Transition Salt Spring

Watershed Resilience Technical Guide

Maxwell Creek Watershed Research Project 2023

Photo: Rob Lowrie

PRODUCED BY THE CLIMATE ADAPTATION AND RESEARCH LAB OF TRANSITION SALT SPRING WITH FUNDING AND SUPPORT FROM:

This project was undertaken with the financial support of:
Ce projet a été réalisé avec l'appui financier de :

Environment and Climate Change Canada | Environnement et Changement climatique Canada

NORTH SALT SPRING WATERWORKS DISTRICT

Contents

Chapter 1. Context

The Maxwell Creek Watershed Project is a watershed-level restoration initiative. As the project name indicates, its focus is the Maxwell Creek Watershed on Salt Spring Island (SSI), BC. The project aims to improve ecological integrity within local forests while simultaneously strengthening understanding of, and addressing:

- The risk and spread of catastrophic wildfire
- Water quality and supply
- Other vulnerabilities due to extreme weather and other climate change impacts.

This project seeks to fill existing knowledge gaps by compiling a baseline dataset, recording the current conditions of a representative watershed for the Gulf Islands and other areas within the Coastal Douglas-fir (CDF) bio-geoclimatic zone. Though its impetus was motivated by an interest in reducing climate change vulnerabilities locally, its execution has region-wide implications as the state of SSI's natural systems is much like other islands and coastal communities around the Salish Sea. As such, one outcome of this project is that it will serve as a demonstration site, providing an easily replicable project framework and methodology. Another outcome is the creation of a regional community of practice, so resources and learnings can be shared along with project data through an online data portal. The project team hopes this will reduce duplication of effort among different islands, and increase collaboration between historically siloed communities.

Note: Already at the time of writing, another key vulnerability has been identified- not-to-code road construction and heavy rains leading to washouts and the movement of sediment and nutrients into the lake supplying potable water for the community. Road and ditch management using Natural infrastructure has been added as another project, and methods, analysis, and design techniques will be added in the next update for this guidebook.

Within BC's current political matrix, climate change response has been limited. At a local level, there is no one organization clearly responsible for responding to increasing risk from fire, reduced water quality and availability, and other threats to ecological integrity. Governments were designed for periods of stability, not instability. Despite declaring climate emergencies, local governance agencies have yet to develop tools to address the complexity and intersectionality of climate change. The only way forward is collaboration among a diverse collection of experts and local knowledge holders.

Transition Salt Spring (TSS) engaged the community in the development of The Salt Spring Climate Action Plan 2.0. The plan outlines 250 recommendations for individual community members to address the climate crisis locally, including reducing greenhouse gas emissions by

50% by 2030. Another part of this work was the completion of risk assessments to support the identification of highly vulnerable areas. This brought different agencies and groups together to identify the highest priorities of, and greatest obstacles to, meaningful climate action.
The issues and actions outlined in the Plan are shared with other communities throughout the Salish Sea and the larger Coastal Douglas-fir Zone. This process made it clear that addressing fire risk and water supply concerns is an absolute top priority. Good relationships are easier to build in rural settings, where there is a shared (and growing) awareness of the scale of the challenge of problems. More difficult is to find core funding application to implement a community-based, collaborative climate action project. The work supporting this Technical Guidebook arises from work initiated by TSS in the Climate Adaptation Research Lab, a community supported field restoration and climate research project aimed at answering key questions about resilience and regenerative methods, and documenting practical tools and methods for use by this and other Salish Sea Communities.

A major driver in the design and implementation of this project is the need for an easily replicable project model. The initiation of this trial or beta version of the project, will ultimately remove the need for other organizations to design projects from scratch. The aim is to increase the capacity of other regional organizations by providing and sharing resources and information to advance climate resilience actions. The aim is not just initiating a stand-alone project, but rather creating a community of practice inclusive of practitioners working throughout the CDF zone.

Photo taken by Natasha Kong

Multiple practitioners working under the umbrella of the Maxwell Creek Watershed Project (MCWP or "the Project") have contributed to each installment of the Field Files series. Ruth Waldick from Transition Salt Spring and Shauna Doll from Raincoast Conservation Foundation contributed to the growing narrative through these chapters with other team members.

Chapter 2. Design and Project Scope Considerations

The project takes a watershed-wide scope to improve understanding of both existing and historical ecological conditions. The first question we aim to answer is: How has modification via forestry, fire, wetland drainage, etc., influenced hydrological dynamics, availability and quality of freshwater (i.e., source drinking water), and local forest ecology? We seek to find answers to this baseline-informing question through field-based research. We will then apply findings to inform the design and implementation of management prescriptions to answer our second question: What can restoration practitioners, land managers, and other experts do to enhance ecological integrity while also increasing community climate resilience?

Starting with a literature review

Considering existing baseline documentation (and perspectives of various local stakeholders) is the first step and one that continues as we develop and explore appropriate methodologies. The second step is mobilizing available geospatial information, including layers from various sources, such as recent LiDAR data generated by a geophysical engineer living at the border of the Maxwell Creek Watershed, to conduct geospatial analyses. The third step is implementing the on-the-ground observational study to establish baseline conditions and inform the design of future management prescriptions (e.g., restoring drained wetlands by altering human-dug channels and ditches, thinning overly dense third-growth forest, etc.). Technically speaking, we are implementing a stratified random sampling design taking a two (2×2) factorial approach, contrasting open versus closed canopy and wet versus dry site conditions. Baseline data is currently being collected to paint a general picture of how conditions vary across those gradients.

		Independent Variable 1	
		Level 1	Level 2
Independent Variable 2	Level 1	Dependent variable	Dependent variable
	Level 2	Dependent variable	Dependent variable

2×2 Factorial Design. Figure created by Shauna Doll, modified from Statology, 2021.

The baseline or reference gradient will allow us to identify characteristics of the forest in the context of local light, soil, and moisture conditions. This will help us design appropriate goals for restoration. This is key, as restoration ecology can be challenging. Whether a wetland is being restored, the way water flows across the landscape is being altered, or the density of a forest is being reduced, one can anticipate certain effects, but until they are implemented, there is always a small amount of guesswork involved. In this project, an amazing amount of work has been done looking purely through the lens of LiDAR to develop a study design that maps out existing conditions and tests some of the assumptions we have about what potential management prescriptions might achieve. We can ask questions through the lens of existing conditions like: What happens if the forest canopy is open? Does an open forest canopy mean a denser understorey? Does that, in turn, mean higher or lower levels of soil moisture sustained throughout the year?

How were these methodologies developed?

The 2×2 factorial approach parallels the methods used for my master's research, in which examined the impact of seasonal drought on flowering plant communities and bumblebee populations within the Coastal Douglas-fir biogeoclimatic zone (Simon, 2020). For the study, I was interested in contrasting the intersection between soil moisture availability and disturbance, resulting in four extreme site conditions: 1) dry semi-natural environments (woodlands and rock outcrops); 2) wet semi-natural environments (wetlands); 3) dry modified environments (disturbed upland areas such as clear-cuts); and, 4) wet modified environments (rural areas including gardens, orchards, and fields). I established six sites per condition, for a total of 24 sites, to collect data and investigate the relationship between the intersecting factors. Some important findings emerged from that study, including predictions about the abundance and decline of various plant and bee families under the drought conditions expected due to climate change.

		Independent Variable 1: Soil moisture availability	
		Level 1: Dry	Level 2: Wet
Independent Variable 2: Disturbance	Level 1: Semi-Natural	Dry Semi-Natural	Wet Semi-Natural
	Level 2: Modified	Dry Modified	Wet Modified

2×2 Factorial Design example using variables from Simon, 2020. Figure created by Shauna Doll, modified from Statology, 2021.

Designing a study to differentiate effects of light and moisture

In developing the study design for Maxwell Creek, the same model used in my master's research was adapted, though it could also be deconstructed into a gradient-based approach. The 2×2 factorial will allow us to get as close as possible to isolating the conditions of interest, which, as mentioned above, are canopy coverage and soil moisture. Canopy coverage was chosen as the first condition to align with the restoration goal of opening forest canopy/decreasing density to approximate a more mature forest structural state. Soil moisture was chosen as the second condition in alignment with wetland restoration goals. Together, these restoration goals are expected to increase abundance and diversity in the understorey and slow water movement across the landscape, thus reducing risk of drought, fire, and water supply instability.

Role of remote-sensed data

Something that differs between the approach taken during my master's studies and the Maxwell Creek project is the inclusion of LIDAR data. For my study, I relied on Terrestrial Ecosystem Mapping (TEM) (Madrone, 2008) and other approaches to stratify the landscape. Conversely, the Mount Maxwell Project has benefitted from LiDAR models. To stratify open canopy versus closed canopy conditions, we subtracted the digital elevation model of Maxwell Creek Watershed from the digital surface model.

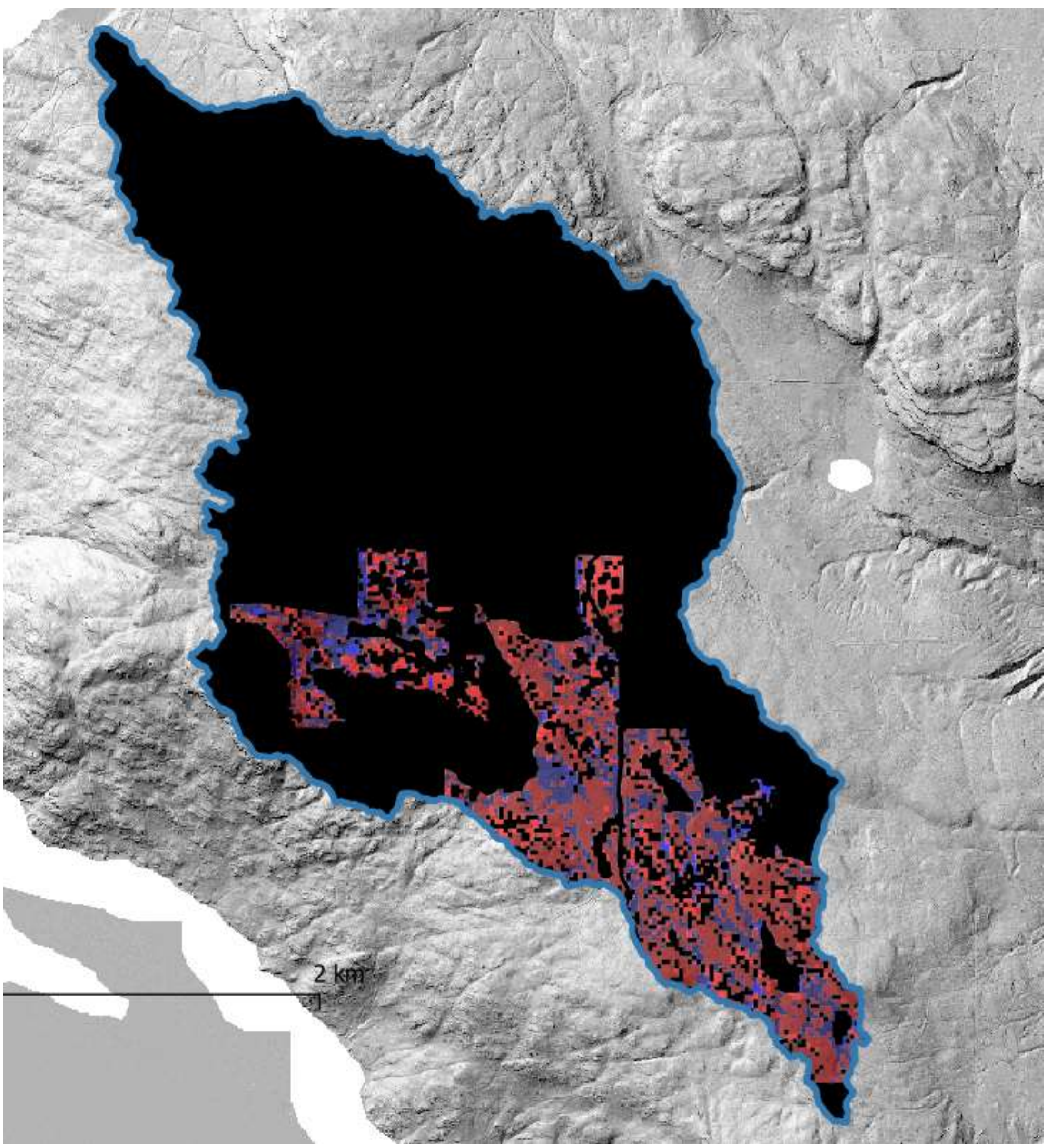
- <u>Digital surface model (DSM):</u> a representation that captures both the environment's natural and artificial features. It includes the tops of buildings, trees, powerlines, and any other objects. Commonly, this is interpreted as a canopy model and only 'see's ground where there is nothing else above it (modified from Up42).
- <u>Digital elevation model (DEM):</u> a representation of the bare ground (bare earth) topographic surface of the Earth excluding trees, buildings, and any other surface objects (United States Geological Survey)

		Independent Variable 1: Soil moisture	
		Level 1: Relatively Dry	Level 2: Relatively Wet
Independent Variable 2: Canopy Coverage	Level 1: Open Canopy	Relatively Dry Open Canopy	Relatively Wet Open Canopy
	Level 2: Closed Canopy	Relatively Dry Closed Canopy	Relatively Wet Closed Canopy

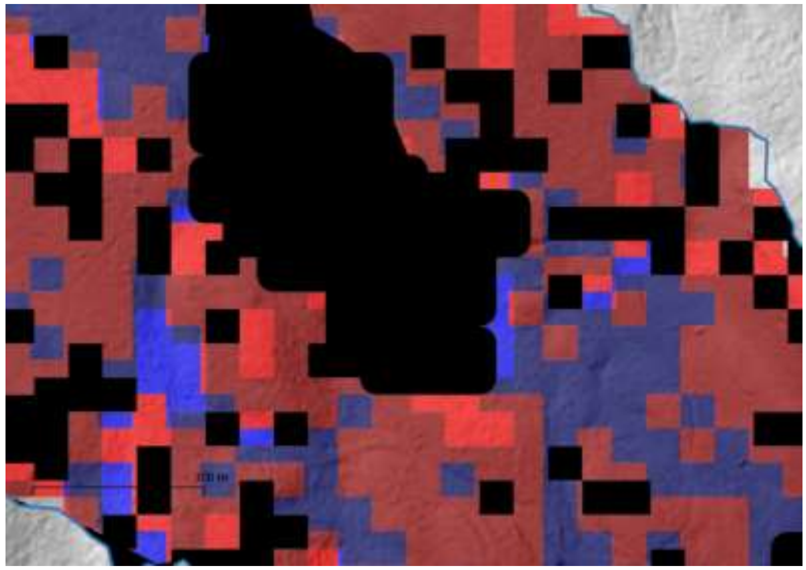
Maxwell Creek Watershed 2×2 Factorial Design. Figure created by Shauna Doll, modified from Statology, 2021.

To stratify wet versus dry sites, a raster layer representing the soil moisture regime was derived from a terrain analysis of LiDAR data. We did this by extracting everything that was upslope or "water-shedding" into one layer, and everything downslope, including flat areas, ravines, gullies, and other depressions on the landscape into another, thereby segregating the contrasting conditions.

Finally, we intersected all four resulting layers delineating the four possible conditions:
1) relatively dry, open canopy;
2) relatively dry closed canopy;
3) relatively wet open canopy; and
4) relatively wet closed canopy.



Stratification map legend:
Bright red = Open-dry site conditions;
Dark red = Closed-dry site conditions;
Bright blue = Open-wet site conditions;
Dark blue = Closed-wet site conditions;
Black = Area excluded based on exclusion criteria;
Basemap: 1 m Bare earth hillshade



Prior to identifying potential study sites, some a priori exclusion criteria were implemented. For example, we included a 10 m buffer around roads to avoid edge effects. Next, we implemented balanced acceptance sampling, a geometric algorithm that produces what is essentially a simple random sample with better spatial balance (i.e., avoids dense clusters of points in close proximity to each other). This yielded 400 potential sites for the observational study, the majority of which were rejected based on a set of a priori selection criteria. For example, some sites may be completely inaccessible for sampling, or the LiDAR may have accurately detected an area as wet, but it may also be very rocky and thus not ideal for assessing soil moisture variability. As such, it was essential to go out in the field to run through a site selection procedure.

Ground-truthing

When ground-truthing potential study sites, it is ideal to visit them in the sequence generated to achieve a spatially balanced final sample. The best way our research team could do this in the field was to divide points into clusters and move through them sequentially. At each site,we ran through the selection criteria and ultimately identified and established 10 permanent plots within each of the four conditions for a total of 40 plots.

At each plot, we installed flagging tape to designate its centre and cardinal points, where two intersecting transects will be established to measure soil moisture availability using a soil moisture probe and conduct percent coverage vegetation surveys. The plots will also be sampled by forestry practitioners, who will measure the amount of coarse woody debris/fine fuels (CWH) and the diameter at breast height (DBH) of trees within each plot. Other factors that are being measured include decomposition rates and the amount of light breaking through the canopy. We targeted open and wet conditions as potential proxies for the ideal state we might want to achieve via forest and wetland restoration measures.


Marking plot centres. Photo taken by Andrew Simon.

Because this is an observational study, we are not controlling variables to an extent that we can determine causality. Instead, we are investigating how conditions co-vary in relation to each other. For example, if there is a dense understorey, does that correlate with an open canopy? If those two things correlate, do they also correlate with more elevated soil moisture levels in the late season when drought sets in?

Further down the road, we will produce regression models: generalized, linear, and mixed effects models. There is a whole suite of possible models we might apply depending on the independent and response variables to better understand correlations between these different conditions, and perhaps extrapolate our findings to apply to other, similar sites within the region potentially.

What are the expected outcomes of the project?
As mentioned throughout this article, we aim to implement restoration measures that will both help restore ecological integrity and to serve as a demonstration for future projects. The scale on which we are able to implement said restoration will depend on the resources available and whether permission from property owners/managers is granted. This is the nature of restoration; it is a careful process with a great deal of learning and observation.

In addition to restoration treatments, one of the large intended outcomes for this work is the development of recommendations for North Salt Spring Waterworks, who owns the property. When this project was conceived, the team wanted to take a no holds barred approach to envision what could be possible if all required resources were available. This approach was meant to define the project by possibilities, as opposed to limitations. In this way, it is aspirational–imagining a new way to manage land outside conventional extractive paradigms.

A dense third-growth forest that may be a good candidate for thinning treatment to restore understorey diversity. Photo by Pierre Mineau.

Sharing what we discover

All of this information (i.e., an overview of methodologies, analyses, results, barriers, and recommendations) will be compiled into a publicly available report, with all data from the observational study stored in the online data portal with the aim of creating a framework that is easily replicable. While it is unlikely to be perfectly reproducible, the idea is to provide vignettes, or key project facets summarized in a succinct and easily understandable format accompanied by visualizations/story maps. In this way, if the Maxwell Project eventually comes to some sort of conclusion - and I say 'if' here because restoration work generally needs to be continuous over the long term to achieve desired ecological outcomes -, the framework will live on, evolve, and become the "source code" so to speak for future projects. Having all these skilled experts and practitioners working together creates a broad horizon of possibilities to continue to adapt these frameworks and tools. So along with the very specific technical framework that will come of this project, there is this more social, abstract framework that is evolving in tandem. That will hopefully serve as a resource for communities in this region to use in the future in a whole suite of different settings.

Multiple practitioners working under the umbrella of the Maxwell Creek Watershed Project (MCWP or "the Project") have contributed to each instalment of the *Field Files* series. All maps and images are from Andrew Simon. Shauna Doll from Raincoast Conservation Foundation contributed.

Chapter 3. Mapping the Watershed

Getting Started

One of the first steps to initiate this Project was to compile satellite imagery, ecological and biophysical maps, data layers, and any other field data from the watershed to begin to understand surface water flows, hydrological features, forest structure, and land-use history among other things. Spatial data has been further supported by a growing assortment of field observations from fixed, long-term monitoring stations (water flows, forest, vegetation plots, etc.), experimental/treatment plots, data loggers, and wildlife cameras.

Ultimately, this work aims to tackle the complexities of addressing the cumulative impacts of climate change on local ecosystems while also navigating interagency collaboration. The goal of the Project is to better understand and define the efficacy of nature-based solutions, such as the installation of green infrastructure, in increasing climate resilience and enhancing ecological integrity and biodiversity.

Three actionable objectives of the Project

1. **Forest restoration**

   Like on many Gulf Islands, intensive silvicultural (i.e., timber harvest) activities on Salt Spring Island throughout the 20th century shifted structurally complex and biodiverse Coastal Douglas-fir (CDF) forests to stands that are predominantly homogenous in age, with limited species diversity, closed canopies (i.e., dark), and a lack of wildlife and wildlife features (e.g., wildlife trees, coarse woody debris, etc.). This is certainly the case in the Maxwell Creek Watershed. Despite more than 20 years of protection, the forests within this watershed are dominated by silvicultural characteristics (i.e., dense, low-diversity, and even-aged).

   This has implications for biodiversity and increases vulnerability to climate change/weather extremes. The MCWP focuses on developing, testing, and demonstrating techniques to recover ecological functions and reduce fire hazards within modified forests of the Southern Gulf Islands.

2. **Wetland restoration**

   Climate-induced drought, extreme heat, and exceptional rainfall events have increased the frequency and severity of local emergencies such as road washouts, landslides, and loss of electricity and emergency services. The state of ecosystems in the Maxwell Creek Watershed exemplifies the extent of modification imposed on the landscape since settler arrival in the late 1800's. This includes the loss of approximately 75% of wetlands from this area. The MCWP aims to understand and define priority areas for restoring wetland functions lost due to the installation of roads, ditches, and agricultural drainage systems.

3. **Baseline observational studies**

   As described above, the Project has been designed to increase fire resilience and ecological integrity in forests and wetland ecosystems. Restoring a more complex forest structure requires an understanding of historic and baseline conditions. This means collecting information on factors creating areas of high vulnerability (e.g., fire, washout/flooding, loss of biodiversity/habitat) and identifying key variables influencing ecological functionality in the watershed.

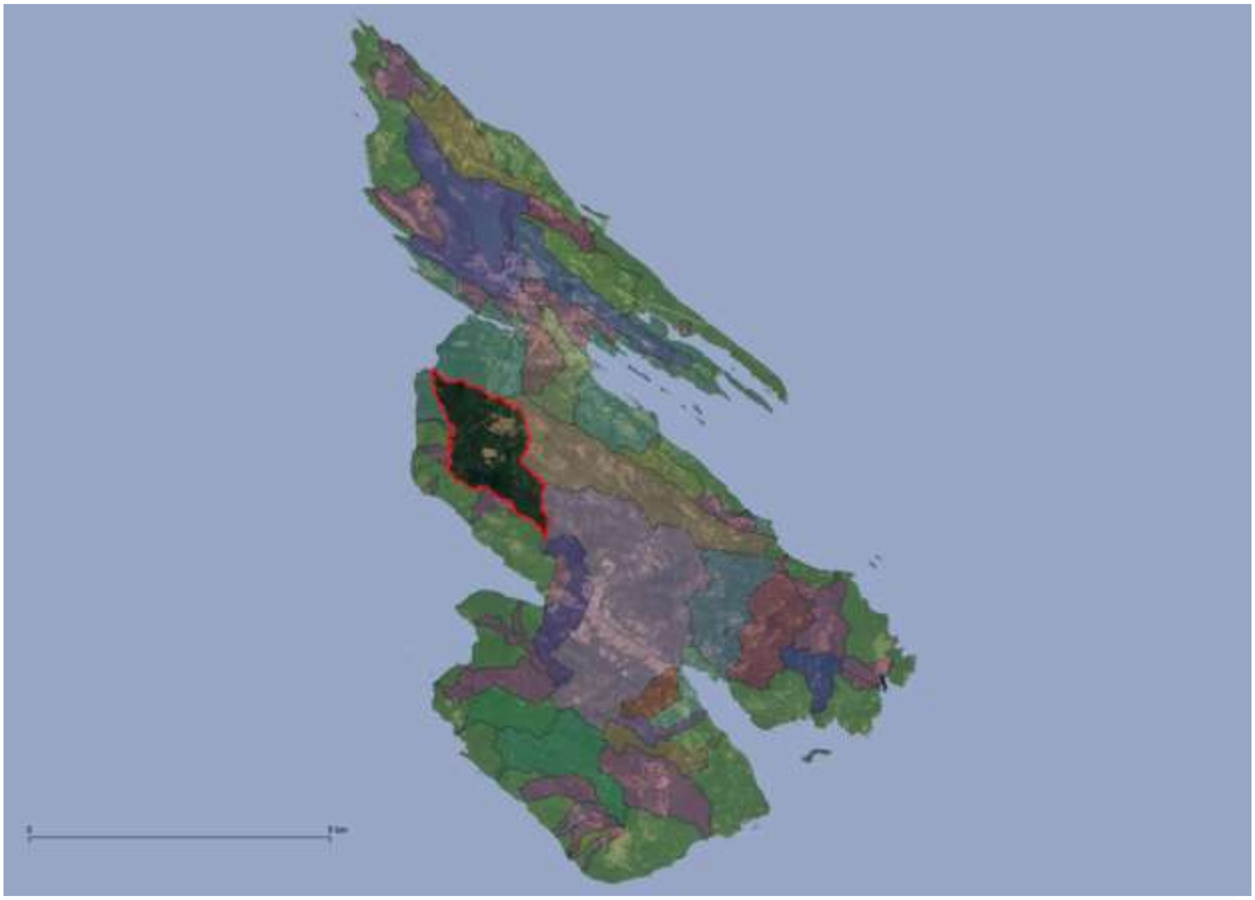
4. **Fire hazard and historic land use**

   As a result of historic forest clearing for agriculture and clearcutting, even areas that have been protected for decades retain characteristics typical of silvicultural stands; predominantly homogenous in age, with limited species diversity, closed canopy, and few large old trees and snags or other features to support native wildlife. Long-term monitoring and experimental restorative and regenerative projects will be necessary to manage the return of biodiversity and the features that sustain resilience in natural systems.

The following photo essay describes the role spatial data has and will continue to play in helping the Project's community of practice to achieve these goals.

The study area: Maxwell Creek Watershed

The Maxwell Creek Watershed was chosen as an area of focus for a number of reasons. In addition to being a protected area at low risk of future development and disturbance, the watershed is essential to the resilience of the Salt Spring Island community. It supplies potable water to nearly 50% of year-round island residents, including the Village of Ganges and the hospital. Maps 1 through 17 will provide additional information about the study area, land-use history, and many other additional details that have been considered in the design and implementation of the MCWP.



Map 1: Capital Regional District watersheds on Salt Spring Island. Maxwell Creek Watershed is outlined in red.

	 **Map 3:** Maxwell Creek Watershed highlighted in red, with a green circle indicating the study area of the Maxwell Creek Watershed Project. Water runs through the watershed from the southeast corner (near Maxwell

 [**Map 2**](): Salt Spring Island. Maxwell Creek Watershed is outlined in red, and Maxwell Lake is highlighted in blue. The watershed is currently well protected through private and public covenants, protected areas, and parks. **Tip**: QGIS ([Welcome to the QGIS project!]()) and Google Earth Pro ([Earth Versions – Google Earth]()) offers an alternative to costly proprietary software for GIS analysis and mapping.	Provincial Park) to the north-northwest. Much of the upper watershed, which supports the water supply to Maxwell Lake, is owned and under the management of the local Improvement District, North Salt Spring Waterworks District, which has been delivering water to the community since 1914.  [**Map 4:**]() To provide some examples of the mapping work being done for the Maxwell Creek Watershed Project, thumbnail maps from the area circled have been provided in Maps 5 through 17. The focus of the MCWP is in the area immediately around Maxwell Lake, a large part of which is owned and stewarded by [NSSWD]().

Key data layers

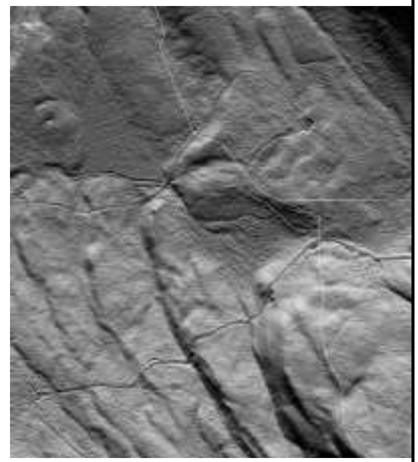
Each map in this collection was taken from the same area within the Maxwell Creek Watershed, as noted in the caption of Map 4. By featuring the same area overlaid with different spatial data layers, we are able to demonstrate how different layers can tell different stories about the same place.

[Map 5: Aerial photos (1946 on).](#)
Aerial imagery provides a historic record of land-use change over time. These images are essential to understanding baseline ecological conditions. As shown in the image above, timber harvest was once a large-scale and recurring activity within the Maxwell Creek Watershed. This explains the structural and age homogeneity within present-day forests in this area. Compare this photo with the satellite and bare earth images in Maps 6 and 7. The site of the original Maxwell Farmstead appears in the top left.

Considerations: Aerial photos may be obtained at a cost (Digital Air Photos of B.C. - Province of British Columbia (gov.bc.ca)). Images are not georeferenced, and technical skills are required to process and interpret images.

Map 6: Satellite imagery (2021). Similar to aerial imagery, but taken at a much wider geographic scale and at a higher level of detail, satellite imagery provides snapshots in time of the different features (e.g., buildings, roads, vegetation) on the Earth's surface. In the ecological context, scientists and other practitioners can identify and differentiate features at a landscape level, helping to identify potential sites for collecting information on vegetation coverage, canopy, and changes in land cover over time.

Looking between Maps 5 and 6 will highlight that natural regeneration since 1946 has closed much of the canopy in this area. Intrusion into the old farmstead by trees is visible, and a site visit showed that the remaining open area is due to a high water table in the area. The site was formerly a wet meadow.



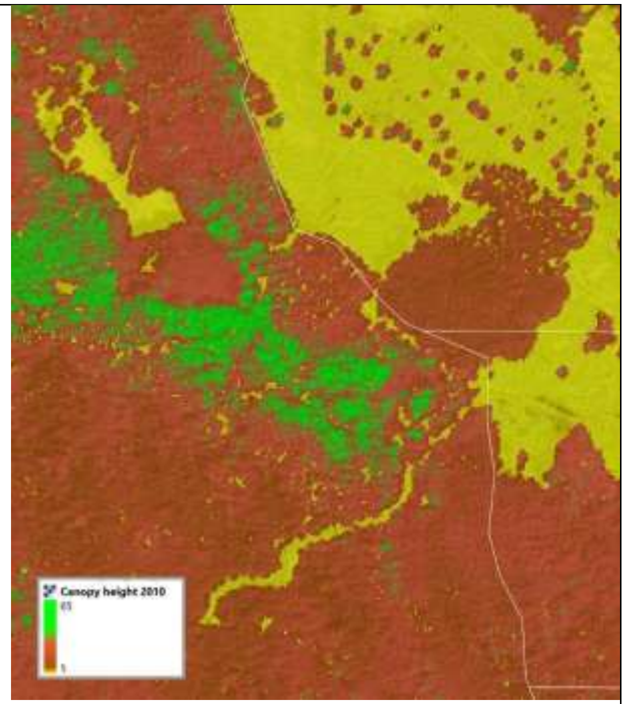
Map 7: Bare Earth LiDAR.
This LiDAR Digital Elevation Model (DEM) covers the same area seen in Maps 5 and 6. However, rather than treetops, it shows the bare earth surface and reveals, along with the geological features, human disturbance - such as old roadbeds, many of which are now trails or access routes, ditches, and agricultural drainage - and other items of interest not visible with aerial photography. In other words, it shows what is under the trees. This map shows several depressions where water is able to accumulate, including the former farm site (top left).

