# Creation of Surface Fuels Photoload Series for Mulched Sagebrush (Artemisia Tridentata)

BY

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I would like to acknowledge this project was completed on the traditional territories of the Tk'emlúps te Secwépemc peoples. This research in this project stemmed from a bigger project that was conjunction with Tk'emlúps te Secwépemc, The BC Wildlife Federation, and Forsite Consultants Ltd. The goal of this project was to complete fuel management, ecosystem restoration, and restore habitat for bighorn sheep. It was an honour and privilege to conduct research as part of this project.

# Table of Contents

# LIST OF TABLES



# LIST OF FIGURES

# INTRODUCTION

With the current mega-fire regime seen on the landscape due to fuel loading, mitigation work is now essential across the landscape to prevent a worsening situation. British Columbia's 2023 wildfire season has been deemed one of the most destructive wildfire seasons in recorded history (BCWS 2023b) with more than 2.84 million hectares of land burned, doubling the previous record of land burned placed back in 2018 (BCWS 2023b). While millions of hectares burnt throughout the province uncontrollably, only 2241.4 hectares burnt in cultural and prescribed fire. These fuel treatments utilize controlled fire to mitigate and remove dead and downed woody debris and excess surface fuels that would otherwise be used as fire fuel during an uncontrolled wildfire.

Although it is too early to say whether the 2023 fire season was driven by the excess fuel loading, previous fire years were all driven by the build-up of fuel. The 2003 Firestorm report identified the record-breaking fire season was driven by fuel loading, which resulted in the difficult fire behaviour and limited fire suppression efforts (Filmon et al. 2003). Following this, the Ministry of Forests declared that the assessment and mitigation of fuel loading is time consuming and costly, which prevents largescale successful treatments across the landscape (MoF 2004). This issue, yet to be resolved, was brought up again in the 2018 Abbott and Chapman report, emphasizing the need to improve fuel management to reduce wildfire risk within the wildland urban interface and on crown forests (Abbott and Chapman 2018). Most recently, amidst the record breaking 2023 fire season, the Forest Practices Board released its yearly special report and a technical report, calling for urgent action to the Government of British Columbia to reduce risk of wildfires by conducting landscape level fuel mitigation treatments (FPB 2023a, FPB 2023b). Fuel management and risk reduction work needs to be conducted across the landscape in a timely, efficient, and non-costly manner as the current status quo is not working (Daniels et al. 2020). To help with the timing, efficiency, and cost of fuel management projects, mulching and mastication of fuels are now seen on the landscape. The issue is the current sampling method, the line intercept method does not quantify this new fuel type prior to the fuel management. This means fuel management prescriptions are not properly completed, there is no value associated with the fuel to consider reduction targets, and the fuels are not properly considered for fire behaviour or ecosystem effects.

### *Line Intercept Fuel Sampling Method*

The current standards for surface fuel data collection are outlined in the British Columbia Wildfire Service (BCWS) *Fuel Management Survey Data Collection Standard* (BCWS 2023a) which follows the method outlined in Environment Canada's report *Measurement and description of fuels and fire behaviour on prescribed burns: A Handbook* (McRae et al. 1979). The sampling of 'natural woody fuels' follows the line intercept fuel sampling method developed by Van Wagner (1965) and further established by Brown (1971, 1974). The woody debris surface fuels sampled are broken up by diameter size. Fine woody debris (FWD) consists of dead and downed woody debris that is below 7cm in diameter, and this is further broken into 5 separate size classes (Table 1). Large diameter woody debris (LDWD) consists of woody debris that is between 7 – 19.9 cm in diameter, where coarse woody debris (CWD) contains all logs that have a diameter >20 cm.

