



Integrating Fire Behaviour Principles when Prescribing Fuel Treatments

Nov. 28th, Rory Colwell and Dana Hicks BCWS

Agenda



- Follow up to June webinar “Planning & Implementing Fuel Treatment Activities in BC”
 - <https://www.youtube.com/watch?v=VLuYAtcXU38>
- Fire Behaviour and Specifying Treatment Targets
- Applying Fuel Management Principles to Various Ecosystems
- Introduction to some of the available tools for Rx development
- Questions

Association of BC Forest Professionals.

2013. Interim Guidelines – Fire and Fuel Management.



BRITISH
COLUMBIA

Practising in the field of fire and fuels management requires a specific education and training in subjects such as, but not limited to: fire ecology, fire effects, fire behaviour, fire regimes, conditions classes, fuel types, fuel moisture content, fire suppression, prescribed burning, fire behaviour modelling, and fire weather in addition to forestry subjects.Education provided at post-secondary school is insufficient and often additional expertise is obtained through experience fighting wildfires or working with a competent forest professional already practising in the field....

*Forest professionals play a key role in fuel management in BC - such as the development of fuel management prescriptions. In particular, forest professionals accredited by the Association of BC Forest Professionals (ABC FP) who possess a **sound understanding of both fire behaviour and resource management will be invaluable in planning for, and achieving, fuel management objectives***

https://member.abcfp.ca/WEB/Files/policies/Fire_Fuel_Management-Interim_Guidelines.pdf?WebsiteKey=4b6af123-da4f-4a97579ada9e5955&=404%3bhttps%3a%2f%2fmember.abcfp.ca%3a443%2fWEB%2fabcfp%2fFiles%2fpolicies%2fFire_Fuel_Management-Interim_Guidelines.pdf

Planning and Prescribing Fuel Mgmt. Treatments



Goals for managing hazardous vegetation fuels on the landscape is to create fire resilient ecosystems and contribute to creating fire adapted communities by:

- From a human life and safety perspective:
 - Reducing fire behaviour so that it is **safer and easier for fire fighters to suppress wildfire** to mitigate negative impacts to the wildland urban interface (WUI).
 - Focusing on creating **FireSmart** communities and infrastructure located in the WUI to reduce the structure ignitability and minimize catastrophic impacts from wildfire events.
- From a resiliency perspective:
 - Reducing fire severity so that it is likely that areas of forest will survive, soil damage will be limited and post-fire restoration activities will be minimized.
 - Restoring the natural cycle of fire-maintained grassland and dry forest ecosystems.

FireSmart works!

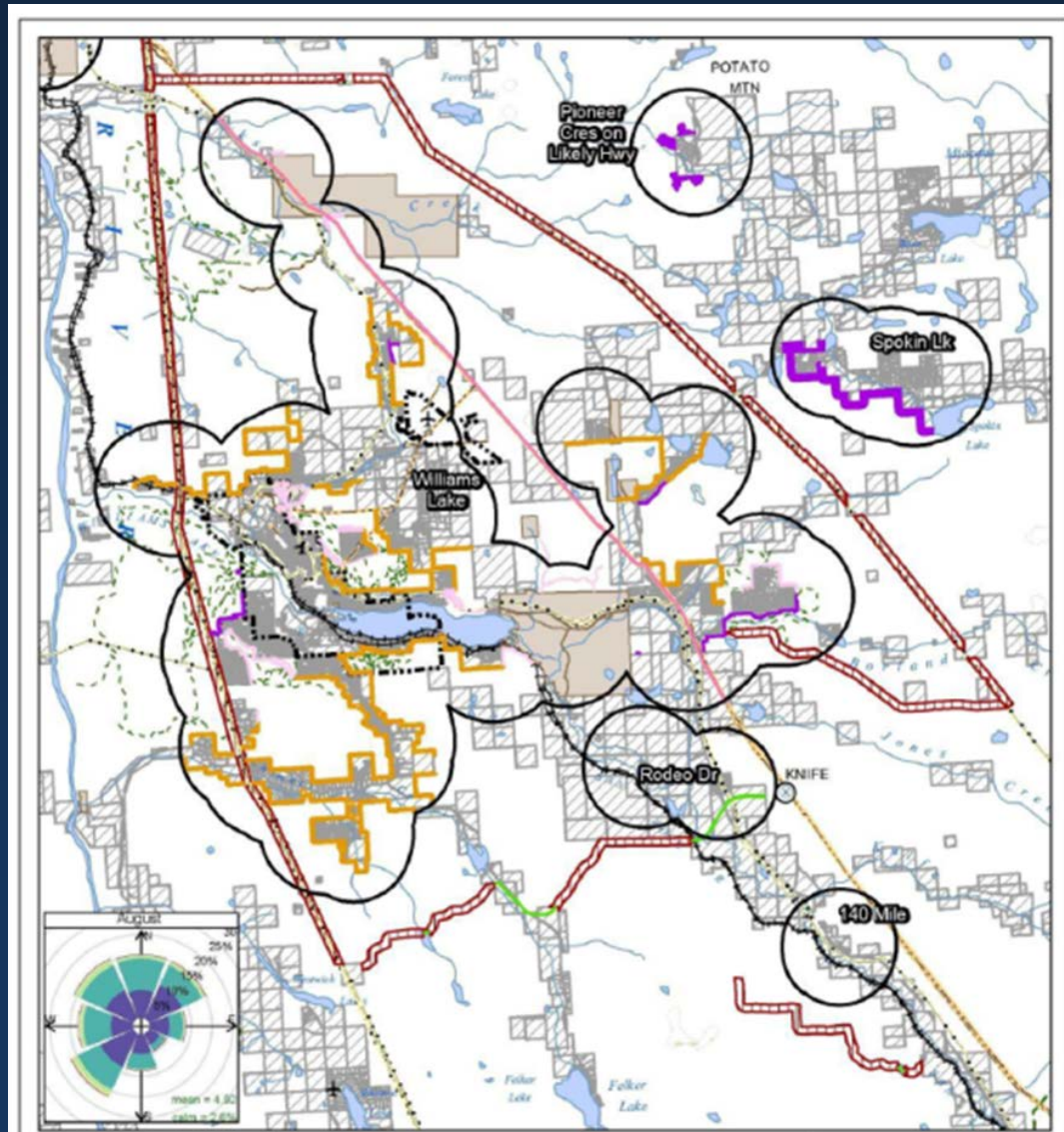
The findings from the **Horse River wildfire** (Fort McMurray) in 2016 suggest that the use of **FireSmart** principles was one of the main reasons why houses survived.



