National guide for wildland-urban-interface fires: guidance on hazard and exposure assessment, property protection, community resilience and emergency planning to minimize the impact of wildland-urban interface fires

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NATIONAL GUIDE FOR WILDLAND-URBAN INTERFACE FIRES

Guidance on hazard and exposure assessment, property protection, community resilience and emergency planning to minimize the impact of wildland-urban interface fires

National Research Council Canada

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National Guide for Wildland-Urban Interface Fires

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List of Abbreviations

AHJ – Authority having jurisdiction
AS – Australian Standard
ASTM – ASTM International
B&CPI – Buildings and core public infrastructure
CC – Construction Class
CFFDRS – Canadian Forest Fire Danger Rating System
CFS – Canadian Forest Service
CRA – Community risk assessment
CRBCPI – Climate-Resilient Buildings and Core Public Infrastructure
CSA – CSA Group
EOC – Emergency operations centre
ERP – Emergency response plan
FBP – Canadian Forest Fire Behaviour Prediction
FUS – Fire Underwriters Survey
FWI – Canadian Forest Fire Weather Index
LPG – Liquefied petroleum gas
NBC – National Building Code of Canada
NFC – National Fire Code of Canada
NFPA – National Fire Protection Association
NRC – National Research Council of Canada
SFM – California State Fire Marshal
TC – Technical Committee
TG – Task Group
ULC – ULC Standards
WPG – Wildfire Preparedness Guide
WUI – Wildland-urban interface

List of Defined Terms[13]

Accessory structure: *building* or *structure* used to shelter or support any material, equipment, chattel, or occupancy other than a habitable *building* [1].

Approved: acceptable to the *authority having jurisdiction (AHJ)* [1].

Authority having jurisdiction (AHJ): governmental body responsible for the enforcement of any provisions of this Guide, where adopted; or the official or agency designated by that body to exercise such a function [2].

Background traffic: vehicles engaged in normal travel activities that are not part of an active *evacuation* [3].

Building: *structure* used or intended for supporting or sheltering any use or occupancy [2].

Canadian Forest Fire Behaviour Prediction (FBP) System Fuel Type (FBP Fuel Type): association of fuel elements of distinctive species, form, size, arrangement, and continuity that is identified in the FBP System and that exhibits characteristic fire behaviour under defined burning conditions [4]. (See Appendix F for further details.) (See also *Fuel complex*.)

Capability: ability to perform required actions [1].

Combustible: 1. [in relation to *wildland* fuels] capable of undergoing combustion [5]; 2. [in relation to *building* materials] fails to meet the acceptance criteria of CAN/ULC-S114, “Test for Determination of Non-Combustibility in Building Materials” [2],[6].

Communication: process of transmission or exchange of information through verbal, written, or electronic means [7].

Community: group of two or more *dwellings* of separate legal title that are under the administrative responsibility of a single incorporated municipal or indigenous government.

Note 1 to entry: *Communities* range from rural to high-density residential.

Community plan: document prepared by the *community* to identify what they want to improve or achieve in their area.

Construction Class (CC): type of construction related to the *Exposure Level* and extent of following recommended *Priority Zone mitigation* measures.

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[13] Definitions without references were developed by the Guide’s TC.

Construction Class CC1: *Construction Class* where, primarily through the use of *noncombustible* materials, a level of resistance to ignition and sustained flaming exists that is expected to reduce losses from a wildland-urban interface (*WUI*) *fire* where conditions exist that could potentially expose the *building*, or elements of the *building*, to direct flame impingement and a high level of thermal irradiation and *burning embers*.

Note 1 to entry: Thermal radiation levels are expected to be higher than 25 kW/m^2.

Note 2 to entry: *Construction Class CC1*(FR) has exterior walls with a *fire-resistance rating* of not less than either 1 h where no *Priority Zones* follow the recommended *mitigation* measures relating to *fuel management* and adjacent *combustible structures* or 45 min where recommendations have only been followed for *Priority Zone 1A* and the *Exposure Level* is Moderate or higher.

Construction Class CC2: *Construction Class* where, through the use of a combination of *noncombustible* and *ignition-resistant* materials, a level of resistance to ignition and sustained flaming exists that is expected to reduce losses from a *WUI fire* where conditions exist that could potentially expose the *building*, or elements of the *building*, to a moderate level of thermal irradiation and *burning embers*.

Note 1 to entry: *Exposure* conditions are such that ignition due to *exposure* to direct flame impingement is not likely.

Note 2 to entry: Thermal radiation levels are expected to be higher than 12.5 kW/m^2 but not higher than 25 kW/m^2.

Construction Class CC3: *Construction Class* where, through the use of a combination of *noncombustible* materials, *ignition-resistant* materials, and other *combustible* materials, a level of resistance to ignition and sustained flaming exists that is expected to reduce losses from a *WUI fire* where conditions exist that could potentially expose the *building*, or elements of the *building*, to *burning embers*.

Note 1 to entry: *Exposure* conditions are such that ignition due to *exposure* to direct flame impingement or thermal irradiation is not likely.

Note 2 to entry: Thermal radiation levels are expected to be not higher than 12.5 kW/m^2, the commonly accepted minimum level for piloted ignition of wood.

Critical infrastructure: assets, systems, and networks vital to a *community*, whose incapacitation or destruction would have a debilitating effect on the economy, environment, public health or safety, or any combination thereof (e.g., power lines, medical centres, wastewater services, water supply pumping stations, *emergency communications* centres, *emergency response* facilities for key equipment) [7].

Crown fire: fire that advances through the crown fuel layer, usually in conjunction with a surface fire [4].

Demographics: variables related to characteristics of a population, such as age, socio-economic status, gender, etc.

Disaster: serious disruption of the functioning of a *community* or a society at any scale due to hazardous events interacting with conditions of *exposure*, *vulnerability*, and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts [8].

Driveway: vehicular ingress and egress route that typically serves a single-family *dwelling* but may be designed to serve multiple *structures* or units.

Dwelling (unit): suite operated as a housekeeping unit, used or intended to be used by one or more persons and usually containing cooking, eating, living, sleeping, and sanitary facilities [2].

Ember: particle of solid material that emits radiant energy due either to its temperature or the process of combustion on its surface and poses a *risk* of ignition to materials upon which it is incident [9]. (See also *Firebrand*.)

Emergency: event that by its nature requires immediate *response* and logistical coordination to limit *risk* to the safety, health, or welfare of people and the natural and built environment.

Emergency communication: system by which *communities* and the responding agencies in an area can be alerted to defined threats to the *community* and take actions that mitigate the threats and limit the course and impact of the events.

Emergency management: organization and management of *resources* and responsibilities for addressing aspects of an *emergency*, including *preparedness*, *response*, *recovery*, and *mitigation* [7].

Emergency management plan: document identifying *risks* and potential events that may affect the *community*, designated roles in an *emergency*, the responsibilities of those designated to act, specific actions in an *emergency*, the coordination of responding agencies, the *communication* of required actions, including alerting those impacted by an event, and the management of changes to the plan as the *community* changes over time.

Emergency responder: organization required to plan and prepare a *response* to an *emergency* [7].

Evacuation: rapid movement of people away from the immediate threat or impact of an *emergency* to a safer place [7].

Note 1 to entry: In a *WUI fire* context, an *evacuation* may be mandatory, advised, or spontaneous.

Evacuation order: instruction or movement of *community* members out of a defined area given an immediate threat to life and property [7].

Evacuation plan: pre-identified and agreed upon operating procedures, responsibilities, and *resources*, usually recorded and shared in written form, to facilitate and organize the timely and coordinated actions of all relevant *stakeholders* in case an *emergency evacuation* should become necessary [7].

Evacuee: person who has evacuated a hazardous location in response to the threat of an *emergency*, either through their own initiative and *resources* (self-evacuated) or through the direction and assistance of authorities or *emergency responders* [7].

Exposed building face: that part of the exterior wall of a *building* that faces one direction and is located between ground level and the ceiling of its top storey, as well as, for the purposes of this Guide, the roof above that part of the exterior wall; adapted from [2].

Exposure: proportion of a *value-at-risk* (*structure*) that interacts with a *hazard*; *exposure* is a function of time and distance that depends on the physical process being considered (e.g., *ember* transport versus radiant heating) [4].

Exposure Level: degree to which *structures* are likely to be exposed to *embers*, radiation, or flame contact.

Note 1 to entry: The *risk* of ignition for each *Exposure Level* can be adjusted by following construction recommendations for a particular *Construction Class* and/or by following *Priority Zone mitigation* measures. (See Sentence 3.2.2(1), Table 7, and Section 3.4.)

Firebrand (flying ember, burning ember): airborne piece of flaming or *smouldering ember* material capable of acting as an ignition source [4]. (See also *Ember*.)

Firebreak: barrier to fire spread built by clearing or significantly thinning fuels on a strip of strategically located land [10].

Fire chief: highest ranking officer in charge of a *fire department* [11].

Fire department: organization providing fire suppression, rescue, and related activities [12].

Fire front (flame front): strip of primarily flaming combustion along the fire perimeter, that is, a particularly active fire edge [4].

Note 1 to entry: Fine fuels typically produce a narrow *fire front*, whereas dry heavy fuels produce a wider zone or band of flames.

Fire intensity: heat energy released per unit time per unit length of part of the fire perimeter (e.g., head fire, flank fire, or back *fire intensity*); adapted from [4].

Note 1 to entry: Flame size is the main visual manifestation of *fire intensity*.

Note 2 to entry: Numerically, *fire intensity* is equal to the product of the quantity of fuel consumed per unit area of *flame front*, the linear rate of fire spread, and the net heat of combustion.

Note 3 to entry: *Fire intensity* is typically at a maximum at the head of the fire and decreases along the fire perimeter to a minimum at the back of the fire.

Note 4 to entry: The recommended units for measuring *fire intensity* are kilowatts per metre (kW/m).

Fireline: that portion of the fire upon which *resources* are deployed and are actively engaged in the *incident*, that is, the working area around a fire [4].

Fire-protection rating: time in minutes or hours that a closure, such as a door or window, will withstand the passage of flame when exposed to fire under specified conditions of test and performance criteria, or as otherwise prescribed in this Guide [2].

Fire-resistance rating: time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria, or as determined by extension or interpretation of information derived therefrom as prescribed in this Guide [2].

Fire-retardant-treated wood: wood or a wood product that has had its surface-burning characteristics, such as flame spread, rate of fuel contribution, and density of *smoke* developed, reduced by impregnation with fire-retardant chemicals [2].

Fire season: period of the year when fires are likely to start, spread, and do damage to *values-at-risk* (*structures*, *critical infrastructure*, and the natural environment) sufficient to warrant organized fire suppression, which is set out and commonly referred to in fire *prevention* legislation [4].

Note 1 to entry: The *fire season* is usually subdivided on the basis of the seasonal combustibility of fuel types (e.g., spring, summer, and fall).

Fire weather: collectively, those weather parameters that influence fire occurrence and subsequent fire behaviour (e.g., dry-bulb temperature, relative humidity, wind speed and direction, precipitation, moisture content, atmospheric stability, winds aloft) [4].

Flame-spread rating: index or classification indicating the extent of spread-of-flame on the surface of a material or an assembly of materials as determined in a standard fire test as prescribed in the NBC and used in this Guide [2].

Forecast: estimate of the likely occurrence of a future event for a specific location [7].

Fuel break: trench dug down to mineral soil that stops surface fire spread [10].

Fuel complex: association of *combustible* vegetative fuel elements (e.g., aerial and downed live and dead needles, leaves, twigs, bark flakes, dead stems, and organic matter on the ground) of distinctive species, form, size, arrangement, and continuity [4]. (See also *FBP Fuel Type*.)

Fuel load: dry weight of *combustible* material per unit area [4].

Fuel management: planned manipulation and/or reduction of living or dead forest fuels for forest management and other land use objectives (e.g., *hazard* reduction, silvicultural purposes, wildlife habitat improvement) by: *prescribed fire*; mechanical, chemical, or biological means; and/or changing stand structure and species composition [4].

Hazard: potentially damaging physical event, phenomenon, or human activity that could cause the loss of life or injury, property damage, social and economic disruption, or environmental degradation [13].

High fuel hazard: vegetation consisting of fuel types such as *FBP Fuel Types* C2, C4, M3, and M4. (See Appendix F for further details.)

Ignition-resistant: [in relation to *building* materials] resists ignition or sustained flaming combustion sufficiently to reduce losses from *WUI* conflagrations under worst-case weather and fuel conditions with *WUI fire exposure* of *burning embers* and small flames [1].

Impairment: permanent or temporary condition to which an individual is subjected that impacts upon performance. The condition might be sensory, cognitive, physical, situational, etc. [7].

Incident: occurrence, either caused by humans or natural phenomena that requires a *response* to prevent or minimize loss of life or damage to property and/or the environment [4].

Local government: *AHJ* with respect to measures identified in this Guide, which may be a municipal government, a provincial or territorial government, or, for the purposes of this Guide, a local Indigenous *community* authority.

Log wall construction: type of construction in which exterior walls are constructed of solid wood members and where the smallest horizontal dimension of each solid wood member is at least 152 mm (6 in.) [1].

Low fuel hazard: vegetation consisting of fuel types such as *FBP Fuel Types* D1, M1 and M2 with ≤ 25% conifers, O1, S1, S2, and S3. (See Appendix F for further details.)

Mass evacuation: *evacuation* of whole *communities*, neighbourhoods, or geographical areas [7].

Mitigation: actions taken to reduce the impact of a *hazard* in order to protect lives, property, and the environment, and to reduce economic disruption [4].

Moderate fuel hazard: vegetation consisting of fuel types such as *FBP Fuel Types* C1, C3, C5, C6, C7, and M1 and M2 with > 25% conifers. (See Appendix F for further details.)

Noncombustible: [in relation to *building* materials] meets the acceptance criteria of CAN/ULC-S114, “Test for Determination of Non-Combustibility in Building Materials” [2],[6].

Noncombustible construction: type of construction in which a degree of fire safety is attained by the use of *noncombustible* materials for structural members and other *building* assemblies [2].

Notification: automatic *communication* by a system, individual, or organization to warn and inform a target population of an *incident* (and possibly to inform them of the required *response*).

Pre-attack plan: written or verbal *incident* action plan stating the overall objectives, strategy, and specific tactics for a specified period of time [14].

Preparedness: continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action in an effort to ensure effective coordination during *incident response* [4].

Prescribed burning: knowledgeable application of fire to a specific land area to accomplish predetermined forest management or other land use objectives [4].

Prescribed fire: fire utilized for *prescribed burning* that is usually ignited according to agency policy and management objectives [4].

Prevention: actions taken to avoid the occurrence of negative consequences associated with a given threat; *prevention* activities may be included as part of *mitigation* [4].

Priority Zone: zone around a building or other point source where specific *fuel management* measures are used.

Priority Zone 1A: *Priority Zone* that is immediately adjacent to a *building* and extends to 1.5 m outward in all directions from the furthest projection of the *building*.

Note 1 to entry: The main objective of the management of vegetation and *combustible* material in this zone is to limit the *risk* of *burning embers* landing and igniting material near the *building* or *building* attachments or projections (e.g., decks), and to create an environment that will not support fire of any kind.

Priority Zone 1: *Priority Zone* that is beyond 1.5 m and extends to 10 m outward in all directions from the furthest projection of the *building*.

Note 1 to entry: The main objective of the management of vegetation and *combustible* material in this zone is to create an environment that will not support fire of any kind.

Priority Zone 2: *Priority Zone* that is beyond 10 m and extends to 30 m outward in all directions from the furthest projection of the *building*.

Note 1 to entry: The main objective of *fuel management* within this zone is to create an environment that will only support fires of lower intensity and rate of spread.

Note 2 to entry: The 30 m outer radius of *Priority Zone 2* is adjusted if the *slope* of the *Priority Zone* is greater than 30%. (See Section 3.4.2.)

Priority Zone 3: *Priority Zone* that is beyond 30 m and extends to 100 m outward in all directions from the furthest projection of the *building*.

Note 1 to entry: The 30 m inner and 100 m outer radius of *Priority Zone 3* are adjusted accordingly when the 30 m outer radius of *Priority Zone 2* is adjusted for *slope*.

Note 2 to entry: The 100 m outer radius of *Priority Zone 3* is adjusted if the *slope* of the *Priority Zone* is greater than 30%. (See Section 3.4.2.)

Qualified professional: person with experience and training in the pertinent discipline, who is a qualified expert with expertise appropriate for the relevant area or subject.

Recovery: activities and programs designed to return conditions to a level that is acceptable to the organization following an *incident* [13].

Re-entry: return of populations to a previously evacuated area [7].

Residence time: length of time required for the flaming zone or *fire front* of a spreading forest fire to pass a given point [4].

Note 1 to entry: *Residence time* is most commonly expressed in minutes and/or seconds.

Note 2 to entry: Numerically, *residence time* is equal to the flame depth divided by the rate of spread.

Resilience: capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Resource management: system for identifying available *resources* to enable timely access to *resources* needed to prevent, mitigate, prepare for, respond to, maintain continuity during, or recover from an *incident* [15].

Resources: personnel, major items of equipment, supplies, and facilities available or potentially available for assignment to *incident* operations and for which status is maintained. *Resources* may be used in operational support or supervisory capacities at an *incident* [4].

Response: actions taken immediately before, during, or after an *incident* to manage its consequences [13].

Risk: combination of the likelihood and the consequence of a specified *hazard* being realized, with reference to the *vulnerability*, proximity, or *exposure* to the *hazard*, which affects the likelihood of adverse impact [13].

Risk assessment: overall process of *risk* identification, *risk* analysis, and *risk* evaluation [13].

Situational awareness: ongoing assessment by an individual of what is going on around them in the complex and dynamic environment of a fire *incident*, and sensitization of the individual to the *risks* in the context of their role in an *incident* or specific tactic; adapted from [16].

Slope: upward or downward inclination of the earth's surface (i.e., the deviation in terrain from level or flat ground). *Slope* is most commonly expressed as a percentage calculated as the vertical rise or fall in elevation divided by the horizontal distance and then multiplied by 100 [4].

Smoke: visible products of combustion rising above a fire [4].

Smoke column: *smoke* and other gases that form a column-shaped mass above a fire, characterized by sharply defined, billowed edges [4].

Smouldering: fire burning without flame and with a low rate of spread [4].

Spotfire: fire ignited by *firebrands* that are carried outside the main fire perimeter by air currents, by gravity, and/or by convection and turbulence or rotational effects in the *smoke column* [4].

Spotting: production of *spotfires* as a result of *firebrands* being transported downwind of the fire perimeter by buoyancy, convection, and rotational effects [4].

Stakeholder: person, group, organization, or government with an interest or concern in a particular measure, proposal, or event [4].

Structure: that which is built or constructed [1].

Structure Ignition Zone: area in *Priority Zones 1A* to *3* around a specific *structure* and associated *accessory structures*, including all vegetation that constitutes potential fuel for ignition [17].

Subdivision: division of a tract, lot, or parcel of land into two or more lots, plats, sites, or other divisions of land [1].

Topography: collective physical features of a geographic area, such as those represented on a map, especially the relief and contours of the land [18].

Traffic management: implementation of measures to manage traffic (e.g., traffic control systems, variable message signs) [7].

Tree crown: part of a tree containing live foliage, that is, the treetop [19].

Trigger: precursor to a key event, such as initiation of *evacuation* [7].

Values-at-risk: specific or collective set of natural *resources* and man-made improvements or developments that have measurable or intrinsic worth and that could be destroyed or otherwise altered by fire in any given area [4].

Vehicle capacity: maximum number of vehicles that can pass a given point during a specified period under prevailing roadway, traffic, and control conditions [20].

Vulnerability: characteristics and circumstances of a *community*, system, or asset that make it susceptible to the damaging effects of a *hazard*, including the propensity to be adversely affected, and the degree to which a socio-economic system is either susceptible or resilient to the impact of natural *hazards* and related technological and environmental *disasters* (determined by a combination of several factors, including *hazard* awareness, the condition of human settlements and infrastructure, public policy and administration, *resilience*, adaptive capacity, and organized abilities in all fields of *disaster* management).

Vulnerable land uses: types of land use occupied by vulnerable populations (e.g., schools, hospitals, care homes).

Wildfire: unplanned or unwanted natural or human-caused fire in live or dead *combustible* vegetation, as contrasted with a *prescribed fire*.

Wildfire mitigation: implementation of various measures designed to minimize the destructive effects a *wildfire* has on property and lands [21].

Wildfire risk: combination of the likelihood of a *wildfire* occurring combined with the potential impacts of that fire. (See also *Risk*.)

Wildland: area in which development is essentially nonexistent, except for roads, railroads, power lines and other linear infrastructure.

Note 1 to entry: Any *buildings* or *structures* present in a *wildland* are usually widely scattered.

Note 2 to entry: In this Guide, farmland development, such as a wheat field, is not considered *wildland*.

Wildland fire: fire in *combustible* vegetation in a *wildland* (e.g., forest fire, grass fire, brush fire).

Note 1 to entry: *Wildland fires* include both *prescribed fires* and *wildfires*.

Wildland-urban interface (WUI): area where various *structures*, usually private homes, and other human developments meet or are intermingled with *wildland* (vegetative) fuels or can be impacted by the heat transfer mechanisms of a *wildfire*, including *ember* transport.

Wildland-urban interface fire (WUI fire): *wildfire* that has spread into the *wildland-urban interface*.

Note 1 to entry: A *WUI fire* may or may not involve the ignition and burning of *structures*.

National Guide for Wildland-Urban Interface Fires

NRC Team

Preface

Fires in the wildland-urban interface (WUI) have become a global issue, with disasters taking place all over the world recently. The drivers of increasing WUI fire risk—increasing population and expansion of urban areas into wildlands, and climate change—are global-scale phenomena. In the coming decades, WUI fire risk is expected to increase both in regions with a long history of fires and in regions that have had been less affected over past decades. WUI fires can cause the ignition of many structures through the spread of flames and radiant heat and the deposition of burning embers over a short period of time. This can overwhelm protection capabilities, lead to large evacuations, and cause disasters with the potential for the total loss of hundreds of structures in a few hours.

As discussed in Chapter 1 of this Guide, over the last decade, an average of 5 533 wildfires have occurred each year in Canada, involving 2.9 million hectares of wildland area. The number of evacuations caused by wildfires increased by about 1.5 evacuations per year between 1980 and 2014, with more than 20 evacuations per year after 2010. The substantial negative impacts of WUI fires were illustrated by the Okanagan Mountain Park Fire, which affected Kelowna in 2003; the Flat Top Complex Wildfire, which destroyed significant parts of Slave Lake in 2011; and the Horse River Fire, which immensely affected Fort McMurray in 2016 and was the most costly insured loss event in Canadian history. These disasters resulted in a loss of over 2 400 structures and roughly 3 400 dwelling units. Total insured losses from these wildland fire disasters and the 2017 wildland fire catastrophic events in British Columbia are currently estimated to be $4.8 billion. Despite all efforts, wildfires pose a significant challenge to the residential population, to mitigation efforts, and to existing infrastructure when located in a WUI setting. Wildfires are likely to become more severe and frequent as a result of climate change.

This Guide is a product of the Climate-Resilient Buildings and Core Public Infrastructure (CRBCPI) Initiative of the National Research Council of Canada (NRC) and Infrastructure Canada, which was undertaken to improve the resilience of Canada's new and existing buildings and core public infrastructure (B&CPI) to the effects of climate change and extreme weather events (e.g., wildfires). As part of this Initiative, the NRC identified the need to develop a national guide for WUI fires because of a lack of national guidance addressing the impact of WUI fires on communities and addressing WUI fires in a holistic manner. Thus, the objective of this Guide is to provide guidance on how to break the WUI fire disaster sequence at various points (see Appendix A). The guidance is intended to enhance life safety and property protection by reducing the wildfire threat posed by the surrounding environment and by enhancing the fire protection provided by structures. To ensure that the development of the Guide was inclusive and consensus-based, an international TC composed of experts from government, academia, industry, and consultancy was formed to drive the development process.

While the TC has made its best efforts to ensure the recommended measures are consistent with applicable codes and regulations, these measures are not the product of Canada's national code development process. Therefore, these measures have not been subject to the level of scrutiny that is part of that process, nor to a detailed review to ensure the Guide recommendations would not create conflicts with existing codes, applicable standards, or other regulatory requirements. Additionally, the best practices presented in the Guide have not been reviewed from a building science perspective to ensure their use would not result in adverse effects to the building as a system. Authorities having jurisdiction (AHJs) are therefore advised that this Guide is only intended to provide informed recommendations on best construction practice and community development in the WUI given the threat of wildfire, and should be read accordingly.

National Guide for Wildland-Urban Interface Fires

NRC Team

Chapter 1 Introduction

1.1 Terminology

In the context of this document, a *wildland-urban interface* (*WUI*) is an area where various *structures*, usually private homes, and other human developments meet or are intermingled with *wildland* (vegetative) fuels or can be impacted by the heat transfer mechanisms of a *wildfire*, including *ember* transport.

A *WUI fire* is a *wildfire* that has spread into the *WUI*. A *WUI fire* may or may not involve the ignition and burning of *structures*.

Explanations of other terms and abbreviations used in this Guide are given in the List of Defined Terms and the List of Abbreviations.

1.2 Wildfires in Canada

1.2.1 Incidence

Over the past 10 years, a yearly average of 5 533 *wildfires* have burned 2.9 million hectares of *wildland* throughout Canada [22]. Between 1981 and 2018, 302 905 *wildfires* occurred in Canada [22]; 685 (0.2%) of these fires resulted in the *evacuation* of approximately 400 000 people, and 96 of these events resulted in loss of homes, recreational property, or businesses, comprising approximately 4 015 *structures* [23]. See footnote for US *wildfire* statistics.[14]

1.2.2 Fire Suppression

Approximately $1 billion per year is spent to suppress *wildfires* that occur on about 200 million hectares of land where fire can affect *communities* and *resource* values [24]. However, because it is recognized that *wildfire* is a natural ecological process in Canada [25], and because fire

[14] According to Bryner's analysis of US *wildfires*, between 1985 and 2015, there were 75 000 *wildfires* on average per year. Of these, approximately 97% were contained to below 10 acres in size [146]. The remaining 3% of the *wildfires* spread beyond 10 acres. Of these, 3% spread into *communities*—representing less than 100 *WUI* fires per year.

suppression is costly, fires that occur on approximately half the forest in Canada that are not threatening populated places or resource values are not suppressed.

Fire suppression can be effective in containing most *wildland fires* that are actioned. However, the logistical *response* to fires is dependent on a variety of factors, including geographic location, disposition of *resources* to respond to the fire, and weather; consequently, some *wildfires* will inevitably spread to and impact *communities*.

1.2.3 Losses

When *wildfires* spread into *communities*, the consequences of such *incidents* can be extreme—resulting in billions of dollars of losses for residents, governments, and insurers, as well as substantial social impacts, damaging the short-term and long-term viability of a *community*, and displacing or injuring *community* residents. For example, a recent study indicated that the economic impact of *smoke* on residents' health can amount to billions of dollars [27].

For example, approximately 90 000 people (residents and workers) were evacuated and 1 600 *structures* destroyed during the 2016 Horse River Fire that affected the Fort McMurray *community* (see Box 1). The Horse River Fire had a total cost (including insured and uninsured losses and indirect costs) of approximately $9 billion [28]. The Horse River Fire generated tens of thousands of property insurance claims and was the single most costly insured loss event in Canadian history. In addition, the psychological toll on those affected by the fire is just starting to be understood.

Box 1: Horse River Fire (Regional Municipality of Wood Buffalo and Fort McMurray, AB), 2016 [7],[26]

On May 1, 2016, at approximately 4 p.m., agriculture and forestry crews spotted a 2 ha (0.02 km^2) *wildfire* in the Regional Municipality of Wood Buffalo, burning deep in the forest, 15–20 km southwest of the urban service area of Fort McMurray. The Regional Municipality of Wood Buffalo is home to both rural and urban *communities*, with a population of more than 125 000. Strong winds and elevated temperatures promoted the development of the fire. Water bombers were quickly deployed, and warnings of possible *evacuation* were issued to campgrounds in Gregorie and Prairie Creek. Within six hours of the fire initially being spotted, an *evacuation* centre was opened on MacDonald Island and a local state of *emergency* declared. Late the following day, warning levels were reduced because wind conditions appeared favourable: the wind was blowing the fire away from the city.

On May 3, conditions changed, and the fire entered Fort McMurray, leading to the *evacuation* of 12 neighbourhoods and tens of thousands of people to *evacuation* centres. Some centres were affected by changing conditions, requiring them to be subsequently evacuated. During this *evacuation*, two people were killed in a car accident. By the end of the day, over 60 000 residents had evacuated, including all 105 patients at the Northern Lights Regional Health Centre. Highways were quickly overloaded with traffic. To cope with the traffic, convoys were formed.

By May 4, 1 600 *structures* had been destroyed and 10 000 ha (100 km^2) of *wildland* had been involved in the fire. A provincial state of *emergency* was declared and 80 000 people were instructed to leave their homes. By May 5, 49 separate fires were burning, and 4 000 people had to be airlifted from work camps north of Fort McMurray. On May 6, 8 000 workers were evacuated from 19 oil sites as the fire spread north.

Most people who fled the region did not have short-term contingency plans in place other than getting out of immediate danger. Reception centres were put up across Alberta, in Anzac, Athabasca, Bonnyville, Calgary, Drayton Valley, Edmonton, Fort Chipewyan, Fort McKay, Grassland, Janvier, Lac La Biche, Smoky Lake, and St. Paul.

On May 6, Alberta Premier Rachel Notley announced *emergency* funds for *evacuees*. The Canadian Red Cross provided additional funding. The fire continued to grow, move, and spread throughout the month of May. The use of firefighting *resources* peaked on June 3, with approximately 2 197 firefighters engaged. The Government of Alberta kept Albertans informed of the *wildfire* situation with news conferences, information bulletins, social media, websites, call centres, emails, telephone town halls, etc. Eventually, more than 88 000 people were evacuated.

Insured losses from the five examples of fire *disasters* summarized in Table 1 totalled roughly $4.8 billion (adjusted to 2017). Most insured losses during *wildland fire disasters* are associated with property (i.e., residential/home) insurance claims. The three largest *structure* loss events (Horse River, Flat Top Complex, and Okanagan Mountain Park (see Box 2)) occurred in higher density urbanized areas with potential for *structure*-to-*structure* spread. Many other *structure* loss events were associated with lower density rural areas or small settlements.

While the examples in Table 1 are noteworthy due to *structures* lost and damage sustained, there have been many other events, and several *communities* across Canada have also experienced "near misses" with *wildfires*, including Salmon Arm, BC, La Ronge, SK, Timmins, ON, and Halifax/Dartmouth, NS.

Box 2: Okanagan Mountain Park Fire (Kelowna, BC), 2003 [7],[29],[30]

The Okanagan Mountain Park *wildfire* began on August 16, 2003. It was ignited by overnight lightning on a steep *slope* within the very rugged and largely roadless 10 000 ha Okanagan Mountain Park and spread approximately 12–15 kilometres northwest to the outskirts of Kelowna, BC. It grew to 266 km^2 (26 600 ha) before being extinguished nearly 30 days later. Most home losses occurred within the first seven days. Many *wildfires* burned in British Columbia during 2003 with at least 50 fires that threatened urbanised areas. Many large fires were still burning in British Columbia at the time of the Kelowna *disaster*. At Kelowna, the *wildfire* spread through several outlying rural areas along Lakeshore Road on the outskirts of the city before directly impinging upon the recently developed *subdivisions* of Crawford, Mission Hills, and Mission Estates within the city limits.

Kelowna is in one of the hottest and driest areas of British Colombia. The province at the time had recently suffered from a three-year drought increasing the likelihood of fire occurrences. The terrain in the affected area was challenging (gullied, rolling hills and multiple drainages). The affected private properties were located on 10–20% northwest facing *slopes* close to Okanagan Lake. The affected area included mature forest underlain by dense thickets of conifers and shrubs. Maximum ambient temperatures during the *disaster* period ranged from 25–30°C, while humidity varied from 17–38% with winds at 7–33 km/h.

The *subdivisions* of Crawford, Mission Hills, and Mission Estates are located on the outer southeast margin of Kelowna. They were new areas including pockets of underdeveloped housing, natural vegetation, parks, steep terrain, gullies with housing largely bounded by natural grassland and open forest (i.e., *wildland-urban interface* and intermix conditions). The housing examined was typically single large plots or small clusters of houses representing middle to upper-class housing.

238 private homes were destroyed in the City of Kelowna and on nearby acreages during the 2003 *wildfire*. Within the city, the majority of these losses occurred in a few, relatively large clusters of homes as the *wildfire* spread to the northeast and across the *slopes* above Okanagan Mountain Park.

Losses caused by *WUI fires* are attributed to both total and partial destruction of *structures*. While the total destruction of *structures* is extremely expensive and has a considerable negative impact on households and families, the partial destruction of *structures* by *smoke* and fire can also result in significant insured losses.

Table 1: WUI Fire Disasters in Canada since 2000 with Estimated Insured Losses Exceeding $25 Million

WUI Fire Disaster Event	Year	Insured Loss, $M (Adjusted to 2017)	Number of Homes or Structures Lost
Okanagan Mountain Park (Kelowna, BC)	2003	254 [31]	334 homes, many businesses [32]
Flat Top Complex (Slave Lake, AB)	2011	574 [31]	510 *structures* [33]
Horse River (Regional Municipality of Wood Buffalo and Fort McMurray, AB)	2016	3,811 [31]	1 595 *structures* containing 2 579 *dwelling units* [34]
Wildfires in Thompson-Nicola Regional District, BC	2017	27 [35]	215 *structures* [36]
Wildfires in areas surrounding Williams Lake, BC	2017	100 [35]	107 *structures* [37]

1.2.4 Fire Risk

WUI fire is a global phenomenon. Canada is only one of many countries that have experienced increasing *WUI fire risk*; recent *disasters* have occurred on almost every continent [38]. This is because drivers of increasing *WUI fire risk*, such as increasing population, expansion of urban areas into *wildlands*, and climate change, are global scale phenomena [39]–[48]. In the coming decades *WUI fire risk* is expected to increase both in regions with a long history of fires [7] and in regions that have been less affected over past decades [38]. We can learn from *WUI incidents* and *mitigation* practices in other jurisdictions as well as from those in Canada.

The expansion of smaller towns and *communities* into forested areas, an increase in the population of many isolated rural areas, and increasing demand for recreational properties in *WUI* areas has contributed to the expansion of the Canadian *WUI* [39]–[41]. Urban sprawl is also expected to increase the *exposure* of the Canadian population and built environment to *WUI fire hazards* [40],[41]. Further, although suppression activities have been effective for the reduction of *WUI fire disasters*, suppression over several decades may have contributed to increases in stand density and older forests with more biomass (forest fuels) and *hazard* in some areas [41]–[44],[49].

In Canada, the impacts of climate change are expected to contribute to an increase in the length of *fire seasons* and increased *wildland fire risk* in areas that have not historically experienced significant *wildland fire hazards* [46]. Human- and lightning-caused fire occurrence [47] and area burned by *wildland fires* [50]–[53] are expected to increase (given environmental and population changes), as are incidences of larger, more intense *wildland fire* events [53]–[55]. Provincial fire management agencies have reported that *fire seasons* are becoming longer, starting earlier, and exhibiting more frequent extreme fire *hazard* weather [50],[53]. Further, an increase in *WUI fires* places greater stress on *wildland* firefighting capacity, particularly when significant investments are at *risk* of being destroyed by fire and *critical infrastructure* becomes vulnerable [45],[56]. *Incidents* of unmanageable fires [57] and the number of fires that escape initial attack are further expected to increase under changing climate conditions [58].

1.2.5 National Wildland Fire Strategy

The Canadian Wildland Fire Strategy was signed by all provincial and territorial resource ministers in 2005 and reaffirmed in 2016. This strategy for *wildland fire* management has three goals [46]:

1) to foster resilient *communities* and an empowered public
2) to develop healthy and productive forest ecosystems
3) to incorporate modern business practices

Investment in both property and *community*-level actions, including many of the measures identified in this Guide, is a key component of developing *WUI fire* resilient *communities* in Canada [46].

1.2.6 Existing Guidance

Some countries have developed standards concerning measures for *response* planning, *prevention*, protection, firefighting, etc. in relation to *WUI fires*. Other countries rely on guidelines and provisions that cover *WUI fires*, but are included in other general codes (e.g., *building* codes). The International Code Council currently produces a *WUI fire* code [1]. The development of standards, such as CSA S504, “Fire Resilient Planning for Northern Communities” [59], can be critical for reducing the negative impacts of *WUI fires* on the *communities* through appropriate dedicated measures. While the Canadian FireSmart guidelines [10],[60],[61] are being used by numerous local, provincial, and territorial authorities to enhance capacity to manage *WUI fire* events and limit negative impacts, there is no national guide or code to minimize and manage the impact of *WUI fires*. In addition, *wildfire* concerns are not explicitly addressed in the National Building Code of Canada (NBC) [2] or the National Fire Code of Canada (NFC) [62].

1.3 About This Guide

1.3.1 General

This document represents the NRC's efforts to develop a national guide for *WUI fires* (see Box 3). The Guide was developed in partnership with and under the oversight of an international TC.

> **Box 3: The National Guide for Wildland-Urban Interface Fires**
>
> This Guide is a product of a research and development project that was part of a partnership between the NRC and Infrastructure Canada. The project investigated CRBCPI in order to develop new and revised codes, standards, specifications, guidelines, and decision support tools to ensure that Canada's new and existing B&CPI are more resilient to the effects of climate change and extreme weather events. The effort brought together experts from across Canada, including experts on *buildings*, bridges, and roads, to address *resilience* to climate change (e.g., more intense precipitation) and to extreme events (e.g., *wildfires*) that can affect B&CPI across the country.

This Guide provides informed guidance on *community* development in the *WUI* given the threat of *wildfire*. The guidance is derived from existing international reference documents, including codes, standards, and guidelines, and from new insights provided by the TC. The reference documents that were reviewed [56] for this Guide include: the NBC [2]; the NFC [62]; National Fire Protection Association (NFPA) 72, "National Fire Alarm and Signaling Code" [9]; NFPA 1141, "Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas" [63]; NFPA 1142, "Standard on Water Supplies for Suburban and Rural Fire Fighting" [12]; NFPA 1143, "Standard for Wildland Fire Management" [64]; NFPA 1144, "Standard for Reducing Structure Ignition Hazards from Wildland Fire" [17]; NFPA 1300, "Standard on Community Risk Assessment and Community Risk Reduction Plan Development" [65]; NFPA 1600, "Standard on Continuity, Emergency, and Crisis Management" [15]; NFPA 1616, "Standard on Mass Evacuation, Sheltering, and Re-entry Programs" [66]; NFPA 1730, "Standard on Organization and Deployment of Fire Prevention Inspection and Code Enforcement, Plan Review, Investigation, and Public Education Operations" [67]; the NFPA Firewise website [68]; the FireSmart guidelines [10],[60],[61]; and the International Wildland-Urban Interface Code [1].

In particular, it should be noted that the scope and objectives of the FireSmart guidelines and the guidance presented here are not identical. The FireSmart guidelines may be more focussed on enhancing the *resilience* of existing *communities*; this Guide addresses broader aspects, with the potential for eventually being considered for code provisions.