**Table 1.** Breakdown of the British Columbia Wildfire Service Fine Woody Debris fuel size classes by cm (BCWS 2023a).

| Size Class Number | Size Class Diameter (cm) |
|---|---|
| 1 | 0.1-0.49 |
| 2 | 0.5-0.99 |
| 3 | 1.0-2.99 |
| 4 | 3.0-4.99 |
| 5 | 5.0-6.99 |

In the line intercept method, a triangle transect with 30 m sides are sampled for all BCWS FWD size classes in 5m increments (BCWS 2023a). Within the first 5 m, all FWD samples that cross the transect are counted based on size class. From 5 – 10 m, size classes 2 – 5 are sampled, 10 – 15 m, size classes 3 – 5 are sampled, 15 – 20 m, size classes 4 – 5 are sampled and finally at 20 – 25 m, just size class 5 is sampled. This is repeated for all 3 sides of the transect triangle. LDWD and CWD are sampled across the entire 30 m of the transect triangles on all three sides. Decay of the woody debris is noted for these samples using the British Columbia Decay Class standards (MFLNRO 2018).

Currently, standards for sampling vegetative surface fuels are lacking, as it is not mandatory to determine fuel loads of grasses, shrubs, or herbs. This includes mulched or masticated fuels, including mulched sagebrush (*Artemisia Tridentata*). When sampling for these vegetative surface fuels, a description of the general composition is all that is required when writing a fuel management prescription (BCWS 2023a). However, vegetative surface fuels should be quantified as a fuel to include the combustion, physical, and ecological effects the differing species may have on fire behaviour (Loudermilk et al. 2022). This allows for an understanding of how the entire ecosystem plays into wildfire threat, rather than just the dead and down woody debris.

The line intercept fuel sampling method for assessing surface fuel is also utilized by the US Forest Service (Lutes et al. 2006) with an adaption of the method for their fuel classification system. However, the US Forest Service has begun testing a new method which quickly and accurately estimates surface fuel loadings, the photoload sampling technique (Keane and Dickinson 2007a). This technique is currently being adapted to British Columbia to improve fuel loading sampling (Hughes 2024).

### *Photoload Sampling Technique*

The photoload sampling method uses downward looking visual assessments of loading referenced photos to depict estimated fuel loading for each fuel component. Photoload sampling allows efficient data collection of both woody debris and vegetative surface fuels for consistent fuel loadings at an accuracy required for fuel management prescriptions and treatment planning (Keane and Dickinson 2007a). This method is user friendly in the field and is faster and more efficient while having approximately the same biases as the line intercept method (Sikkink and Keane 2008).

The original photoload series used synthetic photographs (Keane and Dickinson 2007a). These photoload series were created using synthetically constructed fuel beds with specific measured fuel loads in identified increments for 1-, 10-, and 100- hour fuels. Downward-looking, and close-up oblique photographs were taken for each of the fuel types, with a focus on the fuel components common in the northern Rocky Mountains of Montana, USA.

Methods for using the synthetic photoload sampling technique have been developed (Keane and Dickinson 2007b). The photoload series can be implemented using microplots, macroplots, and at the stand level, each with a slightly different approach. The microplot method involves delineating a sampling area typically the size of the fuelbeds within the photoload series, then repeating this in a grid pattern across the sampling unit. The macroplot method uses a $400m^2$ plot in which the area is divided into distinct fuel loadings, proportions of those area are estimated, fuel loadings are estimated for each area, then those fuel loadings by proportion area are averaged. The stand level method uses the same technique as the macroplot method but used across the entire sampling unit. Whether the microplot, macroplot, or stand level approach is used, the basic use of the photoload series is the same. Associate the fuel loading on the ground with that of the fuel loading in the photoload series that looks most like the sampling area.

Since the initial development of the photoload sampling technique from Keane and Dickinson (2007a, 2007b), this method is starting to be adapted to British Columbia within the biogeoclimatic (BEC) zone ecosystem stratification (Hughes 2024). This initial pilot study laid the groundwork for methods to create photoload series for the province to use in different fuel types, including those that cannot be sampled under the line intercept method.

### *Objectives*

From the Creation of Surface Fuels Photoload Series pilot study (Hughes 2024), this project will use similar methods so an in-field photoload series can be produced for mulched sagebrush. The goal is to create a photoload series that can be immediately implemented for field use to quantify various loadings of mulched sagebrush prior to Burn Plan Prescriptions. This photoload series may also give users the opportunity to understand how this new fuel type may react or generate different fire behaviour and alter an ecosystems ecology.