**Photo credit: Regional Municipality of Wood Buffalo*

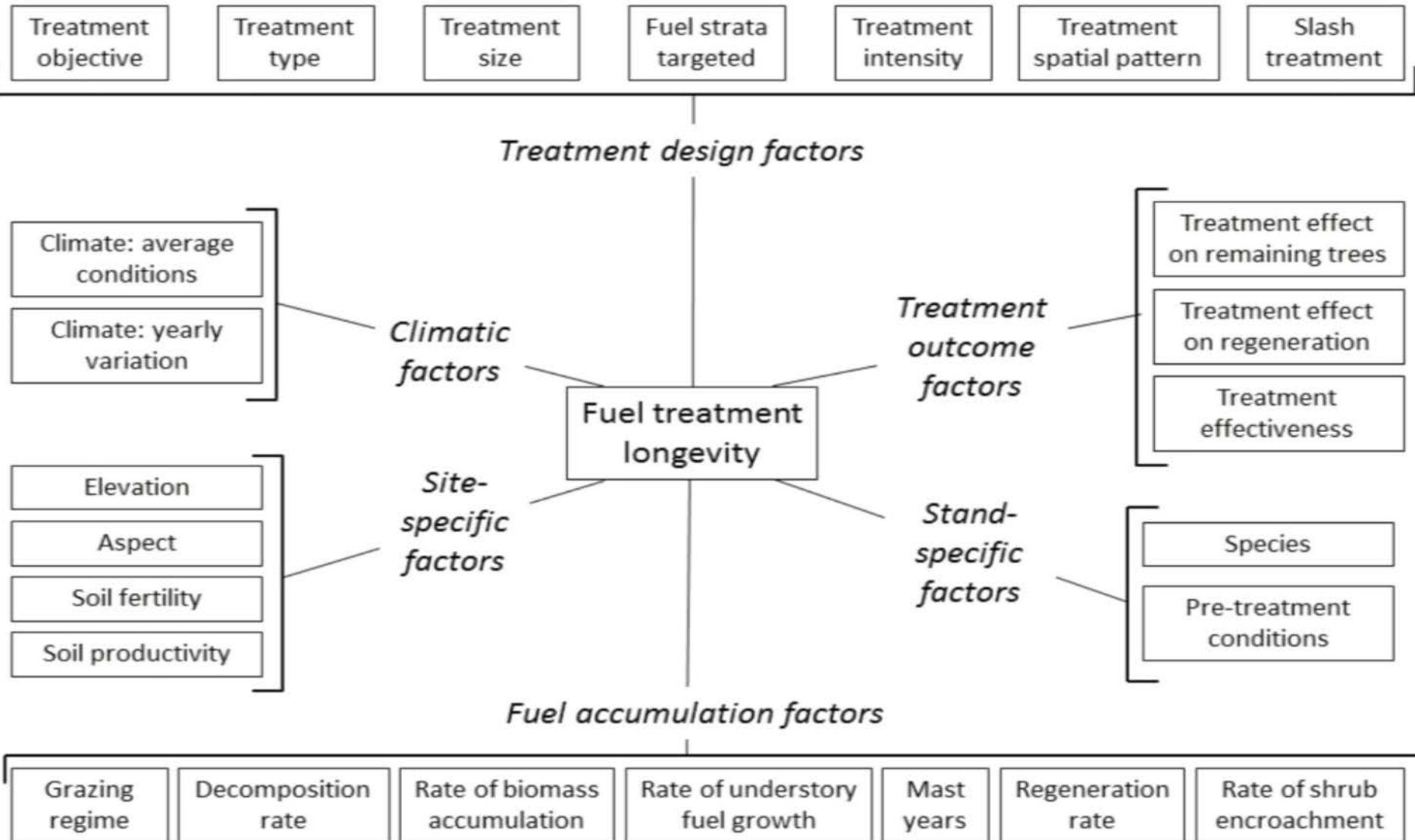


Tactical Fuel Treatment Planning

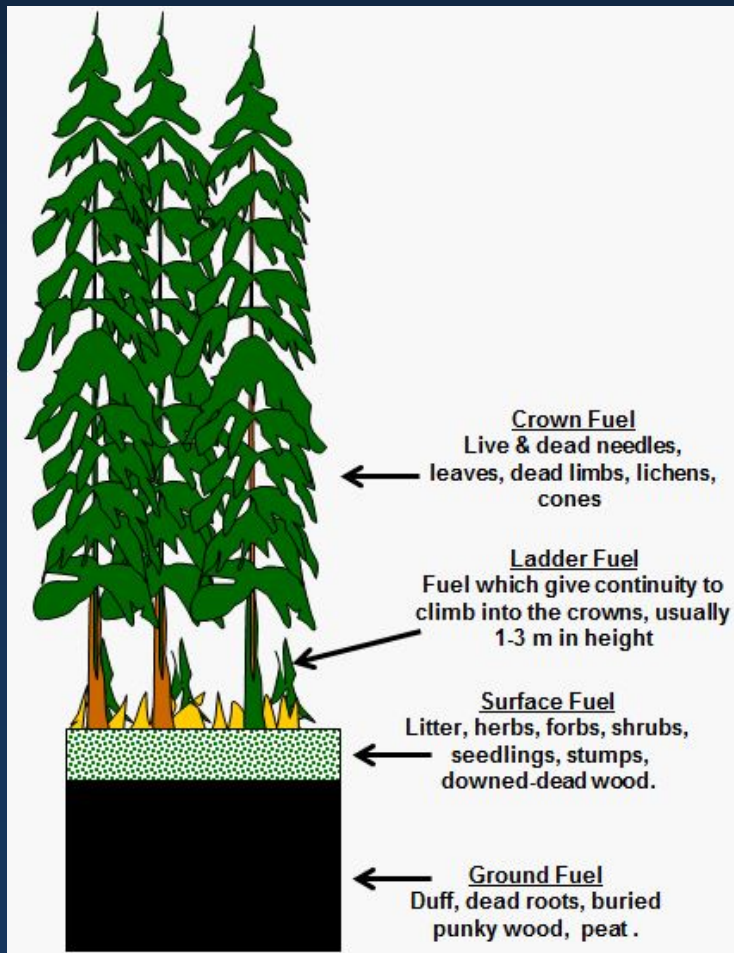


Fuel Management Complexity

Cook, Philip S. and Jay O’Laughlin. 2014. Fuel Treatments in Idaho’s Forests: Effectiveness, Constraints, and Opportunities. Policy Analysis Group – College of Natural Resources. Report No. 35. University of Idaho.



Thought Process on Forest Practices



- Are you adding to the surface fuel loading?
- What are you doing to the vertical fuel arrangement?
- What are you doing to the horizontal fuel arrangement?



PRESCRIBES SPECIFIC AND MEASURABLE TARGETS FOR FIRE BEHAVIOUR REDUCTION

- A fuel management prescription describes the recommended fuel management activities with measurable fire behaviour outcomes identified.
- For each treatment unit, specific and measurable fuel targets are described so that post treatment outcomes can be measured.
- Prescriptions must ensure a cost effective and measurable reduction in expected fire behaviour with the consideration and management of other values on the landscape.
- Prescriptions need to consider the balance between potential fire behaviour implications and resource values and meet all legislative and non-statutory requirements.

CONTAINS SITE SPECIFIC CONSIDERATIONS TIED TO (WRR) OBJECTIVES

- Prescription considers the unique variability that exists in each stand, including but not limited to: vertical fuel strata, horizontal fuel continuity, extent of the surrounding fuel, fire weather components, topography, and values at risk, and is stratified out if required.
- Treatments are appropriate for the given Biogeoclimatic (BGC) area (site series) and consider factors such as rate of decay for slash, shaded fuel breaks, controlling canopy density, and retaining suitable residual species that are resilient to the post treatment conditions, including but not limited to fire disturbance.

Fuel Management Principles



- The best method of reducing wildfire risk is linking treatment units together to form continuous area of fuel treatments into fuel breaks.
- The main objective of linking treatment units together is landscape connectivity.
- These fuel break offers the best chance of wildfire risk mitigation to a large flaming front of a wildfire impact a value(s) at risk.

Fuel Management Principles & Fire Behaviour Outcomes