It is recognized that our understanding of many aspects of *wildfire* events is still in its infancy (e.g., impact of *wildfire* on infrastructure, *evacuation* performance, interaction between elements of the *wildfire* itself, *building*-to-*building* fire progression). This Guide represents a distillation of our current understanding. It is the first iteration of an ongoing process and will be updated as more understanding is accrued.

Details about the Guide are provided in the following sections.

1.3.2 Objectives and Building Functions

Wildfires mainly spread via a *flame front* in the direction of the wind through radiation and convection, and via *embers* that are lofted ahead of the fire, starting *spotfires*, or that are released from the flaming front. Fires spread from *wildland* fuels to *communities* and built *structures* following the same processes.

This chain of events—fire spread from *wildland* fuels to *structures*, from *structures* to *wildland* fuels, and from *structure* to *structure*—is termed the *WUI fire disaster* sequence [42] and influences all the chapters in this Guide. The main objective of the Guide is to provide guidance on how to break the *WUI fire disaster* sequence at various points to enhance life safety and property protection by reducing the *wildfire* threat posed by the surrounding environment and by enhancing the fire protection provided by *structures*. Further information on the *WUI fire disaster* sequence can be found in Appendix A, which includes diagrams illustrating some of the factors that influence the progression of *wildfire disasters* with potential *evacuations* and *structure* losses, the critical decision or branching points, and the potential outcomes.

This Guide does not provide explicit instructions or design requirements intended to reduce the probability of *structure*-to-*structure* fire progression, in order to maintain consistency with current NBC provisions for spatial separation and *exposure* protection of *buildings* (Subsections 3.2.3., 9.10.14., and 9.10.15. of the NBC). However, it does recognize the impact of *structure* configuration and density on *community vulnerability* (see Chapter 4) and the subsequent need for additional *community* actions in the wake of increased *vulnerability*.

In addition to the elevated temperatures produced by the presence of fire, the fire emissions may also pose significant *risk* of injury or fatality. *Smoke* produced by the fire can include a range of toxic gases (e.g., carbon monoxide, hydrocarbons) and fine particulates (i.e., respirable atmospheric particulate matter with a diameter of less than 2.5 µm (PM2.5)) that might affect the health of *evacuees* and also impede their movement. Given that *smoke* can be transported far ahead of the *fire front*, it might pose significant *risks* beyond the fire development itself. This should be considered when managing *community response* to a *wildfire incident*.[15] However, *smoke* is not dealt with specifically in this Guide.

The objectives and associated *building* functions listed below are inspired by the 2015 edition of the NBC. It should be noted that the objectives and associated *building* functions of this Guide are recommendations only; the goals described by the NBC objectives have not been altered. The guidance in the following chapters addresses these objectives either directly or indirectly.

[15] In addition to the short-term impact of the *WUI* fire on the well-being of the *community*, such events can have significant long-term mental and physical impact on the affected *community*. It can also significantly disrupt the *community* given dispersal of the population and reduction in the social and physical infrastructure.

1.3.2.1 Objectives

If, with the support of all provincial and territorial *building* safety authorities, the objectives of this Guide were to be incorporated into the policy goals of the NBC, those objectives would have to reflect the specific application to the *WUI* area and extend to *communities*.

In addition to the concerns and applications captured in the objectives of the NBC and NFC, the specific concerns of this Guide would be limiting the probability of:

- injuries to persons caused by a *WUI fire* or explosion impacting areas beyond its point of origin,
- injuries to persons being delayed in or impeded from moving to a safe place during a *WUI fire emergency*, and
- damage to *buildings* or facilities caused by a *WUI fire* or explosion impacting areas beyond its point of origin.

1.3.2.2 Building Functions Addressed in the Guide

The specific *building* functions of this Guide that contribute to achieving its objectives are similar to the functional statements already in the NBC and NFC, but address the concerns associated with the *WUI fire* sequence:

- to limit the severity and effects of *WUI fire* or explosions
- to retard the effects of *WUI fire* on areas beyond its point of origin
- to facilitate the timely movement of persons to a safe place in a *WUI fire emergency*
- to notify persons, in a timely manner, of the need to take action in a *WUI fire emergency*
- to facilitate a *WUI fire emergency response*.

The guidance provided in Chapter 3 to Chapter 5 addresses one or more of these *building* functions and contributes to achieving the objectives listed in Section 1.3.2.1.

1.3.3 Scope, Applications, and Limitations of the Guide

This Guide provides guidance for two application scenarios:

1) the development of a new *community*
2) the expansion or modification of an existing *community* (e.g., adding new properties) or the introduction of new *fuel management* efforts for such a *community*

Although the provisions in this Guide are primarily intended for these two application scenarios, users are not precluded from identifying new application scenarios and drawing insights from the guidance as they see fit.

The guidance may also benefit individual *structures* (e.g., independent or isolated structures not attached to a wider *community*, *structures* constructed as infill or custom development, *structures* undergoing reconstruction, renovation, or repair). In such cases, the guidance should be applied in accordance with the capacity of the user to affect the *building* and the surrounding area (see Section 1.3.5).

The measures in this Guide are intended to apply to all types of *buildings* (including accessory *buildings*) and infrastructure located in the *WUI*. However, for certain types of *buildings* and infrastructure where the information contained herein is of limited applicability or not applicable, modifications and alternatives are presented and/or additional sources of information are provided, where possible. Residential properties face particular challenges with respect to *WUI fires*, given the lack of regulatory safety procedures and dedicated fire protection *resources*. Although most of the measures outlined herein are of particular use to residential properties, the measures are also applicable and, in some cases, specifically target other *community structures* and infrastructure.

Due to multiple and complex *exposure* and *vulnerability* factors that potentially interact, the application of the measures described in the Guide does not guarantee that *structures* will not be damaged or destroyed during *WUI fire* events. Furthermore, while the measures presented in this document support *WUI fire* management, they may not represent the full scope of measures required for *community*-scale *WUI fire risk* reduction. Users should consult additional *resources* for strategies concerning cross-training of structural and *wildland* firefighters, education of users, management of vegetation in areas surrounding *communities* (see Chapter 3), development of legislation or by-laws, and improved inter-agency cooperation, among other factors essential to a comprehensive *community*-scale *WUI fire* management plan.

It is important to note that *community vulnerability* to *wildfires* is highly variable over time and space (see Chapter 2). *Community vulnerability* may be affected by multiple factors, including resource availability, accessibility, physical and environmental conditions (e.g., type of vegetation surrounding the *community*, *topography*), *building* design, and *demographic* characteristics.

It is hoped that insights provided herein will be of value to many *communities*; however, it is recognized that not all *communities* will have the capacity to implement any or all of the measures outlined in the Guide. Where *resources* are limited, *communities* may apply their *resources* to priorities that are more pressing to the health and safety of their residents than *wildfires*. Many Indigenous or remote *communities* in Canada do not have staff to devote to reducing *wildfire risk*. For these *communities*, external agency support and additional funding may be needed for implementation of the guidance presented herein.

1.3.4 Content

The content of the Guide is outlined in Figure 1. Four core elements have been identified to capture and categorize the key factors that might influence a *WUI fire*—both the likelihood of it occurring and the consequences should it occur. This Guide outlines measures that may be applied to address each of these core elements (and associated factors):

1) *Hazard* and *Exposure* Factors (vegetation, *topography*, weather, historical conditions, effects of climate change)

2) Property Factors (*Priority Zones*, construction materials, property perimeter, *building* access, presence of on-site fire protection measures)
3) *Community* Planning and *Resources* (*community* size, type and configuration, access routes, population, *community vulnerability*, firefighting *resources*)
4) *Emergency* Planning and Outreach (*community emergency* plans, *evacuation* procedures, public outreach activities)

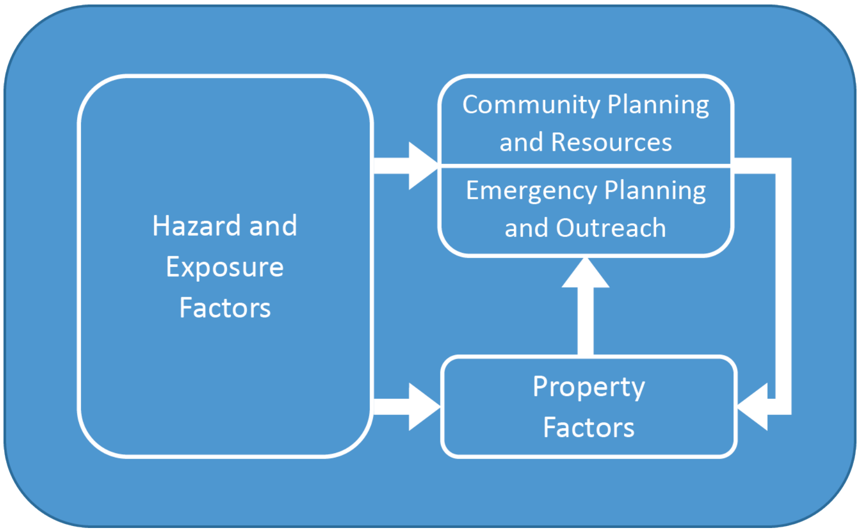

Figure 1. Core elements addressed by the Guide.

Hazard and *exposure* factors include those aspects of weather, climate, terrain, and vegetation (fuel) that contribute to the *WUI fire hazard* associated with an area or *community*. These are typically “external factors” that fall outside of the control of an individual property owner. However, certain users may be able to influence some of these factors (e.g., developers may be able to remove vegetation in an area of the *community* or to use a setback at the crest of a *slope* to protect *buildings* from direct flame contact, convective heat, and *firebrands*). However, every user of this Guide should consider *hazard* and *exposure* factors when assessing the *vulnerability* of a *structure* or *community* to *WUI fire*.

Property factors include those aspects of the individual property itself that contribute to *WUI fire hazard*, including construction materials, *building* design, and surrounding vegetation. Property factors are within the control of the *local government* and the developer or builder in the case of new construction and within control of the property owner in the case of existing construction. As such, these factors represent a *risk mitigation* opportunity for these parties and *stakeholders*.

Community planning and *resources* includes factors such as the current or expected number of residents in a *community*, the access routes into and out of the *community*, the utilities (and their capacity) located within the *community*, and the firefighting *resources* available to the *community*. In a new *community*, the development team or the *local government* may be able to influence these factors, depending on their specific roles and responsibilities. In an existing *community*, the *community resources* and design may already be in place and, therefore, may not offer a *risk mitigation* opportunity, irrespective of the user's role and responsibilities. In such situations, *resources* beyond the scope of this Guide may need to be sought. *Emergency* planning and outreach includes factors such as *emergency* plans, *evacuation* procedures, and outreach activities that have been developed for a new or existing *community*. Primarily, these factors allow the *local government* to support the *community response* to a *WUI fire*. As such, they represent a *risk mitigation* opportunity.

Many of these factors are similar to the *community risk assessment* (CRA) factors identified in NFPA 1300 [65], NFPA 1616 [66], NFPA 1730 [67], which are outlined in Appendix B. The factors addressed herein are those of the NFPA CRA factors that are deemed most influential and practical.

This Guide provides guidance on good practice regarding the four core elements identified in Figure 1. It also provides a means for the user to assess whether a *community* can cope with the projected *WUI fire emergency* conditions given the elements in place. This *vulnerability* assessment is achieved by identifying the suggested good practice for a *community* based on the elements in place and then comparing the suggested practice to the proposed or existing practice to establish the *vulnerability* of the *community* to *WUI fire* (in terms of property protection and life safety). Such a qualitative assessment of *community vulnerability* (i.e., the gap between proposed or existing practice and suggested practice) can be carried out for Chapter 3 to Chapter 5 (with reference to the life safety *vulnerability* assessment in Appendix C for Chapter 4 and Chapter 5). The assessment will indicate if and how the *community's vulnerability* can be reduced by modifying elements in accordance with the good practice in this Guide.

The specific measures outlined in the Guide act by reducing the likelihood or severity of a *WUI fire*, preventing the spread of a *WUI fire*, or increasing the effectiveness of actions in *response* to a *WUI fire*. They are collected from numerous international sources [56]. In some cases, a set of alternatives offering different degrees of performance is provided.

1.3.5 Audience

This Guide targets the parties and *stakeholders* that are most likely to be involved in *community* development and *WUI fire mitigation*: *local government* (e.g., planners, *emergency managers*, *emergency responders*) and the development team. These parties and *stakeholders* are also the most likely to perform a *vulnerability* assessment of an existing or new *community* to identify any shortfall in *WUI fire* protection measures and to identify appropriate *mitigation* options.

Though the Guide is primarily oriented toward *local government*, development teams, and others who can play a direct role in mitigating the *WUI fire risk* of a *community*, the Guide serves as a resource for other key *stakeholders* involved in *WUI fire* management, *risk* reduction, and *recovery*. These *stakeholders* include property owners, who may benefit from certain sections of the Guide and the insights provided. The *stakeholders* also include fire management agencies, insurers, and others who find value in an internationally vetted guide that has undergone a rigorous development process.

The core elements addressed in the Guide are shown in Figure 2. Different user types have differing abilities to influence these elements that affect *community vulnerability* to *WUI fire*, as shown in more detail in Figure 3. The user can assess *vulnerability* levels with respect to the elements they are able to influence (green boxes) by comparing the suggested practice in the Guide to the proposed or existing practice for new or existing properties (as outlined in Section 1.4). Where the discrepancy is large, the user may need to adjust the proposed or existing practice to reduce the *vulnerability* level.

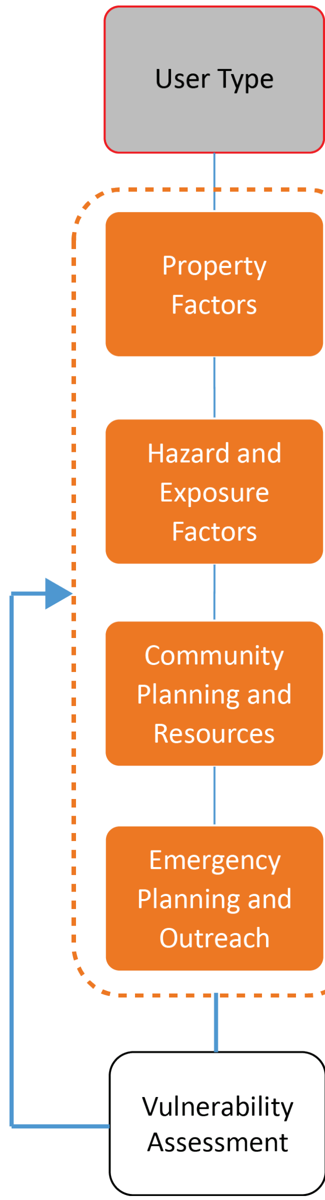

Figure 2. The influence of user type on core elements affecting community vulnerability to WUI fire.

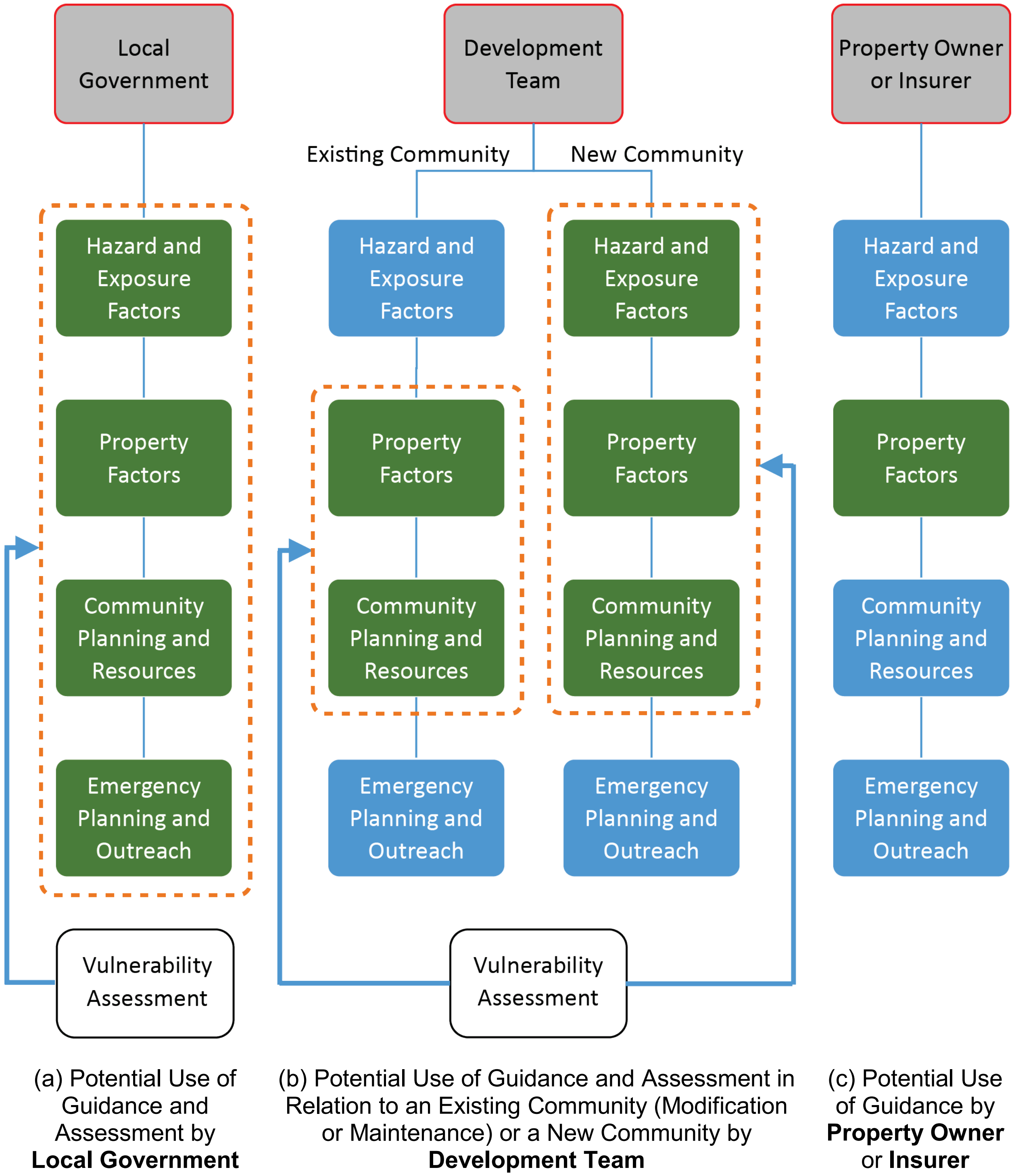

Figure 3. Differing abilities of different user types to influence core elements affecting community vulnerability to WUI fire. (Blue = cannot be influenced by user; green = can be influenced by user.)

The opportunities for different user types to influence *vulnerability* levels will vary in different scenarios. If the scenario is a new *community*, the user can influence more elements of the *community* and, in turn, can use multiple chapters of this Guide to reduce *vulnerability* levels, should they wish to do so. If the scenario is an existing *community*, the user will be able to influence fewer elements of the *community*, as many will already exist. In this case, the user may use the relevant chapters of this Guide to establish the *community's* current *vulnerability* levels and may choose to work with other user types to reduce the *vulnerability* levels.

It should be noted that Figure 3 and the discussion below describe typical modes of use of this Guide, rather than a definitive approach, and are certainly not intended to limit the benefits of the provisions outlined herein. They are also not intended to imply that different user types have any specific responsibilities for the various elements affecting *vulnerability* levels. They are simply intended to indicate the provisions of this Guide that are expected to be of most interest to different user types (i.e., to serve as a reading aid).

In the following sections, the three principal user types represented in Figure 3 are discussed in more detail: *local government* users, development team users, and property owners.

1.3.5.1 Local Government

Irrespective of whether the scenario is a new or existing *community*, a *local government* user is assumed to be able to influence property factors,[16] *community* planning and *resources*, and *emergency* planning and outreach, in addition to *hazard* and *exposure* factors (see Figure 3(a)). Should the *vulnerability* assessment of the *community* suggest that it does not meet a sufficient level of life safety, these three elements might afford an opportunity for the *local government* user to enhance life safety.

[16] *Local governments* may influence property factors through legislation.

1.3.5.2 Development Team

The capacity of the development team to influence the *vulnerability* levels of a *community* depends on the scenario. Where additions or modifications are being made to an existing *community*, the development team is assumed to only be able to influence property factors and *community* planning and *resources* because the other elements already exist and are beyond their control (see the left-hand path in Figure 3(b)). Where a new *community* is being built, the development team is assumed to be able to influence property factors (e.g., construction materials), *community* planning and *resources* (e.g., *community* configuration; excluding firefighting and other services provided by the *local government*), and *hazard* and *exposure* factors (e.g., removal of vegetation) (see the right-hand path in Figure 3(b)).

Different members of the development team can influence different elements affecting *community vulnerability* to *WUI fire*. Builders (e.g., general contributors, contractors) are assumed to only be able to influence minor aspects of *community* planning and *resources*, irrespective of the scenario, but are otherwise assumed to be able to influence the same elements as the main development team.

Designers (e.g., architects, engineers) are assumed to be able to influence *community* planning and *resources* where additions or modifications are being made to an existing *community*, in addition to the same elements as the main development team (i.e., they can influence more factors than the main development team).

1.3.5.3 Property Owners

Property owners are assumed to only be able to influence property factors, irrespective of the scenario (see Figure 3(c)). It is also assumed that they will not have access to the range of information required to perform a *vulnerability* assessment. As such, they will likely use this Guide for instructions and guidance, rather than as a means of assessment.

Renters and other residents who are not property owners may also be able to influence property factors in the spirit of shared social responsibility.

1.3.5.4 Insurers

Insurers are other potential users of the information in this Guide. The Guide may be used to help educate policy holders or to develop educational materials concerning *WUI fire risk* and lot-level *risk* reduction measures.[17] The Guide may also be used to enhance insurers' understanding of *WUI fire risk* for the purposes of setting policy pricing, terms, and conditions. Insurers are capable of influencing property factors during the rebuild and repair processes following total and partial loss events (see Figure 3(c)). In these scenarios, insurers may choose to directly incorporate, or to encourage incorporation of, *WUI fire risk* reduction interventions

[17] The development of such material is left to third parties and is not the responsibility of the NRC.

(i.e., the provisions of this Guide) into rebuilds and repairs in regions of Canada prone to *WUI fire*.

1.4 How to Use This Guide

1.4.1 Overview

It was noted above that different users of this Guide will be able to influence the factors affecting property protection and life safety to varying degrees, depending on whether the *community* is new or has existing elements. This section outlines in more detail how users can assess the *vulnerability* of a *community* to a *wildfire incident* and where they can seek guidance within this document.

1.4.1.1 Hazard Level

Figure 4 outlines the process linking the chapters of this Guide. Initially, the user should identify the *community* being examined. If the *community* has *structures* within 500 m of F1, F2, or F3 fuels (see Table 2 in Chapter 2), an assessment is recommended.

The user should then locate the *community* on the Hazard Level map (Figure 6) presented in Chapter 2. Examining the *hazard* map allows the Hazard Level (HL) of the *community* to be established on the basis of regional topographic, fuel, and weather conditions, *wildfire* ignitions, and the potential for extreme fire behaviour. The Hazard Level is a coarse-scale rating that indicates the likelihood of occurrence of a large, intense fire with the potential to cause widespread damage to a *community* in a *WUI* area. (The *WUI fire hazard* of a *community* could also be determined directly or by using available coarse- or fine-scale models, as discussed in Chapter 2.)

If there is no identifiable *WUI fire hazard*, the Hazard Level of the *community* is deemed to be 1 (Nil–Very Low), and there is no need to proceed further. If the Hazard Level is greater than 1, further assessment is required.

The assessment proceeds along two parallel paths addressing life safety and property protection respectively. These paths relate to different objectives (see Section 1.3.2.1) and involve different types of assessments and *community responses*.

1.4.1.2 Life Safety

On the life safety path, the life safety *vulnerability* of the existing or proposed *community* is assessed to determine additional measures addressing life safety. This assessment involves answering the questions posed in Appendix C and then examining the guidance outlined in Chapter 4 and Chapter 5 to determine whether the existing or proposed life safety measures produce an acceptable degree of performance. If not, then further *community*-based life safety measures should be implemented until this *vulnerability* assessment produces satisfactory results. Such satisfactory results should provide flexibility and redundancy in the *response* of all *community* members to the *WUI fire* scenarios that might be faced (e.g., *evacuation* to a remote place of safety, shelter in place[18] if instructed).

1.4.1.3 Property Protection

On the property protection path, the *Exposure Level* of the *community* needs to be established on the basis of local fuel and topographic conditions and the potential for *ember* transport, radiant heat, or direct flame contact should fuels near *structures* in the *community* be ignited (see Chapter 2). *Exposure Level* assessment considers finer-scale (< 2 km) factors that affect specific properties by influencing *ember* transport, radiant heat, and direct flame contact.

If the *Exposure Level* is Nil, no further action is required regarding property protection. If the *Exposure Level* is greater than Nil, the property protection provisions in Chapter 3 should be considered.

If the *community* is entirely new, the measures addressing property protection corresponding to the *Exposure Level* of the *community* should be followed. If the *community* is not entirely new (e.g., where new *structures* are being added to an existing *community* or new *fuel management* procedures are being introduced), then the existing or proposed property protection measures should be assessed to determine the *vulnerability* of the *community* to the *Exposure Level* identified.

For any new construction, the property protection measures in Chapter 3 should be followed as described above for a new *community*. For existing construction, the existing or proposed property protection measures should be compared to those in Chapter 3.

If the existing or proposed property protection measures are found to be suitable, then the property protection assessment is complete. If the existing or proposed property protection measures are not acceptable, then existing *structures* should be upgraded following the guidance provided in Chapter 3, where possible. This is especially important when the *structure* upgrades being considered are intended to adhere closely to the measures outlined in Chapter 3 in the future.

The property protection guidance for a *community* should be assessed in this manner whenever a major modification is made or every 5 years, whichever represents a more frequent assessment.

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[18] "Shelter in place" should not be considered as or confused with "stay and defend."

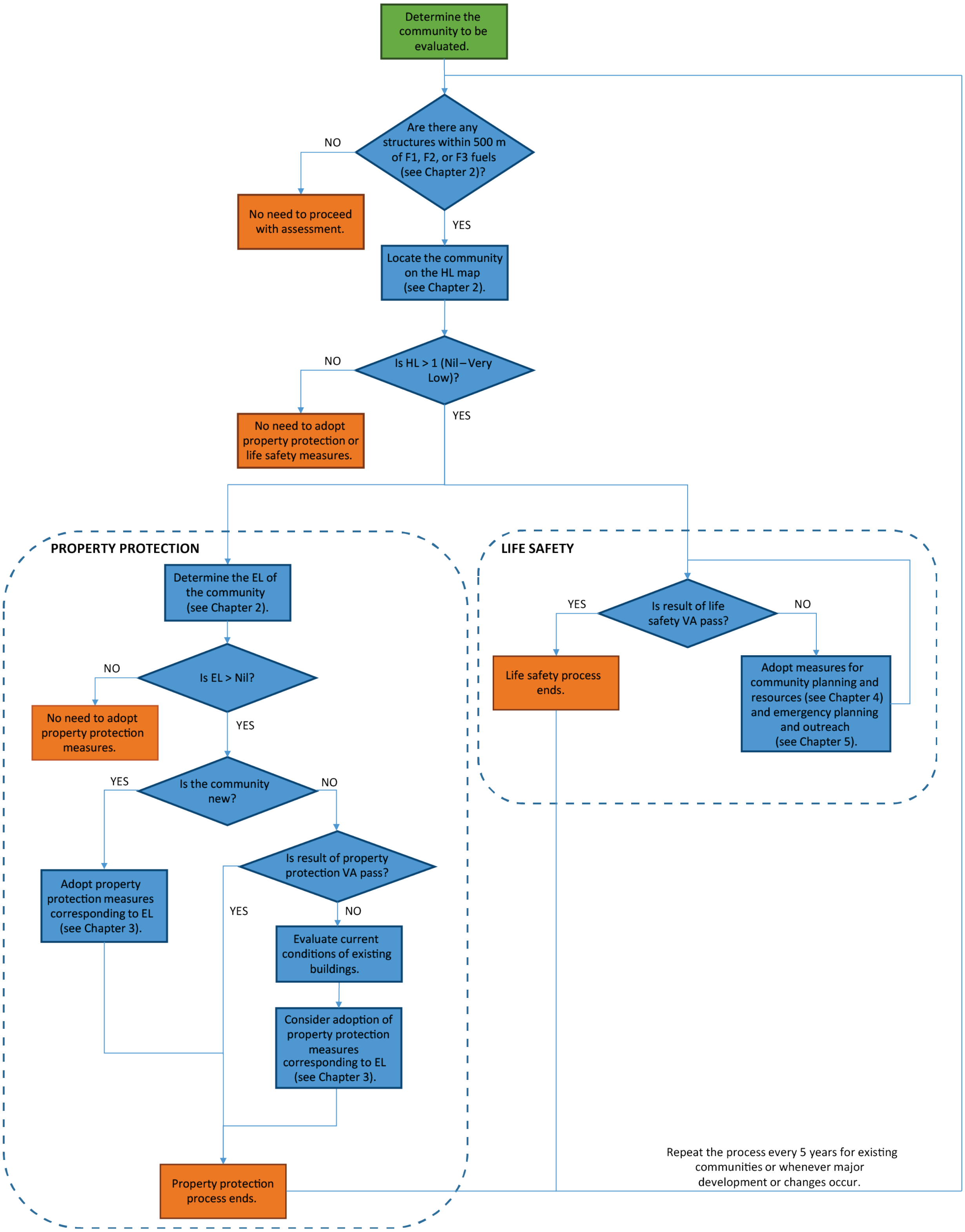

Figure 4. Flowchart of use of this Guide. (EL = Exposure Level, HL = Hazard Level, VA = vulnerability assessment.)

1.4.2 Administrative Considerations

This Guide is a voluntary guideline developed by the NRC for consideration by any government, institution, organization, professional, or individual interested in the *mitigation* of *WUI fire risk* at a site, lot, or *building* scale or in a *community* (see Section 1.3.5). Users of this Guide may consider the voluntary implementation of the *risk* reduction interventions outlined in the Guide, including the construction measures and vegetation management interventions in Chapter 3 and the *community*-scale interventions outlined in Chapter 4 and Chapter 5. Suggested administrative considerations are provided in Appendix D for organizations exploring the implementation of the recommendations.

Because this Guide is intended as a voluntary guideline for consideration by *AHJs* and other users, detailed considerations recommending administrative procedures typically associated with technical documents are provided in Appendix D. The guidance in Appendix D may not be universally applicable to all organizations and could, therefore, be used in whole or in part at the discretion of the user.

Chapter 2 Hazard and Exposure

2.1 General

The purpose of this Chapter is to establish a basic background on those elements of the fire environment that ultimately influence the *exposure* of *structures* and *communities* to the impact of *wildfire* and to describe methods of assessing *WUI fire hazard* and *exposure*. As such, Section 2.2 reviews some characteristics of *wildland fires*, Sections 2.3 and 2.4 discuss the *hazard* and *exposure* factors associated with *wildland fires* respectively, and Sections 2.5 and 2.6 outline the suggested *hazard* and *exposure* assessment methods. The potential effects of climate change on *WUI fire hazard* are discussed in Appendix E.

This Chapter deals only with *wildfire* behaviour and does not consider *structure*-to-*structure* ignition and fire spread. The *mitigation* of *structure*-to-*structure* ignition and fire spread is addressed by the NBC, and it is assumed that *structures* are built in accordance with the NBC [2].

The *WUI fire hazard* and *exposure* assessment methods presented herein do not consider the creation of ignition sources as the result of a *structure* itself burning; they focus only on the characteristics of fires burning in *wildland* fuels and the resulting production of ignition sources, which impact *hazard* and *exposure*.[19] The assessment of *WUI fire hazard* and *exposure* is key to assessing the *vulnerability* of the property (see Figure 4 in Chapter 1). *Hazard* assessment establishes whether all the provisions in this Guide need to be addressed; *exposure* assessment indicates the specific threat posed to property protection.

2.2 Characteristics of Wildland Fires

To provide some context for the following discussion of *hazard* and *exposure* factors, it is worth summarizing some general characteristics of *wildland fires* that may contribute to *exposure*.

2.2.1 Fire Behaviour

Fire behaviour refers to the manner in which fuel ignites, flame develops, and fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and *topography*. Fire behaviour is often characterized by metrics such as *fire intensity*, rate of spread, fuel consumption, and the degree of *tree crown* involvement (e.g., surface fire, intermittent *crown fire*, continuous *crown fire*).

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[19] Typically, *hazard* and *exposure* assessments should include some measure of fire likelihood. An estimate of the probability of a fire igniting and burning provides a strong complement to these assessments.

2.2.2 Fire Intensity

The concept of *fire intensity* is used in *wildland fire* management around the world. In the *wildland fire* management community, *fire intensity* (more formally known as Byram's *fire intensity* [69]) represents the total amount of heat energy released per unit time per unit length of fire perimeter by a fire spreading through forest fuels by flaming combustion. It is important to note that *fire intensity* is defined in terms of energy flux per unit length (typically measured in kW/m), whereas the commonly used physical definition of intensity is in terms of energy flux per unit area (typically measured in W/m^2).

Fire intensity is a good indicator of the size of flames and the buoyant force created by the fire. The latter is a critical factor in determining *firebrand* transport height and, therefore, the distance over which *ember* rain may extend from an active fire. Because of its relation to flame size (and hence to energy transfer from flames) and its common use in *wildland fire* management, there are a number of simple rules of thumb linking *fire intensity* with limitations in the effectiveness of different types of suppression *resources*.

In *wildfires* in Canada, *fire intensity* typically varies from about 10 kW/m (for a barely sustainable flaming ignition) to about 100 000 kW/m. For example, a running *crown fire* typically burns with a minimum *fire intensity* of about 10 000 kW/m. *Fire intensity* scales linearly with the amount of fuel burning during flaming combustion and with the spread rate of the fire, but is mathematically the product of these two factors.

2.2.3 Flame Length

Flames can vary in length from about 0.05 m (at the marginally sustainable level) to 50 m or more (in high-intensity *crown fires*). Flame length is typically defined as the length of the visible flame as measured from the middle of the fuel bed to the tip of the flame. For *wildfires*, flame length is a function of the square root of *fire intensity*.

2.2.4 Flame Temperature

Typically, the temperature of the visible tip of flames in *wildland fires* is estimated to be around 300–400°C. The gas temperature at the centre of large flames in *wildland fires* has been measured as about 1 000–1 200°C in a wide range of fuels. The predominant mechanism of heat transfer from flames is radiation, largely from very fine soot particles within the flames. A very thick flame (on the order of several metres) will radiate with an emissivity close to that of a blackbody.

2.2.5 Flame Front

Simplistically, the passage of a *flame front* can be broken into two main stages: the passage of the main coherent *flame front* and the subsequent less spatially coherent burn-out of larger fuels. The passage of the main flaming part of a *flame front* is typically governed by the burning of fine dry fuels (< 1 cm in diameter), some live fuels (e.g., conifer needles, leaves, and branchwood < 1 cm in diameter), and other volatile material in the *fuel complex*. In natural forest and rangeland (e.g., grasslands) in Canada, the length of time required for the main *flame front* to pass a point is typically less than 1 min; the actual length of time within this range depends on the amount of larger diameter fuel contributing to combustion energy release.

2.2.6 Spread Rate

The spread rate of a *wildfire* is strongly influenced by the effects of wind on the flames. Grass fires (which burn a large quantity of fine fuels and generate low buoyancy) can spread at rates of up to 15 km/h in very high wind. In Canada, forest fires typically spread at rates far below 10 km/h. The vast majority of high-intensity *wildfires* in Canada spread at rates less than 5 km/h. The spread rate in this type of fire, once established and running in conifer forest types, is most strongly dependent on the wind speed pushing the flames.

2.3 Hazard Factors

In the training of *wildland fire* managers, the concept of the "fire behaviour triangle" is often used to describe high-level elements of the *wildland fire* environment that have a significant influence on fire behaviour: fuel, *topography*, and weather (see Figure 5). These elements are discussed in more detail in this Section.

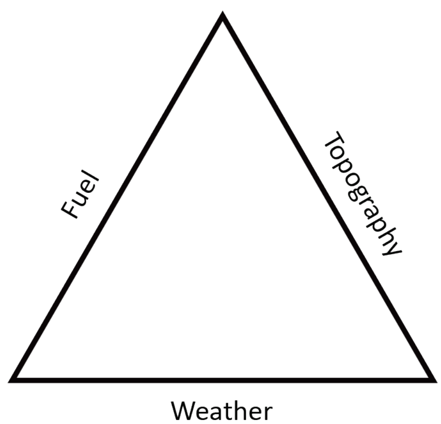

Figure 5. Fire behaviour triangle.

Multiple definitions of fire *hazard* are used in the natural *hazard* community and in the *wildfire* management community. In the operational *wildland fire* management context, fire *hazard* often refers to the somewhat static factors (in terms of day-to-day change) of the physical environment that contribute to fire behaviour at a specific site. Weather and its influence on fuels in the *wildland fire* environment clearly have a significant impact on fire behaviour. However, it is useful to separate the more temporally dynamic aspects of weather from other more static aspects of the *wildland fire* environment. This definition of fire *hazard*, like many definitions of real-world processes, is imperfect, but is useful in the context of the *WUI* and is used herein.

2.3.1 Fuel

Clearly, *wildland fire* must travel through and consume fuel in order to spread. Within the context of fire behaviour, both the amount of fuel that is present in a *fuel complex* and the arrangement of fuel elements in the complex are important. It is important to understand what burns and what does not in the passage of a flaming *wildland fire* through a forest or rangeland *fuel complex*, in other words, what fuels contribute to the fire *hazard*.

In the passage of the main *flame front*, typically only small-diameter (< 1 cm) fuels are completely consumed and thereby contribute their biomass to the *fire intensity*. Some larger-diameter woody fuels (e.g., branches, dead boles of trees) and a portion of heavier decomposing organic material on the forest floor may also be consumed and contribute to the *fire intensity*; however, most of these heavier fuels are typically consumed in burn-out after the passage of the main *flame front*. This longer-term burn-out (which may last minutes, hours, or days, depending on the dryness and quantity of heavier fuels present) releases considerable energy, but does not contribute to the *flame front* or buoyancy of the main fire. The live boles and larger-diameter (> 1 or 2 cm) live branches are typically not consumed at all during the passage of the main *flame front*, even an extremely high-intensity *flame front*, or during the passage of a secondary flaming behind the main *flame front*.

The passage of the main *flame front* through a stand occurs with a flaming *residence time* typically on the order of less than 1 min. This *flame front residence time* is controlled by the amount of fine-diameter fuel that burns (dead fuels < 1 cm in diameter and some live fuels < 0.5 cm in diameter). It is 10–30 s in grass and can be several minutes in heavier fuels like slash. Within a specific *fuel complex*, however, it does not vary much with resultant fire behaviour (e.g., rate of spread).

The *fuel complex* is an important factor governing fire behaviour but one which can be influenced by human activity; it is indeed this element of the fire behaviour triangle where much of *wildland* fuels management activity in the *WUI* is focussed. Selective tree removal can reduce the amount of fuel consumed in the passage of a fire, thereby reducing the *fire intensity*, which thereby reduces the lofting height and transport distance of *firebrands*. A reduction in a tree's vertical fuel structure and continuity (i.e., through pruning) reduces the potential for *tree crowns* to ignite and decreases the intensity and flame length (and consequently lofting height and *ember* transport distance). Removal of fine surface materials from the surface of a forest or rangeland through physical means (e.g., raking) or through controlled burning can reduce the subsequent *fire intensity* of a surface fire through that stand, which may then reduce the potential for *crown fire* development and an increase in *fire intensity* brought by crown engagement.

