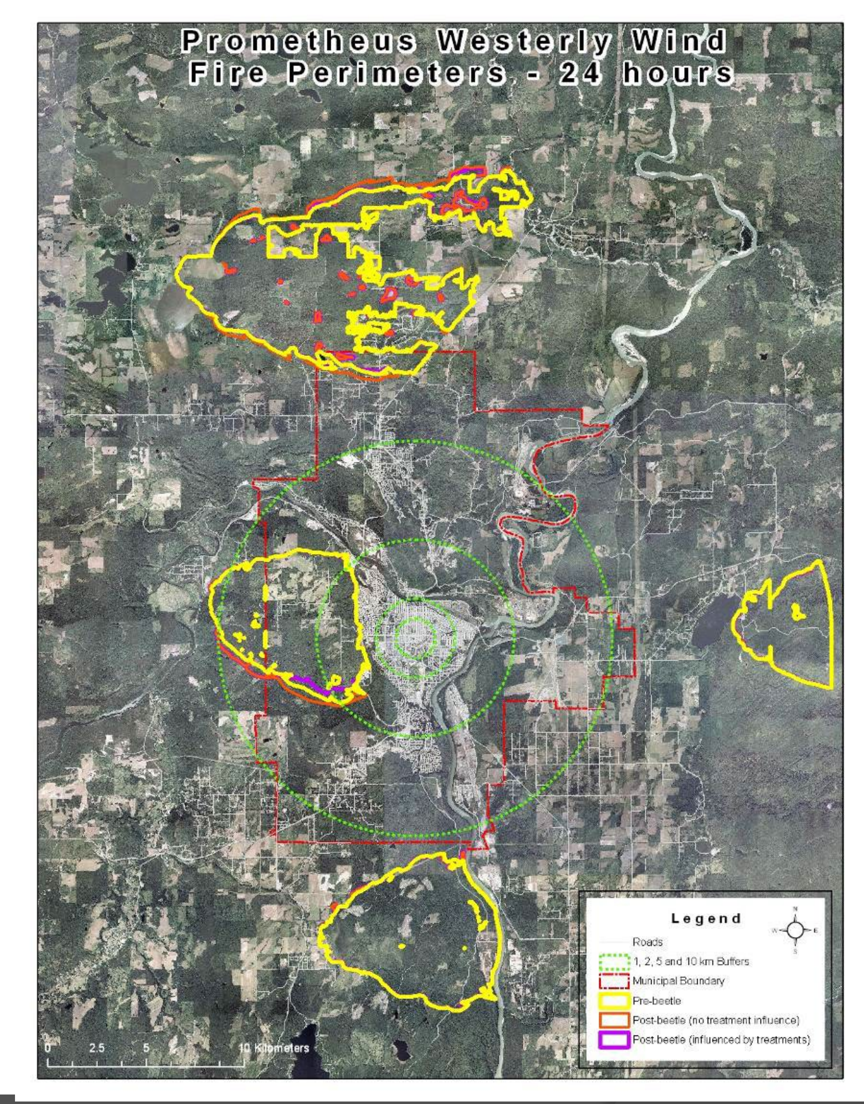
Prometheus Results

- Under extreme fire weather conditions, fuels to the west of town and, to some extent, the south are contiguous and capable of supporting fire behaviour that results in rapid forward rate of spread into high density interface. Fuels, to the west, are also supporting crown fire behaviour, which would result in spotting ahead of the fire front into the interface.

- While the current fuel treatment programs have effectively mitigated risk of fire in their immediate vicinity of City limits, the modelling suggests that additional, strategically placed fuel treatments would be needed to mitigate landscape level fire risks from a fire to the west of the City.