- At a minimum, the first 100m of fuel treatments closest to the value(s), shall focus on reducing surface fuel loading to achieve potential surface fire intensity levels below 2,000 (kW/m) or below critical surface fire intensity thresholds;
- Increase the crown base height through a reduction in ladder fuels to reduce potential for crown fire initiation
- Reduction in crown closure (BA/sph) and/ or canopy bulk density as necessary to reduce crown fire initiation and behaviour (e.g. spread rate, spotting).

Tools for fuel mgmt.



Tools for Fuel Management

In preparing to develop a treatment plan to mitigate wildfire threat near values at risk, users may find the below suite of tools helpful in quantifying threat, developing treatment options, and prescribing a treatment plan.

ABCFP Interim Guidelines - Fire and Fuel Management

- [ABCFP Interim Guidelines – Fire and Fuel Management](#) (PDF)

Wildfire Risk Reduction Planning Standard

- [Wildfire Risk Reduction Planning Standard](#) (PDF, 354 KB)

Fuel Management Prescription

- [2019 Fuel Management Prescription Guidance](#) (PDF, 462
- [2019 Fuel Management Prescription Specimen](#)



BCWS Fuel Management Prescription Guidance 2019

FUEL MANAGEMENT PRESCRIPTION GUIDANCE

Provided by BC Wildfire Service

PURPOSE

The purpose of this document is to provide direction on fuel management components for stand level prescriptions that are being prepared for a wildfire risk reduction (WRR) objective (otherwise known as “fuel management prescriptions”) that are funded by the Forest Enhancement Society of BC (FESBC), the Community Resiliency Investment (CRI) program or other government programs. This document assumes that all other approaches to, and components within, the prescription meet legal requirements and follow Association of BC Forest Professionals (ABCFP) published guidance, specifically around quality prescription development including, but not limited to: [Standards of Professional Practice: Guidelines for Interpretation](#), [Interim Guidelines – Fire and Fuel Management](#); [Guidance for Professional Quality Field work](#), and [Guidance for Professional Quality Rationales and Comments](#).

BC Wildfire Service (BCWS) has developed a suite of tools to support fuel management activities that are located on the [BCWS Tools for Fuel Management webpage](#). These tools and other direct supporting information are hyperlinked in this document.

