Savary Island Community Wildfire Protection Plan

B.A. Blackwell & Associates Ltd.
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SAVARY ISLAND

COMMUNITY WILDFIRE PROTECTION PLAN

Considerations for Wildland Urban Interface Management on Savary Island, British Columbia

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1.0 Introduction

In 2008 B.A. Blackwell and Associates Ltd. were retained to assist Savary Island and the Powell River Regional District (PRRD) in developing a Community Wildfire Protection Plan (CWPP) for the Island. 'FireSmart – Protecting Your Community from Wildfire' (Partners in Protection 2004) was used to guide the protection planning process. The assessment considered important elements of community wildfire protection that included communication and education, structure protection, training, emergency response, and vegetation management.

The social, economic and environmental losses associated with the 2003 fire season emphasized the need for greater consideration and due diligence in regard to fire risk in the wildland urban interface (WUI). In considering wildfire risk in the WUI, it is important to understand the specific risk profile of a given community, which can be defined by the probability and the associated consequence of wildfire within that community. While the probability of fire in coastal communities is substantially lower when compared to the interior of British Columbia, the consequences of a large fire are likely to be very significant on Savary Island given the difficulties of evacuation, population size, values at risk, and environmental considerations.

The CWPP will provide the Island and Regional District with a framework that can be used to review and assess areas of identified high fire risk. Additionally, the information contained in this report should help to guide the development of emergency plans, emergency response, communication and education programs, bylaw development in areas of fire risk, and the management of forest lands adjacent to the community.

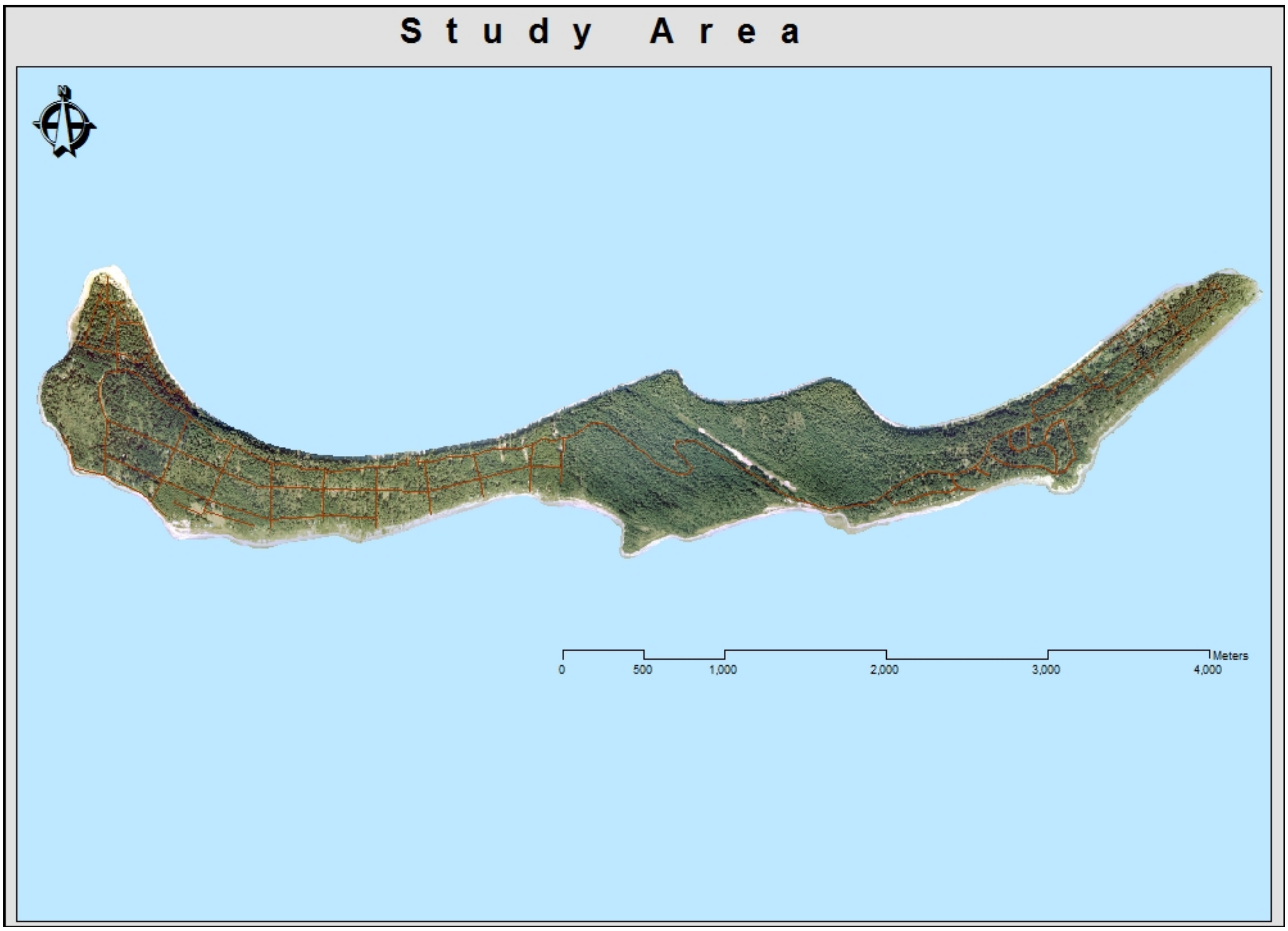
The scope of this project included three distinct phases of work:

- **Phase I** –Assessment of fire risk and development of a Wildfire Risk Management System to spatially quantify the probability and consequence of fire.
- **Phase II –** Identification of hazardous fuel types.
- **Phase III –** Development of the Plan, which outlines measures to mitigate the identified risk through structure protection, emergency response, training, communication, and education.

2.0 Savary Island

2.1 Study Area

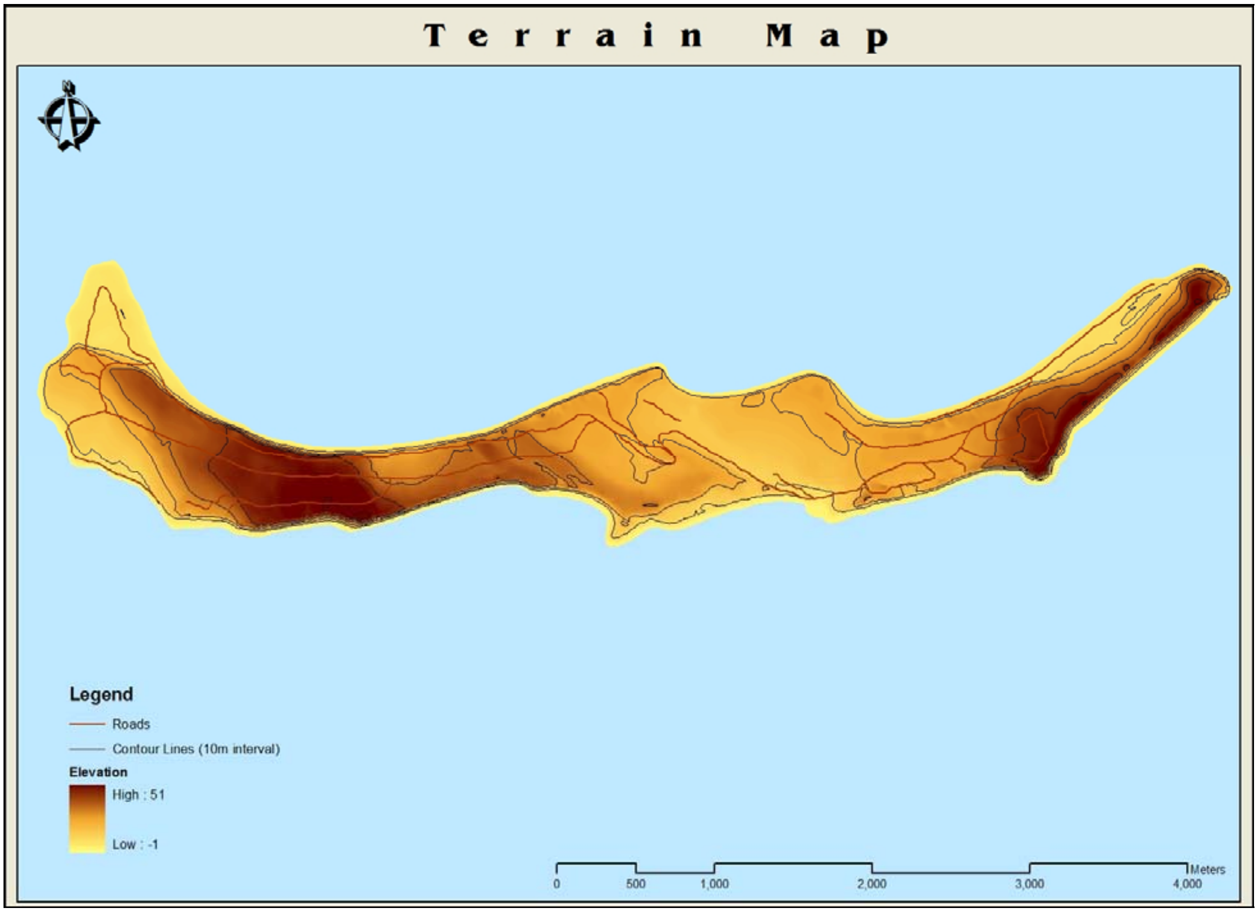
Savary Island is located in the Straight of Georgia, 21 km north of the City of Powell River. The Island is 519 ha in size (Map 1) and is accessed via private water ferries from Lund. Much of the Island is private land with 647 of the 1360 lots already developed. There are 800 landowners on the assessment roll but the permanent population of the Island is only about 50. However, due to the unique recreational opportunities provided by the relatively warm waters and sandy beaches, the population swells to around 2000 during the dry summer months.



Map 1. View of the Savary Island study area.

2.2 Topography

The Island is a remnant of the Quadra sands which were deposited by meltwater streams during the Pleistocene Epoch. The Island is primarily composed of subdued rolling terrain, sand dunes and a steep foreshore subject to soil erosion (Map 2). The only exception to this is granitic rock found on the east end of the Island near Mace Point. The most continuous slopes occur on the east end of the Island, which is also the most heavily populated.



Map 2. Topographic relief in the study area.

2.3 Infrastructure

Infrastructure on the Island consists of the road network, propane depot, government dock and Fire Department structures. The Savary Island Volunteer Fire Department (SIVFD) provides structural and initial wildland fire response. The Island is not serviced by BC Hydro. There is one small community water system servicing the Savary Shores subdivision, but most water is drawn from aquifers or rainwater collection systems. The dock is the primary access to the Island and would be integral in any evacuation efforts in the event of a wildfire.

2.4 Environmental Values

Environmental values are high on the Island. The study area is defined by the regional climate of the Coastal Douglas-fir moist maritime (CDFmm). The CDFmm is characterized by warm, dry summers and mild wet winters. The growing seasons are very long and there are pronounced water deficits on zonal or drier sites (Green and Klinka 1994). The relatively small extent of the CDFmm and extensive urbanization of the zone has resulted in habitat loss and degradation to these ecosystems. The Island is unique in that it is one of the best examples of coastal dunes in Canada (Dunster 2000). It contains red-listed ecosystems and species (Henderson 2003) and has examples of Garry Oak and associated ecosystems. The dune habitat and foreshore are particularly sensitive to disturbance and erosion. Most of the red-listed species and communities occur on these sites. Plant communities are important in maintaining the stability of these areas, and loss due to wildfire would result in increased erosion rates. However, many of the dune areas are dominated by invasive species such as Scotch broom (*Cytisus scoparius*), which is highly flammable.

3.0 Fire Environment

3.1 Fire Weather

The Canadian Forest Fire Danger Rating System (CFFDRS), developed by the Canadian Forestry Service, is used to assess fire danger and potential fire behaviour. The Ministry of Forests and Range (MOFR) maintains a network of fire weather stations during the fire season that is used to determine fire danger on forestlands within the community. The information is commonly used by municipalities and regional districts to determine hazard ratings and associated fire bans and closures within their respective municipalities. Key fire weather parameters summarized as part of the analysis included:

- Drought Code: The Drought Code represents the moisture in deep, compact organic matter with a nominal depth of about 18 cm and a dry fuel load of 25 kg/m^2. It is a measure of long-term drought as it relates to fire behaviour.

- Days above Danger Class Rating IV and V: The Danger Class Rating is derived from fire weather indices and has 5 classes: I) Very Low Danger; II) Low Danger; III) Moderate Danger; IV) High Danger; and V) Extreme Danger.

It is important to understand the likelihood of exposure to periods of high fire danger, defined as Danger Class IV (high) and V (extreme), in order to determine appropriate prevention programs, levels of response, and management strategies.

Fire danger within the study area can vary significantly from season to season. The study area lies in the rain shadow of Vancouver Island. Summers are warm and dry and winters are mild and wet. Figure 1 is a compilation of available weather station data within the CDFmm biogeoclimatic unit (representative of the study area) and provides a summary of the total number of Danger Class IV and V-days from May through to August of each year. This compilation shows that fire danger can fluctuate substantially between years. On average, the number of Danger Class V-days within the CDFmm is 20 per year. Typically, the most extreme fire weather occurs between late July and the third week of August.

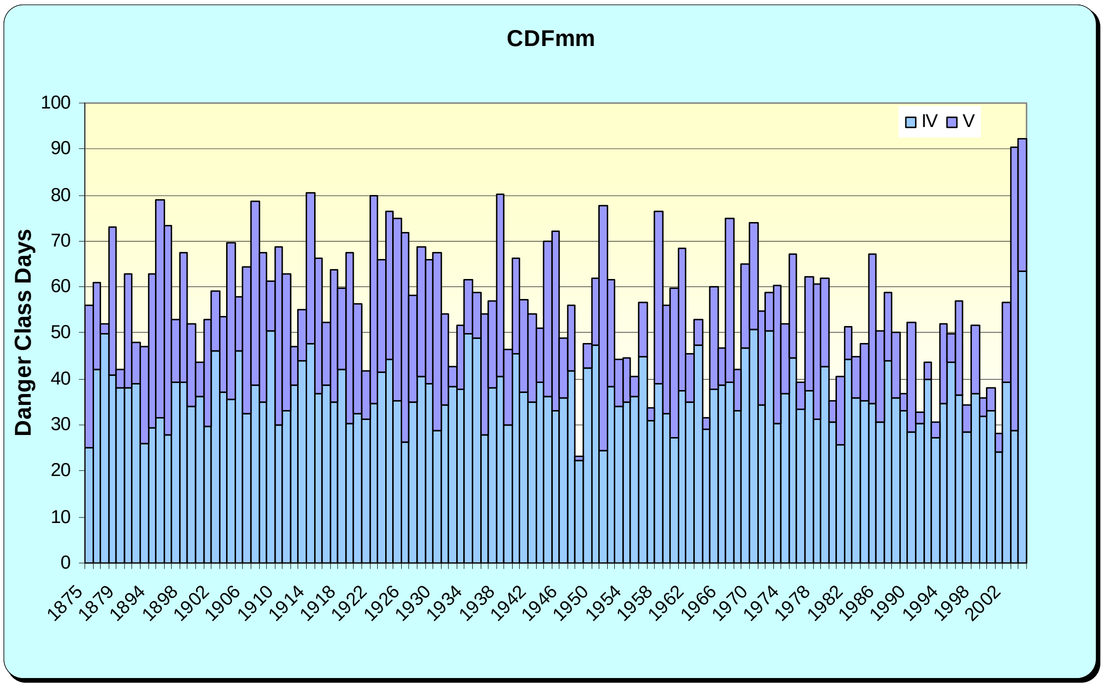


Figure 1. Seasonal variability (May-August) in the number of Danger Class IV and V-days within the study area as described by the regional climate of the CDFmm.

A summary of historic drought codes provides a similar comparison to danger class days (Figure 2). A drought code that exceeds 350 is considered high and is associated with high fire behaviour. A drought code exceeding 500 is considered extreme. Based on annual averages, drought codes rarely exceed 500 (Figure 2). As no weather data is available for Savary Island, the data from the closest weather station at Powell River Airport was used to determine local drought codes. A comparison of monthly values reveals that this is attributable to low values for May and June, extending into July (Figure 3). During the months of September and August, drought code values commonly exceed 350. During this period, fire danger in the study area has typically been high or extreme.

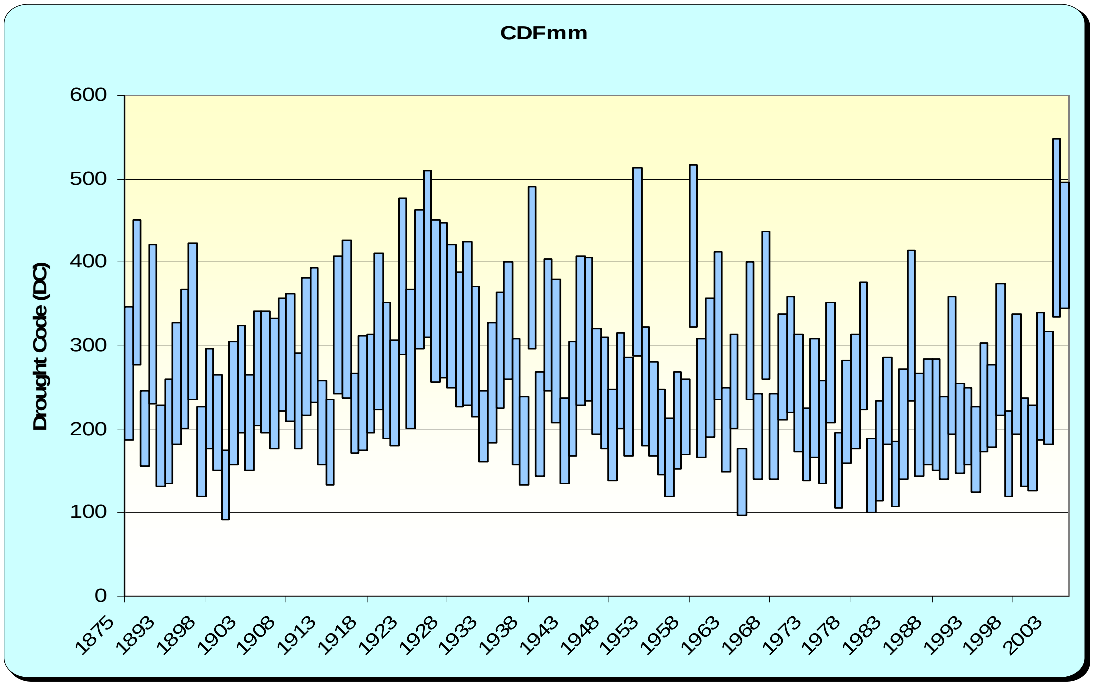


Figure 2. Summary of seasonal (May-August) high and low drought codes by year for the CDFmm (1875-2005).