Prometheus Outputs

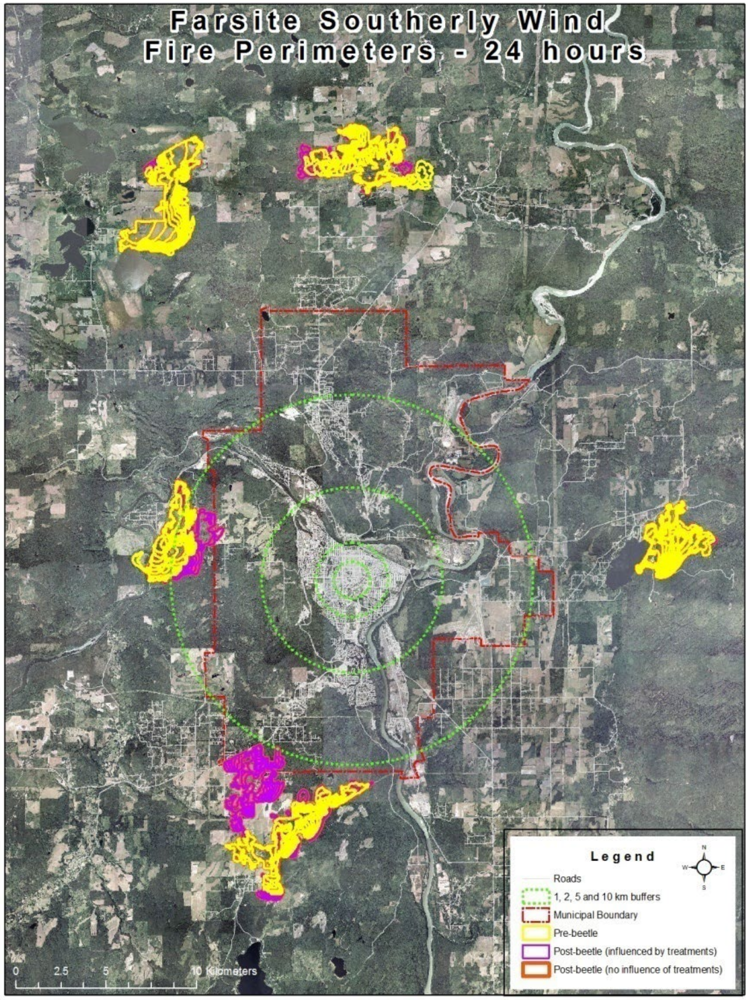


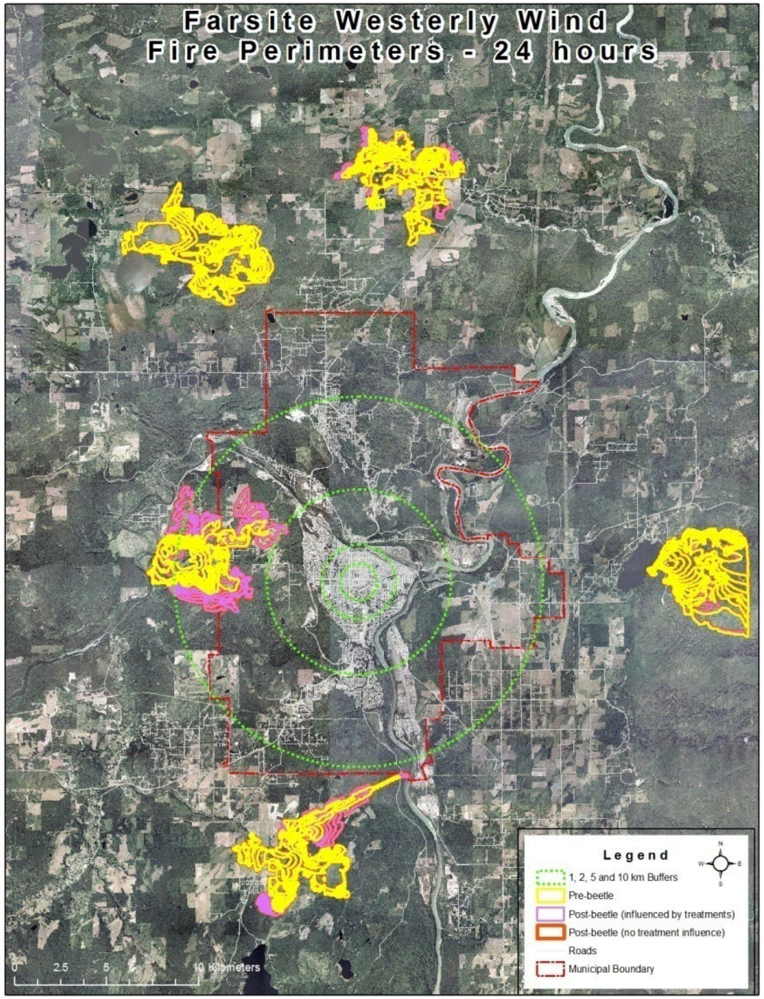


Farsite Results

- FARSITE runs also indicate that, under extreme fire weather conditions, fuels to the west of town are capable of supporting fire behaviour that results in rapid forward rate of spread into high density interface.
- Fuels are also capable of supporting crown fire behaviour, which would result in spotting ahead of the fire front into the interface.
- Farsite is more sensitive to changes in fuels on the landscape because of the flexibility of its inputs.