# METHODS

## *Site Description*

Data collection for the photoload series took place on the traditional territory of the Tk'emlúps te Secwépemc peoples within the Kamloops 1 Reserve (Figure 1). A 1ha site was sampled (50.68542º N, 120.20539º W) for all samples collected which is actively being fuel managed by mulching the sagebrush.

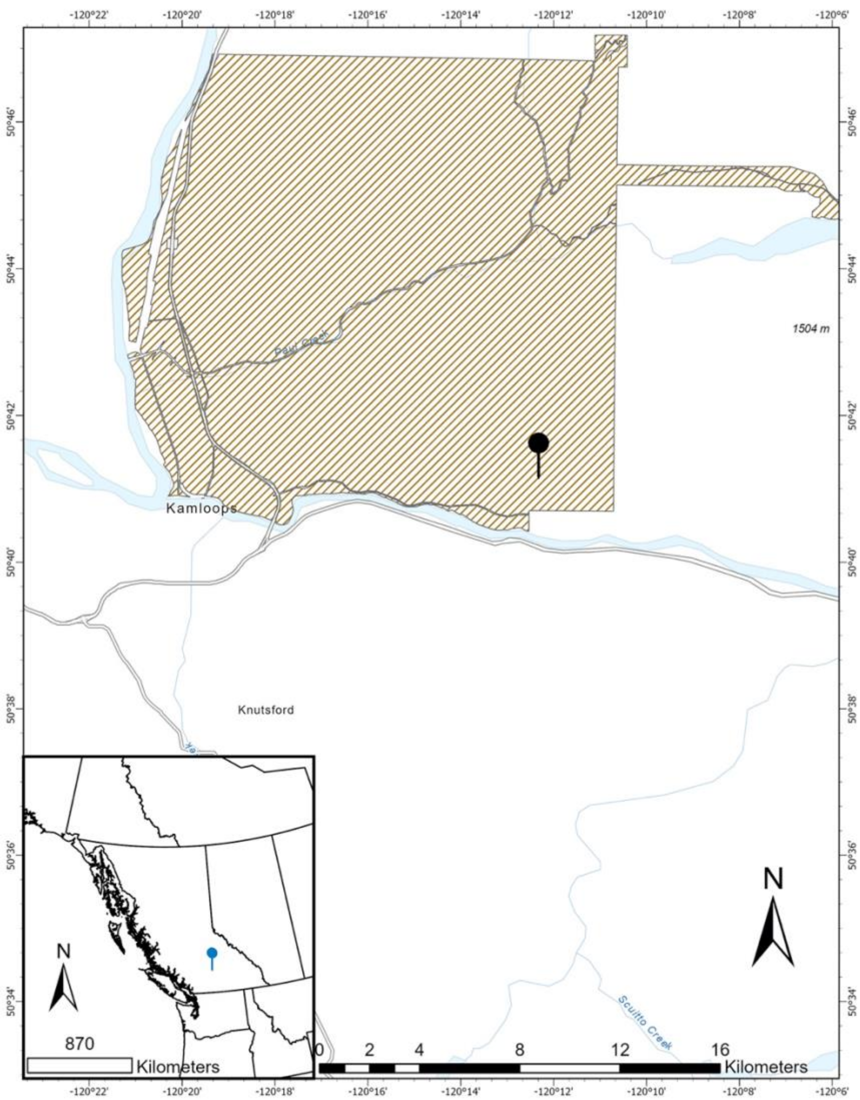


**Figure 1.** The study sites near Kamloops, British Columbia, Canada (50.68542º N, 120.20539º W). This site is located on the traditional territories of the Tk'emlúps te Secwépemc peoples. Sampling was conducted on the Kamloops 1 Reserve and is outlined on the map. *Map produced using ArcPro application.*

This site falls within the Thompson Very Dry Hot Bunchgrass (BHxh2) BEC Zone. The vegetation on the site is classifies the area as a shrub-steppe ecosystem with Big Sagebrush outcompeting all the other plants (Ryan et al. 2022). Under the sagebrush layer, Bluebunch Wheatgrass (*Pseudorogneria spicata*) can be found in sparse patches. Due to fire exclusion on the landscape, the sagebrush has been allowed the ecosystem that was once a grassland area to transition to a full sagebrush-steppe area. On top of the sagebrush limiting plant growth, a herd of wild horses have competed with the population of bighorn sheep for the limited amount of vegetation left. This has pushed the bighorn sheep population away from this area.