2.3.1.1 High Fuel Hazard

High-*hazard fuel complexes* are those in which fuel could burn readily and create large flames. In forest fuels, conifers burn readily. Trees with live needles or significant dead branches that are very thin and begin near the ground can carry flames up above the tops of the trees. Large flames create the potential to loft *embers* and are a significant source of radiant energy. Fuel structures, such as those found in typical black spruce stands, will readily produce large flames and should be considered a high *hazard*. A conifer stand in which the live foliage is well separated from the ground may also be a high *hazard* if there is significant fuel buildup on the forest floor or if there is volatile vegetation (like coniferous trees) growing under the main stand that may act as "ladder fuel" to carry flames vertically. Both of these situations could potentially lead to large flames under the canopy. Forest stands with significant portions that are dead and dried (e.g., as a result of extended periods of insect attack) will also typically produce high-intensity fires with large flames and should be considered a potentially high *hazard*. *Canadian Forest Fire Behaviour Prediction* (*FBP*) *System Fuel Types* (*FBP Fuel Types*) C2, C4, M3, and M4 are examples of *high fuel hazard* vegetation (see Appendix F).

2.3.1.2 Moderate Fuel Hazard

When fuels in the canopy of a conifer or mixed conifer and deciduous forest are separated from the ground, and there is not a significant buildup of fuel on the ground or a significant presence of ladder fuels, the *fuel complex* may be considered a moderate *hazard*. Although the trees in such a *fuel complex* can burn and create large flames under very extreme *fire weather*, overall this *fuel complex* is less volatile than those described as a *high fuel hazard* in Section 2.3.1.1. Deciduous stands are often considered a low *hazard* for burning in summer when their green leaves have fully emerged. However, in spring before leaf emergence, these forests can burn as high-intensity surface fires and create large flames. These forests should be considered a moderate *hazard* during the spring if a buildup of dry material is present on the forest floor. Similarly, mixed conifer and deciduous forest stands should be considered a *moderate fuel hazard* during the spring, particularly if there is a coniferous component (e.g., spruce) in the understory. *FBP Fuel Types* C1, C3, C5, C6, C7, and M1 and M2 with > 25% conifers are examples of *moderate fuel hazard* vegetation (see Appendix F).

Grasslands with continuous, non-mowed grasses may be considered a moderate *hazard* given their high spread potential when fully cured (in early spring or late fall). Short-distance *spotting* may be possible from this fuel type, but large flames are unlikely and, therefore, the radiation potential is reduced. However, rapid flame spread may occur in grasslands due to the presence of a continuous bed of fine fuel not found in treed areas. Similarly, exposed harvest residuals (i.e., slash) when dry may pose a significant *ember*-generation *hazard*, though the flames would not be large and, therefore, the *hazard* due to radiant energy acting on *building structures* would be lower.

2.3.1.3 Low Fuel Hazard

In summer, fuels made up of green annual vegetation (e.g., green grass, fresh green leaves) present a low *hazard*.[20] However, these fuels can pose a *hazard* in spring before annual vegetation has greened up or in late fall when annual vegetation has lost its greenness. In

[20] It should be noted that green-up vegetation could also burn under extreme conditions.

deciduous-dominated stands with little buildup of surface fuels, the *hazard* is likely low. Provided that the potential for direct flame contact has been eliminated (by clearing fuel near a *structure*), the potential for significant radiant transfer of energy is low from grasslands and harvest residuals, though some potential for *ember* generation may exist. *FBP Fuel Types* D1, M1 and M2 with ≤ 25% conifers, O1, S1, S2, and S3 are examples of *low fuel hazard* vegetation (see Appendix F).

2.3.2 Topography

Generally, fires burn up *slopes* faster than across flat ground. *Slopes* bend the upslope fuels closer to the flames, thereby shortening the distance for energy transfer between the flames and fuels, and improving the “view factor” of the fuels in terms of receiving radiant energy that may preheat them in advance of the arrival of the flames. In the FBP System [70], the spread rate on a 70% *slope* is estimated to be 10 times that of an identical fuel on flat ground under windless conditions. Since *fire intensity* is linearly related to spread rate, a corresponding increase in intensity of an order of magnitude occurs as well. Clearly this can have significant implications for potential fire characteristics and *exposure* to high-intensity fire in the *WUI* environment.

Topography can also influence the flow of wind on the landscape, with structural features like narrow canyons leading to locally increased wind speeds. The aspect (i.e., orientation) of a *slope* influences its solar radiation *exposure*. The solar radiation *exposure* of a *slope* influences the microclimate within forest and rangeland *fuel complexes* on the *slope* and thereby changes important elements that influence fire behaviour, such as fuel moisture and the vegetation composition itself.

2.3.3 Weather

Many aspects of weather influence fire behaviour. Because the weather is highly dynamic, it is the critical factor in the day-to-day variability in fire behaviour on any landscape. In *wildfire* operations, it is the element of the fire environment to which everyone pays attention. Weather influences the moisture content of dead fuels in the forest, which in turn strongly influences ignition and the potential for surface spread of flames. *Wildfire*-spread rates are influenced directly by both moisture in dead fuels (up to a point) and the wind. Atmospheric dynamics also provide a significant ignition source (e.g., lightning) that strongly shapes both the pattern and total extent of fire on the Canadian forest landscape. Atmospheric instability is a weather factor that has a significant influence on fire behaviour, including *fire intensity* and rate of spread, and is a precursor to extreme, blow-up fire conditions.

2.4 Exposure Mechanisms

Fire is a natural element of the Canadian landscape. However, when vegetation near *structures* burns, the fire *risk* to those *structures* is a concern. Fires burning in vegetation near a *structure* can impact the *structure* through several different *exposure* mechanisms that provide pathways for heat and *firebrands* to ignite the *combustible* components of the *structure*.

2.4.1 Ember Transport

The energy released during flaming combustion creates a buoyant upward flow from the combustion zone. This buoyancy has the ability to carry material hundreds of metres above the flaming zone. As *fire intensity* increases, the upward buoyant force increases and larger pieces of material from within the combustion zone can be lofted above the fire and transported downwind from the combustion zone. The generation, or lofting, of *firebrands* occurs when burning material from the fire is lofted through this process. The descent and landing of *burning embers* downwind, ahead of a burning fire, is referred to as "*spotting*" or, in the case of the *WUI*, "*ember* rain." It is helpful to think of the behaviour of *embers* as similar to drifting snow. *Embers* can collect in roof valleys, between deck members, and along the bases of *buildings*. *Embers* can also migrate through soffit vents into roofs.

Spotting (i.e., *ember* rain) from *wildfires* is commonly observed; however, predicting the development of *spotfires* at specific distances, particularly at medium and long distances, ahead of a fire remains quite challenging. *Ember* transport distance from fires has been studied and modelled in a range of complexity, from simple empirical/statistical models to complex fluid dynamics approaches. In the *wildland* context, an *ember* that is transported downwind of a fire must land in fuels that are capable of igniting from a small energy source. The development of flames and spread of the fire are strongly influenced by the moisture content of the fine fuels where the *ember* lands, by the wind blowing on the *burning ember* subsequent to its landing, and by the characteristics of the fuel bed upon which the *ember* lands. The factors influencing the ignition of fuels, the development of flames, and the spread of fire are relatively well understood. However, the process of *ember* generation within the *wildfire* combustion zone itself and its influence on the number and size of *embers* lofted into a buoyant *smoke column* above a fire is poorly understood. At a high (first-order) level, this process is thought to be influenced by elements like the type of forest stand burning (which influences the material within the combustion zone that is available to be lofted), the health of that stand (which also influences the material available to be lofted), and the *fire intensity*.

The distances potentially travelled by *firebrands* are clearly important in the *WUI exposure* context. During forest fires in Canada, *firebrands* have been observed to commonly travel distances of 1–2 km and to travel distances of up to 4 km or farther in some extreme circumstances. However, such *spotting* distances are not associated with a significant density of *ember* rain. *Firebrands* are most important as a mechanism by which spreading *wildfires* may breach a wide *fuel break* (e.g., a 1 km wide river). A high density of short-range *firebrand* deposition, on the order of tens of metres ahead of the *fireline*, is quite commonly observed in *wildfires*. Middle-distance *spotting* (between about 50 m and 500 m) is observed under many conditions when surface fuels are very dry and receptive to ignition.

The primary elements that influence the density of *burning embers* landing at a certain point ahead of a fire are: the distance of that point from the *flame front*, the intensity of the *flame front*, the density of *flying embers* being lofted out of the flaming combustion zone, and the wind speed.

2.4.2 Radiation

Flames are the most obvious immediate attribute of *wildland fires*. Fine soot particles contained within the flames emit radiant energy to their surroundings and increase temperatures. The combustion of fuels during the spread of *wildland fires* releases considerable energy. Most of the energy released flows vertically, as air and gases in the flame zone, heated to around 1 000°C, exert a considerable buoyant force upwards, out of the combustion zone. However, some of the energy released is transferred out in all directions in the form of radiation. Radiant energy is often considered to represent about 15–20% of total energy release from a fire (as characterized by Byram's *fire intensity* [69]), depending on flame size and other factors.

Flame temperatures have been measured in many types of fires. In *crown fires*, flame temperatures typically reach around 1 000–1 100°C at their maximum [71]. Often, flames thick enough to reach such temperatures are assumed to radiate like a blackbody (i.e., with a radiant intensity of around 150–200 kW/m^2); observations on high-intensity *crown fires* support this assumption [72]. Note that the *residence time* of flaming within the canopy of an actively spreading forest fire is around 30 s; so while radiant intensity may be high, the duration of the peak radiant energy flux is quite short. This short duration of peak radiant energy flux and the rapid drop in energy with distance from the flame mean that flame radiation is important as an ignition source only for objects relatively close to the flame. In the context of ignition in the *WUI*, a 30 m distance is often used as the limit for significant radiative heating of surfaces.

Flame and radiation *exposure* from *wildfires* differs from that from *building*-to-*building* fires in that the *exposure* time is on the order of seconds, not hours. Thus, ignition resistance is a key parameter in relation to *wildfires*.

2.4.3 Convection and Direct Flame Contact

The movement of a forest fire at ground level relies on the preheating of fuel. This preheating generates flammable vapours, mainly from fine fuels, which are heated to their ignition temperature by the *flame front*. Particularly when wind-assisted, both flame impingement and radiation are mechanisms for preheating and igniting these fuels.

Fire gases that are transported by convection and that carry burning fuels aloft eventually cool as air becomes entrapped in the plume. This cooling leads to fall-out of *burning embers*. *Ember* deposition can occur on vegetation and on *structures* where *combustible* material has accumulated, such as in eaves and gutters, which can lead to ignition.

Structures can also be exposed to flames and hot gases in the direct path of a fire, but these *exposure* mechanisms are generally only significant within a zone of not more than 30 m from a point of interest (i.e., *Priority Zones 1A* to *2* as defined below in Figure 9) due to the high percentage of mass transfer by buoyancy into the fire plume and the predominance of radiation from flames over convection. This situation changes once the point of interest is directly exposed to flames, as the *structure* becomes enveloped or directly impacted by the *fire front* (if it has not already been ignited by radiation).

The horizontal distances defining the region impacted by direct flame contact and convection are on the same order of magnitude as the flame heights in a high-intensity forest fire.

2.5 Overview of Hazard and Exposure Assessment

The probability that a *structure* in the *WUI* will be exposed to *embers*, radiation, or flames from a *wildland fire* depends on a host of factors influencing the *wildland* environment, including the potential for accidental or deliberate ignition, the distribution and properties of fuels, the weather conditions, and the availability of fire suppression *resources*. When considering *structure* design or means of reducing the *WUI fire hazard* in an area surrounding a *structure*, a long-term and necessarily simple assessment must be applied. The main factors considered in the assessment of *Exposure Level* are the possibility of a large high-intensity fire burning near a *structure* at any time over the life of the *structure*, the potential *fire intensity* and *ember/firebrand* production associated with nearby *wildland* fuels, and the potential distance between the *structure* and a fire.

The assessment of Hazard and *Exposure Levels* in this Guide has three parts: 1) determination of need for assessment, 2) *hazard* assessment, and 3) *exposure* assessment.

1) Determination of need for assessment. An assessment is recommended if there are *wildland* (vegetative) fuels that could sustain *wildfire* spread within 500 m of a *structure*.

2) Hazard assessment. The *hazard* assessment characterizes the likelihood of a large high-intensity *wildfire* occurring within 500 m of a *structure* in the *WUI*.

Looking across the globe and over time, we find that *wildfires* occur wherever fuels are available to burn. However, the frequency (or return period) of fire of a particular intensity varies greatly with climate, the ignition rate from lightning and human sources, and the types and continuity of *wildland* fuels.

There are numerous ways of assessing the potential for large fires across the landscape of Canada. The Canadian Forest Fire Danger Rating System (CFFDRS), which is described in Appendix G, provides accepted and operationally used methods for integrating both the influence of weather on ignition and spread potential (Canadian Forest Fire Weather Index (FWI) System [73]) and the influence of fuel type on the intensity of a spreading fire (FBP System [70],[74]) [75]. These systems can be used to provide both coarse-scale and fine-scale indications of how weather, fuels, and ignition probability combine to influence the potential for a high-intensity fire to occur in any portion of the landscape. There is also an increasingly complex suite of tools that can be used to estimate the long-term likelihood of a severe fire burning a point on the landscape (i.e., the local *hazard* of burning) either through statistical modelling or simulation (e.g., Burn-P3 [76]).

The Hazard Level map in this Guide (Figure 6) combines the influences of current *wildland* fuels, *topography*, probable ignition density with current fire management capacity, and *fire weather* [77].

The caveat in *hazard* assessments, like the one in this Guide, that are based on any or all of weather and ignition records and current forest fuel maps is that the observation period for these records and maps is quite short. Therefore, extreme events may be underestimated. Furthermore, forest fuel characteristics can change markedly over a period of decades.

The goal of the Hazard Level assessment is to assess the likelihood of a high-intensity fire occurring in a particular location; local considerations or knowledge should be considered if available and if the Hazard Level map suggests a likelihood that contradicts local expert opinion.

3) Exposure assessment. The *exposure* assessment characterizes the potential *exposure* of a *structure* to ignition sources should a high-intensity fire occur nearby.

The assessment considers the potential for *ember* transport from a distance of up to 500 m, flame radiation within 30 m of a *structure*, and immediate flame contact. The actual *exposure* of *structures* to these ignition sources in any particular *wildland fire* event varies with the environmental conditions (e.g., fuels, *topography*, wind speed and direction) that influence *fire intensity* and spread direction, and *ember* production and transport.

The assessment in this Guide does not consider the potential *exposure* of a *structure* to radiation and *embers* from adjacent burning *structures* (which is addressed in Subsections 3.2.3., 9.10.14., and 9.10.15. of the NBC [2]); the assessment is limited to the potential *exposure* of a *structure* to ignition sources from burning *wildland* fuels.

All three steps described above involve an assessment of the fuels surrounding a *structure*. Fuel assessment is not an exact science and depends on assessing the structure of the *fuel complex* as it affects potential fire behaviour. It is important to consider that the state of fuel changes over time. Green annual vegetation typically moderates fuel volatility to some extent, but in spring and autumn this green vegetation is not a moderating influence and may even add to *fuel load* and consequent *fire intensity*.

It should be noted that when the data necessary to complete any of the assessments is not available, a knowledgeable professional should be consulted to obtain the necessary information.

The following section describes procedures for *hazard* and *exposure* assessment. Some examples of the application of these procedures are provided in Appendix H.

2.6 Hazard and Exposure Assessment Procedures

2.6.1 Determination of Need for Assessment

If *wildland* fuel type F1, F2, or F3 as described in Table 2 is present within 500 m of a *structure*, an assessment is recommended. If not, no further action is necessary. Refer to Appendix F for a detailed description of the *FBP Fuel Types* [70].

Table 2: Wildland Fuel Types

Fuel Type	Description[1]
F0	Non-vegetated land Irrigated or cultivated landscapes and cropland (excluding cereal crops) Non-coniferous shrubs Treeless bogs, fens, and swamps
F1	Deciduous forest Mixed coniferous and deciduous forest with ≤ 25% conifers Grassland and cereal cropland Logging and land-clearing slash (e.g., *FBP Fuel Types* D1, M1 and M2 with ≤ 25% conifers, O1, S1, S2, S3)
F2	Mature conifer forest (excluding upland boreal black spruce forest) with ≤ 20% standing dead trees Mixed coniferous and deciduous forest with > 25% conifers (e.g., *FBP Fuel Types* C1, C3, C5, C6, C7, M1 and M2 with > 25% conifers)
F3	Upland boreal black spruce forest Dense immature jack pine forest Mature conifer forest with > 20% standing dead trees (e.g., *FBP Fuel Types* C2, C4, M3, M4)

Note to Table 2:
(1) These groupings of fuels into types are meant as examples only. Fuel typing is challenging and requires a significant level of expertise in fire behaviour and the FBP System.

2.6.2 Hazard Assessment

If it is determined in Section 2.6.1 that an assessment is recommended, a *hazard* assessment should be conducted as follows:

1) The Hazard Level for the location is determined from the Hazard Level map (Figure 6) as one of the following Hazard Levels: 1 (Nil–Very Low), 2 (Low), 3 (Moderate), and 4 (High).
2) If the Hazard Level is 1 (Nil–Very Low), then no further action is necessary.
3) If the Hazard Level is greater than 1 (i.e., Low, Moderate, or High), then
    a) the *exposure* assessment in Section 2.6.3.1 or 2.6.3.2 should be carried out to determine the *Exposure Level*, and
    b) the *community*-scale guidance presented in Chapter 4 and Chapter 5 should be considered (with reference to the life safety *vulnerability* assessment in Appendix C).

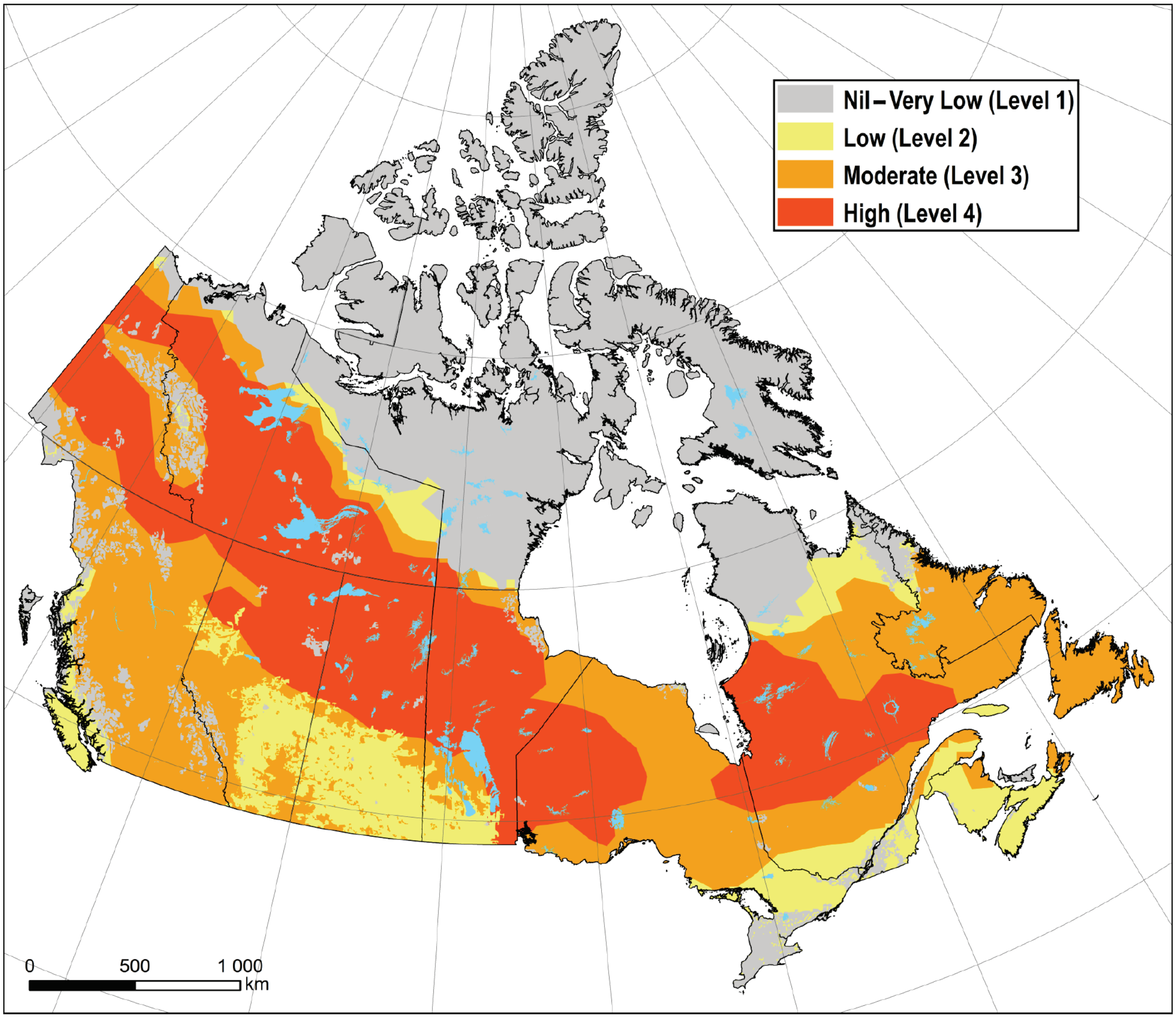

Figure 6. Historical wildfire hazard mapped from spatial burn probability outputs based on wildfire growth simulations driven by historical weather and wildfire locations.[21] (Note: the map was generated from a 30-year fire history. The wildfire hazard shown on the map may be impacted by future climate change (see Appendix E).)

[21] Provided by the Canadian Forest Service, Natural Resources Canada. Created as output from a project funded by a Canadian Safety and Security Program grant to Xianli Wang and Steve W. Taylor (CSSP-2016-CP-2286).

2.6.3 Exposure Assessment

If the Hazard Level is determined to be greater than 1 in Section 2.6.2, an *exposure* assessment should be carried out. Two alternative *exposure* assessment methods are presented in this Guide: the Simplified Method and the Detailed Method. Each method yields an *Exposure Level* that is used in conjunction with *Priority Zone fuel management* to determine the *Construction Class* in Chapter 3.

The Simplified Method described in Section 2.6.3.1 is recommended when only mapping data on fuel types in the location of interest is available or when a low level of accuracy of the assessment is sufficient and will not impact the results of the assessment.

The Detailed Method described in Section 2.6.3.2 is recommended when mapping data on fuel types, fuel densities, and topographical *slopes* in the location of interest is available. This method is also recommended when a higher level of accuracy is necessary or when the Hazard Level is High.

2.6.3.1 Simplified Method

In this method, a simple approach is used to assess the *exposure* of a location of interest with a Hazard Level greater than 1 (see Section 2.6.2). The *exposure* is assessed based on fuel type to determine the *Exposure Level* of the location, which is used in Chapter 3 in conjunction with *Priority Zone fuel management* (including adjustments for *slope*) to determine the required *Construction Class*.

The Simplified Method, which is, for the most part, adapted from the FireSmart Wildfire Exposure Assessment [78], assesses the expected *exposure* to radiant heat and *flying embers* based on the type of fuel surrounding the location of interest. It considers four levels of radiant heat *exposure* (Nil, Low, Moderate, and High), which reflect the potential for *exposure* to large flames from a nearby *wildfire*. It also considers two levels of *ember exposure* (Yes and No).

This method only considers the fuel types within a 500 m radius of the location. Although *spotting* from distances beyond 500 m is possible and has been observed for high-intensity fires, *spotting* from such distances does not typically constitute *ember* rain that might impinge on a *structure* and lead to ignition. An exception to the 500 m limit could be made when high *ember/firebrand* producing trees are present in the forest stands in the region just beyond 500 m (e.g., a spruce stand with very significant tree mortality due to insect damage). In this case, a conservative assessment that *ember exposure* is possible would be reasonable.

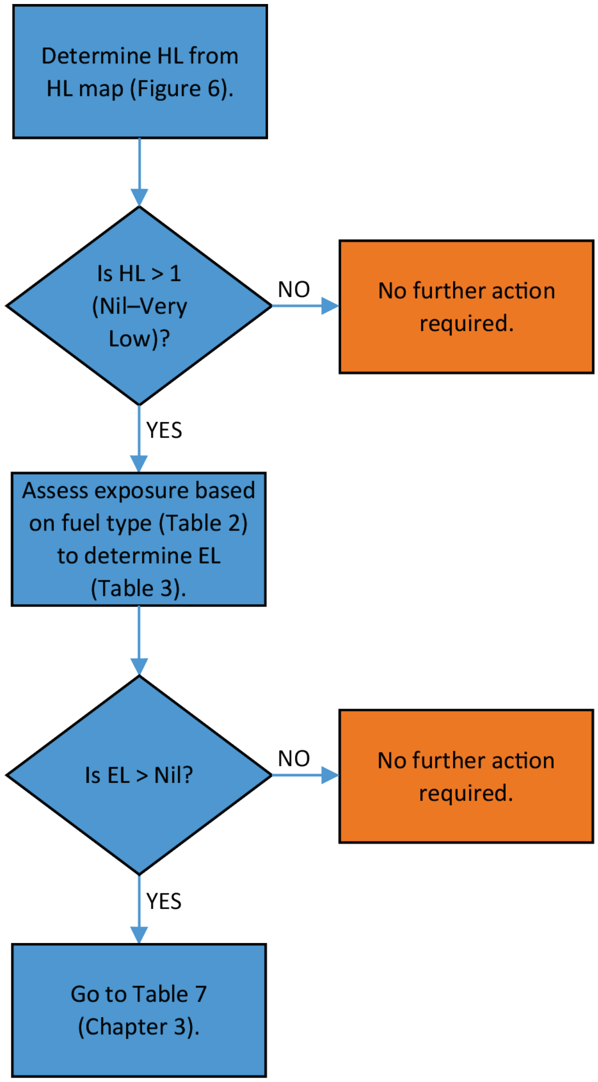

Figure 7. Flowchart of assessment of hazard and exposure using the Simplified Method. (EL = Exposure Level, HL = Hazard Level.)

Research (which has also been considered in AS 3959, “Construction of buildings in bushfire-prone areas” [79]) suggests that radiant heat could have an influence at distances up to 100 m as a conservative estimate [80].

Thus, the maximum distances considered in the assessment of *exposure* to radiant heat and *flying embers* are 100 m (i.e., *Priority Zones 1A* to *3* as defined in Figure 9) and 500 m (i.e., Exposure Zone 4 as defined in Figure 9), respectively.

Figure 7 and Table 3 summarize the Simplified Method of *exposure* assessment for a *structure* in a *WUI* area. First, to assess radiant heat *exposure*, the type of fuel within a radius of 100 m surrounding the *structure* is determined from Table 2. Note that there is also *ember exposure* whenever there is radiant heat *exposure*. To assess *ember exposure* when there is no radiant heat *exposure*, the type of fuel at a radius of 100–500 m surrounding the *structure* is also determined from Table 2.

The *Exposure Level* of the *structure*, which will be used in Chapter 3, is then determined from the levels of radiant heat *exposure* and *ember exposure* in accordance with Table 3.

Table 3: Determination of Exposure Level Using the Simplified Method

Fuel Type at 0–100 m from Structure	Fuel Type at 100–500 m from Structure	Exposure Level(1)	Action(2)
F0	F0, grassland	Nil	None required
	F1–F3, except grassland	*Ember*-Only	Go to Table 7 (Chapter 3)
F1	F0–F3	Low	Go to Table 7 (Chapter 3)
F2	F0–F3	Moderate	Go to Table 7 (Chapter 3)
F3	F0–F3	High	Go to Table 7 (Chapter 3)

Notes to Table 3:
(1) The *Exposure Level* is determined based on the fuel type(s) at 0–100 m and 100–500 m from the *structure*, which are described in Table 2 (Section 2.6.1).
(2) The action required depends on the *Exposure Level* determined: either no action is required, or the *Exposure Level* is applied in Table 7 (Chapter 3).

2.6.3.2 Detailed Method

In this method, a more detailed approach is used to assess the *exposure* of a location of interest with a Hazard Level greater than 1 (see Section 2.6.2). The *exposure* of a location is first assessed based on fuel type, fuel percent cover [81], *topography*, and fuel *ember* production capacity. Then the *exposure* is combined with the Hazard Level of the location to determine the *Exposure Level* of the location, which is used in Chapter 3 in conjunction with *Priority Zone fuel management* to determine the required *Construction Class*. Figure 8 shows a flowchart of the Detailed Method.

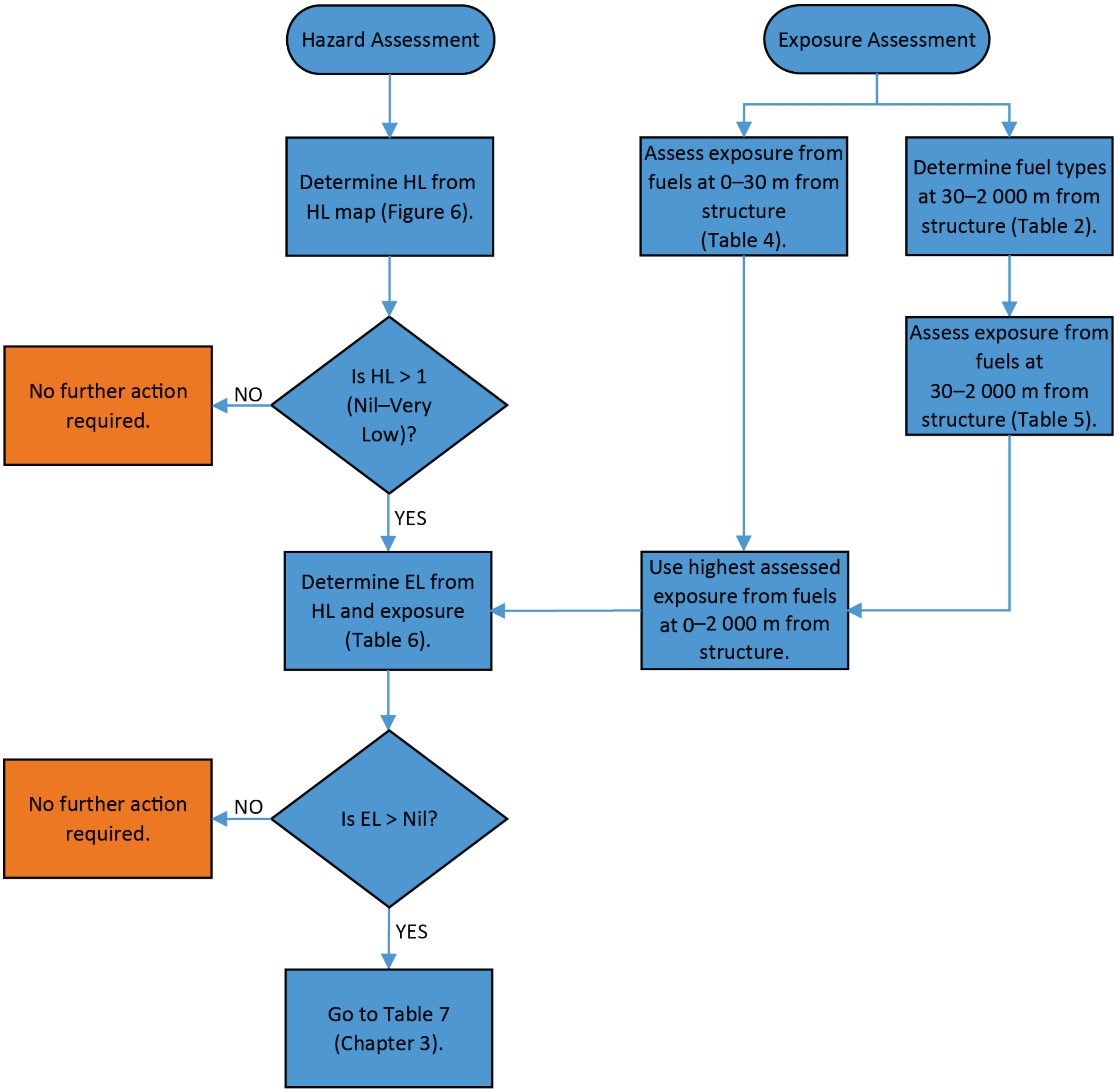

Figure 8. Flowchart of assessment of hazard and exposure using the Detailed Method. (EL = Exposure Level, HL = Hazard Level.)

Exposure Assessment

The detailed *exposure* assessment considers the influence of local fuels and *topography*—two key elements that influence fire behaviour—within 2 km of a *structure* on *flying ember*, radiant heat, and direct flame *exposure*. This assessment assumes that a severe fire spreads into or within the 2 km zone around the *structure* under extreme *fire weather* conditions (consistent with the local climate). The assessment is adapted from the FireSmart Wildfire Exposure

Assessment [78], but considers *topography* in addition to fuel type. It classifies *exposure* into qualitative categories based on fuel type that, in the case of fuels in *Priority Zone 3* (30–100 m from the *structure*) and Exposure Zone 4 (100–500 m from the *structure*), are adjusted based on *slope*.

To assess the *exposure* of a *structure*, the area 2 km in radius surrounding the *structure* is classified into zones, as shown in Figure 9. The *exposure* assessment begins with the closest zone and is carried out as follows:

1) The *exposure* for *Priority Zones 1A* to *2* (0–30 m from the *structure*) is assessed in accordance with Table 4. The *exposure* in this step is taken as the highest of *flying ember*, radiant heat, and direct flame *exposure*.
2) The fuel types in *Priority Zone 3* and Exposure Zones 4 and 5 (30–2 000 m from the *structure*) are determined in accordance with Table 2 (Section 2.6.1).
3) The *exposure* for *Priority Zone 3* and Exposure Zones 4 and 5 is assessed in accordance with Table 5. The *exposure* in this step is taken as the highest *exposure* of *Priority Zone 3* and Exposure Zones 4 and 5.
4) The overall *exposure* is taken as the highest of those obtained in steps 1 and 3 (i.e., the highest *exposure* of all the zones).

The *exposure* determined from Table 4 in step 1 reflects the potential for the fuels in *Priority Zones 1A* to *2* (0–30 m from *structure*) to generate *embers* or radiant heat affecting a *structure* and the potential for surface fire to spread to and contact the *structure*.

The *exposure* determined from Table 5 in step 3 reflects the potential for the fuels in *Priority Zone 3* and Exposure Zones 4 and 5 (30–2 000 m from the *structure*) to generate *embers*/*firebrands* and the potential *fire intensity* for those fuels in severe *fire weather* conditions (*fire intensity* influences the distance that *firebrands* are transported in the *smoke column*). *Slope* is included as a modifier in Table 5 to reflect its influence on fire spread and intensity.

The *exposures* for the different zones are not additive; the overall *exposure* is taken as the highest *exposure* of all the zones.

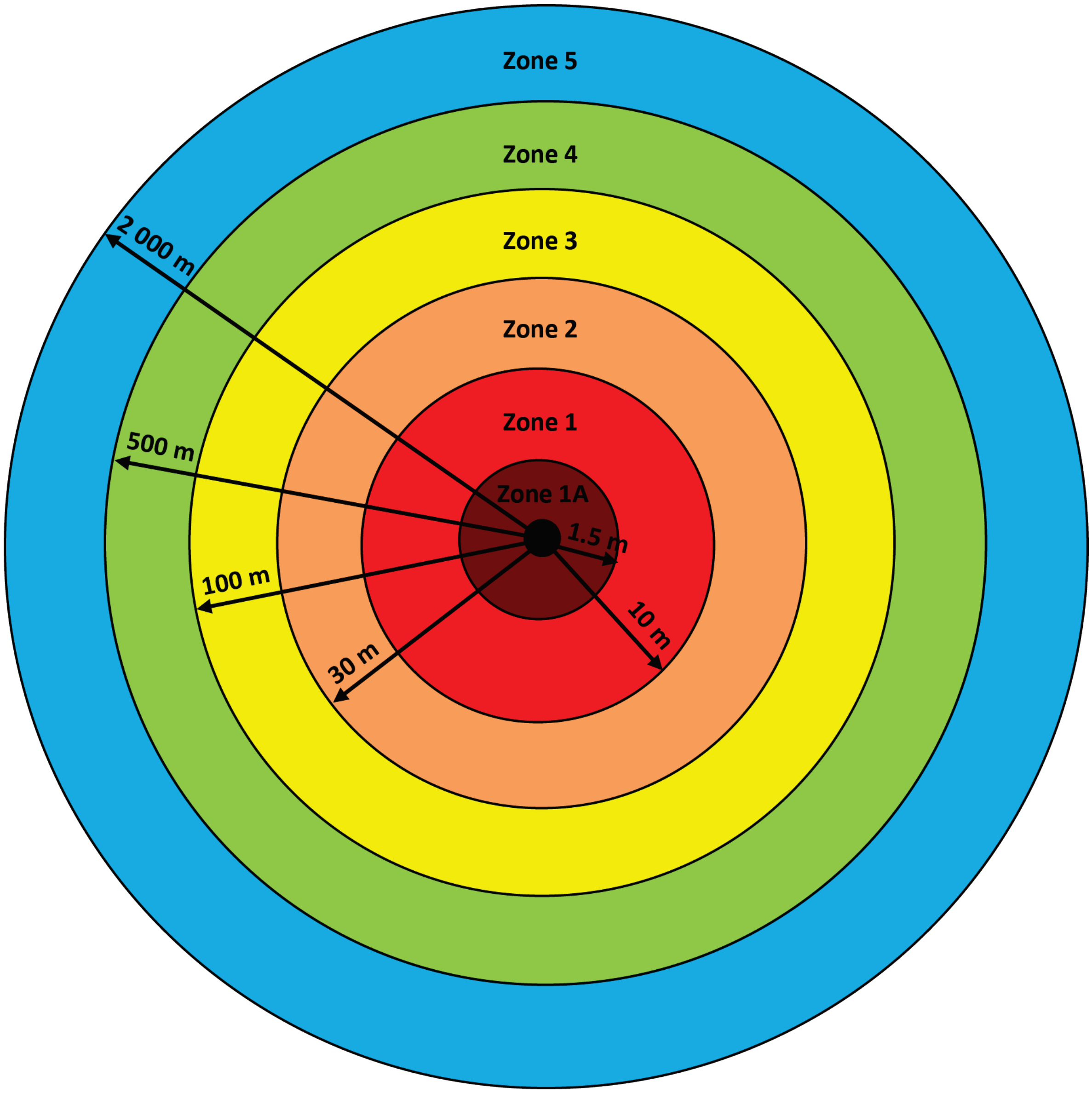

Figure 9. Priority Zones 1A to 3 and Exposure Zones 4 and 5 surrounding the structure.[22]

[22] Note that zone radii are not to scale.

Table 4: Exposure from Fuels in Priority Zones 1A to 2 (0–30 m from the Structure)

Distance from Structure, m	Surface Fuel	Tree Canopy (Fuel Type)	Exposure
0–3	Green lawn, non-woody plants, or non-vegetated	–	Nil
	Continuous plant litter, dry grass, bark mulch	–	Moderate
	Hazard shrubs or trees	–	High
3–30	Green lawn or vegetation	Deciduous or no tree canopy (F0, F1)	Nil
		≤ 25% conifer tree cover[1] (F2, F3)	Moderate
		> 25% conifer tree cover[1] (F2, F3)	High
	Continuous plant litter or dry grass	Deciduous or no tree canopy (F0, F1)	Low
		≤ 25% conifer tree cover[1] (F2, F3)	High
		> 25% conifer tree cover[1] (F2, F3)	High

Note to Table 4:
[1] Tree cover refers to the percentage of the ground covered by a vertical projection of the outermost perimeter of the natural spread of the foliage.