Farsite Outputs



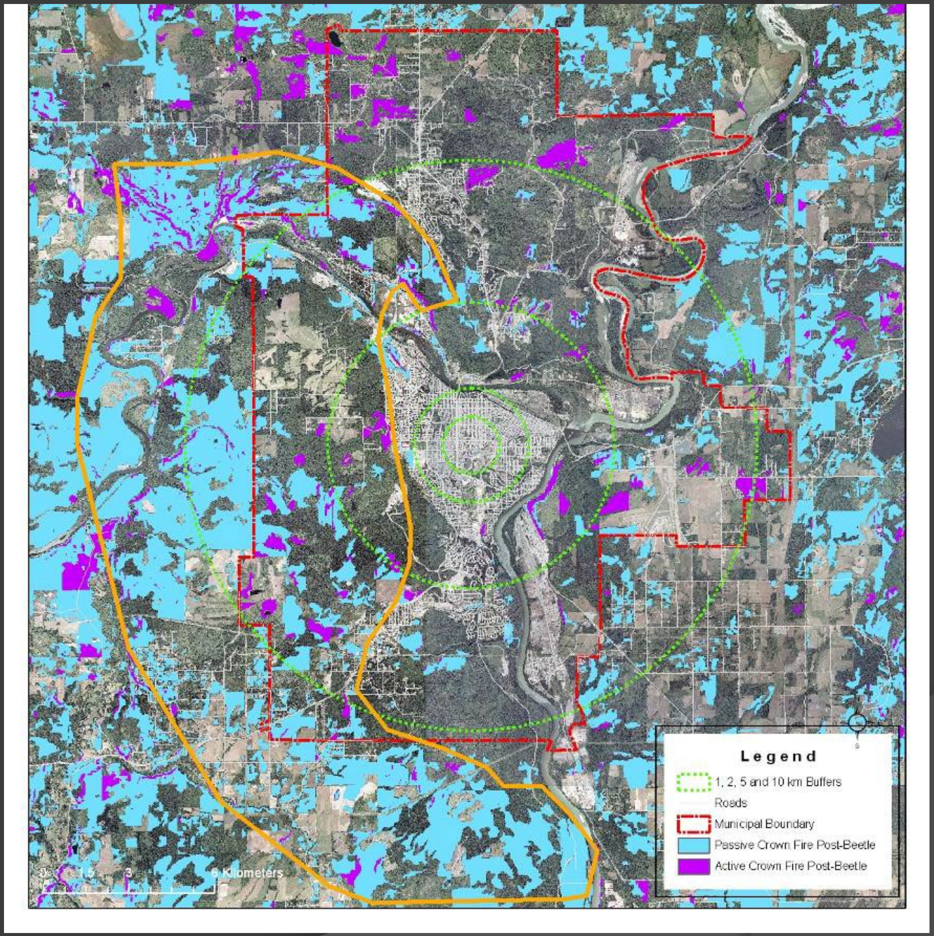


Summary of Hazardous Fuels

- While modelling indicates that large fires are possible in the north and the east of the City, it is fires advancing from the west and, potentially, the south that pose the greatest threat to the high density interface of Prince George.
- This is due to prevailing wind directions and the location of the high density interface. Areas of particular concern for extreme fire behaviour include Cranbrook Hill and the Nechako Ridge.
- The large area of deciduous fuels that flanks the interface to the west and south of the City provides a natural fuel break and the fuel treatment currently planned at the western boundary of the City would further fortify that natural break.