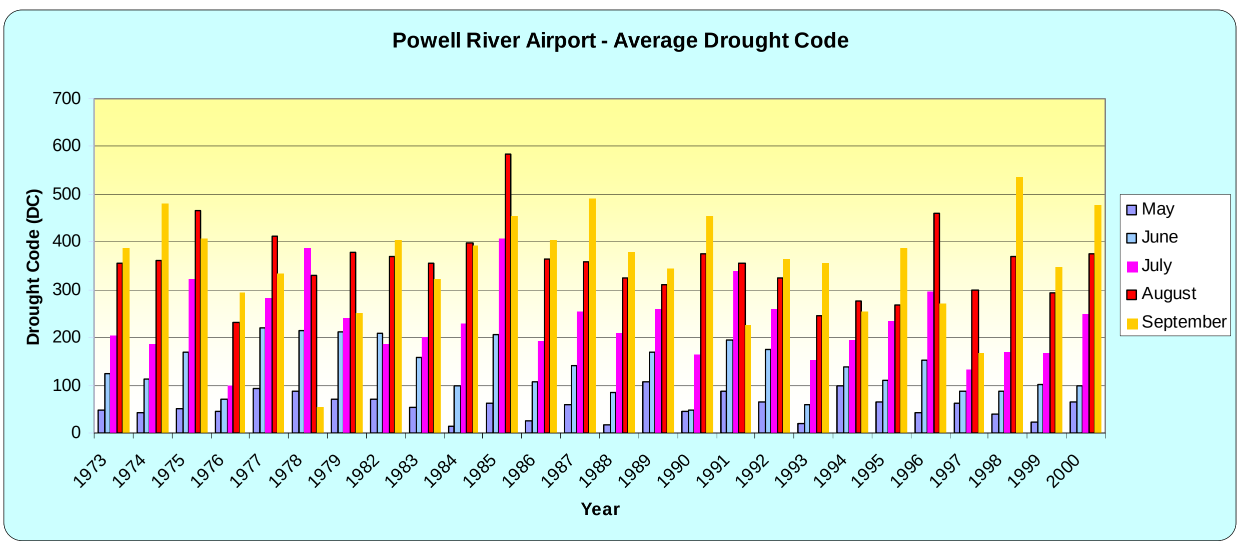


Figure 3. Average drought code by month during the fire season for Powell River Airport weather station (1973-2003).

Fuels

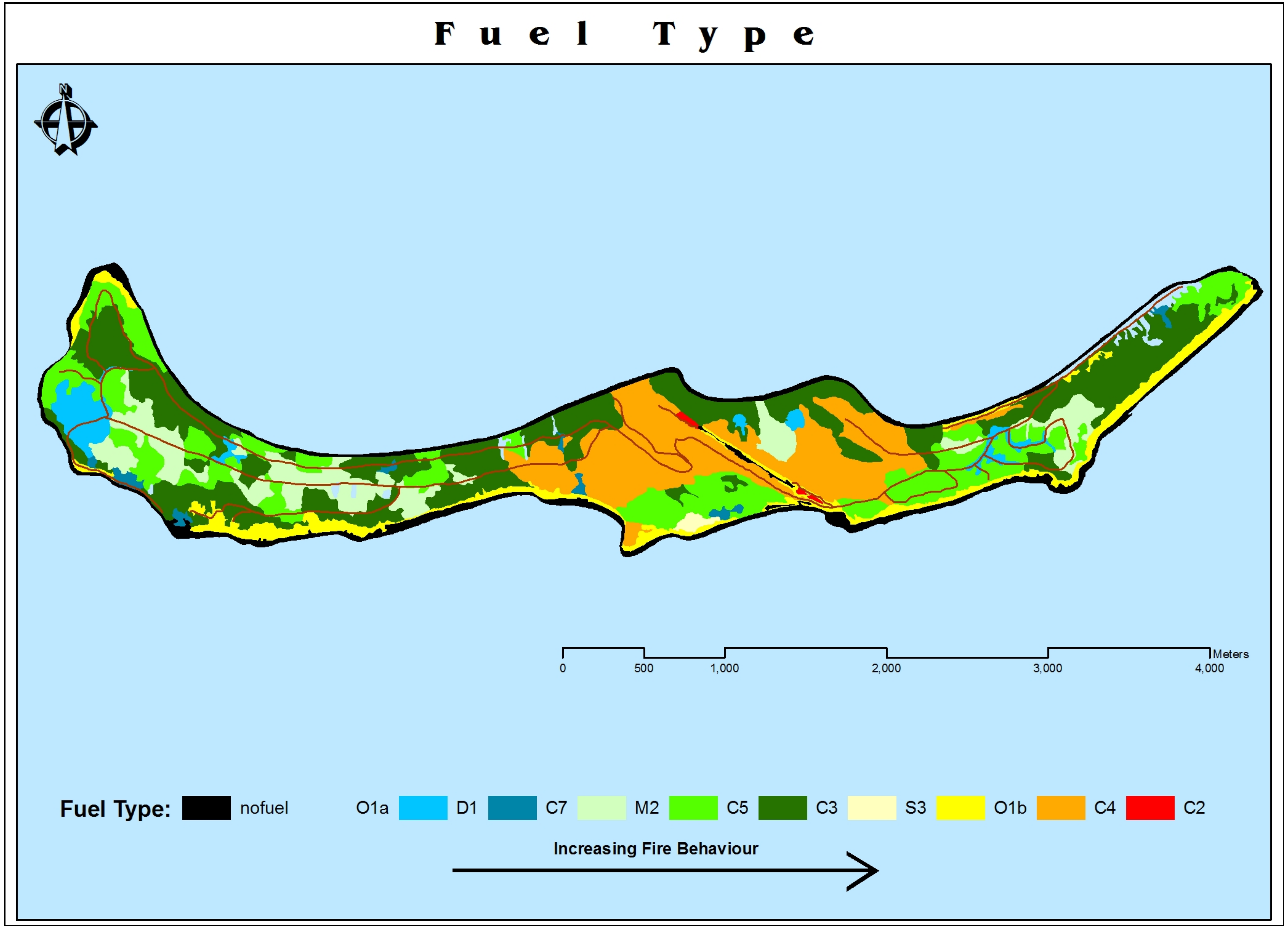
Fuel classification was based on the CFFDRS and a summary of fuel type attributes collected in the field. As the Vegetation Resource Inventory (VRI) data available for the study area was considered insufficient, fuel polygons were typed using orthophotographs. Orthophotographs are images made from photos taken from airplanes which are then joined together to correct for spatial distortion. To attribute the fuel polygons and aid in polygon delimitation, stand and fuels data was collected during field work. Field checks were located across the Island and adjacent to key values at risk. In total 150 field checks were completed. For each fuel type identified in the field, a best approximation of the CFFDRS classification was assigned and supported with a summary of detailed attributes. The Ministry of Forests and Range fuel typing was improved upon and adjusted to incorporate local variation. Map 3 shows the fuel types found on Savary Island.

Fuel Type Summary

In general C2 (dense pole sapling stands) and C4 (pole sapling to young forests) fuel types exhibit the most extreme fire behaviour, followed by O1b (Scotch broom), and C3 (young to mature forest). Table 1 summarizes the fuel types and areas. A description of each fuel type is provided in Appendix 1. It should be note that the O1b fuel type is almost completely dominated by Scotch broom, which has contiguous cover and high spread rates and is the reason it is considered a more hazardous fuel than C3 in this situation.

Table 1. Summary of fuel types based on the total study area.

Fuel Type	C2	C3	C4	C5	C7	D1	M2	Non	01a	O1b	S3	Total
Area (ha)	1	150	95	95	6	18	52	54	7	39	2	519
% Total	0.2	28.8	18.3	18.3	1.1	3.5	10.1	10.4	1.4	7.6	0.4	100.0



Map 3. Updated fuel typing for the study area.

3.2 Historic Ignitions

Due to the relatively small size of Savary Island, there is scant data regarding wildfire history. As well, the provincial data is stored using a relatively coarse spatial grid system which makes it difficult to determine if fires were located on the mainland or on Savary Island.

The Savary Island Fire Chief was contacted to provide historic fire data. The provided list summarizes date, cause, relative size and fire fighting response measures for each fire. Again because of the relatively small size of Savary Island, it is impossible to translate this limited data into probabilities, however general trends can be observed in the record.

Table 2 summarizes the fires that have occurred between 1960 and 2007 in the study area by size class and cause. The total number of fires during this period was 13. One hundred percent of fires with known causes were the result of human ignition (one fire had no known cause). All fires that burned between 1960 and 2007 were smaller than four hectares.

Table 3 summarizes fire cause by decade. Fire starts have increased over the past forty years. The leading cause for fire starts has been fire use with improper supervision, such as debris burning which has escaped control, followed by house fires. The largest fire to date was caused by a campfire near Mace Point which burnt the Scotch broom from the beach to the crest, covering a 130 m wide swath of land and threatening houses at the top of the slope.

Table 2. Provincial data fire history summary within the study area from 1960 - 2007.

Size Class (ha)	Total Number of Fires	% of Total	Lightning Caused	Human Caused
<4.0	13	100	0	13

Table 3. Provincial data summary of fire cause within the study area.

Decade	Campfire	Equipment Use	Fire use	Incendiary	Juvenile fire setter	Lightning	Misc.	House	Smoker	Grand Total
1960							1			1
1970										
1980								2		2
1990			3					1	1	5
2000	1		3		1					5
Total	**1**		**6**		**1**		**1**	**3**	**1**	**13**

4.0 The Wildland Urban Interface

The classical definition of wildland urban interface (WUI) is the place where the "*forest meets the community*". Other configurations of the WUI can be described as intermixed. Intermixed areas include smaller, more isolated developments that are embedded within the forest. An example of an intermixed interface is shown in Figure 4. The WUI on Savary Island consists primarily of Intermix comprised of scattered houses surrounded by natural vegetation. Housing density is highest adjacent to beaches. However this appears to be changing slowly as additional lots in the Island's interior are developed. The area of highest density is on the east end of the Island, where the oldest developments exist. Most structures on the Island have little to no setback from forested edges, often have highly flammable roofing and siding material, and have open decks, eves and footings. This contributes to the aesthetic quality of the Island but elevates the risk associated with wildfire and structural fires.

Fire has the ability to spread from the forest into the community or from the community out into the forest. Although these two scenarios are quite different, they are of equal importance when considering interface fire risk. On the Island, the probability of a fire moving out of the community and into the forest is equal to or greater than the probability of fire moving from the forest into the community. Regardless of which scenario occurs, there will be consequences for the Island and this will have an impact on the way in which the community plans and prepares for interface fires.

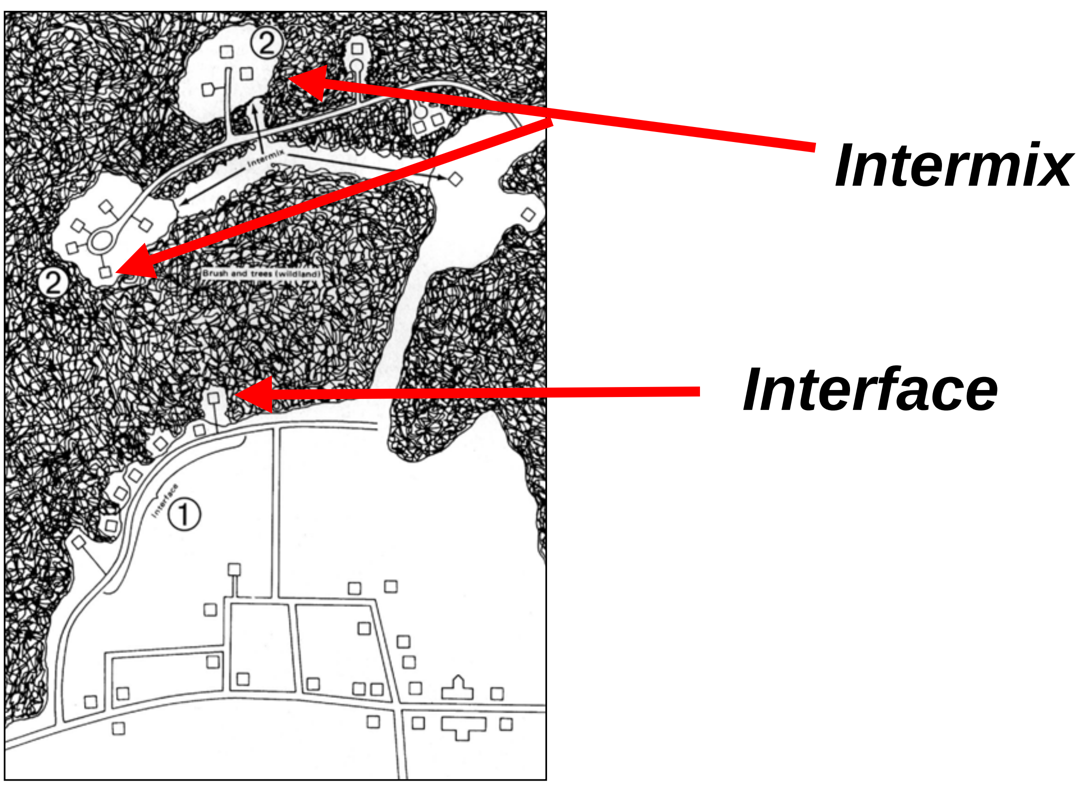


Figure 4. Graphical example showing variation in the definition of interface.

4.1 Vulnerability of the Wildland Urban Interface to Fire

Fires spreading into the WUI from the forest can impact homes in two distinct ways: 1) by sparks or burning embers carried by the wind or convection that start new fires beyond the zone of direct ignition (main advancing fire front) and alight on vulnerable construction materials (*i.e.* roofing, siding, decks etc.) (Figure 5); 2) through direct flame contact, convective heating, conductive heating or radiant heating along the edge of a burning fire front (burning forest) or through structure-to-structure contact. Fire can ignite a vulnerable structure when the structure is in close proximity (within 10 meters of the flame) of either the forest edge or a burning house (Figure 6).

Figure 5. Firebrand caused ignitions: burning embers are carried ahead of the fire front and alight on vulnerable building surfaces.

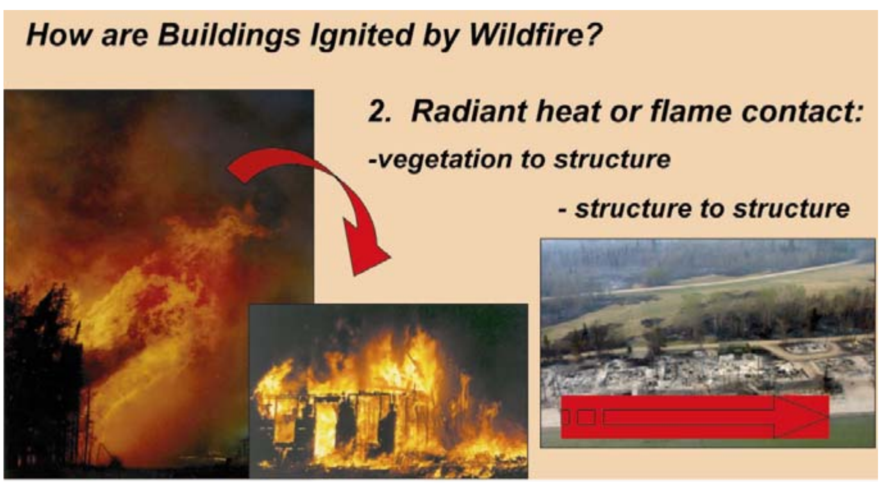


Figure 6. Radiant heat and flame contact allows fire to spread from vegetation to structure or from structure to structure.

The wildland urban interface continuum (Figure 7) summarizes the main options available for addressing WUI fire risk in the Community Wildfire Protection Planning process.