In addition, this document is not meant to cover all aspects of fuel management and fire behaviour and is directed towards experienced professionals working well within their scope of practice as outlined in the 2013 the ABCFP released [Interim Guidelines – Fire and Fuel Management](#);

Fire Weather Indices

What do these values mean?

Fire Weather System

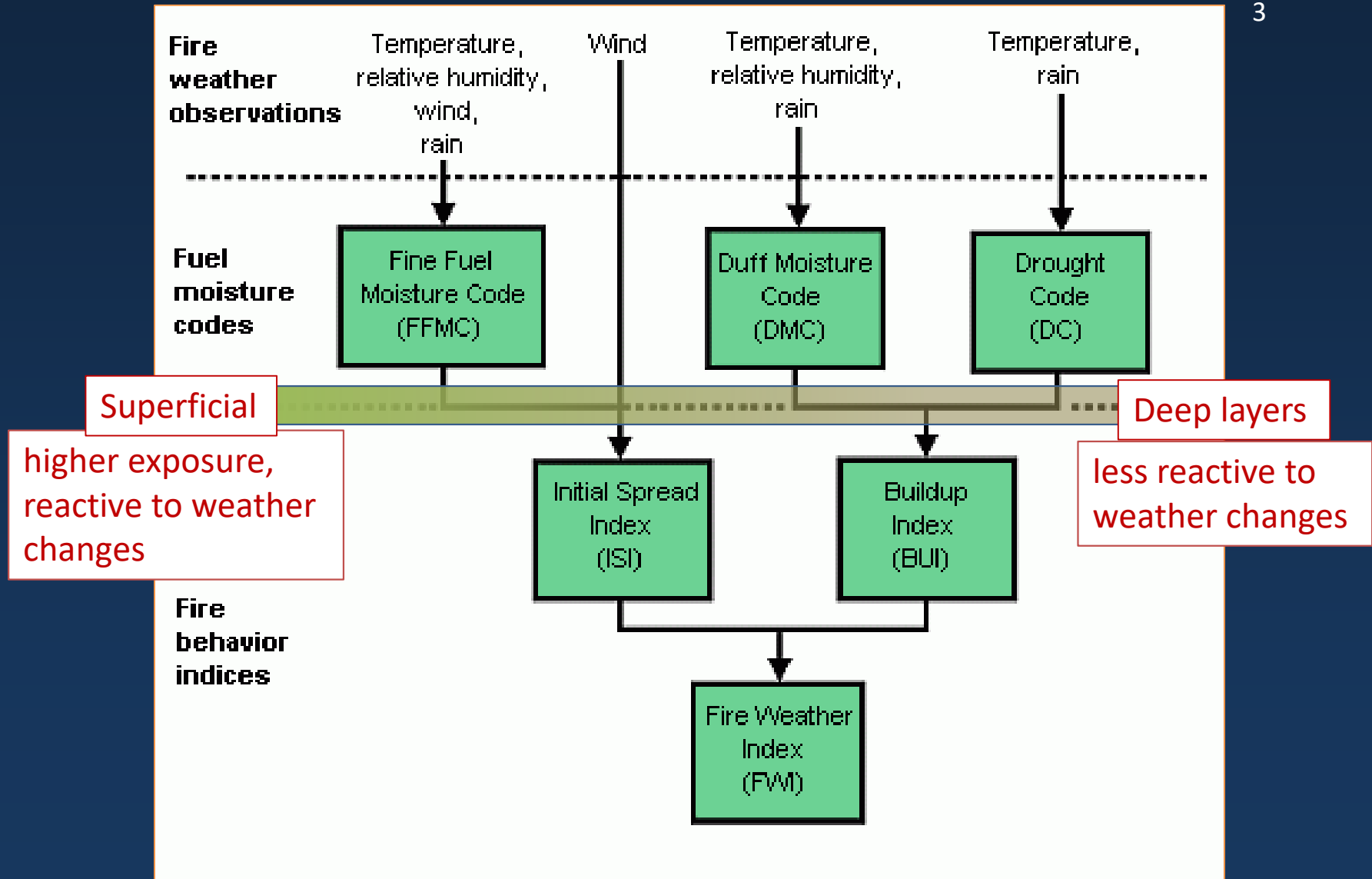
Selected Daily Stations for 2017/07/25

[View Min/Max Data](#)

Station	FFMC	DMC	DC	ISI	BUI	FWI
NELSON FORKS	89.8	17	120	5.2	25	9.3
NADINA	92.3	93	425	8.1	120	29.7
MCBRIDE	85.7	19	330	2.9	34	6.7
ALEXIS CREEK	93.4	61	702	10.3	101	32.3
LILLOOET	95.0	289	911	13.7	322	48.9
DUNCAN	92.6	62	254	8.6	77	24.9