Considerations: Bare earth information is incredibly useful for highlighting linear features and exposing hidden features. For example, linear features in the former farm fields run perpendicular to the movement of water, serving as drainage and irrigation infrastructure. Although the farm has not operated in over 20 years, the drainage system remains, meaning without its removal, the wet meadow will be unable to recover.

[Map 8: LiDAR forest inventory](#)
Light Detection and Ranging (LiDAR) provides detailed and accurate three-dimensional characterization of vertical forest structure, including tree height, basal area, and even tree type.

As the MCWP is focused on fire and preventing the movement of fire into the canopy (i.e., reducing potential catastrophic canopy fire), the high density of trees and absence of natural gaps and structural complexity using LiDAR informs fire hazard and risk assessment.

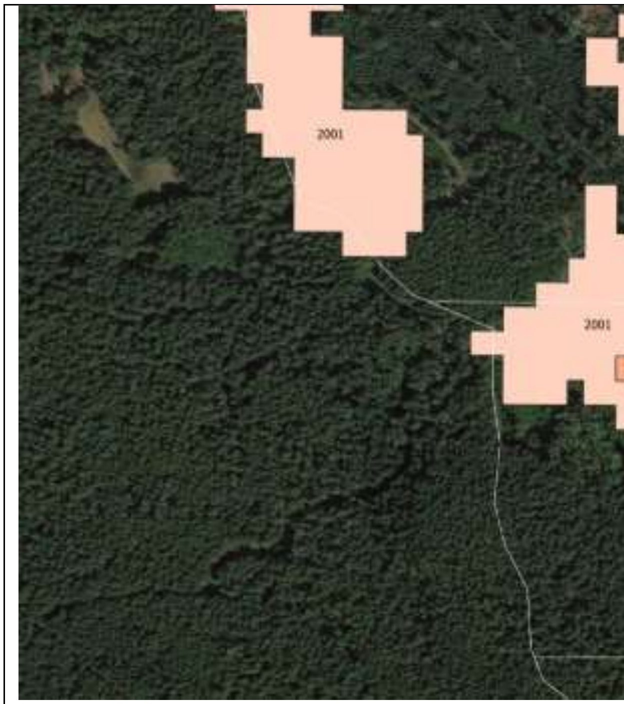
Considerations: LiDAR interpretation requires advanced GIS technical abilities.



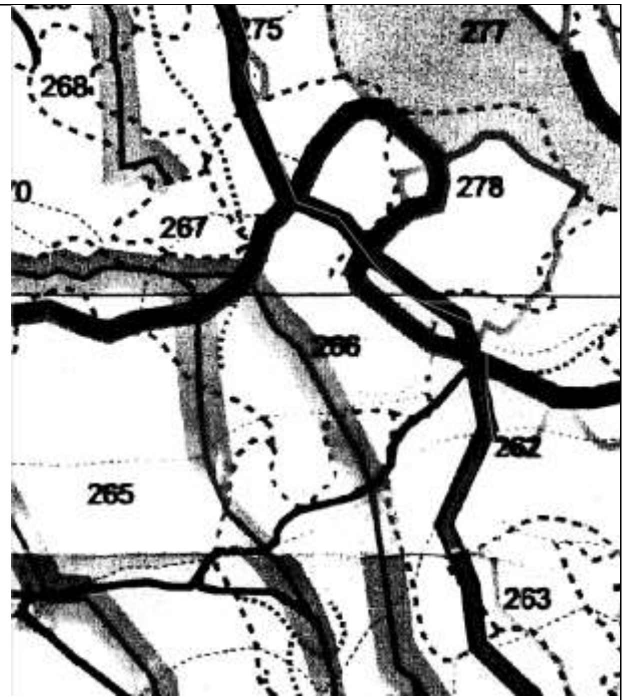
[Map 9: Canopy height 2019. Tallest trees in green.](#)
LiDAR tree height information helps to highlight specific information that may not otherwise be apparent.

In this case, the tallest trees are shown in green, and the shortest canopy (trails/low shrubs/grasses) are shown in yellow and pale brown. This information has proven extremely valuable in detecting areas of higher soil moisture, even when there are no streams or wetlands present (due to the extent of ditching, draining, etc.).

The green area of tall trees indicates areas of good growing conditions, and provides information about potential water availability across the landscape.



Map 10: Recent logging (since 2000)
Satellite data can be used over time to map out areas of harvest. Organizations like Global Forest Watch produce annual maps showing the area of forest loss (since 2020). This type of information allows tree age and regeneration to be evaluated from a 'zero' or baseline year.



Map 11: Forest planting and harvesting map (Texada, 2000)
Official planting and harvesting maps are sometimes available. In this case, detailed breakdowns of cut blocks and their delineations are provided. If the limits of blocks in this map (from December 2000) are compared to the variation in tree canopy in Map 10, the influence of these cutblocks is still visible on the landscape.

Considerations: These maps can be hard to track down and are often not available in digital format. They provide additional information about trees harvested and historic forest attributes. However, expertise is required to interpret this information.

Map 12: Vegetation Resource Inventory (VRI)

The British Columbia VRI is used to describe the location of a resource (e.g., trees to be harvested) and the amount of timber/woody material in a given unit area. VRI begins with photo interpretation to estimate vegetation features within polygons, and is followed by ground sampling to collect detailed information about tree age, basal area, tree height, volume, and composition, as well as ecological characteristics.

Considerations: Although a generalized representation of forest characteristics and forestry-derived, VRI units provide useful information about forest stands and are comparable to Terrestrial Ecosystem Mapping (TEM) or Sensitive Ecosystem Inventory (SEI) polygons.

Map 13: Historic fires

Records of historic fires, including the date and area burned, are being used to understand past fire events (the ones shown in this map are both large-scale forestry-related burns). In the Maxwell Creek Watershed, there is an absence of historic stumps and coarse woody materials on the ground due to the occurrence of large intense fires. Without these historic forest attributes, it is a challenge to understand the ecological history of the place. The historic records are helpful in filling this knowledge gap.

Map 14: Geology

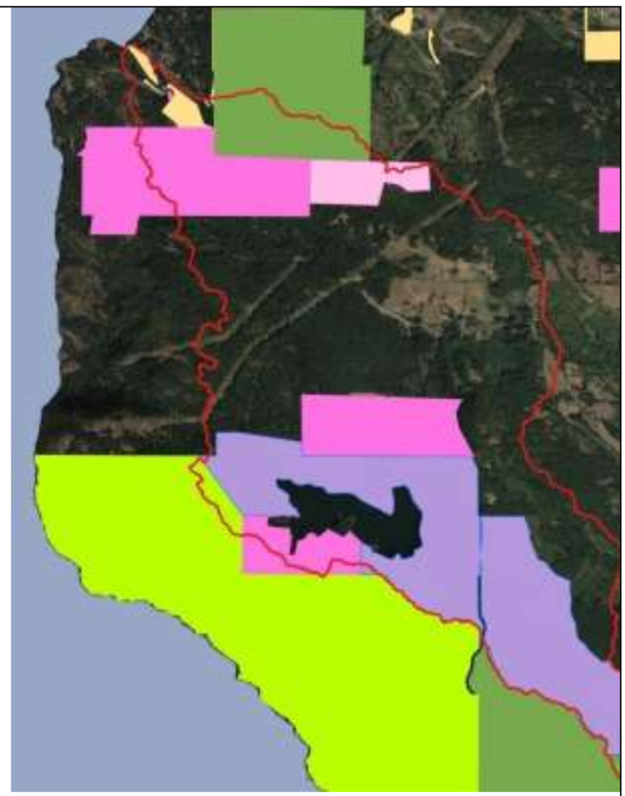
Map 15: Soils

Base rock layers - or local geological layers - can provide information about soils and the movement of water. Salt Spring and other Gulf Islands are characterised by glaciated ridges and valleys that reflect the geometries of the underlying bedrock formations. The islands are underlain by highly faulted sedimentary rocks of the Nanaimo Group. Groundwater aquifers in the bedrock are important ecologically and as a community water supply, but are poorly understood and difficult to map because they are highly partitioned (often in faults).	The Maxwell Creek watershed is characterised by ridges of erosion-resistant sandstone and conglomerate and lower valleys with eroded materials, such as shales, gravelly sand loam, and colluvial materials and a C-horizon consists of fractured bedrock. The Maxwell farmstead was placed on Suffolk soil, which is characterised as loamy sand. These features influence the movement of water across the surface and below ground, influencing the pattern of groundwater recharge and the chemical properties of creeks, wetlands and Maxwell Lake.
 **Map 16: Contours** Contour lines show elevation over sea level. Lines that are close together indicate steep slopes, lines that are farther apart indicate gentle slopes. Contour maps are important in the context of the MCWP, influencing surface water flows, water accumulation, and vegetation and tree cover. The CDF Biogeoclimatic Zone ranges in elevation with ecosystems varying according to aspect, soils, and other biophysical conditions. The topography and ecological niches across the Maxwell Creek Watershed are diverse, ranging from just under 300 m in elevation, including valleys, wetlands, rocky ridges, and ravines. Maxwell Creek ends at the Stuart Channel just north of Erskin Point (an area of suitable Surf smelt forage and spawning habitat). **Considerations**: Contour data is readily accessible and useful for identifying features in the landscape.	 **Map 17: LiDAR-derived drainage channels** Bare Earth information is used in surface-water modelling to understand how water flows within the watershed. In this map, drainage channels (shown) were derived from surface topography to show overland flow. The Maxwell farmstead (top left) shows how water has been rerouted using linear features within the fields, and using a trench running east-west immediately south of the farm. These features accelerate water flows and exacerbate flash flooding and erosion. In fact, the trench intercepts and redirects the waters from the upper watershed away from the fields, toward the Maxwell Road - which is experiencing significant erosion and contributing to sediment and nutrient loading into the creek supplying Maxwell Lake.

It is also useful in models seeking to map surface water flows or identify catchment areas.	

Access challenges

There are two major access challenges that might arise in the context of a landscape level project like the MCWP. The first is on-the-ground property access. Maps 18 to 21 were created to illustrate administrative details relating to land ownership and management within the Maxwell Creek watershed. As the maps show, an overlapping matrix of ownership, ecological protections, zoning, and development permissions can be challenging to navigate. In the context of the MCWP, it has meant that multiple collaborative partnerships had to be established prior to beginning an on-the-ground work. These partnerships will need to be maintained throughout the project's lifetime via regular communications and permitting processes.

 **Map 18: Cadastral (i.e., property) information.** Cadastral data layers are essential to this project as they denote land ownership and, thus, what land-use activities may or may not be permitted. It also helps guide connections with landowners to inform them about the project. Maxwell Creek Watershed is outlined in red, and Maxwell Lake is highlighted in blue. Property lines and detail shown in white.	 **Map 19: Protected areas.** In addition to a large proportion of the land within the Maxwell Creek watershed (outlined in red) being under private ownership, as shown in Map 18, there is a blend of different ecological protections in place. The legend below provides more information on the different levels of protection present within the watershed. ● Purple: Watershed Protection land

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Land managed by North Salt Spring Waterworks and protected under that management regime. Not protected by any associated regulation or legislation (such as a conservation covenant).

Dark green: Provincial park

Protected area managed by BC Parks. Though provincial parks have been set aside in an effort to preserve natural environments, recreation is typically prioritised over maintaining ecological integrity.

Light green: Ecological reserve

Crown lands preserved for ecological purposes. Almost all extractive and disruptive activities are prohibited within ecological reserves, making this one of the highest levels of protection available in BC.

Yellow: Community parks

Generally designated and managed by a local/regional commission for recreational purposes. Most community parks on Salt Spring are managed by the Salt Spring Island Parks and Recreation Commission (PARC).

Light and dark pink: Conservation land

Land protected by a conservation covenant. These lands are either owned by a local land trust or owned privately, but permissible activities are dictated by a protective covenant registered to a property’s title. A conservation covenant is typically managed by one or two local land trusts who engage in regular monitoring.

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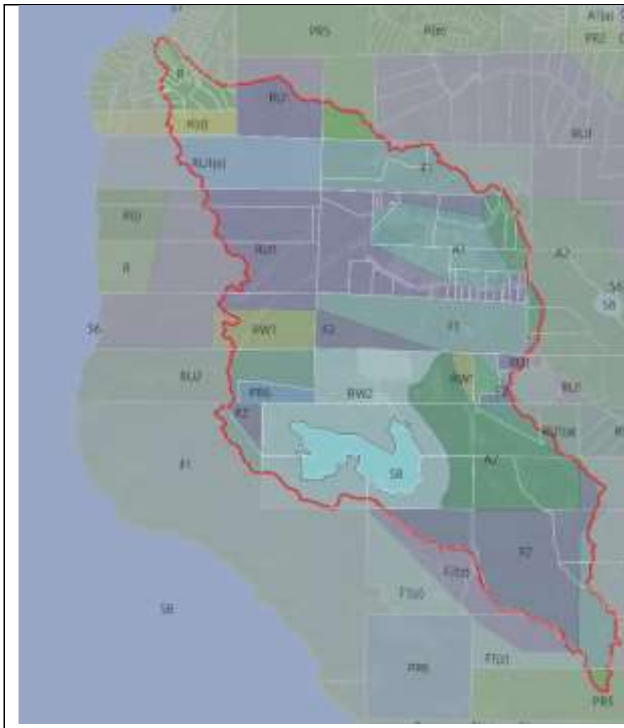


Map 20: Zoning

Zoning is a land planning tool typically available to local governance structures, including municipalities and, in the case of the MCWP study area, the Islands Trust. Zoning bylaws regulate how land is allowed to be used. In the case of the Maxwell Creek Watershed, there is a blend of zoning types (all labels typed in black text):

A: Agricultural
F: Forestry
PR: Parks & Reserves
R: Rural
R1-12: Residential
RU: Rural Uplands
RW: Rural Watershed
S: Shoreline

This information is important to delineate areas to be included in the study. It can also help to improve understanding of historical land use and determine whether proposed restoration activities will be permitted.

Map 21: Development permit areas (DPAs)

Local governing bodies can employ the use of a DPA to specify that certain locations require special treatment when under development consideration. That is, special requirements and guidelines are in effect for any development or alteration of the land within the specified area. This can include the protection of ecologically sensitive areas, avoiding certain hazards (e.g., steep slopes), and maintaining specific form or character, among many other things. Ultimately, locations falling under a DPA require specific permissions prior to undertaking any activity and thus can limit the types of activities that may be allowed.

The MCWP area falls under two DPAs as outlined by the Salt Spring Island Official Community Plan. The first is DPA 4 *Lakes, Streams, and Wetlands,* which is identified in blue on Map 21. This DPA is intended to protect 10 metres horizontally from the natural boundary of streams, 300 m horizontally from the natural boundary of Maxwell Lake, and within 61 m of other lakes. The second is DPA 7 *Riparian Areas*, identified in light green on Map 21.

The other major accessibility issue for a project like this is typically data access. Because of the multi-jurisdictional landscape, with a variety of historical land-uses ranging from industrial (e.g., forestry) to protective (e.g., ecological reserves), there are multiple datasets available with different owners. Luckily, many of these datasets have been compiled and made publicly available to anyone with an interest in seeking them out. Some of the datasets used to create the maps in question were accessed through the following websites:

- https://islandstrust.bc.ca/mapping-resources/mapping/salt-spring/
- https://www.crd.bc.ca/about/data/geospatial-data
- https://www.cdfcp.ca/cdf-data-links/
- https://gis.ubc.ca/data-sources/canada/

Multiple practitioners working under the umbrella of the Maxwell Creek Watershed Project (MCWP or “the Project”) have contributed to each instalment of the *Field Files* series. All maps were made by Nicholas Courtier, who also assisted with map captions. Ruth Waldick from Transition Salt Spring and Shauna Doll from Raincoast Conservation Foundation contributed to building a narrative around these maps.

Chapter 4. Managing fire in a climatically uncertain future

Since settler arrival in the Coastal Douglas-fir (CDF) zone, forests have been extensively harvested. The consequence of this widespread, industrial-scale logging is predominantly second-growth forests that are not only lacking in biodiversity and natural complexity, but also at a higher risk of burning in catastrophic fires. This is of particular concern to Gulf Islanders, most of whom live in the forest/rural interface.

The aim of the Maxwell Creek Watershed Project (MCWP) is to design and test nature-based solutions that reduce the risk of fire and other climatically induced disasters (e.g., flooding, severe windthrow events) n the CDF while also increasing ecological integrity and climate resilience. The Maxwell Creek watershed (“the watershed”) was chosen as the site for this project due to its classic post-harvest structure: approximately 50-60 years into its recovery, densely spaced, and evenly aged. It serves as an accurate representation of CDF forests across the Gulf Islands, and thus will provide an easily replicable template for other restoration practitioners in the region. By no means is this the only stand type found on the Gulf Islands, but it does occur very frequently.


Dense, even-aged forest within the Maxwell Creek watershed. Photo taken by Pierre Mineau.

Fire is a natural process in the Coastal Douglas-fir forests within the Pacific Northwest, occurring as large fires every 100-300 years (Winberley 2002; Dellasala et al., 2004; Franklin & Johson 2012; Hessburg et al. 2015; Littell et al. 2009; Ren et al. 2022). In drier areas, small, low, and mixed-severity fires occurred more frequently, with intervals of 5-35 years (Gedalof et al., 2005). Climate change is expected to increase the severity and frequency of such events, with drought being one of the greatest factors driving extreme fire risk in this region.

Fire intensity, temperatures, and extreme heat events like the one experienced in the Salish Sea in June 2021, have increased in the past 100 years; this is reflected in a growing number of papers reporting on changes in fire behaviour (Gedalof et al. 2005; Littell 2009, 2018; Larson & Churchill, 2012; Holofsky et al. 2018; Coop et al., 2020; Johnston et al., 2020; Loehman et al. 2020; Hagmann et al., 2021). Past silvicultural areas are especially vulnerable due to over 100 years of clearcut logging, ditching, and road construction (see Hessburg et al. 2015), all of which have changed local hydrology and replaced native fire-resistant trees like alder, big leaf maple, bitter cherry with more fire prone species like White pine. Large scale fires have not occurred in most forested areas due to fire suppression. In the Maxwell Lake watershed on Salt Spring Island, the last large fire occurred in 1942 (Figure 3).

The combined effects of more extreme weather (windstorms, heat events, drought) and the self-thinning of large mono-age forest stands create the fire hazard conditions in the Gulf Island Communities. However, as nearly all ignition is from human activities through much of this region, restoration activities can be targeted to those areas of interface where the ignition risks are greatest. Education of community members will also be key, as much of the land area is under private title. As such, a focus on recovering key resilience characteristics will require action by all community members.

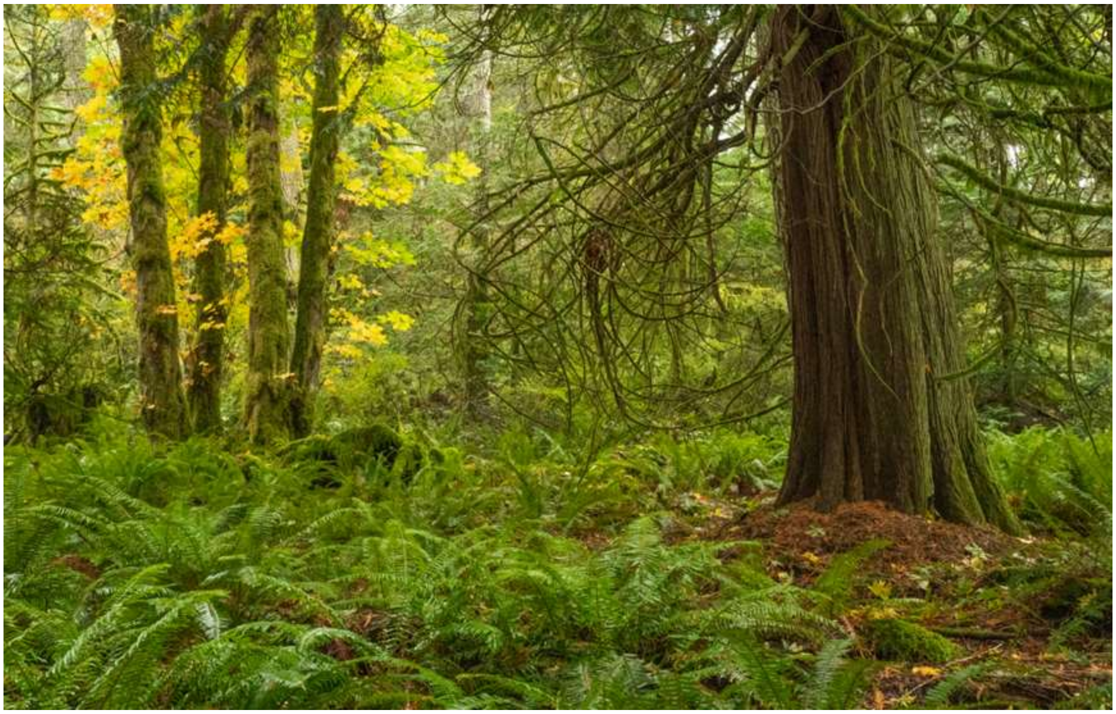
Assessing fire risk: A practice in ecological restoration

Assessing fire risk and understanding how fire might impact the landscape is not just about fire, it requires consideration of all ecological elements that together form the ecosystem. To increase fire resistance, a higher level of biodiversity and ecological integrity must be established and maintained. Some of the forests in the watershed have gone through a self-thinning process which has resulted in large amounts of small woody debris accumulating on the forest floor in some places. Other areas have very high crown closure. Neither scenario is representative of a healthy forest. As an initial treatment, the MCWP team will focus on the latter and moderately reduce canopy closure by thinning out dense stands. This will be a first step toward establishing the “clump-and-gap” structure typical in mature and old-growth forests, where there is enough light, nutrient, and water availability to enhance understorey growth and establish a more heterogeneous forest structure. In other words, this will facilitate a more balanced mix of age and size classes in contrast to the dense stands of uniform size, age, and species currently characteristic of the watershed.

A forest stand post thinning treatment. Photo taken by Tal Engel.

As is the case of all things in nature, this process will take time. Attempting to achieve this vision all at once would mean taking out too many trees, leaving those that remain standing at significant risk from wind throw. The initial treatment of thinning a few trees is just the first step in a longer-term density reduction process that will allow the forest time to grow and become more wind firm prior to the next thinning treatment.

Some thinning was done in the watershed about 20 years ago with timber harvest rather than the ecological recovery in mind. As such, it did not result in significant understorey regeneration, but it *did* provide the opportunity for a second age cohort of trees to establish. This demonstrates that just thinning trees is not enough to facilitate ecosystem recovery. Typically, ecological recovery takes significant time, in the order of hundreds of years. In the case of the Maxwell Creek watershed, it will take significant work to accelerate the process. Work in forest stands with a logging history, like those found in the Maxwell Creek watershed, is always very complex. In many ways, logging sets forests on a different ecological trajectory. To facilitate their recovery means trying to bring them back to a trajectory resembling the one they would have been on if they had never been harvested in the first place.


A mature forest, demonstrative of the natural clump-and-gap structure described by Robert Seaton. Photo taken by Pierre Mineau.

Reintroducing species with low flammability indices: In addition to thinning, a future step may be a widespread understorey replanting effort to reintroduce species diversity to the forest floor, which has largely been eliminated due to lack of light and high competition caused by the current level of tree density. Many understorey plants native to the CDF region are fire adapted, they tend to have water-like sap and moist leaves with low flammability index values. This does not necessarily mean that these plants will not be damaged or even killed by fire, but rather that they will not readily ignite and do not contribute to a fire's intensity. According to an interview with Amy Jo Detweiler, a horticulturist with Oregon State University, these plants can essentially "create a living wall that reduces and blocks intense heat." Restoring the biodiversity of plants would not only enhance habitat values and ecological integrity, but also increase fire resilience.

A list of fire-resistant shrubs native to the CDF zone can be accessed here: FIRE RESISTANT NATIVE PLANTS FOR THE GULF ISLANDS & SOUTH-EASTERN VANCOUVER ISLAND – Transition Salt Spring Society. Also see Appendix.

However, re-establishing the complexity of a mature forest is not only a long but also an expensive process. The level of restoration treatment possible will be dependent on the amount of funding available. Thus to start, replanting in the watershed will occur on a smaller scale with a few trial sites. A few exclusion zones will also be established to measure the impact of deer browse on the regeneration of the understorey post-treatment. The hyperabundant deer population present on Salt Spring - as on most Southern Gulf Islands - has clearly been impactful to the understorey in the project area and beyond, though Robert suspects that the dense forest structure may be more influential to the state of the understorey.

Going forward, significant ongoing monitoring will be needed to determine the efficacy of treatments. If outcomes from this first phase are positive, it is likely that further funding will be secured and additional phases will be possible. Future treatments would include increased reduction of canopy closure and additional planting to push the forest closer to that clump-and-gap structure.

Personalizing the template

In the early 2000’s, Ken Millard, a decades-long volunteer with the Galiano Conservancy Association (GCA), developed a pulley system to simulate windthrow in Douglas-fir plantation forests. The idea was to thin dense stands using non-intrusive methods (i.e., no roads, vehicles, or power tools needed). Downed trees were then either left to decompose in place or redistributed where needed in the forest to enrich soils and create habitat. This is just one example of methods used in this region to restore forests that have been heavily impacted by human activity.

Despite one of the anticipated outcomes of the MCWP being the production of a replicable template, every project will be slightly different. For example, though the MCWP builds on some of the lessons learned from projects like the GCA’s, the Project’s restrictive budget and limited timeline mean that the repeated installation of the handheld pulley system throughout the entire watershed may not be a feasible method of tree removal. Further, the Project’s strong fire focus means much consideration must be given to the distribution of coarse woody debris on the forest floor. Though such debris *does* introduce nutrients to the landscape, it can also create a short-term burst of fine fuels. To manage fire risk, removing some woody debris will be necessary. As such, in planning treatments, it will be essential to identify sites where felled trees can be left behind and where they cannot.

Many of these decisions will have to be made *in situ* based on observed conditions at the time of treatment. Though the Project team has done extensive spatial analysis (see Appendix) and ground truthing, the decision about where to leave coarse woody debris is dependent on the current condition of the understorey. Generally, coarse woody debris is not very flammable; it is like trying to light a log with a match-it does not burn well. However, if there are concentrated piles of fine fuels nearby, heat can be trapped and smolder, in which case the large woody debris can feed the flames, causing a much larger problem.

Treatment Case Study: Managing fine fuels in-situ

The MCWP team is preparing field trials and testing methods for managing fine fuels using 'berm-like' constructions which serve the additional role of providing wildlife habitat and structural complexity that is currently lacking. The goal is to develop in-situ methods that can be readily used, where needed, to increase soil moisture, soil organic content, and reduce nutrient leaching while also increasing fire resilience (see Chapter 5).

If coarse woody debris removal is deemed necessary, it is likely that additional community support will be needed. Removing wood from the site using vehicles or heavy machinery would result in soil compaction and/or significant damage to the understorey. However, to remove it by hand would be incredibly labour intensive and beyond the capacity of the small project team. Inviting a community of volunteers to help could be the solution to this problem. While it would not be economically viable to produce and sell firewood to support this project, if a group of individuals was willing to help, they could keep the wood for their own use or resell it as part of a fundraiser or something similar.

Challenges in translating the project to practice

The high private ‘ownership’ of land on Salt Spring and other Gulf Islands presents many challenges for both protecting communities from fire and forest stewardship. The Project was made possible by public funding, allowing Transition Salt Spring to assemble a community of practice from across the Gulf Islands (and beyond) to combine their expertise to improve understanding of the historic and current ecological conditions within the watershed. It required the buy-in of NSSWD and a community of additional land managers and owners.

All of this effort was necessary to do the predictive and local scale fire risk work in this one area of the island. Once the project funding ends, the community will again be in a situation with minimal resources to actually implement treatments, monitor their impacts, and share learnings with other communities. According to Fire Ecologist Dr. Kira Hoffman, these sorts of individual attempts to control fire risk are largely ineffective in her experience in the interior forests of B.C. They must be undertaken on a wider scale.

Ultimately, the MCWP is a small trial, a demonstration. It is an important project and very much needed, but to start thinking about forests in a way that maximizes biodiversity, a much larger effort is needed with a lot more financial support. On the Gulf Islands, a majority of the land (>80%) is privately owned. Some of these landowners might be interested and willing to apply treatments on their own properties. This sort of community buy-in will also be necessary to ensure the efficacy of this work.

Project outcomes

There are two expected outcomes from this project: the tangible (i.e., on-the-ground methods) and the intangible (i.e., changing thinking about ecological management and fire risk, particularly in the industrial sector).

What we are implementing within the Maxwell Creek watershed, which, as noted above, is an ecosystem similar to many seen across the Gulf Islands, will reduce fire risk and accelerate a more ecologically diverse structure. This sort of management regime is something land managers working at all scales need to be thinking about, particularly as the impacts of climate change become more evident on the landscape. While this is true for restoration projects, like the MCWP, it must also apply to commercial endeavors. In Washington State, thinning treatments are being undertaken with the additional goal of removing viable timber. Though this is a more ecologically viable way of pursuing timber harvest than has been done historically, the machinery used has an impact, and there is still not enough attention paid to restoring ecosystem functions. So some goals are met, but some are not.

We need to be clear about our goals - not just in the CDF but everywhere that forestry exists as an industry. This problem exists all over BC. Government and industry have long claimed that the forestry sector manages for multiple values, but basic management methods and rules on the ground are very much oriented towards timber production. Ecological functionality has not been incorporated into management decisions to the degree it needs to be. We need to answer the question: How does timber production continue while also maintaining stand structure, ecological functionality, wildlife habitat, and cultural forest use? Implementing more restorative practices in the commercial sector would dramatically expand opportunities for enhancing ecological integrity and reducing vulnerabilities to climate change, particularly because projects in this sector tend to have larger operating budgets than those being pursued by charitable or not-for-profit organizations.