Problem Fire

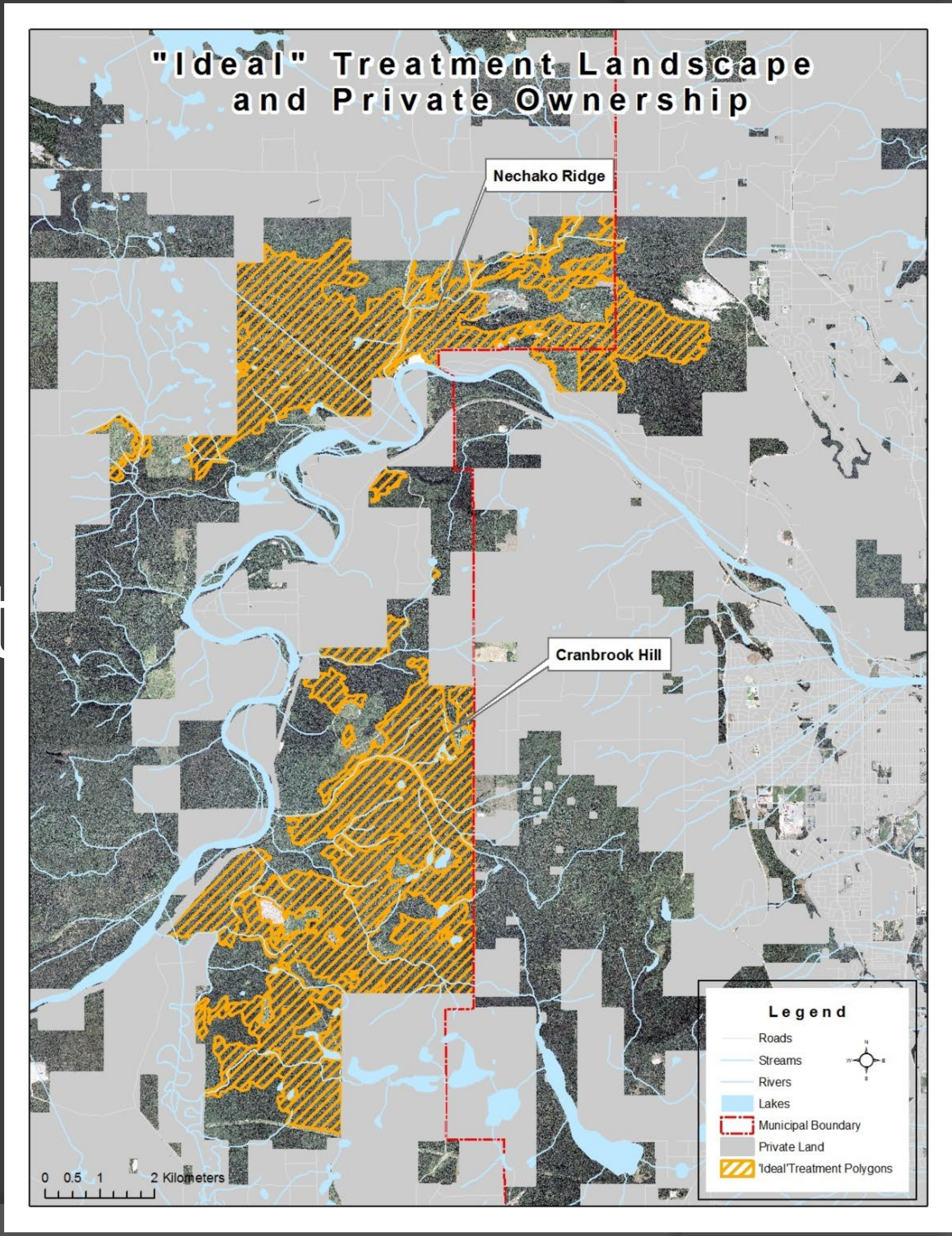
- Based on the analysis, the 'Problem Fire' for Prince George is defined as a large fire advancing from the west through the Cranbrook Hill and/or Nechako Ridge areas under drought or extreme drought fuel moistures coupled with high wind speeds.