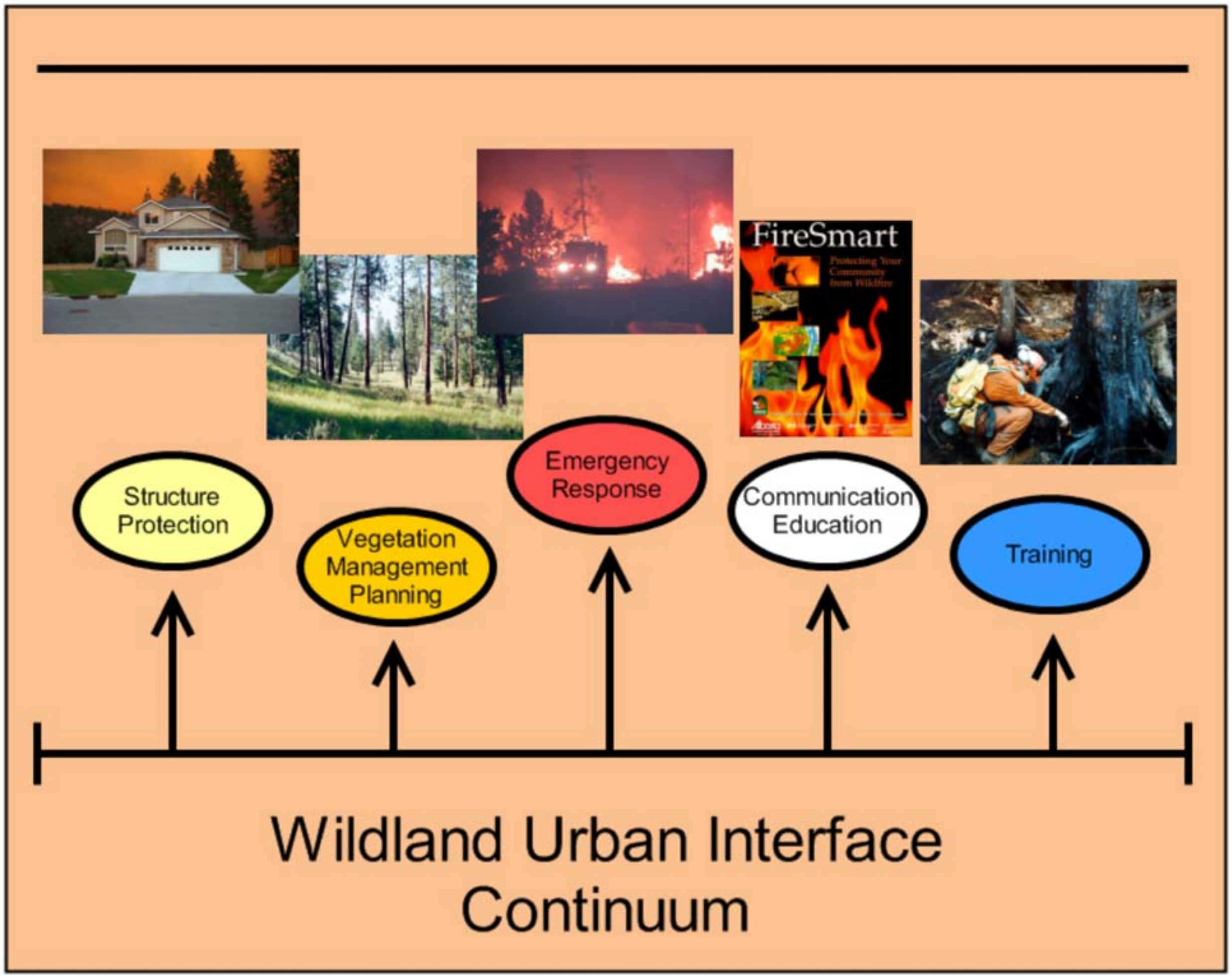


Figure 7. Wildland urban interface continuum.

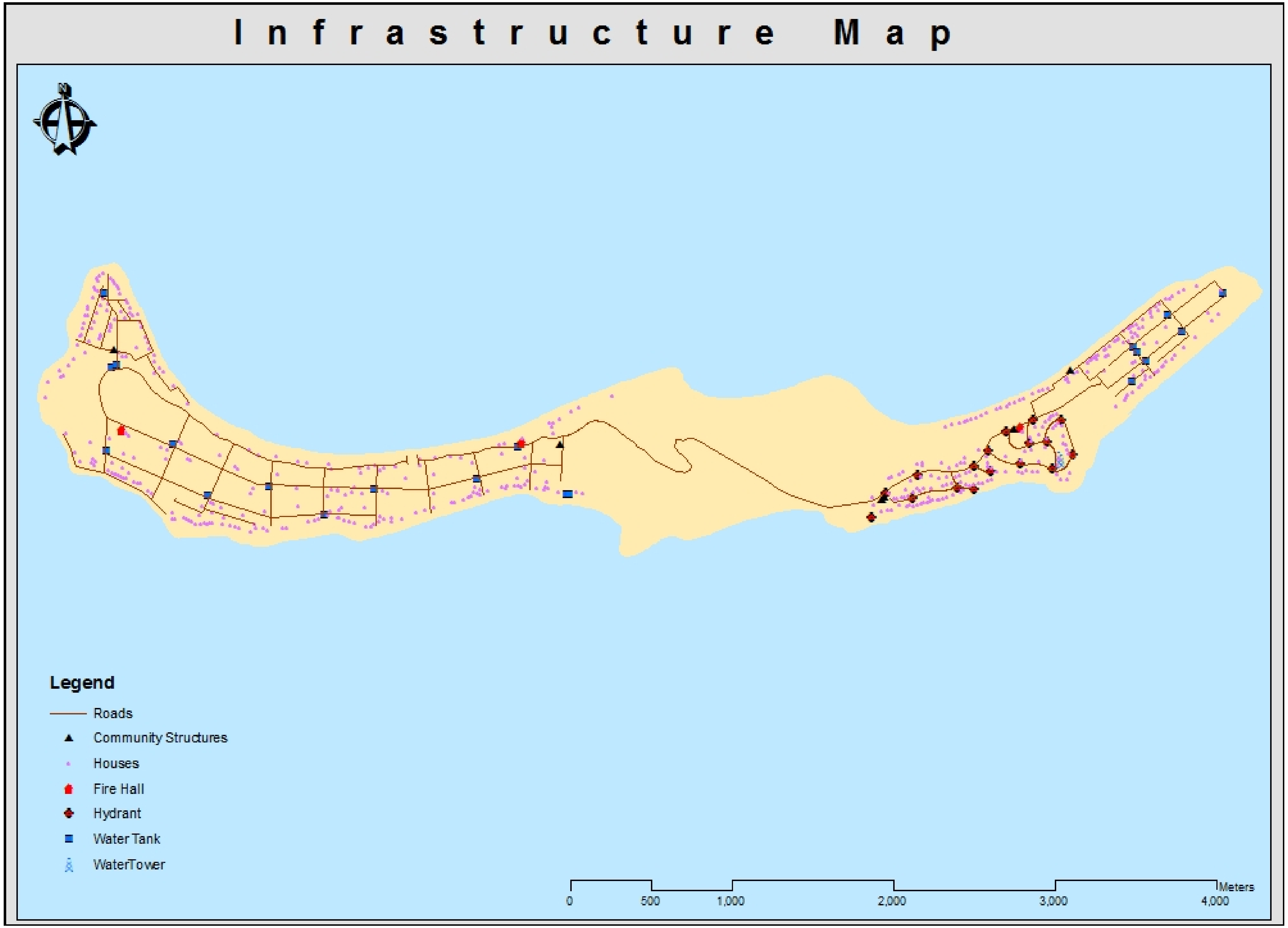
The appropriate management response to a given wildfire risk profile is based on the combination and level of emphasis of several key elements:

- Communication and education.
- Emergency response.
- Training.
- Structure protection.
- Vegetation management.

For example, in an interface area with a high-risk profile, equal weight may be given to all elements. Alternatively, in this same high-risk example, active intervention through vegetation management may be given a higher emphasis. This change in emphasis is based on the values at risk (consequence) and level of desired protection required. In a low risk situation the emphasis may be on communication and education combined with emergency response and training. In other words, a variety of management responses are appropriate within a given community and these can be determined based on the Community Risk Profile.

Map 4 shows the primary interface in the study area. All areas on Savary have housing (except lands in the centre of the Island co-owned by the Nature Trust and a private owner), with the highest structure density on the eastern third of the Island. House points were digitized from the most recently available orthophotos and some points may be missing or incorrectly identified due to photo resolution limitations. The Fire Department has hydrants in the Savary Shores area. All other areas rely on water tanks to supply water for fire fighting activities.

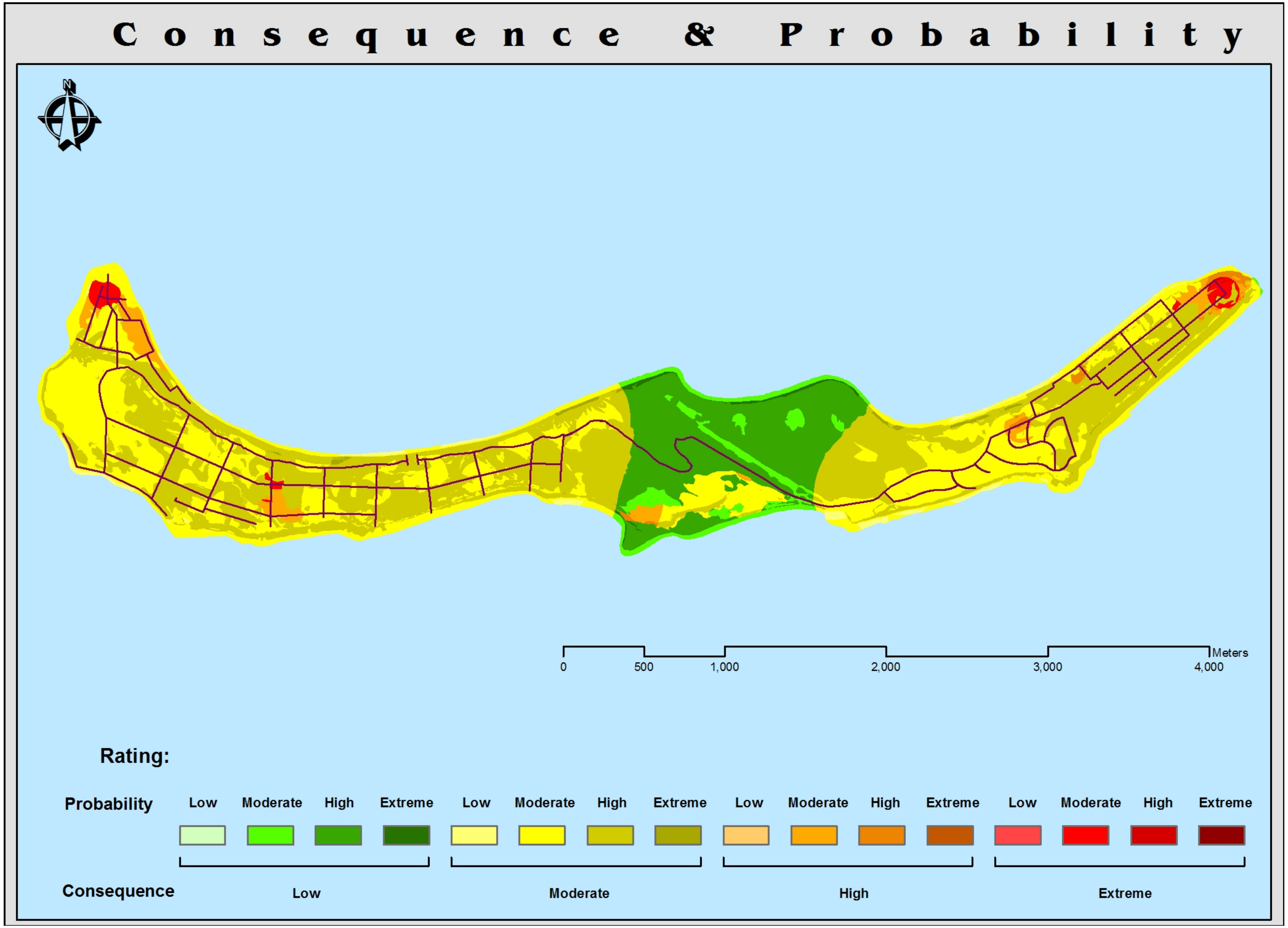
The extensive distribution of intermix interface on Savary, poor access and egress routes, and the absence of an evacuation plan (a plan developed by SIVFD and PRRD is close to completion) or incorporation of FireSmart principles around homes means that human safety is a considerable concern.



Map 4. Purple highlighted areas indicate high density wildland urban interface and infrastructure.

5.0 Community Risk Profile

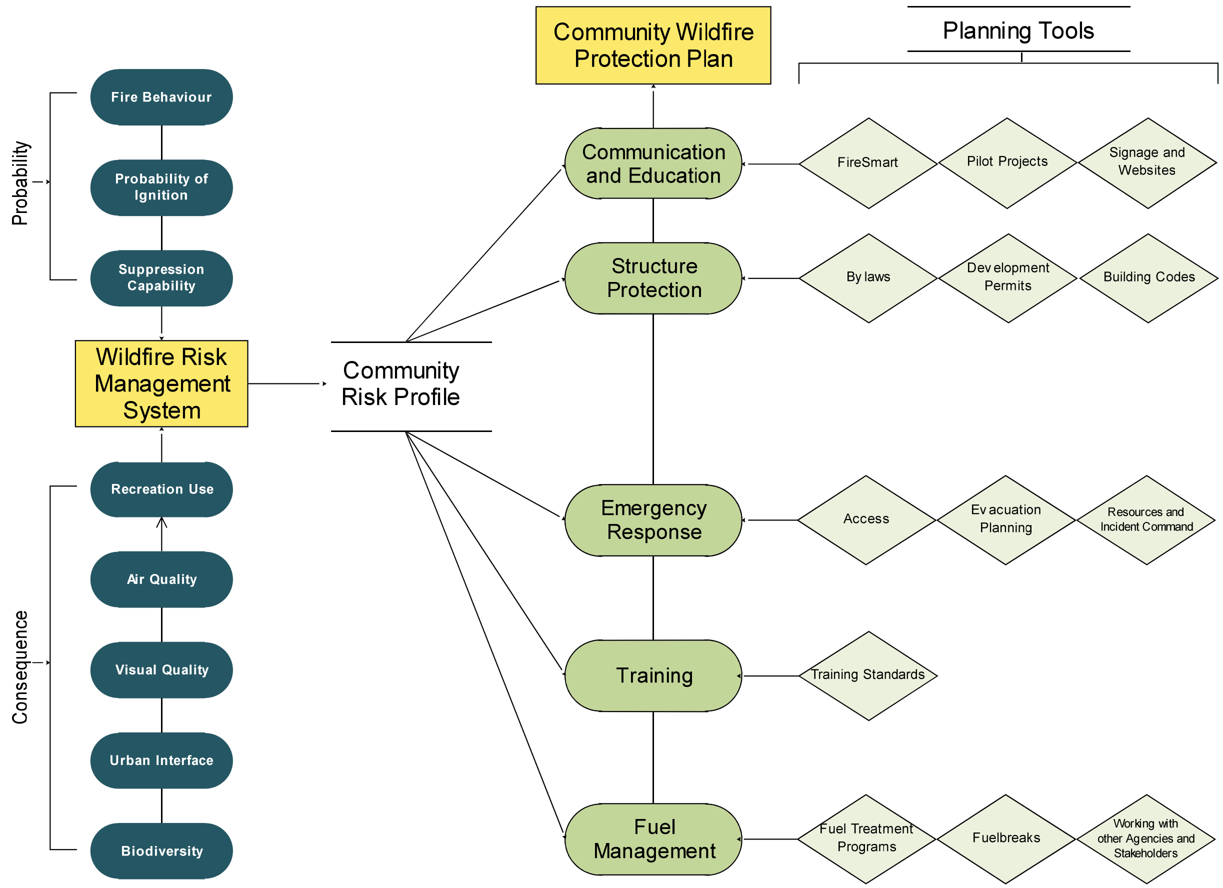
The Wildfire Risk Management System (WRMS) developed in support of this plan identified that the Island has a moderate to high probability of wildfire (Map 5) with moderate to high consequences. The areas of highest probability and consequence are located where the wildland urban interface occurs and fuel types contribute to fire spread, particularly where interface density is higher. The co-owned Nature Trust Lands in the centre of the Island have low consequences (unpopulated and young forests) but high probability due to the fuel types located here. The areas with high consequence are primarily found where houses and older forest coexist. These areas have interface and environmental values. In general, the map shows that public safety, biodiversity, facilities and structures may be severely impacted by a major fire on the Island.



Map 5. Final overlay of probability and consequence from the Wildfire Risk Management System.

6.0 Community Wildfire Protection Planning Process

The following diagram illustrates the components included in the WRMS modeling that are used to generate the community risk profile. The elements of the risk profile are then addressed in the various sections of the community wildfire plan. Various planning tools may be used to change the risk profile of the community.



7.0 Action Plan

The Action Plan consists of the key elements of the Community Wildfire Protection Plan and provides recommendations to address each element. Each of these elements is further explained in Section 8.0 Community Wildfire Protection Planning Background, which provides generic background information to support the Action Plan. Section 8.0 is intended to provide general information about each element considered in community wildfire protection planning; it is not intended to provide information specific to the community.

7.1 Communication and Education

7.1.1 Objectives

- To educate residents and businesses on actions they can take to reduce fire risk on private property and on public property.
- To establish a sense of homeowner and visitor responsibility for reducing fire hazards.
- To raise the awareness of elected officials as to the resources required and the risk that wildfire poses to the community.
- To make residents and visitors aware that the community is an interface community and to educate them about the associated risks.
- To increase awareness of the limitation of municipal and provincial fire fighting resources to encourage proactive and self-reliant attitudes.
- To work diligently to reduce ignitions during periods of high fire danger.
- To develop a community education program in the next two years.
- To establish a FireSmart home pilot project in the next five years.
- To enhance the PRRD website to better communicate wildfire protection planning to the community in the next two years.
- To improve fire danger and evacuation signage in the next two years.

7.1.2 Issues

- Currently there is a lack of information on the PRRD website.
- There is a lack of signage on the Island regarding fire danger (currently being addressed).
- House fires have been the cause of many of the Island's fires; often these are related to chimney fires due to creosote build-up and lack of awareness of fireplace maintenance requirements and related FireSmart principles.

- Due to the large number of visitors, re-education must be an annual event with information and distribution focussed on target user groups.

7.1.3 Communication and Education Recommendations – Savary Island

Recommendation 1: The PRRD and SIVFD should consider developing a communication plan to outline the purpose, methods and desired results of communication and education in the community. Educational information and communication tools need to be stakeholder specific (for example: resident, homeowner, private boat user, and vacationer). To establish effective communication within target groups, the plan should identify spokespersons and methods of information dissemination that best establish communication ties with target audiences and provide the educational information required.

Recommendation 2: The PRRD and SIVFD should investigate the potential for working with local residents to construct a FireSmart show home or public building with FireSmart landscaping as a tool to educate and communicate the principles of FireSmart to the public. The new fire hall would be appropriate for this purpose.

Recommendation 3: The standard for website information about fire should include an outline of community fire risks and fire danger. Information should include fire bylaws, campfire bans and wildfire hazard ratings.

Recommendation 4: The PRRD should access local newspapers or community bulletins to deliver FireSmart educational materials and to communicate information on fire danger during periods of high and extreme fire danger.