Table 5: Exposure from Fuels in Priority Zone 3 and Exposure Zones 4 and 5 (30–2 000 m from the Structure)

Zone (Distance from Structure)	Fuel Type[1]	Fuel Percent Cover	Exposure[2]	Slope Modifying Exposure	Slope-Adjusted Exposure
3 (30–100 m)	F0	–	Nil	–	–
	F1	< 10%	Low	> 20%	Moderate
		10–50%	Moderate	> 20%	High
		> 50%	High	–	–
	F2	< 10%	Moderate	> 20%	High
		10–50%	High	–	–
		> 50%	High	–	–
	F3	> 5%	High	–	–

Zone (Distance from Structure)	Fuel Type[1]	Fuel Percent Cover	Exposure[2]	Slope Modifying Exposure	Slope-Adjusted Exposure
4 (100–500 m)	F0	–	Nil	–	–
	F1	< 10%	Nil	–	–
		10–50%	Low	> 40%	Moderate
		> 50%	Moderate	> 40%	High
	F2	< 10%	Low	> 40%	Moderate
		10–50%	Moderate	> 40%	High
		> 50%	High	–	–
	F3	< 10%	Moderate	> 40%	High
		> 10%	High	–	–
5 (500–2 000 m)	F0 or F1	–	Nil	–	–
	F2 or F3	≤ 50%	Nil	–	–
	F2	> 50%	Low	–	–
	F3	> 50%	Moderate	–	–

Notes to Table 5:
(1) See descriptions of fuel types in Table 2 (Section 2.6.1).
(2) *Exposure* takes into account the ignition potential from a combination of *flying embers* and radiant heat.

Exposure Level Determination

The *Exposure Level* represents the likelihood that a *structure* will be exposed to any or all of *flying embers*, radiant heat, and direct flame contact during its lifetime. The *Exposure Level* determines the measures in Chapter 3 that are necessary to mitigate the *risk* of ignition in the *Structure Ignition Zone* (*Priority Zones 1A* to *3*).

In the Detailed Method, the *Exposure Level* is determined by combining the Hazard Level (see Section 2.6.2) and the overall *exposure* of the *structure* in accordance with Table 6.

Fire *hazard* and *exposure* are multiplicative processes; a *structure* will have negligible *exposure* if the likelihood of a severe fire occurring in or reaching the *WUI* is Nil–Very Low, even when hazardous fuels are present in the vicinity of the *structure*.

The resultant *Exposure Level* (Nil, Low, Moderate, or High) is used in Table 7 (Chapter 3), in conjunction with *Priority Zone fuel management*, to determine the *Construction Class* of the *structure*.

Table 6: Determination of Exposure Level (Coloured Cells) from Hazard Level and Exposure

Hazard Level	Exposure			
	Nil	Low	Moderate	High
	Exposure Level			
Nil–Very Low	Nil	Nil	Nil	Nil
Low	Nil	Low	Low	Moderate
Moderate	Nil	Low	Moderate	High
High	Nil	Low	Moderate	High

2.7 Use of Chapter 3 without Performing a Hazard and Exposure Assessment

As outlined in Section 1.4.2, this Guide is a voluntary guideline, developed for consideration by any government, institution, organization, professional, or individual interested in the *mitigation* of *WUI fire risk* at the *community*, site, lot, or *building* scale. As such, it is recognized that some users may not have the ability to undertake the *hazard* and *exposure* assessment outlined in this Chapter. Users may experience limited availability of or access to appropriate data, information, and/or expertise (e.g., knowledgeable professionals), resulting in an inability to undertake the *hazard* and *exposure* assessment.

Where a user finds the application of the construction and *risk* reduction methods outlined in Chapter 3 to be appropriate, but is unable to undertake the *hazard* and *exposure* assessment outlined in Chapter 2, they may choose to assume that the *Exposure Level* is High to guide decision making concerning the application of interventions to reduce *WUI fire risk*.

Chapter 3 WUI Fire Risk Mitigation in the Structure Ignition Zone

3.1 General

This Chapter outlines *fuel management* measures and related construction measures for the protection of property from *WUI fire hazard* in relation to the *Exposure Level* determined in Chapter 2. It provides a qualitative means of assessing property *vulnerability* and establishing remedial actions appropriate for the severity of this *vulnerability*. See Appendix I for explanatory material related to this Chapter.

The recommended measures in this Chapter are not the product of Canada's national code development process. Therefore, they have not been subject to the level of scrutiny that is part of that process, nor to a detailed review to ensure the Guide recommendations would not create conflicts with existing *building*, energy and safety codes, applicable standards, or other regulatory requirements. Additionally, the best practices presented here have not been reviewed from a *building* science or energy efficiency perspective to ensure their use would not result in adverse effects to the *building* as a system.

3.1.1 Scope of This Chapter

This Chapter addresses *risk*-based design and construction measures to limit the probability of ignition of *buildings* and minimize the damage to *buildings* due to the impacts of *WUI fires*.

3.1.2 Application of This Chapter

The measures in this Chapter may be used for new and existing *buildings* and sites located within a *WUI* area.

3.1.3 Objective of This Chapter

This Chapter addresses property protection by establishing *fuel management* measures for the different *Priority Zones* around *buildings* and construction measures for *buildings*. These measures are consistent with nationally recognized good practice for the protection of *buildings* exposed to *WUI fires*. They are intended to mitigate the *risk* to *buildings* posed by *exposure* to *WUI fire*. The construction measures are categorized according to *Construction Class*, which reflects the *Exposure Level* and the extent to which the *fuel management* measures for the *Priority Zones* have been put in place.

This Chapter provides guidance for sites and *buildings* to support *evacuation* times sufficient for life safety. Advice regarding access and egress routes and areas of refuge is found in Chapter 4.

3.1.4 Implementation of the Recommendations in This Chapter

1) The implementation of this Chapter may be achieved by
   a) using the recommended measures and guidelines as written, or
   b) using alternative measures that achieve the same performance as intended by the stated objectives and functions described in Chapter 1.
2) When implementing this Chapter as described in Clause (1)(b), a detailed analysis should be performed of the objectives and functions, as described in Chapter 1, that are related to property protection.[23]
3) Appendix H offers more details on implementing the recommendations in this Chapter.

3.2 Exposure Levels and Construction Classes

3.2.1 Determination of Exposure Level

1) Except as described in Sentences (3) and (4), the *Exposure Level* of a *building* is related to the *hazard* and *exposure* assessment outlined in Chapter 2 as either
   a) *Ember*-Only,
   b) Low,
   c) Moderate, or
   d) High.
2) *Qualified professionals* may assist in the determination of *Exposure Level*.
3) If *wildland* fuel type F1, F2, or F3 as described in Table 2 (Chapter 2) is not present within 500 m of a *structure* however, the *hazard* and *exposure* assessment outlined in Chapter 2 would not be necessary. Appendix F contains a detailed description of the *FBP Fuel Types* [70].
4) Where a user finds the application of the construction and *risk* reduction methods outlined in this Chapter to be appropriate, but is unable to undertake the *hazard* and *exposure* assessment outlined in Chapter 2, they may choose to assume that the *Exposure Level* is High. (See Section 2.7.)

3.2.2 Determination of Construction Class

1) The appropriate *Construction Class* of a *building* can be determined using Table 7 on the basis of its *Exposure Level*, as described in Section 3.2.1 and in relation to the extent to which the *Priority Zones* surrounding the *building* are constructed as recommended in Section 3.4. For new development, the measures implemented in the *Priority Zones* as described in Section 3.4 should be based on a *Priority Zone* vegetation plan.

[23] Life safety is addressed in Chapter 4 and Chapter 5.

Table 7: Determination of Construction Classes

Exposure Level	Recommended Construction Classes for Use with Mitigation Measures Applied in the Listed Priority Zones				
	None	1A	1A and 1	1A to 2	1A to 3
Ember-Only or Low	*CC1*(FR)[(1)]	*CC1*	*CC3*	*CC3*	*CC3*
Moderate	*CC1*(FR)[(1)]	*CC1*(FR)[(2)]	*CC2*	*CC3*	*CC3*
High	*CC1*(FR)[(1)]	*CC1*(FR)[(2)]	*CC1*	*CC2*	*CC3*

Notes to Table 7:
(1) Where the *Priority Zones* do not align with the guidance described in Section 3.4, the exterior walls of *buildings* in *Construction Class CC1*(FR) should have a *fire-resistance rating* of not less than 1 h based on fire *exposure* described in Clause 3.3.2(7)(a).
(2) Where only *Priority Zone 1A* aligns with the guidance described in Section 3.4, the exterior walls of *buildings* in *Construction Class CC1*(FR) should have a *fire-resistance rating* of not less than 45 min based on fire *exposure* described in Clause 3.3.2(7)(b).

3.3 Construction Measures

3.3.1 Existing Applicable Regulations

1) It should be noted that relevant requirements of the NBC [2]; provincial, territorial, or local codes; standards; and by-laws apply to new construction and renovations in accordance with applicable law. Where these requirements are exceeded by the measures described in this Chapter, care should be taken during implementation so as not to contravene the applicable codes.

3.3.2 Exterior Walls

1) This section applies to all exterior wall surfaces, components, openings, and gaps subject to *WUI fire exposure*.
2) Except as described in Sentences (6) and (11), exterior wall cladding on *buildings* in *Construction Classes CC1*(FR) to *CC3* should be selected using Table 8.

Table 8: Minimum Recommended Exterior Wall Cladding by Construction Class

Construction Class	Minimum Recommended Exterior Wall Cladding
CC1(FR) or *CC1*	*Noncombustible*[(1)]
CC2	*Ignition-resistant*[(2)]
CC3	Limited *ignition-resistant*[(3)]

Notes to Table 8:
(1) *Noncombustible* cladding is described in Sentences (3) to (5), (7), and (8).
(2) *Noncombustible* or *combustible* cladding is described in Sentences (3) to (5), (8) or (9), and (10).
(3) *Noncombustible* or *combustible* cladding is described in Sentences (3) to (5).

3) The exterior wall cladding should extend from the top of the foundation to
    a) the top plate (track) of the exterior wall,
    b) the bottom chord of the roof truss,
    c) the intersection of the exterior wall and the soffit, or
    d) the bottom of the built-up roof deck.
4) All joints in the exterior wall cladding or related wall components should be covered, sealed, overlapped, backed, or butt-jointed with no unprotected gaps greater than 3 mm.
5) All openings and penetrations in the exterior wall cladding or related wall components should be sealed with no gaps greater than 3 mm.
6) Exterior vertical surfaces that are less than 200 mm from the ground or a deck, roof, or similar horizontal surface where *embers* may accumulate should be protected on the exterior by
    a) *noncombustible* material, or
    b) at least one layer of Type X exterior gypsum sheathing or cement board.
7) For *buildings* in *Construction Class CC1*(FR), exterior walls should be constructed from a material or assembly of materials having a *fire-resistance rating*, established using the results of tests conducted in conformance with CAN/ULC-S101, “Fire Endurance Tests of Building Construction and Materials” [82], or by using Appendix D of the NBC [2] or the construction specifications presented in Table 9.10.3.1.-A of the NBC [2] (as appropriate) of not less than
    a) 1 h, where none of the *mitigation* measures have been applied in the listed *Priority Zones* surrounding the *building*, or
    b) 45 min, where *mitigation* measures have been applied only in *Priority Zone 1A*.
8) Except as described in Sentence (9), exterior wall assemblies on *buildings* in *Construction Classes CC1* and *CC2* should
    a) be clad with masonry or concrete having a thickness not less than 25 mm, or
    b) meet the recommended acceptance criteria stated in Table 9 when tested using ASTM E2707, “Standard Test Method for Determining Fire Penetration of Exterior Wall Assemblies Using a Direct Flame Impingement Exposure” [83].
9) Exterior wall cladding on *buildings* in *Construction Class CC2* could be made of *ignition-resistant* material that
    a) has an exterior surface *flame-spread rating* of not more than 25 when tested using CAN/ULC-S102, “Test for Surface Burning Characteristics of Building Materials and Assemblies” [84], or
    b) meets the recommended acceptance criteria stated in Table 9 when tested using ASTM E2768, “Standard Test Method for Extended Duration Surface Burning Characteristics of Building Materials (30 min Tunnel Test)” [85].
10) Where the exterior wall cladding referred to in Sentence (9) is *combustible* cladding made of *fire-retardant-treated wood*, the cladding should also be subjected to an accelerated weathering test as specified in ASTM D2898, “Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing” [86], prior to the testing described in Sentence (9).
11) Exterior walls on *buildings* in *Construction Classes CC2* and *CC3*, exterior walls can be made of *log wall construction*.

Table 9: Recommended Acceptance Criteria for ASTM Fire Test Standards

Fire Test Standard	Recommended Acceptance Criteria	Source
ASTM E2632, “Standard Test Method for Evaluating the Under-Deck Fire Test Response of Deck Materials” [87]	1. Effective net peak heat release rate of less than or equal to 269 kW/m^2 (25 $kW/ft.^2$) 2. Absence of sustained flaming or glowing combustion at the end of the 40-min observation period 3. Absence of falling particles that are still burning when reaching the burner or floor	Adapted from Chapter 7A, Materials and Construction Methods for Exterior Wildfire Exposure, of the 2019 California Building Code [88]
ASTM E2707, “Standard Test Method for Determining Fire Penetration of Exterior Wall Assemblies Using a Direct Flame Impingement Exposure [83]	1. Absence of flame penetration through the wall assembly at any time 2. Absence of evidence of glowing combustion on the interior surface of the assembly at the end of the 70-min test	
ASTM E2726, “Standard Test Method for Evaluating the Fire-Test-Response of Deck Structures to Burning Brands” [89]	1. Absence of sustained flaming or glowing combustion at the end of the 40-min observation period 2. Absence of falling particles that are still burning when reaching the burner or floor	
ASTM E2768, “Standard Test Method for Extended Duration Surface Burning Characteristics of Building Materials (30-min Tunnel Test)” [85]	1. Flame-spread rating of 25 or less as determined for the initial 10-min test period 2. Flame front that does not progress more than 3.2 m (10.5 ft.) beyond the centreline of the burners at any time during the 30-min test period[24]	Adapted from Clause 13, Conditions of Classification, of ASTM E2768 [85]

[24] This criterion is considered evidence of no significant progressive combustion in this test method.

3.3.3 Foundation Walls

1) Except as described in Sentence (2), where possible foundation walls should be constructed of concrete or unit masonry.
2) Foundation walls could also be constructed using insulating concrete forms or permanent wood foundations, considering the following conditions:
    a) for *buildings* in *Construction Class CC1*(FR), the exposed portion of the foundation wall should be
        i) constructed from a material or assembly of materials having a *fire-resistance rating* based on fire *exposure* from both sides using the results of tests conducted in conformance with CAN/ULC-S101, “Fire Endurance Tests of Building Construction and Materials” (Standards Council of Canada 2014), or by using Appendix D of the NBC [2],
            - of not less than 1 h, where none of the *mitigation* measures have been applied in the listed *Priority Zones* surrounding the *building*, or
            - not less than 45 min, where *mitigation* measures have been applied only in *Priority Zone 1A*, and
        ii) protected on its exterior face with *noncombustible* material or at least one layer of Type X exterior gypsum sheathing or cement board,
    b) for *buildings* in *Construction Classes CC1* and *CC2*, the exposed portion of the foundation wall should be protected on its exterior face with
        i) *noncombustible* material, or
        ii) at least one layer of Type X exterior gypsum sheathing or cement board, and
    c) for *buildings* in *Construction Class CC3*, the exposed portion of the foundation wall should be protected on its exterior face to a height of at least 200 mm above grade with
        i) *noncombustible* material,
        ii) at least one layer of Type X exterior gypsum sheathing or cement board, or
        iii) *fire-retardant-treated wood*.
3) All joints in the external wall cladding or related wall components of the foundation wall should be covered, sealed, overlapped, backed or butt-jointed with no unprotected gaps greater than 3 mm.
4) All openings and penetrations in the exterior wall cladding or related wall components of the foundation wall should be sealed with no gaps greater than 3 mm.

3.3.4 Raised[25] or Elevated Buildings

1) Except as described in Sentences (2) and (3), ideally all supporting elements for a raised or elevated *building* should be of *noncombustible construction*.
2) The supporting elements described in Sentence (1) may be made of combustible material, considering the following conditions
    a) the *building* should be raised not less than 2 m above the adjacent ground level,
    b) except as described in Sentence (3) (for heavy timber construction), where the *building* is in *Construction Class CC1*(FR), the exposed portion of any supporting element should be
        i) constructed from a material or assembly of materials having a *fire-resistance rating* using the results of tests conducted in conformance with CAN/ULC-S101, "Fire Endurance Tests of Building Construction and Materials" [82], or using Appendix D of the NBC,
            - of not less than 1 h, where none of the *mitigation* measures have been applied in the listed *Priority Zones* surrounding the *building*, or
            - not less than 45 min, where *mitigation* measures have been applied only in *Priority Zone 1A*, and
        ii) protected on its exterior face with *noncombustible* material or at least one layer of Type X exterior gypsum sheathing or cement board,
    c) except as described in Sentence (3) (for heavy timber construction), where the *building* is in *Construction Class CC1* or *CC2*, the exposed portion of any supporting element should be protected on its exterior face with
        i) *noncombustible* material, or
        ii) at least one layer of Type X exterior gypsum sheathing or cement board, and
    d) except as described in Sentence (3) (for heavy timber construction), where the *building* is in *Construction Class CC3*, the exposed portion of any supporting element should be protected on its exterior face to a height of at least 300 mm above grade with
        i) *noncombustible* material,
        ii) at least one layer of Type X exterior gypsum sheathing or cement board, or
        iii) *fire-retardant-treated wood*.
3) The supporting elements referred to in Sentence (2) may be constructed of heavy timber construction with a minimum nominal dimension not less than 150 mm.
4) Spaces underneath a raised or elevated *building* should be enclosed to prevent storage under the *building* and to discourage growth of vegetation.

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[25] "Raised *building*" refers to a *building* with all or part of its first storey raised at least 2 m above average grade and without basement.

3.3.5 Roofing Materials

1) Roof coverings should have a Class A classification when tested using CAN/ULC-S107, "Fire Tests of Roof Coverings" [90].
2) Valley and hip flashing, roof penetration flashing, sill plate flashing, and any other flashing that could be exposed to accumulated *embers* should be *noncombustible*.
3) Drip edges should
    a) be *noncombustible*, and
    b) extend at least 75 mm upslope from the edge of the roof.
4) Cant strips, roof curbs, nailing strips, and similar components used in the installation of roofing may be *combustible*.
5) Roof penetrations, such as pipes, should be *noncombustible*.
6) Any gaps larger than 3 mm on the roof, including gaps at junctions or around penetrations or attachments, that could allow the entry of *embers* should be sealed with *noncombustible* material.

3.3.6 Gutters and Downspouts

1) Gutters and downspouts should be
    a) *noncombustible*,
    b) fitted with corrosion-resistant, *noncombustible* screens or guards to prevent the buildup of *combustible* materials in the gutters and downspouts, and
    c) regularly cleaned to remove accumulated material from gutters and guard surfaces.

3.3.7 Eaves, Soffits, and Roof Projections

1) Eaves, soffits, and roof projections on *buildings* in *Construction Classes CC1*(FR), *CC1*, and *CC2* should be constructed of materials tested using ASTM E2957, "Standard Test Method for Resistance to Wildfire Penetration of Eaves, Soffits and Other Projections" [91]. Three replicate tests should be performed, and in all three replicates the following acceptance criteria should be considered:
    a) absence of flame penetration of the eave or roof projection assembly at any time during the test,
    b) absence of structural failure of the eave or roof projection subassembly at any time, and
    c) absence of sustained combustion of any kind at the conclusion of the 40-min test.

   Three additional tests may be run until the recommended acceptance criteria are reached if one of the first three replicates does not meet the recommended acceptance criteria.
2) Eaves, soffits, and roof projections on *buildings* in *Construction Classes CC1*(FR), *CC1*, and *CC2* should be finished with *noncombustible* material.
3) Eaves, soffits, and roof projections on *buildings* in *Construction Class CC3* may also be finished with *noncombustible* or *combustible* material.
4) Except as described in Section 3.3.8, eaves, soffits, and roof projections should be enclosed without openings.

3.3.8 Service Openings and Vents

1) Openings required for soffit venting or the ventilation of roof spaces should be enclosed by materials tested using ASTM E2886, “Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement” [92], or screened with corrosion-resistant, *noncombustible* wire mesh with a maximum mesh aperture of 3 mm. When testing using ASTM E2886 [92], three replicate tests should be performed, and in all three replicates the following acceptance criteria should be considered:
    a) there should be no flaming ignition of the cotton material during the Ember Intrusion Test,
    b) there should be no flaming ignition during the Integrity Test portion of the Flame Intrusion Test, and
    c) the maximum temperature of the unexposed side of the opening should not exceed 350°C (662°F).
2) Where required for the ventilation of wall assemblies, ventilation gaps greater than 3 mm in width should be covered by *noncombustible* screening with a maximum mesh aperture of 3 mm.

3.3.9 Doors and Windows

1) Exterior doors on *buildings* in *Construction Classes CC1*(FR) and *CC1* should
    a) be *noncombustible*, and
    b) have a *fire-protection rating* of not less than 20 min when tested using CAN/ULC-S104, “Standard Method for Fire Tests of Door Assemblies” [93].
2) Glazing in exterior doors in *Construction Classes CC1*(FR) and *CC1* should include an outer pane of tempered or heat-strengthened glass.
3) Where installed, secondary screen doors provided for exterior doors should
    a) be *noncombustible*,
    b) be fitted with
        i) a corrosion-resistant, *noncombustible* wire mesh with a maximum mesh aperture of 3 mm, or
        ii) shutters conforming to Sentence (6),
    c) have no gaps greater than 3 mm at the perimeter of the screen assembly where it is fitted to the door, and
    d) be equipped with a self-closing device to keep the screen door in the closed position when not in use.
4) Window glazing and skylights should be tested using SFM Standard 12-7A-2, “Exterior Windows” [94].
5) All windows should be fitted with a screen that
    a) is made of corrosion-resistant, *noncombustible* wire mesh with a maximum mesh aperture of 3 mm,
    b) has no gaps greater than 3 mm at its perimeter where it is fitted to the window, and
    c) is supported by a metal frame.

6) Where installed, shutters should
   a) be made of *noncombustible* material,
   b) be fixed to the *building*,
   c) when in the closed position, have no gaps greater than 3 mm between the shutter and the wall, the sill, or the head,
   d) be readily manually operable from either inside or outside, and
   e) protect the entire window assembly or door assembly.

3.3.10 Decks,[26] Balconies, and Other Building Attachments

1) For *buildings* in *Construction Classes CC1*(FR) and *CC1*, decks, balconies, porches, and other similar *buildings* elements or *buildings* attached to or within 10 m of the primary *building structure* should
   a) be constructed of *noncombustible* materials, or
   b) meet the recommended acceptance criteria stated in Table 9 when tested using ASTM E2726, "Standard Test Method for Evaluating the Fire-Test-Response of Deck Structures to Burning Brands" [89], and ASTM E2632, "Standard Test Method for Evaluating the Under-Deck Fire Test Response of Deck Materials" [87].
2) For *buildings* in *Construction Class CC2*, decks, balconies, porches, and other similar *building* extensions should be constructed of
   a) *noncombustible* materials,
   b) *combustible* materials, such that the construction is solid and continuous without slots or other openings larger than 3 mm, or
   c) materials that meet the recommended acceptance criteria stated in Table 9 when tested using ASTM E2632, "Standard Test Method for Evaluating the Under-Deck Fire Test Response of Deck Materials" [87].
3) For *buildings* in *Construction Class CC3*, decks, balconies, porches and other similar *building* extensions should be constructed of
   a) *noncombustible* materials,
   b) *combustible* materials, such that the construction is solid and continuous without slots or other openings larger than 3 mm,
   c) *combustible* materials, where any *combustible* supporting elements located below slotted openings are provided with *noncombustible* caps or coverings, or
   d) materials that meet the recommended acceptance criteria stated in Table 9 when tested using ASTM E2632, "Standard Test Method for Evaluating the Under-Deck Fire Test Response of Deck Materials" [87].
4) For *buildings* in *Construction Classes CC2* and *CC3* constructed on *slopes* that have a grade greater than 30%, the underside of decks, balconies, porches, and other similar *building* extensions that are constructed of *combustible* materials should be enclosed to grade with solid *noncombustible* material not less than 12 mm thick.
5) Openings in the enclosed assemblies described in Sentence (4) required for ventilation or access should be

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[26] Decks are considered to include any attached stairs and membranes.

a) enclosed with no openings larger than 3 mm in any dimension, or
b) screened with corrosion-resistant, *noncombustible* wire mesh with a maximum mesh aperture of 3 mm.

6) All graded surfaces below decks, balconies, porches, raised *buildings*, and other similar *building* extensions should be *noncombustible*.
7) For *buildings* in *Construction Classes CC1*(FR) and *CC1*, fencing within 10 m of the furthest projection of the *building* should be constructed of *noncombustible* materials.
8) For *buildings* in *Construction Class CC2* or *CC3*, fencing within 1.5 m of the furthest projection of the *building* should be constructed of *noncombustible* materials.

3.3.11 Liquefied Petroleum Gas Tanks

1) Liquefied petroleum gas (LPG) tanks located within 100 m of any *building* should rest upon a *noncombustible* surface that extends not less than 1.5 m outward in all directions from the perimeter of the tank.
2) All vegetation and *combustible* material should be removed within a zone of not less than 3 m extending outward in all directions from the perimeter of LPG tanks located within 100 m of any *building*.
3) The clearance between an LPG tank and any *building* wall should be not less than 2 m.
4) LPG tanks should be not stored under a deck, balcony, or roof eave or soffit.

3.3.12 Fire Department Access Routes

1) Access routes for *fire department* use should be provided to all *buildings* in accordance with the applicable regulatory provisions.

3.3.13 Access Route Design

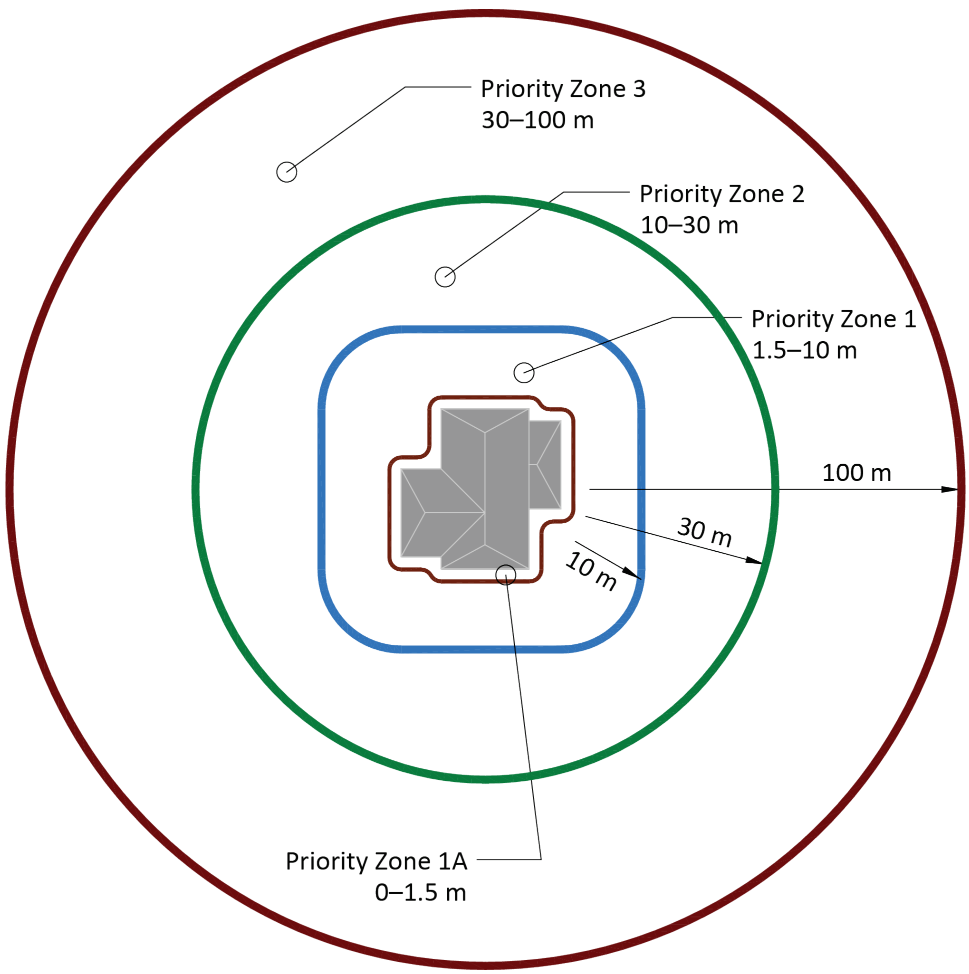
1) Access route design should comply with the applicable regulatory provisions.

3.4 Priority Zones

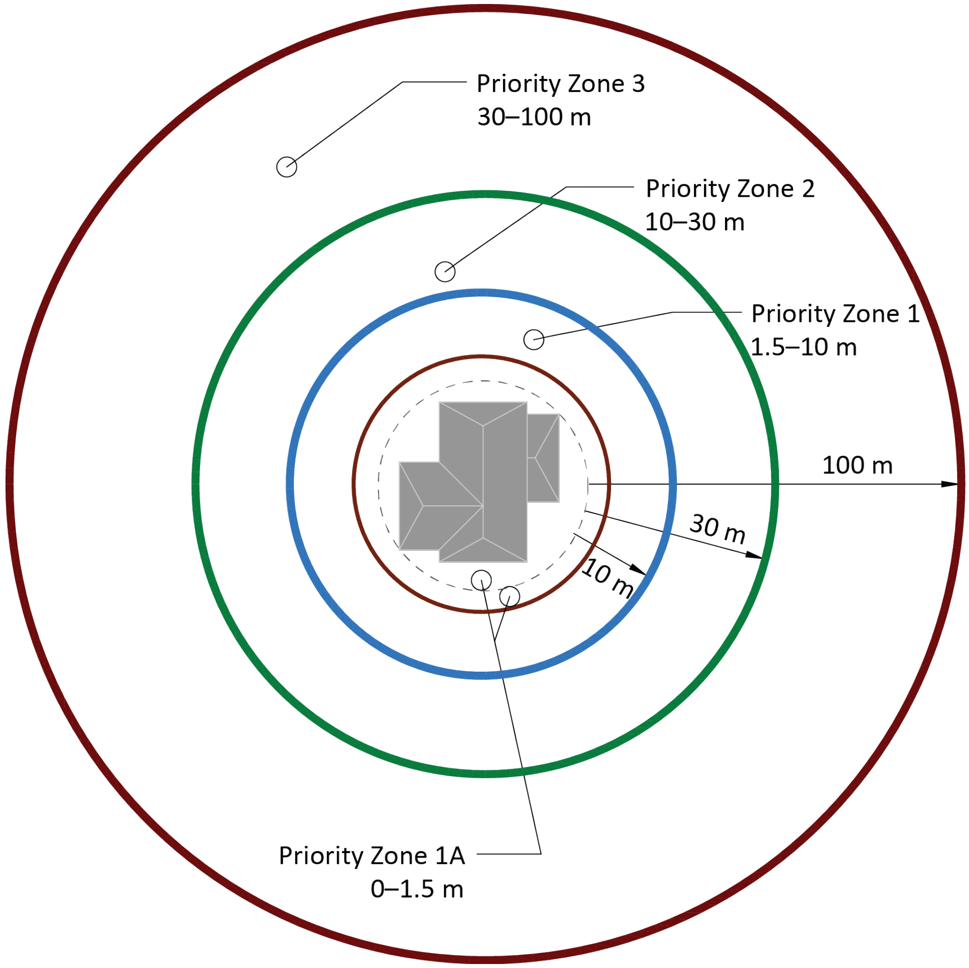
3.4.1 Priority Zone Requirements

In addition to the construction measures stated in Section 3.3, fuel should be managed in zones within a certain radius of the *structure*, which are called *Priority Zones*. See Appendix I for information and guidance on *fuel management*.

Figure 10, which is based on the FireSmart zone concept [10], shows the *Structure Ignition Zone*, which includes *Priority Zones 1A* to *3* as described below. Figure 10(a) shows a practical definition of the *Priority Zones*, particularly Zones *1A* and *1*. Figure 10(b) shows a more conservative definition of the *Priority Zones*, particularly Zone *1A*, which may not be necessary, especially for *buildings* that are longer in one dimension.



(a) Practical Definition



(b) More Conservative Definition

Figure 10. Structure Ignition Zone, which includes Priority Zones 1A to 3.[27]

3.4.1.1 Priority Zone 1A

1) Within a zone of not more than 1.5 m extending outward in all directions from the furthest projection of the *building*, the following measures should be used:

[27] The *Priority Zones* extend outward in all directions within the indicated distances from the furthest projection of the *building*. Note that zone radii are not to scale.

   a) vegetation and *combustible* material, including woody shrubs, trees, and tree branches, should be completely removed down to mineral soil, and
   b) *noncombustible* materials, such as gravel, brick, and concrete, should be used for landscaping features.
2) For raised or elevated *buildings*, *combustible* materials should not be stored underneath the *building* and the accumulation of *combustible* debris underneath the *building* should be prevented by the installation of a non-removable mesh or guard made of corrosion-resistant, *noncombustible* material.

3.4.1.2 Priority Zone 1

1) Within a zone beyond 1.5 m and not more than 10 m extending outward in all directions from the furthest projection of the *building*, the following measures should be used:
   a) annual grasses should be mowed to a height of not more than 10 cm,
   b) ground litter and downed trees should be removed at a frequency not less than annually,
   c) over-mature, dead, and dying trees with potential to ignite and carry fire should be removed,
   d) highly flammable species of trees with potential to ignite and carry fire should be removed,
   e) vegetation should be thinned and pruned to prevent a fire from being carried toward or away from the *building*,
   f) remaining vegetation should be converted to less fire-prone species if compatible with ecological considerations,
   g) *combustible* debris and items, including firewood piles, construction materials, furniture, decorative items, trailers, recreational vehicles, storage sheds, and ancillary *structures*, should not be present, and
   h) *firebreaks* should be provided as described in Section 3.4.4, where
      i) a *slope* increases the *WUI fire risk* to the *building* or the *subdivision*, or
      ii) the *building* is located adjacent to a *slope* without the setback required by Sentence 3.4.3.
2) An *approved* vegetation plan documenting the *WUI fire risk mitigation* strategies for *Priority Zone 1* should be established.

3.4.1.3 Priority Zone 2

1) Except as described in Sentence (2), within a zone beyond 10 m and not more than 30 m extending outward in all directions from the furthest projection of the *building*, the following measures should be used:
   a) fuel should be reduced through selective removal of coniferous trees to maintain a horizontal separation not less than 3 m between single and grouped *tree crowns*,
   b) branches located up to a height not less than 2 m from the ground should be removed from remaining trees, and
   c) accumulations of fallen branches, dry grass, and needles should be removed to the greatest extent reasonably practicable.
2) The outer radius of the zone described in Sentence (1) should be adjusted for *slope* as described in Section 3.4.2.
3) An *approved* vegetation plan documenting the *WUI fire risk mitigation* strategies for *Priority Zone 2* should be established.

3.4.1.4 Priority Zone 3

1) Except as described in Sentence (2), within a zone beyond 30 m and not more than 100 m extending outward in all directions from the furthest projection of the *building*, the measures of Clauses 3.4.1.2(1)(b) and (e) and Sentence 3.4.1.3(1) should be used.
2) The outer radius of the zone described in Sentence (1) should be adjusted for *slope* as described in Section 3.4.2.
3) An *approved* vegetation plan documenting the *WUI fire risk mitigation* strategies for *Priority Zone 3* should be established.

3.4.2 Slope-Adjusted Priority Zones

1) Except as described in Sentence (2), the outer radii of *Priority Zones 2* and *3* should be adjusted for *slope* as described in Sentences (3) and (4).[28]
2) The adjustment for *slope* described in Sentence (1) need not apply where the effects of *slope* in *Priority Zone 3* and Exposure Zone 4 are considered through the use of the detailed method to assess the *Exposure Level* of the *building*, as described in Chapter 2.
3) Where the *slope* of *Priority Zone 2* or *3* is greater than 30% and less than or equal to 55%, the outer radius of the zone should be increased (see Figure 11) by
    - a factor of 2 in the downslope direction, and
    - a factor of 1.5 in the horizontal direction.
4) Where the *slope* of *Priority Zone 2* or *3* is greater than 55%, the outer radius of the zone should be increased (see Figure 11) by
    - a factor of 4 in the downslope direction, and
    - a factor of 2 in the horizontal direction.

3.4.3 Setbacks

1) Except as described in Sentence (2), it is recommended that *buildings* in *Priority Zone 1* be located at a distance not less than 10 m from the crest of any hill (see Figure 12).
2) Where a setback as described in Sentence (1) is not possible, the *Construction Class* of the *exposed building face* facing the downslope should be taken as *CC1*(FR).

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[28] The location of the inner radius of Zone 3 shifts to coincide with the new position of the outer radius of Zone 2 after any adjustment.