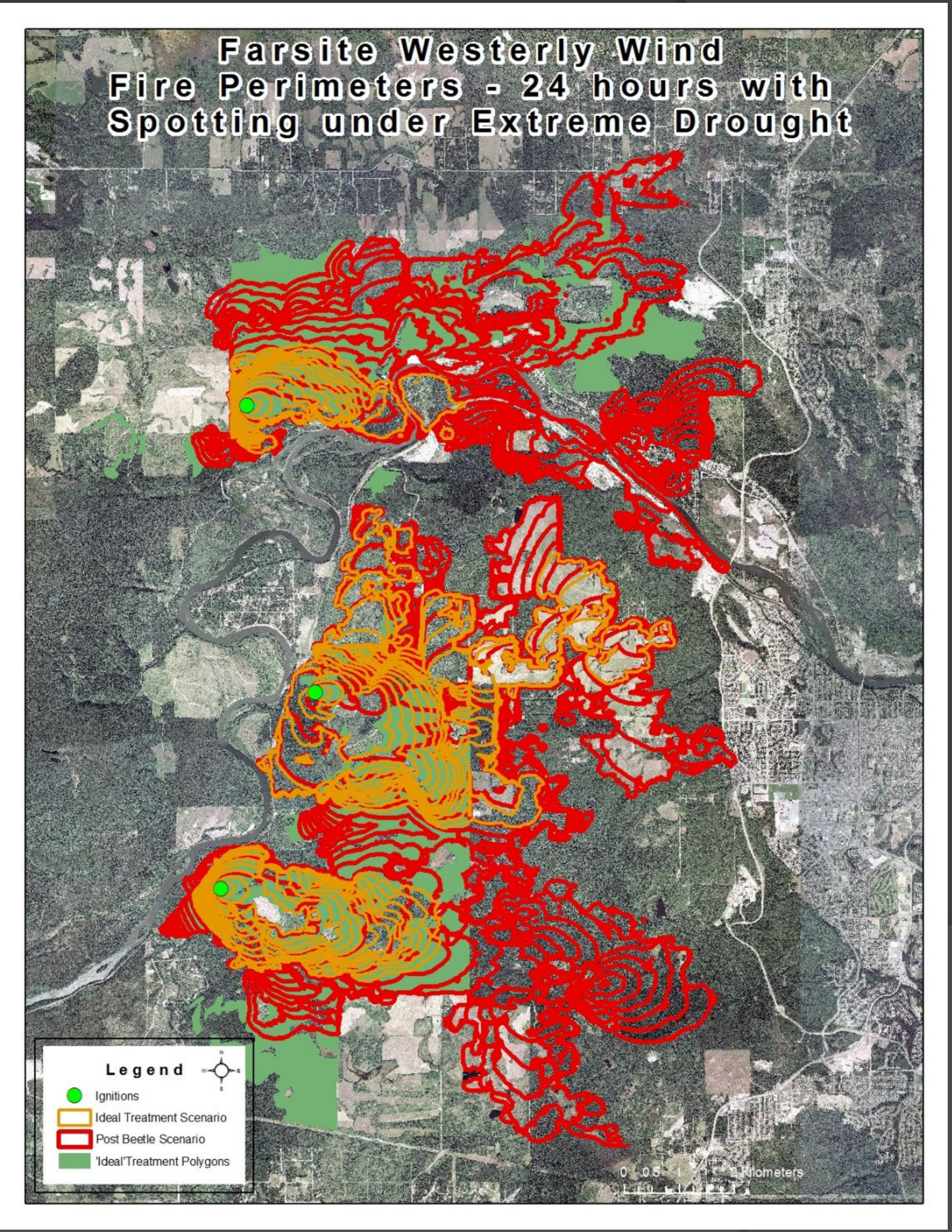
Ideal Treatment

- It was determined that fuels in the vicinity of Cranbrook Hill and the Nechako Ridge were the key areas of concern given their continuity and the extreme fire behaviour.
- Treatments would be focused within 10 km of the interface as beyond that spotting risk would be very low.
- The gross ‘ideal’ fuel treatment areas were run in FARSITE under the same ignitions and extreme drought fuel moisture conditions.
- The modified fuel areas result in a dramatic reduction in fire growth over the 24 hour period. The fire is slowed by the ‘ideal’ treatments but, in the Nechako Ridge area, still spots over the river.
- FlamMap’s Treatment Optimization model was used to refine the ‘ideal’ treatment area after we ran it in FARSITE