Recommendation 5: The large influx of summer residents and visitors requires a proactive approach to education. Signage consisting of current fire danger, campfire bans and general warnings regarding fire safety should be posted as people leave the main dock and other areas where people congregate. Education of visitors who access Savary with boats via South Beach is important as campfires are common during summer. Signage consisting of current fire danger, campfire bans and general warnings regarding fire safety should be posted at this location. The new signs being developed meet these information objectives.

Recommendation 6: Given that people can be pre-occupied when arriving on the Island; it is recommended that signage be supplemented by additional information material. Pamphlets could be handed out on the Lund Water Taxi, and could be posted at the general store, detailing the findings of the CWPP, fire bylaw information, evacuation planning, fire prevention measures (chimney cleaning, dangers of unattended burning etc.) and general FireSmart measures.

Recommendation 7: The PRRD should consider providing start-up and annual funding for the development and distribution of educational material and for compensation of the volunteers who disseminate the information on the Island.

Recommendation 8: The SIVFD should work with local tourism businesses to educate the local business community on FireSmart preparation and planning.

7.2 Structure Protection

7.2.1 Objectives

- To adopt a FireSmart approach to site and structure hazard assessment and structure protection.
- To develop policy tools to adopt FireSmart standards over the next five years.

7.2.2 Issues

- Many homes do not meet the FireSmart structure hazard standards for interface fire safety.
- Currently there is no fire vulnerability standard for roofing material used on the Island. Many new homes are constructed with unrated roofing materials and older homes often have unrated roofs that are vulnerable to spot fires. In addition to the vulnerability of roofing materials within the community, adjacent vegetation is often in contact with roofs, roof surfaces are often covered with litter fall and leaves from nearby trees, and open decks are common. As well, many homes are elevated which provides entrance for embers and elevates the risk of a structure fire. See examples in Figure 8 and Figure 9.
- Unrated roofing materials contribute significantly to fire risk. In the short term, a resolution to this issue is difficult given the significant cost to homeowners. However, over the long-term, building code or bylaws to encourage a change in roofing materials when roof replacement of individual residences is required may be a solution.
- Combustible materials stored within 10 m of residences are also considered a significant issue. Woodpiles or other flammable materials adjacent to the home provide fuel and ignitable surfaces for embers.

- Structure setbacks from forest edges are often absent, which facilitates fire transmission to or from residences.
- No formal power or gas infrastructure exists on the island therefore most homes are powered by generators. Fuel sources for power and heating are often stored close to houses. During structural fires and wildfires they pose a considerable danger to suppression crews as they may explode if structurally compromised..

Figure 8. Photograph showing no setback from forested vegetation and unrated roofing material present on some homes within the wildland urban interface.

Figure 9. Example of a home with wood siding and open deck and no setback to forest vegetation.

Figure 10. Shows the gasoline station and adjacent vegetation.

Figure 11. Shows the propane depot and 10 m setbacks from forested edges.

7.2.3 Structure Protection Recommendations – Savary Island

Recommendation 9: The PRRD and SIVFD should investigate the policy tools available for reducing wildfire risk on the Island. These include voluntary fire risk reduction for landowners, bylaws for building materials, covenants for vegetation setbacks, incentives such as exclusion from a fire protection tax, and education. Specifically, the PRRD and the Fire Department should investigate a process to create and/or review and revise existing bylaws to be consistent with the development of a FireSmart community.

Recommendation 10: It is recognized that much of the attraction associated with Savary Island is related to its forested lands and unique architecture. However, homes and businesses built immediately adjacent to the forest edge are difficult to defend in the event of a wildfire and could easily transmit structural fires to the adjacent forest. To reduce these risks, home owners should consider removing volatile vegetation within 10 m of their residences. The PRRD should consider incorporating building setbacks with a minimum distance of 10 m for new buildings that border volatile forest interface into any new bylaw process developed for the Island. Due to the narrow lot sizes and abundance of lots found on Savary Island, a modification of this recommendation may be necessary to avoid excessive deforestation, depending on the scale of future developments.

Recommendation 11: The PRRD and the SIVFD should educate property owners regarding FireSmart principles and assessments and encourage owners to conduct their own assessments to identify and mitigate hazards.

Recommendation 12: The PRRD should consider regulating tank location and physical separation from fuels into any new bylaw process developed for the Island. The SIVFD and the propane distributor should work in conjunction to help educate residents on the proper storage and maintenance of their tanks. Propane tanks can ignite and explode and pose a significant hazard to emergency personnel and others. Tanks should be stored at least 10 m from residential buildings and 10 m away from other fuels, preferably on a concrete pad. Valves should be protected from accidental breakage by covers. During a wildfire event and if it is safe to do so, tanks should be turned off prior to evacuating the residence.

Recommendation 13: The PRRD should consider supporting the SIVRD to review the propane station and gas station to ensure that setbacks from forested edges are appropriate (see Figure 10 and Figure 11). A vegetation setback of at least one and a half tree lengths from the propane depot is recommended to prevent burning trees from falling on the station. Covers should be installed to ensure that valves on tanks are not damaged by falling debris. Tanks should be checked periodically for leaks.

Recommendation 14: The PRRD should consider requiring roofing materials that are fire retardant with a Class A and Class B rating for new structures. The PRRD should consider obtaining legal advice regarding the implementation of building requirements that are more restrictive than the BC Building Code. While restrictions to rated roofing are not supported in the Code at this time, there are several communities which have undergone or are undergoing various processes (e.g., lobbying, legal opinion, declaration of hazard by Fire Chief) to enact roofing bylaws.

7.3 Emergency Response

7.3.1 Objectives

- To develop an emergency response plan that enables effective evacuation, improves firefighter suppression capability and maintains firefighter safety.
- To improve access within portions of the community over the next 10 years.
- To review the community evacuation plan in the next 12 months.

7.3.2 Issues

- Evacuation of residents and access for emergency personnel is the most important consideration given the difficulty of evacuating the Island and the amount of forest fuels in close proximity to many homes and evacuation routes.
- There are many routes with densely vegetated rights-of-way and only one or two access and evacuation routes available to motor vehicles and emergency responders. Generally, these routes are narrow and bordered by forest (see Figure 12). Smoke and poor visibility can further complicate access, creating the necessity for traffic control in some locations. As part of emergency and evacuation planning, where alternate routes exist, routes should be identified and dedicated for evacuation, leaving other routes dedicated for emergency response crews.
- The road through the co-owned Nature Trust lands, which bisect the Island, is very narrow and bordered by hazardous C4 fuel types. Evacuation and emergency access via this road could complicate both evacuation and suppression efforts.
- Most houses lack house numbers, which can increase emergency response times, particularly for emergency responders not familiar with the Island.
- In addition to the evacuation of residents, safety of fire fighting personnel is a major consideration. Under extreme fire conditions it may be difficult for SIVFD or Provincial fire suppression crews to access specific areas due to the potential for resources to be isolated or cut off. Defence of these locations would be secondary to safety.
- A wildfire could cut off egress from parts of the Island. Evacuation plans need to be developed to address this scenario. As many visitors are unfamiliar with much of the Island, the plans should ideally be posted by all property owners, especially owners of rental properties.
- Water quality may be affected by retardants or salt water employed in fire fighting.

Figure 12. Narrow road ways may complicate access and evacuation during wildfire events.

7.3.3 Emergency Response Recommendations – Savary Island

Recommendation 15: Residents on the Island depend on aquifers for their water. The PRRD and SIVFD should communicate with the regional fire centre to ensure that wildfire suppression efforts avoid the use of large amounts of retardants or salt water when possible to avoid impacting water quality.

Recommendation 16: The PRRD and SIVFD should encourage home owners to post house numbers for all residences in a manner that makes them clearly visible. These will aid emergency response and evacuation efforts.

Recommendation 17: Some of the Island has poor emergency response access (one way in and out or poorly built road). The PRRD should consider supporting the SIVFD to address access constraints to private residences should be addressed. Homeowners in these areas should be made aware of access constraints that may prevent or limit the response capability of the Fire Department attending a fire that threatens their property.

Recommendation 18: The PRRD should consider supporting the SIVFD to develop a community evacuation plan. Appropriate evacuation routes should be mapped, considering Disaster Response Routes (DRR). Evacuation routes should be signed and communicated to the public. The plan should identify loop roads and ensure access routes have sufficient width for two way traffic. In addition, alternative emergency responder access should be considered.

Recommendation 19: As part of the evacuation plans, marshalling points should be established on beaches where boat or air access is possible. Signage and evacuation planning maps should indicate the location of these points. Preliminary locations were identified by the SIVFD. These are shown on Map 6.

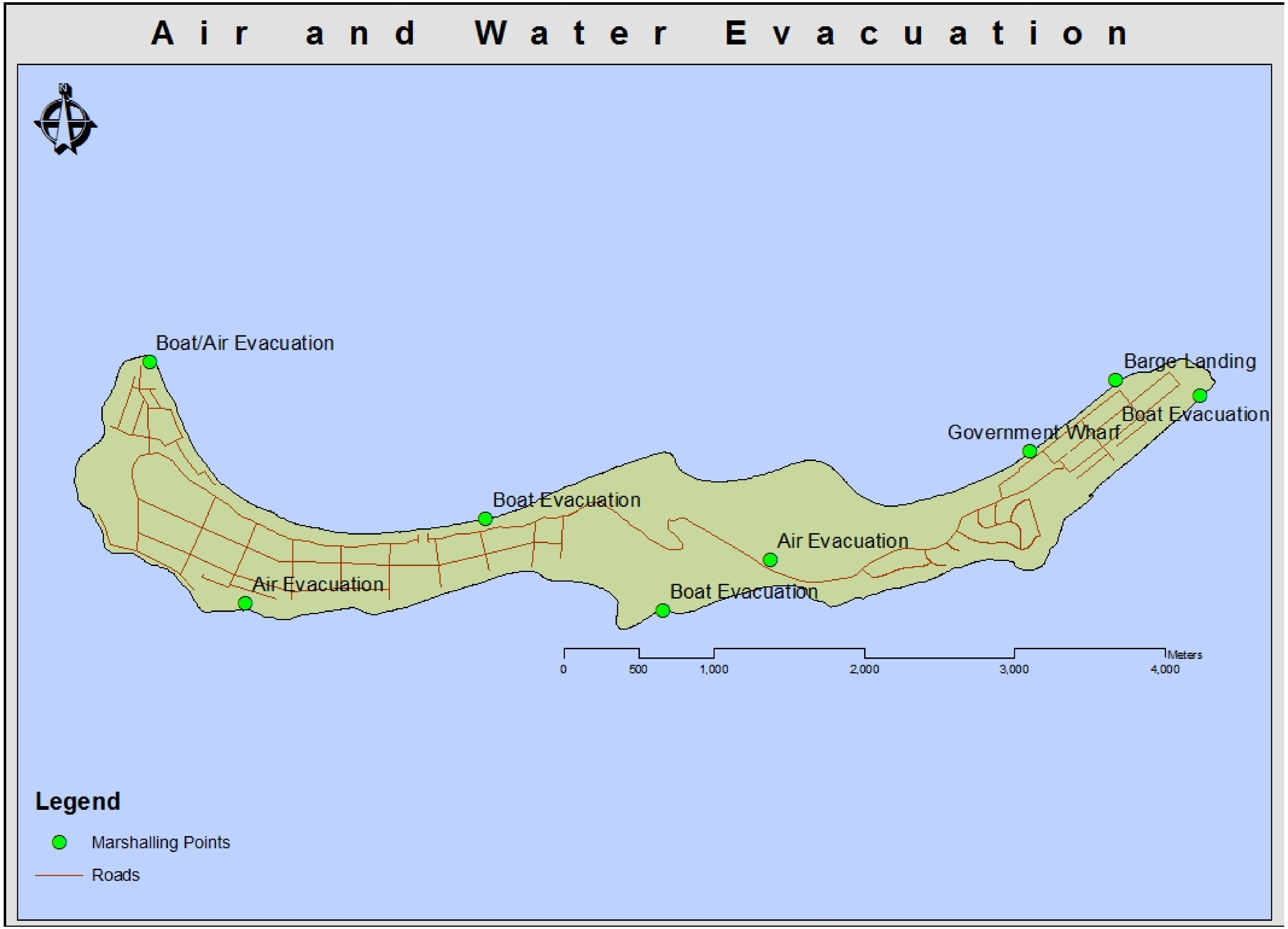
Recommendation 20: The PRRD should consider initiating discussions with the Ministry of Transport and owners of the area known as the Nature Trust Lands regarding increasing the road right-of-way, thinning and appropriately disposing of right-of-way vegetation, and increasing lines of sight to improve safety. The PRRD should consider working with the Ministry of Transport and Savary Island residents to improve access in areas of the community that are considered isolated or that have inadequately developed access for evacuation and fire control (for example, by opening dead end roads, widening cleared road rights-of-way and connecting roads). Discussion with the Ministry of Transportation regarding the maintenance of road rights-of-way should be initiated.

Recommendation 21: The PRRD should consider supporting the SIVFD in a review of critical water infrastructure to determine the adequacy of the water supply, water delivery volumes and pressures and the vulnerability of reservoirs.

Recommendation 22: The PRRD should consider supporting the SIVFD in developing a warning system using the three fire hall sirens. This could be developed for multiple emergency scenarios that would require alerting and evacuating the public quickly.

Recommendation 23: Given the values at risk identified in this plan, it is recommended that, during periods of high and extreme fire danger (danger class IV and V), the Island work with the PRRD, adjacent municipalities and the MOFR to maintain a local helicopter with a bucket on standby within 30 minutes of the community (generally, a helicopter is stationed at Powell River Fire Base which meets this requirement).

Recommendation 24: Ecological values are high on Savary Island, especially habitat on dunes and scarps and in old forests. The PRRD and SIVFD should communicate with the regional fire centre to ensure that crews undertaking suppression are cognizant of their impacts on values at risk.



Map 6. Potential air and water evacuation sites.

7.4 Training/Equipment

7.4.1 Objectives

- To ensure adequate and consistent training for firefighter personnel and to build firefighter experience.
- To continue to train all Fire Department personnel to the provincial standard (S100 or S215) on an annual basis.
- To ensure adequate equipment is available for wildfire suppression crews.
- To continue to conduct cross training exercises with MOFR wildfire suppression crews

7.4.2 Issues

- Savary Island Volunteer Fire Department personnel have received training to Ministry of Forests and Range (MOFR) standards. However, some personnel require training updates.

7.4.3 Training/Equipment Recommendations – Savary Island

Recommendation 25: The following training should be maintained: 1) The S100 course training should be continued on an annual basis; 2) A review of the S215 course instruction should be given on a yearly basis; 3) The S215 course instruction and Incident Command System training should be given to the Fire Chief and Deputy Chief.

Recommendation 26: The SIVFD should conduct an annual review of its existing inventory of interface firefighting equipment to ensure that items such as large volume fire hoses, portable pumps and firefighter personal protection equipment (PPE) are adequate to resource the interface area. Fire Department personnel should have correct personal protective equipment and wildland fire fighting tools. Hoses, pumps and other equipment should be compatible with MOFR wildland fire fighting equipment.

Recommendation 27: The SIVFD should meet with the MOFR prior to the fire season to review the incident command system structure in the event of a major wildland fire. They should work in conjunction to establish clear command structures and lines of communication with MOFR to ensure efficient operations during wildfire events. This should include designated radio channels and operating procedures.

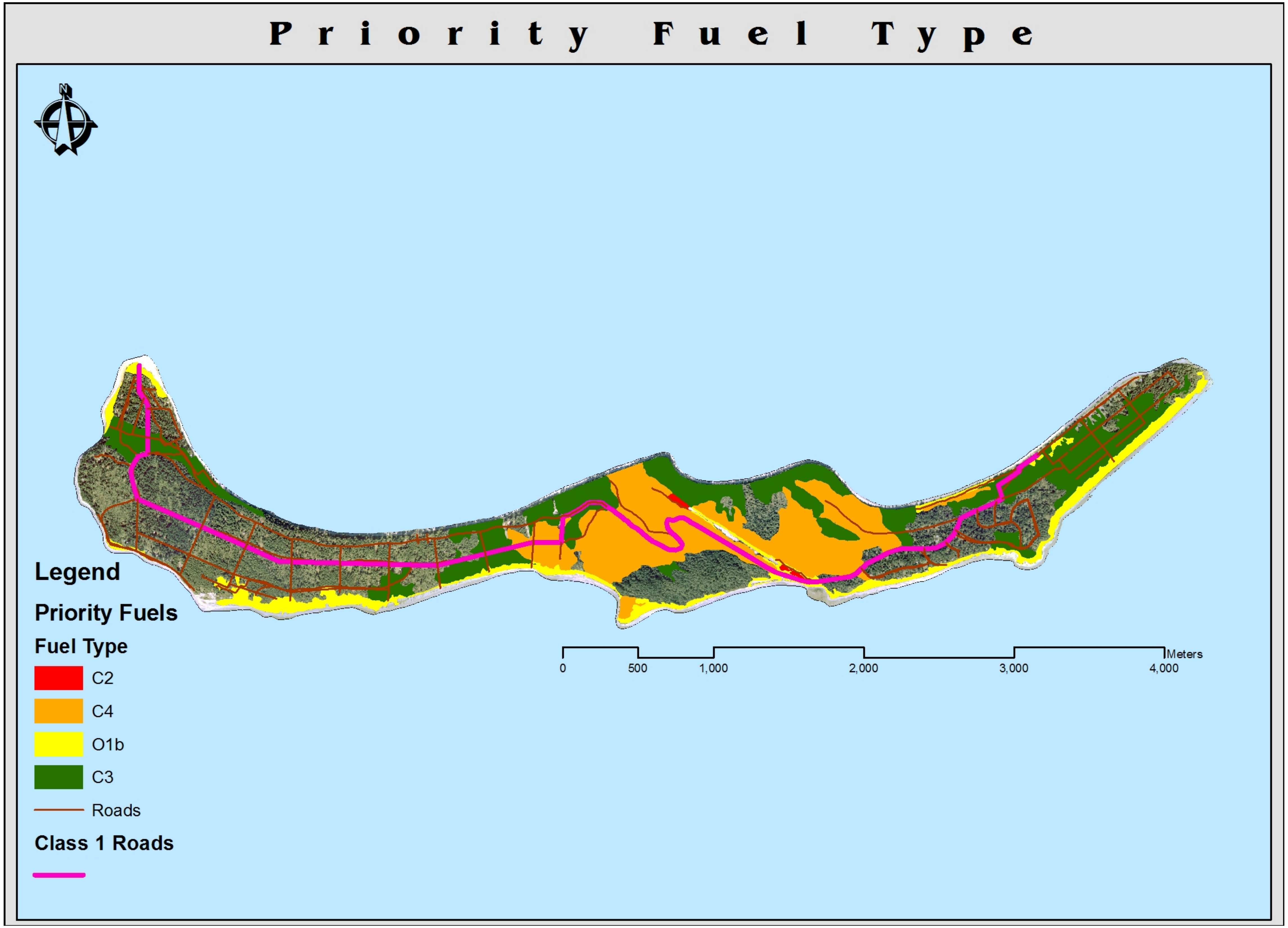
7.5 Vegetation (Fuel) Management

7.5.1 Objectives

- To proactively reduce potential fire behaviour, thereby increasing the probability of successful suppression and minimizing adverse impact.
- To reduce the hazardous fuel types (O1b, C2, C3, and C4) found on the Island. Ideally, over the next five years, the majority of these fuel types within the study area would be converted to less hazardous fuel types.
- To reduce fuels along Class 1 roads (identified in the Official Community Plan - OCP), specifically where they intersect hazardous fuel types, to improve egress and access, reduce ignition potential along roadways, and create fuel breaks.