One way to understand this is thinking of the MCWP as an “after-the-fact” attempt at restoring a heavily altered landscape. However, in the future, we need to employ “before-the-fact” approaches, managing landscapes and industries in such a way as to avoid causing problems we are seeing now, like increased fire risk, flooding, and biodiversity loss.

> Are you a restoration practitioner, forester, woodlot owner, or other professional working in the CDF zone and interested in better understanding fire risk in the region?
>
> Watch the virtual workshop *Fire Risk Reduction in the Coastal Douglas-fir Biogeoclimatic Zone*, organized by Transition Salt Spring -TSS Mount Maxwell Fire Risk Rfeduction Webinar.

Chapter 5. Approach to Restoration

This project is designed to increase fire resilience and health in forests by helping move the trees toward a mature state with thickened fire-resistant bark and more complex forest structure (Franklin & Johson, 2012; Hessburg et al., 2015; Creutzburg et al., 2017; Halofsky et al., 2020); to increase the native understorey by reducing local competition for light and moisture in carefully selected areas (Franklin et al., 2002; Downing et al., 2019); and to establish a more gradual and sustained input of these coarse wood inputs to the forest floor for wildlife habitat (Lonsdale et al., 2008; Kuehene et al., 2015; Chamberlain et al. 2021)[1].

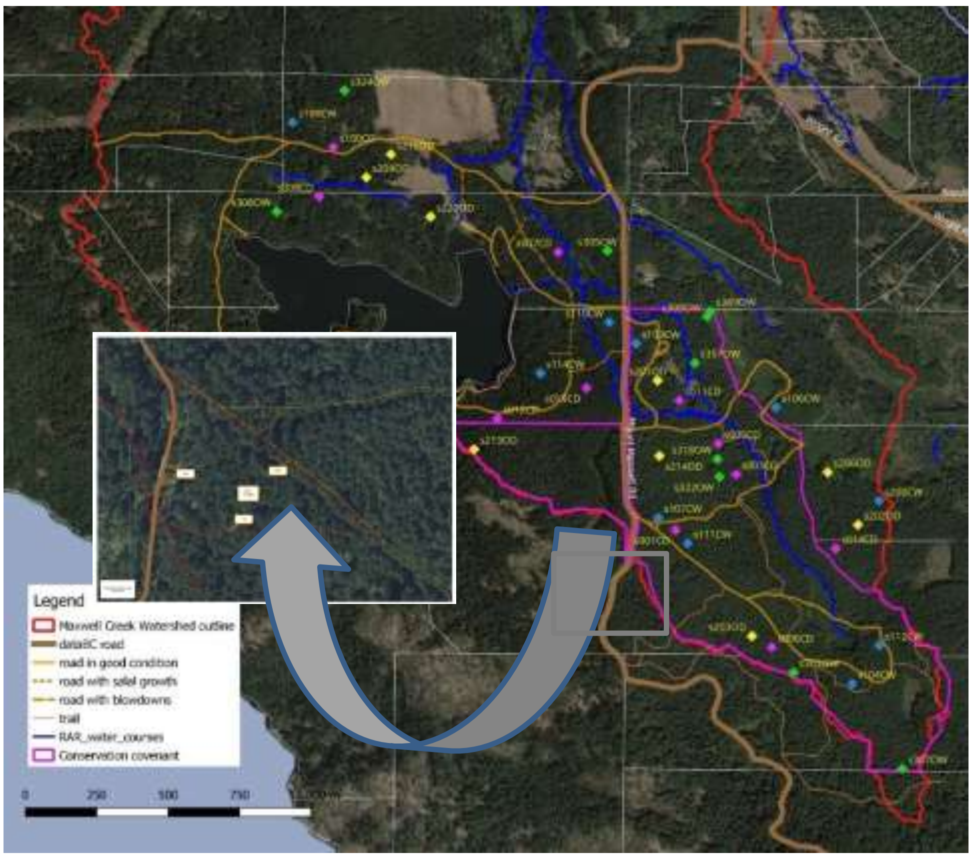


Figure 4: Map showing the focal portion of Maxwell Creek Watershed for this project. The covenanted area to which this document refers is shown outlined in pink. Long-term monitoring plots are indicated by coloured diamonds (representing a range of site conditions). Creeks are in blue. The inset shows a detailed view of the proposed treatment area (note the dense closure of the canopy).

The covenanted area within the Maxwell Creek Watershed is a disturbed forest stand predominated by trees between 60 and 80 years of age. The past emphasis on fire

[1] Brinkman Earth Systems has been applying these techniques in forests across British Columbia for over 30 years.

suppression, wood production, and livestock/agriculture removed large and old trees of fire-tolerant species in favour of high-volume species. This has changed successional and ecological pathways and these less complex systems are more prone to fire in the absence of active management (Franklin et al., 2002; Dellasala et al., 2004; Hessburg et al. 2015; Halofsky et al. 2020). Our goal is not to eliminate fire risk completely, but to restore tree clump and gap patterns, tree sizes (living and dead), and shrub and herb (or forb) compositions which will serve to reduce the extent and severity of fire in the landscape. This will also increase available habitat, particularly snags and coarse woody material, which typically becomes limited in mono-age stands after a period of high inputs during the thinning phase (Kuehene et al. 2015; Stanturf et al. 2014; Stanturf 2021). This is important at local scales for a variety of rare and threatened habitats and species, and part of this work will include planning for sustained inputs of coarse wood, snags, and other wildlife habitat features (Lonsdale et al., 2008; Larson & Churchill 2012; Hessburg et al. 2015; Stanturf et al. 2014).

There are two aspects to the proposed restoration work: i., monitoring and long-term study of the interplay between moisture, light, seed bank, and herbivory on species composition and structure at 40 reference plots, 21 of which are within the covenant area (Figure 4); ii. Trial thinning of an area of forest with high potential for canopy fire in a forest stand proximal to the main road within the covenant area with pre-and post-treatment measurement of change (Figure 4). The proposed activities described below include the rationale and any potential implications of the activities.

> **NOTE:** This project is a pilot application and proof-of-concept application of restorative techniques that include documentation, data collection, and evaluation for further strategy development.[2]

[2] Although the time frame of this proposed work is defined to 2024, aligning with current funding, the project team is committed to continue this work with North Salt Spring Waterworks, the Salt Spring Island Conservancy to develop resilience in this watershed. At the time of writing – August 13, 2022 – new partnerships are emerging for continued work (Capital Regional District, Local Islands Trust, SS Fire Rescue Services, Coastal Douglas-fir Conservation Partnership), with potential additional funding from CRD, SSFR and LTC.

Table 1: Summary of activities associated with proposed restoration work in MXCK watershed.

Activity	Outcome	Considerations	Timing (2022)	Timing (2023/4)	Monitoring activities (see Appendix)
1. Establish reference sites	Long-term monitoring plots (21 - 5.64 m radius plots) with an additional 10 Treatment plots (will be set up in stand proposed for thinning, 3., below).	Observational only, but will require placing location markers at the centre of the plot and two reference points. Monitoring protocols adapted from: Marshall et al., 2000; Woodward et al., 2009; FLNRO 2018	June/ July August	June/ July	• Vascular plant/shrub monitoring • Fine and Coarse woody material survey • Tree diameter measurements • Soil profile[3] (Martin-Guey et al. 2022) • Soil moisture (10 plots)[4] • Wood decomposition measures (10 plots) • Tree age (N=20 cores)
2. Fire hazard mapping/site selection	Identify potential thinning treatment and location for experimental plots	Combination of LiDAR and ground validation, historic information on site. Section 2 this document.	N/A	N/A	No impact, ground truthing only using established trails.
3. Thinning treatment (2 acres affected)	Cutting of trees and enhancement of woody materials	Trees selected for thinning will be marked and managed to reduce damage to the forest floor.[5] See prescription for further details.	Oct 24-Nov 30	N/A	• Monitoring of soils, tree Diameter-breast-height, CWD, understorey plant surveys (as per 1. Reference site, above)

[3] Soil profiles will vary in depth according to soil and site properties. Soil pits will be dug once only as part of this project (five cores per plot, 0-20 cm deep and 15 cm across. Pits will be refilled after characterization, and a limited number (total 10) will be subsampled for texture and carbon analysis).
[4] Soil moisture probes are taken in the root-zone, in-situ and will be taken at all monitoring and treatment plots (4.5" or 8" probes). A limited use of soil moisture data loggers will be employed in the ten treatment sites for continuous moisture recordings, these will be managed and placed by Dr. Tara Martin, SSI Conservancy Director.
[5] Trees selected for thinning will capture spatial heterogeneity of canopy layers and successional patch dynamics (see section below). Tree felling and placement details are provided in the Appendix.

4.Restoration of native vegetation (seeds and small shrubs)	Experimental treatments (identify the role soil moisture, light, herbivory, $ seed stocks on understorey complexity & plant composition).	1. Seedbank treatment (native seed introduced) 2. Light treatment (pre- /post- tree thinning 3., above) 3. Browse treatment – planting of 5-10 Oregon grape per plot.	Nov 15 – Dec 15	June/ July	As described in restoration treatments, above[6]: -annual plant monitoring; canopy light; browse index; woody decomposition rates. Monitoring annually to end of project and beyond.
5. Sustainability of project over time.	Ongoing monitoring, surveying and maintenance of treatment and reference plots. Data analysis, publication of reports and management and upkeep of data.	1. TSS's Ecological Research Network group is overseeing all work, volunteer engagement and ensuring ongoing monitoring and maintenance/reporting beyond the funding period. 2. TSS is actively working on additional grant funding to continue the work and has a dedicated suite of volunteers and an emerging partnership with the Restoration Ecology program at UVic to continue monitoring and field activities persist through and beyond 2024. 3. TSS has three active project expansions being discussed with Water Preservation Society, SS Fire Rescue, CRD/Diamond Head Consulting, Coastal Douglas-fir Conservation Partnership, Local Island Trust Planners.	Nov 15 – Dec 31	2024 and beyond	Monitoring activities will continue, as above. Water Preservation Society and TSS are committed to tracking long-term outcomes and maintaining the data and reporting from this project beyond the 2024 funding end date. WPS is a covenant holder and property holder around Maxwell Lake. A plan for a long-term monitoring program will be developed in consultation with NSSWD as part of this project work.

[6] Flora of the Mount Maxwel Reserve (flora.pdf (bcparks.ca) 1974.

Experimental forest restoration methodologies.

Over a century of aggressive logging practices, fire suppression, and a myriad of additional disturbances have resulted in a major loss of ecological functionality in our regional forests. Mechanized logging, in conjunction with slash burning practices (or out-of-control wildfires, where too much slash remained) and salvage logging, have resulted in the loss of centuries of carbon bank in the form of roots, tree biomass, including Coarse Woody Material (CWM (sometimes also referred to as Coarse Woody Debris (CWD). Combined with high fuel loads, lacking structural complexity, poor hydrological regulation, and severe overdensity, many forests would be more aptly described as *tree farms* or *tree plantations* due to their profound ecological deficits.

If the effects of climate change were less immediate and the current state of forests less degraded, the natural decomposition of wood might be enough to neutralize the threat of excessive fuel loads. Unfortunately, this is not the case.

The difference between conventional and ecological forestry

What differentiates ecological forestry from traditional production forestry is a rejection of the notion that humans can do better than Nature. Conventional forestry seems to operate on the idea that Nature is somehow flawed and that we can fix it and make it better, or more productive. Conversely, ecological management practices are based on research into natural disturbance and succession regimes in unmanaged forest ecosystems. With the exception of the scant remnants of old-growth forests in BC, most forests have been logged at least once, often twice, and even three times in some cases, over the past 150 years. Even for ecosystems that naturally experience frequent disturbance (e.g., dry interior frequent-fire forests), humans have imposed an overly intensive disturbance regime. Thus, the key to uncovering Nature-informed forest restoration regimes lies in post-disturbance ecology.

Transforming ecologically barren tree farms into forests

Ecological thinning treatments, such as Variable Density Thinning (VDT), are primary means of restoring a degree of resilience and ecological integrity to forest ecosystems. Such treatments involve thinning dense forest stands, selling off a proportion of marketable logs to offset the costs of restoration, and what is left from the thinning treatment is burnt in large slash piles. Often, when possible, a controlled burn will be prescribed to further reduce fuel loads and enhance the forest’s fire-resilience and structural complexity (especially in terms of ladder and fine fuel reduction). This approach reestablishes structural complexity while reducing fire risk and creating ashes which reinvigorate soils and encourage regeneration. In many ways, this approach effectively replicates natural disturbance and succession regimes. However, a major shortcoming is the removal of the majority of slowly-composing CWM structures from the forest ecosystem.

Ladder fuel: Mostly made up of low hanging, dry, dead branches, ladder fuels provide the opportunity for ground fires to climb upward, into the canopy, where both their intensity and their potential to spread uncontrollably drastically increases. High concentrations of small-diameter trees, both living and dead, are another typical upward vector for ground fires.

CWM increases forest moisture retention potential and fire-resilience, provides habitat for countless organisms, and generates organic inputs that dramatically improve forest soil health and nutrient availability. Unlike clearcuts, natural disturbances, even extreme and rare wildfires, leave behind biological abundance which supports regeneration. However, the replacement of slowly decomposing CWM with ash means the long-term legacy of CWM is lost. Though ash can be an important soil input, its contributions are comparatively short-lived. Ash, being highly dissolvable, does not stick around when there is not enough CWM and organic-matter soil content to absorb it. In their commonly degraded condition, it is likely that much of the nutrient and mineral content of ash would be lost from forests and potentially pollute water sources in the process.

Another shortcoming of burning slash piles and CWM is the release of large amounts of carbon which would otherwise be stored in the soil or only very gradually released. Finally, the production of high levels of smoke and potentially harmful airborne particulates can exacerbate the already significant challenge of persuading the public, especially those living in wildland interface communities, as well as regulatory bodies, to accept prescribed burnings, which in some ecosystems are necessary.

In-situ experiments

As noted throughout the *Field Files* series, the forests of the MCW are representative of the dense and even-aged second and third-growth Coastal Douglas-fir forests found throughout the Gulf Islands. These forests are remnants of intensive logging and ecologically bereft management practices. The MCW project seeks to moderately reduce canopy closure by thinning out dense stands and by doing so, reintroduce biodiversity and ecological integrity to the landscape while reducing fire risk. However, this work presents a new problem: managing increased fuel loads (i.e., CWM) resulting from thinning work. Tal’s work aims to provide solutions to this problem.

Two techniques, Assembled Nurse Logs (ASNLs) and Mycelial Grafting, will be tested with the intention of providing demonstrations of ecologically-oriented options for managing fuel loads in-situ. Test sites will be established in the field by Tal under Dr. Waldick’s leadership with the assistance of Grace Fields, a Sustainable Resource Management student who works with TSS. Sites will be established in early March 2023, shortly following the first thinning treatment.

A treated (i.e., thinned) forest stand that was once overdense and fire-prone. Five ASNLs can be seen in this area, which also contains several obscured Mycelial Grafts and intentional snags. Photo taken by Tal Engel.

A canopy shot of the area captured in the previous photo exhibiting a significantly reduced canopy closure and overall density resulting from the thinning treatment, as demonstrated by the amount of visible sky. Photo taken by Tal Engel.

The Assembled Nurse Log technique and Mycelial Graft procedure were developed as an alternative to the shortcomings of commonly practiced approaches such as VDT. They are informed by a restoration philosophy founded on two core tenets: 1) Imitate nature as closely as possible and 2) Transform the forest's problems into solutions. The conditions that qualify so many of BC's forests as tree farms can be used as building blocks to transform ecological deficiencies into ecological abundance. That is, those materials constituting an over-dense forest structure can become the growth engine behind the forest's ecological rebirth.

Methods explained

Put simply, the primary goal of the proposed techniques is to safely, effectively, and, most importantly, ecologically manage potentially hazardous fuels. This is achieved by creating conditions that exert maximal mycelial decomposition pressure upon post-thinning fuels. Considering the risks of wildfire, it is easy to understand the motivation to aggressively thin and burn all excessive forest "fuel." Yet, there is so much potential in natural fungal decomposition to minimize fire threats in a manner that safeguards carbon stores and ecological processes. As any organic farmer knows from their experience with practices like composting, mulching, and cover-cropping, there are countless simple ways to augment and hasten natural decomposition processes. This forest restoration regime is a marriage between ecological forestry and organic agriculture principles.

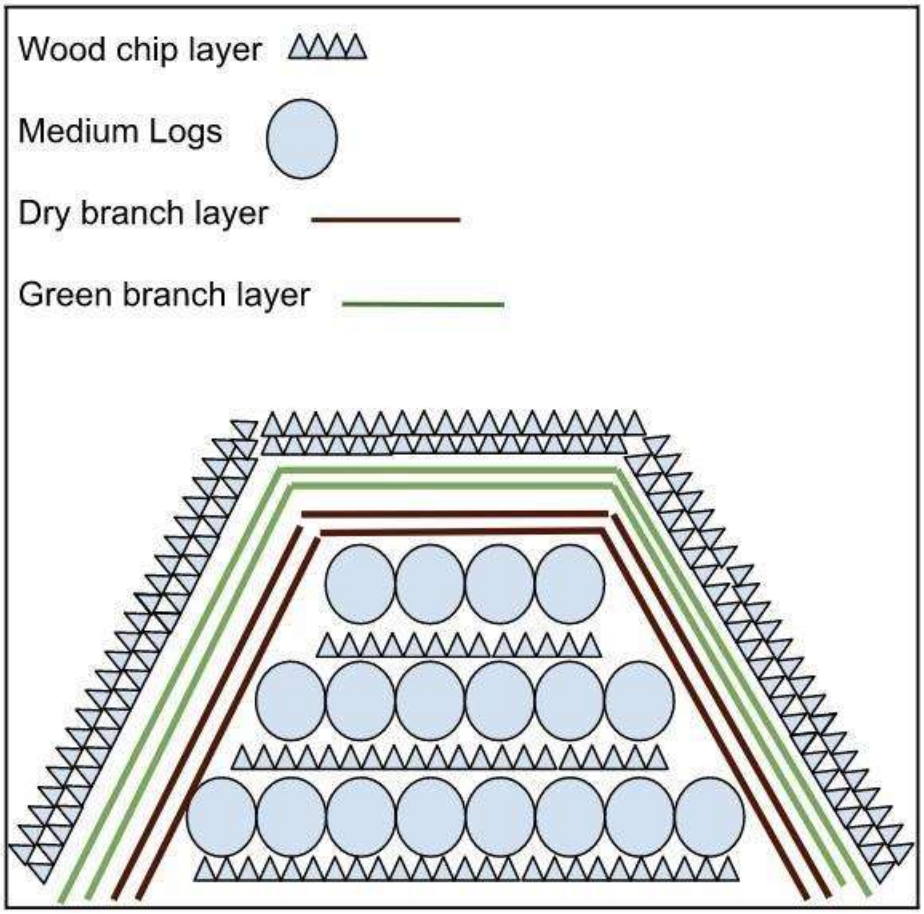
Example of the Mycelial Graft procedure. Photo taken by Tal Engel.

Example of the Assembled Nurse Log technique overseen by Raffi, the Austrailian Shepherd. Photo taken by Tal Engel.

It is essential to stress here that nothing can replace the key ecological processes decomposing old-growth trees facilitate, however, it takes hundreds of years for trees to grow, die, fall, and decompose sufficiently to perform this role. It is hypothesized that the methods described here, which will be tested by the MCW Project, have the potential to accelerate maturation toward old-growth conditions, while simultaneously providing surrogate structures until such conditions develop naturally.

Assembled Nurse Logs

The ASNL technique is inspired by both old-growth ecological structures and agricultural decomposition-augmenting methods. It is designed to replicate a segment of an old-growth diameter nurse log (generally ~70 cm+ in diameter, but this can vary depending upon stand condition) using smaller diameter wood. As previously mentioned, this structure is designed to exert maximal mycelial-decomposition pressure and minimize the structure's flammability. This is achieved by layering logs, branches, and wood chips and introducing new mycelial colonization vectors. All fuel categories (i.e., branches, small-diameter logs, and medium-diameter logs), with the exception of the large-diameter log category, are incorporated into this structure.



Assembled nurse log graphic visualisation.

To prevent an unnatural scenario in which the forest's nutrients and moisture are excessively aggregated in ASNL structure areas. To the detriment of other parts of the stand, it is important to leave a proportion of medium (10~30 cm) and large (30 cm+) logs diffused throughout the forest. These logs should be limbed and bucked to an appropriate length, which maximizes soil contact and, thus, moisture retention and decomposition. This should be practiced with moderation to prevent excessive fuel loading. A proportion of large logs will be subjected to the Mycelial Graft procedure (described below) to accelerate decomposition.

All of the materials needed to assemble an ASNL are generated in the process of thinning an overly dense stand. Ideally, they are gathered shortly after or during the thinning process. As a prime example of transforming the forest's problems into solutions, the fine fuels generated during thinning, which are the most flammable fuel category, are converted into moisture-retaining, fire retardant elements: small diameter trees (2.5~10 cm) are chipped, and branches are utilized as insulative air traps in the moisture seal that surrounds the structure. That the fine materials most liable to spark a fire become an insulative blanket that protects CWM from combustion is true alchemy.

Putting it all together

The core of the pile consists of alternating layers of medium diameter logs (4-12") and wood chips generated by a lightweight, highly maneuverable 4" chipper. Photo taken by Tal Engel.

The completed core of chips and trunks, prior to the establishment of the moisture seal which, will surround it. Photo taken by Tal Engel.

A branch layer is deposited directly atop the core, first the dry branches, followed by the green branches. This serves both as an insulator and as a high-surface matrix to which the coming chip layer can adhere. Photo taken by Tal Engel

A thick layer of chips is spread on top of the branches, completing the structure's moisture seal. Volunteer posing by the completed ASNL for scale. Photo taken by Tal Engel

Under-trenching and over-cropping are two optional steps that can further increase an ASNLs ecological significance and moisture retention. These steps are particularly relevant for steeper, drier, or more fire-prone sites.

 *Creating an under-trench below the ASNL creates a water-holding basin that further increases moisture content. This technique is especially relevant for steep watersheds, where it effectively creates a terrace that slows the water flow around the structure, thus increasing soil water penetration rates. Photo taken by Tal Engel.*	 *Native Trailing (or Pacific) Blackberry (Rubus ursinus) is an ideal cover crop candidate for an ASNL. It flourishes on elevated habitats that limit competition, grows extremely quickly, and can be easily propagated via cuttings. Its foliage increases the efficacy of the moisture seal, while the roots grow into the piles and aid in the breakdown of the material. Moss is another excellent cover-crop option. Photo taken by Tal Engel.*

Mycelial Grafting procedure

In contrast to the ASNL technique, which is designed to accelerate the decomposition of fine-medium fuels, the Mycelial Grafting procedure is designed to accelerate the decomposition of large diameter fuels. It can be argued that treating wood of this diameter is unnecessary since coarse fuels do not typically act as ignition sources. However, an overabundance of un-decomposed, dry, large-diameter fuels can certainly accelerate and exacerbate a burning fire. More importantly, since BC's forests are already critically deficient in CWM structures, particularly those that are significantly decomposed, accelerating large-diameter fuel decomposition is an important goal. This procedure simultaneously reduces the forest's fire-severity potential while expediting the reestablishment of impaired ecological functions.

Early fungal colonization (within two months of introduction) of an ungrafted woodpecker crevice. By Tal Engel.

This method is also inspired by natural forest processes. The crevices created imitate the essential primary deconstruction work that woodpeckers do, hence the name “woodpecker crevices.” Even prior to grafting, these crevices, like their natural counterparts, expose deeper layers of wood to mycelial colonization, accelerating the log’s decomposition rate and creating essential habitat for myriad organisms. However, when the crevices are Mycelially Grafted, the process is further accelerated and results in a more efficient fungal colonization of the log. To avoid creating waterlogged anaerobic conditions in the crevice, a perpendicular drainage slit is cut.

A typical Mycelial Graft consists of a mixture of old-growth inoculant (highly decayed and fungal-colonized wood from old stumps and logs) with needle-rich wood chips from recently thinned materials. The old-growth inoculant serves as a moisture-retaining medium, as well as a source of existing fungal hyphae and spores, while the fresh chips and green needles serve as fungal food and a nitrogen source to further facilitate breakdown. Each grafted crevice can be thought of as a fungal garden, in which the inoculant serves as both the soil and the seed, while the chips and needles are the fertilizers and soil amendments. The result is the ideal fungal habitat grafted directly into a log's heartwood. This means fungal decomposition pressure can be promptly exerted without first penetrating the natural defenses of bark and outer wood layers.

Mycelial Graft of old-growth inoculant mixed with fresh chips and needles. By Tal Engel.

An optional final touch in sites with an abundant moss layer is to press moss into firm contact with the mycelial grafts. This is expected to increase the log's moisture retention and decomposition rate and may provide better habitat for some critters.

Complementary alternative methods

To maximize ecological integrity within forest stands where methods like the ASNL are being implemented, Tal recommends incorporating a suite of additional commonly used methods, such as understorey restoration (or “underplanting”) and creating wildlife trees (or “snags”). These complementary methods are outlined in more detail below.

Underplanting

Biodiversity is expected to naturally increase following a thinning treatment, especially when complemented by techniques outlined here. However, some species, especially long-absent tree species with remote seed sources, may be unable to naturally find their way back to the stand. Underplanting can help to re-establish species diversity. While understorey species, like salal, Oregon-grape, huckleberry, salmonberry, and others, may be better able to naturally re-establish due to seed dispersal by animals and might not require human intervention to be reintroduced, some additional planting may be helpful. Certain underplanted species require browsing protection, such as fencing.

For the most part, second and third-growth Coastal Douglas-fir forests are composed almost exclusively of even-aged, single-canopy Douglas-firs. These forests typically lack a diverse understorey shrub layer, as well as a shade-tolerant midstory tree layer. Deciduous/broadleaf species are also usually missing from these stands. Western redcedar and coastal western hemlock have significant ecological roles to play in coastal forests. These species enrich soils with their basal leaf deposits and can be easily reintroduced due to their high shade tolerance. Grand fir requires moderate light, and a population can be established in forest openings created by thinning techniques along with native broadleaf tree species, including Pacific crab apple, bitter cherry, cascaras, maples, alders, and others. Even if these underplanted species cannot outcompete the existing Douglas-fir cohort, establishing these species in the stand is likely to create a seed bank and provide an opportunity for a population to eventually flourish as natural mortality occurs.

Intentional Snags and Microsnags

Undisturbed forest ecosystems are typically rich in both downed and standing CWM. Standing CWM, or standing dead trees (i.e., snags), provide critical habitat for cavity-nesting species. While ecological thinning treatments almost always avoid removing the largest trees, some medium-diameter trees can be girdled, rather than be downed, during the thinning process to create intentional snags. While these snags are unlikely to be ideal habitats for larger-cavity dwellers, and are less durable than larger-diameter snags, they can still provide viable habitats for some species and are a good option when working toward establishing ecological integrity in young forests.

Intentional snags are most appropriately introduced when falling a tree could be complicated or dangerous, or when caution is required due to the proximity of underrepresented tree species, valuable larger snags and stumps, or built infrastructure that might be damaged by falling trees. It is important to employ this technique in moderation to avoid accumulating an excessive fuel load.

A related restoration method is the creation of “microsnags” or tall stumps. While the creation of snags is common practice in ecoforestry, microsnags are a method developed by Tal. Shorter than snags, and taller than typical stumps, microsnags provide habitat and feeding sites for various forest dwellers (e.g., woodpeckers, insect borers, etc.) and offer an elevated spore-releasing surface through which fungal fruiting bodies can spread spores via wind more effectively than would be possible from shorter structures.

Ladder fuel limbing

Monocrop, even-sized, Douglas-fir forests younger than 60, on average, often have high volumes of low-hanging, dry ladder fuels since they have not had sufficient time to self-limb. The low humidity level in such stands (compared to old forests) limits decomposition, increasing the flammability index of ladder fuels, while delaying self-limbing timelines. Furthermore, despite typically being dead and needleless, the high density of low-hanging branches shade an already light-starved forest floor. Though ecological thinning treatments are, in essence, designed to increase light penetration, the light-depriving effect of ladder fuels is often overlooked, with fuel-management typically being the sole perceived benefit of ladder-fuel treatments.

Limbing every tree in overdense “dog hair” forests can be a daunting task and, therefore, should only take place after thinning has occurred. This significantly reduces the quantity of trees that require limbing. Under a conventional ecological treatment framework, the large accumulation of dry branches would pose a significant fire hazard if not immediately burned. However, when coupled with the novel approaches laid out here, the accumulated branch woody debris are a valuable moisture-retaining substrate when chipped or incorporated whole into the ASNL moisture-seal.

Experimental alternative methods

In addition to the methods described above, Tal has been experimenting with a number of additional techniques to reintroduce complexity to the forests under his care.

Honeycomb Matrix thinning

VDT treatments typically seek to establish structural heterogeneity by creating gaps (clearings) and skips (untouched areas), with each category constituting 10-20% of the stand’s area. The remaining 60-80% of the stand is referred to as the “matrix.” The most common approach for thinning the matrix follows production forestry methods, which are generally not ecologically oriented. The alternative Honeycomb Matrix method, currently under development, draws inspiration from the structure of honeycomb. Its intention is to introduce structural complexity not only in a stand’s skips and gaps but also in the matrix, which represents the vast majority of a stand.

The main difference between spaces created within “cells” of the honeycomb matrix and VDT gaps is their scale. While a VDT gap is large enough to prevent canopy closure by surrounding trees and will remain open until sufficient regeneration occurs, honeycomb matrix gaps are small enough to eventually (though it may take a long time) be closed by the elongating canopies of surrounding trees.

The Honeycomb Matrix method explained *(all diagrams by Tal Engel)*

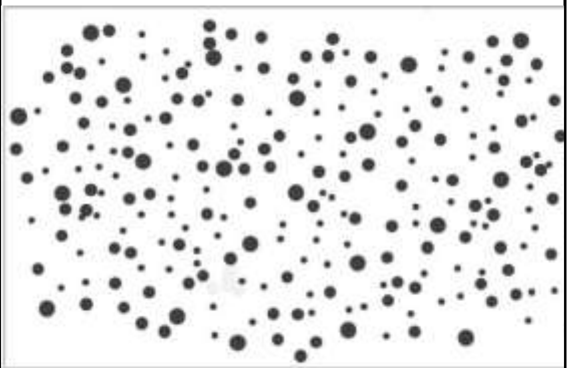


Diagram: Stem diagram of typical mono-crop, even aged overdense Douglas-fir dominated forest with three tree size categories (large, medium, small).