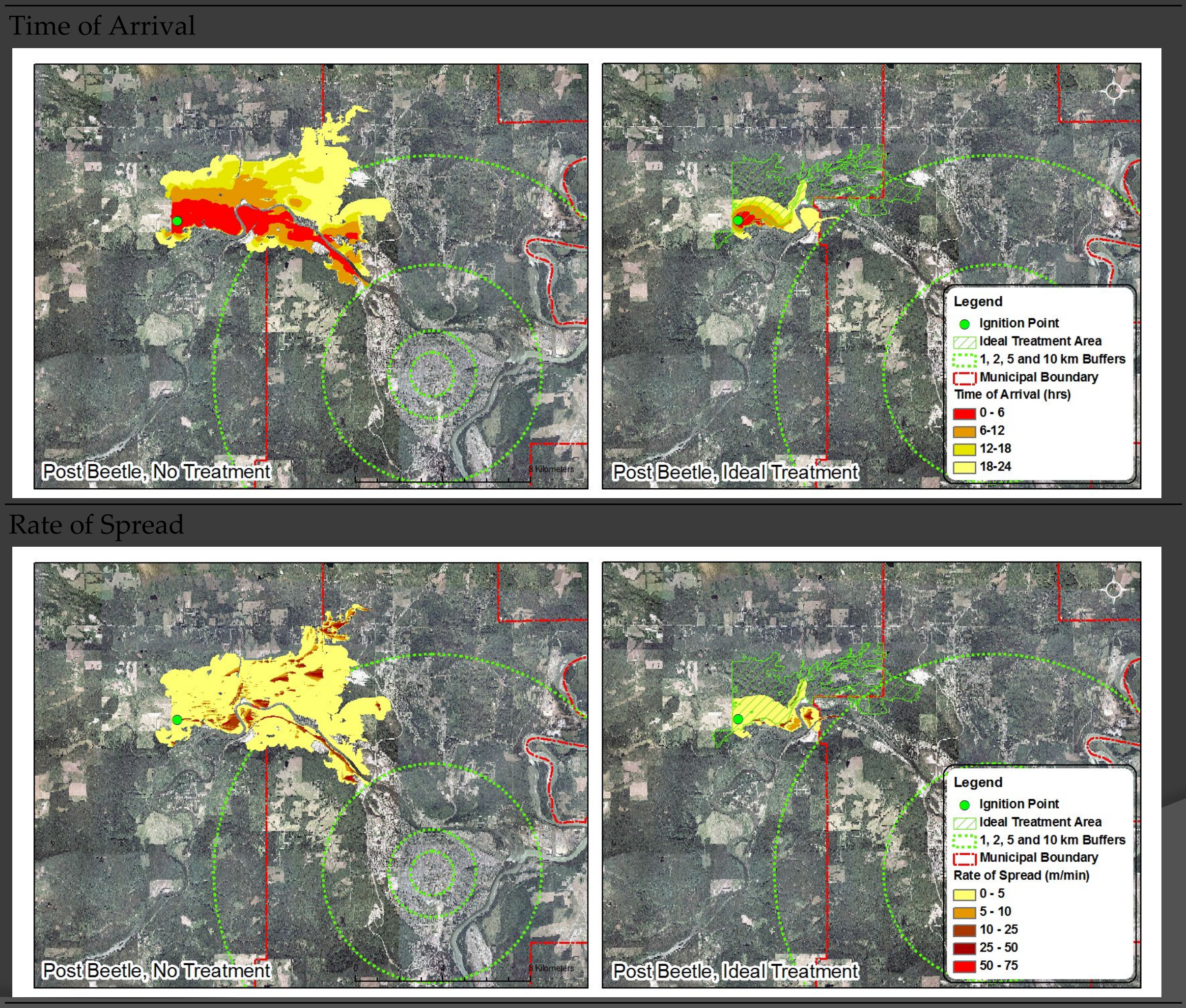
Ideal Treatment



Modeling the Ideal Treatment



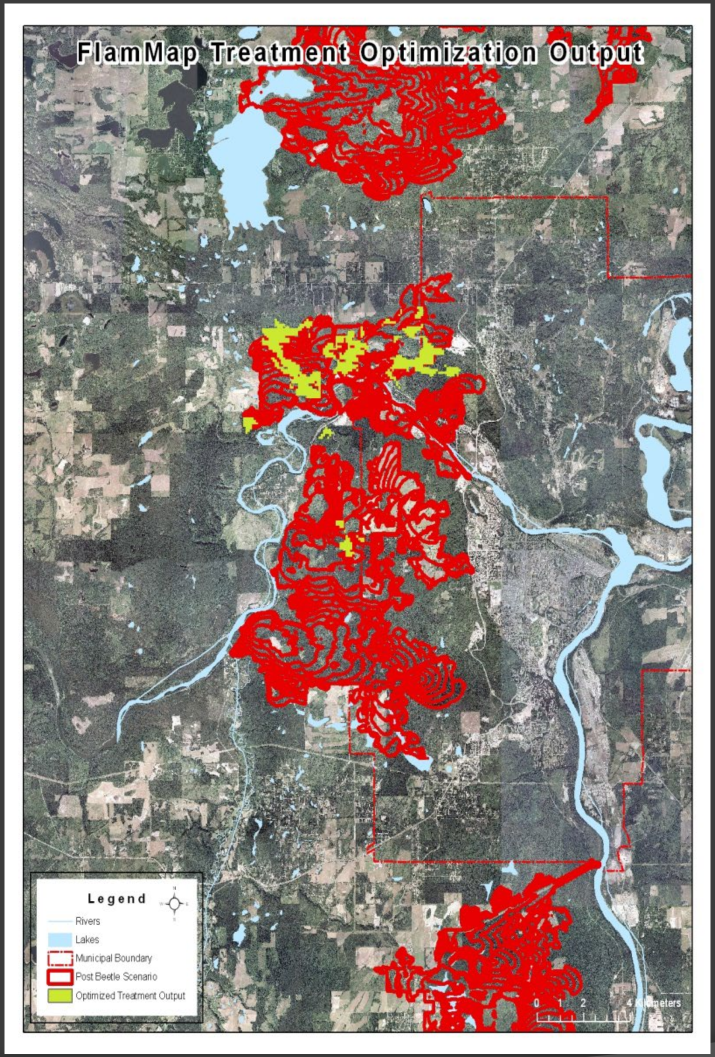
How does treatment change things?

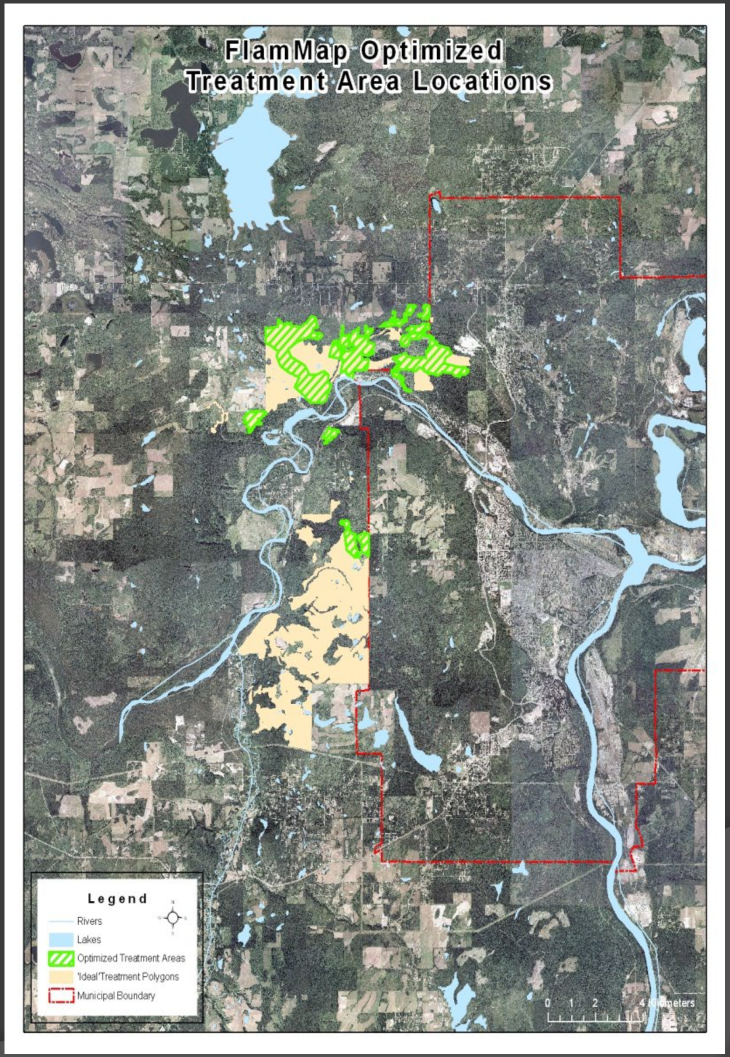


How much area should be treated and where?

- Based on the FlamMap outputs a polygon treatment area was defined.
- The total area that should be prioritized for treatment is 958 ha.
- Ground-truthing of these polygons is essential prior to any the expansion of the Community Forest or implementation of fuel treatments.
- Ground-truthing and professional judgement may yield additional or alternative treatment areas.