This site is undergoing an active fuel and restoration treatment to increase the quality of the site for multiple objectives. The sagebrush on the site is undergoing a mulching treatment to reduce the fuel loading caused by the excessive sagebrush. Prescribed/ cultural burning practices will be applied once the mulching is completed to remove the remaining mulch onsite. This is the current state of the site (Figure 2). Prescribed/ cultural burning practices will be applied once the mulching is completed to remove the remaining mulch onsite, which will be followed be seeding the area with a native seed mix. These actions will not only decrease the fire risk in the area, but also restore the grasslands and bring the bighorn sheep back to the area by providing adequate forage and habitat.

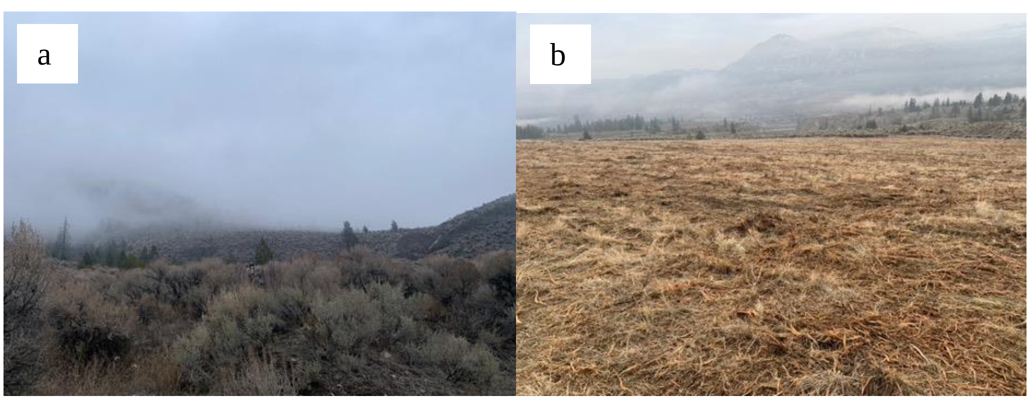


**Figure 2.** General surroundings of the site sampled for mulched sagebrush. **(a)** Dense sagebrush community that surrounds the site. Example what the site would have looked like prior to treatment. **(b)** Site of the sagebrush mulching treatment. All sagebrush mulched, limited grass cover underneath. *(February 2024).*

### ***Field Methods***

Methods used to sample the sites for the photoload series followed the basic outlined procedures presented by Hughes' creation of surface fuels photoload series pilot study (2024). Sampling took place on November 3, 2023, for all mulched sagebrush samples.

A square sampling frame of 1 x 1 m ($1m^2$) was used to define the boundaries of each surface fuel plot. The $1m^2$ plot size for these fuels were chosen based on previous fuel spatial scale analysis (Keane et al. 2012). This size is also convenient to capture fine fuel size and loadings as the frame is already in the correct units of per $m^2$ (Stalling and Keane 2020). Locations of all plots were randomly identified on the day of the collection with the goal to sample a gradient of surface fuels. This was done by sampling areas with visually high fuel loadings, then moving the plot frames to areas of less fuel loadings until the lowest fuel loaded area was captured.

Once sample locations were selected, the plot frame was laid down facing north. A whiteboard was used to write the plot number, date, and coordinates, and placed in the top right corner outside the plot frame. These actions standardized the direction of the photo. Two photos of each plot were taken, which included the whiteboard in the photo. Photos were taken directly over top the plot frame, so the photo captured the entire plot at a flat angle.

All dead mulched sagebrush biomass was collected from within the plot frame and stored into labeled paper bags. Biomass that extended outside of the plot was clipped so only material that fell inside of the frame was collected. Only biomass above the litter layer was collected. If debris was partially buried in litter along the horizontal axis, the material was collected if its central growing point was above the litter layer.