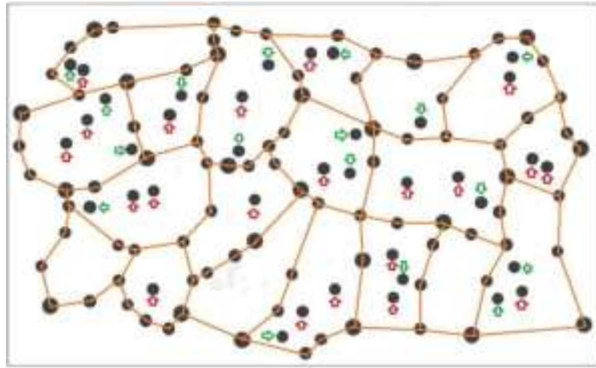
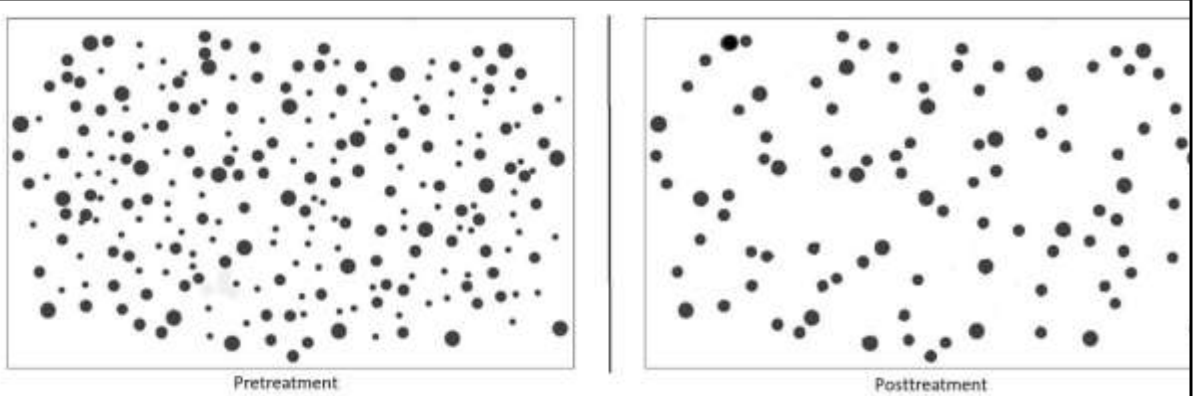
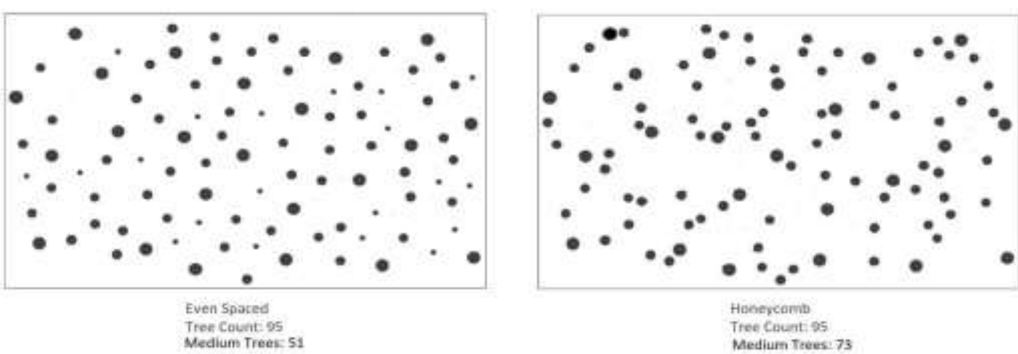


Diagram: After thinning the majority of fire-prone, mostly dead or dying trees of the "small" category, cells are established (hence "honeycomb"), and strategic thinning of medium trees takes place. All large-diameter trees are retained.



Side-by-side comparison of the pre-treatment and post-treatment stand.



Side-by-side comparison of even-spaced thinning and Honeycomb Matrix thinning of the same original stand. Even when controlled for the quantity of post-thinning trees, the latter results in a 40% higher retention of medium-class trees compared to the former. Further, it yielded a more heterogeneous stand that better resembles the structure of a natural stand.

Cedar Rehabilitation Protocol

On the tail of the total annihilation of BC's white pine population by blister rust, and the significant impact of bark beetle on interior pine populations, another foundational conifer is in trouble. Moisture-loving western redcedar is at significant risk due to climate change induced droughts, whose effects are exacerbated by the nutrient-deficient conditions left behind by decades of industrial-scale forestry. In the case of western redcedar, depleted calcium is particularly harmful, as this species depends on calcium for hydrological function and overall health more than other species.

Unlike the delving taproots of Douglas-fir, redcedar root systems are diffuse and shallow and thus disproportionately affected by surface moisture levels compared to other species. Moisture retention within topsoil is heavily influenced by the presence of CWM, which both increases organic matter and nutrient levels and creates large-scale moisture capacitor structures.

Tal is currently experimenting with a three-pronged (or "trident") procedure designed to protect, and perhaps (in some cases) reverse redcedar decline. The nature of redcedar mortality is counterintuitive: large, established trees die from the top down ("topkill"), while small trees survive, this is due to an inability of tall redcedars' to pump dwindling water supplies all the way to their tops using depleted calcium stores.

The trident approach applies a combination of the methodologies described throughout this article, with a direct focus on improving outcomes for western redcedar populations. The three approaches employed to this end include:

1. increasing CWM accumulation (via establishment of ASNLs, Mycelial Grafts, Intentional and Microsnags, and diffuse chipping) around established redcedars,
2. spreading wood ash (which contains ~25% calcium), and
3. long, high-surface area, low branch limbing.

Low branch limbing, in particular, has potential to immediately mitigate symptoms by lowering the redcedar's overall evapotranspiration requirement, conserving hydrologic pressure for the most afflicted canopy segment (i.e., higher branches). The small woody debris produced in the limbing process also provides a calcium-rich chipping medium. Though these three approaches are best implemented together (i.e., ashes are best deposited in CWM structures (e.g., ASNL) to limit leaching, and calcium rich redcedar foliage is best chipped (into the ASNL and diffusely)), they can each be implemented separately based on the restoration practitioner's available resources. One final element to be considered when working to improve redcedar condition is southern-aspect shading. Being highly shade tolerant, it is best to limit thinning south of redcedars to provide shade and increase the moisture content of surrounding soil.

Ash application and collection

It is now widely understood that fire suppression has had significant impacts on forest ecosystems across BC. Yet, there are many sites where reintroduction of fire would be incredibly dangerous due to widespread loss of fire-resilience and high woodland/residential interface. There is another opportunity for infusing forests with nutrient-rich ash without open burning, however: wood stoves! While some households use ash as a soil amendment for gardens and fields, most do not make any use of it at all, and instead dispose of it. There is a significant opportunity to return ash generated from wood, to the forest, completing a cycle of reciprocity.

Ash applied to an ASNL installed under the healthier redcedar (described above) serves three purposes: first, it is expected to slowly enrich the surrounding soil, second, its mineral and nutrient-rich composition catalyzes and nourishes microbial and fungal processes within the ASNL structure, and third, it increases its moisture retention capacity.

Photo taken by Tal Engel.

Ash is incredibly concentrated. An entire winter's worth is unlikely to exceed the volume of a typical residential garbage bin. To bring an ash application methodology to scale, a collection initiative would likely be required. For those who do not have forest lands to restore, such an initiative would provide an ecologically-oriented alternative to dumping their ash in the trash. A single truck load of ashes could potentially benefit vast tracts of forests. To minimize run-off and potential leaching into surrounding water supply, ashes can be incorporated into ASNL structures, but simply spreading them around older redcedars and newly planted trees, as well as lightly diffusing them throughout a forest during growing season could still have far-reaching benefits.

The Role of Community

All of the methods described in this article are labour intensive. Though there are employment opportunities under an ecological forestry model, community volunteers can take these methods a long way. Much of the work undertaken on Tal's property has been performed by a community of dedicated international volunteers. There are countless people out there who feel hopeless and overwhelmed about the state of our planet. These feelings can breed paralysis and despair. Taking meaningful, on-the-ground action has the power to lighten this burden. This work can be made simple and accessible for the average person. It is a way for people and communities to contribute to climate change adaptation with their own two hands through ecosystem restoration.

Myriad employment opportunities could arise in a ‘restoration economy’ from the widespread adoption of ecological-informed forestry practices. As an example, there are thousands of highly capable and motivated tree-planters who might be disillusioned with endlessly planting mono-crop, ecologically barren tree-farms that will be promptly harvested. Or they might just be looking for work during the off-season (though this work can take place any time, it ideally occurs in winter when possible). Tree planters have a potential to become a firm backbone of forest restoration endeavors.

Outcomes of Treatment

Because the outlined methodologies are designed to replicate biological legacies following significant natural disturbance, their benefits also extend into stand developmental trends, habitat, and biodiversity establishment, biological resilience, structural and functional complexity, soil enrichment, and fire and hydrological regime regulation. Varying degrees of implementation of the different methods described will result in a sliding scale of benefits; however, even when certain elements are omitted, if the overarching vision is upheld, a significant proportion of these beneficial effects are likely to be conferred. For the purpose of this discussion, a full implementation of the restoration regime will be assumed.

As discussed throughout this article, this treatment regime is designed to increase forest resilience in an ever-deteriorating climatic reality. Similar to organic agriculture, it is designed to foster overall forest health rather than focus on mechanical/chemical solutions for specific problems. In other words, the proposed treatments could increase the probability that forests will reach an old-growth state with as many integral ecological functions intact as possible.

A very tangible measure for this is the development of large trees growing at a lower density with a more heterogeneous size-class and species composition—hallmarks of old-growth forests. Such well-established trees can withstand environmental pressures—from pathogens, to invasive species, to drought, flood, windthrow, and most importantly, fire—far more effectively than small trees, and are far more efficient in their water uptake and usage. More light, less competition, increased soil moisture and nutrient levels, and numerous other factors, are conjectured to greatly accelerate large-tree development under this regime. An increase in biodiversity following these treatments is likely to mean that, as the forest matures, a higher proportion of essential players will be present and well-established.

It is important to note that most methodologies and procedures outlined in this article are still experimental. Some will be implemented in the course of the MCW project. The Climate Adaptation Lab has been established under the MCW project umbrella to monitor pre- and post-treatment changes and demonstrate/share potential benefits with practitioners and the broader community.

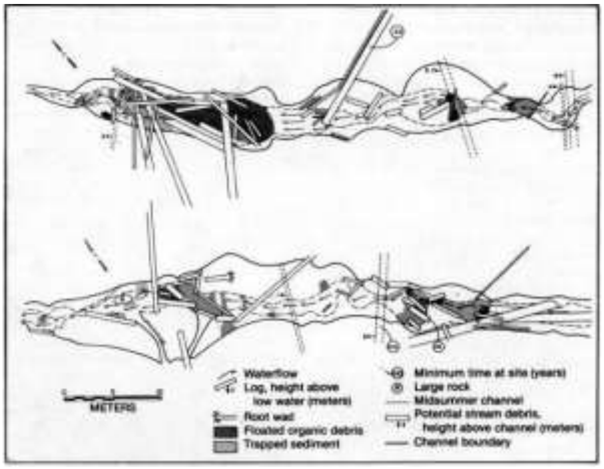
Fire resilience

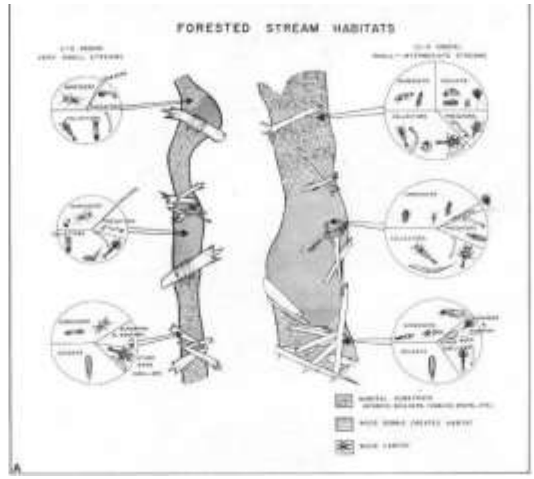
For a forest to be both mature and healthy, it must first survive. Fire-resilience is thus a crucial factor. There are many variables that determine a forest’s overall fire-resilience, but a handful are especially crucial: tree diameter, overall moisture retention potential, fine fuel volume, species composition, and structural attributes—particularly overall density, canopy closure rates, and ladder fuel conditions. When assessing a stand’s fire-resilience based on these variables, it is evident that the proposed treatment regime could have a profound effect.

Both localized and diffuse moisture levels are expected to increase following a wide-scale implementation of ASNL and Mycelial Grafting procedures, which would be of particular importance throughout the drought seasons of summer and fall. As these structures decompose, the stand’s overall moisture-retention is likely to increase. Reemergence (or planting) of soil-building tree species and the understorey shrub layer provides additional moisture-insulation for soil, aiding in fire suppression--particularly if practitioners focus on reintroducing species with a low flammability index. By incorporating them into ASNL structures, fine fuels and ladder fuels can be transformed from a threat to a safety-measure, both limiting the probability of in-stand combustion and preventing off-stand ground fires from climbing into the canopy. Further, the treated stand’s heterogeneous structure and composition are expected to prevent off-stand crown fires from increasing in intensity, and may even prevent them from spreading further into the stand. Finally, large-diameter trees are orders of magnitude more fire-resilient due to their thick bark, low surface area to volume ratios, and tall canopies.

Hydrological Regime Regulation

The effects of any restoration regime on hydrological functions must be considered. The critical role ecologically functional forests play in hydrological regulation cannot be overstated. Presence and proliferation of CWM structures in various stages of decay, combined with level of biodiversity, tree size, and stem density are important variables in determining the cumulative hydrological regulation potential of a forest. For example, the reintroduction of deciduous species, which are more efficient water users than their coniferous counterparts, and contribute to soil organic matter content, should have a positive hydrological effect. Similarly, a reestablished understorey and shade-tolerant redcedar and hemlock midstory provide rain interception layers that slow drip rates, thus reducing soil compaction, and increasing soil water retention. Reduction in tree density and the resulting heterogeneous forest structure and expedited growth of large trees, should also have a significant effect. Large, deep-rooted trees are generally more efficient in their water usage, and are capable of accessing and redistributing deeper groundwater deposits than smaller trees.





Two diagrams from Jerry Franklin's seminal 1981 paper Ecological characteristics of old-growth Douglas-fir forests. They demonstrate the integral role CWM plays in watersheds, wetlands, and rivers, where it serves both as a natural damming agent that slows the downward waterflow and increases its soil-penetration rates, and as the first, foundational link in the food-chain of terrestrial aquatic environments.

Finally, soil organic matter content and CWM structures (e.g. ASNL) act as natural dams and sponges that facilitate moist conditions. It is here that the proposed regime should have the most significant advantage in terms of hydrological regulation compared to other methods. When thinned wood is redistributed back into the forest rather than being burned or harvested, then its hydrological potential has been maximized. An increase in both soil and air moisture can be expected once sufficient decomposition takes place. When implemented across an entire watershed, these structures are likely to have a significant rainwater-interception effect, yielding a more balanced hydrological regime to buffer against both floods and droughts.

Habitat and biodiversity

It is hypothesized that practically every layer of the ecosystem will benefit from the proposed restoration regime—from bacteria to apex predators. For herbivores (e.g. deer), omnivores (e.g. bears), distinct predators (e.g., eagles), and the many bird and invertebrate species in between, the understorey is a fundamental part of forest food chains. The surge of light and enhanced moisture and nutrient regimes provided by the proposed treatments should result in a revitalization of the understorey. However, it is in terms of habitat provision that the wildlife potential of this regime truly shines.

The concept of "life boating" refers to structures that sustain small populations that depend upon them after severe disturbances, like a lifeboat safeguarding survivors after a shipwreck. Ecological lifeboats allow certain species, which would otherwise be entirely wiped out of an area, to survive. If/when surrounding conditions improve these survivors function as "seeds" to repopulate the area. When life boat structures are absent, as is the case with clearcuts, repopulation can take a very long time, and in some cases, it does not happen at all. For example, amphibians and other drought-sensitive species may find ideal habitats in an ASNL structure during drier months.

Biological Resilience

In addition to climatic stressors, forests are grappling with increasing competition from invasive species. Poor overall conditions make forests more susceptible to invasion. Common invaders like English holly and Scotch broom tend to be more prevalent in more degraded ecosystems. Likewise, bacteria and pests tend to be more impactful on already-stressed individuals. For example, arbutus trees have historically peacefully coexisted with a number of bacteria and fungi, but under changing climatic conditions are becoming more susceptible to their impacts, resulting in root rot and defoliation. Restoring ecological integrity to forest ecosystems is the best way to prepare them for worsening climatic conditions and potentially new or intensifying biological invasions.

Soil Enrichment

As noted earlier in this article, continuous cycles of intensive harvest have resulted in a dramatic decline, and, in some cases, the complete loss of many essential soil-building species. Forest soils are now critically depleted of essential components and nutrients. Nitrogen is a prime example. Salmon were once a significant nitrogen source, with salmon caracasses being carried into ecosystems by predator species including bears and eagles. Salmon are now far less abundant. Similarly, once virtually omnipresent nitrogen-fixing cyanobacteria and lichens (e.g., Lungwort (*Lobaria Pulmonaria)*), are no longer significant nitrogen contributors. Finally, alder trees, having been targeted by production foresters for decades using aggressive herbicides (Roundup), are another dwindling nitrogen-fixation source; even where they haven’t been exterminated, excessive cash-crop tree competition has wiped them out.

This treatment regime, particularly thinning combined with the two MCW project experiment methods (ASNL and Mycelial Graft), and the reintroduction of essential understorey species, is hypothesized to increase soil fertility and integrity. Large volumes of decomposing wood, both above and below ground, are expected to provide a slow release of essential nutrients over time. Perhaps by reestablishing ecological integrity, essential nitrogen-fixing species like Lungwort will reemerge on the landscape. Additionally, planting soil-building tree species like maple, alder, willow, redcedar, and hemlock is likely to help increase soil nutrient levels as time passes.

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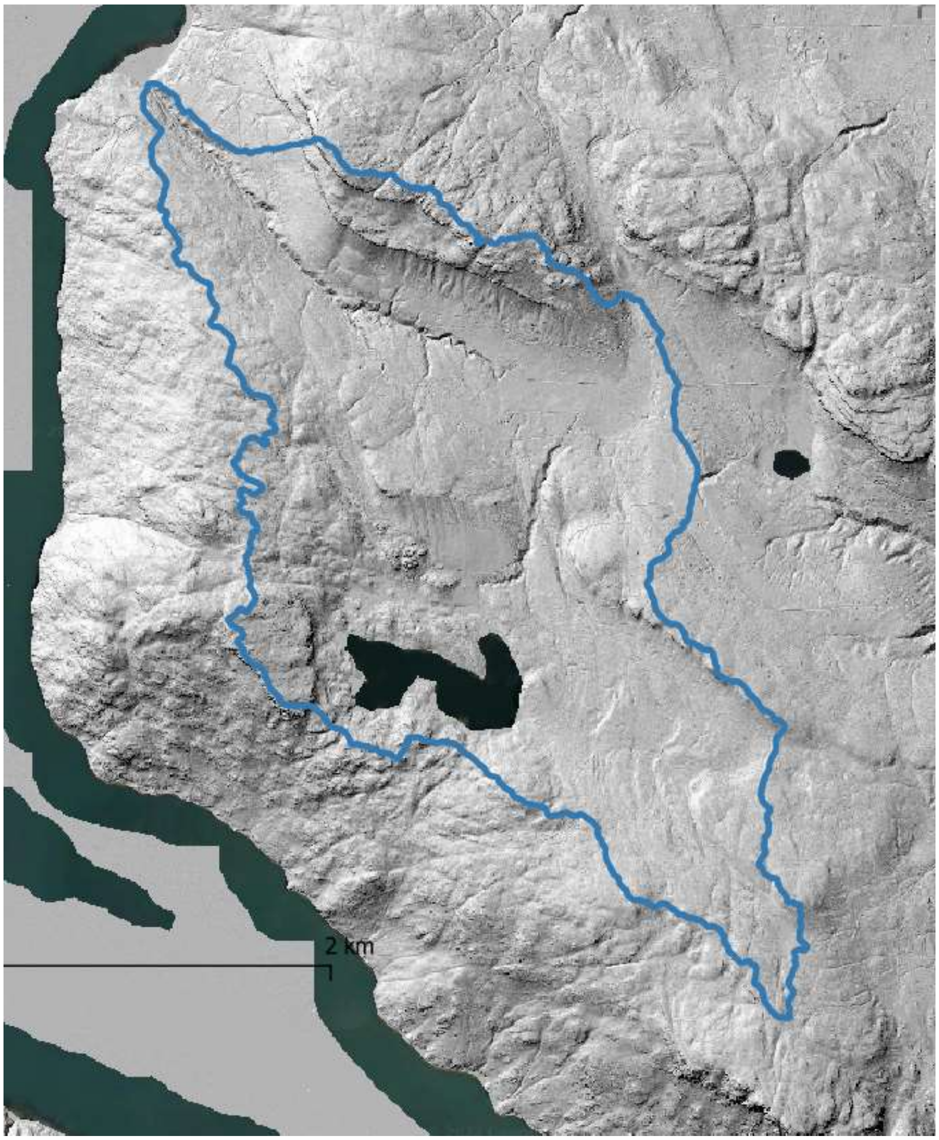
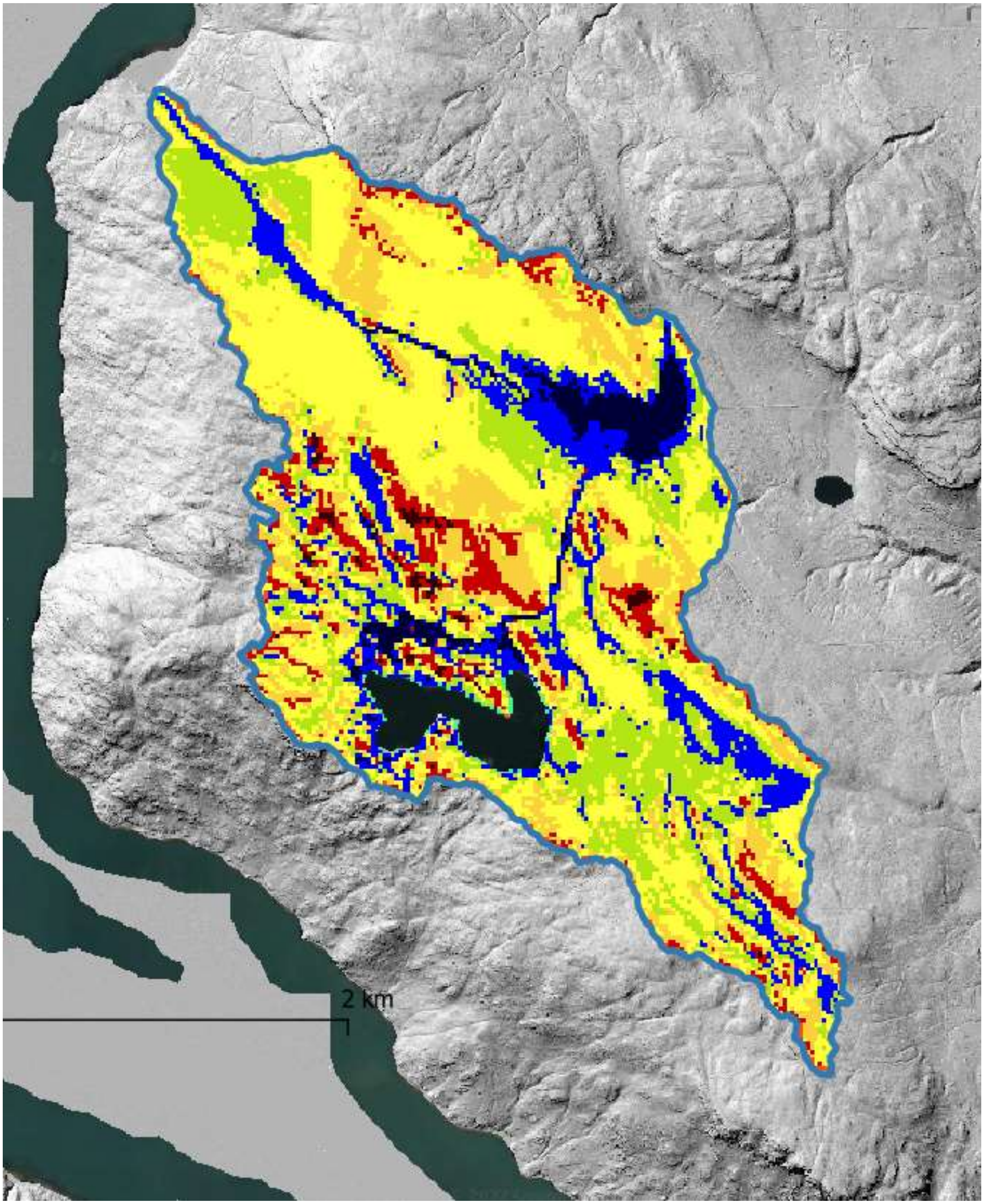
APPENDIX I: Stratification for Random Sampling Design.

Stratification based on the DEM: Methodology Overview

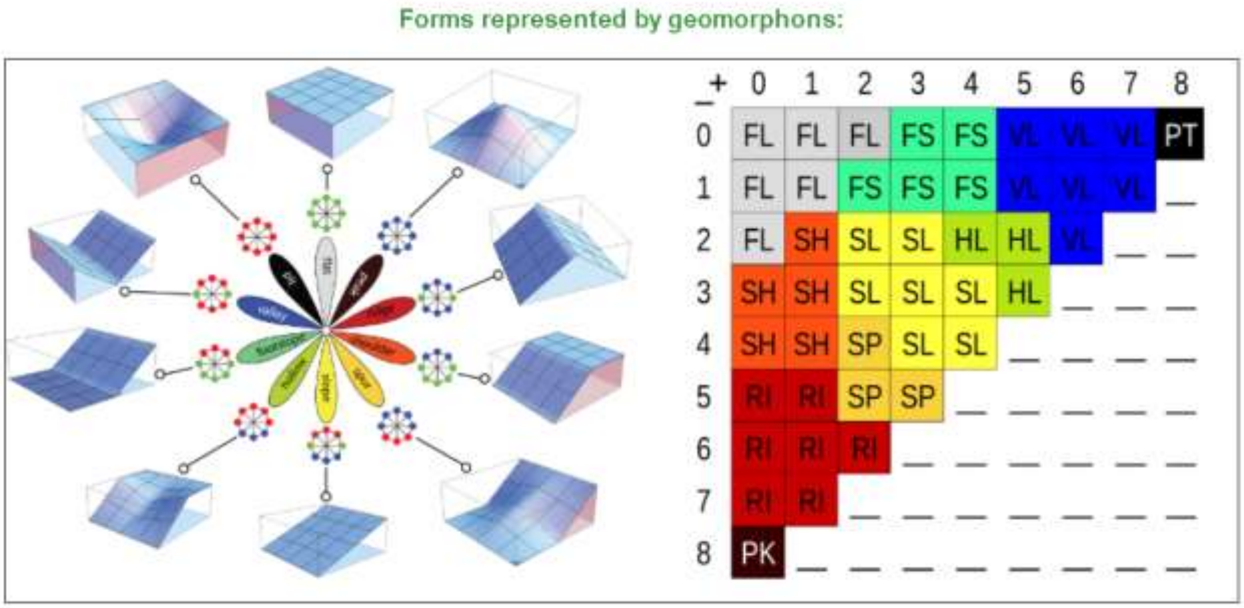
Below is a visual summary of the outcomes. I propose that SSI folks take our preliminary stratification based on this output and go for a hike to see whether the predictions feel meaningful on the ground.



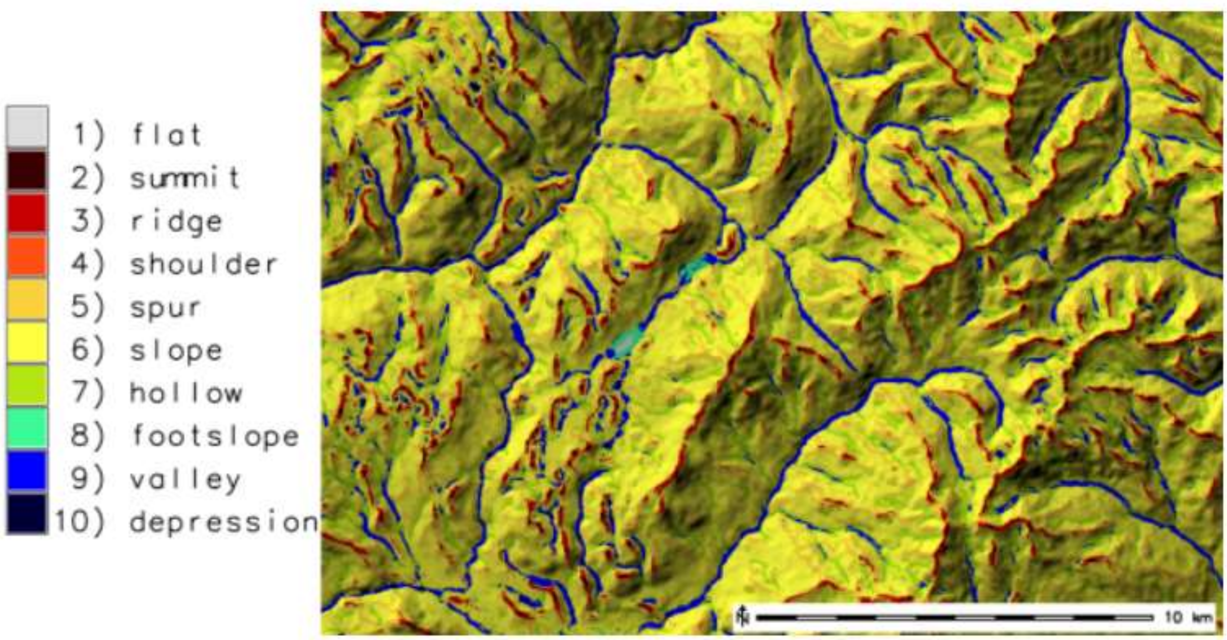
20x20m DEM.