FlamMap Optimization





Cost Benefit - $5000/ha

Stand Conditions					**Commentary**
	Cruise Volume		300	m³/ ha	Average SBS degraded stand
	Biomass		219	BDT/ ha	15% moisture content; 1.3x stand biomass multiplier; 660Kg/ m³ wood density
	Net caloric value		2,133	GJ/ ha	15 MJ/ kg; 65% energy conversion
	Carbon dioxide equivalent		401	tonnes CO2e/ ha	

			Low	Med	Hi	Units	Commentary
Treatment Benefits							
Commercial benefits							
	Merchantible log utilization		17%	30%	50%		
	Biomass recovery		83%	70%	50%		
	Merchantible lumber and chip recovery		41	73	122	m³/ ha	Includes mill LRF and CRF
	Biomass bycatch		204	192	174	BDT/ ha	Includes mill fibre bycatch
	Lumber and chip value		$ 4,180	$ 7,524	$ 12,540	$/ ha	Prices: $120/m³ lumber; $80/ m³ chip
	Thermal value of energy		$ 16,293	$ 15,334	$ 13,895		Natural gas of $8.20
	Cogeneration avoidance of petrochemical		$ 993	$ 935	$ 847		Carbon tax of $0.5/ GJ or $10/ tonne CO2e
			$ 21,466	**$ 23,793**	**$ 27,282**		
Avoided costs							
On site	Fire fighting/ suppression		$ 4,200	$ 4,200	$ 4,200	$/ ha	Provincial average: $3000/ ha
		Fatalities	$ -	$ -	$ -		US: $25/ ha
		Facility losses	$ -	$ -	$ -		US: $200 - $400/ ha
	Timber losses		$ 4,180	$ 7,524	$ 12,540		See above
	Stumpage revenue		$ 239	$ 431	$ 718		Logs: $10/ m³; Chips: $0.25/m³
	Wild-crafting (non-timber) losses		$ -	$ -	$ -		
	Biomass energy losses		$ 16,293	$ 15,334	$ 13,895		See above
	Regeneration/ restoration		$ 1,200	$ 1,200	$ 1,200		Planting, prep, planning
Off site	Community values		$ 156.00	$ 156.00	$ 156.00		US: $156/ ha
		Property value					
		Property insurance	$ -	$ -	$ -		
		Willingness to pay	$ -	$ -	$ -		
		Rural jobs	$ -	$ -	$ -		
		Recreation/ amenity activity	$ -	$ -	$ -		
	Regional economic values	Economic multiplier (2:1)	$ -	$ -	$ -		
Ecosystem goods and services			$ 159	$ 159	$ 159		Pembina Institute BWEAS
	Aesthetics		$ -	$ -	$ -		
	Hydrology	Erosion	$ -	$ -	$ -		
		Flooding	$ -	$ -	$ -		
		Quality	$ -	$ -	$ -		
	Habitat		$ -	$ -	$ -		
	Smoke and emissions		$ 11,510	$ 11,510	$ 11,510		Assume 20% combustion; GWP for: CO2, CO, NOx, CH4, PM 2.5
	Post fire emissions		$ 4,270	$ 4,270	$ 4,270		30-years decomposition and reduced sequestration
	Carbon sequestration		$ 4,015	$ 4,015	$ 4,015		
			$ 46,222	**$ 48,798**	**$ 52,662**		
Treatment Costs							
	Planning and prep		$ 500	$ 500	$ 500	$/ ha	$250 - $750
	Treatment		$ 5,000	$ 5,000	$ 5,000		$2,500 - $10,000
	Environmental Impacts		$ -	$ -	$ -		
Total			**$ 5,500**	**$ 5,500**	**$ 5,500**		
Cost: Benefit			**$ 40,722**	**$ 43,298**	**$ 47,162**	$/ ha	

Cost/Benefit - $20,000/ha

Stand Conditions	Value	Unit	Commentary
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		Willingness to pay	$ -	$ -	$ -		
		Rural jobs	$ -	$ -	$ -		
		Recreation/ amenity activity	$ -	$ -	$ -		
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	Treatment		$ 20,000	$ 20,000	$ 20,000		$2,500 - $10,000
	Environmental Impacts		$ -	$ -	$ -		
Total			**$ 20,500**	**$ 20,500**	**$ 20,500**		
Cost: Benefit			$ 25,722	$ 28,298	$ 32,162	$/ ha	