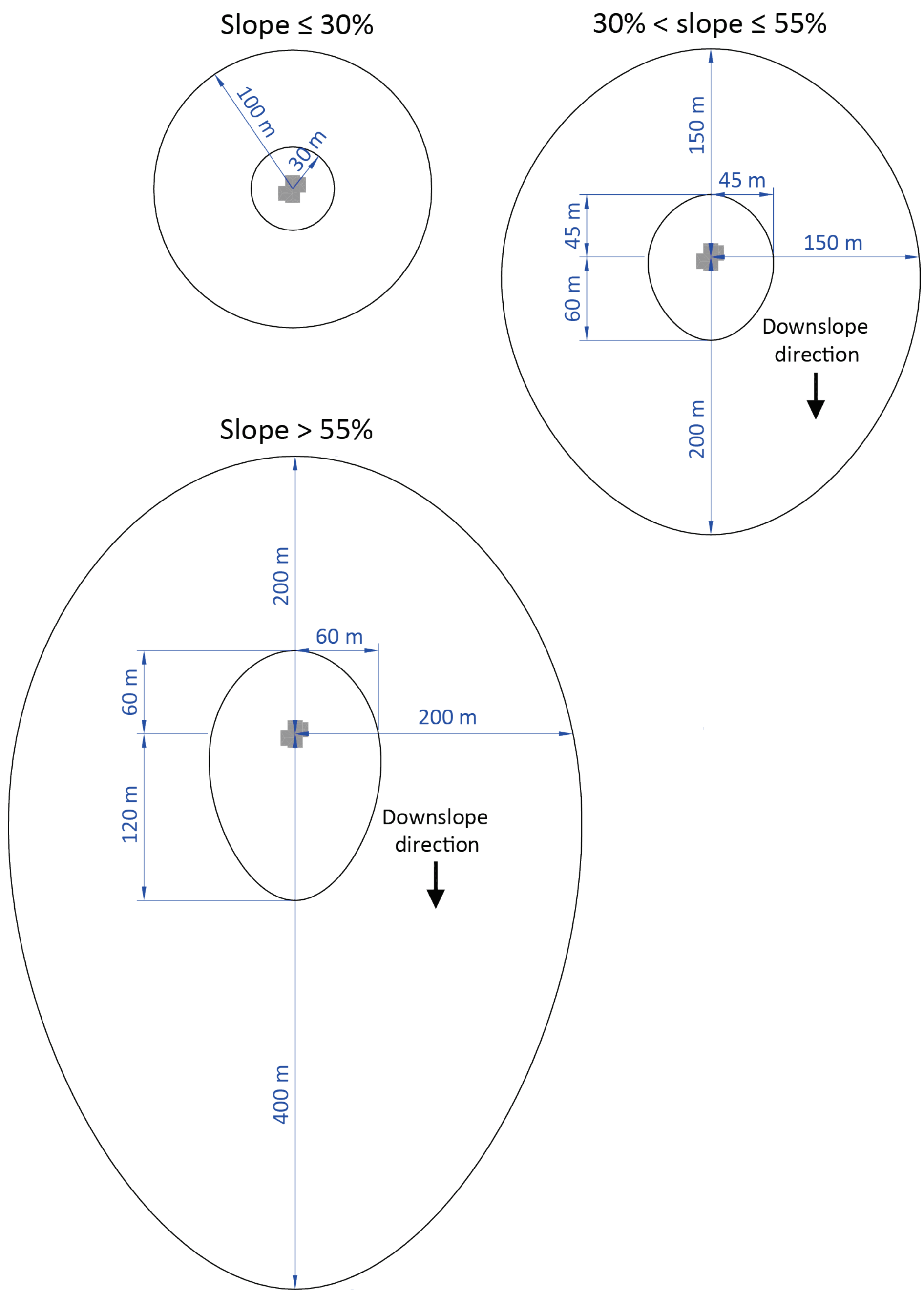

Figure 11. Adjustment of Priority Zones 2 and 3 for slope, as described in Section 3.4.2.

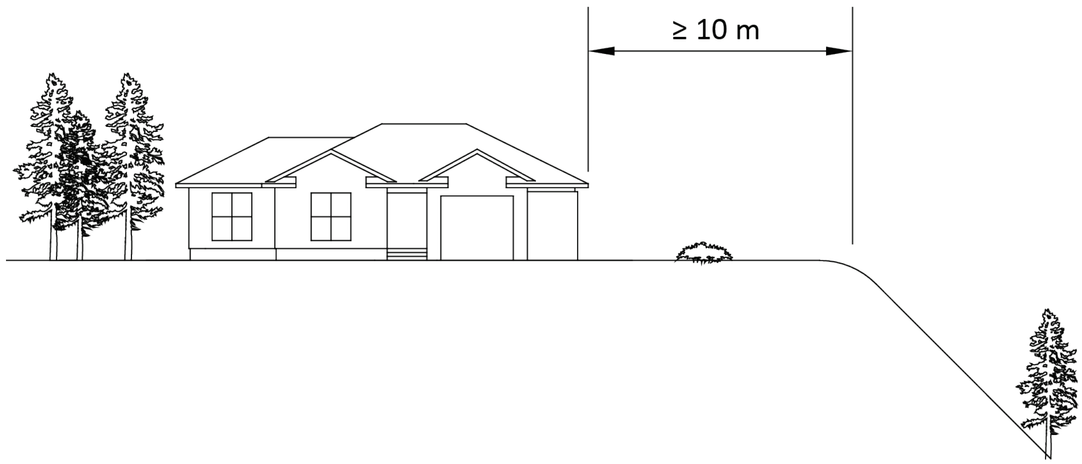

Figure 12. Required setback, as described in Sentence 3.4.3(1).

3.4.4 Firebreaks and Fuel Breaks

1) The minimum width of the *firebreak* described in Clause 3.4.1.2(1)(h) should be based on the magnitude of the *slope* in accordance with Table 10.

Table 10: Minimum Width of Firebreaks

Slope, %	Minimum Width of Firebreak, m
≤ 5	30
> 5 and ≤ 15	40
> 15	50

2) *Fuel breaks* should be provided on both sides of the *firebreak* referred to in Sentence (1) (see Figure 13).
3) Vegetative fuels should be completely removed down to mineral soil from the *fuel breaks* referred to in Sentence (2).

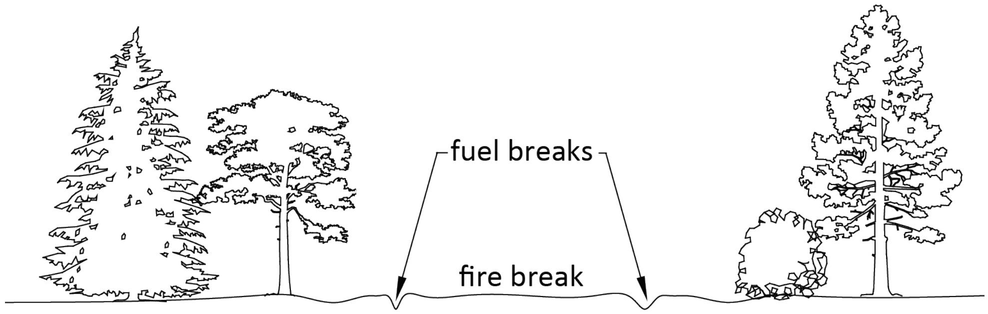

Figure 13. Fuel breaks on both sides of a firebreak, as described in Sentence 3.4.4(2).

Chapter 4 Community Planning and Resources

4.1 General

This Chapter provides guidance on enhancing the life safety of residents and workers by:

- better understanding the *resources* available to the *community* that might affect their capacity to respond to a *wildfire emergency*, and
- determining whether the design of the *community* itself contributes to this capacity.

The primary objectives of this Chapter are to limit the probability that a person will be exposed to an unacceptable *risk* of injury and to limit the probability that a *building* will be exposed to an unacceptable *risk* of damage, refer to the objectives and *building* functions described in Section 1.3.2.

The guidance provided in this Chapter should be of interest to *communities* that are subject to at least some threat of *wildfire exposure*. Chapter 2 of this Guide should be consulted to assess the Hazard Level of a particular *community*. If the *community* is exposed to a Hazard Level greater than 1 (Nil–Very Low), the guidance provided in this Chapter should be considered.

There is a need to consider addressing the effects of *WUI fires*, beyond the immediate impact of the fires themselves, to contribute to the *recovery* of the *community* (and the affected population[29]). These longer-term effects include health considerations (e.g., ongoing impact of *exposure* to *smoke*, elevated temperatures, and toxins on *community* members), economic implications (e.g., damage repair costs, loss of tourism, business downturn, reduced external business investment, and reallocation of funds to address *community recovery*), social implications (e.g., *community* displacement and relocation, reduction in staff, supplies and equipment available for vital social functions such as health care and education, and decline in social capital and sense of *community*), among many others. Although these issues fall outside of the scope of this Guide, guidance on addressing some of them can be found in Appendix J.

4.2 Planning the Wildland-Urban Interface

Decisions are made on a daily basis across Canada that affect the social, economic, and environmental fabric of *communities*: to construct new roads, to build or replace *structures*, to install landscaping, to modify natural areas, to relocate to new towns or cities, to approve new development, and more. Many of these decisions can have implications for the *WUI* because changes to the built and natural environment affect the *wildfire hazard* to people, property, and

[29] People requiring immediate assistance during an *emergency*, including basic survival needs such as food, water, shelter, sanitation, and immediate medical assistance.

infrastructure. These implications make the *WUI* a dynamic planning topic that requires regular evaluation during each stage of the *community* planning and design process.

The legal framework and norms that guide land use planning differ by *community*. Indigenous *communities* manage their lands independently of provincial or territorial legislation in some provinces and territories. In other *communities*, municipal land use planning is governed by provincial or territorial legislation. Provinces and territories implement provincial/territorial and regional plans, which provide high-level objectives for land use, growth management, economic development, environmental protection, and more. At a local level, municipalities develop and implement more detailed tools for land use planning, including *community plans*,[30] zoning by-laws, *subdivision* plans or land severances, site plan approvals, and *building* permits.

As a result of the differing frameworks and norms, the process for administering and implementing land use planning varies across the country. This Chapter sets out guidance to help planners, *emergency responders*, and other decision-makers incorporate *wildfire hazard* considerations into the *community* planning and design process at different stages and scales of development.

4.2.1 Demographics

Demographics are statistics about the population of a specific geographic area and are based on a number of variables, which typically include population, age, housing, family type, language, income, immigration and citizenship, mobility, and education (see Appendix B for more examples). Planners, *emergency managers*, policy-makers, and other decision-makers can use census profile data and other *community demographics* to inform aspects of land use planning for the *WUI*, such as:

- planning for new residential growth and associated services that may add pressure to expand the *WUI*
- assessing the level of *preparedness* and local *resources* for *wildfire mitigation*
- planning for safe and effective *evacuation* and *emergency response* for existing *WUI communities*
- anticipating the adaptive capacity of *WUI communities* to recover from a *wildfire incident*

Table 11 provides common *demographic* characteristics and their potential applications to support planning for the *WUI*, *emergency response*, and *disaster recovery*. Additional *demographic* characteristics that may be useful for planning include the number of household dependants, the ownership of livestock and pets, and the number of households with internet access, as well as other socio-economic factors.

[30] Also referred to as official plans, official *community* plans, development plans, municipal plans, or plan d'urbanisme.

Table 11: Demographic Characteristics That May Affect WUI Planning

Demographic Characteristic	Potential Effect on WUI Planning
Population	• Population growth or decline will affect future demand for new construction and infrastructure. • Increase in population may mean more revenue (e.g., from taxes) for initiatives to reduce fire *risk*.
Age of Population	• Older populations may have less physical ability or fewer financial *resources* to implement recommended, voluntary property *mitigation* measures (pre-event) and to evacuate during a *wildfire emergency*. However, older populations may also have more time to implement *wildfire mitigation* measures. • Populations with household dependants need to be considered during *evacuation* planning.
Housing Ownership	• Owner-occupiers often have more direct control over property management and *mitigation* decisions. • Different *communication* and engagement activities are recommended for seasonal populations. • Effects of a *wildfire disaster* on the housing market vary by type of occupancy, *resources*, and ownership patterns.
Age of Housing Stock	• Older housing stock, which is less likely to comply with modern *building* codes, may increase the susceptibility of some neighbourhoods. Incentives to mitigate the *risk* by retrofitting homes are recommended.
Language	• *Communication* materials and engagement activities should reflect the diversity of local languages to ensure that different populations can access and benefit from pre-event *wildfire* program materials and understand *evacuation* instructions during a *wildfire emergency*.
Community Coordination	• Coordination is required for governance, land management, and *evacuation* planning related to *wildfire emergencies*.
Income	• Income levels may inform the capacity and financial *resources* available to implement required or voluntary *mitigation* measures (pre-event) and *evacuations* during a *wildfire emergency*. • Populations with lower income levels are often disproportionately affected by *wildfire disasters* and require additional *recovery* assistance.
Disability	• Populations with physical or mental disabilities need to be considered in *evacuation* planning.

Demographic Characteristic	Potential Effect on WUI Planning
Mobility	• Populations with limited access to personal vehicles or in areas with restricted driving can face challenges during *evacuations*.
Employment	• Employment hubs can influence commuting patterns, which should be considered during *evacuation* planning. • Some industries (e.g., tourism) may be more vulnerable to *wildfire disasters* or may experience short-term effects during *evacuations*. Depending on the economic strength and resiliency of an area before the *disaster*, the impact of the interruption of business on that area's economy may last beyond the short term as other impacts from the interruption compound.

4.2.1.1 Sources of Demographic Information

Planners, *emergency responders*, and other decision-makers can find information on *demographics* from multiple sources, including: the Statistics Canada Census Program, which provides a statistical portrait of the country every 5 years, including data for First Nations people, Métis, and Inuit; provincial and territorial statistical offices; regional plans, official plans, development plans, and other plans adopted by *local governments* and Indigenous *communities*; and university-based research programs and studies.

Supplemental guidance regarding *demographic* considerations can be found in Appendix J. This Appendix examines factors reflecting a subset of the *demographic* characteristics identified above and how some of these factors might affect social *vulnerability*.

4.2.2 Land Use and Development

A number of factors influence the susceptibility of development in the *WUI* to fire, many of which can be controlled or regulated through land use planning. This section focuses on the appropriate type and scale of development to inform land use planning decisions to reduce the *community wildfire hazard*. See Chapter 3 for measures and guidance specific to *structures* and construction materials. In some cases, land use planning decisions may affect the susceptibility of *structures* to fire (e.g., the allowable density of *structures* in a designated area or zone). This susceptibility may be exacerbated by limitations in extending the existing water supply and other infrastructure in *WUI* areas. As a result, recommended construction measures and *Priority Zone mitigation* guidance may be altered (see Chapter 3 for further information about *Priority Zones*). Table 12 lists *community* planning issues related to the *WUI* and offers corresponding policy and regulatory guidance for planning departments and other agencies.

The guidance contained in this section has been derived from various international sources, including "Planning the Wildland-Urban Interface" [95], "Guidelines for Planning in Bushfire Prone Areas" [96], and "Fire Hazard Planning" [97].

Table 12: Policy and Regulatory Guidance for WUI Land Use Planning

WUI Planning Issue	Policy and Regulatory Guidance
Policy for Location of New Development	• New development should be located in areas that pose (with *mitigation* measures, where necessary) the lowest possible *wildfire hazard* to people and to property, infrastructure, and other assets deemed essential for the safety, welfare, *resilience*, and sustainability of the *community*.
Alignment	• Establish planning goals and objectives for proposed new development that consider the *WUI*, including minimizing *wildfire hazard* to people, property, and infrastructure; reducing habitat fragmentation and loss of biodiversity; and protecting natural areas with ecosystem services[(1)].
Hazard Evaluation	• Evaluate proposed new development and other changes to land use based on Hazard Level (see Chapter 2), and locate development activities in areas that can achieve the lowest *wildfire hazard* following the use of *mitigation* measures (see Chapter 3). • Evaluate the *wildfire hazard* within the larger *hazard* context to ensure that *mitigation* against ignitions does not exacerbate other *hazards* (e.g., the removal of vegetation should not result in increased erosion or flooding).
Infrastructure	• Consider connecting new development to existing roads and existing firefighting infrastructure or, where this is not possible, seek agreements with developers providing options for equivalent measures (private water supply, roads, and *mitigation* measures) to ensure the safety of future residents and, where appropriate, *emergency responders* (see Sections 4.2.3 and 4.3).
Intensification	• Avoid intensification of development in areas that have a high *wildfire Exposure Level* that cannot be mitigated to an acceptable *Exposure Level* due to site constraints (e.g., *topography*, *slope*, or *fuel loading*) without compromising the integrity of the landscape.
Sensitive Areas	• Avoid development in areas that are in or adjacent to environmentally sensitive areas (e.g., conservation areas, high-biodiversity areas, riparian areas) where vegetation management to protect people and property would compromise sensitive areas.
Unavoidable Development	• Establish criteria to determine the types of development and conditions under which development may be *approved* in areas with a high *Exposure Level* that cannot be mitigated, (e.g., where the placement of new infrastructure results in increased public benefits that outweigh the potential *wildfire hazard* to a *community*).

WUI Planning Issue	Policy and Regulatory Guidance
Policy for Community Design and Development – Residential	• *Community* design and layout should incorporate safety features to minimize the *wildfire hazard* to people, property, and adjacent land. The following issues should be addressed when planning for development in an existing or generated *WUI*.
Access and Circulation	• Evaluate the adequacy of existing road networks to allow safe and effective ingress and egress during *emergency evacuations* (see Section 4.2.3). • Avoid development that results in cul-de-sacs, dead-ends, long *driveways*, and other features with limited access and circulation, unless the *risk* associated with these features can be mitigated through the implementation of adequate *emergency* access routes, turnarounds, vegetation management, or other measures. • Consider limiting *driveways* to serve no more than two *buildings* or *structures*, not including *accessory structures*, or no more than five *dwelling units*. • Consider *subdivision* designs that utilize perimeter roads or other external networks (e.g., multi-purpose trails) to facilitate efficient *emergency* access and *response*.
Lot Size and Density	• Establish the maximum number of lots in *subdivisions* by considering the ability for all habitable *structures* to follow recommended construction measures and *Priority Zone mitigation* measures (see Chapter 3). • Development patterns that result in increased *structure* density (e.g., clustered development, conservation *subdivisions*[2]) should follow the recommended construction measures relative to the respective *Priority Zones* (see Chapter 3 and Appendix K).
Phasing of Development	• Ensure that each phase of development adequately addresses the current *wildfire hazard*. Implementing *mitigation* measures, including *emergency* access, should not be left for the final phase of completion. • Ensure ongoing vegetation management on vacant or undeveloped parcels of land to ensure that they do not pose a threat to adjacent developed properties.
Slopes and Ridgetops	• Avoid development on steep *slopes*, on ridgetops, and near the edges of canyons or chimneys. Where development in these areas is unavoidable, recommend that plans be reviewed and *approved* by the local fire protection agency following the recommendations for *slope*-adjusted *Priority Zone mitigation* measures (see Chapter 3). • For development on gradual to moderate *slopes*, adjust *Priority Zone mitigation* measures (see Chapter 3). • Recommend minimum setbacks of *structures* from the crest of a hill (see Chapter 3).

WUI Planning Issue	Policy and Regulatory Guidance
Vegetation Management and Property Landscaping	• Integrate landscape-scale features (e.g., golf courses, trails, easements, and other potential vegetation buffers) that can act as *firebreaks* or encourage improved access for *emergency responders* (see Chapter 3 for further information on *firebreaks* and *fuel breaks*). • Establish maintenance agreements with developers, property owners, etc. to maintain *fuel management* in common areas (e.g., open spaces) and individual properties. • Recommend minimum setbacks at the rear and side property lines of lots to ensure that habitable *structures* follow *Priority Zone mitigation* measures (see Section 3.4.3).
Water Supply	• Avoid new development that significantly increases the demand on existing water supply systems unless the systems can adequately support the development or an additional water supply can be secured (see Section 4.3.1.2). • Review water conservation policies and requirements to ensure compatibility with *Priority Zone mitigation* measures. • If new development significantly increases the demand on the existing water supply system, or if extending the existing water supply system is impractical due to factors such as distance or *topography*, seek agreements with developers providing options for a private water supply, with or without other *mitigation* measures, that are acceptable to the *AHJ*. • Plan to use natural or added water supply features as part of the private water supply, if required, or as a static water supply for firefighting services and other responding agencies.
Policy for Community Design and Development – Non-Residential	• Commercial and industrial areas should incorporate safety features to minimize the threat of *wildfire* to people, property, and adjacent land uses. These features are similar to residential design and layout, but present additional issues for planning, as discussed below.
Commercial Design Guidelines and Standards	• Ensure that design guidelines, architectural standards, historic preservation recommendations, and similar criteria for commercial development follow recommended construction measures and *Priority Zone mitigation* measures.
Landscaping, Screening,[3] and Buffering[4]	• Modify recommended measures for landscaping, screening, and buffering to avoid regulatory conflicts between development standards and *Priority Zone mitigation* measures. • Ensure that tree preservation recommendations do not prevent the removal of hazardous trees.
Vulnerable Land Uses[5]	• Assess *vulnerable land uses* (e.g., nursing homes, hospitals, centres for persons with disabilities, schools) to determine the degree to which the population will be able to respond in a *wildfire emergency*

WUI Planning Issue	Policy and Regulatory Guidance
	and implement appropriate *mitigation* measures. (See the *vulnerability* assessment in Appendix C.)
Hazardous Land Uses[(6)]	• Ensure local land management planning addresses hazardous land uses that may potentially ignite a *wildfire*, prolong its duration, or increase its intensity (e.g., power plants, lumberyards, sawmills, warehouses with hazardous materials, outdoor shooting ranges). • Apply *mitigation* measures, which may include construction provisions, setbacks or separations from other land uses, *Priority Zone mitigation* measures, *hazard* management plans, or other conditions.
Temporary Land Uses	• Assess temporary land uses (e.g., for fireworks, outdoor mass gatherings) by Hazard Level and *Exposure Level* (see Chapter 2), type of activity, number of persons, and other factors; and recommend appropriate *mitigation* measures as a condition of approval.
Outdoor Refuge Areas	• Discussions on the use of outdoor refuge areas should occur in close coordination with local fire protection *resources* to ensure safety measures are adequately integrated into the planning process.

Notes to Table 12:

(1) "Ecosystem services" refers to the benefits people obtain from ecosystems. These include provisioning services, such as food and water; regulating services, such as flood and disease control; cultural services, such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.

(2) "Conservation *subdivisions*" refers to a residential *subdivision* that devotes at least half of its potentially buildable land area to undivided, permanently protected open space. In contrast, conventional *subdivisions* devote all, or nearly all, buildable land area to individual lots and streets.

(3) "Screen" refers to any landscaping or *structure*, such as walls, landscaped berms, and hedges, used to conceal or reduce the negative visual and audio impacts of certain land uses or activities from streets or adjacent development. The height of a screen is measured from the highest finished grade abutting the element to be screened.

(4) "Buffering" refers to the on-site use of landscaping elements, screening devices, open space, drainage ways, and landforms for the reduction of the potentially adverse impacts of adjoining, dissimilar land uses.

(5) "*Vulnerable land uses*" refers to types of land use that may put vulnerable populations at *risk* during a *wildfire emergency*.

(6) "Hazardous land uses" refers to types of land use with *combustible* properties and requiring different forms of *mitigation* or *evacuation* planning.

Additional explanatory material regarding land use planning can be found in Appendix K, which expands on several of the planning topics presented in Table 12 and provides examples of existing guidance.

4.2.2.1 Regulatory Considerations

Ideally, all land uses should be evaluated to determine whether they are in a *wildfire hazard* area and, if so, the appropriate type and level of *mitigation*. However, local municipalities and any other *AHJs* must also consider their capacity to administer and enforce regulations, which may vary considerably across provinces and territories. The following guidance can support *local governments* in the development and adoption of land use planning requirements that address the *wildfire hazard* in the *WUI*.

- Incorporate the goal of minimizing the *wildfire hazard* to people, property, and infrastructure at all stages of the land use planning process. This often begins with plans containing high-level goals and objectives. Although plans may not be legally binding, this policy direction creates a foundation for future implementation through by-laws and other regulatory instruments.

- Apply an approach that matches scale with level of detail. In other words, *mitigation* measures should become increasingly more detailed as the scale becomes more refined and the application process becomes more definitive.

- Establish clear criteria for when a *wildfire hazard mitigation* plan should be required and the type of information the plan must contain. For example, a plan should be required when an application involves an area with a Hazard Level greater than 1 (Nil–Very Low) (see Chapter 2).

- Include *wildfire hazard exposure* zones in *community* mapping.

- Evaluate development patterns in terms of broader advantages or disadvantages related to economic feasibility, *wildfire* safety, *mitigation*, and suppression. For example, low-density *subdivisions* with large lots may enable property owners to manage their *Priority Zone 2* independently from their neighbours if property lines and *structures* are separated by a distance of 30 m or more. However, such low-density development patterns may bring additional challenges for *emergency response* and increased costs of infrastructure because of the expanded footprint of the *community*. Conversely, high-density development patterns may decrease sprawl but increase reliance on neighbours to achieve effective *hazard mitigation*.

- Integrate agencies that have responsibility for *WUI fire* management in both *wildlands* and developed areas (e.g., local engineering departments, local *fire departments*, fire protection districts, and provincial/territorial *wildfire* agencies) into the review and approval process as appropriate. These agencies should be engaged early in the process, not just prior to the final stages of development approval when it may be difficult to make significant adjustments.

- Consider all types of potential development in the *WUI* (i.e., new development, existing development, and redevelopment) and how each can be addressed through policies and regulations.

- Finally, undertake a comprehensive review of existing zoning by-laws, and applicable codes (e.g., *building*, fire) and regulations as part of any adoption process for *wildfire* measures. This review will ensure that existing and new regulations are compatible and without conflicts.

Box 4: Development Permits

British Columbia Example
In British Columbia, legislation gives *local governments* the authority to designate development permit areas. These areas serve a specific purpose, for example, to protect development from *hazards*, and require special treatment.

Local governments may designate a development permit area in an official *community plan*. (For example, the Regional District of Central Okanagan has several such plans.) The plan must describe the special conditions or objectives that justify the designation. The *local government* must also specify guidelines for how proposed development in that area can address the special conditions or objectives. These guidelines may be specified by zoning by-laws.

Within a development permit area, property owners must obtain a development permit before:

- subdividing land
- constructing, altering, or adding to a *building*

This type of legislation is not limited to BC. Other provinces have similar legislation that provides the authority and parameters for *local governments* to regulate development.

Colorado Example
Summit County, Colorado (US), made significant changes to its zoning regulations and *subdivision* regulations in 2017. The changes were made to incorporate improved fire protection measures, forest management and fuel reduction planning requirements, and sophisticated zoning amendments. For more details, see Chapters 3 and 8 in the Summit County Land Use and Development Code (http://www.co.summit.co.us/255/Land-Use-Development-Code) [98].

4.2.3 Access and Egress Routes

Roads need to have sufficient *vehicle capacity* to both meet *community evacuation* demands and accommodate the arrival of *emergency responders* during a *wildfire emergency*.

Roads serve three functions during a *wildfire*:

1) as access routes for *emergency responders* and their vehicles and equipment. Access routes should be robust enough to cope with large, heavy equipment and vehicles (e.g., 20 tonne firetrucks) [60],[99]
2) as escape (or egress) routes for residents
3) as *firebreaks* to interrupt or slow the progress of the fire and assist firefighting efforts

The first two functions are covered in Sections 4.2.3.1 and 4.2.3.2, which focus on access and egress routes on public property within a *community*, and in Section 3.3.12, which addresses *fire department* access routes. The third function is covered in Section 3.4, which addresses *Priority Zone mitigation* measures, including *firebreaks*.

4.2.3.1 Access Routes

Existing Canadian *building* and fire codes do not explicitly address *WUI* areas [2],[62]. Since existing US standards and codes (NFPA 1141, "Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas" [63], and the International Code Council 2018 International Wildland-Urban Interface Code [1]) provide requirements for access and egress routes (i.e., the road network) in *WUI* areas, these requirements were considered during the development of the Guide.

The US requirements cover the following general topics:

- the types of access routes required in the areas at *risk* and/or the minimum number of access routes required in the areas
- road geometry, materials to be used, parking lots and devoted lanes (e.g., fire lanes) for both main access routes and dead-end roads
- markings to be used on access routes, as well as street and *dwelling* markers

Table 13 summarizes some of the US requirements more specifically.

Table 13: NFPA 1141 Recommendations for Access and Egress Routes

Access and Egress Subject	Recommendations
Access Routes, Number	• Number of access routes is determined by number of households or parking spots (see NFPA 1141 [63] for further details). • If multiple access routes are available, these routes should not be close to one other; one route should be reserved for *emergency* use only. • Additional restrictions exist in NFPA 1141 [63] for roads with security features (e.g., gates).
Main Roadways	• Roadways should be built of a hard, all-weather surface. • Minimum clear width is 3.7 m (12 ft.) for each lane (including curves, excluding shoulders and parking). • Minimum vertical clearance is 4.1 m (13 ft. 6 in.) for full width of roadway. • Minimum radius of turns is 18.3 m (60 ft.) measured to the outside of the turn. • Intersections should have left-turn lanes, traffic signals, and/or automatic controls to facilitate the passage of firefighting equipment. • Intersections should have grades suitable to prevent the accumulation of water or ice and should follow sight distance requirements (see NFPA 1141 [63]). • Use of traffic calming measures (e.g., speed bumps or humps) should be restricted (see NFPA 1141 [63]).

Access and Egress Subject	Recommendations
	• Bridges and culverts should be designed for a flood elevation corresponding to a specific recurrence interval (e.g., a 100-year flood elevation) (see NFPA 1141 [63]). • Maximum grade is 10%; and maximum angles of approach and departure are 8°. • Road centres should be crowned, if grades are less than 0.5%. • *Emergency* pull-off areas should be provided at an appropriate spacing (see NFPA 1141 [63]).

Dead-End, Cul-de-Sac, and Gated Roads	• Dead-end roads longer than 91 m (300 ft.) should have a turnaround at the end with a minimum outside diameter of 36.6 m (120 ft.).
	• Cul-de-sac roads longer than 366 m (1 200 ft.) should have intermediate turnarounds at a maximum interval of 366 m (1 200 ft.).
	• Gates should:
	    ◦ be more than 9.144 m (30 ft.) from intersections
	    ◦ open in the direction of *emergency* vehicle travel
	    ◦ have a clear width at least 0.6 m (2 ft.) larger than the access route they control

Fire Lanes	• Parking lot lanes, delivery lanes, and private roads can be used as fire lanes if they:
	    ◦ are built of a hard, all-weather surface
	    ◦ have a maximum grade of 10%
	    ◦ have a minimum lane width of 5 m (16 ft.), or 7.3 m (24 ft.) for two-way roads, excluding shoulders, sidewalks, and drainage facilities
	    ◦ follow other requirements for grades, vertical clearance, and maximum angles applying to main roads
	• Outside curb line should have a minimum radius of 15.2 m (50 ft.).
	• Curb cuts should extend at least 0.6 m (2 ft.) beyond both sides of fire lanes connecting to roads.

Parking Lots	• Minimum parking stall length and minimum aisle width (for either one- or two-way aisles) depend upon parking angle (see NFPA 1141 [63] for further details).

Markings (Including Road Signs and Markers)	• Different types of signs should be posted at various locations within the *community* to indicate:
	    ◦ load limits at entrances of bridges
	    ◦ the nearest waterway (if required by the *AHJ*)
	    ◦ dead-end roads or single-access routes

Access and Egress Subject	Recommendations

	• Signs for road names should be made of *noncombustible* materials and installed at each intersection at a minimum of 2.1 m (7 ft.) above the roadway.
	• All premises with an assigned address should be identified by signage bearing the assigned address to aid responding fire services identifying locations where assistance has been requested.
	• Sign lettering should
	  ◦ have a minimum height of 0.1 m (4 in.)
	  ◦ have a minimum stroke of 0.0127 m (0.5 in.)
	  ◦ be reflective and contrasting to the background
	• Spacing between letters and numbers on signs should be between 0.0127 m (0.5 in.) and 0.025 m (1 in.).
	• A minimum border of 0.025 m (1 in.) should be included for letters or numerals only for premises addresses.
	• Additional signage should
	  ◦ appear at the end of the *driveway* where address signage is not visible from the roadway
	  ◦ follow with the recommendations for signage
	  ◦ be mounted between 1.2 m (4.0 ft.) and 2.1 m (7.0 ft.) above grade
	  ◦ be posted less than 1.5 m (5.0 ft.) from the *driveway* or roadway
	  ◦ be on the same side of the road as the *driveway*
	  ◦ be perpendicular to the direction of travel on the roadway
	  ◦ be kept free of visual obstructions and replaced whenever damaged or degraded
	• On markers:
	  ◦ addresses should be consistently assigned
	  ◦ street names should be phonetically unique

4.2.3.2 Egress Routes

In addition to the recommendations for roads listed above, designers and planners may wish to consider the questions in Table 14 below regarding egress. These questions can benefit road network design and planning in terms of egress, regardless of the destination of the population movement (e.g., to a pre-determined shelter, to a designated local assembly point, or to a more remote location). These questions are not comprehensive, but bring forward key design and analysis considerations.

The questions below pertain to the assessment of the *risk* and potential challenges of undertaking the protective action of *evacuation* referred to in Figure 4 (Chapter 1). These questions relate to factors that affect the access and egress routes of a *community*. The questions serve as a checklist for Guide users to ensure a broad range of considerations are addressed. These questions should be of particular help to *local government* (when issuing *evacuation* notices and estimating *community evacuation* time) and developers (when incorporating *evacuation* considerations into designs).

Table 14: Egress Questions and Considerations

Egress Question	Considerations
How are you trying to move people?	• Consider whether walking is a feasible option to reach safety or to access other modes of transportation. • Consider whether motorized transportation is required.
How many access and egress routes are there?	• There should be more than one route for egress (i.e., redundancy) so that if one is unusable for any reason (e.g., blocked by fire or obstructed by *response* vehicles), the other(s) can be used.
What are the characteristics of these roads and routes?	• Consider: ◦ number of lanes for each road and lane width ◦ shoulders: if present and shoulder width, if they could be used as an additional lane, if they provide room for disabled vehicles ◦ clearance from roadside obstacles ◦ design speeds and typical operational speeds ◦ road congestion at different times of day ◦ degree to which each road is likely to be threatened by *hazards* ◦ number of access or egress points for each road, since ◦ these points cause the merging or diverging of traffic and affect speed. ◦ whether vehicles will be able to safely exit should the *hazard* suddenly threaten the road

Egress Question	Considerations
	• whether the routes connect at-*risk communities* with preferred *evacuation* (and shelter) destinations • familiarity of potential *evacuees* with the main and alternative routes
Do the egress routes overlap (i.e., share links)?	• Routes that overlap cannot be considered independent. If a common link becomes unusable, all routes sharing that link simultaneously fail. • Traffic slows at the point of overlap because it is the location where the traffic will merge. • Routes that overlap do not have additive capacities. • Even routes that do not overlap may be similarly affected by the same *hazard* if they are in close proximity.

What is the vehicle capacity of the egress route?	• Consider points of overlap in the route.
	• Consider how the following may reduce *vehicle capacity*:
	  • *emergency response* vehicles
	  • the *hazard*
	  • poor visibility (e.g., *smoke*)
	  • vehicle *incidents* (e.g., accidents, disabled vehicles)
	  • *background traffic* (can it be diverted through ramp or road closures, etc.?), which can be a significant issues at certain times of day and in certain locations
	• Consider how the following may enhance *vehicle capacity*:
	  • use of inbound lanes for egress
	  • use of shoulders
	  • changes in traffic control (e.g., signal timing adjustments)
	• See also other potential *resources*: Highway Capacity Manual [20], design documents from departments of transportation or other road agencies.

How many vehicles could actually be moved in a specified time period?	• Households may want to take multiple vehicles. Consider advising each take only one. • Consider that vehicles may also be towing trailers, which reduce *vehicle capacity* and increase vehicle size.

What type of guidance about egress routes should be disseminated locally?	• Consider:
	  • threats to each route
	  • time to impact at origin
	  • connectivity to shelter locations
	  • congestion
	• The *community* should be made aware of egress routes and alternatives, and become familiar with them.

Egress Question	Considerations
How far in advance should the decision to evacuate a community be made (considering the vehicle capacity and redundancy of an egress route)?	• *Vehicle capacity* under *hazard* conditions can influence the amount of notice required. • *Vehicle capacity* should be considered relative to the number of vehicles that must be moved in a given time period. • *Background traffic* levels may also have a major role in determining when *evacuation* notices must be given. • Time of day and *communication* with the public must also be considered (see Section 5.2).

While many technical components of road and network design have been mentioned above and are more completely covered in technical guidance for the assessment of road design and *vehicle capacity*, only theoretical *vehicle capacity* values are provided in that guidance. During a real *wildfire emergency*, many components (e.g., the *wildfire hazard*, environment, weather, warning systems, *emergency responders*, residents) interact that may make the actual conditions different from theoretical values. For instance, the distribution of firefighting equipment on a road may vary, based on firefighter decisions, and may affect the degree to which that road is usable for egress, if at all. Additionally, the *hazard* conditions are dynamic and may make routes unusable with little notice. Some redundancy should be factored into network capacity to account for the conditions and subsequent performance.

Complexity in a real *wildfire emergency* is also added by the human participants (e.g., *evacuees*) who receive information from a variety of sources (e.g., warnings, environmental cues) and make decisions about whether to evacuate or stay, when to leave, where to go, and how to get to the destination. Even though multiple routes may be available for egress, the routes must serve the individual *evacuee's* needs (e.g., safety, desired shelter location, reasonable travel time) and he or she must be aware of the route and its destination. Reasons for selecting a route for *evacuation* include familiarity as well as the belief that it will be the quickest and shortest route [100]. *Evacuees* may be less familiar with or unaware of special *emergency* roads. *Evacuees* may also have a heavy preference for a particular route, which could prevent total *vehicle capacity* from being used effectively [101]. *Evacuees* may be influenced by traffic reports and other information when determining the quickest route as well as by personal anticipation of conditions. Real *evacuee* behaviour may vary across the population and include selecting unofficial *evacuation* routes, switching routes, or adhering to a route regardless of congestion [3].

Despite all of these complexities, a few general considerations are recommended. First, multiple routes for access and egress are preferred to single a route. Second, the *community* should be made aware of these alternatives and become familiar with them. Third, ensure that egress roads are designed to accommodate firefighting equipment and potential evacuating traffic while taking into consideration overlap of routes as much as possible. Fourth, recognize that real conditions are not likely to reach the theoretically ideal conditions. Finally, when *evacuation* is required and possible, early *evacuation* is recommended.

4.2.3.3 Areas of Refuge

Evacuation can be a long and complex process; and, in some cases, safe and effective *evacuation* may not be achievable. Safe areas of refuge within the *community* become critical, for example, in the following cases example:

- high *risk* populations with ambulation and/or resource limitations
- aggressive, fast moving *wildfires* that impinge on *evacuation* routes prior to *evacuation* initiation or completion
- low visibility due to *smoke* that makes *evacuation* unsafe
- *incidents* that impede traffic on *evacuation* routes (e.g., motor vehicle *incidents*, bridge failures, downed power lines)

Areas of refuge can be best integrated into *communities* by designating existing *community* facilities. Or *wildfire mitigation* can be incorporated into the decision-making process to determine the location and size of new *community* facilities. The following *community* facilities can be used as areas of refuge:

- schools and school fields
- sports fields and facilities
- *community* centres
- golf courses
- parking lots
- urban parks

Consider the following factors when designating or planning a facility to ensure it will be a safe and effective area of refuge for the expected number and *demographic* of occupants:

- appropriate identification and accessibility
- appropriate size and location to prevent *exposure* to detrimental radiant or convective heat under predicted *wildfire emergency* conditions
- appropriate location, air conditioning, and filtration to prevent *exposure* to detrimental *smoke* levels under predicted *wildfire emergency* conditions (opening of windows should be avoided)
- no *exposure* to other *hazards* (e.g., power lines, dangerous chemicals, falling trees)
- control measures and space for physical distancing, where required
- location outside of flood zones

To evaluate the above factors, a *wildland fire* behaviour specialist and other safety specialists must be consulted for guidance regarding specific site conditions and anticipated impacts.

Box 5: The Importance of Road System Design

California Example
According to news reports, Paradise, CA had a street system designed to “maximize buildable space”, which led to many dead-end roads and few high capacity roads. The town’s *vulnerability* was highlighted during the 2008 Humboldt fire that burned 87 homes and caused residents to evacuate via congested roads. According to the *LA Times* article entitled, “Here’s how Paradise ignored warnings and became a deathtrap”, after the fire, “the Butte County grand jury warned that the town faced disastrous consequences if it did not address the capacity limits of its roads.”

Although a forest road was paved to provide additional routes into and out of the city, during the 2018 Camp fire, which destroyed 13,900 homes and claimed the lives of 86 people, this passage became very congested. The bodies of some of those that perished were found in burned out vehicles along *evacuation* routes. The *LA Times* article highlights the *evacuation* traffic issues, including the convergence of high population growth, dead-end streets, severe congestion, road capacity limits, lack of egress routes, and abandoned cars affecting egress capacity (https://www.latimes.com/local/california/la-me-camp-fire-deathtrap-20181230-story.html).