### ***Laboratory Methods***

All samples were dried in a drying oven for a minimum of 48 hours at 90°C. After the drying process, the samples were removed and immediately weighed outside of the paper bag for the dry weight using an analytical scale (Fisher Scientific-acci-4102). Weights were calculated in kg, which could be easily converted to kg/ $m^2$. The total plot weights were then associated with the photos of each plot to develop the photoload series. The photos chosen for each plot of the series were based on highest quality showing the entirety of the plot frame. Photos in the sequence are ordered from lowest quantity of fuels to highest, representing the entire gradient of fuels across the site. Nine total images were used per photoload series.

# RESULTS

***Photoload Series***

From a total of 10 plots sampled, only nine plots were used for the photoload series (Figure 3). The photoload series is ordered by ascending total plot fuel loading. Selection of the plots for the photoload series were based on photo quality and how the photos would create a gradient of fuel loadings. The lightest amount of fuel collected on the site was 0.214 kg/m$^2$ and the heaviest amount was 5.020 kg/m$^2$. Both these amounts are presented in the photoload series to represent the minimum and maximum values that could be found on site.

Distribution of fuel loadings from photo-to-photo vary, creating inconsistent increases throughout the photoload series. The first four images of the photoload series represent mulched sagebrush fuel loadings that are below 1 kg/m$^2$, which increase by approximately 0.2 kg/m$^2$ per photo. This increase pattern is also seen by the following two photos in the series. Increases from photo six throughout to photo 8 are inconsistent with the increases. Finally, the fuel loading increase between the last two photos is 2.9 kg/m$^2$.

## Photoload Series: Mulched Sagebrush

TOTAL – 0.214 kg/m²

TOTAL – 0.473 kg/m²

TOTAL – 0.702 kg/m²

TOTAL – 0.822 kg/m²

TOTAL – 1.087 kg/m²

TOTAL – 1.112 kg/m²

TOTAL – 1.786 kg/m²

TOTAL – 2.166 kg/m²

TOTAL – 5.020 kg/m²

**Figure 3**. Mulched sagebrush photoload series for British Columbia.

# DISCUSSION

The development of the mulched sagebrush photoload series will be beneficial for the use of identifying fuel loading during fuel management prescriptions. The design of the single page photoload series with only nine images allows for quick visual evaluations in the field. Since there was no pervious field method to quantifying mulched or masticated fuel loadings, the photoload series method allows this to occur quickly so decisions about fire behaviour and ecosystem affects can be made. This technique is beneficial when time and money may be limited, while still having accurate estimates of fuel loadings (Sikkink and Keane 2008). The development of this photoload series indicates the initial success of this project and will allow for further development and improvement.

If the line intercept fuel sampling method was attempted to be used to quantify the mulched and masticated fuels, accuracy of the loadings may be higher. However, this comes at a great cost of time and effort put into sampling the heavily fuel loaded areas. A previous study conducted comparing the line intercept fuel sampling method to the photoload series stated it took expert samplers 100 – 180 minutes to estimate just the dead and downed woody debris at the site (Sikkink and Keane 2008). As the province works to improve the efficiency of landscape level fuel management, sampling with the photoload series can be more efficient while maintaining the same bias as the line intercept method (Sikkink and Keane 2008). The efficiency of using the photoload series will depend on the methods of using the series in the field (Sikkink and Keane 2008). The methods of using the series and their efficiencies are discussed below.

### *Using the Photoload Series in Field*

The first step in using the photoload series in the field is determining the scale at which to make assessments at, which will affect the accuracy and efficiency of the results produced. The photoload series may be implemented at three different scales which vary in the time, funding and resources needed. The three different scales include the microplot, the macroplot, and the stand level methods (Keane and Dickinson 2007b).