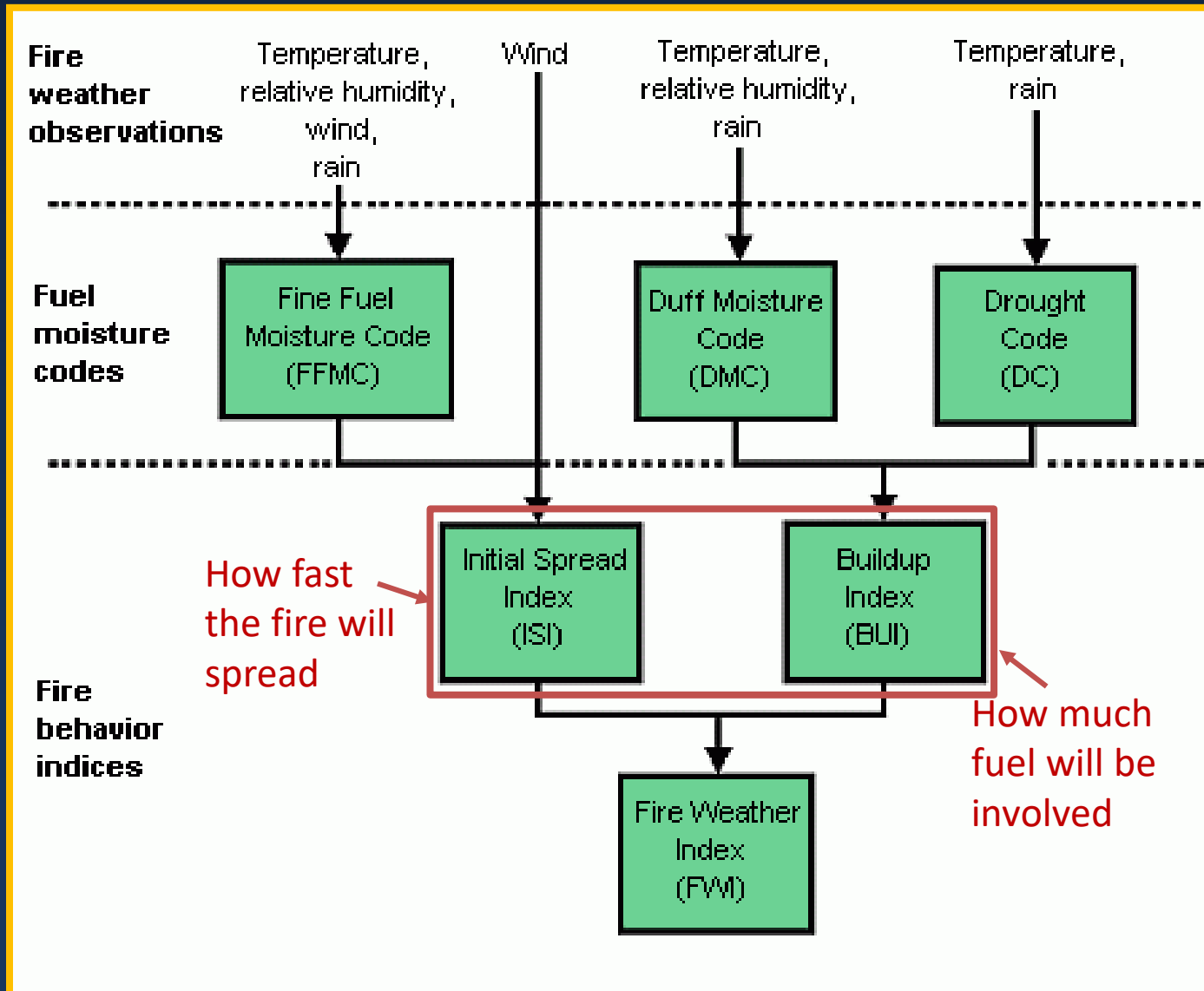
Fire Weather Index

3



Fire Weather Index

3



Topography

- Flat or slopes
- Aspect



Weather

- Wind
- Temperature
- Relative Humidity
- Precipitation

Fuel

- Fine or Heavy
- Arrangement & continuity
- Fuel Moisture

Wildfire Risk Reduction (WRR) Rx objectives.

What is the desired result/ effect?

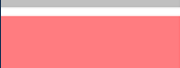
Fuel treatments designed to alter fire behaviour

➤ Reduce:

- fire intensity
- crown fire → surface fire
- rate of spread
- spotting potential (ember production & reception)
- probability of crown fire initiation

Fire Intensity

Intensity Class

	1	<10 kW/m
	2	10 - 500
	3	500 – 2,000
	4	2,000 – 4,000
	5	4,000 – 10,000
	6	>10,000+

 Fire behaviour characteristics and fire suppression interpretations associated with Fire Intensity Classes					
Fire Intensity Class	Surface head fire			Type of fire and fire suppression difficulty	Fire Weather Index (FWI)
	Frontal Fire Intensity (kW/m)	Flame Length (m)	Flame Height (m)		
1	<10	<0.2	<0.1	Fire brands that cause an ignition to occur are self-extinguishing (i.e. fire fails to spread). Going fires remain of the smouldering ground or subsurface variety, provided there is a forest floor layer of significant depth and general level of dryness. Extensive mop-up is generally required.	0 - 3
2	10-500	0.2-1.4	0.1-1.0	Creeping or gentle surface fire. Direct manual attack at the fire's head or flanks by firefighters with hand tools and water is possible. Constructed fireguard should hold.	4 - 13
3	500-2 000	1.4-2.6	1.0-1.9	Low vigor to moderately or high vigorous surface fire. Hand constructed fireguards likely to be challenged. Heavy equipment (bulldozers, pumps, retardant aircraft, skimmers, helicopter with bucket generally successful in controlling fire.	14 - 23
4	2 000 – 4 000	2.6-3.5	1.9-2.5	Very vigorous or extremely intense surface fire (torching common). Control efforts at fire's head may fail.	24-28
5	>4 000	>3.5	>2.5	Intermittent crown fire to active crown fire development (> 10 000 kW/m). Very difficult to control. Suppression action must be restricted to fire flanks. Indirect attack with aerial ignition (i.e. helitorch or A.I.D. dispenser) may be effective.	>29

* Adapted from poster "Fire Behaviour in Jack Pine Stands – as it relates to the Canadian Forest Fire Weather Index (FWI) System – M.E. Alexander W.J. DeGroot 1988 Northern Forestry Center, Edmonton AB

Fire Intensity targets

For minimum of
100m closest to the
value

- $< 2,000 \text{ kW/m}$
- $< \text{Critical surface intensity (CSI)}$

approx. $1,200 \text{ kW/m}$ →
& increasing...



Crown to surface fire transition



Requires time and space.

Treatments (fuel breaks) with substantial edge adjacent to untreated units are likely to suffer substantial mortality, even if fire behaviour is reduced.