4.3 Community Resources

Planning for the use of *community resources* is also necessary during a *wildfire emergency*. This section provides guidance on planning for the use of utilities, public transportation, and firefighting *capabilities*.

4.3.1 Utilities

4.3.1.1 Power Supply

Electrical power is a significant concern in relation to most large *WUI fire disasters* as it is an ignition source for *wildfires*, a safety *hazard*, and an essential resource. Power transmission lines have been determined to be the cause of a number of *wildfires* across North America. Overhead transmission lines can be a *hazard* to firefighters spraying water, to low-flying aircraft used for fire suppression, and to heavy equipment used near the lines. In many cases, *combustible* and *noncombustible* poles supporting the power lines are burned or cannot support design loads when they reach a certain temperature. As a result, power lines fall or sag, creating a *hazard* to firefighters and the public at ground level [102],[103]. To prevent outages, regular inspection and maintenance programs should be implemented for underground utility services and above-ground support *structures* (e.g., utility poles) to ensure that the structural integrity of power lines and their support *structures* is maintained.

Electrical power transmission that is either interrupted by the failure of power line supports, or by heavy *smoke* that causes the lines to arc and short out, will cause power failure for *critical infrastructure*, such as water treatment plants, pumping stations, and hospitals. This, in turn, can interrupt water supplies for fire suppression and compromise human health and safety.

Rural and Indigenous *communities* are especially vulnerable.[31] They have concerns about power lines that run not only through their *communities*, but also through remote locations within traditional Indigenous territories. Due to these remote locations and the resulting difficulty in monitoring, the ability to respond in a timely manner is a concern when an ignition does occur.

Loss of power is also a major concern for *communities* because power is not only required for water and treatment plants, but also for homes and *community* facilities such as health centres. A resulting lack of water supply may impair automatic sprinkler systems, irrigation systems used for wet-down purposes, or other *building* systems, such as roof-top sprinklers used to prevent the ignition of roofs in *WUI* areas. Lengthy power outages not only affect general living conditions especially for rural and Indigenous *communities*, but also food storage, which is a greater *risk* since traditional Indigenous food is more difficult to replace.

Urban, rural, and Indigenous *communities* also have concerns about the safety *hazard* to fire suppression responders (e.g., firefighters) and *community* members due to downed power lines. During an *evacuation*, sometimes only one or two access or egress roads are available for a remote location (see Section 4.2.3). Some remote locations may not even have roads. If qualified and trained personnel cannot reach the location of downed power lines in a timely manner, untrained *community* members are left at *risk*.

See Table 15 for guidance on electrical power *risk mitigation* in the *WUI*.

Table 15: Guidance on Electrical Power Risk Mitigation

Resource	Guidance on Electrical Power Risk Mitigation
Underground Power Supply Lines	• The *AHJ* should consider installing underground power supply lines wherever possible. However, as compared to overhead power supply lines, underground power supply lines may result in increased costs and increased *risk* of potential damage from other *hazards* including flooding, earthquakes, excavation work, and corrosion, along with increased time to locate and repair.
Overhead Power Supply Lines (Power Line Right of Way)	• Power supply lines for essential services should be run underground wherever possible; if run overhead, they should be installed to avoid interruption by *WUI fires* and away from *structures*. • Maintain a minimum of 5 m distance between vegetation and power lines. • Assess for hazardous trees and remove any hazardous trees that are within a distance of 1.5 times the tree height of the power line. • Manage vegetation within the power line right of way to promote low flammability vegetation with discontinuous ground cover.

[31] Urban areas and non-Indigenous *communities* are also vulnerable, but perhaps to a lesser degree.

<table>
<tr><th>Resource</th><th>Guidance on Electrical Power Risk Mitigation</th></tr>
<tr><td></td><td>Involve Indigenous communities to ensure not only that invasive species are NOT introduced, but also that traditional food sources are not affected or contaminated by any weed control products used.
Remove all slash and heavy fuel buildup within the right of way.
Establish fuel breaks parallel to power line orientation.
Maintain clearance around all essential electrical power service structures that may be located within the right of way, including transformers, substations, etc.</td></tr>
<tr><td>Overhead Power Line Support Structures (Poles)</td><td>Whenever possible, install noncombustible or ignition-resistant support structures for power lines. If combustible support structures are used, the following are recommended:
a 1.5 m noncombustible surface under (if applicable) and extending horizontally outwards from the combustible support structures
noncombustible protection or ignition-resistant materials or coatings extending a minimum of 0.15 m vertically upwards from the base of the structure
vegetation management with consideration that invasive species/chemical applications affecting food supply are NOT introduced and to support a maximum low vigour surface fire, for a distance extending 10 m (refer to the Priority Zones described in Section 3.4) horizontally outwards from the furthest extent of the combustible support structure
vegetation management that extends an additional 20 m (refer to the Priority Zones described in Section 3.4) horizontally outwards from the furthest extent of the combustible support structure that ensures invasive species or chemical applications affecting the food supply are NOT introduced
regular inspection and maintenance of the support structure is encouraged and should include an assessment of the potential fire risks to the support structure and elimination of any problems identified, where possible (e.g., avoid cracks or gaps that are capable of trapping burning embers)</td></tr>
</table>

4.3.1.2 Water Supply for Firefighting

Manual firefighting in the *WUI* relies on the availability of a continuous water supply. Even under normal conditions, the water supply for fire suppression may be compromised. During a *wildfire emergency*, the available water supply may be difficult to access if individual hydrants and hose lines are exposed to fire. While most public hydrants are tested regularly by the *AHJ*, private hydrants and water supplies may not be. Aerial and ground attacks may be severely hampered by direct *exposure* to fire or obscuration by *smoke*.

During *wildfire emergencies*, the water supply may also be impacted for the following reasons:

- Many public and private water supplies rely on gravity and pumps to achieve adequate flow and pressure to the distribution system. For non-gravity systems, the interruption of electrical power may compromise water delivery unless either diesel fire pumps or back-up power supplies are used. Pumphouses may also be vulnerable to interruption by fire and should be adequately protected against *wildfires*.
- During a *wildfire emergency*, the volume and pressure of a municipal or private water supply for fire suppression can be significantly reduced. Increased demand on a *community*-wide scale draws on the system, and open flow occurs in multiple individual service lines where *structures* have been destroyed.
- A number of existing *structures* and infrastructure within some *communities* (e.g., rural, small, Indigenous) were not constructed to code or regulation. Many of these *communities* are not currently equipped with even minimal water supply systems. Significant infrastructure investment may be required or alternate strategies for mitigating *risk* may need to be developed for existing non-conforming water supplies in the *WUI*.
- *Community* water supply systems that rely on wells for potable water or for firefighting generally have reduced capacity. As such, they may require other supplementary sources of large volumes of water for firefighting. Some potable water treatment facilities have reasonable storage and retention, partly because they need to supply water for drinking and other household uses during power outages. Many systems have back-up power to be able to supply in these situations.

Table 16 provides guidance regarding the water supply in preparation for wildfire emergencies.

Table 16: Water Supply Guidance

Water Supply Subject	Guidance
Water Supply Mitigation	• An acceptable water source should have an adequate volume and flow of water for manual fire suppression to protect *structures* from exterior or interior fires within the *WUI* area. • For *structures* not located in an area with a local municipal water supply system, the water source, either man-made or natural, should be located not more than 305 m (1 000 ft.) from the *building* and be acceptable to the *AHJ*. • Private water supplies may be gravity-fed or equipped with pumps to achieve the minimum acceptable pressure for firefighting equipment.
Man-made Water Sources(1)	• Man-made water sources for manual firefighting or automatic sprinklers should be equipped with an acceptable hydrant or suction point and should meet the minimum usable water volume required by the *AHJ*.

Water Supply Subject	Guidance
	- If feeding dry (non-freezing) hydrants, these water sources should provide the minimum suction pressure required by firefighting equipment. - If supplying automatic sprinklers, higher volumes, flows, and pressures are typically recommended. • The water level for firefighting or sprinkler systems may be maintained by the natural accumulation of groundwater (including seasonal high water) in wells, reservoirs, streams, or rivers if accessible for suction or, if necessary, by tender shuttles. - Suction supplies should have a maximum lift of 4.6 m. - Specific guidance for water supply needs in areas not served by public or private water supply infrastructure can be found in NFPA 13 [104], NFPA 1141 [63] and NFPA 1142 [12].
Natural Water Sources	• Natural water sources, including lakes, may be used as a suction supply for aerial firefighting operations. • Natural water sources may be used as a suction supply for firefighting equipment through rights of way and other points. • Natural water sources, including lakes and rivers, may be used as a suction supply for fire pumps that are designed in accordance with NFPA 20 [105] and Fisheries and Oceans Canada requirements.(2) • Natural water sources should have a minimum annual water level or flow that meets the water supply needs in an *emergency* as determined by the *AHJ*. • Natural water sources used as a suction supply for manual firefighting should be accessible, even during periods of freezing, by a draft site that is *approved* by the *AHJ*. Water flow accessibility and water source access rights, including those granted by fishery authorities and other agencies, should be ensured in a form acceptable to the *AHJ*. • For areas not served by public fire protection or private water supplies for firefighting, specific guidance on water flow for manual firefighting can be found in NFPA 1142 [12]. Guidance on systems supplying automatic sprinkler and other water-based fire suppression systems can be found in NFPA 13 [104] and other pertinent standards.
Draft Sites	• *Approved* draft sites may be provided at natural water sources intended for use as fire protection where no public or private water supply infrastructure is provided. • The design, construction, location, access, and maintenance of draft sites should be *approved* by the *AHJ*.

Water Supply Subject	Guidance
	• Specific guidance regarding design, construction, location, access, and maintenance requirements can be found in NFPA 1142 [12]. • Approval from Indigenous *communities* must be considered prior to accessing potential draft sites within their *communities* and traditional territories.
Access	• The draft site should allow *emergency* vehicle access from an access route in accordance with Section 4.2.3.
Firefighting Equipment Access Point(s)	• The firefighting equipment (or fire apparatus) access point should be either an *emergency* vehicle access area alongside a conforming access route or an *approved driveway* that is maximum 45 720 mm (150 ft.) long. • Firefighting equipment access points should be designed and constructed in accordance with all codes and by-laws enforced by the *AHJ*. The firefighting equipment access points should not obstruct any roads or *driveways*. • Access points on public rights of way should be maintained by the landowner (typically, the provincial, territorial, or federal ministry of transportation).
Hydrants	• Hydrants should be designed and constructed in accordance with nationally recognized standards and should be compatible with the firefighting equipment of the responding agencies. • The location and access of hydrants and suction points should be *approved* by the *AHJ*.

Adequate Water Supply	• For areas with public or private water supply infrastructure, the appropriate fire flows may be determined in accordance with the Water Supply for Public Fire Protection published by Fire Underwriters Survey (FUS) [106], NFPA 1142 [12] or another guideline for fire flow determination.
	• Adequate water supply should be determined for initial attack and flame front control in accordance with the International Wildland-Urban Interface Code [1] or NFPA 1142 [12], as follows:
	    • For one- and two-family dwellings:
	        o having a fire flow calculation area of not more than 334 m^2 (3,600 $ft.^2$), the required water supply should be 63.1 L/s (1 000 gal./min) for at least 30 min.
	        o having a fire flow calculation area of more than 334 m^2 (3,600 $ft.^2$), the required water supply should be 95 L/s (1 500 gal./min) for at least 30 min.
	    • For buildings other than one- and two-family dwellings, the required water supply should be as *approved* by the AHJ, but should be at least 95 L/s (1 500 gal./min) for 2 h.

Water Supply Subject	Guidance
Fire Department	• The required water supply and infrastructure stated above should only be used where a suitably trained and equipped *fire department* is available that is rated Class 9 or better in accordance with FUS Public Fire Protection Classification [107] or the Public Protection Classification in the ISO Fire Suppression Rating Schedule [108]. • Across Canada, the standard of *response* is highly variable and many areas have no effective level of service. Also, as stated in Note A-3 of the NBC, there is an "assumption that firefighting capabilities are available in the event of a fire *emergency*". These firefighting capabilities may take the form of a paid or volunteer public *fire department* or, in some cases, a private fire brigade. If effective firefighting capabilities are not available locally, additional fire safety measures should be required [2]. (See also Section 4.3.3.)
Obstructions	• Access to public, private, and other water sources should be unobstructed at all times. • The *AHJ* should not be deterred or hindered from gaining immediate access to water source equipment, fire protection equipment, essential valves, or hydrants.
Identification	• Water sources, public or private water supply facilities, draft sites, hydrants, and other fire protection equipment should be clearly identified to show their location as acceptable to the *AHJ* to facilitate maintenance and to prevent their obstruction by unauthorized development, vehicles (e.g., cars, trailers) and other physical obstacles.
Testing and Maintenance	• Public and private water supplies, draft sites, hydrants, and other fire protection equipment should be tested periodically as required by the *AHJ* or, where appropriate, the owner. • Such equipment, once installed, should be maintained in accordance with the relevant standards, where available, including NFPA 20 [105] and NFPA 24 [109]. • Equipment should be operative at all times and should be repaired or replaced where defective. • Additions, repairs, alterations, and servicing of such fire protection equipment and *resources* should be carried out in accordance with accepted standards.
Structure Ignition Zone Mitigation	• The *Structure Ignition Zone* around water tank *structures*, water supply pumps, and pump houses should be mitigated using the guidance in Chapter 3.
Standby or Back-up Power	• Standby or back-up power should be provided for pumps, controllers, and other related electrical equipment so that

Water Supply Subject	Guidance
	stationary water supply facilities within the *WUI* area that are dependent on electrical power can provide the required water supply during an *emergency*. In certain cases, single diesel-driven pumps and/or portable generators may be used if acceptable to the *AHJ*.

Notes to Table 16:
(1) "Man-made water sources" refers to artificial water sources.
(2) https://www.dfo-mpo.gc.ca/pnw-ppe/codes/screen-ecran-eng.html

4.3.2 Public Transportation during Emergencies[32]

4.3.2.1 Buses and Other Land Transportation

Where an insufficient number of personal vehicles are available within the *community*, an increase in the reliance on public transportation vehicles (e.g., bus, train) will occur. This reliance requires coordination between local authorities and transportation companies as part of *emergency* planning. The reallocation and use of public transportation vehicles (primarily buses) may be required to evacuate individuals, assuming that routine service is insufficient or unavailable. The modification of vehicles may also be required to accommodate *emergency* transit. For instance, in some jurisdictions, a strategy exists where public transportation buses can be quickly retrofit to accommodate stretchers for use in mass-casualty or mass non-ambulatory patient transportation (i.e., evacuating health care facilities).

The use of public transportation systems during an *emergency* also requires *communications* to ensure passenger safety. Quick *notification* of *hazard* areas (in this case, *wildfire* location) is required so the public transportation system can be diverted or halted if necessary. This *communication* would typically be based on the current and expected fire behaviour and spread direction (which would also guide *evacuations*). This topic may be outside the scope of *wildfire*-specific planning and within the scope of the larger *emergency management plan* that most municipalities are required to have.

4.3.2.2 Public Watercraft

For shore *communities* that rely heavily on watercraft for access, the coordination of public and private water vessels should be incorporated into local *emergency* planning for *evacuation preparedness*. Vessel size, *capabilities*, passenger-carrying capacity, passenger accessibility, operator qualifications, Transport Canada requirements, shore access requirements, marine conditions, and distance to *evacuation* reception centres should all be considered when

[32] For more information about *evacuations* during *emergencies*, see Chapter 5.

planning for *evacuations* by watercraft. In areas with regular passenger ferry or water taxi service, these services should be engaged and evaluated for use during *evacuations* similar to public transportation.

4.3.3 Firefighting Capabilities

4.3.3.1 Firefighting Resources

Most *wildfire emergencies* can be successfully managed with the typical fire *resources* available to a *community* if adequate pre-attack planning (for expected *incidents*) has been implemented. However, planning should also account for the small percentage of fires that will quickly exceed the *capabilities* of locally available *resources* and require immediate additional *resources*. *WUI fire response* is extremely complex and requires specialized training and equipment. Requirements related to *WUI fire response* can also change over time due to *community* growth and land-use changes. The amount of administration, *capabilities*, and firefighting *resources* needed in a *community* depends on the amount of high-value *resources* being protected and the potential fire conditions to which the *community* is exposed. Specific details of fire *response* planning are beyond the scope of this Guide and are determined by provincial or territorial and local authorities.

Given the complexity of *wildfire emergencies* and the challenges related to *response* and *resource management*, firefighting personnel should be trained to at least Incident Command System I-100 level [110].

4.3.3.2 Firefighting Response Plan

The impact of land-use change on fire protection services should be assessed; consider the possibility of addressing a likely increase in the volume of calls with the current number of firefighters, firefighting equipment, and fire stations in their current location. Also consider the possibility of introducing special services.

Mitigation measures should be determined if the assessment results are negative.

Safety requirements for firefighters (regarding protection, equipment, etc.) are regulated mainly by provincial or territorial legislation; national *wildland fire* safety guidance (Canadian Interagency Forest Fire Centre [111]); and NFPA standards (NFPA 1451, “Standard for a Fire and Emergency Service Vehicle Operations Training Program” [112]; NFPA 1500, “Standard on Fire Department Occupational Safety, Health, and Wellness Program” [11]; NFPA 1521, “Standard for Fire Department Safety Officer Professional Qualifications” [113]; NFPA 1582, “Standard on Fire Department Safety Officer Professional Qualifications Comprehensive Occupational Medical Program for Fire Departments” [114]; and NFPA 1977, “Standard on Protective Clothing and Equipment for Wildland Fire Fighting” [115]). Firefighters should be appropriately trained and qualified to fight *wildfires* (NFPA 1051, “Standard for Wildland Firefighting Personnel Professional Qualifications” [14]).

Wildfire and WUI Fire Pre-Attack Plan. The *pre-attack plan* is a comprehensive compilation of essential *wildfire* management information (location of water sources, cultural *resources*, and sensitive environmental sites, etc.) needed to add efficiency to fire suppression operations. This plan must be reviewed and, if necessary, revised prior to every *fire season*. Appendix L provides a *pre-attack plan* checklist.

Box 6: Wildfire Firefighting Response Plans

Alberta Example
Alberta is currently the only province in Canada that provides a standardized firefighting *response* plan template for *communities* in the form of a "Wildfire Preparedness Guide" (WPG). The document is intended to increase the *situational awareness* of *emergency* personnel to a *wildfire emergency*. A WPG has two components: the operational map, which depicts important spatial information overlaid onto a *community* map; and an information sheet, which contains information relating to *emergency* contacts, *communications*, *values-at-risk*, *evacuation* protocol, and functional roles. The WPG may also be the foundation of the Incident Action Plan; the WPG has value throughout the duration of an *incident*. For guidance on developing a WPG, see the Alberta government website (https://open.alberta.ca/publications/9781460146095).

British Columbia Example
In British Columbia, the District of Logan Lake and City of Kamloops offer examples of locally developed *response* plans. See their respective websites for further information (http://www.loganlake.ca/files/documents/188/logan-lakecwppfinal-reportjuly-3-2014.pdf; https://www.kamloops.ca/sites/default/files/docs/city_of_kamloops_cwpp_july_20_2016_final.pdf).

WUI Fire Preparedness Condition Levels. Pre-attack planning is most commonly guided by *preparedness* condition levels, which are closely tied to the daily *wildfire* danger rating levels determined by provincial or territorial agencies using the CFFDRS [75].[33] Appendix L provides a sample table of *WUI fire preparedness* condition levels. Local jurisdictions should consult their provincial or territorial counterparts to address the items outlined in Appendix L.

4.3.3.3 Authorized Firefighter Interventions

Generally, firefighters are authorized by provincial or territorial Fire Services Acts to enter private property and initiate life-saving or property-protection actions. These actions may include removing trees or fences and evacuating non-defendable *buildings*. The provincial or territorial Fire Service Acts should be consulted for specific requirements (see Appendix L).

Many provinces and territories have legislation in place that provides certain rights of entry onto lands or property without warrant by the *fire department* or *AHJ*. For the purpose of firefighting or providing rescue or *emergency* services, these rights may also pertain to entry on adjacent lands where a *wildfire* or *emergency* has occurred or is occurring. These rights of entry also apply for the purpose of removing or reducing a serious threat to the health and safety of any persons or to the quality of the natural environment.

Entry may be permitted where a fire has occurred or is likely to occur and where reasonable grounds exist to believe that a *risk* of fire poses an immediate threat to life.

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[33] https://cwfis.cfs.nrcan.gc.ca/background/summary/fdr

For the purposes of removing or reducing the threat of a *wildfire*, the following may be undertaken by the *AHJ*:

- removal of persons from the land or premises[34]
- posting of a *wildfire* watch
- removal of combustibles or things that may constitute a *wildfire* menace
- elimination of ignition sources
- installation of temporary safeguards
- performance of minor repairs to existing fire safety systems
- pulling down or removal of *buildings*, *structures*, or things on or attached to the lands or premises or on adjacent lands or premises where removal is necessary to prevent the spread of *wildfire*
- completion of any other action where reasonable grounds exist to believe that urgency is required to remove or reduce the threat to life

There may also be provisions that permit the entry onto lands outside a municipal boundary where, for the purposes of firefighting or providing rescue or *emergency* services, the *wildfire* threatens persons, property, or the environment within that jurisdiction and there is no other *fire department* or other *emergency response capability* for the area in which the lands or premises are situated.

Homeowners and landholders should gain awareness of the provisions in place in their respective province or territory.

[34] Applies only to some, not all, jurisdictions.

Chapter 5 Emergency Planning and Outreach

5.1 General

This Chapter provides guidance for *communities* on *emergency* planning, both for *evacuation* and *communications* during *wildfire emergencies*, and on public outreach and education to mitigate against and prevent future *wildfire emergencies*.

The primary objective of this Chapter is therefore to limit the probability that a person in or adjacent to the *building* will be exposed to an unacceptable *risk* of injury, refer to the objectives and *building* functions described in Section 1.3.2.

The guidance provided in this Chapter should be of interest to *communities* that are exposed to some threat of *wildfires*. Chapter 2 of this Guide should be consulted to assess the Hazard Level of a particular *community*. If the *community* is exposed to a Hazard Level greater than 1 (Nil–Very Low), the guidance provided in this Chapter should be considered.

An approach to life safety assessment is outlined in Chapter 1 (see Figure 4). The factors addressed are derived from the NFPA standards listed in Appendix B. Chapter 4 facilitates the identification of the current vulnerabilities of the *community* given *community* planning and *resources*. This Chapter outlines the means by which *emergency* planning may mitigate this *vulnerability*. Appendix C facilitates the identification of life safety vulnerabilities in the *community*, which may be addressed by adopting the provisions outlined in this Chapter.

5.2 Community Emergency Planning

At-*risk* jurisdictions are strongly encouraged to also plan for *wildfire emergencies* in their *emergency response* plans (ERPs), which may be facilitated by the guidance in this section. This section consolidates guidance from different subject domains and national standards (e.g., (Canadian) CSA Z1600, "Emergency and Continuity Management Program" [13]; (American) NFPA 1616, "Standard on Mass Evacuation, Sheltering, and Re-entry Programs" [66], and NFPA 1600, "Standard on Continuity, Emergency Management, and Crisis Management" [15]).

This Chapter does not provide requirements, but instead provides a set of considerations for *wildfire emergency preparedness* based on best practice and understanding. Sections 5.2.1 and 5.2.2 aid *evacuation* planning and the development of *emergency communication* strategies during *wildfire emergencies*. Legislation pertaining to municipal *emergency response* varies by province or territory. When developing *emergency* plans specific to *wildfire emergencies*, first consider local requirements.

5.2.1 WUI Evacuation Planning

The following questions in this section are adapted from NFPA 1616 [66] and CSA Z1600 [13]. These questions can serve as a checklist during *evacuation* planning for *wildfire emergencies*. (See also Appendix J.)

Evacuation planning should consider where those who live and work in the *community* will go, how contact will be maintained among family members, how the most vulnerable will be protected, and how culture and tradition will be maintained throughout the *evacuation* process. Also, extra measures should be taken when planning for and conducting an *evacuation* due to *wildfire* during a pandemic or other concurrent *hazard* [116]. Please refer to national, provincial or territorial, and local *resources* for additional information.

5.2.1.1 Evacuation Planning before a WUI Fire

Which areas should be prioritized for *evacuation* (as determined by a variety of factors, such as the identification of at-*risk* populations, the number of those currently at *risk*, and the type of assistance those at *risk* require for *evacuation*)?

- Are additional *resources* required for *evacuation*?
- Is extended time for *evacuation* required?
- Who has the authority to *trigger evacuation* and what method of *communication* will be used (see Section 5.2.2; this information is not always obvious, nor communicated to those directly involved)?

What is the expected lead time needed to evacuate areas on the basis of the needs of the population, the personnel and technological *resources* available, and current and *forecasted wildfire* behaviour?[35]

- According to the Government of Alberta's Community Evacuation Guidelines and Planning Considerations document, the following formula may be used to calculate a general *evacuation* timeline for localized zones or entire *communities* [117]:

  Time taken to notify *community* (drafting, dissemination, confirmation) (min) +
  time taken to mobilize *community* (preparation, vulnerable populations, etc.) (min) +
  time taken to physically conduct the *evacuation* (phased *evacuations*, multiple routes, etc.)
  (min) + 120 min = *trigger* point for *evacuation* (min)

- According to Taylor and Alexander [74], a spatial *trigger* point is the critical distance from a fire crew to a fire that would *trigger* tactical withdrawal. The same approach could be used

[35] The formulas provided should be used by experts or the *AHJ*.

to define the critical distance from a populated area to a fire that would *trigger* an *evacuation* of that affected area, as shown below:

Critical distance (m) = rate of spread of the fire (m/min) × [escape time (min) + safety margin (min)]

Note: the Escape time in this equation should encompass the times listed in the Government of Alberta's Community Evacuation Guidelines and Planning Considerations document [117], including the time to notify residents, the time to mobilize residents, and the time to physically conduct the *evacuation*.

The time to physically conduct the *evacuation* includes the time to evacuate the *building*, the time to move on foot (to safety or to a transportation mode), and the time to move via transportation mode to safety (if applicable). The time to evacuate the *building* can be significant in some cases (e.g., large *buildings*). The current NFC contains detailed provisions on *evacuation* from *buildings* and special *evacuation* requirements for certain classes of *buildings* (e.g., prisons and hospitals) [62].

- Furthermore, decision-makers could also define a temporal *trigger* point, which would be the time of day when a fire is expected to reach a critical distance or point on the landscape, as shown below:

Projected *trigger* time of day (h) = current time (h) + distance to fire front (km) / rate of spread (km/h) – *evacuation* time (h) + margin of safety (h)

Box 7: Example of a Temporal Trigger Point

Suppose it was 10:00 am, and a *wildfire* is 5 km away and expected to spread at 20 m/min or 1.2 km/h. The wildfire would be expected to arrive in 4.17 h (250 min or at 2:10 pm). If the *evacuation* time + safety margin were 3 h (180 min), then *evacuation* for the affected *community* should be *triggered* no later than 11:10 am.

Since the prediction of fire spread is not an exact science and *evacuation* data from *wildfire emergencies* are lacking, decision-makers should estimate required times conservatively.

The *evacuation* time (or escape time) for a *community* is determined by multiple factors; all should be taken into account when estimating *evacuation* (or escape) time. All assumptions made about human behaviour should be documented. The factors include the following:

- which households (i.e., residents of a house) evacuate and which do not
- when households leave their homes (and enter the traffic network)
- what destinations or locations are chosen as places of safety
- what routes households take to reach these destinations (the shortest or quickest routes are not always chosen by *evacuees*, and re-routing en route can occur; see Section 4.2.3.2)

- what modes of transportation are used by households for *evacuation* (households may choose to evacuate with multiple vehicles and make also tow trailers, decreasing expected *vehicle capacity* on the road network; see Section 4.3.2)
- what type of behaviour drivers are expected to demonstrate (this factor includes speed, flow of vehicles, and re-routing, especially under *emergency* conditions). How does the behaviour of drivers change where routes are blocked by *wildfire*, traffic congestion, or environmental conditions cause decreased visibility on the roads?

What *resources* are available to assist the *evacuation* of an area where required? Have those involved been made aware of their roles in a *wildfire emergency*?

- What alternative *resources* are available should the primary *resources* be unavailable or depleted?
- How does a potential lack of *resources* affect planning timelines?
- Does the *evacuation* strategy include information on who will provide security, how, and when security will be provided for the evacuated area?
- Does the *evacuation* strategy accommodate remote *communities* that may only be accessed using airplanes or boats?
- Do hospitals and other health care facilities for residents have *emergency response* plans in place that include both shelter in place and *evacuation* provisions?
- Are *resources* available for those without a means of transportation, including for individuals with access and functional needs (who may require additional assistance with *evacuation*)?
- What support is available for *evacuees* along *evacuation* routes, such as sources of fuel, tow trucks, and rest stops?
- Have the transportation officials been identified who will ensure effective *traffic management* occurs during *evacuations*, given the anticipated number of vehicles, egress routes, and contra-flow[36] lanes?
- What *resources* are provided for *emergency responders* (both fire and medical) along *evacuation* routes to address fires, motor vehicle collisions, and medical issues?
- What continuity plans are in place for *emergency* personnel and their families (e.g., mutual or automatic aid agreements with nearby *communities* to share *emergency* personnel)?
- Are provisions in place for mass transportation[37] officials (who will operate mass transportation assets during *evacuation*), including provisions for their family members, and potentially using mutual aid agreements with nearby *communities*?

[36] "Contra-flow" refers to a temporary traffic operation strategy in which flow in an opposing direction of travel is reversed to serve flow in the other direction. It may include some or all lanes of a roadway and is controlled using a variety of restrictions, depending on the speed and access conditions of the roadway.
[37] "Mass transportation" refers to any kind of transportation system in which large numbers of people are carried.

5.2.1.2 Considerations for Evacuation during a Wildfire Emergency

What seasonal and environmental conditions should be considered?

What is the *forecasted* weather and what predicted impact will the weather have on fire behaviour for the next one to three operational periods[38]?

What is the current and predicted:

- rate of fire spread?
- intensity of the *wildfire*?
- proximity of the *wildfire* to human life?
- impact on essential functions to life safety (e.g., egress routes)?

What cultural and religious practices should be considered?

What is the *risk* of cascading effects and secondary *disasters* over time?

Can transportation systems and routes deliver life-sustaining materials to the affected area, if necessary?

What success have previous or ongoing fire suppression efforts had? What is the likely success of future fire suppression efforts given predicted fire behaviour?

5.2.1.3 Shelter in Place

Evacuation is the preferred way to reduce *risk* of death and injury from *wildfire emergencies*. However, in some circumstances, dedicated personnel (e.g., essential services) may be required to remain in an area under *evacuation order*. In extreme circumstances where no *evacuation* options are available, individuals may need to shelter in place. This latter option may be particularly relevant for many Indigenous *communities* in Canada.

5.2.1.4 Emergency Response Plan and Evacuation Plan Recommendations

(See NFPA 1616, Section 5.1.2. [66])

Have the ERP and *evacuation plan* been made available to all involved (e.g., residents, government and local authorities, *fire departments*)?

Have the ERP and *evacuation plan* documented the following:

[38] "Operation period" refers to the period of time scheduled for the execution of a given set of tactical actions, as specified in the Incident Action Plan. Operational periods can be of various lengths, although they are usually not more than 24 h.

- the assumptions made during the planning process (see NFPA 1616, Section 5.3 [66]) regarding the following:
  - human behaviour under imminent threat, according to findings from the field of social sciences
  - identification of the *wildfire hazard* and *risk assessment*
  - analysis of requirements and *resources*
  - number of people requiring assistance during the *wildfire emergency* (*evacuation*, public shelter, eventual *re-entry*, etc.)
  - whether animals will be evacuated, as appropriate (see also NFPA 150, “Fire and Life Safety in Animal Housing Facilities Code” [118]; and NFPA 1616, Annex H [66])
  - types of vehicles needed to transport people, including those with access and functional needs
  - number of *emergency responders* needed to complete the *evacuation* process
  - the presence of major industrial facilities (e.g., for chemical, oil, or gas production) that may present an additional fuel or explosion *risk*
- those responsible for specific actions in an *evacuation*, sheltering, and *re-entry*. What are the functional roles and responsibilities of internal and external agencies, organizations, departments, and positions, and what are the lines of authority for the following:
  - *trigger* points to execute the *evacuation plan*, where applicable
  - required logistics support and *resource management*
  - *disaster* cascade sequences before establishing *evacuation* routes and refuge areas
  - operational *communications*
- the public information to be provided, including warnings, *notification*, and *communications*. How will this information be disseminated?

5.2.2 Developing Emergency Communication Strategies

This section focuses on *emergency communication* strategies, i.e., ways to alert and warn the public during the imminent threat of *wildfire emergencies*. An alert is meant to grab people’s attention and can consist of a sound, tone and/or a short message. A warning is meant to convey information relating to the *incident* and the required public response.

This section may be helpful to any authority responsible for alerting or warning that is involved in developing strategies or messages for *emergency communication*. The following *stakeholders* are included: *emergency managers* and personnel, *emergency responders*, government agencies, the media, businesses, and others responsible for communicating with the public in the *response* phase of a *wildfire emergency*. The following guidance in the form of questions is adapted from NFPA 1616 [66], CSA Z1600 [13], and Appendix K of NFPA 1600 [15].

When developing the *emergency communications* strategy for *WUI fires*, consider the following important questions.

- What alerting and warning strategies will be used (public systems using conventional public media, social media, and websites)?
- What secondary or alternative strategies for *notification* will be available given a possible loss of power or channels (e.g., vehicular public address systems, door-to-door *notification*)?
- What information will be provided (e.g., about who should act, when they should act, and what actions must be taken)?
- What protocol will be used for clearing information for release?
- How will coordinated messages be developed and delivered (before, during, and after the event)?
- What *communication* strategies will be available that differentiate between groups that need to evacuate and those that do not (e.g., identifying consequences of unnecessary or unaffected area *evacuations* on the availability of *resources*)?
- Does the *communication* strategy address the need to inform animal owners of *evacuation* and public sheltering policies (e.g., taking animals when evacuating, where feasible; see examples in [119]–[122])?
- What *resources* will be available to assist with *evacuation notification* when required? How many will be available and for how long? If needed, how will these *resources* be obtained and assigned so that information is provided in a timely manner?
- Does the strategy address individuals who refuse to leave under mandatory *evacuation orders* (NFPA 1616, Table C.1 [66])?
- How will the *communication* promote understanding, respect, compassion, and clear lines of *communication* between the agencies and the public?
- What alerting and warning strategies are in place to communicate with special needs populations?
- How will the conventional public media, social media, and websites be used to provide detailed information after the *evacuation* has occurred (e.g., regarding status of homes, safety of residents, and *re-entry*, including when it is safe to return)?

Box 8: Alert and Warning Programs

California Example

In March 2019, the Governor's Office of Emergency Services in California issued the *State of California Alert & Warning Guidelines* [123]. These guidelines were issued in *response* to the 2017–2018 *wildfires*, which highlighted differences and inconsistencies among alerting and warning programs across California. This document provides guidance and expectations for jurisdictions and other designated alerting authorities implementing an alert and warning program in the state, focusing on the following:

- roles and responsibilities
- when and how to issue an alert or warning to the public
- methods and technologies
- alerting coordination
- training requirements
- system testing and exercise requirements

In addition, California passed a Bill [124] that authorizes each county, including a city and county, to enter into an agreement (e.g., with public utilities) to access contact information for residents to enroll the residents in a county-operated public *emergency* warning system [124]. This opt-out system would allow alerts and warnings to reach a larger population (since participation in opt-in systems has been low). This system uses push *communication*, such as landline or cell phone calls or mobile texts (http://calalerts.org/documents/2019-CA-Alert-Warning-Guidelines.pdf).

The following sections provide additional information and guidance on channels or modes of *communication*, message content, and message timing and frequency.

5.2.2.1 Channels of Communication

Alerts and warnings can be provided using various modes of *communication*. Where the public is under imminent threat from a *wildfire emergency*, the methods described in Table 17 should be considered.

Table 17: Channels of Communication

Channel	Communication Details
Emergency Alerting System (Alert Ready)	• designed to deliver alert and warning messages via Canadian radio and television, cable and satellite operators, and on compatible wireless devices connected to wireless networks • developed and operates in partnership with federal, provincial, and territorial *emergency management* officials, Environment and Climate Change Canada, Pelmorex, the broadcasting industry, and wireless service providers • messages disseminated through this system include a header, an alert tone (i.e., Canadian Alert Attention Signal), and the message text itself • no user sign-up required
Social Media	• increasingly being used to provide alerting and warning information before, during, and after *emergencies* • users must sign-up to receive messages • messages can include photos, videos, graphics, and text • during *evacuations*, warning information can include maps, instructions, site and shelter locations, and directions and routes

Channel	Communication Details
	• quick dissemination of information, two-way *communication capabilities*, correction of false information, inexpensive, and familiar • information filtering is required; the scope of information can be constrained (e.g., by character limits) • a local electricity supply may be required • information has a long duration
Automated Messaging (Phone, Email)	• allows third-parties to send out messages about the *wildfire* event (e.g., the need for *evacuation*) on behalf of local officials; users must sign up to receive these alerts or warnings prior to the *wildfire* event • can often provide summary and detailed reports of everyone contacted, including message delivery time, conformation of message receipt, and feedback from users receiving the message
Radio/TV Broadcasts	• can be used as an alerting or warning channel for people under imminent threat. Depending upon the *community*, local television and radio broadcasters can be trusted sources of news and information during *wildfire* events
Internet (Pop-ups, Routine Posts, Streaming Posts, or Blogs)	• can be used as a channel to disseminate *emergency* information during *wildfires*. Warning information is often posted directly onto the front page of the website, making it easier for the public to find; however, posted information requires constant updating as the fire conditions change
Door-to-Door Communication	• can be used to alert and warn individuals in affected areas of the need to evacuate • can be used by small *communities* that rely on phone trees for *emergency communication* • may not be practical for notifying many individuals or households because of the need for personnel (possibly reassigned to *notification* duties from firefighting or operational tasks) • can be a very effective strategy to elicit *evacuation* behaviour
Outdoor Siren Systems	• can consist of interconnected sirens designed to alert individuals located outdoors (or within hearing distance) of an approaching threat • some systems disseminate both sound alerts and voice *communication*, while others broadcast only sound alerts • if sound only, individuals should be trained on what this alert means and how to respond to it • to reach more individuals, some systems may also include strobe lights, especially to alert those unable to hear the siren • may be difficult to hear indoors and may not effectively wake individuals from sleep

Channel	Communication Details
Weather Radios	• can provide geographic coverage for target populations within the range of a specific weather radio transmitter • only a small percentage of the general public has receivers

Use multiple channels. The more channels, the better as long as the information provided via each of the channels is clear, accurate, and consistent. After receiving messages people are very likely to engage in milling behaviour, whereby they interact with others to better understand the event and the action to take. When others have received the same message, confirmation of the threat and *risk* is more likely to occur, which can lead to safer and more effective *evacuations*.

Both push and pull *communication* should be used to disseminate messages. Push *communication* has the *capability* to reach the public without requiring the audience to actively search for information. Pull *communication*, on the other hand, requires the public to be motivated and take action to search for the information.