7.5.2 Issues

- Most of the lands on the Island are privately owned and therefore any fuel treatments must be conducted at the expense of the land owner.
- The Wildfire Risk Management System developed in support of this plan identified that the centre of the Island is at very high risk from wildfire. In addition, there are areas of extreme wildfire probability immediately adjacent to the interface. Public safety, and many of the important values, facilities and structures, may be severely impacted by a major fire.
- There some existing natural fuel breaks on the Island including deciduous and low grassland fuel types (refer to Map 8). Fuel treatments within hazardous fuel types adjacent to these breaks will enhance their effectiveness on the landscape.
- There are a number of hazardous stands of O1b (39 ha) C2 (1 ha), C3 (150 ha) and C4 (95 ha) fuel types in the study area (Map 7, Table 4, Table 5). Treatment of other fuel types is not considered a priority. The areas of hazardous fuels should be the focus of a prioritized long-term fuel reduction program. The goals of thinning are to remove hazardous fuels and to reduce the overall fire behaviour potential adjacent to the community. An example of hazardous fuels is shown in Figure 13, where treatment of hazardous fuels is unlikely as these fuels are located on private property.



Map 7. Priority fuel types for treatment consideration.

Table 4. Fuel type polygons that are a priority for treatment consideration and area where these polygons intersect road ROW.

Fuel Type	Road ROW (ha)	Total Area (ha)
C2	0	1
C3	1.2	150
C4	2.3	95
O1b	.4	39
Total Area	3.8	285

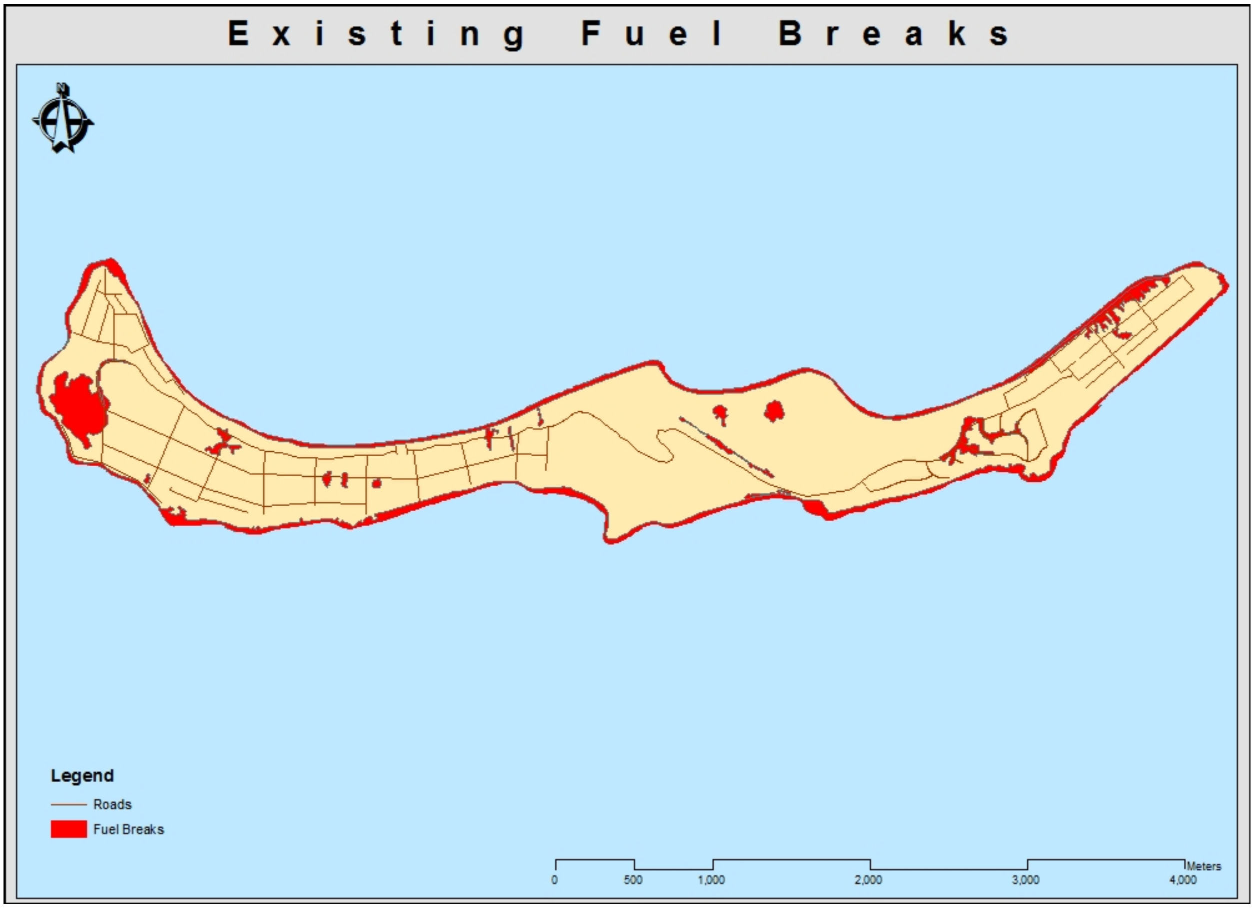
Table 5. Total area associated with Level 1 roads that should be reviewed as Pilot Projects.

Level 1 Road Length (m)	ROW Width (m) (both sides)	Area (ha)
8178	10	8.2
Total Area		8.2

Figure 13. Photo of hazardous C4 fuel type in the study area.

Figure 14. Photo of Scotch broom on slopes below houses.

Figure 15. Example of Scotch broom removal and slope stabilization employing less flammable shrub species.



Map 8. Existing fuel breaks where deciduous, non fuel, water, or O1a short grass/wetland occurs.

7.5.3 Vegetation (Fuel) Management Recommendations – Savary Island

Recommendation 28: The PRRD and SIVFD should investigate the potential for fuel management. A number of high hazard areas on the Island have been identified. Some high hazard fuels occur on Crown Land managed by the Ministry of Transportation. The PRRD and SIVRD should work with the Ministry of Transportation to improve vegetation and debris management on these rights-of-way. This would both reduce fire hazard and improve road safety. It is recognized that much of the area of hazardous fuels is located on private property and therefore the PRRD and SIVFD cannot propose or carry out fuel treatments on these lands. Property owners should be encouraged through education programs to reduce fuels on their properties where hazardous fuels have been identified. The highest priority areas of O1b, C2, and C4 fuel types are identified in Map 7. Any treatments that take place on sloped sites should be prescribed with consideration given to slope stability and erosion. Where slope stability may be an issue, a Professional Geotechnical Engineer should review the treatment prescription.

Recommendation 29: The PRRD should consider creating an education and cleanup program to encourage fuel reduction on private property. Similar to programs in cities such as Kamloops where the removal of beetle killed trees was funded by the city, the PRRD should consider providing funding to rent a curtain burner or other machinery that residents could use to dispose of fuel treatment waste. This would also reduce ignitions due to backyard burning. The frequency of the fuel waste disposal could be determined by the community response and funding opportunities.

Recommendation 30: The PRRD and SIVFD should work with BC Ministry of Transportation to ensure that the road right-of-way vegetation management strategy includes consultation with the Fire Department so that rights-of-way are maintained at suitable widths and wood waste accumulations do not contribute to unacceptable fuel loading or diminish the ability of the right-of-way to act as a fuel break. If funding can be accessed, a pilot project along the right-of-way should be considered, specifically where it intersects hazardous fuel types (Map 7, Table 4, Table 5). This project should focus on Level 1 roads as identified in the OCP. It is recognized that no right-of-way exists in the co-owned Nature Trust Lands. It is recommended that the PRRD consider initiating discussions with the owners regarding obtaining suitable rights-of-way.

Recommendation 31: It is recognized that Scotch broom is currently important in the stabilization of foreshore banks; however it poses a considerable fire hazard to houses located at the top of these slopes. Maintaining broom at 30 cm height for 10 to 20 m below houses will reduce flame length and help protect structures should a wildfire start at the slope base. Long-term replacement of broom with a less flammable species that will fulfill the role of slope stabilization is desirable. Where broom is not integral in slope stabilization it should be removed, especially on dune habitats where it encroaches on species at risk.

7.6 Wildfire Rehabilitation Planning

7.6.1 Goals

- To reduce the impact of negative post-wildfire effects on the community by preparing a strategic, effective and rapid post-wildfire response.

7.6.2 Objectives

- Develop advanced planning for post-fire stabilization and rehabilitation in the next five years.

7.6.3 Issues

- Aquifers that provide drinking water for some residents and these could be negatively impacted by wildfire due to increased surface runoff due to soil hydrophobicity changes and changes in vegetation complexes.
- There are numerous scarps that could potentially have terrain stability concerns if substantial tree or shrub cover were to be removed by wildfire.

7.6.4 Recommendations

Recommendation 32: The PRRD should develop a plan for post fire rehabilitation that considers the procurement of seed, seedlings and materials required to regenerate an extensive burn area. The initial opportunity to conduct meaningful rehabilitation post fire will be limited to a short fall season (September to November). The focus of initial rehabilitation efforts should be on slope stabilization and infrastructure protection. These issues should form the foundation of an action plan that lays out the necessary steps to stabilize and rehabilitate the burn area

8.0 Community Wildfire Protection Planning Background

8.1 Communication and Education

One of the key elements to developing FireSmart communities and neighbourhoods is cultivating an understanding of fire risk in the wildland urban interface. An effective communication strategy should target elected officials (regional and local governments), structural and wildland fire personnel, appropriate municipal departments (planning, bylaw, and environment), the public and the private sector. The principles of effective communication include:

- Developing clear and explicit objectives, or working toward clear understanding;
- Involving all interested parties in a transparent process;
- Identifying and addressing specific interests of different groups;
- Coordinating with a broad range of organizations and groups;
- Not minimizing or exaggerating the level of risk;
- Only making commitments that you can keep;
- Planning carefully and evaluating your effort; and
- Listening to the concerns of your target audience.

To effectively minimize fire risk in the interface zone requires the coordination and cooperation of many levels of government including the B.C. Ministry of Forests and Range, Powell River Regional District, local municipal government departments, and other government agencies. However, if prevention programs are to be effective, fire risk reduction within interface areas of the study area must engage the local residents. This requires a commitment to well-planned education and communication programs that are dedicated to interface fire risk reduction.

There is generally a lack of understanding about interface fire and the simple steps that can be taken to minimize risk in communities. Typically, there is either apathy and/or an aversion to dealing with many of the issues highlighted in this report. Public perception of fire risk is often underdeveloped due to public confidence and reliance on local and provincial fire rescue services. Two useful websites that provide links to wildfire education resources and basic fire information include www.efire.org and http://www.pssg.gov.bc.ca/firecom/. Figure 16 shows a screen capture from the City of Chilliwack's public wildfire education website as an example of a clear, navigable and informative public communication method.

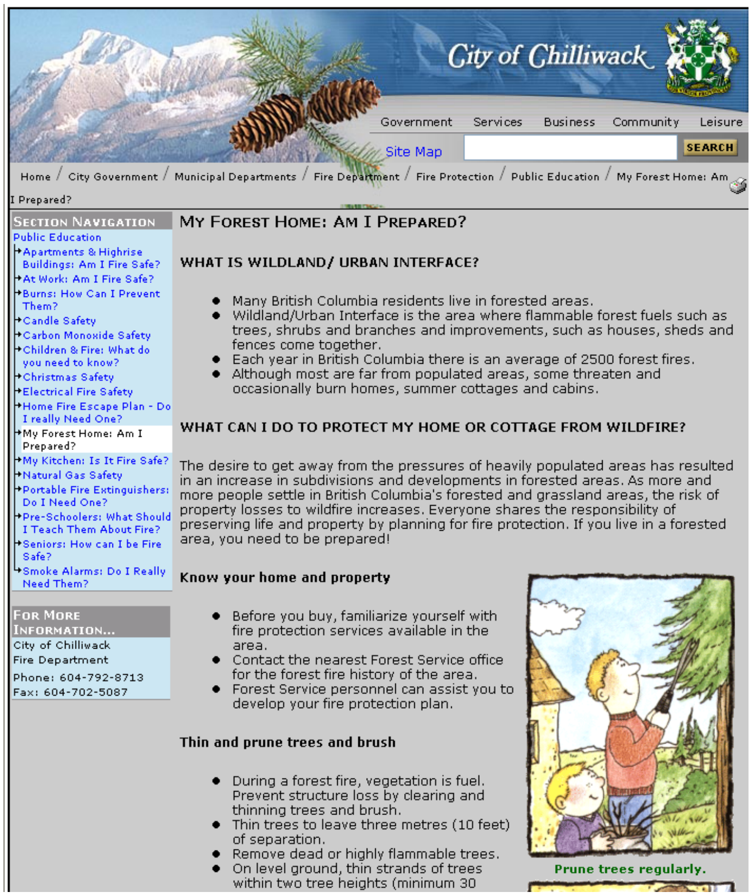


Figure 16. Example of municipal website providing fire education information (http://www.chilliwack.com/main/page.cfm?id=627).

8.1.1 Target Audiences

Historically, there has been limited understanding of wildland urban interface fire risks within many communities of British Columbia. However, the lessons learned from the 2003 fire season have significantly increased local fire rescue service awareness and local, regional, and provincial organizations have upgraded fire suppression understanding and capability. Despite this, there is limited understanding among key community stakeholders and decision makers. Education and communication programs must target the broad spectrum of stakeholder groups within communities. The target audience should include, but not be limited to, the following groups:

- Homeowners within areas that could be impacted by interface fire;
- Local businesses;
- Municipal councils and staff;
- Regional District directors;

- Local utilities; and
- Media.

8.1.2 Pilot Projects

Pilot projects that demonstrate and communicate the principles of FireSmart and its application to Community Wildfire Protection should be considered. The focus of these pilot projects should be to demonstrate appropriate building materials and construction techniques in combination with the FireSmart principles of vegetation management, and to showcase effective fuel management techniques. Several homes and businesses could be identified by the Island to serve a communication and education function that would allow residents to see the proper implementation of FireSmart principles. The fuel treatment pilot should generally focus on hazardous fuel types identified in the CWPP, however as most land on the Island is private, treatments along road ROWs should be considered.

These pilot projects are considered a high priority for the urban interface to provide information on different fire hazard reduction techniques and demonstrate appropriate fire risk reduction methods to the community including municipal staff, community leaders and the public. These demonstration areas will also provide sites for improved public understanding of the methods to mitigate fire risk that can be applied on individual properties.

8.1.3 Website

Websites are considered one of the best and most cost effective methods of communication available. Fire related information such as fire danger and fire restrictions, as well as fire risk assessment information should be included on any fire protection website. Pictures and text that outline demonstration/pilot projects can also be effective in demonstrating progress and success of fire risk reduction activities. During fire season it is particularly important that wildfire safety related information be posted so that it is easily accessible to the general public.

8.1.4 Media Contacts, Use and Coordination

Media contact plays an essential role in improving public awareness about fire risk in the community. Interest in wildfire protection can be cultivated and encouraged to improve the transfer of information to the public by more frequent media contact.

Key issues in dealing with the media include:

- Assigning a media spokesperson for the Island;
- Providing regular information updates during the fire season regarding conditions and hazards; and
- Providing news releases regarding the interface issues and risks facing the community.

8.1.5 Other Methods

Educational information and communication tools need to be stakeholder specific. To establish effective communication within target groups, spokespersons who can best establish communication ties and provide the educational information required should be selected. The following subsections outline potential communication methods for specific stakeholder groups.

8.1.5.1 Homeowners

- Conduct surveys and consult the public to ascertain current attitudes.
- Designate spokespersons to communicate to this group and establish a rapport.
- Establish community information meetings conducted by spokespersons.
- Mail out informational material.
- Provide information on Lund Water Taxi and at the General Store
- Provide FireSmart hazard assessment forms and information.
- Provide signage at the main dock trailheads and other prominent locations.

8.1.5.2 Government Ministries, District and Municipal Officials, Disaster Planning Services

- Develop material specific to the educational needs of the officials.
- Present councils with information and encourage cooperative projects between municipalities.
- Establish memoranda of understanding between agencies.
- Appoint a spokesperson to communicate to the groups and help foster inter-agency communication.
- Raise awareness of officials as to the views of the public regarding interface risks in their community.