Crown to surface fire transition

approx. 25m gap →

Avg. total width 100m

(still under construction 2017)



Crown to surface fire transition

approx. 30-35m gap

Existing opening with
Aspen & willow

Mechanical (harvesting)
& hand treatment in 2010



Logged/thinned ~ 2002

Wildfire 2017



Rate of spread

FFMC = 92, Wind = ~12km/h. ISI = 10, BUI =100



Fuel type = C-7...

ROS = 3.3m/minute, surface fire



Fuel type = O-1b...

55% cure ROS= 4.6m/minute

85% cure ROS = 23m/minute

Limiting spotting potential

Fire brand/ember sources



Surface fuel load (SFL) < 7cm
Avg. ~17 t/ha or 1.7kg/m²



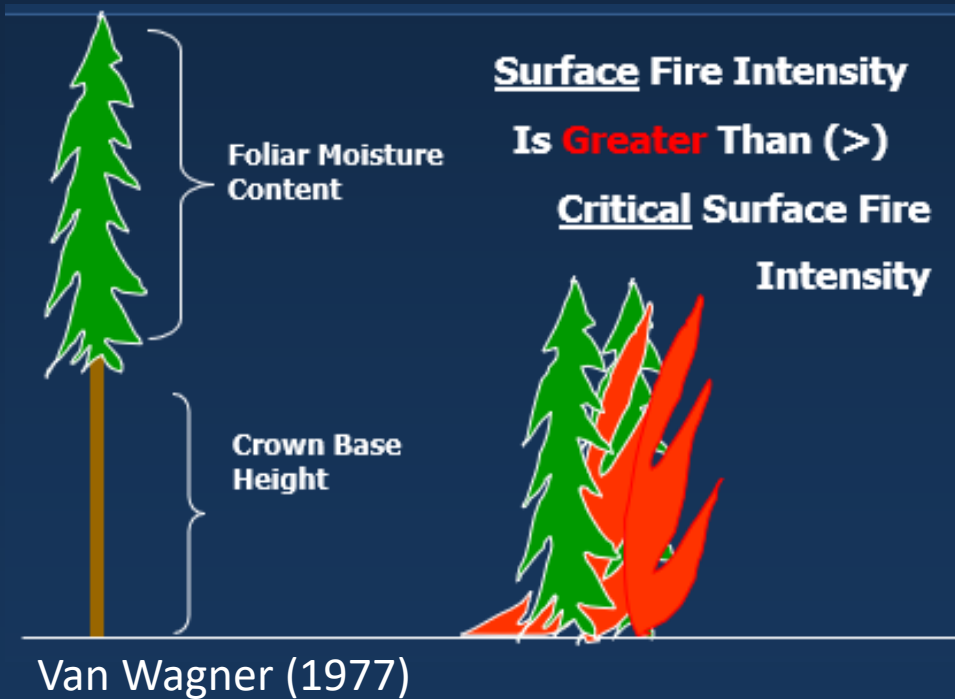
Adjacent debris piles (fine fuel accumulations)

Limiting spotting potential

Fire brand/ember reception



Crown fire initiation



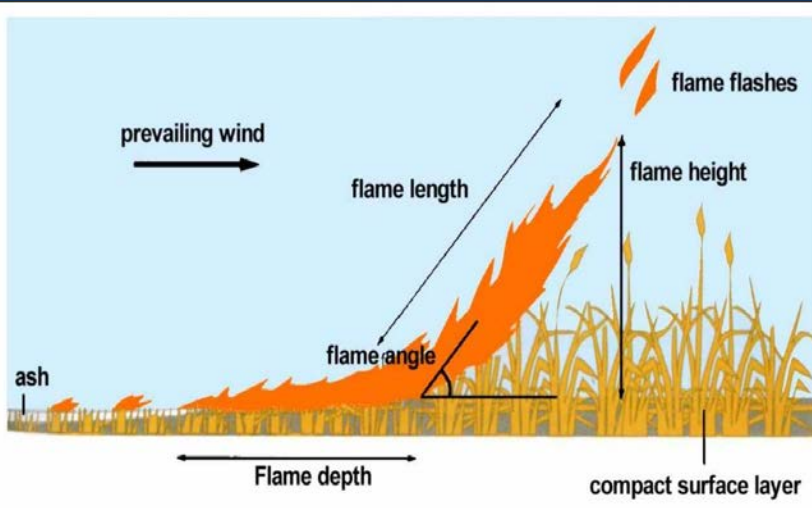
Don't fall into the trap of average CBH, crowning occurs at the weakest link

Critical Surface Intensity

Critical Surface Fire Intensity for Initial Crown Combustion (kW/m)

Foliar Moisture Content (%)	Live Crown Base Height/ Fuel Stratum Gap (Meters)												
	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
120	214	393	606	847	1113	1402	1713	2045	2395	2763	3148	3550	3967
115	202	372	573	801	1053	1327	1621	1934	2266	2614	2978	3358	3753
110	191	351	541	756	994	1253	1530	1826	2139	2467	2812	3170	3543
105	180	331	510	712	936	1180	1441	1718	2014	2324	2648	2986	3337
100	169	311	479	669	880	1108	1354	1616	1893	2183	2488	2805	3135
95	159	291	449	627	824	1038	1269	1514	1773	2046	2331	2628	2937
90	148	272	419	586	770	970	1185	1414	1657	1911	2178	2455	2744
85	138	253	390	545	717	903	1104	1317	1542	1780	2028	2286	2555
80	128	235	362	506	665	838	1024	1222	1431	1651	1881	2121	2371

Note: The standard average foliar moisture content is 95% (drought conditions). At 80% the foliar is dying and won't recover.