**The Microplot Method**- This method of measuring fuel loadings with the photoload series will use the most resources, time, and funding. The tradeoff is this method has the highest accuracy with the small-scale application (Keane and Dickinson 2007b). 1m-by-1m plot frames will be used to determine a small sampling area to visually estimate the fuel loading. Plots are laid out in a grid pattern across the site, so it covers the entire array of fuels within the area without bias. Enough grids are placed across the landscape to cover 10% of the entire area (Keane and Dickinson 2007a). Each plot of the grid is visually compared to the photoload series, and the most accurate loading is chosen and recorded for the grid. Once all grids are completed, the fuel loading of each plot is summed, then can be scaled up to the size of the site. Expert evaluators can complete an evaluation of the fuel loading of a site for all fuel in 125 minutes (Sikkink and Keane 2008).

**The Macroplot Method-** This method will slightly decrease the accuracy of the final loading compared to the microplot method, but also decrease the resources, time, and funding needed to sample (Keane and Dickinson 2007b). The site is divided into macroplots that will cover approximately 10% of the area. Each macroplot is visually divided into sections of similar fuels. For each of these sections, the proportion of the area and the loading should be estimated. The fuel loading average can then be calculated for the entire macroplot. Based on the proportions of each fuel designation, all the macroplots together can be scaled up or averaged for the sites fuel loading. Visual assessments for the fuel loadings of a site can be conducted in 6 to 7 minutes total and the results are not statistically different from other methods (Sikkink and Keane 2008).

**The Stand Level Method-** This method employs using the macroplot or microplot method to cover an entire stand at a large scale (Keane and Dickinson 2007b). Of the three methods, the accuracy may be the lowest, however large areas can be covered quickly limiting the time, resources and funding needed. The entire stand is stratified by visual divisions of fuel, then the proportions of the divisions are estimated. Each of the divisions fuel loadings are estimated. If the divisions are too large to visually estimate, the microplot or macroplot method can be deployed within each stratified area. The fuel loading average can then be calculated for the stratified sections and can be scaled up or averaged for the sites fuel loading. Efficiency of evaluating fuel loadings at a stand level is dependent on the method to estimate the fuel loading of large divisions.

The photoload series was designed for ocular estimates of the fuel loading, so individuals must calibrate themselves to the photoload series and site to not let any additional factors influence the estimate (Keane and Dickinson 2007b). The visual assessment is based on fuel loading characteristics alone, and not any other environmental characteristics. The estimates are for the surface fuel situated above the litter layer. Buried fuel in the litter layer should not be included in the fuel loading estimate. To minimize confusion with the use of the photoload series in the field, the lowest fuel loaded areas should be estimated first then work up to higher fuel loaded areas (Keane and Dickinson 2007b). The most important part of using the photoload series to estimate surface fuels is gaining the experience to estimate the loading values accurately and precisely across the landscape.

***Limitations***

The limitations of this photoload series should be improved upon with any subsequent photoload series development. The largest limitation within the mulched sagebrush photoload series is the large gap between the eighth and nineth photos (Figure 3). The increase of fuel loading is nearly 2.9 $kg/m^2$, where all the other increases in fuel loadings between the other plots increase less than 1.0 $kg/m^2$. The site was sampled so the maximum and minimum values of mulched sagebrush on site where collected, however with only 10 sampled total this prevented a larger gradient of fuel loadings to be captured to make the photoload series. The inconsistent fuel loading increases from photo to photo in the series suggests more sampling should be done to fill in missing loadings.

As this photoload series suggested, it is composed of just mulched sagebrush. This series cannot be used for other mulched or masticated fuels, such as fine slash. Additional photoload series will need to be made for other mulched and masticated fuel types. However, this project can be used to establish the methods for developing further photoload series for the other similar fuel types.

### *Conclusion*

In conclusion, this project provides the first photoload series for the province of British Columba that can be used to estimate the surface fuel loadings of mulched sagebrush for any fuel management planning. The single page photoload series with nine images sorted ascending by fuel loading will allow for quick and easy visual evaluation in the field. Discussion was conducted on the strengths and limitations of the development of this photoload series. As further photoload series are developed and improved upon for mulched and masticated fuel types, sampling efforts should increase to capture a larger gradient of the fuel loading. Continual improvement to the photoload series can be made as the series are implemented in the field. This study should contribute as the starting point for further photoload series development across the province of British Columbia for mulched and masticated fuel types.

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