8.1.6 General Messages

Education and communication messages should be simple yet comprehensive. The level of complexity and detail of the message should be specific to the target audience. A complex, wordy message with overly technical jargon will be less effective than a simple, straightforward message. A basic level of background information is required to enable a solid understanding of fire risk issues. Generally, messages should have at least the following three components:

1. Background Information

- Outline general issues facing interface communities.
- Communicate specific conditions in the community that cause concern.
- Provide examples of potential wildfire behaviour in the community.
- Provide examples of how wildfire has affected other communities.
- Explain the effects that a wildfire could have upon the community.
- Convey FireSmart principles.

2. Current Implementation and Future Interface Planning
    - Provide information on the current planning situation.
    - Explain who is involved in interface planning.
    - Explain the objectives of interface wildfire planning.
    - Explain the limitations of fire fighting crews and equipment in case of a wildfire.
    - Outline the emergency procedure during a wildfire.
3. Responsibilities and Actions
    - Outline the responsibilities of each group in reducing wildfire hazards.
    - Explain the actions that each group may take to meet these responsibilities.

8.2 Structure Protection

8.2.1 FireSmart

Another important consideration in protecting the wildland urban interface zone from fire is ensuring that homes can withstand an interface fire event. Often, it is a burning ember traveling some distance (spotting) and landing on vulnerable housing materials, rather than direct fire/flame (vegetation to house) contact, that ignites a structure. Alternatively, the convective or radiant heating produced by one structure may ignite an adjacent structure if it is within close proximity. Structure protection is focused on ensuring that building materials and construction standards are appropriate to protect individual homes from interface fire. Materials and construction standards used in roofing, exterior siding, window and door glazing, eaves, vents, openings, balconies, decks and porches are primary considerations in developing FireSmart neighbourhoods. Housing built using appropriate construction techniques and materials is less likely to be impacted by interface fires.

While many communities established to date in BC were built without significant consideration with regard to interface fire, there are still ways to reduce home vulnerability. Changes to roofing materials, siding, and decking can ultimately be achieved through long-term changes in bylaws and building codes. It is recognized that these measures may not be desired by some Islanders who enjoy the rustic nature of Savary but the principles are presented to help raise awareness and hopefully long-term change.

The FireSmart approach has been adopted by a wide range of governments and is a recognized template for reducing and managing fire risk in the wildland urban interface. The most important components of the FireSmart approach are the adoption of the hazard assessment systems for wildfire, site and structure hazard assessment, and the proposed solutions and mitigation outlined for vegetation management, structure protection, and infrastructure. Where fire risk is unacceptable, the FireSmart standard should, at a minimum, be applied to new developments and, wherever possible, the standard should be integrated into changes to, and new construction within, existing developed areas.

8.2.1.1 Roofing Material

Roofing material is one of the most important characteristics influencing a home's vulnerability to fire. Roofing materials that can be ignited by burning embers increase the probability of fire related damage to a home during an interface fire event.

In many communities there is no fire vulnerability standard for roofing material. Homes are often constructed with unrated materials that are considered a major hazard during a large fire event. In addition to the vulnerability of roofing materials, adjacent vegetation may be in contact with roofs, or roof surfaces may be covered with litter fall and leaves from adjacent trees. This increases the hazard by increasing the ignitable surfaces and potentially enabling direct flame contact between vegetation and structures.

8.2.1.2 Building Exterior - Siding Material

Building exteriors constructed of wood are considered the second highest contributor to structural hazard after roofing material. Wood siding within the interface zone is vulnerable to direct flame or may ignite when sufficiently heated by nearby burning fuels. Winds caused by convection will transport burning embers, which may lodge against siding materials. Siding materials, such as wood shingles, boards, or vinyl are susceptible to fire. Brick, stucco, or heavy timber materials offer much better resistance to fire.

8.2.1.3 Balconies, Decking and Elevated Houses

Open balconies and decks or raised houses increase fire vulnerability through their ability to trap rising heat, by permitting the entry of sparks and embers, and by enabling fire access to these areas. Closing these structures off limits ember access to these areas and reduces fire vulnerability.

8.2.1.4 Combustible Materials

Combustible materials stored within 10 m of residences are also considered a significant issue. Woodpiles or other flammable materials adjacent to the home provide fuel and ignitable surfaces for embers. Locating these fuels away from structures helps to reduce structural fire hazards.

8.2.2 Planning and Bylaws

There are two types of wildfire safety regulations most commonly used by local governments: Type 1) regulations that restrict the use of fire; and, Type 2) regulations that restrict building materials, require setbacks or restrict zoning. While most municipalities have bylaws for Type 1 regulations, Type 2 regulations are not as common. However, these regulations are an important contributor to wildfire risk reduction. Several Type 2 policy options are generally available to local governments. These primarily include:

- Voluntary fire risk reduction for landowners (building materials and landscaping)
- Bylaws for building materials and subdivision design
- Covenants requiring setbacks and vegetation spacing
- Site assessments that determine the imposition of fire protection taxes
- Education
- Zoning in fire prone areas
- Treatments on private and public land (commercial thinning, non-commercial mechanical thinning, clear-cut commercial harvesting or prescribed burning)

There are two prominent issues that may be corrected through the bylaw process. Unrated roofing materials contribute significantly to fire risk. In the short term, a resolution to this issue is difficult given the significant cost to homeowners. However, over the long-term, altering building codes or bylaws to encourage a change in roofing materials when roof replacement of individual residences is required is generally a viable option.

The second prominent issue relates to the creation of large setbacks between buildings and the forest. Where forest trees encroach onto balconies and building faces, the potential for structure ignition is greater and may result in more houses being engaged by fire, thereby reducing firefighter ability to successfully extinguish both wildland and structural fires throughout a community. These two suggestions represent only a fraction of the changes that can be considered and more can be identified on a community specific basis by completing a thorough review of current bylaws as they relate to fire risk.

Local governments have an important role in managing community fire hazard and risk. Through the Local Government Act, Development Permit Areas authorize local governments to regulate development in sensitive or hazardous areas where special conditions exist.

For example, Development Permit Areas can be designated for such purposes as:

- Protection of the natural environment;
- Protection from hazardous conditions;
- Protection of provincial or municipal heritage sites;

- Revitalization of designated commercial areas; or
- Regulation of form and character of commercial, industrial and multi-family residential development.

As a land use planning tool, the establishment of Development Permit Areas for interface fire hazards could protect new developments from wildfire in the urban interface. For the purpose of fire hazard and risk reduction a development permit may:

- Include specific requirements related to building character, landscaping, setbacks, form and finish; and
- Establish restrictions on type and placement of trees and other vegetation in proximity to the development.

8.2.3 Sprinklers

As part of the Firestorm 2003 Provincial Review, the provincial government responded to the interface fire issue by purchasing mobile sprinkler kits that can be deployed during interface fires. Given the value of the interface in many communities, it is appropriate to consider employing a sprinkler system in these areas. Training may be required to ensure appropriate deployment and use during an interface fire emergency. It is recognized that due to the small size of Savary Island and limited personnel, the time required to deploy a sprinkler system may be better spent on initial attack.

8.2.4 Joint Municipality Cooperation

Interagency cooperation on issues related to resource capacity, training, mutual aid, and equipment sharing is common practice in BC. An expanded role for this relationship could include developing community based communication and education tools for use at a regional scale. Currently, many municipalities are developing in house standards and materials to improve public awareness. A more unified approach could improve efficiency, create consistent messages, and more broadly inform the public of interface fire issues and risk.

8.2.5 Structured FireSmart Assessments of High Risk Areas

The Wildfire Risk Management System (WRMS) provides a tool to identify specific areas of high risk within municipalities. The WRMS provides a sound scientific framework on which to complete more detailed local neighbourhood risk assessments.

8.3 Emergency Response

The availability and timing of emergency response personnel often dictates whether interface fire protection is successful. Well-planned strategies to deal with different and difficult interface fire scenarios are part of a comprehensive approach to addressing interface fire risk. In communities where the risk is considered low, emergency response alone may be considered an adequate management response to protect the community. As risk increases so too should the level of emergency response. Emergency response alone may not be an adequate management strategy to develop depending on the level of risk.

Unlike static emergencies (*e.g.* landslides), fires are dynamic and situations can change dramatically over short periods of time, potentially overwhelming resources. Therefore, it is important to consider a wide range of issues including, but not limited to, evacuation strategies, access for emergency vehicles and equipment, and availability of key fire fighting infrastructure during a fire event.

8.3.1 Access and Evacuation

Evacuation of residents and access for emergency personnel is an important consideration in any community. The main planning tool in case of emergency is the Powell River Regional District Emergency Plan which will coordinate emergency response and evacuation . It is particularly important on Savary Island as access and egress are limited and forest fuels are in close proximity to homes. Given that a forest fire is a dynamic event, evacuation planning is considered of critical importance. The Fire Department must be prepared for evacuation of the sick, disabled, and the elderly when dealing with a wildland fire emergency. Evacuation can be further complicated by smoke and poor visibility, creating the necessity for traffic control. This is likely going to be the case during a large wildfire event on Savary and establishing secondary or alternate evacuation routes is essential as is improving existing routes.

While residents may be able to evacuate to the beach to avoid fires, depending upon wind direction, smoke could make these refuges hazardous. Establishing marshalling points to aid the speedy evacuation of the Island will help reduce exposure time of residents.

In addition to the evacuation of residents, safety of fire fighting personnel is a major consideration. Where access is one-way in and out, there is the potential for resources to be isolated or cut off. Defence of neighbourhoods with poor access is secondary to safety considerations.

8.3.2 Fire Response

Fire suppression efforts are constrained by the ability of firefighters to successfully defend residences with:

- Contiguous fuels between the forest and adjacent homes;
- Steep slopes of greater than 35%; and
- Human caused fuel accumulations and fuel tanks adjacent to homes.

Close proximity of fuels to homes and vulnerable roofing material are the two most significant factors that reduce the ability of firefighters to defend residences. During ember showers, multiple fires can ignite on vulnerable roofs within the wildland urban interface. Fuel continuity can provide a pathway for fire between the forest and homes. A lack of fuel breaks between houses and forest is likely to increase suppression resource requirements. While there will always be a limited ability to protect homes from extreme fire behaviour, or to modify fuels and topography, communities do have control over issues such as defensible space and home construction materials, and can make changes to reduce community vulnerability to fire.

Residences and businesses on steep slopes are vulnerable to increased fire behaviour potential and should be the immediate focus of initial attack if there is a fire start within these areas. Flame length and rate of spread will increase on these slopes, resulting in suppression difficulty and increased safety issues for both wildland and structural firefighters.

In the event of forest fire, municipalities rely heavily on the MOFR to fight fires in the forests within the community. During periods of high fire load throughout the province, resources of the MOFR can be stretched thin. Often high fire activity is concentrated in the interior of the province and availability of aircraft and equipment can be limited on the coast. In steep heavily forested terrain, the most effective method of fire control is generally air tanker action or bucketing with water from a helicopter. Therefore, under extreme fire conditions it may be appropriate for some municipalities to retain a contract helicopter on standby. This may substantially improve the community's probability of containing a fire during the most severe part of the fire season, and may provide the MOFR with the time necessary to mobilize equipment and resources from other parts of the province.

8.4 Training Needs

The events of the 2003 fire season increased municipal awareness with regard to necessary training and equipment improvements. The division between local fire departments/rescue services and the MOFR Protection Branch has narrowed through improved training and communication. Training is fundamental to managing interface fire risk. Crossover abilities between provincial wildland fire and municipal structural fire personnel will enhance and improve the collective agency response to wildland urban interface fire. Therefore, all management strategies designed to protect the wildland urban interface should be supported by an adequate level of training to ensure emergency response addresses both wildland and structural fire.

All municipal firefighters should be trained in the S-100 Basic Wildland Fire Fighting course on a yearly basis. This is carried out by instructors endorsed by the B.C. Forest Service.

In general, it is recommended that:

- The S-100 course instruction be continued on an annual basis;
- A review of the S-215 course instruction be given on a yearly basis;
- The S-215 course instruction should be given to new volunteer fire fighters on an ongoing basis;

- Incident Command System training be given to the Fire Chief and Deputy Fire Chief; and
- Although not a true course, it is also recommended that the fire department meet with the B.C. Forest Service prior to the fire season to review the Incident Command System structure in the event of a major wildland fire. This is based on the suggested training from above.

8.5 Vegetation (Fuel) Management

Vegetation management is considered a key element of the FireSmart approach. Given public concerns, vegetation management is often difficult to implement and must be carefully rationalized in an open and transparent process. Vegetation management should be strategically focused on minimizing impact while maximizing value to the community. For example, understory thinning or surface fuel removal may suffice to lower fire risk. In situations where the risk is high, a more aggressive vegetation management strategy may be necessary. Vegetation management must be evaluated against the other elements outlined above to determine its necessity. Its effectiveness depends on the longevity of treatment (vegetation grows back), cost, and the resultant effect on fire behaviour.

Savary Island is relatively unique in British Columbia as most of the land is private not crown land. This complicates fuel management and reduces the efficacy of fuel treatments. One option that should be explored is the maintenance of road ROWs as fuel breaks. The reduction of surface fuels along the ROW, thinning of smaller trees, and pruning to raise tree crowns would create fuel breaks. However the effectiveness of these fuel breaks would be less than that provided by breaks designed based upon fuels, topography and interface proximity.

Homeowners need to be encouraged to conduct their own fuel reduction treatments. Treatments along ROWs could serve as educational tools to help home owners understand the goals and methods of fuel treatment reduction.

8.5.1 Principles of Fuel Management

8.5.1.1 Definition

Fuel management is the planned manipulation and/or reduction of living and dead forest fuels for land management objectives (*e.g.* hazard reduction). It can be achieved by a number of methods including:

- Prescribed fire;
- Mechanical means; and
- Biological means.

8.5.1.2 Purpose

The goal is to proactively lessen the potential fire behaviour, thereby increasing the probability of successful containment and minimizing adverse impacts. More specifically, the goal is to decrease the rate of fire spread, and in turn fire size and intensity, as well as crowning and spotting potential (Alexander 2003).

Fire triangle

Fire is a chemical reaction that requires three main ingredients:

- Fuel (carbon);
- Oxygen; and
- Heat.

These three ingredients make up the fire triangle. If any one is not present, a fire will not burn.

Fuel is generally available in ample quantities in the forest. Fuel must contain carbon. It comes from living or dead plant materials (organic matter). Trees and branches lying on the ground are a major source of fuel in a forest. Such fuel can accumulate gradually as trees in the stand die. Fuel can also build up in large amounts after catastrophic events, such as insect infestations or disease.

Oxygen is present in the air. As oxygen is used up by fire, it is replenished quickly by wind.

Heat is needed to start and maintain a fire. Heat can be supplied by nature through lightning. People also supply a heat source through misuse of matches, campfires, trash fires, and cigarettes. Once a fire has started, it provides its own heat source as it spreads.

8.5.1.3 Forest Fuels

The amount of fuel available to burn on any site is a function of biomass production and decomposition. Many of the forest ecosystems within British Columbia have the potential to produce large amounts of vegetation biomass. Variation in the amount of biomass produced is typically a function of site productivity and climate. The disposition or removal of vegetation biomass is a function of decomposition. Decomposition is regulated by temperature and moisture. In wet maritime coastal climates the rates of decomposition are relatively high when compared with drier cooler continental climates of the interior. Rates of decomposition can be accelerated naturally by fire and/or anthropogenically by humans.

A hazardous fuel type can be defined by high surface fuel loadings; high proportions of fine fuels (<1 cm) relative to larger size classes, high fuel continuity between the ground surface and overstory tree canopies, and high stand densities. A fuel complex is defined by any combination of these attributes at the stand level and may include groupings of stands.

8.5.1.4 Surface Fuels

Surface fuels consist of forest floor, understory vegetation (grasses, herbs and shrubs, and small trees), and coarse woody debris that are in contact with the forest floor (Figure 17). Forest fuel loading is a function of natural disturbance, tree mortality and/or human related disturbance.

Surface fuels typically include all combustible material lying on or immediately above the ground. Often roots and organic soils have the potential to be consumed by fire and are included in the surface fuel category.

Surface fuels that are less than 12 cm in diameter contribute to surface fire spread; these fuels often dry quickly and are ignited more easily than larger diameter fuels. Therefore, this category of fuel is the most important when considering a fuel reduction treatment. Larger surface fuels greater than 12 cm are important in the contribution to sustained burning conditions, but are often not as contiguous and are less flammable because of delayed drying and high moisture content, when compared with smaller size classes. In some cases where these larger size classes form a contiguous surface layer, such as following a windthrow event or wildfire, they can contribute an enormous amount of fuel, which will increase fire severity and potential for fire damage.

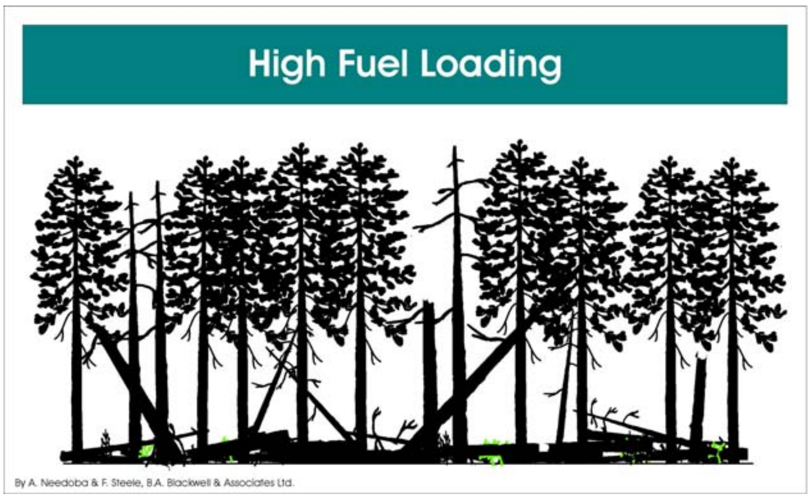


Figure 17. High surface fuel loading under a forest canopy

8.5.1.5 Aerial Fuels

Aerial fuels include all dead and living material that is not in direct contact with the forest floor surface. The fire potential of these fuels is dependent on type, size, moisture content, and overall vertical continuity. Dead branches and bark on trees and snags (dead standing trees) are important aerial fuel. Concentrations of dead branches and foliage increase the aerial fuel bulk density and enable fire to move from tree to tree. The exception is for deciduous trees where the live leaves will not normally carry fire. Numerous species of moss, lichens, and plants hanging on trees are light and flashy aerial fuels. All of the fuels above the ground surface and below the upper forest canopy are described as ladder fuels.