Calculating intensity from observed fire behaviour

Field approximation for **SURFACE FIRES ONLY**

$$I = 300 (L)^2$$

I = Intensity (kW/m)

L = flame length (m)

Surface fire intensity

Predicting surface fire intensity using Byram's equation

$$I = Hwr$$

Intensity = heat of combustion x weight of the fuel x rate of spread

$$I = 300wr$$



Surface fuel load (SFL) < 7cm

Avg. ~17 t/ha or 1.7kg/m²

Wildfire Intensity (I = HWR) Bryam	
To find:	
Wildfire Intensity	2040.0
Enter	
Weight of the fuel (kg/m ²)	1.7
and	
Rate of Spread (m/min)	4

Surface fire intensity

Calculated surface fire intensity = 1,350 kW/m

Critical Surface Fire Intensity for Initial Crown Combustion (kW/m)

Foliar Moisture Content (%)	Live Crown Base Height/ Fuel Stratum Gap (Meters)												
	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
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Note: The standard average foliar moisture content is 95% (drought conditions). At 80% the foliar is dying and won't recover.



Wildfire Intensity (I = HWR) Bryam

To find:

Wildfire Intensity

750.0

1050.0

Enter

Weight of the fuel (kg/m²)

0.5

0.7

and

Rate of Spread (m/min)

5

5

Treatment and Effect Summary



Principle	Effect	Advantage	Concerns
Reduce surface fuels	Reduces potential flame length	Control easier; less torching	Surface disturbance less with fire than other techniques
Increase height to live crown	Requires longer flame length to begin torching	Less torching	Opens understory; may allow surface wind to increase
Decrease crown density	Makes tree-to-tree crown fire less probable	Reduces crown fire potential	Surface wind may increase and surface fuels may be drier
Keep big trees of resistant species	Less mortality for same fire intensity	Generally restores historic structure	Less economical; may keep trees at risk of insect attack

Principles of fire resistance for dry forests (adapted from Agee, 2002 and Hessburg and Agee, 2003)

Fire Intensity targets

+/- 2,000 kW/m) →



What does the post wildfire stand conditions look like?

FIRE BEHAVIOUR OUTCOMES

Slash loading equals higher fire intensity and site damage



Applying FM principles to various ecosystems/ stand types



Spruce forests

Wildfire spring 2019 →



Applying FM principles to various ecosystems/ stand types

Coastal and interior wet-belt forests



Applying FM principles to various ecosystems/ stand types



Pine forests

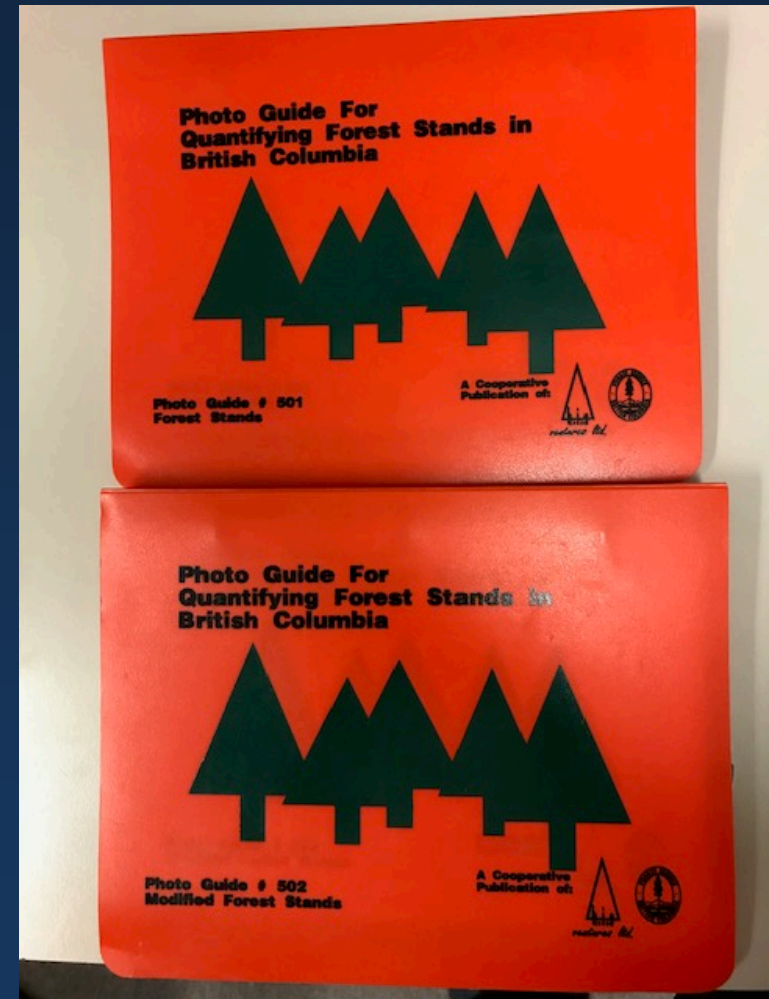


Surface Fuel Data Collection

Surface fuel data collection should be consistent with the general methodologies outlined in the documents located under the heading **Inventorying Downed Woody Material**.

Photo Guide for Quantifying Forest Stands in British Columbia Photo Guide #501 – Forest Stands

Photo Guide for Quantifying Forest Stands in British Columbia Photo Guide #502 – Modified Forest Stands



<https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/for-industry-commercial-operators/hazard-assessment-abatement>

Tools & resources

BC Wildfire Service Tools for Fuel Management webpage

<https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management>

90th Percentile Fire Weather Index Conditions

- *Under Construction**
(*Contact Dana.Hicks@gov.bc.ca for further information.)