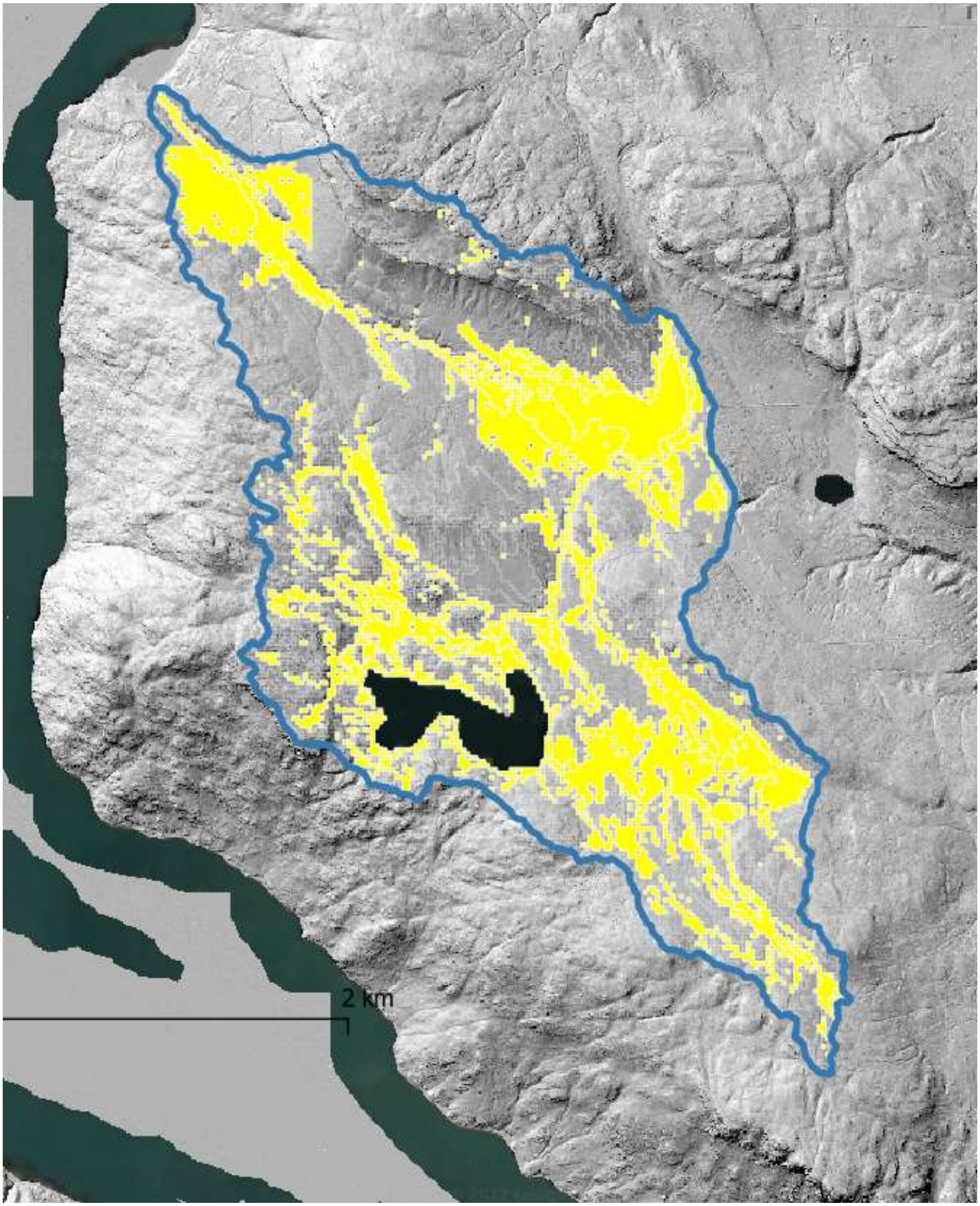
r.geomorphon using 20x20m DEM w 100 m processing window



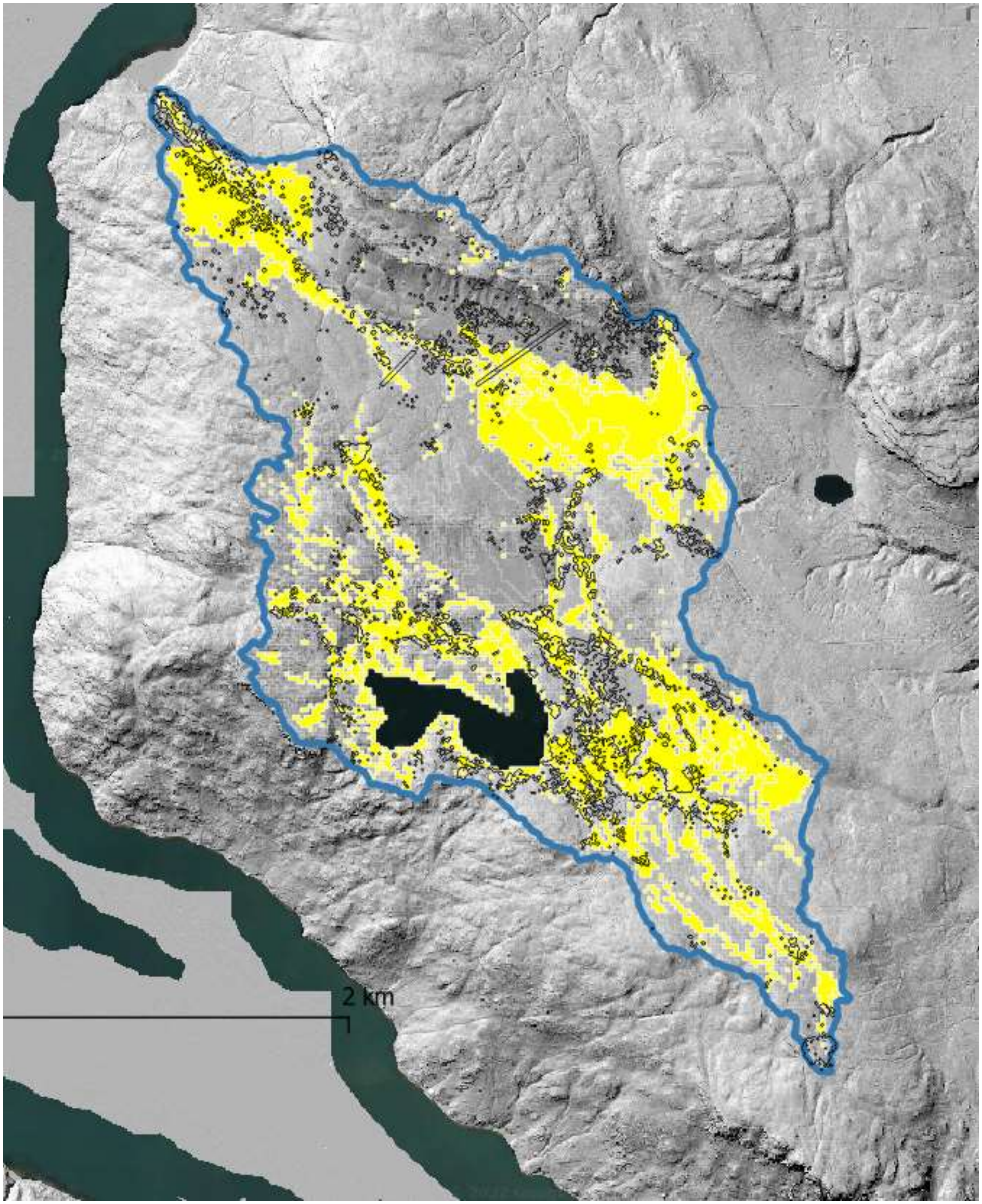
Legend



Extracting hollows, footslopes, valleys, and depressions



How well does this predict tall trees?


2 km

Study Design

Increase the number of replicates to accommodate for a more complex study design accounting for an assessment of potential deer browse effects. This would convert our two factorial design to a three factorial design, adding to the number of plots we would need to sample / monitor. It would add the browsing dimension relative to light/canopy and seed bank because they would put up fencing to establish exclosures.

Our short-term focus will remain on canopy/light and moisture effects. Since we will not be able to stratify deer browsing conditions prior to our field-based site selection process, I am not sure how this will factor into our discussion at this stage. We may want to develop some exclusion / site selection criteria related to this objective when we come around to visiting potential sites based on our stratified random sampling design, though. Some aspects of this topic would probably be better reserved for the topic of exclusion criteria below.

Canopy density - Robert Seaton's canopy density index serves as a reliable basis for defining this factor (Fig. 1);

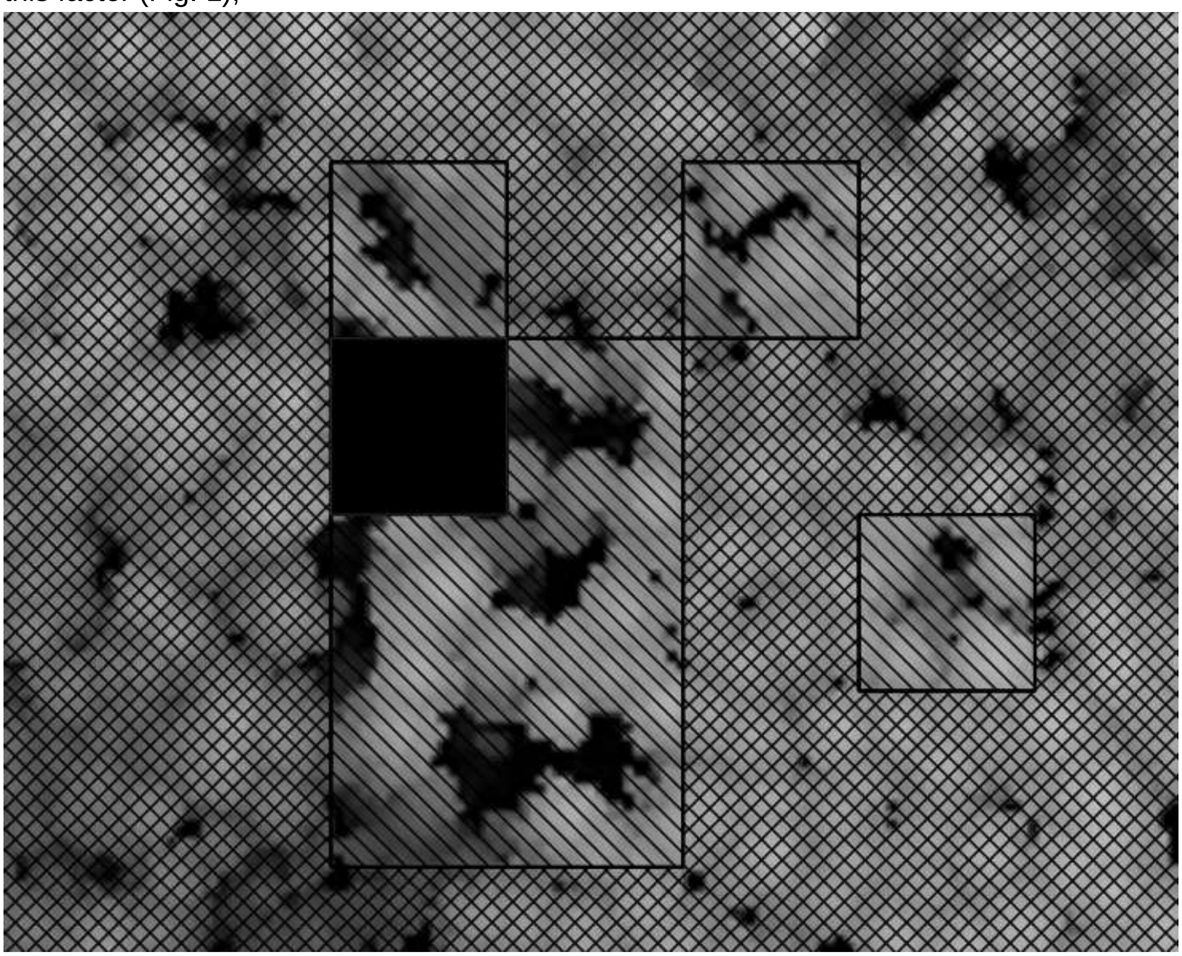


Figure 1. Stratification of canopy density index (Canopy Height Model as base map). Double hatched squares = closed canopy; single hatch = open canopy; black = clearings (excluded conditions, open fields, edges, etc.) Base map = Canopy Height Model

Canopy density conditions currently stratified based on the following formulae:

- closed canopy (75-100% canopy density)
- open canopy (60-75% canopy density)
- edges/clearings = 0-60% canopy density

Reviewing these outputs, however, it may be better to sample at a higher resolution (10x10m scale) for the purpose of stratification. At a 20x20m scale, when we compare with the Canopy Height Model, we note that we may not be capturing open canopy conditions in certain cases (Fig.2). Resampling the canopy density index at 10x10m resolution may provide a more reliable index for our purposes. Otherwise, some potential plots assigned to closed canopies will likely fall within relatively open conditions. These potential plots can be discarded in the field through the site selection protocol, but it would probably be more desirable to resample this index at 10x10m to get more accurate predictions ab initio.

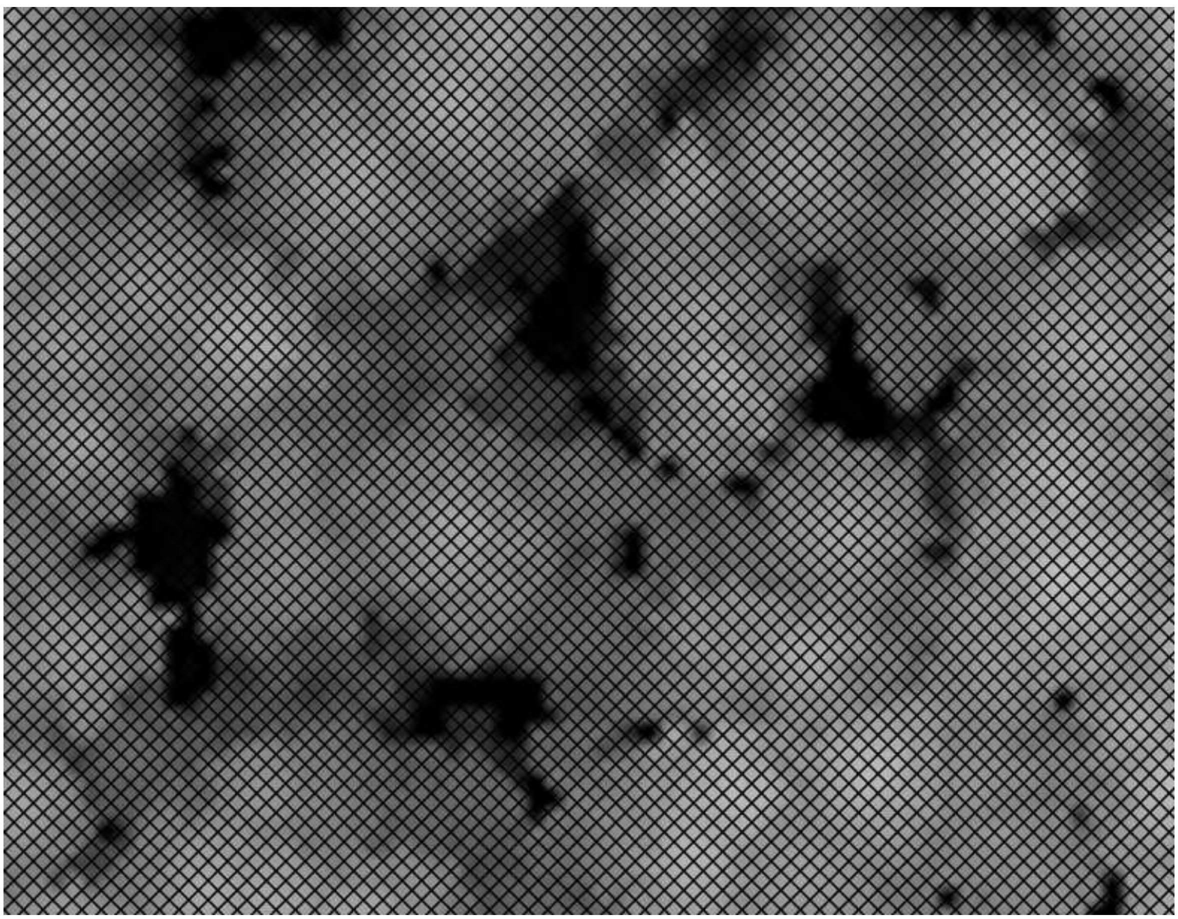


Figure 2. Some gaps in the canopy are not captured as open canopy conditions when stratified at 20x20m scale. Base map = Canopy Height Model

Moisture Regime

So far, we have not had much success with any terrain analysis/classification tools for stratifying hygric (relatively wet or water-receiving) conditions vs. mesic (relatively dry or water-shedding) conditions. In the past, I have seen good results stratifying based on terrain curvature but perhaps because of the high resolution of the DEM we are using, the result of terrain classification/curvature analysis tends to result in stratification of really fine depressions on the landscape which likely do not meaningfully correspond with the conditions we're interested in. Greg is going to look into whether Foresite can provide us with LiDAR-based terrain classification (isolating ridges from slopes from depressions etc) for this purpose. We can also try resampling the DEM at a lower resolution and rerunning the terrain classification tools to see if we get better outputs.

The best index for this factor so far is the Canopy Height Model because the tallest trees are reliably correlated with water-receiving depressions on the landscape (Fig. 3). It would probably be sufficient for our purposes to stratify based on the CHM, but it would probably be more satisfying/sound/defensible for us to stratify based on some topographic index. Hopefully, Foresite can help us out.

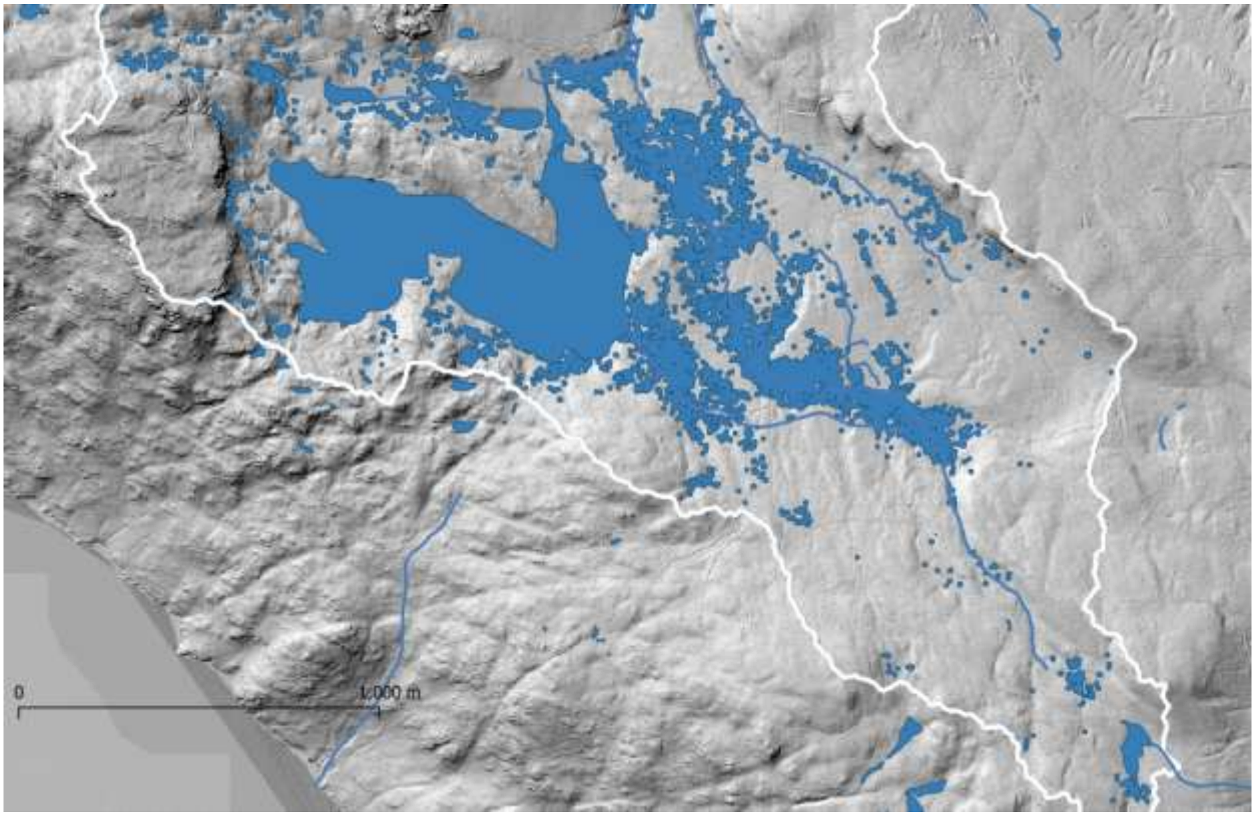


Figure 3. Tall trees (>40 m) with a 5m buffer are highlighted in blue in relation to water features (also blue); This is the most reliable index we have so far to stratify hygric conditions. Base map = hillshade DEM

Notes: When comparing the stratification applied thus far, we find that our hygric sites tend to be closed canopy (75-100% canopy density). There are indeed hygric x open canopy conditions (60-75% canopy density) represented on the landscape, though these conditions occur less frequently (Fig. 4). If we were to stratify canopy closure based on a higher resolution (10x10m) canopy density index, we would likely see a broader distribution of this condition. Regardless, we will definitely be able to achieve a reasonable stratification of this condition using this approach, ideally incorporating a terrain classification index for hygric vs. mesic conditions instead of the CHM.

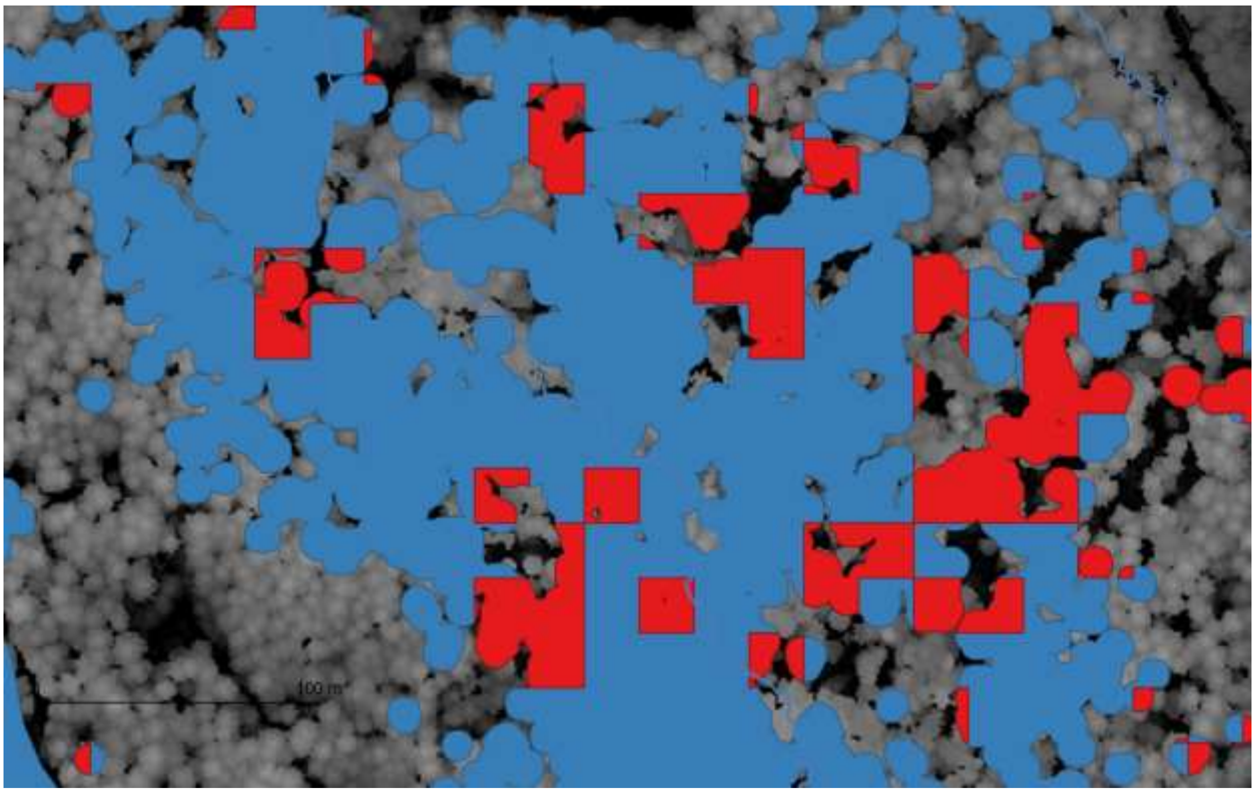


Figure 4. Red highlights hygric x open canopy conditions. Blue = trees >40m tall w 5m buffer, representing our best index of hygric conditions thus far. Hygric x open canopy conditions (red) are fairly sparsely represented in the study area, but this is to be expected. Base map = Canopy Height Model

Geology

Evaluating the outputs of our preliminary stratification in relation to the geological mapping of the watershed, we observe:

Certain key features of interest are well-defined in relation to geological mapping (e.g., the rise to the west of Maxwell Lake is a conglomerate unit that is more resistant to erosion vs other sedimentary units to the east; where some units meet (e.g. granite vs sandstone) we also find that this gives rise to topographic effects that shape the conditions we're interested in. Geological mapping also meaningfully corresponds with the TEM. So we can easily exclude certain conditions based on the TEM. For example, the upland woodlands that are prevalent on the conglomerate unit to the west of Maxwell Lake map are mapped as DA (Douglas-fir arbutus) and RO (rock outcrop). So excluding these areas is easy based on a simple query of the TEM.

We may want to consider excluding certain geological units to limit our observational study to one unit. In general, most of the watershed/area of interest falls within areas mapped in the sedimentary (sandstone and shale) geological unit, so we might exclude the conglomerate, maffic/volcanic, and granitic geological units. It is not necessarily clear that vegetation dynamics vary significantly across these geological units (though some general trends have been detected in relation to the geology) but it may nevertheless be a good idea to account for this heterogeneity in our study design.

Preliminary exclusion criteria As preliminary exclusion criteria, we exclude (Fig. 5):

- Openings/clearings/edges (0-60% canopy density), including a 10 m buffer (if we resample to a 10x10m resolution grid scale).
- Wetlands / open water bodies, including a 10 m buffer
- Anthropogenic clearings and linear features, including a 10 m buffer
- Upland woodland sites (TEM classifications: RO, DA, etc.) that are outside the areas of interest for our proposed treatments

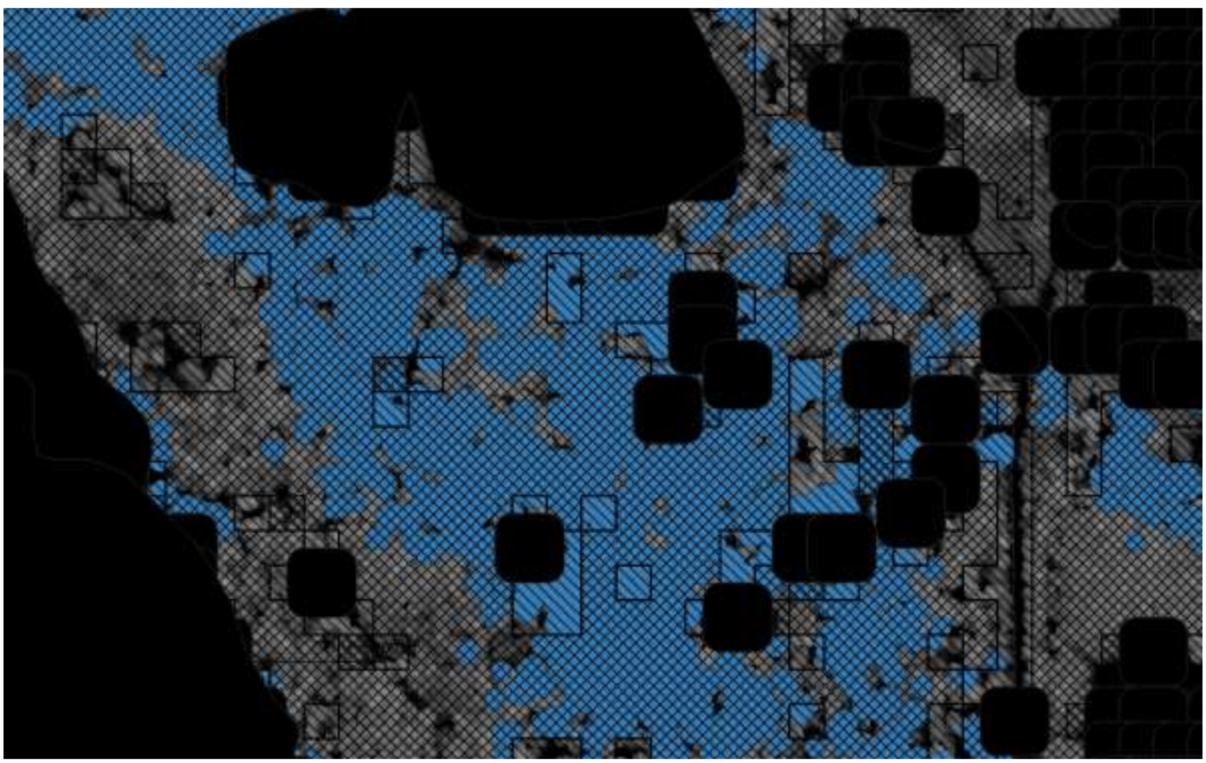


Figure 5. Preliminary exclusion criteria provide a decent "first pass" on stratification of site conditions of interest. Blue = hygric conditions based on CHM index (to be improved upon); Grey = mesic conditions, reflecting the underlying basemap (CHM); double hatch = closed canopy (75-100% canopy density); single-hatch = open canopy conditions (60-75% canopy density); black = exclusion criteria, including 10m buffer.

APPENDIX II: Restoration Activities (assessment).

3.1. Restoration Activity 1. Establish reference plots. Monitoring of reference plots to track changes in: vegetation, tree growth, light, soil characteristics across a range of soil and canopy conditions (Xeric to Mesic). These references sites will be tracked across years, and used to compare and contrast with treatment plots.

- Establish long-term reference plots within and outside treatment areas
- Placement of 6” rebar at centroid of 5.64m radius plots (40 reference)
- Study potential factors that may be limiting understorey regeneration:
- Soil moisture: Soil testing and profile at plots (small pits dug and refilled to characterize horizon and duff layers). Soil moisture measures with probe, vegetation surveys, woody debris monitoring
- Canopy closure and vegetation: photographic light analysis. Forest Panorama photography. Ground cover photography.

Considerations: We do not foresee any negative consequences of much of the monitoring fieldwork that will be carried out. Plots were established and will be surveyed for vegetation and downed woody debris. Stakes will be placed in the ground to delineate the study plots; some will stay in situ for the duration of the experimental work (3 years), and a few markers, such as tree tags and short lengths of buried rebar, will be left in place permanently so that plots can be found and resurveyed years, or decades after the experiment has ended. This will provide the first detailed and only long-term information on the covenanted area since 2001.

Harm reduction will be managed through training and awareness. Personnel will be trained to be aware of their surroundings and avoid treading on slugs or amphibians or disturbing birds if alarm calling and/or engaged in nesting activities. Given the overgrowth situation of the forest where much of the work will be taking place, there is a very low probability of this type of impact because the area has limited and predictable biota. Personnel will be moving through the area in pairs. Site visits will be limited to the following activity types:

Type 1. soil moisture monitoring: measured three times each a year (June, August/September, December/January) by two people traveling on foot. No disruptive activities.