The benefits and challenges associated with each *communication* channel must be assessed when planning the strategy. Consider the benefits of a strategy with the *capability* of reaching the public without requiring individuals to search for the information; these strategies are also known as push technology. The Alert Ready System, depending upon the *notification* options selected by users for social media and automated message systems, is an example of push technology. *Emergency communication* strategies that include push channels increase the likelihood of the public receiving the information disseminated in a *wildfire emergency*.

Also, attention should be given to the increased use of social media and the public's expectations to receive and provide information on social media platforms. Consider also the tendency of traditional media to monitor and retransmit information from social media. Monitoring social media can help organizations identify misinformation about an event and develop and maintain their own social media platforms. If misinformation is identified, *communication* systems (e.g., traditional and social media) can be used to provide accurate information (A6.2.5.2 in CSA Z1600 [13]).

5.2.2.2 Message Content

As mentioned earlier, an alert is meant to grab attention, and a warning is meant to convey information related to the *wildfire* and the required public response. Guidance, based on research in the field of social science, can be provided on the content of alerts and warnings to prompt the safer and more effective *evacuation* of those under imminent threat from *wildfire emergencies*.

To be effective, public alerts should differ from ambient sound, which should be reduced or removed during *notification* to decrease interference. Additionally, dynamic, flashing lights should be used to attract attention to visual warnings.

To be effective, warning messages should be clear, timely, consistent, and accurate. Regardless of the channel of *communication* used to deliver the message, an effective warning message should include the guidance in Table 18.

Table 18: Guidance on Message Content

Message Element	Guidance
Content Language	• Use short, simple words and simple sentences. • Avoid double negatives. • Emphasize main ideas, followed by conditions or exceptions. • Write the message for a Grade 6 reading level (Note: readability and grade level can be checked by programs such as Microsoft Word). • Use active voice and present tense. • Use the predominant language(s) of the affected area (i.e., a version of the message in each language).

Content Features	• State the source of the message for credibility.
	• The source should be a trusted authority (managers and *emergency* personnel should identify candidate sources prior to the *wildfire emergency*).
	• State:
	    ◦ *hazard* type (e.g., a *wildfire*) and its consequences
	    ◦ *hazard* location and who should evacuate
	    ◦ *hazard* timeline (i.e., when action should be taken)
	    ◦ protective actions to be taken (e.g., *evacuation* of a particular area or neighbourhood)

Content Order	• For messages under 360 characters, use the following content order: message source, protective actions, *hazard* type or consequences, *hazard* location, and *hazard* timeline. • For longer messages, use the following content order: message source, *hazard* type or consequences, *hazard* location, protective actions, and *hazard* timeline.

5.2.2.3 Other Message Considerations

Guidance can also be provided on message timing and frequency, based on research from the social sciences. Disseminate warning messages as early as practicable.

Expect to provide numerous alerting or warning messages, reflecting changing events. New messages should be accompanied with an explanation of changes. Include feedback where events did not occur as expected.

Remember that certain populations may have limited or no access to *notification*s about the *wildfire emergency* (see Appendix J). Examples of populations with potentially limited access to *hazard* information during *WUI fires* include the homeless, those without access to technology, those without access to push technology (e.g., outside the audible range of sirens, outside cell or internet network coverage), and tourists. Therefore, consider the *notification* strategies that best fit the population who will be receiving the alert or warning. Alerts and warnings should also be considered for marine locations.

5.3 Public Outreach and Education

Effective public outreach is the key to preventing or mitigating fire *risk* in the *WUI* and protecting the public should a *wildfire emergency* occur. These actions should be taken before the actual *emergency* and are differentiated from the *emergency* steps listed above. Public outreach also prompts *evacuation* or sheltering. Elected officials, *community* planners, developers, government, industry, and homeowners all play important roles. Ongoing public outreach and education are critical to ensure that all *community* members have the information they need to act and make informed decisions.

This section is adapted from various sources.[39] The purpose of this section is to provide guidance to individuals whose role is to communicate effectively about:

- *wildfire emergency prevention* and control
- *evacuation* and sheltering *response* plans
- *recovery* plans or post-fire *mitigation* planning

While this Guide does not cover *recovery* planning, the same principles of effective *communication*, training, and education apply.

5.3.1 Public Education

Successfully implementing any *mitigation*, *response*, or *recovery* strategy requires the understanding and support of the public. Public education can be the most challenging component of any *community emergency* plan. Many residents do not understand the *risks* associated with *wildfires* and may assume that *emergency* personnel will be able to protect the *community*.

[39] "FireSmart: Protecting your Community from Wildfire" (Chapter 6, Communications and Public Education) [10], "FireSmart Guidebook for Community Protection" (Chapter II.4.1, Community Engagement) [60], and "Communicator's Guide for Wildland Fire Management: Fire Education, Prevention and Mitigation Practices" [147].

A well-thought-out education program helps the public understand the *risks*, the proactive steps they can take to protect property, and the *wildfire emergency* procedures in place to protect lives and property.

5.3.2 Developing a Communication Plan

A *communication* plan is used to organize the strategies and initiatives that will comprise your public education program. The key elements of such a *communication* plan are listed in Table 19.

Table 19: Guidance on the Communication Plan

Plan Element	Guidance
Goals and Objectives	• Outline what your *communication* plan is trying to achieve. • Develop objectives that can be easily measured.
Communications Team	• Identify who is responsible for carrying out the initiatives outlined in the plan. • Include *community* representatives since they can lend credibility to the initiatives and will provide continuity for future planning. • Also include representatives from municipal and provincial or territorial governments, residents, *community* groups, industry, and Indigenous *communities*.
Target Audience	• Identify the intended recipient of the *communication*. • Include *community* residents, government representatives, Indigenous *communities*, journalists/news media, and non-governmental organizations.

Messages	• Identify what should be communicated to the target audience.
	• Be clear, compelling, and consistent.
	• Make messages actionable, where appropriate, so that they motivate the target audience to act in addition to educating.
	• Solicit participation from the target audience, where appropriate (staying informed, supporting efforts, or getting involved in activities).
	• Develop key messages as well as supporting points, where appropriate:
	    ◦ Key messages are umbrella or general statements that agencies and organizations are encouraged to incorporate into their *communication*, education, information, and *prevention* efforts.
	    ◦ Supporting points provide more detail about the key messages, enabling further explanation of certain concepts.
	• See Box 9 below.

Plan Element	Guidance
Channels of Message Distribution	• List the intended channels of message distribution, including: ◦ *community* workshops and presentations during meetings of resident associations and civic and social groups ◦ online, e.g., dedicated webpage, electronic newsletters, email *notifications*, and social media posts (see BC *wildfire* status website that allows users to estimate when they might need to evacuate and plan travel [101], and provides information on air quality [102]) ◦ dedicated print newsletters, pamphlets, brochures, fact sheets or inserts (distributed at local libraries and other municipal information centres, at *community* events and meetings, and via mail or door-to-door drop-off) ◦ informational posters displayed in public places (e.g., trailheads) ◦ open houses at *fire departments*, municipal offices, or other appropriate locations where the audience can go for information and ask questions ◦ articles or news briefs in *community* print and online publications (magazines, newspapers, newsletters, church bulletins, websites) ◦ inserts mailed with bills and correspondence from utilities, insurance, real estate, and other home-related industries ◦ radio or television advertisements or public service announcements ◦ in-person visits to neighbourhoods and homes ◦ social media (identify members of the *community* who can help spread the message on social media (i.e., influencers) to their followers and social groups) (Note: social media can provide an efficient way to share information with the public. Popular social media platforms include Facebook, Twitter, Snapchat, YouTube, Instagram, and Nextdoor. While social media can provide opportunities for public outreach and education on *wildfires*, this media presents challenges, including outreach to those in rural *communities* or without internet access.)
Plan Timeline	• Identify when various components of the *communication* plan will occur.
Budget	• Outline the total budget of the education program and how the money will be allocated to the various initiatives within the *communication* plan.

Box 9: Reference for Educational Messages

NFPA Example
The NFPA's "Educational Messages Desk Reference," Chapter 17 – Wildfires, contains messaging on *prevention*, protecting homes from *wildfires*, and *community*-wide *wildfire* safety, including *evacuation*. This document provides consistent messaging and is used by *fire departments*, Offices of the Fire Marshal, Offices of the Fire Commissioner, and other groups and agencies across North America. The messaging was developed by the Educational Messaging Advisory Committee, which included members of the NFPA's *wildfire* division [125] (https://www.nfpa.org/Public-Education/Resources/Educational-messaging).

Overall, strive to understand the *capabilities* of your *community* and use the channels of distribution that ensure the message has the best possibility of being understood by all individuals within the *community*, regardless of level of ability.

Another important consideration is the spokesperson or source of the information disseminated via the channels of distribution described above. Public education should be delivered by people and organizations that are trusted by the audience receiving the information. For some *communities*, credible sources may include *fire chiefs* and other *fire department* personnel, *emergency managers*, and city officials. Credible sources may also exist outside the government, including local media; *community* service organizations; and religious, cultural, and other groups.

Box 10: Additional NFPA Publications

NFPA has examples of public education messages and fact sheets, included in Chapter 17 of the "Educational Messages Desk Reference" and also found online, e.g., a safety tips sheet (https://www.nfpa.org/-/media/Images/Public-Education/By-topic/Outdoors/7-Firewise-Tips-(1).pdf).

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Appendix A The WUI Fire Disaster Sequence

The “WUI fire disaster sequence” is the chain of events that occurs where fire spreads from wildland fuels to structures and sometimes from structure to structure [42]. The course of events and potential outcomes of a WUI fire disaster are illustrated in Figure 14 below. The objective of this Guide is to provide guidance to break the disaster sequence from the point of primary structure ignition, but this Guide does not explicitly address structure-to-structure fire spread or ignition.

Wildland fires in Canada can burn a variety of wildland fuel types, including forests, shrublands, grasslands, and slash from land clearing or logging [70]. In forests, fires typically begin and spread as surface fires in needle and leaf litter and forest floor organic matter, with spread rates less than 0.3 km/h and moderate fire intensities and flame heights [70]. Such fires are usually controllable by firefighting resources. However, if the surface fire intensity increases and generates enough heat to ignite canopy fuels, fires in closed coniferous forests can spread to and across the tree crowns. In general, spread rates of 6.0 km/h have been observed in crown fires in coniferous forests in Canada, with flame heights reaching more than twice the tree height and with extreme fire intensities. It is often not possible to contain high-intensity crown fires with direct firefighting methods.

In deciduous forests, on the other hand, surface fires occur in spring after snowmelt, but spread more slowly after green-up and do not often support crown fires. In open vegetation (grassland or shrubland) or slash, fires spread in surface fuels and vegetation only, but rates of spread can reach 12 km/h and flame heights can reach 10 m or more in extreme conditions.

Wildland fires spread with a more or less continuous flame front. They spread in the direction the wind is blowing by preheating vegetative fuels ahead of the fire through radiation and convection, and by lofting embers ahead of the fire, starting pilot ignitions. The density of flying embers (”ember rain”) declines with ember transport distance from the flame front; dense spotting occurs at distances of 10–30 m, lower-density spotting at distances of 100–300 m, and rare long-range spotting at distances of 1–30 km.

Fires spread from wildland fuels to communities and built structures following the same process.

If unbroken organic fuels are present between the wildland and a structure, fire can spread and ignite structures through direct flame contact. While radiant and convective heat from wildfires is intense, the flame residence time is usually less than one minute, and heat flux declines with distance from the flame front. However, if a high-intensity crown fire spreads to within about 30 m of a house, the fire may ignite siding or landscaping through radiant and convective heating.

However, the main form of structure ignition is from burning embers landing and starting pilot ignitions in needles or debris in gutters or on roofs or decks, inside vents, or in adjacent structures or items (e.g., fences, sheds, woodpiles, landscaping, vehicles). The fire can then spread to houses.

Houses and other structures are significant fuel sources. If structures are ignited and firefighting resources are unavailable, fires can spread from structure to structure in suburban and urban settings.

If firefighting resources are available and can be deployed safely, structures that have been ignited or are threatened by wildfire can often be saved. However, wildfires that ignite structures are often very intense and may be very large. In these circumstances, firefighters may not be able to remain and work safely near structures or houses, or firefighting capacity may be overwhelmed if more than a few structures are ignited.

Communities may require evacuation when a wildfire may possibly reach a settled area. Some evacuation factors, events, and outcomes are illustrated in Figure 15 below. (See also Section 5.2.1.1.)

It is apparent that the simplified process of this Guide (as shown in Figure 4 in Chapter 1) addresses a subset of the disaster sequence shown in Figure 14 and Figure 15. The process shown in Figure 4 addresses fewer factors and involves fewer decisions. It is important that factors from key domains (e.g. construction, hazard, population) are represented in this process. Each domain has an influence over vulnerability (which is not dominated by one domain, such as construction). Although addressing a subset of the disaster sequence, this process enables the user to comprehensively assess the vulnerability of their community. In particular, the process provides a consistent and representative approach to life safety vulnerability assessment (Appendix C) that is derived from authoritative sources (e.g., NFPA 1730 [67]; see Appendix B).

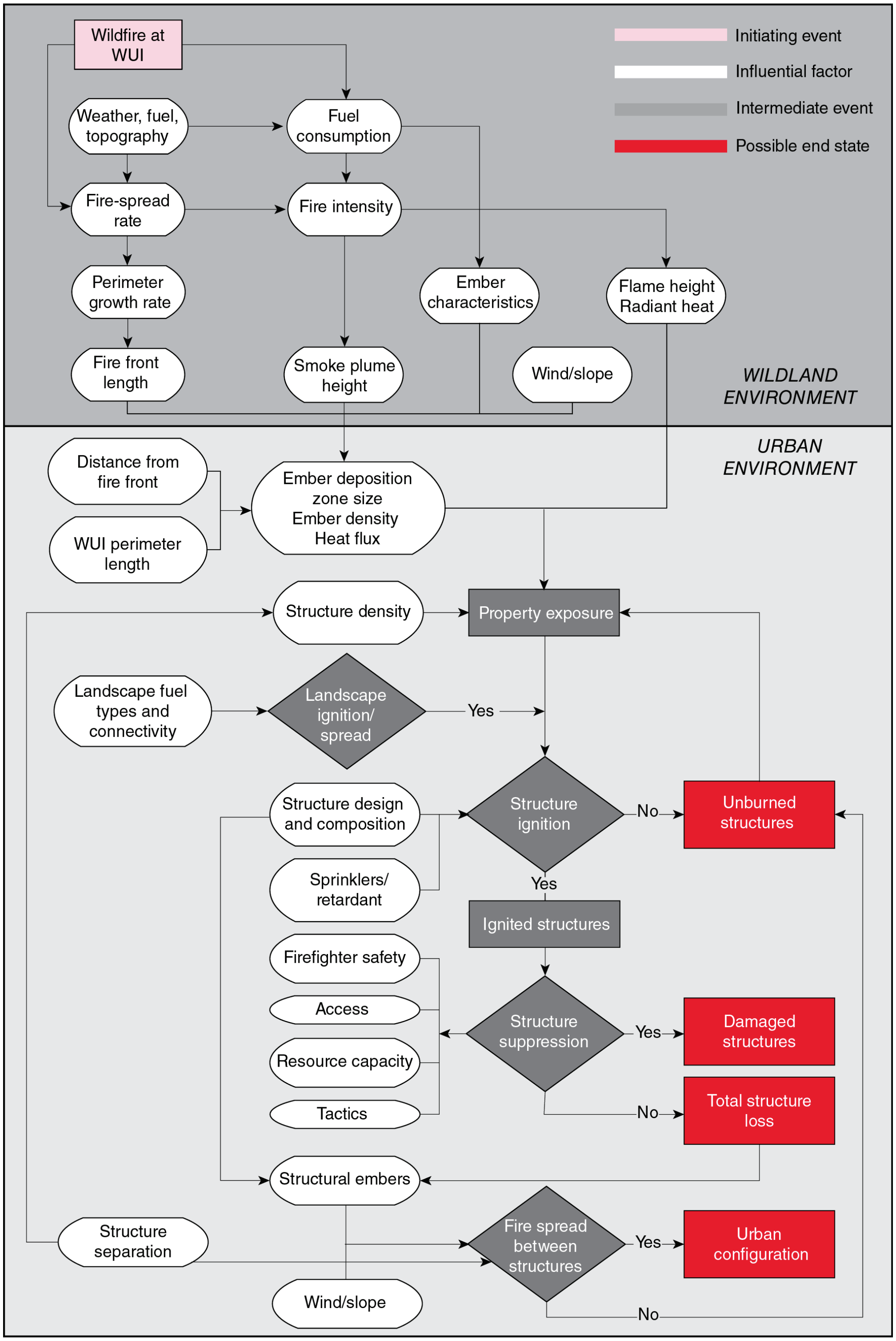

Figure 14. Some of the factors, events, and beginning and end states in the progression of a WUI fire scenario with exposed structures.

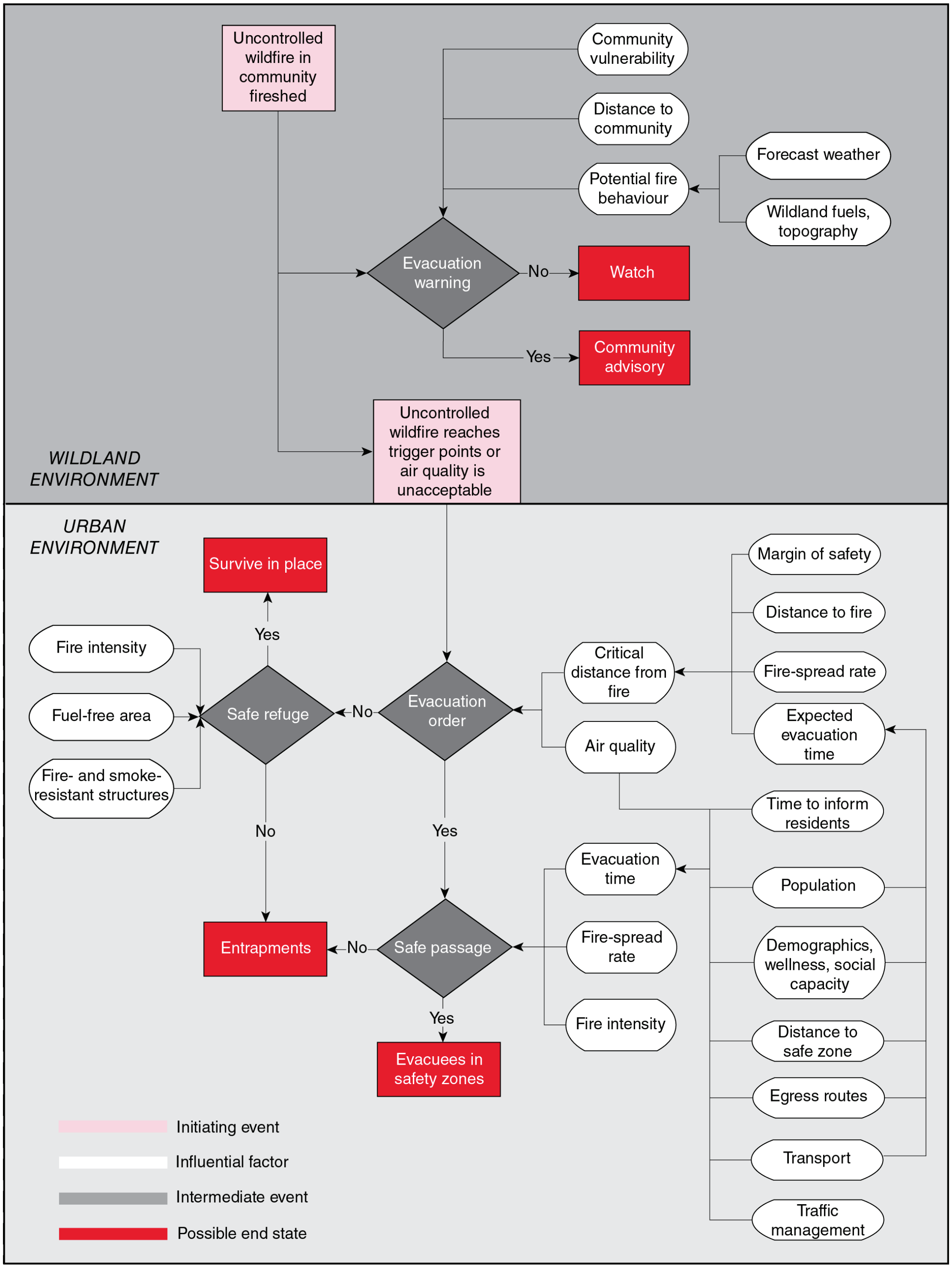

Figure 15. Some of the factors, decisions, events, and beginning and end states in the progression of a WUI fire evacuation scenario. (Note: although not shown in the figure, the capacity of fire management resources to respond to uncontrolled wildfires that spread into the WUI is also a factor in evacuation decisions.)

Appendix B Community Risk Assessment Factors

The NFPA produces several documents that describe evacuation, community evacuation, and wildfire procedures. The three standards listed below describe factors to consider when completing a CRA related to the threats posed by wildfire:

- NFPA 1300, “Standard on Community Risk Assessment and Community Risk Reduction Plan Development” [65]
- NFPA 1616, “Standard on Mass Evacuation, Sheltering, and Re-entry Programs” [66]
- NFPA 1730, “Standard on Organization and Deployment of Fire Prevention Inspection and Code Enforcement, Plan Review, Investigation, and Public Education Operations” [67]

These standards identify factors that influence community WUI fire risk, which are outlined below.

Several of these factors are addressed in this Guide (see Chapter 2 to Chapter 5 and Appendix C). NFPA 1300 [65], NFPA 1616 [66], and NFPA 1730 [67] suggest completing a requirements analysis to address the following:

- characteristics of the population affected
- mandatory requirements related to evacuation
- incident characteristics, including speed, magnitude, location, direction, and duration
- weather, seasonal, and environmental conditions
- potential loss of key infrastructure and associated functionality
- transportation infrastructure

In addition, NFPA 1300 [65], NFPA 1616 [66], and NFPA 1730 [67] provide a qualitative approach to identifying community strengths and vulnerabilities by assessing the level of conformity (i.e., conforming, partially conforming, or non-conforming) with the requirements in these standards. A similar, but simplified, approach is described in Chapter 3 to Chapter 5 and Appendix C.

B.1 List of Community Risk Assessment Factors (NFPA 1730)

Chapter 5 and Annex B of NFPA 1730 [67] suggest that a CRA take into account the following factors: demographics, geographic overview, building stock, fire experience, responses, hazard, and economic profile. These factors are listed below (see also Appendix C for more information where cross-referenced).

1. Demographics (*see also Appendix C)
   - Age*
   - Gender
   - Education
   - Socio-economic status*

- Vulnerable individuals/occupancies*
- Ethnic/cultural considerations
- Transient population*

2. Geographic overview
   - Waterways
   - Highways
   - Canyons and other landforms
   - Rail
   - WUI
   - Bridges

3. Building stock (*see also Chapter 4 and Appendix J)
   - Building density*
   - Occupancy type
   - Age of building stock
   - High fire risk occupancies
   - High life safety risk occupancies
   - Historical/cultural important buildings

4. Fire experience (*see also Chapter 4 and Appendix C)
   - Fires by occupancy type*
   - Death/injury by occupancy/property type
   - Death/injury by age/gender
   - Amount of loss (in $)
   - Causes
   - Smoke alarm status*
   - Suppression system status*

5. Responses/type of calls (see also, in general, Chapter 4)
   - Medical
   - Carbon monoxide
   - Motor vehicle accidents
   - Rescue

6. Hazard (see also, in general, Chapter 2 for contributing factors)
   - Human-caused
   - Technological
   - Natural

7. Economic profile (see also, in general, Chapter 4 and Appendix C)
   - Infrastructure
   - Employees
   - Industries
   - Institutions
   - Events
   - Attractions

B.2 Community Risk Assessment and Risk Reduction Plan Development (NFPA 1300)

NFPA 1300 [65] supersedes NFPA 1730 [67] and more explicitly outlines the CRA process. However, this standard discusses the factors in less detail. Instead, it provides categories to be addressed, expanding on those presented in NFPA 1730 [67]. The categories are described below:

- Demographics: population size and dispersion, age, gender, cultural background, language, education, socio-economic status, transience, other considerations
- Geographic: waterways, highways, canyons, railroads, wildland interface, landforms, bridges
- Building stock: classification types, number of buildings
- Public safety response agencies: response incident types, response capabilities
- Community service organizations: services provided by non-governmental agencies including advocacy groups, mental health organizations, faith-based charities, Red Cross
- Hazard: natural, human-caused, technological
- Economic: affected sectors critical to financial sustainability
- Past loss/event history: previous deaths, injuries, causation, financial loss
- Infrastructure: critical systems

NFPA 1300 [65] has additional categories than those addressed in NFPA 1730 [67]. NFPA 1300 [65] also outlines the tools that may be adopted as part of the CRA to address the following stages:

- Identification of risks and root causes ("5 why" analysis to identify the causes; fishbone diagram to link causes to effects)
- Identification of mitigation strategies
- Collection of data on community status
- Identification of discrepancies between the current status and expected levels of performance
- Identification of associated risk levels and whether these levels are acceptable (risk matrix to map the impact of these effects with data identifying frequency)

The CRA is required to identify specific risks, especially to high-risk occupancies and critical facilities (e.g., hospitals, schools, transport hubs and facilities, government structures). The CRA then provides a foundation for action. It tacitly acknowledges that this can be a challenging task requiring some expertise, noting: “In the absence of staff and resources to conduct an in-depth risk assessment, at a minimum an analysis should be conducted of the local data to identify more prevalent conditions.”

B.3 Mass Evacuation, Sheltering, and Re-entry Programs (NFPA 1616)

Although NFPA 1616 [66] addresses broader concerns beyond wildfire scenarios, it does refer to a number of WUI topics, including community and public information (see NFPA 1616, Section 5.8); warnings, notifications, and communications (see NFPA 1616, Section 5.9); and operational procedural planning (see NFPA 1616, Section 5.10). These closely align with Chapter 5 of this Guide. NFPA 1616 [66] provides a self-assessment to establish the level of conformity of the community with the requirements of the standard (i.e., conforms, partially conforms, or does not conform).

Appendix C Life Safety Vulnerability Assessment

As discussed in Chapter 1, a life safety vulnerability assessment should be conducted to determine whether the provisions related to life safety in combination with the community design and planning conditions are likely to produce an acceptable degree of performance. If not, then further community-based provisions should be developed until the life safety vulnerability assessment produces satisfactory results.

If the user of this Guide is not able to perform the assessment (e.g., gather the necessary information or apply the resources identified), then they should approach community safety officers or local officials for assistance.

Acceptability is established by following the steps outlined in Figure 4 (Chapter 1) where suggested actions (and implied acceptable conditions) are identified based on the hazard faced. In Figure 4, the vulnerability assessment of this Guide is divided into property protection and life safety vulnerability assessments. The vulnerability assessment described in Section C.1 below relates specifically to life safety. (The property protection vulnerability assessment is primarily addressed by the Construction Class and Priority Zone management measures in Chapter 3, along with the identification of Hazard Levels and Exposure Levels in Chapter 2.)

The following life safety vulnerability assessment reflects many of the key factors of the NFPA standards outlined in Appendix B. Given the different types of Guide users and the differences in resources and expertise available to them, this vulnerability assessment has been simplified to a set of general questions (i.e., requiring a “yes” or “no” answer). A more complex assessment would be less useful.

C.1 Life Safety Vulnerability Assessment Questions

1) If the answer to *any* of the following questions is “yes,” refer to the provisions in Chapter 4 and Chapter 5 to mitigate the threat to the safety of vulnerable community members.

    - Is the unemployment level of the community[40] greater than the national average?
    - Is the percentage of seniors (i.e., those over 65 years old) in the community (current/projected population) greater than the national average?
    - Is the percentage of persons with disabilities[41] in the community greater than the national average?

[40] “Community” refers to the population of either the existing or projected community.
[41] Known cases or registered cases in a database.

2) If the answer to *any* of the following questions is “no,” then specific vulnerabilities to the life safety of the community should be identifiable; refer to the provisions in Chapter 4 and Chapter 5 to mitigate the threat to the safety of community members.

- Evacuation plan:
  - Is there an existing evacuation plan that explicitly identifies evacuation routes, trigger points, traffic management solutions, public shelters and places, evacuation zones, etc.?
  - Is there a plan for at-risk occupancies or vulnerable land uses such as hospitals, assisted living centres, commercial centres, schools, airports, emergency operation centres, mobile homes, industrial facilities, roadways, railroads?

- Experience or familiarity with wildfire emergencies and evacuation plan:
  - In the last 5 years, has the community experienced a wildfire emergency that prompted evacuation?
  - In the last 5 years, has the community practiced the wildfire evacuation plan via training and drills?

- Emergency communications:
  - Is there a communication strategy (including identified means) to notify community members of an evacuation?
  - Is there a strategy (including identified means) to communicate with evacuees during the evacuation?
  - Does the community have extensive and reliable cell phone service?

- Access/egress routes:
  - If the community has fewer than 600 households, are there two or more access/egress routes?
  - If the community has more than 600 households, are there three or more access/egress routes?

- Refuge areas:
  - Are there pre-identified outdoor or indoor refuge areas (for last-minute refuge)?

- Water supply:
  - Will adequate water be supplied during a wildfire emergency (based on the recommendations provided in Section 4.3.1.2)?

- Power supply:
  - Will adequate power be supplied during a wildfire emergency (based on the recommendations provided in Section 4.3.1.1)?

Answering these questions should enable the identification of any vulnerabilities that the community might have. If vulnerabilities are found, it is important that the user review Chapter 4 to identify ways in which these vulnerabilities can, to some extent, be addressed.

Appendix D Administrative Considerations

AHJs and other organizations may consider voluntary implementation of the risk reduction recommendations outlined in the Guide. The suggested administrative considerations provided in this Appendix may assist any AHJ or organization in the implementation of the Guide's measures.

D.1 Application

1) This Guide addresses buildings and infrastructure, and may be used for existing or new buildings or communities.

D.2 Implementing This Guide

1) Implementing this Guide may be achieved by
    a) using the recommended measures and guidelines as written,
    b) using alternative measures that can achieve same performance as intended by the stated objectives and building functions addressed in these guidelines, or
    c) following guidance on recommended levels of vulnerability related to both property protection and life safety.

D.3 Applicable Statutes

1) The use of this Guide should align with the mandate of the organization and should respect any applicable laws, statutes, and regulations.

D.4 Additions and Alterations to Existing Buildings and Communities

1) The recommendations in the Guide may be extended to voluntary renovations, additions, and alterations of any building, structure, or community in the same way they are used for new buildings, structures, or communities. The measures may be used on portions of the existing building, structure, or community.

D.5 Plans and Drawings

D.5.1 General Information

1) Documentation should show that the proposed new work will follow the recommendations in this Guide and how adjacent property may be affected, if applicable.
2) All plans should be drawn to scale and should indicate the nature and extent of the work in sufficient detail to establish that, when completed, the work follows the recommendations in this Guide.
3) Information about changes during construction or mitigation should follow the recommendations for proposed new work.

D.5.2 Site Plans

1) In addition to accepted practice, such as that used for building codes, site plans should show
    a) topography,
    b) road configuration, as well as access, egress, parking, and supporting infrastructure,
    c) natural and developed landscape and vegetation details, short and long term,
    d) location of existing or proposed
        i) structures or building envelopes and their appendages,
        ii) utilities, lighting, and other infrastructure, above and below ground,
    e) occupancy classifications of buildings,
    f) types of construction materials,
    g) roof classifications of buildings, and
    h) site water supply systems.

The organization administering the implementation of the Guide may waive or modify the requirement for a site plan where the project is an alteration or repair, or where otherwise recommended.

D.5.3 Vegetation Plans

1) Vegetation plans should be prepared and submitted to the organization administering the Guide for review and consideration.

D.5.4 Vicinity Plans

1) In addition to site plans, vicinity plans, where available, should show details regarding the vicinity within 100 m of lot lines, including other structures, slope, vegetation, fuel breaks, water supply systems, and access roads.

D.6 Verification of Completed Measures

D.6.1 General

1) The completion of the construction or work for which this Guide offers recommended practices should be verified.
2) The persons undertaking the work should ensure the completed mitigation measures are visible and accessible until the completion of the measure can be assessed to avoid costly removal or replacement of any material required to allow access.
3) Organizations implementing the recommendations in this Guide should take care not to interfere with counteracting regulations that are otherwise applicable. Other laws apply on their own merits and are unaffected by the verification of completed measures recommended in this Guide. A survey of the Priority Zones should be conducted to verify that the Priority Zone recommendations described in Section 3.4 have been followed and that the building or structure is located where indicated on the plans.

D.6.2 Frequency of Surveys and Verification

1) The frequency of verifications and surveys should allow time for the correction of conditions in buildings and on premises where

a) these conditions can be reasonably expected to cause fire or contribute to its spread, or
b) recommendations in this Guide (or any other law or standard affecting fire safety) have not been followed.

D.7 Enabling Implementation

D.7.1 Request for Work

1) The intention to undertake any of the recommendations in this Guide should be formally submitted in writing. Every such application should
    a) identify and describe the work, activity, operation, practice, or function to be covered by the permit for which application is made,
    b) describe the land on which the proposed work, activity, operation, practice, or function is to be done by legal description, street address, or similar description that will readily identify and definitely locate it,
    c) indicate the use or occupancy for which the proposed work, activity, operation, practice, or function is intended,
    d) be accompanied by plans, diagrams, computations, specifications, and other data as suggested by the organization implementing the Guide,
    e) state the valuation of any new building or structure or any addition, remodelling, or alteration to an existing building, and
    f) be signed by who intend to undertake the work and/or who own the premise, building or land.

D.7.2 Initial survey

1) Before the organization implementing this Guide engages in applying recommended mitigation measures on a specific project, the organization may survey and examine the equipment, buildings, devices, premises, and spaces or areas to be used.

D.7.3 Giving the Go-ahead

1) Before an organization implementing this Guide issues the go-ahead for a project, it should review appropriate uses, occupancies, and structures.
2) Where laws or regulations are enforceable by other agencies or departments, a collaborative approach should be used with the agencies or departments involved.

Appendix E Potential Effects of Climate Change on WUI Fire Hazard in Canada

Climate change is one of the biggest challenges facing many countries around the world. Observational records indicate that air temperatures in Canada have increased by 1.5°C between 1950 and 2010, which is approximately twice the increase recorded across the globe during that time [126]. This figure indicates that Canada on average is more susceptible to climate change impacts than the rest of the world. Because of the long lifetime of greenhouse gases, such as CO_2, in the climate system, the emissions from the past and the present will continue to influence the Canadian climate in the future [127].

Studies have shown that climate change is exacerbating wildfire risk in Canada. For instance, researchers at Environment and Climate Change Canada found that the hot and dry weather caused by greenhouse gas emissions has increased wildfire activity in British Columbia by up to a factor of 4 and has increased the area burnt by wildfires by up to a factor of 11 [128]. Scientists have predicted that, as a consequence of climate change, the wildland areas of Canada will have more dry fuels susceptible to burning, more frequent lightning strikes that can start fires, and more frequent and extreme dry, windy weather able to propagate the flames [129]. Climate change impact assessment studies predicting future wildfire behaviour, such as Flannigan et al. [52], have estimated that the total area burnt by wildfire in Canada may increase by 74% to 118% by the end of the 21st century under a three-fold increase in global CO_2 concentration. Wotton et al. predicted that wildfire occurrence in Canada may increase by up to 140% in the future as a consequence of climate change [50]. Wotton et al. also predicted that the occurrence of most unmanageable and intense crown fires is likely to increase in the future across Canada's boreal forests as a consequence of climate change [130]. In addition, the total number of days when fire intensities could exceed the capabilities of suppression resources is also projected to increase or even double in some future greenhouse gas emission scenarios [130]. Indeed, large future increases in wildfire suppression costs have been projected across Canada [54].

As a result of increased wildfire activity, infrastructure and communities located in WUI areas will be exposed to unprecedented levels of wildfire hazard. As such, it is important to put into place national-level guidelines, standards, and codes to support the design of wildfire-resilient infrastructure and communities in the WUI areas of Canada. Not doing so may result in early failure of the infrastructure, and may even lead to fatalities, injuries, and illness among residents living in communities in WUI areas. The wildfire adaptation strategies outlined in this Guide will provide city planners and wildfire management authorities with important information that they can use to adapt to the risk of wildfire, which is predicted to increase in the future as a consequence of climate change.

Appendix F Fuel Types According to the FBP System

F.1 Map of FBP Fuel Types

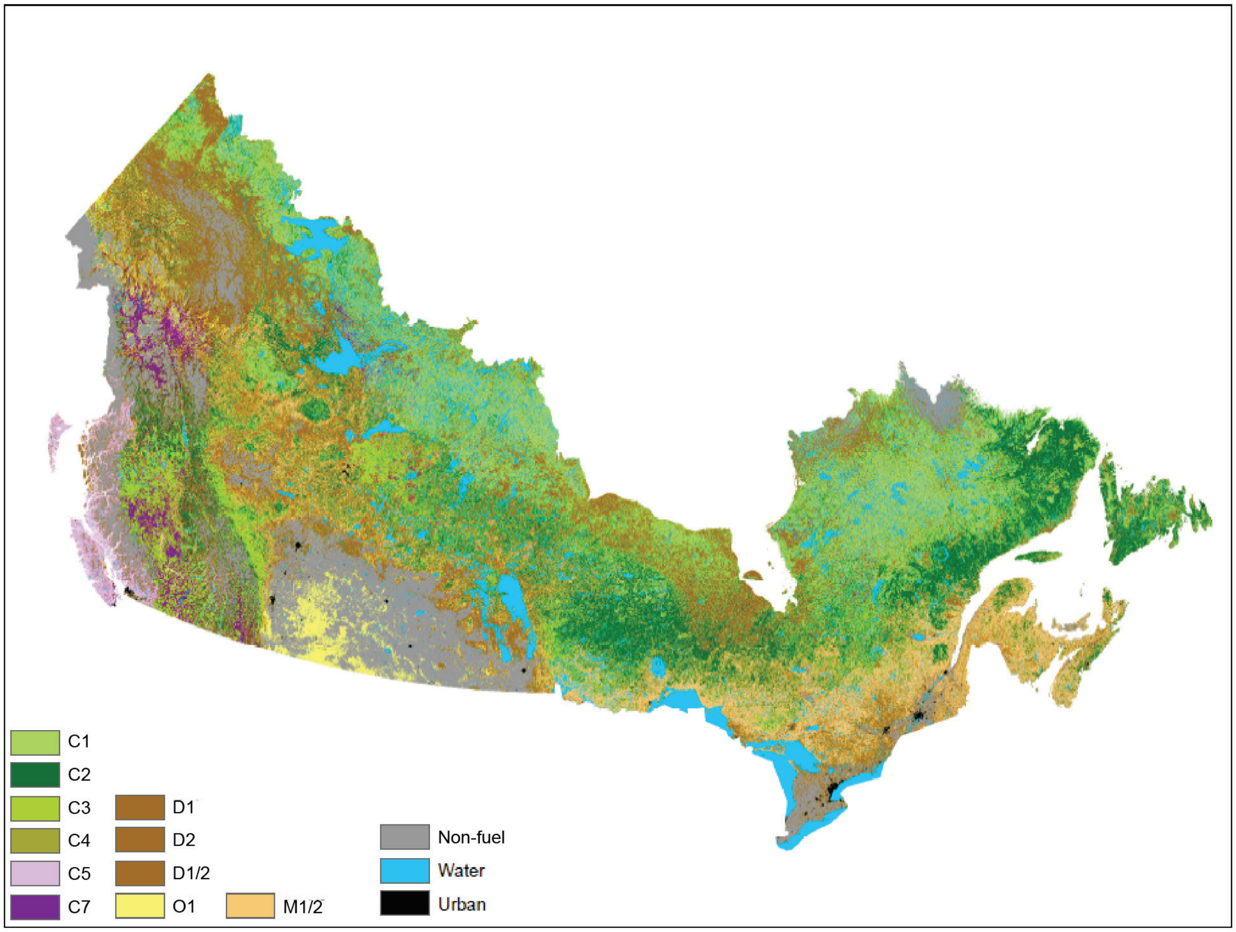

Figure 16. Map of FBP Fuel Types in Canada as described in Section F.2.[42,43]

[42] Provided by Natural Resources Canada.
[43] D2 = green aspen.