Initial Spread Index Roses

- [Initial Spread Index Roses](#)

Inventorying Downed Woody Material

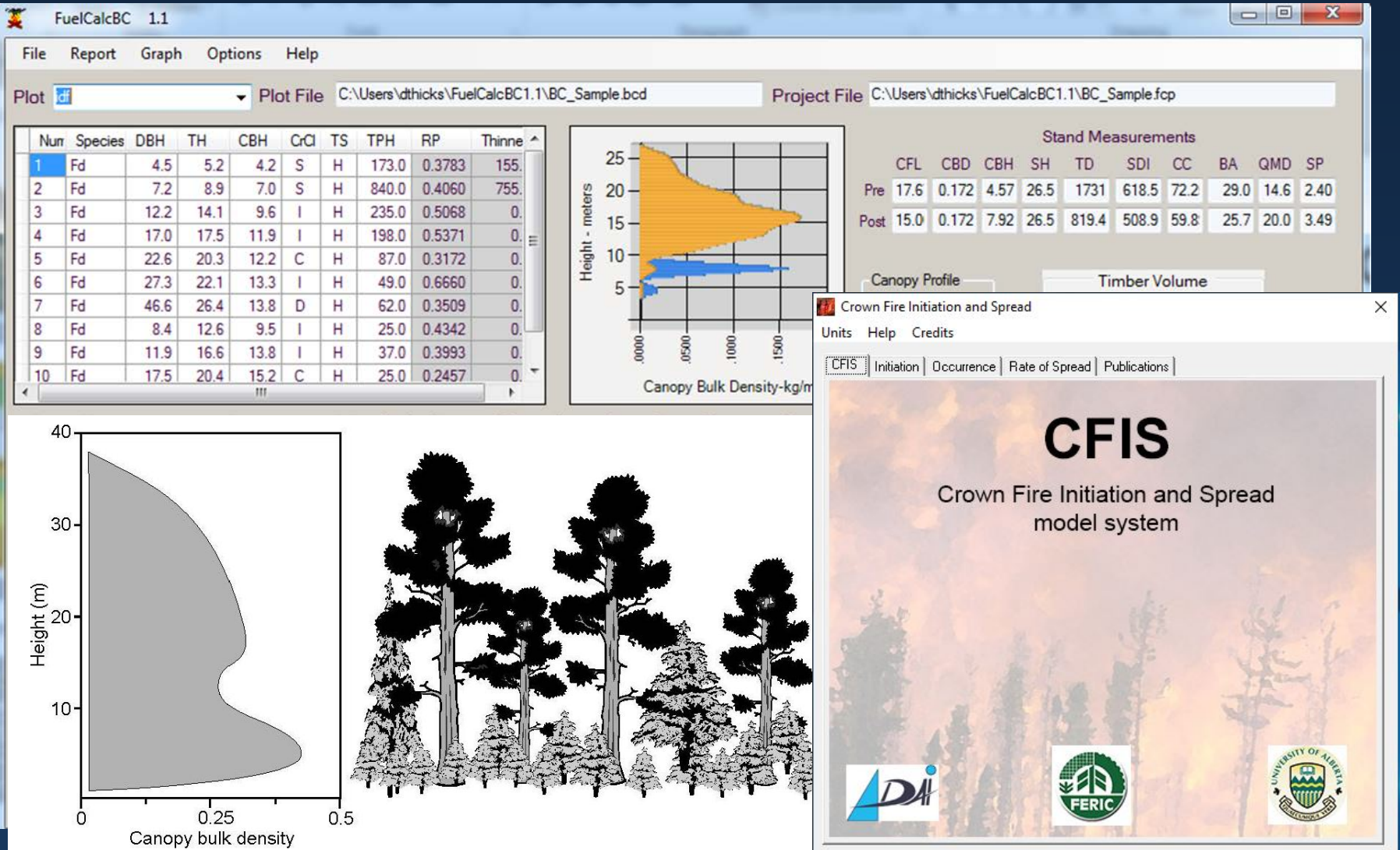
- [Inventorying Downed Woody Material](#) (PDF, 1 MB)
- [CNF Browns Transect Guide](#) (PDF, 361 KB)
- [Tally Line Intersect Form](#) (XLS, 52 KB)
- [Line Intersect Calculator](#) (XLS, 234 KB)
- [Field Handbook for Prescribed Fire](#) (PDF, 1 MB)

Fuel Treatment Design Wildfire Intensity Tool

- [Critical Surface Intensity Worksheet](#) (XLSX, 576 MB)



Other tools & programs



Example of Success

West Kelowna Estates



Treatment instrumental in reducing fire intensity which allowed for control prior to wildfire spreading to the adjacent subdivision.

Untreated burned area



Treated burned area

- Thinned, pruned and surface fuels removed



At the end of the day ..

It is about responder and public safety



References

- Canadian Wildland Fire Information System.
<http://cwfis.cfs.nrcan.gc.ca/background/summary/fwi>
- Natural Resources Canada. Canadian Fire Weather Index System.
<https://www.frames.gov/files/6014/1576/1411/FWI-history.pdf>
- https://www.firescience.gov/projects/09-S-03-1/project/09-S-03-1_AlexanderCruz_2012_IJWF_FlameLenFireLineInten.pdf
- <https://phys.org/news/2017-12-ember-smaller-fastest-biggest-fire-spreading.html>
- “Fire Behaviour in Jack Pine Stands – as it relates to the Canadian Forest Fire Weather Index (FWI) System – M.E. Alexander W.J. DeGroot 1988 Northern Forestry Center, Edmonton AB
- <https://www.frames.gov/applied-fire-behavior/cfis>

Acknowledgements & Contacts



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Mike Aldred
Kamloops Fire Centre
Shannon Irvine
Northwest Fire Centre
Andrea Rainey
Prince George Fire Centre
Mike Morrow
Southeast Fire Centre



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Questions?