Moisture probes with 4.5” probe ends will be inserted into the forest floor along two transect lines in each plot three times a year to record spatial and temporal variability in soil moisture conditions along vegetation monitoring transects in each plot. There are no disruptive outcomes of these measures: the probe is <0.5 cm diameter. Sampling occurs at 1 m intervals along two fixed transect lines. The goal of this monitoring is to relate soil moisture and soil characteristics to the herb and shrub vegetation observed along the transects (Harrop-Archibald 2006; Simon et al. 2021).

Type 2. Canopy and vegetation monitoring will take place once-yearly for annual and perennial plant cover and woody material. Each plot will be visited once coincident with the soil moisture monitoring in June.

This monitoring is non-disruptive, involving only observation and photographing of canopy and ground cover. These data, along with the soil moisture information will be used to develop relational information that explains the current distribution of vascular plants in the watershed (Simon et al., 2021).

Timing: See specific details in Table 1.

3.2 Restoration Activity 2. Fire Hazard Mapping for site selection: identify areas of high canopy and ground fire hazard in the Maxwell Creek Watershed. A report was prepared to summarize the fire risk within the watershed, with particular attention to the covenanted area to the east of Maxwell Lake (Figure 2; Appendix).

Considerations: This computer-based work was completed in order to identify potential areas of high fire risk that would benefit from restorative activities designed to reduce the potential for the spread of fire, while enhancing soil and wildlife habitat properties. These maps were used in combination with ground validation of criteria outlined in Appendix 1 to select a trial treatment area in the Maxwell Creek Watershed.

Stand Selection for Treatments We have selected an area of high risk in close proximity to the main road in an area of extreme risk for fire ignition and movement into the canopy. The high accessibility of this stand and its position along a disturbed edge of the forest along the main road makes it ideal for restoration work; it targets an area that will benefit from the fire risk reduction treatment, presents easy access for work and activities associated with thinning, and would be beneficially impacted by the proposed restoration and regenerative activities. **This work did not involve any activities that disrupted flora or fauna.**

Timing: Complete.

3.3 Restoration Activity 3. Thinning of small patches of stunted conifer trees. To reduce competition for light and moisture in overly dense forest stand and encourage the forest toward a more mature, structurally complex state, a professional forester will visit the site and identify (mark) trees that will achieve these objectives. A detailed description of the proposed thinning can be found in the Prescription (Appendix) at the end of this document. The area will be ≤ 2 acres.

NOTE: the high density of trees per hectare in Maxwell Creek Watershed requires that thinning be conducted in stages over a series of stages (decades). This reduces potential windthrow or other stress on trees by limiting the rate at which they are exposed to changes in the surrounding forest. This trial is seen as a first step in moving the forest to a more mature state (Franklin et al. 2002; Schorz et al. 2004; Kuehene et al. 2015; Stanturf et al. 2014; Stanturf 2021).

There are several aspects to this work that will directly affect flora. We are requesting permitting to allow us to undertake a short window of careful thinning for the following purposes:

- Restore large living and dead trees, spatial heterogeneity and biological diversity (downed wood, snags, native understorey complexity) lost through past, intensive clearcutting and forest management activities.
- Increase light by removing carefully selected dying and unhealthy trees to create gaps in canopy that will encourage native understorey revegetation and reduce potential for fire to spread to canopy.
- Restore soil properties and ensure ongoing inputs of coarse wood over time. (Seed treatments, placement of downed coarse wood from felled trees to re-establish coarse wood biomass where absent).
- Long-term monitoring of benefits in growth and complexity features related to competitive release on living trees and understorey vegetation (increased plant species and structural diversity, increased water retention by soils.

Considerations: Removal/Destruction of flora

The main permissions required have to do with the removal and/or destruction of flora. We are proposing to carry out thinning of young trees, which by definition will be a removal of native flora. Some 'bystander plants' will also be negatively affected in the process of downing trees. The extent of thinning is outlined in the accompanying proposal. Thinning of a young overgrown forest is a recognized method of increasing light penetration, favouring understorey vegetation, more complex age structure, improved soil carbon (moisture retention), and increased biodiversity. We believe that the benefits will far outweigh the slight amount of initial damage to the vegetation.

Activities:

- Cutting of selected small and stunted trees to simulate natural gaps at targeted treatment areas (increase light penetration)
- Retaining and restoring missing habitat features for wildlife (restore native understorey, mature trees, potential nest sites)
- Managing coarse woody debris to maximize water retention (retain, and if cut or suspended, place in contact with forest floor and, if necessary, remove to another location)

We are proposing to leave most of the downed trees in situ so as to allow them to decompose and provide nutrients and add to the soil profile, increasing moisture retention qualities and carbon. Thinning will be carried out in the fall when there is a low risk to native species such as nesting birds and when the risk of fire from mechanized equipment is also low.

Thinning will be conducted by a licensed and registered forester under the direction of Robert Seaton of Brinkman Earth Systems[7] using a gas-operated chainsaw and a crew of two foresters. Thinning will target weakened pole trees that are dying and dead, and will leave standing dead snags and future snags of larger diameter in place as wildlife habitat. Trees that are cut will be left in contact with the surface at densities expected in forests of this age and type within the CDF Zone to facilitate soil organic content.

Woody Material. We are, however, asking for the flexibility of **moving some of the downed wood** away from the property to reduce any potential for fire near areas of

[7] Brinkman Earth Systems has over 30 years of experience working with large and small forestry operations, providing training and management in the adoption of ecological principles

human activity. Where downed wood is not left in place, it will be cut into lengths that can be transported by hand, to move it away from existing trails so as to reduce the probability of ignition from passers by; e.g. discarded cigarettes. Any movement of downed trees within the forest will be done by hand, as described above, and moved offsite with soft thread vehicles on existing trails, taking as much care as possible to reduce the amount of soil compaction.

Care will be taken to thin the experimental plots as carefully as possible and with the least trampling possible. Any downed wood will be kept intact as much as possible, and placed below existing vegetation. However, it is not possible to completely avoid a certain amount of vegetation trampling and loss of a few herbaceous plants in the process. We will be conducting pre and post thinning monitoring of the treatment areas at the start and finish of each active day of thinning. Any damage will be noted and monitored in follow up, to determine if any further restorative action may be necessary.

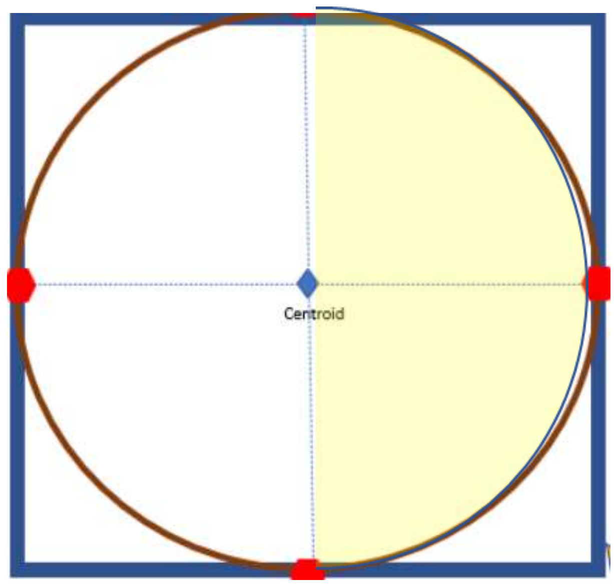
This proposal has been set up as a trial for evaluating and documenting changes in forest structure, soil and understorey conditions associated with biologically driven thinning. The degree of thinning being targeted is small, in order to enhance growth in the remaining trees and prevent further potential for windfall by allowing trees to grow into the new conditions. If allowances are not possible on the covenant site under the Ecogift program, an alternative forest area outside the covenant area will become the focus of this work, however, the SS Conservancy and TSS are committed to initiating restorative actions in the covenanted forest area, and the hope is that this proof-of-concept is an important first step.

Tree Thinning: the primary emphasis for the initial, small thinning application is to demonstrate the treatments and to develop and provide evidence that the thinning treatments will not cause harm or impacts to the forest, ecology and species within the covenant area. A primary objective for the project is to demonstrate, measure and validate that the techniques may be done with minimal impact; the aim is to build confidence and capacity/technique for expanding the restorative thinning work to other sites. A section of covenanted forest area was purposely selected for this initial work at a location known to be a major access point for people illegally entering the watershed; this makes this site of especially high potential for ignition of a fire (human-caused fire account for over 95% of fires in the Southern Gulf Islands – SS Fire Rescue, personal communication). The presence of the project team during monitoring and other field activities and high visibility of the treatment area will provide a means to support the SS Conservancy and NSSWD in their efforts to reduce access by the public while restoring a forest area that is stressed not only as a forest edge immediately along a roadway, but also as a source of sediment, contamination and potential fire associated with its location.

The details of proposed thinning activities, including selection and thinning techniques used are described in the Appendix.

TIMING: The thinning described here (Appendix) will occur between October 24th and November 30th, 2022.

3.4 Restoration Activity 4.



Restoration Treatments have been designed to identify variables that may be influencing the presence, distribution, and growth of herbs, forbs and tree species in the watershed. Several factors are known to be important in secondary forests in our region: soil properties (soil and duff characters, moisture, depth), light conditions, browse/herbivory, and the presence of seed stock (Kern et al., 2017). In some instances, seed banks may be limited to few high shade-tolerant species, as well as those more tolerant of other factors negatively impacting growth and survival (e.g., ungulate browsing).

Long-term monitoring plots will help identify which plants have been most limited in the study area by the absence of species expected in Western hemlock ecosystems. The 40 reference plots were selected to establish a range of conditions from xeric to mesic that can be used for comparison to the conditions in the treatment area for both open and closed canopy.

- The restoration treatments will allow us to explore the various influence of canopy closure, soil moisture, seed stocks, and herbivory, all key factors that may be limiting herb, forb regeneration in areas that will be the target of thinning. For the ten treatment plots, these include:
- Browse effect: fence a subset of plots and compare vegetation changes over time; plant young Oregon grape and monitor for browse effects in fenced and unfenced areas (Defrees et al., 2020; 2021). Oregon grape is proposed because transplant success is relatively high compared to other shrubs and lends itself to qualitative browse measurement (DD).

- <u>Seedbank and Moisture effect:</u> Seeding within the fenced and unfenced area will be set up at each of the 10 treatment plots by dividing each plot into two halves for pairwise comparison on germination (Figure 5); select native forest species and tracking of germination success will be tracked in both conditions over the next two growing seasons. Short-lived species will be selected to test the suitability of plots for species with differing light and moisture tolerances. Seeds will be scatter distributed in quantities sufficient to allow some seeds to come in direct contact with soil. Seed availability will affect choice, our target list includes species we have observed in our June vegetation surveys: *Collomia heterophylla*, *Rorippa curvisiliqua, Claytonia perfoliate/sibirica/siberians, Lathryus nevadensis, Trientalis borealis, Tiarella trifoliata, Osmorhiza berteroi, Nemophila parviflora.*
- <u>Moisture effect:</u> Soil testing and profile at plots (small pits dug and refilled to characterize horizon and duff layers; Mackenzie et al., 2010). Soil moisture measures will be recorded using a FieldScout TDR 250 Soil Moisture probe[8], vegetation surveys, woody debris monitoring.
- <u>Canopy closure effect</u>: Light penetration will be measured pre- and post- thinning at plots and tracked annually (Gap Light Analyzer[9]). The light data will be related to observed changes in soil moisture using *in situ* soil data logger (to be installed by Dr. Tara Martin, SSIC) as well as quarterly monitoring of soil moisture at finer time and spatial scale within the treatment plots (each meter along north-south and east-west transects). Canopy closure (light) and soil moisture levels will be related to plant germination success within paired treatment areas.

Considerations: We are seeking permission to dig a few small, shallow pits in each of our study plots in order to document the soil profile (MacKenzie et al. 2010). These will be refilled immediately. Small holes will also be required to install data loggers to capture year-round soil measures. These would remain in situ through the duration of this project and would be installed by the SS Conservancy Board member, Dr. Tara Martin, Salt Spring Island Conservancy.

We are also seeking permission to introduce native plant seeds[10] within each of the ten plots. Native seeds will be broadcast at high density within each experimental plot to simulate natural dispersal and ensure contact with soil without disruption to the vegetative cover. Only native seeds approved by the Salt Spring Island Conservancy will be used. We are also requesting permission to transplant locally sourced Oregon grape immediately outside each of the 10 experimental plots (four per plot at cardinal points) so as to reduce interactive effects and trampling/digging within each plot. Oregon grape has been selected due to its high transplant success, soil moisture

[8] Spectrum Technologies, Inc.
[9] Gap Light Analyzer - Forest Ecology and Management (FEAM) Group - Simon Fraser University (sfu.ca)
[10] Satinflower nurseries: https://satinflower.ca/

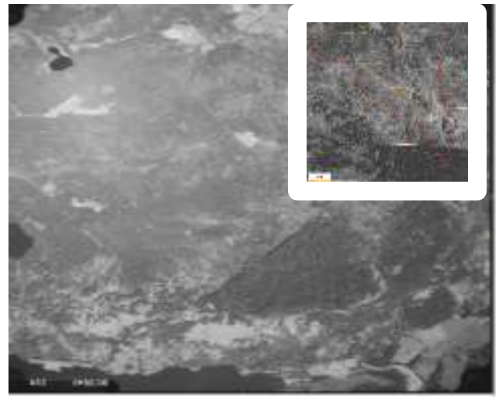
requirements, and because it is subject to light to moderate browse by deer (Tara Martin, personal communication).

The purpose of these activities is to collect information regarding the degree to which seed bank and herbivory have compromised regeneration in areas of the watershed devoid of vegetation relative to light and soil characteristics (Keigley et al., 2008; Defree et al., 2020;2021).

The goal of the experimental treatments is not to provide evidence of browsing intensity or dispersal, but to collect information to help differentiate the importance of different potential factors on the recovery of understorey vegetation. All plants, stumps and other natural features will be left intact to the greatest extent possible.

Planting, distribution of seeds, and placing of fencing will be done by hand by the project lead – Ruth Waldick – to oversee and ensure minimal disturbance to the understorey, trees,and wildlife. Plastic deer fencingwill be used to create temporary barriers to deer and other herbivores (rabbits) and will remain up through the experimental period of this project (2.5 years). The fencing will beset up using wooden stakes andwire and will not require digging orother foreseeable disruptions to vegetation or other wildlife, particularly as fencing will be limited to 5.64 m radius areas, areas much smaller than the larger disruptions created by windthrow and the creation of large piles of downed wood (Figure 6). This equates to ½ of each of the 10 treatment plots being fenced, with the remaining ½ serving as a control. Fencing and all other temporary objects will be removed after five years by Transition Salt Spring (2027). Due to the use of fragile fencing material, enclosures will be checked regularly to ensure they remain standing and closed following storms and during the spring when browse pressures are expected to increase.

We are also requesting permission to core a limited number of trees of differing size within the covenant area (not limited to the treatment area); this will be limited to Western red cedar and Coastal Douglas-fir, the predominant species. The purpose of these cores is to compare growth of trees in relation to the environmental and edaphic conditions in the watershed. Historic air photos (Figure 7) and the original Maxwell Covenant documentation indicate that extensive clearcutting occurred through most of the watershed in the 1950s. The presence of large diameter, tall trees in some parts of the watershed suggest that soil and light conditions in these limited areas may have allowed trees to reach a more mature condition than their surrounding cohort. Coring in the final year of this project will allow us to determine the age of these trees and to examine the annual growth rates. Those trees observed in the historic aerial photographs will be compared to diameter, annual growth rate and site conditions with a set of tall trees of undetermined age from elsewhere in the watershed. The total will be limited to 15 trees within the proposed treatment stand (area of thinning) and a total of ten trees representing tall, large diameter trees from elsewhere in the covenant area (two from each of five reference plots). Reference site trees will be selected to capture taller trees identified in the 2019 Lidar data.



The cores will be used to: i) Establish the age of oldest trees in upper watershed for individual trees known from the 1940's aerial photos but of unknown current age; ii) Determine annual growth rates in relation site conditions (i.e., regressions using information on all cored trees over time within and outside the treatment area relative to each other and site features), iii) Effect of light on growth rate following thinning – a relative measure of growth of trees relative to light/canopy characters will be looked at for evidence of changes in growth rate following thinning treatment (longitudinal).

Although tree coring is regularly used by forestry and ecological professionals, there is a small potential for harm to the affected trees. Selection of trees and the cores will be done by a licensed and registered professional forester with over 30 years of experience using these methods. Trees will be cored at a time of year that minimizes risk of harm or disease, and monitored monthly for the first four months to ensure proper healing and closure. Any sign of complication will be addressed by bringing in a certified tree expert to assess and recommend treatment.

Monitoring will continue at the long-term reference sites and treatment plots beyond the duration of this project. Monitoring will determine the outcomes and successes of the restoration treatment, and identify the nature and timing (or expansion) of further restoration treatments to ensure success. Reference plots (ecosystems), restorative treatments, and monitoring form part of an educational adaptive management framework that is supported by the property owner submitting this request to do restoration work (North Salt Spring Waterworks District), Transition Salt Spring, and a third covenant holder in this watershed (Water Preservation Society).

> **TIMING**: Installation of fencing at 10 experimental plots (August-September, pending approval from SS Conservancy and ECCC). Seeding with native seed and planting of small Oregon grape plants in the 10 experimental plots (November 1st to November 30th, 2022).

3.5 Project Sustainability. (see Table 1.0). The pilot work outlined in this document describe the first step, or 'proof-of-concept' and validation work for the larger collaboration between TSS and North Salt Spring Waterworks. This work will generate a reference database for the current conditions within the watershed – notably here, for the covenanted area of the watershed – as well as short term observational data about the conditions affecting the growth and composition of ground cover and understorey vegetation.

- Ongoing monitoring, surveying and maintenance of treatment and reference plots. Data analysis, publication of reports and management and upkeep of data will be overseen by Transition Salt Spring's Climate Adaptation, Planning and Integration (CAPI) committee as part of the overall collaborative project component of the Climate Action Network (CAN) of TSS.
- CAPI/TSS is actively working on partnerships for regional capacity development with the aim of addressing key aspects of climate action, specifically: reducing the risk of catastrophic fire (building fire resilience); enhancing watershed health and the resilience of the Coastal Douglas-fir systems on SSI, enhancing forest growth, carbon sequestration and storage (https://transitionsaltspring.com/responding-to-climate-change/)
- North Salt Spring Waterworks is committed to supporting the long-term monitoring and remediation of the upper watershed in collaboration with other responsible authorities – SS Conservancy, SS Fire Rescue Services, TSS, CRD, and Local Trust planners.
- Transition Salt Spring has been an active organization and shown a track record of long-term partnership and programming for 25 years. TSS has an agreement in principle with North Salt Spring Waterworks District to sustain and oversee ongoing volunteer-based monitoring until 2027, in order to establish a full five years of baseline and post-treatment monitoring and data collection.

Summary of Activities and Considerations

Activity	Monitoring Frequency	Date initiated	Considerations
Long-term reference plots	Vegetation – annually Soil Moisture - seasonally Decomposition rates – annually Tree growth – every two years	June 2022 Quarterly – July 2022 (4x/year) October 2022 July 2022	Monitoring will continue as described annually.
Experimental (treatment) forest	Tree thinning, seed and plantings Canopy, understorey and trees, soil measurements (pre and post-treatment)	October/November 2022 September 2022 (pre) and again in April 2023 and June 2023. Monitoring will continue on these dates in subsequent years.	Pre-treatment (baseline) and post treatment impacts will be monitored as described (n=10 plots). Reference plots will be used for comparative purposes (n=40).

Considerations: Transition Salt Spring, in partnership with North Salt Spring Waterworks District and the Water Preservation Society are committed to sustaining a minimum sampling regime for the next five years (to 2027). More detailed monitoring and field work are subject to additional funding awards, which are being pursued by the named partners. As noted through this document, any evidence and materials established as part of this work will be extricated in 2027, should continued support for monitoring and research fail to be achieved.

APPENDIX III Brief Report: Fire Risk Modeling – Maxwell Watershed, Salt Spring Island

Brinkman Earth Systems
March 31, 2022

Goals
The goals of this project were:

1. To provide fuel risk assessments for stands in the North Saltspring Waterworks District lands, and some surrounding parcels
2. To provide current condition data on canopy closure and tree heights for monitoring which would examine the relationship between stand variables and understorey vegetation and soil moisture retention
3. To provide current condition data for proposed trial thinning treatments.

The goal of this project was not to undertake fire behaviour modeling. In a limited area such as the Maxwell watershed, risk identification is more critical than fire behaviour modeling, since any out-of-control wildfire could rapidly sweep the entire watershed. However, the fuel risk mapping generated by this project could be used to help populate a fire behaviour model.

Background
The Maxwell watershed lies to the north of Mount Maxwell on Saltspring Island, and includes Maxwell Lake, a major water supply reservoir for the North Saltspring Waterworks District. Most of the watershed has been harvested over the last 100 years, although small undisturbed patches do remain. Some of the harvest was associated with large burn areas.

Regeneration on currently forested areas has largely been to Douglas Fir dominated stands, as well as smaller deciduous dominated stands in some moister areas. Western Red Cedar and Hemlock are largely found as scattered individuals, as well as understorey regeneration in some areas. Non-forested areas within the watershed are largely associated with farms, hydro right of ways, wetlands and domestic clearing.

As is typical of many regenerated Douglas Fir forests in the Coastal Douglas Fir zone, much of the regeneration was relatively dense, and has created largely closed canopy stands with significant potential to carry canopy fire. The densest of these stands are now going through a significant self thinning process, which is temporarily reducing canopy closure, but increasing course woody debris levels. There are also patches of root rot scattered through the watershed which are creating small openings.

One small area within the lands owned by the Waterworks District was thinned approximately 20 years ago. These stands show increased growth, no blow down, and canopy closure appears to be rapidly increasing. Overall, the closed canopy conditions, combined with ground and environmental conditions, create a significant risk of wildfire, which could have major impacts on lives, homes, and infrastructure.

Methods
The work undertaken was focused on identifying risk areas for four principal fuel types: Understorey fine fuels; Understorey course fuels; Fire ladders; Canopy fuels.

This risk assessment was completed using a three step process.

Step 0. Preliminary walkthrough
Along with other team members, a walkthrough was undertaken of the area around Lake Maxwell, and up to Dry Lake, near the headwaters of the watershed. This walkthrough identified a core area of investigation on the Waterworks District lands which was typified by closed canopy or self thinning Douglas Fir dominated stands with high canopy closure, across a range of mesic to xeric sites.

Step 1. Preliminary area stratification based on LiDAR interpretation and existing datasets, to identify sample points.
Data used
• Provincial LiDAR data (2019), classified for ground (class 2) versus non ground points
• Provincial Vegetation Resource Inventory (VRI) data

Methods
• Density of non-ground points was extracted from LiDAR data using both 3m by 3m and 20m by 20m raster grids
• Tree height was extracted using a 3m by 3m raster grid
• Within the core area of investigation, sites were identified for sampling covering a 2 by 2 grid of higher and lower canopy closure, and higher and lower tree height.

Step 2. Field work to calibrate the model development
17 plots were installed at pre-identified locations in the core area, covering the range of tree heights and canopy closure. Plots were designed to produce calibration data between specific sites and LiDAR and other datasets, rather than statistically significant quantitative data. Site selection was aimed at representation, not random or systematic distribution. Data collected included (Table, below):
• Vertical canopy photos
• Horizontal stand photos
• Basal area estimates based on prism plots
• Qualitative grading of fire ladder risk
• % cover of fine and course ground fuels
• % of standing stems which were dead
• Canopy contact and gap estimates
• A qualitative description of the site.

Step 3. Final modeling of each fuel type

Data used
• Provincial LiDAR data (2019)
• Provincial Vegetation Resource Inventory (VRI) data
• Field plot data

Methods
• Cleaned versions of the same LiDAR datasets were provided by Greg Johnson
• LiDAR points (other than Class 2 ground points) were reclassified using the following classes a. Class 3 – Low vegetation. Points between 0 and 1m above ground. These points included returns from both low vegetation and course woody debris.
b. Class 4 – Medium vegetation. Points between 1 and 5m above ground. These points included taller salal, ocean spray, and similar vegetation, as well as some suspended course woody debris.
c. Class 5 – Canopy. Points greater than 5m above ground. These points captured the canopy of most of the trees, which had largely self pruned to heights above 5m. Some cedar canopies and canopies of trees bordering openings were included in lower classes, but this class was expected to capture 95%+ of the canopy.

• Maximum tree height was extracted using a 20m by 20m raster grid. The 3m by 3m raster grid used in the preliminary classification captured too much noise, and the 20m grid was expected to be more useful for management purposes.
• Canopy closure (Class 5 points as a percentage of all points) was calculated using a 20m by 20m raster grid.
• Raster grids were vectorized, intersected, and combined with the VRI polygons to produce a single polygon layer capturing the three datasets.
• The data in the polygon layer was compared with the data from the field plots, as well as qualitative observations from the walkthrough, to calibrate relations between crown closure, tree height, and VRI data, and fuel loads in each of the fuel categories. In the case of the canopy fuel layer, classes were derived directly from the LiDAR canopy closure dataset. For the other fuel types, proxies were identified in the LiDAR and VRI data for each fuel type. The final classification criteria were:

1. Course Fuels a. Canopy % >40 AND Canopy % <80 AND
b. Tree Ht. <35 AND Tree Ht. > 20 AND
c. Basal Area > 35
2. Fine Fuels
a. Canopy % > 80 AND
b. Tree Ht. > 35
3. Ladder Fuels
a. Canopy % < 45

• Using these criteria, the area covered by the LIDAR dataset was classified for each of the fuel types.
• Ignition Risk areas were identified where fine fuels, ladder fuels, and trails or human use areas coincided.

It is important to recognize that these classification criteria are locationally and temporally specific – they reflect the particular stand age and development processes occurring within the watershed at this time. Development of similar criteria for other locations, or classification within this watershed at a significantly different time, would require doing all of the steps discussed above for the time and location of interest.

Results

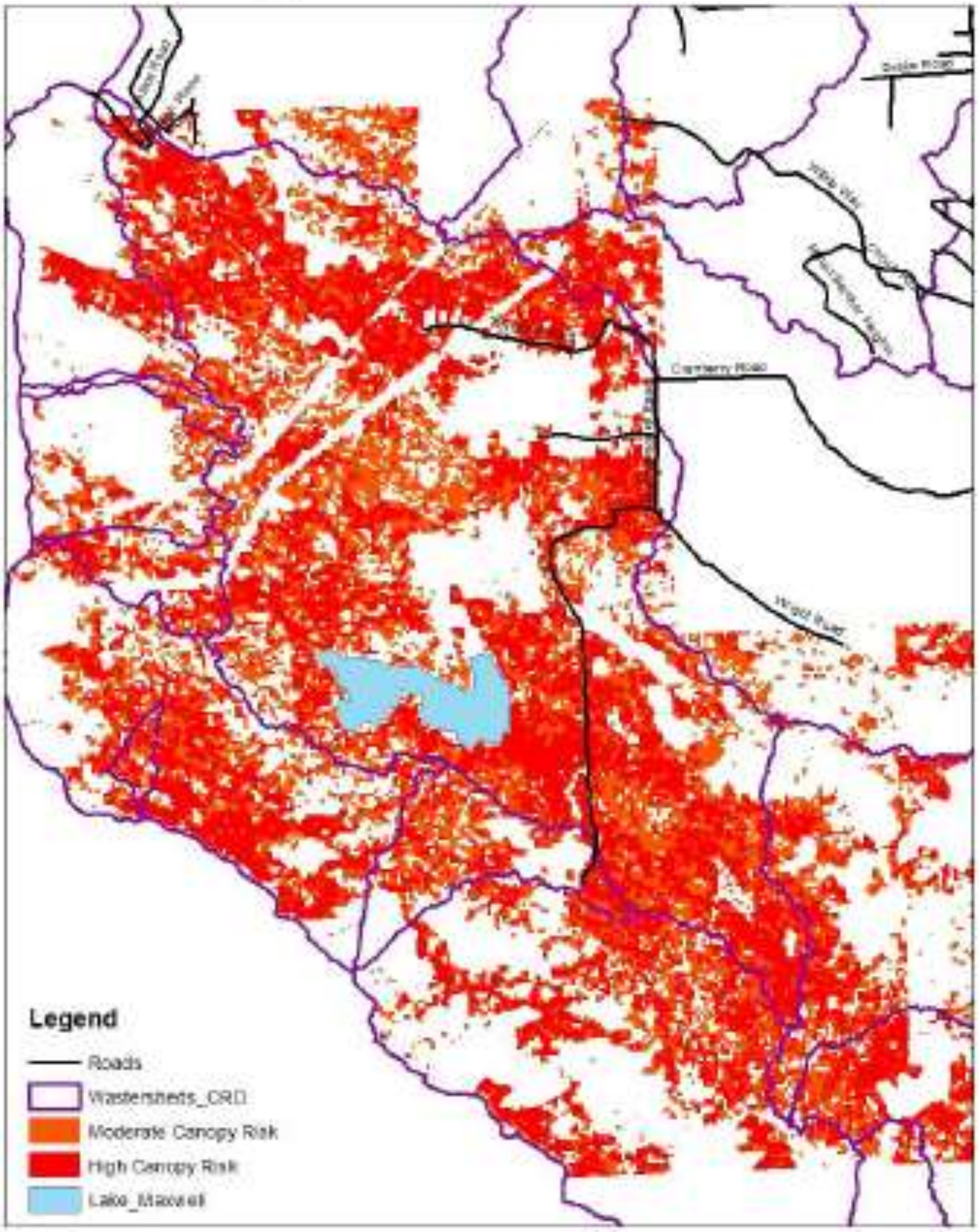
The work undertaken resulted in five maps of the study area (Appendices 2 through 6), showing risk areas for each of the fuel types, and high ignition risk areas.

Apart from canopy fuels, fuel risk mapping was undertaken using proxies. While these proxies were well calibrated with field data, the resulting maps (Figure, below) should not be interpreted as showing where fuel types are or are not, but rather as showing where increased likelihoods of significant loads of these fuel types are. Areas of high fuel density could occur outside of these mapped areas, and areas of low fuel density could occur within them. However overall these maps should be useful for identifying risk areas for particular fuel types and fire processes, and in identifying areas where on-the-ground fuel reduction measures should be considered.