Two measures that describe crown fire potential of aerial fuels are the height to live crown and crown closure (Figure 18 and Figure 19). The height to live crown describes fuel continuity between the ground surface and lower limit of the upper tree canopy. Crown closure describes the inter-tree crown continuity and reflects how easily fire can be propagated from tree to tree.

In addition to crown closure, tree density is an important measure of the distribution of aerial fuels and has significant influence on the overall crown and surface fire conditions (Figure 20). Higher stand density is associated with lower inter tree spacing, which increases overall crown continuity. While high density stands may increase the potential for fire spread in the upper canopy, a combination of high crown closure and high stand density usually results in a reduction in light levels associated with these stand types. Reduced light levels accelerate self-tree pruning, inhibit the growth of lower branches, and decrease the cover and biomass of understory vegetation.

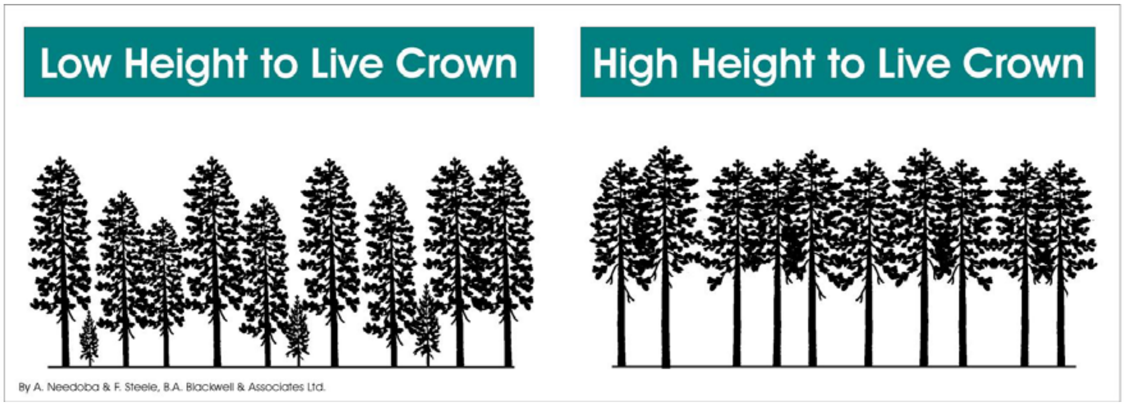


Figure 18. Comparisons showing stand level differences in the height to live crown.

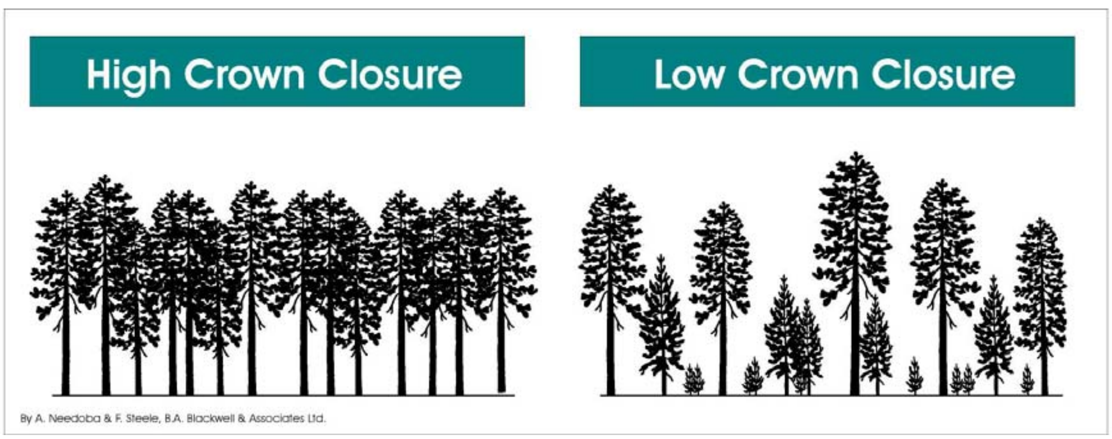


Figure 19. Comparisons showing stand level differences in crown closure.

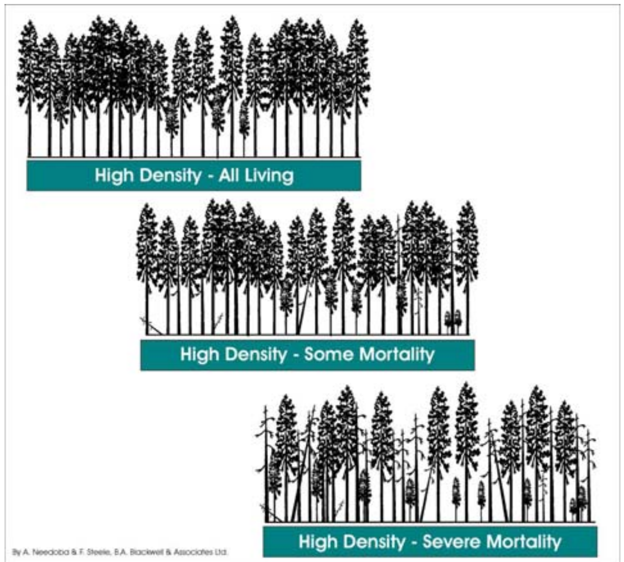


Figure 20. Comparisons showing stand level differences in density and mortality.

Thinning is a preferred approach to fuels treatment (Figure 21) and offers several advantages compared to other methods:

- Thinning provides the most control over stand level attributes such as species composition, vertical structure, tree density, and spatial pattern, as well as the retention of snags and coarse woody debris for maintenance of wildlife habitat and biodiversity.
- Unlike prescribed fire treatments, thinning is comparatively low risk, is not constrained to short weather windows, and can be implemented at any time except during total fire bans.
- Thinning may provide marketable materials that can be utilized by the local economy.
- Thinning can be carried out using sensitive methods that limit soil disturbance, minimize damage to leave trees, and provide benefits to other values such as wildlife.

The following summarizes the guiding principles that should be applied in developing thinning prescriptions:

- Protect public safety and property both within and adjacent to the urban interface.
- Reduce the risk of human caused fires in the immediate vicinity of the urban interface.

- Improve fire suppression capability in the immediate vicinity of the urban interface.
- Reduce the continuity of overstory fuel loads and related high crown fire risk.
- Maintain the diversity of wildlife habitat through the removal of dense understory western hemlock, western red cedar, Douglas fir and minor tree species.
- Minimize negative impacts on aesthetic values, soil, non-targeted vegetation, water and air quality, and wildlife.

The main wildfire objective of thinning is to shift stands from having a high crown fire potential to having a low surface fire potential. In general, the goals of thinning are to:

- Reduce stem density below a critical threshold to minimize the potential for crown fire spread. Target crown closure is less than 35%;
- Prune to increase the height to live crown to a minimum of 2.5 meters or 30% of the live crown (the lesser of the two) to reduce the potential of surface fire spreading into tree crowns; and
- Remove slash created by spacing and pruning to maintain surface fuel loadings below 5 kg/m^2. To measure fuel loading: fuels greater than 1 cm and less than 12 cm in diameter can be collected from 1 m^2 plots. These must be dried to a constant weight and then can be weighed.

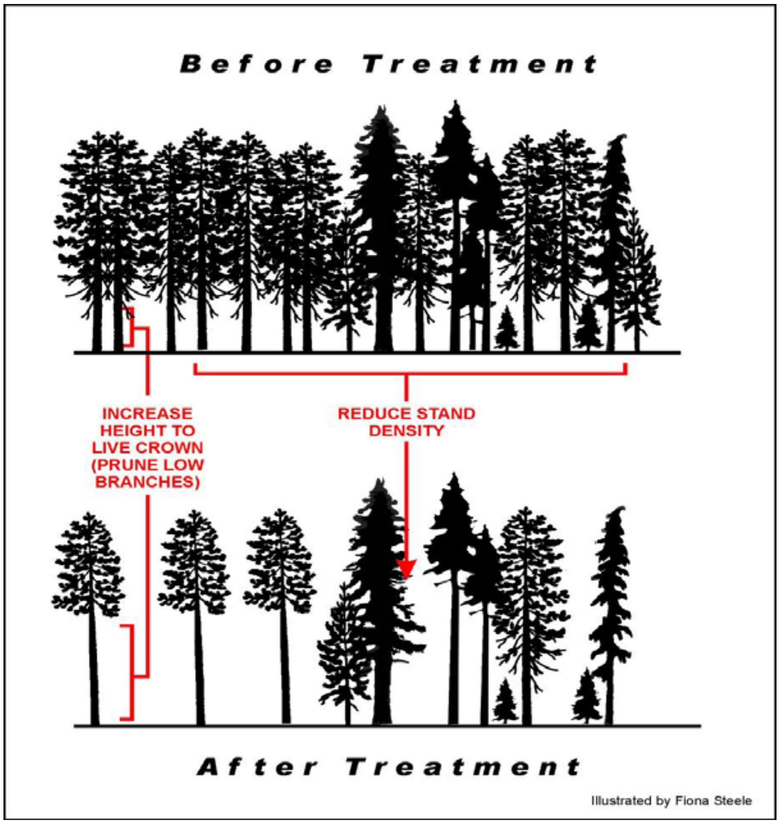


Figure 21. Schematic showing the principles of thinning to reduce stand level hazard.

8.5.1.6 The Principles of Landscape Fuelbreak Design

Fuelbreaks can be defined as strategically placed strips of low volume fuel where firefighters can make a stand against fire and provide safe access for fire crews in the vicinity of wildfires, often for the purpose of lighting backfires. Fuelbreaks act as staging areas where fire suppression crews could anchor their fire suppression efforts, thus increasing the likelihood that fires could be stopped, or fire behaviour minimized, so that the potential for a fire to move fluidly through a community and into the interface is substantially reduced. The principles of fuelbreak design are described in detail in Appendix 2.

The Island must be sensitive to visual concerns and public perception. Therefore, specific area treatments or other manual/mechanical methods are most desirable. A fuel treatment is created by reducing surface fuels, increasing height to live crown and lowering stand density through tree removal (Figure 22). Fuelbreaks can be developed using a variety of prescriptive methods that may include understory and overstory fuel removal, timing of treatment, synergistic effects with other treatments, and placement on the landscape so that they break up hazardous fuel types or utilize existing natural fuel breaks.

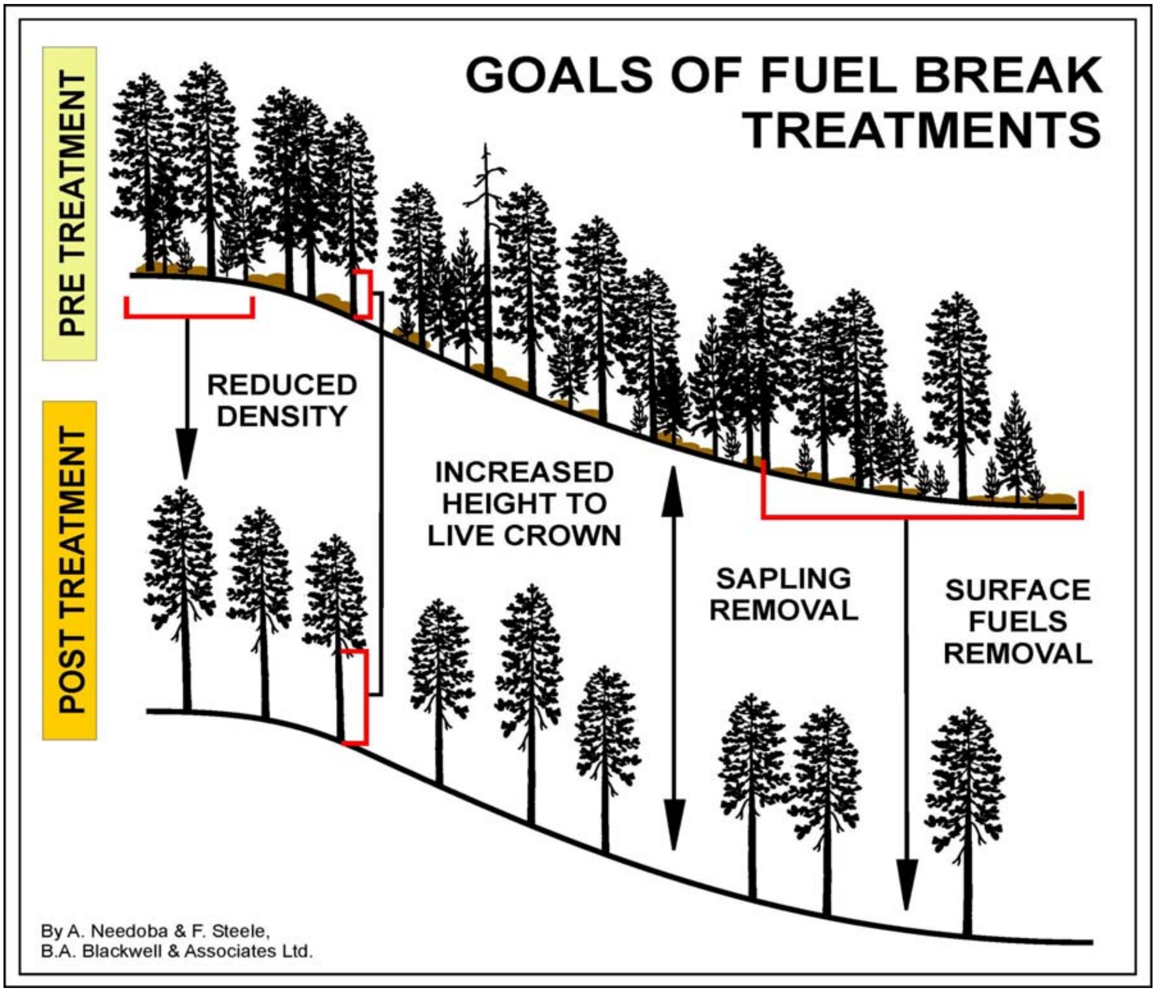


Figure 22. Conceptual diagram of a shaded fuelbreak pre treatment and post treatment.

When developing fuelbreak prescriptions, the Canadian Forest Fire Danger Rating System (CFFDRS) fuel type classification for the area and the potential fire behaviour must be considered in order to predict the change in fire behaviour that will result from altering fuel conditions. The identification of potential candidate areas for fuelbreaks should be focused on areas that will isolate and limit fire spread, and provide solid anchors for fire control actions. The search for candidate areas should be conducted using a combination of aerial photographs, Terrestrial Resources Information Mapping (TRIM), topographic maps, and personal field experience.

Prior to finalizing the location of fuelbreaks, fire behaviour modeling using the Canadian Fire Behaviour Prediction system (FBP) should be applied to test the effectiveness of the size and scale of proposed treatments. These model runs should include basic information from fieldwork pertaining to the fuel types, height to live crown base, crown fuel load, surface loads, and topography. The model runs should be used to demonstrate the effectiveness of treatments in altering fire behaviour potential.

Treatment prescription development must also consider the method of fuel treatment. Methods include manual (chainsaw), mechanical, and pile burning or any combination of these treatments. To be successful, manual treatments should be considered in combination with prescribed burning of broadcast fuels (fuels which have been evenly but contiguously distributed) or pile and burn. Mechanical treatments involve machinery and must be sensitive to ground disturbance and impacts on hydrology and watercourses. Typically, these types of treatments reduce the overstory fuel loads but increase the surface fuel load. The surface fuel load must be removed in order to significantly reduce the fire behaviour potential. Increased surface fuel load is often the reason that prescribed burning or pile and burn are combined in the treatment prescription.

Final selection of the most appropriate fuelbreak location will depend on a number of factors including:

- Protection of recreation values
- Protection of public safety;
- Reduction of potential liabilities;
- Minimizing future suppression costs;
- Improved knowledge;
- Impacts on visual quality;
- The economics of the treatments and the potential benefits;
- Treatment cost recovery;
- The impact of treatments on the alteration of fire behaviour; and
- Public review and comment.

Fuelbreaks should not be considered stand-alone treatments to the exclusion of other important strategies already discussed in this plan. To be successful, Savary Island needs to integrate a fuelbreak plan with strategic initiatives such as structure protection, emergency response, training, communication and education. An integrated strategy will help to mitigate landscape level fire risk, reduce unwanted wildland fire effects and the potential negative social, economic and environmental effects that large catastrophic fires can cause.

8.5.2 Maintenance

Once a community commits to the development of a fuelbreak strategy, decision makers and municipal staff must recognize that they are embarking on a long-term commitment to these types of treatments and that future maintenance will be required. Additionally, the financial commitment required to develop these treatments in the absence of any revenue will be high. A component of the material to be removed to create fuelbreaks has an economic value and could potentially be used to offset the cost of treatment, thereby providing benefits to municipalities and the local economy.

Fuelbreaks require ongoing treatment to maintain low fuel loadings. Following treatment, tree growth and understory development start the process of fuel accumulation and, if left unchecked, over time the fuelbreak will degrade to conditions that existed prior to treatment. Some form of follow-up treatment is required. Follow-up is dependent on the productivity of the site, and may be required as frequently as every 10 to 15 years in order to maintain the site in a condition of low fire behaviour potential.

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Appendix 1 – Fuel Type Descriptions

Fuel Type Descriptions

The following is a general description of the dominant fuel types within the study area.

C3 fuel type

Area of Fuel Type (ha)	150
Structure Classification	Late pole sapling to late young forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Thuja plicata* (western redcedar), *Abies grandis* (grand fir), *Arbutus menziesii* (Arbutus), *Pinus contorta* (lodgepole pine), *Tsuga heterophylla* (western hemlock)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Low (< 50% cover)
Age	40 – 80 yrs
Height	20 – 35 m
Stand Density	700 – 1,200 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	Average 8 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty (relative to suppression efforts)	Moderate; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 23. Example of evenly stocked, moderate density second growth stand – classified as a C3 fuel type.