F.2 Description of FBP Fuel Types

F.2.1 C1 – Spruce–Lichen Woodland

This fuel type is characterized by stands of open, parklike black spruce (*Picea mariana* (Mill.) B.S.P.) occupying well-drained uplands in the subarctic zone of western and northern Canada. Jack pine (*Pinus banksiana* Lamb.) and white birch (*Betula papyrifera* Marsh.) are minor associates in the overstorey. Forest cover occurs as widely spaced individuals and dense clumps. Tree heights vary considerably, but bole branches (live and dead) uniformly extend to the forest floor and layering development is extensive. Woody surface fuel accumulation is very light and scattered. Shrub cover is exceedingly sparse. The ground surface is fully exposed to the sun and covered by a nearly continuous mat of reindeer lichens (*Cladonia* spp.), averaging 3–4 cm in depth above mineral soil.

F.2.2 C2 – Boreal Spruce

This fuel type is characterized by stands of pure, moderately well-stocked black spruce (*Picea mariana* (Mill.) B.S.P.) on lowland (excluding *Sphagnum* bogs) and upland sites. Tree crowns extend to or near the ground, and dead branches are typically draped with bearded lichens (*Usnea* spp.). The flaky nature of the bark on the lower portion of stem boles is pronounced. Low to moderate volumes of down woody material are present. Labrador tea (*Ledum groenlandicum* Oeder) is often the major shrub component. The forest floor is dominated by a carpet of feather mosses and/or ground-dwelling lichens (chiefly *Cladonia*). *Sphagnum* mosses may occasionally be present, but they are of little hindrance to surface fire spread. A compacted organic layer commonly exceeds a depth of 20–30 cm.

F.2.3 C3 – Mature Jack or Lodgepole Pine

This fuel type is characterized by stands of pure, fully stocked (1 000–2 000 stems/ha) jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.) that have matured at least to the stage of complete crown closure. The base of live crown is well above the ground. Dead surface fuels are light and scattered. Ground cover is feather moss (*Pleurozium schreberi*) over a moderately deep (approximately 10 cm), compacted organic layer. A sparse conifer understory may be present.

F.2.4 C4 – Immature Jack or Lodgepole Pine

This fuel type is characterized by stands (10 000–30 000 stems/ha) of pure, dense jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.) in which natural thinning mortality results in a large quantity of standing dead stems and dead downed woody fuel. Vertical and horizontal fuel continuity is characteristic of this fuel type. Surface fuel loadings are greater than in fuel type C3, and organic layers are shallower and less compact. Ground cover is mainly needle litter suspended within a low shrub layer (*Vaccinium* spp.).

F.2.5 C5 – Red and White Pine

This fuel type is characterized by mature stands of red pine (*Pinus resinosa* Ait.) and eastern white pine (*Pinus strobus* L.) in various proportions, sometimes with small components of white spruce (*Picea glauca* (Moench) Voss) and old white birch (*Betula papyrifera* Marsh.) or aspen (*Populus* spp.). The understory is of moderate density, usually red maple (*Acer rubrum* L.) or balsam fir (*Abies balsamea* (L.) Mill.). A shrub layer, usually beaked hazel (*Corylus cornuta* Marsh.), may be present in moderate proportions. The ground surface cover is a combination of herbs and pine litter. The organic layer is usually 5–10 cm deep.

F.2.6 C6 – Conifer Plantation

This fuel type is characterized by pure, fully stocked conifer plantations with closed crowns and no understory or shrub layer. The forest floor is covered by needle litter with an underlying duff layer up to 10 cm deep. The crown base height is taken into account in predicting fire-spread rate and crowning.

F.2.7 C7 – Ponderosa Pine–Douglas-Fir

This fuel type is characterized by uneven-aged stands of ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in various proportions. Western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) may be significant stand components on some sites and at some elevations. Stands are open, with occasional clumpy thickets of multi-aged Douglas-fir and/or larch as a discontinuous understory. Canopy closure is less than 50% overall, although thickets are closed and often dense. Woody surface fuel accumulations are light and scattered. Except within Douglas-fir thickets, the forest floor is dominated by perennial grasses, herbs, and scattered shrubs. Within tree thickets, needle litter is the predominant surface fuel. Duff layers are non-existent to shallow (< 3 cm).

F.2.8 M1 – Boreal Mixedwood: Leafless

This fuel type (and its "green" counterpart, M2) is characterized by stand mixtures consisting of the following coniferous and deciduous tree species in varying proportions: black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). On any specific site, individual species can be present or absent from the mixture. In addition to the diversity in species composition, stands exhibit wide variability in structure and development, but are generally confined to moderately well-drained upland sites. M1, the first phase of seasonal variation in flammability, occurs during the spring and fall. The rate of spread is weighted according to the proportion (expressed as a percentage) of softwood and hardwood components.

F.2.9 M2 – Boreal Mixedwood: Green

This fuel type (and its "leafless" counterpart, M1) is characterized by stand mixtures consisting of the following coniferous and deciduous tree species in varying proportions: black spruce

(*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), balsam fir (*Abies balsamea* (L.) Mill.), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.). On any specific site, individual species can be present or absent from the mixture. In addition to the diversity in species composition, stands exhibit wide variability in structure and development, but are generally confined to moderately well-drained upland sites. M2, the second phase of seasonal variation in flammability, occurs during the summer. The rate of spread is weighted according to the proportion (expressed as a percentage) of softwood and hardwood components. In the summer, when the deciduous overstorey and understory are in leaf, fire spread is greatly reduced, with maximum spread rates only one-fifth that of spring or fall fires under similar burning conditions.

F.2.10 M3 – Dead Balsam Fir Mixedwood: Leafless

This fuel type (and its “green” counterpart, M4) is characterized by mixedwood stands in which balsam fir (*Abies balsamea* (L.) Mill.) grows, often as an understory species, in a heterogeneous mix with spruce (*Picea* spp.), pine (*Pinus* spp.), and birch (*Betula* spp.). These stands are found in the Great Lakes–St. Lawrence and boreal forest regions of Canada and are not to be confused with the pure balsam fir stands typical of Nova Scotia and New Brunswick. Repeated annual defoliation (due to attack by spruce budworm (*Choristoneura fumiferana* Clemens)) causes balsam fir mortality, followed by peeling bark, development of draped lichen (Spanish moss or old man's beard, *Usnea* spp.), top breakage, and windthrow, peaking 5–8 years after mortality. The volume of down woody material is initially low but increases substantially with progressive stand decomposition following mortality. The forest floor is a mixture of feather mosses, conifer needles, and hardwood leaves. The organic layer is moderately compacted and 8–10 cm deep. After mortality, spring fires in this fuel type behave extremely vigorously, with continuous crowning and downwind spotting.

F.2.11 M4 – Dead Balsam Fir Mixedwood: Green

This fuel type (and its “leafless” counterpart, M3) is characterized by mixedwood stands in which balsam fir (*Abies balsamea* (L.) Mill.) grows, often as an understory species, in a heterogeneous mix with spruce (*Picea* spp.), pine (*Pinus* spp.), and birch (*Betula* spp.). These stands are found in the Great Lakes-St. Lawrence and boreal forest regions of Canada and are not to be confused with the pure balsam fir stands typical of Nova Scotia and New Brunswick. Repeated annual defoliation (due to attack by spruce budworm (*Choristoneura fumiferana* Clemens)) causes balsam fir mortality, followed by peeling bark, development of draped lichen (Spanish moss or old man’s beard, *Usnea* spp.), top breakage, and windthrow, peaking 5–8 years after mortality. The volume of down woody material is initially low but increases substantially with progressive stand decomposition following mortality. The forest floor is a mixture of feather mosses, conifer needles, and hardwood leaves. The organic layer is moderately compacted and 8–10 cm deep. Summer fires are hampered by the proliferation of green understory vegetation resulting from the opening of stand canopy. As sufficient surface fuel accumulates through stand decomposition (usually after 4–5 years), fires will spread through the fuel complex, although not as vigorously as in spring. Forest fire behaviour potential is greatest 5–8 years after mortality, decreasing gradually as the surface fuels decompose and the understory vegetation continues to proliferate.

F.2.12 D1 – Leafless Aspen

This fuel type is characterized by pure, semi-mature stands of trembling aspen (*Populus tremuloides* Michx.) before bud break in the spring or following leaf fall and curing of the lesser vegetation in the autumn. A conifer understory is noticeably absent, but a well-developed medium to tall shrub layer is typically present. Dead and down roundwood fuels are a minor component of the fuel complex. The principal fire-carrying surface fuel consists chiefly of deciduous leaf litter and cured herbaceous material that is directly exposed to wind and solar radiation. In the spring the duff mantle (F and H horizons) seldom contributes to the available combustion fuel because of its high moisture content.

F.2.13 S1 – Jack or Lodgepole Pine Slash

This fuel type is characterized by slash resulting from tractor or skidder clear-cut logging of mature stands of jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.). The slash is typically one or two seasons old, retaining up to 50% of the foliage, particularly on branches closest to the ground. No post-logging treatment has been applied, and slash fuels are continuous. Tops and branches left on site result in moderate fuel loads and depths. Ground cover is continuous feather moss mixed with discontinuous fallen needle litter. Organic layers are moderately deep and fairly compact.

F.2.14 S2 – White Spruce–Balsam Slash

This fuel type is characterized by slash resulting from tractor or skidder clear-cut logging of mature to over-mature stands of white spruce (*Picea glauca* (Moench) Voss) and sub-alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) or balsam fir (*Abies balsamea* (L.) Mill.). Slash is typically one or two seasons old, retaining from 10% to 50% of the foliage on the branches. No post-logging treatment has been applied. Fuel continuity may be broken by skid trails unless the site was logged in winter. Tops have been left on site, and most branch fuels have broken off during skidding of logs to landings, which results in moderate *fuel loads* and depths. Quantities of shattered large and rotten woody fuels may be significant. Ground cover is feather moss with considerable needle litter fallen from the slash. Organic layers are moderately deep and compact.

F.2.15 S3 – Coastal Cedar–Hemlock–Douglas-Fir Slash

This fuel type is characterized by slash resulting from high-lead clear-cut logging of mature to over-mature stands of coastal British Columbia mixed conifer. Predominant species are western red cedar (*Thuja plicata* Donn.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Slash is typically one season old, with the cedar component retaining all its foliage in a cured condition on the branches, whereas the hemlock and Douglas-fir components will have dropped up to 50% of their foliage. Slash fuels tend to be continuous and uncompacted. Very large loadings of broken and rotten unmerchantable material may be present, depending on the degree of stand decadence. Slash fuel depths may range from 0.5 to 2.0 m. Ground cover may be feather moss or just compact old needle litter under significant quantities of recent needle litter fallen from the slash. Organic layers are moderately deep to deep and compact. Minor to moderate shrub and herbaceous understory components may be present. This fuel type designation may also be applied to wet belt cedar–hemlock slash of coastal and interior British Columbia where the Douglas-fir component is absent.

F.2.16 O1 – Grass

This fuel type is characterized by continuous grass cover, with no more than occasional trees or shrub clumps, which do not appreciably affect fire behaviour. Two subtype designations are available for grasslands: one for the matted grass condition common after snowmelt or in the spring (O1-a); and the other for standing dead grass common in late summer to early fall (O1-b). The proportion of cured or dead material in grasslands has a pronounced effect on fire spread there and must be estimated with care.

Appendix G Canadian Forest Fire Danger Rating System

The CFFDRS is used every day of the fire season at all fire weather stations across Canada to provide foundational intelligence about the wildland environment for the operational fire management decision-making process [75]. The system is the product of more than 80 years of research by the Canadian Forest Service (CFS), and continues to develop as new research is carried out and new fire management planning challenges emerge. The maintenance and further development of the CFFDRS is a core part of the CFS Science and Technology program. Given these considerations, the CFFDRS is a logical core system of fire models to form the foundation of hazard and exposure assessments for this Guide.

Moving forward, while enhanced models and capability may be introduced to the CFFDRS, these changes will be carefully considered, vetted, and documented by the CFS. By doing so, the foundations of the system will remain rooted in providing a realistic assessment of the wildfire environment in Canadian forest and rangeland fuels.

The core subsystems of the CFFDRS are the FWI System [73] and the FBP System [70]. The FWI System integrates daily observed fire weather (noon temperature, relative humidity, wind speed, and rainfall) into a series of three moisture codes and three behaviour indices. The moisture codes track moisture content in three distinct layers of the forest floor in a closed canopy pine stand; the moisture in these layers influences different aspects of wildfire potential. The behaviour indices are relative indicators of potential fuel consumption, spread rate, and intensity. The FWI itself, while it is a scaled representation of Byram's fire intensity in closed canopy pine, is also the rating used to inform the public about the level of fire danger in a region through roadside fire danger signs.

The FBP System integrates fuel type, weather, fuel moisture (as indicated by the FWI System), and other factors to create quantitative predictions of fire behaviour, such as spread rate, fuel consumption, fire type (e.g., surface or crown fire), and fire intensity. The models used to develop these quantitative predictions, while based on a simple physical understanding of how fires behave, are calibrated using observations from decades of large-plot experimental burning and detailed documentation of spreading wildfires in a range of the most common fuels across Canada's forested landscapes. These models, therefore, give a realistic prediction of fire behaviour across a range of fuel types and conditions found in Canada and, because of this, are relied upon in wildfire operations in every jurisdiction in Canada.

Appendix H Implementation of Interventions Outlined in Chapter 3

If considering whether to mandate the WUI fire risk mitigation interventions outlined in Chapter 3, local governments should be aware that, unlike the provisions contained in the national codes developed by the Canadian Commission on Building and Fire Codes, the measures contained in this Chapter are not a product of Canada’s code development process. Therefore, these measures have not been subject to the level of rigour that is part of that well-established consensus process.

The interventions outlined in Chapter 3 may also be adopted on a voluntary basis by any stakeholder concerned with full or partial mitigation of WUI fire risk at the building, lot, or site scale. Local authorities may explore the use of non-regulatory and voluntary tools to promote implementation of the interventions (see Table 20).

The degree to which the implementation of the interventions outlined in Chapter 3 is necessary depends on the outcome of the vulnerability assessment, which is conducted at the local scale by Guide users and AHJs. When the Guide users or AHJs have deemed the outcome of the vulnerability assessment to be satisfactory, the process of implementing the interventions is complete (see Section 1.4). Because the Guide users or AHJs determine acceptability of the outcome, full implementation of the interventions will not necessarily be required. For example, buildings constructed in accordance with the provisions for Construction Class CC1(FR) may be considered to have an acceptably low level of vulnerability, even where the fuel in the Priority Zones surrounding the building has not been managed (see Table 7 in Chapter 3).

Table 20: Authorities Having Jurisdiction and Potential Tools to Encourage Implementation of the WUI Fire Risk Mitigation Interventions Outlined in Chapter 3

Mitigation Intervention(1)(2)	AHJs and Potential Regulatory Tools		Potential Non-Regulatory Tools
	New Construction or Major Renovation	Existing Construction or Minor Renovation	
Fuel management in Priority Zone 1A	Provinces/territories • Provincial/territorial construction codes • Development regulations Local governments • Development regulations	Local governments • Property standards by-laws	• National model construction codes • Developer incentive initiatives (local government) • Insurer incentives/disincentives • Provincial/territorial disaster relief program mitigation incentives • Build Back Better programs tied to disaster/loss scenarios (provincial/territorial disaster relief, insurance) • Resident education and engagement programs • Local government/builder labelling programs
Fuel management in Priority Zone 1	Local governments • Development regulations	Local governments • Property standards by-laws	• Landowner education and incentive programs • Developer incentive initiatives (local government)
Fuel management in Priority Zones 2 and 3	Provinces/territories • Forest management regulations Local authorities • Development regulations	Local governments • Property standards by-laws	• Landowner education and incentive programs
Construction provisions relating to: • Roof covering materials • Gutters, downspouts • Drip edges • Exterior cladding • Eaves and roof projections • Service openings and vents • Doors	Provinces/territories • Provincial/territorial construction codes • Development regulations Local governments • Development regulations • Zoning by-laws may apply for certain interventions (e.g., roof material, exterior cladding)	Local governments • Development regulations • Zoning by-laws may apply for certain interventions (e.g., roof material, exterior cladding)	• National model construction codes • Developer incentive initiatives (local government) • Insurer incentives/disincentives • Provincial/territorial disaster relief program mitigation incentives • Build Back Better programs tied to disaster/loss scenarios (provincial/territorial disaster relief, insurance) • Resident education and engagement programs • Local government/builder labelling programs

Mitigation Intervention(1)(2)	AHJs and Potential Regulatory Tools		Potential Non-Regulatory Tools
	New Construction or Major Renovation	Existing Construction or Minor Renovation	
Provisions relating to decks, balconies, and other projections	Provinces/territories • Provincial/territorial construction codes Local governments • Development regulations • Deck by-laws	Local governments • Deck by-laws • Property standards by-laws	• National model construction codes • Developer incentive initiatives (local government) • Insurer incentives/disincentives • Provincial/territorial disaster relief program mitigation incentives • Build Back Better programs tied to disaster/loss scenarios (provincial/territorial disaster relief, insurance) • Resident education and engagement programs • Local government/builder labelling programs
Provisions relating to fences	Local governments • Fence by-laws • Property standards by-laws	Local governments • Fence by-laws • Property standards by-laws	• Developer incentive initiatives (local government) • Insurer incentives/disincentives • Provincial/territorial disaster relief program mitigation incentives • Build Back Better programs tied to disaster/loss scenarios (provincial/territorial disaster relief, insurance) • Resident education and engagement programs • Local government/builder labelling programs
Provisions relating to liquefied petroleum gas tanks	–	–	• Provincial/territorial disaster relief program mitigation incentives • Build Back Better programs tied to disaster/loss scenarios (provincial/territorial disaster relief, insurance) • Resident education and engagement programs • Local government/builder labelling programs

Notes to Table 20:

(1) The mitigation interventions are assumed to be applied in residential subdivisions composed of buildings covered under Part 9 of the NBC [2], where the provisions of provincial or territorial fire codes would likely not apply.

(2) Chapter 3 of the Guide has been organized such that construction provisions can be implemented regardless of whether community- and landscape-scale interventions, such as fuel management in Priority Zones, are implemented. For example, buildings for which no Priority Zone fuel management has been completed are to be categorized in Construction Class CC1(FR) (see Table 7).

Appendix I Explanatory Material for Chapter 3

I.1 3.1.3 Objective of Chapter 3

The objective of Chapter 3 is to increase the resiliency of buildings, and consequently the community, by limiting the probability of damage to property that is exposed to risk associated with WUI fires.

The measures in this Chapter are not intended to ensure adequate life safety for building occupants or firefighters. The assumption is that building occupants will have been evacuated before the wildfire reaches the WUI and exposes the building to ignition hazards.

The measures in this Chapter are also not intended to prevent damage to buildings. They will not guarantee survival of the building.

I.2 3.2 Exposure Levels and Construction Classes

Although Chapter 3 provides Construction Classes for the highest Exposure Level, an AHJ may not support the construction of new buildings where the WUI fire risk is deemed beyond mitigation.

A summary of the Exposure Levels used in this Guide and their associated Construction Classes is presented in Table 21 below.

Table 21: Exposure Levels and Associated Construction Classes

Exposure Level	Exposure from WUI Fire			
	Direct Flame Impingement	Thermal Radiation, kW/m^2	Embers	Associated Construction Classes[(1)]
Ember-Only or Low	Not likely	< 12.5	Present	CC3
Moderate	Not likely	≥ 12.5 and ≤ 25	Present	CC2
High	Possible	> 25	Present	CC1(FR), CC1

Note to Table 21:
(1) It should be noted that the Construction Class assigned to a building depends on the extent to which the Priority Zones surrounding the building align with Section 3.4 (see Table 7 for more detail).

Examples of Determination of Construction Class in Accordance with Table 7

1) For a new building: A new building is supposed to be located in a WUI area where moderate fuel hazard vegetation surrounding the property leads to an Exposure Level of

Moderate for the building. Conditions on the ground only allow for Priority Zones 1A and 1 to follow the recommendations in Section 3.4. Therefore, according to Table 7, the Construction Class of the building is determined to be CC2, and the construction measures for this Construction Class in Section 3.3 should be used.

If it were not possible to follow recommended measures for Priority Zones 1 and 1A, the construction measures for Construction Class CC1(FR) would be applicable. Conversely, if it were possible to follow at least the recommendations for Priority Zones 1A, 1, and 2, the construction measures for Construction Class CC3 could be used.

2) For an existing building: An existing building is located in a WUI area where high fuel hazard vegetation surrounding the property leads to an Exposure Level of High for the building. The building's existing construction only follows the construction measures for Construction Class CC3. According to Table 7, the mitigation of Priority Zones 1A to 3 should follow the recommendations in Section 3.4.

If the same building could be upgraded to follow the construction measures for Construction Class CC2, only the recommendations for Priority Zones 1A to 2 would need to be followed. If the upgraded building were located where only a moderate fuel hazard exists, the Exposure Level of the building would be Moderate, and only the recommendations for Priority Zones 1A and 1 would need to be followed.

I.3 3.3.1 Application of Construction Measures

Chapter 3 sets out construction measures that are intended to mitigate the unique risks associated with buildings constructed in WUI areas. These measures are intended to be applied in addition to the applicable requirements of other existing construction regulations. The relaxations and alternatives provided in Chapter 3 for buildings in Construction Classes CC2 and CC3 may not exempt these buildings from any requirements of other construction regulations that may apply due to major occupancy, building size, or proximity to other buildings, for example.

I.4 3.4.1.2(1), 3.4.1.3(1), and 3.4.1.4(1) Recommendations for Removal of Ground-Level Fuels, Piled Debris, and Other Combustible Items, and for Fuel Conversion

Recommended Guidelines for Removal of Ground-Level Fuels

Remove downed tree trunks along with smaller branch materials. Remove finer twigs, needles, and litter by raking into piles and burning or hauling away.

If it is feasible, prescribed burning of scattered fuels by fire specialists under controlled conditions can also accomplish adequate fuel removal. Consult local authorities for approval and to obtain a burning permit.

Remove small trees and shrubs. Flammable species, such as juniper and pine trees and cured grasses, are particularly hazardous. Keep grasses within 10 m of the building watered and trimmed to a height of not more than 10 cm, or replace with non-flammable walkways, patios, or other landscaping features.

Fuel modification will result in increased surface vegetation (grass and shrubs). These surface fuels will be more flammable, but will burn with reduced intensity. Maintenance will be needed periodically to reduce surface fuel accumulations.

Recommended Guidelines for Removal of Piled Debris and Other Combustible Items

Avoid landscaping with flammable wood or pine needle mulch to reduce the potential for ignition and fire spread. Keep firewood, combustible debris, and outbuildings and other structures at least 10 m from the building. It is recommended that neighboring structures be located at least 10 m from the building. Avoid locating combustible material downslope from the building. If this is not possible, increase the specified distance from the building.

Recommended Guidelines for Fuel Conversion

Plants that are low-growing and woody or deciduous are referred to as low-fuel-volume plants. These plants are ideal replacements for more flammable species growing close to buildings or in areas where a firebreak is planned.

The type of vegetation and topography in an area will determine the degree of management needed. Replace highly flammable species, such as juniper and cedar, adjacent to buildings with watered lawns and low-fuel-volume plants. Individual trees and shrubs may be kept, if this vegetation would not readily transmit fire to the building. Consider the stability of slopes in any vegetation plan.

Different regions of Canada have different climates and soils that require different vegetation management strategies. Nursery and landscaping professionals often have lists of recommended plants for specific regions of the country. Cross-referencing these lists with the recommended guidelines of fire officials will enable homeowners to achieve a suitable conversion to fire-resistive plants [131],[132].

In some locations, it may be desirable to replace coniferous trees with deciduous trees.

In deciding which vegetation to remove, reduce, or replace in a program of fuel management, it is important to know the characteristics that make one species of vegetation more flammable than another. The most flammable plants include plants that rapidly accumulate quantities of dead foliage and branches, dead and diseased trees, vegetation with high oil or resin content, and plants that dry quickly in arid weather. When planting a new landscape, avoid choosing a species with these characteristics.

Most plants will burn under extreme fire weather conditions, such as drought aggravated by high winds, but they will burn at different intensities and with different rates of spread. Fire-resistive plants burn at a relatively low intensity, with a low rate of spread.

WUI residents should use fire-resistive vegetation when planting new landscapes.

Abnormal weather patterns can cause severe fire behaviour to occur in normally fire-resistive vegetation. These recommendations on fuel conversion and fire-resistive vegetation are based on general principles and typical weather patterns.

Appendix J Explanatory Material for Section 4.2.1

This Appendix expands upon Section 4.2.1. It presents examples of factors that may be used to assess the impact of the demographic characteristics identified in Table 11 (Section 4.2.1). That Table outlines several characteristics that may inhibit the ability of community members to cope with a wildfire emergency [133]–[140].

The impact of these characteristics becomes more of an issue where the socio-economic status of a community precludes members from following guidance such as that offered in this Guide (e.g., where a community is under-resourced and/or remote). In fact, many of the recommendations within this Guide may not be practical in some communities. For example, Section 4.2.3 discusses access and egress routes for evacuation by road. However, in remote communities with limited or no road access, these recommendations would be largely irrelevant. Many remote communities are particularly vulnerable to wildland fire and are frequently evacuated. A more detailed consideration of local WUI fire risk, resources, and socio-economic factors is recommended in such situations to enable these communities to implement some of the recommendations outlined in this Guide.

Demographic factors also exist that make communities more resilient against the hazards faced, such as social capital. Social capital refers to the existence of social networks and the potential collaboration they generate among individuals, groups, and communities, as well as the benefits of such social networks in achieving mutual goals [141],[142].

In this Appendix, we examine the following factors:

- Socio-economic status – This factor reflects income, employment, age of housing stock, and education.
- Age – This factor reflects age of population and health (a number of health conditions become increasingly likely with age).
- Impairment – This factor reflects disability, health, and access to resources.
- Length of residence – This factor reflects degree of connectedness, relationship with property, and degree of preparedness.

These factors were selected because their impact on the initial delay to respond, the resources available, and the capacity to act is well established. Moreover, criteria for these factors can be practically established for different communities and used in the vulnerability assessment presented in Appendix C.

At least these factors should be considered when assessing the capacity of community members to reach a place of safety. These factors may affect several outcomes, for example, the ability to self-evacuate using a private vehicle and the implementation of preparatory or protective actions.

The socio-economic status of a community influences the likelihood of community members owning a vehicle. The age and impairment level of community members influence the likelihood of residents independently using vehicles during an incident (and therefore the likelihood of them using other modes of transport). These factors therefore directly influence the capacity of community members to independently move to remote places of safety during evacuation processes (see Figure 17).

The socio-economic status of a community influences the ability of community members to access resources (e.g., material, expertise) required to perform preparatory or protective actions. The length of residence in a community influences member awareness of the need for preparatory or protective actions and the likelihood of members acquiring the resources to perform preparatory or protective actions (e.g., through exposure to previous incidents, planning, and outreach). The ages and impairment levels of community members influence the likelihood of members independently performing preparatory or protective actions. These factors directly influence the capacity of community members to effectively protect themselves and their property (see Figure 17).

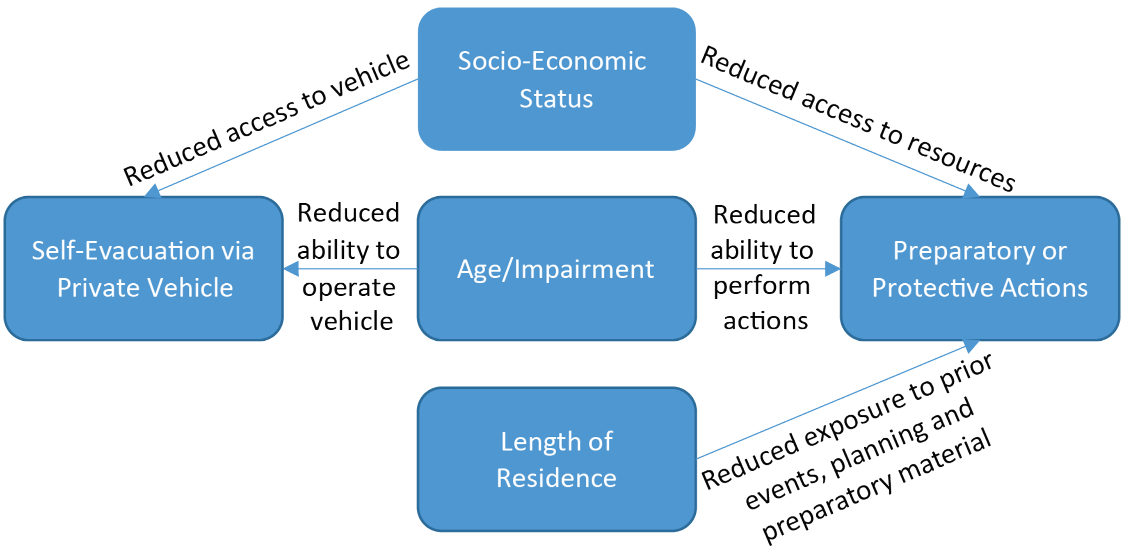

Figure 17. Potential impact of demographic factors on self-evacuation via private vehicle and implementation of preparatory or protective actions.

Appendix K Explanatory Material for Section 4.2.2

This Appendix expands upon Section 4.2.2 and provides examples of existing guidance that may assist in the interpretation of the section. The intent is to provide additional resources and information, but not to present additional recommendations beyond those specified in Chapter 4.

Decisions related to development in new or existing communities should include information about wildfire risk [60]. Information normally gathered as part of a development permit application can help the assessment of wildfire risk, for example:

- location of structures in relation to those in adjacent areas (to assess proximity and issues with fuel modification)
- location of structures in relation to those in the same community/lot (to assess building density, etc.)
- community shape by structure location and spacing (i.e., comparing various community shapes and reducing perimeter/area ratios; promoting round, dense shapes; reducing “peninsulas”)
- landscaping (amount, type, and location of ornamental vegetation present) [60]
- access and internal traffic circulation (to assess access and egress routes)
- topography
- proposed exterior building materials
- location of existing and proposed fire suppression infrastructure

The first four bullets are discussed in this Appendix.

In high-density housing, structures are close enough to adjacent structures to influence the exposure during a wildfire emergency.

FireSmart indicates that high-density housing may exist in WUI areas and should potentially be considered a priority [60]. If high-density housing exists, FireSmart recommends the use of ignition-resistant materials for such structures (see Chapter 3) and also encourages the use of ignition-resistant vegetation in adjacent areas to reduce the hazard around the structures (see Chapter 3) [60]. This represents an attempt to maintain the physical distance between the fire front and the structure and, in turn, reduce the likelihood of structural ignition.

NFPA 1144 contains two provisions regarding building separation:

- Separation distances between the primary structure and accessory structures (e.g., outbuildings) on each lot and structures on adjacent lots shall not be less than 9.2 m (30 ft.) (see Section 5.1.3.1 in NFPA 1144 [17]).
- Buildings located closer than 9.2 m (30 ft.) to a vegetated slope shall require special mitigation measures as determined by the AHJ (see Section 5.1.3.2 in NFPA 1144 [17]).

Comparable provisions are required by FireSmart in relation to surrounding vegetation (discussed in more detail in Chapter 3). These provisions indicate the significance of community density and aggregate configuration.

High-density wildland developments of construction using noncombustible and/or ignition-resistant materials are desirable as they will have a smaller community perimeter relative to lower-density developments of the same number of properties. The smaller community perimeter reduces the length along which a community may be exposed to an approaching wildfire.

In urban locations, fires are more likely to originate within a structure and then spread between structures. In such locations, fire suppression response times are short given the local presence of firefighting services. Higher-density developments have been proven to have proportionally lower costs for fire suppression compared to areas in more isolated locations with lower-density development [143]. The possible remoteness of firefighting services and the presence of vegetation mean that building spacing needs to be greater in WUI areas; structures are much more likely to ignite from the outside, and emergency response times might be considerably longer (see Section 4.3.3 on firefighting capabilities).

Guidance on spacing is provided in more detail in NFPA 1141 [63] (see Table 22). The specifications in NFPA 1141 regarding the separation of principal and accessory buildings are included here as structural separation recommendations and are not to be considered requirements.

Table 22: Minimum Separations in Section 6.2 of NFPA 1141

	Principal Buildings			Accessory Buildings	
Condition	Both principal and neighbouring buildings sprinklered	> 2 storeys or > 9.2 m (30 ft.) in height	All other *buildings*	< 38 m^2 (400 $ft.^2$) in area AND both accessory and principal buildings 9.2 m (30 ft.) from property line	< 38 m^2 (400 $ft.^2$) in area AND accessory building 9.2 m (30 ft.) from principal building
Minimum Separation	4.6 m (15 ft.) from neighbouring building	15.2 m (50 ft.) from neighbouring building	9.2 m (30 ft.) from neighbouring building	4.6 m (15 ft.) from principal building	–
	4.6 m (15 ft.) from property line	9.2 m (30 ft.) from property line	9.2 m (30 ft.) from property line	–	4.6 m (15 ft.) from property line

In locations not considered to be part of the WUI (neither interface nor intermix, such as urban areas), structures can still be at risk from wildfires given that the wind may carry burning embers from remote fire locations. Furthermore, structures may also be at risk from secondary sources of fire when nearby structures within the community are already on fire. As noted above, the likelihood of these “structure-to-structure” fires is related to the spacing and configuration of the community, although certainly mitigated through adherence to NBC requirements. Higher-density wildland developments can generate a potentially more extreme ignition risk to neighbouring structures, with fire more easily moving between structures. It is in these situations that the majority of catastrophic losses to structures occur due to wildfires.

In addition to structure density, community shape can also influence the amount of exposure to wildfires. For instance, the impact of the shape of the community on potential ignition was examined by Beverley and Herd [144]. Although the impact of the community dimensions and shape are appreciated, the impact of the interaction between the various factors described cannot currently be quantified.

Another development consideration for communities relates to the optimal separation between structures and wildland vegetation. For example, in community planning, green spaces such as parks or golf courses can be placed as fuel breaks that provide a buffer between community structures and wildland areas [145]. Community planning in areas with wildfire activity should also incorporate evacuation routes, sufficient access for firefighting equipment, and access to fire suppression equipment such as hydrants (see Section 4.3.3).

Appendix L Explanatory Material for Section 4.3.3

L.1 Pre-Attack Planning Checklist

The following planning checklist should be used to develop pre-attack wildfire suppression plans and maps.

- Command
  - Escape Fire Situation Analysis (if appropriate)
  - Pre-positioning needs
  - Draft delegation of authority
  - Management constraints
  - Interagency agreements
  - Evacuation procedures
  - Structural protection needs
  - Closure procedures
- Operations
  - Heli-spot, heli-base locations, flight routes, restrictions, water sources
  - Control line locations
  - Natural barriers
  - Safety zone options
  - Staging area locations
  - Fuel caches
  - GPS locations for helicopter access
- Logistics
  - Base camp locations
  - Road, trails (including limitations)
  - Utilities
  - Medical facilities
  - Stores, restaurants, service stations, accommodations
  - Transportation resources location
  - Rental equipment sources (by type)
  - Construction contractors
  - Sanitary facilities
  - Police, fire departments, forest service, ambulance
  - Power utility companies
    - Gas and pipeline companies
    - Community utilities

- Communications (radio and frequencies, telephone)
- Sanitary landfills
- Potable water sources
- Maintenance facilities

- Planning
  - Community base map
  - Topographic maps
  - Infrared imagery
  - Vegetation/fuel maps
  - Hazard locations (ground and aerial)
  - Archeological and cultural base map
  - Endangered species critical habitats
  - Sensitive plant populations
  - Water sources
  - Land status
  - Priority zoning
  - Access and egress points and routes
  - High risk facilities (e.g., schools, hospitals)
  - Infrastructure

L.2 Wildfire Preparedness Condition Levels

The following preparedness condition level table, Table 23[44], should be used as guidance in developing local action guidelines in response to preparedness levels.

Table 23: Preparedness Condition Levels

Preparedness Condition (Prep-Con) Level	Action Guidelines
I Low	All community staff on normal shifts Community staff will update fire danger signs
II Moderate	All community staff on normal shifts Natural parks and resources staff Community fire and rescue staff

[44] Based on the City of Kamloops Community Wildfire Protection Plan [148].

Preparedness Condition (Prep-Con) Level	Action Guidelines
III High	All community staff on normal shifts Daily detection patrols by community staff Regional fire situation evaluated Daily fire behaviour advisory issued Wildland fire-trained community staff and emergency operations centre (EOC) staff notified of Prep-Con level Establish weekly communications with local wildland fire agency contacts Hourly rain profile for all weather stations after lightning storms Park technician or /fire rescue service member will update fire danger signs
IV Extreme	Rain profile (see Level III) Daily detection patrols by community staff Daily fire behaviour advisory issued Regional fire situation evaluated EOC staff considered for stand-by Wildfire incident command team members considered for stand-by and extended shifts Designated community staff members who are water tender and heavy machinery operators or arborists may be considered for stand-by and extended shifts Consider initiating natural area closures to align with regional fire situation Provide regular updates about the fire to media and community staff Update public website as new information is available

Preparedness Condition (Prep-Con) Level	Action Guidelines
V Fire(s) Ongoing	All Level IV conditions apply (regardless of actual fire danger rating) Provide regular updates about the fire to the media, structural fire departments, and park staff Mobilize EOC support if evacuation is possible, or fire event requires additional support Mobilize Wildfire Incident Command Team under the direction of the Fire Chief Implement evacuation alerts and orders based on predicted fire behaviour and under the direction of the Fire Chief Implement natural area closures based on predicted fire behaviour and evacuation alerts

The incident commander (individual responsible for the management of all incident operations at the incident site) should judge the extent of the fire on their arrival at the fire and they should take the appropriate decisions by assessing:

- special/unusual hazards
- type/amount of fuel
- terrain
- weather conditions (present/predicted)
- fire behaviour
- resources
- need for specialized firefighters/equipment

The AHJ should prepare incident reports, if required. They, together with Incident Commander, should review the firefighting actions undertaken. Those actions should be reviewed by fire personnel, with the aim of improving and correct the procedures. Those evaluations should address:

- examinations of accidents occurred, their causes and contributing factors
- the actions undertaken
- the evaluation of the new procedures used during the incident
- the identification of possible alternative procedures
- examinations of the incident (fire causes, contributing factors)

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