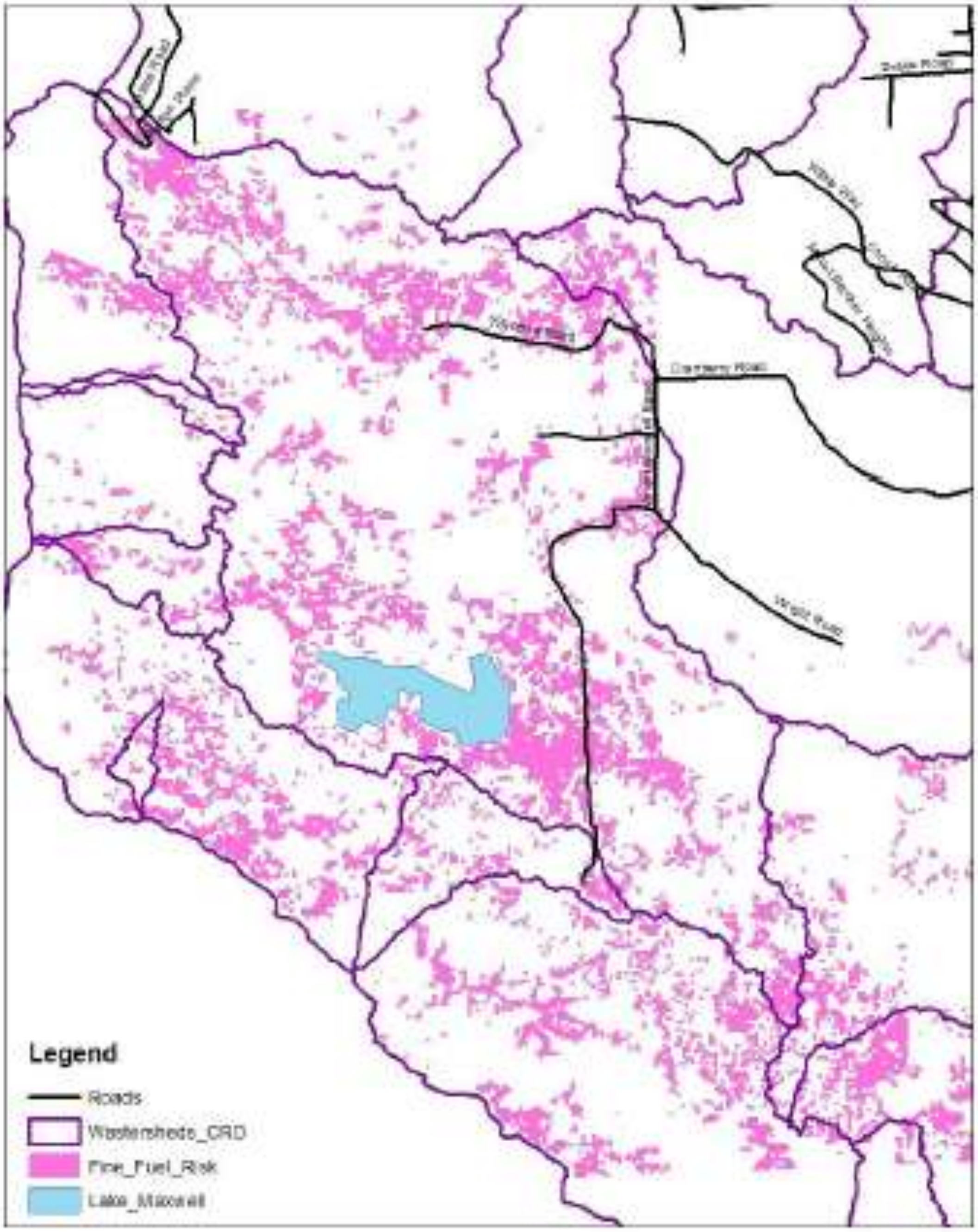
Table 2 Fire Risk Field Data.

Plot	Prism count	Basal area (m2/ha)	Fire Ladder	Fine Fuels	Course fuels	Standing dead	Description	Other notes	Canopy
1	10	30	0	3%	0%	0%	Fd dominated stand which was thinned +/- 20 years ago - great demonstration site of the benefits of thinning. Appears that thinned stems were removed. May consider minor future thinning. Limited understorey.		Most crowns in contact with at least 2 other trees, moderate gaps
2	10	30	1	1%	2%	0%	Similar to Point 1, but an understorey layer of Hw is developing, showing movement toward OG structure	L4 = Hw 100	Most crowns in contact with at least 2 other trees. Minor gaps
3	13	39	1	1%	5%	0%	Similar to Point 2. Much of the course fuel is showing substantial decay.	L4 = Hw95Cw5	Most crowns in contact with 3 or more trees, minor gaps
4	17	51	1	40%	2%	2%	Streamside plot, not thinned. Dense Fd/Cw stand with some large trees. Good site. Some opportunity to thin.		Most crowns in contact with 3 or more trees
5	15	45	0	20%	4%	5%	Similar to plot 4, nearer the road, has experienced blowdown (1 - 55cm Cw)		Most crowns in contact with 3 or more trees, minor gaps
6	7	21	1	5%	1%	0%	Open Fd dominated stand with good understorey salal cover. At least 50% mortality in L3/L4 - probably due to heat/drought	L3 = Cw100, L4 = Hw 100	Most crowns in contact with at least 2 other trees, but major gaps
7	8	24	1	3%	15%	15%	Plots 1 - 6 were in good to medium sites. Plot 7 is in medium to poor site regenerated with a somewhat higher density of trees, and shows a lot of mortality in the codominant layer. Some salal remains in the understorey.		Most crowns in contact with at least 2 other trees, but major gaps, standing dead
8	15	45	1	1%	10%	10%	Similar to plot 7, but somewhat higher tree density.		Most crowns in contact with at least 2 other trees. Minor gaps

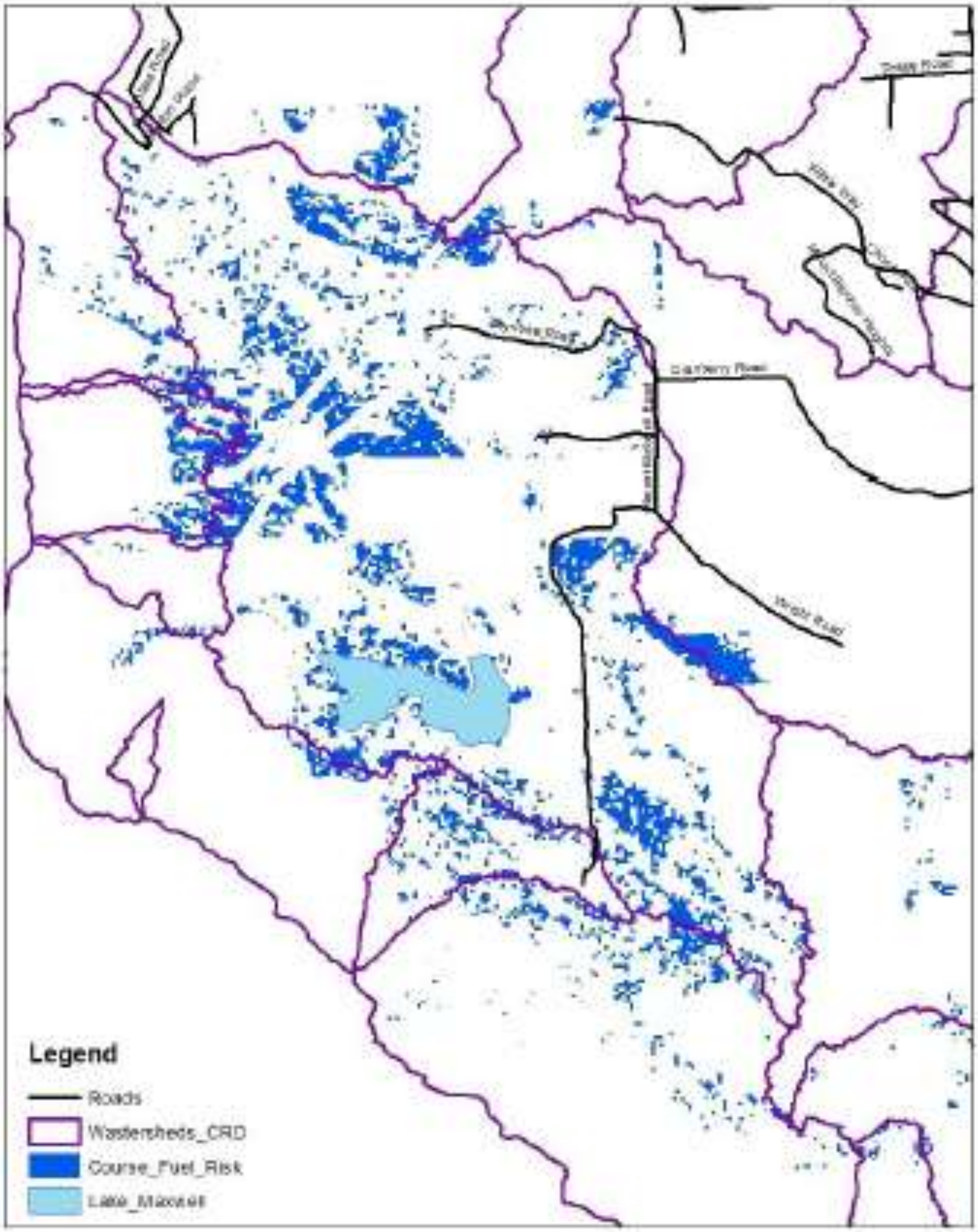
Maxwell Canopy Fire Risk



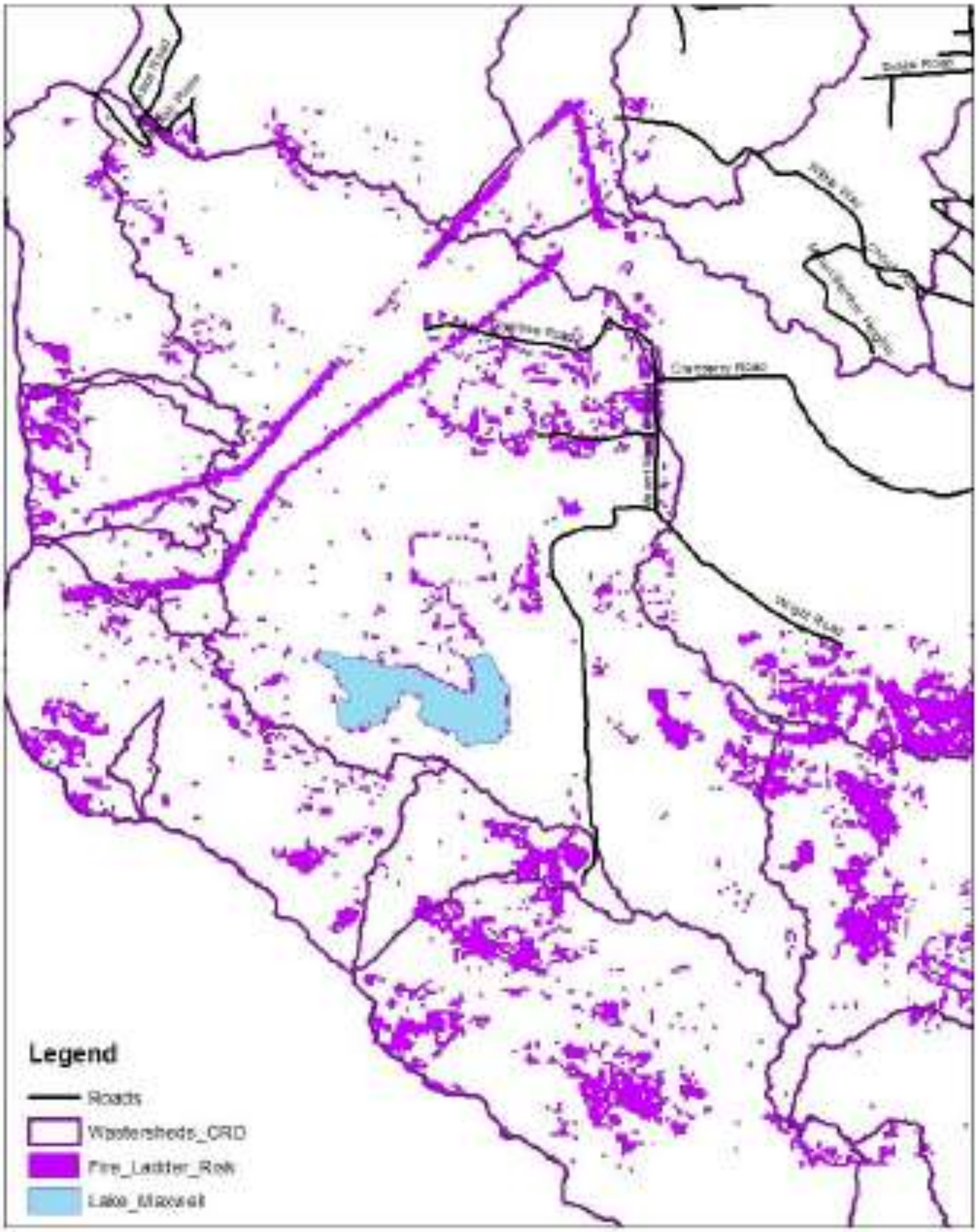
Maxwell Fine Fuel Risk



Maxwell Course Fuel Risk



Maxwell Fire Ladder Risk



Restoration Prescription

Site Name : Mount Maxwell Test Site
Location : See attached map
Owner : North Salt Spring Waterworks District
Restoration Manager : Transition Salt Spring Society
Covenant Holder : Salt Spring Island Conservancy; Land Trust of British Columbia.

Site Description

Site is located on the north slope of Mount Maxwell, to the East of Mount Maxwell Road. Along with much of the surrounding area, the site was clearcut around 70 years ago, and regenerated naturally to uniform age high density Coastal Douglas Fir (inset). This high density stand has resulted in high crown closure, and significant shade an root competition, which, together with browse pressures, has been a significant driver of widespread loss of native understorey species

Portions of the surrounding area regenerated at a higher density, and have already experienced significant self thinning. This self thinning has:

- Created canopy gaps where increased light is reaching the ground, which may encourage the re-establishment of native understorey vegetation
- Reduced the canopy closure and canopy to canopy interconnection, providing some reduction in the likelihood that the stand would carry a canopy fire.
- Created areas with a short-term increase in fine fuel loads on the forest floor, which has increased the ability of these areas to carry ground fire.
- Deposited significant levels of course woody debris (logs over 10 cm diameter), which are currently criss-crossed and providing some barrier to ungulate access.
- Created a gap and clump structure which will help to initiate the development of a mor heterogenous, old growth structure in the stand in the future.

In comparison, the treatment site has not experienced self thinning, and retains:

- High canopy closure and shading of the ground
- High risk of transmitting crown fire and high local ignition (being next to a major path used to enter the covenant area by the public).
- Highly impacted forest edge subject to fire risk, human disturbance, as well as sedimentation and pollution from the road.
- Lower levels of course woody debris, and few barriers to ungulate access
- A more homogenous stand structure, which is likely to persist for a significant period of time before natural development toward a heterogenous stand structure.

Treatment Goals

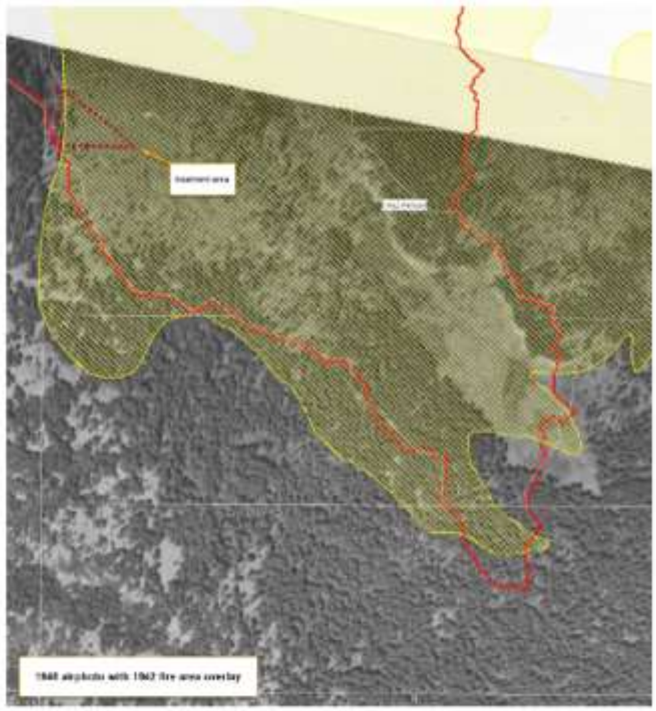
The treatment goal is to accelerate the progression of the stand toward an old growth stand structure while reducing the risk of damage or loss of the stand due to ground or canopy fire.

This will be accomplished by creating a more heterogenous gap/clump canopy structure to

- Accelerate the development of old growth stand structure, including more heterogenous tree sizes, species and ages by increasing growth rates of dominant trees released from competition, while creating openings where seedlings can become established.
- Reduce the risk of canopy fire spread by reducing the canopy closure and canopy to canopy contact.
- Maintain and enhance forest understorey vegetation and biodiversity by increasing the light reaching the forest floor. This site has some remaining understorey of keystone species such as Salal and Oregon Grape, as it did not close canopy as early as some of the surrounding areas. However, without treatment the understorey cover and diversity will continue to decline.

- Reduce ease of access for ungulates (Coastal Blacktail Deer) by retaining course woody debris in the stand post harvest, without creating course fuel concentrations which increase fire hazard
- Reduce the deposition of fine fuels during the thinning process, as compared with natural thinning, to limit the impacts of the thinning on ground fire risk.

General description of proposed stand treatments to reduce fire risk at the Maxwell trial area



The trial area within the Maxwell watershed currently consists of a dense approximately 60 year old Douglas Fir dominated stand. Although this site underwent a large area fire in 1942 in association with clearcutting, our study of fuel loads and fire risk shows that this stand has regrown an extreme canopy fire risk (inset); this is due to the relatively dense, homogenous tree canopies and hydrological changes associated with past clearcutting. The high stand density is reducing understorey richness and inhibiting regeneration of new trees which would begin moving the stand towards a multi-aged old growth condition. The stands are also significantly low in downed large wood, which is a key habitat feature in healthy forests.

Target conditions for the stand would see a density reduction of at least 50%, with a pattern of clumps and gaps increasing the number of ecological niches within the stand, enabling regeneration of a new cohort of trees in the gaps, and providing reduced canopy continuity and fire risk. However, undertaking this treatment in one pass would result in higher windthrow risk within the stand. The proposed treatment is therefore to remove between 30 and 40% of the trees, but with a focus on smaller trees which are struggling.

No cedars will be removed, as cedars are a minor species in this stand which should be retained as part of the long-term stand composition. Removal will not be homogenous across the stand, but will be targeted to begin developing a clump/gap distribution.

Because the focus will be on smaller trees, initial canopy reduction will be around 20%. This degree of canopy reduction will encourage remaining trees to become more windfirm, and accelerate their growth, without significant increase in windthrow risk.

Significant amounts of the course wood will be retained within the stand, consistent with not causing unacceptable fire risk increase. Fine debris (smaller branches, twigs) will be chopped and either distributed or removed, with the goal of retaining biomass in the forest while not creating a fine fuel blanket which could carry ground fire. This treatment should be followed by a subsequent thinning treatment in about 10 years to achieve target densities and tree distributions.

A similar thinning treatment and rate of removal was undertaken on adjacent stands in the Maxwell Creek Watershed about 20 years ago, but without the focus on creating stand heterogeneity (Figure 8). Since this time, the canopy has closed and the trees have a larger Diameter-at-breast-height than trees in the covenanted forest.

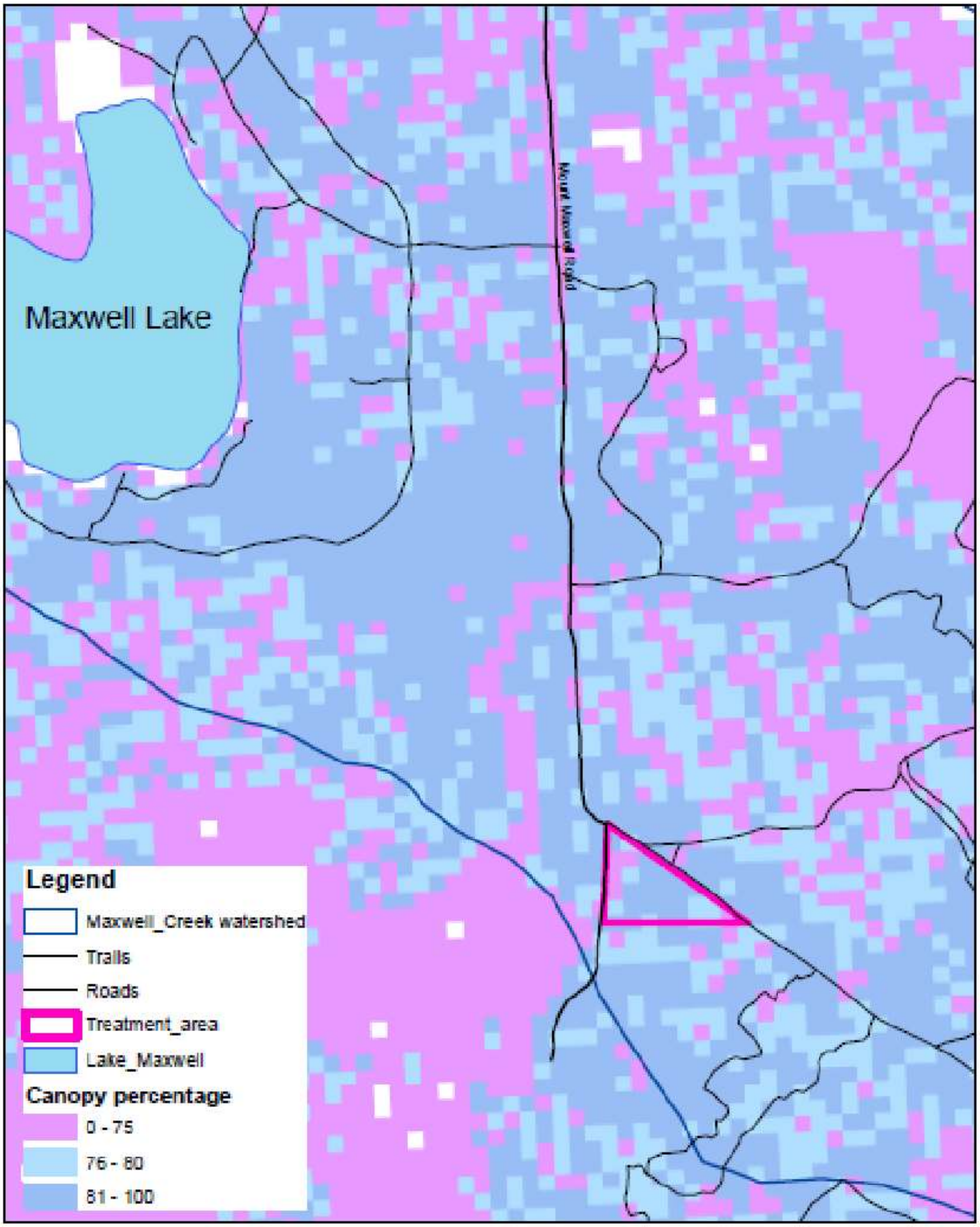
The results of the thinning treatment found within the covenant area show that this rate of removal did not result in increased windthrow, and did accelerate the growth of the remaining trees onsite. Because the trees left behind were relatively evenly spaced, development of understorey diversity has been modest, but there are areas where a second layer of young hemlock has begun to develop. Preliminary views of archival aerial photos suggest trees are of a similar age and history to other forested areas in the covenant, however, tree aging will be required to determine rates of growth and tree age.

Treatment will be undertaken using 100% marking, indicating the trees to be removed, the target direction of falling, and whether the downed tree will be retained as course woody debris, or removed. This will be preceded by evaluation by a licensed Danger Tree Expert. This approach will give the project team good control over the final stand and understorey condition, and will allow review of the plan on the ground by the landowner, covenant holders, and others prior to undertaking the work.

The resulting stand will be in a condition which will accelerate development of old forest conditions, and increase biodiversity, while reducing fire risk.

Figure 8. Photographs showing conditions found in the covenant forests at Maxwell Creek Watershed. Left photo: image showing trees in high density area that is the target area of this work. Right photograph: photo of similar age stand in covenant thinned ~2000.

Maxwell Watershed Fire Risk Reduction Treatment Area



Treatment methods

Selection and Marking

- All trees to be felled/topped during the treatment must be marked prior to the beginning of treatment. Marking should indicate the following classes:
    - Trees to be topped
    - Trees to be felled and removed
    - Trees to be felled and retained onsite
- For trees to be felled, target direction of felling will also be indicated, with the goal of optimizing the distribution of course woody debris, and minimizing impacts from trees to be removed.
- Prior to marking a wildlife/danger tree survey of the treatment area must be undertaken. Wildlife trees must be marked for retention, including surrounding trees where necessary to retain wildlife values. Danger trees must be marked for removal. The Wildlife/danger tree surveyor may establish conditions under which marking may take place prior to removal of the danger trees. All danger trees must be removed prior to treatment.
- Tree selection should result in creation of gaps (15% of the area), clumps (15% of the area), and heterogenous stands[11] (70% of the area)
- Priority for felling/topping will be given to trees which are
    - Subdominant in the canopy (smaller trees first)
    - Show signs of tree health issues including fungal or insect attack, root rot, or root instability.
    - Within areas selected for creation of a gap
- Gaps will be
    - Not less than 0.75 tree heights across, nor more than 1.5 tree heights across
    - May include one or two dominant trees retained within the gap
    - Where root rot is found, centered on the root rot incidence tree or trees, and including the removal of uninfected trees around the infected trees
- Clumps will be
    - Not less than 0.75 tree heights across, nor more than 1.5 tree heights across
    - Centered around one or more dominant trees showing good form and health.
    - Not contain any trees showing evidence of root rot
    - May include felling or topping of trees within the clump to provide growth room for dominant trees
- Heterogenous stand will

[11] Heterogeneous stand area refers to 70% of the total area, which will be left with an uneven distribution of closed and open spaced trees of uneven distribution. This is in contrast to the uniform and equi-distant spacing used for silvicultural purposes, which leaves a homogenous stand structure (contrast Figure 8 photos, evenly vs heterogenous spacing is visible). The 70% is the end target of the directed thinning activities in this 2 acre site.

    - Contain a 7 to 1 inter-tree spacing range (i.e. if the smallest distance between any two neighbouring retained trees is 1.5 meters, the greatest distance will be 10.5 meters)
    - Have an average canopy closure of not less than 60% nor more than 70%, not counting trees less than 5 meters tall.
    - Retain tree species and age diversity where-ever possible (i.e trees younger or older than the dominant stand, and species other than Douglas Fir will be given priority for retention if they are healthy and vigorous)
- All trees less than 5 meters tall are to be retained
- Topping (removal of the stem to below the lowest live limb or 10 meters, whichever is greater) may be used as a treatment on up to 10% of the trees to provide habitat (snags and future Coarse wood) for key species, including bats, woodpeckers, etc.
- Topping may not be used if there is a trail, road, or other area with signs of consistent human use within 1.5 times the anticipated height of the topped tree.
- Where potential fire ladders exist (typically along roads or trails) trees may be marked for pruning of lower live branches up to 5m or half the canopy height, whichever is less, to provide a fuel break.

<u>Thinning and topping</u> – thinning activities will be organized in collaboration with those with responsibilities to the Maxwell Road (Maxwell Provincial Park, BC Ministry of Transportation, and local residents (through the NSSWD) to provide early notification of the proposed work, dates and details of how the road and community safety and management of the road will be undertaken. North Salt Spring Waterworks will lead the communication and coordination and oversight, including signage and notification. The project team will secure the treatment area during thinning and follow up work using visible markers with personnel at all points of possible trespass or interaction with the community.

- Felling and topping may only be undertaken by practitioners with appropriate training, certification and insurance.
- Where treatments are within 1.5 tree heights of a road or trail, traffic control personnel must stop traffic on the road or trail during each period of active felling or topping
- Topping trees must be sound. Topping should take place prior to falling, to minimize the risk of destabilization of the tree to be topped.
- Primary priority in determining the method and direction of felling must be determined based on (in order of consideration)
    - Safety of the feller, other staff, and the public
    - Minimization of potential for damage to other trees or understorey vegetation during both felling and subsequent movin of timber and fine woody debris
    - The direction designated during layout.

- Trees to be removed should be bucked to firewood lengths onsite, rather than yarded or skidded as a log, to minimize onsite damage. The resulting rounds will be removed from the stand by hand, to the nearest NSSWD access trail. Once at the trail, a small quad and trailer or similar low ground pressure narrow track equipment will be used (existing trail used by NSSWD, no new trails and no quads will enter forested area). Foot removal trails will be designated during layout.
- Limbs and tops of trees must be either removed or bucked into pieces < I m in length and lying in close contact with the ground, which may require some movement and distribution of bucked pieces. Decisions on removal versus bucking may be made during treatment, and will depend on the fine fuel loading in the area.
- Trees to be retained should be bucked where required to reduce the maximum height of the timber off the ground to less than 1 m. Depending on fine fuel loading, some limbing and removal of fine fuels may be required.

Understorey re-establishment and herbivory protection

- Where existing sources of propagules or root sprouts are not present, planting of keystone native species will be undertaken to re-introduce the species to the site. Planted stock is typically highly attractive to ungulates immediately after planting, and will be protected using localized fencing for two years, after which this will be removed.
- Enhanced seedbeds for native species re-establishment will be created by, as and if necessary, modest soil disturbance, and potential adding of seeds of short lived species, which can add nutrients and organic matter to the soil.
- Some areas will be fenced to make deer access difficult. These exclosure areas will allow the impact of herbivory on understorey species establishment and growth to be measures. Exclosures will be retained for a 5 years (Activity 3; 2027), and will include areas which have been planted or had seedbed prepared.

Treatment Risks and Mitigation Techniques – prior to any activities in the designated project site, NSSWD and TSS will notify residents of the upcoming work, including the timing, nature of the work, safety precautions (as described earlier in the Treatment and Methods Section).

a. Treatment increases the risk of windthrow
   Risk: Thinning treatments can reduce the stability of the stand as a whole, and individual trees, during major wind events, resulting in excessive losses of trees.
   Mitigation
   - Treatment during this treatment phase will remove not more than 30% of the canopy trees. The resulting density will be higher than typical densities of old growth stands, and at least a second treatment in 20 – 30 years will be required to once again reduce tree density and canopy closure to continue moving toward more OG stand characteristics.