C2 fuel type

Area of Fuel Type (ha)	1
Structure Classification	Early to late pole sapling
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Thuja plicata* (western redcedar), *Abies grandis* (grand fir), *Arbutus menziesii* (Arbutus), *Pinus contorta* (lodgepole pine), *Tsuga heterophylla* (western hemlock)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Low (< 50% cover)
Age	20 – 40 yrs
Height	10 – 15 m
Stand Density	>1000 stems/ha
Crown Closure	70- 100 %
Height to Live Crown	Average 2 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Extreme; high potential for extreme fire behaviour and active crown fire.

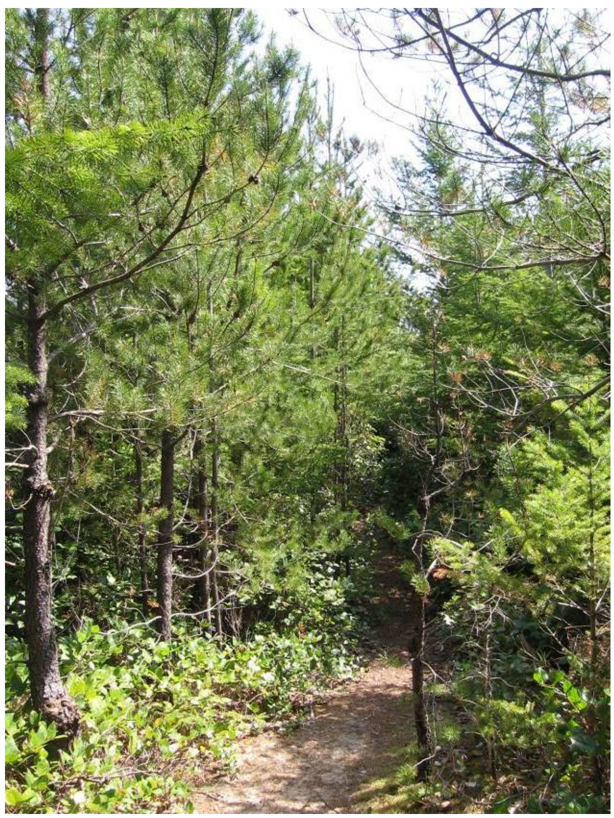

Figure 24. Example of evenly stocked, high density pole sapling stand – classified as a C2 fuel type.

C4 fuel type

Area of Fuel Type (ha)	95
Structure Classification	Pole sapling
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Thuja plicata* (western redcedar), *Abies grandis* (grand fir), *Arbutus menziesii* (Arbutus), *Pinus contorta* (lodgepole pine), *Tsuga heterophylla* (western hemlock)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Low (< 25% cover)
Age	20 – 40 yrs
Height	10 – 25 m
Stand Density	700 – 2000 stems/ha
Crown Closure	40 – 80 %
Height to Live Crown	Average 4 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate to high; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 25. Example of a moderate to high-density second growth stand of red cedar and Douglas-fir classified as a C4 fuel type.

C5 fuel type

Area of Fuel Type (ha)	95
Structure Classification	Mature and old forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Thuja plicata* (western redcedar), *Abies grandis* (grand fir), *Arbutus menziesii* (Arbutus), *Acer macrophyllum* (bigleaf maple), *Alnus rubra* (red alder)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Moderate (> 40% cover)
Average Age	> 80 yrs
Average Height	30 – 40 m
Stand Density	700 – 900 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	Average 18 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Low; however, if fire is wind driven then there is a moderate potential for active crown fire.

Figure 26. Example of mature forest of Douglas fir and western red cedar – classified as a C5 fuel type

C7 fuel type

Area of Fuel Type (ha)	6
Structure Classification	Young forest to mature forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Arbutus menziesii* (Arbutus)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Variable depending on site quality and moisture availability
Average Age	20 – 80 yrs
Average Height	10 – 30 m
Stand Density	Variable, typically less than 500 stems/ha
Crown Closure	20 – 40%
Height to Live Crown	Average 4 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Low; however, if fire is wind driven then there is a moderate potential for active crown fire.

Figure 27. Example of an open Douglas-fir and Arbutus forest – classified as a C7 fuel type.

D1 fuel type

Area of Fuel Type (ha)	18
Structure Classification	Pole sapling to mature forest
Dominant Tree Species	*Acer macrophyllum* (bigleaf maple), *Alnus rubra* (red alder)
Tree Species Type	> 80% Deciduous
Understory Vegetation	High (> 90% cover)
Average Age	> 20 yrs
Average Height	>10 m
Stand Density	600 – 2,000 stems/ha
Crown Closure	20 – 100 %
Height to Live Crown	< 10 m
Surface Fuel Loading	< 3 kg/m^2
Burn Difficulty	Low

Figure 28. Moist rich site dominated by red alder – classified as a D1 fuel type.

M2 fuel type

Area of Fuel Type (ha)	52
Structure Classification	Pole sapling, young forest, mature and old forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Thuja Plicata* (western redcedar), *Abies grandis* (grand fir), *Tsuga heterophylla* (western hemlock) *Acer macrophyllum* (bigleaf maple), *Alnus rubra* (red alder)
Tree Species Types	Coniferous 20-80% / Deciduous
Understory Vegetation	variable
Average Age	> 20 yrs
Average Height	> 10 m
Stand Density	600-1500 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	6 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 29. Mixed fir/cedar/sword fern site with a deciduous component of red alder and big leaf maple – classified as an M2 fuel type.

O1b fuel type

Area of Fuel Type (ha)	39
Structure Classification	Shrub/Herb
Dominant Tree Species	None
Tree Species Type	
Understory Vegetation	High (> 90% cover)
Average Age	<20 yrs
Average Height	<3 m
Stand Density	<50 stems/ha
Crown Closure	<20%
Height to Live Crown	
Surface Fuel Loading	< 3 kg/m^2
Burn Difficulty	Low

Figure 30. Volatile shrub dominated fuel type – classified as O1b.

O1a fuel type

Area of Fuel Type (ha)	7
Structure Classification	Herb/shrub
Dominant Tree Species	None
Tree Species Type	
Understory Vegetation	High (> 90% cover)
Average Age	< 10 yrs
Average Height	< 1m
Stand Density	< 50 stems/ha
Crown Closure	< 20%
Height to Live Crown	
Surface Fuel Loading	< 3 kg/m^2
Burn Difficulty	High

Figure 31. Low volatility Herb/shrub dominated fuel type – classified as O1a.

S3 fuel type

Area of Fuel Type (ha)	2
Structure Classification	Slash
Dominant Tree Species	None
Tree Species Type	
Understory Vegetation	Variable
Average Age	Variable
Average Height	Variable
Stand Density	Variable
Crown Closure	Variable
Height to Live Crown	
Surface Fuel Loading	> 15 kg/m^2
Burn Difficulty	High

Figure 32. Slash dominated fuel type – classified as S3.

Appendix 2 – Principles of Fuel Break Design

The information contained within this section has been inserted from "The Use of Fuelbreaks in Landscape Fire Management" by James K. Agee, Benii Bahro, Mark A. Finney, Philip N. Omi, David B. Sapsis, Carl N. Skinner, Jan W. van Wagtendonk, and C. Phill Weatherspoon. This article succinctly describes the principles and use of fuelbreaks in landscape fire management.

> The principal objective behind the use of fuelbreaks, as well as any other fuel treatment, is to alter fire behaviour over the area of treatment. As discussed above, fuelbreaks provide points of anchor for suppression activities.
>
> - Surface Fire Behaviour
>
> Surface fuel management can limit fireline intensity (Byram 1959) and lower potential fire severity (Ryan and Noste 1985). The management of surface fuels so that potential fireline intensity remains below some critical level can be accomplished through several strategies and techniques. Among the common strategies are fuel removal by prescribed fire, adjusting fuel arrangement to produce a less flammable fuelbed (e.g., crushing), or "introducing" live understory vegetation to raise average moisture content of surface fuels (Agee 1996). Wildland fire behaviour has been observed to decrease with fuel treatment (Buckley 1992), and simulations conducted by van Wagtendonk (1996) found both pile burning and prescribed fire, which reduced fuel loads, to decrease subsequent fire behaviour. These treatments usually result in efficient fire line construction rates, so that control potential (reducing "resistance to control") can increase dramatically after fuel treatment.
>
> The various surface fuel categories interact with one another to influence fireline intensity. Although more litter and fine branch fuel on the forest floor usually results in higher intensities, that is not always the case. If additional fuels are packed tightly (low fuelbed porosity), they may result in lower intensities. Although larger fuels (>3 inches) - are not included in fire spread models, as they do not usually affect the spread of the fire (unless decomposed [Rothennel 1991]), they may result in higher energy releases over longer periods of time when a fire occurs, having significant effects on fire severity, and they reduce rates of fireline construction.
>
> The effect of herb and shrub fuels on fireline intensity is not simply predicted. First of all, more herb and shrub fuels usually imply more open conditions. These should be associated with lower relative humidity and higher surface windspeeds. Dead fuels may be drier - and the rate of spread may be higher - because of the altered microclimate compared to more closed canopy forest with less understory. Live fuels, with higher foliar moisture while green, will have a dampening effect on fire behaviour. However, if the grasses and forbs cure, the fine dead fuel can increase fireline intensity and localized spotting.

- Conditions That Initiate Crown Fire

A fire moving through a stand of trees may move as a surface fire, an independent crown fire, or as a combination of intermediate types of fire (Van Wagner 1977). The initiation of crown fire behaviour is a function of surface fireline intensity and of the forest canopy: its height above ground and moisture content (Van Wagner 1977). The critical surface fire intensity needed to initiate crown fire behaviour can be calculated for a range of crown base heights and foliar moisture contents, and represents the minimum level of fireline intensity necessary to initiate crown fire (Table 1); Alexander 1988, Agee 1996). Fireline intensity or flame length below this critical level may result in fires that do not crown but may still be of stand replacement severity. For the limited range of crown base heights and foliar moistures shown in Table 3, the critical levels of flame length appear more sensitive to height to crown base than to foliar moisture (Alexander 1988).

Table 1. Flame lengths associated with critical levels of fireline intensity that are associated with initiating crown fire, using Byram's (1959) equation.

Foliar Moisture Content (%)	Height of Crown Base in meters and feet			
	2 meters	6 meters	12 meters	20 meters
	6 feet	20 feet	40 feet	66 feet
	M ft	M ft	M ft	M ft
70	1.1 4	2.3 8	3.7 12	5.3 17
80	1.2 4	2.5 8	4.0 13	5.7 19
90	1.3 4	2.7 9	4.3 14	6.1 20
100	1.3 4	2.8 9	4.6 15	6.5 21
120	1.5 5	3.2 10	5.1 17	7.3 24

If the structural dimensions of a stand and information about foliar moisture are known, then critical levels of fireline intensity that will be associated with crown fire for that stand can be calculated. Fireline intensity can be predicted for a range of stand fuel conditions, topographic situations such as slope and aspect, and anticipated weather conditions, making it possible to link on-the-ground conditions with the initiating potential for crown fires. In order to avoid crown fire initiation, fireline intensity must be kept below the critical level. Managing surface fuels can accomplish this such that fireline intensity is kept well below the critical level or by raising crown base heights such that the critical fireline intensity is difficult to reach. In the field, the variability in fuels, topography and microclimate will result in varying levels of potential fireline intensity, critical fireline intensity, and therefore varying crown fire potential.

- Conditions That Allow Crown Fire To Spread

The crown of a forest is similar to any other porous fuel medium in its ability to burn and the conditions under which crown fire will or will not spread. The heat from a spreading crown fire into unburned crown ahead is a function of the crown rate of spread, the crown bulk density, and the crown foliage ignition energy. The crown fire rate of spread is not the same as the surface fire rate of spread, and often includes effects of short-range spotting. The crown bulk density is the mass of crown fuel, including needles, fine twigs, lichens, etc., per unit of crown volume (analogous to soil bulk density). Crown foliage ignition energy is the net energy content of the fuel and varies primarily by foliar moisture content, although species differences in energy content are apparent (van Wagtendonk et al. 1998). Crown fires will stop spreading, but not necessarily stop torching, if either the crown fire rate of spread or crown bulk density falls below some minimum value.

If surface fireline intensity rises above the critical surface intensity needed to initiate crown fire behaviour, the crown will likely become involved in combustion. Three phases of crown fire behaviour can be described by critical levels of surface fireline intensity and crown fire rates of spread (Van Wagner 1977, 1993): (1) a passive crown fire, where the crown fire rate of spread is equal to the surface fire rate of spread, and crown fire activity is limited to individual tree torching; (2) an active crown fire, where the crown fire rate of spread is above some minimum spread rate; and (3) an independent crown fire, where crown fire rate of spread is largely independent of heat from the surface fire intensity. Scott and Reinhardt (in prep.) have defined an additional class, (4) conditional surface fire, where the active crowning spread rate exceeds a critical level, but the critical level for surface fire intensity is not met. A crown fire will not initiate from a surface fire in this stand, but an active crown fire may spread through the stand if it initiates in an adjacent stand.

Critical conditions can be defined below which active or independent crown fire spread is unlikely. To derive these conditions, visualize a crown fire as a mass of fuel being carried on a "conveyor belt" through a stationary flaming front. The amount of fine fuel passing through the front per unit time (the mass flow rate) depends on the speed of the conveyor belt (crown fire rate of spread) and the density of the forest crown fuel (crown bulk density). If the mass flow rate falls below some minimum level (Van Wagner 1977) crown fires will not spread. Individual crown torching, and/or crown scorch of varying degrees, may still occur.

Defining a set of critical conditions that may be influenced by management activities is difficult. At least two alternative methods can define conditions such that crown fire spread would be unlikely (that is, mass flow rate is too low). One is to calculate critical windspeeds for given levels of crown bulk density (Scott and Reinhardt, in prep.), and the other is to define empirically derived thresholds of crown fire rate of spread so that critical levels of crown bulk density can be defined (Agee 1996). Crown bulk densities of 0.2 kg m^{-3} are common in boreal forests that burn with crown fire (Johnson 1992), and in mixed conifer forests, Agee (1996) estimated that at levels below 0.10 kg m^{-3} crown fire spread was unlikely, but no definitive single "threshold" is likely to exist.

Therefore, reducing surface fuels, increasing the height to the live crown base, and opening canopies should result in (a) lower fire intensity, (b) less probability of torching, and (c) lower probability of independent crown fire. There are two caveats to these conclusions. The first is that a grassy cover is often preferred as the fuelbreak ground cover, and while fireline intensity may decrease in the fuelbreak, rate of spread may increase. Van Wagtendonk (1996) simulated fire behaviour in untreated mixed conifer forests and fuelbreaks with a grassy understory, and found fireline intensity decreased in the fuelbreak (flame length decline from 0.83 to 0.63 m [2.7 to 2.1 ft]) but rate of spread in the grassy cover increased by a factor of 4 (0.81 to 3.35 m/min [2.7-11.05 ft/min]). This flashy fuel is an advantage for backfiring large areas in the fuelbreak as a wildland fire is approaching (Green 1977), as well as for other purposes described later, but if a fireline is not established in the fuelbreak, the fine fuels will allow the fire to pass through the fuelbreak quickly. The second caveat is that more open canopies will result in an altered microclimate near the ground surface, with somewhat lower fuel moisture and higher windspeeds in the open understory (van Wagtendonk 1996).

- Fuelbreak Effectiveness

The effectiveness of fuelbreaks continues to be questioned because they have been constructed to varying standards, "tested" under a wide variety of wildland fire conditions, and measured by different standards of effectiveness. Green (1977) describes a number of situations where traditional fuelbreaks were successful in stopping wildland fires, and some where fuelbreaks were not effective due to excessive spotting of wildland fires approaching the fuelbreaks.

Fuelbreak construction standards, the behaviour of the approaching wildland fire, and the level of suppression each contribute to the effectiveness of a fuelbreak. Wider fuelbreaks appear more effective than narrow ones. Fuel treatment outside the fuelbreak may also contribute to their effectiveness (van Wagtendonk 1996). Area treatment such as prescribed fire beyond the fuelbreak may be used to lower fireline intensity and reduce spotting as a wildland fire approaches a fuelbreak, thereby increasing its effectiveness. Suppression forces must be willing and able to apply appropriate suppression tactics in the fuelbreak. They must also know that the fuelbreaks exist, a common problem in the past. The effectiveness of suppression forces depends on the level of funding for people, equipment, and aerial application of retardant, which can more easily reach surface fuels in a fuelbreak. Effectiveness is also dependent on the psychology of firefighters regarding their safety. Narrow or unmaintained fuelbreaks are less likely to be entered than wider, well-maintained ones.

No absolute standards for width or fuel manipulation are available. Fuelbreak widths have always been quite variable, in both recommendations and construction. A minimum of 90 m (300 ft) was typically specified for primary fuelbreaks (Green 1977). As early as the 1960's, fuelbreaks as wide as 300 m (1000 ft) were included in gaming simulations of fuelbreak effectiveness (Davis 1965), and the recent proposal for northern California national forests by the Quincy Library Group (see web site http://www.qlg.org for details) includes fuelbreaks 390 m (0.25 mi) wide. Fuelbreak simulations for the Sierra Nevada Ecosystem Project (SNEP) adopted similar wide fuelbreaks (van Wagtendonk 1996, Sessions et al. 1996).

Fuel manipulations can be achieved using a variety of techniques (Green 1977) with the intent of removing surface fuels, increasing the height to the live crown of residual trees, and spacing the crowns to prevent independent crown fire activity. In the Sierra Nevada simulations, pruning of residual trees to 3 m (10 ft) height was assumed, with canopy cover at 1-20% (van Wagtendonk 1996). Canopy cover less than 40% has been proposed for the Lassen National Forest in northern California. Clearly, prescriptions for creation of fuelbreaks must not only specify what is to be removed, but must describe the residual structure in terms of standard or custom fuel models so that potential fire behaviour can be analyzed.