- Trees to be retained will be selected for soundness.
- Some isolated windthrow is an acceptable part of the treatment, continuing to move the stand toward OG structure, and creating useful areas of soil disturbance which enhance the establishment of understorey species and new tree regeneration, adding to the stand age diversity.

b. Treatment results in significantly increased risk of ground fire carrying through the stand.
   Risk: The treatment may result in an initial increase in ground level fine fuel loading.
   Mitigation
   - Treatment will take place in the fall, which will allow needles and fine fuels to fall and begin to decay during winter, when fire risk is very low.
   - Fine fuels will be dropped into contact with the ground, to increase decay rates and moisture levels in the fuels
   - Where unacceptable fine fuel accumulations occur, fine fuels will be removed from the stand for offsite disposal.

c. Treatment does not sufficiently reduce canopy fire risk
   Risk: Canopy interconnection reduces the wind speeds and increases the fuel moisture levels which will allow fire to carry in the canopy. The planned thinning levels may not substantially reduce this risk.
   Mitigation
   - Treatment levels will be a balance between reducing canopy fire risk, and retaining sufficient stand stability to manage windthrow risk.
   - Siting of canopy gaps will take into account other stand features (presence of higher soil moisture, deciduous species, etc.) to enhance the ability of canopy gaps to provide some resistance to canopy fore carrying through the stand.
   - Where ladder fuels may exist, such as along roads or trails, pruning will be used to reduce the risk of fire laddering.

d. Treatment results in significant compaction or disturbance of understorey soil and plants
   Risk: Extraction of wood and fine fuels can damage understorey vegetation and compact soils.
   Mitigation
   - Removals will be undertaken by hand, and bulk removal will only be undertaken outside the forest stand using narrow track, low ground pressure machinery (equipment will be used in this regard only on the Maxwell Road and NSSWD operations trail).

- Removals will be undertaken along marked paths, chose to minimize the risks to understorey vegetation or soils.

e. Treatment does not create conditions required for regeneration of understorey plants and another generation of trees.
Risk: In many areas the understorey has been so suppressed by shading, root competition, and herbivory, that few extant plants remain. The level of canopy removal and microsite creation may not be sufficient to allow understorey plants to establish, or no propagules may be present.
Mitigation
    - In areas with little or no retained understorey vegetation, keystone species may be planted, with short term herbivory protection to allow plants to establish.
    - Exclosures may be used to provide longer term restrictions to herbivory in some areas
    - The gap areas will provide higher light levels, and serve as preferred establishment sites for native vegetation
    - In some of the gap areas, manual disturbance of the soil may be used to emulate natural conditions after windthrow, providing sites foe seed establishment

f. Treatment duration is insufficiently long to observe responses to treatments.
Risk: Measuring ecological change during a short window (two growing seasons) is limited and may not accurately reflect ecosystem response(s) to restoration activities. The end date of 2024 may lead to a failure to document changes and response, thereby providing limited information during the duration of this proposed work.
Mitigation
    - Treatment plots are being included to more directly examine the factors limiting regeneration, notably: light, herbivory, soil moisture, and readily available seedbank. Native plant seed for carefully selected annual and biannual species will be introduced in thinned and un-treated long-term monitoring plots within the forest treatment. Species will include those with different light and soil moisture requirements in fenced and unfenced plots.
    - Herbivory and species present in the understorey within the experimental plots described here will be monitored regularly during the period of this work by active team members. Students and community volunteers, including members of the ERN will continue the monitoring over time to capture emerging patterns and changes in plant species composition, changes in tree DBH and recruitment, etc.
    - TSS will work to develop opportunities with the newly formed Naturalist Club, the UVic Restoration Program, and RainCoast.

g. Treatment increases the risk of root rot spread
   Risk: Harvest or thinning can increase the risk of root rot spread in a stand, providing fungal organisms with enhanced growth sites in dead roots.
   Mitigation
   - Typical mitigation techniques (removal of stumps) are not possible during this treatment.
   - Where possible, existing root rot sites will be buffered during treatment
   - Root rot resistant species (Red cedar, alder) may be recommended for planting in some gaps around root rot centres at a future date, to reduce the risk of spread to other trees.[12] This will not be an activity undertaken as part of this proposed work, but may be recommended.

The short tenure and scope of this pilot treatment requires that data be analysed using a Before-After-Control-Impact design to isolate the effect of treatment from natural variability (Smokorowski & Randall 2017). The central intervention, or impact, is gap thinning of trees in a 2 acre forested area. Pre- and Post- treatment will be monitored for 5-10 plots within the thinned area and compared against a reference subsample (10 control plots) drawn from the existing 40 reference plots based on key variables (canopy closure, soil moisture, tree density).

Before- and After- variables to measure impact will be monitored at all treatment plots and control plots described above. These will include: seed germination counts for forbs/herbs along four transects (light effect); tree growth rates (coring in 2024 to establish annual growth rates); plant species diversity. Monitoring frequency will differ among measurements as follows: Pre/Post seed germination – May/June and July/August in 2023, 2024, 2025; Pre/Post tree growth rates – determined from cores taken in 2024 (winter); plant species diversity – May/June and July/August (timing of the thinning treatment in 2022 does not allow for before and after sampling design, so plant species diversity will be analyzed using the Reference Condition Approach as described by Bowman & Sanders 2005).

[12] This is not necessary to control the spread of root rot, and would only be considered if the treatment forest is found to have a high count of affected treats. Preliminary assessment suggests this is unlikely to be required. Any such plantings would be limited to introducing sapling alder directly to affected areas.

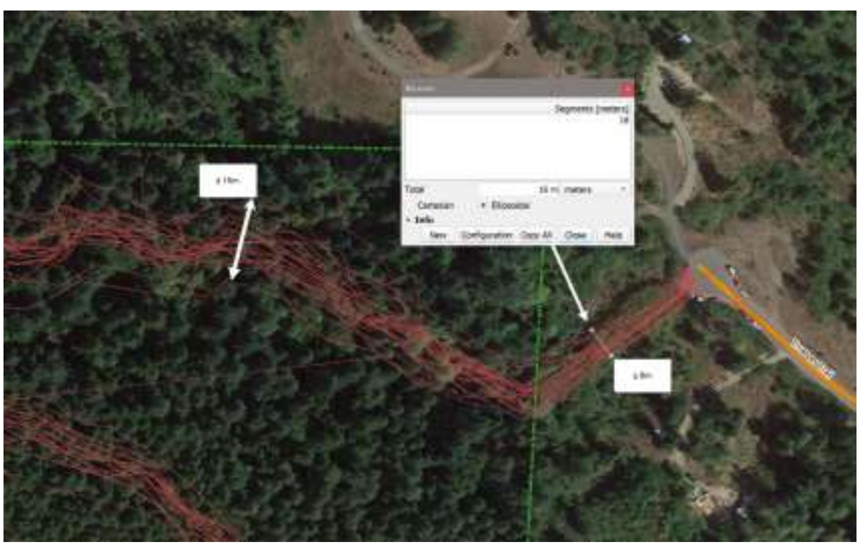
APPENDIX IV: Maxwell Creek Fire Risk Reduction and Watershed Restoration Project Site Selection Methods.

Objective: Site selection aims to identify 10 sites for each of four classifications of interest (closed/wet, closed/dry, open/wet, open/dry). Sites will be visited in a ranked sequence that has been mapped with coordinates to identify them in the field.

The site numbering reflects the condition
S001-S100 (first digit 0) closed-dry
S101-S200 (first digit 1) closed-wet
S201-S300 (first digit 2) open-dry
S301-S400 (first digit 3) open-wet

Inclusion/exclusion
Sites will be included unless there is an obvious anomaly or accessibility issue (eg., on steep slope, site is submerged by water, or too close to structures). We will review these together.

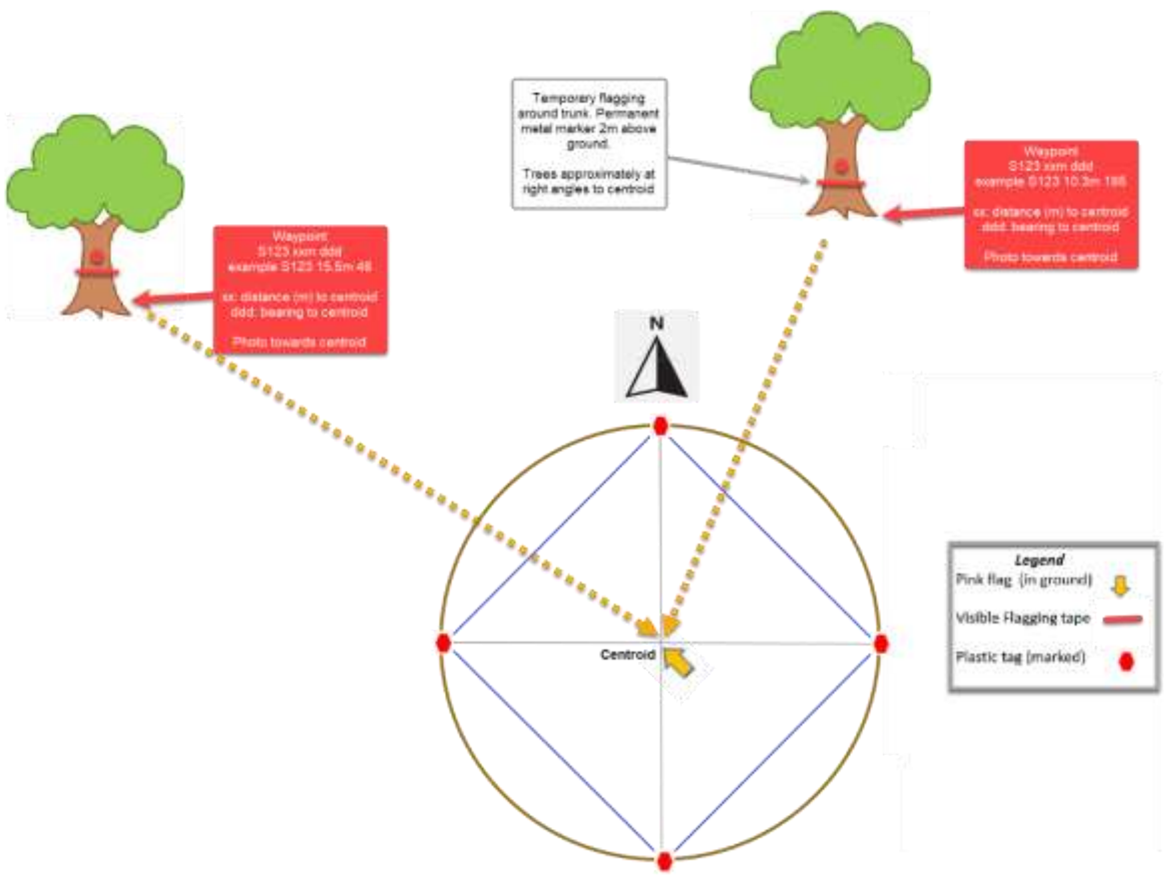
Mapping and Documentation:
Site details to collect are outlined here. This will be very important, as GPS coordinates are unreliable, and it is well established that tracks can vary by up to 15m using different handheld GPS devices (see below).



Site Mapping:
Once identified and selected (fail to exclude), a flag and plastic marker will be placed at the *centroid.* The tag number will be noted, and the flag and tag at the centroid will both be marked with the site id and cardinal point (i.e., S123C) using permanent markers provided.

Each of four cardinal points will also be flagged and labelled as seen in the figure, indicating name and cardinal point (i.e., S123E for east, etc). We will walk through the flagging and mapping together.

Labelling for plastic tags:
Centroid: S123C
Four corners of plot: S123N, S123E, S123S, S123E



Data collection

All photos and data for site selection survey should be uploaded to its appropriate site folder in /MXCK/. Example /MXCK/data/spatial_data/study_data/Site123/

Standardized nomenclature will be used. For example,
Waypoint names:

- Permanent reference markers: eg., S123 22m 111 where 111=magnetic bearing to centroid, 22=distance (m) to centroid.
- Canopy cover: S123 CC 011 where third field is percentage canopy cover
- Moisture meter: S123 MM 09 where third field is Rapitest moisture meter 0-10

For site selection, the following are the list of data to be collected at each site:

1) **Waypoints at Centroid and four corners of plot**
   Centroid waypoint name: S123C
   Corner waypoint names: S123N, S123S, S123W, S123E

2) **Waypoints on two or three reference trees**. Temporary flagging tape around trunk. Nicholas will demonstrate how to do this in the field.
   Example for site S123: Waypoint name S123 xxm bbb
   where xx distance in meters to centroid.1, bbb = magnetic bearing of centroid

3) **Photo records:**
   a) Eight compass point photos from centroid. (Theodolite or camera)
   NB. *PHOTO angled to capture ground cover and lower 3m of trees in background.*
   One photo, from each permanent reference marker (tree), of centroid in center of frame (Theodolite or camera)
   b) One photo of canopy above centroid. View north up, vertical. Also use CanopyCoverApp to get a quick estimate of cover for checklist

   NOTE Configure Theodolite to embed Site_id and data in photo image. When taking photos keep horizontal axis at 0 degrees.

4) **Record Sheet:**
   Completed site form, with any additional notes
   Site ID
   Rank No.
   Accept/Reject
   Geolocation equipment used (iPad, GPS type, phone, etc)
   Centroid Lat/Long (from file/map)

Percent cover (from app, at Centroid)
Tree (TWaypoint 1) distance to centroid*
Tree (TWaypoint 2) distance to centroid*

5) Checklist:

[ ] Cardinal points flagged/labelled
[ ] Centroid flagged with photos (8)
[ ] Tree waypoint photos (toward centroid) (2)
[ ] Canopy photo (from centroid, percent cover from app) (1)
[ ] Unusual features photo
[ ] Ground cover estimate (qualitative - shrub, herb, CWD, fine fuels, etc)
[ ] Presence of stumps (notes - large, small)

APPENDIX V: List of Fire-resistant Native Plants in the CDF Zone.

Genus & Species	Common Name	Water Needs	Sun=s / Shade=sh Full=f / Part=p
Trees			
Acer glabrum	Douglas maple	low - med	fs - psh
Acer macrophyllum	Big leaf maple	med	fs
Alnus rubra	Red Alder	med	fs - psh
Arbutus menziesii	Arbutus or Madrone	low	fs
Cornusnattallii	Pacific Dogwood	med	fs - psh
Malus fusca	Pacific crabapple	med - high	fs - psh
Populus spp	Cottonwood	med - high	fs
Quercus garryana	Garry Oak	low - med	fs
Sorbus sitchensis	Sitka Mountain Ash	high	fs - psh
Shrubs			
Corylus cournuta california	Beaked Hazelnut	med	fs - psh
Cornus sericea	Red Osier Dogwood	med - high	fs
Galtheria shallon	Salal	high	fs - psh
Holociscus discolor	Oceanspray	med	fs - psh
Mahonia aquifolium	Tall Oregon Grape	low	fs - psh
Mahonia nervosa	Dull Oregon Grape	low - med	
Oemleria cerasiformis	Indigenous Plum	low - med	fs - psh
Physocarpus opulifolius	Ninebark	low - med	fs - psh
Prunusemarginata	Bittercherry	med - high	fs - psh
Rhododendron Albiflorum	White-Flowered Rhodo	high	fs - psh
Rosa nutkana	Nootka Rose	med	fs
Ribes spp.	Wild Currants	low - high	fs - psh
Rubus spectabile	Salmonberry	high	fs - psh
Rubus spp.	Blackcap, Thimbleberry	low - med	fs - psh
Salix spp.	Willow	high	fs
Sambucus spp	Elderberry	low	fs - psh
Spirea douglasii	W. spirea, Hardhack	med	fs - psh
Symphoricarpos albus	Snowberry	med	fs - psh
Vaccinium spp	Blueberry, Huckleberry	med - high	fs - psh

Vines and Groundcovers			
Antennaria rosea	Pussytoes	low - med	fs
Actostaphylos uva-ursi	Kinnickinnick	very low	fs - psh
Lonicera spp.	Honeysuckle	low - med	fs - psh
Sedum spp.	Stonecrop	very low	fs - psh
Rushes and Sedges			
Carex spp.	Sedges	fs - psh	high
Scirpus spp.	Bulrushes, Tule	fs	high
Perennials & Biennials			
Achillea millefolium	Yarrow	very low	fs
Anaphalis margaritacea	Pearly Everlasting	low	fs
Aquilegia Formosa	Columbine	med	fs - psh
Armeria maritima	Sea Pinks	med	fs - psh
Aster spp.	Asters	med	fs
Cerastium arvense	Field Chickweed	low	fs
Claytonia spp.	Miner's Lettuce	high	fs - psh
Dodecatheon spp.	Shooting Stars	high	psh - fsh
Epilobium augustifolium	Fireweed	low	fs - psh
Erigeron philadelphicus	Fleabane	low	fs
Eriophyllum lanatum	Woolly Sunflower	low	fs
Fragaria spp.	Wild Strawberry	med	fs
Geum macrophyllum	Large-leaved Avens	low - med	fs - psh
Heuchera spp.	Alumroot, Coral Bells	low - med	fs - psh
Lupinus spp.	Arctic & Seashore Lupines	low - med	fs
Oenothera contorta	Contorted Pod Primrose	low	fs - psh
Potentilla spp.	Cinquefoils, Silverweed	med - high	fs - psh
Saxifrage spp.	Saxifrages	med - high	fs - psh
Solidago spp	Goldenrod	med	fs
Veronica spp.	Speedwell	med - high	fs - psh
Viola spp.	Violets	low -high	fs - psh

Bulbs			
Allium spp.	Nodding & Hooker's Onion	low- med	fs - psh
Brodiaea spp.	Fool's onion, Compact Lily	low	fs
Camassia quamash	Camas	low - med	fs
Erythronium spp.	Fawn & Glacier Lilies	med - high	fs - psh
Fritillaria spp.	Chocolate Lily, Rice Root	med - high	fs
Ferns, Horsetails, Mosses	many species	low - high	fs - fsh

Please note: in cases where more than one native species is noted, please consult a local reference to avoid planting other species within the genus that are not native to this region.

In General: Deciduous plants are less flammable than evergreens.
Broadleaf plants are less flammable than those with needle and blade-like leaves.
Moist and supple leaves are less flammable than stiff and leathery leaves.
Thick leaves are less flammable than fine or thin leaves.
Plants that produce little dead material are less flammable than those with a lot of litter.
Plants with watery sap are less flammable than plants with thick, gummy or resinous sap.
Plants without fragrance are less flammable than plants with aromatic qualities.
Plants with silver or gray leaves are less flammable than those without. However, some plants, such as the highly ignitable native fragrant sages, do not follow this rule.
Plant leaves without hair (cilia) are less flammable than those with hair on top or underneath.

APPENDIX VI: Technical Guide for Assembled Nurse Log.

Background:

This project involves the creation of two types of understorey fine fuel and coarse woody debris management techniques, assembled nurse logs and mycelial grafting. Assembled nurse logs (ASNL's) are exactly what they sound like- human-constructed objects that attempt to mimic naturally occurring, old growth nurse logs. ASNL's consist of several different parts that can include (but are not limited to) smaller logs from a thinning treatment, fine fuel branches and foliage, and wood chips. ASNL's attempt to provide an alternative solution to common fuel management practices that involve removing biological components from a forest entirely, and instead keep them on site in a way that will reduce their fire risk while creating a host of ecological benefits. Grafting is a technique designed to help aid the decomposition of larger logs on the forest floor. Any larger logs that are left on site during this project will be used for this purpose. Holes will be cut, vertically from the top, reaching the heartwood in the middle of the tree, and perpendicular to the vertical cut, allowing for drainage so that anaerobic conditions don't occur. The holes are then filled with different materials that are intended to help speed up the decomposition.

Each technique will be trailed in the Maxwell Creek Watershed, on Salt Spring Island, British Columbia. The projects will be set up over the course of a weekend and will be measured for an adaptive amount of time depending on initial results. Thinning will occur prior to the construction of the ASNL's and grafting and some m,aterials will be left on site from the thinning which will, then be used to build them.

Assembled Nurse Logs:

Materials:

The materials will need to be evenly distributed between the iterations. Each ASNL will be the same shape and size, but there will be differences between the iterations. The exact number of iterations will depend on the amount of materials left from the thinning. This will need to be evaluated before starting construction. More information about the materials can be found in the assembly step.

Site Selection:

Each ASNL should be made as uniform as possible and therefore all site characteristics should be as similar as possible. There are several factors to consider when choosing sites. This project is serving as a proof of concept, so the sites with best chances of success for our results should be chosen. Some important site characteristics are:

1. Moisture

    a. Soil moisture probes should be taken several times around each site before construction so that an average measurement can be calculated.
    b. If there are multiple potential locations, sites with higher moisture levels should be chosen.
2. Slope surrounding site
    a. Consider where on the slope the ASNL will be and how this can influence its interaction with water runoff etcetera.
3. Levelness of the ground
    a. On the immediate site, level ground is preferred. However, if this is not possible, the ground can be leveled later on with a base layer of wood chips.
4. Canopy open-ness
    a. Canopy composition above the ASNL can affect the amount of water, light, and temperature of the ASNL.
    b. Open canopies above the ASNL's are preferred, and positioning ASNL's under canopy drip lines may be beneficial to increase their moisture levels.
5. Understorey composition
    a. Less disturbance of understorey is preferable.
6. Proximity to materials
    a. Some materials may be heavy and immobile, in which case the ASNL's will have to be built around them.

Assembly

Each ASNL will be the same shape and size, but there will be differences between the iterations.

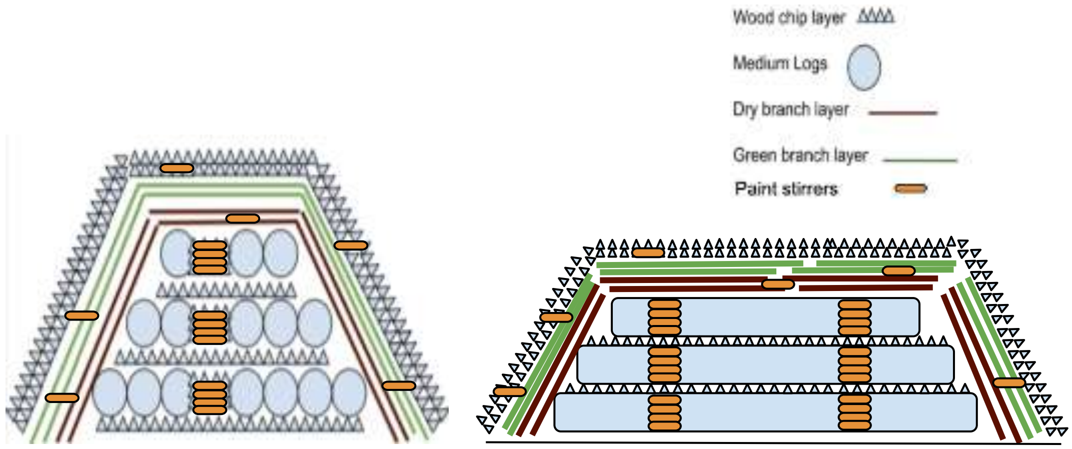
<u>The different designs include:</u>

1. Control
    a. The control is based on how the materials are typically distributed after a thinning
    b. Medium logs- left with ground contact
    c. Fine fuels- piled together
2. Pile (1) with stacked logs and foliage (no wood chips)
3. Piles (number T.B.D.) with stacked logs, wood chips, and foliage

<u>General structure:</u>

- Medium diameter (4-12 inches) logs create base and majority of mass of pile, cut to around 2M in length
- Small diameter logs (1-4 inches) primarily used for chipping
- Anything under 1 inch is used for moisture seal (foliage)

ASNL Cross Section Views



Cross section visualizations of an ASNL. Diagram created by Tal Engel and Grace Fields.

Measurements:

- In creation
    - Same amount of logs and branches in each, measure volume
    - Wood chips by measuring volume (5 gallon bucket)
    - Overall volume or weight of moisture insulation, divide into trials
    - Soil
    - Overall volume of logs (thickest part of diameter and length)

Steps to assembly:

1. Measurements of materials
    a. Same amount of logs and branches in each, measure volume
    b. Wood chips by measuring volume (of bucket?)
    c. Overall volume or weight of moisture insulation, divide into trials
2. Base
    a. Woodchip base created to level the ground, wood chips dispersed in approximate shape of pile
3. Layering
    a. Bottom layer of medium diameter logs, limbed so they can be in as close of contact as possible with each other
    b. We will be leaving a gap in the middle of the logs, and then fill it with wood chips as pictured on the diagram above, to leave room for the paint stirrers.
    c. Piles will make a pyramid with most logs in bottom layer and fewer as it builds up
        i. I.e. 9 logs on bottom layer, 5 in middle layer, 3 on top layer
    d. Layer of wood chips chips in between each layer
    e. Place paint stirrers in between layers, tied to nylon string that will be used to pull the stirrers out of the pile once they are buried. The strings will be arranged so that they are not buried and stick out of the piles.
4. Final touches

a. Wood chips and foliage are layered over the entire pile once all logs are piled. Coverage of these materials should be as consistent as possible across the ASNL.
b. Potential final touch of bucking a few logs on each end of the ASNL to encourage better coverage on ends of piles (so materials don't slide off)

Monitoring and Analysis

- Measurements:
    - Decay class of logs
    - Soil moisture probes
        - Above site, in pile, below site
    - Decomposition
        - Spruce paint stirrers
            - 6 sites throughout each ASNL with four stirrers at each site.
            - Two sites along the length of the log, with one in between each layer of logs (6 total)
            - Stirrers arranged in a way where they do not disturb one another when they are pulled out
                - Attach stirrers to strings and tie strings onto stakes based on order of removal
            - Another 6 stirrers dispersed throughout outside fine fuel layer
                - Outside branch and woochip layers, different depths
            - Within controls
                - 9 in fine fuels
                - Others below larger logs in control
            - Nylon string will be tied to the groove of the stirrers and used as a point of reference for their location and allow for them to be pulled out easily.
            - Stirrers will be pulled out at adaptable times depending on the progress of the experiment. There is potentially a large range for this.
    - Observe/document understorey development around
        - Photographs, measurements, and written records
    - Observed fungal development
        - Recording what we do see/photographs/visible observations such as fruiting bodies
        - Potential lab soil composition analysis eventually
    - Tree cores compare thinned sites with and without adjacent structures.

<u>Analysis of results:</u>
- Statistical analysis

Grafting:

Organization and materials

The grafted logs will be made out of any logs not used in the ASNL's. The amount of logs will affect how many repetitions we have of the types of grafts.

Site selection

Site selection is less important in grafting than in ASNL's. Most of the logs used in grafting will not be moveable. The only considerations to be made, if possible, are to shift the logs so that they are as close to the ground as possible, throughout the length of the log. Limbing can also be completed if necessary to help this.

Assembly

Each graft will be the same shape and size, but there will be differences between individual types.

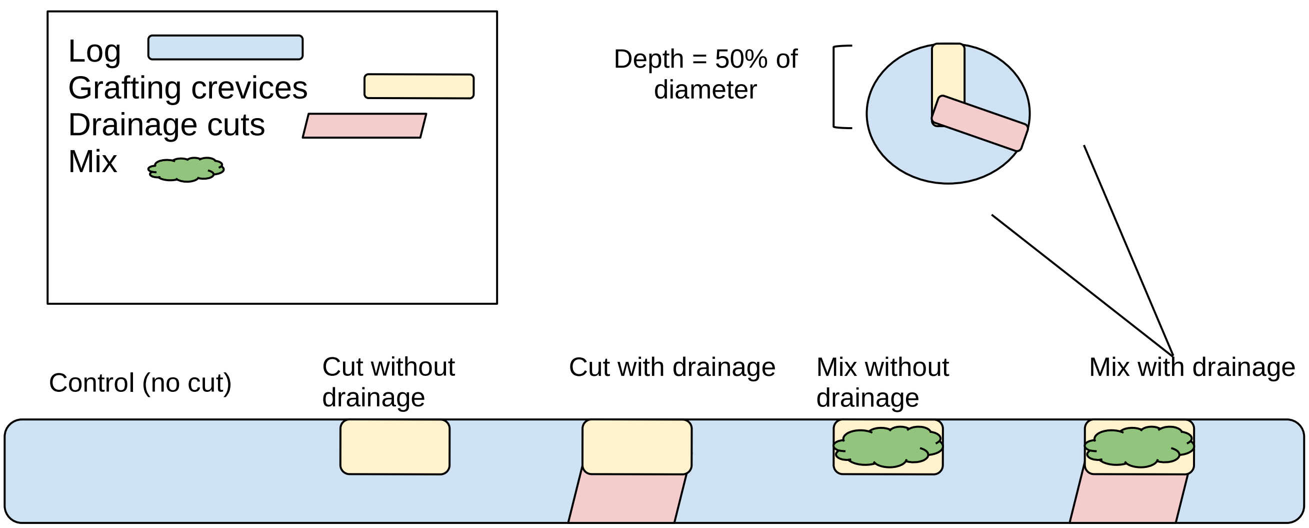
<u>The different designs include:</u>

1. Control
    a. One large log without cuts
    b. No cut in the log/skips within the randomization
2. Crevice (no fill)
3. Crevice and drainage (no fill)
4. Chips/inoculant/needles (mix) and drainage
5. Chips/inoculant/needles (mix) without drainage

<u>General structure:</u>

- Will be used in logs with a 12+ inches diameter not used in ASNL's.
- The depth of each cut will go down to the center of the log, or the length of its radius, each cut will be made straight down.
- The perpendicular cut will be made with a slightly downward angle to encourage drainage.
- Each cut will be approximately 12 inches in length and ~2 inches in width.
- Gaps between each graft will be 2x the graft length, or 24 inches. This is adaptable depending on the amount of material we have.

Grafting cross sections



Cross section visualizations of a grafted log. Diagram created by Grace Fields.

Measurements:

- In creation
    - Measure and mark radius, length of cuts, and perpendicular cut locations down the entire log
    - Three paint stirrers will be put into each graft in a row
    - Source and then pre-mix the needle, chip, and inoculant mix, make sure equal amounts go into each crevice by volume/weight.

Steps to assembly:

1. Measure
    a. Initial site/log measurements
    b. Measure and prepare for the cuts
    c. Measure the length of the logs and determine the number of individual grafts that will be able to be made, in groups of 5
2. Randomization
    a. The groups of five types of grafts will be repeated as many times as possible based on the measurements made
    b. The order of the five grafts (no cut, crevice (no fill), crevice with drainage (no fill), crevice with mix, crevice with mix with drainage) will be randomized.
    c. Goal: 100 crevices, 20 iterations of each type, although we know this may not be possible.

3. Cut
    a. All of the cuts will then be made
4. Fill
    a. Materials will be prepped and filled into the grafts according to their order
5. Place paint stirrers

Evaluation and Monitoring

Measurements:

- Decay class of logs
    - DOI: 10.1139/X07-139
- Soil moisture probes
    - Above site, in graft, below site
- Decomposition
    - Paint stirrers
        - Three in each graft, observations by removal over a period of time (T.B.D., the time over which the stirrers will be pulled for observation is adaptive based on initial progress of the project).
        - It is assumed that they will be long enough to stick out of the graph, but if this is not the case then strings will be tied to the stirrers in a similar fashion to the ASNL's.
- Observe/document understorey development around
    - Photographs, measurements, and written records
- Observed fungal development
    - Recording what we do see/photographs/visible observations such as fruiting bodies
    - Potential lab soil composition analysis eventually
- Tree cores compare thinned sites with and without adjacent structures.

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